Multibeam mapping of remote fjords in Southeast-Greenland – a survey on a vintage vessel

Wilhelm WEINREBE and Kristian K. KJELDSEN

Key Words: Multibeam Mapping, South-East Greenland, Vintage Survey Vessel, Timmiarmiut-Fjord, Skjoldungen-Fjord-System

SUMMARY

The fjords of Southeast-Greenland are among the most remote areas of the northern Hemisphere. Access to this area is hampered by a broad belt of sea ice floating along the East-Greenland coast from north to south. Consequently, the majority of those fjords have never been surveyed until now. During an expedition by the Center of GeoGenetics of the University of Copenhagen in summer of 2014 we were able to map the Skjoldungen Fjord system with multibeam bathymetry. The topsail schooner *"ACTIV"*, built 1951 as a cargo ship to supply remote settlements in Greenland was chosen for the expedition. Though a vintage vessel, the *"ACTIV"* was well suited to cross the belt of sea ice and to cruise the ice covered fjords. A portable ELAC-Seabeam 1050 multibeam system was temporarily installed on the vessel. The two transducer of the system were mounted at the lower end of a 6 m long pole attached outboard at port side. Though the installation was quite demanding without any winches or cranes, the construction was sufficiently stable and easy to manage throughout the entire cruise. The area which was mapped had never been surveyed before using a multibeam system, furthermore, for great parts of the region no sounding information were available at all. The conditions for multibeam surveys in this area and particularly on this cruise were difficult, and of course this has actually affected the quality of the data. Anyhow, the results of the multibeam surveys clearly demonstrate that it is actually possible using a ship such as the *"ACTIV"* and a temporary installation to achieve bathymetric maps of satisfactory quality even under difficult conditions in remote areas.

1. INTRODUCTION

High resolution mapping of the seafloor in unexplored Arctic waters with abundant floating icebergs and ice floes isn't an easy job by itself. Furthermore, if the survey vessel is a vintage topsail schooner and the multibeam system had to be temporarily installed using a pole over the side, difficulties and problems will definitely show up. Yet, if there is no other boat available, you just have the option to try or to drop the job. In the end, it can be successful.

1.1. Background of the Project

The impact of climate change on our environment is most obviously visible through the recession of Arctic glaciers. Consequently, the Centre for GeoGenetics of the Museum for Natural History of Copenhagen University runs the long-term project "Greenland Ice Sheet over the past Millennium". For this purpose sediment cores of glacier lakes close to the rim of the ice sheet are taken. Whereas in earlier years the field work was accomplished by means of helicopter, it happened that in summer of 2014 a vessel was available for the expedition (fig. 1). Thus the opportunity for hydrographic work in addition to geological sampling arose. As the target areas for the expedition, two remote fjords in Southeast Greenland, were virtually unmapped so far, multibeam surveys of those fjords were planned.

Figure 1: Topsail Schooner *"ACTIV"* moored in Skjoldungen Fjord

1.2. Survey area

The fjords of Southeast-Greenland are among the most remote areas of the northern Hemisphere. Access to this area is hampered by a broad belt of sea ice floating along the East-Greenland coast from north to south. In addition, the ice sheet extends as far as to the sea nearly all along the coast leaving no strip for human settlements. Therefore a stretch of about 600 km from the southern tip of Greenland up to the village of Tasilaq in the north is virtually uninhabited. The negligible anthropogenic impact into this environment makes this pristine area optimal for the geological sampling. Consequently, the majority of the fjords along this coast have never been surveyed in detail. Two of those, the Timmiarmiut Fjord and the Skjoldungen Fjord system (fig. 2) were chosen as target areas for the expedition.

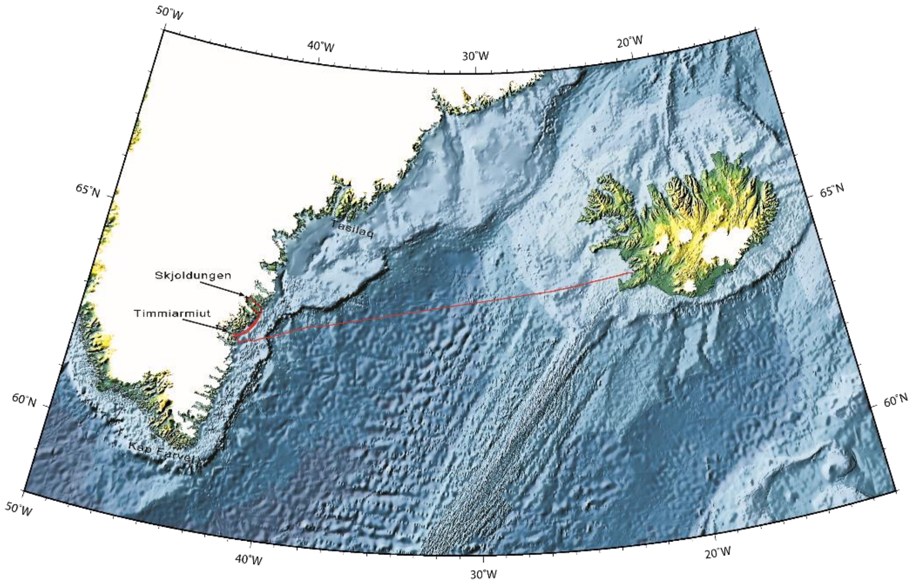

Figure 2: The survey area in Southeast-Greenland

1.3. Survey Vessel

The vessel *"ACTIV"* was built 1951 in Svendborg, Denmark as a cargo ship to supply remote settlements in Greenland. The hull was made from Danish oak timber and constructed to withstand rough North-Atlantic waters and ice-covered Arctic seas. In the late 1970'es the freight service to Greenland was abandoned. As a consequence the *"ACTIV"* was sold and retrofitted to a historic three-master topsail schooner just like those quite common before World War I in the Baltic Sea. The hull has a length of 30 m, width of 7.2 m and draft of 3.35 m. The overall length of the vessel is 42 m, it features a sail area of 640 m^2 and an engine of 250 hp. All of the 13 sails of its rig are operated manually by means of blocks and tackles. The vessel is used for commercial and leisure activities as well as for expeditions. The *"ACTIV"* gained fame as *"Pequod"* in the recent film adaption of Melville's novel *"Moby Dick"*. Though a vintage vessel, the *"ACTIV"* is well suited to cross the belt of sea ice and to cruise the ice covered fjords, however it is not at all intended and qualified for hydrographic work. Precise navigation instruments as well as echo-sounders are missing, furthermore basic requirements such as sufficient lab space, stable power supply and the ability to keep constant speed along profile lines are lacking. Most distressing, however, is the absence of any electric or hydraulic winches or cranes, which makes it awful difficult to deploy or recover any instruments into the water.

2. FIELD SURVEY

2.1. Equipment Used

As there were no mapping echo-sounders available onboard, we used a portable ELAC-Seabeam 1050 multibeam system temporarily installed on the vessel.

The Seabeam 1050 multibeam echosounder collects bathymetry data with beams as narrow as 1.5° by 1.5° and a swath width of up to 153°. The 50 kHz signal achieves a depth range of more than 2,000 m. Different to other multibeam systems which transmit a full swath of acoustic energy and use directed reception (*beam forming*), the Seabeam 1050 applies beam forming at transmission and reception, thus achieving a very high side lobe suppression of 36 dB with very low error-rates. The disadvantage of this technique is a slightly lower ping rate. The system is completely stabilized for roll of the ship if an adequate motion sensor is installed. The Seabeam 1050 employs two transducer arrays, port and starboard, both capable of transmitting and receiving. Their acoustic planes are tilted 38° to the vertical. The arrays are normally installed fixed to the ship's hull, but on *"ACTIV"* they were mounted using a pole over the side of the vessel. The technical specifications of the Seabeam 1050 are listed in table 1. The additional equipment, in particular the ancillary sensors are listed in table 2.

Table 1: specifications of multibeam system Seabeam 1050

frequency	50 kHz
maximum depth	3,000 m
beam width	1.5° by 1.5°
maximum swath width	153°
maximum number of beams	126
beam spacing	equiangular
pulse length	0.15 msec – 10 msec
side lobe suppression	36 dB (transmission and reception)

Table 2: ancillary sensors

navigation, heading and attitude sensor	CodaOctopus F180R+
sound velocity profiler	Sea&Sun CTD48M
data acquisition system	Laptop DELL Inspiron 9400
post-processing system	Laptop Toshiba Portege R830

2.2. Multibeam System Installation

To be able to operate the Seabeam 1050, two multibeam transducer, the electronic cabinet, two laptops and the motion sensor F180R+ had to be installed onboard *"ACTIV"*. The installation took about one day. Before the cruise, a pole of 6 m length to hold the transducer head had been constructed and a U-shaped bracket as well as a clip with a swivel to hold the pole had been attached to the hull outboards at port side midships (fig. 3). It was quite laborious and demanding to mount the pole including transducer head and the two transducers into this outboard position without any winches or cranes, just by means of blocks and tackles and muscle work (fig. 4). In addition to the bracket and the clip the transducer head was secured by two Dyneema ropes attached to the vessel, fig. 5 shows the whole configuration in survey placement. For transits and in ice covered areas the entire pole could be hoisted up into a safe position (fig. 6).

Though the installation was quite demanding without any winches or cranes, the construction was sufficiently stable and easy to manage throughout the entire cruise. This very unique constellation of a historic ship combined with modern mapping technology was a real challenge but in the end very successful.

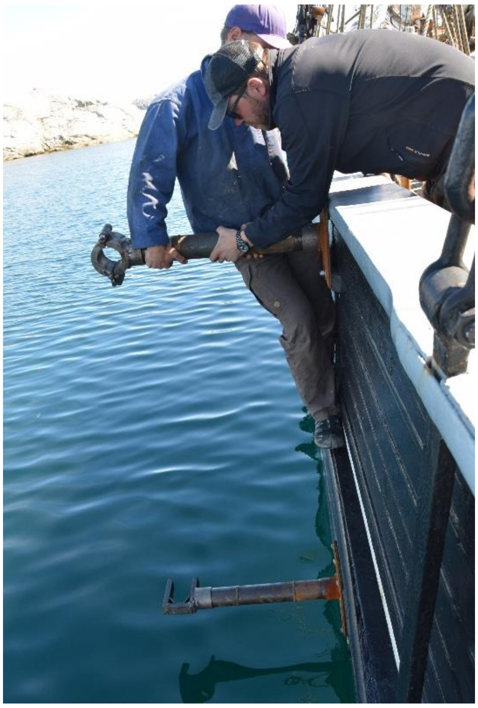

Figure 3: installation of transducer pole

Figure 4: pole with transducer head

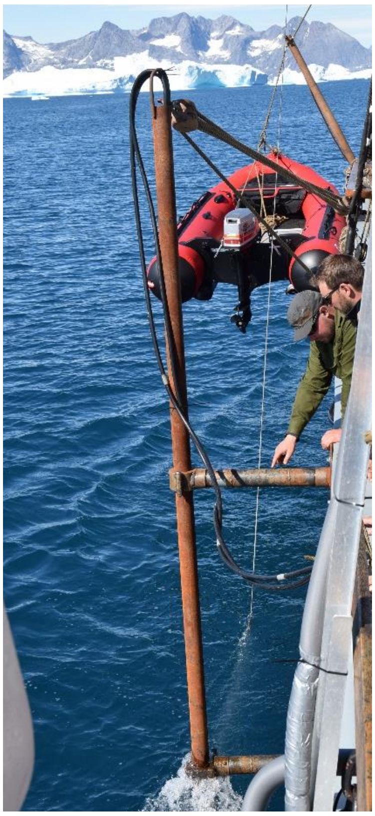

Figure 5: multibeam pole in survey position

Figure 6: multibeam transducer pole in transit position

2.3. Multibeam Survey

During the expedition, the multibeam system was in operation during 10 days along a total profile length of 402 km. While operating the engine and not the sails, the survey speed was maintained between 3 kn and 5 kn. The water sound velocity profile was determined at 11 positions using a CTD-sensor (CTD = conductivity, temperature, depth).

The southern part of the survey area, the Timmiarmiut Fjord was extensively covered by ice floes (fig. 7), thus only a small contiguous area of about 15 km^2 was mapped successfully. On the other hand, in the Skjoldungen Fjord system in the north only a small area was covered by ice floes (fig. 8), therefore the entire Fjord area, leaving only a small gap of about 5 km at the innermost part and small stripes close to the shorelines were mapped. In order to achieve a nearly complete coverage, the fjord was mapped along three lines: one in the centre, one closer to the northern and one closer to the southern shore.

Figure 7: Timmiarmiut fjord

Figure 8: passage in inner Skjoldungen-fjord

2.4. Preliminary Results

Besides the small gap in the inner part, a comprehensive map of the entire Skjoldungen Fjord area can now be presented for the first time (fig. 9). The digital terrain model (DTM) of the seafloor has been calculated on a regular grid using a cell size of 5 m by 5 m. As an example for the data quality achieved, a detailed map of the area close to the southern entrance is presented in fig. 10.

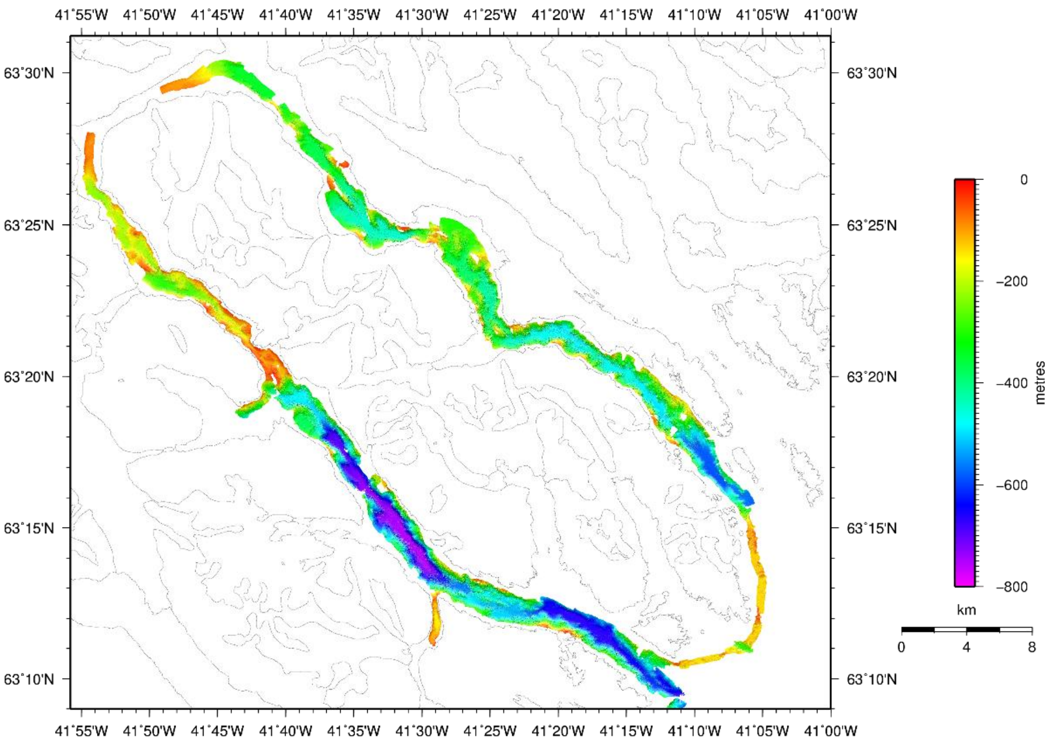

Figure 9: Bathymetry of the Skjoldungen fjord system

The map of the Skjoldungen Fjord displays water depths from close to zero up to 800 m, the deepest part is a stretch of about 10 km length in the south-western part. The bathymetry of the northern fjord is remarkably different from the bathymetry of the southern fjord: the southern fjord features an outer deep part showing water depths in the centre between 500 m and 800 m and a shallow inner part with depths never reaching more than 300 m and a prominent sill in between. The northern fjord shows a more gradual increase of water depths from 200 m in the inner part to 600 m at the entrance.

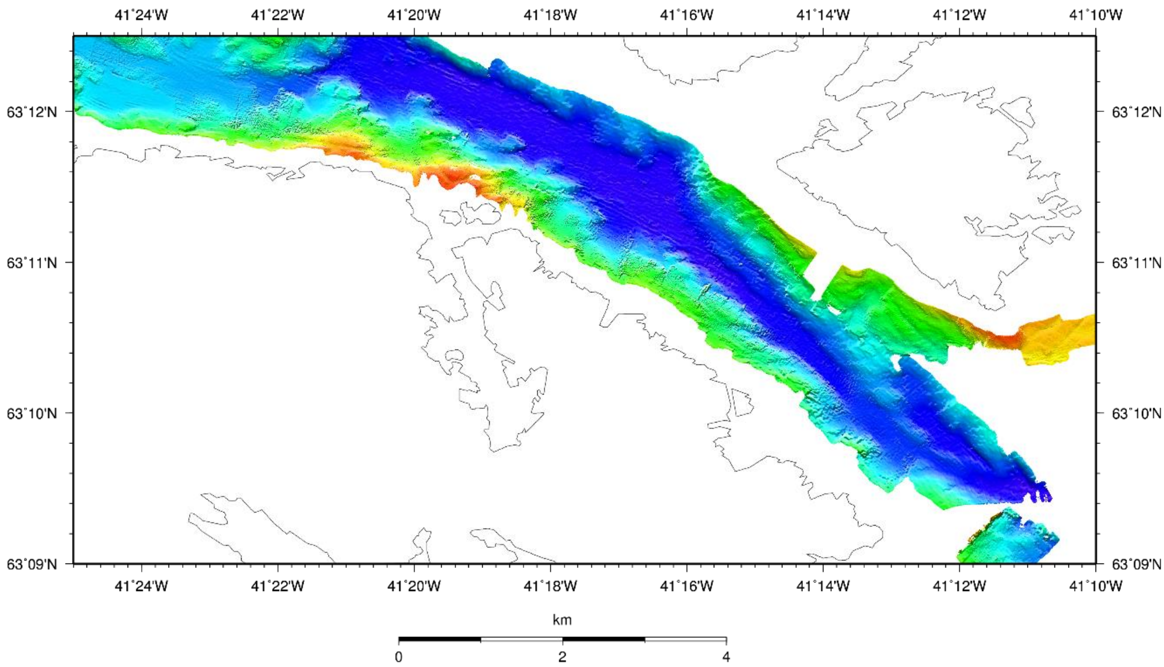

Figure 10: detailed map of the bathymetry of the entrance to southern Skjoldungen fjord

The shape of the seafloor in the fjord system is characterized by glacial erosion and deposition. Of particular interest is the continuation of subaerial relief to submarine morphology (fig. 11).

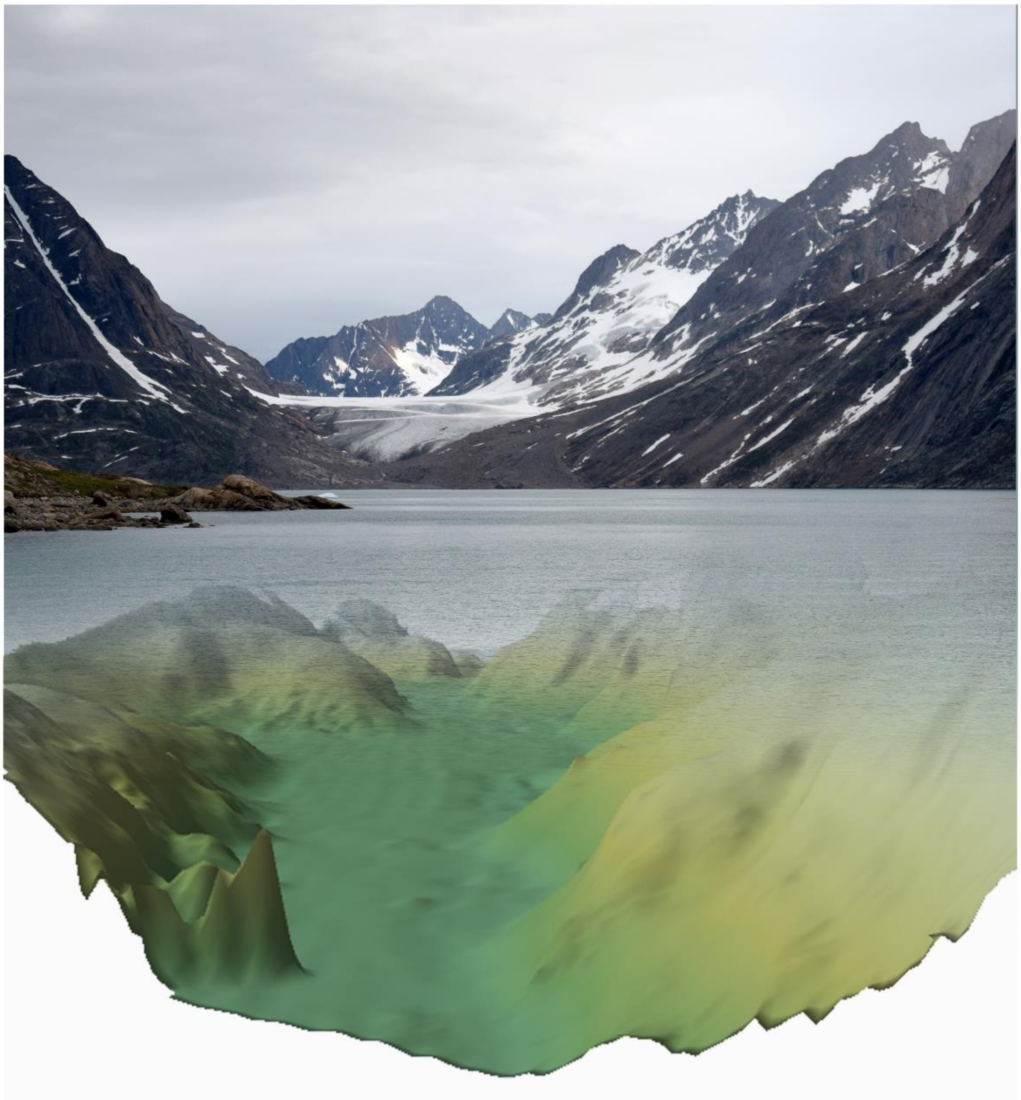

Figure 11: correlation of subaerial topography and submarine relief

3. CONCLUSIONS

The area which was mapped in 2014 during the cruise with *"ACTIV"* had never been surveyed before using a multibeam system, furthermore, for great parts of the region no sounding information were available at all. The maps which had been compiled from the *"ACTIV"* data are the first bathymetric maps of the area. The conditions for multibeam surveys in this area and particularly on this cruise were difficult, and of course this has actually affected the quality of the data.

Multibeam transducers are usually permanently installed in the hull of a vessel. For precise measurements of the water depth the transducers have to be mounted absolutely horizontally and aligned to the centre line of the vessel, minimal deviations are determined by a calibration scheme following the installation. On *"ACTIV"* the transducers were installed temporarily at the lower end of a pole of 6 m length which was then mounted over the side of the vessel. Of course this cannot be as stable as an installation flush in the hull. The pole is prone to vibrations, in addition the hydrostatic pressure of the pipe in the water when moving led to slight bending of the pole. Also floating ice in the water collided with the pole, moving it slightly out of position. A proper survey would have required a new roll calibration each time the pole was deployed into the water, however, the area was not at all suited for a roll calibration which should be run over absolutely planar seafloor.

The motion sensor F180R+ which had been used during the survey relies on good connections to GPS satellites which was very difficult to accomplish inside the fjords due to the high and steep mountains around. So the achieved accuracies of heading and motion information were occasionally out of the specifications leading to a decreased quality of the multibeam data. Other sources of errors in the data are missing tidal information, frequent changes in the water sound velocity due to the influence of melt water as well as abrupt course changes of the vessel due to ice floes.

Anyhow, the results of the multibeam surveys clearly demonstrate that it is actually possible using a ship such as the *"ACTIV"* and a temporary installation to achieve bathymetric maps of satisfactory quality even under difficult conditions in remote areas.

CONTACT:

Dr. Wilhelm Weinrebe
retired from GEOMAR – Helmholtz-Centre for Ocean Research Kiel
Robert-Koch-Str. 33
24116 Kiel, Germany
Phone: +49-431-3970131
eMail: wilhelm@weinrebe-kiel.de
www.weinrebe-kiel.de

Dr. Kristian Kjellerup Kjeldsen
Centre for GeoGenetics, Natural History Museum, University of Copenhagen
Øster Voldgade 5 – 7
1350 København K, Denmark
eMail: kkjeldsen@snm.ku.dk
geogenetik.ku.dk