YOKOSUKA Cruise Report

YK14-14

Evaluation cruise for hybrid submersible gravity observation system for exploration by using the Urashima

Aug. 2nd, 2014 - Aug. 8th, 2014

Japan Agency for Marine-Earth Science and Technology

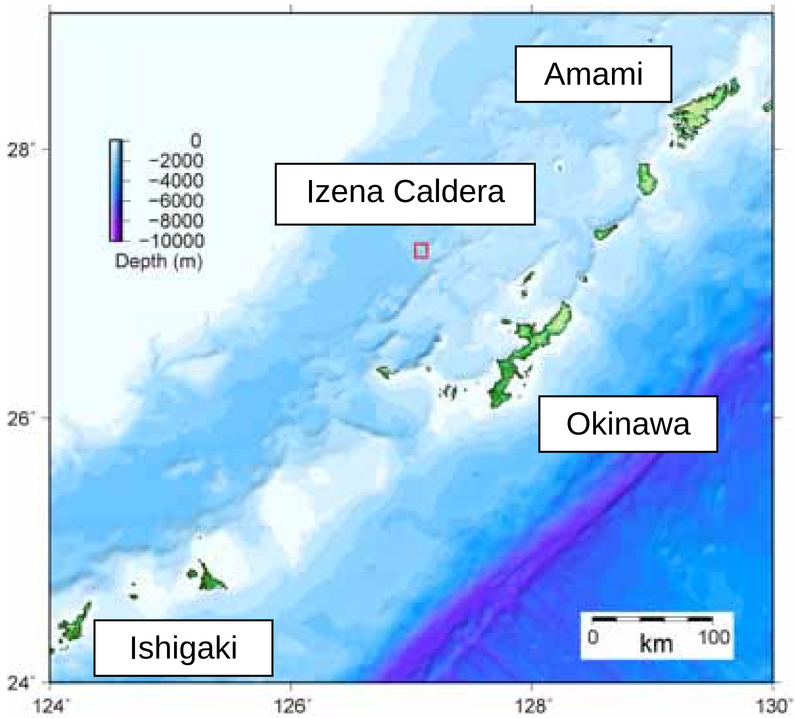
(JAMSTEC)

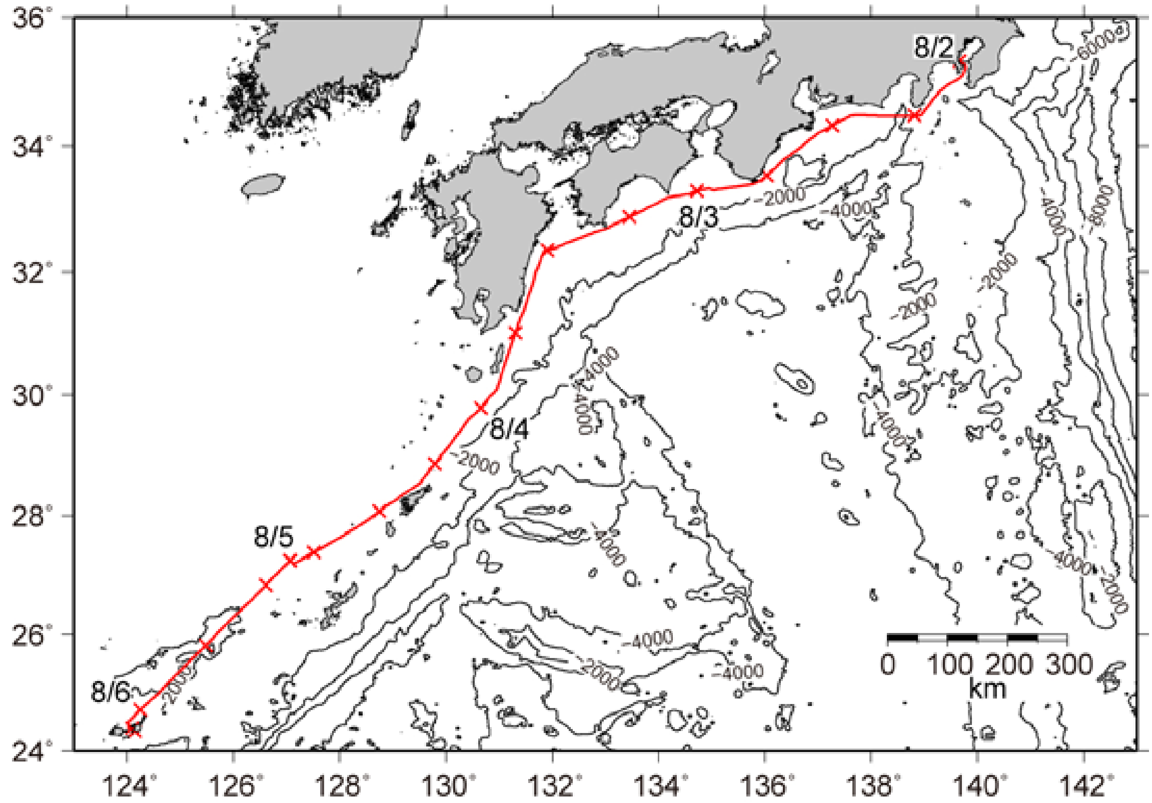
＊ There is no prescribed format. Images such as photographs may be included.

●Contents

1. Cruise Information

- Cruise ID YK14-14
- Name of vessel Yokosuka and Urashima
- Title of the cruise Evaluation cruise for hybrid submersible gravity observation system for exploration by using the Urashima
- Title of proposal Pilot observation for exploration of seafloor hydrothermal deposits by hybrid submersible gravity observation system using an underwater vehicle toward practical survey
- Cruise period From August 2nd, 2014 to August 8th, 2014
- Ports of departure / call / arrival
  From Yokosuka to Ishigaki
- Research area Izena Caldera in the middle Okinawa trough
- Research Map





Ship track of YK14-14

2. Researchers

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3. Observation

- Purpose, Objectives, background

Gravity is one of the powerful indices to profile underground structures. Surface ship gravimeters are a popular tool for the purpose of collecting gravity values in marine regions. They enable us to obtain gravity values from a large area easily, while the resolutions are relatively low because of the large 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 a remote operated vehicle (ROV) and an autonomous underwater vehicle (AUV) is being developed, there is a possibility to measure the gravity by using an ROV or an AUV.

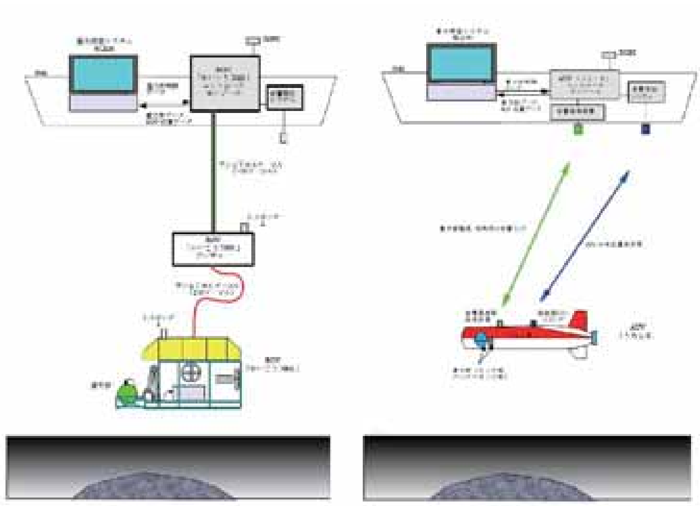

Fig.1 Concepts of submersible gravity measurement system using an ROV and an AUV.

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 1,000 kg m^{-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 400 m, 20 m thick at the center and density difference of 1,000 kg m^{-3}, a resolution of gravity measurement should be approximately 0.1 mgal. In addition, measurement must be carried out 50 m above a seafloor. An 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.

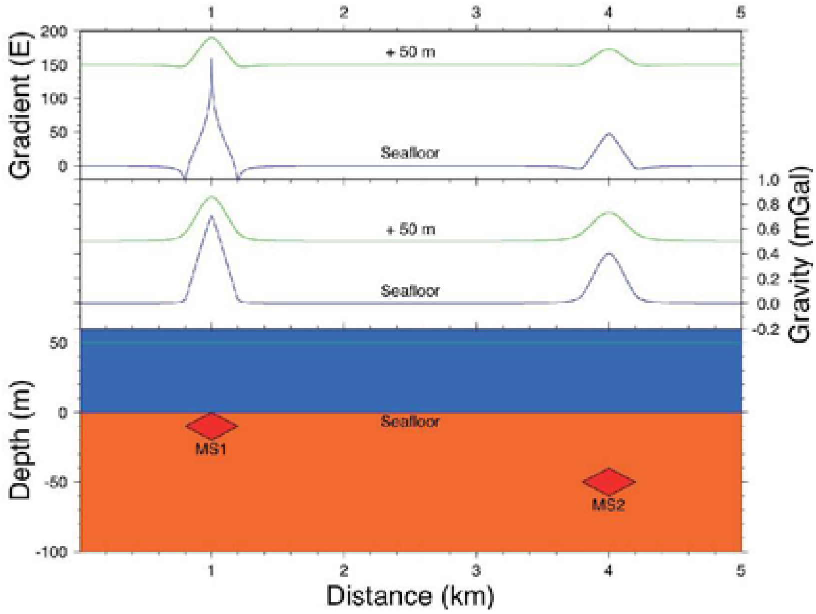

Fig.2 Estimated gravity (middle) and gradient (upper) variations are on a model (bottom). The model has two same shape deposits, MS1 and MS2, which have density differences of 1,000 kg m^{-3} against background.

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. The first measurement was performed in Sagami-Bay. The whole system is controlled and monitored via an 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 the 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.

According to the success of YK12-14, evaluation of new gravimeter and gravity gradiometer jointly by using the Urashima was planned during YK13-13 in Izena Caldera of the middle Okinawa trough (Fig. 5). An existence of seafloor hydrothermal deposits in Izena Caldera has been confirmed by other surveys. However there was no dive to Izena Caldera due to rough sea condition which continued for four days during the YK13-13. On December 13th 2014, the Urashima was launched on the sea, and we tried to dive to Izena Caldera. Because sea condition became worse unfortunately just after launching, we retrieved the Urashima on the M/V Yokosuka.

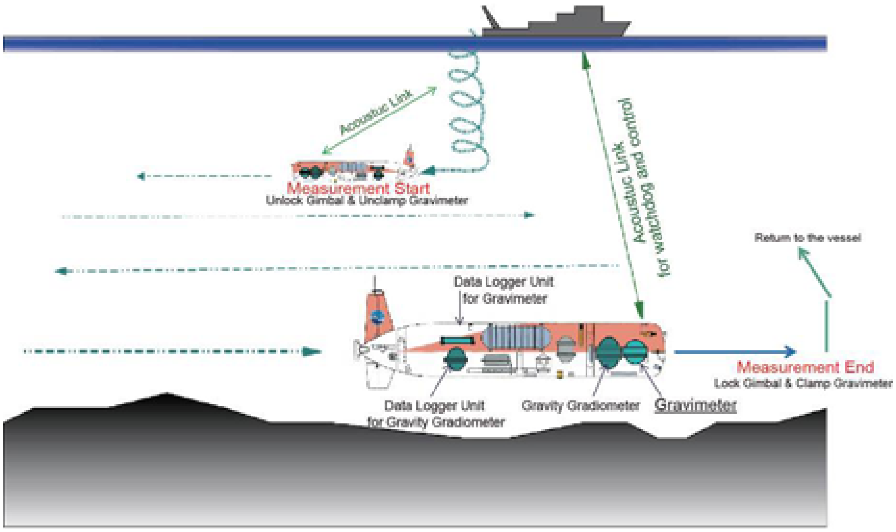

Fig. 3 Schematic of YK12-14 cruise measurement

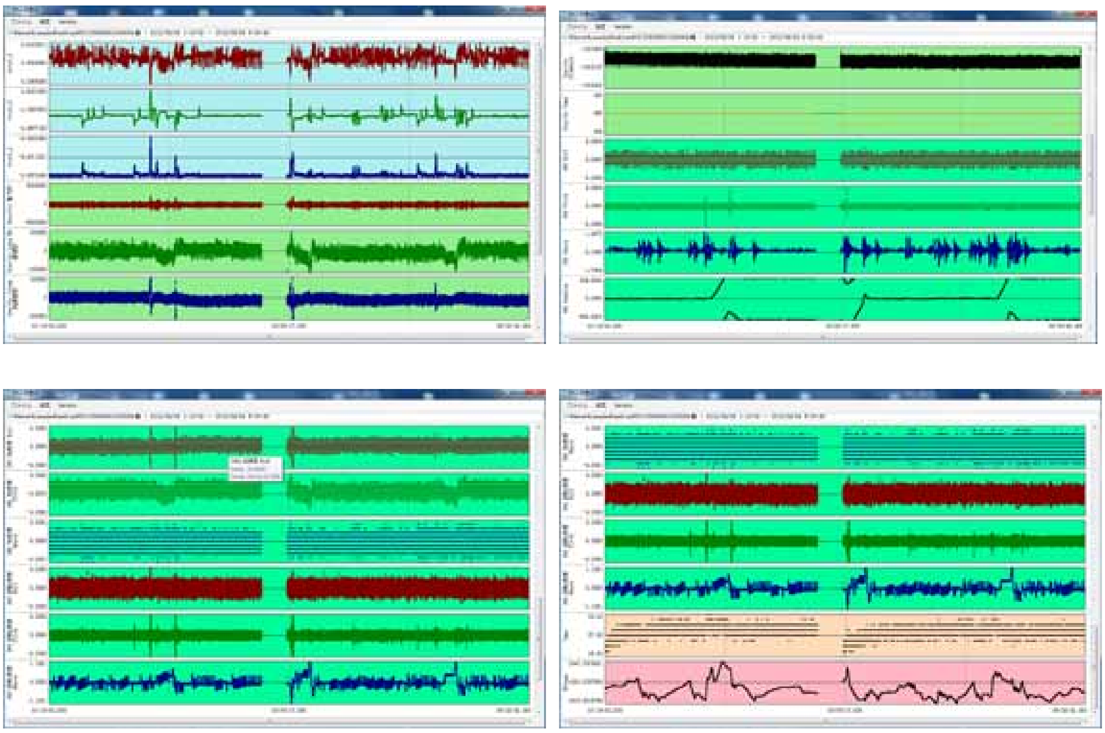

Fig. 4 Gravity and miscellaneous data obtained during the dive.

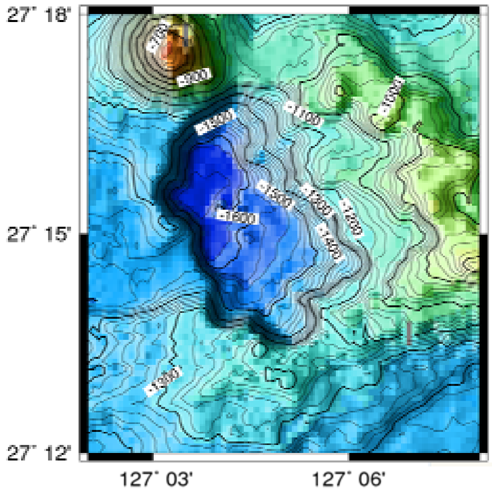

Fig.5 Izena Caldera in the middle Okinawa trough.

The purpose of the YK14-14 cruise is evaluation of the new gravity measurement system by using the Urashima in Izena Caldera where an existence of seafloor hydrothermal deposits has been confirmed. Because we obtained various kinds of data from YK12-14 and YK13-13, the system has been improved for a practical experiment.

- Instruments and methods

We have improved a hybrid submersible gravity observation system to be compact as a part of the project for development of a basic tool for exploration of seafloor hydrothermal deposits after the YK13-13 cruise.

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. 6 and Table 1).

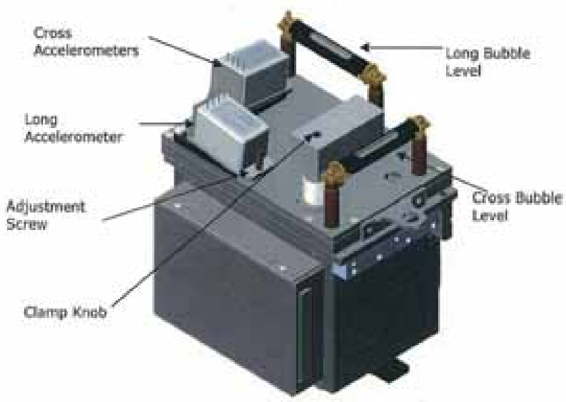

Fig.6 Gravity sensor (Micro-g LaCoste S-174).

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 (an optical 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 a magnetic field of the Earth. The sensor is heated and is totally covered with thermal insulator and sheets of permalloy for magnetic shielding. In order to reduce high frequency noise due to mainly tvehicle motion, data are decimated using a 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. 7). We have improved the gravimeter system to be compact for installation on various underwater vehicles. Re-design of Data Recording Unit has contributed to reducing a size of the system. Although the previous gravimeter system consisted of a pressure sphere and a 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 3,500 m below the sea surface (Fig.8).

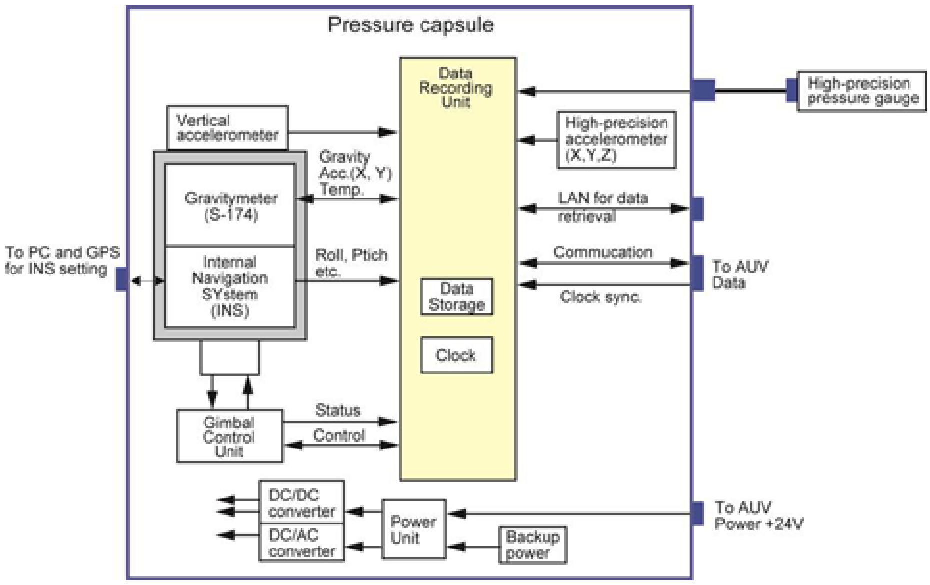

Fig.7 Block diagram of gravimeter system.

Fig.8 Photograph of inside of all-in-one type gravimeter

Gravity gradiometer

The instrument comprises two vertically separated, astatic pendulums, and the gravity gradient can be obtained from the differential signal between the gravity sensors. We have improved a gravity gradiometer system to search for ore deposits located below the seafloor. According to produce a new compact gravity sensor (Fig. 9), the system can reduces a size. A diameter of gravity sensor is decreased from 140 mm to 100 mm.

Fig. 9 A new accelerometer as a gravity sensor.

To be used for submarine application, the whole instrument should remain vertical to reduce centrifugal acceleration due to 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, required detectability of the typical ore deposit can be obtained. In addition, a size of Printed Circuit Boards (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 500 mm in diameter, and the vessel is implemented in an AUV together with a gravimeter (Fig. 10).

Fig. 10 A two-dimensional forced gimbal installed in a pressure vessel.

- Research results and future plans

The first evaluation of the gravimeter and the gravity gradiometer for actual seafloor hydrothermal deposits by using an autonomous underwater vehicle was performed during YK14-14 in Hakurei-site of Izena Caldera. Before beginning of YK14-14, we installed the second generation system for gravity prospecting on the Urashima (Fig. 11). The M/V Yokosuka departed from Yokosuka, Kanagawa Prefecture, and arrived at the research area in the morning of 5th, August, 2014. Immediately, the dive #173 was carried out. The Urashima was launched at 8:40 JST and started a dive. At 09:00, the Urashima reached the seafloor and we started the measurement system by using the acoustic link system between the M/V Yokosuka and the Urashima. The Urashima was navigated on 15 preprogrammed survey lines in the survey area at constant speed and depth (Fig. 12). A recording status of the gravimeter and the gravity gradiometer was continuously monitored during the survey by using the acoustic link system. At 17:00 JST, we deactivated the recording system and a pendulum of the gravimeter was locked by an acoustic command from the M/V Yokosuka. The survey was finished and the Urashima started ascent to the sea surface. The Urashima was recovered to the M/V Yokosuka at 18:30 JST. Because a typhoon was approaching, the M/V Yokosuka was headed for Ishigaki Island immediately to avoid a rough sea condition. We obtained the data from both the gravimeter and the gradiometer with good quality for all the survey lines (Fig. 13).

We have a plan to carry out second evaluation of our gravity measurement system using the Urashima in August 2015. Data and experience from YK14-14 are useful for next evaluation of the system. At present, we continue to improve the system for practical use.

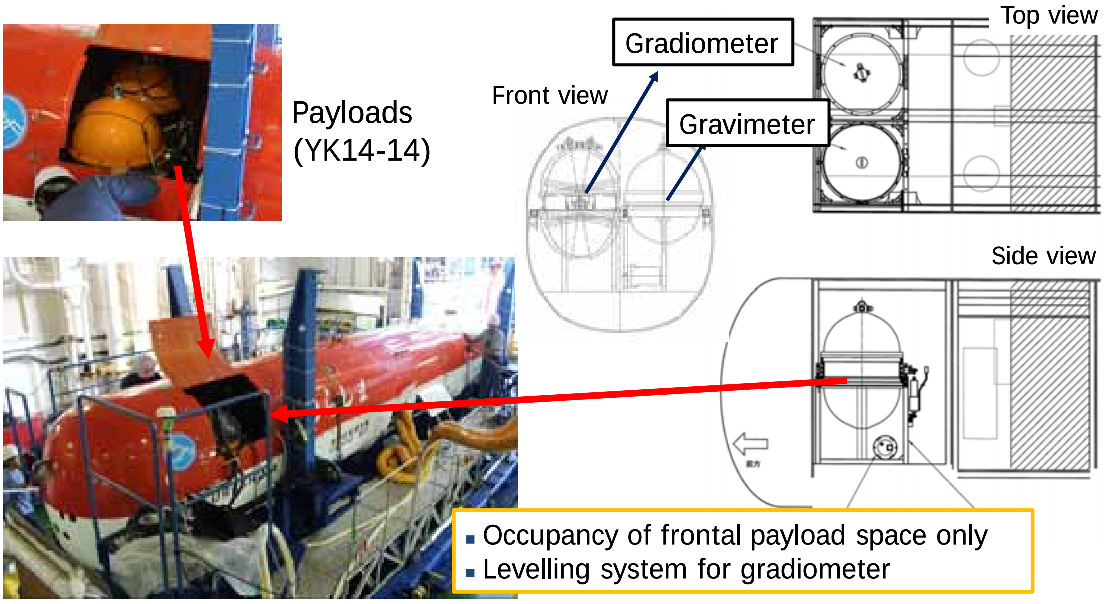

Fig.11 Layout of the system on the Urshima

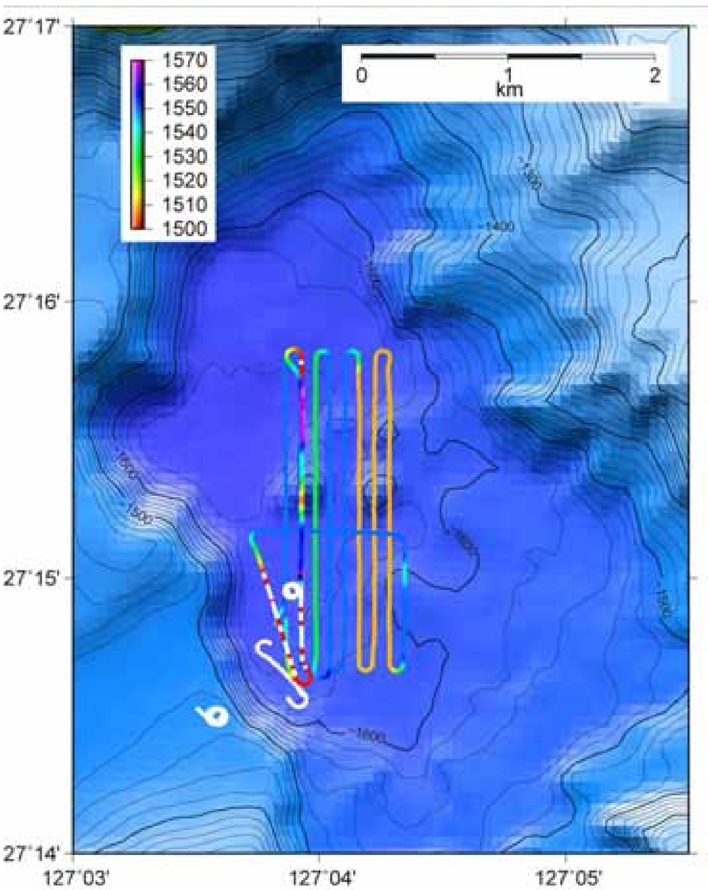

Fig. 12 Ship tracks of the Urashima during YK14-14. Colors on the profiles indicate depth of the Urashima.

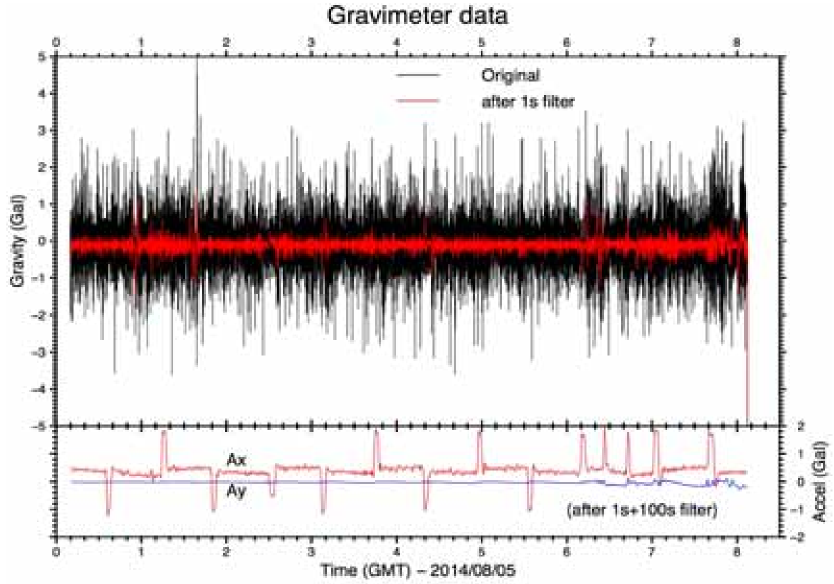

Fig. 13 The gravity data obtained during the Urashima dive #173. We could collect continuous 8 hours data.

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- Cruise log

02 Aug., 2014	*Proceeded to Research Area*
09:00	Start of YK14-14. Onboard and sail out.
10:00 - 10:30	Briefing about ship's life and safety
13:00 - 14:00	Maintenance of the gravity system.
16:45	Praying for the safety of this cruise (Konpira ceremony).

03 Aug., 2014	*Proceeded to Research Area*

04 Aug., 2014	*Proceeded to Research Area*
09:00	Meeting with URASHIMA team.
05 Aug., 2014	*"Urashima" Dive#173.*
05:03	Released XBT<27-12.2087'N, 127-08.4107'E>
05:45	Arrived at research area.
07:15	Hoisted up "Urashima"
07:36	Launched "Urashima"
07:38	"Urashima" started dive#173. < Depth=1460m >
09:01	"Urashima"started cruising.
17:12	"Urashima" released ballast. < Depth=1573m >
17:45	"Urashima" refloated.
18:33	Recovered "Urashima" and finished the operation.
	Proceeded to Ishigaki island.
06 Aug., 2014	*Avoided rough sea at Nagura bay*
11:00	Arrived at Nagura bay(Ishigaki) and started anchoring.
13:00 - 15:00	Unloading of the gravity system from "Urashima".
07 Aug. , 2014	*Avoided rough sea at Nagura bay*
08 Aug., 2014	*Disembarked at Ishigaki pier.*
09:00	Disembarked at Ishigaki pier and end of YK14-14.

4. Notice on Using

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> 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.