The Observation of Sea-ice in the Six Chinese National Arctic Expedition Using Polar-ARV

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***Abstract*—In July of 2014, the Pole-ARV participated in the 6th Chinese National Arctic Research Expedition (CHINARE) for the third time after improved. On the long-term ice station of the 6th CHINARE at north latitude 81 degrees, Pole-ARV worked 7 days and navigated a total of 9 kilometers under ice. It accomplished the survey of the observed area three times in different weather conditions, and got a lot of data, such as ice thickness and spectral irradiance. Through these observed data, the spatial variety of solar radiation energy absorbed by sea-ice could be measured continuously, and the roughness of ice bottom was reflected. This paper mainly describes the application of Polar-ARV in the 6th CHINARE and the results of observation under ice.**

Keywords- Polar-ARV, Arctic Expedition, observation under ice

I. INTRODUCTION

With the continuous development of society, global warming became an indisputable fact, and the change of the Arctic sea-ice is known as the barometer of the global climate, so more and more scientists began to pay attention to the rapid melting of the Arctic sea-ice, but because of the high risks and bad environment, the traditional scientific means is limited in Arctic expedition. Recently, more and more Underwater Unmanned Vehicles (UUV) were applied for observation under the Arctic ice, they could obtain a lot of scientific data through a variety of its onboard observation devices, such as video, ice thickness, optical data etc. It has been proved to be a good means for human to study the sea-ice from underside in Arctic.

Pole-ARV is an UUV mainly used for observation under the Arctic ice. It was developed by the Shenyang Institute of Automation, Chinese Academy of Sciences under the Chinese National 863 Program fund. Pole-ARV has twice participated in the Chinese North Arctic expedition respectively in 2008 and 2010. In 2014 some adaptive improvements of Pole-ARV were made, its volume and weight were reduced by half, in order to enhance maneuverability of Pole-ARV under ice, the layout of propellers was changed, as shown in Figure 1. All of these improvements make it more suitable for observation under the Arctic ice.

A) Pole-ARV before improved B) Pole-ARV after improved

Figure 1. The shape and structure of Pole-ARV

This paper briefly describes the application of Polar-ARV in the 6th CHINARE and the results of observation.

II. VEHICLE DESCRIPTION

The improved polar-ARV adopts frame structure, the dimensions are 1.07 (L) × 0.65(W) × 0.92(H) meters, as shown in Figure 2, its weigh is about 180 kg, and it is slightly negative buoyant in water. It has five thrusters, four of which is arranged in horizontal vector distribution and one in vertical direction, through the action of these thrusters, it can realize the control with 4 DOF. Polar-ARV uses the optical fiber to communicate with surface control system and onboard Li-ion rechargeable accumulator as its energy system, the maximum depth of dive is 100 meters and the operating radius is 3 kilometers. An integrated INS/DVL system is used as its navigation system, the DVL is pointed upward to measure the velocity relative to the bottom of ice. It can not only navigate autonomously with the certain range to survey, but also observe the specified target at the fixed-point.

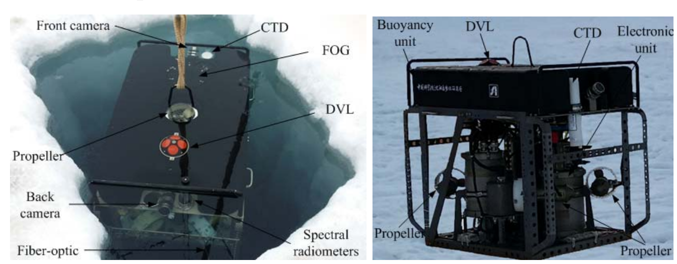

Figure 2. Polar-ARV in the 6th CHINARE.

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In the 6th CHINARE Polar-ARV was equipped with spectral radiometers, CTD, DVL, video, camera and pressure sensor. The data obtained from these devices is as follows: ice thickness, spectral irradiance, video, photo, temperature, salinity, pressure etc. These data can't be obtained from traditional scientific devices on the ice.

III. APPLICATION UNDER ARCTIC SEA ICE

Polar-ARV participated in the 6th CHINARE with the "Snow Dragon" ship from July 11 to September 24, on the long-term ice station at north latitude 81 degrees, Pole-ARV worked 7 days. The observed area is located on the left side of "Snow Dragon" ship, the working environment was built in this area, as shown in Figure 3. An ice hole was excavated on the ice and a container was fixed as a control room. A shelf was set up on the top of the ice hole to ensure the release and recovery of the vehicle, meantime some woods were laid out between the container and ice hole as a slide to move the Polar-ARV. The optical fiber winch was fixed near the ice hole and the power of the surface support system was provided by the "Snow Dragon" ship. Figure 4 shows the working scene on the ice.

Figure 3. Working environment.

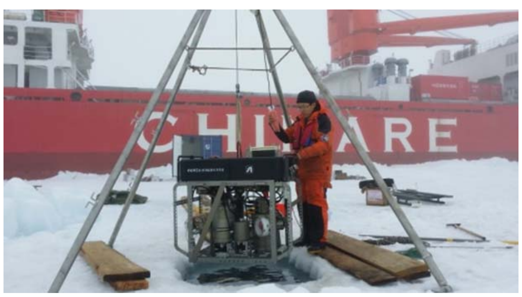

Figure 4. Working scene on the ice.

In order to carry on the high-precision measurements for the observed area, a coordinate system was established, the origin of coordinates was located at the center of ice hole, the east direction is as X axis, and the north direction is as Y axis, as shown in Figure 5. The shape of observed area is rectangle, which vertices are the points A, B, C and D. The edge line AD of the observed area was parallel with the heading of "Snow Dragon" ship, which direction was 28 degrees relative to the north direction, and its length was 100 meters. The line AB was situated at right angles to line AD, its length was also 100 meters. Polar-ARV survey the area along the line drawn in Figure 5 at the depth of 6 meters under ice, and passed through the point 1, point 2 until point 21 in turn, finally, returned directly to the ice hole, the distance of each two adjacent parallel lines was 10 meters. The coordinates of points is shown in Table 1. The surface photograph of observation area is shown in Figure 6, it can be seen from the figure there are many melting pool in this area and ice ridge near the AD side.

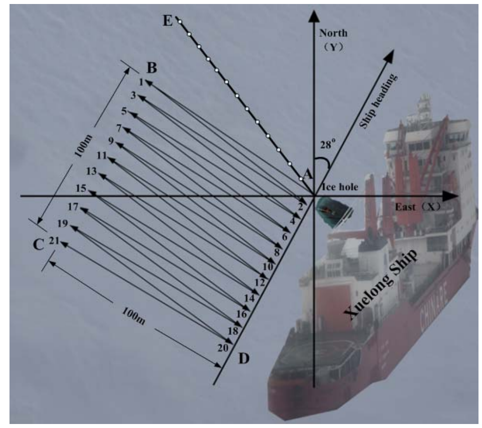

Figure 5. Ice coordinate system.

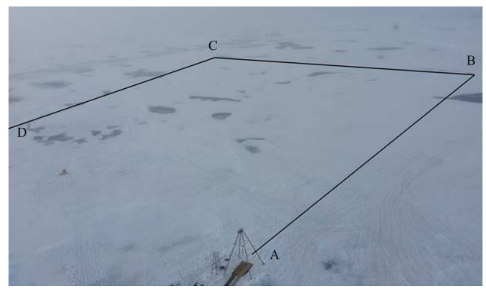

Figure 6. The surface photograph of observation area.

Table 1 The coordinates of way points

Index	1	2	3	4	5	6	7
X(m)	-87	-5	-92	-10	-97	-15	-102
Y(m)	50	-8.6	41	-17	33	-26	24
Index	8	9	10	11	12	13	14
X(m)	-20	-107	-25	-112	-30	-117	-35
Y(m)	-34	18	-43	9	-52	0	-60
Index	15	16	17	18	19	20	21
X(m)	-122	-40	-127	-45	-132	-50	-137
Y(m)	-8	-69	-17	-77	-25	-86	-34

The whole survey process was completed by Polar-ARV autonomously, the operator only needed to watch the screen which showed the state of vehicle, and needn't control it, which reduces the operator's workload to a large extent, and improve the observation efficiency.

IV. RESULTS OF SURVEY

In order to verify the measurement accuracy of the ice thickness, firstly the section AE was chosen in the coordinate system, which departed from the origin, as shown in Figure 5, then we drilled every 10 meters in this section and measured ice thickness in the ice-hole using ruler, finally Polar-ARV was controlled to navigate along this section and measure ice thickness at the depth of 6 meters under ice, the two results were compared. Figure 7 shows the measurement results of ice thickness obtained by drilling and Polar-ARV. It can be seen from this figure that Polar-ARV can give the detail of roughness on ice bottom due to the higher sampling density (0.1m). For example, Polar-ARV is able to capture high frequency variation of the ups and downs on ice bottom in the ice ridge area which is 130m away from origin. The rough bottom surface of ice ridge is shaped when sea ices collide with each other, its high roughness will lead to greater change of observed value of ice thickness if observation points are slightly offset. Besides, Polar-ARV is able to measure the thickness change of the ice in the melt pool area, where drilling is difficult to implement, it also reflect the advantage of using Polar-ARV to observe sea-ice. It will be found that there is little difference at the same position by comparing the observation results measured by ARV and bore-hole, the deviations belong to normal distribution.

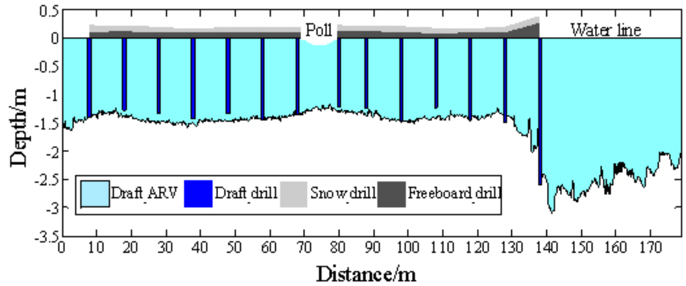

Figure 7. Comparison between sea-ice draft measured by ARV and bore-hole along the section.

On the long-term ice station Polar-ARV accomplished survey for the observed area three times, the survey results are as shown in Table 2.

Table 2 Log of Polar-ARV observations

Date of observation	Depth	Maximum depth	Distance	Range of observation	Section number	Data categories
August 21	6m	35m	1.84km	100m×38.7m	10	Ice thickness, spectral irradiance, video
August 22	6m	36.4m	3.74km	99.2m×87.9m	20	Ice thickness, spectral irradiance, video
August 23	6m	16.7m	3.06km	99.7m×86.7m	18	Ice thickness, spectral irradiance, video

Figure 8 shows the 3D terrain of ice bottom drawn through the ice thickness data measured by Polar-ARV. It can be seen from the figure that gradient of the ice ridge with coordinates (-8, -4) is about 0.05m/m (relative value is 5%), the surface of ice ridge has been highly weathered, the ice ridge was difficult to identify from surface after the snow cover, it fully reflect the advantage of using Polar-ARV to measure ice again. The ice thickness of the survey area measured by Polar-ARV three times were respectively 1.58 ± 0.18m, 1.56 ± 0.13m and 1.52 ± 0.21m, maximum ice thickness were respectively 2.52m, 2.43m and 2.87m, all of these ice thickness were the value below the waterline, based on the observations of borehole, ice freeboard height is 0.10m on average, so the average ice thickness of survey area is about 1.66m.

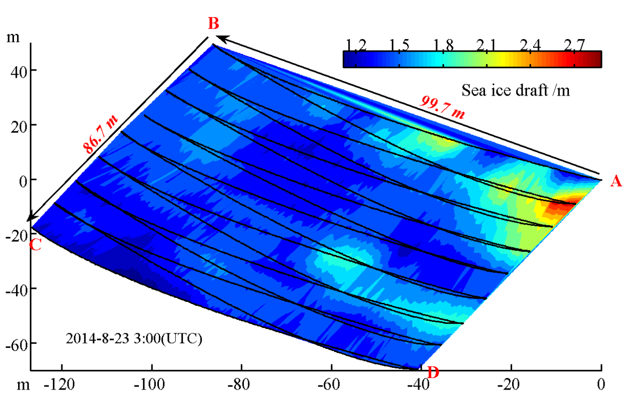

Figure 8. Spatial distribution of ice thickness within survey area measured by the Polar-ARV on 23 August

Figure 9 shows the 3D spatial distribution of spectral irradiance measured by Polar-ARV. It can be seen from the figure that it is same as the spatial distribution of melt pool in this area, because the light transmittance of melt pool is far higher than other areas. But it can be also found that the spectral irradiance did not significantly reduce due to scattering of light in water.

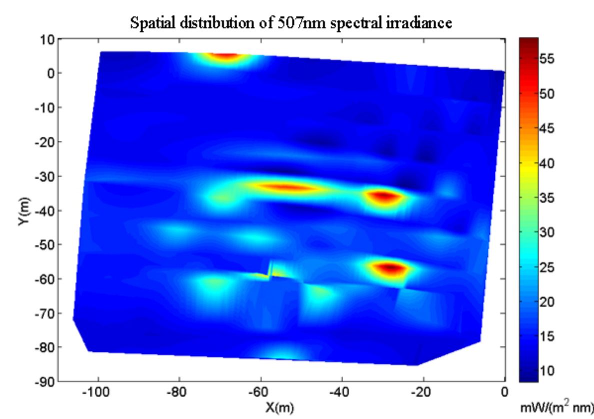

Figure 9. Spatial distribution of spectral irradiance within survey area measured by the Polar-ARV on 22 August

V. CONCLUSION

In this Arctic expedition, Polar-ARV works well and get a lot of scientific data with precise location information, such as ice thickness, spectral irradiance, ice bottom video etc, by analyzing these data, the impact of solar radiation to melting of sea-ice at this latitude can be calculated, meanwhile, the impact of seawater to melting of sea-ice from both kinetic and thermodynamic can be also analyzed, all of these can't realize using conventional observation devices. In the future, we plan to expand the operating range of Polar-ARV, and equip more sensors with it, make it play a greater role in the Arctic Expedition.

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