The Arctic-2010 cruise: bathymetric survey for delineation of the extended continental shelf of the Russian Federation in the Arctic

Sergey Alekseev[1], Ivan Glumov[2], Andrey Morozov[3], Konstantin Stavrov[1], Andrey Zen'kov[1], and Denis Zhilin[4]

[1]State Research Navigation-Hydrographic Institute (OJSC GNINGI) St.Petersberg, Russia
[2]Severnaya Neftegazovaya Kompaniya Open Joint-Stock Company (Severneftegas OJSC), Moscow, Russia
[3]Russian Federal Agency for Subsoil Use, Rosnedra, Moscow, Russia
[4]HYDRO-C, Joint Stock Company, Russia

ABSTRACT

Having ratified the United Nations Convention on the Law of the Sea (UNCLOS) in 1997, the Russian Federation began exploration to specify the outer limit of the continental shelf in the Arctic Ocean. In December 2001, Russia was the first State to present a Submission on the limit of the continental shelf in this region, prepared in compliance with the requirements of UNCLOS, to the Secretary General of the United Nations. In June 2002 the Commission on the Limits of the Continental Shelf prepared its decision concerning the Claim of the Russian Federation and recommendations for its further development.

Starting from 2002, work was conducted with the aim to prepare the revised Submission to the UN Commission. To address bathymetry aspects, digital hydrographic databases were developed and 2D and 3D bathymetric models of the submarine relief for the Arctic Ocean were created. When preparing the materials for the planned 2013 revised Submission to the UN Commission on determining the outer limit of the continental shelf in the Arctic, it became clear that additional complex hydrographic and geophysical surveys were required—approximately 12,000 linear kilometers. To achieve this, the expedition used the research vessel (RV) "Akademik Fedorov" in combination with the "Yamal," one of the most powerful nuclear-powered icebreakers, in heavy ice conditions.

The bathymetric survey in the central part of the Arctic Ocean was conducted to obtain the additional data on the submarine relief using a preplotted grid of bathymetric profiles to be used for delimitation of the Russian continental shelf in the Arctic Ocean.

For the first time, the bathymetric survey in this area of the Arctic Ocean was carried out along the predefined rectilinear bathymetric profiles created according to of the technical guidance of the UN Commission on the Limits of the Continental Shelf.

For a period of 77 days, an enormous volume of work was carried out. The cruise covered a total distance of 23,100 km and the survey was carried out for a total distance of 13,304 linear km, including:

- 9300 linear km for bathymetric survey along the main lines;
- 4004 linear km for bathymetric survey on transits between the main lines;
- 760 km of seismic survey;
- 128 hydrological stations;
- 8 ice reconnaissance operations.

INTRODUCTION

In 1997 the Russian Federation ratified the United Nations Convention on the Law of the Sea and started the explorations intended to specify the outer limit of the continental shelf in the Arctic Ocean. In December 2001 Russia was the first State to present the Submission on the limit of the continental shelf in this region prepared in compliance with the requirements of the Convention to the Secretary General of the United Nations.

In June 2002 the UN Commission on the Limits of the Continental Shelf prepared its decision concerning the submitted Claim of the Russian Federation. The commission recommended further research on the submitted claim. From 2002 the work was conducted with the aim to prepare a revised Submission to the UN Commission and decided to submit a revised claim by 2013 on the outer limit of the continental shelf in the Arctic. When preparing the claim, it became evident that an additional

12,000 linear kilometers of complex hydrographic and geophysical surveys including 9000 kilometers of multibeam bathymetric data were required in the Arctic.

This resulted in a significant hydrographic survey carried out in 2010 in the Arctic by the Russian Federation. A survey was carried out for a period of 77 days covering an astonishing total distance of 23,100 kilometers in ice conditions and acquired 9300 linear km of bathymetry along the main lines (Figure 1) and an additional 4004 linear km of bathymetry on transit lines for a total of 13,304 linear km of multibeam data as well as 760 km of seismic data, occupied 128 hydrological stations and carried out 8 ice reconnaissance operations.

THE ARCTIC SURVEY

The survey was scheduled to be performed during one survey season, from; July until October 2010. Due to the ice- and weather-conditions at this high latitude in combination with the size of the project this became an extremely complicated and challenging task. The research vessel "Akademik Fedorov" was mobilized, in order have the right platform for the survey, together with the nuclear powered icebreaker "Yamal" in order to be able to operate under these heavy ice conditions. Also two helicopters were present, Mi-2 and Mi-8T for further assistance. The survey area, as well as the co-ordinates of the bathymetric sailing directions that had to be covered by the fleet, were defined by the Scientific-technical project team according to the requirements of the UN Commission on the Limits of the Continental Shelf.

The bathymetric survey was carried out by the State Research Navigation-Hydrographic Institute (OJSC "GNINGI") under a Russian State contract; with the Federal Agency on the Use of the Earth's Interior ("ROSNEDRA") on the commercial tender basis. During the cruise bathymetric surveys were carried out. Over 9000 kilometers of survey lines for use in substantiating the outer limit of the continental shelf were collected during the journey.

HYDROMETEOROLOGICAL CONDITIONS

Ice conditions were favorable during the entire period of the survey. The work was conducted mainly in one-year old ice with thicknesses of 1.5 - 2 m and concentrations of 90 – 100 % (9/10-10/10 ice cover). However, in the southern part of the eastern sector,

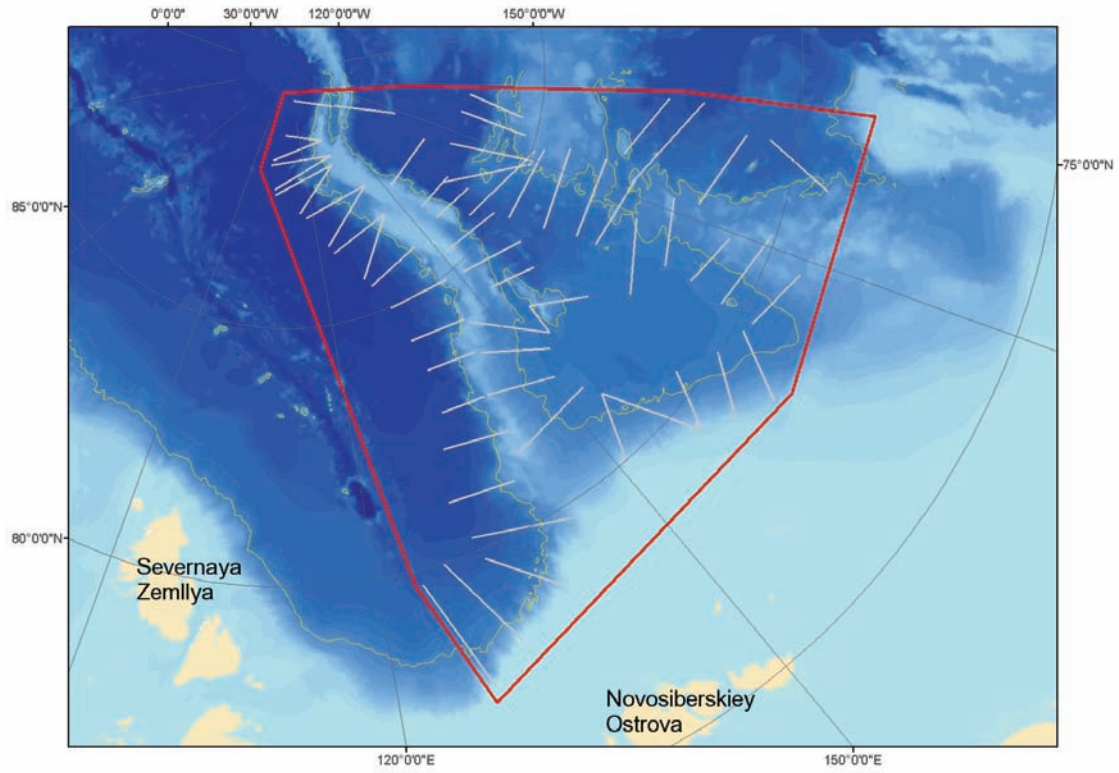

Fig. 1. Map of survey area (outlined in red) showing multibeam transects (transit lines are not shown) containing parts of the Lomonosov and Mendeleev Ridges. White contour shows 2500m depth, and transect lines.

old ice fields up to 4 m thick were encountered within the younger ice. The air temperature during the period did not fall below -18°C degrees.

SURVEY MOBILIZATION

From May 30 until July 7, 2010 the multibeam echo sounder Kongsberg EM 122 was installed on board of the "Akademik Fedorov" at the Turku Repair Yard Ltd..

The bathymetric system consisted of the following components:

- Kongsberg EM122 multibeam echo sounder;
- Kongsberg SIS acquisition software;
- Kongsberg EA 600 single-beam echo sounder;
- Kongsberg TOPAS subbottom profiler with a single-beam echo sounder option;
- Kongsberg Seapath 330 (GPS/GLONASS) primary navigation positioning system;
- C-NAV 2050R secondary navigation positioning system;
- an integrated navigation and hydrographic system Quality Integrated Navigation System (QINSy);
- bathymetric data processing using CARIS HIPS&SIPS Professional and CARIS LOTS.

After installation, a harbor acceptance test of the complete survey outfit was carried out followed by the final sea acceptance in a test area in the Norwegian Sea under supervision of Kongsberg representatives. The Kongsberg representatives compiled a service report that included the description of the test, the results of the calibrations and qualification survey. The survey system on board of the "Akademik Fedorov" was accepted for operation after the analyses of sea trial results.

The icebreaker "Yamal" was also mobilized with the Qinsy software suite. This way the icebreaker could navigate along the pre-planned routes ahead of the "Akademik Fedorov". Via telemetry, the navigation information on position, speed, distance, and direction were exchanged between the two vessels and displayed online.

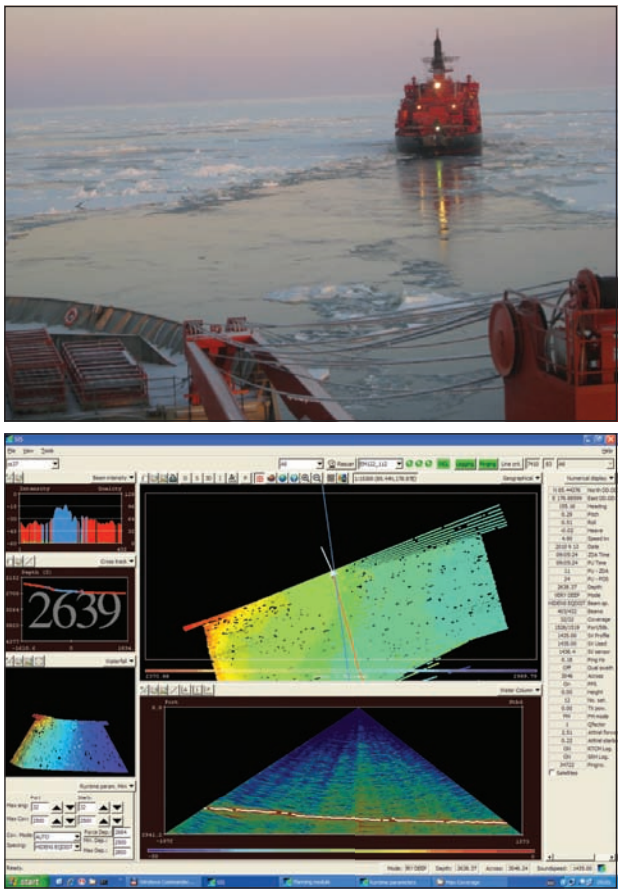

Fig. 2. Example of data acquisition on board of RV "Akademik Fedorov." Swath width shown is approximately 3000m across. Depths range from 2300m (red) to 3000m (deep blue). Location of the detailed profile shown is about 85.4°N and 178.9°E.

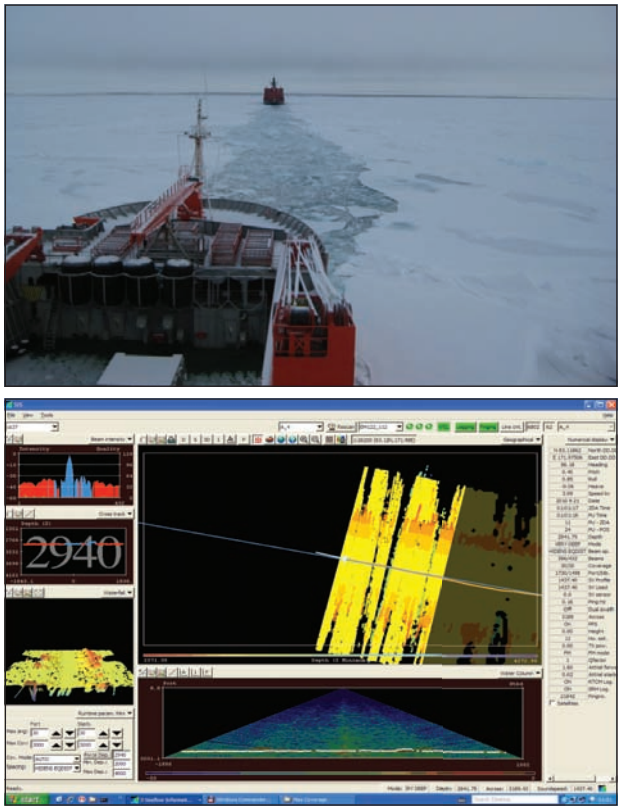

Fig. 3. Data acquisition on board of RV "Akademik Fedorov" with influence of ice conditions. The main swath width is about 3200m across, depths are from 1000m (red) to 4200m (deep blue). The detailed section at 2940m is located at 83.1°N, 172°E.

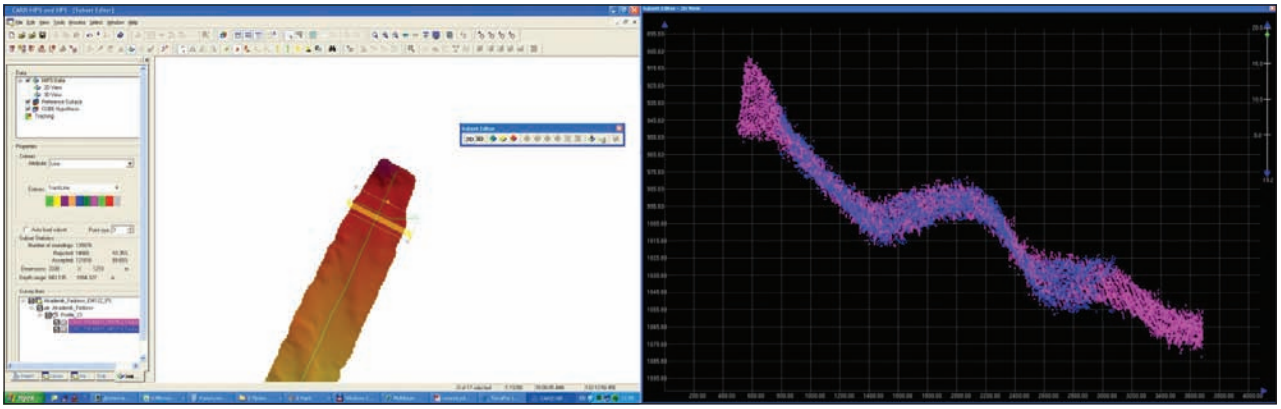

Fig. 4. Example of cross check analyses in CARIS HIPS/SIPS software. The right hand block shows depth vs distance with the corresponding section perpendicular to it. The locality is 78°N, 132.1°E. The matching of these two profiles shows no discrepancies, and thus validates the calibration parameters.

It was essential to enter the parameters of the sound velocity profiles (SVP) in the multibeam echo sounder system. The hydrological measurements were made in the course of the hydrographic surveys on regular basis at least once a day. A total of 128 oceanographic samples were taken of which 29 samples using the Midas Valeport probes to obtain the sound velocity profile, and 99 samples using the expendable XCTD probes.

The strong changes in course direction, ship's engine, machinery, as well as, the ice influenced the data reception by the multibeam echosounder. Noises negatively influenced the quality of the acquired data and in some cases even resulted in data loss.

QUALITY CONTROL

Before the start of the project, calibration tests were performed. In the course of the survey the quality of the bathymetric data was regularly validated. Data from multibeam cross lines were compared to cross lines of the single-beam echo sounder data.

The results of the different mentioned SVP sensor models, MIDAS VALEPORT and XCTDs, were compared with each other in order to ensure data integrity and quality. At the end of the project, calibration tests were carried out again. No changes in the calibration parameters were detected during the survey.

A designated quality control group on board carried out the data analysis and performed data processing. The team was making use of the latest versions of CARIS HIPS Professional and Fledermaus Professional and Geocap processing software. The team corrected the multibeam data disturbances caused by the ice. While processing, the team also ensured that the acquired data met the data quality standards and specifications of UN

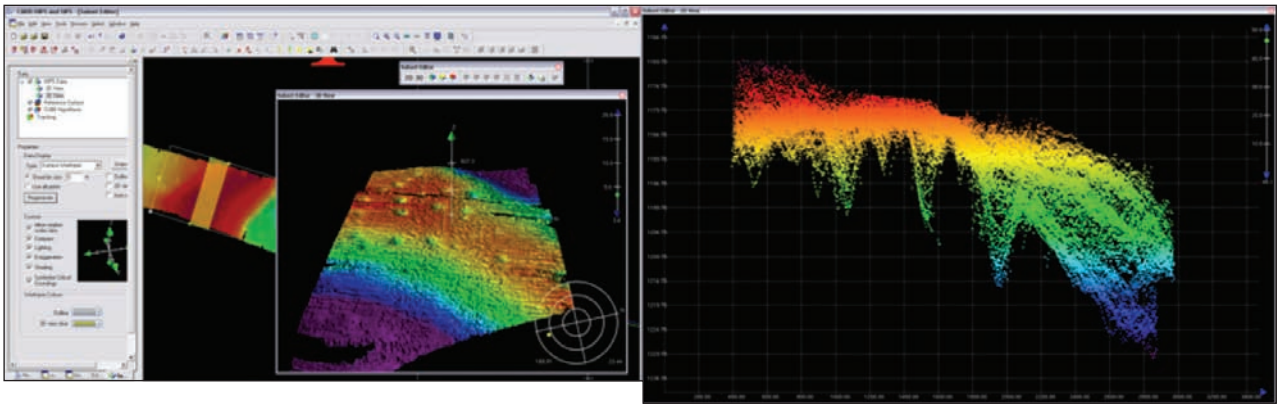

Fig. 5. Analyses of multibeam data in CARIS HIPS/SIPS software. Note the pock marks on the crest of the rise.

Commission on the Limits of the Continental Shelf. The defined standards were based on IHO S-44, Order 2 (IHO, 2008). As a result, the quality of the multibeam survey data was assured along all 59 survey lines.

Geocap and CARIS LOTS software were used for accurate determination of the foot of the slope (FOS) and calculation of the continental shelf boundary limits 60 miles or 100 kilometers from the FOS. These calculations were based on the Scientific and Technical Guidelines of the UN Commission on the Limits of the Continental Shelf. http://www.un.org/depts/los/clcs_new/commission_documents.htm#Guidelines

During multibeam processing, the main task was to provide the operational quality control of the initial data and data cleaning of erroneous measurements and disturbances, evaluation of the processing results and resolving of the remaining ambiguities.

The preliminary evaluation of the data accuracy and quality of the multibeam echo sounder was carried out after the preliminary onboard processing by means of the statistical comparison of the data from the main survey lines obtained by the multibeam echo sounder with the check lines data obtained by the multibeam echo sounder, single-beam echo sounder and subbottom profiler with the option of a single-beam echo sounder.

For additional control, digital terrain models (DTM) based on the CUBE algorithm were created and analyzed using processed data (Figures 7 and 8).

For quality control of positioning data, the offset differences between primary and the secondary positioning systems was monitored. Also positioning of Seapath 330 data was logged in RINEX format by SIS hydrographic software. During onshore processing this data was processed using TerraPos software by Terratec to improve the positioning accuracy. The processed navigation data

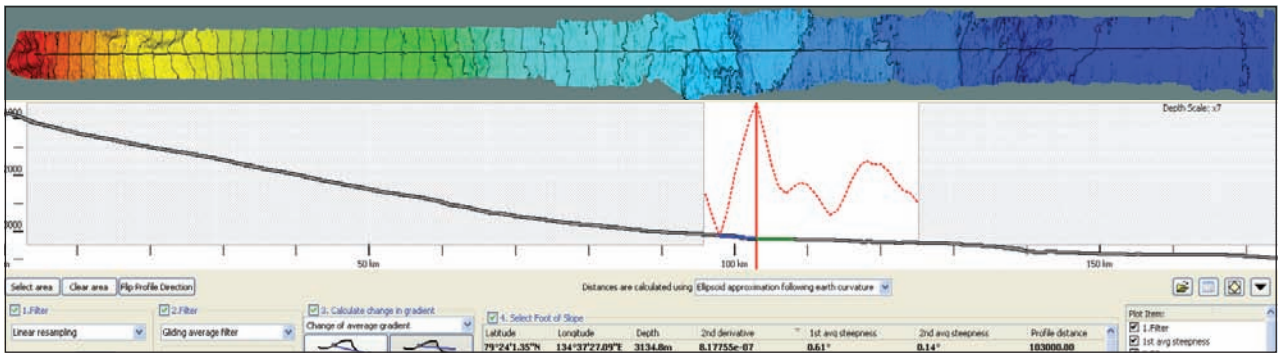

Fig. 6. Example of determination of Foot of Slope in Geocap. Selection of Foot of Slope based on the first derivative of changes in the slope. The foot of slope in this profile is at 71.2°N, 134.4°E.

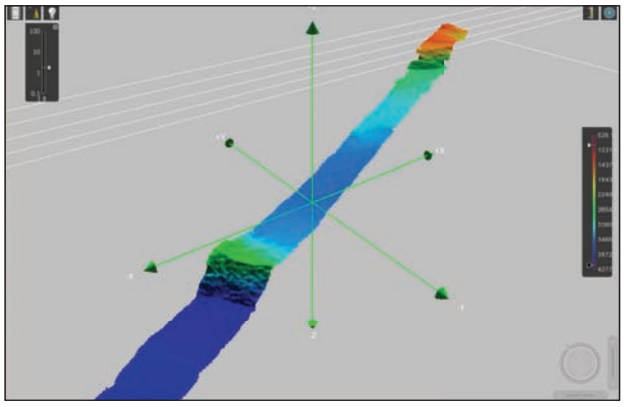

Fig. 7. Example of DTM in 3D mode in CARIS HIPS/SIPS software.

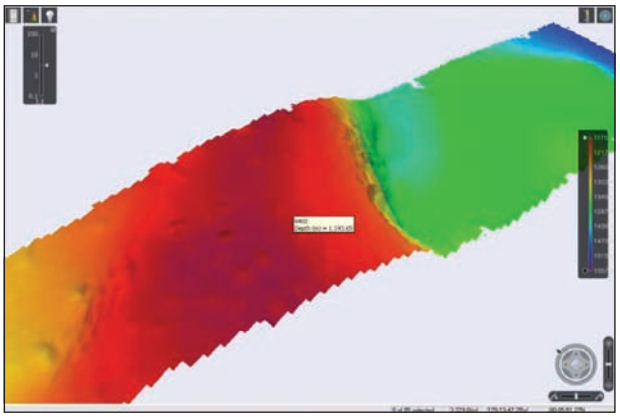

Fig. 8. Example of DTM in 3D mode in CARIS HIPS/SIPS software.

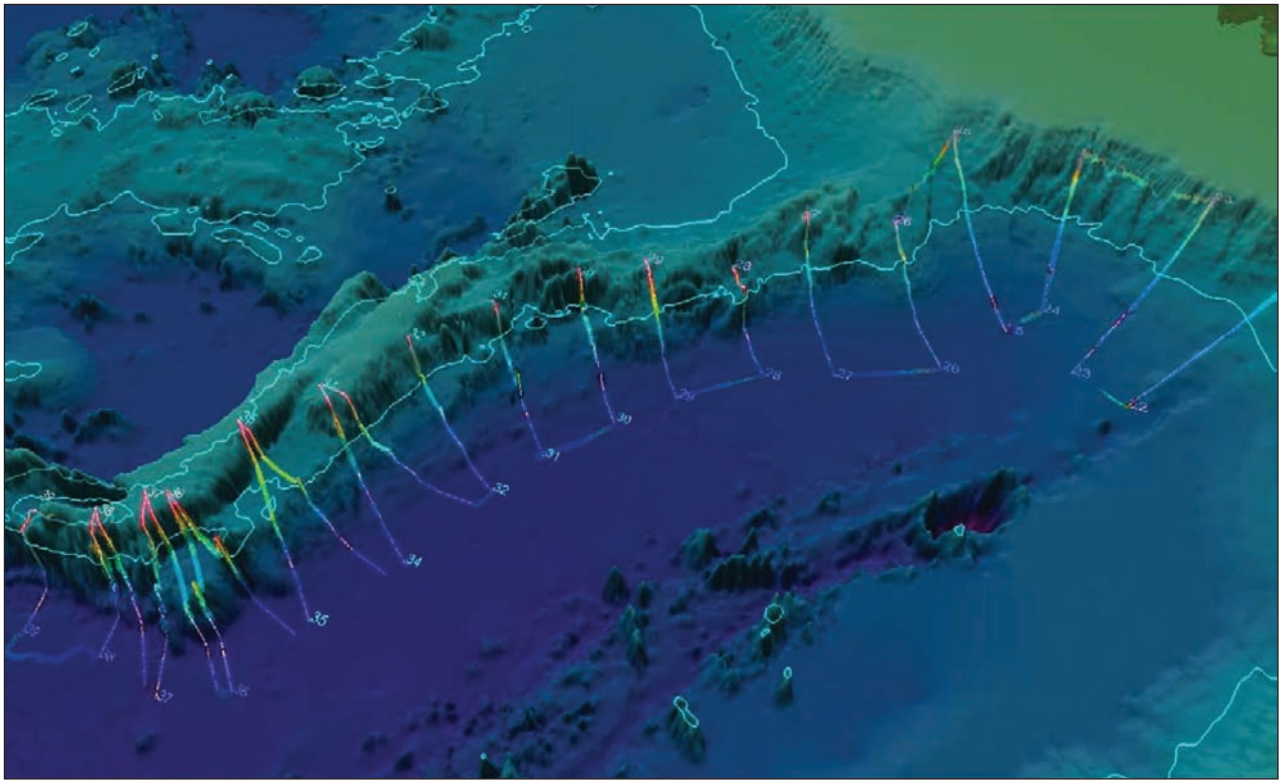

Fig. 9. The path of the multibeam survey on the west slope of the Lomonosov ridge (3D visualization). Note the white 2500m contour line outlining the Lomnosov, Alpha and Mendeleev Ridges

was imported into CARIS HIPS and statistically the original positioning data and processed positioning data were compared in order to determine the accuracy of the processed positioning information.

RESULTS OF THE EXPEDITION

According to quality assessment the acquired data complied well within the required standards in IHO S-44 Order 2 (IHO, 2008) and thus falling within the specified requirements of the UN Commission. The first stage of the survey in the framework of the State task for determination and substantiation of the outer limits of the Russian Federation's continental shelf in the Arctic Ocean was completed according to the set time limits.

REFERENCES

International Hydrographic Organization, 2008. Standards for Hydrographic Surveys
5th Edition, February 2008, Special Publication No. 44, Published by the International Hydrographic Bureau, Monaco. 28 p.