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Underwater gravity survey using autonomous underwater vehicle in Izena caldera, the middle Okinawa Trough

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It is known that there are seafloor mineral deposits around Japan islands. Gravity survey is one of powerful methods to obtain density structure in crust, especially for exploration of underground deposits. In marine area, surface ship gravimeter and ocean bottom gravimeters are often used. Recently the system which can survey a wide area quickly with a higher resolution is required to obtain a high-resolution structure below seafloor. In addition, recent technology of autonomous underwater vehicle (AUV) enables us measure gravity in underwater environment. To estimate structure, measurement of both gravity and gravity gradient has an advantage for precise estimation. A required accuracy of the measurement was estimated by using model calculation. From an expected model of seafloor deposits, it is found that a resolution of gravity measurement should be approximately 0.1 mgal, and 10 eotvos for gradient to estimate deposit below seafloor.

From these objectives and specification, we have developed an underwater gravity measurement system for exploration below a seafloor using an AUV. Our system consists of an underwater gravimeter and an underwater gravity gradiometer. For gravimeter system, the sensor is mounted on a gimbal mechanism to keep vertical. The system is controlled and monitored via acoustic link of the AUV. The gradiometer has two gravimeter aligned vertical at a distances of 50 cm. For practical observation in the sea, we choose AUV Urashima belonging to Japan Agency for Marine-Earth Science and Technology. Because the Urashima is large AUV, Urashima has enough space for installation of the underwater gravity measurement system and stable navigation is possible. All the power is supplied from the Urashima and acoustic communication system on the Urashima enable real-time monitoring during observation. The first observation was carried out in September 2012 in Sagami-Bay, Japan. For the observation, the Urashima was navigated at the constant speed and constant depth on the profiles. We succeeded in obtaining gravity data and other data for compensation of the gravity data along both tracks with good quality. The obtained gravity data were low passed to reduce noise first. Our system has a high-precision water depth meter with resolution of less than 1 cm. Effect of vertical acceleration, which was calculated from these data, was removed from the gravity data. In addition, we made tilt correction using horizontal accelerometers. Finally ordinary data processing for onboard gravimeter were applied. After the data processing, the data from each track show good agreement, and standard deviation of the data are 0.1 mgal. In other words, our system is estimated to have accuracy or repeatability of 0.1 mgal. From comparison with the data between underwater gravimeter and onboard gravimeter, it is found that the underwater gravimeter system recorded more detailed changes of gravity, which seems to correspond to topography mainly.

In August 2014, we carried second gravity survey using our underwater gravity measurement system in the southern region of Izena caldera, the middle Okinawa Trough, where seafloor deposits were found. The survey area is approximately 2 x 2 km. The Urashima was navigated on 15 profiles in the survey area at constant speed and depth. We obtained the data from both gravimeter and gradiometer with good quality for all the profiles. From the obtained gravity data, we estimate gravity anomaly map in the Izena caldera through the processing for noise reduction, which is described above. After the processing, we obtained a free-water gravity anomaly, which corresponds to the seafloor topography. Because the AUV Urashima also has multi-narrow beam echo sounder, detailed seafloor topography was obtained. We also estimate Bouguer anomaly using the detailed topography and assuming density.