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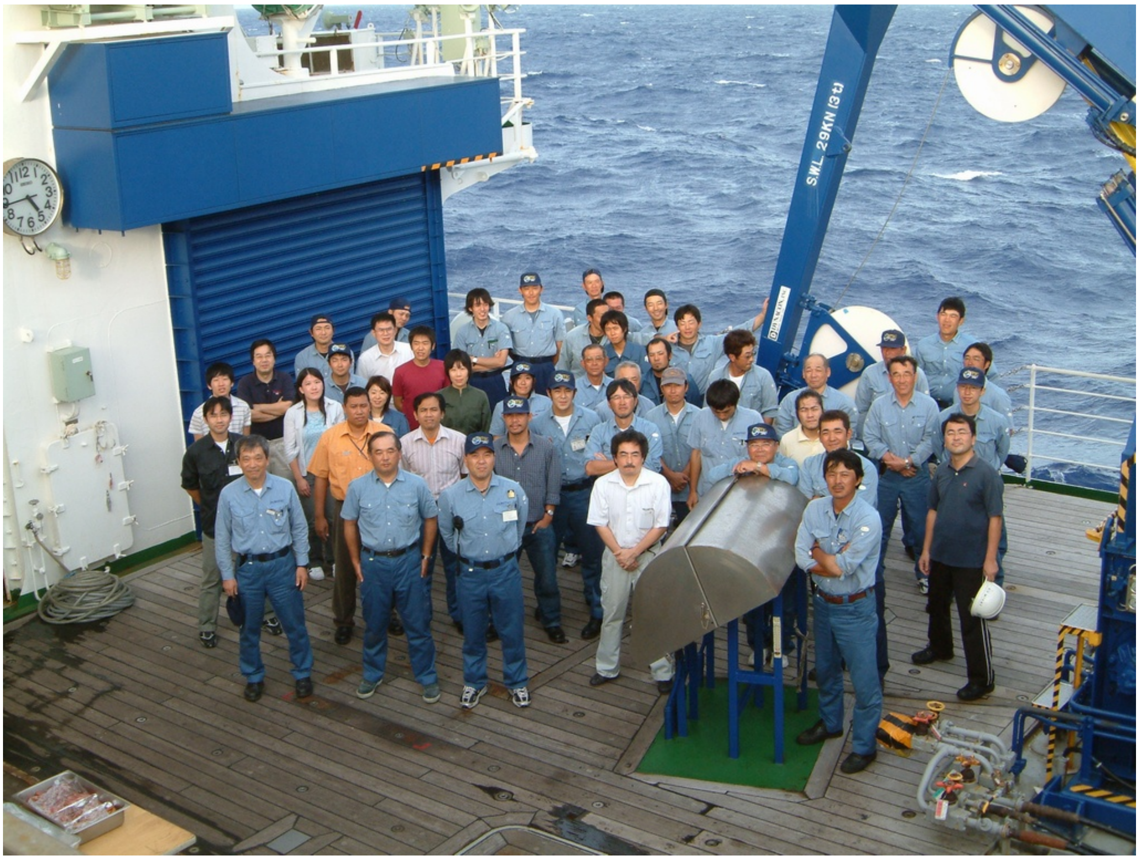
R/V Mirai Cruise Report
MR06-05 Leg 3

December 14, 2006 – January 20, 2007
Tropical Ocean Climate Study (TOCS)

Japan Agency for Marine-Earth Science and Technology
(JAMSTEC)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1. Cruise name and code

Tropical Ocean Climatology Study

MR06-05 Leg 3

Ship: R/V Mirai

Captain: Yujiro Kita

2. Introduction and observation summary

2.1. Introduction

The purpose of this cruise is to observe the ocean and atmosphere in the western tropical Pacific Ocean for better understanding of climate variability involving the ENSO (El Nino/Southern Oscillation) phenomena. In the western equatorial Pacific, there is the warm water pool (WWP) characterized by the highest sea surface temperature in the world, and it plays a major role in driving global atmospheric circulation. The Pacific low-latitude western boundary currents (LLWBCs) in this region, which flow into this region from the mid-latitude, are also attractive theme in the oceanography because past researches showed that LLWBC is an important factor not only for regional climate variability but also for global ocean circulation.

For better understanding of climate variability, time series data with high quality for long period is important. We constructed TRITON (TRIangle Trans-Ocean buoy Network) buoy network in the tropical Pacific and Indian Oceans cooperating with USA, Indonesia, and India. One of the major missions of this cruise is to maintain the network of TRITON buoys along 130E and 137-138E lines in the western equatorial Pacific.

Additionally, the tropical ocean and atmosphere are under the El Nino Condition during this boreal winter. (Southern Oscillation Index during last autumn exceeded 2.0.) Results from observations in the western boundary region of the Pacific under this condition are very valuable for understanding tropical climate variability. We conduct ocean observations using CTD/XCTDs, Caroucel water sampler, shipboard ADCP in order to observe the current, temperature, salinity and others in the western tropical Pacific under this El Nino condition. Atmospheric observations are also conducted using meteorological observational instruments of the R/V Mirai (ceilometer, lider system, sky radiometer, and so on) at the same time.

Furthermore, there are following chemical, biological, and geophysical missions during this cruise:

1) Sea water and air sampling for research of exchange of greenhouse gasses between ocean and atmosphere in the tropical ocean.
2) Halobates (sea skaters) sampling using a net in order to research their distribution and ecology.
3) Recovery of an ocean bottom electromagnetometer (OBEM) at 37-07N, 150-47E.

2.2. Overview

1) Ship

R/V Mirai

Captain Yujiro Kita

2) Cruise code

MR06-05 Leg 3

3) Project name

Tropical Ocean Climate Study (TOCS)

4) Undertaking institutions

This cruise was jointly conducted by following two institutes:

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

Indonesia: Badan Pengkajian Dan Penerapan Teknologi (BPPT)
Jl.M.H.Thamrin 8, Jakarta, 10340, Indonesia

5) Chief scientist

Chief Scientist (Japan)

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

Co-chief Scientist (Indonesia)

Fadli Syamsudin, Badan Pengkajian Dan Penerapan Teknologi (BPPT)

6) Period

December 14, 2007 (Singapore) – January 18, 2007 (Hachinohe)
- January 20, 2007 (Sekinehama, Japan)

7) Research participants

11 scientists and 13 technical staffs from 9 Japanese institutions and companies

Two scientists and one security officer from Indonesia

2.3. Observation summary

TRITON mooring recovery and re-installation:	6 sites
CTD (Salinity, Temperature and Depth) and water sampling:	10 casts at 6 sites
XCTD:	64 sites
Surface water and air sampling	12 sites
Halobates sampling	7 sites
Surface meteorology:	continuous
Current measurements by shipboard ADCP:	continuous
Surface temperature and salinity measurements by intake method:	continuous
OBEM recovery:	We could not recover.

Other specially designed observations were carried out successfully.

On the way to the observation area (western tropical Pacific), sea state was not good in the South China Sea and the cruise course should be changed near the western Philippine coast. Then we found five shipwrecked Filipinos on 18 Dec. 2006 at 14-33.3N, 119-04.5E, and rescued them (Photo 1). Fortunately, no one was missed and injure. We took them to Manila bay of Philippines and passed them to Philippine coast guard on the midnight of Dec. 19. Because of this activity and bad weather mentioned above, cruise was delayed two days behind schedule.

Photo 1. Rescue activity of five shipwrecked Filipinos on 18 Dec. 2006.

Because we cruised in the South China Sea as the innocent passage, no observation involving continuous one (e.g., shipboard ADCP) was conducted until the exit of the Luzon Straight. We started continuous observations from the point at 19-07N, 122-34E on Dec. 21. XCTD observations also started 18-20N, 122-34E along 18-20N line.

We recovered and re-installed six TRITON buoys at 130E and 137-138 lines during this cruise. Although some recovered buoys were damaged by the vandalism, all buoy works were successful without any troubles. Note that recovery works were carried out before deployment works at four TRITON sites because of reuse of nylon ropes from this cruise.

At TRITON sites, we conducted CTD observations and water sampling from the surface to the bottom using SBE-911 plus and 36 Niskin bottles. Sampled water will be analyzed to measure the concentration of salinity, dissolved oxygen, nutrients, TCO_2, N_2O, CH_4, particulate organic matter, chlorophyll-a and micro-flora to research the air-sea exchange of greenhouse effect gasses. Surface water and air were also sampled near the TRITON positions and six additional stations north of 13N for the same purpose.

We sampled Halobates at all TRITON sites and 6N, 130E using the ORI net. Four species, 3802 pieces were successfully caught at these stations. These samples were examined for laboratory ecological experiments during this cruise.

XCTD observations were conducted along 18-20N, 130E, 8N, 7N and 137-138E lines every one degree except near the Philippine coast and south of 138E, where strong boundary currents flow. These observations were successful. Other oceanographical, meteorological and geophysical continuous observations were also successfully carried out during this cruise.

Finally, we tried to recover the OBEM, which was deployed in May 2005 at 37-08N, 150-47E, on the way to Hachinohe on 15 and 16 Jan, 2007. However, we could not recover it, and not determine its precise position because of rough sea state associated with strong northwesterly monsoon.

Observed Oceanic and Atmospheric Conditions

The equatorial Pacific during this (boreal) winter is under weak El Nino condition (Figure 2-1). Southern Oscillation Index by Climate Prediction Center/NOAA reached -2.7 in October 2006. Because of this situation, both of low-latitude western boundary currents, i.e., the Mindanao Current (southward flow) and the New Guinea Coastal Current (northwestward flow), were strong than normal winter (Figure 2-2). For example, current speed of the Mindanao Current reached 1.9 m/s. Depth of 29C isotherm was also shallower than 50m depth south of 2N, 138E.

When this cruise started, this El Nino seemed to be terminated in these months because of eastward propagation of negative temperature anomaly at the thermocline depth by the equatorial Kelvin Wave (Figure 2-3). However, strong Madan Julian Oscillation passed the observation area from the end of December 2006 to the beginning of January 2007 (Figure 2-4) and it may change this status. Strong westerly wind burst was observed during maintenance works of TRITON buoy along 137-138 line due to this phenomenon.

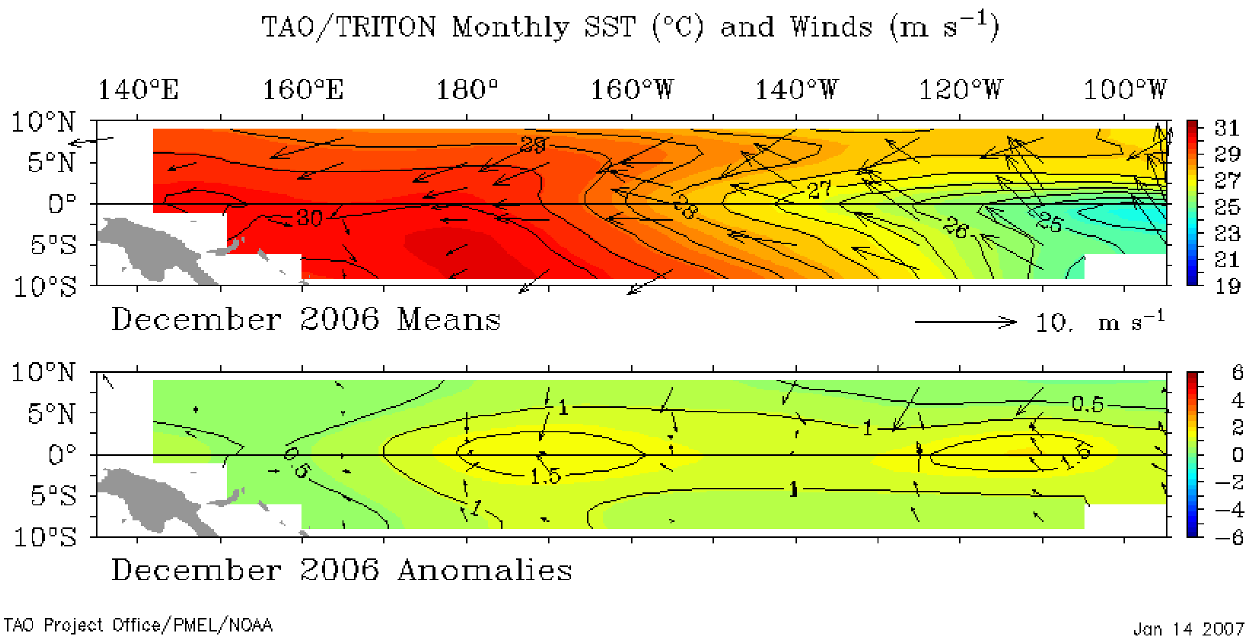

Figure 2-1. Map of monthly sea surface temperature and winds (upper panel), and their anomaly (lower panel) obtained from TAO/TRITON buoy array in December 2006. (http://www.pmel.noaa.gov/tao/jsdisplay/)

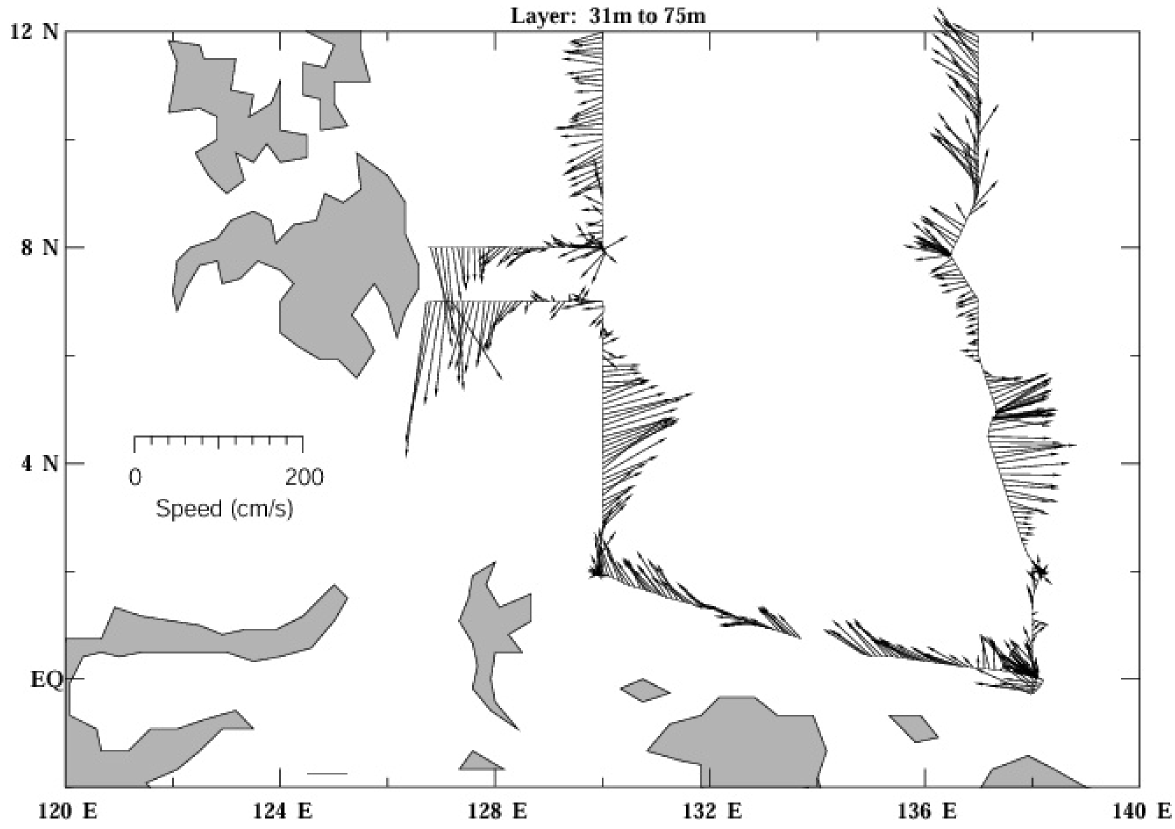

Figure 2-2. Current vector map averaged over 31-75m depth during MR06-05 Leg3 cruise.

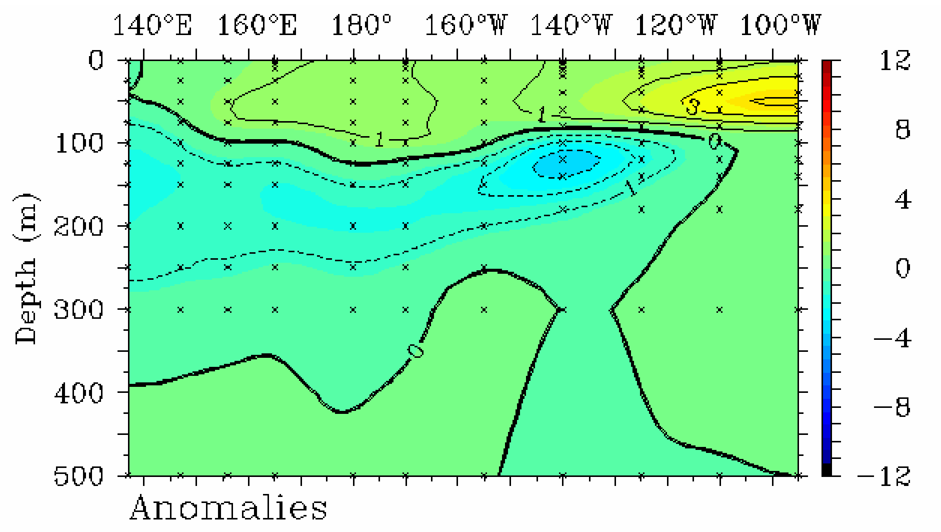

Figure 2-3. Vertical section of five days averaged temperature anomaly along the equator ending on 12 Jan 2007 obtained from TAO/TRITON array.

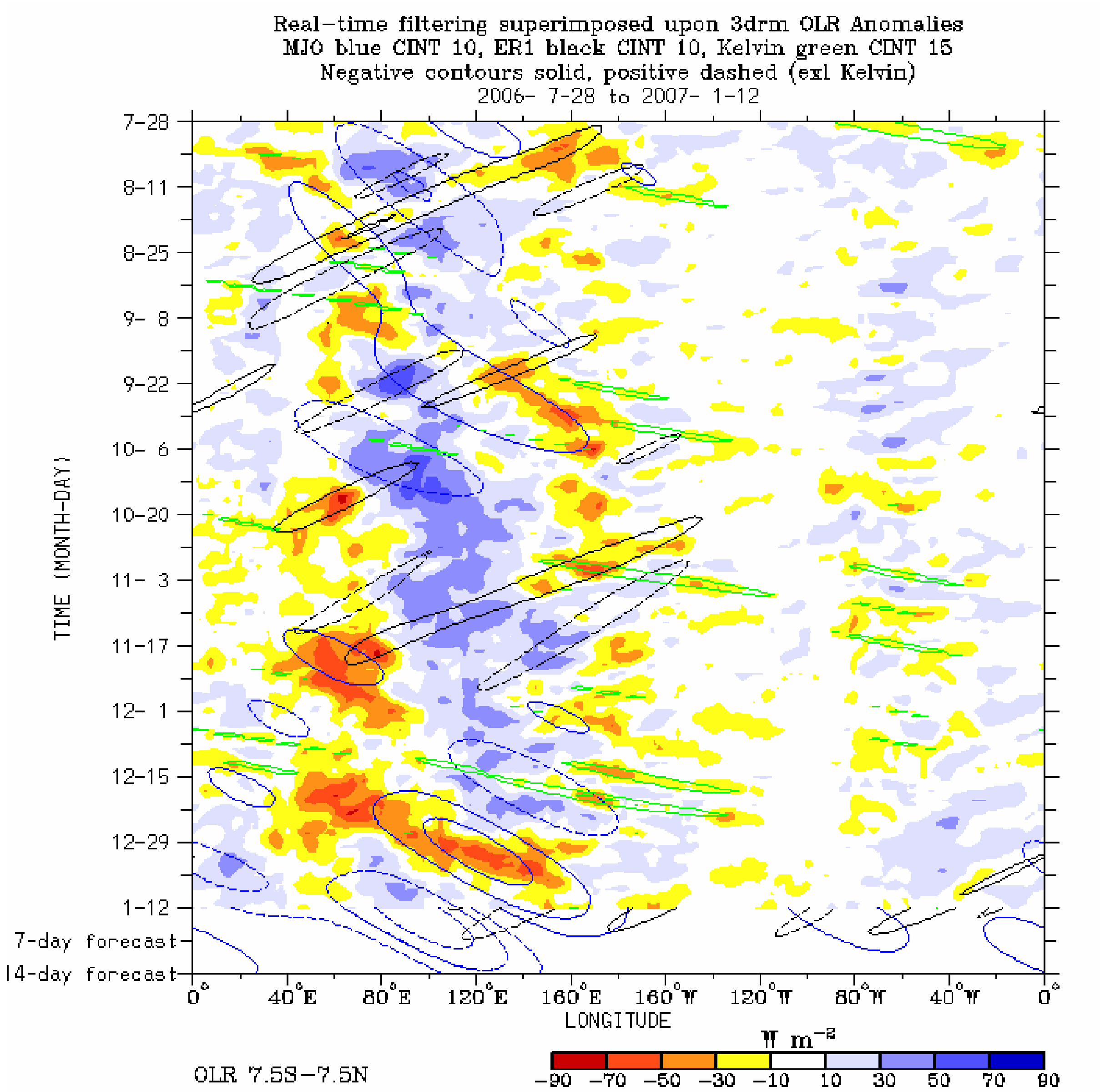

Figure 2-4. Outgoing radiation anomaly averaged over 7.5S-7.5N from the web page of the Climate Diagnostic Center (CDC), National Oceanic and Atmospheric Association (NOAA) (http://www.cdc.noaa.gov/map/clim/olr_modes/).

3. Period, port of call, cruise log and cruise track

3.1 Period

December 14, 2006 - January 20, 2007

3.2 Port of call

Singapore (Departure; December 14, 2006)
Hachinohe, Japan (January 18, 2007)
Sekinehama, Japan (Arrival; January 20, 2007)

3.3 Cruise log

SMT (Ship mean time)	UTC	Event
Dec. 14 (Thu.) 2006		
09:00	01:00	Departure at Singapore (SMT=UTC+08:00)
21:00	13:00	Safety Guidance on the R/V Mirai
Dec. 15 (Fri.) 2006		
10:35	02:35	Surface water sampling pump start
13:00	05:00	Boat station drill
16:45	08:45	Konpira Ceremony
Dec. 16 (Sat.) 2006		
22:00	14:00	Time Adjustment (+1h)
Dec. 17 (Sun.) 2006		
10:30	01:30	Meeting for MR06-05Leg3 observation
Dec. 21 (Thu.) 2006		
02:00	17:00	Start of continuous observations
07:31	22:31	XCTD X-001 (18-19.95N, 122-33.99E, 2609m)
08:36	23:36	XCTD X-002 (18-19.93N, 122-45.03E, 3707m)
09:54	00:54	XCTD X-003 (18-20.09N, 123-00.04E, 4039m)
10:05 - 10:11	01:05 - 01:11	Surface water sampling No.1 (18-20.28N, 123-02.04E)
10:15 - 10:20	01:15 - 01:20	Air sampling No.1 (18-20.39N, 123-02.38E)
12:21	03:21	XCTD X-004 (18-20.01N, 123-30.03E, 5266m)
15:01	06:01	XCTD X-005 (18-19.98N, 124-00.04E, 5072m)
19:23	10:23	XCTD X-006 (18-20.04N, 125-00.01E, 5471m)
23:32	14:32	XCTD X-007 (18-19.91N, 126-00.01E, 5443m)
Dec. 22 (Fri.) 2006		
03:40	18:40	XCTD X-008 (18-20.02N, 127-00.00E, 4945m)
07:43	22:43	XCTD X-009 (18-19.99N, 128-00.02E, 4676m)
07:51 - 07:59	22:51 - 22:59	Surface water sampling No.2 (18-19.97N, 128-01.48E)
08:02 - 08:04	23:02 - 23:04	Air sampling No.2 (18-19.93N, 128-01.76E)
11:53	02:53	XCTD X-010 (18-19.71N, 129-00.02E, 5404m)
15:57	06:57	XCTD X-011 (18-20.01N, 130-00.53E, 5632m)
16:06 - 16:10	07:06 - 07:10	Surface water sampling No.3 (18-19.97N, 130-01.13E)
16:14 - 16:15	07:14 - 07:15	Air sampling No.3 (18-19.68N, 130-01.11E)
18:52	09:52	XCTD X-012 (17-39.92N, 130-00.00E, 5817m)
21:30	12:30	XCTD X-013 (16-59.99N, 130-00.01E, 5224m)
Dec. 23 (Sat.) 2006		

01:30	16:30	XCTD X-014 (15-59.99N, 129-59.98E, 5441m)
05:28	20:28	XCTD X-015 (14-59.99N, 129-59.93E, 5528m)
09:27	00:27	XCTD X-016 (13-59.91N, 130-00.09E, 5683m)
13:22	04:22	XCTD X-017 (13-00.00N, 129-59.96E, 5935m)
13:30 - 13:35	04:30 - 04:35	Surface water sampling No.4 (12-59.23N, 129-59.89E)
13:40 - 13:42	04:40 - 04:42	Air sampling No.4 (12-58.80N, 129-59.85E)
17:28	08:28	XCTD X-018 (11-59.99N, 130-00.00E, 5796m)
21:26	12:26	XCTD X-019 (10-59.99N, 130-00.14E, 5806m)
Dec. 24 (Sun.) 2006		
01:19	16:19	XCTD X-020 (09-59.96N, 130-00.00E, 5972m)
05:11	20:11	XCTD X-021 (08-59.99N, 130-00.06E, 5922m)
09:36	00:36	Arrival at 8N, 130E
09:40 - 13:39	00:40 - 04:39	CTD cast No.1 (07-56.21N, 130-01.79E, Down to 5609m)
10:04 - 10:08	01:04 - 01:08	Surface water sampling No.5 (07-55.61N, 130-02.21E)
10:12 - 10:15	01:12 - 01:15	Air sampling No.5 (07-55.67N, 130-02.15E)
14:34 - 15:03	05:34 - 06:03	Net Sampling No.1 (Start: 07-58.23N, 129-59.85E)
18:00 - 18:48	09:00 - 09:48	Net Sampling No.2 (Start: 07-59.79N, 129-57.50E)
Dec. 25 (Mon.) 2006		
07:57 - 11:53	22:57 - 02:53	Deployment of TRITON #14 (Fixed Position: 07-58.7686N, 130-00.6429E, 5721m)
13:34	04:34	XCTD X-022 (07-59.27N, 129-59.99E, 5709m)
Dec. 26 (Tue.) 2006		
07:58 - 11:58	22:58 - 02:58	Recovery of TRITON #14
15:12	06:12	Departure at 8N, 130E
19:00	10:00	XCTD X-023 (08-00.02N, 128-59.99E, 4677m)
23:14	14:14	XCTD X-024 (08-00.16N, 127-59.99E, 4805m)
Dec. 27 (Wed.) 2006		
01:49	16:49	XCTD X-025 (08-00.01N, 127-29.90E, 6796m)
04:10	19:10	XCTD X-026 (07-59.94N, 126-59.99E, 5930m)
05:03	20:03	XCTD X-027 (07-59.84N, 126-49.99E, 2884m)
11:06	02:06	XCTD X-028 (06-59.37N, 126-48.01E, 4411m)
12:03	03:03	XCTD X-029 (06-59.55N, 127-00.01E, 5591m)
14:09	05:09	XCTD X-030 (07-00.02N, 127-30.01E, 7355m)
16:15	07:15	XCTD X-031 (06-59.93N, 128-00.01E, 4728m)
20:28	11:28	XCTD X-032 (06-59.98N, 129-00.01E, 5056m)
Dec. 28 (Thu.) 2006		
00:38	15:38	XCTD X-033 (06-59.97N, 130-00.01E, 5564m)
04:34	19:34	XCTD X-034 (05-59.99N, 130-00.08E, 5484m)
05:04 - 06:12	20:04 - 21:12	Net Sampling No.3 (Start: 05-56.03N, 130-00.14E)
09:48	00:48	XCTD X-035 (04-59.99N, 130-00.05E, 5052m)
13:53	04:53	XCTD X-036 (03-59.98N, 129-59.97E, 4712m)
18:05	09:05	XCTD X-037 (02-59.99N, 129-59.98E, 3028m)
23:30	14:30	Arrival at 2N, 130E
Dec. 29 (Fri.) 2006		
06:02 - 06:48	21:02 - 21:48	CTD cast No.2 (01-58.91N, 129-57.22E, Down to 1004m)
07:30 - 12:15	22:30 - 03:15	Recovery of TRITON #16
13:35 - 16:29	04:35 - 07:29	CTD cast No.3 (01-56.03N, 129-54.94E, Down to 4395m)
14:02 - 14:07	05:02 - 05:07	Surface water sampling No.6 (00-10.49S, 138-02.15E)

14:10 - 14:13	05:10 - 05:13	Air sampling No.6 (01-56.08N, 129-54.99E)
18:04 - 18:19	09:04 - 09:19	Calibration for magnetometer (clockwise and anti-clockwise rotation)
19:05 - 20:09	10:05 - 11:09	Net Sampling No.4 (Start: 01-55.03N, 129-58.51E)
Dec. 30 (Sat.) 2006		
07:56 - 11:56	22:56 - 02:56	Deployment of TRITON #16 (Fixed Position: 01-56.3788N, 129-56.1226E, 4428m)
12:30	03:30	Departure at 2N, 130E
12:53	03:53	XCTD X-38 (01-57.86N, 129-56.83E, 4422m)
Dec. 31 (Sun.) 2006		
21:54	12:54	Arrival at EQ, 138E
Jan. 2 (Tue.) 2007		
06:33 - 07:20	21:33 - 22:20	CTD cast No.4 (00-03.63N, 138-03.43E, Down to 1003m)
08:26 - 11:48	23:26 - 02:48	Recovery of TRITON #13
13:35 - 16:28	04:35 - 07:28	CTD cast No.5 (00-10.61S, 138-02.19E, Down to 4451m)
14:00 - 14:04	05:00 - 05:04	Surface water sampling No.7 (00-10.49S, 138-02.15E)
14:09 - 14:13	05:09 - 05:13	Air sampling No.7 (00-10.55S, 138-02.15E)
18:05 - 18:20	09:05 - 09:20	Calibration for magnetometer (clockwise and anti-clockwise rotation)
19:03 - 20:08	10:03 - 11:08	Net Sampling No.5 (Start: 00-16.36S, 137-58.40E)
Jan. 3 (Wed.) 2007		
07:57 - 11:05	22:57 - 02:05	Deployment of TRITON #13 (Fixed Position: 00-04.3883N, 138-03.2807E, 4206m)
11:06	02:06	Departure at EQ, 138E
11:13	02:13	XCTD X-039 (00-05.32N, 138-03.20E, 4151m)
13:07	04:07	XCTD X-040 (00-30.02N, 138-00.00E, 3945m)
15:19	06:19	XCTD X-041 (01-00.01N, 137-59.99E, 4231m)
17:27	08:27	XCTD X-042 (01-30.00N, 138-00.09E, 4387m)
19:42	10:42	Arrival at 2N, 138E
Jan. 4 (Thu.) 2007		
06:03 - 06:47	21:03 - 21:47	CTD cast No.6 (01-58.59S, 138-11.44E, Down to 1002m)
07:56 - 11:19	22:56 - 02:19	Recovery of TRITON #12
13:01 - 15:53	04:01 - 06:53	CTD cast No.7 (01-57.49N, 138-10.59E, Down to 4277m)
14:26 - 14:31	05:26 - 05:31	Surface water sampling No.8 (01-57.34N, 138-10.56E)
14:34 - 14:37	05:34 - 05:37	Air sampling No.8 (01-57.25S, 138-10.56E)
19:03 - 20:10	10:03 - 11:10	Net Sampling No.6 (Start: 01-58.35N, 138-10.27E)
Jan. 5 (Fri.) 2007		
07:57 - 11:03	22:57 - 02:03	Deployment of TRITON #12 (Fixed Position: 01-59.7845N, 138-06.3073E, 4321m)
12:36	03:36	Departure at 2N, 138E
12:44	03:44	XCTD X-043 (01-59.54N, 138-06.86E, 4325m)
15:20	06:20	XCTD X-044 (02-30.01N, 137-50.00E, 4426m)
17:38	08:38	XCTD X-045 (03-00.01N, 137-40.00E, 4775m)
19:57	10:57	XCTD X-046 (03-30.00N, 137-30.01E, 4342m)
22:18	13:18	XCTD X-047 (04-00.01N, 137-20.04E, 4657m)
Jan. 6 (Sat.) 2007		
00:36	15:36	XCTD X-048 (04-30.01N, 137-10.01E, 4948m)

02:12	17:12	Arrival at 5N, 137E
07:55 - 10:56	22:55 - 01:56	Deployment of TRITON #11 (Fixed Position: 04-51.4244N, 137-16.1621E, 4097m)
11:06	02:06	XCTD X-049 (04-51.90N, 137-16.79E, 4108m)
13:02 - 15:47	04:02 - 06:47	CTD cast No.8 (04-55.65N, 137-19.14E, Down to 4120m)
13:29 - 13:33	04:29 - 04:33	Surface water sampling No.9 (04-55.41N, 137-19.36E)
13:38 - 13:41	04:38 - 04:41	Air sampling No.9 (04-55.33N, 137-19.39E)
19:02 - 20:06	10:02 - 11:06	Net Sampling No.7 (Start: 04-49.87N, 137-17.08E)
Jan. 7 (Sun.) 2007		
07:55 - 11:27	22:55 - 02:27	Recovery of TRITON #11
11:30	02:30	Departure at 5N, 137E
16:06	07:06	XCTD X-050 (06-01.43N, 136-59.99E, 4307m)
19:57	10:57	XCTD X-051 (07-00.02N, 136-59.99E, 4251m)
Jan. 8 (Mon.) 2007		
00:18	15:18	Arrival at 8N, 137E
06:01 - 06:44	21:01 - 21:44	CTD cast No.9 (07-52.24N, 136-27.87E, Down to 1002m)
07:55 - 11:07	22:55 - 02:07	Recovery of TRITON #10
13:01 - 15:23	04:01 - 06:23	CTD cast No.10 (07-52.72N, 136-28.64E, Down to 3322m)
13:26 - 13:29	04:26 - 04:29	Surface water sampling No.10 (07-52.38N, 136-28.86E)
13:33 - 13:36	04:33 - 04:36	Air sampling No.10 (07-52.46N, 136-28.81E)
17:56 - 18:12	08:56 - 09:12	Calibration for magnetometer (clockwise and anti-clockwise rotation)
19:02 - 19:43	10:02 - 10:43	Net Sampling No.8 (Start: 07-59.61N, 136-24.48E)
Jan. 9 (Tue.) 2007		
07:57 - 10:48	22:57 - 01:48	Deployment of TRITON #10 (Fixed Position: 07-51.7346N, 136-29.0503E, 3351m)
12:42	03:42	Departure at 8N, 137E
12:46	03:46	XCTD X-052 (07-52.20N, 136-28.29E, 3351m)
18:15	09:15	XCTD X-053 (09-00.00N, 137-00.00E, 3600m)
22:40	13:40	XCTD X-054 (10-00.01N, 137-00.43E, 4960m)
Jan. 10 (Wed.) 2007		
03:04	18:04	XCTD X-055 (11-00.01N, 137-00.03E, 4923m)
07:34	22:34	XCTD X-056 (12-00.01N, 136-59.99E, 5284m)
12:09 - 12:12	03:09 - 03:12	Surface water sampling No.11 (12-59.89N, 137-00.08E)
12:18 - 12:20	03:18 - 03:20	Air sampling No.11 (12-59.76N, 137-00.05E)
12:22	03:22	XCTD X-057 (13-00.16N, 137-00.03E, 4939m)
16:52	07:52	XCTD X-058 (14-00.84N, 137-00.01E, 4712m)
23:16	14:16	XCTD X-059 (15-00.01N, 136-59.94E, 5210m)
Jan. 11 (Thu.) 2007		
03:39	18:39	XCTD X-060 (16-00.00N, 137-00.01E, 5310m)
08:07	23:07	XCTD X-061 (17-00.01N, 136-59.96E, 4843m)
12:25	03:25	XCTD X-062 (18-00.00N, 137-00.00E, 4922m)
12:36 - 12:38	03:36 - 03:38	Surface water sampling No.12 (18-01.46N, 137-00.14E)
12:44 - 12:47	03:44 - 03:47	Air sampling No.12 (18-01.25N, 137-00.17E)
16:54	07:54	XCTD X-063 (19-00.02N, 137-00.00E, 4829m)
21:05	12:05	XCTD X-064 (20-00.01N, 137-00.11E, 4779m)
Jan. 15 (Mon.) 2007		
12:48	03:48	Arrival at OBEM recovery point (37-07N, 150-47E)
12:54 - 16:10	03:54 - 07:10	Positioning of OBEM(Ocean Bottom Electro Magnetometer)

Jan. 16 (Tue.) 2007		
10:10 - 12:51	01:10 - 03:51	Positioning of OBEM(Ocean Bottom Electro Magnetometer)
Jan. 17 (Wed.) 2007		
08:59	23:59	Surface water sampling pump stop
Jan. 18 (Thu.) 2007		
08:40	23:40	Arrived at Hachinohe, Japan
15:40	06:40	Departure at Hachinohe, Japan
Jan. 20 (Fri.) 2007		
08:30	23:30	Arrived at Sekinehama, Japan

3.4 Cruise Track

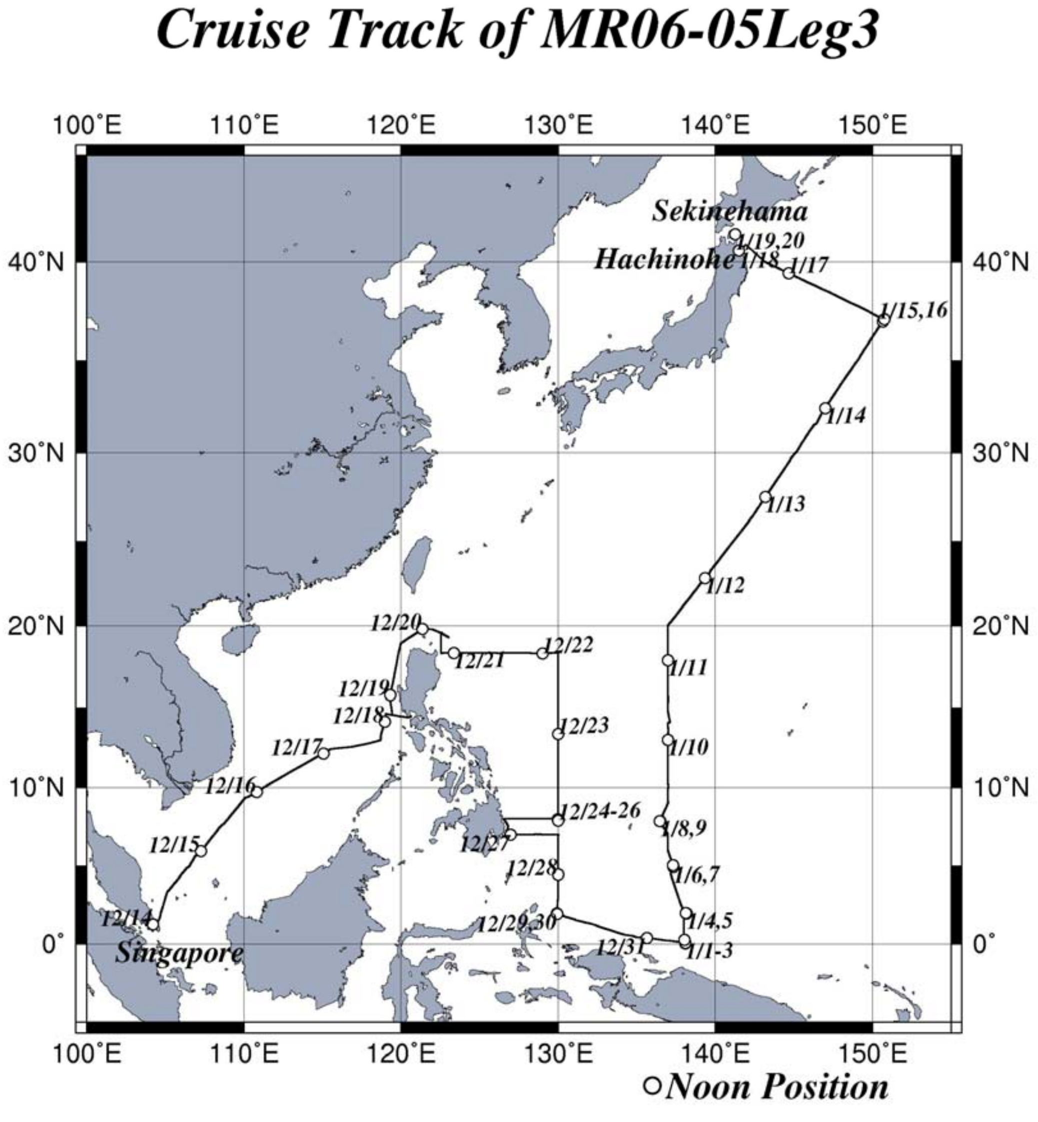

Fig 3.4-1 Cruise Track and Noon Position.

4. Chief scientist

Chief Scientist

Yuji Kashino

Research Scientist

Institute of Observational Research for Global Change (IORGC),

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

2-15, Natsushima-cho, Yokosuka, 237-0061, Japan

Co-chief Scientist

Fadli Syamsudin

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5. Participants list

5.1 R/V MIRAI scientist and technical staff

Yuji Kashino	Scientist (IORGC/JAMSTEC)
Aki Ito	Scientist (IFREE/JAMSTEC)
Kiyoshi Baba	Scientist (Earthquake Research Institute / Univ. of Tokyo)
Ayako Fujii	Scientist (Tokyo Institute of Technology)
Mayumi Horikawa	Scientist (Nagoya University)
Shinichi Yokote	Scientist (Chiba University)
Tetsuo Harada	Scientist (Kochi University)
Mitsuru Nakajo	Scientist (Kochi University)
Takao Inoue	Scientist (Kochi University)
Yasurou Kurusu	Scientist (Ibaraki University)
Makoto Ocho	Scientist (Ibaraki University)
Fadli Syamsudin	Scientist (Badan Pengkajian Dan Penerapan Teknologi, Indonesia)
Lukijanto	Scientist (Badan Pengkajian Dan Penerapan Teknologi, Indonesia)
Gentio Harsono	Security Officer (Indonesian Navy)
Hiroshi Matsunaga	Technical Staff (Marine Works Japan Co. Ltd.)
Kenichi Katayama	Technical Staff (Marine Works Japan Co. Ltd.)
Keisuke Matsumoto	Technical Staff (Marine Works Japan Co. Ltd.)
Hiroki Ushiromura	Technical Staff (Marine Works Japan Co. Ltd.)
Tatsuya Tanaka	Technical Staff (Marine Works Japan Co. Ltd.)
Toru Idai	Technical Staff (Marine Works Japan Co. Ltd.)
Masatomo Hisazumi	Technical Staff (Marine Works Japan Co. Ltd.)
Tetsuharu Iino	Technical Staff (Marine Works Japan Co. Ltd.)
Masanori Enoki	Technical Staff (Marine Works Japan Co. Ltd.)
Junji Matsushita	Technical Staff (Marine Works Japan Co. Ltd.)
Miyo Ikeda	Technical Staff (Marine Works Japan Co. Ltd.)
Shinya Okumura	Technical Staff (Global Ocean Development Inc.)
Ryo Oyama	Technical Staff (Global Ocean Development Inc.)

5.2 R/V MIRAI crew member

Yujiro Kita	Master
Haruhiko Inoue	Chief Officer
Takeshi Isohi	1st Officer
Yasushi Ishioka	Jr. 1st Officer
Tomoo Hikichi	2nd Officer
Ryo Katakura	3rd Officer
Hajime Matsuo	Jr. 3rd Officer
Koichi Higashi	Chief Engineer
Hiroyuki Doi	1st Engineer
Kaoru Minami	2nd Engineer
Hiroyuki Tohken	3rd Engineer
Toshio Kiuchi	Jr. 3rd Engineer
Kazuo Sagawa	C/R Officer
Hisao Oguni	Boatswain
Keiji Yamauchi	Able Seaman
Masami Sugami	Able Seaman
Akito Hodai	Able Seaman
Yukiharu Suzuki	Able Seaman
Toshiharu Honzo	Able Seaman
Shozo Matsumoto	Able Seaman
Kazuyoshi Kudo	Able Seaman
Tsuyoshi Monzawa	Able Seaman
Masashige Okada	Able Seaman
Shuji Komata	Able Seaman
Sadanori Honda	NO.1 Oiler
Yukitoshi Horiuchi	Oiler
Toshimi Yoshikawa	Oiler
Shigeaki Kinoshita	Oiler
Nobuo Boshita	Oiler
Daisuke Taniguchi	Oiler
Hitoshi Ota	Chief Steward
Kitoshi Sugimoto	Cook
Hatsuji Hiraishi	Cook
Tamotsu Uemura	Cook
Wataru Sasaki	Cook
Kanjyuro Murakami	Cook

6 General Observation

6.1 Meteorological measurement

6.1.1 Surface Meteorological Observation

(1) Personnel

Kunio Yoneyama	(JAMSTEC) Principal Investigator / Not on-board
Shinya Okumura	(Global Ocean Development Inc., GODI)
Ryo Ohyama	(GODI)

(2) Objectives

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

(3) Methods

The surface meteorological parameters were observed throughout the MR06-05Leg3 cruise. During this cruise, we used two systems for the observation.

1) MIRAI Surface Meteorological observation (SMET) system
2) Shipboard Oceanographic and Atmospheric Radiation (SOAR) system

1) MIRAI Surface Meteorological observation (SMET) system

Instruments of SMET system are listed in Table 6.1.1-1 and measured parameters are listed in Table 6.1.1-2 Data was collected and processed by KOAC-7800 weather data processor made by Koshin-Denki, Japan. The data set consists of 6-second averaged data.

2) Shipboard Oceanographic and Atmospheric Radiation (SOAR) system

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

i) Portable Radiation Package (PRP) designed by BNL – short and long wave downward radiation.

ii) Zeno Meteorological (Zeno/Met) system designed by BNL – wind, air temperature, relative humidity, pressure, and rainfall measurement.

iii) Scientific Computer System (SCS) designed by NOAA (National Oceanic and Atmospheric Administration, USA) – centralized data acquisition and logging of all data sets.

SCS recorded PRP data every 6 seconds, Zeno/Met data every 10 seconds. Instruments and their locations are listed in Table6.1.1-3 and measured parameters are listed in Table 6.1.1-4.

We have checked the following sensors, before and after the cruise for the quality control as post processing.

a) Young Rain gauge (SMET and SOAR)
Inspecting the linearity of output value from the rain gauge sensor to change input value by adding fixed quantity of test water.

b) Barometer (SMET and SOAR)
Comparing with the portable barometer value, PTB220CASE, VAISALA.

c) Thermometer (air temperature and relative humidity) (SMET and SOAR)
Comparing with the portable thermometer value, HMP41/45, VAISALA.

(4) Preliminary results

Figures 6.1.1-1 to Figures 6.1.1-3 shows the time series of the following parameters;
Wind (SOAR)
Air temperature (SOAR)
Relative humidity (SOAR)

Precipitation (SOAR, ORG)
Short/long wave radiation (SOAR)
Pressure (SOAR)
Sea surface temperature (from EPCS)
Significant wave height (SMET)

(5) Data archives

These raw data will be submitted to the Marine-Earth Data and Information Department (MEDID) of JAMSTEC just after the cruise.

(6) Remarks

The following period of valid SST(Sea Surface Temperature) data during the cruise.

20 Dec. 2006 17:00UTC - 16 Jan. 2007 24:00UTC

Table 6.1.1-1 Instruments and installations of MIRAI Surface Meteorological observation system

Sensors	Type	Manufacturer	Location (altitude from surface)
Anemometer	KE-500	Koshin Denki, Japan	foremast (24 m)
Tair/RH	HMP45A	Vaisala, Finland	
with 43408 Gill aspirated radiation shield		R.M. Young, USA	compass deck (21 m) starboard side and port side
Thermometer: SST	RFN1-0	Koshin Denki, Japan	4th deck (-1m, inlet -5m)
Barometer	AP370	Koshin Denki, Japan	captain deck (13 m) weather observation room
Rain gauge	50202	R. M. Young, USA	compass deck (19 m)
Optical rain gauge	ORG-815DR	Osi, USA	compass deck (19 m)
Radiometer (short wave)	MS-801	Eiko Seiki, Japan	radar mast (28 m)
Radiometer (long wave)	MS-202	Eiko Seiki, Japan	radar mast (28 m)
Wave height meter	MW-2	Tsurumi-seiki, Japan	bow (10 m)

Table 6.1.1-2 Parameters of MIRAI Surface Meteorological observation system

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

Table 6.1.1-3 Instrument and installation locations of SOAR system

Sensors (*Zeno/Met*)	Type	Manufacturer	Location (altitude from surface)
Anemometer	05106	R.M. Young, USA	foremast (25 m)
Tair/RH	HMP45A	Vaisala, Finland	
with 43408 Gill aspirated radiation shield		R.M. Young, USA	foremast (24 m)
Barometer	61201	R.M. Young, USA	
with 61002 Gill pressure port		R.M. Young, USA	foremast (24 m)
Rain gauge	50202	R. M. Young, USA	foremast (24 m)
Optical rain gauge	ORG-815DA	Osi, USA	foremast (24 m)

Sensors (*PRP*)	Type	Manufacturer	Location (altitude from surface)
Radiometer (short wave)	PSP	Epply Labs, USA	foremast (25 m)
Radiometer (long wave)	PIR	Epply Labs, USA	foremast (25 m)
Fast rotating shadowband radiometer		Yankee, USA	foremast (25 m)

Table 6.1.1-4 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/m^2	
13	Down welling infra-red radiation	W/m^2	
14	Defuse irradiance	W/m^2	

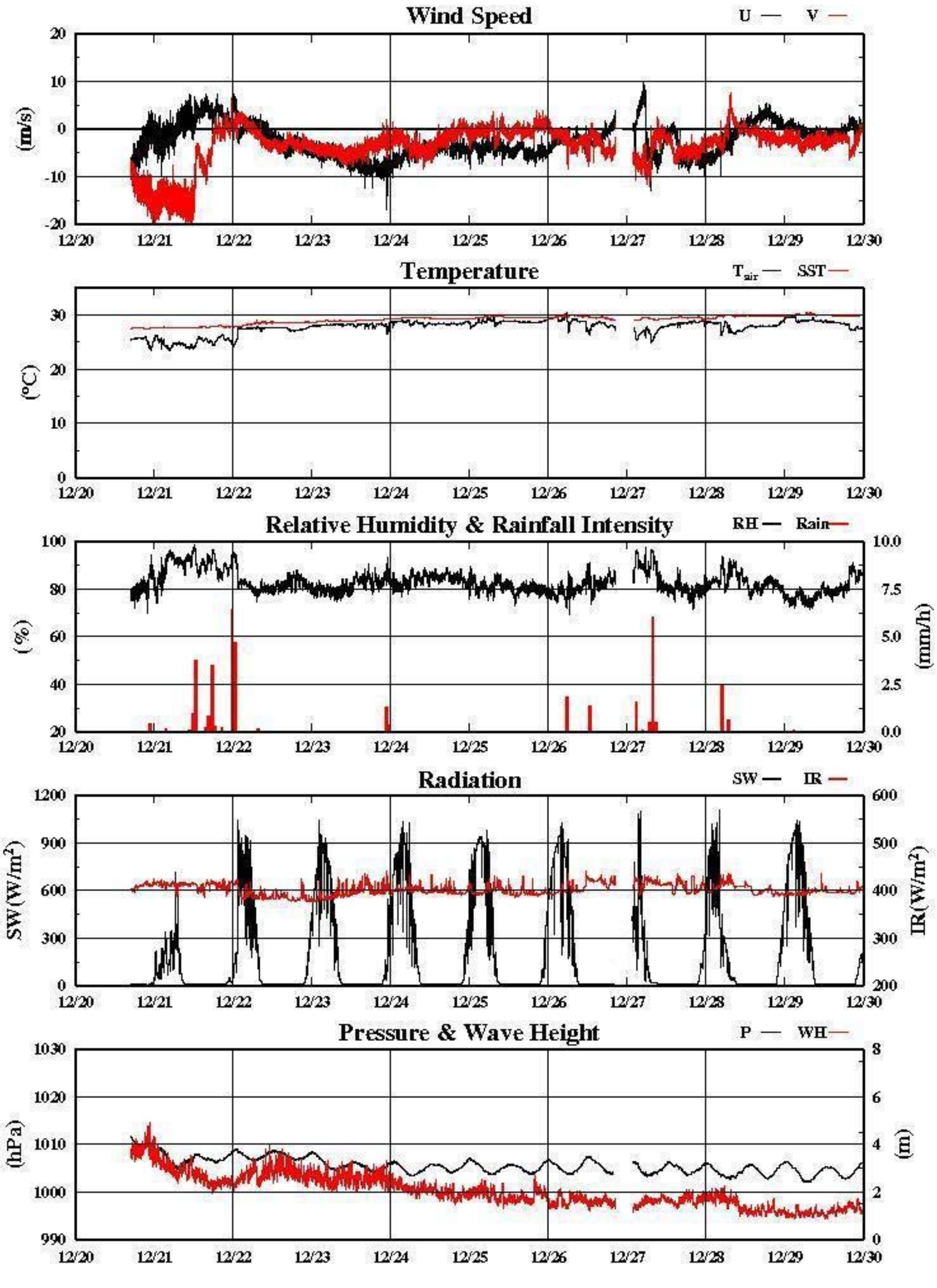


Fig.6.1.1-1 Time series of surface meteorological parameters during the MR06-05Leg3 cruise

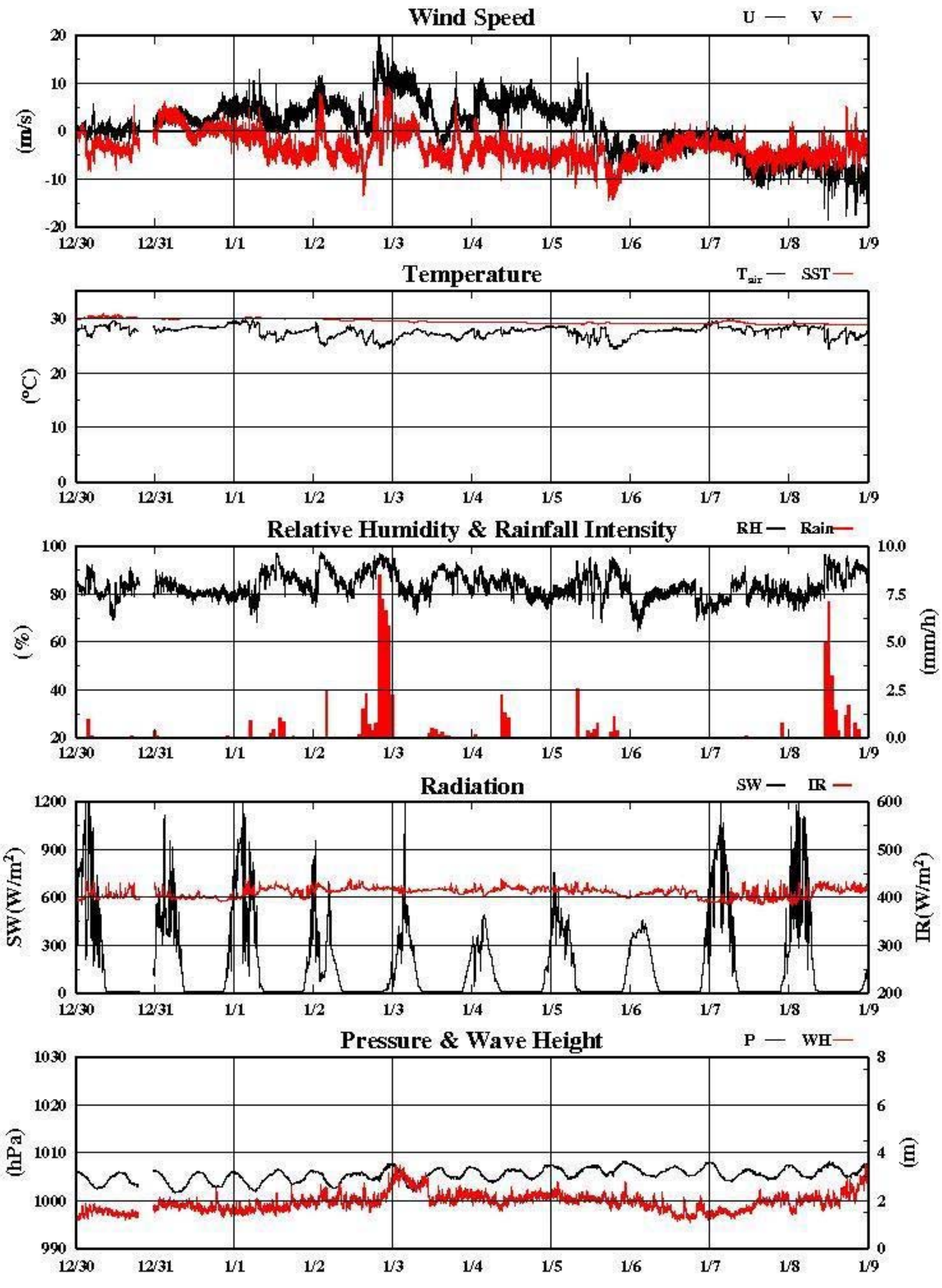


Fig.6.1.1-2 Time series of surface meteorological parameters during the MR06-05Leg3 cruise

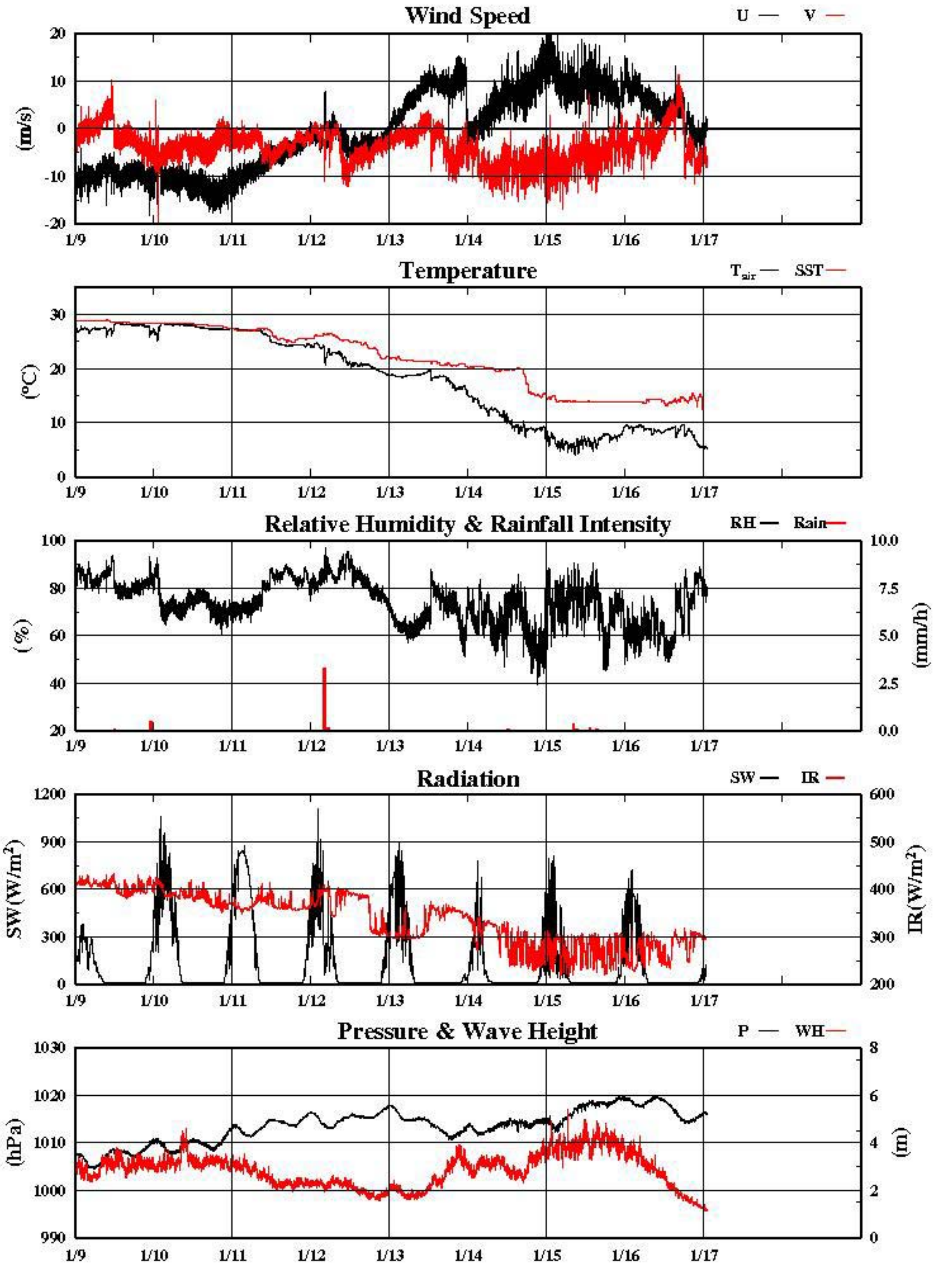


Fig.6.1.1-3 Time series of surface meteorological parameters during the MR06-05Leg3 cruise

6.1.2 Ceilometer Observation

(1) Personnel

Kunio Yoneyama	(JAMSTEC) Principal Investigator / Not on-board
Shinya Okumura	(Global Ocean Development Inc., GODI)
Ryo Ohyama	(GODI)

(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) Methods

We measured cloud base height and backscatter profile using ceilometer (CT-25K, VAISALA, Finland) throughout the MR06-05Leg3 cruise. Major parameters to be measured are 1) cloud base height in meters, 2) backscatter profiles, and 3) estimated cloud amount in octas.

Specifications of the system are as follows.

Laser source:	Indium Gallium Arsenide Diode
Transmitting wavelength:	905±5 mm at 25 degC
Transmitting average power:	8.9 mW
Repetition rate:	5.57 kHz
Detector:	Silicon avalanche photodiode (APD)
Responsibility at 905 nm:	65 A/W
Measurement range:	0 ~ 7.5 km
Resolution:	50 ft in full range
Sampling rate:	60 sec
Sky Condition:	0, 1, 3, 5, 7, 8 octas (9: Vertical Visibility) (0: Sky Clear, 1:Few, 3:Scattered, 5-7: Broken, 8: Overcast)

On the archive dataset, cloud base height and backscatter profile are recorded with the resolution of 30 m (100 ft).

(4) Preliminary results

Figure 6.1.2-1 shows the time series of the first, second and third lowest cloud base height during the cruise.

(5) Data archives

Ceilometer data obtained during this cruise will be submitted to and archived by the Marine-Earth Data and Information Department (MEDID) of JAMSTEC.

(6) Remarks

Window cleaning (UTC) : 23:22, 18 December 2006
04:33, 23 December 2006
00:37, 31 December 2006
00:45, 07 January 2007
00:36, 14 January 2007

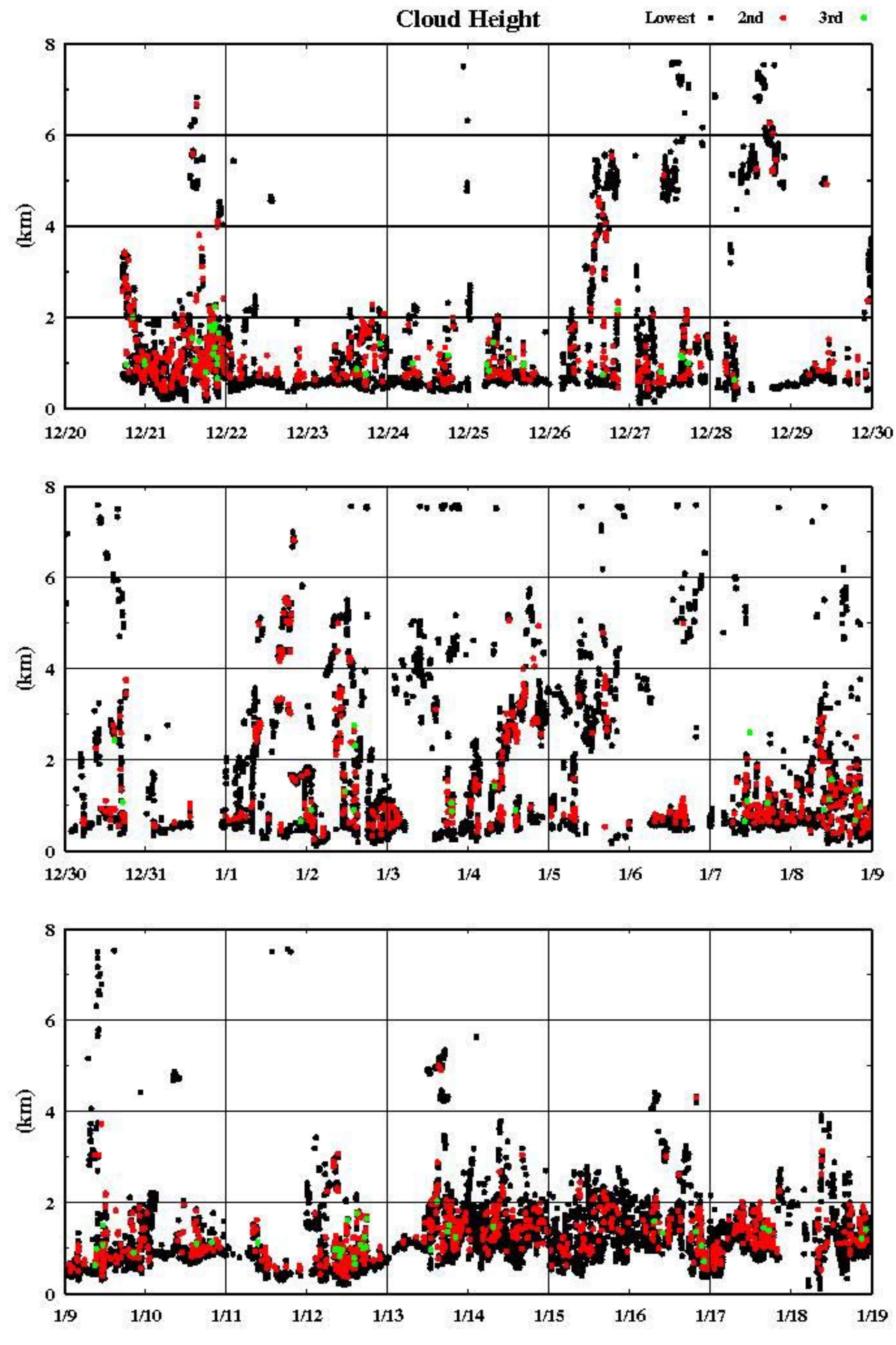


Fig.6.1.2-1 1st (black) 2nd (red) and 3rd (green) lowest cloud base height.

6.2. CTD/XCTD

6.2.1. CTD

Personnel	Yuuji Kashino	(JAMSTEC): Principal investigator
	Kenichi Katayama	(MWJ): Operation leader
	Tatsuya Tanaka	(MWJ)

(1) Objective

Investigation of oceanic structure and water sampling.

(2) Overview of the equipment and observation

CTD/Carousel water sampling system (CTD system), which is 36-position Carousel Water Sampler (SBE 32) with SBE 9plus (Sea-Bird Electronics Inc) attached with sensors, was used during this cruise. 12-litter Niskin bottles were used for sampling seawater. The CTD system was deployed from starboard on working deck. During this cruise, 10 CTD observations were carried out (see Table 6.2.1-1). Sampling layers were shown in Table 6.2.1-2.

(3) List of sensors and equipments

Under water unit:	SBE, Inc., SBE 9plus, S/N 0357
Temperature sensor:	SBE, Inc., SBE 03-04/F, S/N 031359
Conductivity sensor:	SBE, Inc., SBE 04C, S/N 042854
Oxygen sensor:	SBE, Inc., SBE 43, S/N 430330
Pump:	SBE, Inc., SBE 5T, S/N 053118
Altimeter:	Benthos, Inc, PSA-916T, S/N 1157
Fluorometer:	Seapoint Sensors, Inc, Chlorophyll, S/N 2579
Deck unit:	SBE, Inc., SBE 11plus, S/N 11P9833-0308
Carousel Water Sampler:	SBE, Inc., SBE 32, S/N 3227443-0278
Water sample bottle:	General Oceanics, Inc., 12-litre Niskin-X

(4) Data processing

The SEASOFT-Win32 (Ver. 5.27b) was used for processing the CTD data. Descriptions and settings of the parameters for the SEASOFT were written as follows.

DATCNV converted the raw data to scan number, pressure, depth, time elapsed, temperature, conductivity, oxygen voltage, altitude, descent rate, modulo error count and pump status. DATCNV also extracted bottle information where scans were marked with the bottle confirm bit during acquisition. The duration was set to 3.0 seconds, and the offset was set to 0.0 seconds.

ROSSUM created a summary of the bottle data. The bottle position, date, time were output as the first two columns. Scan number, pressure, depth, temperature, conductivity, oxygen voltage, fluorometer, altimter and descent rate were over 3.0 seconds. And oxygen, salinity, sigma-theta and potential temperature were computed.

ALIGNCTD converted the time-sequence of oxygen sensor outputs into the pressure sequence to ensure that all calculations were made using measurements from the same parcel of water. For a SBE 9plus CTD with the ducted temperature and conductivity sensors and a 3000 rpm pump, the typical net advance of the conductivity relative to the temperature is 0.073 seconds. So, the SBE 11plus deck unit S/N 11P9833-0308 was set to advance the primary conductivity for 1.73 scans (1.75/24 = 0.073 seconds). Oxygen data are also systematically delayed with respect to depth mainly because of the long time constant of the oxygen sensor and of an additional delay from the transit time of water in the pumped plumbing line. This delay was compensated by 6 seconds advancing oxygen sensor output (oxygen voltage) relative to the pressure.

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

CELLTM used a recursive filter to 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 performed a low pass filter on pressure with a time constant of 0.15 seconds. In order to produce zero phase lag (no time shift) the filter runs forward first then backwards.

WFILTER performed a median filter on fluorometer with a window size of 49.

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

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

DERIVE was used to compute oxygen.

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

DERIVE was re-used to compute salinity, sigma-theta and potential temperature

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

(5) Preliminary Results

Date, time and locations of the CTD casts are listed in Table 6.2.1-1. Vertical profile of temperature salinity and oxygen with pressure are shown in Figure 6.2.1-1, 6.2.1-2, 6.2.1-3.

(6) Data archive

All raw and processed data files will be submitted to the Data Management Office (DMO) and will be opened to public via "R/V MIRAI Data Web Page" in the JAMSTEC web site.

Table 6.2.1-1 CTD Casttable

Stnnbr	Castno	Date(UTC)	Time(UTC)		Start Position		Depth	Wire Out	HT Above Bottom	Max Depth	Max Pressure	CTD Filename	Remark
		(mmddyy)	Start	End	Latitude	Longitude							
C01	1	122406	0:44	4:37	07-55.47N	130-02.42E	5630	5743.1	21.6	5609.5	5715.1	C01M01	TRITON Recovery (Deep)
C02	1	122806	21:07	21:45	01-58.94N	129-57.23E	4412	1007.1	-	1002.8	1010.9	C02M01	TRITON Recovery (Shallow)
C03	1	122906	4:39	7:26	01-56.09N	129-55.08E	4423	4409.1	22.4	4394.4	4465.7	C03M01	TRITON Recovery (Deep)
C04	1	010107	21:38	22:16	00-03.80N	138-03.50E	4206	1012.2	-	1001.9	1010.3	C04M01	TRITON Recovery (Shallow)
C05	1	010207	4:39	7:25	00-10.39S	138-02.15E	4487	4469.7	20.3	4450.4	4523.7	C05M01	TRITON Recovery (Deep)
C06	1	010307	21:07	21:44	01-58.62N	138-11.45E	4314	1003.4	-	1000.2	1007.4	C06M01	TRITON Recovery (Shallow)
C07	1	010407	4:05	6:51	01-58.33N	138-10.63E	4319	4412.2	17.5	4276.4	4344.2	C07M01	TRITON Recovery (Deep)
C08	1	010607	4:07	6:45	04-55.62N	137-19.15E	4135	4194.5	19.0	4117.3	4180.8	C08M01	TRITON Recovery (Deep)
C09	1	010707	21:04	21:41	07-52.17N	136-28.03E	3346	1014.8	-	999.5	1007.3	C09M01	TRITON Recovery (Shallow)
C10	1	010807	4:05	6:20	07-52.24N	136-29.14E	3344	3450.9	19.2	3320.3	3365.9	C10M01	TRITON Recovery (Deep)

Table 6.2.1-2 Sampling Layler

Stn : C01		Stn : C02		Stn : C03		Stn : C04		Stn : C05		Stn : C06		Stn : C07		Stn : C08		Stn : C09		Stn : C10	
Niskin No.	Depth [m]	Niskin No.	Depth [m]	Niskin No.	Depth [m]	Niskin No.	Depth [m]	Niskin No.	Depth [m]	Niskin No.	Depth [m]	Niskin No.	Depth [m]	Niskin No.	Depth [m]	Niskin No.	Depth [m]	Niskin No.	Depth [m]
1	Bottom	1	1000	1	Bottom	1	1000	1	Bottom	1	1000	1	Bottom	1	Bottom	1	1000	1	Bottom
2	4000	2	750	2	4000	2	750	2	4000	2	750	2	3830	2	4000	2	750	2	3000
3	2000	3	-	3	2000	3	-	3	2000	3	-	3	2000	3	2000	3	-	3	2000
4	1400	4	-	4	1400	4	-	4	1400	4	-	4	1400	4	1400	4	-	4	1400
5	1000	5	-	5	1000	5	-	5	1000	5	-	5	1000	5	1000	5	-	5	1000
6	800	6	-	6	800	6	-	6	800	6	-	6	800	6	800	6	-	6	800
7	600	7	-	7	600	7	-	7	600	7	-	7	600	7	600	7	-	7	600
8	500	8	-	8	500	8	-	8	500	8	-	8	500	8	500	8	-	8	500
9	400	9	-	9	400	9	-	9	400	9	-	9	400	9	400	9	-	9	400
10	300	10	-	10	300	10	-	10	300	10	-	10	300	10	300	10	-	10	300
11	250	11	-	11	250	11	-	11	250	11	-	11	900	11	250	11	-	11	Bottom
12	200	12	-	12	200	12	-	12	200	12	-	12	900	12	250	12	-	12	2000
13	150	13	-	13	150	13	-	13	150	13	-	13	900	13	250	13	-	13	1000
14	100	14	-	14	100	14	-	14	100	14	-	14	900	14	250	14	-	14	500
15	50	15	-	15	50	15	-	15	50	15	-	15	900	15	250	15	-	15	10
16	10	16	-	16	10	16	-	16	10	16	-	16	900	16	250	16	-	16	-
17	10	17	-	17	10	17	-	17	10	17	-	17	-	17	-	17	-	17	-
18	300	18	-	18	900	18	-	18	625	18	-	18	-	18	-	18	-	18	-
19	175	19	-	19	150	19	-	19	145	19	-	19	150	19	160	19	-	19	170
20	125	20	-	20	100	20	-	20	95	20	-	20	100	20	110	20	-	20	120
21	75	21	-	21	50	21	-	21	45	21	-	21	50	21	60	21	-	21	70
22	Bottom	22	-	22	Bottom	22	-	22	Bottom	22	-	22	Bottom	22	Bottom	22	-	22	Bottom
23	4000	23	-	23	2000	23	-	23	2000	23	-	23	2000	23	2000	23	-	23	2000
24	2000	24	-	24	1000	24	-	24	1000	24	-	24	1000	24	1000	24	-	24	1000
25	1000	25	-	25	500	25	-	25	500	25	-	25	500	25	500	25	-	25	500
26	500	26	-	26	10	26	-	26	10	26	-	26	10	26	10	26	-	26	10
27	10	27	-	27	300	27	-	27	100	27	-	27	Bottom	27	Bottom	27	-	27	Bottom
28	150	28	-	28	-	28	-	28	Bottom	28	-	28	250	28	250	28	-	28	250
29	Bottom	29	-	29	-	29	-	29	-	29	-	29	200	29	200	29	-	29	200
30	4000	30	-	30	-	30	-	30	-	30	-	30	150	30	150	30	-	30	150
31	2000	31	-	31	-	31	-	31	-	31	-	31	100	31	100	31	-	31	100
32	1000	32	-	32	-	32	-	32	-	32	-	32	50	32	50	32	-	32	50
33	10	33	-	33	-	33	-	33	-	33	-	33	10	33	10	33	-	33	10
34	-	34	-	34	-	34	-	34	-	34	-	34	10	34	10	34	-	34	10
35	-	35	-	35	-	35	-	35	-	35	-	35	900	35	250	35	-	35	800
36	-	36	-	36	-	36	-	36	-	36	-	36	100	36	800	36	-	36	300

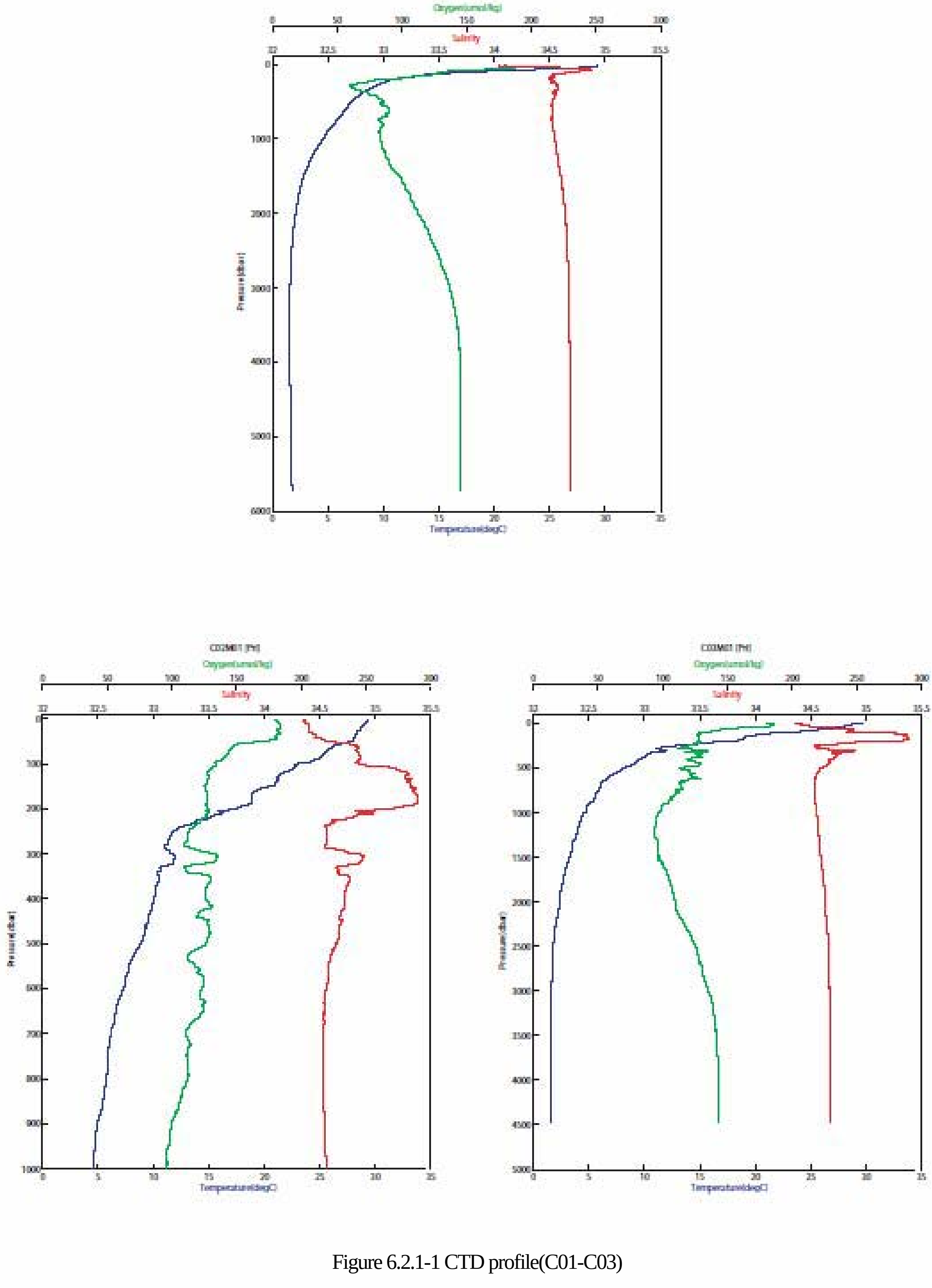


Figure 6.2.1-1 CTD profile(C01-C03)

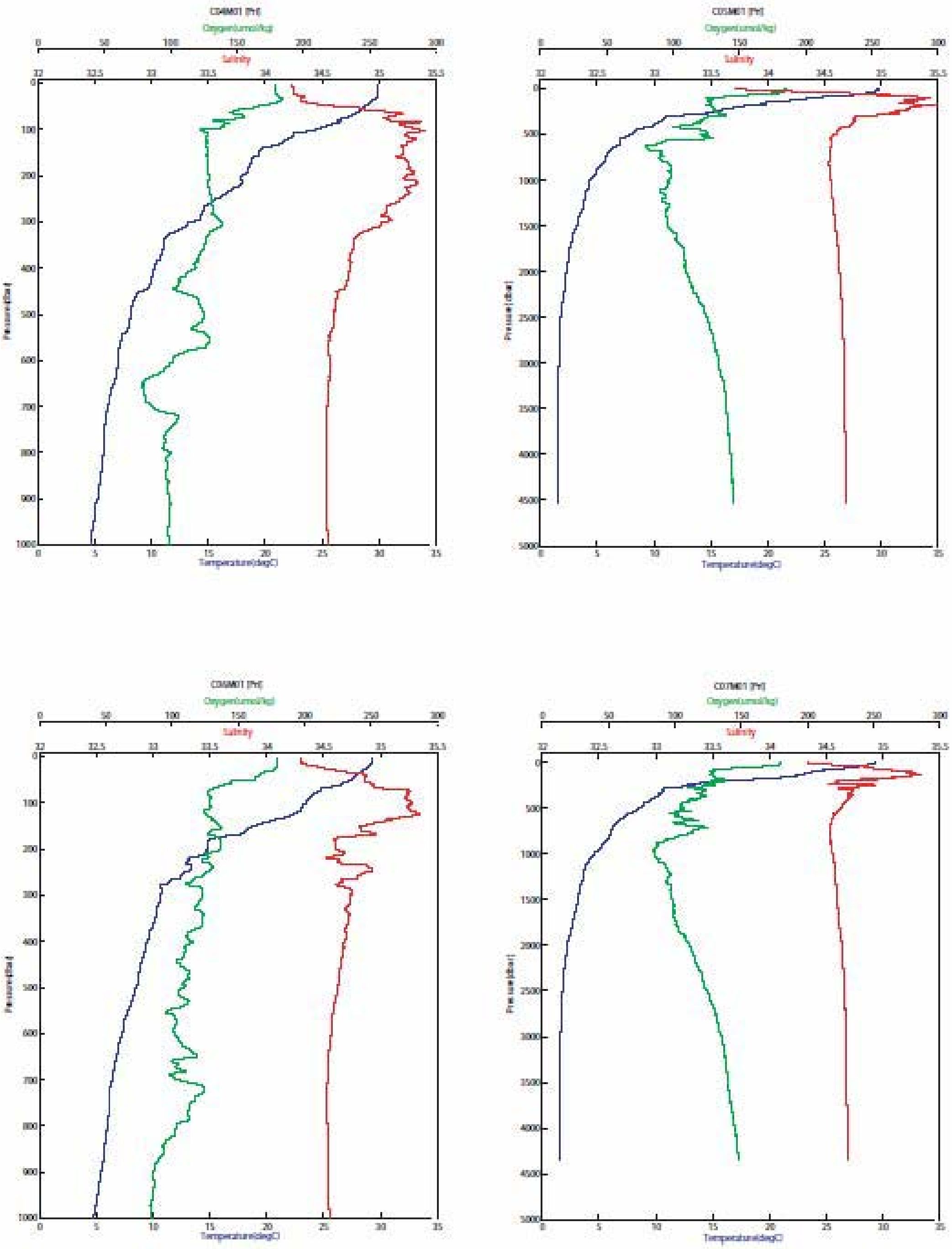


Figure 6.2.1-2 CTD profile(C04-C07)

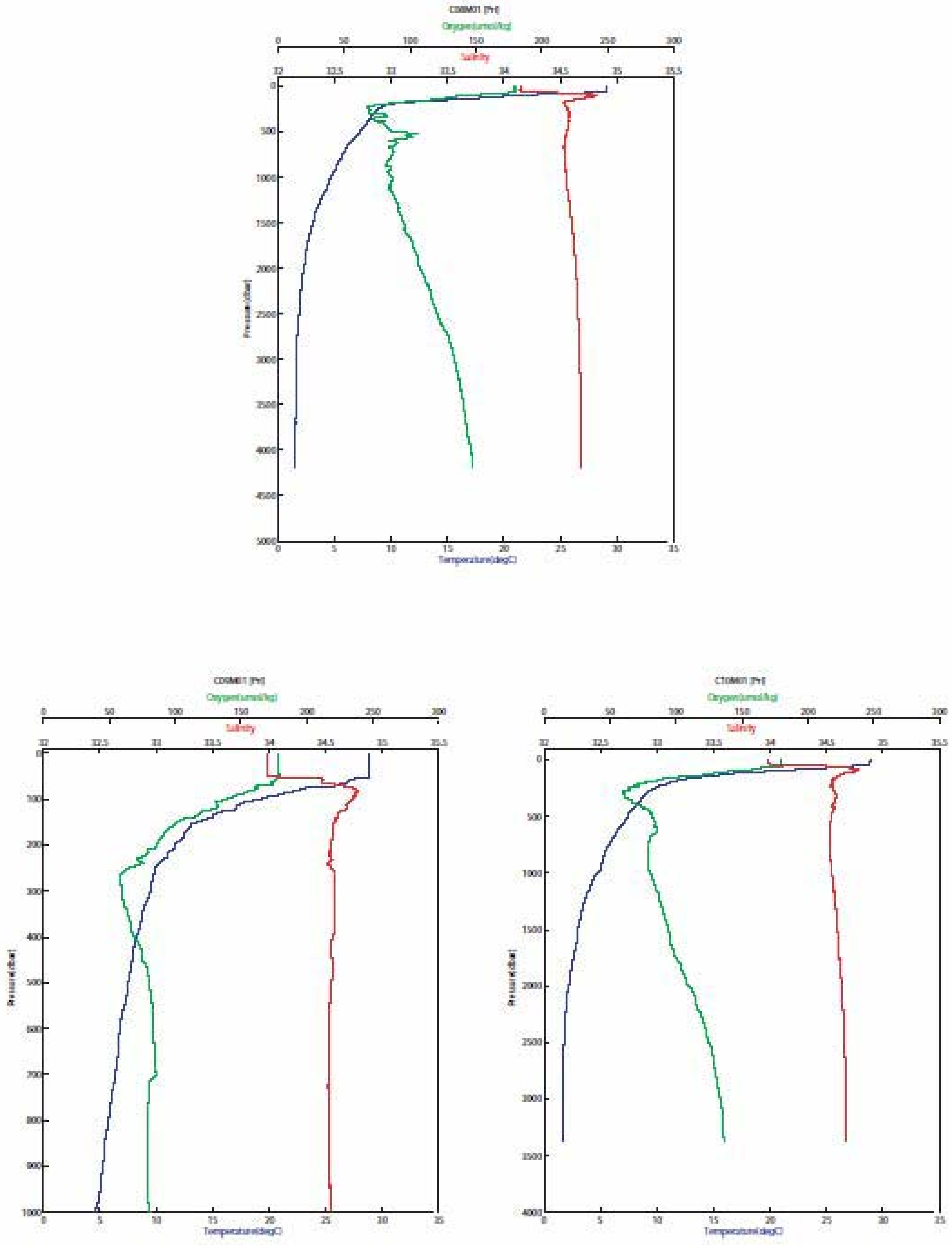


Figure 6.2.1-3 CTD profile(C08-C10)

6.2.2 XCTD observation

(1) Personnel

Yuji Kashino	(JAMSTEC): Principal Investigator
Shinya Okumura	(Global Ocean Development Inc.: GODI)
Ryo Ohyama	(GODI)

(2) Objectives

Investigation of oceanic structure.

(3) Parameters

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

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	

(4) 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-100, Tsurumi-Seiki Co. and was recorded by WinXCTD software (Ver.1.08) provided by Tsurumi-Seiki Co.. We launched 67 probes (X001 – X064) by using automatic launcher. The summary of XCTD observation and launching log were shown in Table 6.2.2-1.

(5) Preliminary results

Position of XCTD observation, Vertical temperature and salinity sections were shown in the following Fig. 6.2.2-1 to 6.2.2-6

(6) Data archive

XCTD data obtained during this cruise will be submitted to the JAMSTEC and will be available via “R/V Mirai Data Web Page” in JAMSTEC home page.

Table 6.2.2-1 Summary of XCTD observation and launching log

Station	Date	Start	Finish	Launched Position		Measured	Water	Suerface	Suerface	Probe
No.		time	time	Latitude	Longitude	depth	depth	temp	salinity	S/N
001	12/20/06	22:31:19	22:37	18-19.9490N	122-33.9873E	1036	2609	27.472	34.465	05022159
002	12/20/06	23:36:51	23:42	18-19.9274N	122-45.0322E	1031	3707	27.606	34.468	05022151
003	12/21/06	00:54:28	01:00	18-20.0853N	123-00.0404E	1016	4039	27.591	34.405	05022152
004	12/21/06	03:41:59	03:47	18-20.0059N	123-30.0252E	994	5266	27.568	34.360	05022155
005	12/21/06	06:01:59	06:07	18-19.9829N	124-00.0377E	1018	5072	27.541	34.426	05022148
006	12/21/06	10:23:00	10:28	18-20.0410N	125-00.0091E	1035	5471	27.623	34.269	05126226
007	12/21/06	14:31:37	14:37	18-19.9145N	126-00.0168E	1035	5443	27.701	34.451	05126231
008	12/21/06	18:40:19	18:45	18-20.0168N	127-00.0043E	1035	4945	27.799	34.462	05022154
009	12/21/06	22:43:26	22:48	18-19.9891N	128-00.0155E	1035	4676	27.722	34.411	05022153
010	12/22/06	02:53:26	02:58	18-19.7085N	129-00.0159E	1035	5404	27.937	34.501	05126234
011	12/22/06	06:56:42	07:02	18-20.0099N	130-00.5308E	1036	5632	28.438	34.491	05022158
012	12/22/06	09:51:47	09:57	17-39.9166N	129-59.9970E	1036	5817	28.431	34.475	05022157
013	12/22/06	12:30:20	12:35	16-59.9964N	130-00.0127E	1034	5224	28.548	34.437	05126227
014	12/22/06	16:30:20	16:35	15-59.9912N	129-59.9814E	1034	5441	28.579	34.288	05126230
015	12/22/06	20:28:17	20:33	14-59.9912N	129-59.9308E	1035	5528	28.576	34.282	05126233
016	12/23/06	00:27:26	00:32	13-59.9915N	130-00.0970E	1035	5683	28.601	34.302	05126229
017	12/23/06	04:22:53	04:28	13-00.0025N	129-59.9567E	1035	5935	28.931	34.213	05126237
018	12/23/06	08:28:07	08:33	11-59.9908N	130-00.0016E	1035	5796	28.919	34.309	05126236
019	12/23/06	12:25:40	12:31	10-59.9943N	130-00.1359E	1035	5806	28.802	34.060	05126247
020	12/23/06	16:19:56	16:25	09-59.9616N	130-00.0003E	1035	5972	29.075	34.142	05126232
021	12/23/06	20:11:49	20:17	08-59.9913N	130-00.0577E	1033	5922	29.077	34.126	05126235
022	12/25/06	04:34:29	04:39	07-59.2684N	129-59.9926E	1034	5709	29.654	34.030	05125244
023	12/26/06	09:59:37	10:05	08-00.0162N	128-59.9886E	1033	4677	29.726	34.086	05126245
024	12/26/06	14:23:15	14:28	08-00.1628N	127-59.9936E	1035	4781	29.417	34.136	05126248
025	12/26/06	16:49:21	16:54	08-00.0134N	127-29.9614E	1033	6796	29.448	34.010	05126246
026	12/26/06	19:09:07	19:15	07-59.9376N	126-59.9949E	1035	5930	29.157	34.136	05126243
027	12/26/06	20:02:39	20:08	07-59.8389N	126-49.9876E	1034	2884	29.077	34.221	05126241
028	12/27/06	02:06:03	02:11	06-59.3687N	126-48.0124E	1035	4411	29.000	34.141	05126239
029	12/27/06	03:03:58	03:09	06-59.5539N	127-00.0145E	1035	5591	29.005	34.063	05126255
030	12/27/06	05:09:08	05:14	07-00.0201N	127-30.0068E	1035	7355	29.466	33.989	05126259
031	12/27/06	07:15:38	07:21	06-59.9298N	128-00.0060E	1034	4728	29.307	33.991	05126251
032	12/27/06	11:27:37	11:33	06-59.9836N	129-00.0076E	1035	5056	29.252	34.047	05126254
033	12/27/06	15:38:52	15:44	06-59.9650N	130-00.0089E	1035	5564	29.585	34.080	05126256
034	12/27/06	19:33:38	19:39	05-59.9854N	130-00.0759E	1035	5484	29.520	33.956	05126252
035	12/28/06	00:47:57	00:53	04-59.9898N	130-00.0471E	1035	5052	29.292	33.843	05126257
036	12/28/06	04:53:31	04:59	03-59.9817N	129-59.9665E	1035	4712	29.864	34.311	05126250
037	12/28/06	09:05:24	09:10	02-59.9943N	129-59.9819E	1035	3028	29.664	34.364	05126256
038	12/30/06	03:35:33	03:41	01-57.8567N	129-56.8274E	1034	4422	30.006	34.362	05126258
039	01/03/07	02:13:48	02:19	00-05.3252N	138-03.2027E	1033	4151	29.378	34.254	06079198
040	01/03/07	04:07:57	04:13	00-30.0153N	137-59.9979E	1034	3945	29.542	34.363	05126261
041	01/03/07	06:19:24	06:24	01-00.0083N	137-59.9944E	1035	4231	29.125	34.461	05126260
042	01/03/07	08:27:17	08:32	01-30.0110N	138-00.0856E	1033	4387	29.404	34.379	05126259
043	01/05/07	03:44:47	03:49	01-59.5506N	138-06.8519E	814	4325	29.002	34.380	06079196
044	01/05/07	06:20:43	06:26	02-30.0159N	137-49.9945E	1035	4426	28.959	34.371	06079190
045	01/05/07	08:38:45	08:44	03-00.0134N	137-39.9955E	1033	4775	28.986	34.421	06079195
046	01/05/07	10:57:41	11:03	03-30.0007N	137-30.0142E	1034	4342	29.179	34.319	06079194
047	01/05/07	13:18:43	13:24	04-00.0054N	137-20.0360E	1035	4657	28.999	34.212	06079197
048	01/05/07	15:36:06	15:41	04-30.0114N	137-10.0055E	1034	4948	29.101	34.209	06079193
049	01/06/07	02:06:57	02:12	04-51.8996N	137-16.7868E	1035	4108	29.035	34.155	06079191
050	01/07/07	07:06:45	07:12	06-01.4324N	136-59.9947E	1035	4307	29.607	34.027	06079192
051	01/07/07	10:57:53	11:03	07-00.0197N	136-59.9934E	1035	4251	29.12	34.131	06079188
052	01/09/07	03:46:55	03:52	07-52.1986N	136-28.2915E	1032	3351	28.764	33.987	06079187
053	01/09/07	09:15:30	09:21	09-00.0042N	137-00.0001E	1032	3600	28.764	33.987	06079186
054	01/09/07	13:40:48	13:46	10-00.0096N	137-00.4336E	1035	4960	28.61	33.963	06079179
055	01/09/07	18:04:54	18:10	11-00.0130N	137-00.0276E	1035	4923	28.414	34.177	06079176
056	01/09/07	22:34:04	22:39	12-00.0091N	136-59.9899E	1035	5284	28.377	34.340	06079183
057	01/10/07	03:22:59	03:28	13-00.1638N	137-00.0305E	1035	4939	28.314	34.276	06079180
058	01/10/07	07:52:02	07:57	14-00.8366N	137-00.0063E	1035	4714	28.275	34.382	06079178
059	01/10/07	14:16:32	14:22	15-00.0076N	136-59.9373E	1035	5210	28.001	34.528	06079177
060	01/10/07	18:39:33	18:45	16-00.0042N	137-00.0117E	1035	5310	27.848	34.515	06079181
061	01/10/07	23:07:41	23:13	17-00.0105N	136-59.9581E	1034	4843	27.321	34.582	06079175
062	01/11/07	03:25:42	03:31	18-00.0013N	137-00.0035E	1035	4922	26.942	34.640	06079182
063	01/11/07	07:54:32	08:00	19-00.0231N	137-00.0036E	1035	4829	27.265	34.627	06079184
064	01/11/07	12:05:19	12:11	20-00.0066N	137-00.1080E	1034	4779	26.668	34.605	06079185

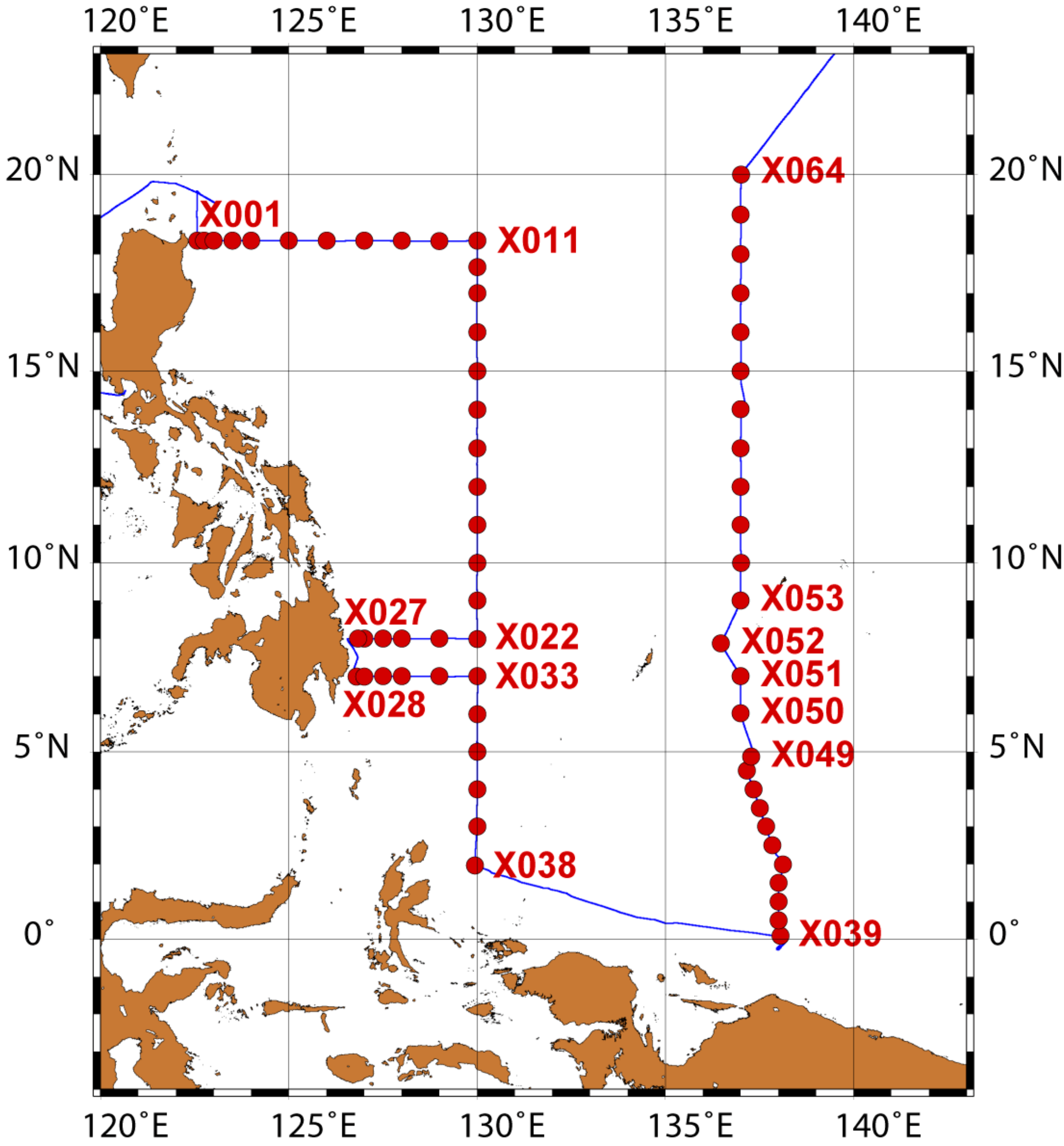


Fig. 6.2.2-1 Position of XCTD observation.

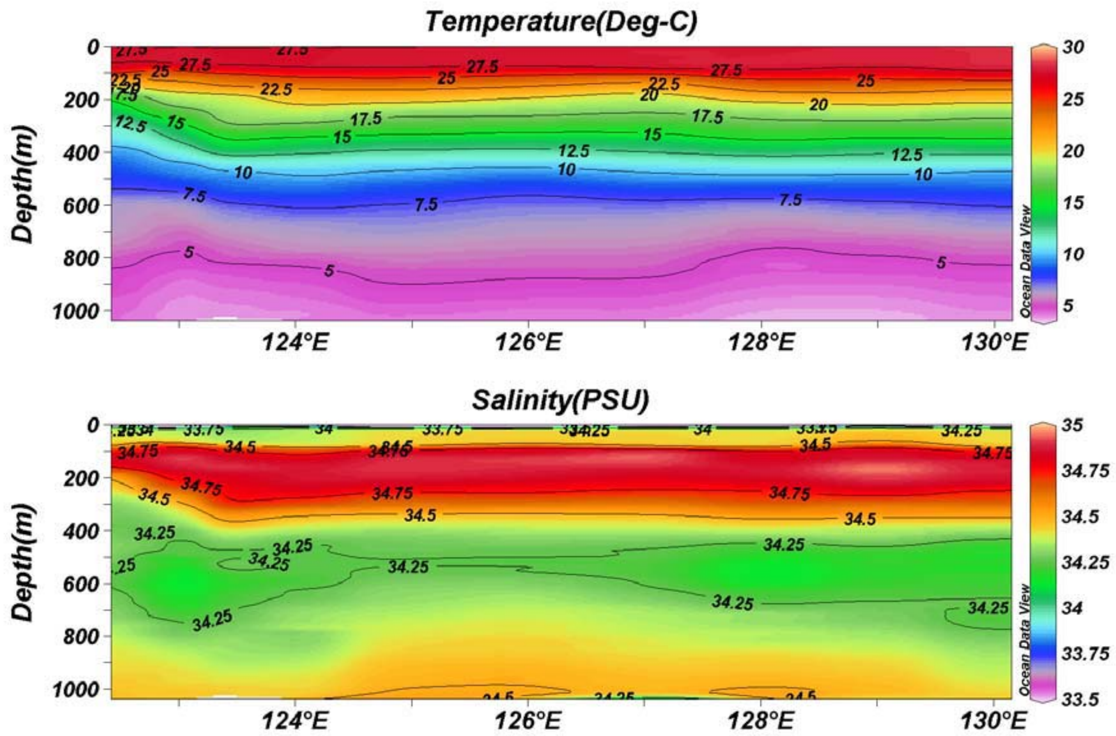


Fig. 6.2.2-2 Vertical section of Temperature (upper) Salinity (lower) along 18N line (X001 – X011).

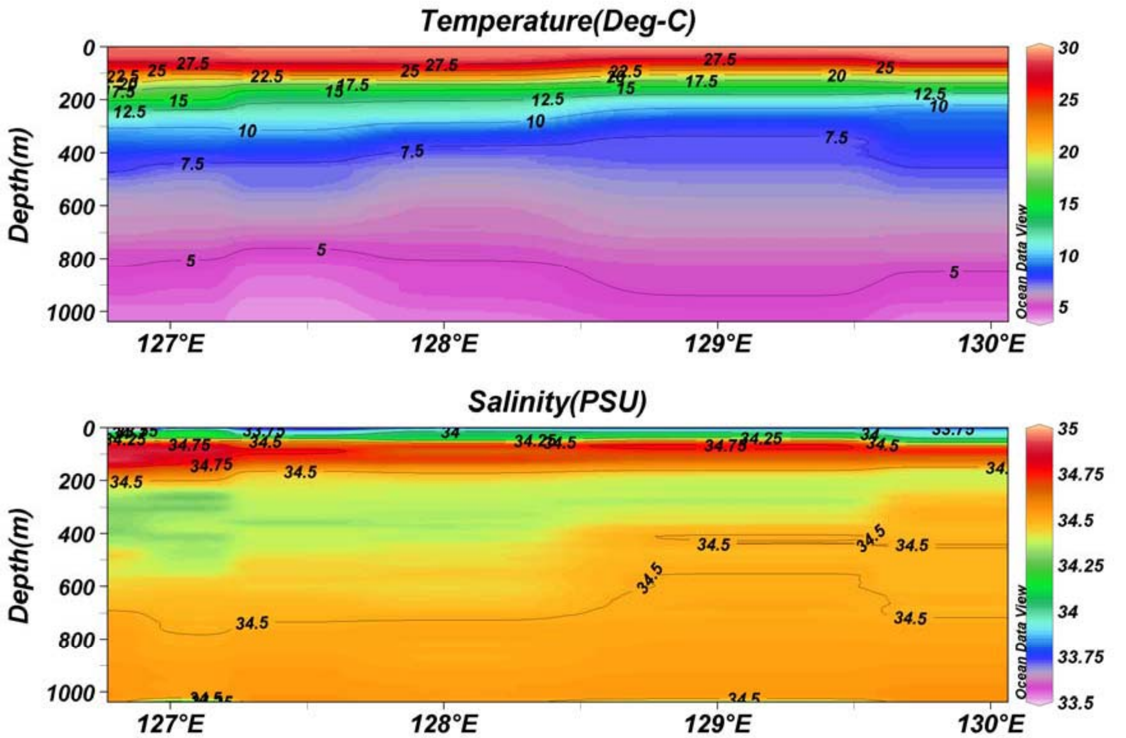


Fig. 6.2.2-3 Vertical section of Temperature (upper) Salinity (lower) along 8N line (X022 – X027).

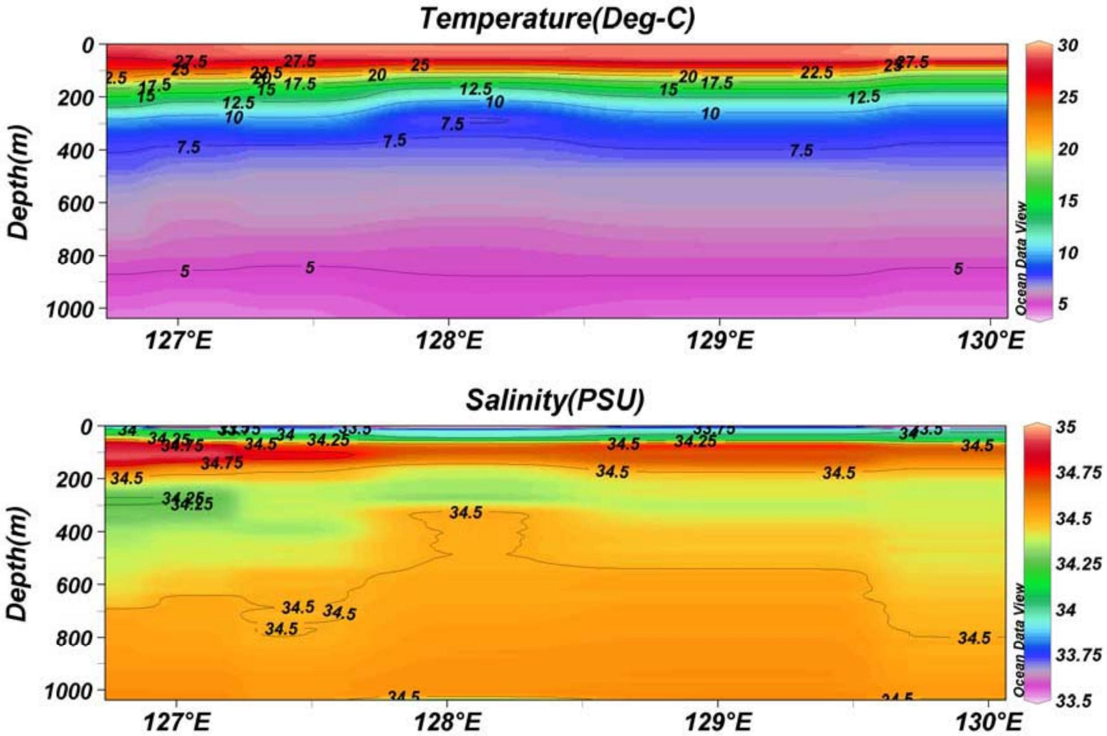


Fig. 6.2.2-4 Vertical section of Temperature (upper) Salinity (lower) along 7N line (X028 – X033).

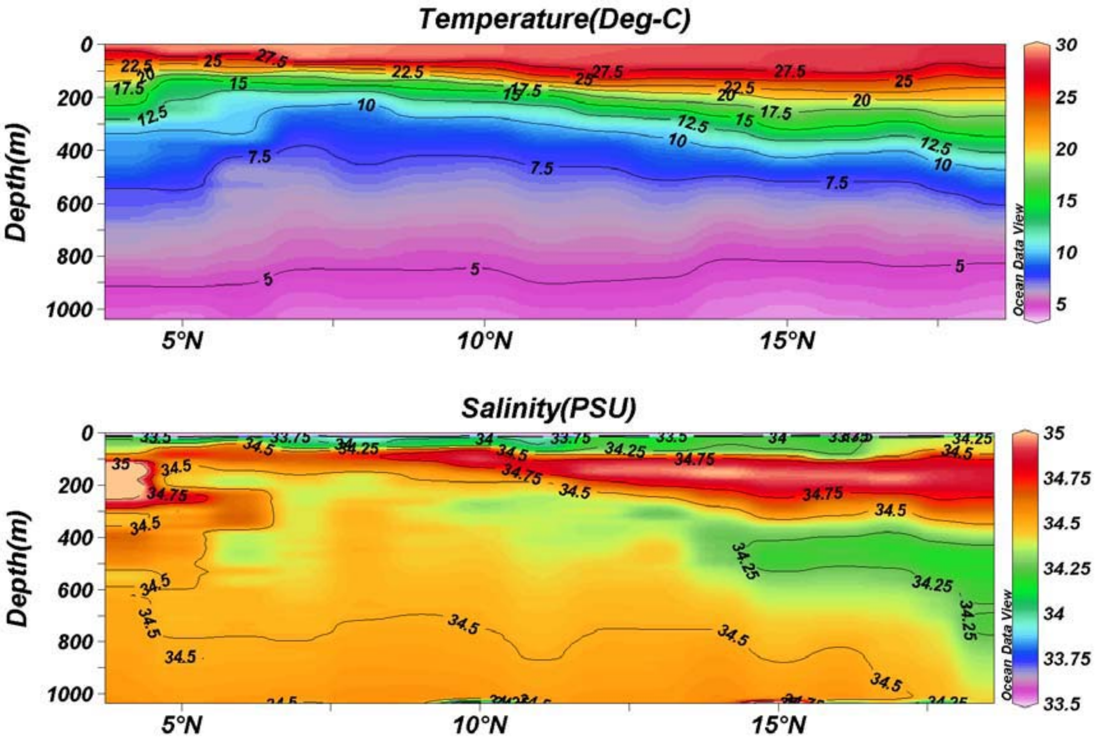


Fig.6.2.2-5 Vertical section of Temperature (upper) Salinity (lower) along 130E line (X011 – X022, X033 – X038).

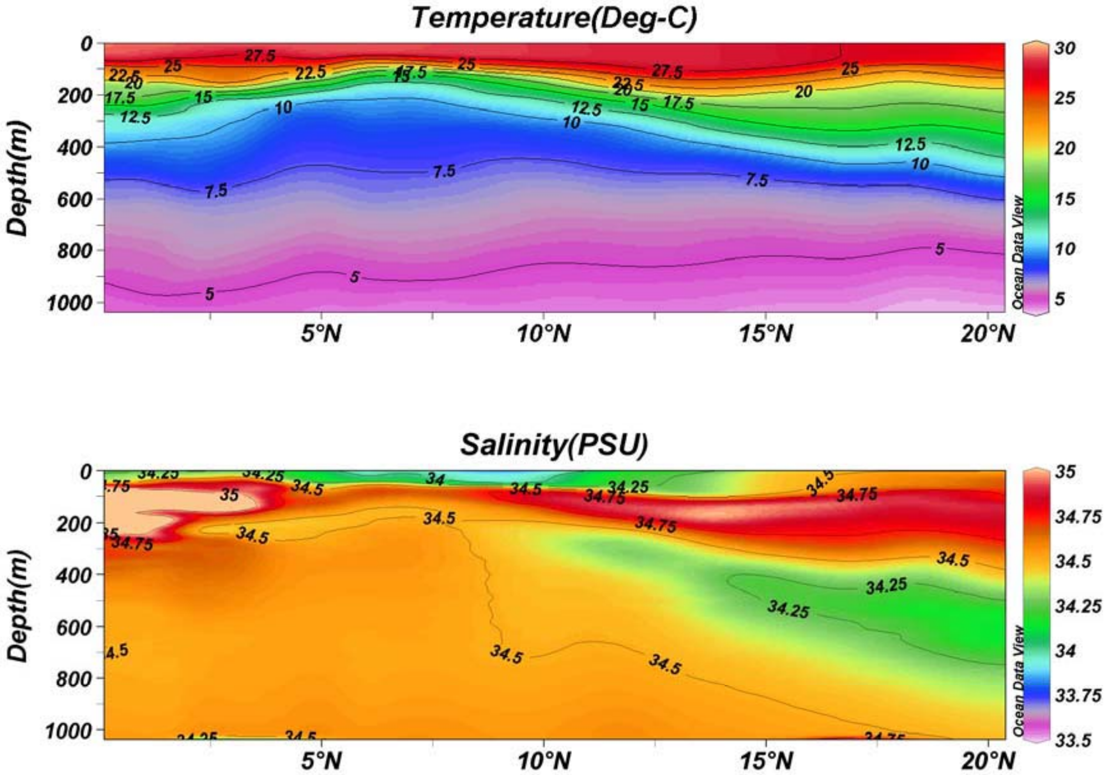


Fig.6.2.2-6 Vertical section of Temperature (upper) Salinity (lower) along 137-138E line (X039–X064).

6.3. Water sampling

6.3.1 Salinity

(1) Personnel

Tatsuya Tanaka (MWJ) : Operation Leader

(2) Objectives

To measure bottle salinity obtained by CTD casts, bucket and EPCS.

(3) Method

(3-1) Salinity Sample Collection

Seawater samples were collected with 12 liter Niskin-X bottles, bucket and EPCS. The 250ml brown glass bottle was used to collect the sample water. The sample bottle was sealed with a plastic insert thimble and a screw cap. Each bottle was rinsed three times with the sample water, and was filled with sample water to the bottle shoulder. Its cap and thimble were also thoroughly rinsed. The bottle was stored more than 24 hours in 'AUTOSAL ROOM' before the salinity measurement.

(3-2) Instruments and Methods

The salinity analysis was carried out on R/V MIRAI during the cruise of MR06-05 Leg3 using the salinometer (Model 8400B "AUTOSAL" ; Guildline Instruments Ltd.: S/N 62556), with additional peristaltic-type intake pump (Ocean Scientific International, Ltd.). We also used two precision digital thermometers (Model 9540 ; Guildline Instruments Ltd.). One thermometer monitored an ambient temperature and the other monitored a bath temperature.

The specifications of 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 restandardization
Maximum Resolution	:	Better than ±0.0002 (PSU) at 35 (PSU)

Thermometer (Model 9540 ; Guildline Instruments Ltd.)

Measurement Range	:	-40 to +180 deg C
Resolution	:	0.001
Limits of error ±deg C	:	0.01 (24 hours @ 23 deg C ±1 deg C)
Repeatability	:	±2 least significant digits

The measurement system was almost 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. An ambient temperature varied from approximately 21.0 deg C to 24.0 deg C, while a bath temperature is very stable and varied within +/- 0.004 deg C on rare occasion. We measured sub-standard seawater and confirmed that the salinometer was stable before the routine measurement of the day. The measurement for each sample was done with a double conductivity ratio that is defined as median of 31 times reading of the salinometer. Data collection was started in 5 seconds after filling sample to the cell 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 after five times rinse of the cell. In case the difference between the double conductivity ratio of these two fillings is smaller than 0.00002, the average value of these double conductivity ratio was used to calculate the bottle salinity with the algorithm for practical salinity scale, 1978 (UNESCO, 1981). If the difference was greater than or equal to 0.00003, we measured eighth filling of the cell. In case the double conductivity ratio of eighth filling did not satisfy the criteria above, we measured ninth filling of the cell.

The measurement was conducted about 12 hours per day (typically from 09:00 to 21:00) and the cell was cleaned with soap after the measurement of the day. We measured 186 samples in total.

The kind and number of samples are shown as follows ;

Table 5.19.2-1: Kind and number of samples

Kind of samples	Number of samples
Samples for CTD	153
Samples for bucket	6
Samples for EPCS	27
Total	186

(3-3) Standard Seawater

Standardization control was set to 887 and all the measurements were done by this setting. We used IAPSO Standard Seawater (SSW) batch P145 as the standard for salinity. And we measured the SSW in order to correct the measured salinity at the measurement of a day. We measured 22 bottles in total.

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

Standard seawater (SSW)

batch	:	P145
conductivity ratio	:	0.99981
salinity	:	34.993
preparation date	:	15-Jul.-2004

(3-4) Sub-Standard Seawater

We also used sub-standard seawater which was obtained from 2,500m depth in MR06-02 cruise filtered by Millipore filter (pore size of 0.45 μm), which was stored in a 20 liter polyethylene container and stirred for at least 24 hours before measuring. It was measured every about six samples in order to check the drift of the salinometer. During the whole measurements, there was no detectable sudden drift of the salinometer.

(4) Results

(4-1) Standard Seawater

The average and standard deviation of SSW were respectively 34.9919 and 0.0003 in salinity. After correction for the double conductivity ratio at the measurement of a day, the average and standard deviation were respectively 34.9925 and 0.0003 in salinity.

(4-2) Replicate Samples

We took 26 pairs of replicate samples. Fig.6.3.1-1 shows the histogram of the absolute difference between replicate samples. The average and the standard deviation of the absolute deference of replicate samples were respectively 0.00020 and 0.00016 in salinity.

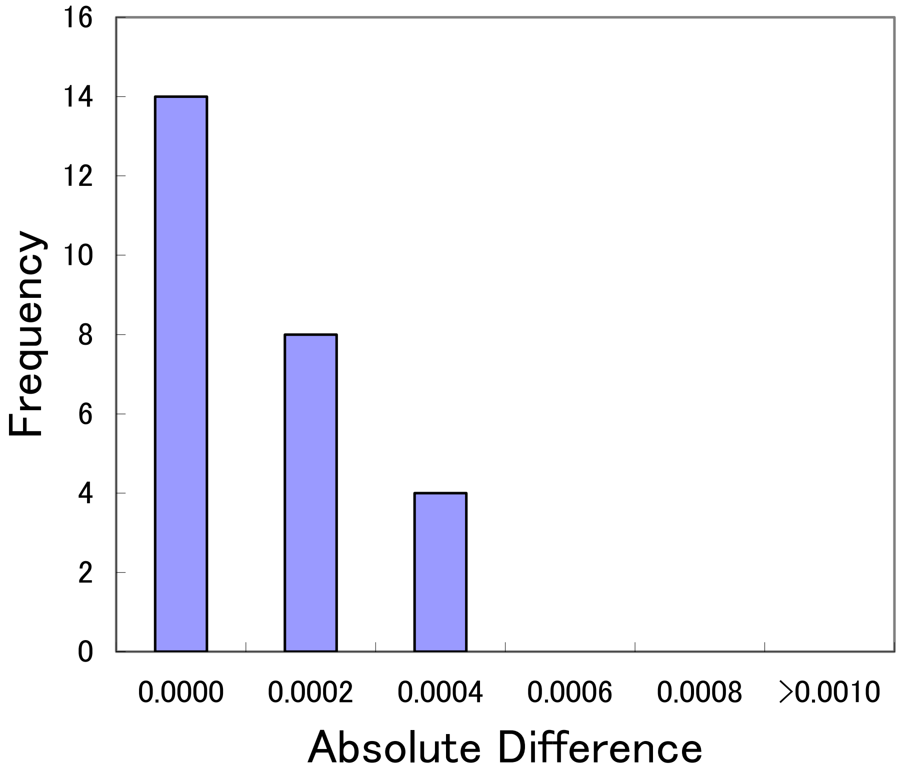


Fig. 6.3.1-1 : The histogram of absolute difference between replicate samples

(5) Data Archive

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

(6) Remarks

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 Technical Papers in Marine Science*, 36, 25 pp., 1981

6.3.2 Dissolved oxygen measurement

(1) Personnel

Miyo IKEDA(Marine Works Japan Co. Ltd.)

Masanori ENOKI (Marine Works Japan Co. Ltd.)

(2) Objectives

Determination of dissolved oxygen in seawater by Winkler titration.

(3) Measured parameters

Dissolved oxygen of sampled seawater

(4) Instruments and Methods

a. Reagents

Pickling Reagent I: Manganous chloride solution (3M)

Pickling Reagent II: Sodium hydroxide (8M) / sodium iodide solution (4M)

Sulfuric acid solution (5M)

Sodium thiosulfate (0.025M)

Potassium iodate (0.001667M)

b. Instruments:

Burette for sodium thiosulfate;

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

Burette for potassium iodate;

APB-410 manufactured by Kyoto Electronic Co. Ltd. / 20 cm^3 of titration vessel

Detector and Software; Automatic photometric titrator manufactured by Kimoto Electronic Co. Ltd.

c. Sampling

Following procedure is based on the WHP Operations and Methods (Dickson, 1996).

Seawater samples were collected with Niskin bottle attached to the CTD-system. Seawater for oxygen measurement was transferred from Niskin sampler bottle to a volume calibrated flask (about 100 cm^3). Three times volume of the flask of seawater was overflowed. Temperature was measured by digital thermometer during the overflowing. Then two reagent solutions (Reagent I and II) of 0.5 cm^3 each were added immediately into the sample flask and the stopper was inserted carefully into the flask. The sample flask was then shaken vigorously to mix the contents and to disperse the precipitate finely throughout. After the precipitate has settled at least halfway down the flask, the flask was shaken again vigorously to disperse the precipitate. The sample flasks containing pickled samples were stored in a laboratory until they were titrated.

d. Sample measurement

At the least two hours after the re-shaking, the pickled samples were measured on board. A magnetic stirrer bar and 1 cm^3 sulfuric acid solution were added into the sample flask and stirring began. Samples were titrated by sodium thiosulfate solution whose morality was determined by potassium iodate solution. Temperature of sodium thiosulfate during titration was recorded by a digital thermometer. During this cruise we measured dissolved oxygen concentration using two sets of the titration apparatus (DOT-01 and DOT-02). Dissolved oxygen concentration (μmol kg^{-1}) was calculated by sample temperature during seawater sampling, salinity of the sample, and titrated volume of sodium thiosulfate solution without the blank.

e. Standardization and determination of the blank

Concentration of sodium thiosulfate titrant (about 0.025M) was determined by potassium iodate solution. Pure potassium iodate was dried in an oven at 130°C. 1.7835 g potassium iodate weighed out accurately was dissolved in deionized water and diluted to final volume of 5 dm^3 in a calibrated volumetric flask (0.001667M). 10 cm^3 of the standard potassium iodate solution was added to a flask using a calibrated dispenser. Then 90 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I were added into the flask in order. Amount of sodium thiosulfate titrated gave the morality of sodium thiosulfate titrant.

The blank from the presence of redox species apart from oxygen in the reagents was determined as follows. Firstly, 1 cm^3 of the standard potassium iodate solution was added to a flask using a calibrated dispenser. Then 100 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I were added into the flask in order. Secondary, 2 cm^3 of the standard potassium iodate solution was added to a flask using a calibrated dispenser. Then 100 cm^3 of deionized water, 1 cm^3 of sulfuric acid solution, and 0.5 cm^3 of pickling reagent solution II and I were added into the flask in order. The blank was determined by difference between the first and second titrated volumes of the sodium thiosulfate.

Table 6.3.2-1 shows results of the standardization and the blank determination during this cruise.

Table 6.3.2-1 Results of the standardization and the blank determinations during this cruise.

Date (UTC)	KIO_3 #	KIO_3 bottle	DOT-01 (cm^3) $Na_2S_2O_3$	DOT-01 E.P.	DOT-01 blank	DOT-02 (cm^3) $Na_2S_2O_3$	DOT-02 E.P.	DOT-02 blank	Samples (Stations)
2006/12/21	8	20060419-08-01	20061217-1	3.955	-0.007	-	-	-	B01,B02,B03,B04
2006/12/24	8	20060419-08-05	20061217-1	3.952	-0.010	20061217-2	3.955	-0.008	C01
2006/12/29	8	20060419-08-07	20061217-1	3.955	-0.009	20061217-2	3.954	-0.008	C03
2007/1/2	8	20060419-08-08	20061217-1	3.955	-0.008	20061217-2	3.954	-0.008	C05,C07
2007/1/6	9	20060419-09-01	20061217-3	3.958	-0.008	20061217-4	3.959	-0.008	C08,C10,B05,B06

Batch number of the KIO_3 standard solution.

f. Reproducibility of sample measurement

Replicate samples were taken at every CTD cast; usually these were 5 - 10 % of seawater samples of each cast during this cruise. Results of the replicate samples were shown in Table 6.3.2-2 and this histogram shown in Fig.6.3.2-1. The standard deviation was calculated by a procedure (SOP23) in DOE (1994).

Table 6.3.2-2 Results of the replicate sample measurements

Number of replicate sample pairs	Oxygen concentration (μmol/kg) Standard Deviation.
42	0.071

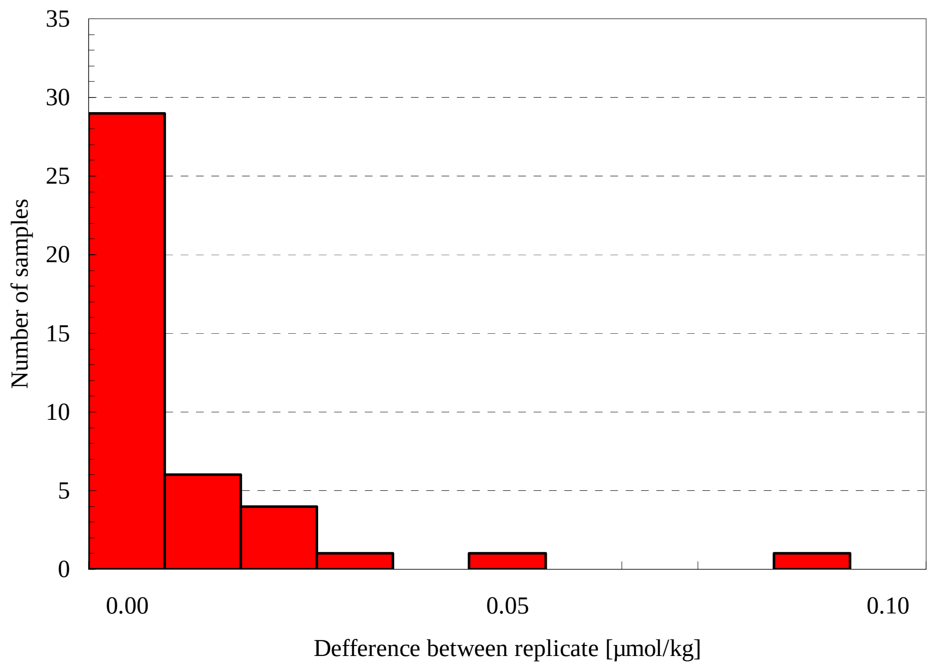


Fig 6.3.2-1 Results of the replicate sample measurements

(5) Preliminary Result

During this cruise, we measured oxygen concentration in 168 seawater samples at 12 stations (CTD cast:6th, bucket cast:6th

(6) Data archive

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

(7) Reference

Dickson, A. (1996) Dissolved Oxygen, in WHP Operations and Methods, Woods Hole, pp1-13.

DOE (1994) Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water; version 2. A.G. Dickson and C. Goyet (eds), ORNL/CDIAC-74.

Emerson, S, S. Mecking and J.Abell (2001) The biological pump in the subtropical North Pacific Ocean: nutrient sources, redfield ratios, and recent changes. *Global Biogeochem. Cycles*, 15, 535-554.

Watanabe, Y. W., T. Ono, A. Shimamoto, T. Sugimoto, M. Wakita and S. Watanabe (2001) Probability of a reduction in the formation rate of subsurface water in the North Pacific during the 1980s and 1990s. *Geophys. Res. Letts*., 28, 3298-3292.

6.4 Continuous monitoring of surface seawater

6.4.1 EPCS

(1) Personnel

Masanori ENOKI (MWJ)
Junji MATSUSHITA (MWJ)
Miyo IKEDA (MWJ)

(2) Objectives

To measure salinity, temperature, dissolved oxygen, and fluorescence of near-sea surface water.

(3) Instruments and Methods

The *Continuous Sea Surface Water Monitoring System* (Nippon Kaiyo Co. Ltd.) has five kind of sensors and can automatically measure salinity, temperature (two systems), dissolved oxygen and fluorescence in near-sea surface water continuously, every 1-minute. Salinity is calculated by conductivity on the basis of PSS78. This system is located in the "*sea surface monitoring laboratory*" on R/V MIRAI. This system is connected to shipboard LAN-system. Measured data is stored in a hard disk of PC every 1-minute together with time and position of ship, and displayed in the data management PC machine.

Near-surface water was continuously pumped up to the laboratory and flowed into the *Continuous Sea Surface Water Monitoring System* through a vinyl-chloride pipe. The flow rate for the system is controlled by several valves and was 12L/min except with fluorometer (about 0.5L/min). The flow rate is measured with two flow meters.

Specification of the each sensor in this system of listed below.

a) Temperature and Conductivity sensor

SEACAT THERMOSALINOGRAPH
Model: SBE-21, SEA-BIRD ELECTRONICS, INC.
Serial number: 2126391-3126
Measurement range: Temperature -5 to +35℃, Conductivity 0 to 6.5 S m-1
Accuracy: Temperature 0.01℃ 6month-1,Conductivity 0.001 S m-1 month-1
Resolution: Temperatures 0.001℃, Conductivity 0.0001 S m-1

b) Bottom of ship thermometer

Model: SBE 3S, SEA-BIRD ELECTRONICS, INC.
Serial number: 032607

Measurement range: -5 to +35℃
Resolution: ±0.001℃
Stability: 0.002℃ year-1

c) Dissolved oxygen sensor
Model: 2127A, HACH ULTRA ANALYTICS JAPAN, INC.
Serial number: 44733
Measurement range: 0 to 14 ppm
Accuracy: ±1% at 5℃ of correction range
Stability: 1% month-1

d) Fluorometer
Model: 10-AU-005, TURNER DESIGNS
Serial number: 5562 FRXX
Detection limit: 5 ppt or less for chlorophyll a
Stability: 0.5% month-1 of full scale

e) Flow meter
Model: EMARG2W, Aichi Watch Electronics LTD.
Serial number: 8672
Measurement range: 0 to 30 l min-1
Accuracy: ±1%
Stability: ±1% day-1

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

Start : 2006/12/20 11:46 Stop : 2007/01/16 23:59

(4) Preliminary Result

Preliminary data of temperature (thermometer of ship bottom), salinity, dissolved oxygen, fluorescence at sea surface during this cruise are shown in Fig.6.4.1-1. We collected samples to compare a bottle data with a sensor value of salinity once a day. Samples of dissolved oxygen ware collected before and after CTD cast. Samples for correcting fluorescence were collected twice a day. They are shown in Fig.6.4.1-2~4. All salinity samples were analyzed by the Guildline AUTOSAL 8400B, dissolve oxygen samples were analyzed by the KIMOTO DOT-01, fluorescence samples were analyzed by Non-acidification method, using 10-AU-005,TURNER

DESIGNS.

(5) Data archive

The data were stored on a magnetic optical disk, which will be submitted to the Data Management Office (DMO) JAMSTEC, and will be opened to public via "R/V MIRAI Data Web Page" in JAMSTEC homepage.

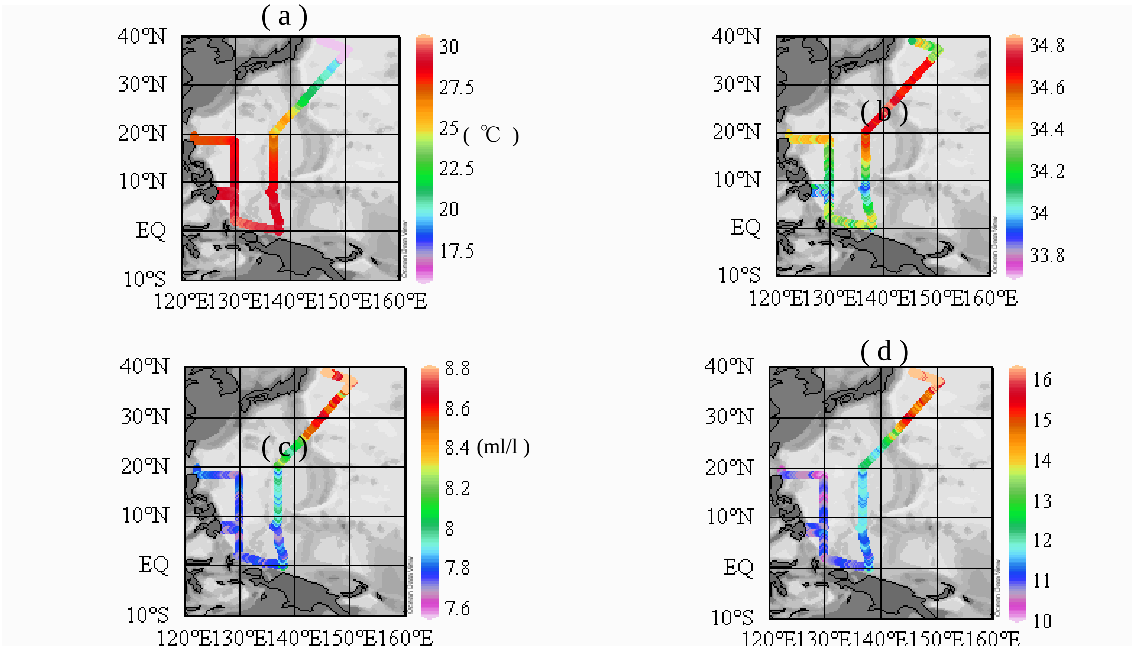


Fig. 6.4.1-1 Contour line of temperature(a), salinity(b), dissolved oxygen(c), fluorescence(d) of the sea surface water during this cruise.

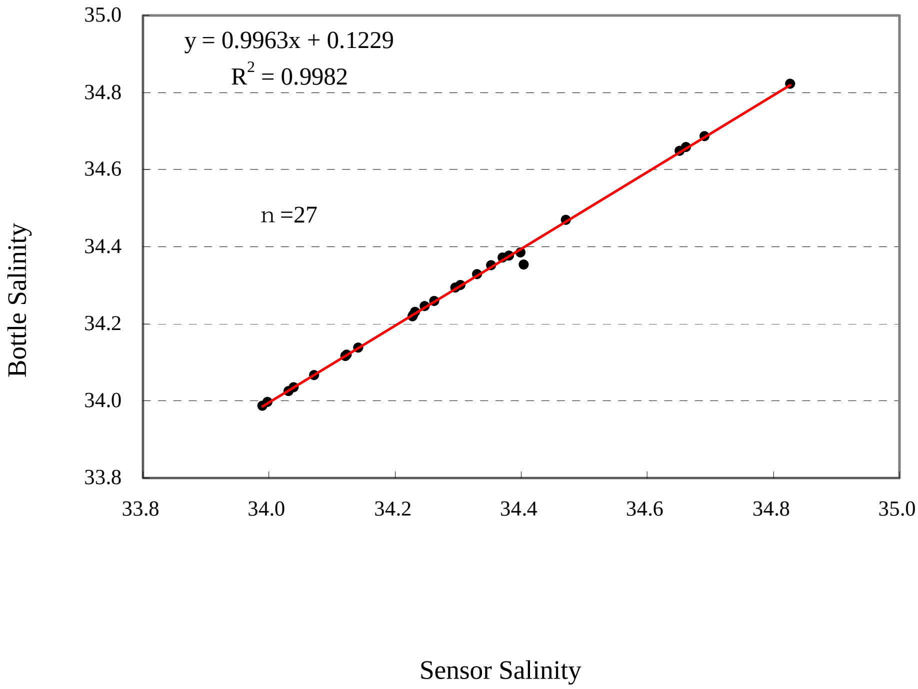


Fig.6.4.1-2 Comparison between salinity sensor and bottle data.

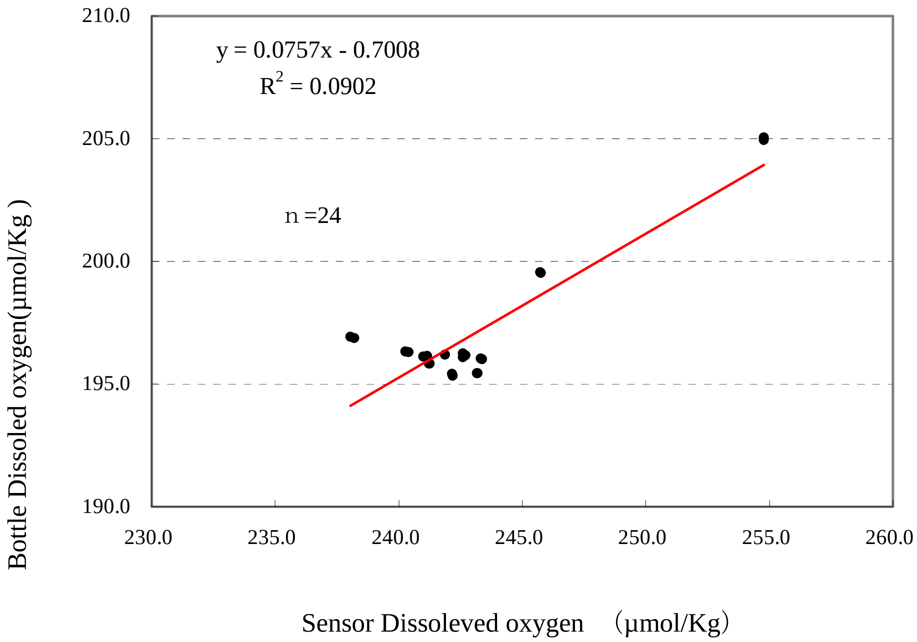


Fig.6.4.1-3 Comparison between dissolved oxygen sensor and bottle data.

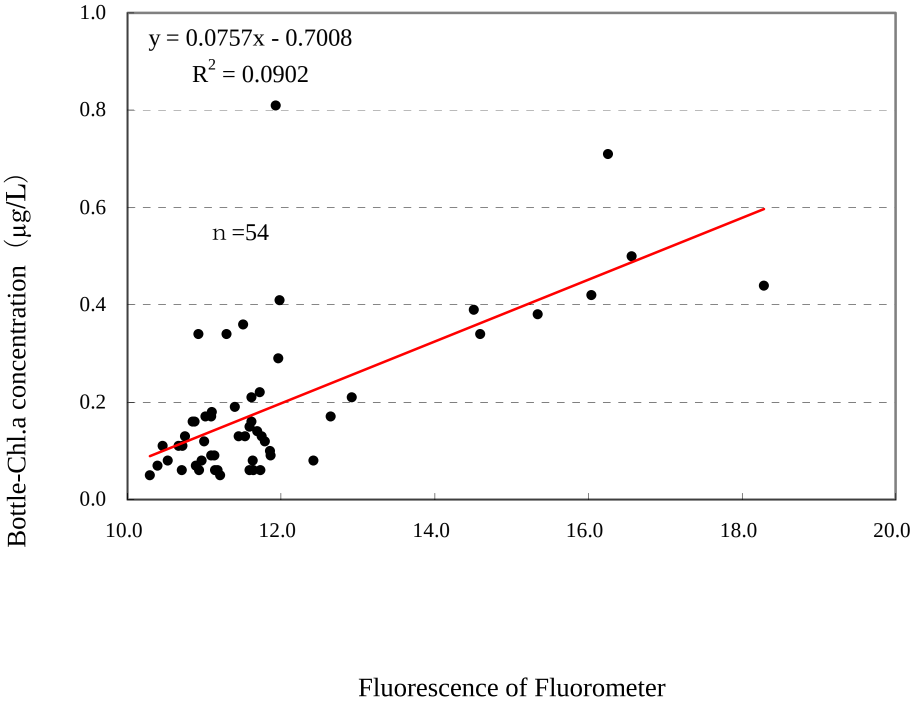


Fig.5.18.1-4 Comparison between Fluorometer sensor and bottle data.

6.5 Shipboard ADCP

(1) Personnel

Yuji Kashino (JAMSTEC): Principal Investigator
Shinya Okumura (Global Ocean Development Inc., GODI)
Ryo Oyama (GODI)

(2) Objective

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

(3) Methods

Upper ocean current measurements were made throughout MR06-05 Leg3 cruise, using the hull-mounted Acoustic Doppler Current Profiler (ADCP) system that is permanently installed on the R/V Mirai. For most of its operation, the instrument was configured for water-tracking mode recording. Bottom-tracking mode, interleaved bottom-ping with water-ping, was made in shallower water region to get the calibration data for evaluating transducer misalignment angle. The system consists of following components;

ⅰ) 75 kHz Broadband (coded-pulse) profiler with 4-beam Doppler sonar operating (RD Instruments, USA), mounted with beams pointing 30 degrees from the vertical and 45 degrees azimuth from the keel;

ⅱ) the Ship's main gyro compass (Tokimec, Japan), continuously providing ship's heading measurements to the ADCP;

ⅲ) a GPS navigation receiver (Trimble 4000DS) providing position fixes;

ⅳ) a personal computer running data acquisition software (VmDas version 1.4.0, RD Instruments, USA). The clock of the logging PC are adjusted to GPS time every 10 minutes.

ⅴ) high-precision attitude information, heading, pitch and roll, are also stored in N2R data files with a time stamp.

The ADCP was configured for 16 m processing bin and 8 m blanking distance. The sound speed at the transducer is calculated from temperature, salinity (constant value; 35.0 psu) and depth (6.5 m; transducer depth) by equation in Medwin (1975). Data was made at 16-m intervals starting 31-m below the surface. Every ping was recorded as raw ensemble data (.ENR). Also, 60 seconds and 300 seconds averaged data were recorded as short term average (.STA) and long term average (.LTA) data, respectively. Major parameters for the measurement (Direct Command) are shown Table 6.5.1 Major parameters.

(4) Preliminary results

Fig. 6.5-1 to Fig. 6.5-3 were showed water current vector along the ship track. The data were processed LTA data using CODAS (Common Oceanographic Data Access System) software, developed at the University of Hawaii.

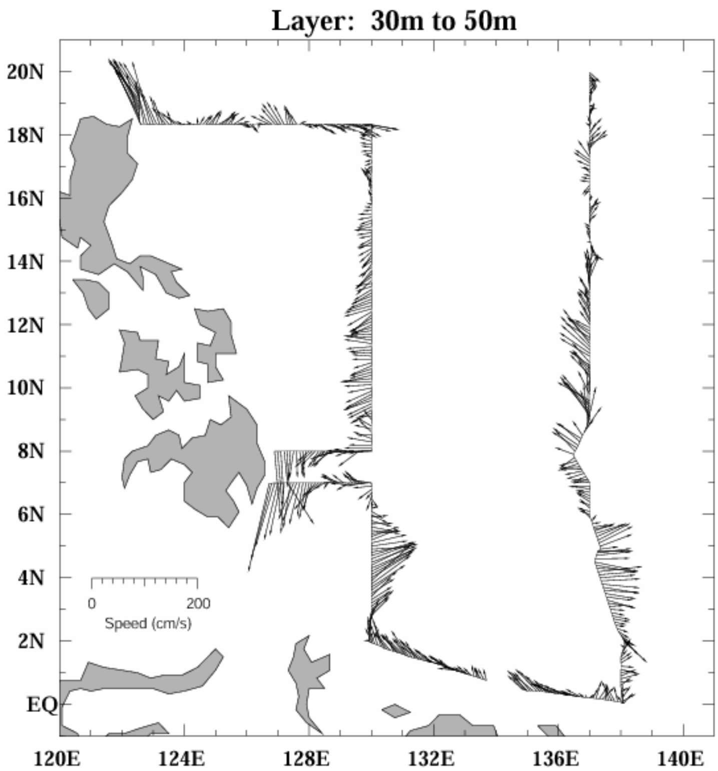
(5) Data archive

These data obtained in this cruise will be submitted to the Marine-Earth Data and Information Department（MEDID）of JAMSTEC, and will be opened to the public via "R/V Mirai Data Web Page" in JAMSTEC home page.

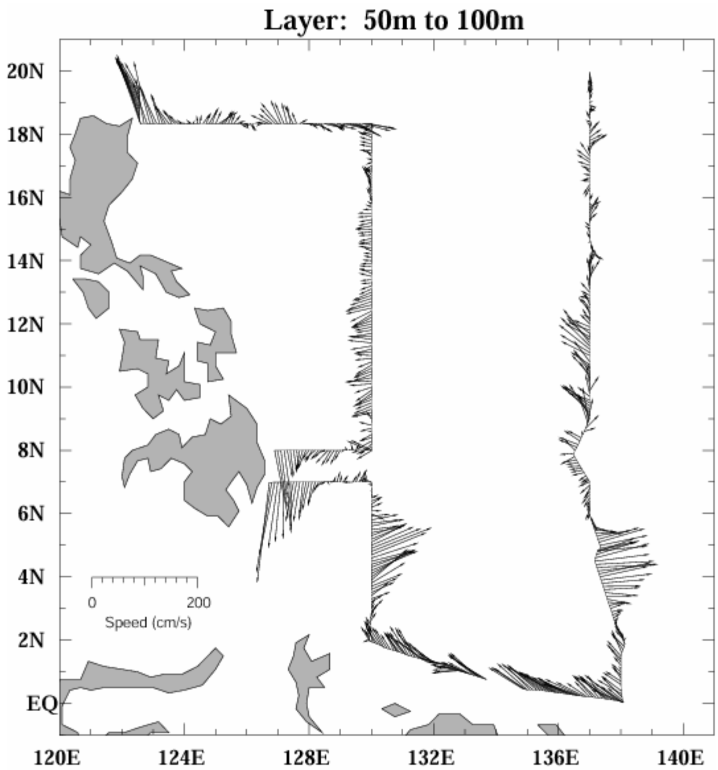
(6) Remarks

Table 6.5.1 Major parameters

Bottom-Track Commands	
BP = 001	Pings per Ensemble
Environmental Sensor Commands	
EA = +00000	Heading Alignment (1/100 deg)
EB = +00000	Heading Bias (1/100 deg)
ED = 00065	Transducer Depth (0 - 65535 dm)
EF = +0001	Pitch/Roll Divisor/Multiplier (pos/neg) [1/99 - 99]
EH = 00000	Heading (1/100 deg)
ES = 35	Salinity (0-40 pp thousand)
EX = 00000	Coord Transform (Xform:Type; Tilts; 3Bm; Map)
EZ = 1020001	Sensor Source (C;D;H;P;R;S;T) C(1): Sound velocity calculate 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
Timing Commands	
TE = 00:00:02.00	Time per Ensemble (hrs:min:sec.sec/100)
TP = 00:02.00	Time per Ping (min:sec.sec/100)
Water-Track Commands	
WA = 255	False Target Threshold (Max) (0-255 counts)
WB = 1	Mode 1 Bandwidth Control (0=Wid,1=Med,2=Nar)
WC = 064	Low Correlation Threshold (0-255)
WD = 111 111 111	Data Out (V;C;A PG;St;Vsum Vsum^2;#G;P0)
WE = 5000	Error Velocity Threshold (0-5000 mm/s)
WF = 0800	Blank After Transmit (cm)
WG = 001	Percent Good Minimum (0-100%)
WI = 0	Clip Data Past Bottom (0=OFF,1=ON)
WJ = 1	Rcvr Gain Select (0=Low,1=High)
WM = 1	Profiling Mode (1-8)
WN = 040	Number of depth cells (1-128)
WP = 00001	Pings per Ensemble (0-16384)
WS = 1600	Depth Cell Size (cm)
WT = 000	Transmit Length (cm) [0 = Bin Length]
WV = 999	Mode 1 Ambiguity Velocity (cm/s radial)

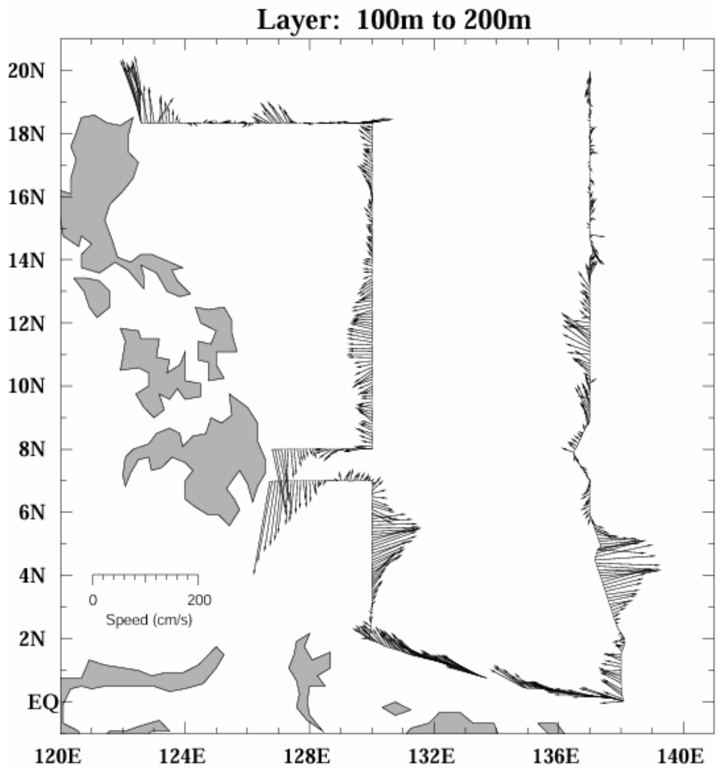


Water depth: 30 m to 50 m

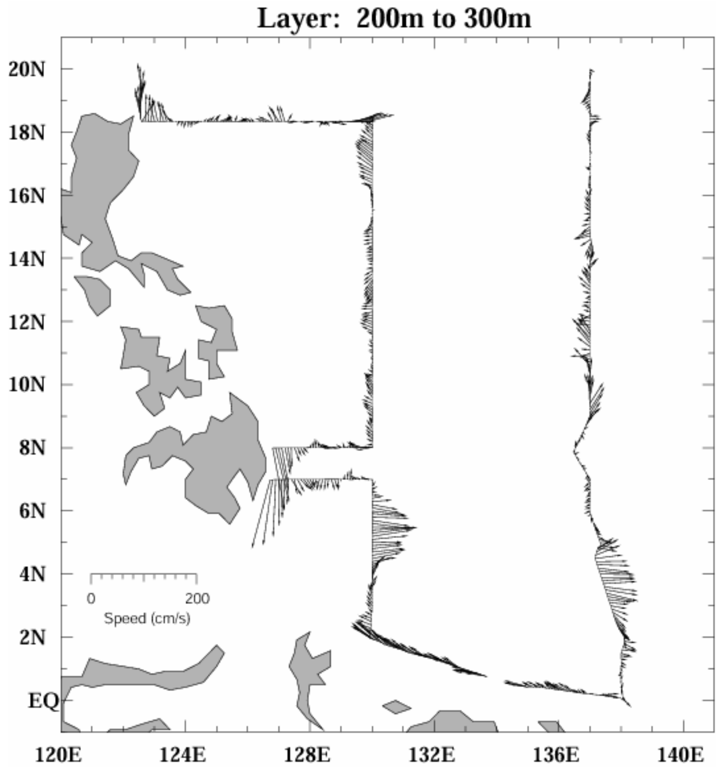


Water depth: 50 m to 100 m

Fig. 6.5-1 Water current vector.

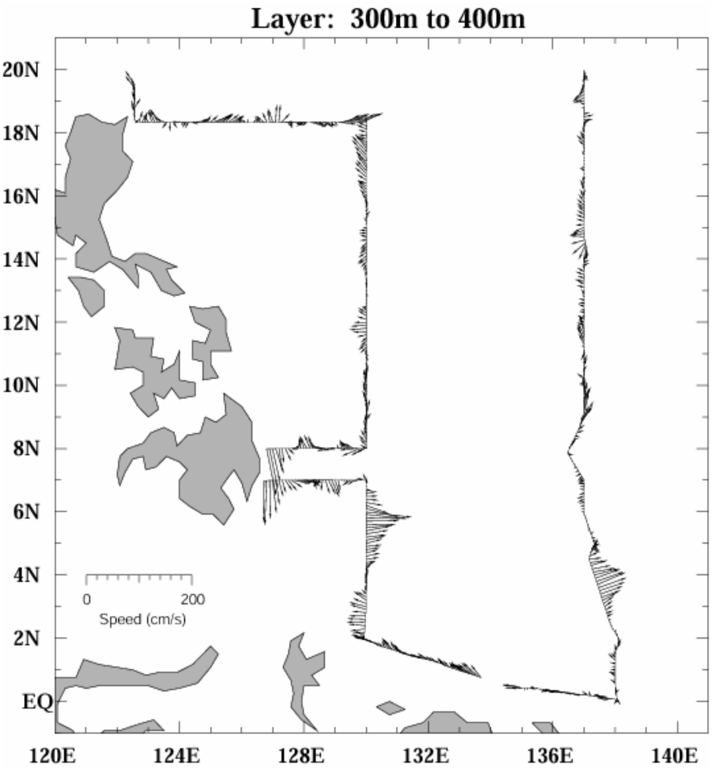


Water depth: 100 m to 200 m

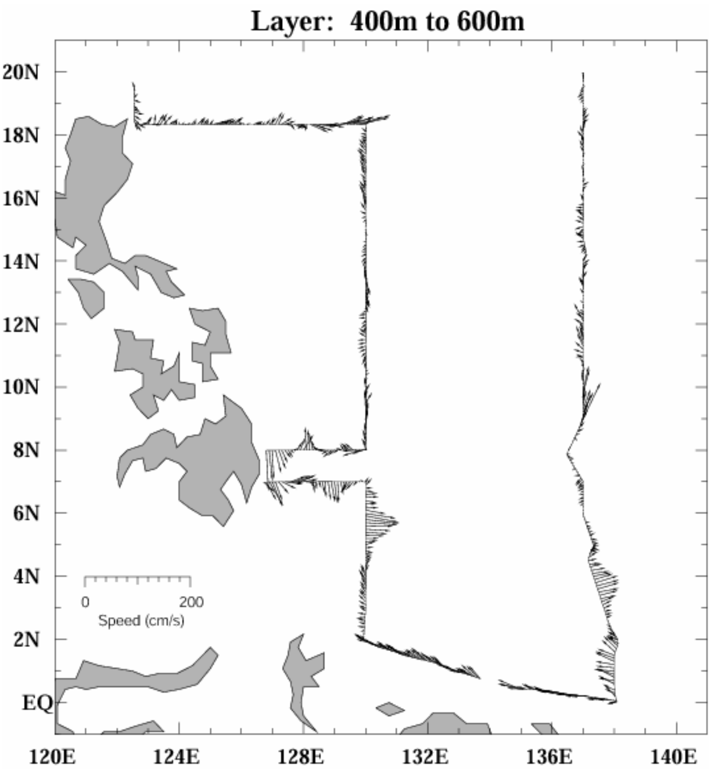


Water depth: 200 m to 300 m

Fig. 6.5-2 Water current vector.



Water depth: 300 m to 400 m



Water depth: 400 m to 600 m

Fig. 6.5-3 Water current vector.

6.6 Underway geophysics

6.6.1 Sea Surface Gravity

(1) Personnel

Takeshi Matsumoto (University of the Ryukyus) Principal Investigator (Not on-board)
Shinya Okumura (Global Ocean Development Inc.: GODI)
Ryo Ohyama (GODI)

(2) Introduction

The distribution of local gravity is an important parameter in geophysics and geodesy. We collected gravity data at the sea surface during the MR06-05 Leg3 cruise.

(3) Parameters

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

(4) Data Acquisition

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

(5) Preliminary Results

Absolute gravity shown in Table 6.6.1-1

Table 6.6.1-1

Date	U.T.C.	Port	Absolute Gravity [mGal]	Sea Level [cm]	Draft [cm]	Gravity at Sensor *[1] [mGal]	L&R *[2] Gravity [mGal]
Oct./03/06	03:33	Sekinehama	980371.95	227	635	980372.70	12712.31
Jan./20/07	01:43	Sekinehama	980371.94	252	640	980372.77	12713.12

*[1]: Gravity at Sensor = Absolute Gravity + Sea Level*0.3086/100 + (Draft-530)/100*0.0431
*[2]: LaCoste and Romberg air-sea gravity meter S-116

(6) Data Archives

Gravity data obtained during this cruise will be submitted to the Marine-Earth Data and Information Department （MEDID） in JAMSTEC, and archived there.

6.6.2 Sea Surface Three-Component Magnetic Field

(1) Personnel

Takeshi Matsumoto (University of the Ryukyus) Principal Investigator (Not on-board)
Shinya Okumura (Global Ocean Development Inc.: GODI)
Ryo Ohyama (GODI)

(2) Introduction

Measurement of magnetic force on the sea is required for the geophysical investigations of marine magnetic anomaly caused by magnetization in upper crustal structure. We measured geomagnetic field using a three-component magnetometer during the MR06-05Leg3 cruise.

(3) Parameters

Three-component magnetic force [nT]
Ship’s attitude [1/100 deg]

(4) Method of Data Acquisition

A sensor of three-component fluxgate magnetometer is set on the top of foremast. Sampling is controlled by 1pps (pulse per second) standard clock of GPS signals. Navigation information, 8 Hz three-component of magnetic force, and VRU (Vertical Reference Unit) data are recorded every one second.

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

29 Dec 2006, 09:04 to 09:19 about at 01-55N, 129-58E
2 Jan 2007, 09:05 to 09:20 about at 00-16N, 137-57E
8 Jan 2007, 08:56 to 09:12 about at 07-56N, 136-24E

(5) Preliminary Results

The results will be published after primary processing.

(6) Data Archives

Magnetic force data obtained during this cruise will be submitted to the Marine-Earth Data and Information Department （MEDID） in JAMSTEC, and archived there.

(7) Remarks

Data acquisition was suspended, because we rebooted the logging computer:

6 Jan 2007, 05:51:15 to 05:52:41

6.6.3 Swath Bathymetry

(1) Personnel

Takeshi Matsumoto	(University of the Ryukyus)	Principal Investigator (Not on-board)
Shinya Okumura	(Global Ocean Development Inc.: GODI)	
Ryo Ohyama	(GODI)	

(2) Introduction

R/V MIRAI is equipped with a Multi Narrow Beam Echo Sounding system (MNBES), SEABEAM 2112.004 (SeaBeam Instruments Inc.). Sub Bottom Profiler (SBP) is an add-on option to the "SEABEAM 2100". SBP subsystem collects vertical sediments information.

The major objective of MNBES is site survey. So we gathered necessary bathymetric and sub-sediment information around the core sampling point. And also, the other objective is collecting continuous bathymetric data along ship's track to make a contribution to geological and geophysical investigations and global datasets. In addition, we need to estimate the depth at the location of deployment of TRITON buoys in order to design these mooring systems.

(3) Data Acquisition

The "SEABEAM 2100" on R/V MIRAI was used for bathymetry mapping during the MR06-05 Leg3. To get accurate sound velocity of water column for ray-path correction of acoustic multibeam, we used Surface Sound Velocimeter (SSV) data at the surface (6.2m) sound velocity, and the others depth sound velocity calculated temperature and salinity profiles from CTD and XCTD data by the equation in Mackenzie (1981) during the cruise.

Table 6.6.3-1 listed system configuration and performance of SEABEAM 2112.004 system and SBP subsystem.

Table 6.6.3-1 System configuration and performance

SEABEAM 2112.004 (12 kHz system)	
Frequency:	12 kHz
Transmit beam width:	2 degree
Transmit power:	20 kW
Transmit pulse length:	3 to 20 msec.
Depth range:	100 to 11,000 m
Beam spacing:	1 degree athwart ship
Swath width:	150 degree (max) 120 degree to 4,500 m 100 degree to 6,000 m 90 degree to 11,000 m
Depth accuracy:	Within < 0.5% of depth or +/-1m, whichever is greater, over the entire swath. (Nadir beam has greater accuracy; typically within < 0.2% of depth or +/-1m, whichever is greater)

(4) Preliminary Results

The results will be published after primary processing.

(5) Data Archives

Bathymetric data obtained during this cruise will be submitted to the Marine-Earth Data and Information Department （MEDID） in JAMSTEC, and archived there.

(6) Remark

The original SSV data was incorrect, because of sea water was not circulated around the sensor. So we recalculated SSV as constant value 1544 m/s between 7 Jan 2007 04:45 to 10:01.

7 Special Observations

7.1 TRITON moorings

7.1.1 TRITON Mooring Operation

(1) Personnel

Yuji Kashino	(JAMSTEC): Principal Investigator
Hiroshi Matsunaga	(MWJ): Operation Leader
Toru Idai	(MWJ): Technical Staff
Kenichi Katayama	(MWJ): Technical Staff
Keisuke Matsumoto	(MWJ): Technical Staff
Tetsuharu Iino	(MWJ): Technical Staff
Masanori Enoki	(MWJ): Technical Staff
Hiroki Ushiromura	(MWJ): Technical Staff
Tatsuya Tanaka	(MWJ): Technical Staff
Junji Matsushita	(MWJ): Technical Staff
Masatomo Hisazumi	(MWJ): Technical Staff
Miyo Ikeda	(MWJ): Technical Staff

(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).

Six TRITON buoys have been successfully recovered and deployed during this R/V MIRAI cruise (MR06-05 Leg3).

(3) Measured parameters

Meteorological parameters:	wind speed, direction, atmospheric pressure, air temperature, relative humidity, radiation, precipitation.
Oceanic parameters:	water temperature and conductivity at 1.5m, 25m, 50m, 75m, 100m, 125m, 150m, 200m, 300m, 500m 750m, depth at 300m and 750m, currents at 10m.

(4) Instrument

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 : 1500kHz

Sampling interval : 1200sec

Average interval : 120sec

3) Meteorological sensors

Precipitation

R.M.YOUNG COMPANY MODEL50202/50203

Atmospheric pressure

PAROPSCIENTIFIC.Inc. DIGIQUARTZ FLOATING BAROMETER 6000SERIES

Relative humidity/air temperature,Shortwave radiation, Wind speed/direction

Woods Hole Institution ASIMET

Sampling interval : 60sec

Data analysis : 600sec averaged

(5) Locations of TRITON buoys deployment

Nominal location	8N, 137E
ID number at JAMSTEC	10006
Number on surface float	T04
ARGOS PTT number	20451
ARGOS backup PTT number	29708
Deployed date	09 Jan. 2007
Exact location	07 - 51.73N, 136 - 29.05Ｅ
Depth	3,351 m

Nominal location	5N, 137E
ID number at JAMSTEC	11006
Number on surface float	T05
ARGOS PTT number	20374
ARGOS backup PTT number	07861
Deployed date	06 Jan. 2007
Exact location	04 - 51.42N, 137 - 16.16Ｅ
Depth	4,097 m

Nominal location	2N, 138E
ID number at JAMSTEC	12008
Number on surface float	T06
ARGOS PTT number	11826
ARGOS backup PTT number	07864
Deployed date	05 Jan. 2007
Exact location	01 - 59.78N, 138 - 06.31Ｅ

Depth	4,321m
Nominal location	EQ, 138E
ID number at JAMSTEC	13008
Number on surface float	T15
ARGOS PTT number	None
ARGOS backup PTT number	07871, 07881
Deployed date	03 Jan. 2007
Exact location	00 - 04.39N, 138 - 03.28E
Depth	4,206 m

Nominal location	8N, 130E
ID number at JAMSTEC	14005
Number on surface float	T07
ARGOS PTT number	03594
ARGOS backup PTT number	11584
Deployed date	25 Dec. 2006
Exact location	07 - 58.77N, 130 - 00.64E
Depth	5,721 m

Nominal location	2N, 130E
ID number at JAMSTEC	16006
Number on surface float	T16
ARGOS PTT number	None
ARGOS backup PTT number	11592, 11593
Deployed date	30 Dec. 2006
Exact location	01 - 56.38N, 129 - 56.12E
Depth	4,428 m

(6) TRITON recovered

Nominal location	8N, 137E
ID number at JAMSTEC	10005
Number on surface float	T02
ARGOS PTT number	07883
ARGOS backup PTT number	29692
Deployed date	06 Jul. 2005
Recovered date	08 Jan. 2007
Exact location	07 - 52.21N, 136 - 29.12E
Depth	3,348 m

Nominal location	5N, 137E
ID number at JAMSTEC	11005
Number on surface float	T03
ARGOS PTT number	28868
ARGOS backup PTT number	29694
Deployed date	08 Jul. 2005
Recovered date	07 Jan. 2007
Exact location	04 - 56.86N, 137 - 18.45E

Depth	4,139 m

Nominal location	2N, 138E
ID number at JAMSTEC	12007
Number on surface float	T13
ARGOS PTT number	09427
ARGOS backup PTT number	29695
Deployed date	10 Jul. 2005
Recovered date	04 Jan. 2007
Exact location	01 - 59.77N, 138 - 06.18E
Depth	4,322m

Nominal location	EQ, 138E
ID number at JAMSTEC	13007
Number on surface float	T20
ARGOS PTT number	None
ARGOS backup PTT number	24232, 29696
Deployed date	12 Jul. 2005
Recovered date	02 Jan. 2007
Exact location	00 - 04.43N, 138 - 03.13E
Depth	4,211 m

Nominal location	8N, 130E
ID number at JAMSTEC	14004
Number on surface float	T22
ARGOS PTT number	23470
ARGOS backup PTT number	29697
Deployed date	17 Jul. 2005
Recovered date	26 Dec. 2006
Exact location	07 - 55.65N, 130 - 03.88E
Depth	5,636 m

Nominal location	2N, 130E
ID number at JAMSTEC	16005
Number on surface float	T23
ARGOS PTT number	None
ARGOS backup PTT number	13065, 29698
Deployed date	21 Jul. 2005
Recovered date	29 Dec. 2006
Exact location	01 - 57.76N, 129 - 55.99E
Depth	4,425 m

*: Dates are UTC and represent anchor drop times for deployments and release time for recoveries, respectively.

(6) Details of deployed

We had deployed two TRITON buoys, described them details in the list.

Deployed TRITON buoys

Observation No.	Location.	Details.
10006	8N-137E	Deploy with full spec.
11006	5N-137E	Deploy with full spec and one optional CT sensor.
12008	2N-138E	Deploy with full spec and one optional CT sensor.
13008	EQ-138E	Deploy with ten CT sensor, two CTD sensor, one current meter and one optional CT sensor.
14005	8N-130E	Deploy with ten CT sensor, two CTD sensor, one current meter and one optional CT sensor.
16006	2N-130E	Deploy with ten CT sensor, two CTD sensor, one current meter and one optional CT sensor.

(7) 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 The JAMSTEC Mutsu Institute.

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

7.1.2 Inter-comparison between shipboard CTD and TRITON data

(1) Personnel

Yuji kashino	(JAMSTEC): Principal Investigator
Hiroshi Matsunaga	(MWJ): Operation Leader
Kenichi Katayama	(MWJ): Technical staff
Keisuke Matsumoto	(MWJ): Technical staff

(2) Objectives

TRITON CTD data validation

(3) Measured parameters

- Temperature
- Conductivity
- Pressure

(4) Methods

TRITON buoy underwater sensors are equipped along a wire cable of the buoy below sea surface. We used the same CTD (SBE 9/11Plus) system with general CTD (or XCTD) observation on R/V MIRAI for this intercomparison. We conducted 1 CTD cast at each TRITON buoy site before recovery, conducted 1 XCTD cast at each TRITON buoy site after deployment. The cast was performed immediately after the deployment and before recovery. R/V MIRAI was kept the distance from the TRITON buoy within about 2 nm.

TRITON buoy data was sampled every 1 hour except for transmission to the ship. We compared CTD (or XCTD) observation by R/V MIRAI data with TRITON buoy data using the 1 hour averaged value.

As our temperature sensors are expected to be more stable than conductivity sensors, conductivity data and salinity data are selected at the same value of temperature data. Then, we calculate difference of salinity from conductivity between the shipboard CTD (or XCTD) data on R/V MIRAI and the TRITON buoy data for each deployment and recovery of buoys.

Compared site

Observation No.	Latitude	Longitude	Condition
10006	8N	137E	After Deployment
11006	5N	137E	After Deployment
12008	2N	138E	After Deploymant
14005	8N	130E	After Deploymant
14004	8N	130E	Before Recover

(5) Results

Most of temperature, conductivity and salinity data from TRITON buoy showed good agreement with CTD (or XCTD) cast data in T-S diagrams. See the Figures 7.1.2-1(a)(b).

To evaluate the performance of the conductivity sensors on TRITON buoy, the data from had deployed buoy and shipboard XCTD data at the same location were analyzed.

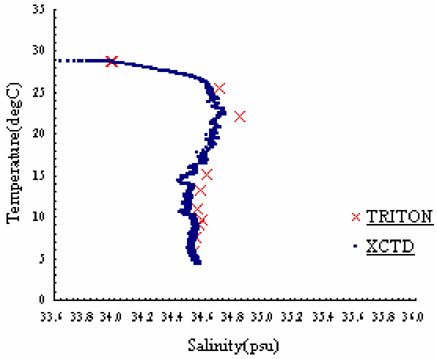
The estimations were calculated as deployed buoy data minus shipboard XCTD data. The salinity differences are from 0.002 to 1.290 for all depths. Below 300db, salinity differences are from 0.057 to 0.024 (See the Figures 7.1.2-2 (a) and Table 7.1.2-1 (a)). The absolute average of all salinity differences was 0.025 with absolute standard deviation of 0.017.

The estimations were calculated as recovered buoy data minus shipboard CTD (9Plus) data. The salinity differences are from –0.504 to 0.067 for all depths. Below 300db, salinity differences are from –0.093 to 0.001 (See the Figures 7.1.2-2(b) and Table 7.1.2-1 (b)). The absolute average of salinity differences was 0.115 with absolute standard deviation of 0.054.

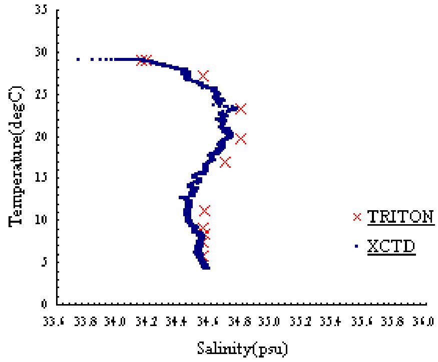
The estimations of time-drift were calculated as recovered buoy data minus deployed buoy data. The difference of salinity over 1 year had the variation ranging from 0.000 to 0.495, for all depths. Below 300db, the difference of salinity over 1 year had the variation ranging from 0.000 to 0.089 (See the figures 7.1.2-2(c)). The absolute average of salinity differences was 0.105 with absolute standard deviation of 0.163.

(6) Data archive

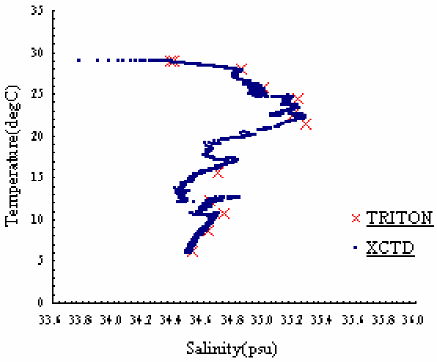
All raw and processed CTD data files were copied on 3.5 inch magnetic optical disks and submitted to JAMSTEC TOCS group of the Ocean Observation and Research Department. All original data will be stored at JAMSTEC Mutsu brunch. (See section 5)



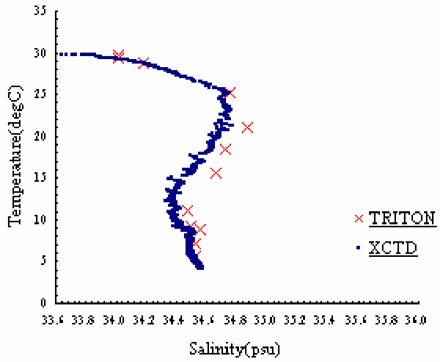
Observation No. 10006 after Deployment



Observation No. 11006 after Deployment

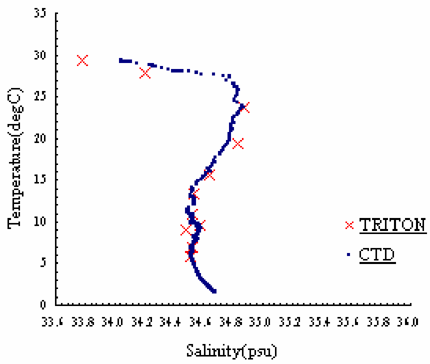


Observation No. 12008 after Deployment



Observation No. 14005 after Deployment

Fig.7.1.2.-1(a) T-S diagram of TRITON buoys data and shipboard XCTD data



Observation No. 14004 Before Recovery

Fig.7.1.2.-1(b) T-S diagram of TRITON buoys data and shipboard CTD data

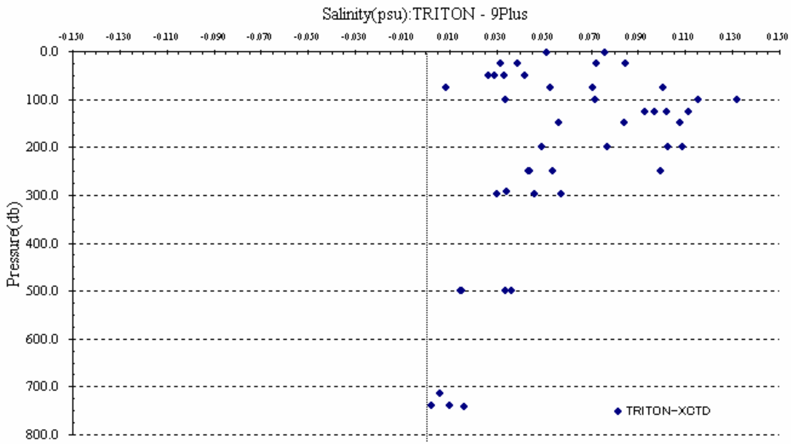


Fig.7.1.2.-2 (a) Salinity differences between TRITON buoys data and shipboard XCTD data after deployment

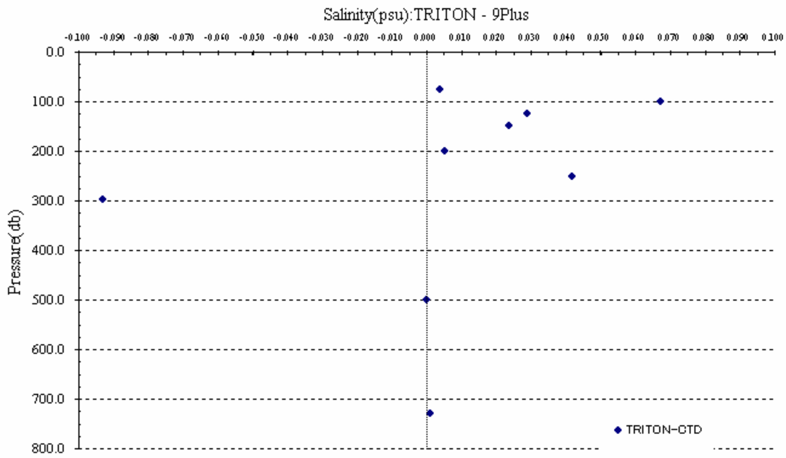


Fig.7.1.2.-2 (b) Salinity differences between TRITON buoys data and shipboard CTD data before recovery

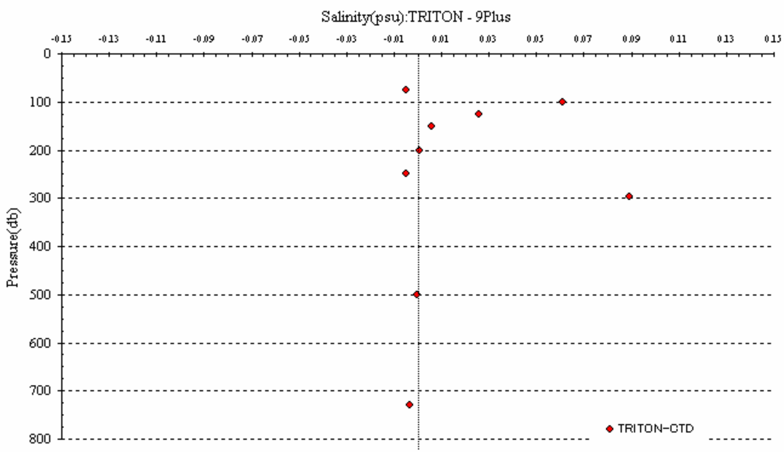


Fig.7.1.2.-2 (c) Salinity differences between deployment data and recovery data for 1year Observation No.14

Table 7.1.2.-1(a) Data differences between TRITON buoys data and ship board CTD data after deployment

Observation No.	Pressure (db)	Temperature (degC)	Conductivety (S/m)	Salinity (psu)
10006	1.5	-0.03	0.009	0.076
10006	25.0	-0.03	0.011	0.073
10006	50.0	-0.01	0.007	0.033
10006	75.0	-0.11	0.001	0.071
10006	100.0	-0.10	0.007	0.116
10006	125.0	0.01	0.014	0.111
10006	150.0	0.00	0.008	0.056
10006	200.0	0.00	0.006	0.049
10006	250.0	-0.01	0.005	0.044
10006	297.7	0.00	0.005	0.030
10006	500.0	-0.02	0.001	0.015
10006	740.4	0.00	0.001	0.002
11006	1.5	-0.02	0.202	1.290
11006	25.0	-0.02	0.007	0.039
11006	50.0	0.00	0.008	0.029
11006	75.0	0.01	0.016	0.101
11006	100.0	0.00	0.005	0.034
11006	125.0	0.03	0.016	0.093
11006	150.0	-0.03	0.010	0.084
11006	200.0	0.02	0.017	0.109
11006	250.0	-0.01	0.007	0.054
11006	292.1	0.00	0.005	0.034
11006	500.0	0.00	0.003	0.015
11006	714.4	0.10	0.010	0.006
12008	1.5	-0.01	0.007	0.051
12008	25.0	0.01	0.009	0.032
12008	50.0	0.00	0.009	0.042
12008	75.0	-0.17	-0.009	0.053
12008	100.0	-0.02	0.011	0.072
12008	125.0	-0.01	0.015	0.102
12008	150.0	-0.18	-0.002	0.108
12008	200.0	0.03	0.018	0.103
12008	250.0	-0.02	-0.007	0.044
12008	297.9	0.00	0.006	0.046
12008	500.0	0.01	0.005	0.034
12008	741.7	-0.03	0.000	0.016
14005	1.5	-0.04	0.031	0.242
14005	25.0	-0.04	0.011	0.085
14005	50.0	0.03	0.010	0.027
14005	75.0	-0.03	0.000	0.009
14005	100.0	-0.19	-0.004	0.132
14005	125.0	0.00	0.013	0.097
14005	150.0	0.04	0.025	0.165
14005	200.0	-0.02	0.009	0.077
14005	250.0	-0.01	0.012	0.100
14005	298.2	0.00	0.006	0.057
14005	500.0	0.00	0.005	0.036
14005	738.4	0.00	0.002	0.010

bad data

Table 7.1.2.-1(b) Data differences between TRITON buoys data and ship board CTD data before recovery

Observation No.	Pressure (db)	Temperature (degC)	Conductivety (S/m)	Salinity (psu)
14004	1.5	0.07	-0.033	-0.267
14004	25.0	0.01	-0.073	-0.504
14004	50.0	-0.06	-0.056	-0.348
14004	75.0	0.07	0.008	0.004
14004	100.0	0.05	0.013	0.067
14004	125.0	0.03	0.006	0.029
14004	150.0	0.07	0.010	0.024
14004	200.0	-0.02	-0.002	0.005
14004	250.0	-0.07	-0.003	0.042
14004	297.1	-0.03	-0.012	-0.093
14004	500.0	-0.01	-0.001	0.000
14004	729.4	0.00	-0.001	0.001

7.2 Lidar observations of clouds and aerosols

(1) Personnel

Nobuo Sugimoto

(National Institute for Environmental Studies, NIES) Principal Investigator / not onboard

Ichiro Matsui, Atsushi Shimizu (NIES) not onboard

lidar operation was supported by Mr. Shin'ichi Yokote from Chiba University, and Global Ocean Development Inc. (GODI).

(2) Objective

Objective of the observations in this cruise is to study distribution and optical characteristics of ice/water clouds and marine aerosols using a two-wavelength lidar.

(3) Measured parameters

– Vertical profiles of backscattering coefficient at 532 nm
– Vertical profiles of backscattering coefficient at 1064 nm
– Depolarization ratio at 532 nm

(4) Method

Vertical profiles of aerosols and clouds were measured with a two-wavelength lidar. The lidar employs a Nd:YAG laser as a light source which generates the fundamental output at 1064 nm and the second harmonic at 532 nm. Transmitted laser energy is typically 100 mJ per pulse at 1064 nm and 50 mJ per pulse at 532 nm. The pulse repetition rate is 10 Hz. The receiver telescope has a diameter of 20 cm. The receiver has three detection channels to receive the lidar signals at 1064 nm and the parallel and perpendicular polarization components at 532 nm. An analog-mode avalanche photo diode (APD) is used as a detector for 1064 nm, and photomultiplier tubes (PMTs) are used for 532 nm. The detected signals are recorded with a digital oscilloscope and stored on a hard disk with a computer. The lidar system was installed in the radiosonde container on the compass deck. The container has a glass window on the roof, and the lidar was operated continuously regardless of weather.

(5) Results

Although data obtained in this cruise will be analyzed at NIES, some of observation results were transferred to NIES. Figure1 is an example plot of vertical profiles from lidar observation. There were surface aerosol layer below a cloud located at 2.0 km height, and another high cloud (cirrus) was detected around 10.5 – 12.5 km. These profiles were corrected every 15 minites during whole cruise.

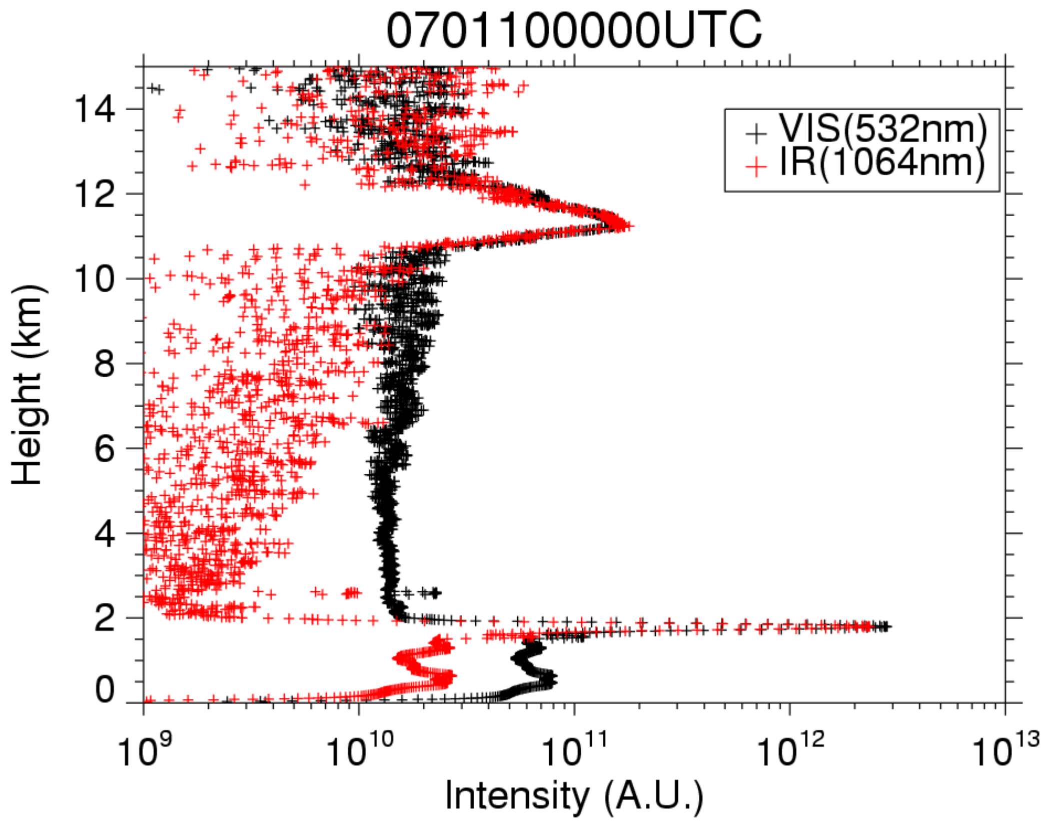


Figure 1 : Vertical profiles of backscattering intensity at 532 nm (black) and 1064 nm (red) obtained at 0000UTC on January 11, 2007.

(6) Data archive

- raw data

lidar signal at 532 nm

lidar signal at 1064 nm

depolarization ratio at 532 nm

temporal resolution 15 min.

vertical resolution 6 m.

data period : December 20, 2006 – January 19, 2007

- processed data

  cloud base height, apparent cloud top height

  phase of clouds (ice/water)

  cloud fraction

  boundary layer height (aerosol layer upper boundary height)

  backscatter coefficient of aerosols

  particle depolarization ratio of aerosols

7.3 Observation of cloud properties by synergy use of infrared radiometer and 95GHz cloud profiling radar

a) Infrared radiometer

(1) Personnel

Hajime Okamoto (CAOS, Tohoku University): Principal Investigator

Naoki Mashiko (CAOS, Tohoku University): Student (Master 1)

Kaori Sato (CAOS, Tohoku University): Student, Doctor Course 1

Nobuo Sugimoto (National Institute for Environmental Studies)

Ichiro Matsui (National Institute for Environmental Studies)

(2) Objective

The infrared radiometer (hereafter IR) is used to derive the temperature of the cloud base and emissivity of the thin ice clouds. Main objectives are to use study clouds and climate system in tropics by the combination of IR with active sensors such as lidar and 95GHz cloud radar. From these integrated approach, it is expected to extend our knowledge of clouds and climate system. Special emphasis is made to retrieve cloud microphysics in upper part of clouds, including sub-visual clouds that are recognized to be a key component for the exchange of water amount between troposphere and stratosphere.

(3) Method

IR instrument directly provides broadband infrared temperature (9.6-10.5 m).

General specifications of IR system (KT 19II, HEITRONICS)

Temperature range	-100 to 100^{o}C
Accuracy	0.5 ^{o}C
Mode	24hours
Time resolution	1 min.
Field of view	Less than 1^{o} (will be estimated later)
Spectral region	9.6-10.5 m

This is converted to broadband radiance around the wavelength region. This is further combined with the lidar or radar for the retrieval of cloud microphysics such as optical thickness at visible wavelength, effective particle size. The applicability of the retrieval technique of the synergetic use of radar/IR or lidar/IR is so far limited to ice clouds. The microphysics of clouds from these techniques will be compared with other retrieval technique such as radar/lidar one or radar with multi-parameter.

(4) Preliminary data

Fig. 1 displays the temperature measured by IRT on Jun. 07, 2007.

The horizontal line denotes the hours (UTC) and vertical axis is the temperature. When the rain reach the surface, IRT should be protected and the measurements are not made during the period, e.g., 10-11 UTC&21-24 UTC.

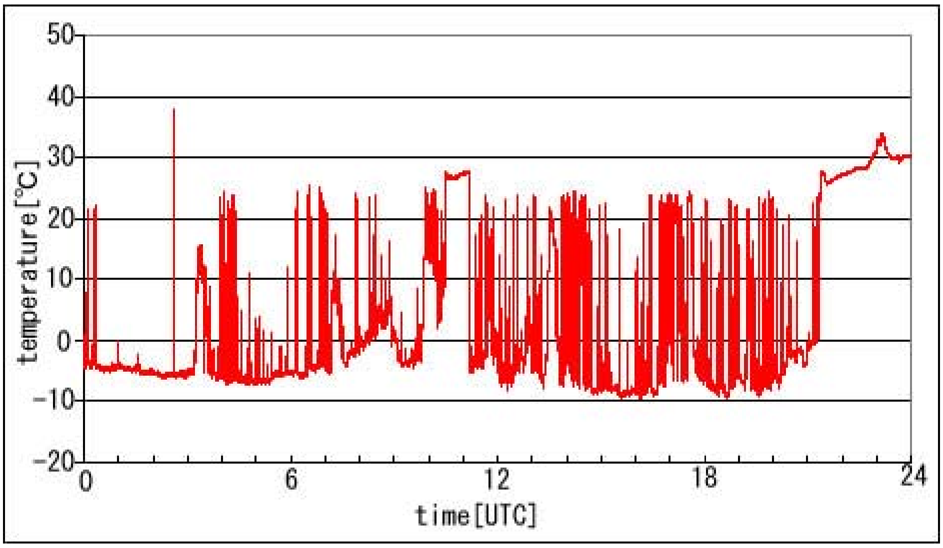


Fig 1.Temperature measured by the IRT in Jun. 07, 2007. during MR06-05 leg. 3 cruise.

(5) Data archive

The data archive server is set inside Tohoku University and the original data and the results of the analyses will be available from us.

(6) Remarks

Basically the IRT is operated for 24 hours. In order to avoid the damage of the lens due to precipitation, we use the shutter (cover) on the top of the lens.

b) 95GHz cloud profiling radar

(1) Personnel

Hajime Okamoto (CAOS, Tohoku University): Principal Investigator

Naoki Mashiko (CAOS, Tohoku University): Student, Master course 1

Kaori Sato ((CAOS, Tohoku University): Student, Doctor Course 1

Toshiaki Takano (Chiba University)

Yoshinori Kinoshita (Chiba University): Student, Master course 1

Shinichi Yokote (Chiba University): Student, Master course 1

Nobuo Sugimoto (National Institute for Environmental Studies)

Ichiro Matsui (National Institute for Environmental Studies)

(2) Objective

Main objective for the 95GHz cloud radar is to detect vertical structure of cloud and precipitation in the observed region. Combinational use of the radar and lidar is recognized to be a powerful tool to study vertical distribution of cloud microphysics, i.e., particle size and liquid/ice water content (LWC/IWC).

(3) Method

Basic output from data is cloud occurrence, radar reflectivity factor and cloud microphysics. In order to derive reliable cloud amount and cloud occurrence, we need to have radar and lidar for the same record.

Radar / lidar retrieval algorithm has been developed in Tohoku University. The algorithm is applied to water cloud in low level and also cirrus cloud in high altitude. In order to analyze the radar data, it is first necessary to calibrate the signal to convert the received power to radar reflectivity factor, which is proportional to backscattering coefficient in the frequency of interest. Then we can interpolate radar and lidar data to match the same time and vertical resolution. Finally we can apply radar/lidar algorithm to infer cloud microphysics.

(4) Results

The time height cross-section of radar reflectivity factor obtained in Jan. 06, 2007 during MR-06-05 leg.3 cruise. Vertical extent is 20km. It is seen that there are several convective activities and melting layer are located at about 5km.

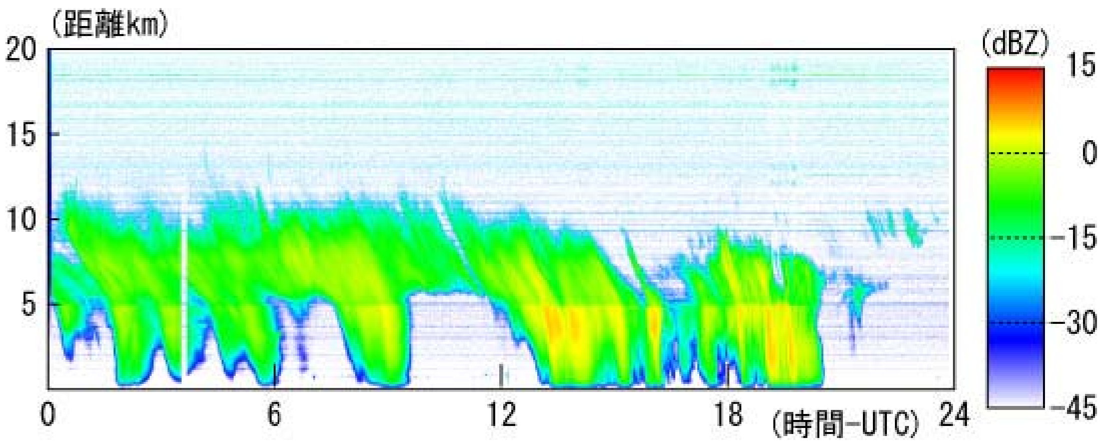


Fig 2 Time height cross section of radar reflectivity factor in dBZe in Jan. 06, 2007 during MR06-05 leg. 3 cruise.

(5) Data archive

The data archive server is set inside Tohoku University and the original data and the results of the analyses will be available from us.

(6) Remarks

The cloud radar is successfully operated for 24 hours.

7.4 Aerosol optical characteristics measured by Shipborne Sky radiometer

(1) Personnel

Principal Investigator :

Kazuma Aoki (University of Toyama) Associate Professor / not onboard

Co-workers:

Tatsuo Endoh (Tottori University of Environmental Studies) Professor / not onboard

Tamio Takamura (CEReS, Chiba University) Professor / not onboard

Teruyuki Nakajima (CCSR, The University of Tokyo) Professor / not onboard

Nobuo Sugimoto (NIES) Chief Research Scientist / not onboard

Operation was supported by Global Ocean Development Inc. (GODI).

(2) Objective

Objective of the observations in this aerosol is to study distribution and optical characteristics of marine aerosols by using a sky radiometer (POM-01 MKII). Furthermore, collections of the data for calibration and validation to the remote sensing data were performed simultaneously

(3) Methods

Sky radiometer is measuring the direct solar irradiance and the solar aureole radiance distribution, has seven interference filters. Analysis of these data is performed by SKYRAD.pack version 4.2 developed by Nakajima *et al*. 1996.

(4) Results

Data obtained in this cruise will be analyzed at University of Toyama.

@ Measured parameters

- Aerosol optical thickness at 5 wavelengths (400, 500, 675, 870 and 1020 nm)
- Ångström exponent
- Single scattering albedo at 5 wavelengths
- Size distribution of volume (0.01 μm – 20 μm)

GPS provides the position with longitude and latitude and heading direction of the vessel, and azimuth and elevation angle of sun. Horizon sensor provides rolling and pitching angles.

(5) Data Archives

Measurements of aerosol optical data are not archived so soon and developed, examined, arranged and finally provided as available data after a certain duration. All data will archived at University of Toyama (K.Aoki, SKYNET/SKY: http://skyrad.sci.u-toyama.ac.jp/) and Chiba University (T.Takamura, SKYNET) after the quality check and submitted to JAMSTEC within 3-year.

7.5 Surface Atmospheric Turbulent Flux Measurement

Personnel

Kunio Yoneyama (JAMSTEC) Principal Investigator / Not-onboard
Osamu Tsukamoto (Okayama University) Not-onboard
Shinya Okumura (Global Ocean Development Inc.: GODI)
Ryo Ohyama (GODI)

Objective

To better understand the air-sea interaction, accurate measurements of surface heat and fresh water budgets are necessary as well as momentum exchange through the sea surface. In addition, the evaluation of surface flux of carbon dioxide is also indispensable for the study of global warming. Sea surface turbulent fluxes of momentum, sensible heat, latent heat, and carbon dioxide were measured by using the eddy correlation method that is thought to be most accurate and free from assumptions. These surface heat flux data are combined with radiation fluxes and water temperature profiles to derive the surface energy budget.

Methods

The surface turbulent flux measurement system (Fig. 7.5-1) consists of turbulence instruments (Kaijo Co., Ltd.) and ship motion sensors (Kanto Aircraft Instrument Co., Ltd.). The turbulence sensors include a three-dimensional sonic anemometer-thermometer (Kaijo, DA-600) and an infrared gas analyzer(LICOR, LI-7500). The sonic anemometer measures three-dimensional wind components relative to the ship. The ship motion sensors include a two-axis inclinometer (Applied Geomechanics, MD-900-T), a three-axis accelerometer (Applied Signal Inc., QA-700-020), and a three-axis rate gyro (Systron Donner, QRS-0050-100). LI7500 is a CO_2/H_2O sensor that measures turbulent fluctuations of carbon dioxide and water vapor simultaneously.

These signals are sampled at 100 Hz by a PC-based data logging system (Labview, National Instruments Co., Ltd.) and averaged over 0.1second basis. By obtaining the ship speed and heading information through the Mirai network system it yields the absolute wind components relative to the ground. Combining the averaged 10Hz turbulence data with the ship motion data, turbulent fluxes and statistics are calculated in a real-time basis. These data are also saved in digital files every 0.1 second for raw data and every 1 minute for statistic data.

Preliminary results

Data will be processed after the cruise at Okayama University.

Data Archive

All data are archived at Okayama University, and will be open to public after quality checks and corrections by K. Yoneyama and/or O. Tsukamoto. Corrected data will be submitted to JAMSTEC Data Management Division.

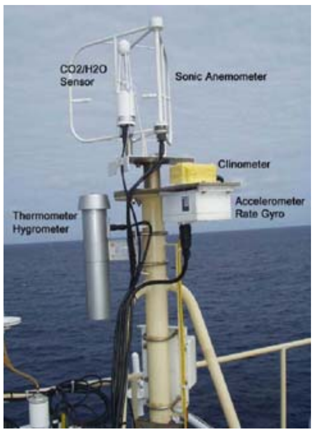


Fig. 7.5-1 Turbulent flux measurement system on the top deck of foremast.

7.6 Water Vapor and rain sampling for Stable Isotope Measurement

(1) Personnel

Naoyuki Kurita (JAMSTEC) Principal Investigator
Kimpei Ichiyanagi (JAMSTEC)
Mayumi Horikawa (Nagoya University)

(2) Objective

Stable isotopes in water (HDO and $H_2^{18}O$) are powerful tool to study of the moisture origin of precipitation associated with MJO or other tropical disturbances. Sampling of rainwater and atmospheric moisture was performed for stable isotope analyses throughout the MR06-05 Leg3 cruise from Singapole on December 14, 2006 to Japan (Hachinohe city) on January 18, 2007.

(3) Method

Following observation was carried out throughout this cruise

- Atmospheric moisture sampling:

  Water vapor was sampled at the two heights above sea level, namely foremast and mainmast height. The cryogenic method that air was drawn at the 3L/min for about 6 hour during daytime and 12 hour during midnight from the intake point through a glass trap cooled by radiator around -100℃ was used for water vapor sampling

- Measurement of the mixing ratio at the sampling levels.

  The 10 min average of air temperature and relative humidity (Vaisala Co. Ltd., HMP45) was measured at the air intake point. The mixing ratio of each level was determined in each level using temerature and relative humidity.

- Rainwater sampling

  Precipitation sampling was collected every 3 hours with auto-precipitation sampler developed by JAMSTEC (Masinax Co., Ltd. , MAS-UK150-1). All precipitation during the period falls through a funnel and pooled in the rain collector, then 10 ml of the water is mechanically transferred to an airtight sample container.

(4) Results

The sampling coordinates and meteorological condition for all water vapor samples are summarized in Table 7.6-1 for foremast (92 samples) and Table 7.6-2 for mainmast (92 samples). The rainfall samples data (23 samples) is summarized in Table 7.6-3. It includes the sampling coordination and rainfall amount. As for the meteorological data, temporal variation of temperature, relative humidity, and mixing ratio are shown in Figure 7.6-1.

(5) Data archive

These raw data obtained during this cruise will be submitted to JAMSTEC Data Management Office. Analyzed stable isotope data (HDO and $H_2^{18}O$) are also available from N. Kurita of JAMSTEC.

Table 7.6-1 Summary of all water vapor data collected at the foremast height.

No	Date	Time UTC	Latitude N	Longitude E	Log Speed	Temp. ℃	RH %	Mixing ratio g/Kg	Sample g
1	20061221	0:00	18.34	123.35	11.15	25.30	0.82	16.67	20.9
2	20061221	6:00	18.33	124.65	13.16	25.00	0.86	17.22	21.9
3	20061221	12:00	18.33	126.81	13.69	25.50	0.86	17.74	22.2
4	20061222	0:00	18.33	129.01	14.48	28.80	0.73	18.46	23.7
5	20061222	6:00	17.86	129.99	14.30	28.50	0.72	17.72	22.3
6	20061222	12:00	15.64	130.00	15.11	27.80	0.78	18.36	22.8
7	20061223	0:00	13.39	130.00	14.60	29.50	0.70	18.40	23.1
8	20061223	6:00	11.80	130.00	15.26	28.80	0.74	18.62	26.0
9	20061223	12:00	9.51	130.00	15.29	28.30	0.80	19.60	23.1
10	20061224	0:00	7.95	130.02	2.30	31.00	0.69	19.78	25.1
11	20061224	6:00	7.99	129.98	1.73	29.30	0.77	20.03	24.9
12	20061224	12:00	7.99	129.99	1.41	28.70	0.80	20.03	24.5
13	20061225	0:00	7.97	130.00	2.40	30.30	0.71	19.44	24.3
14	20061225	6:00	7.94	130.00	1.08	29.50	0.75	19.76	25.4
15	20061225	12:00	7.93	130.03	1.38	29.10	0.75	19.23	23.2
16	20061226	0:00	7.95	130.01	2.52	31.50	0.66	19.49	24.7
17	20061226	6:00	8.00	129.27	15.08	29.90	0.72	19.31	23.0
18	20061227	6:00	7.00	128.41	14.11	26.90	0.84	18.88	23.6
19	20061227	12:00	6.36	129.87	13.51	28.70	0.76	18.96	23.8
20	20061228	0:00	4.45	130.00	14.49	29.40	0.76	19.73	24.2
21	20061228	6:00	3.01	129.99	14.53	27.40	0.82	18.97	23.9
22	20061228	12:00	1.97	129.95	3.13	28.30	0.76	18.74	−99.0
23	20061229	0:00	1.95	129.93	0.94	31.30	0.65	18.89	24.6
24	20061229	6:00	1.92	129.95	2.31	30.10	0.68	18.49	21.6
25	20061229	12:00	1.94	129.93	1.20	28.40	0.77	19.01	23.7
26	20061230	0:00	1.92	130.04	7.91	29.60	0.73	19.32	24.4
27	20061230	6:00	1.51	131.26	15.16	29.40	0.73	18.99	24.7
28	20061231	0:00	0.39	135.60	15.03	29.80	0.73	19.34	24.0
29	20061231	6:00	0.19	137.10	15.21	29.20	0.73	18.77	23.9
30	20061231	12:00	0.03	138.07	2.34	29.00	0.74	19.01	23.8
31	20070101	0:00	0.03	138.10	1.62	31.50	0.67	19.64	24.2
32	20070101	6:00	0.03	138.07	1.41	28.00	0.79	19.01	22.4
33	20070101	12:00	0.04	138.09	1.13	27.00	0.85	19.23	24.7

34	20070101	18:00	0.05	138.07	1.55	28.20	0.78	19.06	23.3
35	20070102	0:00	−0.03	138.06	3.39	27.60	0.81	19.07	23.8
36	20070102	6:00	−0.23	138.00	3.82	27.90	0.79	18.82	24.3
37	20070102	12:00	0.04	138.09	5.12	27.10	0.84	19.13	23.0
38	20070102	18:00	0.05	138.08	2.25	25.60	0.89	18.54	23.6
39	20070103	0:00	0.35	138.03	9.45	27.10	0.80	18.12	23.1
40	20070103	6:00	1.58	138.08	11.61	27.80	0.76	18.05	21.5
41	20070103	12:00	1.97	138.24	1.52	27.20	0.84	19.24	29.3
42	20070103	18:00	1.97	138.20	1.70	27.40	0.81	18.84	20.0
43	20070104	0:00	1.96	138.19	2.09	28.00	0.77	18.49	22.2
44	20070104	6:00	1.97	138.18	3.20	28.00	0.80	19.26	24.3
45	20070104	12:00	1.99	138.12	2.40	28.40	0.76	18.75	41.5
46	20070105	0:00	2.07	138.07	6.86	29.40	0.72	18.91	23.7
47	20070105	6:00	3.08	137.64	13.60	26.80	0.82	18.32	22.3
48	20070105	12:00	4.36	137.27	12.06	26.80	0.80	17.95	23.1
49	20070105	18:00	4.85	137.29	2.04	25.60	0.83	17.28	21.4
50	20070106	0:00	4.89	137.31	2.10	28.50	0.68	16.62	20.7
51	20070106	6:00	4.86	137.30	3.28	28.20	0.74	18.09	23.6
52	20070106	12:00	4.95	137.38	1.75	28.00	0.78	18.78	26.3
53	20070106	18:00	4.96	137.35	2.43	28.70	0.71	17.87	20.4
54	20070107	0:00	5.22	137.25	10.13	30.30	0.66	18.17	21.9
55	20070107	6:00	6.59	136.98	15.12	28.60	0.77	19.16	24.1
56	20070107	12:00	7.81	136.48	5.46	28.20	0.77	18.81	35.9
57	20070108	0:00	7.87	136.47	1.72	30.00	0.69	18.73	23.7
58	20070108	6:00	7.92	136.45	5.76	28.40	0.78	19.23	23.5
59	20070108	12:00	7.87	136.50	2.97	26.60	0.86	19.05	25.5
60	20070108	18:00	7.86	136.47	2.82	27.10	0.85	19.45	24.4
61	20070109	0:00	7.96	136.52	6.69	27.80	0.79	18.71	23.8
62	20070109	6:00	9.03	136.93	13.93	27.70	0.81	19.03	24.0
63	20070109	12:00	11.03	137.00	13.43	28.30	0.76	18.51	39.4
64	20070110	0:00	12.97	137.00	12.77	28.60	0.70	17.22	21.7
65	20070110	6:00	14.05	137.06	9.83	28.50	0.68	16.69	20.1
66	20070110	12:00	15.86	137.00	13.57	27.80	0.69	16.18	20.9
67	20070111	0:00	17.92	137.00	13.64	28.70	0.63	15.57	19.7
68	20070111	6:00	19.27	137.00	14.40	27.20	0.72	16.36	19.5
69	20070111	12:00	20.54	137.45	13.85	24.90	0.80	15.84	22.0
70	20070111	18:00	21.70	138.40	14.66	25.20	0.76	15.31	18.9

71	20070112	0:00	22.83	139.35	14.88	25.30	0.75	15.03	18.7
72	20070112	6:00	23.98	140.31	14.76	22.70	0.82	14.15	18.3
73	20070112	12:00	25.20	141.34	14.68	20.70	0.81	12.30	17.7
74	20070112	18:00	26.38	142.34	14.61	20.20	0.71	10.34	12.5
75	20070113	0:00	27.55	143.23	14.61	20.10	0.57	8.26	10.9
76	20070113	6:00	28.77	144.15	15.24	19.30	0.61	8.49	10.6
77	20070113	12:00	30.63	145.59	14.98	17.80	0.69	8.69	23.1
78	20070114	0:00	32.46	147.01	14.06	14.40	0.64	6.50	8.8
79	20070114	6:00	33.62	147.91	13.54	12.20	0.61	5.39	7.4
80	20070114	12:00	34.76	148.85	13.89	9.60	0.69	5.03	6.6
81	20070114	18:00	35.92	149.78	13.76	9.30	0.55	3.94	5.3
82	20070115	0:00	36.94	150.63	8.92	7.30	0.70	4.42	7.7
83	20070115	6:00	37.13	150.77	2.84	6.20	0.74	4.32	7.7
84	20070115	12:00	37.13	150.78	2.71	7.10	0.70	4.32	9.7
85	20070115	18:00	37.13	150.78	2.18	8.10	0.64	4.22	9.7
86	20070116	0:00	37.13	150.71	3.99	10.20	0.56	4.24	9.9
87	20070116	6:00	37.56	149.63	13.69	8.90	0.60	4.16	9.0
88	20070116	12:00	37.68	149.31	11.61	9.20	0.59	4.20	9.9
89	20070116	18:00	38.78	146.43	14.84	7.70	0.74	4.76	10.7
90	20070117	0:00	39.44	144.66	15.59	5.20	0.68	3.72	8.5
91	20070117	6:00	40.09	142.91	15.14	5.00	0.54	2.87	6.5
92	20070117	12:00	40.76	141.87	5.53	3.20	0.64	3.02	8.8

Table 7.6-2 same as Table 7.6-1 but mainmast height

No	Date	Time UTC	Latitude N	Longitude E	Log Speed	Temp. ℃	RH %	Mixing ratio g/Kg	Sample g
1	20061221	0:00	18.34	123.39	11.18	24.80	0.83	16.46	21.0
2	20061221	6:00	18.33	124.70	13.26	24.40	0.88	16.96	21.4
3	20061221	12:00	18.33	126.85	13.71	25.20	0.87	17.61	−99.0
4	20061222	0:00	18.33	129.06	14.46	27.30	0.79	18.15	23.2
5	20061222	6:00	17.82	130.00	14.32	27.60	0.76	17.71	22.0
6	20061222	12:00	15.60	130.00	15.11	27.30	0.79	18.26	22.7
7	20061223	0:00	13.34	130.00	14.61	28.10	0.76	18.24	23.0
8	20061223	6:00	11.76	130.00	15.23	28.20	0.76	18.43	25.6
9	20061223	12:00	9.46	130.00	15.29	28.00	0.81	19.43	22.9
10	20061224	0:00	7.95	130.02	1.82	29.00	0.76	19.52	24.5

11	20061224	6:00	7.99	129.98	1.71	28.20	0.82	19.87	25.0
12	20061224	12:00	7.99	129.99	1.43	28.30	0.81	19.84	23.1
13	20061225	0:00	7.97	130.00	2.42	28.60	0.77	19.27	24.0
14	20061225	6:00	7.94	129.99	1.05	28.60	0.79	19.62	25.3
15	20061225	12:00	7.93	130.03	1.39	28.60	0.76	19.07	22.8
16	20061226	0:00	7.95	130.01	2.54	29.20	0.75	19.35	24.3
17	20061226	6:00	8.00	129.21	15.32	28.70	0.77	19.32	23.6
18	20061227	6:00	7.00	128.45	14.11	26.60	0.84	18.71	23.4
19	20061227	12:00	6.34	129.88	13.52	28.40	0.76	18.77	23.4
20	20061228	0:00	4.41	130.00	14.46	28.30	0.80	19.61	24.0
21	20061228	6:00	2.98	129.99	14.53	27.00	0.83	18.90	24.3
22	20061228	12:00	1.97	129.95	2.97	28.10	0.77	18.66	23.0
23	20061229	0:00	1.95	129.92	0.90	29.80	0.71	18.88	24.3
24	20061229	6:00	1.92	129.95	2.32	29.10	0.72	18.54	21.9
25	20061229	12:00	1.94	129.93	1.22	28.00	0.79	19.02	23.5
26	20061230	0:00	1.91	130.05	8.20	27.80	0.81	19.18	24.2
27	20061230	6:00	1.51	131.29	15.17	28.80	0.75	18.96	24.9
28	20061231	0:00	0.38	135.65	15.02	28.00	0.80	19.20	23.7
29	20061231	6:00	0.19	137.14	15.22	28.10	0.77	18.73	24.0
30	20061231	12:00	0.03	138.07	2.20	28.70	0.75	18.91	23.5
31	20070101	0:00	0.03	138.10	1.82	28.90	0.77	19.41	25.9
32	20070101	6:00	0.03	138.07	1.13	27.10	0.83	18.96	21.9
33	20070101	12:00	0.04	138.09	1.14	26.60	0.86	19.01	24.1
34	20070101	18:00	0.05	138.07	1.61	27.60	0.80	18.76	23.4
35	20070102	0:00	−0.03	138.06	3.29	26.30	0.86	18.83	23.6
36	20070102	6:00	−0.23	138.00	4.08	27.40	0.80	18.60	24.1
37	20070102	12:00	0.04	138.09	4.89	26.70	0.85	18.96	22.6
38	20070102	18:00	0.05	138.09	2.25	25.10	0.90	18.17	24.0
39	20070103	0:00	0.38	138.03	9.91	26.60	0.80	17.77	22.5
40	20070103	6:00	1.61	138.08	11.35	27.40	0.77	17.86	21.3
41	20070103	12:00	1.97	138.25	1.51	26.80	0.85	19.02	29.0
42	20070103	18:00	1.97	138.20	1.72	26.80	0.83	18.56	20.7
43	20070104	0:00	1.96	138.19	2.04	26.70	0.82	18.23	22.0
44	20070104	6:00	1.97	138.18	3.27	27.40	0.82	19.00	24.2
45	20070104	12:00	1.99	138.12	2.39	27.90	0.77	18.40	46.4
46	20070105	0:00	2.09	138.05	7.23	28.40	0.76	18.72	24.2
47	20070105	6:00	3.13	137.62	13.63	26.30	0.84	18.19	22.0

48	20070105	12:00	4.39	137.27	11.82	26.40	0.81	17.67	22.0
49	20070105	18:00	4.85	137.29	1.98	25.10	0.83	16.85	21.5
50	20070106	0:00	4.90	137.31	2.13	27.40	0.70	16.15	20.2
51	20070106	6:00	4.86	137.30	3.28	27.50	0.76	17.87	24.0
52	20070106	12:00	4.95	137.38	1.75	27.60	0.80	18.70	26.2
53	20070106	18:00	4.96	137.35	2.41	28.00	0.74	17.64	20.6
54	20070107	0:00	5.26	137.24	10.66	28.90	0.71	18.08	22.3
55	20070107	6:00	6.64	136.97	15.10	28.00	0.79	19.05	24.2
56	20070107	12:00	7.82	136.47	5.23	27.80	0.78	18.52	40.9
57	20070108	0:00	7.87	136.47	1.68	28.70	0.74	18.50	23.3
58	20070108	6:00	7.92	136.45	5.99	27.80	0.80	19.02	23.3
59	20070108	12:00	7.87	136.50	2.85	26.40	0.86	18.73	24.8
60	20070108	18:00	7.86	136.47	2.83	26.80	0.85	19.08	24.6
61	20070109	0:00	7.98	136.53	7.13	27.20	0.81	18.47	23.1
62	20070109	6:00	9.08	136.94	13.91	27.10	0.82	18.78	23.5
63	20070109	12:00	11.07	137.00	13.44	27.90	0.77	18.19	39.6
64	20070110	0:00	13.00	137.00	12.77	28.30	0.69	16.76	20.8
65	20070110	6:00	14.08	137.06	9.88	28.10	0.68	16.33	20.5
66	20070110	12:00	15.91	137.00	13.58	27.30	0.69	15.71	20.5
67	20070111	0:00	17.97	137.00	13.65	27.80	0.65	15.17	18.7
68	20070111	6:00	19.31	137.00	14.35	26.60	0.74	16.17	19.3
69	20070111	12:00	20.57	137.47	13.88	24.30	0.82	15.68	21.9
70	20070111	18:00	21.72	138.42	14.69	24.30	0.80	15.12	18.9
71	20070112	0:00	22.86	139.38	14.88	−99.00	−0.99	−99.00	−99.0
72	20070112	6:00	24.00	140.32	14.75	22.00	0.85	14.04	18.7
73	20070112	12:00	25.22	141.36	14.68	20.40	0.81	12.08	17.4
74	20070112	18:00	26.40	142.35	14.61	19.60	0.72	10.15	12.4
75	20070113	0:00	27.58	143.25	14.61	19.00	0.60	8.11	10.6
76	20070113	6:00	28.79	144.17	15.27	18.90	0.62	8.31	10.8
77	20070113	12:00	30.65	145.61	14.96	17.30	0.69	8.40	22.6
78	20070114	0:00	32.48	147.03	14.05	13.70	0.65	6.31	8.5
79	20070114	6:00	33.64	147.93	13.54	11.70	0.60	5.12	7.1
80	20070114	12:00	34.79	148.87	13.90	8.90	0.68	4.77	6.3
81	20070114	18:00	35.94	149.80	13.75	8.60	0.53	3.64	5.0
82	20070115	0:00	36.96	150.65	8.59	6.40	0.69	4.11	7.3
83	20070115	6:00	37.13	150.77	2.82	5.70	0.73	4.10	7.3
84	20070115	12:00	37.12	150.78	2.69	6.50	0.69	4.07	9.4

85	20070115	18:00	37.13	150.78	2.19	7.60	0.64	4.06	9.5
86	20070116	0:00	37.13	150.70	4.38	9.20	0.57	4.09	9.7
87	20070116	6:00	37.57	149.59	13.71	8.40	0.60	4.05	8.8
88	20070116	12:00	38.17	148.04	13.86	8.60	0.61	4.15	9.7
89	20070116	18:00	38.79	146.39	14.88	7.00	0.76	4.66	−99.0
90	20070117	0:00	39.46	144.61	15.56	4.50	0.69	3.57	8.1
91	20070117	6:00	40.11	142.86	15.14	4.40	0.55	2.81	6.3
92	20070117	12:00	40.77	141.87	5.41	2.70	0.65	2.94	8.7

Table 7.6-3 Summary of all precipitation data

No	Rainfall Start					Rainfall Stop					rainfall
	Year	date	time	Lon	Lat	Year	date	time	lon	lat	mm
1	2006	1220	20:00	18.67	122.57	2006	1220	22:00	18.32	122.63	2.7
2	2006	1221	8:00	18.34	124.67	2006	1222	1:00	18.33	128.78	28.4
3	2006	1223	21:00	8.57	130.00	2006	1224	0:00	7.93	130.04	1.9
4	2006	1226	5:00	8.02	129.98	2006	1226	6:00	8.00	129.81	4.4
5	2006	1226	11:00	8.00	128.51	2006	1226	23:00	7.37	126.79	14.6
6	2006	1227	2:00	6.99	126.99	2006	1227	9:00	7.00	128.64	21.8
7	2006	1228	3:00	4.21	130.00	2006	1228	6:00	3.51	130.00	4.7
8	2006	1230	2:00	1.94	129.93	2006	1230	4:00	1.85	130.27	2.6
9	2006	1230	15:00	1.01	132.91	2006	1230	23:00	0.46	134.89	1.1
10	2007	101	3:00	0.04	138.10	2007	101	4:00	0.01	138.09	1.6
11	2007	101	9:00	0.04	138.06	2007	101	15:00	0.05	138.09	43.5
12	2007	102	0:00	0.07	138.05	2007	102	4:00	−0.18	138.04	45.4
13	2007	102	14:00	0.07	138.06	2007	103	1:00	0.07	138.04	65.6
14	2007	103	8:00	1.62	138.04	2007	103	19:00	1.97	138.26	2.5
15	2007	103	23:00	1.97	138.17	2007	104	2:00	1.98	138.17	0.9
16	2007	104	8:00	1.97	138.20	2007	104	10:00	1.96	138.21	3.3
17	2007	105	6:00	2.64	137.79	2007	105	9:00	3.29	137.57	4.1
18	2007	105	8:00	3.07	137.64	2007	105	19:00	4.85	137.28	6.3
19	2007	107	9:00	6.75	137.00	2007	107	21:00	7.87	136.47	1.4
20	2007	108	9:00	7.99	136.41	2007	108	21:00	7.87	136.49	41.6
21	2007	109	3:00	7.90	136.48	2007	110	0:00	12.53	137.00	1.5
22	2007	112	3:00	23.01	139.51	2007	112	4:00	23.18	139.67	10.6
23	2007	114	5:00	33.02	147.43	2007	115	6:00	37.12	150.76	1.2

* Rainfall amount in each sampling period is calculated from SOJ data.

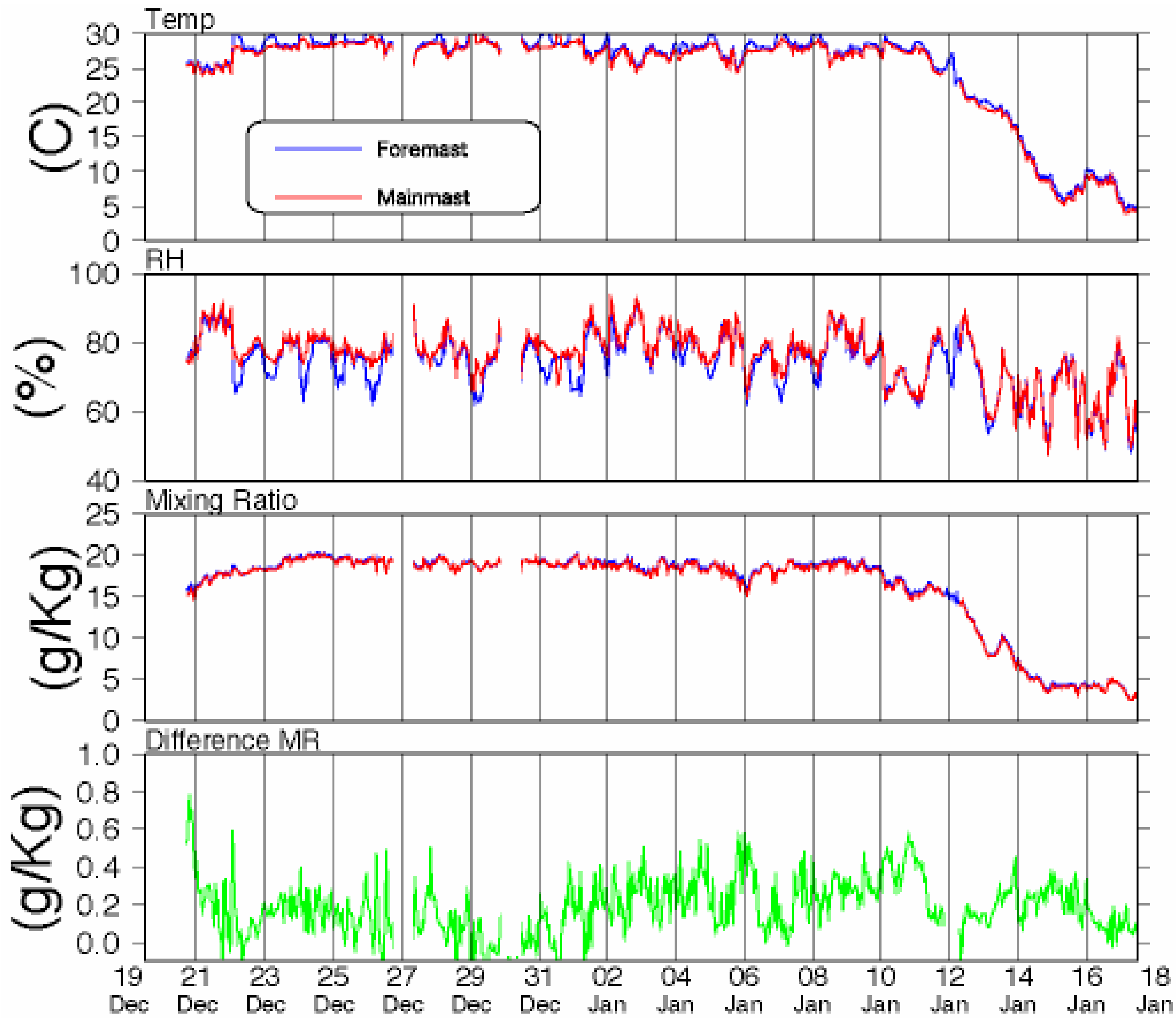


Fig. 7.6-1 Temporal variation of (a) temperature (degK), (b) relative humidity (%), (c) mixing ratio (g/Kg), and (d) difference of mixing ratio between foremast and mainmast height from Singapole to Japan.

7.7 Measurement of greenhouse effect gases and CO2-related microflora at the equatorial area

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(2) Objectives
In the view of the problem of the global warming, it is important to know the concentration level of greenhouse effect gases in the ocean and the penetration rate of these gases trough air-sea surface interface. Our purpose of this cruise is to collect the data of a change of over the years for carbonate (total carbon dioxide), nutrients, nitrogen oxide (N2O) and microflora at the equatorial area.

(3) Parameters
Oceanic parameters for vertical profile: total carbon dioxide (TCO2), nutrients (NO3+NO2-N, NO2-N, PO4-P, SiO2-Si), nitrogen oxide (N2O), microflora.

(4) Methods

a) Total dissolved inorganic carbon (TCO2)
The TCO2 concentration in seawater samples was determined by using the coulometric titration system (UIC Inc., Carbon Coulometer model 5011). Samples for TCO2 analysis were drawn from the Niskin sampler into 125 mL glass vial bottles after an overflow of about 100 mL of the seawater. The samples were immediately poisoned with 50 µl of 50% saturated HgCl2 in order to restrict biological alteration prior to sealing the bottles. All samples were stored at room temperature after sampling and analyzed within a few hours. Seawater was introduced manually into the thermostated (20ºC±0.1ºC) measuring pipette with a volume of ~30 mL by a pressurized headspace CO2-free air that had been passed through the KOH scrubber. The measured volume was then transferred to the extraction vessel. The seawater sample in the extraction vessel was acidified with 1.5 mL of 3.8% phosphoric acid and the CO2 was extracted from the sample for 5 minutes by bubbling with the CO2-free air. After passing through the Ag2SO4 scrubber, polywool and Mg(ClO4)2 scrubber to remove sea salts and water vapor, the evolved CO2 gas was continuously induced to the coulometric titration cell by the stream of the CO2-free air. All reagents were renewed every day. The precision of the TCO2 measurement was tested by analyzing CRMs (batch 72) at the beginning of the measurement of samples every day. We also prepared and analyzed sub-standards that were bottled into 125 mL glass vial bottles from a 20L bottle of filtered and poisoned offshore surface water in order to check the condition of the system and the stability of measurements every day. The resulting standard deviation form replicate analysis of 8 sub-standards was ±1.00 µmol/l.

b) Nutrients
The Bran+Luebbe continuous flow analytical system (Model TRAACS2000) was employed for nutrients analysis. The samples were draw into 50 mL polyethylene bottles from the Niskin sampler and stored in a refrigerator before measurement. The analysis of PO4-P and SiO2-Si will be carried out on land laboratory.
Nitrite (NO2-N): Nitrite was determined by diazotizing with sulfanilamide and coupling with N-1

naphthyl-ethylenediamine (NED) to form a colored azo compound (wavelength: 550 nm, flowcell: 5 cm)
Nitrate + Nitrite (NO3+NO2-N): Nitrate in seawater was reduced to nitrite using a reduction tube (Cd-Cu tube). The reduced nitrare and nitrite were determined by same method as nitrite described above (wavelength: 550 nm, flow cell: 3 cm). Silicate (SiO2-Si) : Silicate was determined by the molybden-yellow (wavelength : 630nm, flow cell : 3 cm). Phosphate (PO4-P): Phosphate was determined by the molybden-blue method (wavelength: 880 nm, flow cell: 5 cm).

c) Nitrous Oxide (N2O)
Samples for N2O analysis were drawn from the Niskin sampler into 125 mL glass vial bottles after an overflow of about 100 mL of the seawater. The samples were immediately poisoned with 50 µl of 50% saturated HgCl2 in order to restrict biological alteration prior to sealing the bottles. All samples were stored in a refrigerator before measurement. The concentration of N2O in seawater was determined using the Shimadzu GC14A gaschromatograph (carrier gas; pure N2 gas 40-50 mL/min., column: Molecular Sieve 5A 60/80 2m x 3ø) with 63Ni electron capture detector. A purge-and-trap method was employed to concentrate N2O from seawater.
Seawater was introduced into a measuring pipette with a volume of 100 mL by a pressurized headspace pure N2 gas (99.9998%). The measured volume was then transferred to the extraction vessel and N2O was extracted from the sample for 10 minutes by bubbling with the pure N2 gas (flow rate: 100 mL/min). After passing through the calcium chloride scrubber to remove water vapor, the evolved N2O gas was continuously induced to the a molecularsieve 13X column (60-80 µm, 0.5 m) column and trapped onto the cooled (-80ºC) column. After bubbling for 10 minutes, the column was heated at 80ºC to desorb the N2O by the stream of the carrier gas (pure N2) and the desorbed N2O was introduced to the gaschromatograph.

d) Microflora
Seawater samples for microflora analysis were collected in 10 L EVA cases from Niskin sampler. After the collection, samples of seawater for microflora analysis were filtered with 0.22-µm filter (Diameter=47mm; MILLIPORE, DURAPORE® MEMBRANE FILTERS), and filters were stored at 10°C. On land laboratory, DNA (deoxyribonucleic acid) extraction from accumulated microorganisms was performed. Seawater microfrola analyses were performed based on extracted DNA samples.

(5) Data archive
All data will be archived at CRIEPI and Ibaraki University after checking of data quality and submitted to the DMO at JAMSTEC within 3 years.

7.8 The production-consumption mechanisms and sea-air flux of greenhouse gases in the western tropical Pacific

(1) Personnel

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(2) Sampling

Sampling of Tokyo Institute of Technology (Yoshida Laboratory) for seawater and ambient air are listed in Table 1, Table 2and Table 3.

(3) Nitrous oxide and related substances

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a) Introduction

Recently it has been attracted attention to emission of biogenic trace gases from ecosystems, since the gases contain a significant amount of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Isotopic signatures of these gases are well recognized to provide constraints for relative source strength and information on reaction dynamics concerning their formation and biological pathways. Nitrous oxide is a very effective heat-trapping gas in the atmosphere because it absorbs outgoing radiant heat in infrared wavelengths that are not captured by the other major greenhouse gases, such as water vapor and CO_2. The annual input of N_2O into the atmosphere is estimated to be about 16.4 Tg N_2O-N yr^{-1}, and the oceans are believed to contribute more than 17% of the total annual input (IPCC, 2001).

N_2O is produced by the biological processes of nitrification and denitrification (Dore et al., 1998; Knowles et al., 1981; Rysgaard et al., 1993; Svensson, 1998; Ueda et al., 1993). Depending on the redox conditions, N_2O is produced from inorganic nitrogenous compounds (NH_3 or NO_3^-), with subsequently different isotopic fractionation factors. The isotopic signatures of N_2O confer constraints on the relative source strength, and the reaction dynamics of N_2O biological production pathways are currently under investigation. Furthermore, isotopomers of N_2O contain more easily interpretable biogeochemical information as to their sources than obtained from conventional bulk ^{15}N and ^{18}O measurements (Yoshida and Toyoda, 2000).

b) Materials and methods

Samples were collected in MR06-05 leg 3 research expedition on the R/V Mirai from December 14, 2006 to January 19, 2007. The production-consumption mechanisms of dissolved N_2O in the western tropical Pacific was investigated by collecting vertical seawater samples (6 stations), dissolved oxygen (DO) (6 stations), chlorophyll a (Chl.a) (6 stations), particulate organic matter (POM) (6 stations), on-board incubation experiments (6 stations). The sea-air fluxes (sampling sea surface water and ambient water) (12 stations). And then, the sea-air flux of N_2O in Western Pacific was investigated by collecting sea surface water and ambient water.

(i) N_2O concentration and isotope analyses

Water samplings were carried out at the indicated depths using a CTD water sampler. For N_2O analyses, water samples were introduced into 225 ml glass vial and then sterilized with mercury chloride (1 ml saturated $HgCl_2$ solution per vial). The vial was then sealed with a butyl-rubber septum and an aluminum cap, taking care to avoid bubble formation, and then brought back to the laboratory and stored at 4˚C until the analyses were conducted. Dissolved N_2O concentrations and its isotopic compositions will be measured by using GC/C/IRMS.

(ii) DO

Samples were collected and measured at stations with CTD observation.

(iii) Nutrients

Samples for nutrients (NH_4^+, NO_3^-, NO_2^-) were collected into 100ml PP bottle and stored at -20˚C. They will be measured by using Auto Analyzer.

(iv) Chlorophyll a (Chl.a)

Samples for Chlorophyll a (Chl.a) were collected. Sea waters are filtrated (1000ml) and stored into 9ml vials satisfied with Dimetylformamid, and stored at -20˚C. They will be measured by using fluorophotometer. These data will be used for calibration with value of fluorescence sensor.

(v) POM

Samples for POM were collected at the depth of Chlorophyll a (Chl.a) concentration maximum and that depth plus 50m and 100m each. After the filtration, the filter were washed with Milli-Q water and then dried at 60˚C for 48 hrs and stored. They will be measured by using EA/IRMS.

(vi) On-board incubation experiment

The water samples for on-board incubation experiments were collected at surface layer (10m) and oxygen minimum layer which expected for the highest N_2O production. Water samples were introduced into 225 ml glass vial sealed with a butyl rubber septum and an aluminum cap. After 2days and 5days at in situ temperature, the sample was then sterilized with mercury chloride and stored at 4˚C until the analyses were conducted. Dissolved N_2O concentrations and its isotopic compositions will be measured by using GC/C/IRMS.

c) Expected results

N_2O concentration of sea surface water affects the sea-air flux directly. And there is a possible that N_2O gases are carried at the place seawater is transporting from deep layer to surface layer like upwelling zone. However, the pathway of N_2O production and consumption mechanisms is also still unresolved. So it is very important to understand vertical profiles of N_2O.Usually N_2O production in surface layer is predominantly carried out nitrification, but denitrification also occurs in the case of oxygen concentration is low (Maribeb and Laura, 2004). In deeper layer during the settling particles or fecal pellets which may produce from phytoplankton or zooplankton, either directly or indirectly. In such pattern, N_2O could be produced through in situ biological processes of settling particles in subsurface layer and the maxima concentrations could be observed. Consequently, the isotopic measurement of these gases becomes a useful parameter for determining the origin and production pathway of N_2O under investigation. at least three factors could be control the N_2O concentration and its isotopic compositions in these study areas are:

(i) The isotopic compositions of dissolved N_2O were governed through the gas exchange with the atmospheric N_2O in the surface layer.

(ii) The well mixing of N_2O in the deeper part may occur due to the transportation from upper layer or the transportation of N_2O from the other area by the occurrence of ocean current.

(iii) The isotopic and compositions of surface and oxygen minimum layer N_2O could provide an information of N_2O production mechanisms, and could be estimate for those N_2O production-consumption rate.

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(4) Methane

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a) Introduction

Atmospheric methane (CH_4) is a trace gas playing an important role in the global carbon cycle as a greenhouse gas. Its concentration has increased by about 1750 ppbv since the pre-industrial era (IPCC, 1995). In order to understand the current global methane cycle, it is necessary to quantify its sources and sinks. At present, there remain large uncertainties in the estimated methane fluxes from sources to sinks. The ocean's source strength for atmospheric methane should be examined in more detail, even though it might be a relatively minor source, previously reported to be 0.005 to 3% of the total input to the atmosphere (Cicerone and Oremland, 1988; Bange et al., 1994).

To estimate an accurate amount of the methane exchange from the ocean to the atmosphere, it is necessary to explore widely and vertically. Distribution of dissolved methane in surface waters from diverse locations in the world ocean is often reported as a characteristic subsurface maximum representing a supersaturation of several folds (Yoshida et al., 2004). Although the origin of the subsurface methane maximum is not clear, some suggestions include advection and/or diffusion from local anoxic environment nearby sources in shelf sediments, and in situ production by methanogenic bacteria, presumably in association with suspended particulate materials (Karl and Tilbrook, 1994). These bacteria are thought to probable live in the anaerobic microenvironments supplied by organic particles or guts of zooplankton (Alldredge and Cohen, 1987).

So, this study investigates in detail profile of methane concentration and stable isotopic distribution in the water column in the central Indian Ocean as open ocean to clarify methane dynamics and estimate the flux of methane to the atmosphere. A better understanding of the CH4 budget, and how it is changing with time, is needed to predict more accurately the future role of CH4 in climate change.

b) Materials and methods

Seawater samples are taken by CTD-CAROUSEL system attached Niskin samplers of 12 L at 21 layers and surface layer taken by plastic bucket. Each sample was carefully subsampled into 30, 125 mL glass vials to avoid air contamination for analysis of methane concentration, carbon isotope ratio, and hydrogen isotope ratio respectively. The seawater samples were poisoned by 20 μL (30 and 125 mL vials) of mercuric chloride solution (Tilbrook and Karl, 1995; Watanabe et al., 1995), and were closed with rubber and aluminum caps. These were stored in a dark and cool place until we got to land, where we conducted gas chromatographic analysis of methane concentration and mass spectrometric analysis of carbon and hydrogen isotopic composition at the laboratory.

The analytical method briefly described here: The system consists of a purge and trap unit, a desiccant unit, rotary valves, a gas chromatograph equipped with a flame ionization detector for concentration of methane, GC/C/IRMS for carbon isotope ratio of methane, GC/TC/IRMS for hydrogen isotope ratio of methane, and data acquisition units. The entire volume of seawater in each glass vial was processed all at once to avoid contamination and loss of methane. Precision obtained from replicate determinations of methane concentration was estimated to be better than 5% for the usual concentration of methane in seawater.

c) Expected results

The Mindanao Dome is a cold cyclonic circulation associated with the upwelling located on the east of the Mindanao Island, and lead to high nutrient sea area. A high nutrient is also supplied from Indonesian islands. Therefore, biological productivity is active in this sea area, and a lot of particulate organic matter are produced. Subsurface maximum concentrations of methane were expected to be observed in the western tropical Pacific. A commonly-encountered distribution in the upper ocean with a methane peak within the pycnocline (e.g., Ward et al., 1987; Owens et al., 1991;

Watanabe et al., 1995). Karl and Tilbrook (1994) suggested the suboxic conditions would further aid the development of microenvironments within particles in which methane could be produced. The organic particles are accumulated in the pycnocline, and methane produced in the micro reducing environment by methanogenic bacteria. Moreover, in situ microbial methane production in the guts of zooplankton can be expected (e.g., Owens et al., 1991; de Angelis and Lee, 1994; Oudot et al., 2002). Watanabe et al. (1995) pointed out that the diffusive flux of methane from subsurface maxima to air-sea interface is sufficient to account for its emission flux to the atmosphere. In the mixed layer above its boundary, the methane is formed and discharged to the atmosphere in part, in the below its boundary, methane diffused to the bottom vertically. By using concentration and isotopic composition of methane and hydrographic parameters for vertical water samples, it is possible to clarify its dynamics such as production and/or consumption in the water column.

Kelley and Jeffrey (2002) observed in the equatorial upwelling region of 10 and 20% supersaturated methane. In this study, in situ methane production result in the property distributions and large methane flux in the western tropical Pacific can be expected.

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Table 1 The sampling position with CTD

No.	Position	
	Latitude	Longitude
1	07-55.73 N	130-02.10 E
2	01-56.08 N	129-54.99 E
3	00-10.49 S	138-02.15 E
4	01-58.08 N	138.10.65 E
5	04-55.41 N	137.19.36 E
6	07-52.38 N	136.28.86 E

Table 2 Sampling conditions for sea–air flux of greenhouse gas

a. Sea surface water

No.	Time		Position	
	UTC	LST	Latitude	Longitude
1	2006.12.21 01:08	2006.12.21 10:08	18-20.36N	123-03.63E
2	2006.12.21 22:54	2006.12.22 07:54	18-19.97N	128-01.48E
3	2006.12.22 07:05	2006.12.22 16:05	18-19.97N	130-01.13E
4	2006.12.23 04:31	2006.12.23 13:31	12-59.23N	129-59.89E
5	2007.01.10 03:09	2007.01.10 12:09	12-59.88N	137-00.08E
6	2007.01.11 03:36	2007.01.11 12:36	18-10.47N	137-00.14E

b. Air

No.	Time		Position		Air temp.	Humidity
	UTC	LST	Latitude	Longitude	(C)	(%)
1	2006.12.21 01:17	2006.12.21 10:17	18-20.36N	123-03.63E	25.1	87
2	2006.12.21 23:02	2006.12.22 08:02	18-19.97N	128-01.48E	25.4	89
3	2006.12.22 07:13	2006.12.22 16:13	18-19.97N	130-01.13E	27.9	78
4	2006.12.23 04:40	2006.12.23 13:40	12-59.23N	129-59.89E	28.4	80
5	2007.01.10 03:18	2007.01.10 12:18	12-59.88N	137-00.08E	28.3	71
6	2007.01.11 03:44	2007.01.11 12:44	18-10.47N	137-00.14E	27.2	74

Table 3   Sampling items

No.	Sampling items
1	N_2O/CH_4 Flux
2	DO
3	N_2O concentration and isotope
4	CH_4 concentration and isotope
5	Nutrients
6	Salinity
7	Chl.a
8	POM
9	Incubation

7.9 Geographical distribution and heat-tolerance in the oceanic sea skaters of *Halobates*. and oceanic dynamics (Heteroptera: Gerridae)

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INTRODUCTION

The insects that inhabit the open sea area are only five species of sea skaters: *Halobates ,micans, H. sericeus, H. germanus, H. splendens,*and *H. sobrinus* (Cheng 1985). Three species, *Halobates sericeus, H. micans* and *H. germanus* inhabit tropical and temperate areas of the Pacific Ocean in the northern hemisphere, including The Kuroshio Current and the East China Sea (Andersen & Polhemus 1976, Cheng 1985). *Halobates sericeus, H. micans and H germanus* are reported from a latitudes of 13ºN-40ºN, 0ºN-35ºNand 0ºN-37ºN, respectively, in the Pacific Ocean (Miyamoto & Senta, 1960, Andersen & Polhemus 1976, Ikawa et al., 2002). However, this information was collected on different cruises and different times of the years. There has been two ecological studies during the two cruises of R/V HAKUHO-MARU: KH-02-01, KH-06-02, based on samples collected in a specific area in a particular season.

During one cruise, KH-02-01, one sea skater species, *Halobates sericeus,* was collected at 18 locations in the East China Sea area (27°10' N- 33°24' N, 124º57' E - 129º30' E) (Harada, 2005), and *H. micans* and/or *H. germanus* at only 8 locations in the area south of 29° 47'N, where water temperatures were more than 25 . At three locations, where the water temperature was less than 23 , neither *H. micans* nor *H. germanus* were caught. However, there have been no such ecological studies performed in the wide area ranged 0°N to 35°N in the Pacific Ocean. One purpose of this study is to make it clear that how the species components and life history dominance among the three oceanic sea skaters appear in such wide latitude area especially in tropical area.

14° 30’ *Halobates micans* were caught at 6 of 7 locations, while *H.germanus* and *H. sericeus* were caught at only 3 and 1 location(s), respectively. However, at 15° 00’ N or northern area, *H. germanus* were caught at 14 of 19 locations, whereas *H. micans* and *H. cericeus* were caught at only 8 and 6 locations, respectively (Harada et al, 2006). However, there have been no continuous samplings in the southern area to 10ºN in the western Pacific Ocean.

Fresh water species in Gerridae seem to have temperature tolerance from -3℃ to 42℃ (Harada, 2003), because water temperature in fresh water in ponds and river highly changes daily and seasonally. However, water temperatures in the ocean are relatively stable and it only ranges from 24℃ to 30 ℃ in the center of Kuroshio current in southern front of western Japan. Adults of *Halobates germanus* showed semi-heat-paralysis (SHP: static posture with no or low frequency to skate on water surface), when they were exposed to temp. higher than 32℃ (Harada unpublished, data in the TANSEIMARU cruise: KT-05-27).

In the tropical ocean area, water temperature is more stable around 30℃rather than that in temperate ocean. Therefore, the tropical species of *H. micans* is hypothesized to have lower tolerances to temperature changes than the temperate species, *H. cericeus*. This hypothesis was true in the laboratory experiment during the cruise of KH-06-02-Leg 5 When the water temperature increased stepwise 1℃ every 1 hour, heat-paralysis occurred at 29 to >35 ℃ (increase by 1 to >7 ℃). Three of four specimens in *Halobates sericeus* were not paralyzed even at 35 ℃ and resistant to temperature change, while only one of nine in *H. micans.* and only four of twelve in *H. germanus* were not paralyzed at 35 ℃. On average, *H. sericeus, H germanus and H. micans* were paralyzed at >35.6 ℃ (SD: 0.89), >32.9 ℃(SD: 2.17) and >31.6 ℃ (SD: 2.60) on average, respectively.

The 0-10º latitude-area northern against the equator has dynamic systems of ocean and atmosphere in very complicated way. Because of such complicated system, water/air temperatures and water conductivity (salinity) can be in dynamic change temporally and spatially. Sea skaters inhabiting in this area might show relatively high tolerance to temperature changes (heat tolerance). In this study, species complex and reproduction of *Halobates* in this dynamic tropical sea area are examined by the samplings with ORI net trailing, and the tolerance to temperature increase is tested with the Temperature Paralysis Experiment on the adults and 5th instar larvae of *Halobates* collected in this area.

MATERIALS AND METHODS

Samplings

Samples were collected in 24th December, 2006 to 8th January, 2007 with an ORI NET (6 m long and with diameter of 1.5 m.)(Photos 1, 2) . ORI net was trailed for 15min.on the sea surface at 7 stations ranged 0 to 8 degrees west of latitude and 130 or 138 degree east of longitude in the western Pacific Ocean on the right side of R/V MIRAI (8687t) which is owned by JAMSTEC (Japan Agency for Marine-earth Science and TECHnology). The trailing was performed for 15min mainly at night with the ship speed of 2.5 knot to the sea water. (Table 1). It was repeated once or twice in each station. Surface area which was swept by ORI NET was expressed as value of flow-meter x diameter of the ORI NET. During the trailing, duration when the flow meter appears above the water surface was measured and the count of flow-meter was compensated due to the duration.

Laboratory experiment

Sea skaters trapped in the pants (white flaxen bag)**(**Photo 3) located and fixed at the end of ORI net were paralyzed with the physical shock due to the trailing of the ORI net. Such paralyzed sea skaters were transferred on the surface of paper towel and able to respire (Photo 4). Then, the paralysis of some ones was cancelled within 20min. When sea skaters were trapped in the jelly of jelly fishes, the jelly was removed from the body of sea skaters very carefully by hand for the recovering out of the paralysis.

All the adults and 5th instars which were recovered out of the paralysis were moved on to the sea water in the aquaria set in the laboratory for the Heat-Paralysis Experiments. Many aquaria (Photo 5) (transparent round shaped aquaria with 30cm diameter and 15cm high, and white cube aquaria with 30cm X 30cm X 40cm) were prepared in the laboratory of the ship for the rearing of the adults and 5^{th} instars which were recovered out of the paralysis due to the trailing. Each aquarium has ten to twenty adults or 5th instars of *Halobates*. Both the room temperature and sea water temperature in the aquaria were kept 29±1℃. More than 8 hours after the collection, sea skaters were kept in the aquaria before the heat-paralysis experiment. Air was supplied to the sea water in all the aquaria to be against the increase of water surface viscosity due to bacterial activity. Without air supplying system, bodies of sea skaters would be caught by the water film several hours later and could not be kept long in the aquaria. All the individuals of *Halobates* kept in the aquaria were fed on shrimps, copepods and small size of fishes collected with the ORI net trailing before the heat-paralysis experiments.

More than several hours before the heat paralysis experiment, the sea skaters were kept in a aquarium covered by the brown simple box located on the table (Photo 6), with fluorescent lamps on the roof to stabilize the ambient temperature for the sea skaters. The transparent aquarium as the experimental arena has sea water with the same temperature (mostly 28 or 29 ℃) as that of the aquarium in the simple brown paper box from which the experimental specimens (4 to 8 individuals at adult or 5th instar larval stage) were moved. Temperature was stepwise increased by 1℃ every 1 hour till the high temperature paralysis occurring in all the experimental specimens.

Temperature was very precisely controlled by handy-on-off-switching to keep in ±0.3 ℃ of the current water temperature. Handy-stirring with wooden stick and supplying a cool sea water of 10℃ with a syringe were effective to keep the precise controlling of the current temperature. Sea skaters on the water surface of the aquarium were recorded with Digital Handy Video Camera (SONY) from above position for the last fifteen or 30min of each 1hour under the current temperature (Photo 6). Temperature at which Semi High Temperature Paralysis (SHTP: no or little movement on the water surface) and High Temperature Paralysis (HTP: ventral surface of the body was caught by sea water film and no ability to skate any more) were recorded.

RESULTS

Distribution

(Table 1). On the longitudinal line of 130ºE, larvae of both *H. micans* and *H. germanus* were very abundant at 6º N, whereas adults of *H. germanus* were alone completely dominant at 2º N. On the longitudinal line of 138ºE, larvae and adults of *H. micans* were alone dominant at 5 º and 8ºN, while adults of *H. germanus* were abundant at 0º and 2ºN. At the two stations of St. 37 (6º N, 130º E) and St. 52 (5º N, 138º E), relatively many number of larvae of *H. sericeus* which has been known to be distributed in the northern area of the Pacific Ocean were collected. At St. 52 (6º N, 138º E), it was heavily rainy around the ship while trailed.

Halobates sp. (Photos 7, 8) was collected at the remaining 5 stations except St 22 (8ºN, 130ºE) and St. 37 (6ºN, 130 ºE). At St. 41(2ºN, 130 ºE), 166 individuals (mostly larvae) of *Halobates* sp. were collected.

Thousands of eggs laid on the substrate of styrene form and attached shells of an arthropod were collected at St 41(2ºN, 130 ºE)(Photo 9). Another mass of eggs (more than thousands) laid on two pieces of sea bird hair were also collected at St. 52 (5º N, 138º E). Both egg masses were incubated at 24-28℃ of sea water temperature for 10-17 days. Many first instars of *H. germanus* from St 41-egg-mass and of *H. micans* from St. 52-mass were hatched out, respectively.

Laboratory experiment (Table 3 with 6 sheets)

When the water temperature increased stepwise 1℃ every 1 hour, semi-heat-paralysis first occurred at 31.0 ºC (±1.9ºC: SD, n=126) on average for adults, and 31.8ºC (±1.8ºC: SD, n=5) for 5^{th} instars (ranged 29º to 36℃). Then heat-paralysis finally occurred at 33.7 ºC (±2.6ºC: SD, n=131) on average for adults, and 34.2ºC (±2.2ºC: SD, n=5) for 5^{th} instars.(ranged 29º to 40ºC). Heat-paralysis occurred when the temperature was increased by 5.3ºC (±2.6ºC: SD, n=136) on average.

All three values of TSHP, THP and GTHP of *Halobates germanus* were significantly higher than those of *H. mican*s for the experimental specimens from the St.37 (06ºN, 130ºN) in which the comparison between the two species were available (Mann-Whitney U-test, TSHP, z=-3.104, P=0.002; THP, z=-3.024, P=0.002; GTHP, z=-3.129, P=0.002)(Table 3). In *H. micans*, extremely high heat tolerance was shown by the specimen from the St. 55 (08ºN, 138ºN) and moderate tolerance by those from the St 52 (05ºN, 137ºN)(Kruskal-Wallis test: TSHP, χ^2value=3.354, df=2, P=0.187; THP, χ^2value=32.961, df=2, P<0.001; GTHP, χ^2value=35.334, df=2, P<0.001)(Table 3), whereas adults or 5^{th} instar larvae from St. 42 (00ºN, 138ºN) and St. 46 (02ºN, 138ºN) showed extremely high heat tolerance in *H. germanus* (Kruskal-Wallis test: TSHP, χ^2value=4.668, df=2, P=0.097; THP, χ^2value=17.281, df=2, P<0.001; GTHP, χ^2value=20.554, df=2, P<0.001). Experimental specimens from the equator had highest heat tolerance (Mann-Whitney U-test between St. 42 and St. 55, TSHP, z=-1.979, P=0.05; THP, z=-2.259, P=0.024, z=-2.430, P=0.015).

Based on the integrated ANOVA analysis, all of the four factors of longitude, latitude, sex and species significantly affected on heat-paralysis (Table 4). Adults and 5^{th} instar larvae of *H. germanus* showed clearly higher THP and GTHP than those of *H. micans.* Individuals from sites on the line of 138ºE also showed clearly higher THP and GTHP than those from 130ºE. Females showed significantly higher TSHP and THP than males, while significant differences in GTHP was shown among several latitude stations from 0º to 8ºN

Additional analysis

The video camera data will be analyzed very soon after the cruise to examine the frequency and speed of skating and their responses to the temperature differences.

DISCUSSION

Distribution and ocean dynamics

Halobates micans seems to, predominantly, inhabit the area of 5º-8ºN and 12º-15ºN in the Pacific Ocean. , based on this study and another study during another cruise, KH-06-02. With two critical lines of around 2ºN and 15N, *H. germanus* may be predominant in southern and northern areas, respectively, instead in the area 5 to 15ºN. Higher amplitudes of the seasonal and climate fluctuations in temperature, photoperiod and salinity might be going on in the area around equator and may relate to be higher fluctuations in the biological conditions, eg. the components of zooplanktons as preys of sea skaters. Higher fluctuations in one or more factors are proposed to affect the changes in dominant species from *Halobates micans to H. germanus* around the equator. Extremely high resistance to temperature increase in this study might be the survival of *H. germanus* in the specific area with dynamic physical activity of atmosphere and ocean climatically. The key factor(s) to affect the change in the dominant species remain(s) to be examined.

Halobates sericeus has been known to be distributed in the northern area ranged 13-40ºN in the pacific ocean. This species was collected at 5 of 7 stations located at 0º-8ºN. At St. 52 (5ºN, 138ºE), many larvae of this species were detected, and reproduction and growing of larvae seem to occur even in such southern area of the western Pacific Ocean. According to the current dynamics during the cruise, MR-06-05-Leg 3, the colony at St. 52 of this species might be possible to be transferred from the northern area of 14ºN by the three currents of NEC, MC and NECC to the area of 5ºN and 138ºE (Syamsudin and Lukijanto, 2007: Figure 7 in the voyage summary of MR-06-05-Leg 3).

Halobates sp of which many larvae were mainly collected at St.41(02ºN, 130ºE) in this study, is possible to be one of *H. sobrinus* and *H. splendens* both of which have been reported to be distributed limitedly in the eastern region of the Pacific Ocean, or *new "6th oceanic species"* in *Halobates*. Body length of male (apical edge of the head to penis like arrow) is about 9 mm., reach of mid-legs is 35 mm in static posture on the surface (Photo 7). Only three species of *H..micans*, *H. germanus and H. sericeus* have been known in the western Pacific Ocean (Chen, 1985), and this *H. sp* is larger than the "largest" species of the three, *H. micans.*

Heat paralysis

Heat-paralysis can be used as the index to show a resistance to the temperature changes. Even in the specimens inhabiting tropical sampling area (0º-8° N) in the Pacific Ocean, *Halobates germanus* were more hardy to the temperature increases than the larger species, *H. micans* in this study. Extremely high heat resistance was shown in the adults of *H. germanus* in the sea area around the equator. Dynamic current and air movements in this area as "Warm-Sea-Water-Pool" around the equator can be related to the high resistance to heat which was shown in this study. Genetic potential of physiological capability of the high resistance in *H. germanus* seems to be selected naturally in this dynamic area.

High resistance to heat was also shown by *H. micans* inhabiting the area of 5º or 8ºN. During the cruise of MR-06-05-Leg 3, the two currents from north MC and from south NGCC going on the longitude line, 128ºN got together in the line, 5ºN (Syamsudin and Lukijanto, 2007: Figure 7 in the voyage summary of MR-06-05-Leg 3) and continued as the current NECC going to the east. Dynamic mixture of the waters from 12ºN and 0ºN might induce higher fluctuation in the sea water temperature of NECC. Such high dynamic change in water temperature which can be proposed might link to the well hardiness to heat shown by *H. micans* collected at 5ºN and 138ºE.

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Table 1. Number of *Halobates* collected at 7 locations in the western region north to equator in Dec 24, 2006 to Jan 8,2007.

(N:Total number of individuals collected; *H.m.: Halobates micans; H.g.: Halobates germanus; H.s.: Halobates sericeus*; *H.sp.*: *H. sobrinus*, *H. splendens or new Halobates species*; Stat: Station number; WT: Water temperature (℃); AT: Air temp.; L: N of larvae; A: N of adults, E: N of exuviae; Date: sampling date; SS: Area of water surface over which the ORI net was trailed by the ship, R/V MIRAI; Sampling was performed for 45min. or 30min (St.55). At St.22 the net was trailed for 15min. from 14:40 and for 30min. From 18:21 on 24 Dec, 2007.) EG: thousands of eggs laid on the substrate of styrene form (St. 41) or hair of sea bird (St. 52) were collected. No eggs on any substrates were collected at the other 5 stations. .

Latitude	Longitude	N	L	A	*H.m.*	*H.g.*	*H.s.*	*H.sp.*	EG	E	Stat	W T	AT	Time of day	S.S.(m2)	Date .
08°00' N	**130°00' E**	**1**	**0**	**1**	**1**	**0**	**0**	**0**	**X**	**0**	**St. 22**	**29.4**	**28.9**	**18:21-(14:40)**	**48118**	**Dec 24**
06°00' N	**130°00' E**	**1109**	**1019**	**90**	**515**	**545**	**49**	**0**	**X**	**57**	**St. 37**	**29.7**	**30.6**	**05:07-**	**51504**	**Dec 28**
02°00' N	**130°00'E**	**1245**	**316**	**929**	**12**	**1066**	**1**	**166**	○	**4**	**St. 41**	**30.2**	**30.3**	**19:07-**	**46440**	**Dec 29**
00°00' N	**138°00'E**	**83**	**5**	**78**	**3**	**74**	**4**	**2**	**X**	**0**	**St. 42**	**29.3**	**28.0**	**19:06-**	**36333**	**Jan 2**
02°00' N	**138°00'E**	**8**	**2**	**6**	**1**	**5**	**0**	**2**	**X**	**1**	**St.46**	**29.1**	**27.5**	**19:05-**	**40440**	**Jan 4**
05°00' N	**137°00'E**	**1218**	**838**	**380**	**1010**	**48**	**153**	**7**	○	**5**	**St. 52**	**28.9**	**27.5**	**19.05-**	**42281**	**Jan 6**
08°00' N	**138°00'E**	**138**	**112**	**26**	**136**	**0**	**1**	**1**	**X**	**0**	**St. 55**	**28.8**	**28.5**	**19:04-**	**28187**	**Jan 8**
Total		**3802**	**2292**	**1510**	**1678**	**1738**	**208**	**178**		**67**					**293303**	.

Table 2-Sheet 1. Results of "heat-paralysis" experiments performed on 5th instars and adults of *Halobates micans* (H.m.), *H.germanus*(H.g.), *H. sericeus*(H.s.) and another *Halobates* species (H.sp.; *H. sobrinus, H. splendens* or new *species*) . TA: temp. at which specimen adapted, TSHP: temp. at which semi-heat-paralysis occurred; THP: temp. at which heat-paralysis occurred ; GTHP: gap temp. for heat paralysis (from base temp.); "Date and Time of day" when experiments were performed.

St.No.	Latitude(N)	Exp.No.	TA	TSHP	THP	GTHP	Species	Stage (sex)	Date	Time of day
1-1	8	1	29	30	30	1	H.m.	Adult (male)	Dec. 25	10:00~
2-1	6	2	29	31	31	2	H.m.	Adult (female)	Dec. 28	20:45~
2-1	6	2	29	31	31	2	H.m.	Adult (male)	Dec. 28	20:45~
2-1	6	2	29	32	32	4	H.m.	Adult (female)	Dec. 28	20:45~
2-3	6	3	28	29	29	1	H.m.	Adult (female)	Dec. 29	08:35~
2-3	6	3	28	29	29	1	H.m.	Adult (male)	Dec. 29	08:35~
2-3	6	3	28	29	29	1	H.m.	Adult (male)	Dec..29	08:35~
2-3	6	3	28	30	30	2	H.m.	Adult (male)	Dec. 29	08:35~
2-1	6	4	28.5	29	29	0.5	H.m.	Adult (female)	Dec. 29	11:10~
2-1	6	4	28.5	30	31	2.5	H.m.	Adult (female)	Dec. 29	11:10~
2-1	6	4	28.5	31	32	3.5	H.m.	Adult (female)	Dec. 29	11:10~
2-1	6	4	28.5	32	32	3.5	H.m.	Adult (female)	Dec. 29	11:10~
2-1	6	5	28	30	31	3	H.m.	Adult (female)	Dec. 29	21:45~|
2-1	6	5	28	30	31	3	H.m.	Adult (female)	Dec. 29	21:45~
2-1	6	5	28	31	32	4	H.m.	Adult (female)	Dec. 29	21:45~
2-1	6	5	28	31	32	4	H.m.	Adult (female)	Dec. 29	21:45~
2-1, 2-3	6	6	28	31	31	3	H.m.	Adult (female)	Dec. 30	08:25~
2-2, 2-3	6	6	28	31	32	4	H.m.	Adult (female)	Dec. 30	08:25~
2-2, 2-3	6	6	28	31	32	4	H.m.	Adult (female)	Dec. 30	08:25~
2-2, 2-3	6	6	28	31	32	4	H.m.	Adult (female)	Dec. 30	08:25~
2-1	6	7	28.5	32	32	3.5	H.g.	Adult (male)	Dec. 30	16:25~
2-1	6	7	28.5	32	33	4.5	H.g.	Adult (male)	Dec. 30	16:25~
2-1	6	7	28.5	32	34	5.5	H.g.	Adult (male)	Dec. 30	16:25~
2-1	6	7	28.5	32	33	4.5	H.g.	Adult (female)	Dec. 30	16:25~
2-1	6	7	28.5	32	34	5.5	H.g.	Adult (female)	Dec. 30	16:25~

Table 2-Sheet 2. Results of "heat-paralysis" experiments performed on 5th instars and adults of *Halobates micans* (H.m.),*H.germanus*(H.g.),*H.sericeus*(H.s.)

St.No.	Latitude(N)	Exp.No.	TA	TSHP	THP	GTHP	Species	Stage (sex)	Date	Time of day
2-3	6	8	28	32	33	5	H.g.	Adult (female)	Dec. 31	09:00~
2-1	6	8	28	30	31	3	H.g.	5th instar	Dec. 31	09:00~
2-1	6	8	28	32	33	5	H.g.	5th instar	Dec. 31	09:00~
3-2	2	9	28	30	32	4	H.g.	Adult (female)	Jan. 2	07:00~
3-2	2	9	28	31	32	4	H.g.	Adult (female)	Jan. 2	07:00~
3-2	2	9	28	30	31	3	H.g.	Adult (male)	Jan. 2	07:00~
3-2	2	9	28	31	31	3	H.g.	Adult (male)	Jan. 2	07:00~
3-2	2	9	28	31	32	4	H.g.	Adult (male)	Jan. 2	07:00~
3-1, 3-2	2	10	29	29	30	1	H.g.	Adult (female)	Jan. 2	12:30~
3-1, 3-2	2	10	29	30	30	1	H.g.	Adult (female)	Jan. 2	12:30~
3-1, 3-2	2	10	29	30	32	3	H.g.	Adult (female)	Jan. 2	12:30~
3-1, 3-2	2	10	29	30	32	3	H.g.	Adult (female)	Jan. 2	12:30~
3-1, 3-2	2	10	29	30	30	1	H.g.	Adult (male)	Jan. 2	12:30~
3-1, 3-2	2	10	29	30	31	2	H.g.	Adult (male)	Jan. 2	12:30~
3-1, 3-2	2	11	29	29	30	1	H.g.	Adult (female)	Jan. 2	20:45~
3-1, 3-2	2	11	29	30	32	3	H.g.	Adult (female)	Jan. 2	20:45~
3-1, 3-2	2	11	29	33	33	4	H.g.	Adult (female)	Jan. 2	20:45~
3-1, 3-2	2	11	29	30	31	2	H.g.	Adult (male)	Jan. 2	20:45~
3-1, 3-2	2	11	29	31	32	3	H.g.	Adult (male)	Jan. 2	20:45~
3-1, 3-2	2	11	29	31	33	4	H.g.	Adult (male)	Jan. 2	20:45~
3-1, 3-2	2	11	29	33	34	5	H.g.	Adult (male)	Jan. 2	20:45~

Table 2-Sheet 3. Results of "heat-paralysis" experiments performed on 5th instars and adults of *Halobates micans* (H.m.),*H.germanus*(H.g.),*H.sericeus*(H.s.).

St.No.	Latitude(N)	Exp.No.	TA	TSHP	THP	GTHP	Species	Stage (sex)	Date	Time of day
4-3	0	12	28	29	38	10	H.g.	Adult (female)	Jan. 3	07:55~
4-3	0	12	28	29	38	10	H.g.	Adult (female)	Jan. 3	07:55~
4-3	0	12	28	30	38	10	H.g.	Adult (female)	Jan. 3	07:55~
4-3	0	12	28	34	38	10	H.g.	Adult (female)	Jan. 3	07:55~
4-3	0	12	28	34	38	10	H.g.	Adult (female)	Jan. 3	07:55~
4-3	0	12	28	33	36	8	H.g.	5th instar	Jan. 3	07:55~
4-3	0	12	28	33	33	5	H.g.	Adult (male)	Jan. 3	07:55~
4-1,2,3	0	13	27.5	29	30	2.5	H.g.	Adult (female)	Jan. 4	05:30~
4-1,2,3	0	13	27.5	29	37	9.5	H.g.	Adult (female)	Jan. 4	05:30~
4-1,2,3	0	13	27.5	30	37	9.5	H.g.	Adult (female)	Jan. 4	05:30~
4-1,2,3	0	13	27.5	30	39	11.5	H.g.	Adult (female)	Jan. 4	05:30~
4-1,2,3	0	13	27.5	31	40	12.5	H.g.	Adult (female)	Jan. 4	05:30~
4-1,2,3	0	13	27.5	29	29	1.5	H.g.	Adult (male)	Jan. 4	05:30~
4-1,2,3	0	13	27.5	29	39	11.5	H.g.	Adult (male)	Jan. 4	05:30~
4-1,2,3	0	13	27.5	36	39	11.5	H.g.	Adult (male)	Jan. 4	05:30~
4-3	0	14	28	28	33	5	H.m	Adult (female)	Jan. 5	05:45~
5-2	2	14	28	29	34	6	H.g.	Adult (male)	Jan. 5	05:45~
5-2	2	14	28	30	35	7	H.g.	Adult (male)	Jan. 5	05:45~
5-3	2	14	28	34	35	7	H.g.	5th instar	Jan. 5	05:45~
6-1	5	15	28.5	30	32	3.5	H.m.	Adult (female)	Jan. 7	05:15~
6-1	5	15	28.5	32	33	4.5	H.m.	Adult (female)	Jan. 7	05:15~
6-1	5	15	28.5	32	33	4.5	H.m.	Adult (female)	Jan. 7	05:15~
6-1	5	15	28.5	30	32	3.5	H.m.	Adult (female)	Jan. 7	05:15~
6-1	5	15	28.5	29	32	3.5	H.m.	Adult (male)	Jan. 7	05:15~
6-1	5	15	28.5	32	33	4.5	H.m.	Adult (male)	Jan. 7	05:15~
6-1	5	15	28.5	32	34	5.5	H.m.	Adult (male)	Jan. 7	05:15~
6-1	5	15	28.5	33	35	6.5	H.m.	Adult (male)	Jan. 7	05:15~

Table 2-Sheet 4. Results of "heat-paralysis" experiments performed on 5th instars and adults of *Halobates micans*(H.m.),*H.germanus*(H.g.),*H.sericeus*(H.s.).

St.No.	Latitude(N)	Exp.No.	TA	TSHP	THP	GTHP	Species	Stage (sex)	Date	Time of day
6-2	5	16	28.5	30	32	3.5	H.m.	Adult (female)	Jan. 7	12:30~
6-2	5	16	28.5	31	32	3.5	H.m.	Adult (female)	Jan. 7	12:30~
6-2	5	16	28.5	31	32	3.5	H.m.	Adult (female)	Jan. 7	12:30~
6-2	5	16	28.5	32	35	6.5	H.m.	Adult (female)	Jan. 7	12:30~
6-2	5	16	28.5	29	30	1.5	H.m.	Adult (male)	Jan. 7	12:30~
6-2	5	16	28.5	29	31	2.5	H.m.	Adult (male)	Jan. 7	12:30~
6-2	5	16	28.5	29	33	4.5	H.m.	Adult (male)	Jan. 7	12:30~
6-2	5	16	28.5	30	35	6.5	H.m.	Adult (male)	Jan. 7	12:30~
6-3	5	17	29	32	35	6	H.m.	Adult (female)	Jan. 8	05:00~
6-3	5	17	29	33	36	7	H.m.	Adult (female)	Jan. 8	05:00~
6-3	5	17	29	35	36	7	H.m.	Adult (female)	Jan. 8	05:00~
6-3	5	17	29	35	37	8	H.m.	Adult (female)	Jan. 8	05:00~
6-3	5	17	29	29	31	2	H.m.	Adult (male)	Jan. 8	05:00~
6-3	5	17	29	31	36	7	H.m.	Adult (male)	Jan. 8	05:00~
6-3	5	17	29	33	36	7	H.m.	Adult (male)	Jan. 8	05:00~
6-3	5	17	29	35	37	8	H.m.	Adult (male)	Jan. 8	05:00~
7-2	8	18	28	31	35	7	H.m.	Adult (female)	Jan. 9	07:30~
7-2	8	18	28	32	35	7	H.m.	Adult (female)	Jan. 9	07:30~
7-2	8	18	28	32	35	7	H.m.	Adult (female)	Jan. 9	07:30~
7-2	8	18	28	34	35	7	H.m.	Adult (female)	Jan. 9	07:30~
7-2	8	18	28	35	36	8	H.m.	Adult (female)	Jan. 9	07:30~
7-2	8	18	28	31	35	7	H.m.	Adult (male)	Jan. 9	07:30~
7-2	8	18	28	31	35	7	H.m.	Adult (male)	Jan. 9	07:30~
7-2	8	18	28	31	37	9	H.m.	Adult (male)	Jan. 9	07:30~

Table 2-Sheet 5. Results of "heat-paralysis" experiments performed on 5th instars and adults of *Halobates micans* (H.m.), *H.germanus*(H.g.),*H.sericeus*(H.s.).

St.No.	Latitude(N)	Exp.No.	TA	TSHP	THP	GTHP	Species	Stage (sex)	Date	Time of day
7-2	8	19	28.5	30	36	7.5	H.m.	5th instar	Jan. 9	18:00~
7-2	8	19	28.8	35	36	7.2	H.sp.	Adult (female)	Jan. 9	18:00~
7-2	8	19	28.7	31	34	5.3	H.m.	Adult (female)	Jan. 9	18:00~
7-2	8	19	28.7	31	35	6.3	H.m.	Adult (female)	Jan. 9	18:00~
7-2	8	19	28.7	-	36	7.3	H.m.	Adult (female)	Jan. 9	18:00~
7-2	8	19	28.7	-	36	7.3	H.m.	Adult (female)	Jan. 9	18:00~
7-2	8	19	28.5	32	35	6.5	H.m.	Adult (male)	Jan. 9	18:00~
7-2	8	19	28.5	-	36	7.5	H.m.	Adult (male)	Jan. 9	18:00~
6-2,6-3	5	20	28.5	30	35	6.5	H.m.	Adult (female)	Jan. 10	02:40~
6-2,6-3	5	20	28.5	33	35	6.5	H.m.	Adult (female)	Jan. 10	02:40~
6-2,6-3	5	20	28.5	35	37	8.5	H.m.	Adult (female)	Jan. 10	02:40~
6-2,6-3	5	20	28.5	36	38	9.5	H.m.	Adult (female)	Jan. 10	02:40~
6-2,6-3	5	20	28.7	29	37	8.3	H.m.	Adult (male)	Jan. 10	02:40~
6-2,6-3	5	20	28.7	30	37	8.3	H.m.	Adult (male)	Jan. 10	02:40~
6-2,6-3	5	20	28.7	33	37	8.3	H.m.	Adult (male)	Jan. 10	02:40~
6-2,6-3	5	20	28.7	35	38	9.3	H.m.	Adult (male)	Jan. 10	02:40~
6-3	5	21	28.7	29	34	5.3	H.m.	Adult (female)	Jan. 10	12:45~
6-3	5	21	28.7	31	35	6.3	H.m.	Adult (female)	Jan. 10	12:45~
6-3	5	21	28.7	33	36	7.3	H.m.	Adult (female)	Jan. 10	12:45~
6-3	5	21	28.7	34	36	7.3	H.m.	Adult (female)	Jan. 10	12:45~
6-1	5	21	28.2	29	34	5.8	H.m.	Adult (male)	Jan. 10	12:45~
6-1	5	21	28.2	30	33	4.8	H.m.	Adult (male)	Jan. 10	12:45~
6-1	5	21	28.2	31	33	4.8	H.m.	Adult (male)	Jan. 10	12:45~
6-1	5	21	28.2	33	36	4.8	H.m.	Adult (male)	Jan. 10	12:45~

Table 2-Sheet 6. Results of "heat-paralysis" experiments performed on 5th instars and adults of *Halobates micans* (H.m.), *H.germanus*(H.g.) and *H. sericeus*(H.s.). TA: temp. at which specimen adapted, THP: temp. at which heat-paralysis occurred."Date and Time of day" when experiments were performed.

St.No.	Latitude(N)	Exp.No.	TA	TSHP	THP	GTHP	Species	Stage (sex)	Date	Time of day
6-3	5	22	28.2	28	33	4.8	H.m.	Adult (female)	Jan. 11	05:00~
6-3	5	22	28.2	33	35	6.8	H.m.	Adult (female)	Jan. 11	05:00~
6-3	5	22	28.2	33	35	6.8	H.m.	Adult (female)	Jan. 11	05:00~
6-1,6-2	5	22	27.5	28	34	6.5	H.m.	Adult (male)	Jan. 11	05:00~
6-1,6-2	5	22	27.5	28	34	6.5	H.m.	Adult (male)	Jan. 11	05:00~
6-1,6-2	5	22	27.5	28	35	7.5	H.m.	Adult (male)	Jan. 11	05:00~
6-1,6-2	5	22	27.5	29	35	7.5	H.m.	Adult (male)	Jan. 11	05:00~
6-1,6-2	5	22	27.5	32	35	7.5	H.m.	Adult (male)	Jan. 11	05:00~
6-3	5	22	28.2	29	34	5.8	H.g.	Adult (female)	Jan. 11	05:00~
4-2	0	23	27.5	29	31	3.5	H.sp.	Adult (male)	Jan. 11	13:25~
5-2	2	23	27.7	29	31	3.3	H.sp.	Adult (female)	Jan. 11	13:25~
6-2	5	23	27.5	29	31	3.5	H.sp.	Adult (male)	Jan. 11	13:25~
6-2	5	23	27.9	30	31	3.1	H.m.	Adult (female)	Jan. 11	13:25~
6-2	5	23	27.9	30	31	3.1	H.m.	Adult (female)	Jan. 11	13:25~
6-3	5	23	27.4	29	32	4.6	H.s.	Adult (female)	Jan. 11	13:25~
6-2	5	23	27.9	30	32	4.1	H.m.	Adult (female)	Jan. 11	13:25~

Table 3. Results of heat paralysis experiment. Temperatures at which semi-heat-paralysis (TSHP, ℃) and heat paralysis (THP, ℃) occurred and gap temperature (temp. difference between adaptation temp and THP, ℃) were shown at each sampling station for *Halobates micans* and *H. germanus*. Data from 12ºN-1717ºN, 130º-140ºE after Harada et al (2006)

	Halobates micans			*H. germanus*		
Station	TSHP	THP	GTHP	TSHP	THP	GTHP
06ºN, 130º N	30.5±0.95 (19)	31.1±1.35 (19)	2.66±1.18 (19)	31.8±0.71 (8)	32.9±0.99 (8)	4.44±1.02 (8)
02ºN, 130ºN	-	-	-	30.5±1.10 (18)	31.6±1.15 (18)	2.83±1.25 (18)
00ºN, 138ºN	28.0 (1)	33.0 (1)	5.0 (1)	31.0±2.35 (15)	36.6±3.31 (15)	8.86±3.29 (15)
02ºN, 138ºN	-	-	-	31.0±2.65 (3)	34.7±0.58 (3)	6.50±0.50 (3)
05ºN, 138ºN	31.3±2.20 (52)	34.4±1.97 (52)	5.92±1.86 (52)	29 (1)	34 (1)	6.5 (1)
08ºN, 138ºN	31.8±1.42 (12)	35.4±0.74 (15)	6.93±0.88 (15)	-	-	-
15 N, 130-140E	-	-	-	-	32.9±2.17 (11)	4.27±1.90 (11)
13 N, 130-140E	-	31.6±2.60 (9)	3.44±2.40 (9)	-	-	-

Table 4. Results of ANOVA on the effects of longitude, latitude, sex and species on TSHP, THP and GTHP.

	TSHP			THP			GTHP		
	df	**F-value**	**P-value**	**df**	**F-value**	**P-value**	**df**	**F-value**	**P-value**
Latitude	4	1.719	0.150	4	2.179	0.075	4	3.85	0.006
Longitude	1	3.414	0.067	1	74.07	<0.001	1	87.04	<0.001
Sex	1	6.620	0.011	1	5.034	0.027	1	2.919	0.090
Species	3	1.645	0.183	3	7.882	< 0.001	3	7.581	<0.001

Photo 1. ORI net trailed on the surface of the western Pacific Ocean on the right side of R/V MIRAI at night with the ship speed of 2.5 knot to the sea water. The net is 6 m long and with diameter of 1.5 m.

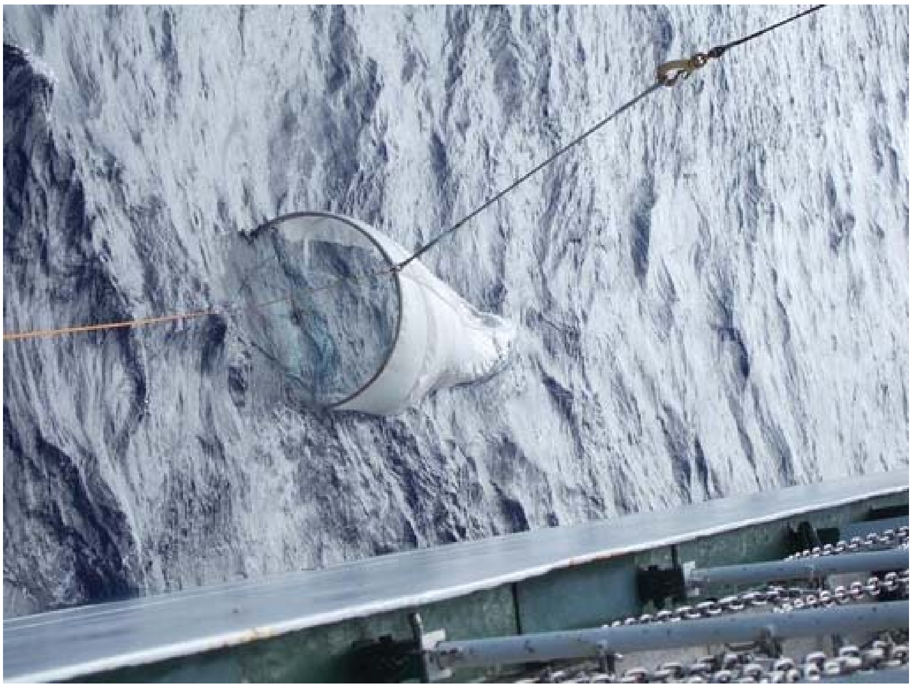

Photo 2. ORI net trailed on the surface of the western Pacific Ocean on the right side of R/V MIRAI during daytime with a ship speed of 2.5 knot to the sea water.

Photo 3. After the trailing of ORI net, the white bag so called "Pants" is being removed from the transparent cylinder united with the end of the net, sea skaters trapped in the Pants transferred to the transparent round-shaped aquarium.

Photo 4. Sea skaters trapped in the pants were paralyzed with the physical shock due to the trailing of the ORI net. However, if such paralyzed sea skaters were transferred on the surface of paper towel and able to respire, the paralysis of some ones can be cancelled. When sea skaters were trapped in the jelly of jelly fishes, the jelly should be removed from the body of sea skaters very carefully by hand for the recovering out of the paralysis. All the adults and 5th instars which were recovered from the paralysis were moved on to the sea water in another aquarium for the Heat-Paralysis Experiments.

Photo 5. Many aquaria seen on the floor have ten to twenty adults or 5th instars of *Halobates.*
Both the room temperature and sea water temperature in the aquaria were kept 29±1℃. For more than 8 hours after the collection, sea skaters were kept in the aquaria. Air was supplied to the sea water in all the aquaria to be against the increase of water surface viscosity due to bacterial activity. Without air supplying system, bodies of sea skaters were caught by the water film several hours later and could not be kept in orders long in the aquaria. More than several hours before the heat paralysis experiment, the sea skaters were moved into the brown simple boxes with fluorescent lamps on the roof to stabilize the ambient temperature for the sea skaters.

Photo 6. A scene of the Heat Paralysis Experiment. A transparent and experimental aquarium has sea water with the same temperature (mostly 28 or 29 ℃) as that of aquarium (in the simple brown paper box) from which the experimental specimens (4 to 8 individuals at adult or 5th instar larval stage) were transferred to the experimental aquarium. Temperature was stepwise increased by 1 ℃ every 1hour till the high temperature paralysis occurring in all the experimental specimens. Temperature was very precisely controlled by handy-on-off-switching to keep in ±0.3 of the current water temperature. Handy-stirring with wooden stick and supplying a cool sea water with 10 ℃ in a syringe were effective to keep the precise controlling of the current temperature. Sea skaters on the water surface of the experimental aquarium were recorded by a handy-video-camera from above for the last fifteen or 30min of each 1hour at the current temperature.

Photo 7. Male adult of *Halobates sp*. which was collected at St 42 (2-00 N, 130-00 E). This specimen is possible to be one of *H. sobrinus* and *H. splendens*, both of which have been reported to be distributed only in the eastern region of the Pacific Ocean, or “the new 6th species” in oceanic *Halobates*. Body length (apical edge of the head to penis like arrow) is about 9 mm. Reach of mid-legs is 35 mm in this posture. Only three species of *H.micans, H. germanus and H. sericeus* have been known, so far, in the western Pacific Ocean, and this specimen is larger than the “largest” species of the three, *H. micans.*

Photo 8. Zoomed-in-photo of Photo 1.

Photo 9. Thousands of eggs laid on the substrate of styrene form and attached shells of an arthropod were collected at St 41, 2-00N, 130-00E. Another mass of eggs laid on two pieces of sea bird hair were also collected at St. 52, 5-00N, 138-00E. Original white color of the styrene form and the arthropod shells were changed to brownish one due to eggs laid all over the surface. Diameter of the transparent tube as scale is 1cm.

7.10 Recovery of OBEM

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Aki Ito (Institute for Research on Earth Evolution / JAMSTEC)

7.10.1 Scientific objectives

This mission is a part of works on an investigation of "Petit Spot", new-type volcanoes recently discovered in northwestern Pacific Ocean (37°30'N, 149°45'E). Volcanoes in the world distribute along plate boundaries, such as mid-ocean ridges (East Pacific Rise, Mid Atlantic Ridge, etc.) and island arcs near trenches (Japan Trench, Izu-Bonin-Mariana Trenches, Tonga Trench, etc.). The magma of these type volcanoes are generated in the upper most mantle (50~100 km below surface), associated with plate accretion and subduction processes. There are some intra-plate volcanoes called hot spots such as Hawaii, islands in French Polynesia, which are not related to the surface plate tectonics but are associated with upwelling from deep in the mantle (650~2900 km below surface). Petit Spot may be categorized as the intra-plate volcanisms. However, Petit Spot consists of very small monogenetic volcanoes (< 1 km diameter) and its generation process is thought to be different from that of the hot spots. Hirano *et al.* (2006) demonstrate some geochemical evidences that the Petit Spot magma originates in the upper most mantle. They also proposed an eruption mechanism that the magma ascends in the cracks produced by flexure of the Pacific Plate in advance of subduction in Japan Trench (Figure 7.10.1). Their hypothesis implies that Petit Spot like volcanoes may occur anywhere else. If so, Petit Spot volcanism is very important for elucidating the thermal and material circulations of the solid Earth.

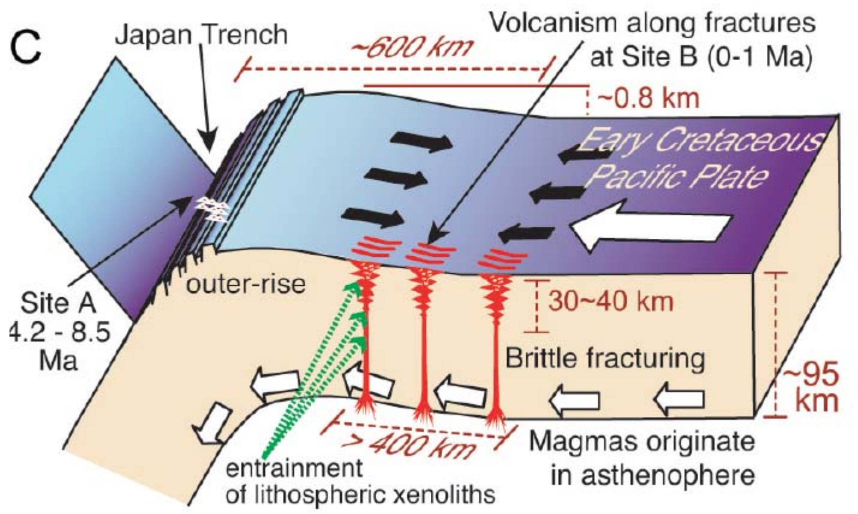

Figure 7.10.1. A conceptual model of the Petit Spot volcanism After Hirano et al., (2006).

A multidiscipline observation project has been started up in order to investigate the processes of the Petit Spot magma generation and eruption and their distributions. The project consists of the high resolution mapping of topography and back scatter intensity using multi-narrow beam sounding system, mapping of the surface gravity and geomagnetic fields, sediment and rock sampling, heat flow measurement, seismic and electromagnetic surveys, and geodynamic modeling study by collaboration among IFREE/JAMSTEC, University of Tokyo, Scripps Institution of Oceanography, and Kyoto University. A magnetotelluric (MT) survey using ocean bottom electromagnetometers (OBEMs) is carried out as a part of this project.

MT soundings provide us an image of electrical feature of Earth's interior. Because electrical conductivity of the mantle materials is strongly dependent of temperature, partial melt, and volatiles such as water, electrical conductivity structure models estimated through seafloor MT surveys are definitely useful to discuss where the source of the Petit Spot volcanic activity is and its relation to the mantle dynamics. For these objectives, we planed a seafloor MT experiment using six OBEMs and deployed them during the cruise “R/V Yokosuka YK05-06” in May, 2005. The experiment targets two

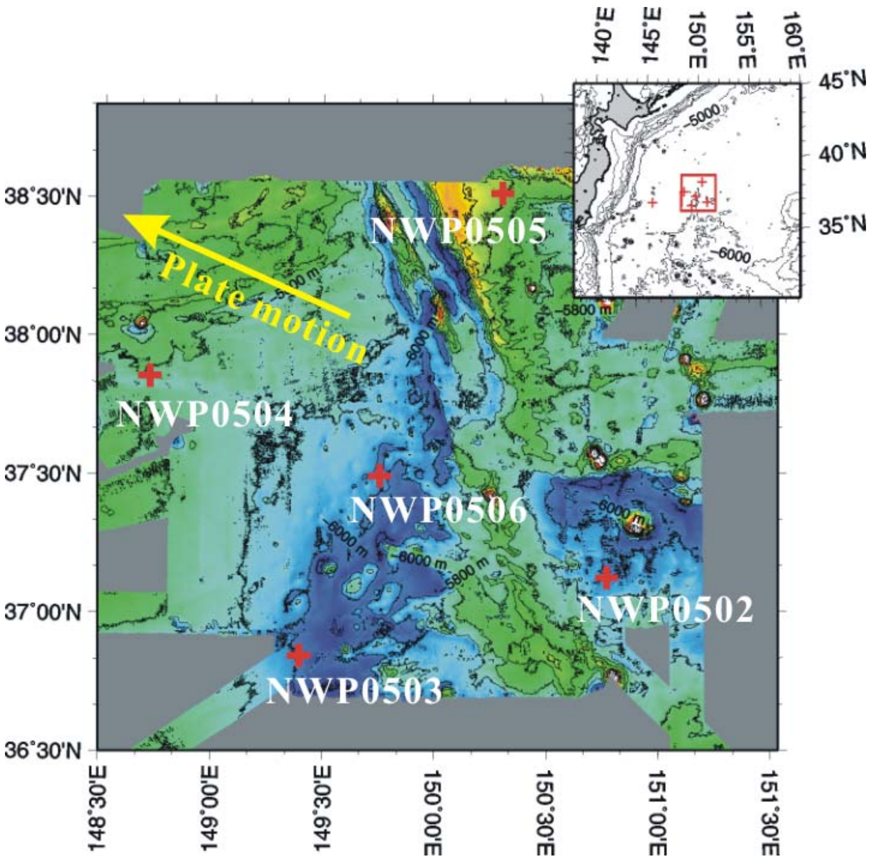

Figure 7.10.2. Bathymetry of the Petit Spot area. Red crosses indicate the locations of the observation sites.

points: 1) Semi-regional structure of the lithosphere and asthenosphere beneath the Petit Spot area based on 10-weeks observation. 2) Regional upper mantle structure in the northwestern Pacific Ocean based on one-year observation.

The first target is focused on the source area of the Petit Spot magma. Five OBEMs are deployed on cross-shape array centering on Yukawa knoll (a volcano that fresh basaltic rocks were sampled.) with ~100 km intervals (Figure 7.10.2). We investigate the electrical conductivity of the lithosphere and asthenosphere down to 200 km depth where the peterological studies suggest that the melt generated. One of the most basic questions, whether the asthenosphere is partially molten everywhere and hence Petit Spot is just an indication of pathway to the surface or the asthenosphere beneath the Petit Spot area is anomalous with high temperature or high contents of volatiles resulting in partial melt, can be answered through the electrical conductivity structure.

The cross-shape observation array is also designed for dealing easily with the anisotropic electrical conductivity, setting the OBEM sites on the lines parallel to and perpendicular to the current motion of the Pacific plate. Recent seafloor MT study has revealed that the electrical conductivity of the asthenosphere in the East Pacific Rise is mainly controlled by water (hydrogen dissolved in minerals) and anisotropic, suggesting the lattice preferred orientation of mantle minerals (Baba *et al.*, 2006). However, it is still unknown whether the electrical conductivity of old oceanic asthenosphere is anisotropic or not. This study is also the first attempt in the world about this point. Observation during ~10 weeks would be enough for the exploration of the asthenospheric depth. Consequently, the OBEMs deployed at the four sites (NWP0503 – NWP0506) were recovered during the cruise "R/V Kairei KR05-10" in August, 2005.

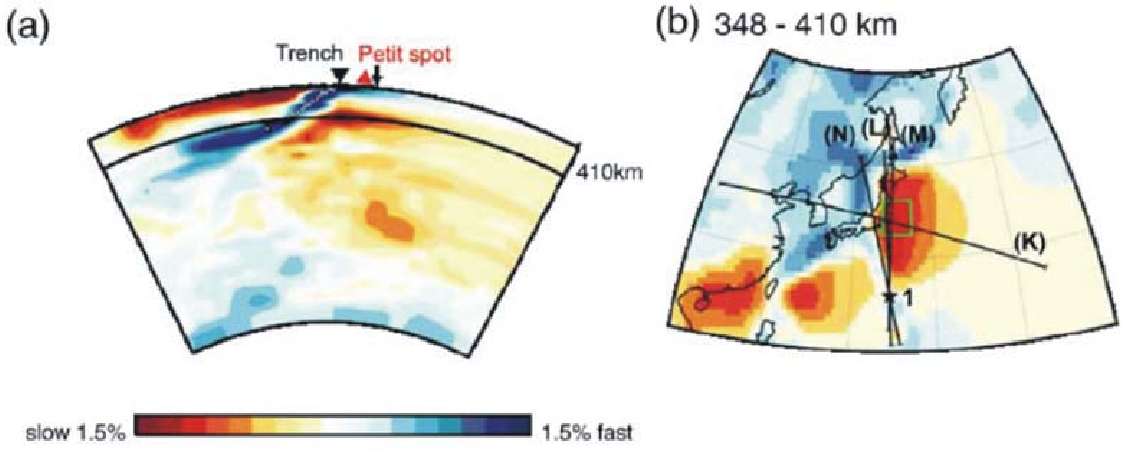

Figure 7.10.3. Seismic tomography model by Obayashi *et al.* (2006). Color indicates the perturbation of P-wave velocity to a reference model. A cross section along the profile K and a plan view map at depth range of 348 – 410 km (b) are shown. Strong slow anomaly exists at ~400 km oceanward of the fast anomaly (subducting Pacific plate).

The other site is common to the long-term site (NWP0502), which locates on the southern east point of the array.

The second target is motivated from a study of global seismic tomography. The P-wave velocity structure model (Obayashi *et al.*, 2006) shows a remarkable low velocity region at depths of 300 – 600 km beneath the outer rise (Figure. 7.10.3). The low velocity region seems to extend to the Petit Spot area, although its eastern margin is not well resolved by the land-based tomography. Low velocity anomalies are frequently interpreted as high temperature anomalies and hence the low velocity region beneath the outer rise may suggest an upwelling of high temperature materials. However, the upwelling adjacent to the downwelling of the Pacific plate is implausible under realistic mantle viscosity. For elucidating the physical state of the mantle more accurately, analyzing both the seismic velocity and electrical conductivity is critical. Ichiki *et al.* (2006) developed a method to distinguish the thermal and compositional (hydrogen)

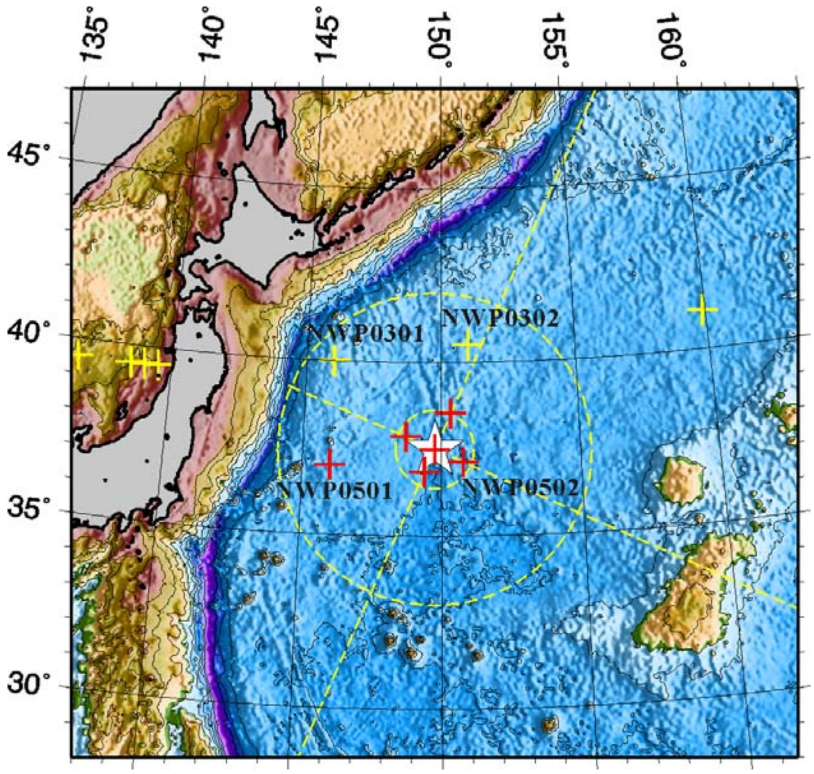

Figure 7.10.4. Regional bathymetry map and MT site locations in northwestern Pacific Ocean. The contour interval is 1000 m. Red crosses are the OBEM sites deployed during the cruise “R/V Yokosuka YK05-06”. Yellow crosses are the sites where MT data were collected in previous experiments. Star indicates the location of Yukawa knoll, where the fresh alkali basalts were discovered. Dashed lines indicate the directions parallel to and perpendicular to the current motion of the Pacific plate and circles centering on Yukawa knoll with diameters of 1000 km and 250 km, respectively.

effects on electrical conductivity by referring seismic P-wave velocity. Applying Ichiki *et al.*'s method to the northwestern Pacific region enables us to discuss the physical states and dynamics, which may be related to Petit Spot.

We have carried out a long-term seafloor MT survey in the northwestern Pacific Ocean since 2003 to reveal the regional structure of the upper mantle down to ~400 km depth. One-year-long MT data were corrected at sites NWP0301 and NWP0302. Two sites were newly deployed during the cruise “R/V Yokosuka YK05-06”, NWP0501 and NWP0502, respectively locate ~350 km south of the sites NWP0301 and NWP0302 (Figure. 7.10.4). These sites are designed for one-year observation. We aim to obtain a three-dimensional (3-D) electrical conductivity structure model of the upper mantle in the region by analyzing these data jointly.

7.10.2 The background of attending the cruise MR06-05 leg 3

The OBEM that we tried to recover in this cruise is the one at site NWP0502 (37°07.8’N, 150°46.7E, 5993m). The other five OBEMs had already been recovered during the cruise “R/V Kairei KR05-10”. The OBEMs at sites NWP0501 and NWP0502, which were deployed for one-year observation, were planed to recover in May, 2006. However, the OBEM at NWP0501 was recovered during the KR05-10 cruise because weak response to the acoustic communication was found. In the same cruise, we also found that the OBEM at NWP0502 did not respond at all but we left it as the original plan without trying the recovery.

The trouble of the acoustics was seen for some of the short-term OBEMs. The OBEMs did not respond stably. However, once the release command was sent and OBEM approached to the surface, the response became clear and stable. All the OBEMs were settled on more than 5000 m deep seafloor. Such deep deployment was the first case for the acoustic system mounted on the OBEMs although it is within the specific. The distance of the reestablishment is not systematic among the OBEMs. We tested the acoustic pressure of the transducer mounted on the OBEM at NWP0501 after the recovery. However, it was strong enough for use in the deep ocean. After all, decay of the acoustic signal due to the long distance is suspected but the true reason is still unknown.

We applied the public offering of JAMSTEC deep see research cruises in order to recover the OBEM at NWP0502 in May 2006, but we failed. Because the battery of the acoustic system of the OBEM is available only two years from the deployment, we must recover the OBEM by May 2007. Thus, we scouted about other possibilities. After hard negotiations, we were given an opportunity to attend this cruise by special goodwill of

JAMSTEC.

7.10.3 The instrument

OBEM is an instrument to measure time variations of magnetic and electric fields on seafloor. The OBEM that we tried to recover in this cruise is the third generation of the two-glass-sphere type OBEM (the model name is OBEM2001R) made by Tierra Tecnica Ltd. (Figure 7.10.5). The one glass sphere houses fluxgate magnetic field sensors for three components, instrument tilt sensors and the data logger. Those are powered by lithium batteries packed in the other glass sphere. An acoustic transponder is also housed in the battery glass sphere. Silver–silver chloride electrodes are attached to the end of each pipe. The data are recorded on a compact flash memory card. Table 7.10.1 shows that the specification of the digital recording system of the OBEM.

The OBEM is equipped with acoustic communication system produced by Kaiyo Denshi Co., Ltd., lead weight, a radio beacon and a flushing light. In recovery time, the OBEM releases the weight according to acoustic command from ship, and then pops up

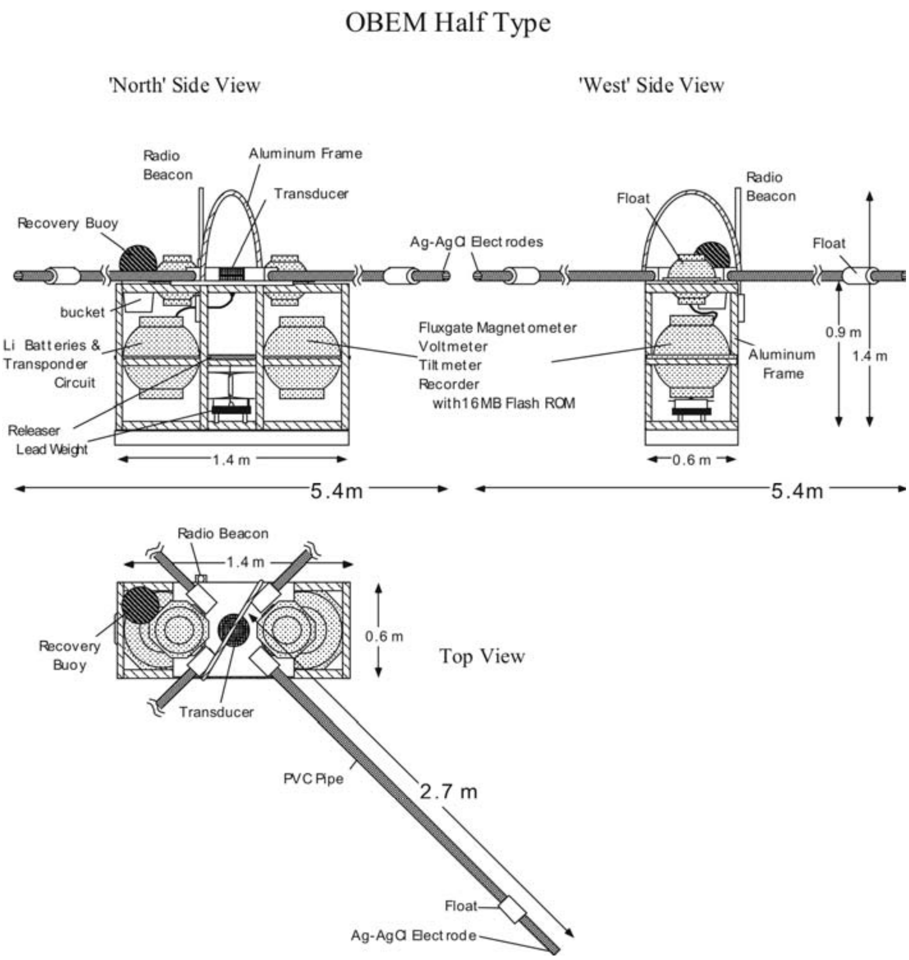

Figure 7.10.5. A sketch of OBEM.

by self-buoyancy. The radio beacon and flushing light have pressure switch which is turned off under water pressure. Once the OBEM reaches to sea surface, they start working and help our finding the OBEM. The flushing light has a light sensor which works when it is dark. It is very useful to find the OBEM in nighttime. The OBEM also mount a recovery buoy-rope system. The buoy is released from a bucket when the lead weight is released, and it drags a rope stored in a bucket. It is for easier recovery of OBEMs at the time of their retrieval. We can easily catch the OBEM from shipboard by catching the buoy and hauling on the rope.

In this cruise, we rented an acoustic relay system from Kobe University and brought it, as an option for the recovery because the OBEM did not respond to the signal from the ship in the previous cruise. The relay system is available in a case that the OBEM can hear the signal from ship but cannot respond with enough volume. The relay system is attached to the CTD frame and suspended at the middle of the water depth. We call the relay system from the ship with different frequency and code (SI-II mode). Then, the relay system calls the OBEM with the right frequency (JX mode, 11.029 kHz) and waits the response and send the result to the ship with SI-II mode.

A further option for calibration of the OBEM's position was prepared. We attach a Benthos transponder housed in 10 inch glass sphere to the CTD frame together with the relay system. The transponder frequencies (Tx: 13.0 kHz, Rx: 14.0 kHz) is available for the hull transducer and SSBL system of the R/V Mirai. Thus, we can track the accurate position of the relay system. It allows us to estimate the OBEM position when slant ranges are measured at least three locations.

Table 7.10.1. Specifics of the OBEM at NWP0502.

Specific of OBEM2001R				
Measurement field	**A/D transform**	**Dynamic range**	**Resolution**	**Note**
Magnetic field	16 bits	± 327.68 nT	10 pT	N,E positive
Electric field	16 bits	± 10mV	0.305176 µV	S,W positive
Instrument tilt	16 bits	± 8.192 deg.	約 0.00025 deg.	N down, W down positive
Temperature	18000 digits	-55～125 °C	0.01 °C	
Specific of the acoustic system (Kaiyo Denshi)				
Transmit frequency		11.029 kHz		
Receive frequency		14.500 kHz		
Release code		1B-3		
Specific of the radio beacon (NOVATECH RF-700A3)				
Frequency		43.528 MHz		
Code		JS1363		

7.10.4 Recovery work and the results

We arrived at the recovery point at 13:00 on January 15th 2007 (JST). The time limit to leave the point was at 13:00 on 16th. We can work only in day time (sun set is about 16:00) for safety. On the first day, we didn't have enough time to recover the OBEM because the ascending rate of the OBEM is about 35 m/min so that it takes about three hours to surface from 6000 m seafloor. Further, the sea state is too bad (wave height is about 4 m) to use the relay system mounted on CTD frame. Thus, we just call the OBEM by using a transducer hanged from the starboard side of the ship. We tried the measurements at three different positions centering the point that the OBEM was launched. We continued calling about 30 minutes at each run. During runs ship was drifted to southeast due mainly to wind and wave (Figure 7.10.6). Acoustic noise condition is not bad although the ship keep letting in the clutch to control its attitude. However, we didn't receive any response from the OBEM at all. We gave up the communication at 16:09.

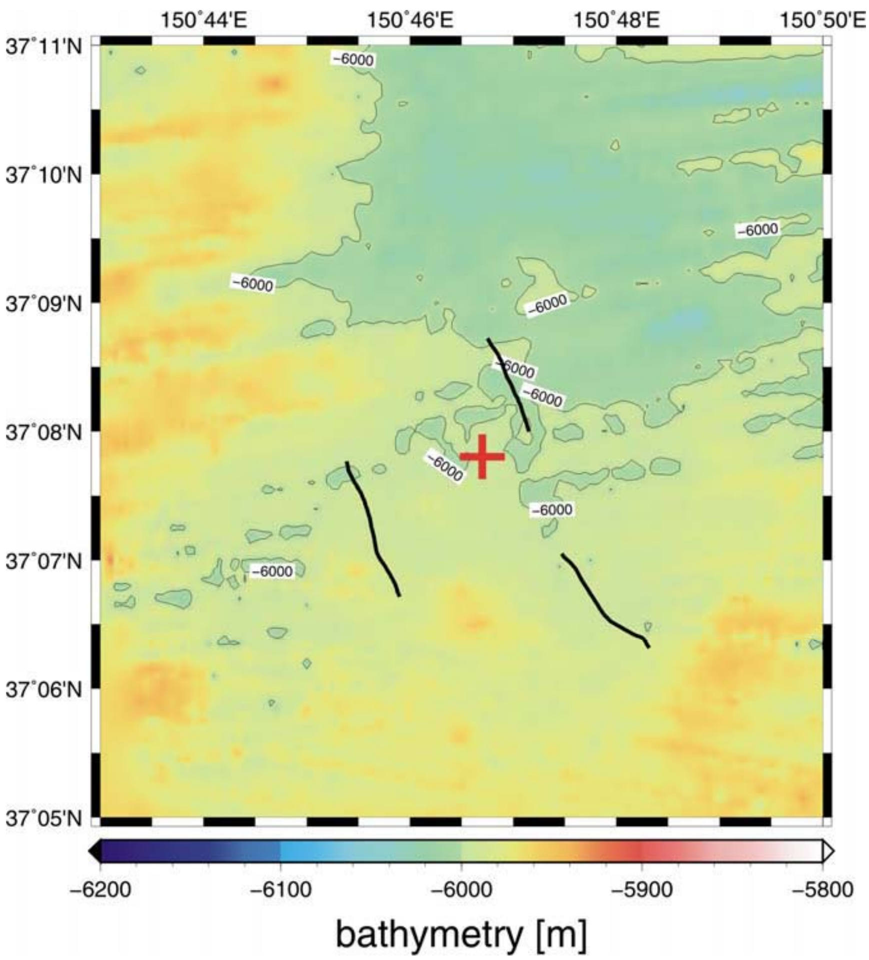

Figure 7.10.6. Ship's position (black lines) during the slant range measurements on January 15th. Red cross is the point that the OBEM was launched in May, 2005.

On the second day (16th), we had stood by since 5:00 in the morning and waited for the recovery of the sea state. For catching the OBEM at the surface, the use of a small working boat is necessary because the deck of R/V Mirai is too high and ship's equipments like hooks attached to bamboo pole are too short to catch the OBEM from the ship directly. Consequently, wave height less than 3 m is the condition required for the sending of the release code. For the slant range measurements using the acoustic relay system, we need the condition that the wind became weak less than 10 m/s. We had a hairbreadth chance to try it at 8:45 but the operation had to stop just before launching the relay system. Unfortunately, the sea didn't calm down until 10:00. We were forced to decide to give up the recovery of the OBEM in this cruise.

We, however, could try to measure the slant ranges using the acoustic relay system from 10:00. We first unreeled the wire to 400 m and test the relay system and the transponder, then unreeled it to 3000 m (Figure 7.10.7).

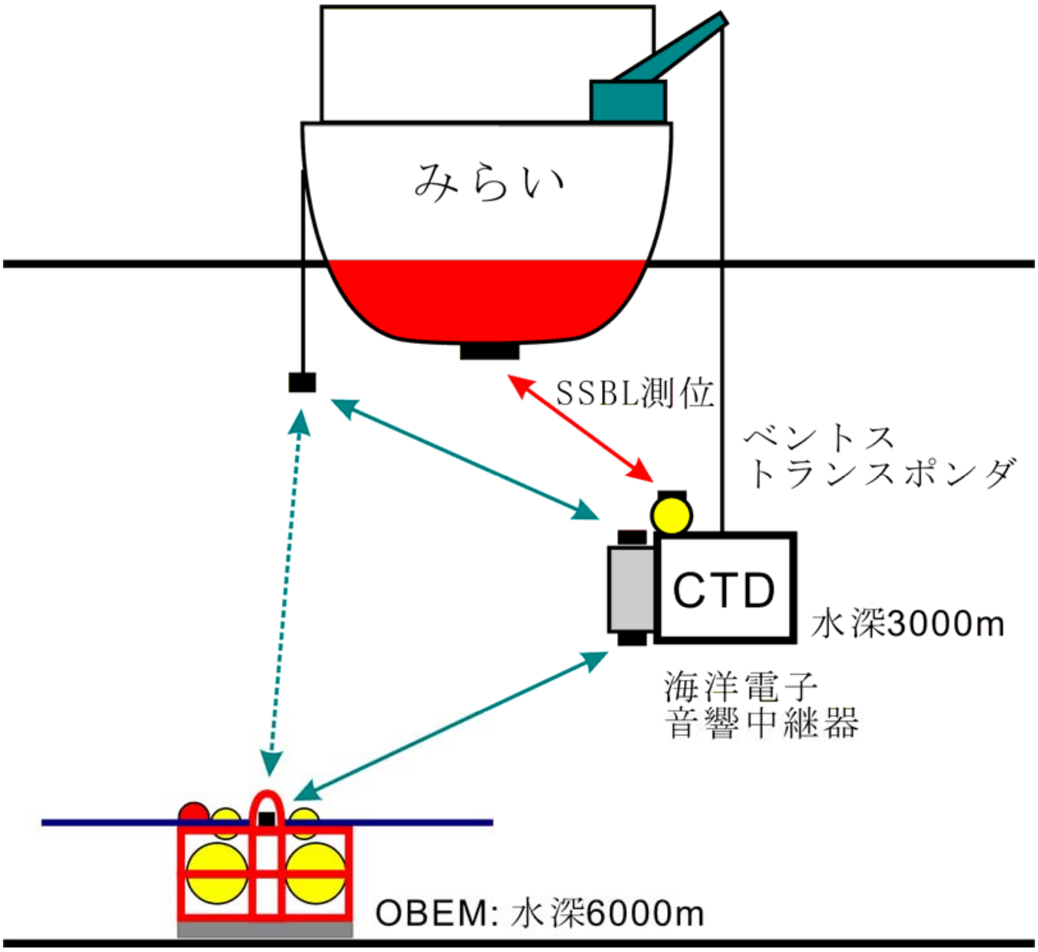

Figure 7.10.7. A sketch of the slant range measurements using the acoustic relay system and Benthos transponder.

The ship had been drifted to SSW direction with meandering and departed from the point that the OBEM was launched; while the location and depth of the relay system is relatively stable (Figure 7.10.8). No response from the OBEM was received, again. We kept on measuring until the time limit but changed the depth of the relay system to 4000, 3500, 2500, 2000, and 1500 m. At the deepest depth (4000 m), we could hear the signal from the relay system but failed to transfer the data. We will pick up the data stored in the memory of the relay system after we are back to the office. For the other depths, we correctly received the signal from the relay system. However, the signal never included the response from the OBEM. We finished the all operation at 13:00.

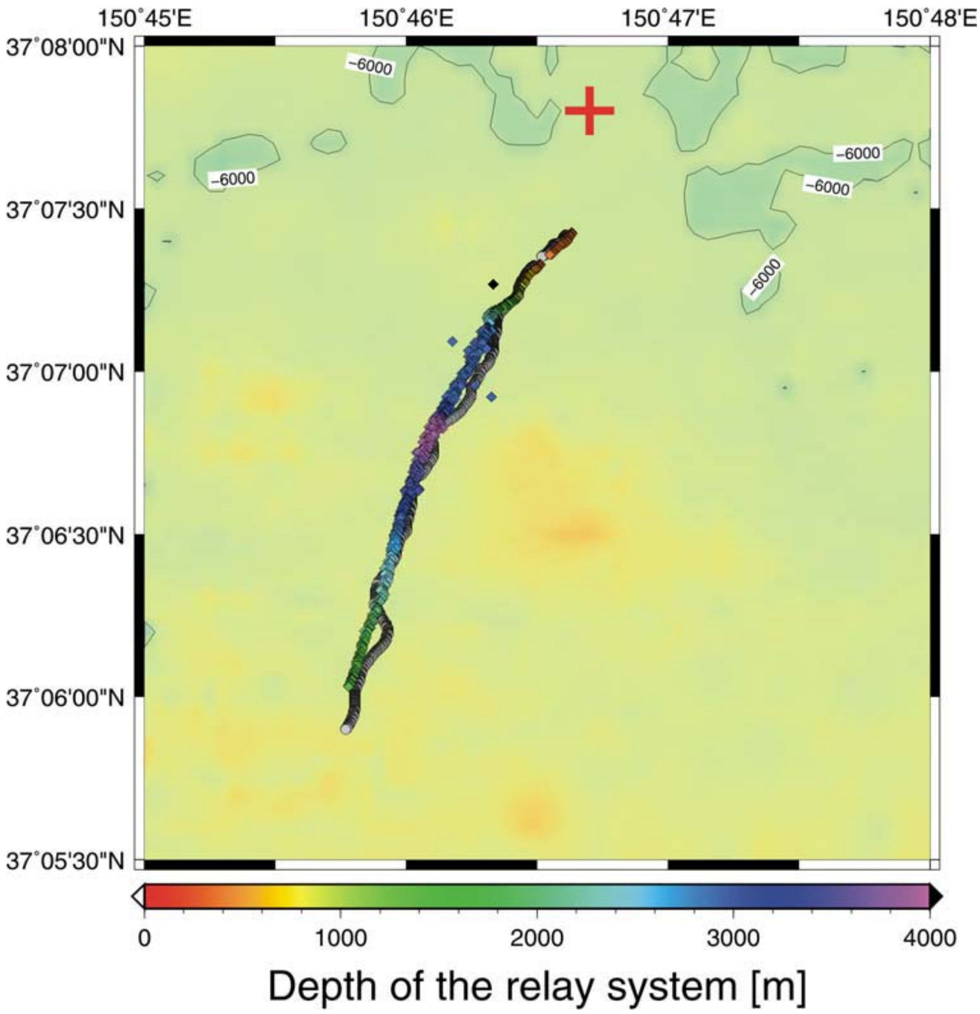

Figure 7.10.8. The tracks of the ship (gray circles) and the acoustic relay system (colored diamonds) during the slant range measurement. Red cross is the point that the OBEM was launched in May, 2005. The color scale for the bathymetry is the same as that of Figure 7.7.6.

7.10.5 Summary and future plan

We attended the R/V Mirai cruise MR05-06 Leg 3 to recover an OBEM deployed in northwestern Pacific Ocean, at 37°07.8'N, 150°46.7E. We had stayed about 24 hours at the point but couldn't send the release command because of bad sea state. We just tried to measure the slant range to the OBEM directly from the ship and using the acoustic relay system. No response from the OBEM was obtained.

There still remains the possibility to recover the OBEM although the time limit of the battery is approaching. The failure of the slant range measurement doesn't mean the failure of the weight releasing system. The OBEM may accept the release command and we have never tried it.

We have applied to the JAMSTEC public cruises of deep sea research in 2007. The official decision has not been made yet. If the proposal is accepted, we will come back the Petit Spot area by R/V Kairei in May. What we have to do in the next chance is just one, send the command!

7.10.6 Acknowledgements

We are grateful to the captain and crew of the R/V Mirai for their cooperation under hard sea state and limited time. This mission was not proposal based and realized through great efforts of many people. We thank the chief scientist of this cruise, Dr. Yuji Kashino, for accepting our request and consequent arrangements on land and on board.

7.10.7 References

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