Deployment of an Autonomous Underwater Vehicle in Ice-covered Sea of Okhotsk : The First Japanese Challenge

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The ice-covered sea in polar area is one of the most severe environment for human being on the planet. It is not surprising that, still, in fact, we have extremely limited means to explore an undersea region in a polar area. Since the greater part of sea surface in polar area is covered with sea ice, it is too risky to send a human-oppupied submersible underneath. The autonomous underwater vehicle (AUV) is a versitile survey tool, especially well-suited to the survey missions in undersea regions that are not or hardly accesible with manned submersibles. Since the first under-ice operation conducted by the university of Washington's UARS, many challenges of numerous untethered, unmanned vehicles have been continued to this day. Among these, recent achievements by Woods Hole Oceanographic Institution (PUMA and JAGUAR vehicles), and by International Submarine Engineering (Explorer vehicle) are especially worth noting. As a pioneer of underwater robotics in Japan, Institute of Industrial Science (IIS), the University of Tokyo has developed a few AUVs of diverse purposes. The Aqua-Explorer 2000a (AE 2000a) is the current main cruising AUV of the IIS, the University of Tokyo, which has completed several dives of diverse practical missions, since its initial trial in Nov. 2011. In Dec. 2011, IIS, the University of Tokyo and Mitsui Engineering & Shipbuilding Co., Ltd. have started a new project of under-ice exploration in arctic sea using an AUV, aiming at the 3-D modeling of the immersed part of an iceberg. This is a R & D project based on a contract with Japan Oil, Gas and Metals National Corporation (JOGMEC), towards the environmental investigation of artic sea, conducted as a part of oil resource development program in artic regions. For the oil resource development in an artic sea area, seabed gouging by a floating iceberg is considered as one of the most significant threat, since it might destroy the pipeline or production platform installed on the seabed. Since it is a definitely discreet phenomenon above the sea surface, little sign of ice gouging can be obtained by the downward-looking observations in the air. In our project, by deploying an AUV under a floating iceberg, we aim to generate a fine-scale 3-D model of the immersed part of it which is to be used for anticipating the development of seabed gouging by the iceberg (Fig. 1). Since this AUV-based under-iceberg exploration is a challenging mission carrying a higher risk, as a prelimanary skirmish toward the arctic sea mission, we conducted an under-ice survey mission in ice-covered Sea of Okhotsk, off Mombetsu, Hokkaido. Figure 2 shows the basic concept of our under-ice survey mission . During the survey mission conducted in March 2012, we deployed AE 2000a for surveying the bottoms of drifting ice-floes in an upward-looking manner (Fig. 3). In deploying an AUV under the ice-covered sea, one of the most significant drawbacks is the restricted fail-safe actions available. For an ordinary dive of an AUV in an ice-free sea, the default fail-safe action is unconditional surfacing. Since it may let the vehicle lost or significantly damaged, however, the fail-safe action of unconditional surfacing is not applicalbe to the ice-covered sea. The "vacuum ballast", shown in Fig. 4 is a newly

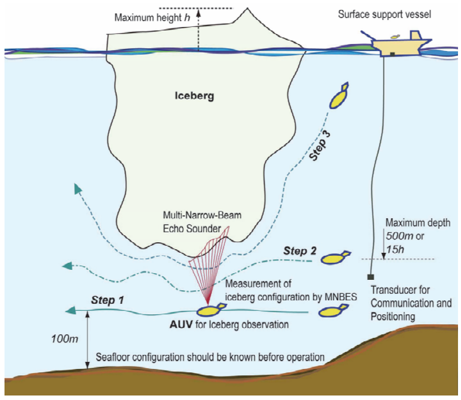


Figure 1. Upward-looking iceberg survey using an AUV.

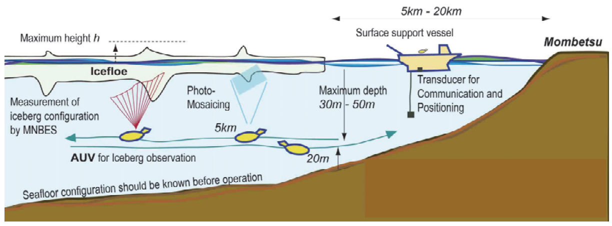


Figure 2. Upward-looking ice-floe survey using an AUV.

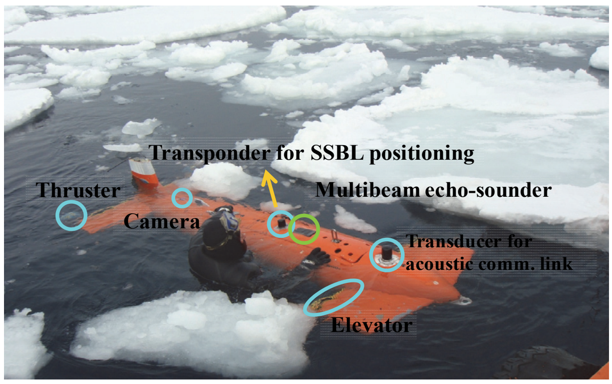


Figure 3. AE2000a outfitted for under-ice survey.

employed device for the fail-safe action during the under-ice dive. While maintained as vacuum during the normal operation, the vacuum ballast is filled with sea water immediately after the occurrence of a fatal trouble on the vehicle has been detected. After being full of the sea water, the vacuum ballast does no more generate the buoyancy, which makes the vehicle land on the seabed. The landing on the seabed is the "fail-safe action" designed for our under-ice survey mission. For the visual survey of the bottom of an ice-floe, we prepared for two upward-looking devices; a multibeam echo sounder (MBES) and a still camera (Figs. 3 and 4). And in order to track the vehicle position during the under-ice mission, we employed high-precision underwater acoustic positioning sytem called GAPS (global acostic positioning system). The GAPS is an ultra-short baseline (USBL) positioning system, providing the position error bounded within 0.2 % of the slant range. In this mission, we succeeded in achieving two under-ice survey dives. Since the ice-covered sea makes it very difficult for the support vessel to follow the vehicle, as the vehicle proceeds further getting away from the vessel, the more limited means are available coping with the troubles during the dive. Therefore, the risk of a dive grows rapidly with the increasing distance between the vehicle and the support vessel. In this respect, the dives were conducted within rather a short interval. Figure 5 shows the subsurface shape and the mosaiced photos of ice-floes taken along the vehcle's tracks. The thicknesses of ice-floes were measured using the upward-looking MBES. As noticed in the figure, centimeter-scale maps of the ice thickness were obtained. During the under-ice dives, we experienced some cold-induced hardware malfunctions. The most significant malfunction was voltage drop on CPU arisen from the cold-induced excessive inrush current. The voltage drop may cause the system rebooting, leading to the activation of fale-safe mode operation. On the basis of the result of ex-post investigation, we isolated the power supply for CPU from the combined power supply with Doppler velocity log (DVL) in order to prevent the electric disturbance. Not only the results of fine under-ice measurements, but also we gained many useful experiences which is to be applied to our future arctic sea mission surveying the immersed parts of huge and threatening icebergs.

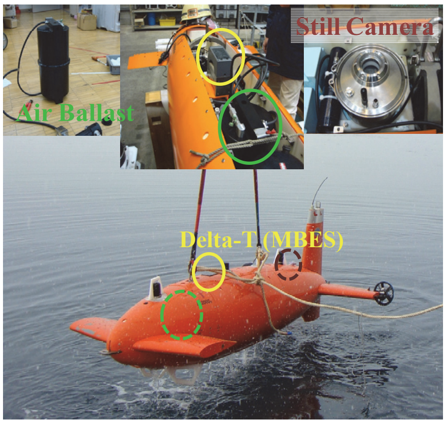
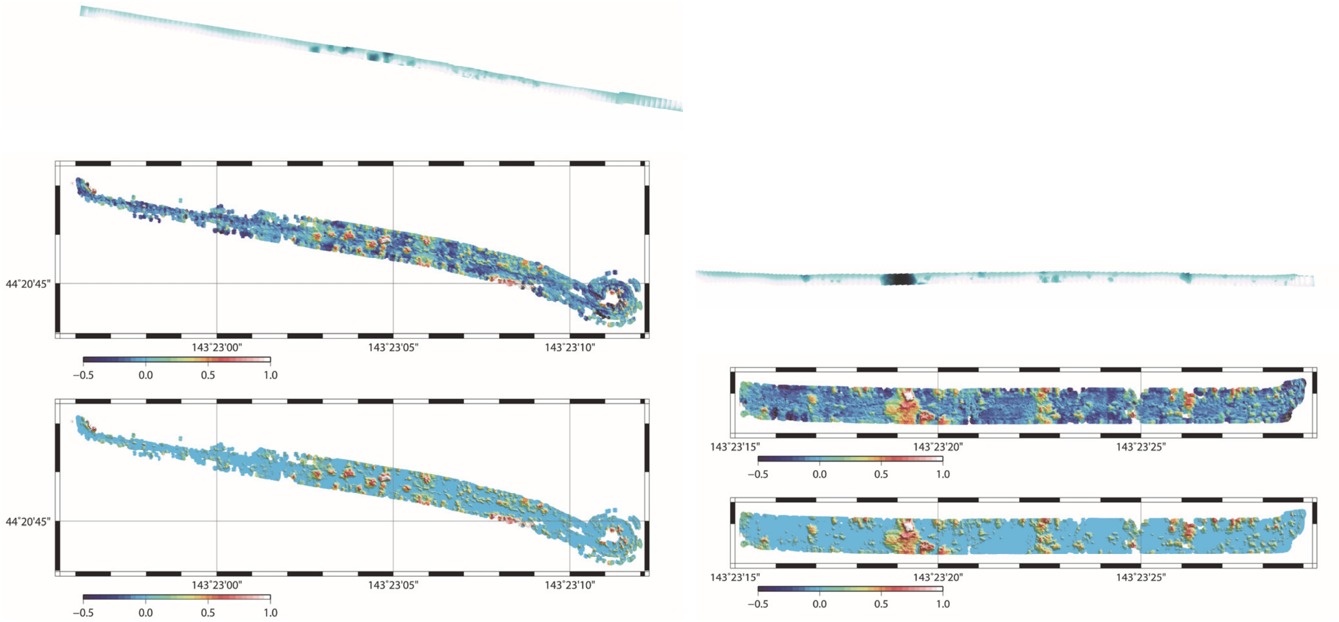


Figure 4. Sensors and equipments.



(a) (b)

Figure 5. Subsurface shapes and mosaiced photos of ice-floes (a) along the track of dive #01 (b) along the track of dive #02.

References

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