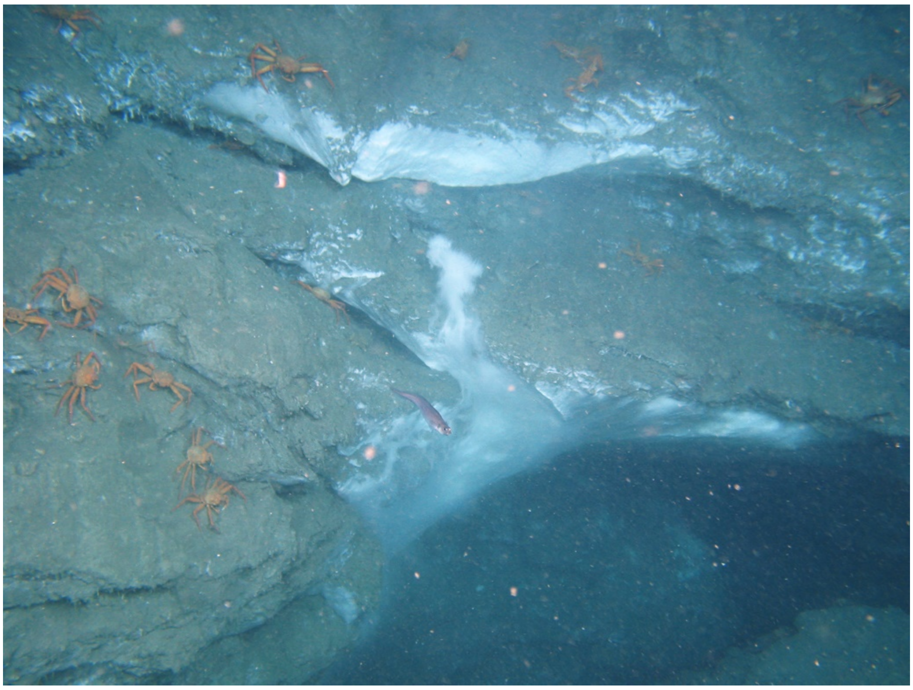
doi : 10.17596/0003078

R/V *Natsushima* Cruise Report

NT12-13

In-situ bio-CCS experiment by guest molecular replacement method with methane hydrate

Japan Sea



May 24 – June 5, 2012

Japan Agency for Marine-Earth Science and Technology

(JAMSTEC)

Contents

1. Cruise Information

1.1 Cruise ID

NT12-13

1.2 Ship Name

R/V *Natsushima*

1.3 Title of the Cruise

In-situ bio-CCS experiment by guest molecular replacement method with methane hydrate

1.4 Chief Scientist

Hideaki Machiyama (JAMSTEC)

1.5 Title of the Proposal & Representative of the Science Party

1. Fumio Inagaki (JAMSTEC)
   In-situ bio-CCS experiment by guest molecular replacement method with methane hydrate
2. Taiyo Kobayashi (JAMSTEC)
   A comprehensive field test of a deep profiling float developed in Japan

1.6 Cruise Period

May 24 – June 5, 2012

1.7 Ports of Call

Naoetsu (Niigata Pref.) – Yokosuka (Kanagawa Pref.)

1.8 Research Area

Japan Sea – western Joetsu Basin and off Yamagata – (Fig. 1)

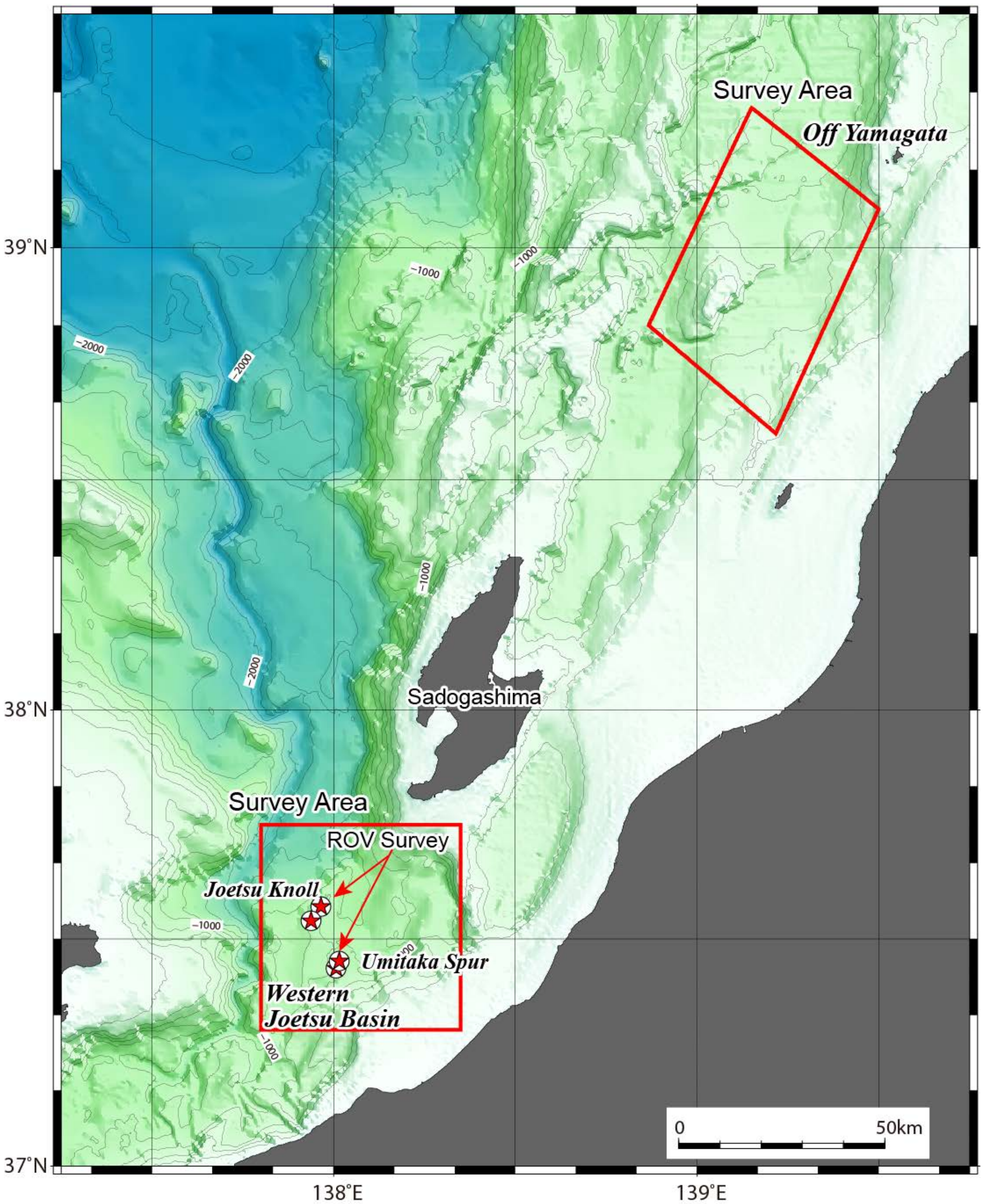


Fig. 1 Index map of the research area and the dive points in the NT12-13 Cruise.

2. Researchers and crews

2.1 Chief scientist

Hideaki MACHIYAMA	JAMSTEC

2.2 Representative of the science party

Proposal 1

Fumio INAGAKI	JAMSTEC

Proposal 2

Taiyo KOBAYASHI	JAMSTEC

2.3 Science party

Proposal 1

Hitoshi TOMARU*	JAMSTEC / University of Tokyo
Atsushi TANI*	JAMSTEC / Osaka University
Koichi IIJIMA*	JAMSTEC
Yoko OHTOMO*	JAMSTEC
Ryo MATSUMOTO*	JAMSTEC / University of Tokyo
Mineo HIROMATSU*	University of Tokyo
Hiroyuki OCHIAI*	University of Tokyo
Takeshi OI*	University of Tokyo
Fumio INAGAKI	JAMSTEC
Yojiro IKEGAWA	JAMSTEC / Central Research Institute of Electric Power Industry
Yuki MORONO	JAMSTEC
Akira IJIRI	JAMSTEC
Fujio YAMAMOTO	JAMSTEC
Goichiro URAMOTO	JAMSTEC
	**Onboard scientists*

Proposal 2

Taiyo KOBAYASHI*	JAMSTEC
Kenichi AMAIKE*	JAMSTEC / Tsurumi-Seiki Co. Ltd
Kazuhiro WATANABE*	JAMSTEC / Tsurumi-Seiki Co. Ltd
Tetsuro INO*	JAMSTEC / Tsurumi-Seiki Co. Ltd
Ken KAWANO	JAMSTEC
Toshio SUGA	JAMSTEC
Kenichi ASAKAWA	JAMSTEC
Tadahiro HYAKUDOME	JAMSTEC
Mitsuhiro TAKAKUSAKI	Tsurumi-Seiki Co. Ltd
Jain SUSHEEL	Tsurumi-Seiki Co. Ltd
	**Onboard scientists*

2.4 Marine Technician

Satomi MINAMIZAWA	Nippon Marine Enterprises, LTD.

2.5 R/V *NATSUSHIMA* Officers and Crew

Captain	Hitoshi Tanaka
Chief Officer	Naoto Kimura
2nd Officer	Isao Maeda
3rd Officer	Motoi Katsumata
Chief Engineer	Minoru Tsukada
1st Engineer	Kimio Matsukawa
2nd Engineer	Takahiro Mori
3rd Engineer	Hozumi Kuratomi
Junior 3rd Engineer	Naoomi Uemura
Chief Electronic Operator	Tokinori Nasu
2nd Electronic Operator	Yoichi Inoue
3rd Electronic Operator	Ryosuke Komatu
Boat Swain	Tadahiko Toguchi
Able Seaman	Yasuo Konno
Able Seaman	Nobuyuki Ichikawa
Able Seaman	Yoshiaki Matsuo
Able Seaman	Hiroaki Murase
Sailor	Kazuho Ikeda
Sailor	Yasunobu Kawabe
Sailor	Yusaku Kanada
No.1 Oiler	Kiyoshi Yahata
Oiler	Katsuyuki Yoshida
Oiler	Ryota Suzuki
Assistant Oiler	Ryo Sato
Assistant Oiler	Taijyun Iwao
Assistant Oiler	Aoi Takamiya
Chief Steward	Teruyuki Yoshikawa
Steward	Shinsuke Tanaka
Steward	Koji Kirita
Steward	Hiroyuki Ohba
Steward	Tatsuya Yamamoto

2.6 ROV *Hyper-Dolphin* operation team

Submersible Operation Manager	Yoshinari Ono
1st Submersible Technical Officer	Homare Wakamatu
2nd Submersible Technical Officer	Katsushi Chiba
2nd Submersible Technical Officer	Yosuke Chida

2nd Submersible Technical Officer	Teppei Kido
2nd Submersible Technical Officer	Yudai Sakakibara
2nd Submersible Technical Officer	Ryo Saigo

3. Cruise log

Date	Local Time (UTC+9h)	Note	Description	Position/Weather /Wind/Sea condition
May 24	 08:00 09:00 11:00 09:30-10:00 13:00-14:00 15:00-15:30	**Sail out, proceeding to research area** boarded let go all shore line, left NAOETSU arrived at research area carried out onboard education & training for scientists practiced boat, fire and collision drills scientific meeting	Joetsu Basin	05/24 12:00 37-30.9N, 137-59.0E Joetsu Basin Fine but cloudy ESE-1 (Light air) 1(Sea calm) 1(Low swell shot) Visibly: 5'
May 25	08:04 08:21 08:50 14:30 14:51 16:19-18:19 18:00	**Deployed Deep-float** released XBT @ 37-37.0988N,139-54.9383E launched Deep-float calibrated Deep-float location by GPS refloated Deep-float commenced proceeding to MBES point carried out MBES mapping survey scientific meeting	@37-37.1663N, 137-55.4961E	05/25 12:00 37-36.6N, 137-58.3E Joetsu Basin Overcast NW-4 (Moderate breeze) 2 (Sea smooth) 1 (Low swell shot) Visibly: 7'
May 26	07:15 08:08 08:12 08:23 08:58 16:13 16:39 16:52 17:42-19:13 18:00-18:10	**ROV Hyper Dolphin dive 1386** arrived at dive point hoisted up HPD launched HPD started HPD#1386 dive operation landed at sea bottom left bottom refloated HPD recovered carried out MBES mapping survey scientific meeting	Middle part of Umitaka Spur Depth: 895m Depth: 881m	05/26 12:00 (UTC+9h) 37-26.1N,138-00.4E Joetsu Basin Fine but cloudy South-1 (Light air) 1 (Calm) 1 (Low swell shot) Visibly: 6'

May 27	 07:15 08:08 08:11 08:24 09:08 16:16 16:44 16:59 18:00-18:10	**ROV Hyper Dolphin dive 1387** arrived at dive point hoisted up HPD launched HPD started HPD#1387 dive operation landed at sea bottom left bottom refloated HPD recovered scientific meeting	 Middle part of Joetsu Knoll Depth: 1009m Depth: 983m	05/27 12:00 (UTC+9h) 37-34.3N,137-57. 9E Joetsu Basin Fine but cloudy ENE-4 (Moderate breeze) 2 (Sea smooth) 1 (Low swell shot) Visibly: 6'
May 28	 07:40 08:05 08:09 08:22 08:54 11:01 11:28 11:44 13:08 13:12 13:23 13:57 16:22 16:51 17:05 18:05-18:15	**ROV Hyper Dolphin dive 1388** **and 1389** arrived at dive point hoisted up HPD launched HPD started HPD#1388 dive operation landed at sea bottom left bottom refloated HPD recovered hoisted up HPD launched HPD started HPD#1389 dive operation landed at sea bottom left bottom refloated HPD recovered scientific meeting	 Northern Umitaka Spur Depth: 915m Depth: 913m Southern Joetsu Knoll Depth: 978m Depth: 976m	05/28 12:00 (UTC+9h) 37-26.8N,138-01. 0E Joetsu Basin Overcast SSE-5 (Fresh breeze) 3 (Sea slight) 1(Low swell shot) Visibly: 6'

May 29	 07:40 08:06 08:15 08:26 08:59 11:32 12:00 12:12 13:38 13:42 13:53 14:29 16:15 16:43 16:56 18:05-18:15	**ROV Hyper Dolphin dive 1390 and 1391** arrived at dive point hoisted up HPD launched HPD started HPD#1390 dive operation landed at sea bottom left bottom refloated HPD recovered hoisted up HPD launched HPD started HPD#1391 dive operation landed at sea bottom left bottom refloated HPD recovered scientific meeting	Southern Joetsu Knoll Depth: 977m Depth: 975m Southern Joetsu Knoll Depth: 977m Depth: 976m	05/29 12:00 (UTC+9h) 37-32.4N,137-56.3E Joetsu Basin Cloudy North-3 (Gentle breeze) 2 (Sea smooth) 2 (Low swell long) Visibly: 7'
May 30	 07:37 08:43-10:21 10:21	**Recovered Deep-float** recovered Deep-float carried out MBES mapping survey commenced proceeding to SAKATA		05/30 12:00 (UTC+9h) 37-36.6N,138-28.0E Off Kashiwazaki Fine but cloudy NNE-3 (Gentle breeze) 3 (Sea slight) 2 (Low swell long) Visibly: 7'

May 31	 07:00 07:25 07:30 08:30-09:00 09:20 09:29 09:54	**MBES mapping survey** arrived at SAKATA 4 scientist embarked and 8 scientist disembarked commenced proceeding to research area carried out onboard education & training for scientists arrived at research area released XBT @ 38-53.8729N,139-18.6747E commenced MBES mapping survey at Area 1	Off YAMAGATA	05/31 12:00 (UTC+9h) 39-05.2N,139-15.3E Off YAMAGATA Fine but cloudy NNE-3 (Gentle breeze) 2(Sea smooth) 2 (Low swell long) Visibly: 7'
June 1	 11:24 12:21-18:51 19:06	**MBES mapping survey** finished MBES mapping survey at Area 1 and proceeding to Area 2 carried out MBES mapping survey at Area 2 commenced MBES mapping survey at Area 4		06/01 12:00 (UTC+9h) 38-51.6N,139-15.2E Off YAMAGATA Overcast North-2 (Light breeze) 2 (Sea smooth) 2 (Low swell long) Visibly: 6'
June 2	 02:44 04:43-10:23 10:25	**MBES mapping survey and Transit to JAMSTEC** finished MBES mapping survey at Area 4 and proceeding to Area 3 carried out MBES mapping survey at Area 3 left research area and commenced proceeding to JAMSTEC		06/02 12:00 (UTC+9h) 39-27.6N,139-23.0E Off Tobi-shima Fine but cloudy North-3(Gentle breeze) 2 (Sea smooth) 2 (Low swell long) Visibly: 7'

June 3		**Transit to JAMSTEC**		06/03 12:00 (UTC+9h) 39-55.2N,142-03.3E Off Miyako Overcast SSE-3 (Gentle breeze) 3 (Sea slight) 3 (Moderate short) Visibly: 6'
June 4	 18:00	**Transit to JAMSTEC** scientific meeting		06/04 12:00 (UTC+9h) 36-01.3N,141-04.4E Off Inubosaki Fog SSE-3 (Gentle breeze) 2 (Sea smooth) 4 (Moderate average) Visibly: 1'
June 5	 09:00 10:00	**Arrived at YOKOSUKA** arrived at YOKOSUKA disembarked from NATSUSHIMA finished NT12-13 cruise		

4. Observation

4.1 Research proposal #1

1) Background and objectives

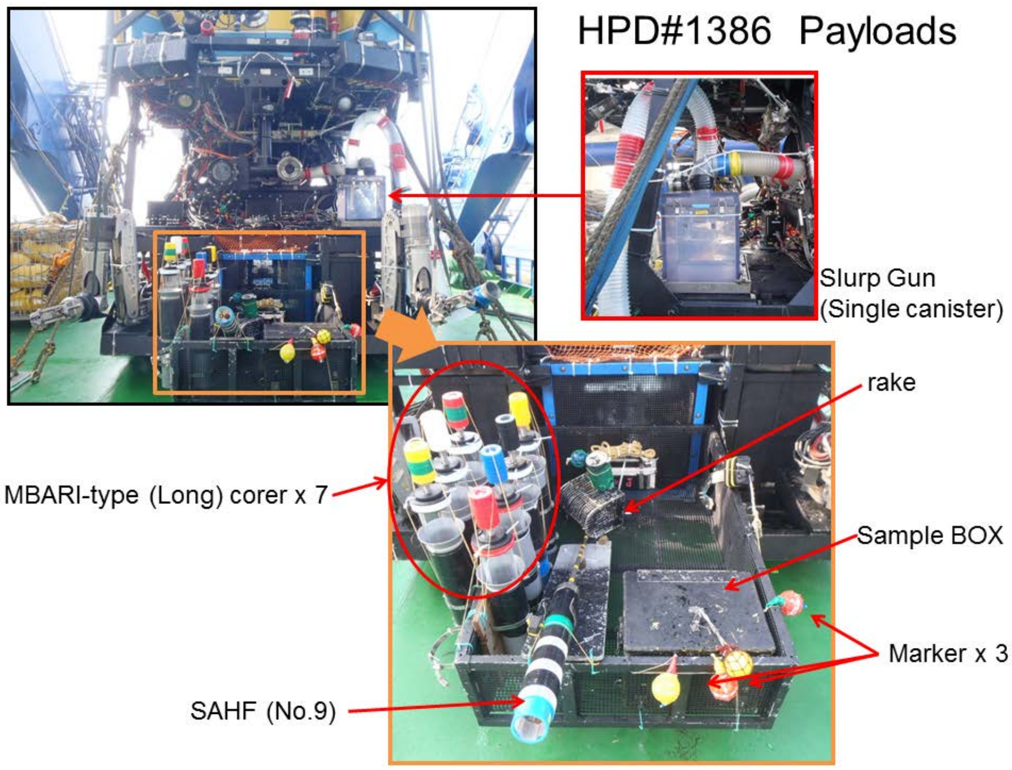
Joetsu Gas Hydrate Field of the western Joetsu Basin in the eastern margin of the Japan Sea is one of the best fields for gas hydrate studies. There are many methane plumes and active methane seeps associated with gas hydrate blocks in the several mounds on the Umitaka Spur and Joetsu Knoll.

The purpose of this research proposal is 1) to understand the occurrence of methane hydrate on sea-floor, 2) to select the best location for in-situ bio-CCS experiment that use a newly-developed heat-zonde CO_2 injection system to tackle the issue of CO_2 sequestration in the deep-sea and sub-seafloor environments, and 3) to obtain the bathymetric data off Yamagata for a methane hydrate study.

2) Observation summary

We conducted two ROV diving surveys around the hydrate mounds on the Umitaka Spur (#1386 & 1388) and four diving surveys on the Joetsu Knoll (#1387, #1389 ~ 1391) (Fig. 2). Three candidate locations for in-situ bio-CCS experiment were selected in this survey area. We recovered a water temperature data logger deployed in NT10-10 Leg2 Cruise, and sampled many sediment cores, two pressure-keeping cores, authigenic carbonate rocks, and many benthos. We also obtained the bathymetric data off Yamagata area.

3) Dive information: payloads



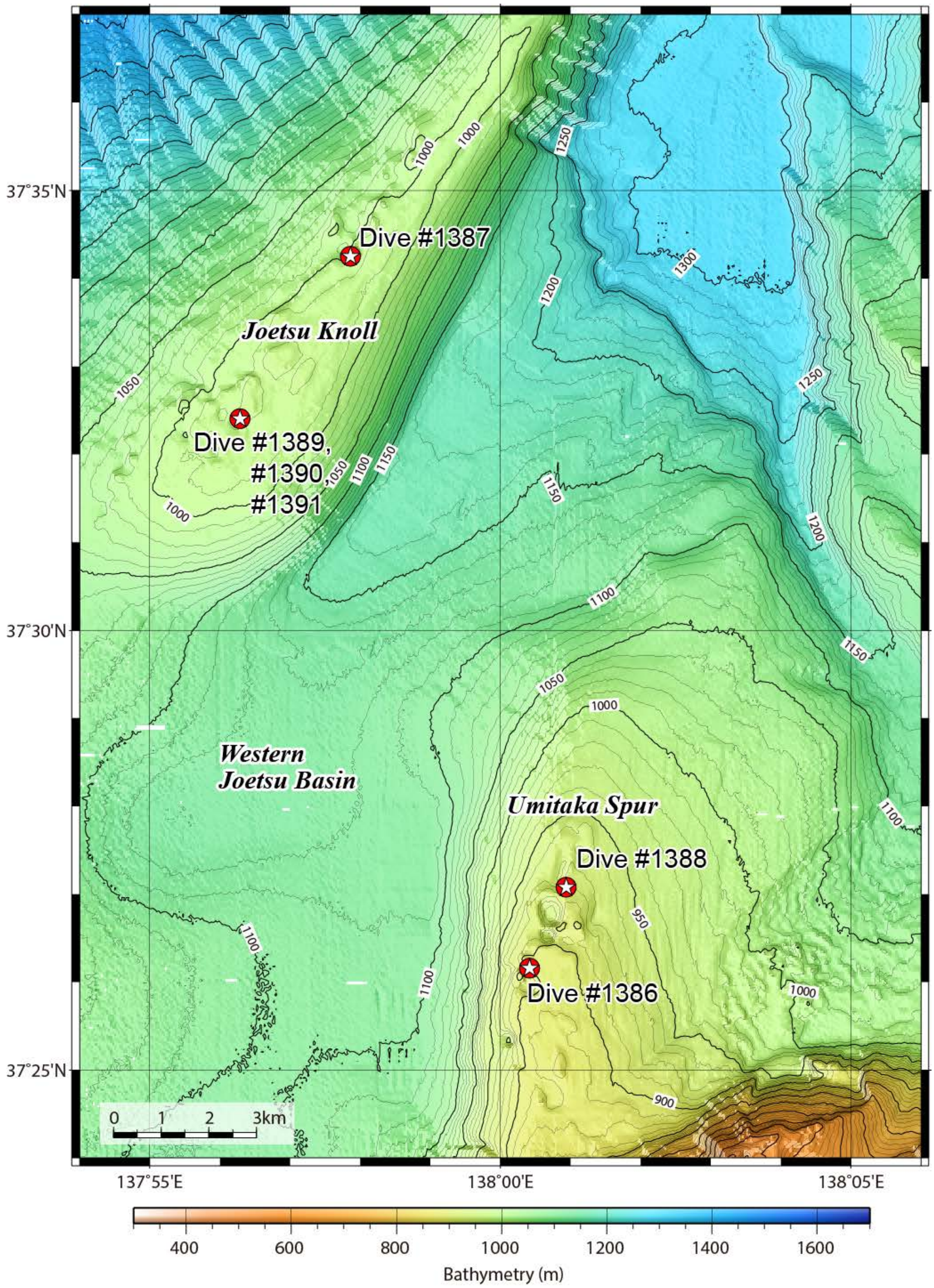
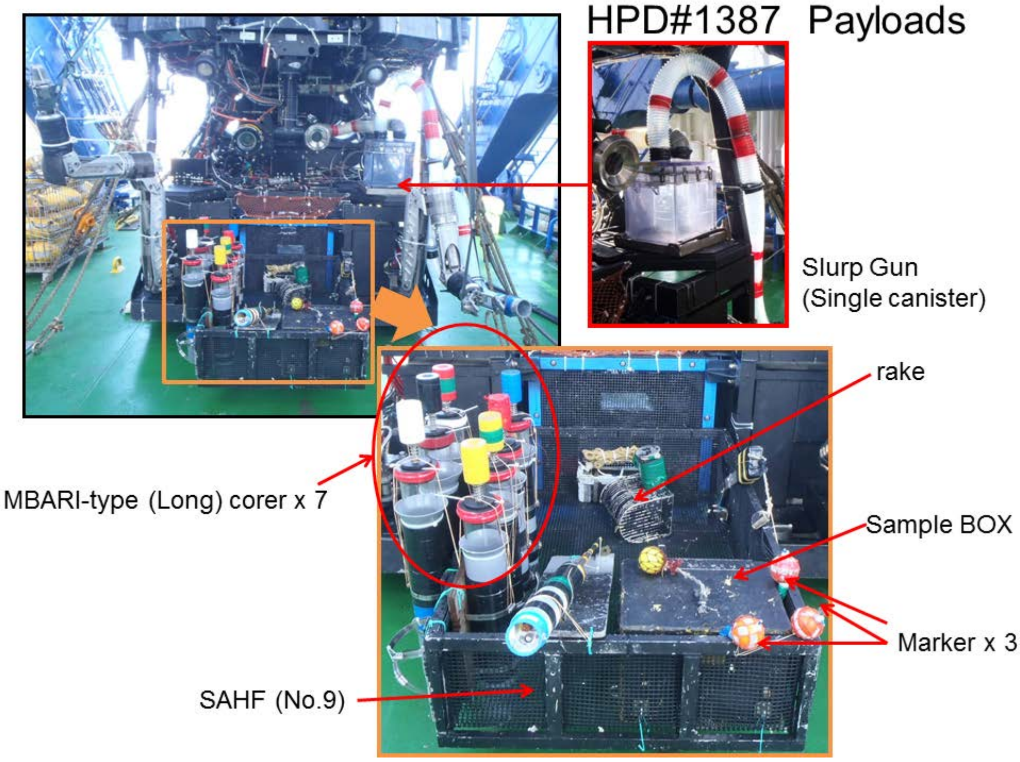
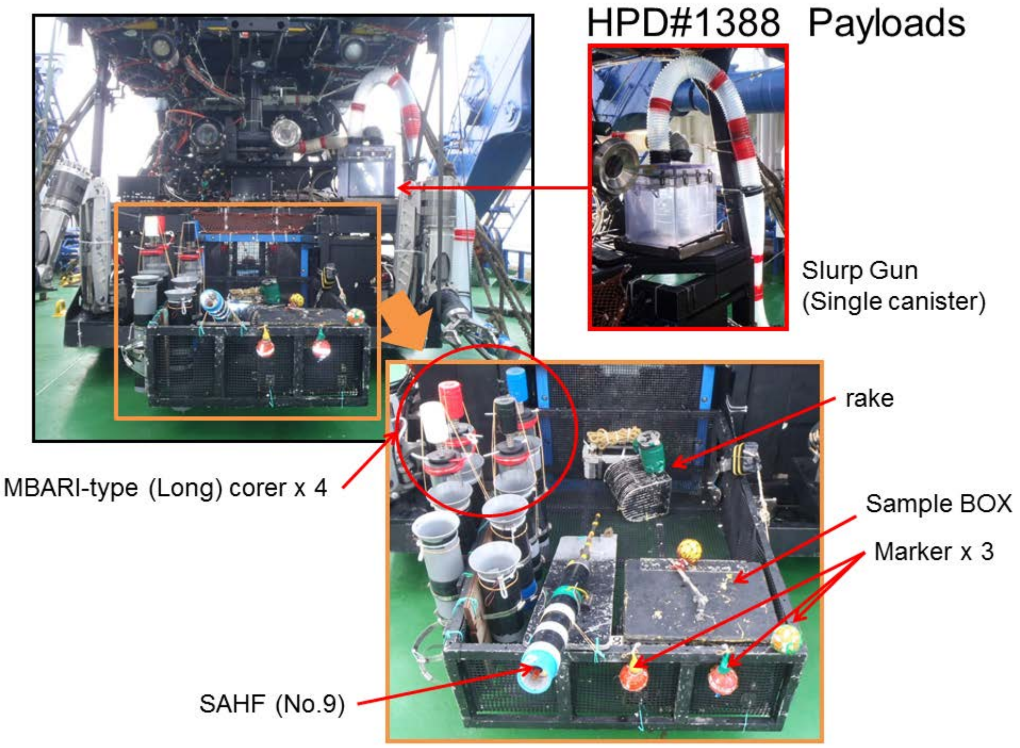
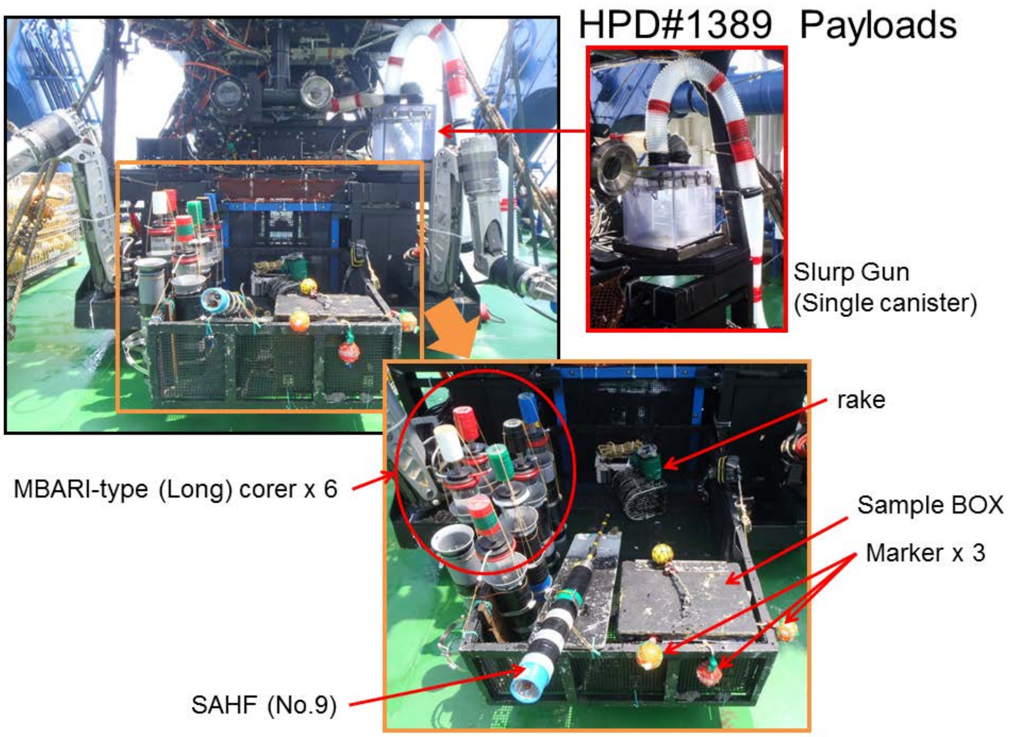
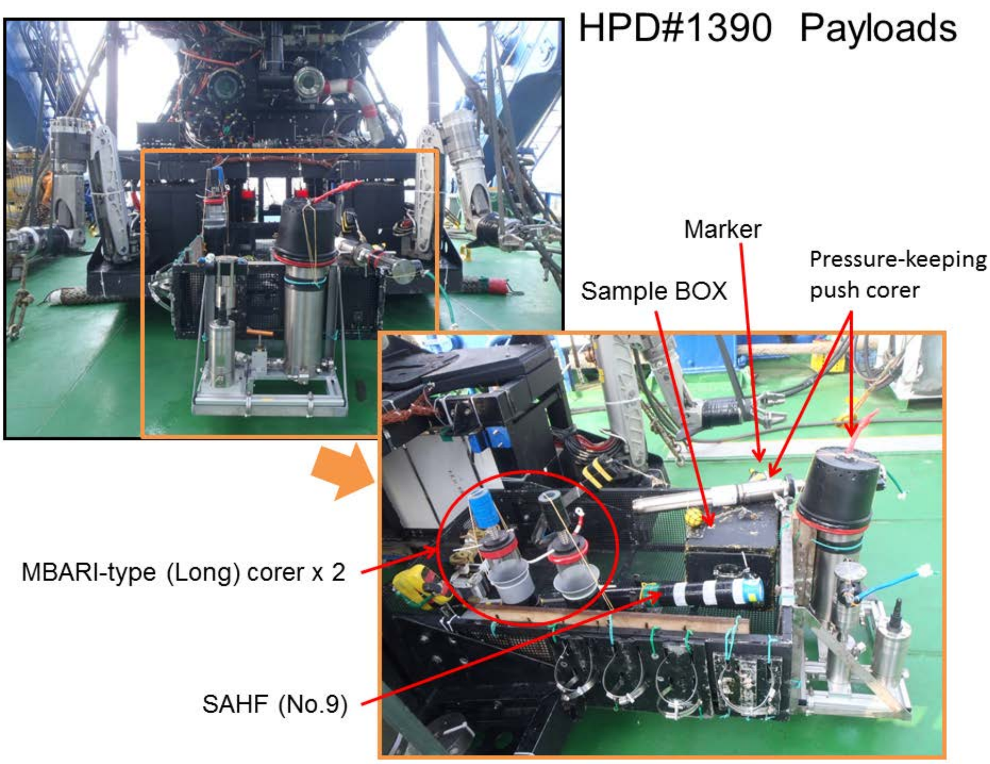


Figure 2 ROV diving survey points in the research area

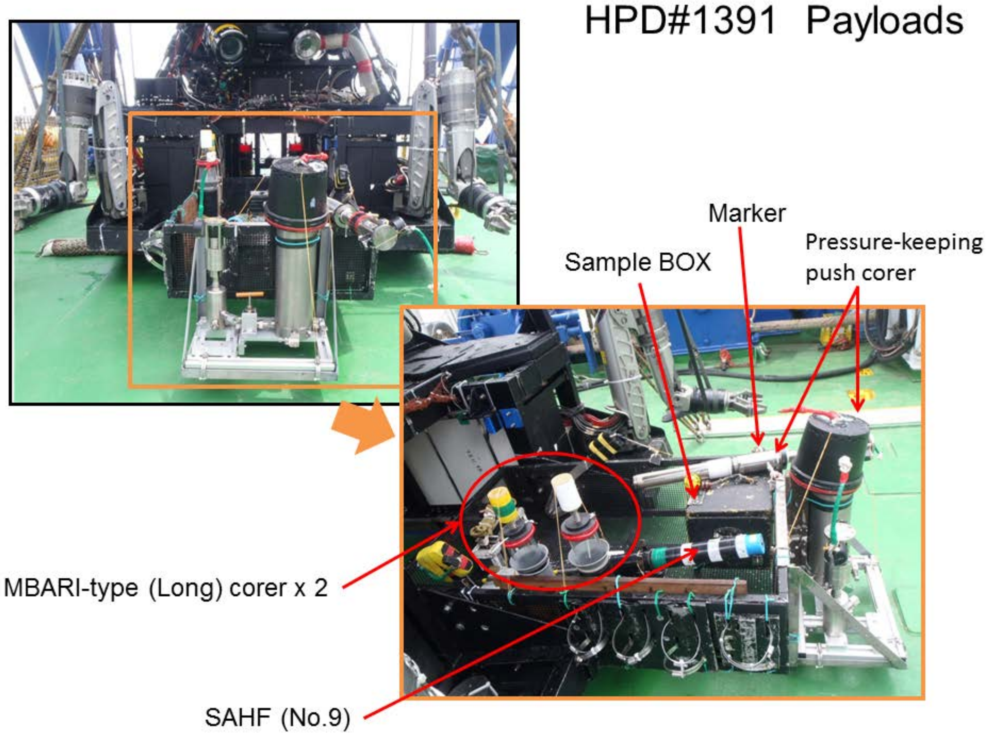

HPD#1387 Payloads
Slurp Gun
(Single canister)
rake
MBARI-type (Long) corer x 7
Sample BOX
Marker x 3
SAHF (No.9)


HPD#1388 Payloads
Slurp Gun
(Single canister)
rake
MBARI-type (Long) corer x 4
Sample BOX
Marker x 3
SAHF (No.9)


HPD#1389 Payloads
Slurp Gun
(Single canister)
rake
MBARI-type (Long) corer x 6
Sample BOX
Marker x 3
SAHF (No.9)

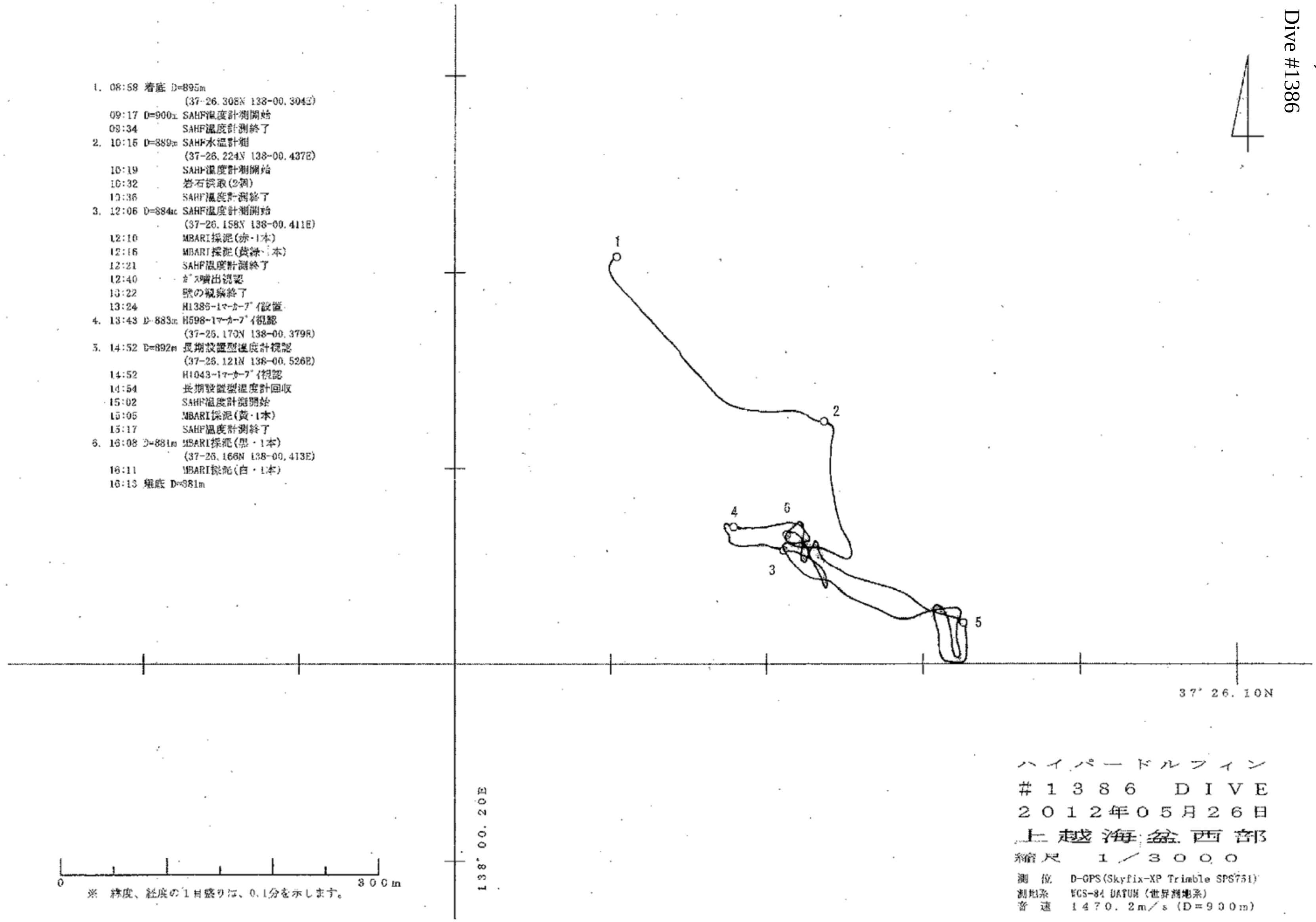

HPD#1390 Payloads
Marker
Pressure-keeping
push corer
Sample BOX
MBARI-type (Long) corer x 2
SAHF (No.9)

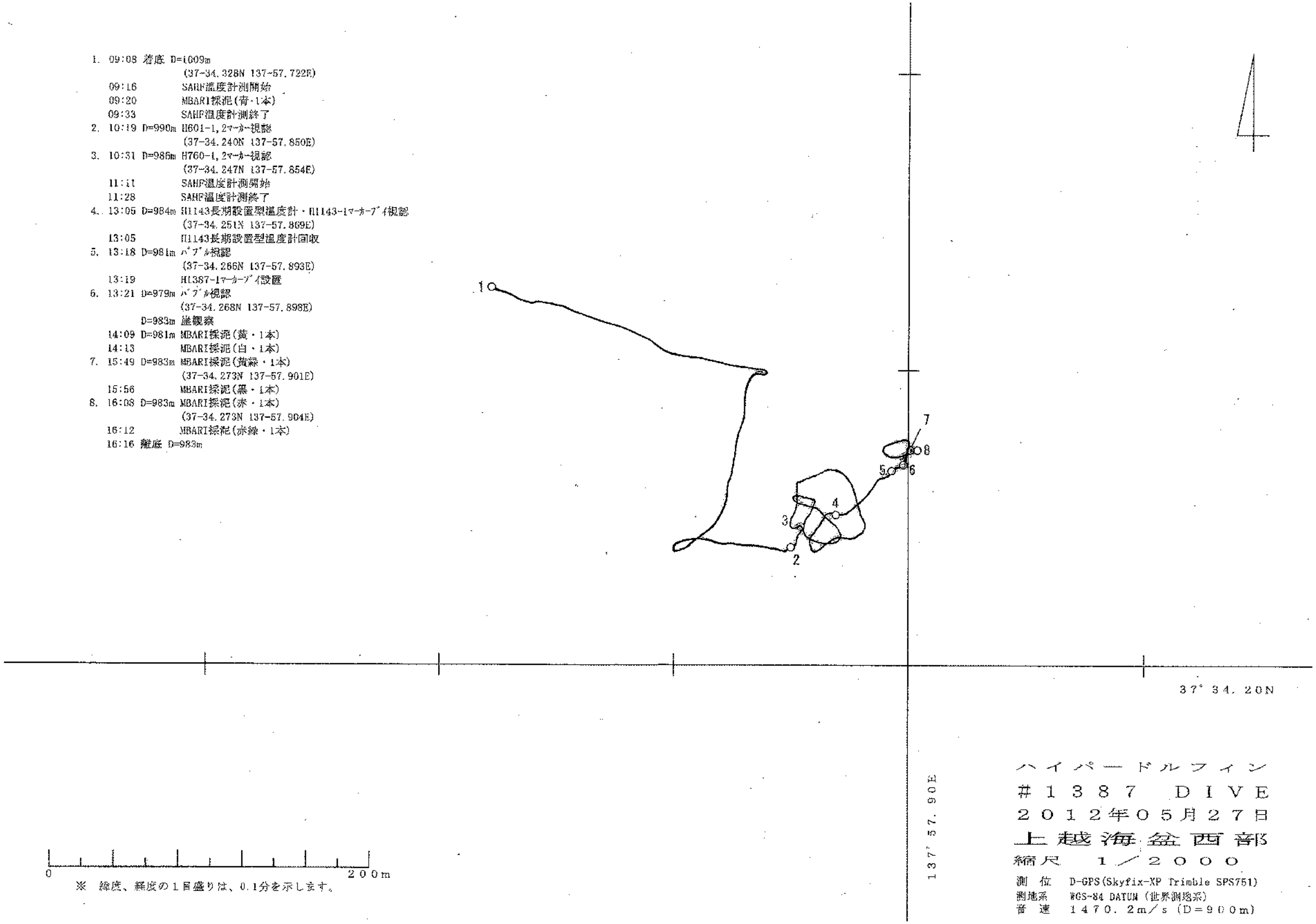
HPD#1391 Payloads

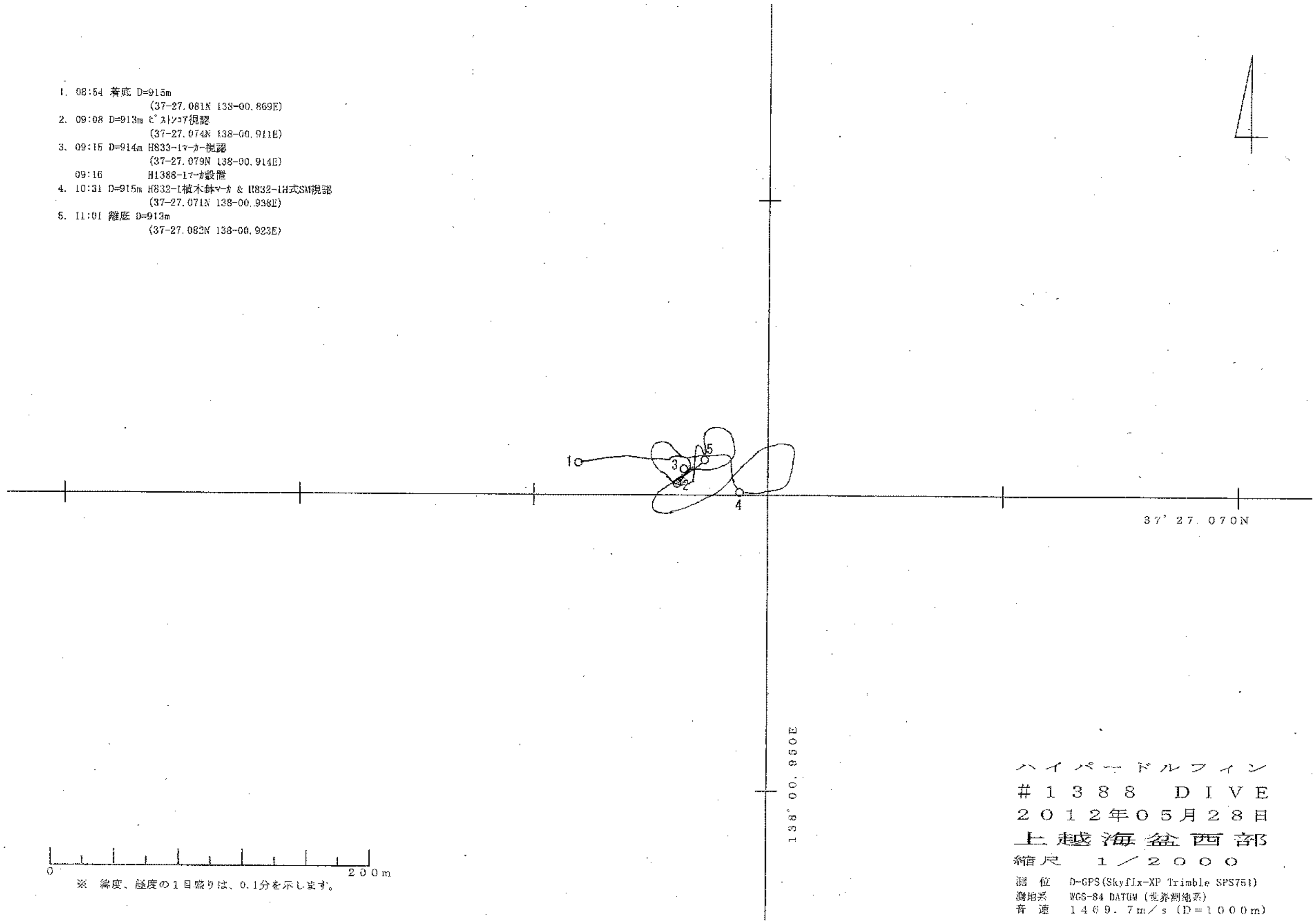


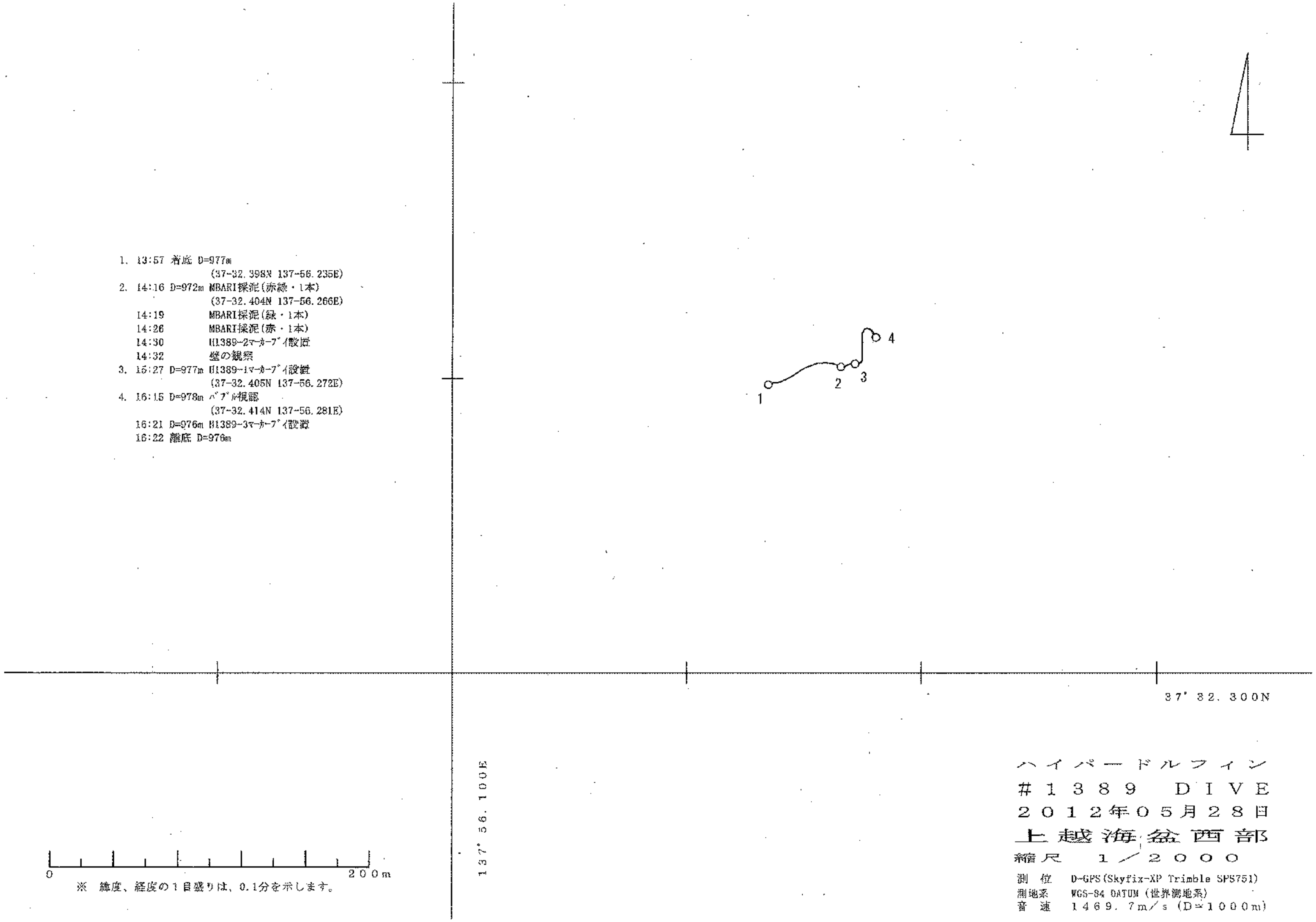
4) Dive information: dive track

Dive #1386

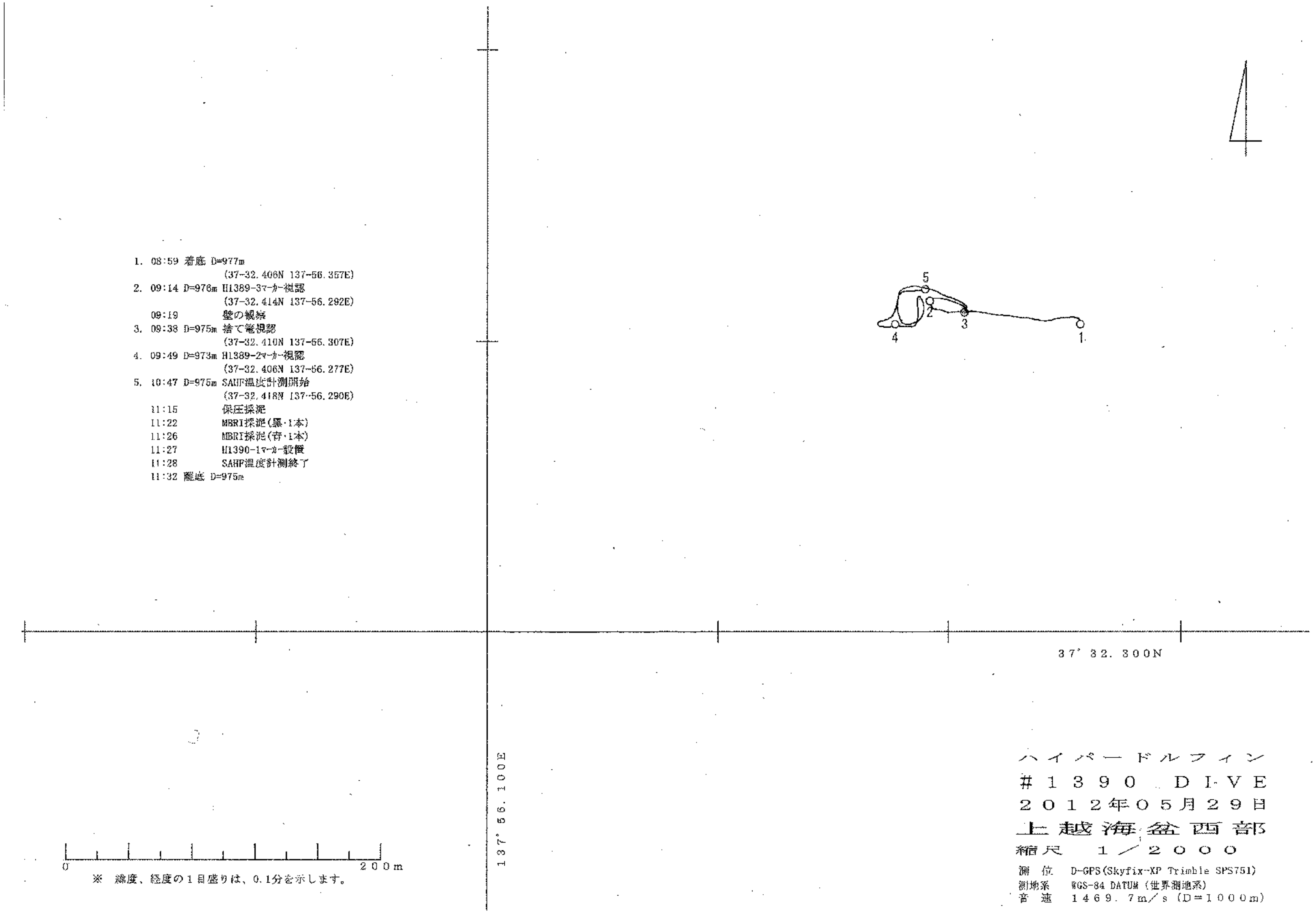


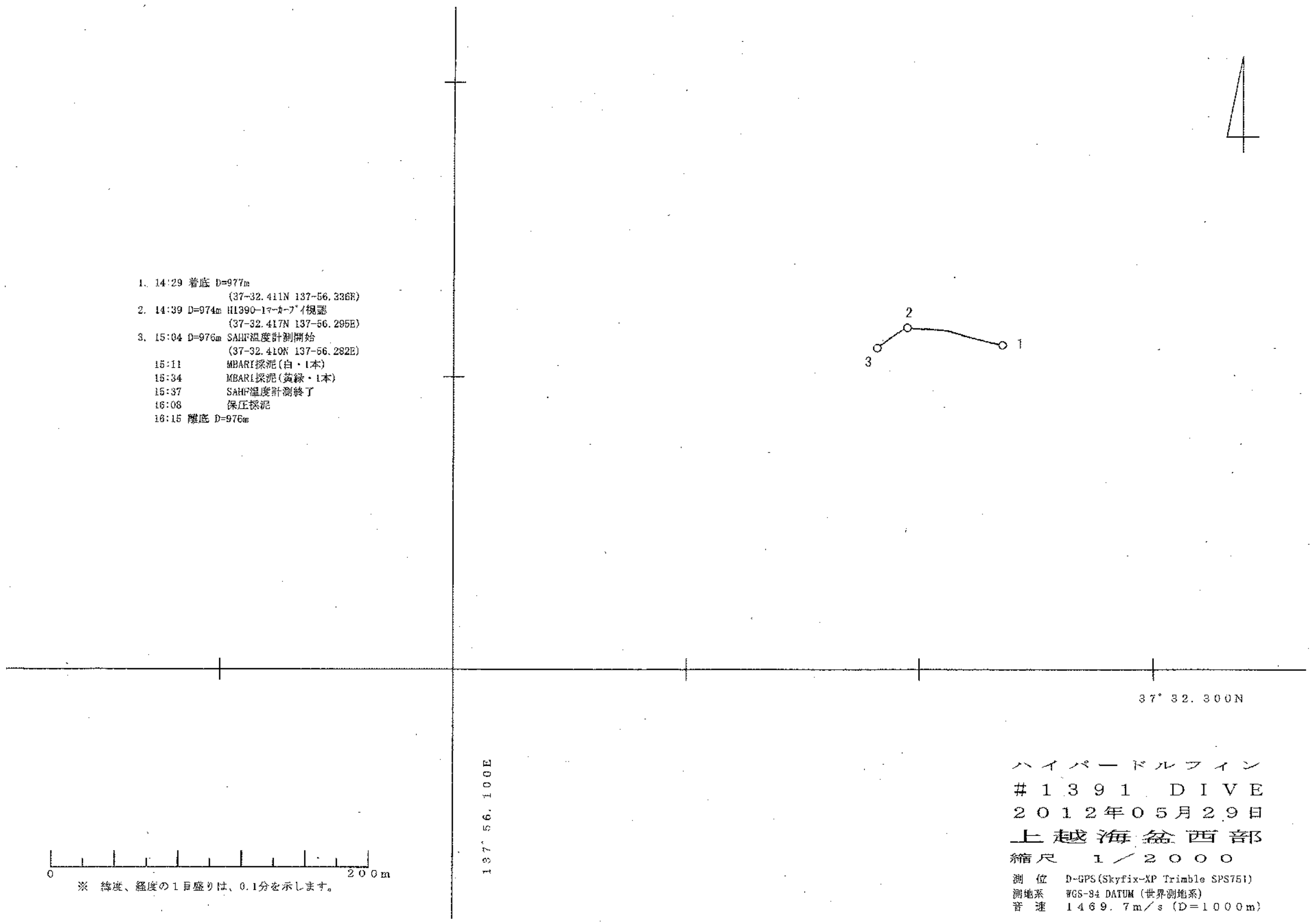

1. 09:08 着底 D=1009m
(37-34.328N 137-57.722E)
09:16 SAHF温度計測開始
09:20 MBARI採泥(青・1本)
09:33 SAHF温度計測終了
2. 10:19 D=990m H601-1,2マーカー視認
(37-34.240N 137-57.850E)
3. 10:31 D=986m H760-1,2マーカー視認
(37-34.247N 137-57.854E)
11:11 SAHF温度計測開始
11:28 SAHF温度計測終了
4. 13:05 D=984m H1143長期設置型温度計・H1143-1マーカーブイ視認
(37-34.251N 137-57.869E)
13:05 H1143長期設置型温度計回収
5. 13:18 D=981m バブル視認
(37-34.266N 137-57.893E)
13:19 H1387-1マーカーブイ設置
6. 13:21 D=979m バブル視認
(37-34.268N 137-57.898E)
D=983m 崖観察
14:09 D=981m MBARI採泥(黄・1本)
14:13 MBARI採泥(白・1本)
7. 15:49 D=983m MBARI採泥(黄緑・1本)
(37-34.273N 137-57.901E)
15:56 MBARI採泥(黒・1本)
8. 16:08 D=983m MBARI採泥(赤・1本)
(37-34.273N 137-57.904E)
16:12 MBARI採泥(赤緑・1本)
16:16 離底 D=983m
1
2
3
4
5
6
7
8
37° 34.20N
137° 57.90E
ハイパードルフィン
#1387 DIVE
2012年05月27日
上越海盆西部
縮尺 1/2000
測 位 D-GPS(Skyfix-XP Trimble SPS751)
測地系 WGS-84 DATUM (世界測地系)
音 速 1470.2m/s (D=900m)
0
200m
※ 緯度、経度の1目盛りは、0.1分を示します。


1. 08:54 着底 D=915m
(37-27.081N 138-00.869E)
2. 09:08 D=913m ピストンコア視認
(37-27.074N 138-00.911E)
3. 09:15 D=914m H833-1マーカー視認
(37-27.079N 138-00.914E)
09:16 H1388-1マーカ設置
4. 10:31 D=915m H832-1植木鉢マーカ & H832-1H式SM視認
(37-27.071N 138-00.938E)
5. 11:01 離底 D=913m
(37-27.082N 138-00.923E)
1
2
3
4
5
37°27.070N
138°00.950E
0
200m
※ 緯度、経度の１目盛りは、0.1分を示します。
ハイパードルフィン
＃１３８８ ＤＩＶＥ
２０１２年０５月２８日
上越海盆西部
縮尺 １／２０００
測位 D-GPS(Skyfix-XP Trimble SPS751)
測地系 WGS-84 DATUM (世界測地系)
音速 １４６９．７m／s (D=１０００m)


1. 13:57 着底 D=977m
(37-32.398N 137-56.235E)
2. 14:16 D=972m MBARI採泥(赤緑・1本)
(37-32.404N 137-56.266E)
14:19 MBARI採泥(緑・1本)
14:26 MBARI採泥(赤・1本)
14:30 H1389-2ﾏｰｶｰﾌﾞｲ設置
14:32 壁の観察
3. 15:27 D=977m H1389-1ﾏｰｶｰﾌﾞｲ設置
(37-32.405N 137-56.272E)
4. 16:15 D=978m ﾊﾞﾌﾞﾙ視認
(37-32.414N 137-56.281E)
16:21 D=976m H1389-3ﾏｰｶｰﾌﾞｲ設置
16:22 離底 D=976m
1
2
3
4
37° 32. 300N
137° 56. 100E
0
200m
※ 緯度、経度の1目盛りは、0.1分を示します。
ハイパードルフィン
#1389 DIVE
2012年05月28日
上越海盆西部
縮尺 1/2000
測位 D-GPS(Skyfix-XP Trimble SPS751)
測地系 WGS-84 DATUM (世界測地系)
音速 1469.7m/s (D≒1000m)

Dive #1390


1. 08:59 着底 D=977m
(37-32.406N 137-56.357E)
2. 09:14 D=976m H1389-3マーカー視認
(37-32.414N 137-56.292E)
09:19 壁の観察
3. 09:38 D=975m 捨て竿視認
(37-32.410N 137-56.307E)
4. 09:49 D=973m H1389-2マーカー視認
(37-32.406N 137-56.277E)
5. 10:47 D=975m SAHF温度計測開始
(37-32.418N 137-56.290E)
11:15 保圧採泥
11:22 MBRI採泥(黒・1本)
11:26 MBRI採泥(苛・1本)
11:27 H1390-1マーカー設置
11:28 SAHF温度計測終了
11:32 離底 D=975m
5
2
4
3
1
37' 32. 300N
137' 56. 100E
0
200m
※ 緯度、経度の1目盛りは、0.1分を示します。
ハイパードルフィン
#1390 DIVE
2012年05月29日
上越海盆西部
縮尺 1／2000
測位 D-GPS(Skyfix-XP Trimble SPS751)
測地系 WGS-84 DATUM (世界測地系)
音速 1469. 7m／s (D=1000m)


1. 14:29 着底 D=977m
(37-32.411N 137-56.336E)
2. 14:39 D=974m H1390-1ﾏｰｶｰﾌﾞｲ視認
(37-32.417N 137-56.295E)
3. 15:04 D=976m SAHF温度計測開始
(37-32.410N 137-56.282E)
15:11 MBARI採泥(白・1本)
15:34 MBARI採泥(黄緑・1本)
15:37 SAHF温度計測終了
16:08 保圧採泥
16:15 離底 D=976m
1
2
3
37° 32. 300N
137° 56. 100E
0
200m
※ 緯度、経度の1目盛りは、0.1分を示します。
ハイパードルフィン
＃1391 DIVE
2012年05月29日
上越海盆西部
縮尺 1／2000
測 位 D-GPS(Skyfix-XP Trimble SPS751)
測地系 WGS-84 DATUM (世界測地系)
音 速 1469. 7m／s (D＝1000m)

4.2 Research proposal #2

1) Backgrounds and purposes in the field test

The ocean plays an important role in the global climate due to its huge capacity of heat and only a little change of its temperature affects the climate largely. Thus, the ocean observation is very important in order to monitor the present status of the ocean and also to predict the future climate. Recently some studies reported that variations in deep layers in the Labrador Sea, a major region of deep water formation, were almost the same level as in the surface layers. Also the deep and bottom waters in the Pacific and Indian Oceans were verified to have warmed significantly during 1990s to 2000s. The heat accumulated in the global ocean deeper layers than 3000 m was estimated at about 1.3×10^{22} J for 15 years from the 1990s to the 2000s and the warming resulted in the rise of sea level by about 0.1 mm yr^{-1}. The estimations, however, have larger errors than those for the other components of the global climate because of sparse observations. Thus, the deep ocean is a component not to be ignored and also a major source of uncertainness in the global climate.

Understanding the anthropogenic global change and predicting its future are important issues in the international community now. Thus, importance of the deep ocean monitoring becomes increasingly recognized from the viewpoints of the social security, too. Thus, an advancement of systematic deep ocean observations was thus approved at OceanObs'09 held in 2009 as an international guideline of observational ocean sciences for the next decade (2010–2019). An observing array by numerous deep profiling floats was an essential component in the system to monitor temperature and salinity in the deep ocean and to estimate the sea surface rise accurately.

The development of the network, however, was not set to start yet, because the maximum observation depth is up to 2000 m for the current types of floats. Thus, some of float makers are now developing deep floats. In Japan, JAMSTEC and Tsurumi-Seiki Co. Ltd (TSK) have developed a new deep profiling float since 2009 and the first prototype of the deep float was assembled in 2011 (Fig. 3).

Control of the float operation in water is one of the most important factors for profiling floats. We have verified that its control soft-ware worked well at on-desk simulations. Also, we had examined its function in coastal waters some times. However, the verifications by such methods were very limited. Situations of the float in water are more complicated than those in the simulations. At the tests in coastal waters the deep float was tied to a fishing line connected to a surface drifting buoy, which hampered the deep float from moving freely in water. The periods of the field tests are also allowed daytime of a day, which is very short considering very slow vertical movements (<10 cm s^{-1}) of the float in water to ascend from and descend to the great depths (more than 500m).

In the cruise we carried out a comprehensive field test of the deep float and the float was tied to nothing to examine the function of its control system under an ideal situation. The period of the test was much longer (about 5 days) than the previous field tests and the float conducted 8 cycles of a preset observation sequence.

Fig. 3: A prototype of the deep profiling floats

2) Details of the field test

A prototype of the deep profiling float was deployed from the ship and then it operated repeatedly preset sequence of observation cycles including descend, drift at a preset depth, ascend, observation by CTD, GPS positioning and data transition at the sea surface. At the end of the test the prototype was drifted on the sea surface and then recovered.

Main parameters of the test are follows:

Period of the observation cycle: 18 hours

Drifting depth: 400 dbar

Profile depth: 800 dbar at odd cycle and 700 dbar at even cycle

3) Results of the field tests

Summary

The results of the field test clarified that the control system of the deep float worked as well as it was expected before. The field test is the first time in which the deep float can move freely in water because of no tied line connecting a surface buoy and it is clarified that the float is apt to descent to deeper depth than the target depth very much (see Fig. 6). Thus, some parameters should be examined again and adjusted. After the adjustment, we expected that the deep float can be examined in deep water.

Details of the test

- Deployed on May 25

  8:15 Float was switched on.

8:20 Float was deployed from the vessel (see Fig. 4).

(8:30 Float waked up.)

8:50 Received messages (e-mails) from the float.

9:23 Identified that the float dived to depth (disappeared at the sea surface).

- 1st surfacing on May 25: 800 dbar for the target profiling depth

14:30 Received the first e-mail from the float, which meant that the float arrived at the sea surface. The maximum depth of the observed profile is 965.8 dbar.

No position data of the float are included; the float failed GPS position fixing at sea surface.

- 2nd surfacing on May 26: 700 dbar for the target profile depth

6:23 Received the first e-mail from the float. The maximum depth of the observed profile is 795.8 dbar.

The float succeeded to fix its position. After then, it never failed GPS positioning during the field test.

- 3rd surfacing on May 27: 800 dbar for the target profiling depth

0:50 Received the first e-mail from the float. The maximum depth of the observed profile is 870.7 dbar.

The e-mails were received actually around 6 o'clock because no data transmission between the vessel and JAMSTEC mail server from 22 to 6 o'clock.

- 4th surfacing on May 27: 700 dbar for the target profile depth

18:24 Received the first e-mail from the float. The maximum depth of the observed profile is 732.8 dbar.

After then we sent an e-mail command to the float via TSK office that it omits parking drift and ascends from 800 dbar at the next cycle. The command will arrive at the float at the next (5th) surfacing and be done at the 6th cycle. Since the time of float surfacing on the day of float recovery (May 30) was shifted from midnight to morning.

- 5th surfacing on May 28: 800 dbar for the target profiling depth

13:27 Received the first e-mail from the float. The maximum depth of the observed profile is 810.2 dbar.

- 6th surfacing on May 28: 800 dbar for the target profile depth

19:43 Received the first e-mail from the float. The maximum depth of the observed profile is 837.3 dbar.

The float arrived at the sea surface at the expected time; control of the float by e-mail commands was succeeded.

- 7th surfacing on May 29: 800 dbar for the target profiling depth

12:20 Received the first e-mail from the float. The maximum depth of the observed profile is 812.7 dbar.

After then we sent an e-mail command to the float via TSK office that the float operation mode is changed to the recovery mode at the next cycle. At the recovery mode, the float drifts on the sea surface and transmits its GPS position every about 10 minutes.

● 8th surfacing on May 30: 700 dbar for the target profile depth

6:02 Received the first e-mail from the float. The maximum depth of the observed profile is 717.5 dbar.

6:32 Received float position data and identified that the float was operated at the recovery mode. After then, the float transmitted its GPS position every about 10 minutes. The vessel went to the float position.

7:20 The vessel arrived at the float position.

7:30 The float on the sea surface was found. Began an operation of recovery.

7:40 The float was on deck; success of the float recovery.

7:50 The float was turned off. The field test was completed.

The deep float prototype was not drifted so much from the deployed position in the test for almost 5 days (see Fig. 5). Temperature and salinity profiles measured by the float are summarized in Fig. F5. They captured typical structure of the water masses in Sea of Japan. For example, very cold (<1 ºC) water with about 34.06 in salinity called as Japan Sea Proper Water is occupied in the deeper layers than 400 dbar. The permanent thermocline (around 150-300 dbar) is covered on the cold water.

Fig: 4: Prototype of the deep float to be deployed from vessel.

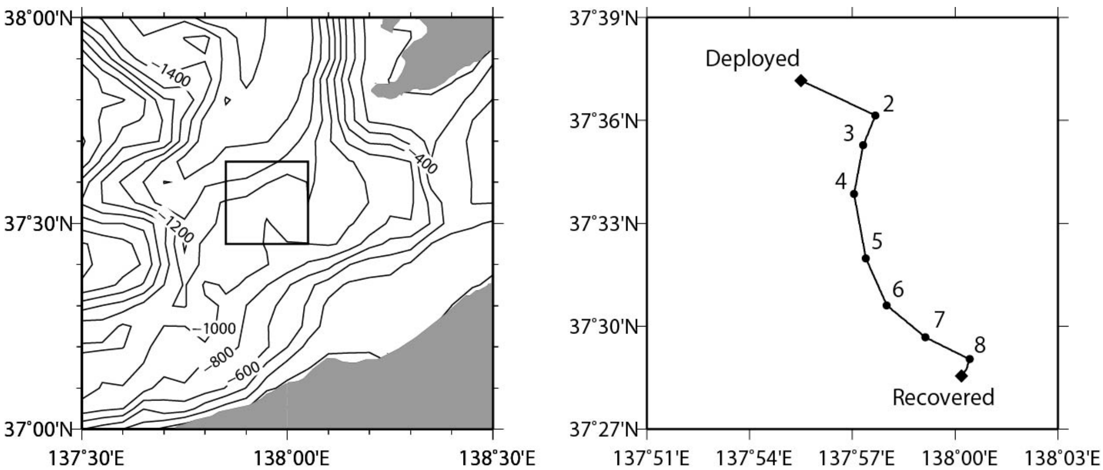


Fig. 5: Float positions fixed by GPS at the deployment, surfacing, and the recovery.

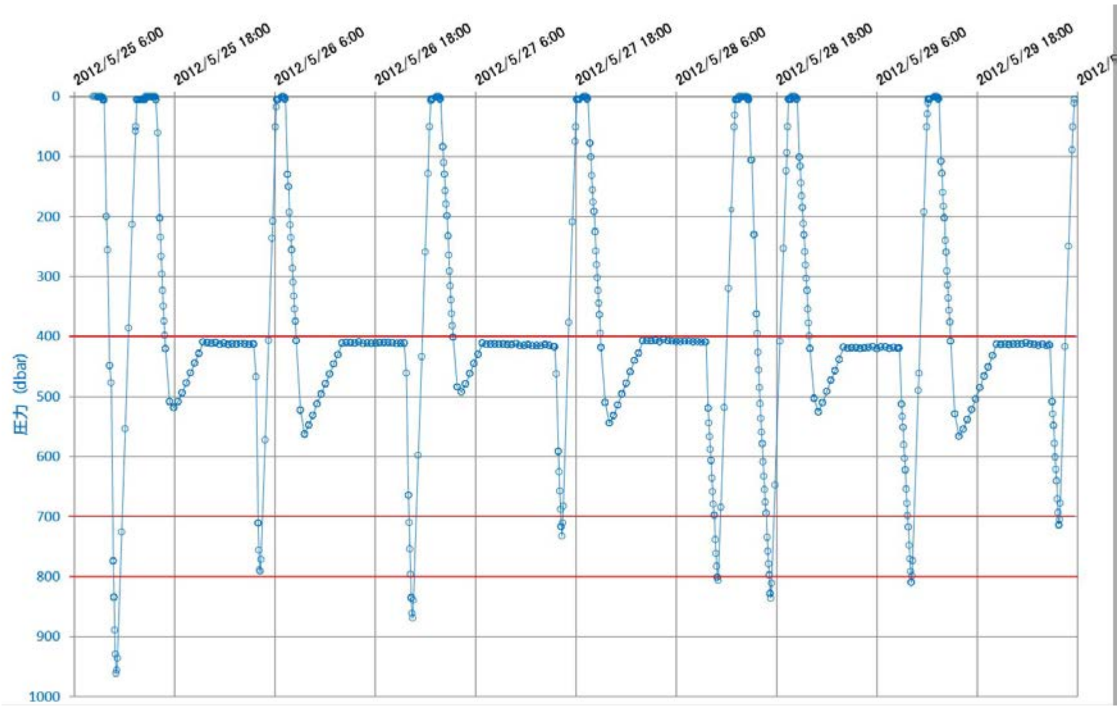


Fig. 6: Vertical movement of the deep float in water during the test. The target depth of each cycle is shown by red arrow.

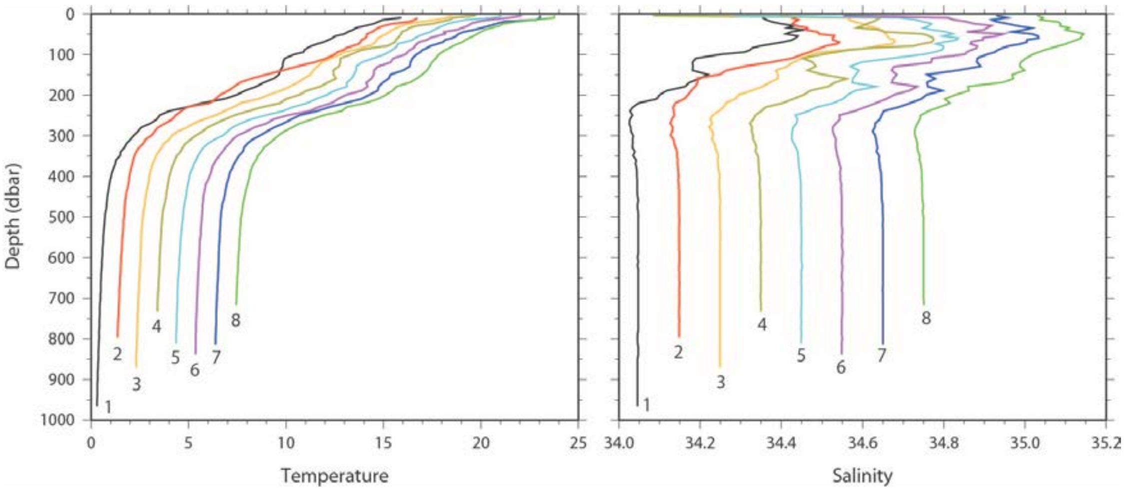


Fig. 7: Temperature (left) and salinity (right) profiles obtained by the float during the test. The number at the tail of each profile represents the number of the float cycle. Each profile is shifted by 1K in temperature and 0.1 in salinity.

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