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R/V Mirai Cruise Report MR18-04 Leg-2

The observational study to construct and extend the "western Pacific super site network"

Tropical western Pacific
August 13, 2018 - September 6, 2018

Japan Agency for Marine-Earth Science and Technology

JAMSTEC, Japan

Cruise Report
MR18-04 Leg-2

--- Contents ---

1. Introduction

The tropical western Pacific (TWP) is a key region in the global weather and climate. For example, the warm water volume in the region is a principle component of El Nino / Southern Oscillation (ENSO). The variation of the warm water volume, and its zonal migration to trigger ENSO, is said to be related closely to the atmospheric variation such as the intraseasonal variation (ISV) or Madden-Julian Oscillation (MJO). In addition, the ocean-atmosphere coupled system over TWP closely related to the weather and climate in the higher latitude in the various temporal scale (e.g. the Pacific-Japan (P-J) pattern, seasonal variation of monsoon over TWP, the boreal summer intraseasonal variation (oscillation) (BSISV/BSISO), and typhoon). Understanding the mechanism of these phenomena is the critical to understand and predict the climate and weather system in Eastern Asia and whole globe. However, the observational evidence to reveal the processes in the atmosphere-ocean interaction over TWP is still insufficient.

To tackle this issue, we JAMSTEC has been conducted observation over TWP. The principle component is the continuous deployment of the surface mooring buoy network, so-called TRITON, to cover the wide area and longer timescale. On the other hand, the intensive observations for short period but very detailed processes have been also conducted, using research vessels, island sites, etc.

The present cruise of research vessel (R/V) Mirai contributes to the both of above component, by deploying / recovering the moorings with conducting intensive observations. The intensive observation nearby the mooring buoys is conducted to enable harmonizing these two components. This activity is a part of the project to deploy and to extend the plural enhanced mooring observation buoy so-called "supersite" over the northwestern Pacific. Furthermore, the cruise contribute to the international project "Tropical Pacific Observing System 2020 (TPOS2020)" to improve the backbone observations and pilot study, especially as the component of "The study the air-sea interaction at the northern edge of the west Pacific warm pool".

This cruise report summarizes the observed items and preliminary results during the present cruise, R/V Mirai MR18-04 Leg-2. In this report, the first several sections describes the basic information such as cruise track, on board personnel list are described. Details of each observation are described in Section 5. Additional information and figures are also attached as Appendices.

*** Remarks ***

This cruise report is a preliminary documentation as of the end of the cruise. The contents may be not updated after the end of the cruise, while the contents may be subject to change without notice. Data on the cruise report may be raw or not processed. Please ask the Chief Scientist and the Principle Investigators for the latest information.

2. Cruise Summary

2.1 Ship

Name	Research Vessel MIRAI
L x B x D	128.6m x 19.0m x 13.2m
Gross Tonnage	8,706 tons
Call Sign	JNSR
Home Port	Mutsu, Aomori Prefecture, Japan

2.2 Cruise Code

MR18-04 (Leg-2)

2.3 Project Name (Main mission)

The observational study to construct and to extend the "western Pacific super site network"

2.4 Undertaking Institute

Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
2-15, Natsushima, Yokosuka, Kanagawa 237-0061, JAPAN

2.5 Chief Scientist

Masaki KATSUMATA
Research and Development Center for Global Change, JAMSTEC

2.6 Periods and Ports of Call

Aug. 13:	departed Chuuk, Federated State of Micronesia
Sep. 4:	called Hachinohe, Japan
Sep. 6:	arrived Sekinehama, Japan

2.8 Observation Summary

Deployment of surface mooring	3 sites
Recovery of surface mooring	3 sites
Replacement of subsurface ADCP mooring	1 site
Launching surface drifter (without recovery)	8 sets
Launching and recovery of surface drifter	2 sets
Launching Argo-type float	1 set
Launching multi-purpose observation float	4 sets

GPS Radiosonde	90 times	Aug. 14 to Sep. 2
C-band Doppler radar	continuously	Aug. 13 to Sep. 1
Disdrometer	continuously	Aug. 13 to Sep. 2
Ceilometer	continuously	Aug. 13 to Sep. 5
Lidar	continuously	Aug. 13 to Sep. 2
Aerosol and gas observations	continuously	Aug. 13 to Sep. 5
Surface Meteorology	continuously	Aug. 13 to Sep. 5
Sea surface water monitoring	continuously	Aug. 13 to Sep. 3

CTD profiling	22 profiles	Aug. 15 to Aug. 27
LADCP profiling	17 profiles	Aug. 25 to Aug. 27
Profiled sea water sampling	14 profiles	Aug. 15 to Aug. 27
eXpendable CTD	17 profiles	Aug. 24 to Aug. 28
Shipboard ADCP	continuously	Aug. 13 to Sep. 5

… and more

2.9 Overview

In order to investigate the oceanic variations in the western Pacific, some focal locations are selected to install specialized mooring observations so-called "supersites". This cruise MR18-04 using R/V Mirai is dedicated to deploy these supersites, and to investigate further multiple items / parameters to enrich the ability of these supersite. This cruise report is to summarize the observations during the 2nd leg of MR18-04 cruise.

The principle part of this cruise was to deploy mooring buoys at three focal points, (Eq, 156E), (8N, 137E), and (13N, 137E). To obtain the continuous time series from the pre-exiting buoys at these points, the moorings were deployed nearby the pre-existing buoys. The recovery of the pre-existing buoys were also conducted. These locations were selected to study the variations of the "warm water pool" in the tropical western Pacific. The site (Eq, 156E) is to study the zonal variation at the eastern edge of the warm water pool, while (8N, 137E) and (13N, 137E) are to study the meridional variation at the northern edge of the warm water pool.

As the study to enrich the mooring observations at these sites, we conducted special observations by deploying various onboard instruments and buoys / floats. The present cruise is especially to focus on the air-sea interaction at the northern edge of the warm water pool. At (13N, 137E), 3-hourly CTD or XCTD profiling and 3-hourly radiosonde launches are the backbone to retrieve detailed temporal variation of the oceanic and atmospheric status. The oceanic near-surface stratification is especially investigated using thermistor cable "SeaSnake", CTD profiling from the vessel, specialized drifting buoys (provided by LOCEAN, France), etc. The cloud and precipitation are observed by C-band polarimetric radar, lidar, etc. The collaborative dual-Doppler radar observation was conducted with the U.S. R/V Thomas G. Thompson during their PISTON project. These observations are mostly done in between the deployment of new mooring buoy and recovery of pre-exited mooring buoy, i.e. the meso-scale oceanic / atmospheric observation network was temporally formed. Furthermore at (8N, 137E), the first deployment of the multiple-purpose observation float (MOF) was successfully completed.

While the preliminary results are summarized in this cruise report, further analyses will be performed to engrave the detail of the processes to promote the air-sea interaction over the warm water pool.

2.10 Acknowledgments

We would like to express our sincere thanks to Captain T. Akutagawa and his crew for their skillful ship operation. Special thanks are extended to the technical staff of Marine Works Japan, Ltd., and Nippon Marine Enterprise Inc., for their continuous and skillful support to conduct the observations. Collaborations by PISTON project (U. S. A.) and LOCEAN (France) are greatly acknowledged. The experimental forecasts using NICAM, by JAMSTEC/DSEP, greatly helps our operation.

3. Cruise Track and Log

3.1 Cruise Track

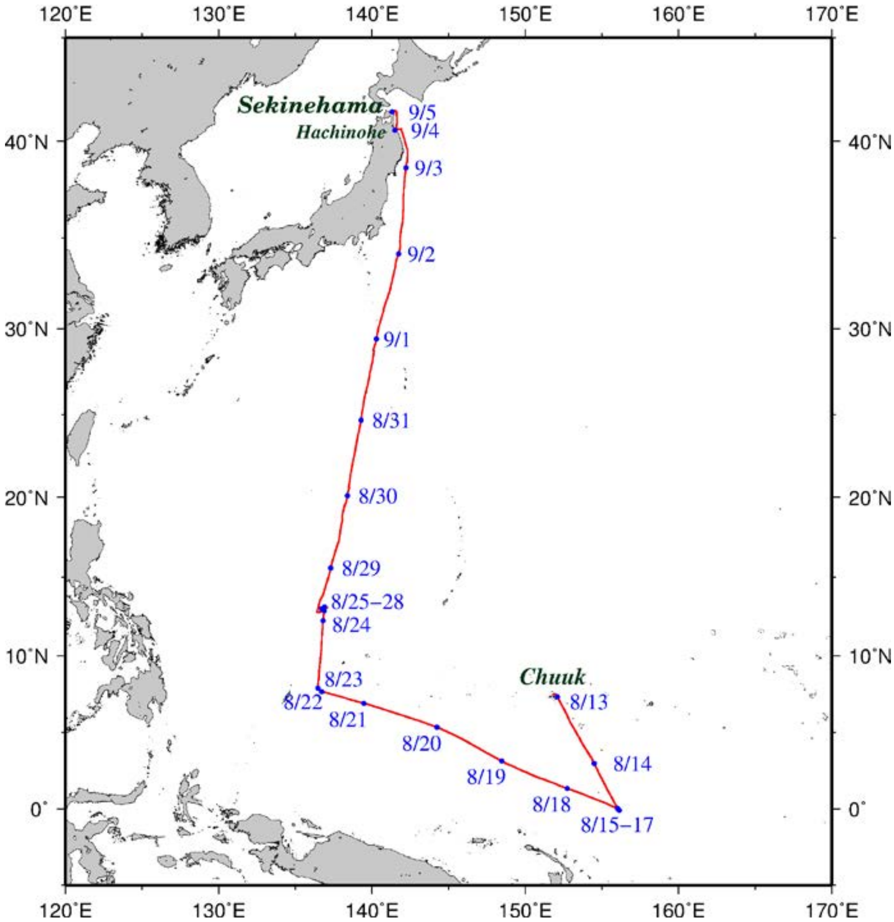


Fig. 3.1-1: Cruise track for all period. Blue dots are for the positions at 12SMT at every day.

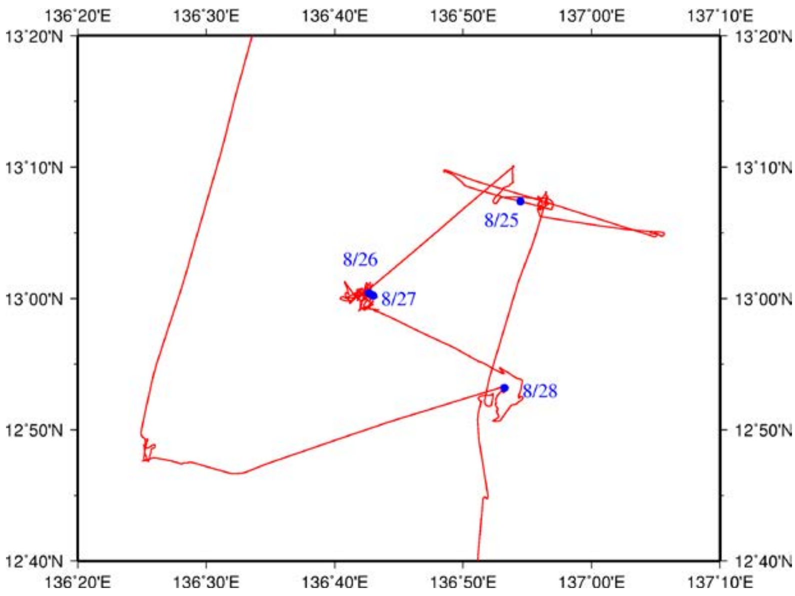


Fig. 3.1-2: Cruise tracks around the station (13N, 137E). The blue dots are same as in Fig. 3.1-1.

3.2 Cruise Log

Date and Time			Location	Event
SMT		UTC		
Aug.13	0930	2330		Depart Chuuk (SMT = UTC+10h)
	1340	0340	07-01.80N, 152-15.26E	Start underway observations
	1342	0342	07-01.44N, 152-15.43E	Start C-band weather radar observation
	1435	0435	06-51.98N, 152-19.95E	Start continuous sea surface monitoring, and swath bathymetry observation
	1605	0605	06-36.75N, 152-28.26E	Deploy drifting buoy
	1618	0618	06-35.66N, 152-28.88E	Deploy drifting buoy
14	0930	2330	03-26.00N, 154-14.82E	Launch Radiosonde
	1530	0530	02-19.85N, 154-48.30E	Launch Radiosonde
	2130	1130	01-21.04N, 155-19.16E	Launch Radiosonde
15	0330	1730	00-26.02N, 155-48.08E	Launch Radiosonde
	0606	2006		Arrive Station T1 (Eq, 156E)
	0809-1042	2209-0042	00-00.97N, 156-02.47E	Deploy TRITON buoy
	0931	2331	00-02.23N, 156-03.04E	Launch Radiosonde
	1307-1410	0307-0410	00-00.45N, 156-03.58E	CTD (900m)
	1530	0530	00-00.64N, 155-59.84E	Launch Radiosonde
	2130	1130	00-01.95N, 156-00.15E	Launch Radiosonde
16	0330	1730	00-01.31N, 155-58.53E	Launch Radiosonde
	0559-0701	1959-2101	00-01.88S, 155-57.57E	CTD (900m)
	0759-1058	2159-0058		Recover TRITON buoy
	0930	2330	00-00.94N, 155-57.86E	Launch Radiosonde
	1530	0530	00-00.41N, 156-07.30E	Launch Radiosonde
	2131	1131	00-02.10S, 156-08.20E	Launch Radiosonde
17	0330	1730	00-01.94S, 156-08.47E	Launch Radiosonde
	0802-0935	2202-2335		Recover ADCP mooring buoy
	0930	2330	00-03.99S, 156-0825E	Launch Radiosonde
	1310-1435	0310-0435		Deploy ADCP mooring buoy
	1530	0530	00-02.24S, 156-08.29E	Launch Radiosonde
	1654	0654		Depart Station T1
	2130	1130	00-21.31N, 155-20.52E	Launch Radiosonde
18	0330	1730	00-45.11N, 154-17.09E	Launch Radiosonde
	0930	2330	01-10.43N, 153-12.03E	Launch Radiosonde
	2130	1130	01-59.50N, 151-00.7E	Launch Radiosonde
19	0330	1730	02-26.76N, 149-55.41E	Launch Radiosonde
	0930	2330	02-52.62N, 148-58.58E	Launch Radiosonde
	2130	1130	04-02.34N, 146-50.31E	Launch Radiosonde
20	0330	1730	04-37.21N, 145-47.88E	Launch Radiosonde

	0930	2330	05-06.01N, 144-47.94E	Launch Radiosonde
	2130	1130	05-58.16N, 142-26.87E	Launch Radiosonde
	2200 (2100)	1200		Change SMT (SMT=UTC+9h)
21	0230	1730	06-20.60N, 141-17.42E	Launch Radiosonde
	0833	2333	06-42.76N, 140-07.32E	Launch Radiosonde
	1430	0530	07-02.55N, 138-58.52E	Launch Radiosonde
	2030	1130	07-22.30N, 137-52.04E	Launch Radiosonde
22	0230	1730	07-37.12N, 136-54.34E	Launch Radiosonde
	0344	1844		Arrive Station T2 (8N, 137E)
	0808-1043	2308-0143	07-38.96N, 136-42.00E	Deploy TRITON buoy
	0835	2335	07-41.03N, 136-43.57E	Launch Radiosonde
	1302-1401	0402-0501	07-38.90N, 136-42.80E	CTD (900m)
	1430	0530	07-42.08N, 136-39.91E	Launch Radiosonde
	2030	1130	07-53.43N, 136-29.68E	Launch Radiosonde
23	0230	1730	07-53.54N, 136-30.54E	Launch Radiosonde
	0547	2047	07-50.78N, 136-30.16E	Deploy MOF #1
	0559-0702	2059-2202	07-51.07N, 136-30.23E	CTD (900m)
	0759-1334	2259-0434		Recover TRITON buoy
	0830	2330	07-51.86N, 136-30.57E	Launch Radiosonde
	1400	0500	07-54.07N, 136-26.87E	Deploy MOF #2
	1402	0502	07-54.11N, 136-26.89E	Deploy MOF #3
	1404	0504	07-54.14N, 136-26.91E	Deploy MOF #4
	1406	0506		Depart Station T2
	1430	0530	07-57.27N, 136-27.69E	Launch Radiosonde
	2030	1130	09-08.29N, 136-34.24E	Launch Radiosonde
24	0230	1730	10-19.26N, 136-41.70E	Launch Radiosonde
	0830	2330	11-32.23N, 136-45.21E	Launch Radiosonde
	1430	0530	12-44.82N, 136-51.79E	Launch Radiosonde
	1512	0612		Arrive Station T3 (13N, 137E)
	1516-1617	0616-0717	12-52.19N, 136-51.35E	CTD (1000m)
	2030	1130	13-07.40N, 136-56.39E	Launch Radiosonde
	2103	1203	13-07.12N, 136-56.53E	XCTD
	2331	1431	13-07.31N, 136-55.90E	Launch Radiosonde
25	0003	1503	13-07.36N, 136-55.94E	XCTD
	0230	1730	13-06.93N, 136-55.98E	Launch Radiosonde
	0302	1802	13-06.48N, 136-55.92E	XCTD
	0530	2030	13-05.09N, 137-04.75E	Launch Radiosonde
	0547	2047	13-04.94N, 137-04.92E	XCTD
	0600	2100	13-04.76N, 137-05.01E	Deploy drifting buoy
	0810-1317	2310-0417		Deploy TRITON (Philippine) buoy
	0830	2330	13-09.62N, 136-48.76E	Launch Radiosonde

	0904	0004	13-09.38N, 136-49.27E	XCTD
	1123	0223	13-07.75N, 136-53.01E	Launch Radiosonde
	1208	0308	13-07.37N, 136-54.64E	XCTD
	1430	0530	13-07.42N, 136-52.72E	Launch Radiosonde
	1446	0546	13-08.32N, 136-53.08E	Deploy Argo float
	1516	0616	13-08.57N, 136-53.58E	XCTD
	1556-1943	0656-1043	13-09.87N, 136-53.22E	CTD (5179m)
	1730	0830	13-09.31N, 136-53.88E	Launch Radiosonde
	1803	0903	13-09.49N, 136-53.85E	XCTD
	2030	1130	13-04.20N, 136-46.91E	Launch Radiosonde
	2107	1207	13-00.14N, 136-41.63E	XCTD
	2330	1430	13-00.44N, 136-41.04E	Launch Radiosonde
	2358-0017	1458-1517	13-00.44N, 136-40.93E	CTD (300m)
26	0230	1730	12-59.70N, 136-41.20E	Launch Radiosonde
	0259-0342	1759-1842	12-59.91N, 136-4106E	CTD (300m)
	0530	2030	12-59.79N, 136-42.01E	Launch Radiosonde
	0601-0620	2101-2120	12-59.99N, 136-42.21E	CTD (300m)
	0830	2330	13-00.27N, 136-42.40E	Launch Radiosonde
	0900-0949	0000-0049	13-00.30N, 136-42.52E	CTD (300m)
	1130	0230	13-00.63N, 136-42.78E	Launch Radiosonde
	1202-1220	0302-0320	13-00.47N, 136-42.68E	CTD (300m)
	1430	0530	12-59.20N, 136-41.97E	Launch Radiosonde
	1458-1544	0558-0644	12-59.12N, 136-42.01E	CTD (300m)
	1730	0830	12-59.62N, 136-42.34E	Launch Radiosonde
	1758-1816	0858-0916	12-59.16N, 136-42.34E	CTD (300m)
	2030	1130	12-59.42N, 136-42.58E	Launch Radiosonde
	2058-2146	1158-1246	12-59.30N, 136-42.67E	CTD (300m)
	2331	1431	12-59.99N, 136-41.84E	Launch Radiosonde
	2359-0018	1459-1518	12-59.92N, 136-41.84E	CTD (300m)
27	0230	1730	12-59.85N, 136-41.27E	Launch Radiosonde
	0257-0336	1757-1836	12-59.75N, 136-41.28E	CTD (300m)
	0530	2030	13-00.22N, 136-41.25E	Launch Radiosonde
	0559-0617	2059-2117	13-00.15N, 136-41.71E	CTD (300m)
	0830	2330	13-00.29N, 136-42.45E	Launch Radiosonde
	0859-0950	2359-0050	13-00.65N, 136-42.59E	CTD (300m)
	1130	0230	13-00.06N, 136-43.24E	Launch Radiosonde
	1157-1215	0257-0315	13-00.22N, 136-42.92E	CTD (300m)
	1430	0530	13-00.64N, 136-42.25E	Launch Radiosonde
	1458-1543	0558-0643	13-00.60N, 136-42.37E	CTD (300m)
	1730	0830	13-00.53N, 136-42.51E	Launch Radiosonde
	1755-1818	0855-0918	13-00.37N, 136-42.14E	CTD (300m)

	2030	1130	12-59.54N, 136-42.98E	Launch Radiosonde
	2058-2146	1158-1246	12-59.46N, 136-42.74E	CTD (300m)
	2330	1430	12-59.16N, 136-43.28E	Launch Radiosonde
28	0004	1504	12-59.12N, 136-43.26E	XCTD
	0230	1730	12-55.14N, 136-51.48E	Launch Radiosonde
	0302	1802	12-54.36N, 136-53.14E	XCTD
	0530	2030	12-51.91N, 136-53.89E	Launch Radiosonde
	0603	2103	12-50.65N, 136-52.58E	XCTD
	0616-1202	2116-0302		Recover TRITON (Philippine) buoy
	0830	2330	12-52.33N, 136-52.55E	Launch Radiosonde
	0905	0005	12-52.62N, 136-52.68E	XCTD
	1130	0230	12-52.96N, 136-53.22E	Launch Radiosonde
	1203	0303	12-53.20N, 136-53.18E	XCTD
	1204-1215	0304-0315	12-53.21N, 136-53.18E	Recover Sea Snake
	1430	0530	12-47.49N, 136-28.43E	Launch Radiosonde
	1433-1440	0533-0540	12-47.49N, 136-28.30E	Recover drifting buoy
	1501	0601	12-47.85N, 136-25.80E	XCTD
	1510-1516	0610-0616	12-47.74N, 136-25.50E	Recover drifting buoy
	1730	0830	12-48.60N, 136-25.92E	Launch Radiosonde
	1802	0902	12-48.68N, 136-25.57E	XCTD
	2030	1130	12-48.87N, 136-25.24E	Launch Radiosonde
	2102	1202	12-49.41N, 136-25.11E	XCTD
	2106	1206		Depart Station T3
29	0230	1730	13-48.01N, 136-45.78E	Launch Radiosonde
	0830	2330	14-55.52N, 137-08.30E	Launch Radiosonde
	1430	0530	16-03.87N, 137-25.90E	Launch Radiosonde
	2030	1130	17-11.02N, 137-48.32E	Launch Radiosonde
	2158-2203	1258-1303	17-27.39N, 137-52.00E	Deploy drifting buoys
30	0230	1730	18-20.80N, 138-01.09E	Launch Radiosonde
	0854	2354	19-32.15N, 138-14.94E	Launch Radiosonde
	1430	0530	20-32.91N, 138-29.84E	Launch Radiosonde
	2130	1130	21-38.98N, 138-39.62E	Launch Radiosonde
31	0230	1730	22-48.12N, 138-54.58E	Launch Radiosonde
	0830	2330	23-58.34N, 139-08.81E	Launch Radiosonde
	1430	0530	25-09.67N, 139-21.35E	Launch Radiosonde
	2030	1130	26-21.50N, 139-36.85E	Launch Radiosonde
Sep.01	0230	1730	27-33.44N, 139-53.57E	Launch Radiosonde
	0830	2330	28-43.40N, 140-06.22E	Launch Radiosonde
	1430	0530	29-54.09N, 140-23.31E	Launch Radiosonde
	2030	1130	31-10.56N, 140-47.32E	Launch Radiosonde
02	0230	1730	32-17.38N, 141-12.39E	Launch Radiosonde

	0730	2230	33-17.22N, 141-29.00E	Stop C-band radar observation
	0830	2330	33-28.88N, 141-31.35E	Launch Radiosonde
Sep.03	1400	0500	34-20.18N, 141-48.09E	Stop continuous sea surface monitoring, and swath bathymetry observation
Sep.04	0840	2340		Arrive Hachinohe
	1630	0730		Depart Hachinohe
Sep.06	0900	0000		Arrive Sekinehama

4. List of Participants

4.1 On-board scientists and technical staff

Name	Affiliation
Masaki KATSUMATA	JAMSTEC
Biao GENG	JAMSTEC
Kyoko TANIGUCHI	JAMSTEC
Kazuki TSUJI	JAMSTEC
Tetsuya NAGAHAMA	JAMSTEC
Kazuho YOSHIDA	Nippon Marine Enterprise Inc. (NME)
Shinya OKUMURA	NME
Yutaro MURAKAMI	NME
Hiroshi MATSUNAGA	Marine Works Japan Ltd. (MWJ)
Keisuke MATSUMOTO	MWJ
Shoko TATAMISASHI	MWJ
Kai FUKUDA	MWJ
Yasuhiro ARII	MWJ
Kenichi KATAYAMA	MWJ
Hiroshi USHIROMURA	MWJ
Keisuke TAKEDA	MWJ
Jun MATSUOKA	MWJ
Masanori ENOKI	MWJ
Hiroshi HOSHINO	MWJ
Masahiro ORUI	MWJ
Elena HAYASHI	MWJ
Keitaro MATSUMOTO	MWJ
Tomomi SONE	MWJ
Erii IRIE	MWJ
Yoshiaki SATO	MWJ

4.2 Ship Crew

Toshihisa AKUTAGAWA	Master
Tatsuo ADACHI	Chief Officer
Haruhiko INOUE	First Officer
Akihiro NUNOME	Second Officer
Shozo FUJII	Jr. Second Officer
Shintaro KAN	Third Officer
Masakazu MATSUZAKI	Jr. Third Officer
Shuichi HASHIDE	Chief Engineer
Jun TAKAHASHI	First Engineer
Kenta IKEGUCHI	Second Engineer
Keisuke YOSHIDA	Third Engineer
Takehito HATTORI	Chief Radio Operator
Yosuke KUWAHARA	Boatswain
Kazuyoshi KUDO	Quarter Master
Tsuyoshi MONZAWA	Quarter Master
Masashige OKADA	Quarter Master
Shuji KOMATA	Quarter Master
Hideaki TAMOTSU	Quarter Master
Satoshi SIMPO	Quarter Master
Masaya TANIKAWA	Quarter Master
Hideyuki OKUBO	Quarter Master
Hibiki NAGANUMA	Sailor
Kodai KAKUBARI	Sailor
Mizuki SUGAWARA	Sailor
Noa SASAKI	Sailor
Kazumi YAMASHITA	No.1 Oiler
Fumihito KAIZUKA	Oiler
Toshiyuki FURUKI	Oiler
Kazuya ANDO	Oiler
Masashi OE	Assistant Oiler
Tsuyoshi UCHIYAMA	Assistant Oiler
Kiyotaka KOSUJI	Chief Steward
Sakae HOSHIKUMA	Steward
Yukio CHIBA	Steward
Toru WADA	Steward
Toshiyuki ASANO	Steward
Koichiro KASHIWAGI	Steward

5 Summary of observations

5.1 TRITON moorings

(1) Personnel

Masaki Katsumata	(JAMSTEC)
Tetsuya Nagahama	(JAMSTEC)
Keisuke Matsumoto	(MWJ): Operation Leader
Shoko Tatamisashi	(MWJ)
Kai Fukuda	(MWJ)
Hiroshi Matsunaga	(MWJ)
Kenichi Katayama	(MWJ)
Hiroki Ushiromura	(MWJ)
Keisuke Takeda	(MWJ)
Jun Matsuoka	(MWJ)
Masanori Enoki	(MWJ)
Yasuhiro Arii	(MWJ)
Hiroshi Hoshino	(MWJ)
Masahiro Orui	(MWJ)
Keitaro Matsumoto	(MWJ)
Elena Hayashi	(MWJ)
Tomomi Sone	(MWJ)
Erii Irie	(MWJ)

(2) Objectives

The large-scale air-sea interaction over the warmest sea surface temperature region in the western tropical Pacific Ocean called warm pool that affects the global atmosphere and causes El Nino phenomena. The formation mechanism of the warm pool and the air-sea interaction over the warm pool have not been well understood. Therefore, long term data sets of temperature, salinity, currents and meteorological elements have been required at fixed locations. The TRITON program aims to obtain the basic data to improve the predictions of El Nino and variations of Asia-Australian Monsoon system.

TRITON buoy array is integrated with the existing TAO (Tropical Atmosphere Ocean) array, which is presently operated by the Pacific Marine Environmental Laboratory/National Oceanic and Atmospheric Administration of the United States. TRITON is a component of international research program of CLIVAR (Climate Variability and Predictability), which is a major component of World Climate Research Program sponsored by the World Meteorological Organization, the International Council of Scientific Unions, and the Intergovernmental Oceanographic Commission of UNESCO. TRITON will also contribute to the development of GOOS (Global Ocean Observing System) and GCOS (Global Climate Observing System).

Two TRITON buoys and one Philippine sea buoy have been recovered, and the same buoys have been deployed during this R/V MIRAI cruise (MR18-04 Leg2).

(3) Measured parameters

The TRITON buoy observes oceanic parameters and meteorological parameters as follow:

Meteorological parameters:

Wind Speed, Direction,
Atmospheric Pressure,
Air Temperature, Relative Humidity,
Shortwave Radiation,
Precipitation.
Longwave Radiation (only Philippine sea)

Oceanic parameters (TRITON):

Water Temperature and Conductivity at
1.5m, 25m,50m, 75m, 100m, 125m, 150m, 200m,
300m, 500m.
Depth at 300m and 500m.
Currents at 10m.

Oceanic parameters (Philippine Sea):

Water Temperature and Conductivity at
1m, 10m, 20m, 40m, 60m, 80m, 90m, 100m,
110m, 120m, 180m, 150m, 200m, 300m.
Depth at
1m, 10m, 40m, 80m, 100m, 120m, 180m,
150m, 300m.
Currents at 1m
Dissolved Oxygen at 80m, 100m, 150m
PH at 1m
CO_2 at sea surface

(4) Instrumentation

Details of the instruments used on the TRITON buoy are summarized as follow:

Oceanic sensors

1) CTD and CT

SBE-37 IM MicroCAT

A/D cycles to average :	4
Sampling interval :	600sec.
Measurement range, Temperature :	-5～+35 deg-C
Measurement range, Conductivity :	0～7 S/m
Measurement range, Pressure :	0～full scale range

2) CRN(Current meter)

SonTek Argonaut ADCM

Sensor frequency :	1500 kHz
Sampling interval :	1200 sec.
Average interval :	120 sec.

Work Horse ADCP

Sensor frequency :	300 kHz
Sampling interval :	20 min.

Meteorological sensors

1) Precipitation

R.M.YOUNG COMPANY MODEL50202/50203

Sampling interval : 600 sec.

2) Atmospheric pressure

PAROPSCIENTIFIC.Inc. DIGIQUARTZ FLOATING BAROMETER 6000SERIES

Sampling interval : 600 sec.

3) Relative humidity/air temperature,
Shortwave radiation,
Longwave radiation,
Wind speed/direction

Woods Hole Institution ASIMET

Sampling interval : 600 sec.

(5) Locations of TRITON buoys and Philippine buoy deployment

Nominal location :	EQ, 156E
ID number at JAMSTEC :	04019
Number on surface float :	T04
ARGOS PTT number :	29765
ARGOS backup PTT number :	27409, 49730
Deployed date :	15 Aug. 2018
Exact location :	00°00.97' N, 156°02.47' E
Depth :	1,953 m

Nominal location :	8N, 137E
ID number at JAMSTEC :	10014
Number on surface float :	T27
ARGOS PTT number :	27958
ARGOS backup PTT number :	27410, 49731
Deployed date :	22 Aug. 2018
Exact location :	07°38.96' N, 136°42.01' E
Depth :	3,171 m

Nominal location :	13N, 137E
ID number at JAMSTEC :	40502
Number on surface float :	J02
Iridium ID number :	300434060153300
ARGOS backup PTT number :	27411
Deployed date :	25 Aug. 2018
Exact location :	13°06.90' N, 136°56.39' E
Depth :	5,327 m

(6) Locations of TRITON buoys and Philippine buoy recovered

Nominal location :	EQ, 156E
ID number at JAMSTEC :	04018
Number on surface float :	T01
ARGOS PTT number :	28320
ARGOS backup PTT number :	29694
Deployed date :	14 Dec. 2016
Recovered date :	16 Aug. 2018
Exact location :	00°00.96' S, 155°57.57' E
Depth :	1,942 m

Nominal location :	8N, 137E
ID number at JAMSTEC :	10013
Number on surface float :	T22
ARGOS PTT number :	27400
ARGOS backup PTT number :	30832
Deployed date :	05 Dec. 2016
Recovered date :	23 Aug. 2018
Exact location :	07°52.03' N, 136°30.03' E
Depth :	3,349 m

Nominal location :	13N, 137E
ID number at JAMSTEC :	40501
Number on surface float :	K03
Iridium ID number :	300434061416080
ARGOS backup PTT number :	28160
Deployed date :	03 Dec. 2016
Recovered date :	28 Aug. 2018
Exact location :	12°52.83' N, 136°55.42' E
Depth :	5,216 m

*Dates are in UTC. The dates are when anchor was dropped for deployments, while when acoustic releaser was on deck for recoveries, respectively.

(7) Details of deployments

Described the optional sensor in the list.

Deployment optional sensor

Observation No.	Location	Details
04019	EQ156E	Deploy with full spec and 2 optional units. SBE37 (CT) :175m JES10-CTD IM: 500m SBE37(CTD): 501m
10014	8N137E	Deploy with full spec and 2 optional units. SBE37 (CT) :175m JES10-CTD IM: 300m SBE37 (CTD): 301m
40502	13N137E	Deploy with full spec and 1 optional unit. Underwater Hydrophone :100m

(8) Data archive

Hourly averaged data are transmitted through ARGOS satellite data transmission system in almost real time. The real time data are provided to meteorological organizations via Global Telecommunication System and utilized for daily weather forecast. The data will be also distributed world wide through Internet from JAMSTEC and PMEL home pages. All data will be archived at JAMSTEC Mutsu Institute.

TRITON Homepage : http://www.jamstec.go.jp/jamstec/triton

5.2 ADCP moorings

(1) Personnel

Iwao Ueki	(JAMSTEC): Principal investigator (not on board)
Masaki Katsumata	(JAMSTEC)
Hiroki Ushiromura	(MWJ): Operation leader
Hiroshi Matsunaga	(MWJ)
Kenichi Katayama	(MWJ)
Keisuke Matsumoto	(MWJ)
Keisuke Takeda	(MWJ)
Yasuhiro Arii	(MWJ)
Masahiro Orui	(MWJ)
Keitaro Matsumoto	(MWJ)
Tomomi Sone	(MWJ)
Erii Irie	(MWJ)

(2) Objectives

The purpose of this ADCP subsurface mooring is to get knowledge of physical process underlying the dynamics of the equatorial current structure and associated processes in the western Pacific Ocean. We have been observing subsurface currents using ADCP moorings along the equator. In this cruise (MR18-04Leg2), we recovered the mooring at Eq-156E and deployed another mooring at the same site.

(3) Parameters

・Current profiles
・Echo intensity
・Pressure, Temperature and Conductivity

(4) Methods

Two instruments are mounted at the top float of the mooring. The first one is ADCP (Acoustic Doppler Current Profiler) to observe upper-ocean currents from subsurface down to around 400m depth. The second instrument mounted on the bottom part of the float is CTD, which observes pressure, temperature and salinity for correction of sound speed and depth variability. Details of the instruments and their parameters are as follows:

1) ADCP

Work horse ADCP 75 kHz (Teledyne RD Instruments, Inc.)

Distance to first bin : 7.04 m

Pings per ensemble : 16

Time per ping : 6.66 seconds

Number of depth cells : 60

Bin length : 8.00 m

Sampling Interval : 3600 seconds

Recovered ADCP

- Serial Number : 1248 (Mooring No. 161216-EQ156E)

Deployed ADCP

- Serial Number : 7176 (Mooring No. 180817-EQ156E)

2) CTD

SBE-16 (Sea Bird Electronics Inc.)

Sampling Interval : 1800 seconds

Recovered CTD

- Serial Number : 1288 (Mooring No. 161216-EQ156E)

Deployed CTD

- Serial Number : 1282(Mooring No. 180817-EQ156E)

3) Other instrument

(a) Acoustic Releaser (BENTHOS,Inc.)

Recovered Acoustic Releaser

- Serial Number : 632 (Mooring No. 161216-EQ156E)
- Serial Number : 666 (Mooring No. 161216-EQ156E)

Deployed Acoustic Releaser

- Serial Number : 600 (Mooring No. 180817-EQ156E)
- Serial Number : 937 (Mooring No. 180817-EQ156E)

(b) Transponder (BENTHOS,Inc.)

Recovered Transponder

- Serial Number : 57069 (Mooring No. 161216-EQ156E)

Deployed Transponder

- Serial Number : 67491 (Mooring No. 180817-EQ156E)

(c) ST-400A Xenon Flasher (MetOcean Data Systems)

Recovered Transponder

- Serial Number : Z03-088 (Mooring No. 161216-EQ156E)

Deployed Transponder

- Serial Number : A02-066 (Mooring No. 180817-EQ156E)

(5) Deployment

Deployment of the ADCP mooring at Eq-156E were planned to mount the ADCP at about 400m depth. During the deployment, we monitored the depth of the acoustic releaser after dropped the anchor.

The position of the mooring No. 180817-EQ156E

Date: 17 Aug. 2018 Lat: 00-02.13S Long: 156-07.97E Depth: 1,950m

The location is mapped as Fin Fig. 5.2-1.

(6) Recovery

We recovered one ADCP mooring which was deployed on 16 Dec 2016 (MR16-08). We uploaded ADCP and CTD data into a computer, and then raw data were converted into ASCII code.

The results of mooring show in Figs. 5.2-2 and 5.2-3.

(7) Data archive

All data will be opened at the following web page:.

http://www.jamstec.go.jp/rcgc/j/tcvrp/ipocvrt/adcp_data.html

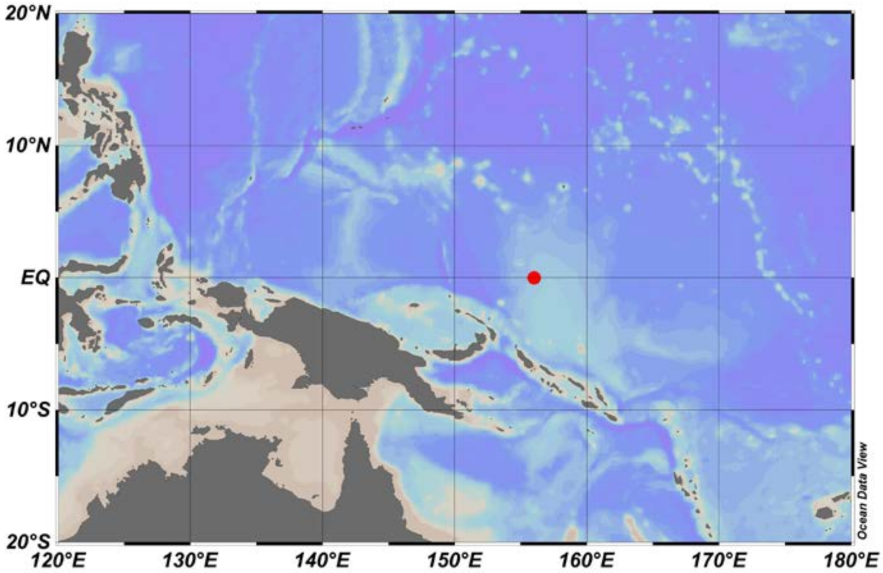


Fig. 5.2-1: Location of the ADCP mooring, recovered and deployed in the present cruise.

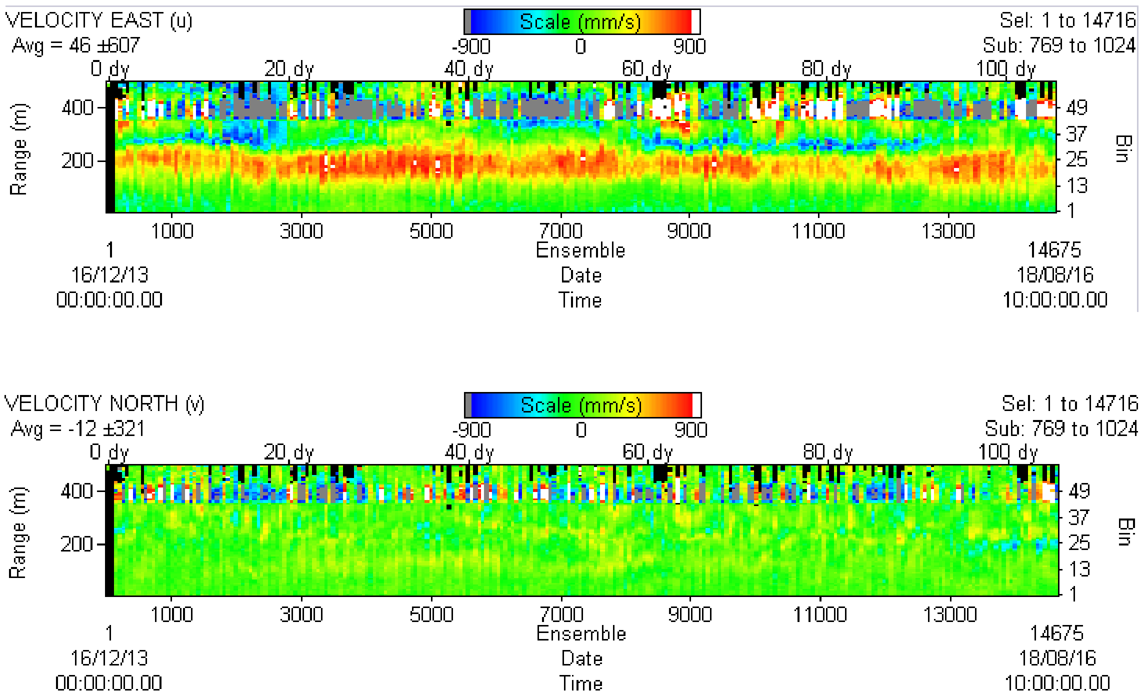


Fig. 5.2-2 Time-depth sections of observed zonal (*top panel*) and meridional (*bottom panel*) currents obtained from ADCP mooring at Eq-156E. (2016/12/16-2018/08/16)

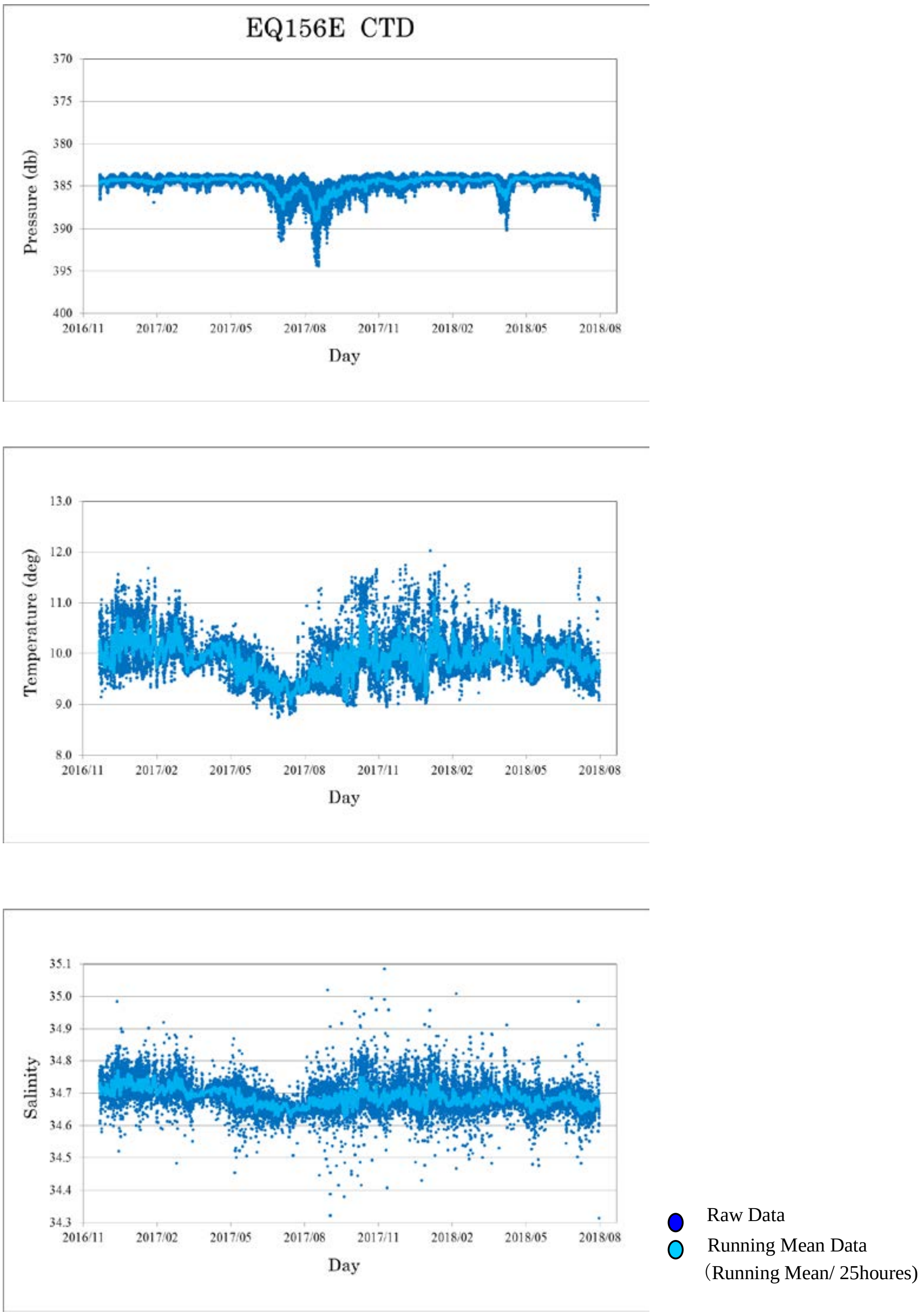


Fig. 5.2-3 Time-series of the observed pressure (*top panel*), temperature (*middle panel*) and salinity (*bottom panel*) obtained from CTD at Eq-156E . The *dark-blue* curve indicates the raw data, while the *light-blue* curve shows the filtered data from 25 hours running-mean. (2016/12/16-2018/08/16)

5.3 Multi-purpose observation float

(1) Personnel

Kensuke Watari	(JAMSTEC/MARITEC)
Masahiro Kaku	(JAMSTEC/MARITEC)
Satoshi Tsubone	(Interlink Co.Ltd)
Keisuke Takeda	(MWJ)

(2) Objective

The sea is strongly related to the global climate. In particular, the occurrence of phenomena called El Niño and Indian Ocean dipole mode, where the water temperature distribution differs greatly from normal, is closely related to abnormal weather around the world. JAMSTEC has built an observation network by Triton buoy as a means to accurately measure such sea anomalies. However, while observation by Triton buoy can acquire precise data at a fixed point, it is costly to install and recover, which is not an economically flexible method. Therefore, we developed an inexpensive and compact automatic raising and lowering float, and by combining it with the Triton buoy, we aim to construct an observation network with a high degree of freedom that can be scaled. In the MR18-04 cruise, the purpose is to test a small observation float "MOF" conducted in the T2 area and to extract future tasks.

(3) Description of instruments deployed

We prepare four MOF prototype machines and conduct test observation mainly focusing on technical information collection. The CTD data obtained by the observation is compared with the observation results of "MIRAI", Triton buoy and peripheral Argo float to confirm the reliability of the data. In addition, we confirm the behavior of the floating and sedimentation sequence and verify the optimization of the dive algorithm for observation for a long time based on the obtained data.

The developed MOF prototype has a total length of 950 mm and weighs about 8 kg, and it can be easily handled with human power. The original CTD sensor is mounted on the head part, and there is a function to transmit the profile observation data from the water depth of 500 m by Iridium communication. Also, when levitating, you can specify observation coordinates with GPS. It is possible to float and settle by an oil bladder, and drift at arbitrary depth when waiting.

Table 1: Deployment list of MOF

Launch Date	Machine No	Deploy point	Target Depth	Drift Depth	Observation Time
2018/8/23	201801	136-30.16118 E 7-50.78532 N	200	200	17:00
2018/8/23	201802	136-26.87287 E 7-54.07176 N	200	200	0:00
2018/8/23	201803	136-26.89097 E 7-54.10451 N	300	300	9:00
2018/8/23	201804	136-26.90767 E 7-54.13923 N	500	500	9:00

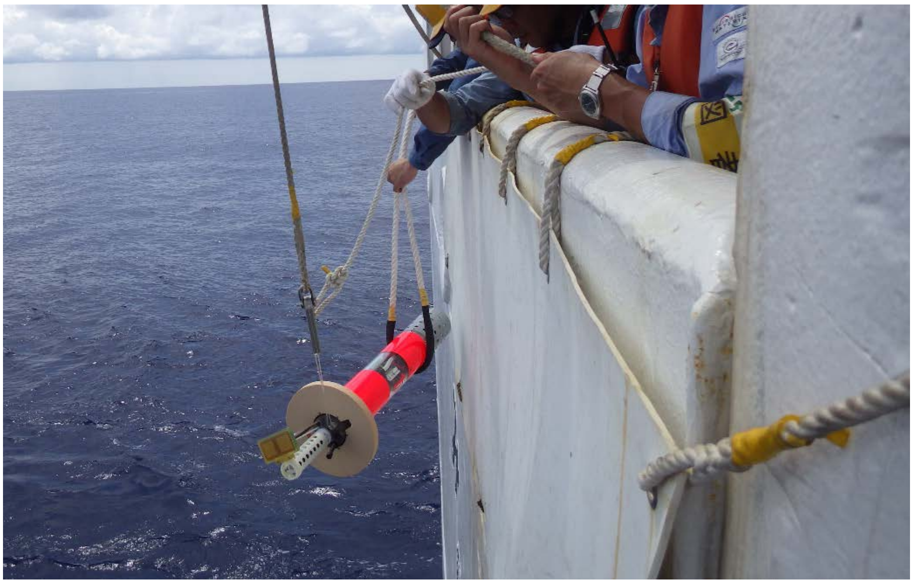


Fig 5.3-1: Photo at the deployment

(4) Preliminary result

The water temperature (Fig. 5.3-2), electric conductivity (Fig. 5.3-3) and salinity (Fig. 5.3-4) data obtained by this observation are shown below. The blue line shows the value of the SBE - 9 Plus sensor mounted on the mirror and the red line shows the observed value at the MOF.

Figure 5.3-5 shows the transition of the driving time of the motor for 13 days. Figure 5.3-6 shows the movement of observation position of MOF 1, 2, 3, until September 3rd. From these observation results, close observations were obtained for water temperature and electrical conductivity compared with 9 Plus. However, with regard to salinity, there was a lot of noise, and it turned out that countermeasures such as synchronization of water temperature and conductivity measurement timing are necessary. In addition, some aircraft have finished observation earlier than expected, improvement of quality and improvement of observation accuracy are required. In the future, we plan to optimize the driving time of the motor and optimize the number of times of control at the time of drifting and to reduce power consumption.

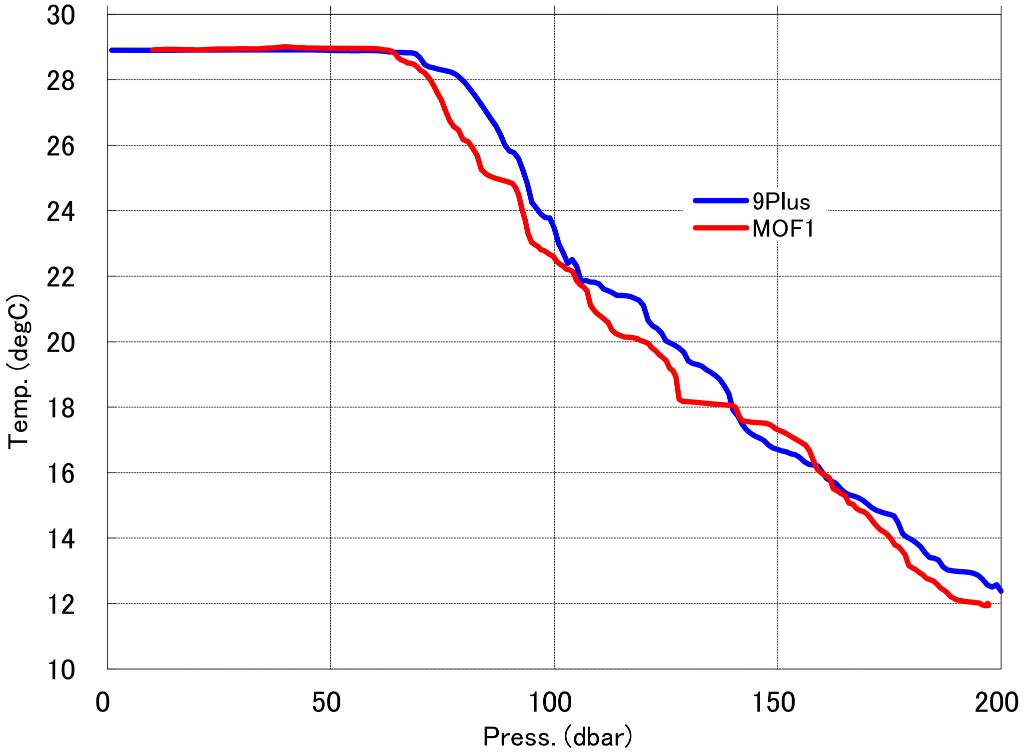


Fig. 5.3-2: Comparison of temperature observations

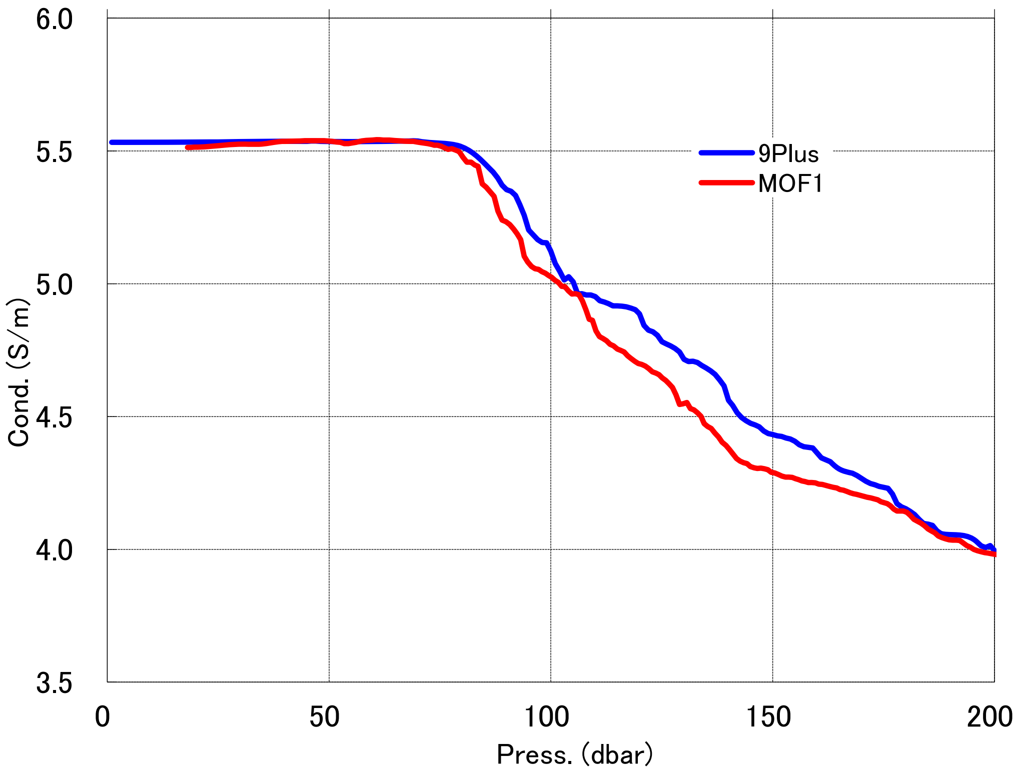


Fig. 5.3-3: Comparison of Conductivity observations

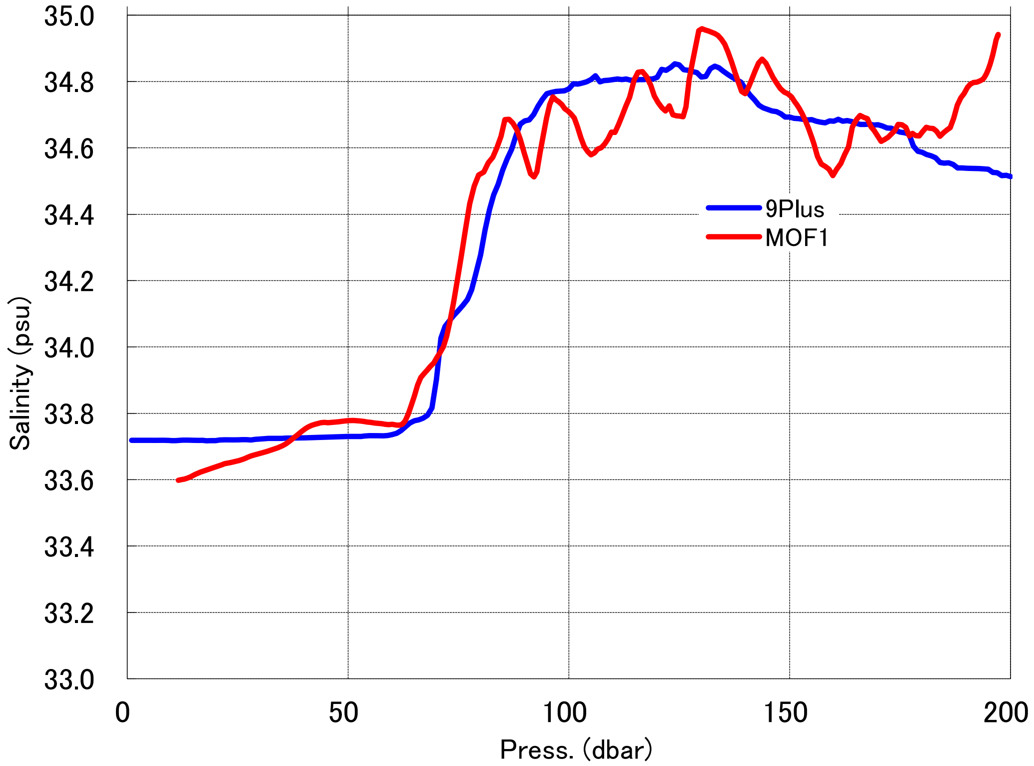


Fig. 5.3-4: Comparison of Salinity observations

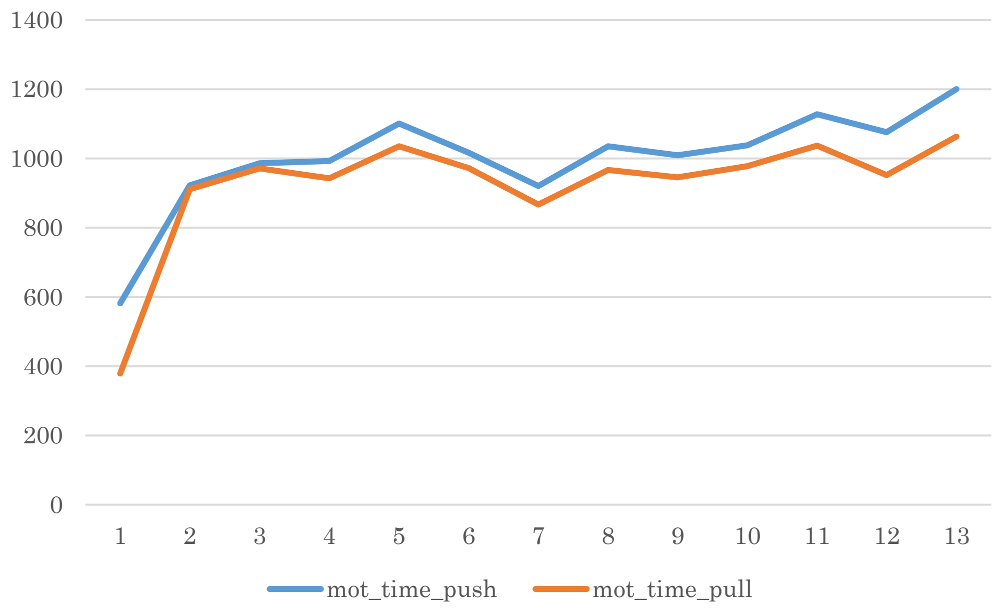


Fig. 5.3-5: Change in motor drive time

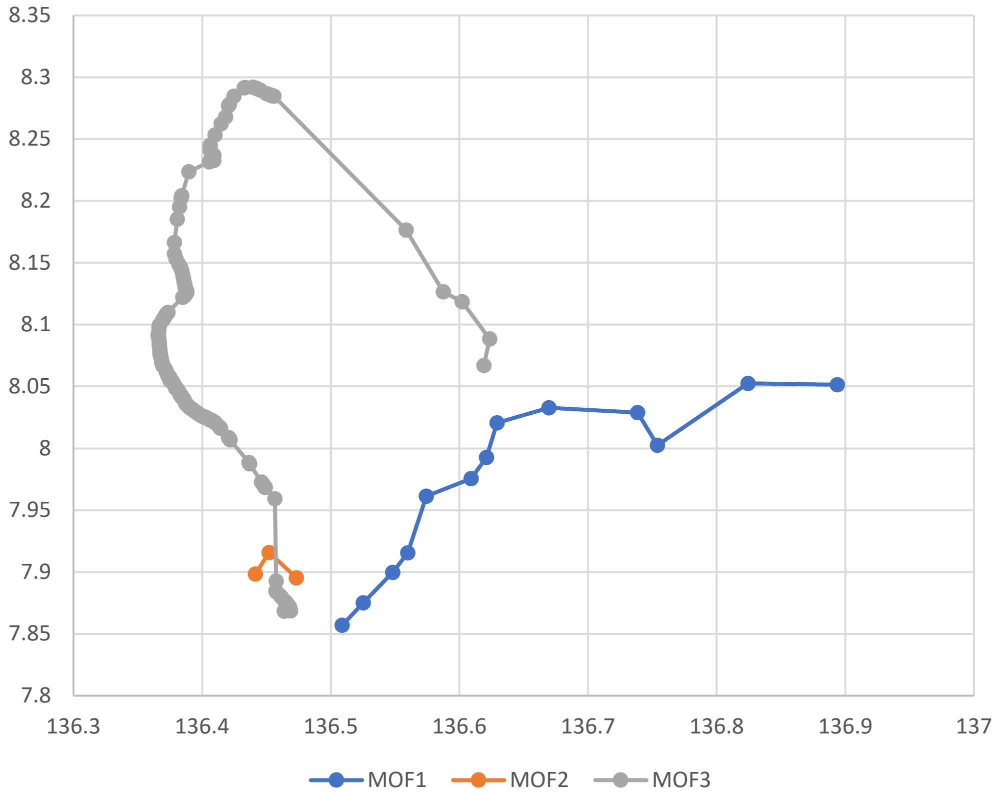


Fig. 5.3-6: Movement of observation position of MOF 1, 2, and 3, until September 3rd

(5) Data archive

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

5.4 Deep Argo floats

(1) Personnel

Shuhei Masuda	(JAMSTEC/RCGC): Principal Investigator (not on board)
Shigeki Hosoda	(JAMSTEC/RCGC): not on board
Mizue Hirano	(JAMSTEC/RCGC): not on board
Kenichi Katayama	(MWJ): Technical Staff (Operation Leader)

(2) Objectives

The objective of this study is to clarify and understand mechanisms of climate and oceanic environment variability and to improve their long-term forecasts of climate changes, monitoring heat and material transports in the global ocean. To achieve the objective, automatically long-term ocean observation buoys, named Argo float” with physical and/or biogeochemical sensors, are deployed in the global ocean, obtaining a large amount of 3-D ocean observational data. In this cruise, one deep Argo float was deployed at the mooring station T3 in the North Pacific Ocean where a part of deep western boundary current flows northward. The deep Argo float is expected to detect seasonal and inter-annual variability of changes in deep ocean environment, circulation and water mass below 2000m depth with temporally more frequent data.

The deep Argo float measures vertical profiles of temperature, salinity and dissolved oxygen down to a depth of 6000dbar every 3-15 days for a few years. Quality control of the sensors are not yet fixed because of higher quality requirement (±0.001ºC, for temperature, ±0.002 for absolute salinity and ±3dbar for pressure). To validate those sensor output with shipboard CTD data at T3 station, the float data will be able to improve their quality to be satisfied with the required deep Argo quality. Also, the information of validation will contribute to fix the method on deep Argo quality control, discussing in international Argo community.

The deep Argo float data will also apply to the ESTOC, which is 4D-VAR data assimilation system to estimate state of global ocean for climate changes, to investigate whole mechanism of long-term changes in the ocean. As deep oceanic data is now very limited in the global ocean, it is expected to improve estimate state of ESTOC with those deep Argo data.

(3) Parameters

Water temperature, conductivity (salinity), pressure, dissolved oxygen.

(4) Methods

i. Profiling float deployment for Deep Argo

We also launched Deep float (Optode Deep APEX) manufactured by Teledyne Webb Research. This float equips SBE61 CTD for deep sensor manufactured by Sea-Bird Electronics Inc. and Optode dissolved oxygen sensor by AANDERAA (Optode4831).

The float drifts at a depth of 4000 dbar (called the parking depth) during waiting measurement, then goes upward from a depth of 6000 dbar to the sea surface every 10 days. During the ascent, physical and biogeochemical values are measured at decided depths in advance following depth table. During surfacing for approximately half an hour, the float sends the all measured data to the land via through the Iridium Rudics service. Those float observation cycle will be continuously conducted for about one year. The status of float and its launching information is shown in Table 5.4.1.

Table 5.4.1 Status of floats and their launches of DeepFloats

DeepFloat (Optode Deep APEX)

Float Type	DeepAPEX Teledyne Webb Research
CTD sensor	SBE61 for Deep manufactured by Sea-Bird Electronics Inc.
Oxygen sensor	Optpde 4831 for manufactured by AANDERAA
Cycle	10 days (approximately 30minutes at the sea surface)
Iridium transmit type	RUDICS Data Service
Target Parking Pressure	4000 dbar
Sampling layers	5dbar interval from 6000 dbar to surface (approximately 1200 layers)

Launches

Float S/N	WMOID	Date and Time of Launch(UTC)	Location of Launch	CTD St. No.
30	5905223	2018/8/25 05:46	13-08.32[N] 136-53.08[E]	T3

(5) Data archive

The Argo float data with real-time quality control are provided to meteorological organizations, research institutes, and universities via Global Data Assembly Center (GDAC: http://www.usgodae.org/argo/argo.html, http://www.coriolis.eu.org/) and Global Telecommunication System (GTS) within 24 hours following the procedure decided by Argo data management team. Delayed mode quality control is conducted for the float data within 6 months ~ 1 year, to satisfy their data accuracy for the use of research. Those quality controlled data are freely available via internet and utilized for not only research use but also weather forecasts and other variable uses. Below figures show vertical profiles of launched Optode Deep APEX (WMO ID: 5905223) as samples.

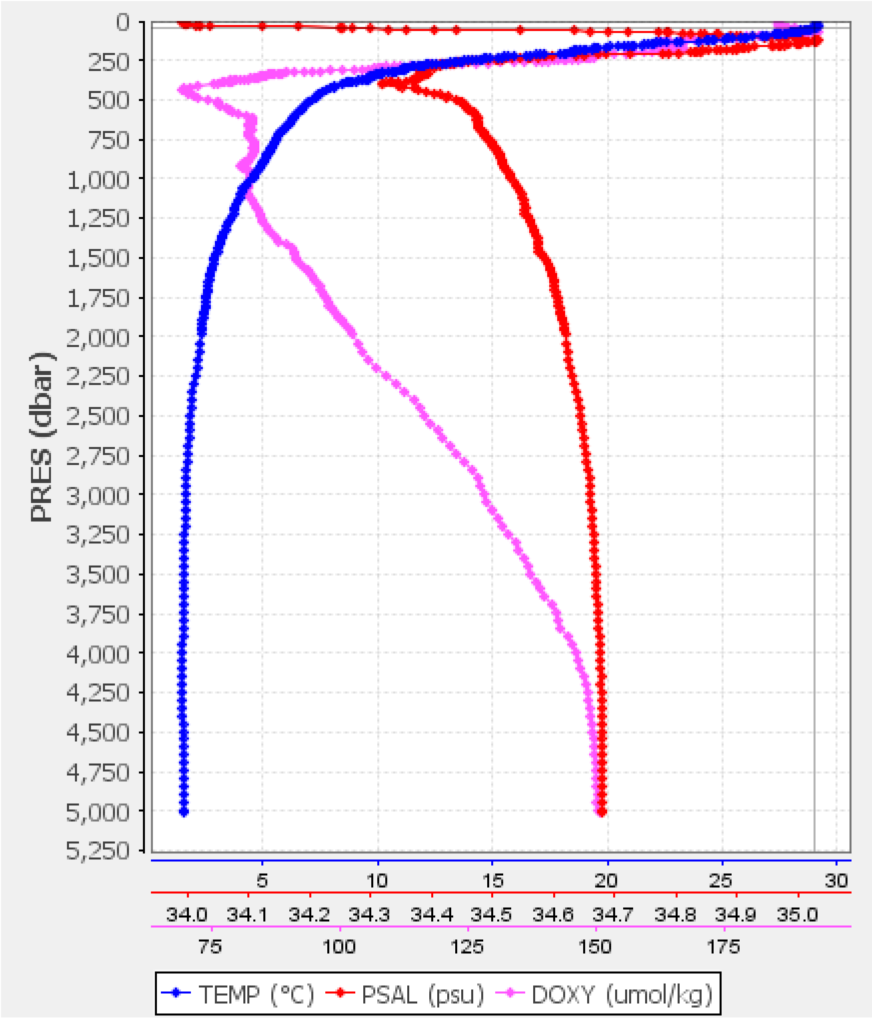


Fig. 5.1.1. Vertical profiles of first measurements on launched deep Argo float.

WMO ID: 5905223

DATE: 2018/08/25 TIME:8:34:46

POSITION: 13.137N, 136.867E

5.5 Surface drifters

(1) Personnel

Akira NAGANO	(JAMSTEC)	(not on board)
Ryuichiro INOUE	(JAMSTEC)	(not on board)
Masaki KATSUMATA	(JAMSTEC)	
Hiroshi MATSUNAGA	(MWJ)	
Keisuke TAKEDA	(MWJ)	

(2) Objectives

The objective of the deployment of the surface drifters is to examine from a Lagrangian viewpoint the modification of sea surface water from above and below the mixed layer and horizontal current structure. The drifter observations supplement the satellite altimetry observation at eastern edge of the western Pacific warm pool and in the Philippine Sea.

(3) Parameters

Temperature and salinity of sea surface water and barometric pressure

(4) Methods

Two Surface Velocity Program drifters with barometric pressure and salinity sensors (SVP-BS drifters) were deployed at the eastern edge of the western Pacific warm pool. These drifters were manufactured by Pacific Gyre (Oceanside, CA USA) and are equipped with SeaBird SBE 37 sensors to measure temperature and salinity of the sea surface water and GPS system to track location of the drifters. External appearance of a SVP-BS drifter is shown in Fig. 5.5-1. Surface float is made of ABS plastic and its diameter is 35 cm. Surface float and holy sock drogue (diameter is 122 cm) is connected with impregnated steel wire rope. The centers of the drogues are set to be located at a depth of 15 m. In addition, we deployed a similar SVP drifter (Data Buoy Instrumentation, FL USA), which measures temperature in the Philippine Sea. The measured data by these drifters are collected in Argos data system (www.argos-system.org) and are expected to be transmitted for 1 to 2 years.

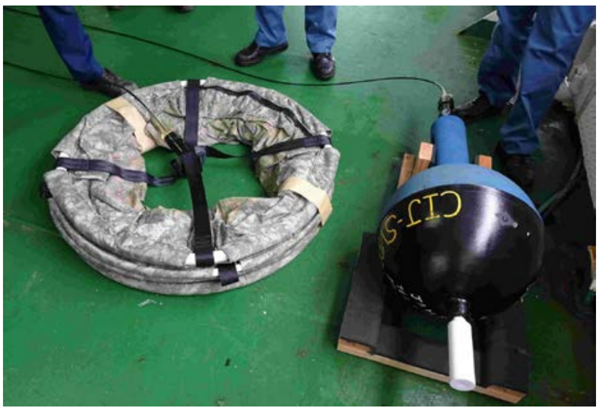


Fig. 5.5-1: External appearance of SVP-BS drifter.

(4) Preliminary Results

Locations and times of deployments are listed in Table 5.5.1.

Table. 5.5-1: Locations and times of SVP and SVP-BS drifters.

Drifter S/N	Date	Time (UTC)	Latitude	Longitude
CIJ-SVPBS-0001	Aug 13, 2018	06:05	6˚ 36.76’ N	152˚ 28.27’ E
CIJ-SVPBS-0002	Aug 13, 2018	06:18	6˚ 35.68’ N	152˚ 28.88’ E
145578	Aug 29, 2018	13:00	17˚7.42’N	137˚52.02’E

(5) Data archive

Data were sent to the world oceanographical and meteorological communities via Global Telecommunication System (GTS) through the Japan Meteorological Agency, immediately after each observation. These raw datasets will be submitted to JAMSTEC Data Management Group (DMG). The corrected datasets will be available from Mirai website (http://www.jamstec.go.jp/cruisedata/mirai/e/).

5.6 Surface drifters for near-surface stratification

(1) Personnel

Masaki Katsumata	(JAMSTEC)	
Gilles Reverdin	(LOCEAN)	(not on board)
Alexsandre Supply	(LOCEAN)	(not on board)
Dimitry Khvorostyanov	(LOCEAN)	(not on board)
Antonio Lourenço	(LOCEAN)	(not on board)
Hugo Bellenger	(CNRS)	(not on board)
Keisuke TAKEDA	(MWJ)	
Hiroshi MATSUNAGA	(MWJ)	

(2) Objective

The oceanic near-surface layer is critical to dominate the (latent and sensible) heat flux to the atmosphere, while the layer is severely affected by the atmospheric processes. To investigate the very detailed spatiotemporal structure of the near-surface layer and its relationship to the ocean-atmosphere processes, we deployed multiple set of the drifter buoys, which are capable to retrieve the stratification within top half meters layer with very high temporal resolutions (seconds to minutes).

(3) Instrumentation

(3-1) Surpact

The Surpact (manufactured by SMRU), is a small drifter buoy. It is designed to have the sensor for water temperature and conductivity at 5-cm depth. The vertical acceleration is also measured to estimate the wave height. In addition, the multi-frequency microphone is also equipped to estimate the rainfall. As well as the GNSS-measured location, obtained data can be stored within the buoy, or be sent by Argos satellite communications. For further detail, see Reverdin et al. (2013). In "short deployment" in the present experiment, we set the sampling interval as 3 seconds, which is the shortest to fully utilize the internal memory.

(3-2) SC40 SVP drifter

The SC40 (manufactured by NKE) is a drifting buoy, with the water temperature sensor at 20-cm depth and the temperature and conductivity sensor at 36-cm depth. The data, along with the GNSS-measured location, can be sent via Iridium satellite. Through the present experiment, we set the sampling interval as 5 minutes, by choosing the shortest option

(3-3) DST-CT / DST-CTD

The DST-CT and DST-CTD (manufactured by Star-ODDI) is a micro-sized (5cm x 1.5cm) package including the sensor for water temperature and conductivity (and pressure for DST-CTD), battery, memory and controlling microprocessor inside the waterproof housing. In the present experiment, we put these sensors to the CARTHE drifter at plural depths. To obtain the detailed spatiotemporal structure, the sampling interval is set as 5 seconds, which is the shortest to fully utilize the internal memory.

(3-4) CARTHE

The CARTHE (manufactured by Pacific Gyre) is a small drifter buoy to provide just the location. It consist of surface buoy and drogue. The vertical length of the drogue panel is 38 cm, while the top of the drogue is at 25 cm depth.

(4) Methods

(4-1) Short deployment

On the "short deployment" experiment, we deployed the drifters for 4 days during the period when Mirai stayed around (13N, 137E). The deployed drifters are grouped to two, and the drifters in each group are tied by 8-m floating line. Each group are shown in Fig. 5.6-1.

Set 1 includes one SC40 SVP drifter with a CARTHE drogue, which locates between 0.6 to 1.0 meters depths. It is attached with a 8-m long floating line to a SURPACT drifter. The Surpact itself was also attached with a 8-m long floating-line to a CARTHE (PacificGyre) with a drogue. The drogue equipped DST-CT and DST-CTD at the top and at the bottom of the drogue, which are equivalent to 28-cm and 61-cm depths. The Surpact was set to obtain data every 3 seconds to store the data inside the drifter.

Set 2 includes one SC40 SVP drifter without drogue. It is attached with a 8-m long floating line to a CARTHE (PacificGyre) with a drogue. The drogue equipped DST-CT and DST-CTD at the top and at the bottom of the drogue, as same as Set 1. In addition, a DST-CTD was attached to the CARTHE float. The depth of this DST-CTD is equivalent to 3 cm. No Surpact was attached for this set.

Both sets were deployed at (13.08N, 137.08E) at 2100UTC on August 24. Set 1 was recovered at (12.79N, 136.47E) at 0535UTC on August 28, while Set 2 was recovered at (12.80N, 136.42E) at 0615UTC on August 28.

After the recovery, all sensors (and RINKO profiler, see Section 5.26) were put in a same bath, filled by seawater for 2 hours, from 0632UTC to 0838UTC on August 28, for the intercomparison.

(4-2) Long deployment

On the "long deployment" experiment, we deployed the drifters at (17.46N, 137.87E), at 13UTC on August 29. The deployed drifters are as follows: One SC40, which tied to Surpact by a 8-m floating line; One SC40; Three CARTHE. Two SC40's are equipped its original drogue, which length is 5 m and centered at 15-m depths.

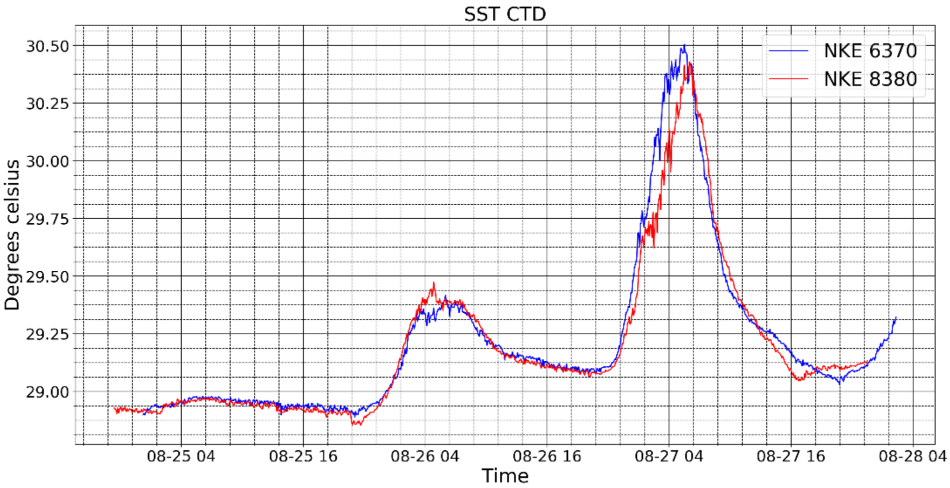
(5) Preliminary Results

During the short deployment, the conditions encountered were the rise of temperature, in particular with a large diurnal cycle on the 27th. Five moderate to small rain events were sampled by SC40s, in particular in Set 1 (with Surpact), as in Fig. 5.6-2. On the other hand, the larger number of the salinity drop was captured by Surpact, as in Fig. 5.6-3. Data quality control and further analyses will be after the cruise.

(6) Data Archive

All data obtained during this cruise will be submitted to the JAMSTEC Data Management Group (DMG), as well as will be archived in LOCEAN, France.

Fig. 5.6-1: The instruments used in the short deployment. Upper panel is for Set 1, consisted of (left) SC40 with CARTHE drogue, (center) Surpact, and (right) CARTHE with DST-CT/CTD. Lower panel for Set 2, consisted of (left) SC40 and (right) CARTHE with DST-CT/CTD.



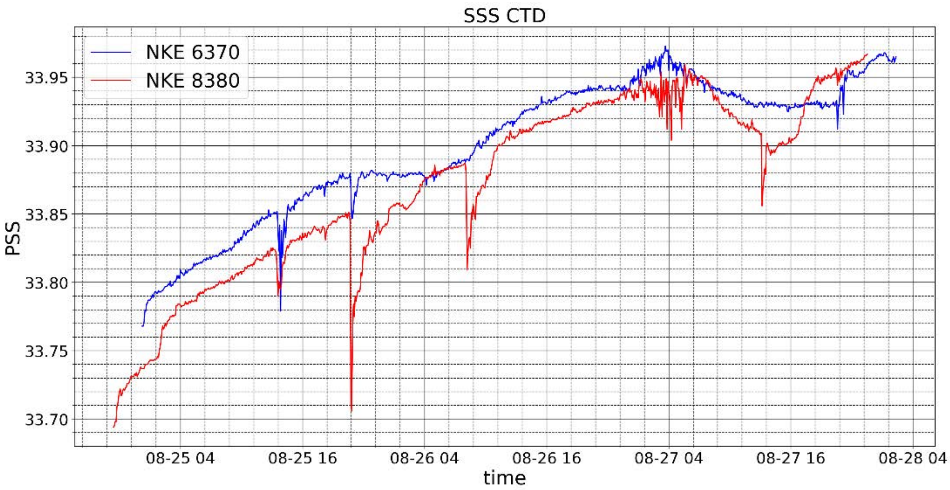


Figure 5.6-2: Time series of the parameters observed by SC40's at 36-cm depth during the short deployment. Upper panel is for temperature, while lower panel is for salinity. Red line is for Set 1 (with Surpact), while blue line is for Set 2 (without Surpact). The salinity data are adjusted by using the data during bathing after the deployment.

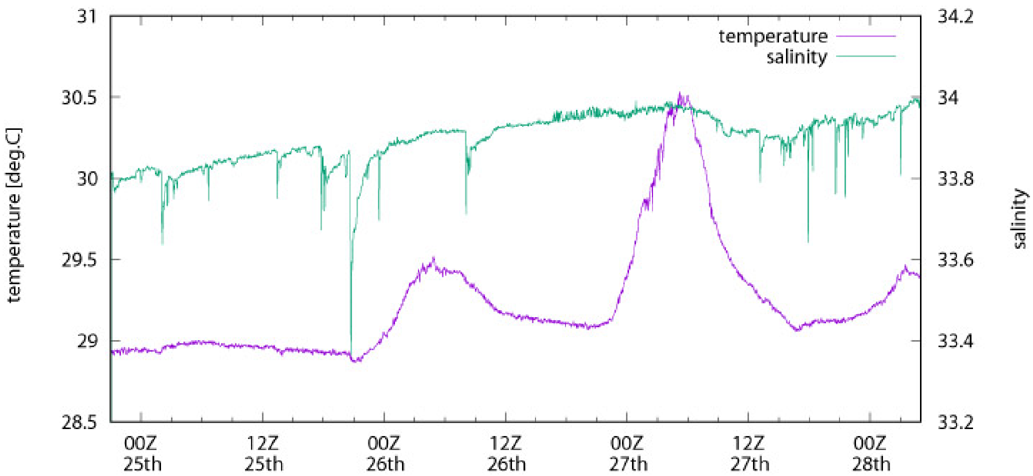


Figure 5.6-3: Time series of the parameters observed by Surpact.

5.7 GPS radiosonde

(1) Personnel

Masaki KATSUMATA	(JAMSTEC)	Principal Investigator
Biao GENG	(JAMSTEC)	
Kyoko TANIGUCHI	(JAMSTEC)	
Kazuki TSUJI	(JAMSTEC)	
Kazuho YOSHIDA	(NME)	Operation Leader
Shinya OKUMURA	(NME)	
Yutaro MURAKAMI	(NME)	
Takehito HATTORI	(MIRAI Crew)	

(2) Objectives

The objective of radiosonde observations is to obtain the atmospheric profiles of temperature, humidity, and wind speed/direction, and their temporal and special variations over the tropical ocean.

(3) Operational methodology

The Vaisala GPS radiosonde sensor (RS41-SGP) was used for the radiosonde observations. The on-board radiosonde system consists of sounding processing system (SPS-311), ground check device (RI41), processing and recording software (MW41), GPS antenna (GA20), UHF antenna (RB21), and automatic balloon launcher (ASAP). The radiosonde sensor was launched with the balloon (TA-200) usually via the automatic balloon launcher. In case the relative wind to the ship was not appropriate for the automatic launching, the radiosonde equipped balloon was launched manually.

(4) Data and preliminary results

The radiosonde observations were conducted from 0000 UTC 14 August to 0000 UTC 2 September 2018. During this period, 90 radiosonde equipped balloons have been launched (Table 5.7-1).

Figure 5.7-1 shows the time-height cross sections for temperature, water vapor mixing ratio, zonal and meridional wind speeds. In Appendix-A, vertical profiles of temperature, dew-point temperature, and wind bars constructed from each sounding are shown.

(5) Data archive

The radiosonde data were sent to the world meteorological community via Global Telecommunication System (GTS) through the Japan Meteorological Agency, after each observation. Raw data are recorded in Vaisala original binary format. The ASCII data are also available. These datasets will be submitted to JAMSTEC Data Integration and Analyses Group.

Table 5.7-1: Radiosonde launch log

ID	SN	Date YYYYMMDDhh	Location Lat. degN	Lon. degE	Surface Values P hPa	T degC	RH %	WD deg	WS m/s	Min. P hPa	Max. Height m
RS001	N5230153	2018081400	3.479	154.219	1007.5	28.3	82	271	3.6	42.1	21793
RS002	N5230166	2018081406	2.473	154.761	1005.2	28.1	77	190	6.3	20.9	26183
RS003	N5230130	2018081412	1.384	155.308	1007.1	29.0	76	200	11.8	25.8	24852
RS004	P0150689	2018081418	0.490	155.776	1005.5	27.2	87	179	12.6	27.6	24377
RS005	P2320194	2018081500	0.042	156.054	1006.8	28.8	77	185	8.4	20.3	26418
RS006	P2320168	2018081506	0.001	156.042	1004.3	26.6	80	231	8.9	26.8	24554
RS007	P2320193	2018081512	0.037	155.994	1006.7	26.2	92	46	2.1	26.7	24596
RS008	P2320165	2018081518	0.025	155.957	1004.6	28.0	80	354	7.6	26.3	24659
RS009	P2320196	2018081600	-0.016	155.964	1006.4	28.2	80	319	7.5	20.8	26255
RS010	P2320195	2018081606	0.002	156.105	1004.2	28.8	77	315	6.6	23.6	25393
RS011	P2320167	2018081612	-0.037	156.128	1007.9	26.2	82	97	1.0	40.0	22041
RS012	P2320275	2018081618	-0.027	156.140	1005.8	27.1	83	276	1.3	24.7	25120
RS013	P2320164	2018081700	-0.058	156.137	1008.0	26.2	85	23	8.0	40.0	22044
RS014	P2320198	2018081706	-0.039	156.139	1004.6	26.6	78	38	8.0	20.1	26462
RS015	P2320163	2018081712	0.325	155.376	1008.2	28.3	72	57	4.1	20.1	26481
RS016	P2320282	2018081718	0.730	154.361	1006.0	28.2	79	58	2.6	22.8	25660
RS017	P2320286	2018081800	1.144	153.281	1008.9	28.8	75	162	4.9	27.3	24474
RS018	P2320166	2018081812	1.994	151.069	1008.7	28.0	81	107	2.9	21.1	26215
RS019	P2320276	2018081818	2.427	150.010	1006.7	28.4	77	89	5.3	22.2	25820
RS020	P2320278	2018081900	2.881	148.969	1009.0	28.3	79	148	2.9	29.0	24121
RS021	N5230142	2018081912	3.996	146.917	1008.7	28.7	79	161	3.4	32.2	23415
RS022	N5230143	2018081918	4.580	145.881	1006.5	28.3	78	130	3.8	20.3	26454
RS023	P0150135	2018082000	5.105	144.789	1008.6	28.5	77	199	5.0	22.4	25775
RS024	N5230179	2018082012	5.939	142.538	1007.8	29.0	77	212	7.7	22.9	25664
RS025	N5230154	2018082018	6.316	141.378	1006.0	28.4	80	207	4.2	20.5	26368
RS026	N5230136	2018082100	6.700	140.165	1008.1	28.8	80	216	6.5	22.9	25646
RS027	N5230140	2018082106	7.023	138.044	1005.1	28.7	80	215	5.1	26.1	24721
RS028	N5230127	2018082112	7.347	137.953	1007.5	27.3	85	190	7.9	27.9	24392
RS029	N5230155	2018082118	7.599	136.979	1006.0	28.3	82	216	5.7	26.9	24589
RS030	P2320281	2018082200	7.689	136.731	1008.3	28.6	77	213	4.8	22.3	25838
RS031	N5230102	2018082206	7.645	136.714	1005.9	28.8	76	226	3.5	22.7	25692
RS032	N5230128	2018082212	7.888	136.500	1009.0	28.2	77	217	2.8	24.0	25373
RS033	N5230134	2018082218	7.885	136.501	1006.7	27.6	77	313	2.8	26.7	24614
RS034	N5230175	2018082300	7.863	136.507	1009.3	27.9	82	39	2.5	32.0	23507

RS035	N5230177	2018082306	7.902	136.448	1007.1	28.3	75	19	3.4	20.2	26438
RS036	N5230129	2018082312	9.050	136.562	1009.4	27.1	86	339	6.8	26.8	24636
RS037	N5230178	2018082318	10.237	136.678	1007.5	27.4	81	17	4.0	23.3	25548
RS038	N5230145	2018082400	11.464	136.742	1009.0	28.0	84	18	4.4	25.3	25024
RS039	N5230186	2018082406	12.707	136.856	1006.8	28.8	77	76	6.1	30.4	23848
RS040	P2320271	2018082412	13.128	136.942	1009.2	26.0	92	144	5.2	57.9	19835
RS041	P2320279	2018082415	13.135	136.941	1008.4	26.9	79	152	2.6	29.1	24176
RS042	P2320274	2018082418	13.121	136.936	1006.8	27.2	79	113	0.7	24.2	25302
RS043	P2320347	2018082421	13.085	137.085	1007.5	27.4	80	224	4.3	24.4	25234
RS044	P2320197	2018082500	13.162	136.808	1008.3	27.7	77	115	2.3	24.7	25171
RS045	P2320273	2018082503	13.133	136.869	1008.3	27.2	82	81	8.0	24.6	25191
RS046	P2320345	2018082506	13.127	136.933	1006.2	26.9	81	104	4.6	23.4	25484
RS047	P2320348	2018082509	13.152	136.898	1006.9	27.0	85	89	5.8	27.5	24465
RS048	P2320272	2018082512	13.140	136.866	1008.9	27.6	84	107	4.7	29.1	24124
RS049	P2320343	2018082515	13.014	136.682	1009.1	27.8	83	85	5.9	21.6	26046
RS050	P2320280	2018082518	13.001	136.684	1007.6	26.4	88	72	3.8	25.4	24955
RS051	P2310618	2018082521	13.004	136.696	1008.2	27.2	83	78	5.3	40.7	22004
RS052	P2320367	2018082600	13.014	136.709	1009.4	28.5	80	115	6.8	27.2	24550
RS053	P2320346	2018082603	13.018	136.715	1008.4	28.6	79	134	6.1	19.8	26559
RS054	P2320337	2018082606	12.991	136.700	1006.9	28.7	78	116	5.8	22.6	25682
RS055	P2310882	2018082609	12.999	136.707	1007.6	28.5	79	143	3.8	23.7	25390
RS056	P2320341	2018082612	12.995	136.716	1009.3	28.2	81	130	1.0	21.2	26167
RS057	P2320342	2018082615	13.009	136.704	1009.6	28.2	81	106	1.9	22.1	25863
RS058	P2320329	2018082618	13.004	136.694	1008.3	27.7	79	141	2.2	24.2	25262
RS059	P2320302	2018082621	13.013	136.702	1009.0	27.7	83	64	0.8	24.3	25233
RS060	P2320330	2018082700	13.004	136.703	1010.1	28.3	79	60	1.8	30.4	23824
RS061	P2320328	2018082703	13.004	136.718	1009.4	28.5	76	9	2.7	24.5	25199
RS062	P2320327	2018082706	13.012	136.699	1007.9	28.7	76	5	2.8	22.0	25923
RS063	P2320326	2018082709	13.009	136.706	1007.7	28.7	74	347	6.6	24.8	25141
RS064	P2320325	2018082712	12.995	136.713	1009.4	28.5	81	347	6.3	24.9	25145
RS065	P2320371	2018082715	12.986	136.715	1009.1	28.2	81	358	5.8	28.2	24344
RS066	P2320368	2018082718	12.935	136.826	1007.1	27.9	87	11	7.0	35.9	22805
RS067	P2320369	2018082721	12.874	136.906	1007.1	28.2	84	15	9.8	21.8	25943
RS068	P2320338	2018082800	12.867	136.876	1008.1	28.8	78	32	7.7	20.9	26217
RS069	P2320291	2018082803	12.881	136.886	1007.2	28.3	82	8	7.5	19.9	26573
RS070	P2320339	2018082806	12.783	136.513	1006.0	28.8	78	2	8.1	18.2	27120
RS071	P2320340	2018082809	12.804	136.428	1006.3	28.7	74	13	7.9	22.4	25833
RS072	P2320304	201808812	12.808	136.420	1007.0	28.6	79	20	9.1	21.0	26206

RS073	N5230147	2018082818	13.729	136.711	1005.9	25.8	93	64	5.7	41.4	21910
RS074	N5230184	2018082900	14.881	137.112	1007.3	28.9	76	107	7.2	25.7	24922
RS075	N5230157	2018082906	16.004	137.406	1005.9	28.5	79	101	7.9	21.4	26109
RS076	N5230135	2018082912	17.121	137.768	1007.9	28.7	78	76	9.0	26.4	24809
RS077	N5230181	2018082918	18.268	137.995	1007.5	28.7	79	78	7.6	29.1	24193
RS078	N5230183	2018083000	19.512	138.227	1009.4	28.7	80	68	9.9	20.4	26459
RS079	N5230137	2018083006	20.493	138.475	1008.2	28.8	81	58	10.7	19.2	26850
RS080	N5230161	2018083012	21.590	138.639	1010.1	28.6	81	61	9.2	20.8	26396
RS081	N5230131	2018083018	22.733	138.882	1009.4	28.1	85	69	12.5	27.4	24597
RS082	N5230180	2018083100	23.920	139.120	1011.5	28.7	77	66	10.7	21.8	26074
RS083	N5230152	2018083106	25.092	139.338	1009.9	28.1	81	62	10.1	22.4	25909
RS084	N5230165	2018083112	26.296	139.587	1011.9	27.7	84	86	8.1	24.9	25291
RS085	N5230167	2018083118	27.473	139.868	1009.9	28.0	77	93	7.8	23.9	25548
RS086	N5230162	2018090100	28.666	140.124	1011.7	28.6	75	147	4.4	22.8	25860
RS087	N5230182	2018090106	29.834	140.378	1010.4	29.1	71	153	6.3	27.3	24702
RS088	N5230185	2018090112	30.986	140.748	1011.0	28.3	77	193	3.0	22.2	26065
RS089	P2320285	2018090118	32.202	141.187	1010.1	27.7	77	190	3.7	22.9	25851
RS090	P2320301	2018090200	33.402	141.518	1011.2	27.6	82	196	6.1	22.8	25870

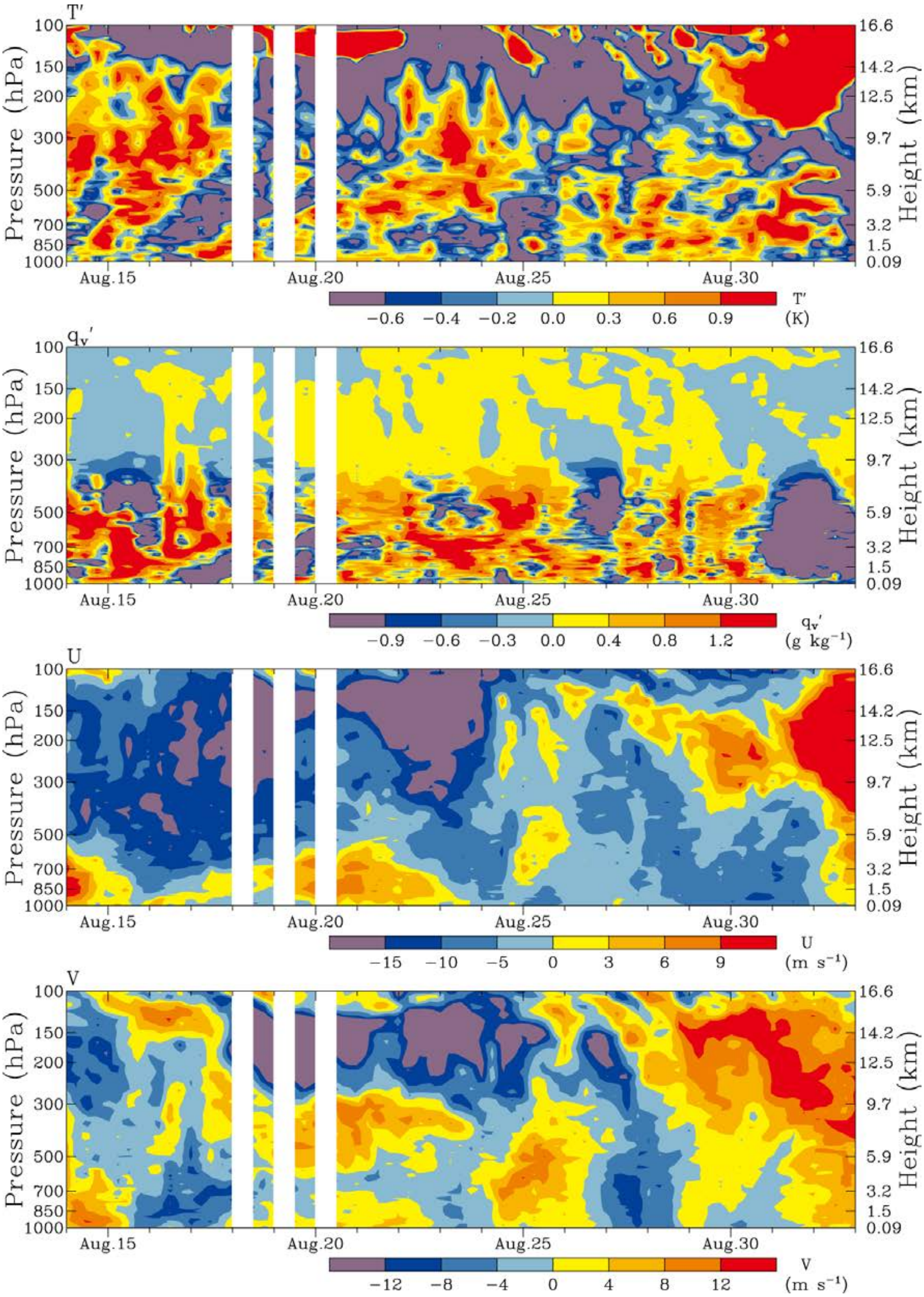


Fig. 5.7-1: Time-height cross sections constructed from the radiosonde observations for temperature anomalies (top panel), anomalies of water vapor mixing ratio (upper middle panel), zonal wind speeds (lower middle panel), and meridional wind speeds (bottom panel). The anomaly of temperature or mixing ratio at a level is defined as the deviation of temperature or mixing ratio from its mean value at that level.

5.8 GNSS precipitable water

(1) Personnel

Masaki KATSUMATA (JAMSTEC)
Mikiko FUJITA (JAMSTEC) (not on board)
Kyoko TANIGUCHI (JAMSTEC)

(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

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.

5.9 C-band Weather Radar

(1) Personnel

Biao GENG	(JAMSTEC)	Principal Investigator
Masaki KATSUMATA	(JAMSTEC)	
Kyoko TANIGUCHI	(JAMSTEC)	
Kazuki TSUJI	(JAMSTEC)	
Kazuho YOSHIDA	(NME)	Operation Leader
Shinya OKUMURA	(NME)	
Yutaro MURAKAMI	(NME)	
Takehito HATTORI	(MIRAI Crew)	

(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 on board 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 in two modes, which are shown in Tables 5.9-1 and 5.9-2, respectively. Mode 1 was operated usually. Mode 2 was operated when a dual-Doppler radar observation was performed together with the research vessel Thomas G. Thompson at around (13N, 137E). 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 from 0400 UTC 13 August to 2230 UTC 1 September 2018, using Mode 1. Among the period, the dual-Doppler radar observation using Mode 2 was conducted from 1000 UTC 24 August to 0130 UTC 29 August 2018.

Figure 5.9-1 shows a time series of the areal coverage of radar echoes. In Figs. 5.9-2 and 5.9-3, the time-height cross sections constructed from the radar observations for the areal coverages of radar reflectivity (Z) and specific differential phase (K_{DP}) are shown, respectively.

(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 5.9-1 Parameters for scans in mode 1

	Survei-llance 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

Table 5.9-2 Parameters for scans in mode 2

<table>
<tr><th></th><th>Survei-llance PPI Scan</th><th colspan="6">Volume Scan</th><th>RHI Scan</th><th>Vertical Point Scan</th></tr>
<tr><td>Repeated Cycle (min.)</td><td>30</td><td colspan="6">7.5</td><td colspan="2">7.5</td></tr>
<tr><td>Times in One Cycle</td><td>1</td><td colspan="6">1</td><td>3</td><td>2</td></tr>
<tr><td>Pulse Width (long / short, in microsec)</td><td>200 / 2</td><td colspan="2">64 / 1</td><td colspan="2">32 / 1</td><td colspan="2">32 / 1</td><td>32 / 1</td><td>32 / 1</td></tr>
<tr><td>Scan Speed (deg/sec)</td><td>18</td><td colspan="2">18</td><td colspan="2">24</td><td colspan="2">36</td><td>9</td><td>36</td></tr>
<tr><td rowspan="2">PRF(s) (Hz)</td><td rowspan="2">400</td><td colspan="6">dual PRF (ray alternative)</td><td rowspan="2">1250</td><td rowspan="2">2000</td></tr>
<tr><td>667</td><td>833</td><td>938</td><td>1250</td><td>1333</td><td>2000</td></tr>
<tr><td>Pulses / Ray</td><td>16</td><td>26</td><td>33</td><td>27</td><td>34</td><td>37</td><td>55</td><td>32</td><td>64</td></tr>
<tr><td>Ray Spacing (deg.)</td><td>0.7</td><td colspan="2">0.7</td><td colspan="2">0.7</td><td colspan="2">1.0</td><td>0.2</td><td>1.0</td></tr>
<tr><td>Azimuth (deg)</td><td colspan="7">Full Circle</td><td>Option</td><td>Full Circle</td></tr>
<tr><td>Bin Spacing (m)</td><td colspan="9">150</td></tr>
<tr><td>Max. Range (km)</td><td>300</td><td colspan="2">150</td><td colspan="2">100</td><td colspan="2">60</td><td>100</td><td>60</td></tr>
<tr><td>Elevation Angle(s) (deg.)</td><td>0.5</td><td colspan="2">0.5</td><td colspan="2">1.0, 1.8, 2.6, 3.4, 4.2, 5.0, 5.8, 6.8, 7.9, 9.2, 10.9, 13.1, 15.7</td><td colspan="2">18.6, 21.9, 25.7, 30.0, 34.6, 40.0</td><td>0.0~ 60.0</td><td>90</td></tr>
</table>

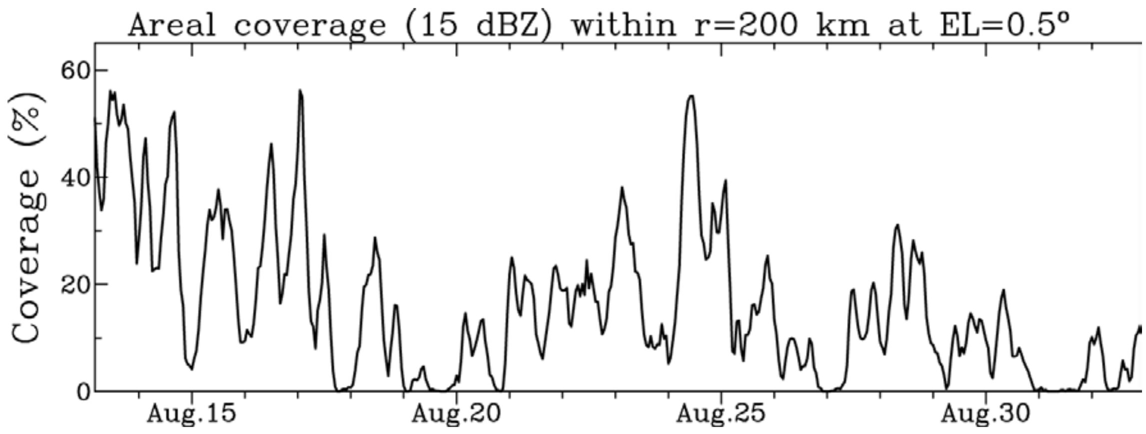


Figure 5.9-1: Time series of the areal coverage of radar echoes (≥ 15 dBZ) within a radius of 200 km from the radar.

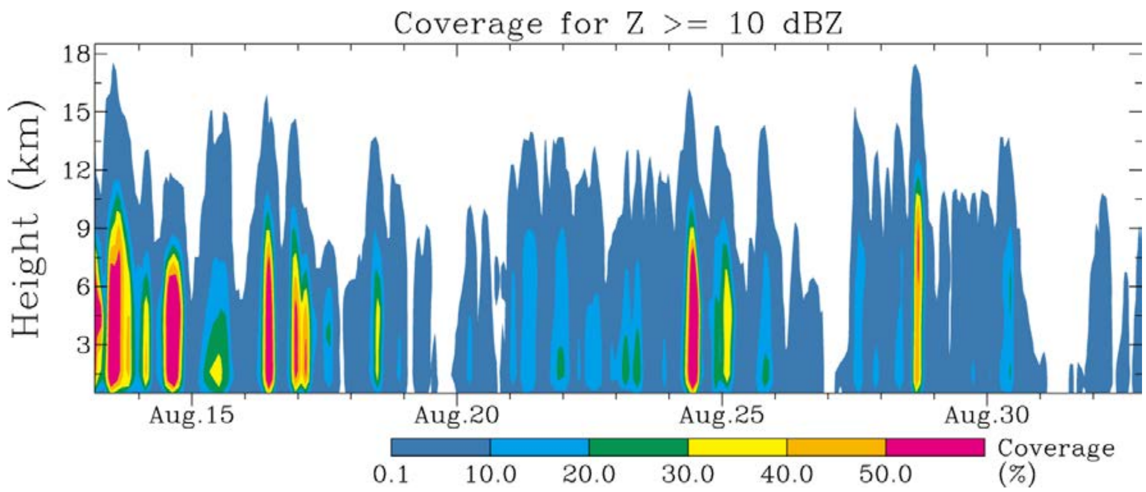


Figure 5.9-2: Time-height cross section for the areal coverage of radar echoes (≥ 10 dBZ) within a radius of 100 km from the radar.

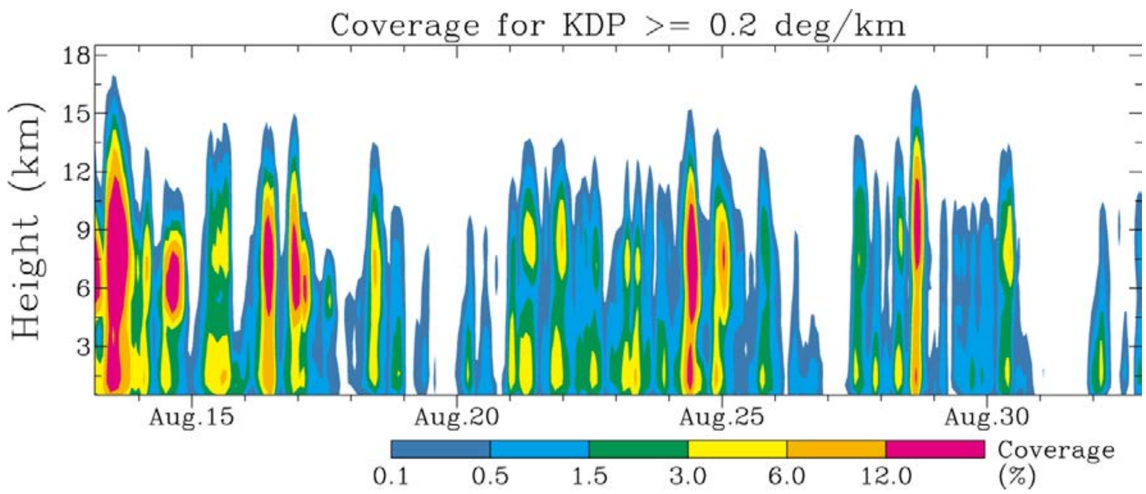


Figure 5.9-3: Time-height cross section for the areal coverage of high K_{DP} (≥ 0.2 deg/km) within a radius of 100 km from the radar.

5.10 Micro Rain Radar

(1) Personnel

Masaki KATSUMATA (JAMSTEC) - Principal Investigator
Biao GENG (JAMSTEC)
Kyoko TANIGUCHI (JAMSTEC)

(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 5.10-1. The antenna unit was installed at the starboard side of the anti-rolling systems (see Fig. 5.10-1), 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 200 meters in range distance (i.e. height) up to 6200 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. 5.10-1: Photo of the antenna unit of MRR

Table 5.10-1: 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 without permission.

Figure 5.10-2 displays an example of the time-height cross section for one day. The temporal variation reasonably corresponds to the rainfall measured by the Mirai Surface Met sensors (see Section 5.11), disdrometers (see Section 5.3), etc. The further analyses will be after the cruise.

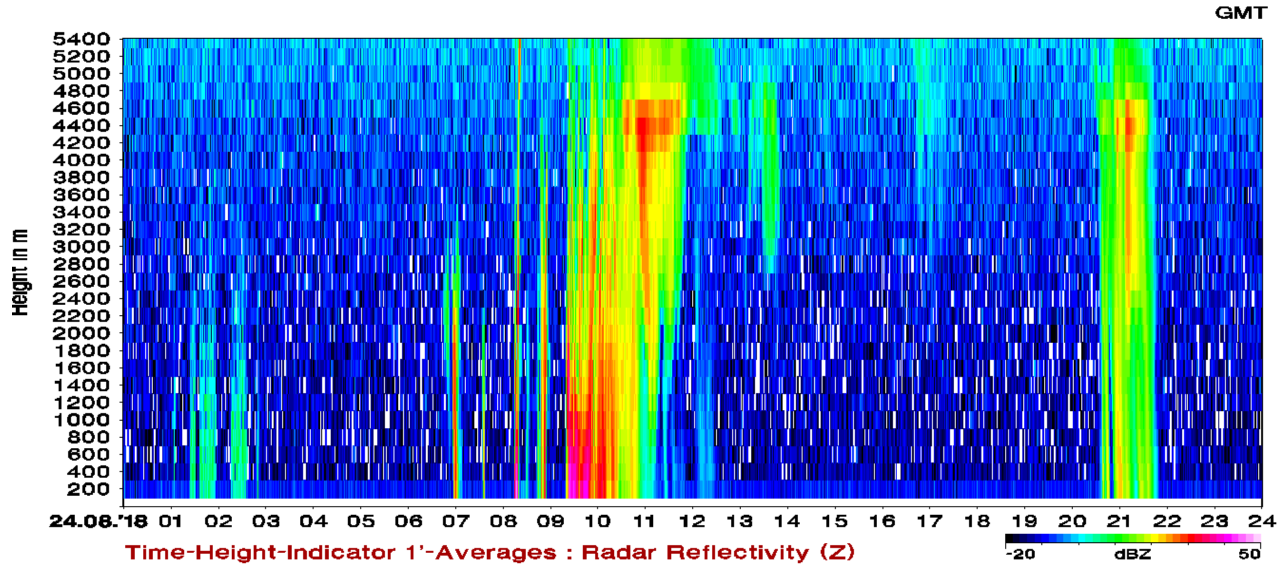


Fig. 5.10-2: An example of the time-height cross section of the radar reflectivity, for 24 hours from 00UTC on August 24.

(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).

5.11 Disdrometers

(1) Personnel

Masaki KATSUMATA	(JAMSTEC)	- Principal Investigator
Biao GENG	(JAMSTEC)	
Kyoko TANIGUCHI	(JAMSTEC)	

(2) Objectives

The disdrometer can continuously obtain size distribution of raindrops. The objective of this observation is (a) to reveal microphysical characteristics of the rainfall, depends on the type, temporal stage, etc. of the precipitating clouds, (b) to retrieve the coefficient to convert radar reflectivity (especially from C-band radar in Section 5.xx) to the rainfall amount, and (c) to validate the algorithms and the products of the satellite-borne precipitation radars; TRMM/PR and GPM/DPR.

(3) Instrumentations and Methods

Two “Laser Precipitation Monitor (LPM)” (Adolf Thies GmbH & Co) are utilized. It is an optical disdrometer. The instrument consists of the transmitter unit which emit the infrared laser, and the receiver unit which detects the intensity of the laser come thru the certain path length in the air. When a precipitating particle fall thru the laser, the received intensity of the laser is reduced. The receiver unit detect the magnitude and the duration of the reduction and then convert them onto particle size and fall speed. The sampling volume, i.e. the size of the laser beam “sheet”, is 20 mm (W) x 228 mm (D) x 0.75 mm (H).

The number of particles are categorized by the detected size and fall speed and counted every minutes. The categories are shown in Table 5.11-1.

The LPMs are installed on the top (roof) of the anti-rolling system, as shown in Fig. 5.11-1. One is installed at the corner at the bow side and the starboard side, while the other at the corner at the bow and the port side. This is to select the data from upwind side.

(4) Preliminary Results

The data have been obtained all through the cruise, except territorial waters without permission. An example of the obtained data is shown in Fig. 5.11-2. The further analyses for the rainfall amount, drop-size-distribution parameters, etc., will be carried out after the cruise.s

(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).

Fig. 5.11-1: The location of the LPM sensors, on the panorama photo looking down toward the bow (from a tower for the radome of the C-band radar). Red broken circle shows the location of LPM sensors.

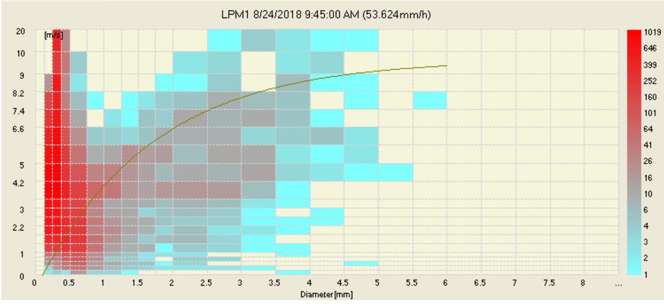


Fig. 5.11-2: An example of 1-minute raw data, obtained by LPM at 0945UTC on Aug. 24, 2018. Data is shown by two-dimensional histogram to display numbers of observed raindrops categorized by diameter (x-axis) and fall speed (y-axis).

Table 5.11-1: Categories of the particle size and the fall speed.

Particle Size		
Class	Diameter [mm]	Class width [mm]
1	≥ 0.125	0.125
2	≥ 0.250	0.125
3	≥ 0.375	0.125
4	≥ 0.500	0.250
5	≥ 0.750	0.250
6	≥ 1.000	0.250
7	≥ 1.250	0.250
8	≥ 1.500	0.250
9	≥ 1.750	0.250
10	≥ 2.000	0.500
11	≥ 2.500	0.500
12	≥ 3.000	0.500
13	≥ 3.500	0.500
14	≥ 4.000	0.500
15	≥ 4.500	0.500
16	≥ 5.000	0.500
17	≥ 5.500	0.500
18	≥ 6.000	0.500
19	≥ 6.500	0.500
20	≥ 7.000	0.500
21	≥ 7.500	0.500
22	≥ 8.000	unlimited

Fall Speed		
Class	Speed [m/s]	Class width [m/s]
1	≥ 0.000	0.200
2	≥ 0.200	0.200
3	≥ 0.400	0.200
4	≥ 0.600	0.200
5	≥ 0.800	0.200
6	≥ 1.000	0.400
7	≥ 1.400	0.400
8	≥ 1.800	0.400
9	≥ 2.200	0.400
10	≥ 2.600	0.400
11	≥ 3.000	0.800
12	≥ 3.400	0.800
13	≥ 4.200	0.800
14	≥ 5.000	0.800
15	≥ 5.800	0.800
16	≥ 6.600	0.800
17	≥ 7.400	0.800
18	≥ 8.200	0.800
19	≥ 9.000	1.000
20	≥ 10.000	10.000

5.12 Lidar

(1) Personal

Masaki KATSUMATA	(JAMSTEC)	- Principal Investigator
Kyoko TANIGUCHI	(JAMSTEC)	
Tomoaki NISHIZAWA	(NIES)	(not on board)
Atsushi SHIMIZU	(NIES)	(not on board)

(2) Objective

To capture distributions of cloud, aerosol and water vapor in high temporal and special resolutions.

(3) Instrumentation and Methods

Mirai lidar system transmits 10 Hz pulse laser in three wavelengths: 1064 nm, 532 nm, and 355 nm. The system detects backscattering at 1064 nm, 532 nm, 355 nm, depolarization at 532 nm and 355 nm to observe rain, clouds, and aerosols. The system also detects Raman water vapor (Raman shift: 3652 cm^{-1}) at 660 nm and 408nm, and Raman nitrogen (Raman shift: 3652 cm^{-1}) at 607 nm and 387 nm at night. The system offers water vapor mixing ratio profiles based on the signal ratio of Raman water vapor and nitrogen after system calibration

(4) Preliminary Results

The lidar observation period in this cruise is from 13 August 2018 to 2 September 2018 in UTC. All data will be reviewed and quality-controlled after the cruise.

Figures 5.12-1 and 5.12-2 shows an example preliminary results of 1064 nm, 532 nm and 355 nm data obtained on 17 August 2018 UTC. On the backscattering signals, (top and middle panels of Fig. 5.12-1, and top panel of Fig. 5.12-2), red-colored areas below 8 km altitude are estimated as bases of thick clouds. The green to light blue areas stretches down from the cloud bases between 3:00 and 11:00 are estimated as the precipitation. The blue-colored areas between 12- and 16-km altitudes are estimated as optically clouds. Dark blue area near the surface are estimated as the layer with high number concentration of aerosols.

Fig 5.12-2 is an example preliminary result of Raman signal ratio of water vapor and nitrogen on the same day. In the top panel of Fig. 5.12-2, dark blue area near the surface are considered as the region of water vapor amount. The temporal variation of the thickness of the layer can be also observed.

(5) Data Archive

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

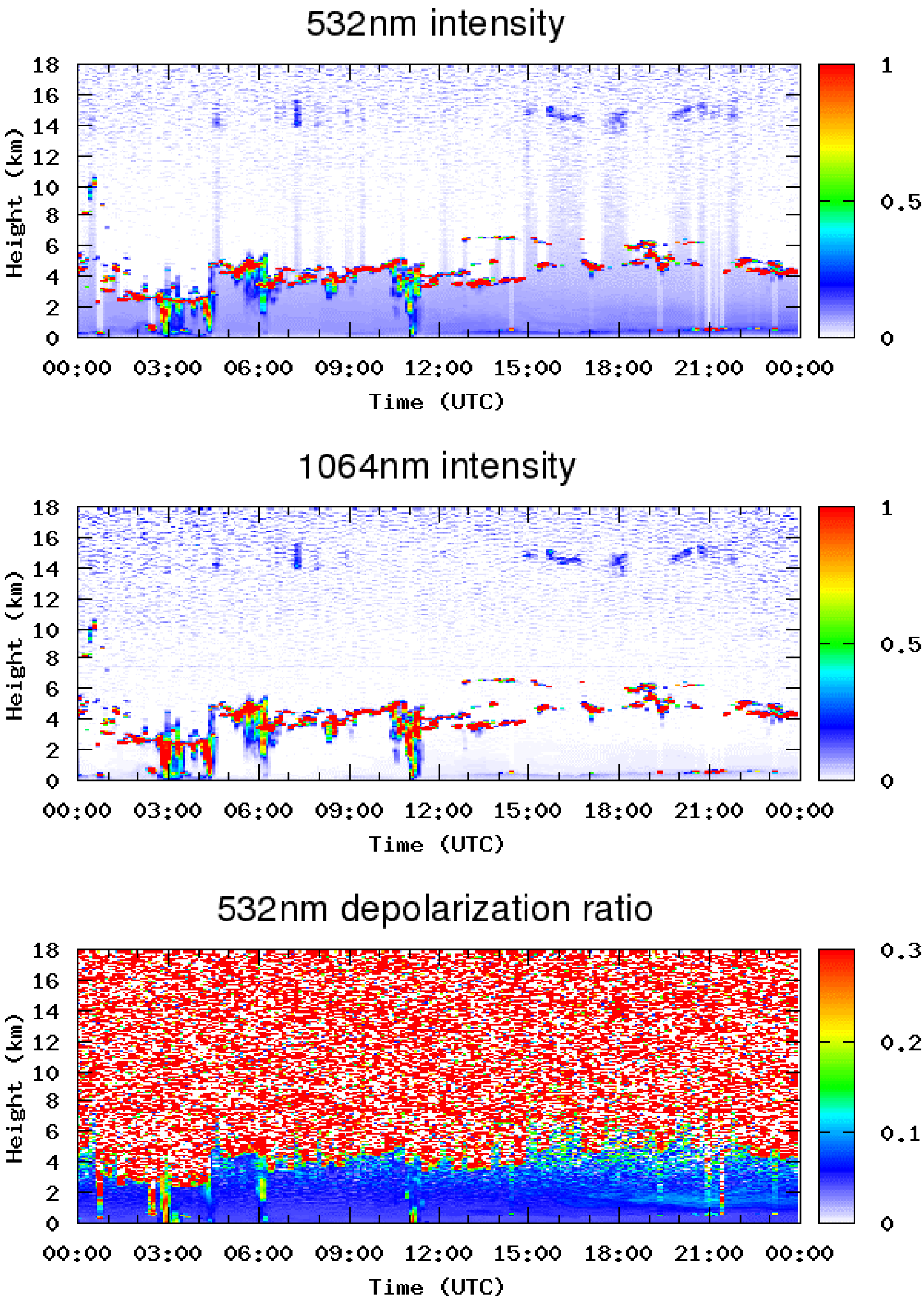


Fig 5.12-1: Preliminary results of Mie scattering obtained on 17 August 2018 UTC, for (top) 532 nm backscattering intensity, (middle) 1064nm backscattering intensity, and (bottom) 532nm depolarization ratio.

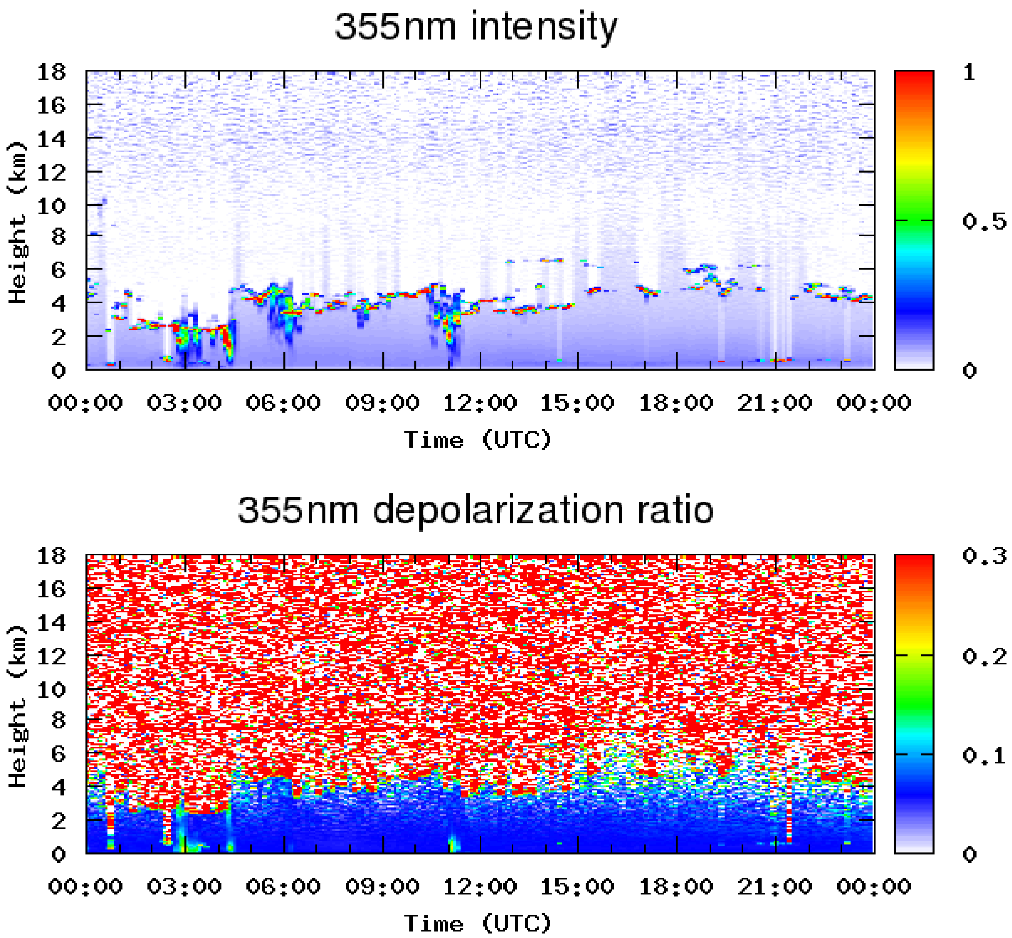


Fig 5.12-2: Same as Fig. 5-12-1, except for (top) 355nm backscattering intensity, and (bottom) 355nm depolarization ratio.

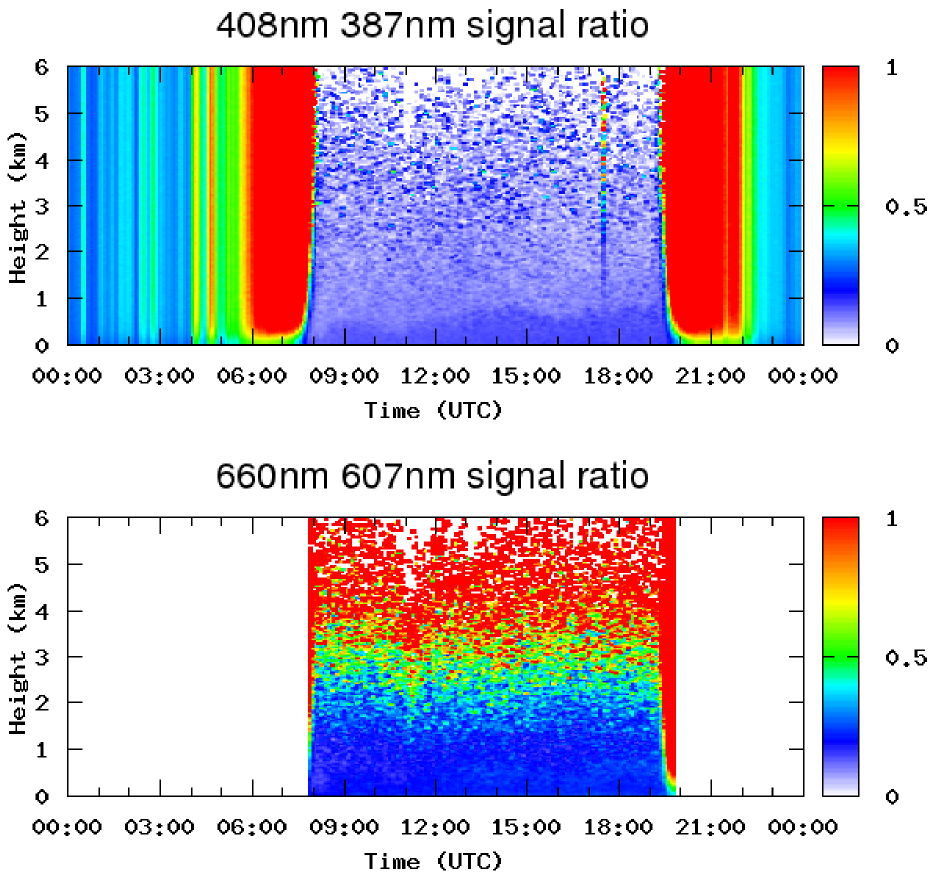


Fig. 5.12-3: Preliminary results of Raman water vapor and nitrogen signal ratio obtained nighttime on 17 August 2018 in UTC. Top panel is for 408nm and 387nm signal ratio, while bottom panel is for 660nm and 607nm signal ratio.

5.13 Ceilometer

(1) Personnel

Masaki KATSUMATA	(JAMSTEC) * Principal Investigator
Kazuho YOSHIDA	(Nippon Marine Enterprises Ltd., NME)
Shinya OKUMURA	(NME)
Yutaro MURAKAMI	(NME)
Takehito HATTORI	(MIRAI Crew)

(2) Objectives

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

(3) Parameters

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

(4) Methods

We measured cloud base height and backscatter profile using ceilometer (CL51, VAISALA, Finland) throughout the MR18-04Leg2 cruise.

Major parameters for the measurement configuration are as follows;

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

On the archive dataset, cloud base height and backscatter profile are recorded with the resolution of 10 m (33 ft).

(5) Preliminary results

Fig. 5.13-1 shows the time series plot of the lowest, second and third cloud base height during the cruise.

(6) Data archive

Ceilometer 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. Window Cleaning was performed at the following times.

   05:57UTC 21 Aug. 2018
   01:21UTC 31 Aug. 2018

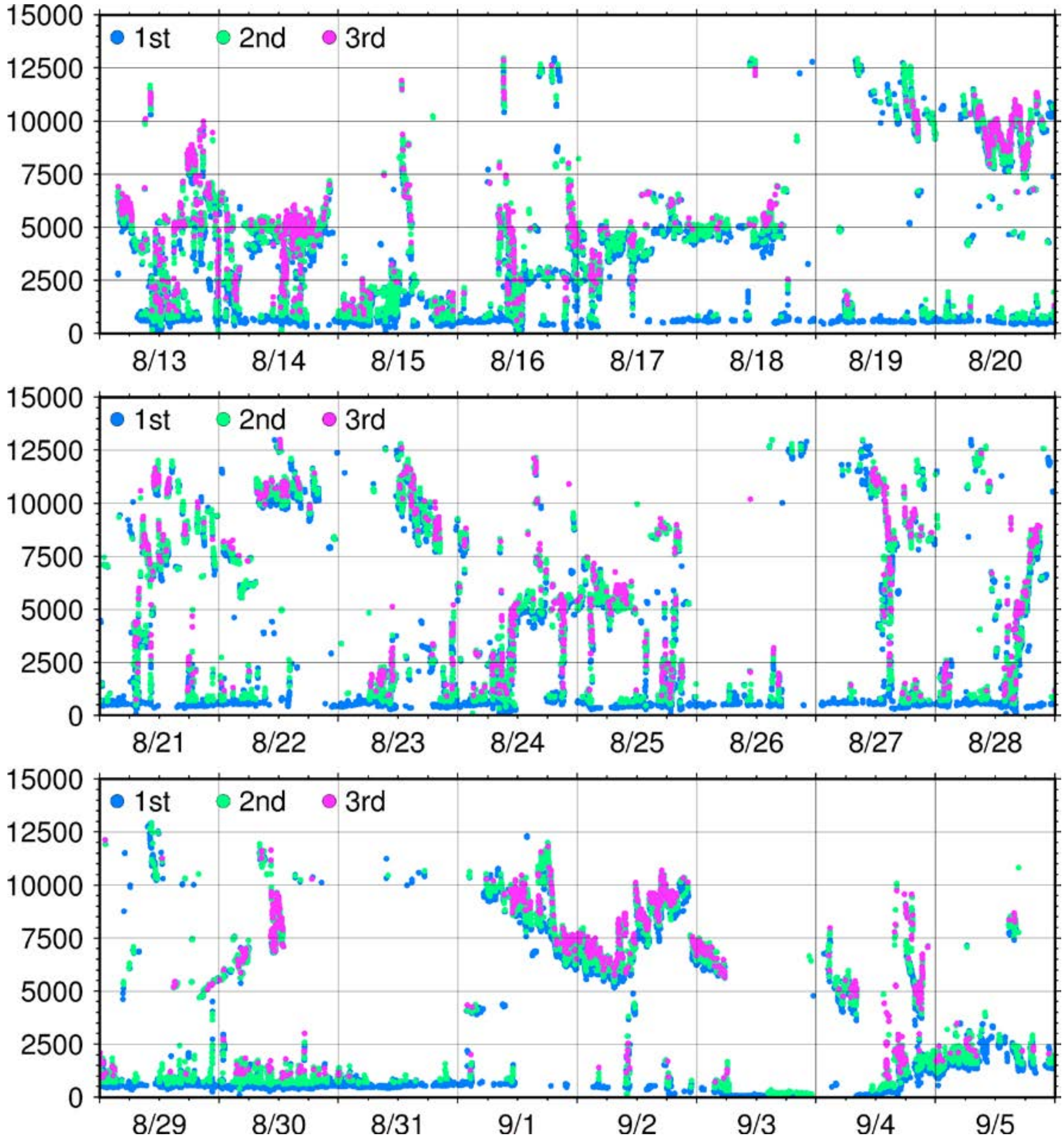


Fig. 5.13-1 First (Blue), 2nd (Green) and 3rd (Red) lowest cloud base height during the cruise.

5.14 Gas and particles observation at the marine Atmosphere

(1) Personnel

Fumikazu TAKETANI (JAMSTEC RCGC)
Yugo KANAYA (JAMSTEC RCGC)
Takuma MIYAKAWA (JAMSTEC RCGC)
Chunmao ZHU (JAMSTEC RCGC)
Takashi SEKIYA (JAMSTEC CEIST)
Kazuma AOKI (Toyama Univ.)

(2) Objective

- To investigate roles of aerosols in the marine atmosphere in relation to climate change
- To investigate contribution of the rain as a nutrients to the marine ecosystem.

(3) Parameters

- Black carbon (BC)
- Particle size distribution and number concentration
- Composition of ambient particles
- Composition of rain
- Surface ozone (O3), and carbon monoxide (CO) mixing ratios
- Aerosol optical thickness and Single scattering albedo

(4) Instruments and methods

i) Online aerosol observations

Particle number concentration and size distribution: The number concentration and size distribution of ambient particles was measured by a handheld optical particle counter (OPC) (KR-12A, Rion).
Black carbon (BC): Number and mass BC concentrations 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:YVO_4 laser operating at 1064 nm were used for detection of single particles of BC.
For SP2 instrument, 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. OPC instrument were installed at the compass deck. The ambient air was directly introduced to the instruments.

ii) Rain sampling

Rain sample was corrected using a hand-made sampler. These sampling logs are listed in Table 5.14-1. To investigate the nutrients in the rain, these samples are going to be analyzed in laboratory.

iii) CO and O_3

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

iv) Aerosol optical thickness and Single scattering albedo

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

(5) Data archive

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

Table 5.14-1: Observation Log.

UTC			Latitude(N)	Longitude(E)
8	29	16:00	18.06	137.96
8	30	0:00	19.54	138.26
9	2	8:00	34.49	141.83

5.15 Surface Meteorological Observations

(1) Personnel

Masaki KATSUMATA	(JAMSTEC) * Principal Investigator
Kazuho YOSHIDA	(Nippon Marine Enterprises Ltd., NME)
Shinya OKUMURA	(NME)
Yutaro MURAKAMI	(NME)
Takehito HATTORI	(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) Methods

Surface meteorological parameters were observed throughout the MR18-04 Leg2 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 5.15-1 and measured parameters are listed in Table 5.15-2. Data were collected and processed by KOAC-7800 weather data processor made by Koshin-Denki, Japan. The data set consists of 6-second averaged data.

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

SOAR system designed by BNL (Brookhaven National Laboratory, USA) consists of major six 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) "SeaSnake" the floating thermistor designed by BNL – skin sea surface temperature (SSST) measurement.
e) Photosynthetically Available Radiation (PAR) and Ultraviolet Irradiance (UV) sensor manufactured by Biospherical Instruments Inc (USA) – PAR and UV measurement
f) 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 5.15-3 and measured parameters are listed in Table 5.15-4.

SeaSnake has two thermistor probes and output voltage was converted to SSST by Steinhart-Hart equation with the following coefficients “a”, “b” and “c”, which were led from the calibration data.

Sensor	a	b	c
T05-005 Sensor:	8.30871E-04	-2.08096E-04	-8.39923E-08
T05-100 Sensor:	7.16729E-04	-2.23402E-04	-4.36271E-08

$y = a + b * x + c * x^{**}3$
$x = \log (1 / ((V_{ref} / V - 1) * R2 - R1))$
$T = 1 / y - 273.15$

V_{ref} = 2500[mV], R1=249000[Ω], R2=1000[Ω]
T: Temperature [degC], V: Sensor output voltage [mV]

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

iv. SeaSnake SSST (SOAR)
SeaSnake thermistor probes were calibrated by the bath equipped with SBE-3 plus, Sea-Bird Electronics, Inc.

(4) Preliminary results

Figure 5.15-1 shows the time series of the following parameters;

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

Figure 5.15-2 shows the time series of SSST compared to sea surface temperature (TSG).

(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 periods, SST data of SMET was available.
   04:30UTC 13 Aug. 2018 - 05:00UTC 03 Sep. 2018

2. The following period, SeaSnake SSST data was available.
   12:10UTC 25 Aug. 2018 - 03:05UTC 28 Aug. 2018

3. The following period. wind speed and direction of SMET contained invalid data, because the anemometer sometimes detected error.
   19:17 UTC 03 Sep. 2018 - 19:58UTC 03 Sep. 2018

Table 5.15-1: 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 with	
43408 Gill aspirated radiation shield		R.M. Young, USA	compass deck (21 m)
			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-815DS	Osi, USA	compass deck (19 m)
Radiometer (short wave)	MS-802	Eko Seiki, Japan	radar mast (28 m)
Radiometer (long wave)	MS-202	Eko Seiki, Japan	radar mast (28 m)
Wave height meter	WM-2	Tsurumi-seiki, Japan	bow (10 m)

Table 5.15-2: 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/m2	6sec. averaged
20	Down welling infra-red radiation	W/m2	6sec. averaged
21	Significant wave height (bow)	m	hourly
22	Significant wave height (aft)	m	hourly
23	Significant wave period (bow)	second	hourly
24	Significant wave period (aft)	second	hourly

Table 5.15-3: Instruments and installation locations of SOAR system

Sensors (Meteorological)	Type	Manufacturer	Location (altitude from surface)
Anemometer	05106	R.M. Young, USA	foremast (25 m)
Barometer	PTB210	Vaisala, Finland	foremast (23 m)
with 61002 Gill pressure port, R.M. Young, USA			
Rain gauge	50202	R.M. Young, USA	foremast (24 m)
Tair/RH	HMP155	Vaisala, Finland	foremast (23 m)
with 43408 Gill aspirated radiation shield R.M. Young, USA			
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 Instrum-ents Inc., USA	Navigation deck (18m)

Sensors (SeaSnake)	Type	Manufacturer	Location (altitude from surface)
Thermistor	107	Campbell Scientific, USA	bow, 5m extension (0 m)

Table 5.15-4: Parameters of SOAR system

Parameter	Units	Remarks
1 Latitude	degree	
2 Longitude	degree	
3 SOG	knot	
4 COG	degree	
5 Relative wind speed	m/s	
6 Relative wind direction	degree	
7 Barometric pressure	hPa	
8 Air temperature	degC	
9 Relative humidity	%	
10 Rain rate (optical rain gauge)	mm/hr	
11 Precipitation (capacitive rain gauge)	mm	reset at 50 mm
12 Down welling shortwave radiation	W/m2	
13 Down welling infra-red radiation	W/m2	
14 Defuse irradiance	W/m2	
15 “SeaSnake” raw data	mV	
16 SSST (SeaSnake)	degC	
17 PAR	microE/cm2/sec.	
18 UV	microW/cm2/nm	

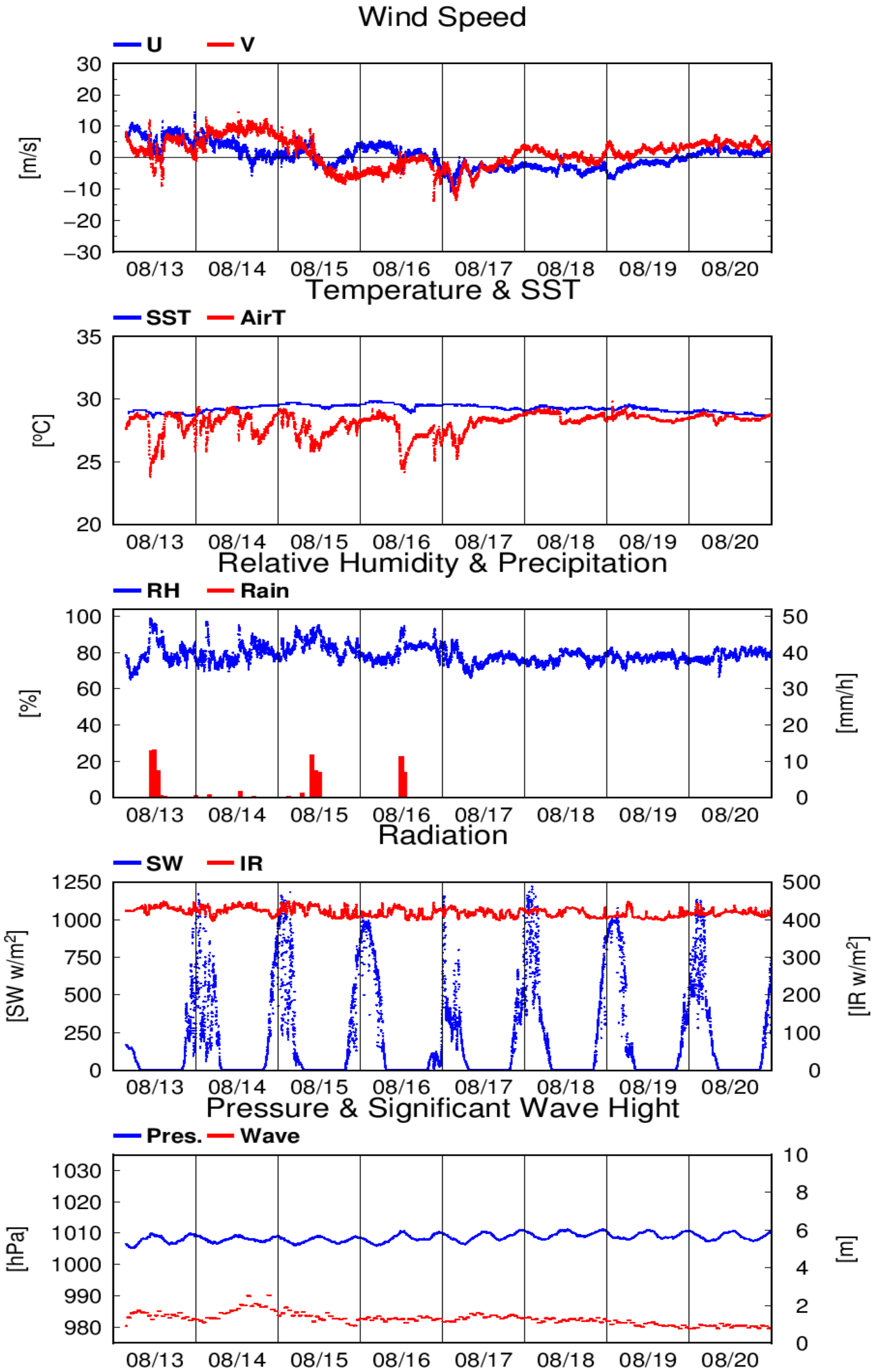


Fig. 5.15-1 Time series of surface meteorological parameters during the cruise

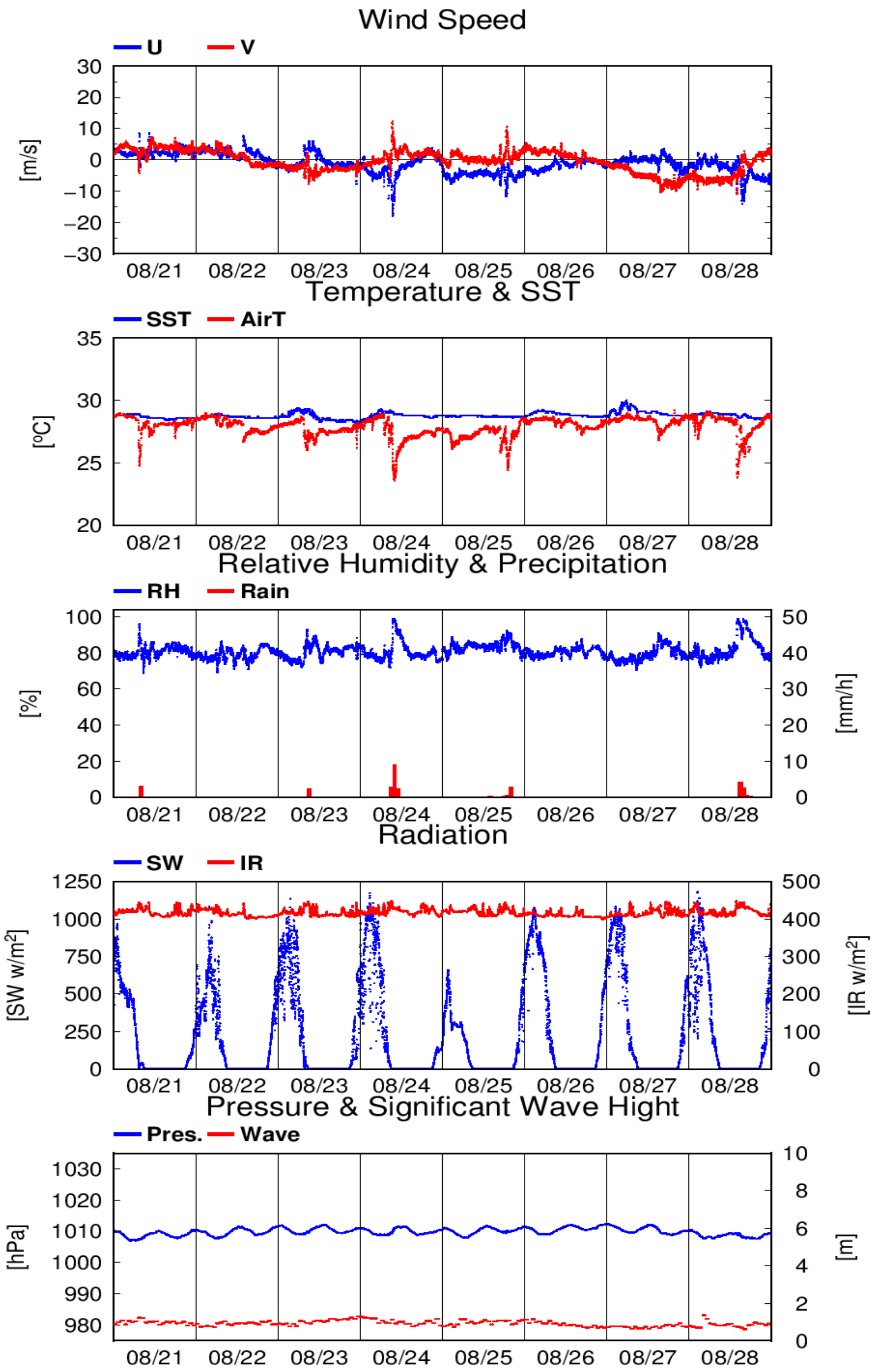


Fig. 5.15-1 (Continued)

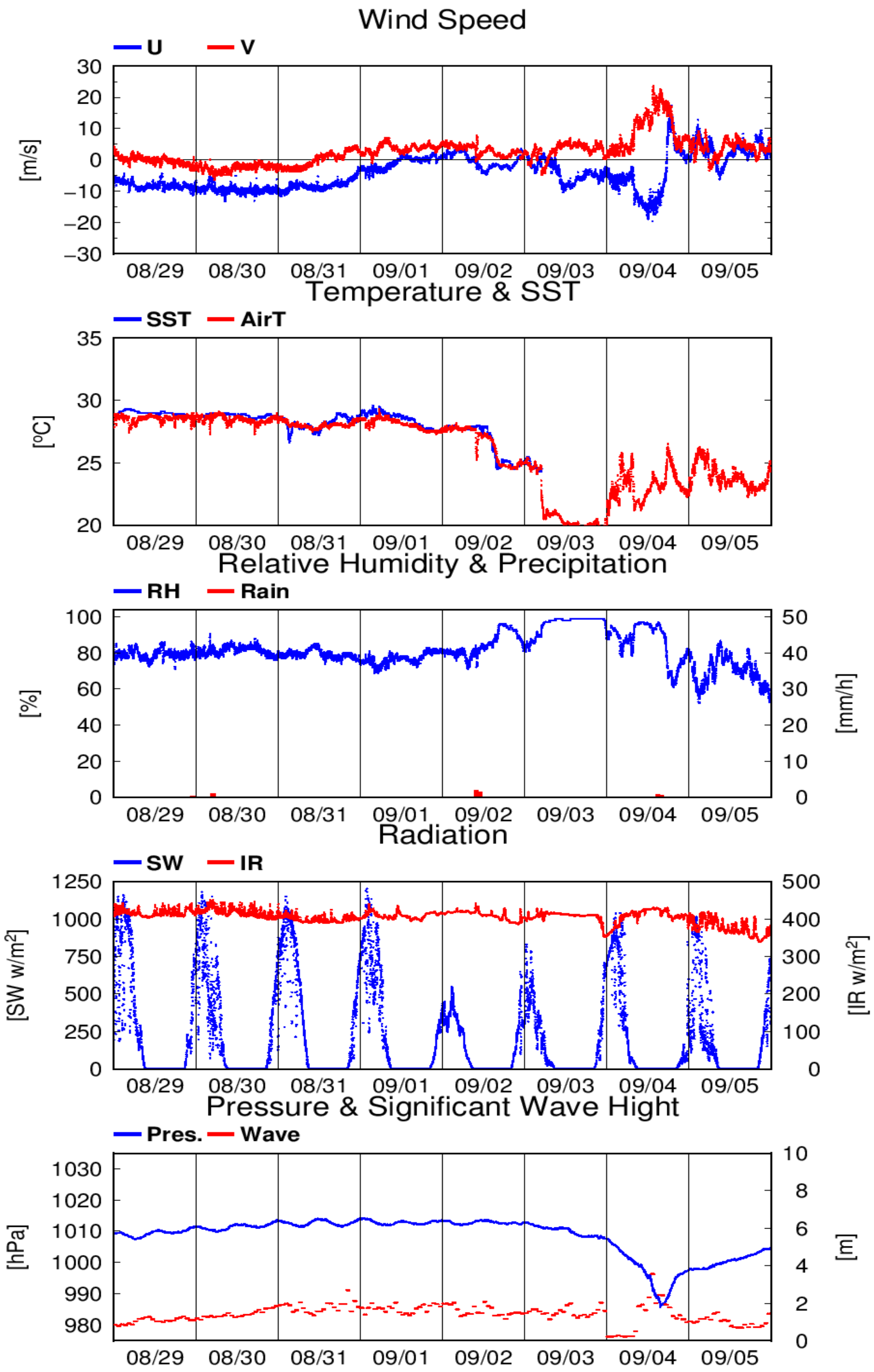


Fig. 5.15-1 (Continued)

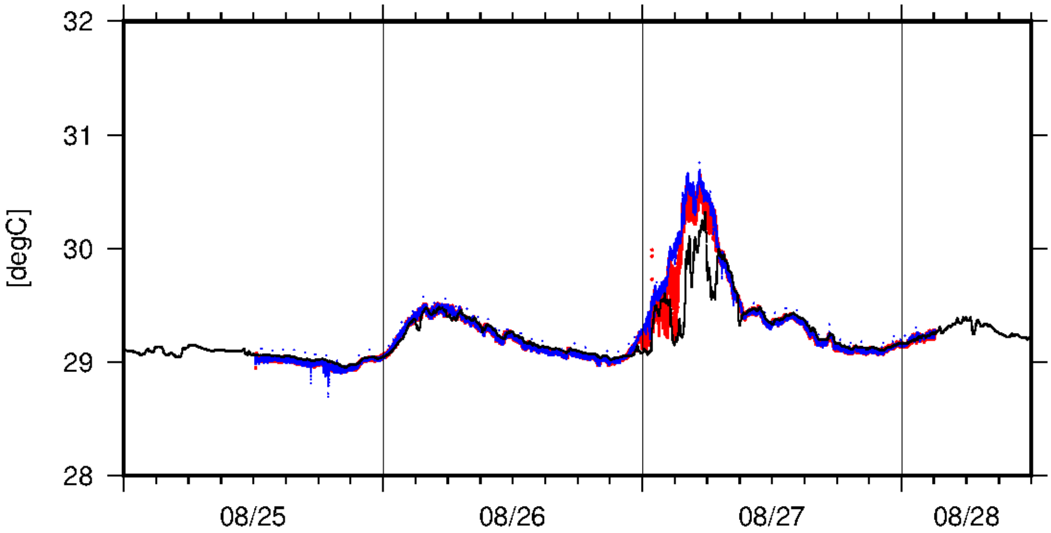


Fig. 5.15-2 Time series of Skin Sea Surface Temperature (SSST; 5cm:Blue, 100cm:Red) and Sea Surface Temperature (TSG:Black).

5.16 Continuous monitoring of surface seawater

(1) Personnel

Masaki Katsumata (JAMSTEC): Principal Investigator

Masahiro Orui (MWJ): Operation leader

Yasuhiro Arii (MWJ)

Erii Irie (MWJ)

(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 four 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 3 dm^3 min^{-1}.

a. Instruments

Software

Seamoni Ver.1.0.0.0

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:	4557820-0319
Measurement range:	Temperature -5 ^{o}C - +35 ^{o}C
	Conductivity 0 S m^{-1} - 7 S m^{-1}
Initial accuracy:	Temperature 0.002 ^{o}C
	Conductivity 0.0003 S m^{-1}
Typical stability (per month):	Temperature 0.0002 ^{o}C
	Conductivity 0.0003 S m^{-1}
Resolution:	Temperature 0.0001 ^{o}C
	Conductivity 0.00001 S m^{-1}

Bottom of ship thermometer

Model:	SBE 38, SEA-BIRD ELECTRONICS, INC.
Serial number:	3857820-0540
Measurement range:	-5 ^{o}C - +35 ^{o}C
Initial accuracy:	±0.001 ^{o}C
Typical stability (per 6 month):	0.001 ^{o}C
Resolution:	0.00025 ^{o}C

Dissolved oxygen sensor

Model:	RINKO II, JFE ADVANTECH CO. LTD.
Serial number:	0013
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 5.16-1.

Table 5.16-1 Events list of the Sea surface water monitoring during MR18-04Leg2

System Date [UTC]	System Time [UTC]	Events	Remarks
2018/08/13	05:19	All the measurements started and data was available.	Start
2018/08/28	04:04-04:10	Filter Cleaning	
2018/09/03	04:58	All the measurements end.	End

We took the surface water samples from this system once a day to compare sensor data with bottle data of salinity, dissolved oxygen, and chlorophyll a. The results are shown in fig. 5.16-2. All the salinity samples were analyzed by the Model 8400B “AUTOSAL” manufactured by Guildline Instruments Ltd. (see 5.20), and dissolve oxygen samples were analyzed by Winkler method (see 5.21), chlorophyll a were analyzed by 10-AU manufactured by Turner Designs. (see 5.23).

(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>

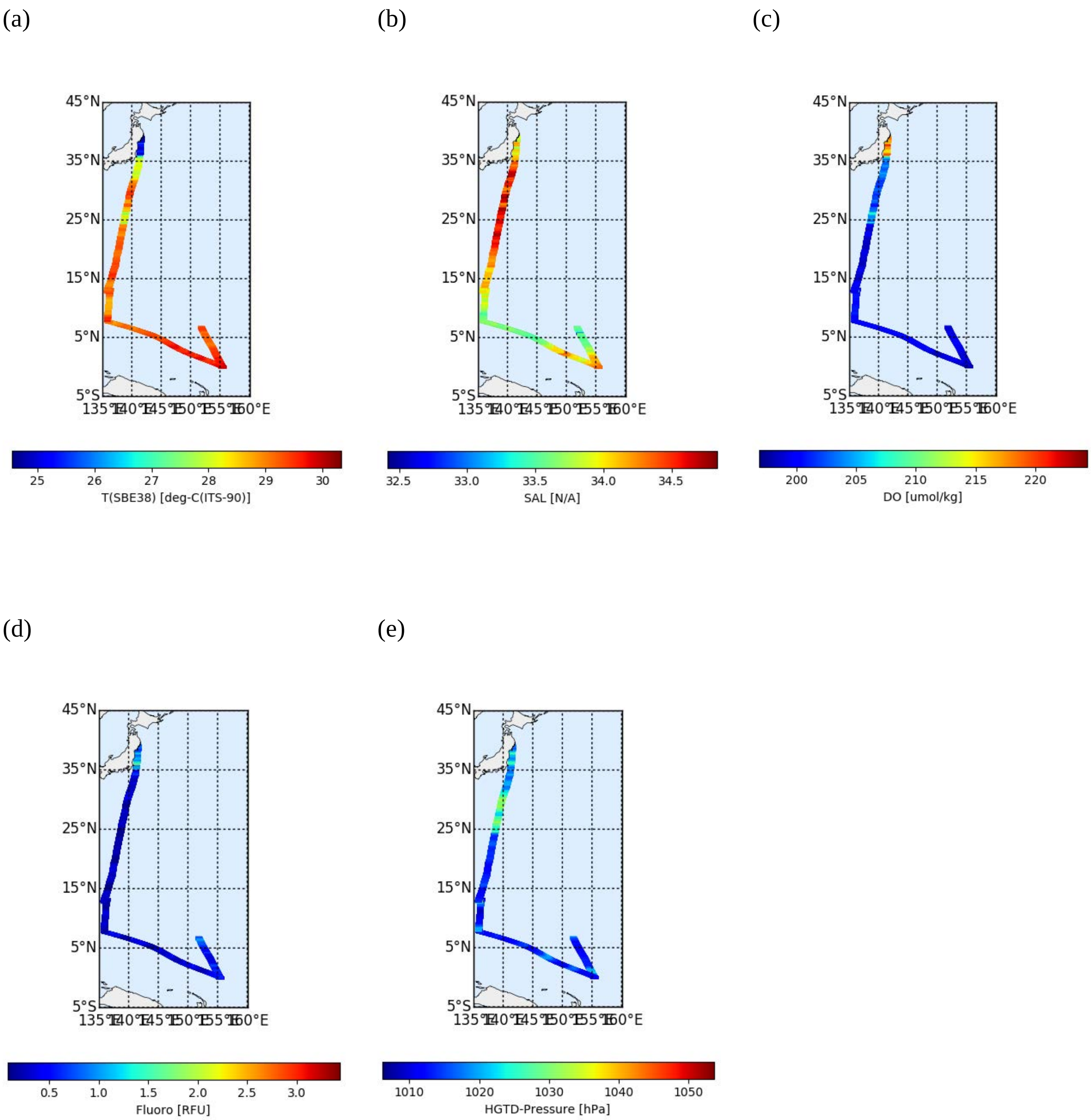


Figure 5.16-1 Spatial and temporal distribution of (a) temperature, (b) salinity, (c) dissolved oxygen, (d) fluorescence and (e) total dissolved gas pressure in MR18-04Leg2 cruise.

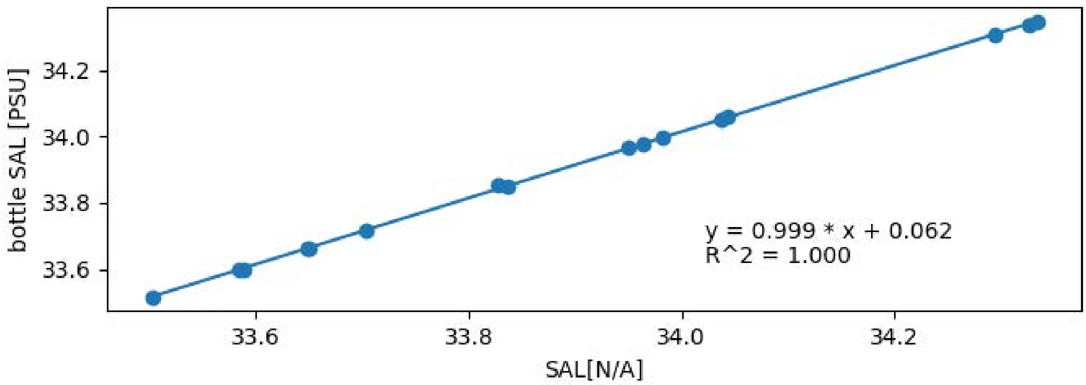


Figure 5.16-2-1 Correlation of salinity between sensor data and bottle data.

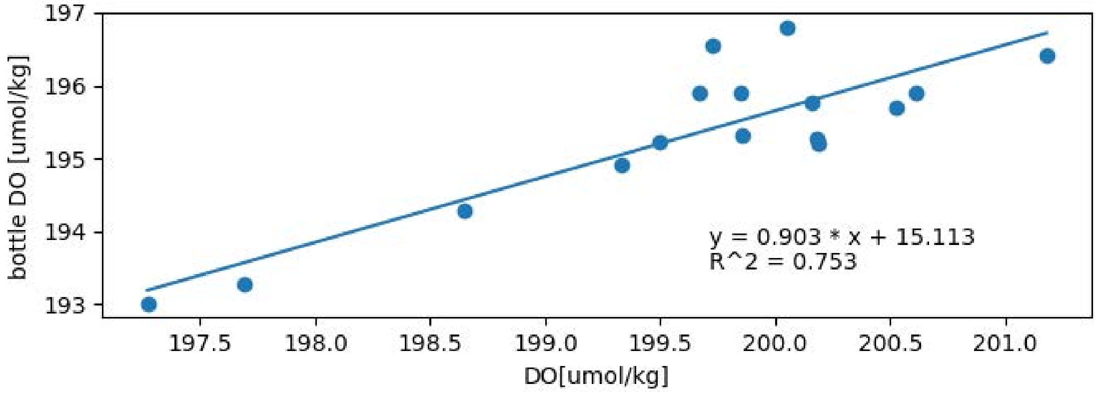


Figure 5.16-2-2 Correlation of dissolved oxygen between sensor data and bottle data.

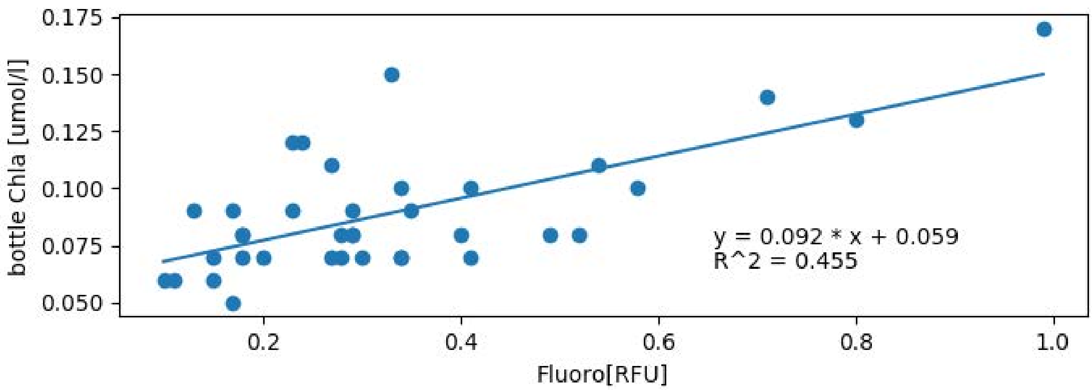


Figure 5.16-2-3 Correlation of fluorescence between sensor data and bottle data.

5.17 CTD profiling

(1) Personnel

Masaki KATSUMATA	(JAMSTEC)	- Principal Investigator
Kenichi KATAYAMA	(MWJ)	- Operation Leader
Jun MATSUOKA	(MWJ)	
Masanori ENOKI	(MWJ)	
Hiroki USHIROMURA	(MWJ)	
Yoshiaki SATO	(MWJ)	
Keisuke TAKEDA	(MWJ)	

(2) Objective

Investigation of oceanic structure and water sampling.

(3) Parameters

Temperature (Primary and Secondary)
Conductivity (Primary and Secondary)
Pressure
Dissolved Oxygen (Primary and Secondary)
Fluorescence
Transmission
Turbidity
Colored Dissolved Organic Material
Sound Velocity
Photosynthetically Active Radiation
Altimeter

(4) Instruments and Methods

CTD/Carousel Water Sampling System, which is a 36-position Carousel Water Sampler (CWS) with Sea-Bird Electronics, Inc. CTD (SBE9plus), was used during this cruise. 12-liter sample bottles were used for sampling seawater. Salinity was calculated by measured values of pressure, conductivity and temperature. The CTD/CWS was deployed from starboard on working deck.

Specifications of the sensors are listed below.

CTD: SBE911plus CTD system

Under water unit:

SBE9plus (S/N: 09P54451-0575, Sea-Bird Electronics, Inc.)

Pressure sensor: Digiquartz pressure sensor (S/N: 117457)

Calibrated Date: 26 Feb. 2018

Carousel water sampler:

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

Temperature sensors:

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

Calibrated Date: 22 Feb. 2018

Secondary: SBE03-04/F (S/N: 031524, Sea-Bird Electronics, Inc.)
Calibrated Date: 27 Feb. 2018

Conductivity sensors:
Primary: SBE04C (S/N: 042435 Sea-Bird Electronics, Inc.)
Calibrated Date: 15 Feb 2018
Secondary: SBE04C (S/N: 041088, Sea-Bird Electronics, Inc.)
Calibrated Date: 16 Feb. 2018

Dissolved Oxygen sensor:
Primary: RINKOIII (S/N:0287_163011BA, JFE Advantech Co., Ltd.)
Calibrated Date: 25 Jun 2018
Secondary: SBE43 (S/N: 432211, Sea-Bird Electronics, Inc.)
Calibrated Date: 03 Feb. 2018

Transmissometer:
C-Star (S/N:CST-1726DR, WET Labs,Inc.)
Calibrated Date: 15 Jun. 2018

Fluorescence:
Chlorophyll Fluorometer (S/N: 3618, Seapoint Sensors, Inc.)
Gain setting: 10X, 0-15 ug/l
Calibrated Date: None
Offset: 0.000

Turbidity:
Turbidity Meter (S/N:14953, Seapoint Sensors, Inc.)
Gain setting: 100×
Calibrated Date: None
Scale factor: 1.000

Colored Dissolved Organic Material
Ultraviolet (S/N:6223, Seapoint Sensors, Inc.)
Range: 50.0
Calibrated Data: None
Offset: 0.0000

Photosynthetically Active Radiation:
PAR sensor (S/N: 1025, Satlantic Inc.)
Calibrated Date: 06 Jul. 2015

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

Deep Ocean Standards Thermometer:
SBE35 (S/N 0022, Sea-Bird Electronics, Inc.)

Calibrated Date: 15 May 2018

Submersible Pump:
Primary: SBE5T (S/N: 055816, Sea-Bird Electronics, Inc.)
Secondary: SBE5T (S/N: 054595, Sea-Bird Electronics, Inc.)

Bottom contact switch: (Sea-Bird Electronics, Inc.)

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

Configuration file: MR1804B.xmlcon
C01M001 – STNM017

The CTD raw data were acquired on real time using the Seasave-Win32 (ver.7.23.2) provided by Sea-Bird Electronics, Inc. and stored on the hard disk of the personal computer. Seawater was sampled during the up cast by sending fire commands from the personal computer.

For depths where vertical gradient of water properties were exchanged to be large, the bottle was exceptionally fired after waiting from the stop for 60 seconds to enhance exchanging the water between inside and outside of the bottle. Otherwise below thermocline we waited for 30 seconds to stabilize then fire. 22 casts of CTD measurements were conducted (Table 5.17-1).

Data processing procedures and used utilities of SBE Data Processing-Win32 (ver.7.26.7.114.) and SEASOFT were as follows:

(The process in order)

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

TCORP (original module): Corrected the pressure sensitivity of the temperature (SBE3) sensor.
S/N1525: 1.714e-008 (degC/dbar)
S/N1524: -2.5868e-007 (degC/dbar)

BOTTLESUM: Create a summary of the bottle data. The data were averaged over 3 seconds.

ALIGNCTD: Convert the time-sequence of sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. Dissolved oxygen data and transmission data are systematically delayed with respect to depth mainly because of the long time constant of the dissolved oxygen sensor and of an additional delay from the transit time of water in the pumped pluming line. This delay ware compensated by 2.0 sec advancing primary oxygen sensor (RINKOIII), 5.0 seconds advancing secondary dissolved oxygen sensor (SBE43) and 2.0 seconds advancing transmissometer output relative to temperature data.

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

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

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

WFILTER: Perform a median filter to remove spikes in the fluorescence, transmissometer, turbidity and colored dissolved organic material data.
A median value was determined by 49 scans of the window.

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

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

DERIVE: Compute dissolved oxygen (SBE43).

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

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

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

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

(5) Station list

During this cruise, 22 casts of CTD observation were carried out on buoy observation, Deep APEX and stationary observation. Date, time and locations of the CTD casts are listed in Table 5.17-1.

(6) Preliminary Results

The time series contours of primary temperature, salinity with pressure are shown in figure 5.17.1. Vertical profile (down cast) of primary temperature, salinity and dissolved oxygen with pressure are shown in the appendix B.

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

STNM001: Dissolved oxygen (SBE43)
Down 4981-4986db : spike

(7) Data archive

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

Table 5.17-1 MR18-04Leg2 CTD cast table

Stnnbr	Castno	Date(UTC)	Time(UTC)		BottomPosition		Depth	Wire	HT Above	Max	Max	CTD	Remark
		(mmddyy)	Start	End	Latitude	Longitude	(m)	Out (m)	Bottom (m)	Depth	Pressure	Filename	
C01	1	081518	03:12	04:10	00-00.46N	156-03.58E	1952.0	904.6	-	902.0	909.0	C01M001	for TRITON deploy
C02	1	081518	20:04	20:59	00-01.89S	155-57.58E	1948.0	901.0	-	901.0	908.0	C02M001	for TRITON recovery
C03	1	082218	04:07	04:59	07-38.90N	136-42.80E	3168.0	900.4	-	901.0	908.0	C03M001	for TRITON deploy
C04	1	082218	21:05	22:00	07-51.08N	136-30.24E	3352.0	903.9	-	901.9	909.0	C04M001	for TRITON recovery
C05	1	082418	06:21	07:15	12-52.19N	136-51.35E	4746.0	1000.0	-	1000.8	1009.0	C05M001	for TRITON recovery
STN	1	082518	07:00	10:40	13-09.22N	136-53.87E	5194.0	5185.0	9.2	5178.8	5273.0	STNM001	for TRITON deploy, Deep APEX
STN	2	082518	15:03	15:15	13-00.42N	136-40.98E	4883.0	300.6	-	300.0	302.0	STNM002	
STN	3	082518	18:04	18:39	12-59.89N	136-41.08E	5027.0	299.9	-	301.0	303.0	STNM003	
STN	4	082518	21:07	21:19	12-59.99N	136-42.22E	5006.0	300.3	-	300.0	302.0	STNM004	
STN	5	082618	00:05	00:47	13-00.31N	136-42.54E	4870.0	302.3	-	303.0	305.0	STNM005	
STN	6	082618	03:07	03:18	13-00.47N	136-42.68E	4818.0	301.5	-	300.0	302.0	STNM006	
STN	7	082618	06:03	06:42	12-59.21N	136-42.01E	5148.0	300.1	-	301.0	303.0	STNM007	
STN	8	082618	09:03	09:14	12-59.16N	136-42.35E	5148.0	300.8	-	301.0	303.0	STNM008	
STN	9	082618	12:03	12:43	12-59.30N	136-42.66E	5081.0	302.8	-	304.0	306.0	STNM009	
STN	10	082618	15:04	15:15	12-59.92N	136-41.84E	5017.0	301.5	-	301.0	303.0	STNM010	
STN	11	082618	18:03	18:33	12-59.75N	136-41.29E	5050.0	299.9	-	301.0	303.0	STNM011	
STN	12	082618	21:04	21:15	13-00.16N	136-41.71E	4998.0	300.6	-	301.0	303.0	STNM012	
STN	13	082718	00:04	00:45	13-00.71N	136-42.58E	4827.0	301.9	-	303.0	305.0	STNM013	
STN	14	082718	03:02	03:13	13-00.23N	136-42.92E	4837.0	301.4	-	301.0	303.0	STNM014	
STN	15	082718	06:03	06:41	13-00.54N	136-42.25E	4881.0	300.1	-	300.0	302.0	STNM015	
STN	16	082718	09:03	09:14	13-00.37N	136-42.17E	4923.0	302.1	-	301.0	303.0	STNM016	
STN	17	082718	12:03	12:40	12-59.45N	136-42.73E	5019.0	304.3	-	304.0	306.0	STNM017	

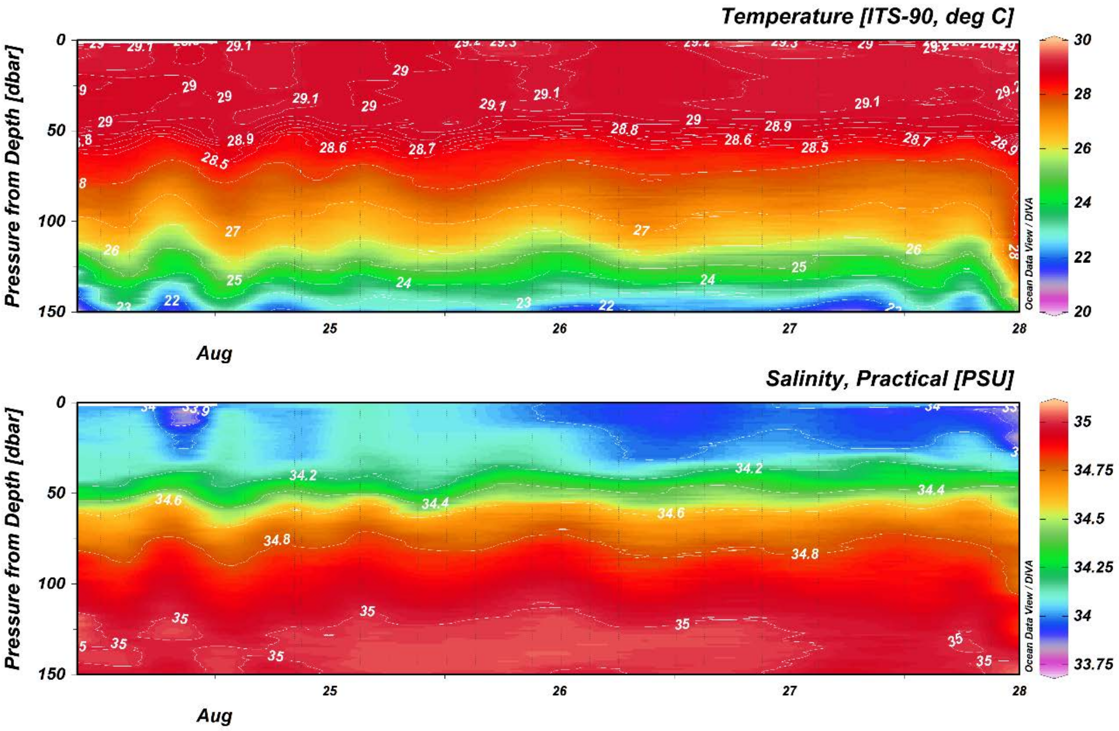


Figure 5.17.1 the time series contours (temperature, salinity) in stationary observation (STNM001 ~ STNM017), including xctd data.

5.18 Special sensors on CTD profiling and post-cruise calibration

(1) Personnel

Hiroshi UCHIDA	(JAMSTEC)	- Person in charge for post-cruise calibration
Masaki KATSUMATA	(JAMSTEC)	
Kenichi KATAYAMA	(MWJ)	
Jun MATSUOKA	(MWJ)	
Masanori ENOKI	(MWJ)	
Hiroki USHIROMURA	(MWJ)	
Yoshiaki SATO	(MWJ)	
Keisuke TAKEDA	(MWJ)	
Shinsuke TOYODA	(MWJ) (post-cruise calibration)	
Rio KOBAYASHI	(MWJ) (post-cruise calibration)	

(2) Objective

Investigation of oceanic structure and water sampling. To test stand-alone CTDs by comparing with the reference CTD.

(3) Parameters

For special sensors

Temperature, Conductivity, and Pressure (RBR CTDs)
Sound Velocity (Mini-SVS)

For post-cruise calibration

Temperature
Conductivity
Pressure
Dissolved Oxygen
Fluorescence
Transmission
Colored Dissolved Organic Material
Photosynthetically Active Radiation

(4) Instruments and Methods

In addition to the CTD profiling observation explaining in section 5.17, stand-alone CTDs and a sound velocity sensor were attached to the CTD system.

Specifications of the sensors are listed below.

Stand-alone CTD: RBRconcerto3 C.T.D
(S/N: 060661, 060669, 060671, 066127, 060128, RBR Ltd., Ottawa, Canada)
Sound velocity sensor: mini-SVS OEM (S/N: 24001, Valeport Ltd., Devon, UK)

(5) Station list

Sound velocity data were obtained at all CTD stations (see Table 5.18-1). RBR CTDs for S/N 060669, 060671, 066127 and 066128 were used for the CTD stations except for one deep cast (STN_001). RBR CTD for S/N 060661 was used only for the deep casat (STN_001).

(6) Post-cruise calibration

Pressure

The CTD pressure sensor offset in the period of the cruise was estimated from the pressure readings on the ship deck. For best results the Paroscientific sensor was powered on for at least 20 minutes before the operation. In order to get the calibration data for the pre- and post-cast pressure sensor drift, the CTD deck pressure was averaged over first and last one minute, respectively. Then the atmospheric pressure deviation from a standard atmospheric pressure (14.7 psi) was subtracted from the CTD deck pressure to check the pressure sensor time drift. The atmospheric pressure was measured at the captain deck (20 m high from the base line) and sub-sampled one-minute interval as a meteorological data. The pre- and the post-casts deck pressure data showed temperature dependency for the pressure sensor (Fig. 5.18-1). The post-cruise correction of the pressure data is not deemed necessary for the pressure sensor.

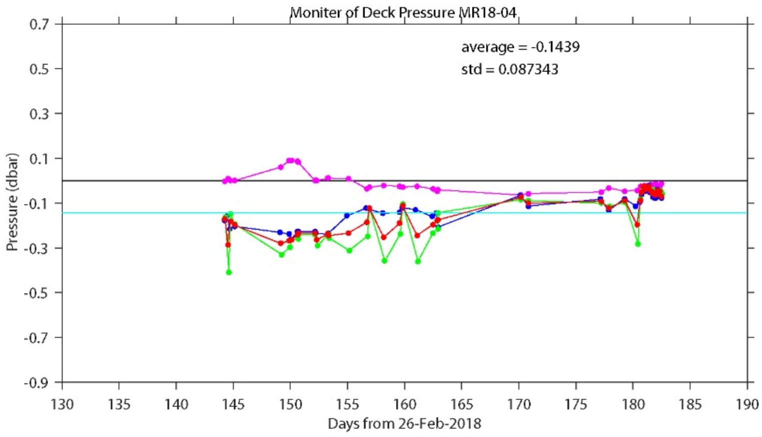


Fig. 5.18-1. Time series of the CTD deck pressure for legs 1 and 2. Atmospheric pressure deviation (magenta dots) from a standard atmospheric pressure was subtracted from the CTD deck pressure. Blue and green dots indicate pre- and post-cast deck pressures, respectively. Red dots indicate averages of the pre- and the post-cast deck pressures.

Temperature

The CTD temperature sensors (SBE 3) were calibrated with the SBE 35 according to a method by Uchida et al. (2007). Post-cruise sensor calibration for the SBE 35 will be performed at JAMSTEC in 2019. The CTD temperature was calibrated as

Calibrated temperature = $T - (c_0 \times P + c_1)$

$c_0 = 2.25402901e\text{-}08$

$c_1 = -4.8567e\text{-}04$

where T is CTD temperature in °C, P is pressure in dbar, and c_0 and c_1 are calibration coefficients. The coefficients were determined using the data for the depths deeper than 1950 dbar. The primary temperature data obtained in legs 1 and 2 were used for the post-cruise calibration. The result of the post-cruise calibration is shown in Fig. 5.18-2.

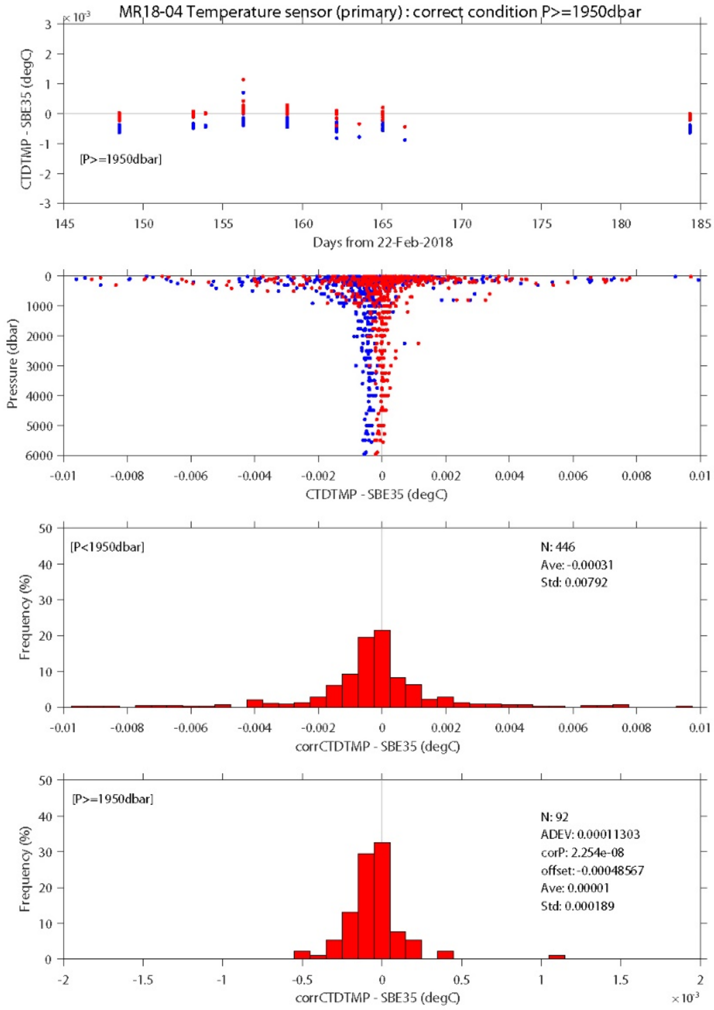


Fig. 5.18-2. Difference between the CTD temperature and the SBE 35 for legs 1 and 2. Blue and red dots indicate before and after the post-cruise calibration using the SBE 35 data, respectively. Lower two panels show histogram of the difference after the calibration.

Salinity

The discrepancy between the CTD conductivity and the conductivity calculated from the bottle salinity data with the CTD temperature and pressure data is considered to be a function of conductivity and pressure. The CTD conductivity was calibrated as

Calibrated conductivity =

$$C - (c_0 \times C + c_1 \times P + c_2 \times C \times P + c_3 \times P^2 + c_4 \times C \times P^2 + c_5 \times C^2 \times P^2 + c_6$$

c_0 = -1.2604070765e-04

c_1 = 4.2082742278e-07

c_2 = -2.1431501985e-07

c_3 = 1.2645079398e-09

c_4 = -5.7357791901e-10

c_5 = 6.0759100571e-11

c_6 = 8.6513154184e-04

where C is CTD conductivity in S/m, P is pressure in dbar, and c_0, c_1, c_2, c_3, c_4, c_5 and c_6 are calibration coefficients. The best fit sets of coefficients were determined by a least square technique to minimize the deviation from the conductivity calculated from the bottle salinity data. The primary conductivity data created by the software module ROSSUM were used after the post-cruise calibration for the temperature data. Data obtained in leg 2 were only used to determine the coefficients. The results of the post-cruise calibration for the CTD salinity is shown in Fig. 3.1.5.

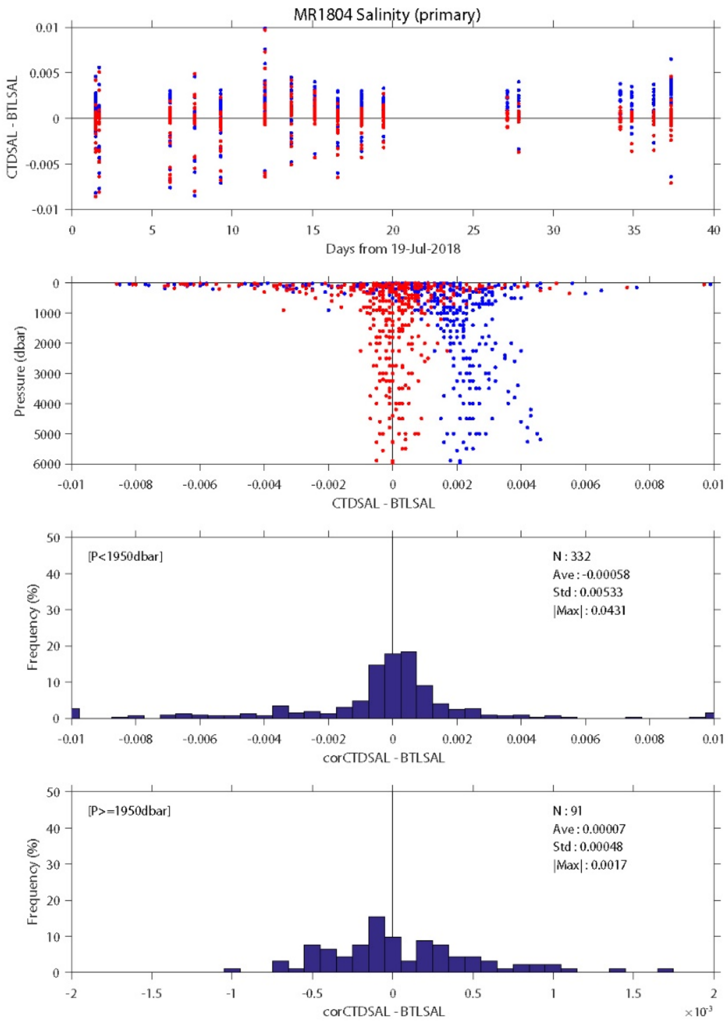


Fig. 5.18-3. Difference between the CTD salinity (primary) and the bottle salinity. Blue and red dots indicate before and after the post-cruise calibration, respectively. Lower two panels show histogram of the difference after the calibration.

Dissolved oxygen

The RINKO oxygen sensor was calibrated and used as the CTD oxygen data, since the RINKO has a fast time response. The pressure-hysteresis corrected RINKO data was calibrated by the modified Stern-Volmer equation, basically according to a method by Uchida et al. (2010) with slight modification:

$$[O_2]\ (\mu mol/l) = [(V_0 / V)^{1.2} - 1] / K_{sv} \times (1 + C_p \times P / 1000)$$

and

$$K_{sv} = C_0 + C_1 \times T + C_2 \times T^2$$
$$V_0 = 1 + C_3 \times T$$
$$V = C_4 + C_5 \times V_b + C_6 \times t + C_7 \times t \times V_b$$

C_0 = 4.374745199579160e-03
C_1 = 1.959889948766195e-04
C_2 = 3.299643594882492e-06
C_3 = 3.393174447187830e-05
C_4 = -8.886509933176687e-02
C_5 = 0.3133749584921368
C_6 = 2.122968503551541e-03
C_7 = 9.721622456140531e-06
C_p = 0.026

where V_b is the RINKO output (voltage), V_0 is voltage in the absence of oxygen, T is temperature in °C, P is pressure in dbar, t is exciting time (days) integrated from the first CTD cast, and C0, C1, C2, C3, C4, C5, C6, C7, and Cp are calibration coefficients. The calibration coefficients were determined by minimizing the sum of absolute deviation with a weight from the bottle oxygen data. The revised quasi-Newton method (DMINF1) was used to determine the sets. The post-cruise calibrated temperature and salinity data were used for the calibration. Data obtained in legs 1 and 2 were used to determine the coefficients. The results of the post-cruise calibration for the RINKO oxygen is shown in Fig. 5.18-4.

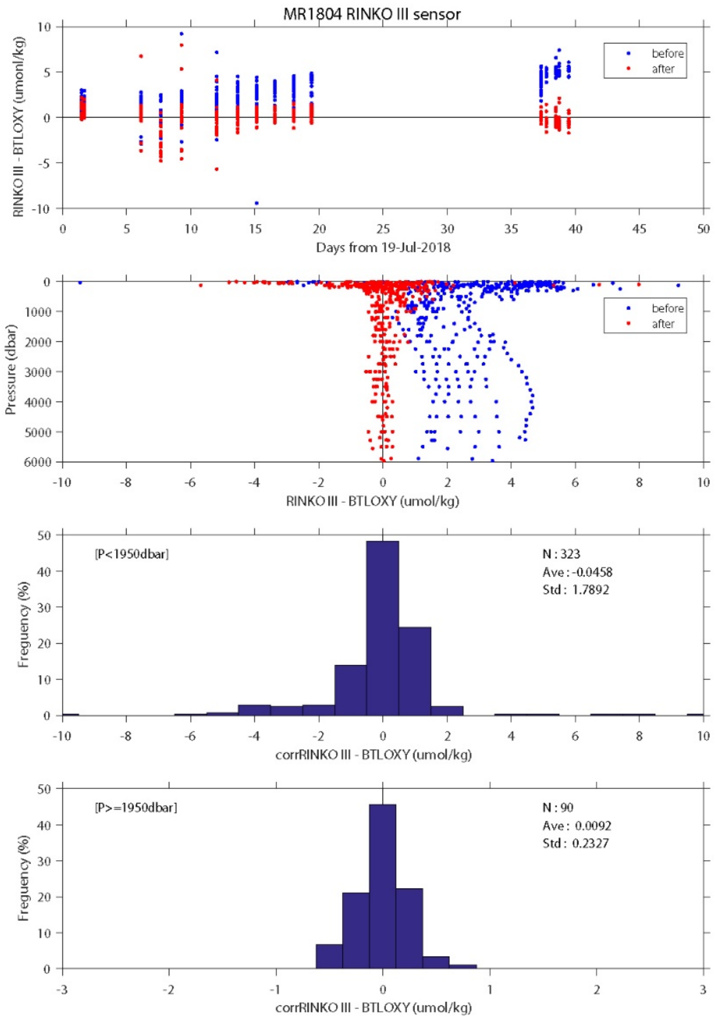


Fig. 5.18-4. Difference between the CTD oxygen and the bottle oxygen. Blue and red dots indicate before and after the post-cruise calibration, respectively. Lower two panels show histogram of the difference after the calibration.

Fluorescence

The CTD fluorometer (FLUOR in μg/L) was calibrated by comparing with the bottle sampled chlorophyll-a as

$$FLUORc = c_0 + c_1 \times FLUOR$$

$$c_0 = 0,\ c_1 = 0.756275283551859\ (\text{for FLUOR} \leq 0.2)$$

$$c_0 = 0.00707774735722697,\ c_1 = 0.720886546765725\ (\text{for FLUOR} > 0.2)$$

where c_0 and c_1 are calibration coefficients. The bottle sampled data obtained at dark condition [PAR (Photosynthetically Available Radiation) < 50 □E/(m^2 sec)] were used for the calibration, since sensitivity of the fluorometer to chlorophyll *a* is different at nighttime and daytime. The results of the post-cruise calibration for the fluorometer is shown in Fig. 5.18-5.

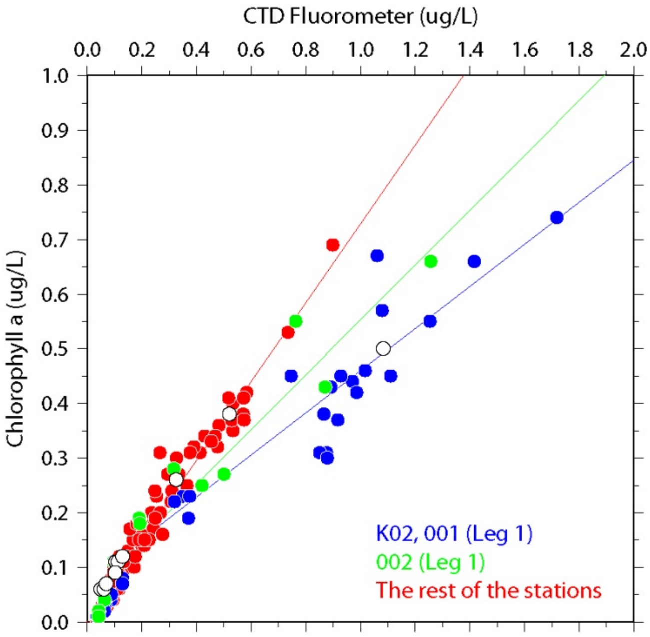


Fig. 5.18-5. Comparison of the CTD fluorometer and the bottle sampled chlorophyll-a. The regression lines are also shown.

Transmission

The transmissometer (T_r in %) is calibrated as

$$T_r = (V - V_d) / (V_r - V_d) \times 100$$

wehre V is the measured signal (voltage), V_d is the dark offset for the instrument, and V_r is the signal for clear water. V_d can be obtained by blocking the light path. V_d and V_{air}, which is the signal for air, were measured on deck before each cast after wiping the optical windows with ethanol. V_d was constant (0.0012) during the cruise. Vr is estimated from the measured maximum signal in the deep ocean at each cast. Since the transmissometer drifted in time, Vr is expressed as

$$V_r = c_0 \times \exp(c_1 \times t) + c_2 \times t + c_3$$

$$c_0 = 9.005603350864108e-02$$

$$c_1 = -0.1636953646978961$$

$$c_2 = 7.157164520392141e-03$$

c_3 = 4.625489007057624

where t is working time (in days) of the transmissometer from the first cast of leg 1, and c_0, c_1, c_2 and c_3 are calibration coefficients. Maximum signal was extracted for each cast. Data whose depth of the maximum signal was shallower than 1300 dbar were not used to estimate V_r.

Colored dissolved organic material

It is known that output from the CDOM sensor is affected by the temperature change (Yamashita et al., 2015). The temperature effect on the CDOM sensor was evaluated in the laboratory before and after the cruise. The effect of temperature is standardized as:

$CDOM_r = CDOM / [1 + \rho \times (T - T_r)]$

$T_r = 20.0$

$\rho = -0.0062$

where CDOM is the output from the CDOM sensor, T is temperature in °C, Tr is reference temperature, and ρ is the temperature coefficient (°C^{-1}). Since output from the CDOM sensor was largely shifted in leg 1, the temperature coefficient evaluated after the cruise is used. In addition, Pressure hysteresis (difference between down- and up-cast profiles) was seen in the output. Therefore, the down-cast profile was corrected to much with up-cast profile as:

$CDOM_c = CDOM_r \times (1 - c_0 \times [P_{max} - P])$

c_0 = 3.5e-6

where P is pressure in dbar, P_{max} is maximum pressure in dbar at the cast, and c_0 is the correction coefficient.

Photosynthetically active radiation

The PAR sensor was calibrated with an offset correction. The offset was estimated from the data measured in the deep ocean during the cruise. The corrected data (PARc) is calculated from the raw data (PAR) as follows:

PARc [μE m^{-2} s^{-1}] = PAR – 0.104.

Sound velocity

The sound velocity sensing elements are a ceramic transducer (signal sound pulse of 2.5 MHz frequency), a signal reflector, and spacer rods to control the sound path length (5 cm), providing a measurement at depths up to 7000 m. The velocimeter was attached to the CTD frame and level of the sound path of the volocimeter was same as that of the CTD temperautre sensor. Sound velocity data were obtained through serial uplink port of the CTD at a sampling rate of 12 Hz and the data will be combined with the CTD temperature and pressure data measurd at a sampling rate of 24 Hz to estimate Absolute Salinity. Absolute Salinity can be back calculated from measured sound velocity, temperature and pressure and will be calibrated in situ referred to the Absolute Salinity data measured by a density meter for water samples obtained in leg 1.

Stand-alone CTDs

Data obtained from the stand-alone CTDs will be compared with the reference CTD (SBE 9plus) and bottle sampled salinity data to evaluate performance of the stand-alone CTDs.

(7) References

Uchida, H., G. C. Johnson, and K. E. McTaggart (2010): CTD oxygen sensor calibration procedures, The GO-SHIP Repeat Hydrography Manual: A collection of expert reports and guidelines, IOCCP Rep., No. 14, ICPO Pub. Ser. No. 134.

Uchida, H., K. Ohyama, S. Ozawa, and M. Fukasawa (2007): In situ calibration of the Sea-Bird 9plus CTD thermometer, *J. Atmos. Oceanic Technol.*, 24, 1961–1967.

Yamashita, Y., C.-J. Liu, H. Ogawa, J. Nishioka, H. Obata, and H. Saito (2015): Application of an in situ fluorometer to determine the distribution of fluorescent organic matter in the open ocean, *Marine Chemistry*, 177, 298–305.

(8) Data archive

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

5.19 Salinity of sampled water

(1) Personnel

Masaki KATSUMATA (JAMSTEC) - Principal Investigator
Kenichi KATAYAMA (MWJ) - Operation Leader

(2) Objective

To provide calibrations for the measurements of salinity collected from CTD casts and the continuous sea surface water monitoring system (TSG).

(3) Method

a. Salinity Sample Collection

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

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

Table 5.19-1 Kind and number of samples

Kind of Samples	Number of Samples
Samples for CTD	107
Samples for TSG	16
Total	123

b. Instruments and Method

The salinity analysis was carried out on R/V MIRAI during the cruise of MR18-04 Leg2 using the salinometer (Model 8400B “AUTOSAL” ; Guildline Instruments Ltd.: S/N 62827) with an additional peristaltic-type intake pump (Ocean Scientific International, Ltd.). A pair of precision digital thermometers (1502A; FLUKE: S/N B78466 and B81550) were used for monitoring the ambient temperature and the bath temperature of the salinometer.

The specifications of the AUTOSAL salinometer and thermometer are shown as follows ;

Salinometer (Model 8400B “AUTOSAL” ; Guildline Instruments Ltd.)

Measurement Range : 0.005 to 42 (PSU)
Accuracy : Better than ±0.002 (PSU) over 24 hours without re-standardization
Maximum Resolution : Better than ±0.0002 (PSU) at 35 (PSU)

Thermometer (1502A: FLUKE)

Measurement Range : 16 to 30 deg C (Full accuracy)

Resolution : 0.001 deg C

Accuracy : 0.006 deg C (@ 0 deg C)

The measurement system was almost the same as Aoyama *et al.* (2002). The salinometer was operated in the air-conditioned ship's laboratory at a bath temperature of 24 deg C. The ambient temperature varied from approximately 21 deg C to 23 deg C, while the bath temperature was very stable and varied within +/- 0.002 deg C on rare occasion. The measurement for each sample was done with a double conductivity ratio and defined as the median of 31 readings of the salinometer. Data collection was started 5 seconds after filling the cell with the sample and it took about 10 seconds to collect 31 readings by a personal computer. Data were taken for the sixth and seventh filling of the cell. In the case of the difference between the double conductivity ratio of these two fillings being smaller than 0.00002, the average value of the double conductivity ratio was used to calculate the bottle salinity with the algorithm for the practical salinity scale, 1978 (UNESCO, 1981). If the difference was greater than or equal to 0.00003, an eighth filling of the cell was done. In the case of the difference between the double conductivity ratio of these two fillings being smaller than 0.00002, the average value of the double conductivity ratio was used to calculate the bottle salinity. The measurement was conducted in about 4 hours per day and the cell was cleaned with soap after the measurement of the day.

(4) Results

a. Standard Seawater

Standardization control of the salinometer was set to 487 and all measurements were done at this setting. The value of STANDBY was 24+5457-5461 and that of ZERO was 0.0±0000-0001. The conductivity ratio of IAPSO Standard Seawater batch P160 was 0.99983 (double conductivity ratio was 1.99966) and was used as the standard for salinity. 8 bottles of P160 were measured.

Fig.5.19-1 shows the time series of the double conductivity ratio of the Standard Seawater batch P160. The average of the double conductivity ratio was 1.99962 and the standard deviation was 0.00001 which is equivalent to 0.0002 in salinity.

Fig.5.19-2 shows the time series of the double conductivity ratio of the Standard Seawater batch P160 after correction. The average of the double conductivity ratio after correction was 1.99966 and the standard deviation was 0.00001, which is equivalent to 0.0002 in salinity.

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

Batch	:	P160
Conductivity ratio	:	0.99983
Salinity	:	34.993
Use by	:	20th Jul. 2019

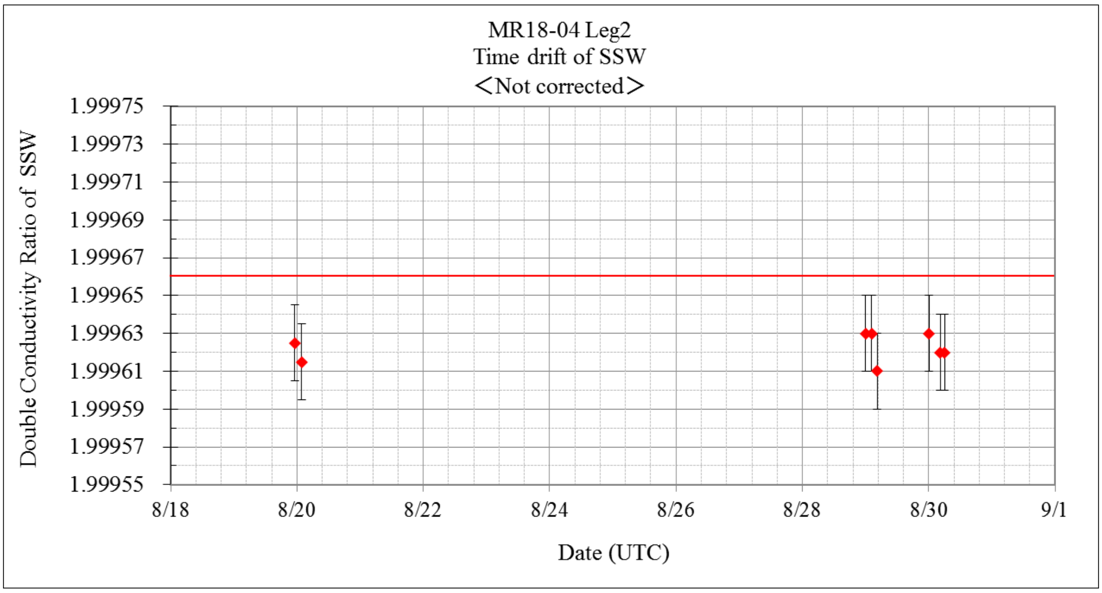


Fig. 5.19-1: Time series of double conductivity ratio for the Standard Seawater batch P160 (before correction)

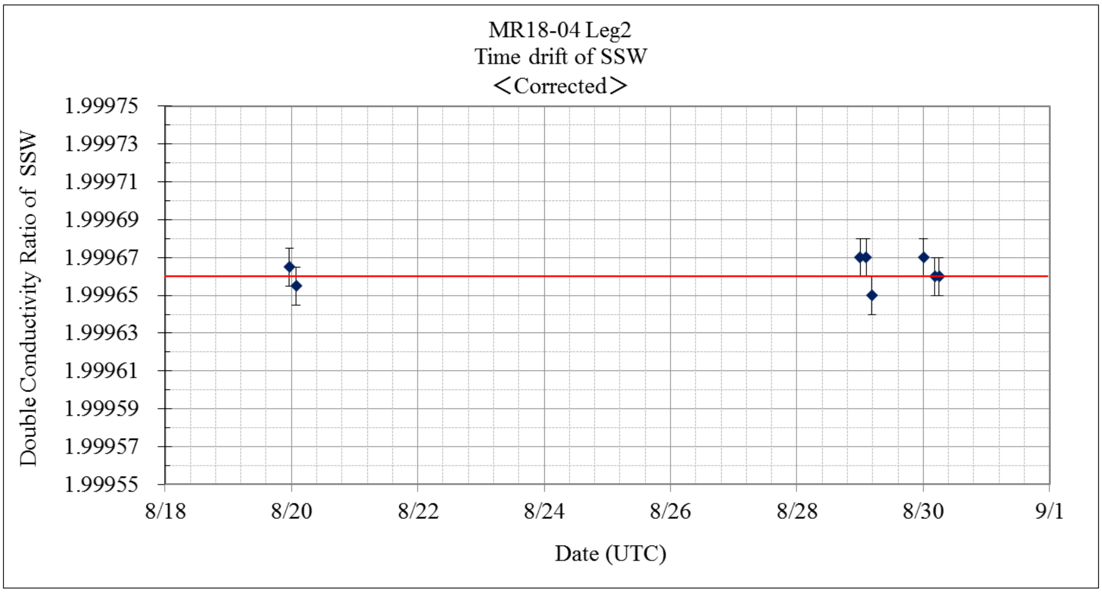


Fig. 5.19-2: Time series of double conductivity ratio for the Standard Seawater batch P160 (after correction)

b. Sub-Standard Seawater

Sub-standard seawater was made from surface sea water filtered by a pore size of 0.2 micrometer and stored in a 20 liter container made of polyethylene and stirred for at least 24 hours before measuring. It was measured about every 6 samples in order to check for the possible sudden drifts of the salinometer.

c. Replicate Samples

We estimated the precision of this method using 11 pairs of replicate samples taken from the same water sampling bottle. The average and the standard deviation of absolute difference among 11 pairs of replicate samples were 0.0002 and 0.0002 in salinity, respectively.

(5) Data archive

These raw datasets will be submitted to JAMSTEC Data Management Group (DMG).

(6) Reference

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

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

5.20 Dissolved Oxygen in the sampled water

(1) Personnel

Masaki KATSUMATA (JAMSTEC): Principal Investigator
Erie IRIE (MWJ): Operation Leader
Masahiro Orui (MWJ)
Yasuhiro Arii (MWJ)

(2) Objective

Determination of dissolved oxygen in seawater by Winkler titration.

(3) Parameters

Dissolved Oxygen

(4) Instruments and Methods

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

i) Instruments

Burette for sodium thiosulfate and potassium iodate;

Automatic piston burette (APB-510 / APB-610 / APB-620) manufactured by Kyoto Electronics Manufacturing Co., Ltd. / 10 cm^3 of titration vessel

Detector;

Automatic photometric titrator (DOT-15X) manufactured by Kimoto Electric Co., Ltd.

Software;

DOT_Terminal Ver. 1.3.1

ii) 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})

iii) Sampling

Seawater samples were collected with Niskin bottle attached to the CTD/Carousel Water Sampling System (CTD system). Seawater for oxygen measurement was transferred from the bottle to a volume calibrated flask (ca. 100 cm^3), and 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.

iv) Sample measurement

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

v) 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

i) Standardization and determination of the blank

Table 5.20-1 shows results of the standardization and the blank determination during this cruise.

Table 5.20-1. Results of the standardization and the blank determinations during cruise

Date (yyyy/mm/dd)	Potassium iodate ID	Sodium thiosulfate ID	DOT-15X (No.9)		DOT-15X (No.10)		Stations
			E.P. (cm^3)	Blank (cm^3)	E.P. (cm^3)	Blank (cm^3)	
2018/08/14	K1805B07	T1806B	3.961	0.002			
2018/08/18	K1805B08	T1806B	3.959	0.001			
2018/08/23	K1805B09	T1806B	3.959	0.000	3.964	0.002	STNM001, STNM003, STNM009, STNM011, STNM017
2018/08/29	K1805B10	T1806B	3.964	0.003	3.966	0.001	

ii) Repeatability of sample measurement

Replicate samples were taken at every CTD casts. The standard deviation of the replicate measurement (Dickson et al., 2007) was 0.09 μmol kg^{-1} (n=8).

(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.

5.21 Nutrients in the sampled water

(1) Personnel

Masaki KATSUMATA (JAMSTEC) : Principal Investigator
Elena HAYASHI (MWJ): Operation Leader
Keitaro MATSUMOTO (MWJ)

(2) Objectives

The objectives of nutrients analyses during the R/V Mirai MR18-04 leg.2 cruise in the Western Pacific Ocean, of which EXPOCODE is 49NZ20180813, is as follows:

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

(3) Parameters

The determinants are nitrate, nitrite, silicate and phosphate in the Western 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 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). The flow diagrams and reagents for each parameter are shown in Figures 5.21-1 to 5.21-4.

(4.2) Nitrate + Nitrite Reagents

50 % Triton solution

50 mL Triton^{TM} 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.

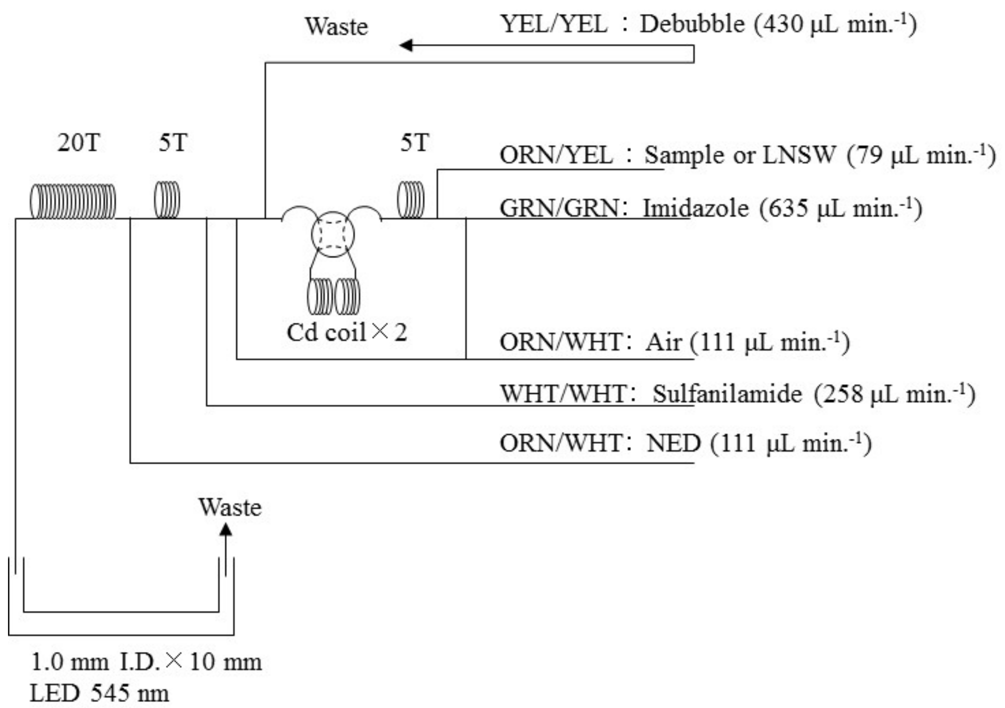


Figure 5.21-1 NO_3+NO_2 (1ch.) Flow diagram.

(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.

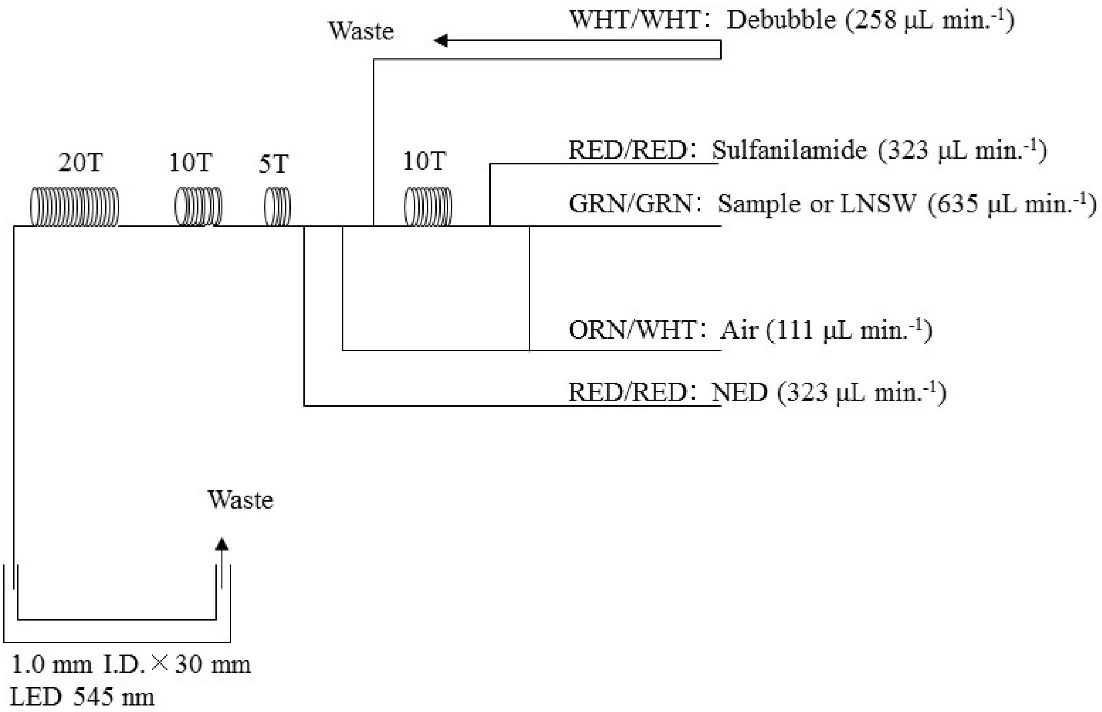


Figure 5.21-2 NO_2 (2ch.) Flow diagram.

(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.

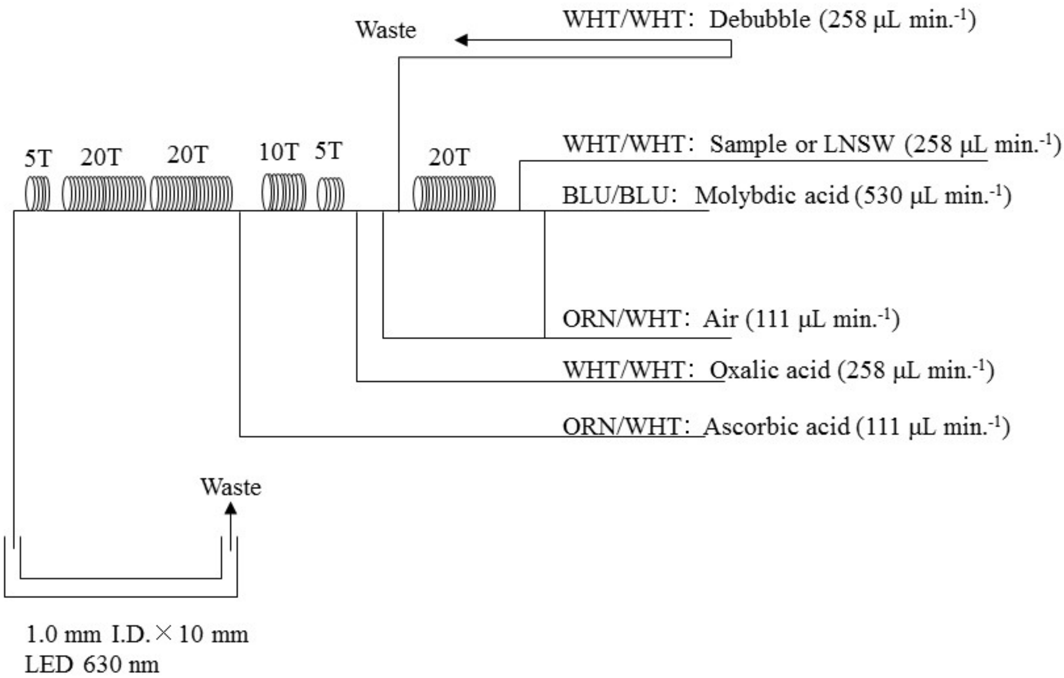


Figure 5.21-3 SiO_2 (3ch.) Flow diagram.

(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.

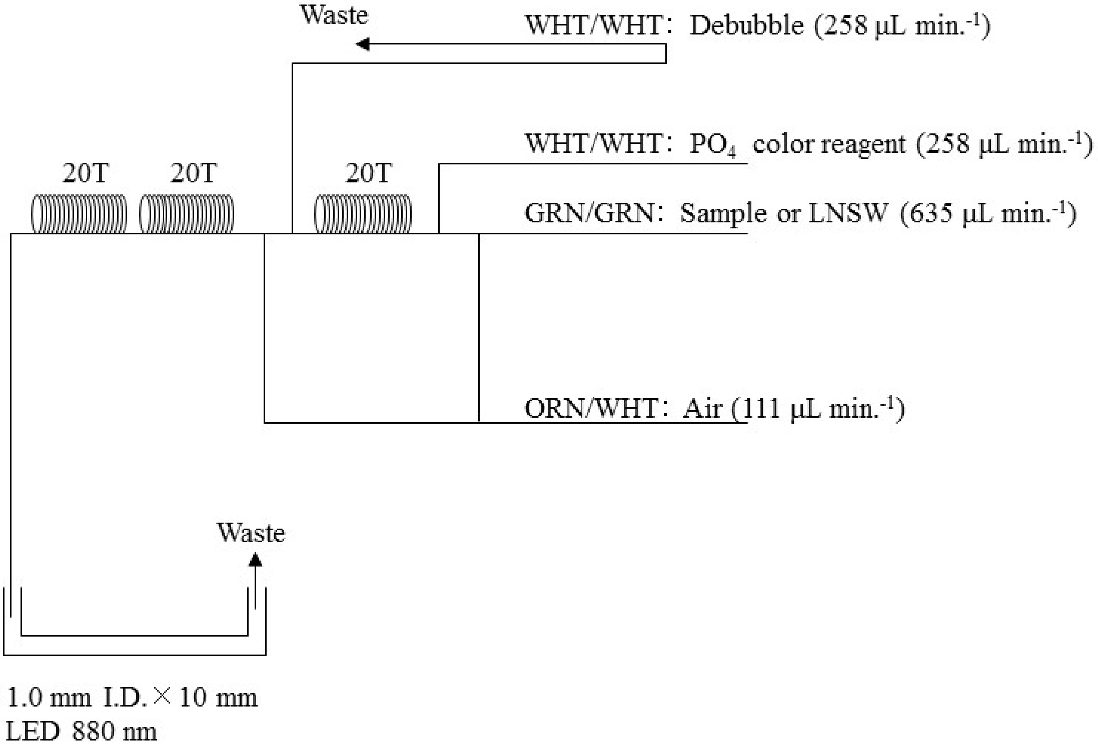


Figure 5.21-4 PO_4 (4ch.) Flow diagram.

(4.7) Sampling procedures

Sampling of nutrients followed that oxygen, salinity and trace gases. Samples were drawn into a virgin 10 mL polyacrylates vials without sample drawing tubes. These were rinsed three times before filling and vials were capped immediately after the drawing. The vials are put into water bath adjusted to ambient temperature, 19.5 ± 0.5 degree Celsius, in about 30 minutes before use to stabilize the temperature of samples.

No transfer was made and the vials were set an auto sampler tray directly. Samples were analyzed after collection within 24 hours.

(4.8) Data processing

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

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

(4.9) Summary of nutrients analysis

We made 3 QuAAtro runs for the water columns sample collected by 8 casts at station "STN" during this cruise. The total amount of layers of the seawater sample reached to 132. We made basically duplicate measurement.

(5) Station list

The sampling station list for nutrients is shown in Table 5.21-1.

Table 5.21-1 List of stations.

Station	Cast	Date (UTC)	Position*		Depth (m)
		(mmddyy)	Latitude	Longitude	
STN	3	082518	12-59.90N	136-41.08E	5027
STN	5	082618	13-00.32N	136-42.55E	4870
STN	7	082618	12-59.21N	136-42.01E	5148
STN	9	082618	12-59.30N	136-42.67E	5081
STN	11	082618	12-59.75N	136-41.29E	5050
STN	13	082718	13-00.71N	136-42.58E	4827
STN	15	082718	13-00.54N	136-42.25E	4881
STN	17	082718	12-59.45N	136-42.73E	5019

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

(6) Certified Reference Material of nutrients in seawater

KANSO CRMs (Lot: CJ) 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.

(6.1) 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 18.0 degree Celsius - 20.4 degree Celsius.

(6.2) CRM concentration

We used nutrients concentrations for CRM lots CJ as shown in Table 5.21-2.

Table 5.21-2 Certified concentration and uncertainty (k=2) of CRMs.

Lot	Nitrate	Nitrite	Silicate	Phosphate
CJ	16.20 ± 0.20	0.03 ± 0.01	38.50 ± 0.40	1.190 ± 0.020

(7) Nutrients standards

(7.1) 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.

(7.1.1) 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.

(7.1.2) 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.

(7.2) Reagents, general considerations

(7.2.1) 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 HC73014836 are used. The silicate concentration is certified by NIST-SRM3150 with the uncertainty of 0.7 %. HC73014836 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.

(7.2.2) 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.

(7.2.3) 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.

(7.2.4) 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 5.21-3. The C standard is prepared according recipes as shown in Table 5.21-4. 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 5.21-3 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	36	54
NO_2 (μM)	21900	870	26	LNSW	0.3	0.5	1.0	1.6
SiO_2 (μM)	35800		2845	LNSW	29	58	115	172
PO_4 (μM)	6000		60	LNSW	0.7	1.3	2.5	3.7

Table 5.21-4 Working calibration standard recipes.

C Std.	B Std.
C-5	30 mL

(7.2.5) Renewal of in-house standard solutions

In-house standard solutions as stated in paragraph (6.2) were renewed as shown in Table 5.21-5 to 5.21-7.

Table 5.21-5 Timing of renewal of in-house standards.

NO_3, NO_2, SiO_2, PO_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
D-1 Std.	maximum 8 days
D-2 Std.	maximum 8 days
B Std. (mixture of A-1, D-2, A-3 and A-4 std.)	maximum 8 days

Table 5.21-6 Timing of renewal of working calibration standards.

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

Table 5.21-7 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

(8) Quality control

(8.1) Precision of nutrients analyses during the cruise

Precision of nutrients analyses during this cruise was evaluated based on the 7 to 10 measurements, which are measured every 6 to 12 samples, during a run at the concentration of C-5 std. Summary of precisions are shown in Table 5.21-8. 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 0.11 % for nitrate, 0.06 % for nitrite, 0.09 % for silicate and 0.06 % for phosphate in terms of median of precision, respectively. Then we can conclude that the analytical precisions for nitrate, nitrite, silicate and phosphate were maintained throughout this cruise.

Table 5.21-8 Summary of precision based on the replicate analyses.

	Nitrate C.V. (%)	Nitrite C.V. (%)	Silicate C.V. (%)	Phosphate C.V. (%)
Median	0.11	0.06	0.09	0.06
Mean	0.11	0.07	0.09	0.06
Maximum	0.16	0.12	0.12	0.09
Minimum	0.07	0.04	0.06	0.03
N	3	3	3	3

(8.2) CRM lot. CJ measurement during this cruise

CRM lot. CJ was measured every run to keep the comparability. The results of lot. CJ during this cruise are shown as Table 5.21-9.

Table 5.21-9 Summary of CRM-CJ in this cruise.

	Nitrate	Nitrite	Silicate	Phosphate
Median (μmol kg^{-1})	16.18	0.04	38.84	1.194
Mean (μmol kg^{-1})	16.16	0.04	38.83	1.194
S.D. (μmol kg^{-1})	0.06	0.00	0.07	0.005
C.V. (%)	0.38	1.50	0.18	0.45
N	4	4	4	4

(8.3) Carry over

We can also summarize the magnitudes of carry over throughout the cruise. These are small enough within acceptable levels as shown in Table 5.21-10.

Table 5.21-10 Summary of carry over throughout this cruise.

	Nitrate %	Nitrite %	Silicate %	Phosphate %
Median	0.11	0.10	0.09	0.11
Mean	0.08	0.10	0.09	0.09
Maximum	0.12	0.12	0.11	0.12
Minimum	0.00	0.09	0.07	0.03
N	3	3	3	3

(9) Problems / improvements occurred and solutions.

Nothing happened during this cruise.

(10) List of reagent

List of reagent is shown in Table 5.21-11.

Table 5.21-11 List of reagent in this cruise.

IUPAC name	CAS Number	Formula	Compound Name	Manufacture	Grade
4-Aminobenzenesulfonamide	63-74-1	C6H8N2O2S	Sulfanilamide	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
Antimony potassium tartrate trihydrate	28300-74-5	K2(SbC4H2O6)2·3H2O	Bis[(+)-tartrato]diantimonate(III) Dipotassium Trihydrate	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	C3H4N2	Imidazole	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
L-Ascorbic acid	50-81-7	C6H8O6	L-Ascorbic Acid	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
N-(1-Naphthalenyl)-1,2-ethanediamine, dihydrochloride	1465-25-4	C12H16Cl2N2	N-1-Naphthylethylenediamine Dihydrochloride	Wako Pure Chemical Industries, Ltd.	for Nitrogen Oxides Analysis
Oxalic acid	144-62-7	C2H2O4	Oxalic Acid	Wako Pure Chemical Industries, Ltd.	Wako Special Grade
Potassium nitrate	7757-79-1	KNO3	Potassium Nitrate	Merck KGaA	Suprapur®
Potassium dihydrogen phosphate	7778-77-0	KH2PO4	Potassium dihydrogen phosphate anhydrous	Merck KGaA	Suprapur®
Sodium dodecyl sulfate	151-21-3	C12H25NaO4S	Sodium Dodecyl Sulfate	Wako Pure Chemical Industries, Ltd.	for Biochemistry
Sodium molybdate dihydrate	10102-40-6	Na2MoO4·2H2O	Disodium Molybdate(VI) Dihydrate	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
Sulfuric acid	7664-93-9	H2SO4	Sulfuric Acid	Wako Pure Chemical Industries, Ltd.	JIS Special Grade
Synonyms: t-Octylphenoxypolyethoxyethanol 4-(1,1,3,3-Tetramethylbutyl)phenyl-polyethylene glycol Polyethylene glycol tert-octylphenyl ether	9002-93-1	(C2H4O)nC14H22O	Triton™ X-100	Sigma-Aldrich Japan G.K.	-

(11) 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>.

(12) 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.

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

5.22 Chlorophyll-a in the sampled water

(1) Personnel

Masaki KATSUMATA (JAMSTEC) : Principal Investigator
Hiroshi HOSHINO (MWJ) : Operation Leader
Tomomi SONE (MWJ)

(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 from 12 depths between the surface and 300 m depth including a chlorophyll *a* maximum layer. The chlorophyll *a* maximum layer was determined by a Chlorophyll Fluorometer (Seapoint Sensors, Inc.) attached to the CTD system.

Seawater samples were vacuum-filtrated (< 0.02 MPa) through glass microfiber filter (Whatman GF/F, 25mm-in diameter). Phytoplankton pigments retained on the filters were immediately extracted in a polypropylene tube with 7 ml of N,N-dimethylformamide (FUJIFILM Wako Pure Chemical Corporation 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, 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). Analytical conditions of this method were listed in table 5.22-1.

(5) Station list

52 samples were collected at the 4 casts conducted at the station STN.

(6) Preliminary Results

Time-series profile for chlorophyll *a* at the station STN were shown in figure 5.22-1. At each cast, water samples were taken in replicate for water of chlorophyll *a* maximum layer. The relative error was 1 % (n = 4).

(7) Data archives

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

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

(8) Reference

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

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

Table 5.22-1. Analytical conditions of non-acidification method for chlorophyll *a* with TURNER DESIGNS flurorometer (10-AU-005).

Excitation filter (nm)	: 436
Emission filter (nm)	: 680
Lamp	: Blue F4T4.5B2 equivalent

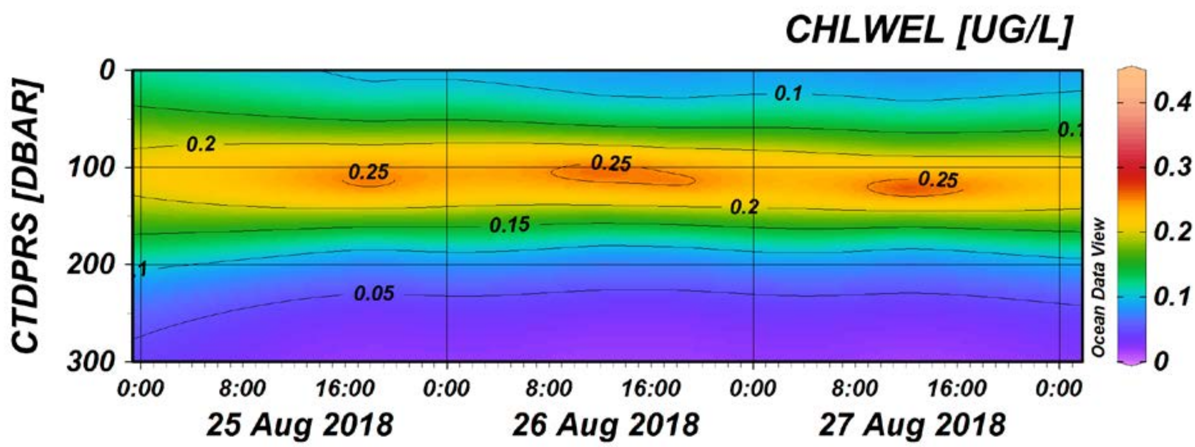


Figure 5.22-1. Time-series profile of total chlorophyll *a* at Stn.STN.

5.23 LADCP

(1) Personnel

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Keisuke TAKEDA	(MWJ)	
Jun MATSUOKA	(MWJ)	
Masanori ENOKI	(MWJ)	
Yoshiaki SATO	(MWJ)	

(2) Objectives

To obtain horizontal current velocity in high vertical resolution.

(3) Methods

In order to measure the velocity structure at fine vertical scales a high frequency ADCP was used in lowered mode (LADCP). The instrument was a Teledyne RDI Workhorse Sentinel 600kHz ADCP (WHS600-I-UG177, S/N 14557) rated for 1000m depth.

The instrument was attached to the frame of the CTD system using a steel collar sealed around the instrument by three bolts on each side, with the collar attached to the rosette frame by two u-bolts on two mounting points (see Figure 5.23-1).

The instrument was deployed during CTD casts between C05M001 and STNM017 (except for STNM001, which was deeper than 5000m), performing well throughout its use. The instrument was self-contained with an internal battery pack. The health of the battery was monitored by the recorded voltage count.

Figure 5.23-1:Mounting of LADCP on CTD System

The instrument was controlled at deploy and recover stages by the RDI software (BBTalk) installed on the Windows PC. The commands sent to the instrument at setup were contained in ladcp600.txt. The instrument was set up to have a relatively small bin depth (2m) and a fast ping rate (every 0.25 sec). The full list of commands sent to the instrument were:

CR1	# Retrieve parameter (default)
TC2	# Ensemble per burst
WP1	# Pings per ensemble
TE 00:00:00.00	# Time per ensemble (time between data collection cycles)
TP 00:00.25	# Time between pings in mm:ss
WN25	# Number of Depth cells
WS0200	# Depth cell size (in cm)
WF0088	# Blank after transit (recommended setting for 600kHz)
WB0	# Mode 1 bandwidth control (default - wide)
WV250	# Ambiguity velocity (in cm/s)
EZ0111101	# Sensor source (speed of sound excluded)
EX00000	# Beam coordinates
CF11101	# Data flow control parameters

(see the RDI Workhorse "Commands and Data Output Format" document for details.)

(4) Preliminary results

During the cruise, 17 profiles were obtained in total. All the data has to be converted and quality-controlled before the analyses. The further analyses will be in near future.

(5) Data archive

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

5.24 XCTD

(1) Personnel

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Yutaro MURAKAMI (NME)
Takehito HATTORI (MIRAI Crew)

(2) Objective

Investigation of oceanic structure.

(3) Methods

We observed the vertical profiles of the sea water temperature and salinity measured by XCTD-1 (manufactured by Tsurumi-Seiki Co.). The signal was converted by MK-150N (Tsurumi-Seiki Co.) and was recorded by AL-12B software (Ver.1.1.4; Tsurumi-Seiki Co). The specifications of the measured parameters are as in Table 5.24-1. We launched probes by using automatic launcher during MR18-04Leg2 cruise as listed in Table 5.24-2.

Table 5.24-1: The range and accuracy of parameters measured by XCTD-1.

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

Table 5.24-2: List of XCTD observations. SST (sea surface temperature) and SSS (sea surface salinity).

No.	Date [YYYY/MM/DD]	Time [hh:mm]	Latitude [dd-mm.mmmm N]	Longitude [ddd-mm.mmmm E]	Depth [m]	SST [deg-C]	SSS [PSU]	Probe S/N
1	2018/08/24	12:03	13-07.1236	136-56.5347	5332	29.202	34.109	18033086
2	2018/08/24	15:03	13-07.3556	136-55.9389	5299	29.124	34.107	18033085
3	2018/08/24	18:02	13-06.4827	136-55.9180	5330	29.140	34.093	18033087
4	2018/08/24	20:47	13-04.9410	136-04.9244	4738	28.937	33.814	18033084
5	2018/08/25	00:04	13-09.3787	136-49.2717	4921	29.108	34.140	18033082
6	2018/08/25	03:08	13-07.3656	136-54.6426	5104	29.134	34.091	18033083
7	2018/08/25	06:16	13-08.5956	136-53.5795	5132	29.143	34.085	18033081
8	2018/08/25	09:03	13-09.4878	136-53.5795	5207	29.102	34.022	18033088
9	2018/08/25	12:07	13-00.1362	136-41.6317	4991	29.056	34.095	18033089
10	2018/08/27	15:04	12-59.1197	136-43.2574	4952	29.360	34.004	18033092
11	2018/08/27	18:02	12-54.3620	136-53.1415	5225	29.163	33.973	18033090
12	2018/08/27	21:03	12-50.6519	136-52.5803	5060	29.122	33.966	18043295
13	2018/08/28	00:05	12-52.6246	136-52.6852	4819	29.165	33.963	18043297
14	2018/08/28	03:03	12-53.1985	136-53.1901	5186	29.251	33.993	18043294
15	2018/08/28	06:00	12-47.8492	136-25.8039	5248	29.375	34.004	18043293
16	2018/08/28	09:02	12-48.6800	136-25.5740	5112	29.250	33.968	18043296
17	2018/08/28	12:02	12-49.4058	136-25.1102	4857	29.204	33.955	18043298

(4) Data archive

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

5.25 CTD profiling for near-surface layer

(1) Personnel

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Jun MATSUOKA	(MWJ)	
Masanori ENOKI	(MWJ)	
Yoshiaki SATO	(MWJ)	

(2) Objectives

The oceanic near-surface layer is critical to dominate the (latent and sensible) heat flux to the atmosphere, while the layer is affected by the various atmospheric (and oceanic) processes. However, the physical characteristics of near-surface few to several meters are not well captured by CTD (Section 5.18) or XCTD (Section 5.25). To obtain the oceanic profile in that layer, we deployed small CTD unit.

(3) Instrumentations and Methods

The RINKO profiler (manufactured by JFE Advantech) is utilized. The profiler is packaged in small body (60mm x 491mm, 1kg (within water)) and equipped sensors for depth, temperature, conductivity (for salinity), chlorophyll-a, turbidity, and dissolved oxygen. The specification of the sensors are shown in Table 5.25-1. The data interval can be set as 0.1 to 1.0 meters in depth, or 0.1 to 600 seconds in time. The profiler is pressure-resistant down to 1000 meters.

We deployed it from the middle of the starboard side (middle of the upper deck, so-called "muster pad"). The profiler was tied to the rope of approximately 25 meters in length, which enable to deploy the sensor down to 10-meter in depth. The data interval was set as every 0.1 meters. When we deploy it, the vessel was maneuvered to minimize disturbing the environmental water as possible, by controlling speed $\leq$ 1 kt, and relative wind comes from the bow.

The deployments were done every 3 hours from 12Z on Aug. 24 to 12Z on Aug. 28, except at 18Z on Aug. 27. Among the period, the data from 12Z on Aug. 25 to 15Z on Aug. 27 were obtained within 2 miles from (13.0N, 136.7E). The other were also obtained within the area of (12.80N to 13.16N, 136.42E to 137.08E).

In addition to the deployment from the deck, we attached the RINKO profiler unit to the CTD frame (used in Section 5.18) at 4 CTD casts, to estimate the difference from the precise measurements in CTD system. On that measurement, we set the data interval as every 1 meter.

(4) Preliminary Results

The time-depth cross sections for the temperature and salinity during 3-hourly observations are shown in Fig. 5.25-1. Daytime warming were well captured. Intermittent salinity drop, especially in top 1 meter, were also observed when rainfall were observed above / nearby the vessel. The further analyses and quality control will be carried out after the cruise.

(5) Data Archive

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

Table 5.25-1: The specification of the sensors in RINKO profiler, as described in the instruction manual.

Parameter	Range	Resolution	Precision	Responce
Depth	0 to 600m/1000m	0.01m	± 0.3%	0.2 s
Temperature	-3 to 45 ℃	0.001 ℃	± 0.01 ℃	0.2 s
Conductivity	0.5 to 70 mS/cm	0.001 mS/cm	± 0.01 mS/cm	0.2 s
(Salinity)	2 to 42	0.001	(not described)	0.2 s
Turbidity	0 to 1000 FTU	0.03 FTU	± 0.3 FTU	0.2 s
Chlorophyll	0 to 400 ppb	0.01 ppb	± 1 % FS	0.2 s
Dissolved Oxygen	0 to 20 mg/l	0.001 mg/l	± 2 % FS	0.4 s

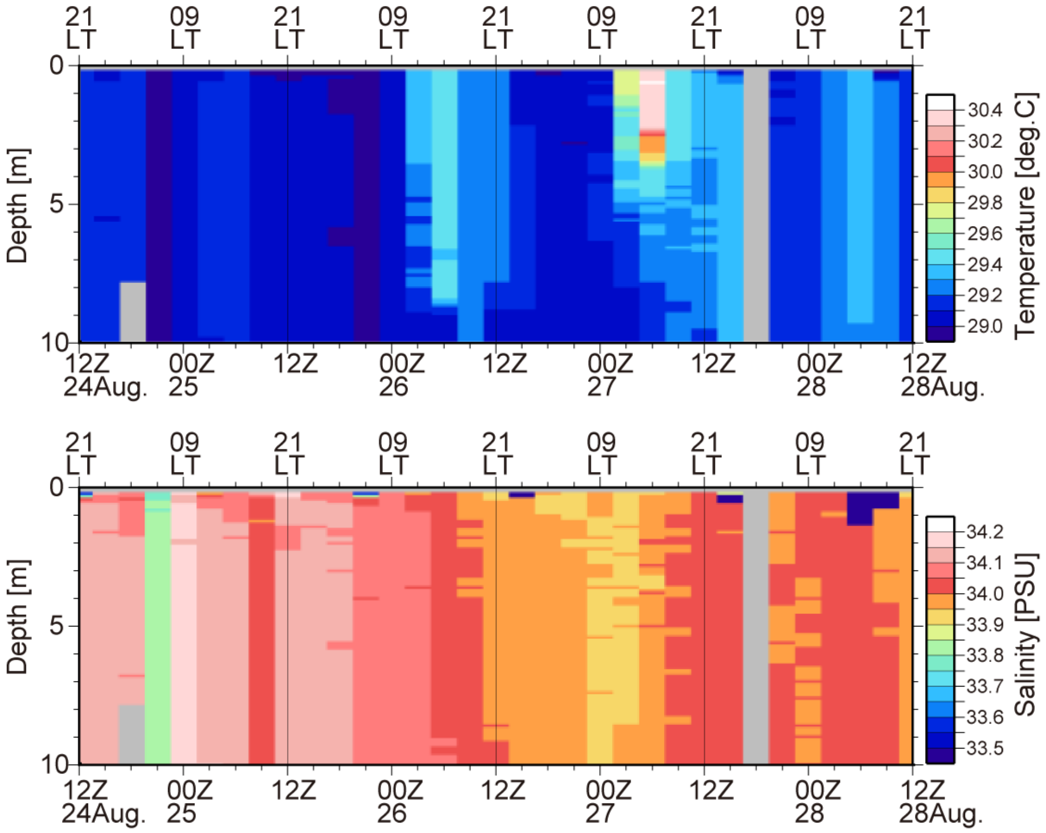


Fig. 5.25-1: Time-depth cross section of observed temperature (upper panel) and salinity (lower panel), for the period of 3-hourly observation from 12Z on Aug.24 to 12Z on Aug.28. Gray-shaded areas are where data is not available.

5.26 Shipboard ADCP

(1) Personnel

Masaki KATSUMATA	(JAMSTEC) * Principal Investigator
Kazuho YOSHIDA	(Nippon Marine Enterprises Ltd., NME)
Shinya OKUMURA	(NME)
Yutaro MURAKAMI	(NME)
Takehito HATTORI	(MIRAI Crew)

(2) Objectives

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

(3) Instruments and methods

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

1. R/V MIRAI has installed the Ocean Surveyor for vessel-mount ADCP (frequency 76.8 kHz; Teledyne RD Instruments, USA). It has a phased-array transducer with single ceramic assembly and creates 4 acoustic beams electronically. We mounted the transducer head rotated to a ship-relative angle of 45 degrees azimuth from the keel.
2. For heading source, we use ship's gyro compass (Tokyo Keiki, Japan), continuously providing heading to the ADCP system directory. Additionally, we have Inertial Navigation System (PHINS, IXBLUE, France) which provide high-precision heading, attitude information, pitch and roll. They are stored in ".N2R" data files with a time stamp.
3. Differential GNSS system (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, 15 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 and Direct Command are shown in Table 5.26-1.

Table 5.26-1: 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; V sum; 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

Fig. 5.26.1 shows horizontal velocity along the ship's track. Fig. 5.26-2 shows the velocity time series at the station point (near 13N137E).

(6) Data Archives

Surface gravity 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> .

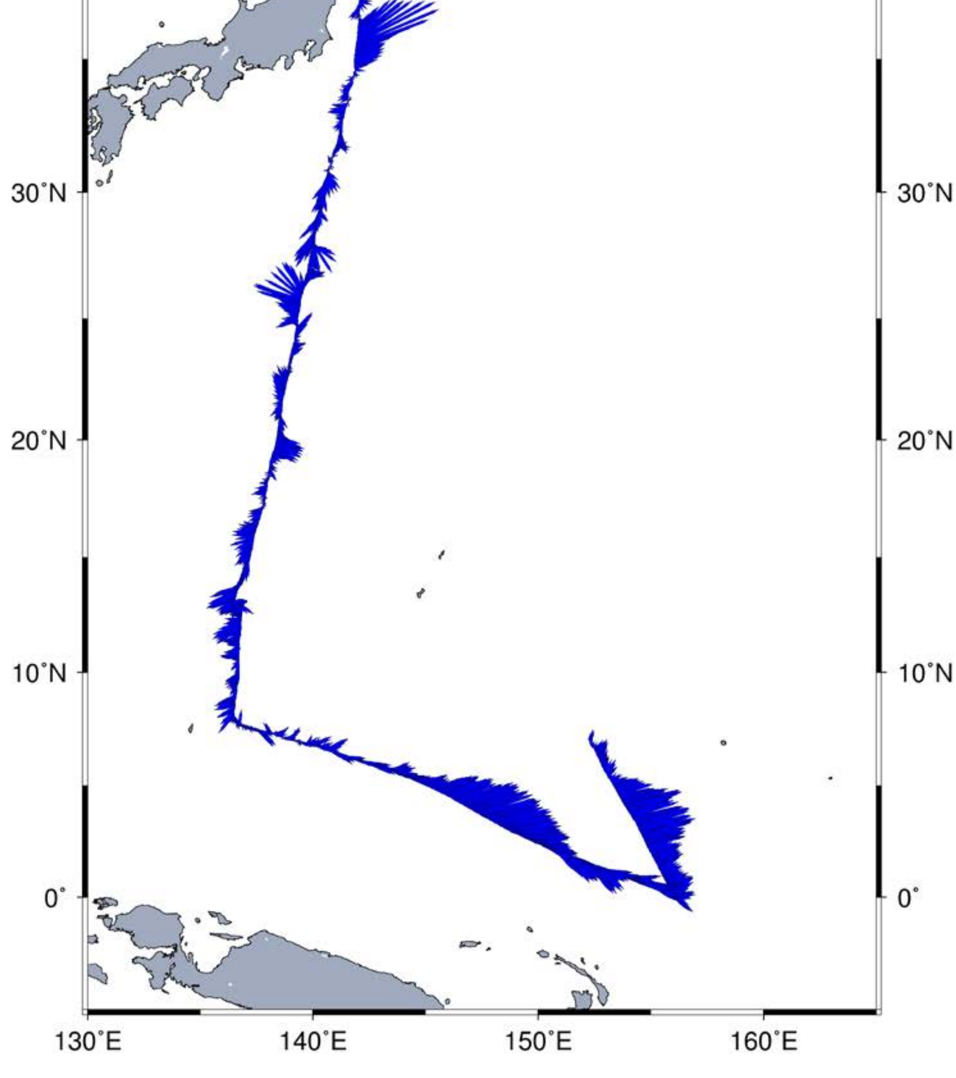


Fig. 5.26-1 Horizontal Velocity along the ship’s track

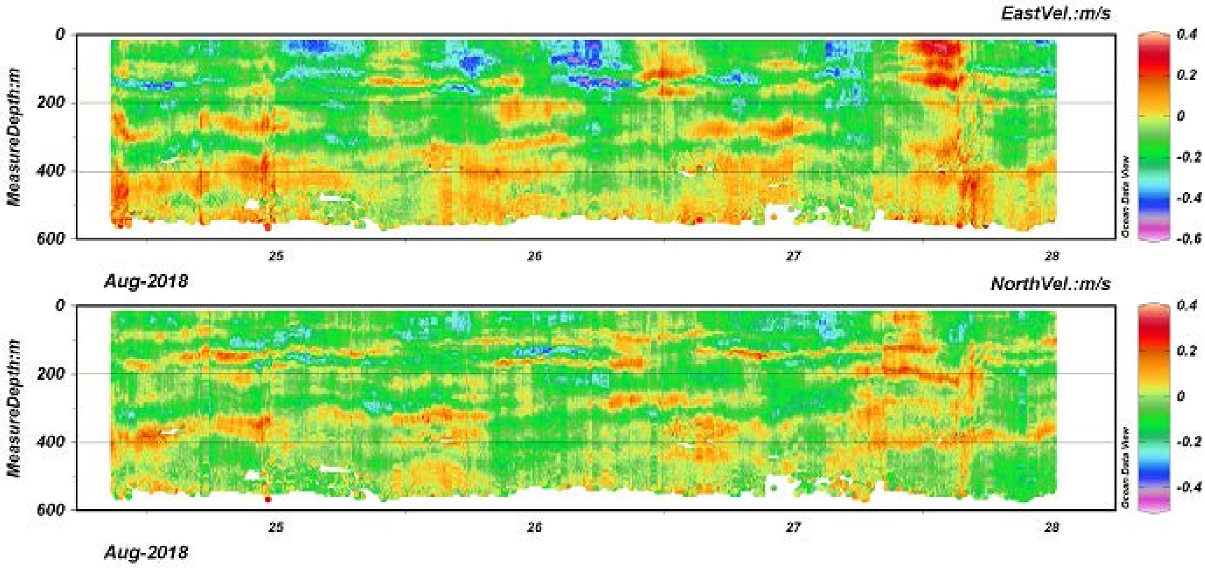


Fig. 5.26-2 current velocity time series at the station point (near 13N137E).

5.27 Underway pCO_2

(1) Personnel

Yoshiyuki NAKANO	(JAMSTEC)	: Principal Investigator
Yasuhiro ARII	(MWJ)	: Operation Leader
Masahiro ORUI	(MWJ)	
Erii IRIE	(MWJ)	

(2) Objective

Our purpose is in-situ measurement of partial pressure of carbon dioxide (pCO_2) in near-sea surface water

(3) Methods, Apparatus and Performance

Oceanic and atmospheric CO_2 concentrations were measured during the cruise using an automated system equipped with a non-dispersive infrared gas analyzer (NDIR; LI-7000, Li-Cor). Measurements were done every about one hour, and 4 standard gasses, atmospheric air, and the CO_2 equilibrated air with sea surface water were analyzed subsequently. The concentrations of the CO_2 standard gases were assigned (229.946, 290.148, 370.100, and 430.155 ppm). Atmospheric air taken from the bow of the ship (approx.13 m above the sea level) was introduced into the NDIR by passing through an electrical cooling unit, a mass flow controller which controls the air flow rate of 0.55 L min^{-1}, and a staring cooler. The CO_2 equilibrated air was the air with its CO_2 concentration was equivalent to the sea surface water. Seawater was taken from an intake placed at the approximately 4.5 m below the sea surface and introduced into the equilibrator at the flow rate of (4 - 5) L min^{-1} by a pump. The equilibrated air was circulated in a closed loop by a pump at flow rate of (0.6 - 0.8) L min^{-1} through two cooling units, the starling cooler, and the NDIR.

(4) Preliminary result

Cruise track during pCO_2 observation is shown in Fig. 5.27-1, and temporal variations of both oceanic and atmospheric CO_2 concentration (xCO_2) in Fig. 5.27-2.

(5) Data archive

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

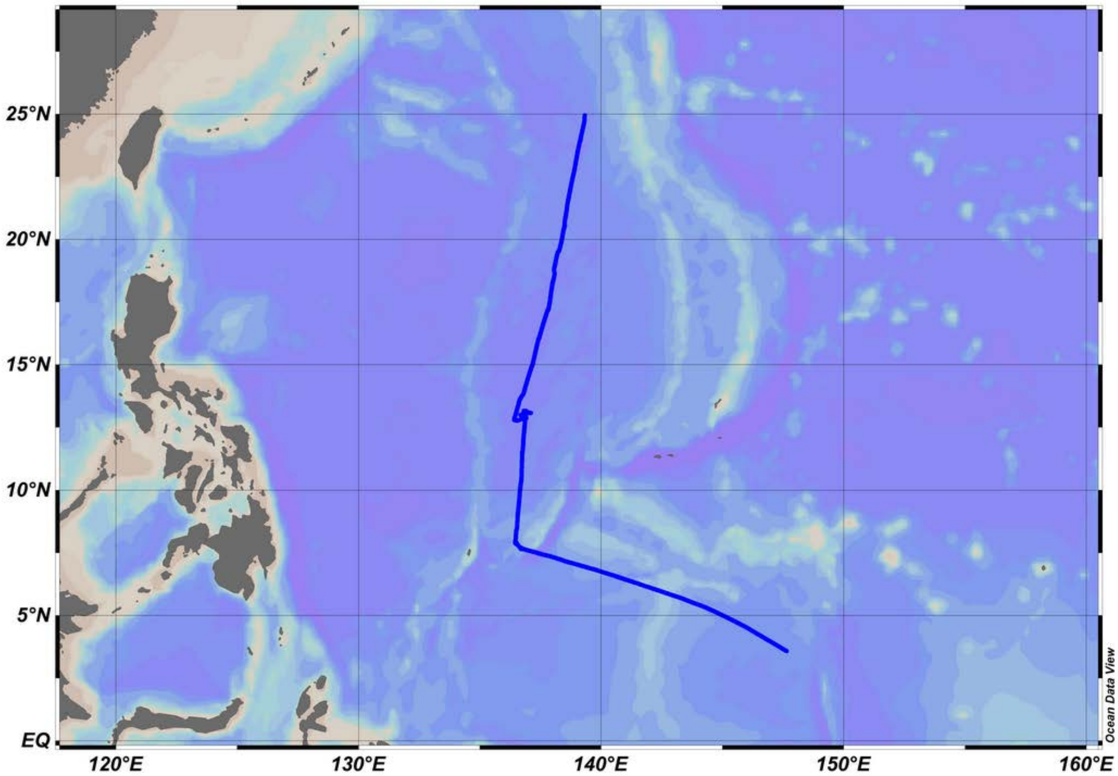


Figure 5.27-1: Observation map.

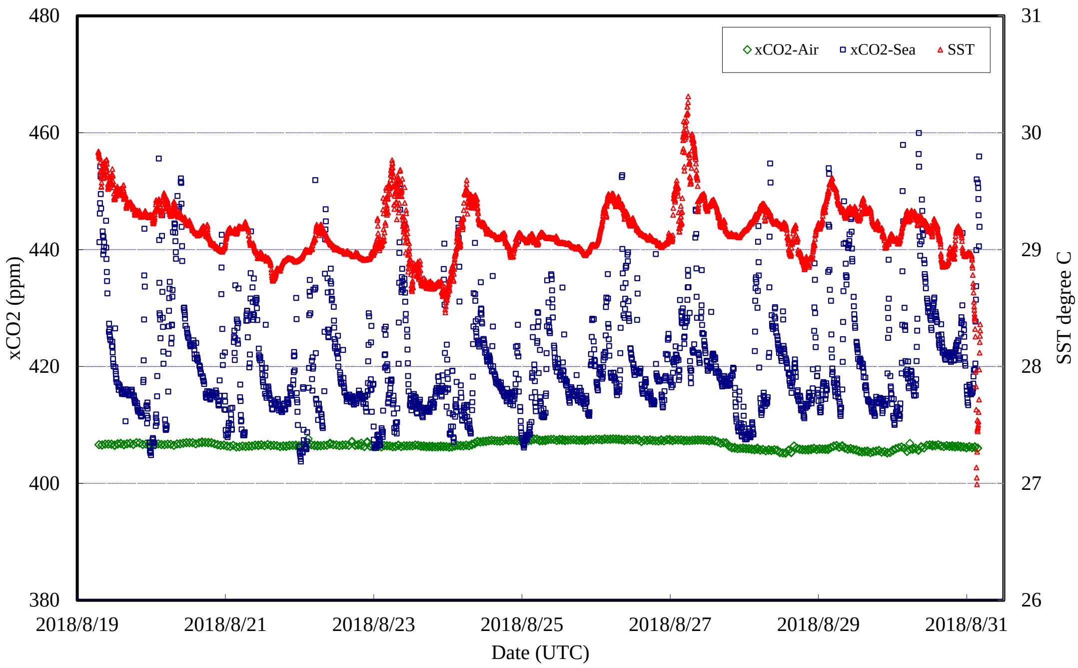


Figure 5.27-2: Temporal variations of oceanic and atmospheric CO_2 concentration (xCO_2). Blue dots represent oceanic xCO_2 variation and green atmospheric xCO_2. SST variation (red) is also shown.

5.28 Underway Geophysics

Personnel

Masaki KATSUMATA	(JAMSTEC)
Kazuho YOSHIDA	(Nippon Marine Enterprises Ltd., NME)
Shinya OKUMURA	(NME)
Yutaro MURAKAMI	(NME)
Takehito HATTORI	(MIRAI Crew)

5.29.1 Sea surface gravity

(1) Introduction

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

(2) Parameters

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

(3) Data Acquisition

We measured relative gravity using LaCoste and Romberg air-sea gravity meter S-116 (Micro-g LaCoste, LLC) during this cruise.

To convert the relative gravity to absolute one, we measured gravity, using portable gravity meter CG-5 (Scintrex), at Port of Shimizu and Sekinehama as the reference points.

(4) Preliminary Results

Absolute gravity table was shown in Table.5.29.1-1.

Table 5.29.1-1 Absolute gravity table

No.	Date and Time [UTC]	Port	Absolut Gravity [mGal]	Sea Level [cm]	Ship Draft [cm]	Gravity at Sensor [mGal]	S-116 Gravity [mGal]
1	Jul.19 00:28	Shimizu	979,729.47	176	649	979,730.28	12,018.00
2	Sep.07 03:03	Sekinehama	980,371.87	214	610	980,372.71	12,658.92

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

(5) Data Archives

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

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

5.29.2 Sea surface three-component magnetometer

(1) Introduction

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

(2) Principle of ship-board geomagnetic vector measurement

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

$Hob = A * R * P * Y * F + Hp$ (a)

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

$B * Hob + Hbp = R * P * Y * F$ (b)

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

(3) Instruments on R/V MIRAI

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

(4) Data Archives

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

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

(5) Remarks

1) For calibration of the ship’s magnetic effect, we made a “figure-eight” turn (a pair of clockwise and counter-clockwise rotation). These calibrations were carried out as below.
   04:28UTC to 04:45UTC, 15 Aug. 2018 around 00-00.1S, 156-03.5E

5.29.3 Swath Bathymetry

(1) Introduction

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

(2) Data Acquisition

The "SEABEAM 3012 Model" on R/V MIRAI was used for bathymetry mapping during this cruise.

To get accurate sound velocity of water column for ray-path correction of acoustic multibeam, we used Surface Sound Velocimeter (SSV) data to get the sea surface (6.62m) sound velocity, and the deeper depth sound velocity profiles were calculated by temperature and salinity profiles from CTD and Argo float data by the equation in Del Grosso (1974) during the cruise. Table 5.29.3-1 shows system configuration and performance of SEABEAM 3012 system.

Table 5.29.3-1 SEABEAM 3012 System configuration and performance

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

(3) Preliminary Results

The results will be published after primary processing.

(4) Data Archives

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

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

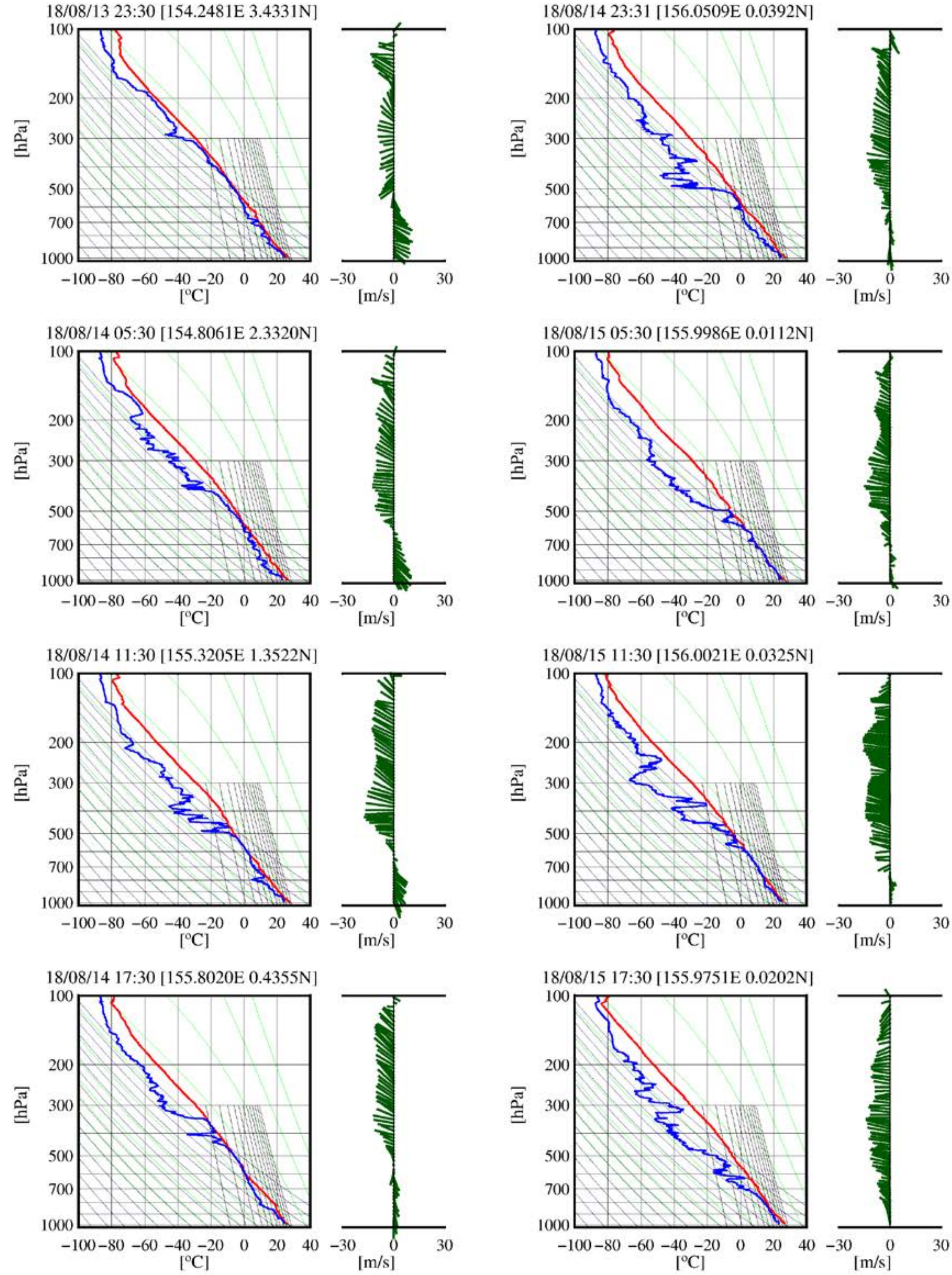
(5) Remarks

1) The following period, data acquisitions were suspended due to system trouble.
20:19UTC - 20:34UTC 13 Aug 2018
05:18UTC - 05:24UTC 02 Sep. 2018

2) The following period, SSV data were calculated from the SST and SSS, because SSV sensor data were not appropriate.
05:24UTC 02 Sep. 2018 - 04:56UTC 03 Sep. 2018

3) The following period, SSV data sometimes contain incorrect data.
13:12UTC 01 Sep. 2018 - 14:21UTC 01 Sep. 2018
17:20UTC 01 Sep. 2018 - 19;16UTC 01 Sep. 2018
00:45UTC 02 Sep. 2018 - 01:54UTC 02 Sep. 2018
04:19UTC 02 Sep. 2018 - 05:13UTC 02 Sep. 2018

Appendix-A: Atmospheric profiles by the radiosonde observations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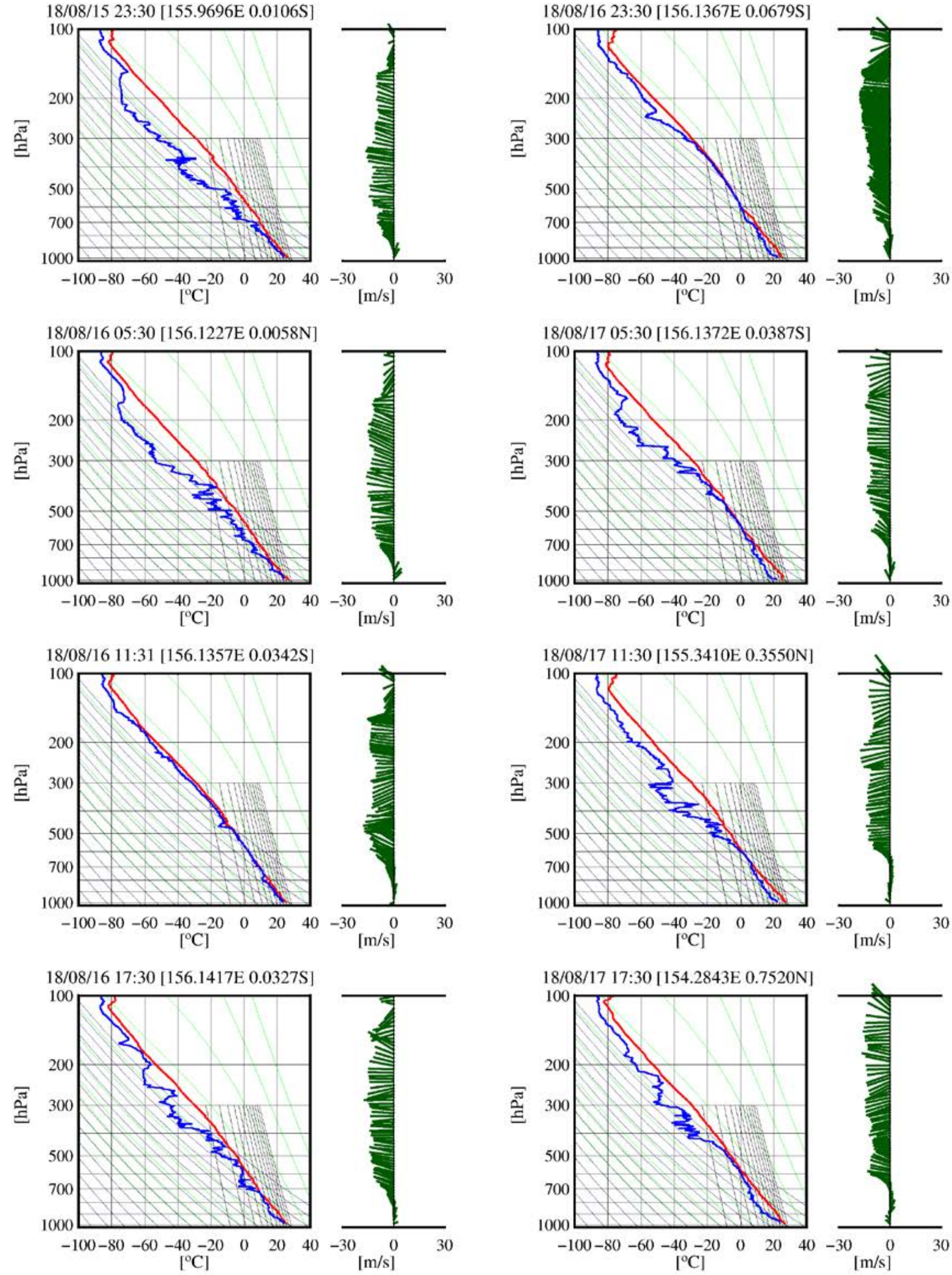
18/08/14 23:31 [156.0509E 0.0392N]
18/08/14 05:30 [154.8061E 2.3320N]
18/08/15 05:30 [155.9986E 0.0112N]
18/08/14 11:30 [155.3205E 1.3522N]
18/08/15 11:30 [156.0021E 0.0325N]
18/08/14 17:30 [155.8020E 0.4355N]
18/08/15 17:30 [155.9751E 0.0202N]
[hPa]
[°C]
[m/s]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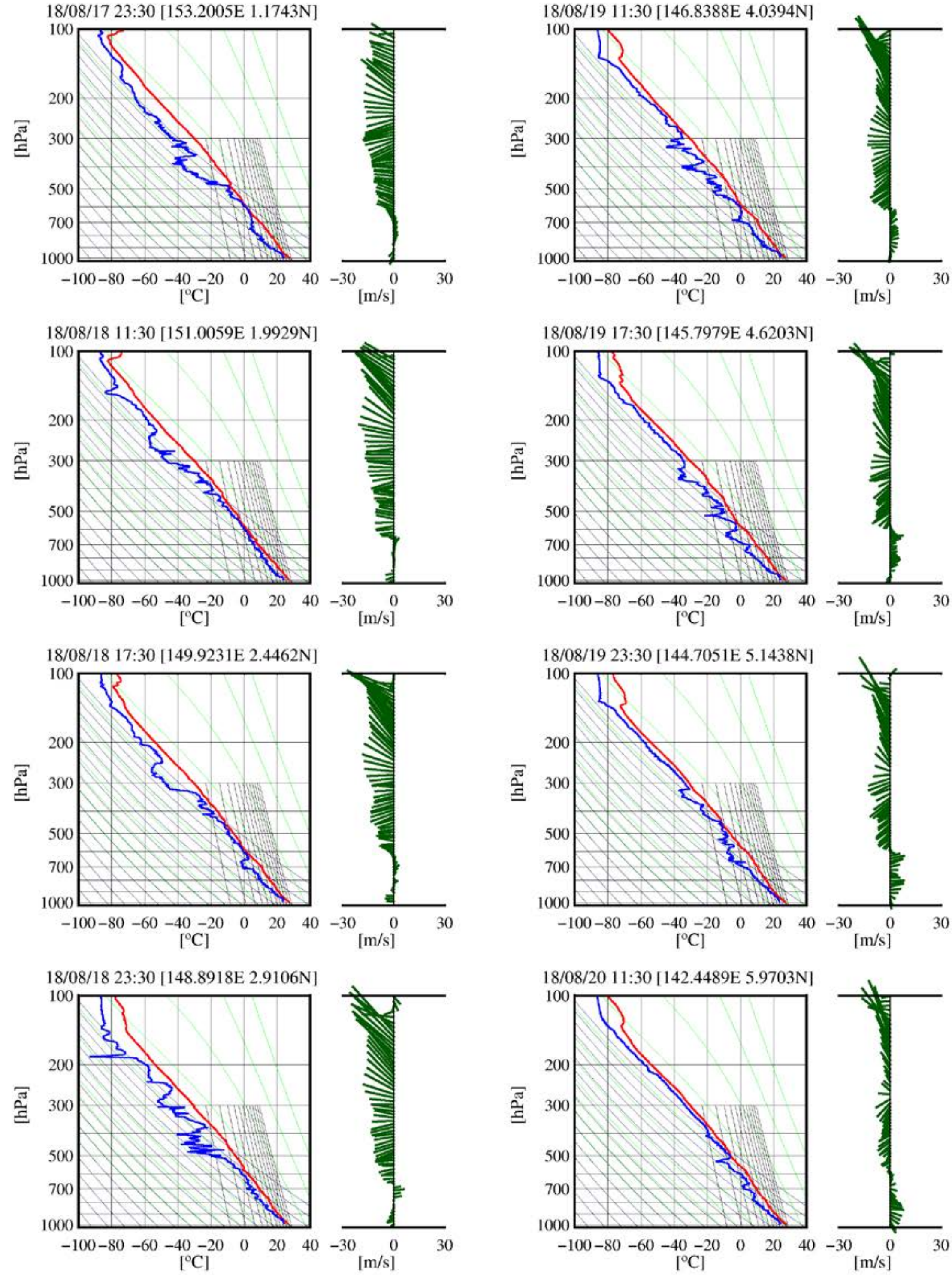
18/08/17 05:30 [156.1372E 0.0387S]
18/08/16 11:31 [156.1357E 0.0342S]
18/08/17 11:30 [155.3410E 0.3550N]
18/08/16 17:30 [156.1417E 0.0327S]
18/08/17 17:30 [154.2843E 0.7520N]
[hPa]
100
200
300
500
700
1000
−100 −80 −60 −40 −20 0 20 40
[°C]
−30 0 30
[m/s]



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18/08/19 11:30 [146.8388E 4.0394N]
18/08/18 11:30 [151.0059E 1.9929N]
18/08/19 17:30 [145.7979E 4.6203N]
18/08/18 17:30 [149.9231E 2.4462N]
18/08/19 23:30 [144.7051E 5.1438N]
18/08/18 23:30 [148.8918E 2.9106N]
18/08/20 11:30 [142.4489E 5.9703N]
[hPa]
100
200
300
500
700
1000
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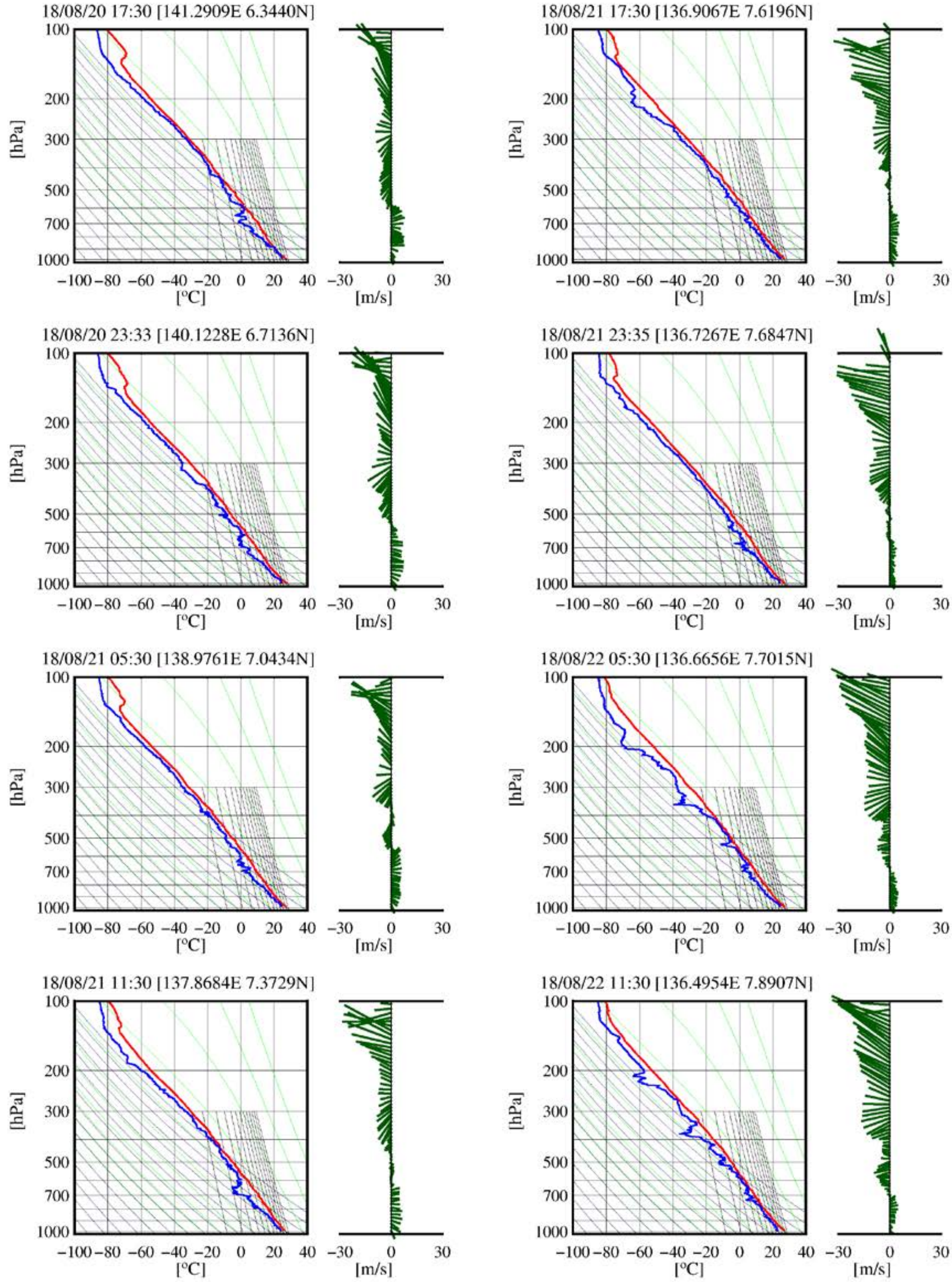
[°C]
−30 0 30
[m/s]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18/08/21 23:35 [136.7267E 7.6847N]
18/08/21 05:30 [138.9761E 7.0434N]
18/08/22 05:30 [136.6656E 7.7015N]
18/08/21 11:30 [137.8684E 7.3729N]
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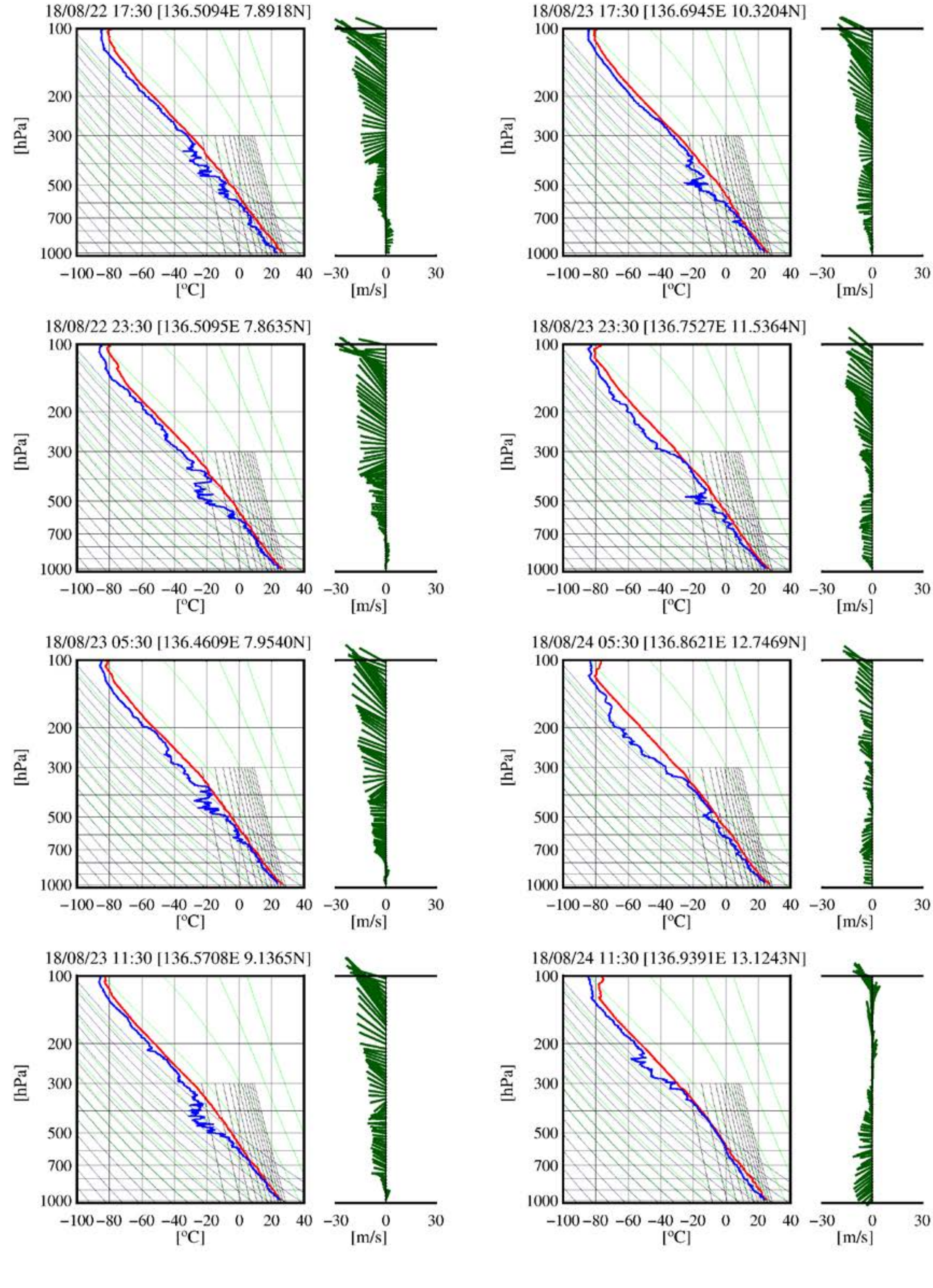
[hPa]
[ºC]
[m/s]



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18/08/23 23:30 [136.7527E 11.5364N]
18/08/23 05:30 [136.4609E 7.9540N]
18/08/24 05:30 [136.8621E 12.7469N]
18/08/23 11:30 [136.5708E 9.1365N]
18/08/24 11:30 [136.9391E 13.1243N]
[hPa]
100
200
300
500
700
1000
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[ºC]
−30 0 30
[m/s]

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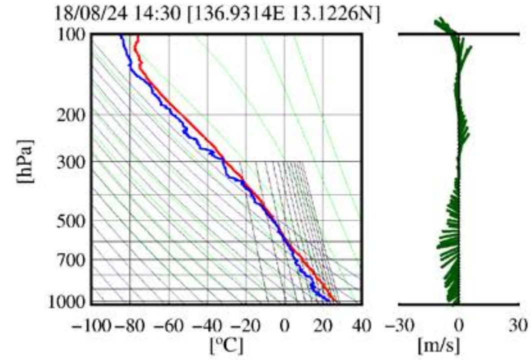

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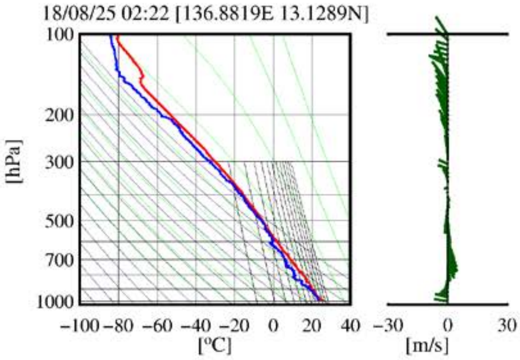

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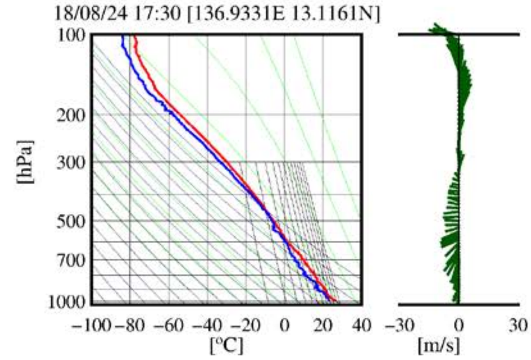

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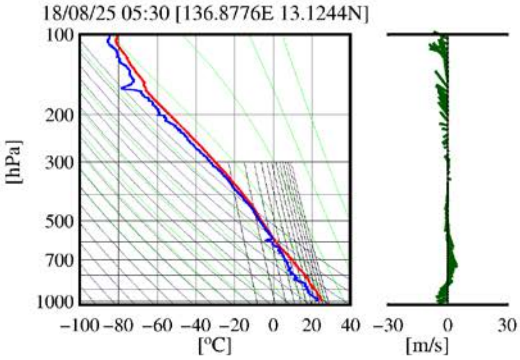

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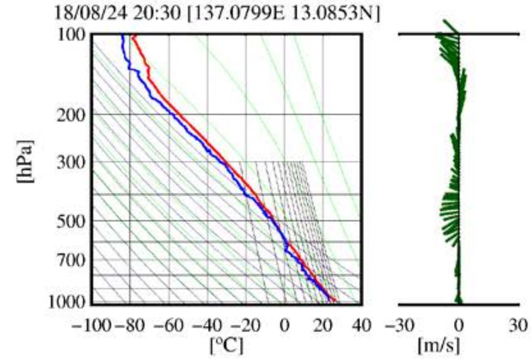

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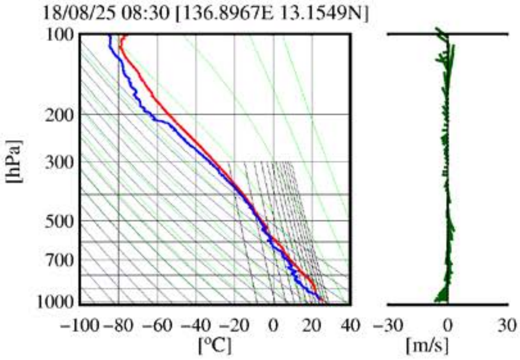

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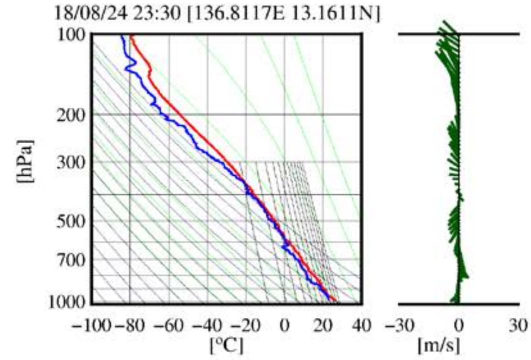

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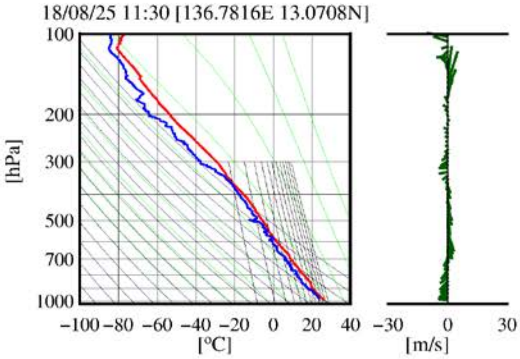

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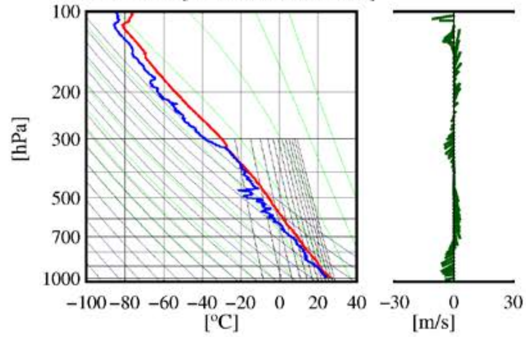

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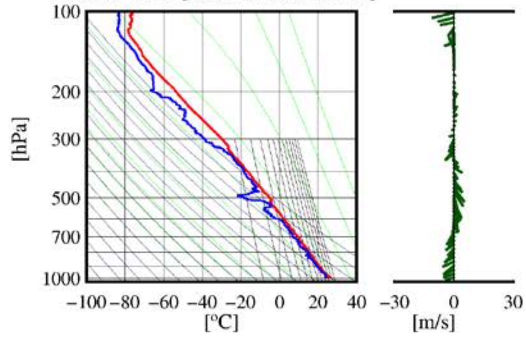

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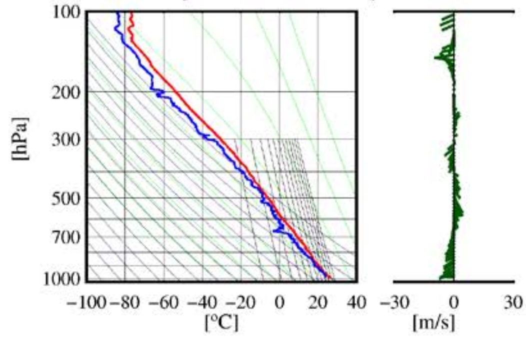

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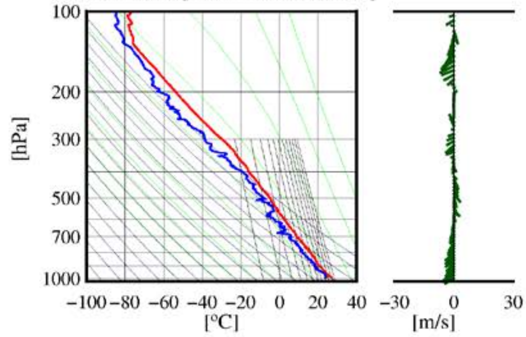

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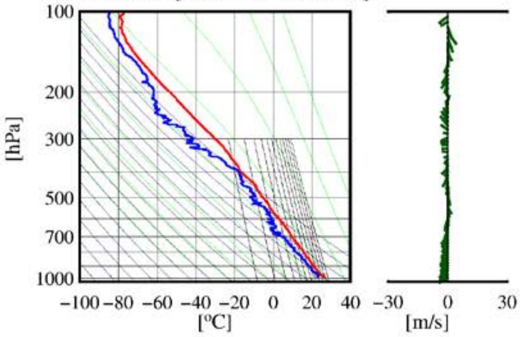

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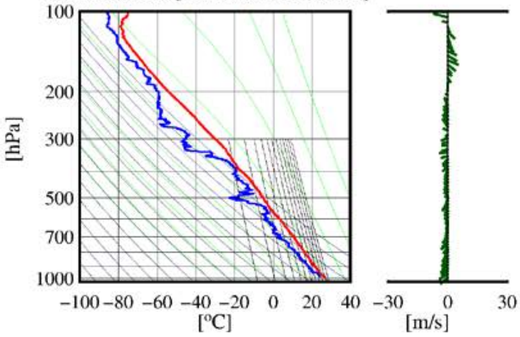

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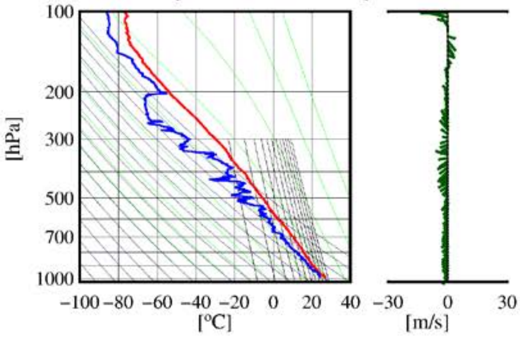
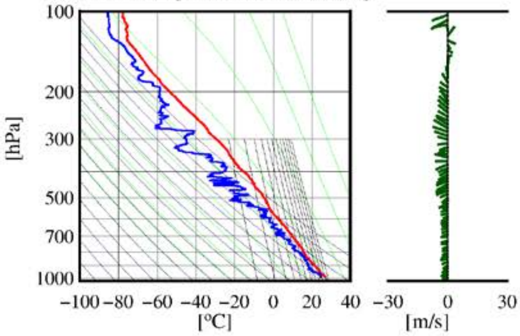
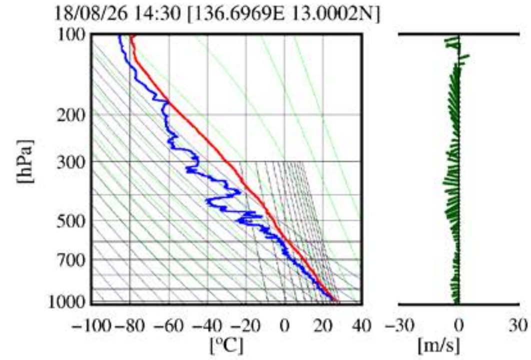


18/08/26 11:30 [136.7096E 12.9909N]

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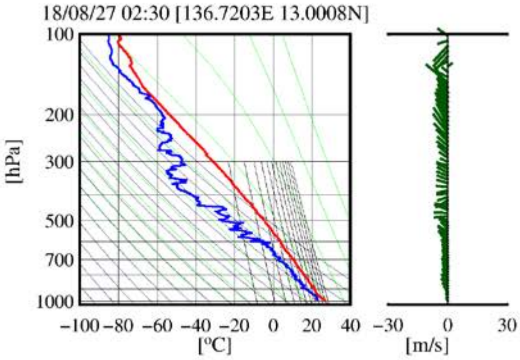
[hPa]
[°C]
[m/s]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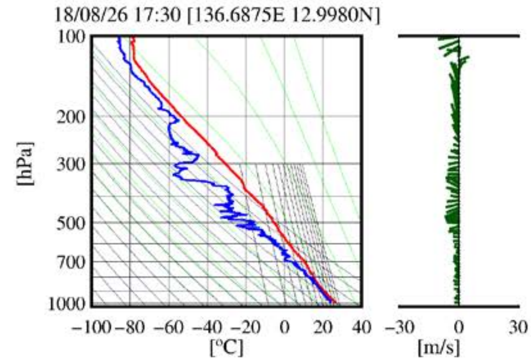
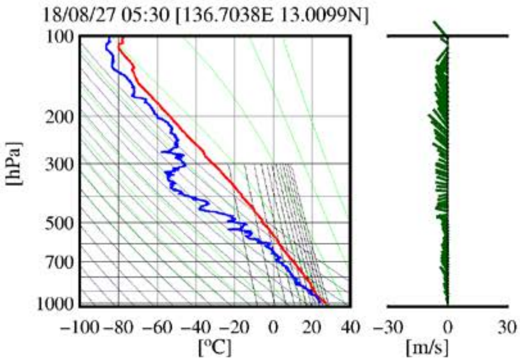
[hPa]
[°C]
[m/s]


18/08/26 17:30 [136.6875E 12.9980N]
[hPa]
[°C]
[m/s]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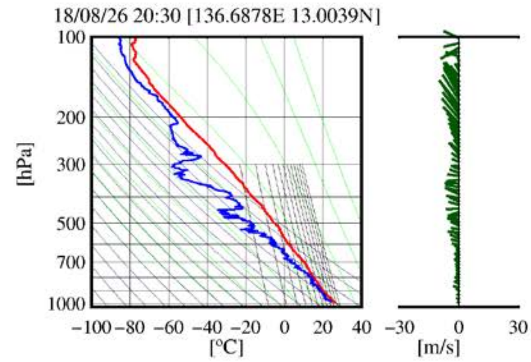
[°C]
[m/s]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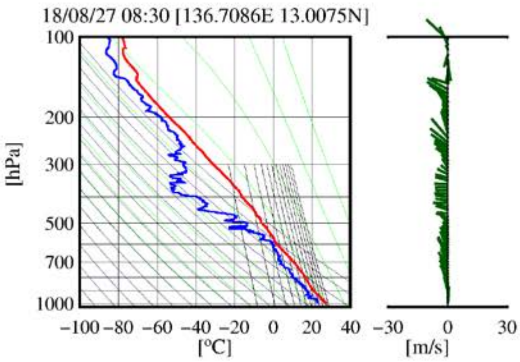
[hPa]
[°C]
[m/s]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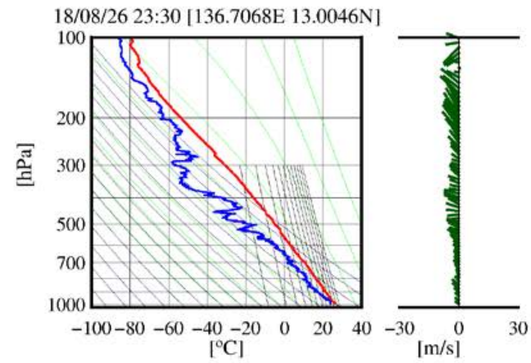
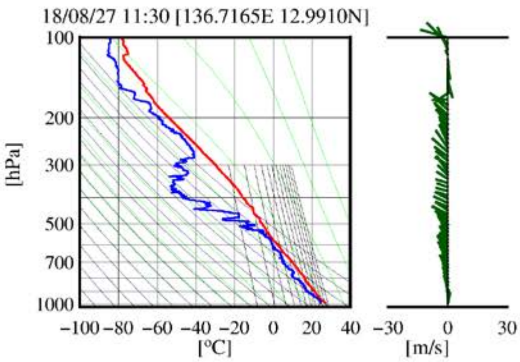
[hPa]
[°C]
[m/s]


18/08/26 23:30 [136.7068E 13.0046N]
[hPa]
[°C]
[m/s]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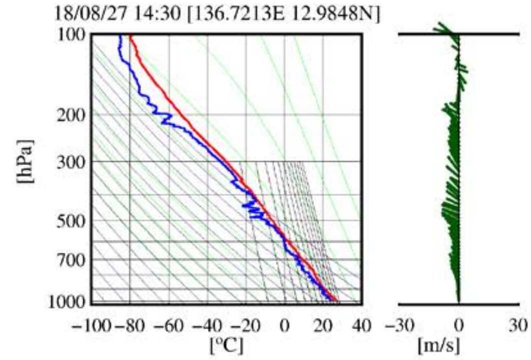
[hPa]
[°C]
[m/s]

18/08/27 14:30 [136.7213E 12.9848N]



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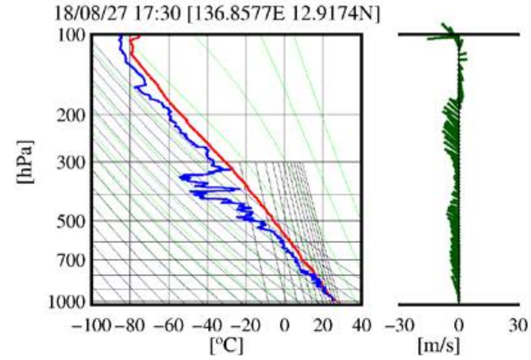
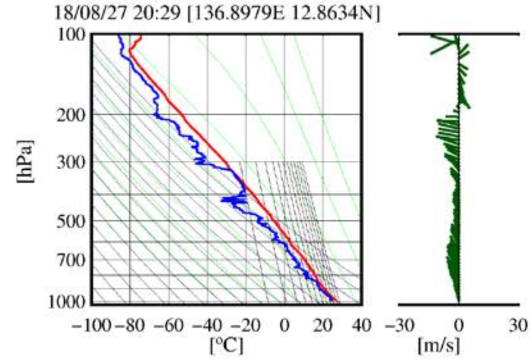


18/08/27 20:29 [136.8979E 12.8634N]



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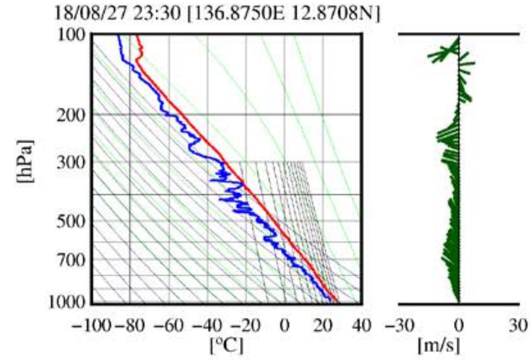

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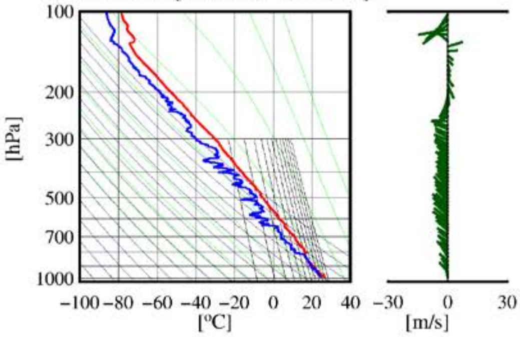

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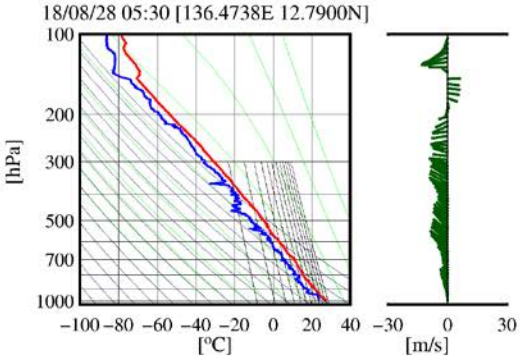

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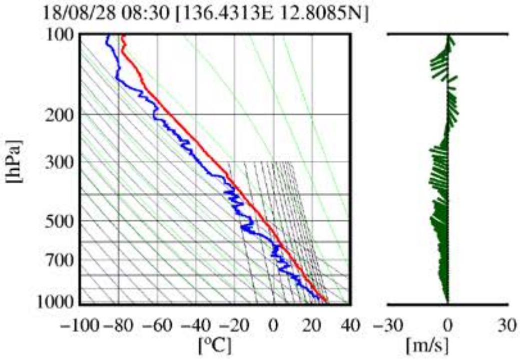

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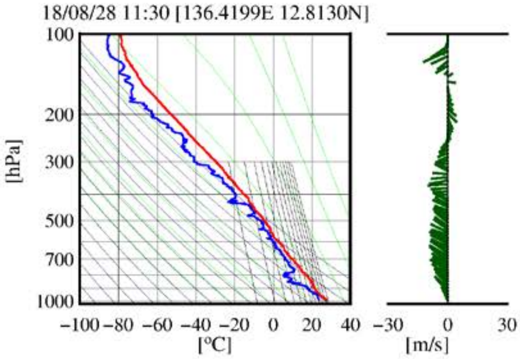

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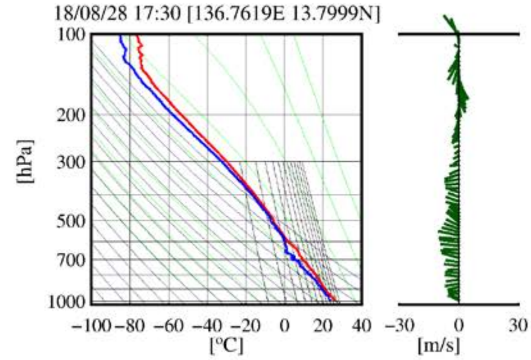

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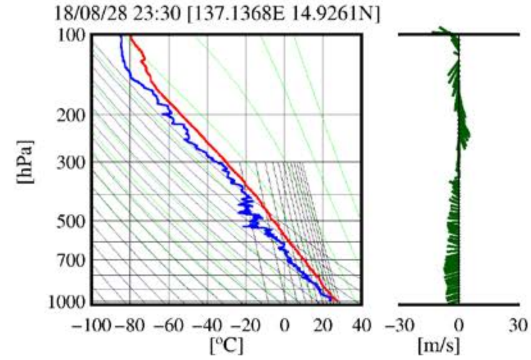
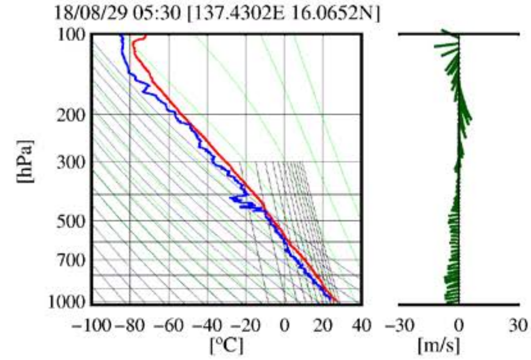
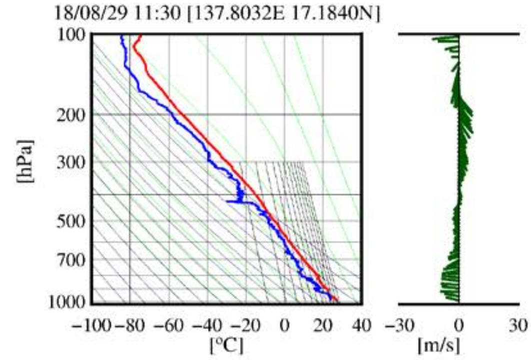


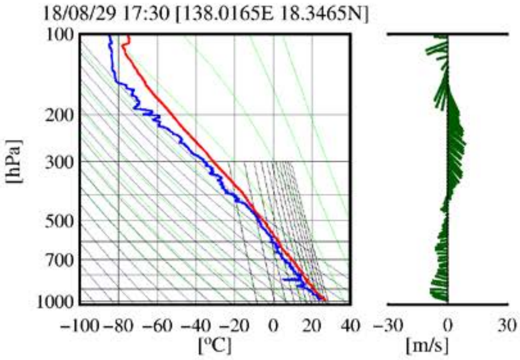
18/08/29 05:30 [137.4302E 16.0652N]



18/08/29 11:30 [137.8032E 17.1840N]



18/08/29 17:30 [138.0165E 18.3465N]



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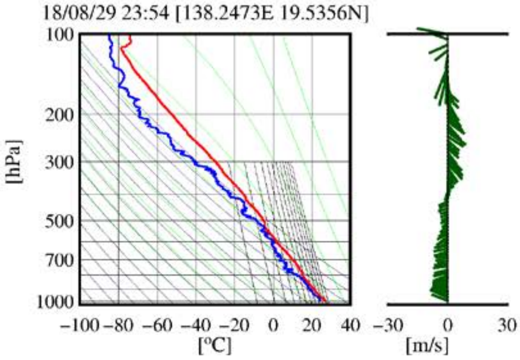
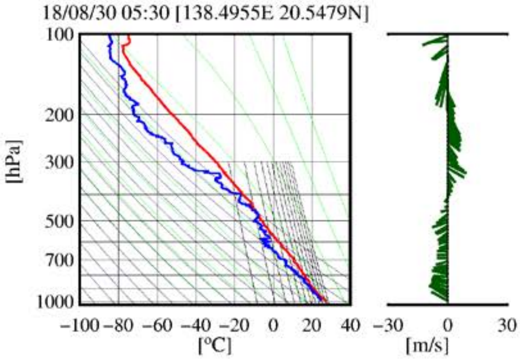
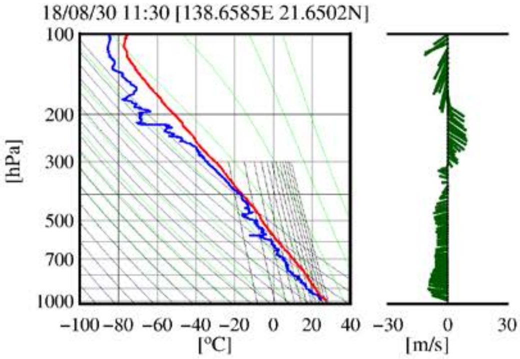
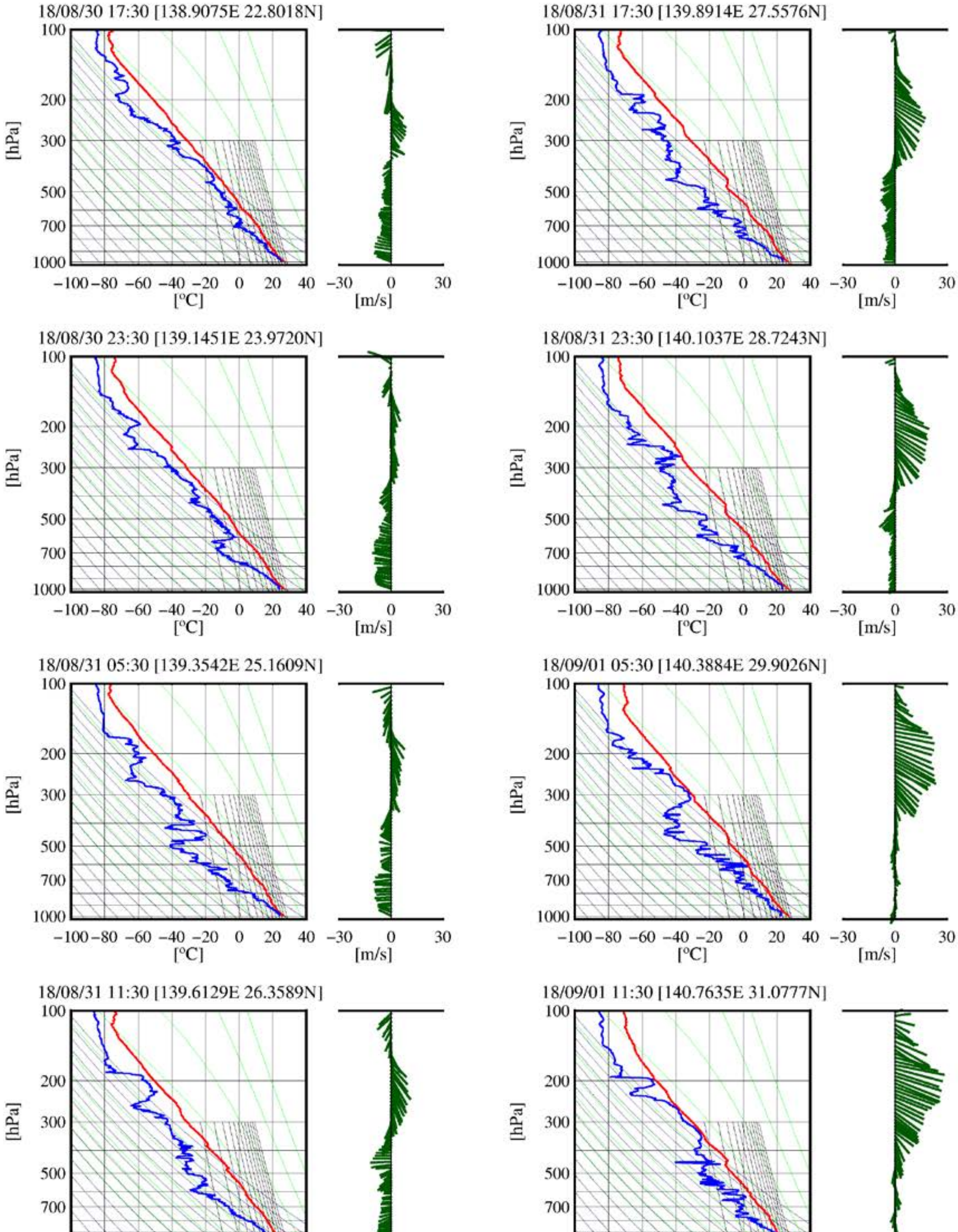


18/08/30 05:30 [138.4955E 20.5479N]



18/08/30 11:30 [138.6585E 21.6502N]




18/08/30 17:30 [138.9075E 22.8018N]
18/08/31 17:30 [139.8914E 27.5576N]
18/08/30 23:30 [139.1451E 23.9720N]
18/08/31 23:30 [140.1037E 28.7243N]
18/08/31 05:30 [139.3542E 25.1609N]
18/09/01 05:30 [140.3884E 29.9026N]
18/08/31 11:30 [139.6129E 26.3589N]
18/09/01 11:30 [140.7635E 31.0777N]
[hPa]
100
200
300
500
700
1000
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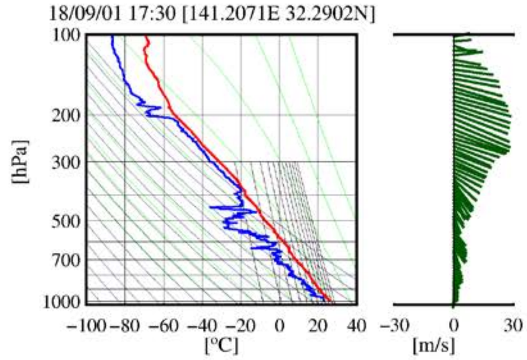
[°C]
−30 0 30
[m/s]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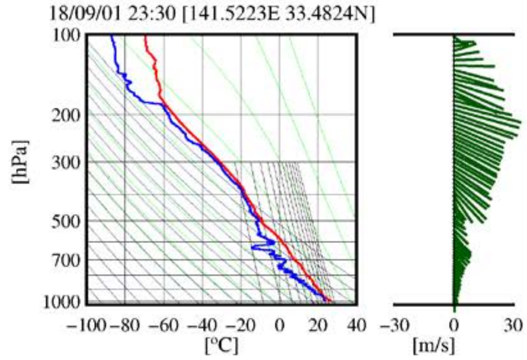
[m/s]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[°C]
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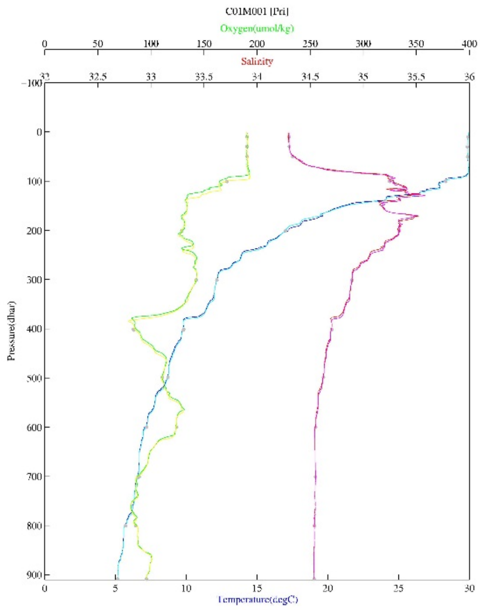
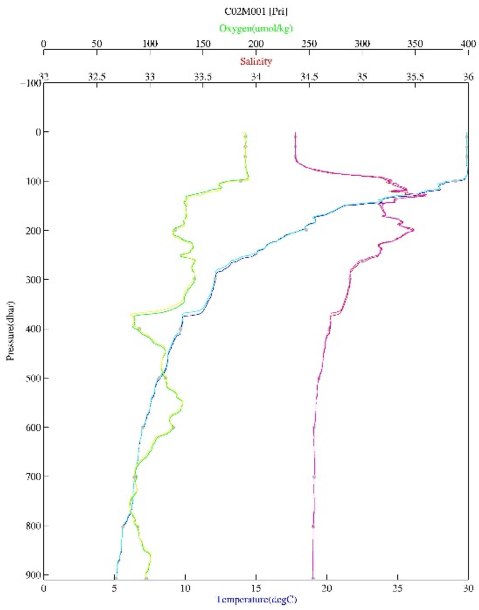
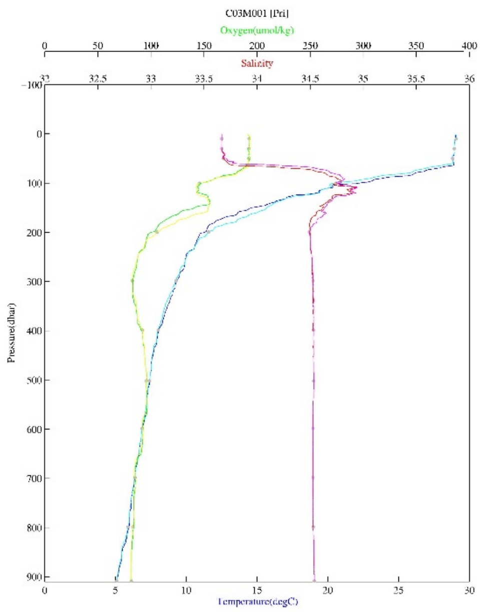
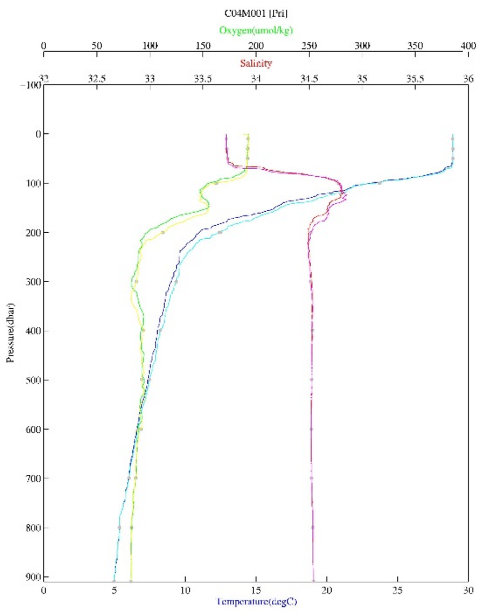
[m/s]

Appendix-B: Oceanic profiles by the CTDO observations

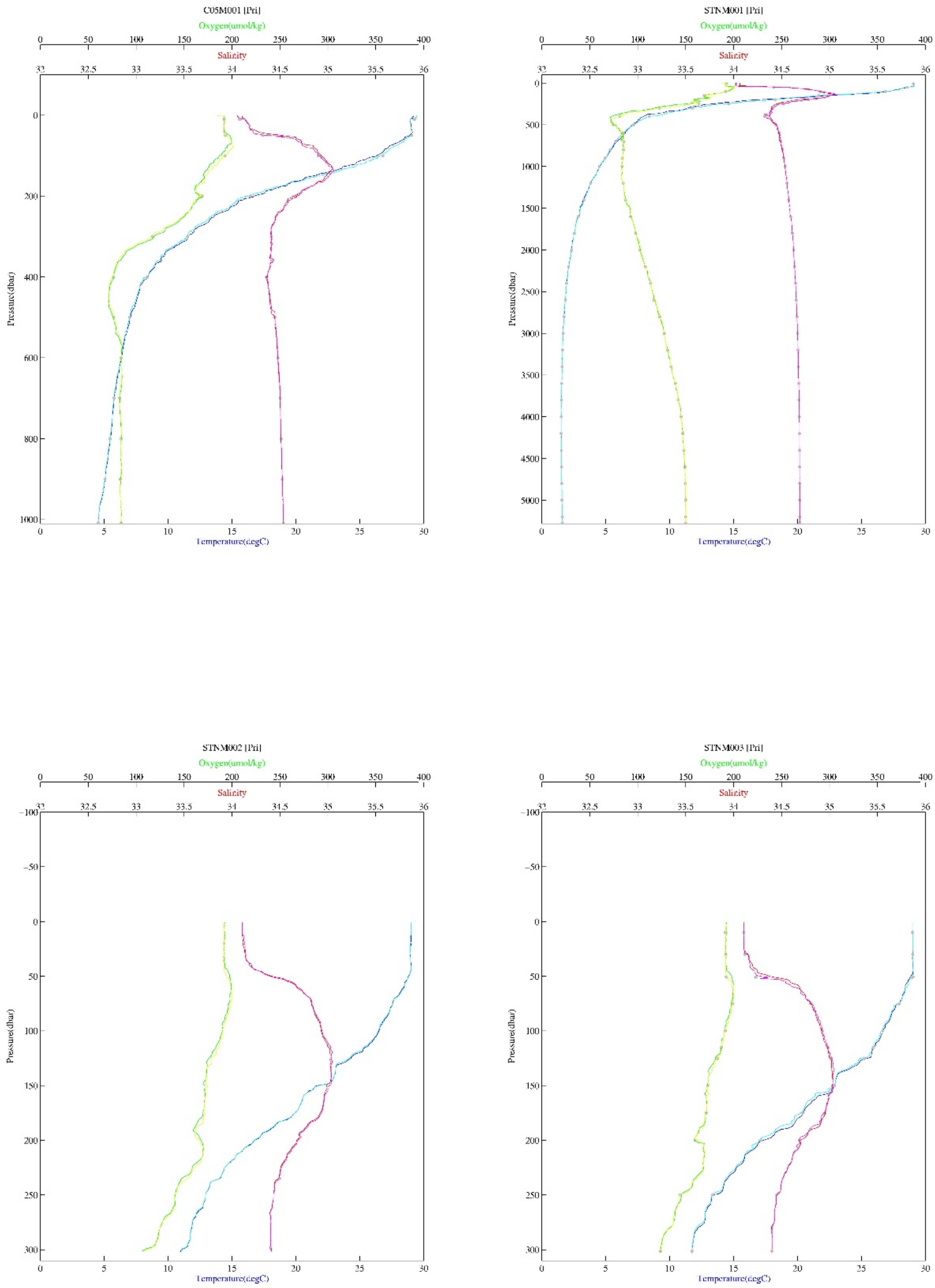




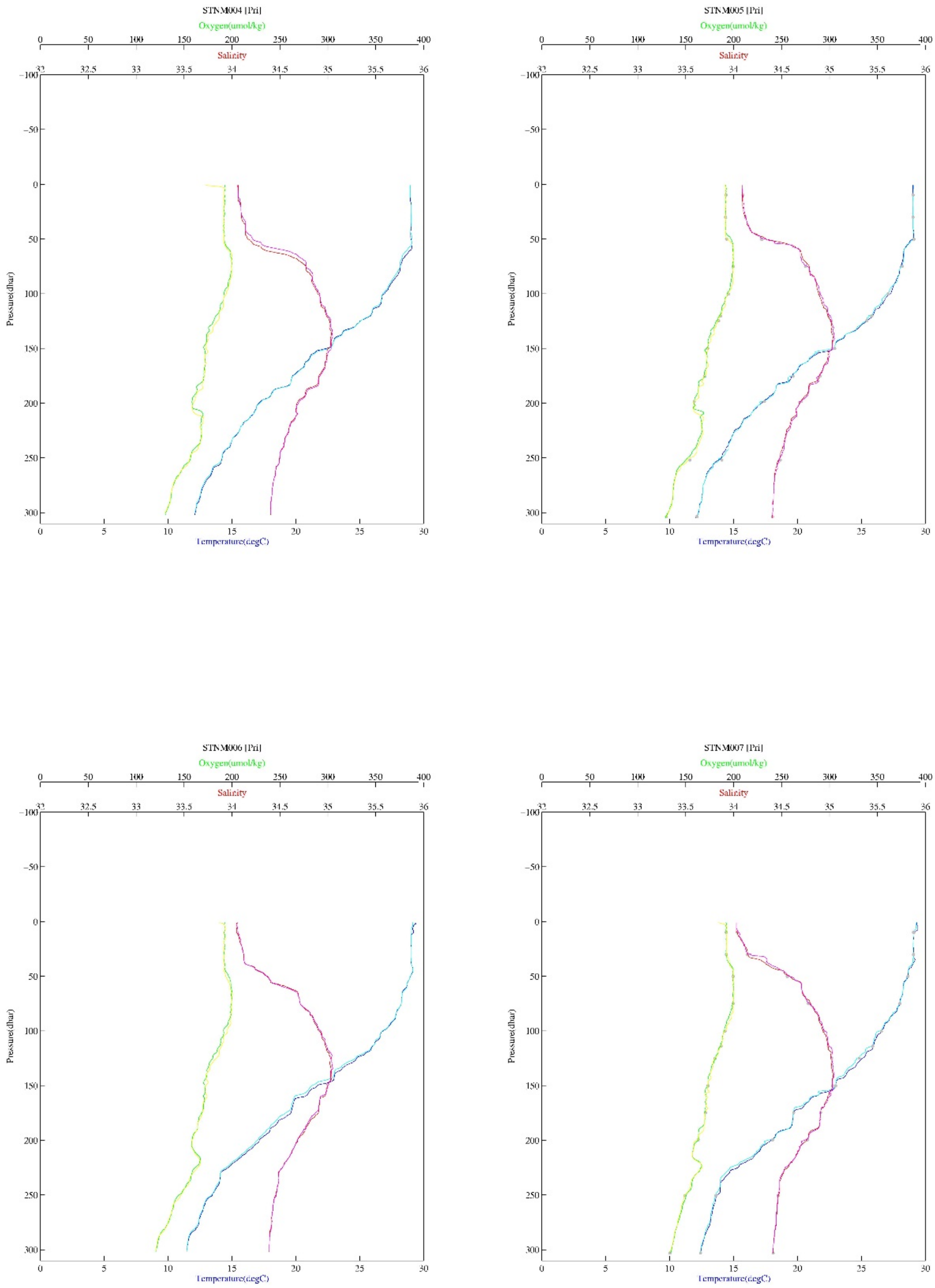




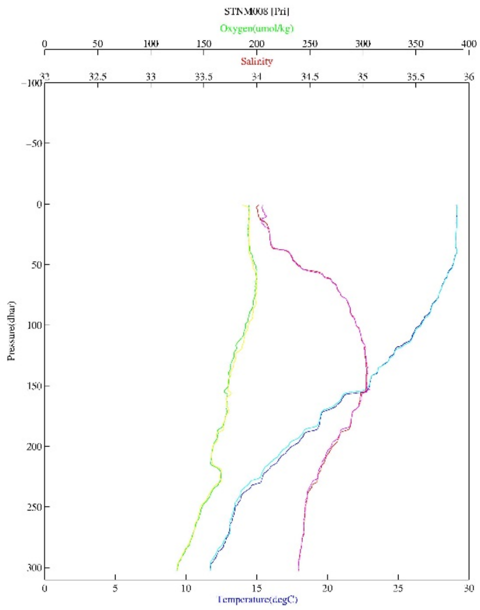
CTD profile (C01M001, C02M001, C03M001 and C04M001)

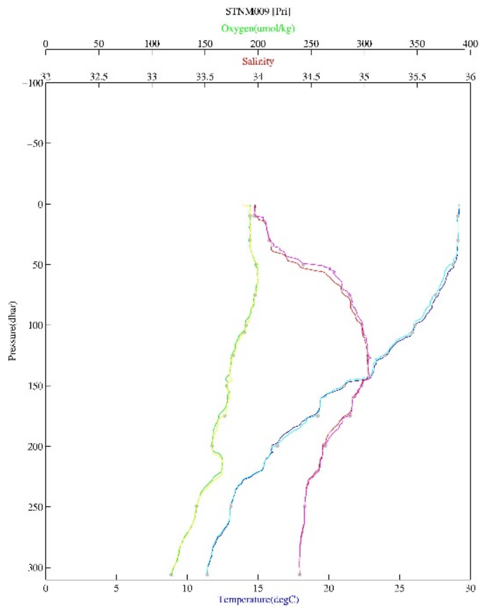


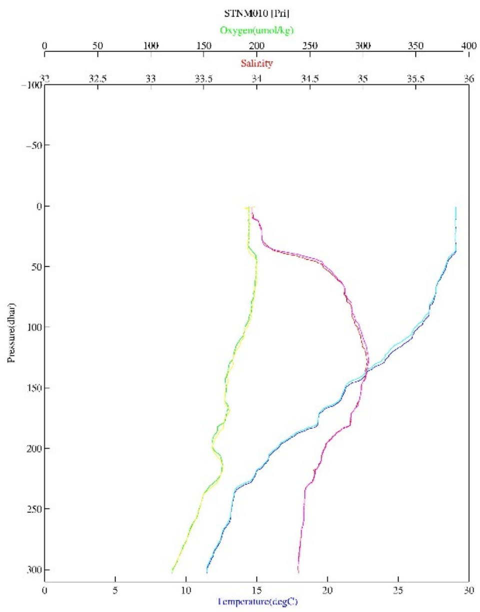
CTD profile (C05M001, STNM001, STNM002 and STNM003)

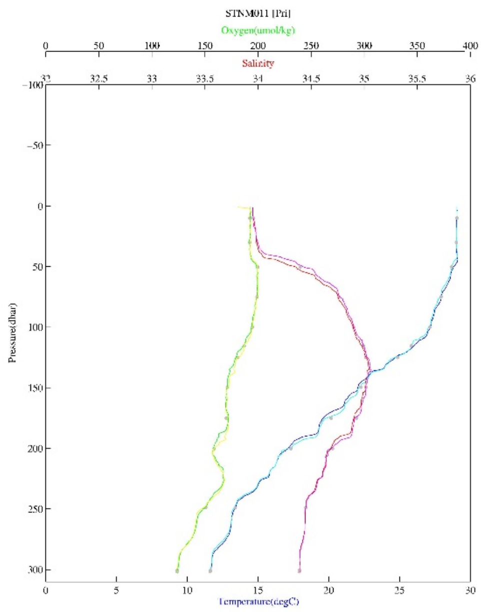


CTD profile (STNM004, STNM005, STNM006 and STNM007)

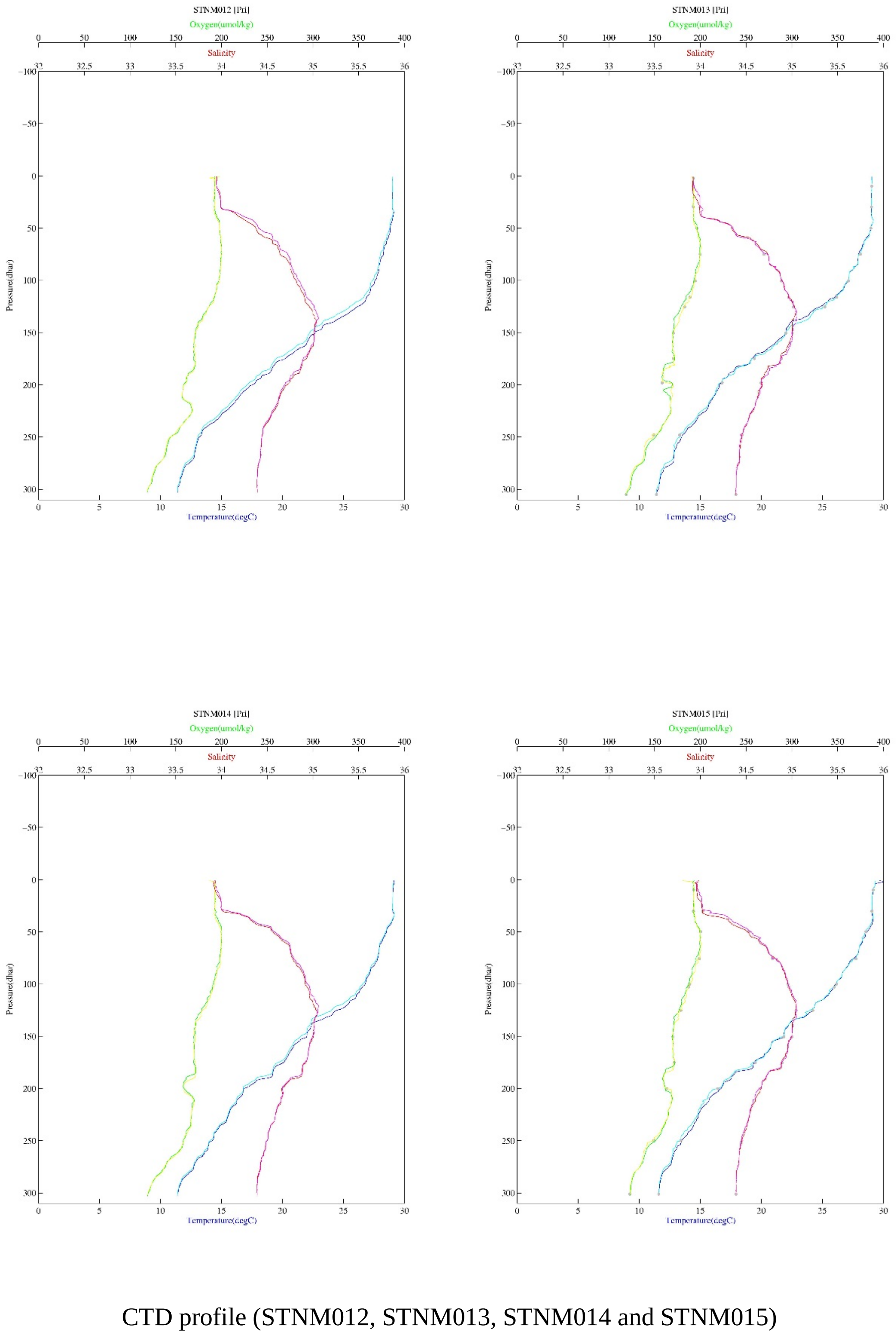




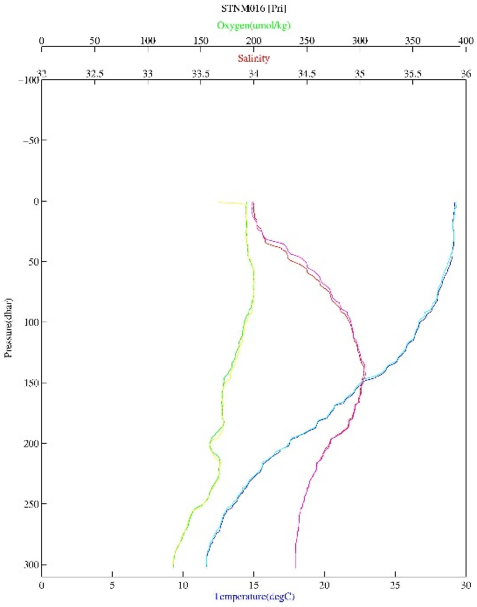


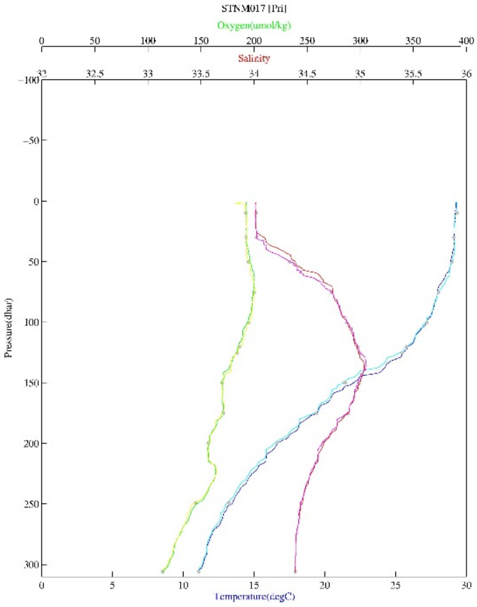


CTD profile (STNM008, STNM009, STNM010 and STNM011)



CTD profile (STNM012, STNM013, STNM014 and STNM015)





CTD profile (STNM016 and STNM017)