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R/V Kaiyo Cruise Report

KY11-10

Field tests of a new buoyancy engine for a virtual mooring shuttle and a deep profiling float in Sagami-Bay

Aug. 9, 2011-Aug. 14, 2011

September 2011

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

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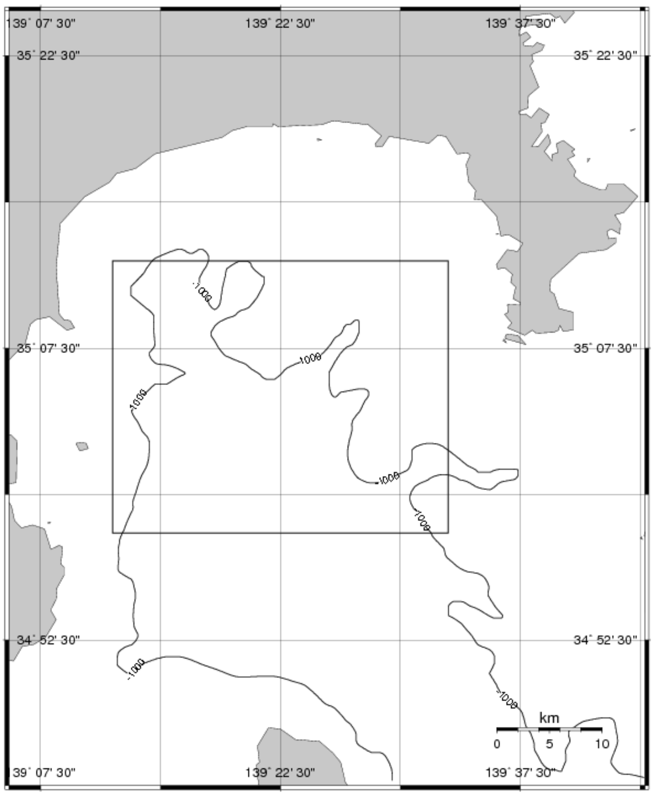
1. Cruise Information

- Cruise ID: KY11-10
- Name of vessel: R/V Kaiyo
- Title of the cruise: Field tests of a new buoyancy engine for a virtual mooring shuttle and a deep profiling float in Sagami-Bay
- Cruise period: August 9, 2011 – August 14, 2011
- Ports of call: JAMSTEC (Yokosuka) - JAMSTEC (Yokosuka)
- Research area: Sagami-Bay
- Research map



The test field is the area within 34° 58’N – 35° 12’N and 139° 12’ – 139° 33’N.

2. Researchers

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  Toshio SUGA / JAMSTEC
  Mitsuhiro TAKAKUSAKI / The Tsurumi-Seiki Co. Ltd
- Title of the original scientific proposal:
  Field tests of a demonstrator of a new buoyancy engine for virtual mooring shuttle and observational studies of air-sea interactions in the Kuroshio Extension
- Representative of the science party: Taiyo KOBAYASHI / JAMSTEC

3. Field tests

3.1 Backgrounds and purposes in the cruise

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 warm significantly during 1990s to 2000s. The heat accumulated in the global ocean deeper layers than 3000 m from 1990s to 2000s was estimated at about $0.4\text{–}0.8 \times 10^{22}$ J 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 in the global climate system and also a major source of uncertainness.

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 as an international guideline of observational ocean sciences for the next decade (2010–2019). An observing array by numerous "float-like vehicles" 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 autonomous vehicles such as floats and gliders. One of the key elements for the vehicles for deep ocean observations is a buoyancy engine, which enables the vehicles to ascend/descend in ocean. JAMSTEC and Tsurumi-Seiki Co. Ltd (TSK) developed an engine with a brand-new mechanism suitable for deep vehicles and we have verified the engine showed a sufficient performance under high pressure mechanically.

In cooperation with JAMSTEC and TSK, two types of vehicles for deep ocean observations, a shuttle for virtual mooring (VM) and a deep profiling float, are being developed with the engine. Controlling the engine in water is another important factor for the autonomous vehicles and we have verified that its control soft-ware worked well at on-desk simulations and in coastal field tests. However, the verifications by such methods were very limited. Situations of the vehicles in water are more complicated than in the simulations and the periods of the field tests are allowed daytime of a day, which is very short considering slow vertical movements (<10 cm s^{-1}) of the vehicles in water to dive to the great depths (more than 1000m).

In the cruise we indented to carry out several field tests of the new buoyancy engine, especially for its control system for the period of long-time, by using a demonstrator of the buoyancy engine for the VM shuttles (Fig. 1a) and a prototype of deep profiling floats (Fig. 1b). Basic functions of the autonomous vehicles, such as bidirectional communication with Iridium system, location fixing by Global Positioning System (GPS), and measurements with a Conductivity-Temperature-Depth (CTD) sensor, were also examined.

Fig. 1: (a) The demonstrator of the buoyancy engine for the VM shuttles (left) and (b) a prototype of deep profiling floats (right).

3.2 Details of the field tests

(1) Location fixing by GPS

Examine the accuracy of position data fixed by GPS on a demonstrator of the buoyancy engine for VM shuttles at the sea surface.

(2) Communication with Iridium system

Verify the stable bidirectional communications (data transmissions) between the autonomous devises on the sea surface and the stations on land.

(3) Control of vertical movements in sallower depth for the demonstrator of the buoyancy engine for VM shuttles

Verify the stable control of the buoyancy engine in shallower depth by using the VM demonstrator. The demonstrator, which is tied to surface drifting GPS buoys by a 1000m-long fishing line, dives once to the depth of up to 500m in the test. The whole system deployed in the sea is shown in Fig. 2 schematically.

(4) Control of vertical movements in deeper depth for the demonstrator of the buoyancy engine for VM shuttles

Verify the stable control of the buoyancy engine in deeper depth by using the VM demonstrator. The demonstrator dives once to the depth of up to 1500m in the test. The test will be carried out only when the above experiment (3) is done well.

(5) Long-term control of vertical movements in sallower depth for a prototype of deep profiling floats

Examine the control sequence of vertical movements for the buoyancy engine by using a prototype of deep profiling floats. The prototype continues the observing cycles for as long a period as possible and the maximum descending depth is set at up to 500m. The prototype is tied to surface drifting GPS buoys by a 1000m-long fishing line. The whole system deployed in the sea is shown in Fig. 2 schematically.

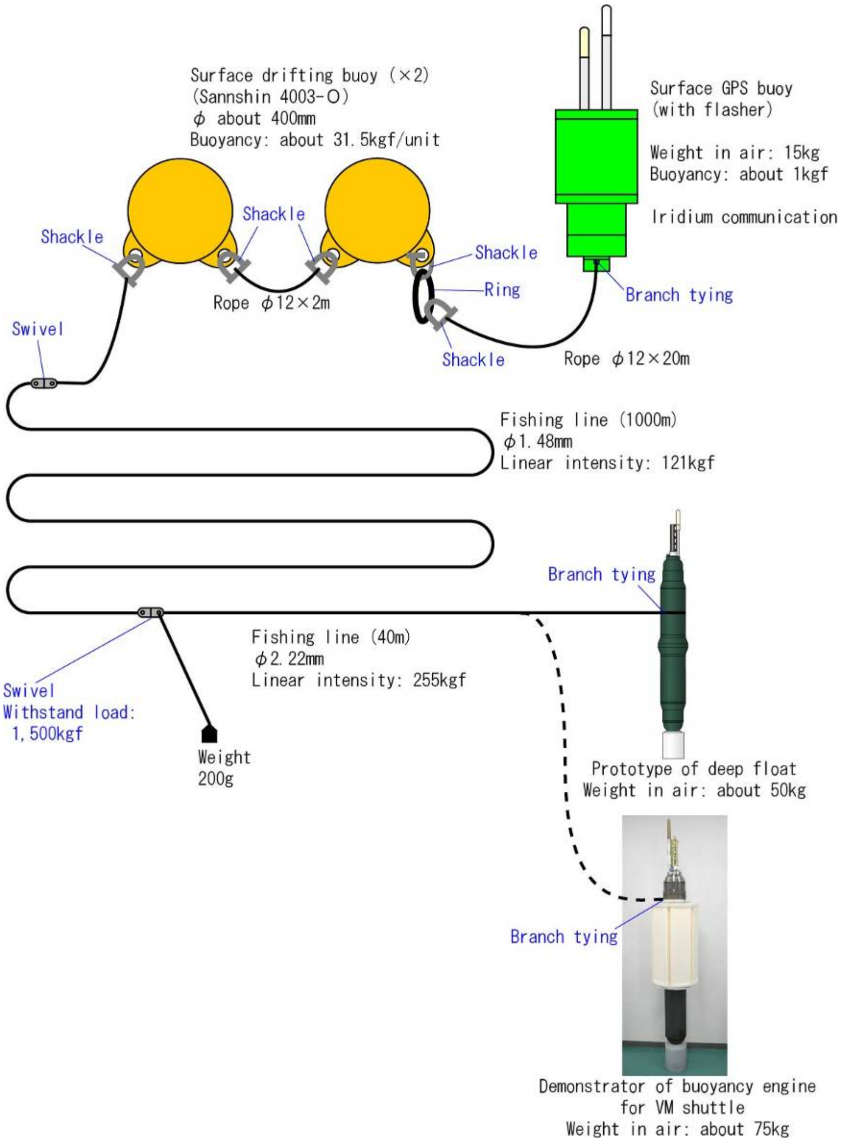

Fig. 2: A schematic figure for the whole deployed system of test (3) and (5).

Fig. 3: The surface GPS buoy used in the tests.

Fig. 4: Surface drifting buoys just before deployed.

3.3 Results of the field tests

In the cruise we cancelled the test (4). The test (5) was carried out three times for the periods of up to 22 hours and the whole drifting system was recovered next early morning. Because …

1. The surface GPS buoy, which is necessary for the tests (3) and (5), did not work well on deck initially. Thus, we repaired the GPS buoy by replacement of its antenna and modem with those of the VM demonstrator.
2. The drifting system could not stay within the test field for longer period than about 1 day due to more rapid currents than expected.
3. It became difficult to continue the long-term test (5) and conduct deploy/recovery operations of the drifting system during daytime in the layer half of the cruise period, which fell on the Bon holiday period, due to appearance of many fishery's boats and yachts in the test field.

Fig. 5: The surface GPS buoy under repair (on 10th August).

Test (1) and (2)

Both tests by using the VM demonstrator were carried out on 9th August. The performance was verified well. However, it was verified that the GPS function of the GPS buoy did not work well. After the test (3) for the VM demonstrator on 10th, its Iridium/GPS antenna and modem were moved into the GPS buoy and then the GPS function of the buoy was recovered.

Fig. 6: The VM demonstrator in the test (1) and (2). The demonstrator transmitted its positions fixed by GPS to land-stations via Iridium satellites every 10 minutes successfully while it drifted on the sea surface for about an hour.

Test (3)

The test was carried out in the daytime on 10th August under eye's monitoring the surface buoys. The VM demonstrator was waken up at 8:25 (JST) and deployed at 8:55. The deployment of the whole drifting system was completed at 9:35. The first profile data from the demonstrator was transmitted at 14:25. After the verification of the float operation change into surface drifting (or the success of the command transmission from land to the demonstrator), a recovery operation of the drifting system was started at 15:00 and completed at 16:10. The test results were as well as expected.

Fig. 7: The VM demonstrator just before deployment.

Fig. 8: Recovery of the VM demonstrator by a workboat of R/V Kaiyo.

Test (5)

First deployment on 11-12th August: The prototype of deep float was waked up at 9:00 on 11th August and deployed at the sea surface at 9:10. The deployment of the whole drifting system was completed at 9:42. The profile data of the first and second ascends were received from the prototype at 15:46 and 23:30. The recovery of the drifting system was started at 5:55 and completed at 6:50 on 12th August. The period of the test was 21 hours 50 minutes and the test was ended when the prototype was operating in the third ascending. The results were well.

Second deployment on 12-13th August: The prototype was waked up at 11:59 on 12th August and deployed at the sea surface at 12:05. The deployment of the whole drifting system was completed at 12:26. The profile data of the first and second ascends were received from the prototype at 17:02 and at 00:13 on 13th. The recovery of the drifting system was started at 5:55 and completed at 6:40 on 13th August. The period of the test was 18 hours 41 minutes and the test was ended when the prototype was operating in the third ascending. The results were well.

Third deployment on 13-14th August: The prototype of deep float was waked up at 11:00 on 13th August and deployed at the sea surface at 11:05. The deployment of the whole drifting system was completed at 11:35. The profile data of the first and second ascends were received from the prototype at 17:30 and 23:30. The recovery of the drifting system was started at 5:55 and completed at 6:35 on 14th August. The period of the test was 19 hours 35 minutes and the test was ended when the prototype was operating in the third ascending. The results were well.

Fig. 9: Final checks of the prototype of deep floats just before deployment (at the second deployment on 12th August).

Fig. 10: Extending the 1000m-long fishing line of the drifting system (at the first deployment on 11th August).

Fig. 11: Just before picking up of the prototype (at the first deployment on 12th August).

Fig. 12: The prototype under maintenance (before the second deployment on 12th August).

3.4 Summary of the tests

At the test (5) the drifting system was extended very long and the prototype of deep floats was considered to be always pulled strongly by the line toward the buoys on the sea surface. It is probably derived from the facts that the prototype in the sea was generally drifted southward (or southeastward) due to the anti-cyclonical coastal currents in the bay and that the surface drifting buoys were blown northward strongly because of their large bodies. Thus, the prototype descended to shallower depths than the expected from the parameters set for the tests except for the first dive at the third trial. However, a self-learning function of its operating program seemed to work well since it dived deeper descend by descend to approach at the target depth.

By the field tests in the cruise we became sure that the operating program of the new buoyancy engine for the autonomous devices can work as well as it was expected. Thus, we are going to step to the next field test in the deep ocean confidently after some defects found here will be improved.

4. Notice on Using

This cruise report is a preliminary documentation as of the end of the cruise and it may be changed without notice. The autonomous vehicles used in the cruise are under development at JAMSTEC and TSK. If any data obtained by them is going to be used, it is required to contact with the Chief Scientist.