



Yokosuka “Cruise Report”

YK17-20

Sea Trial of AUV “YUMEIRUKA”

And

Experiment of Continuous Measurement in Deep Sea
by an Underwater Glider for Long-term Virtual Mooring

Sept. 22, 2017- Sept. 28, 2017

Japan Agency for Marine-Earth Science and Technology

(JAMSTEC)

Contents

1. Cruise Information

2. Researchers

3. Experiment of AUV “YUMEIRUKA”

4. Observation of an Underwater Glider

5. Notice on Using

1. Cruise Information

1.1 Cruise ID

YK17-20

1.2 Name of vessel

Yokosuka

1.3 Title of the cruise

Sea Trial of AUV “YUMEIRUKA” and Experiment of Continuous Measurement in Deep Sea by an Underwater Glider for Long-term Virtual Mooring

1.4 Cruise period

Sept. 22, 2017- Sept. 28, 2017

1.5 Ports of departure / call / arrival

Departure from: JAMSTEC Yokosuka

Arrival at: JAMSTEC Yokosuka

1.6 Research area

Sagami bay and Suruga bay

1.7 Research Map

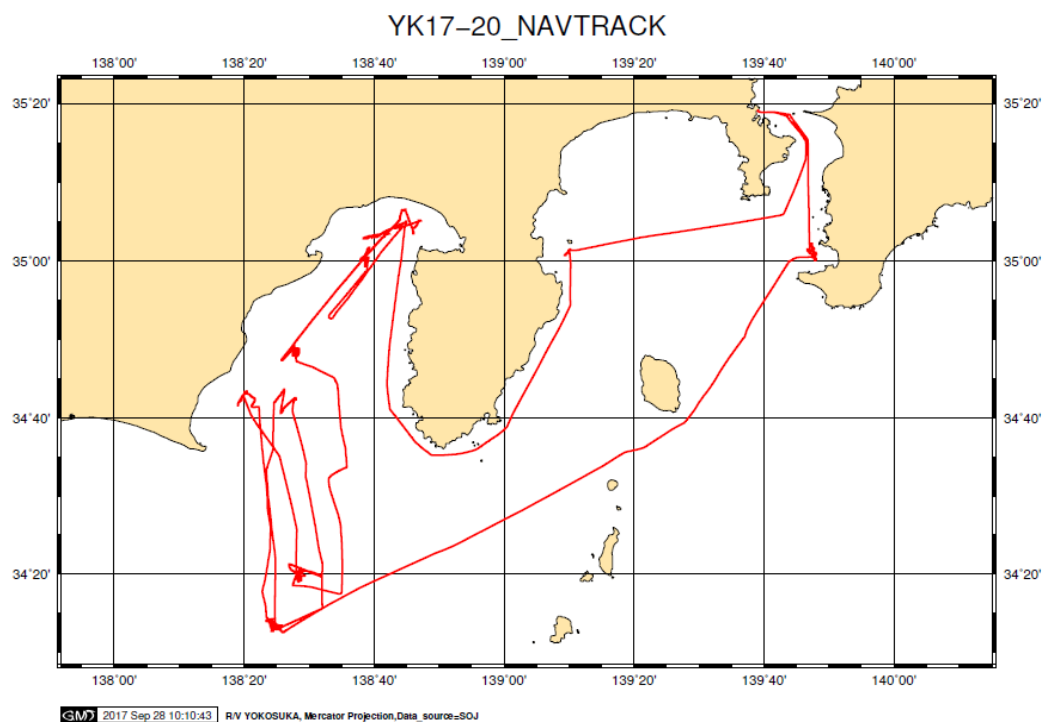


Fig. 1 Cruise track of YK17-20

2. Researchers

2.1 Chief scientist [Affiliation]

Yutaka Ohta	[JAMSTEC]
-------------	-----------

2.2 Science party [Affiliation]

Tuyoshi Yoshiume	[JAMSTEC]
------------------	-----------

Yoshinobu Nambu	[JAMSTEC]
-----------------	-----------

Hiroshi Ochi	[JAMSTEC]
--------------	-----------

Tatsuya Aso	[JAMSTEC]
-------------	-----------

Tadahiro Hyakudome	[JAMSTEC]
--------------------	-----------

Kenichi Asakawa	[JAMSTEC]
-----------------	-----------

Kazuhiro Kanayama	[Mitsubishi Heavy Industries, Ltd]
-------------------	------------------------------------

Hiroyuki Miyake	[Ryoyu System Engineering Co., Ltd.]
-----------------	--------------------------------------

Rei Itoh	[Marine Works Japan, Ltd]
----------	---------------------------

3. Experiment of AUV “YUMEIRUKA”

3.1 Purpose

This cruise was conducted to verify the capability of “Yumeiruka”. Until this sea trial, it’s improved that navigation performance and observation performance. In this sea trial, we checked the degree of the system completion and the stability of systems.

3.2 Activities

Table 1 shows the schedule of the cruise. In this cruise we conducted four dives of AUV “YUMEIRUKA” and one observation with the Underwater Glider.

Table 1 Schedule of the sea trial.

Date	Plans / Place	Actual activities
Sep. 22, Fri.	Depart / JAMSTEC	Launch and recovery test of “YUMEIRUKA”
Sep. 23, Sat.	Sea trial of AUV [1] / Suruga bay	“YUMEIRUKA” Dive# 27
Sep. 24, Sun.	Sea Trial of AUV [2] / Suruga bay	“YUMEIRUKA” Dive# 28
Sep. 25, Mon.	Sea Trial of AUV [3] / Off Suruga bay	Observation of the Underwater Glider
Sep. 26, Tue.	Sea Trial of AUV [4] / Off Suruga bay	“YUMEIRUKA” Dive# 29
Sep. 27, Wed.	Observation of the Underwater Glider [1] / Off Suruga bay	“YUMEIRUKA” Dive# 29
Sep.28, Thu.	Arrive at JAMSTEC	Unloading the equipment

3.3 Results

Table 2 shows the dive information of AUV “YUMEIRUKA”. We conducted two dives (#27, #28) for testing the navigation performance with altitude control and the observation performance of bathymetric and sub-bottom profiling with equipped sonar. Moreover, other two dives (#29, #30) were for testing the acoustic telemetry at 3,000 m with navigation and observation performance check.

Table 2 Dive information.

Dive#	Date, Time	Remarks
#27	Sep. 23 13:07(Launch) ~ 16:11(Surfacing)	Nav. and observation test
#28	Sep. 24 09:09(Launch) ~ 15:03(Surfacing)	Nav. and observation test
#29	Sep. 26 08:05(Launch) ~ 14:19 (Surfacing)	Nav., observation and avoustic telemetry test @3,000 m depth
#30	Sep. 27 08:10(Launch) ~ 14:18 (Surfacing)	Nav., observation and avoustic telemetry test @3,000 m depth

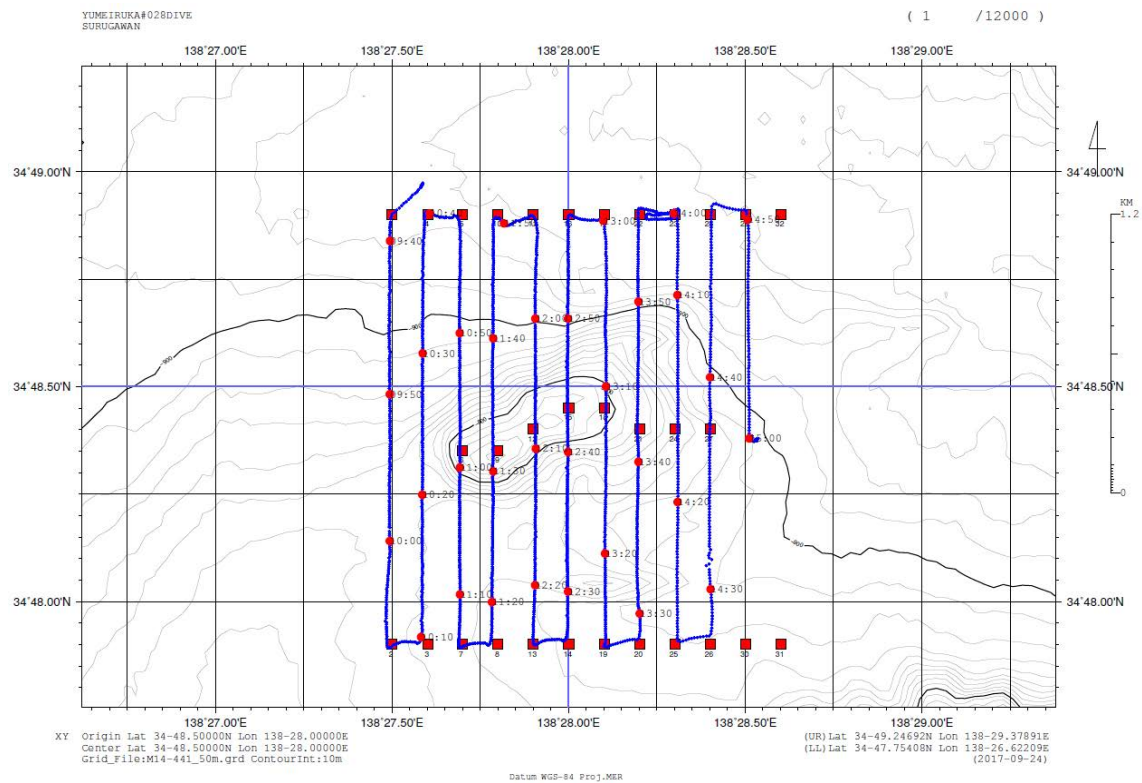


Fig 2. Cruise track of “YUMEIRUKA” dive #28.

3.4 About “Yumeiruka”

AUV "Yumeiruka" was developed to perform seabed resource survey. "Yumeiruka" is equipped with two sets of X-rudders, one in the front, and one in the rear part of the vehicle. This arrangement of the rudders enables the vehicle to trace the sea bottom with controlled attitude. For example, "Yumeiruka" can follow the terrain of an irregular seabed with its pitch angle fixed to 0 degree. The attitude control capability allows the vehicle to aim the onboard sensors vertically at the sea bottom, resulting in more efficient survey of the seafloor.

Table. 3 Specifications of “Yumeiruka”

Items	Specification
Dimensions (L, B, H)	5.0 m, 1.4 m, 1.4 m
Weight (in air)	2,700 kg
Maximum Operation Depth	3,000 m
Cruising Speeds	2 knots (Max. 3 knots)
Propulsion System	4 × 400W thrusters, 2 × X-rudders (fore and rear)
Power Source	Rechargeable lithium ion battery
Endurance	16 hours
Navigation sensors	INS, DVL, SSBL
Observation sensors	CTD, pH meter, fluoro meter, IFS, SAS, SBP



Fig. 3 AUV “Yumeiruka”

4. Observation of an Underwater Glider

4. 1 Back ground and Purpose of the Cruise

Recently underwater gliders have drawn attention and have been used widely. They can travel autonomously over long distances, gathering ocean data at reasonable cost. However, their operating duration is limited to several months. They cannot conduct long-term monitoring of several years as profiling floats can do.

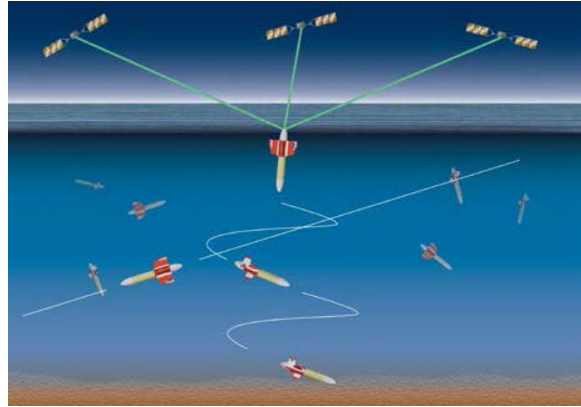


Fig. 4 Operation image of underwater gliders for virtual mooring

We proposed a new type of an underwater glider that can sleep on the sea-floor or while drifting underwater so that it can elongate its operation time. It will be able to conduct a long-term monitoring staying in a designated area for several years. We are now developing its prototype.

Fig. 4 portrays an image of its operation. It will ascend and descend between the seafloor and the sea surface while monitoring the sea environment. It can sleep for a fixed time on the seafloor or while drifting underwater to extend the observation period. It will locate its position when ascending to the sea surface using GPS. Then it will send data via Iridium. It will glide back toward the designated area if it drifted away.

The first sea test was conducted in March 2012 using R/V Kaiyo (KY12-04). In that sea test, although a thin string was connected to the vehicle for the security, it descended to 470 m depth and ascended back to the sea surface independently. Although the thin string restricted the descent depth, we confirmed the vehicle's basic functions including control of the buoyancy engine (BE), control of the gravity-center-controller (GCC), positioning using GPS, and Iridium communication.

In 2013, we have developed a new small-sized BE having higher energy efficiency and replaced with the original one. We evaluated its performance using R/V Kaiyo (KY13-12). As results of this cruise, we could confirm the operation performance of the new BE. Although a thin string was still attached to the vehicle for safety, we could confirm the superior performance of the new BE, pitch control, depth control, communication via Iridium and GPS positioning.

In 2014, we have conducted a series of sea tests using a small boat, and succeeded in heading control and

autonomous gliding toward the destination. Because we had to tow the glider from the port because of the limited capability of the boat, the gliding was conducted in shallow waters, and the maximum depth is limited to 200 m.

In 2015, we have conducted the gliding test to 1,000 m depth using R/V Natsushima (NT15-09). In this test, we could again confirm that it could go ahead towards the destination in real environment while gliding to 1,000 m depth.

In 2015, we have conducted another sea test using a small research vessel Tsukuba-II, and confirmed its ability to touch down on the sea-floor and sleep there for a designated time. In this test, the glider landed onto the seafloor slowly and softly, and slept there for ten minutes. After wake-up, it ascent to the seafloor while monitoring the sea environment with a newly mounted CTD sensor.

In 2016, we have conducted the second deep-gliding test to 1,500 m water depth and drifting sleep test at 1,000 m water depth using R/V vessel Kairei (KY16-06). In this test we could again confirmed that it can glide toward the destination and can sleep while drifting at the designated depth of 1,000 m. However, because of a small parameters mismatch, it began to ascend soon after it waked up from sleep at 1000 m depth, and could not descend to 1,500 m depth.

4.2 Outline of the Prototype Underwater Glider

Fig. 5 and Fig. 6 show the photo and the general arrangement of the underwater glider respectively. Its weight in air and the maximum descending depth are 160kg and 2,100m respectively. The pressure-tight housing is made of aluminum alloy. The shape of wings was determined after hydrodynamic tests using a small-sized model.

Main onboard equipment includes a GCC, a BE, an acoustic transponder, a GPS/Iridium antenna and a CTD sensor. The GCC controls the pitch angle and roll angle of the vehicle by moving the weight longitudinally and rotating it around the longitudinal axis. The weight consists of batteries and lead weights. By rotating the weight, we can roll the vehicle. Then the direction of the lift forces and moments acting on the wing change, and the vehicle rotates. Consequently, the vehicle can control its heading and the direction of gliding.

BE pull and push the oil between the oil reservoir mounted in the pressure-tight housing and the oil bladder placed outside of the pressure-tight housing. By moving the oil between them, it can change the volume and the underwater weight of the vehicle. When descending, it pulls oil from the oil bladder to the oil reservoir. When ascending, it pushes the oil from the oil reservoir to the oil bladder. It can pull and push oil and control its underwater weight against the water pressure up to 21 MPa.

The acoustic transponder is mounted on the glider to localize its underwater position. It is compatible with the acoustic positioning system of Kairei. Therefore, we can localize the underwater position of the vehicle when it dives and can trace the vehicle.

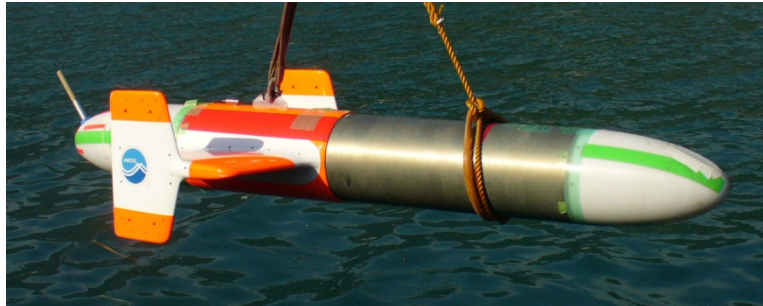
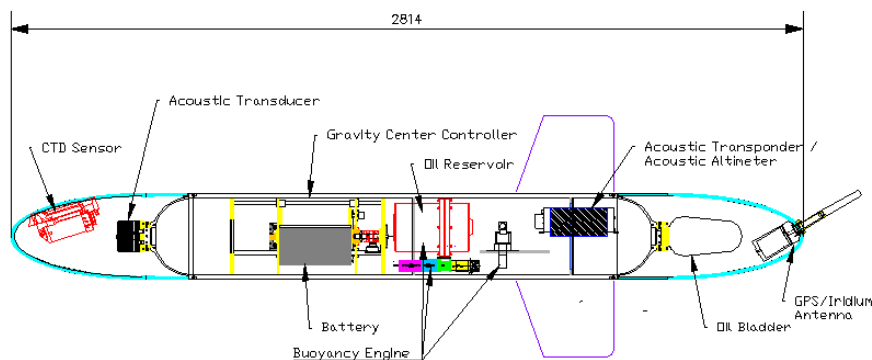


Fig. 5 The Photo of the glider



Unit: mm

Fig. 6 The general arrangement of the prototype glider

4.3 Purpose of this cruise

The purpose of this cruise is to evaluate the function of spiral-descending to 1,500 m and spiral-ascending. At the same time, we will conduct an observation experiment using the onboard CTD sensor. We also evaluate the function to stay at the designated depth and sleep there for a fixed time again.

In the previous tests, it was already confirmed that we could control and change the heading of the underwater glider when the pitching was set to ± 15 degrees. In this cruise, to increase the descending and ascending velocity with lower energy consumption, the heading was set to 20 degrees, and the dynamic characteristics were evaluated. The mounting angle of the GPS/Iridium antenna was increased so that it can protrude more clearly from the sea-surface when the underwater glider ascends to the surface.

The maximum descending depth was set to 1,500 m because we had to recover the underwater glider during the daytime with sufficient margin.

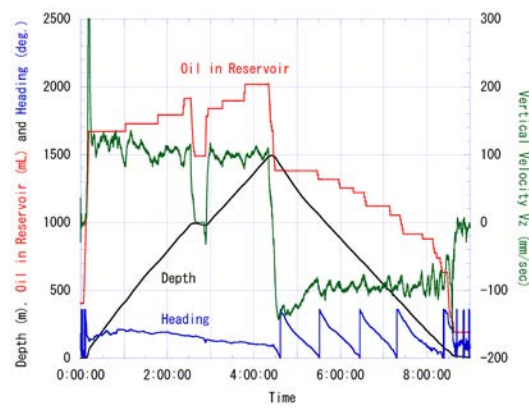


Fig. 7 Recorded log

4.4 Test Results

The experiment was conducted on September 25th, 2017. It was programmed first to descend to 1,000 m in depth and slept there for 10 minutes. After wake-up, it descended to 1,500 m in depth, and ascended to the sea-surface. It was also programmed to move spirally during descending and ascending.

Fig. 7 and fig. 8 show the recorded log and the footprint of the underwater glider that was located by the acoustic positioning system of the mother vessel.

From these figures and other records, the following points became clear.

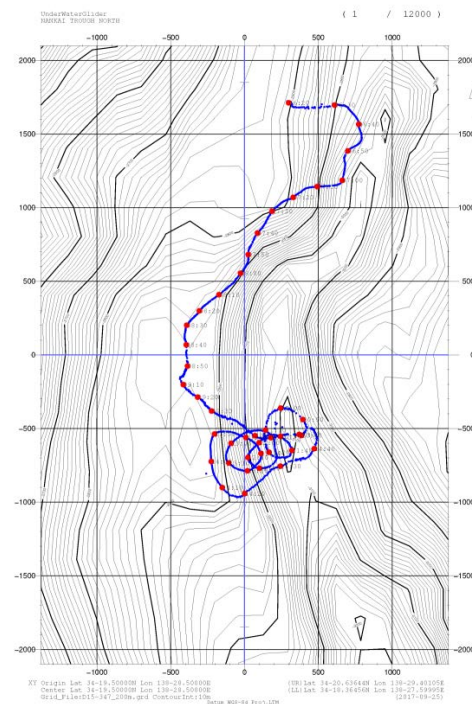


Fig. 8 Footprint of the underwater glider

- (1) The underwater glider moved spirally when ascending and stayed at keep almost same horizontal position, however it could not move spirally when descending.
- (2) The control of the vertical velocity (V_z -control), depth-control and sleep-control were conducted well.
- (3) Other functions including GPS positioning, Iridium communication, pitching-control and CTD measurement worked well.

[Spiral movement]

We are now investigating the cause why it could not move spirally when descending, although it could while ascending. However, in the previous test, it was already confirmed that when the pitching was set to +15 deg. and the GPS/Iridium antenna was fixed in the previous position, the underwater glider could control its heading while descending and ascending. It means that the glider can descend spirally in that condition.

[V_z control]

When descending and ascending, the vertical velocity (V_z) was estimated by differentiating the depth signal. When the V_z became lower than the designated value, the BE was activated to control the underwater weight and V_z . We can see from fig. 7 that the V_z was well controlled by driving the BE.

Descending close to 1,000 m in depth, to prepare to sleep, the BE was activated to obtain neutral buoyancy. When V_z became almost zero, all the electric power was shut down except the clock and the underwater glider began to sleep for ten minutes. From fig. 7 the underwater glider maintained nearly constant water depth.

4.5 Conclusion

From this cruise, the following points became clear.

- (1) The underwater glider moved spirally when ascending and stayed at keep almost same horizontal position. However, when descending, the heading control characteristic depends on the pitch angle and/or the mounting angle of the GPS/Iridium antenna.
- (2) The V_z -control, depth-control and sleep-control were conducted well.
- (3) Other functions including GPS positioning, Iridium communication, pitching control and CTD measurement worked well.

We are now planning to carry out longer observation experiment to show that it can conduct long-term monitoring staying in designated water.

4.6 Acknowledgements

We are grateful to the captain Satoshi Susami and the all crews of the R/V Yokosuka for their invaluable supports during the cruise. We also would like to express deepest appreciation to Prof. Masahiko Nakamura of Kyushu University and Taiyo Kobayashi who contribute to analyze and evaluate the obtained data.

5. Notice on Using

Notice on using: Insert the following notice to users regarding the data and samples obtained.

This cruise report is a preliminary documentation as of the end of the cruise.

This report may not be corrected even if changes on contents (i.e. taxonomic classifications) may be found after its publication. This report may also be changed without notice. Data on this cruise report may be raw or unprocessed. If you are going to use or refer to the data written on this report, please ask the Chief Scientist for latest information.

Users of data or results on this cruise report are requested to submit their results to the Data Management Group of JAMSTEC.