YOKOSUKA Cruise Report

YK13-13

Evaluation cruise for hybrid submersible gravity observation system for exploration Izena Caldera in the middle Okinawa trough

Dec. 6, 2013 - Dec. 14, 2013

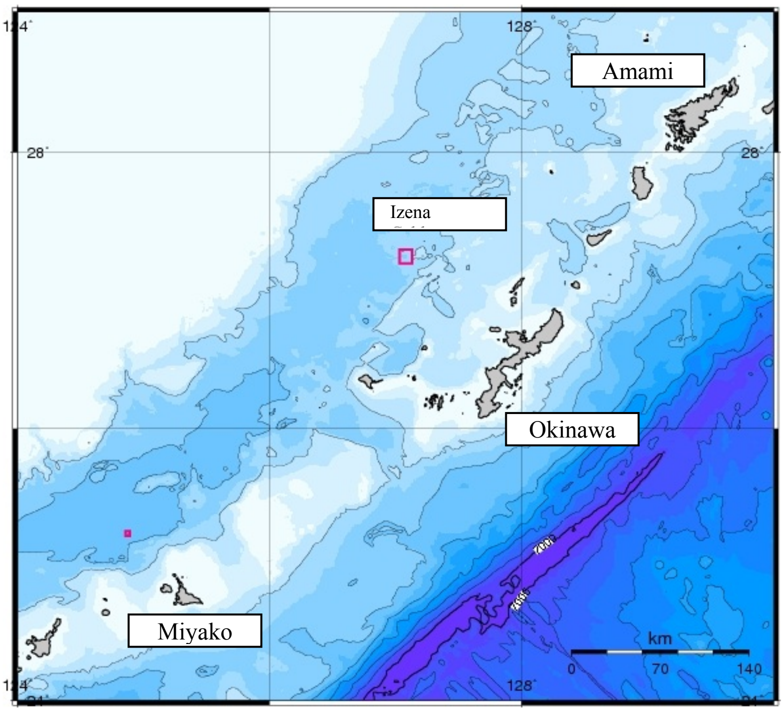
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

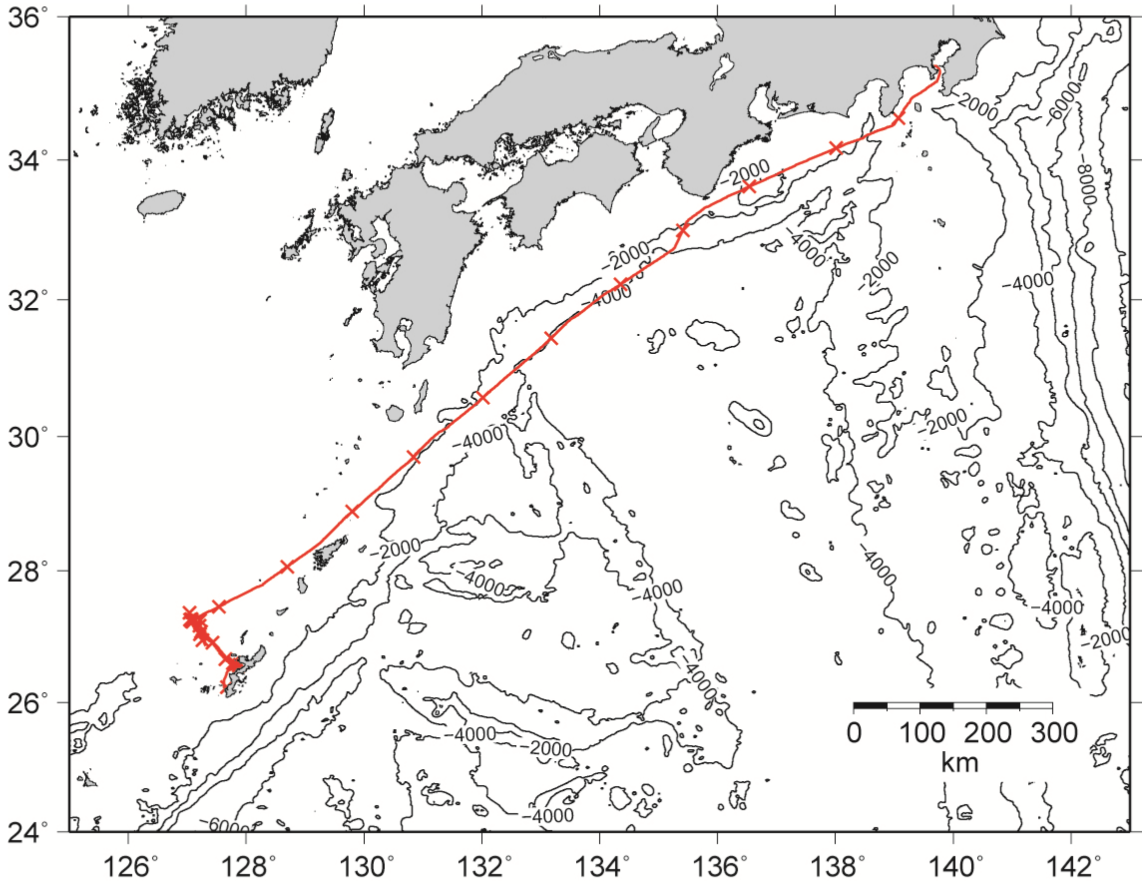
＊ There is no prescribed format. Images such as photographs may be included.

●**Contents**

1. Cruise Information

- Cruise ID YK13-13
- Name of vessel YOKOSUKA and URASHIMA
- Title of the cruise Evaluation cruise for hybrid submersible gravity observation system for exploration
- Title of proposal Evaluation of hybrid submersible gravity observation system for exploration of seafloor hydrothermal deposits by using an underwater vehicle
- Cruise period From December 6th, 2013 to December 14th, 2013
- Ports of call From Yokosuka to Naha
- Research area Izena Caldera in the middle Okinawa trough
- Research Map





Ship track of YK13-13

2. Researchers

● Chief scientist [Affiliation]

Masanao SHINOHARA [Earthquake Research Institute, University of Tokyo]

● Representative of the science party [Affiliation]

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Hiromi Fujimoto	[IRIDeS, Tohoku University]
Yagi Takeo	[University of Tokyo]
Tomokazu Matsuo	[University of Tokyo]
Satoshi Tsukioka	[JAMSTEC]
Takeshi Yoshiume	[JAMSTEC]
Shirasaki Yuichi	[Marine Eco Tech Ltd]
Shingo Kamoshida	[LINK LAB. Inc.]
Yuki Toyoshima	[Q・I Inc]
Soji Shimono	[Q・I Inc]
Shigeo Matsuda	[Clovertech Inc]
Isao Kozono	[NME]

3. Observation

- Purpose, Objectives, background

Gravity is one of the powerful indices to profile underground structures. Surface ship gravimeters are popular tool for the purpose of collecting gravity values in marine region. They enable us to obtain gravity values from large area easily, while the resolutions are relatively low because of the distance between the sea surface and bottom. Otherwise, ocean bottom gravimeters are able to be observed gravity with high resolution, but they have still covered few limited sites so that they are designed to make observation in quiet only. In some cases, such as hydrothermal deposit survey, the medium performance both in resolution and size of survey area are required (Fig. 1). Because technology of remote operated vehicle (ROV) and autonomous underwater vehicle (AUV) is been developing, there is a possibility to measure the gravity by using ROV or AUV.

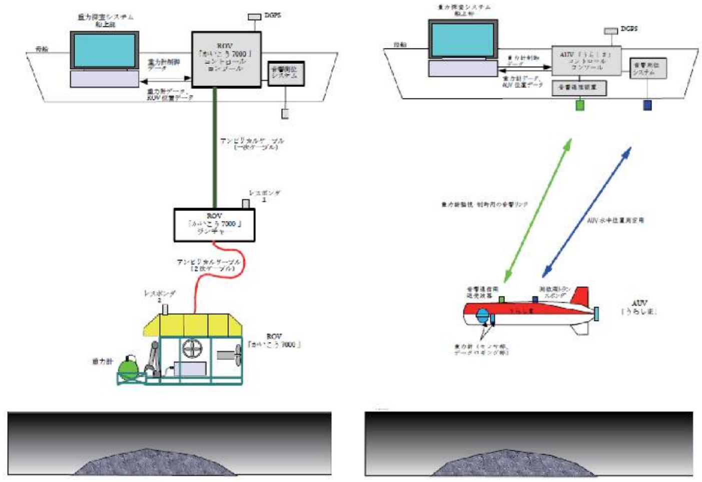

Fig.1 Concepts of submersible gravity measurement system using ROV and AUV.

Our target is to detect gravity anomalies less than 1 mgal by using an underwater vehicle. This setting is roughly equivalent to find a typical hydrothermal deposit with a dimension of 0.5 km x 0.5 km x 10 m and a density contrast of 1 g/cm^3 when the sensor is positioned 50 m above the seafloor. To obtain a position and amount of seafloor hydrothermal deposit that has a diamond shape with a diameter of 400m, 20m thick at the center and density difference of 1 g/cm^3, a resolution of gravity measurement should be approximately 0.1 mgal. In addition, measurement must be carried out 50m above a seafloor. AUV is suitable for such measurement near seafloor (Fig. 2). Compared to gravimeters, gravity gradiometers are insensitive to common disturbances such as parallel acceleration, thermal drift, and apparent gravity effect (Eötvös effect); however, during measurement using a mobile object, they are sensitive to centrifugal acceleration associated with instrument rotation, which should be removed by controlling the instrument’s vertical orientation. Therefore, we have developed a two-dimensional forced gimbal whose orientations are controlled referred to both fiber-optic gyroscopes and tiltmeters.

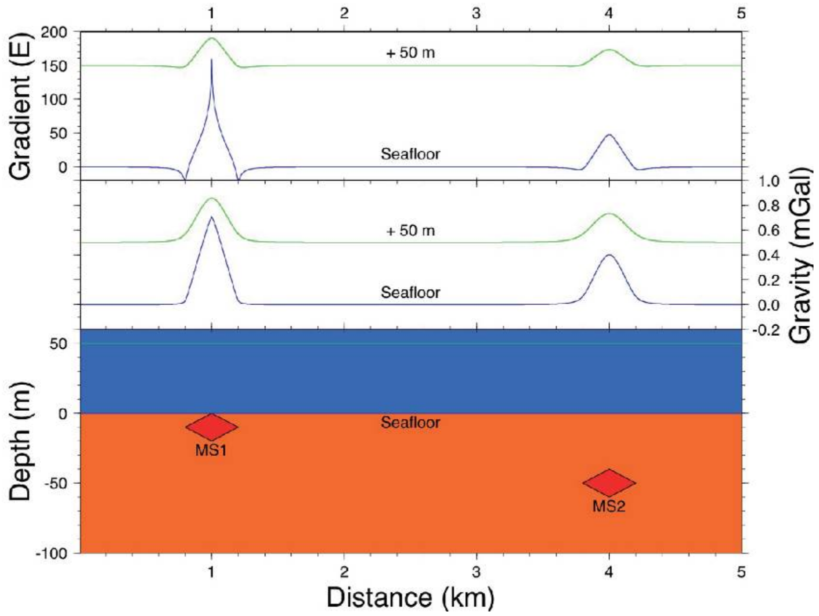

Fig.2 Estimated gravity (middle) and gradient (upper) variations are on a model (bottom). The model has two same shape deposits, MS1 and MS2, which have density differences of $1 g/cm^3$ against background.

For a survey of a seafloor hydrothermal deposit, we have been developing a submersible gravimeter system on underwater vehicles. And we carried out the first evaluation of our gravimeter system using the URASHIMA during YK12-14. The first cruise was carried out in September 2012 to evaluate this gravimeter and gravity gradiometer jointly by using an autonomous underwater vehicle, URASHIMA (Figs. 14 and 15). The first measurement was performed in Sagami-Bay. The whole system is controlled and monitored via acoustic link of the URASHIMA. We obtained gravity and miscellaneous data multiple traces along two tracks (Fig. 3). One of the tracks is above relatively flat sea bed, and the other is not. From these surveys, we obtained the gravity data and supplemental data for compensation of the gravity data with good quality (Fig. 4). From preliminary analyses, the resolution of the gravity data from the first practical measurement is estimated to reach 0.1 mgal. The data have enough qualities to evaluate the performance of the system.

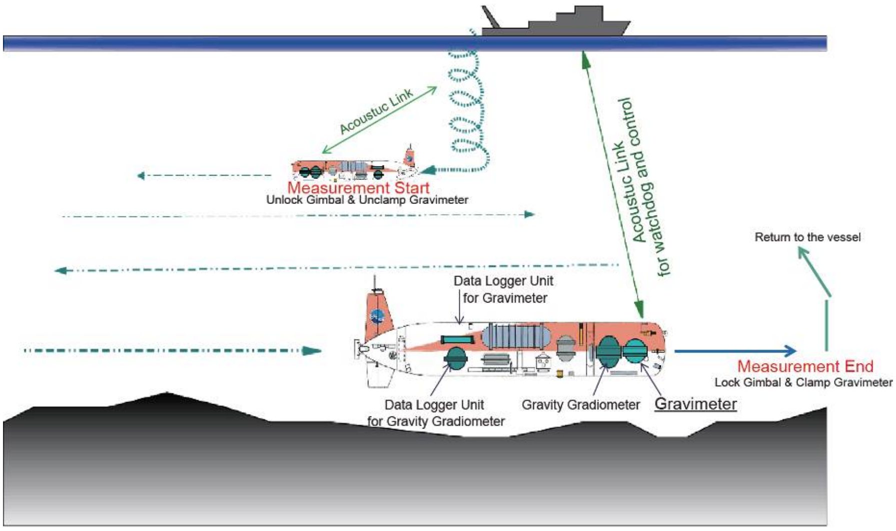

Fig. 3 Schematic of YK12-14 cruise measurement

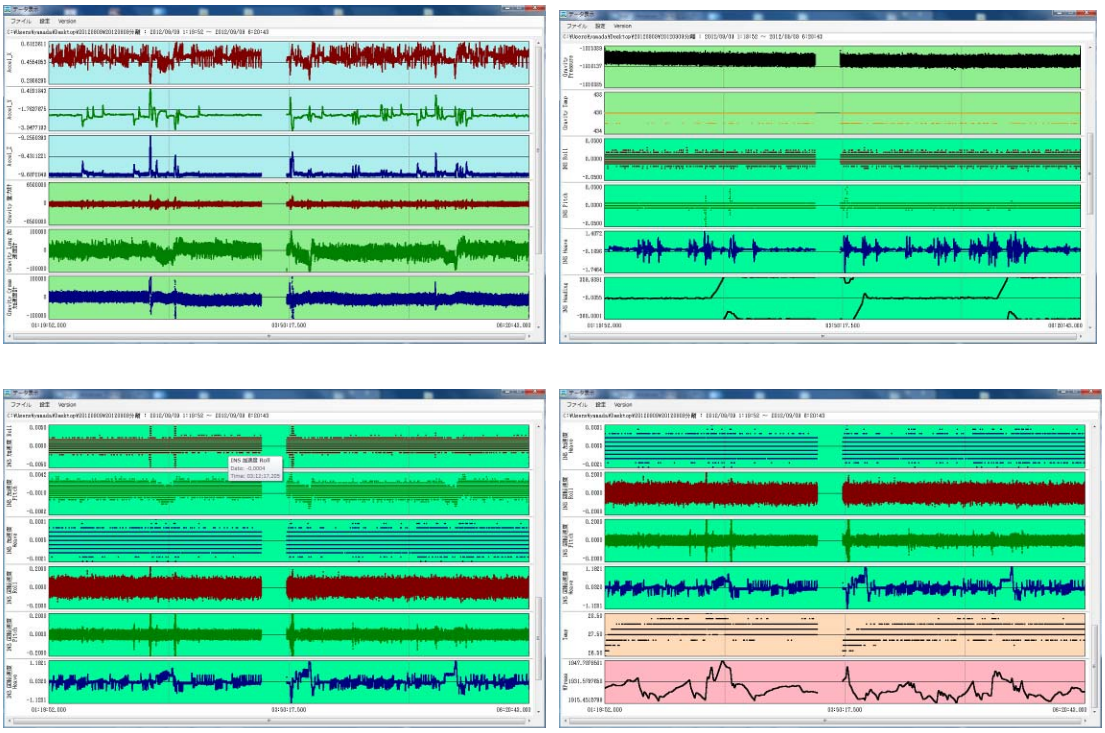

Fig. 4 Gravity and miscellaneous data obtained during the dive.

- Instruments and methods

We have improved a hybrid submersible gravity observation system to be compact as a part of the project for development of basic tool for exploration of seafloor hydrothermal deposits after the YK13-14

Curise.

Gravimeter system

We had to resolve some problems such as noise reduction, robustness and downsizing for an underwater gravimeter for exploration. Our hybrid gravimeter system consists of an underwater gravimeter and an underwater gravity gradiometer. We adopted Micro-g LaCoste S-174 as a gravity sensor for the gravimeter system (Fig. 5 and Table 1).

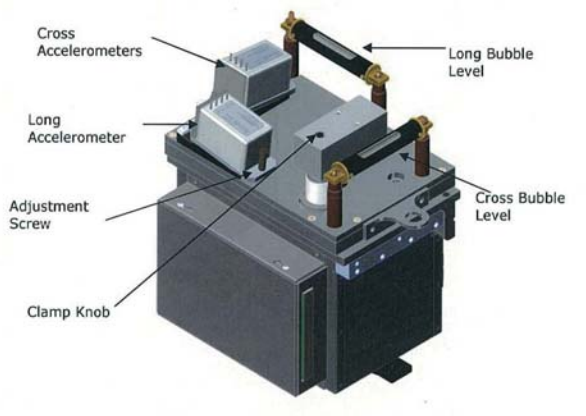

Fig.5 Gravity sensor (Micro-g LaCoste S-174).

Parameter		Test conditions
Sensor Temp	60.4 deg C	Thermo stated at the noose
Ambient Temp/sensitivity	< 0.05 mGal/deg C	Tested in range 27-53 deg C
Clamp Unclamp Repeats	0.1 mGal	
Sensor Drift	< 1 mGal/month	Linear drift
Sensor Noise	0.12 mGal/√ Hz	
Sensor Noise @ 100s	0.012 mGal	
Static Precision	< 0.050 mGal	

Table 1 Specifications of the gravity sensor S-174.

The gravity sensor is mounted on a gimbal control unit with an inertial navigation sensor (a fiber gyroscope, IXSEA PHINS) to keep vertical. For acquisition of high resolution gravity data, the gravity sensor must keep a constant temperature (60.4°C) and avoid effect of magnetic field of the Earth. The sensor is heated and is totally covered with thermal insulation and sheet of permalloy for magnetic shielding. In order to reduce high frequency noise due to mainly the vehicle motion, the data are decimated using low-pass filter and stored at sampling rates of approximately 100 Hz. Various kinds of data (for example, acceleration, depth, roll, pitch, etc.) for compensating gravity data are also recorded (Fig. 6). We have improved the gravimeter system to be compact for installation of various underwater vehicles. Re-design of Data Recording Unit contributes reducing a size of the system. Although the previous gravimeter system consisted of pressure sphere and cylinder-shape canister, the new system is stored in a sphere vessel made of titanium alloy (105 kgf in air, 15 kgf in water) and it is available in 3500 m below sea surface (Fig.7).

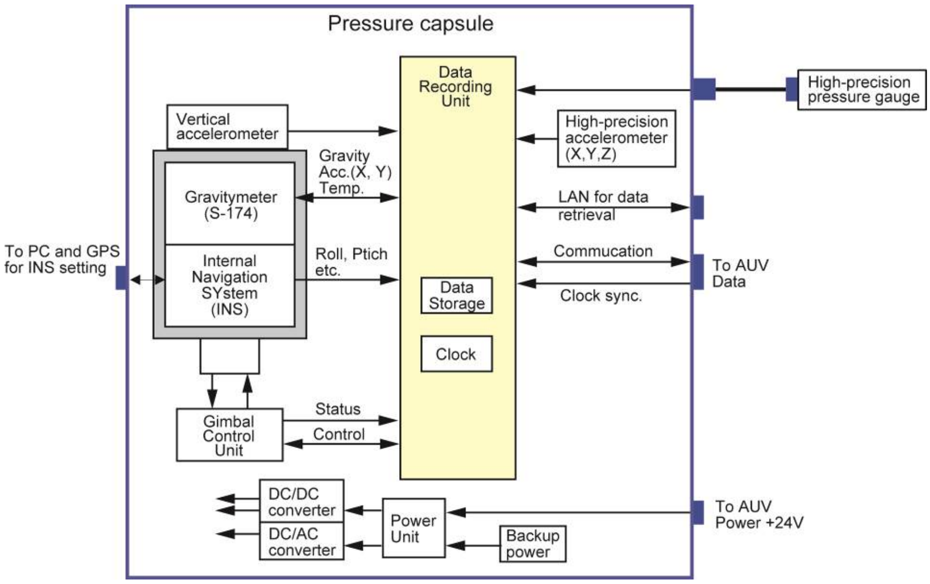

Fig.6 Block diagram of gravimeter system.

Fig.7 Photograph of inside of all-in-one type gravimater

Gravity gradiometer

We improve a gravity gradiometer system to search for ore deposits located below the seafloor. The instrument comprises two vertically separated, astatic pendulums, and the gravity gradient can be obtained from the differential signal between the gravity sensors. According to produce a new compact gravity sensor (Fig. 8), the system can reduces a size. A diameter of gravity sensor is decreased from 140 mm to 100 mm.

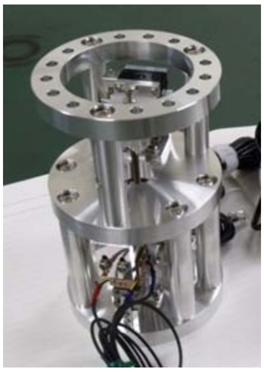
Fig. 8 A new accelerometer as a gravity sensor.

To be used for submarine application, the whole instrument should remain vertical to reduce centrifugal acceleration involved with rotation of a submersible vehicle. We also improved the two-dimensional gimbal which is supported by hinges to freely rotate without friction. The orientation is sensed by MEMS gyroscopes. The gimbal is successfully controlled to vertical within required precision. From these results, by combining the gravity gradiometer with the two-dimensional forced gimbal, detectability of the typical ore deposit can be obtained. In addition, a size of PCBs for data recording and system control was reduced. Therefore, the system can be installed in one pressure-proof vessel, made of titanium alloy, with 500mm in diameter, and the vessel is implemented in an AUV together with a gravimeter (Fig. 9).


Fig. 9 A two-dimensional forced gimbal installed in a pressure vessel.

- Research results and future plans

Evaluation of new gravimeter and gravity gradiometer jointly by using an autonomous underwater vehicle, URASHIMA was planned during YK13-13 (Fig. 10) in Izena Caldera in the middle Okinawa trough. An existence of seafloor hydrothermal deposits within Izena Caldera has been confirmed by other surveys.

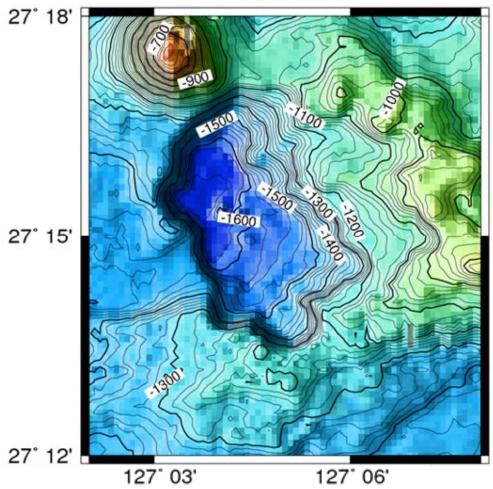

Fig.10 Izena Caldera in the middle Okinawa trough.

The newly developed system was installed on the URASHIMA before beginning of YK13-13 (Fig. 11). However there was no dive to Izena Caldera due to rough sea condition which continued for four days. On December 13th, URASHIMA was landed on the sea, and we tried to dive to Izena Caldera. Because sea condition became worse unfortunately just after landing, we retrieved URASHIMA on the M/V YOKOSUKA. Our system was exposed to a severe condition of large acceleration and shocks due to strong wind and rough sea during this trial (Fig. 12), however, there was no trouble for our system. We could confirm durability of the system.

We have a plan to carry out evaluation of our gravity measurement system using URASHIMA in August 2014. Data and experience from YK13-13 are useful for next evaluation of the system. At present, we continue to improve the system for practical use.

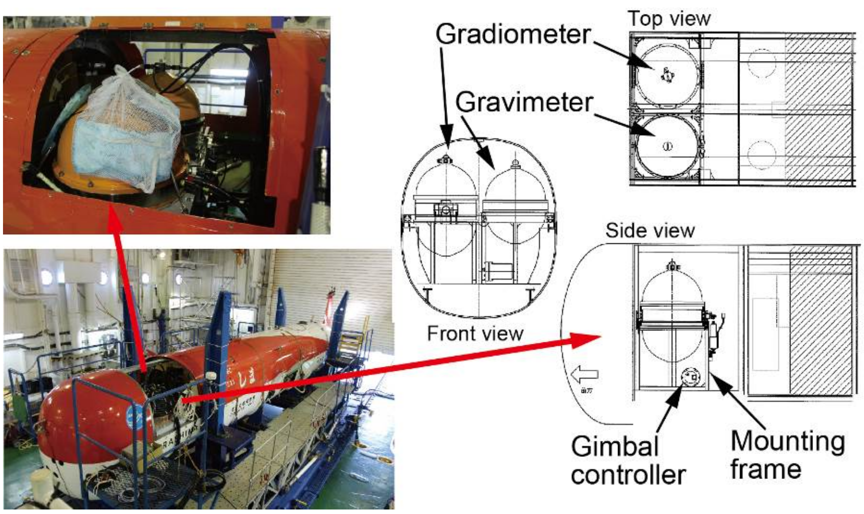

Fig.11 Layout of the system on the URASHIMA

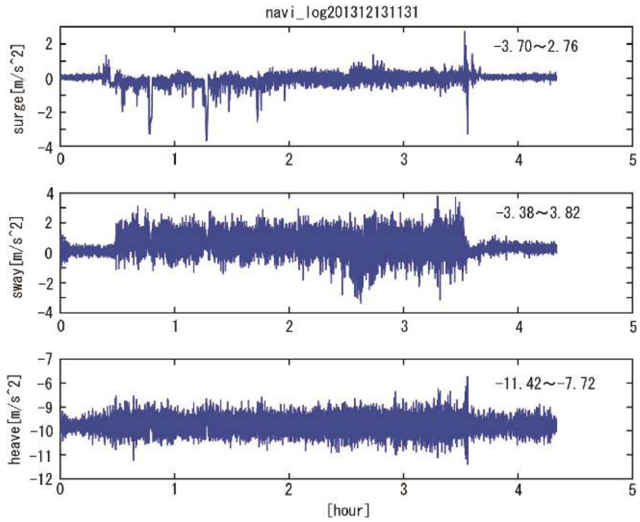

Fig. 12 Acceleration of URASHIMA on the rough sea. Maximum acceleration reached to 11.42 m/s^2.

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- Cruise log

2013/12/06

09:00	Onboard
10:00	Let go all shore lines. Left YOKOSUKA for research area.
10:30	Scientific meeting and general briefing about URASHIMA.
13:00	Carried out shipboard education & training for scientists.
16:40	Praying for the safety of this cruise (Konpira ceremony).

2013/12/07

13:00 - 16:00	Maintenance of the gravity system.

2013/12/08

08:00 - 08:50	Meeting with URASHIMA team.
09:00 - 12:00	Maintenance of the gravity system.
12:00 - 16:00	Continued maintenance.

2013/12/09

06:00	Starting preparation of URASHIMA dive.
07:00	Suspended URASHIMA operation due to bad weather and headed for off-Nago to maintain the system.

13:30	Arrived on off-Nago and stayed. Carrying out system maintenance.
2013/12/10	
07:00	Decided to stay at off-Nago due to bad weather.
2013/12/11	
07:00	Postponed decision to 09:00.
09:00	Postponed decision to 11:00 again.
11:00	Suspended URASHIMA operation due to bad weather.
13:00	Starting survey of bathymetry and gravity using shipboard gravimeter.
2013/12/12	
06:00	Starting preparation of URASHIMA dive.
07:00-13:00	Waiting and seeing the sea condition.
13:00	Suspended URASHIMA operation due to bad weather.
2013/12/13	
06:00	Starting preparation of URASHIMA dive.
07:00	Launched URASHIMA, but suspended URASHIMA operation due to bad weather.
10:20	Recovered URASHIMA and finished operation.
11:30	Headed for off-Nago to evaluate the system.
16:00	Completed the evaluation of the system.
2013/12/14	
	Put into the port of Naha, Okinawa, and end of YK13-13.

4. Notice on Using

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