



R/V NATSUSHIMA Cruise Report

NT15-09

Continuous Monitoring Experiments
of a Prototype Underwater Glider
for Long-term Virtual Mooring

Sagami Bay

from June 3, 2015 to June 5, 2015

Japan Agency for Marine-Earth Science and Technology

(JAMSTEC)

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1. Cruise Information

- (1) Cruise ID: NT15-09
- (2) Name of vessel: Natsushima
- (3) Captain Shinya Ryono
- (4) Title of cruise／Title of proposal:
Continuous Monitoring Experiments of a Prototype Underwater
Glider for Long-term Virtual Mooring
- (5) Chief scientist: Kenichi Asakawa (JAMSTEC)
- (6) Representative of the Science Party Kenichi Asakawa (JAMSTEC)
- (7) Cruise period: Three days, from June 3rd 2015 to June 5th 2015
- (8) Port of call : from Sumitomo Heavy Industries, Ltd. Yokosuka to JAMSTEC
Yokosuka
- (9) Research area: Sagami Bay

(10) Research Map Fig. 1

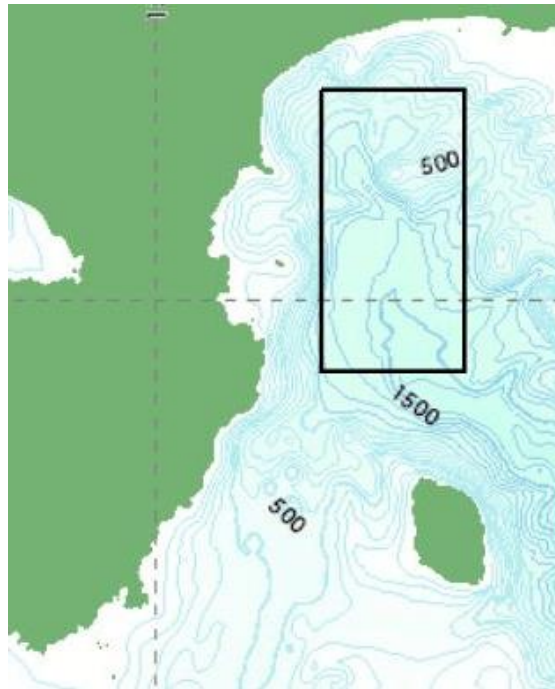


Fig. 1 Research Map

The test field is within
35° 14.0'N –139° 13.0'E, 35° 14.0'N –139° 25.0'E
34° 55.0'N –139° 13.0'E, 34° 55.0'N – 139° 25.0'E.

2. Researchers

- (1) Chief Scientist: Kenichi Asakawa (JAMSTEC)
- (2) Scientists on board: Tadahiro Hyakudome (JAMSTEC)
- Masahiko Nakamura (Kyushu University)
- Ryotaro Suga (JAMSTEC)
- (3) Chief Engineer onboard: Hiroki Ushiromura (MWJ)

3. Background and purpose of this cruise

Recently underwater gliders have drawn attention and have been used widely. They can travel autonomously over long distances, gathering ocean data at a 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.

We are now developing a prototype of an underwater glider for virtual mooring. It will be able to conduct long-term monitoring while remaining in designated waters.

Fig. 2 portrays an image of its operation. It can sleep for a fixed time on the seafloor or while drifting underwater to extend the observation period. It will wake-up periodically to ascend and descend between the seafloor and the sea surface while monitoring the sea environment. 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 drifts 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

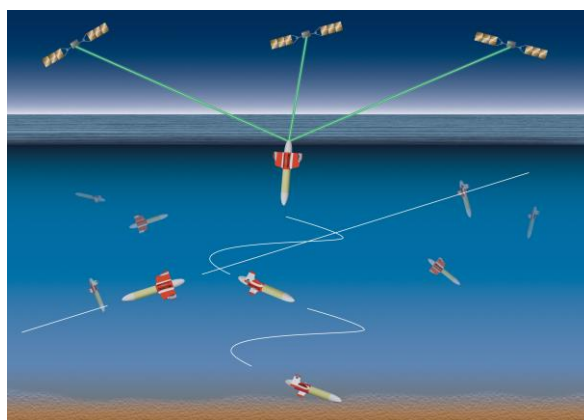


Fig. 2 Operation image of underwater gliders for virtual mooring

descent depth, we confirmed the vehicle's basic functions including control of the buoyancy engine, control of the gravity-center-controller (GCC), positioning using GPS, and Iridium communication.

In 2013, we have developed a new small-sized buoyancy engine 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 buoyancy engine. Although a thin string was still attached to the vehicle for safety, we could confirm the good performance of the new buoyancy engine, pitch control, depth control, communication via Iridium and GPS positioning.

In 2014 and 2015, 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.

The purpose of this cruise is to evaluate the gliding performance of the glider to deeper waters and the ability to approach the destination in real underwater environment.

4. Outline of the underwater glider

Fig. 3 and Fig. 4 show the photo and the general arrangement of the underwater glider respectively. Its weight in air and the maximum descending depth are 150kg 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.

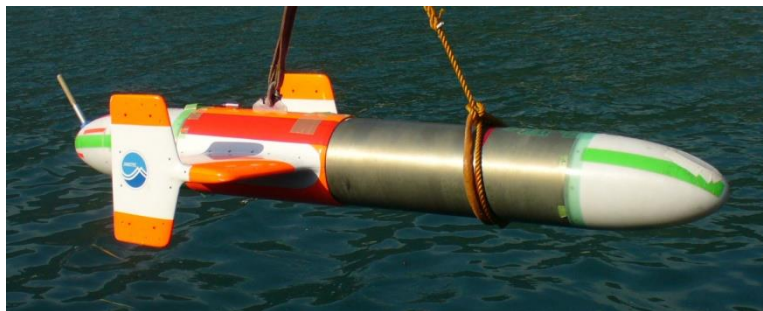


Fig. 3 The Photo of the glider

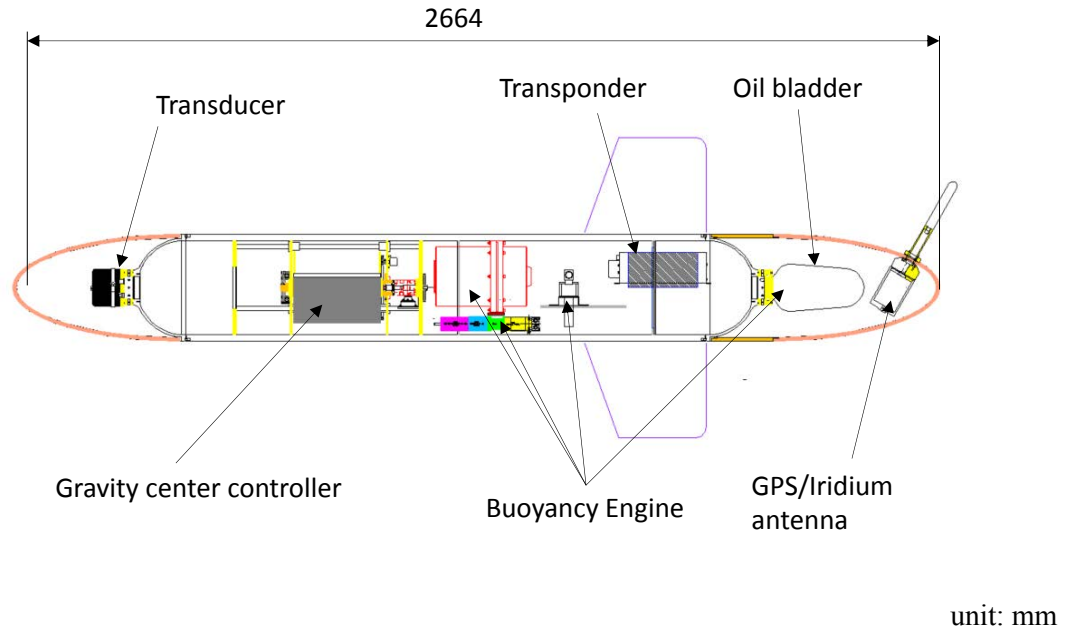


Fig. 4 The general arrangement of Tsukuyomi

Main onboard equipment includes a gravity center controller, a buoyancy engine, an acoustic transponder and a GPS/Iridium antenna.

The gravity center controller 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, and the vehicle changes its heading. For example, when descending, it can rotate clockwise by downing the left side. When ascending, it can rotate clockwise by downing the right side. Then the vehicle can control its heading and the direction of gliding.

The buoyancy engine 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 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 used to localize the underwater position of the vehicle. It is compatible with the acoustic positioning system of Natsushima. That means we can localize the position of the vehicle when it dives and can trace the vehicle.

5. Sea Tests

5.1 Test Items

The purpose of this cruise is to confirm that the gliding performance of the glider to deeper waters and to evaluate the ability to approach the destination in real underwater environment. Because the ship time for experiment is restricted to one day, the maximum descending depth was set to 1,000 m.

5.2 Safety Measure

For the sake of safety, the glider has a ballast releaser on which a ballast was set. Fig. 5 and Fig. 6 show the ballast itself and the ballast mounted on the vehicle. The ballast can be released on command that is sent to the vehicle from Natsushima via the acoustic positioning system. Its ballast-dropping mechanism is same as that of the ballast releaser for ocean bottom seismometers. The ballast can also be dropped by using a timer. The timer activate the ballast releaser when designated time is past after the electric power is set on. The battery for the acoustic positioning system and the



Fig. 5 Ballast



Fig. 6 Ballast on the vehicle

ballast releaser is independent from that of the vehicle. Therefore even if the power system of the vehicle is broken, it could drop the ballast and could ascend to the sea-surface. Because the acoustic positioning system is also independent from the vehicle's electric system, we could localize the underwater position of the vehicle, and could recover it even if the power system of the vehicle is broken,



Fig. 7 Photo of the vehicle being raised up by the A-frame

5.3 Test Results

The sea test has been conducted successfully. Fig. 7 and Fig. 8 show the vehicle when being raised by the A-frame of Natsushima and floating before starting to dive.

The vehicle is programmed to glide toward the designated destination when descending. After the vehicle dived to 1,000 meter in depth, it was programmed to take the maximum pitch and ascend to the sea surface. The heading was not controlled while ascending. Before starting to dive, it got its position by GPS. The latitude and the longitude of the destination were given to the vehicle beforehand. Therefore it could calculate the gliding direction toward the destination. Fig. 9 shows the data recorded by the vehicle. It shows that the vehicle was controlled as it was programmed. Its heading was almost coincide with the targeted direction. The pitching was controlled to -15 degrees while descending and took its maximum while ascending. The maximum descending depth was 1,000



Fig. 8 Photo of the vehicle floating before starting to drive

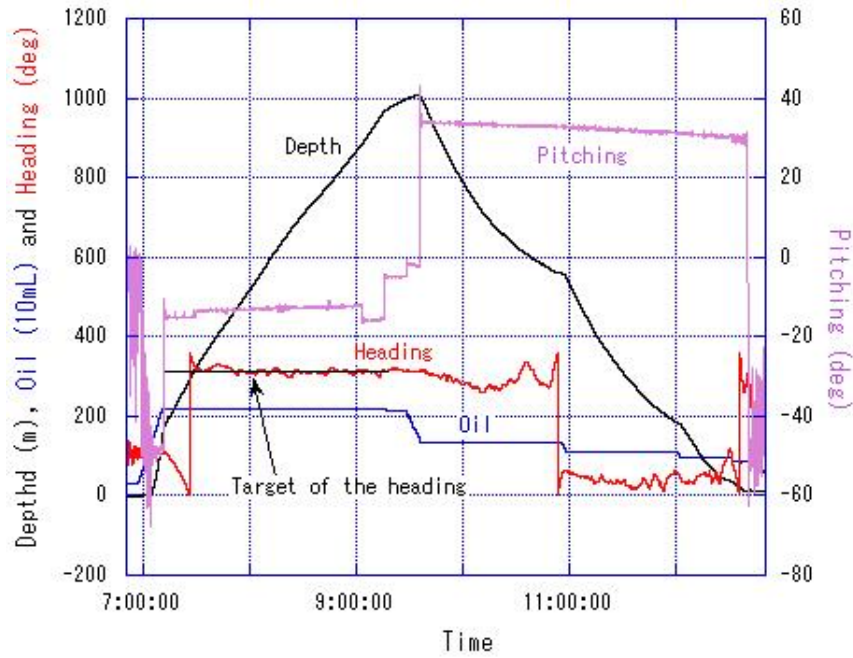


Fig. 9 Gliding data recorded by the glider

meters. We could confirm that the pitching, heading and underwater weight were well controlled as it was programmed.

Fig. 10 shows the start and end positions of descension. The arrow in Fig. 10 show the targeted gliding direction of the vehicle while descending. We can confirm that the vehicle glided toward the destination in the real underwater environment.

6. Summary

We have conducted the sea test to evaluate the gliding performance of the prototype underwater glider for long-term virtual mooring, and the ability to approach the destination in real underwater environment. In the test, because the ship time for experiment is restricted to one day, the maximum descending depth was set to 1,000 m. As the result of the sea test, we could confirm that the vehicle had good gliding performance and can glide toward the destination in the real underwater environment.

7. Acknowledgements

We are grateful to the captain Shinya Ryono and the all crews of the R/V Natsushima for their invaluable supports during the cruise.

8. Notice on Using

This cruise report is a preliminary documentation as of the end of the cruise and it may be changed without notice. If any data in this report is going to be used, it is required to contact with the Chief Scientist and get his acceptance.

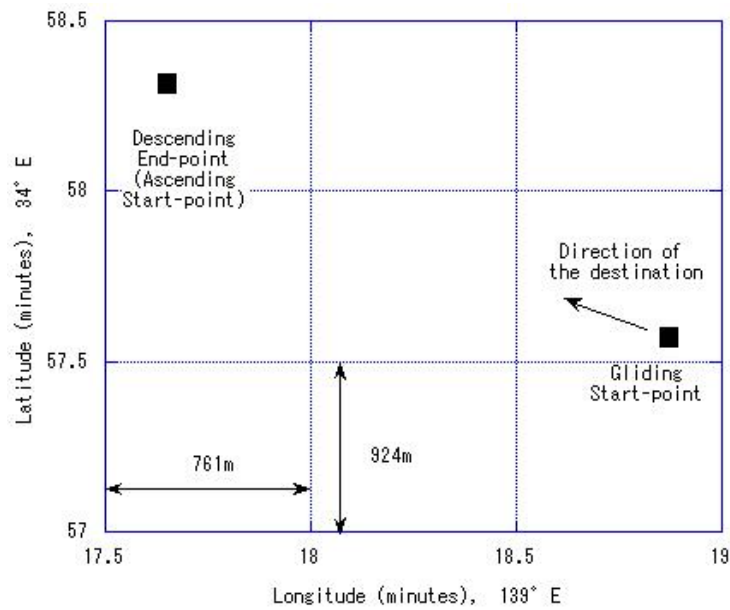


Fig. 10 Gliding direction of the vehicle while descending