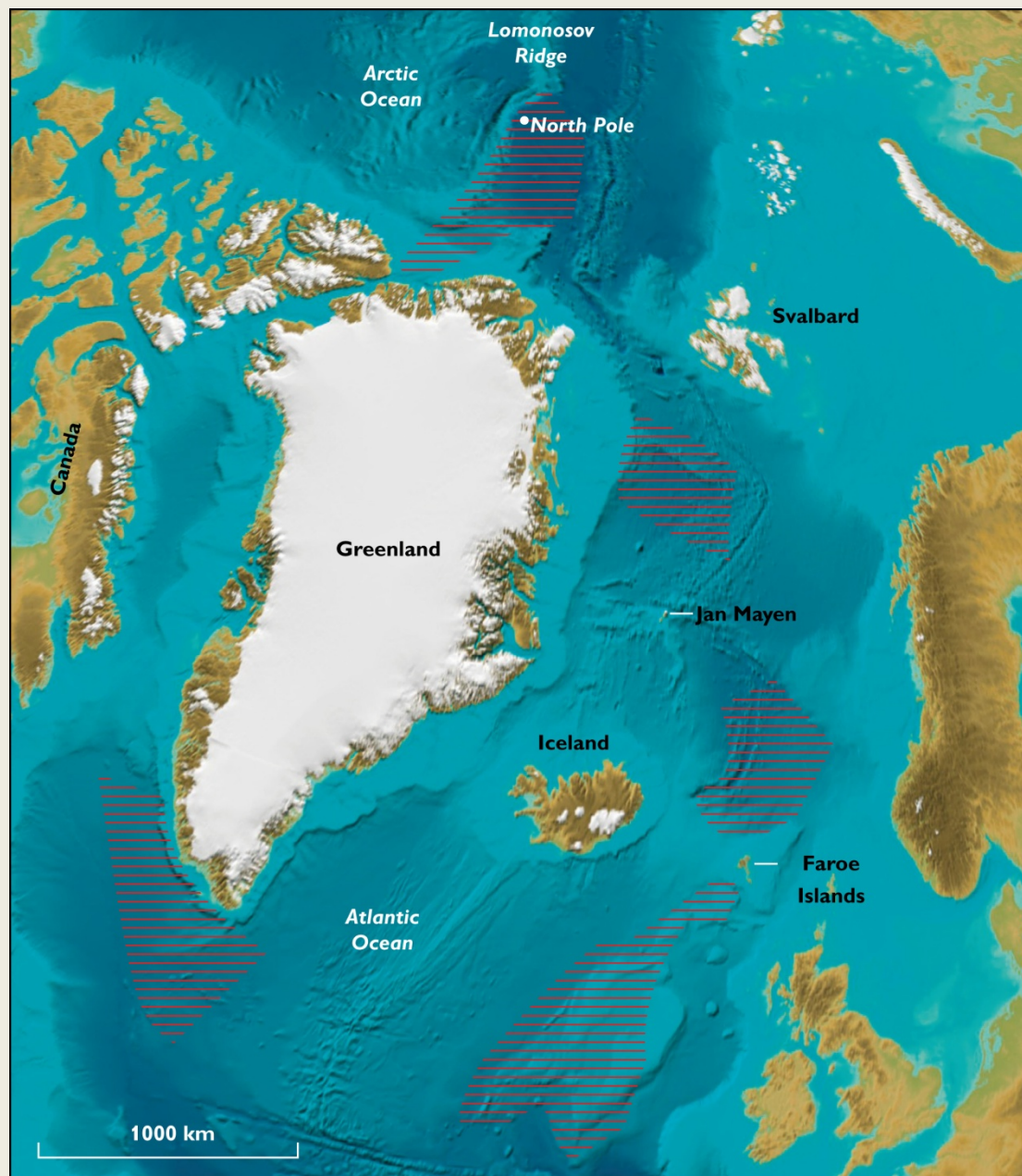


***Operating conditions in the Arctic:
Data acquisition in the Arctic Ocean by the
Continental Shelf Project of the Kingdom of Denmark***

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Continental shelf project of the Kingdom of Denmark - Areas of interest

2 areas around the Faroe Islands

3 areas around Greenland

Submission for the area N of the Faroe Islands submitted in April 2009

Submission for the area S of the Faroe Islands submitted in December 2010

Ongoing work in the areas around Greenland with a deadline at the end of 2014.

Extended continental shelf issues (1)

- A coastal State's entitlement to extended sovereign rights depends on the width of its continental margin.
- To qualify, the State must meet the criteria specified in Article 76 of the United Nations Conventions on the Law of the Sea (UNCLOS), which are based on a consideration of seafloor morphology, bathymetry and of underlying sediment thickness.
- To meet these criteria, it is necessary to assemble and analyze data for reliably determining the locations of three undersea features:
 1. the foot of slope, defined as the point of maximum change of gradient at the base of the continental slope;
 2. the 2500 m isobath; and
 3. the location of the so-called Gardiner Points where the sediment thickness equals one percent of the distance back to the foot of slope.

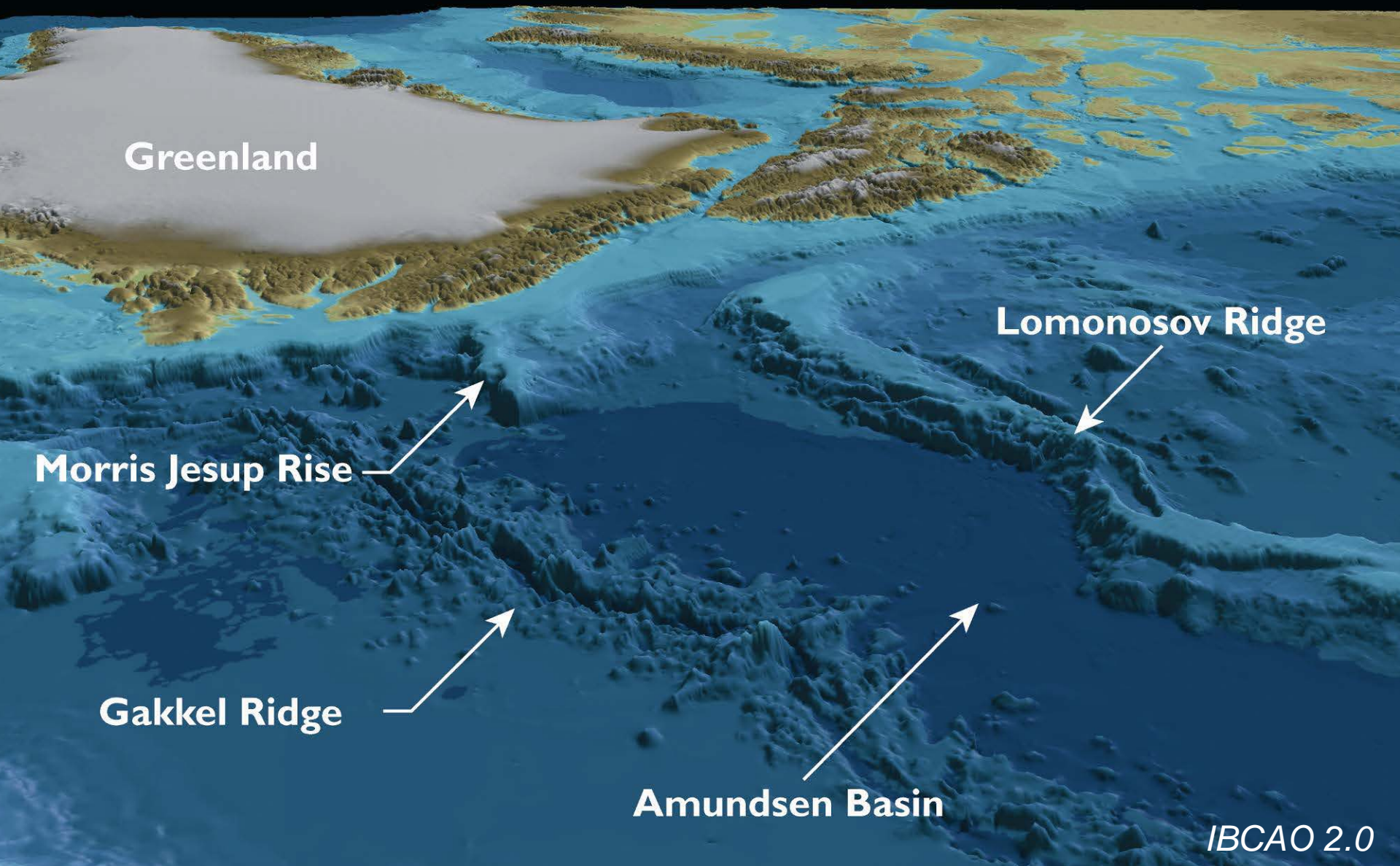
Extended continental shelf issues (2)

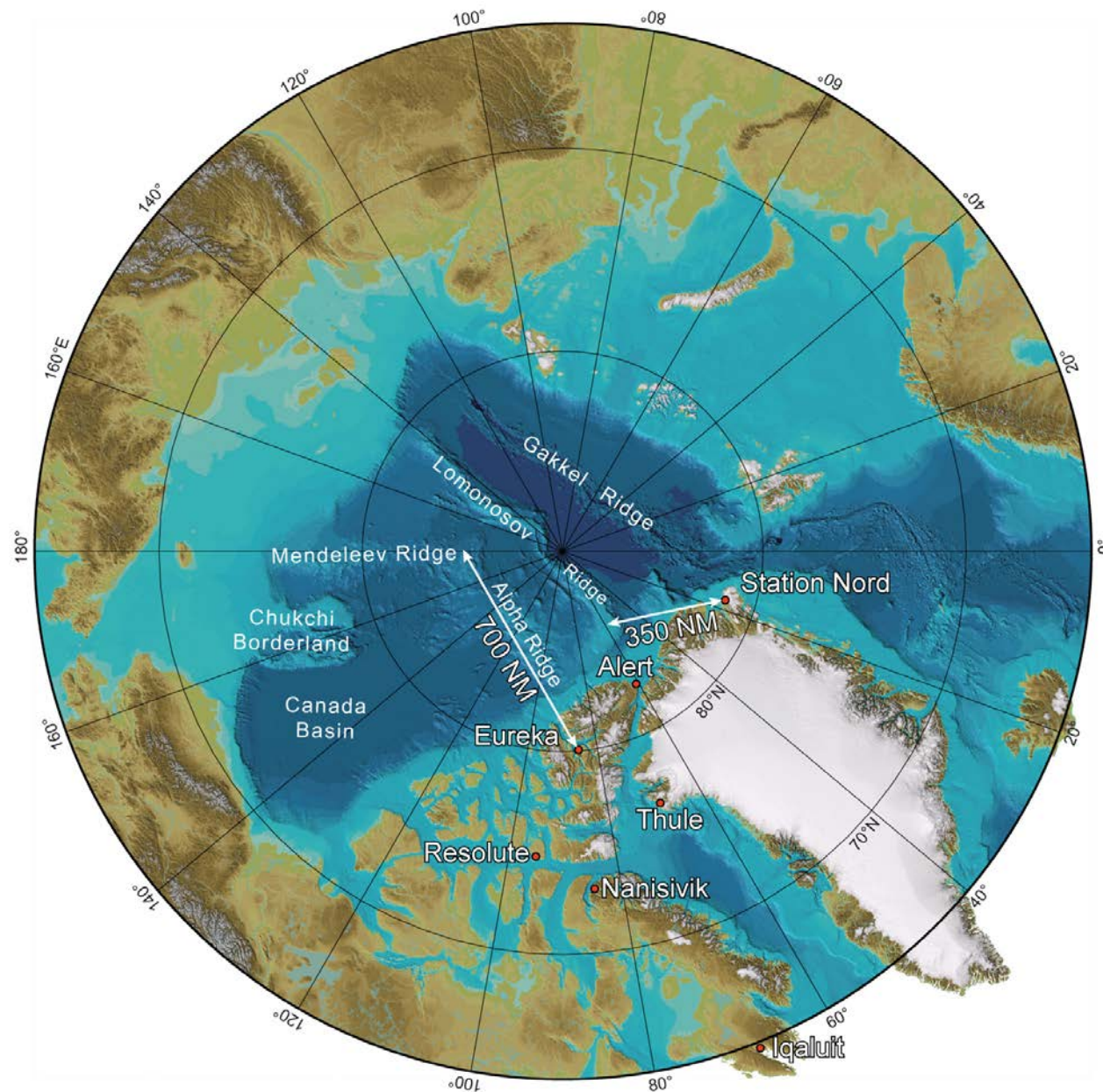
Which type of data are needed?

- **Geodetic** data are needed to define the territorial sea baseline.
- **Bathymetric** data are needed to define the Foot of the Slope (FOS) and the 2500 meter isobath.
- **Seismic data** are needed to map the sediment thickness.
- Other geophysical (seismic refraction, gravimetric and magnetic data) and geological data (sampling, drilling) can support a submission.
- In ice covered areas (Arctic Ocean) potential field data might be used to interpolate between seismic profiles.
- The scientific and technical guidelines of the Commission on the Limits of the Continental Shelf (CLCS) define in more detail how data should be documented.



The Challenge: Operational difficulties for field work on sea ice or from polar ice breakers in the area north of Greenland





Remoteness

Very sparse
infrastructure

IBCAO - Version 2.23

Weather

- Average Temperature - Alert

March - 32.4° C

April - 24.4° C

May - 11.8° C

June - 0.8° C

July 3.2° C

Aug 0.8° C

Sep - 9.2° C

Oct - 19.4° C

- Hours Daylight

Zero: between October 15 to February 25

24 hours: from April 7 to September 5

Survey Seasons

- **Winter**
 - March and April
 - Daylight Returns
 - Stable Ice conditions
 - Cold and Clear Weather
- **Summer**
 - August and September
 - Maximum Ice Melt
 - Optimum period for icebreaker operations

Costs

- Icebreakers: \$65,000 to \$200,000 / Day
- Aircraft: \$1300 to \$12500 / Hour; Minimums 3 - 4 Hr / Day
- Fuel:
 - Fuel \$750 per metric ton HFO 180 (LS max 1,0%)
Oden: 48 tons per day (average 2009), total more than \$2 mill.
 - Jet Fuel Resolute: \$2.50 / L by sea; \$7 / L by air

Eureka: \$3.50 / L by sea; \$8 / L by air
Alert: \$10 / L by air
Ice Camp: \$14 - \$20 / L by air
Remote fuel camp: \$30 - \$35 / L by air

300,000 - 400,000 L per Winter Survey = 1500 – 2000 drums

Logistical challenges

- No commercial survey vessels can operate in this region of the Arctic Ocean
- Only a few Polar Class icebreakers are available
- “SCICEX” US submarines have been decommissioned, AUV concept “under the ice” had to be developed
- Specialized ice strengthened bathymetry and seismic equipment for icebreaker surveys has to be developed
- Former experience and equipment used in the 80ʹties for on-ice surveys had aged
- Establishment of ice camps on more unstable sea ice

The concept

- Sharing of knowledge and cost through cooperation between Canada and Greenland/Denmark
- Cooperation with Canada started in 2002
- Formal Memorandum of Understanding signed in June 2005.
- Cooperation with other scientist working with similar data acquisition in the Arctic Ocean to share knowledge.
- Cooperation with Sweden regarding the use of the Swedish research icebreaker *Oden*.
- Cooperation with Russia. USA, Germany ...
- Innermost parts of survey area: logistics based on ice camps
- Remaining parts based on data acquisition from icebreakers
- “Learning by doing”



Photo: Ron Verrall

Lorita expedition 2006

Acquisition of seismic refraction data on the sea ice:

Study of the crustal structure from the shelf onto the Lomonosov Ridge.

Results published in Geophysical Journal International, 2010.

CHS bathymetric data acquisition March – April 2007



- A** *drainage of sea ice from the Lincoln Sea through the Nares Strait.*
- B** *Helicopters with no horizon in spring of 2007 – data acquisition not possible and complete season lost.*

A



Photo: Uni Bull

B



Photo: Uni Bull

Bathymetric measurements 2009

Joint Canadian-Danish fieldwork based on sea ice in the spring of 2009.

Temperatures ranged from -50°C in March to -20°C in the beginning of May.

Data will be included in the new version 3 of the International Bathymetric Chart of the Arctic Ocean (IBCAO)

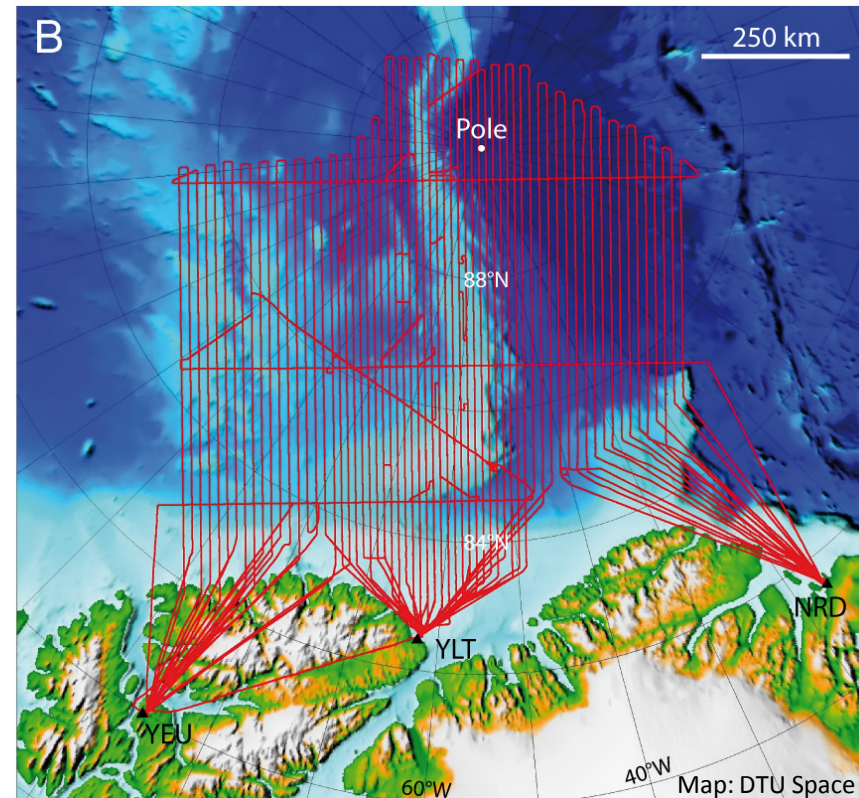
<http://www.ngdc.noaa.gov/mgg/bathymetry/arctic/>

A



Photo: Janice Lang, NRCan/DRDC

B

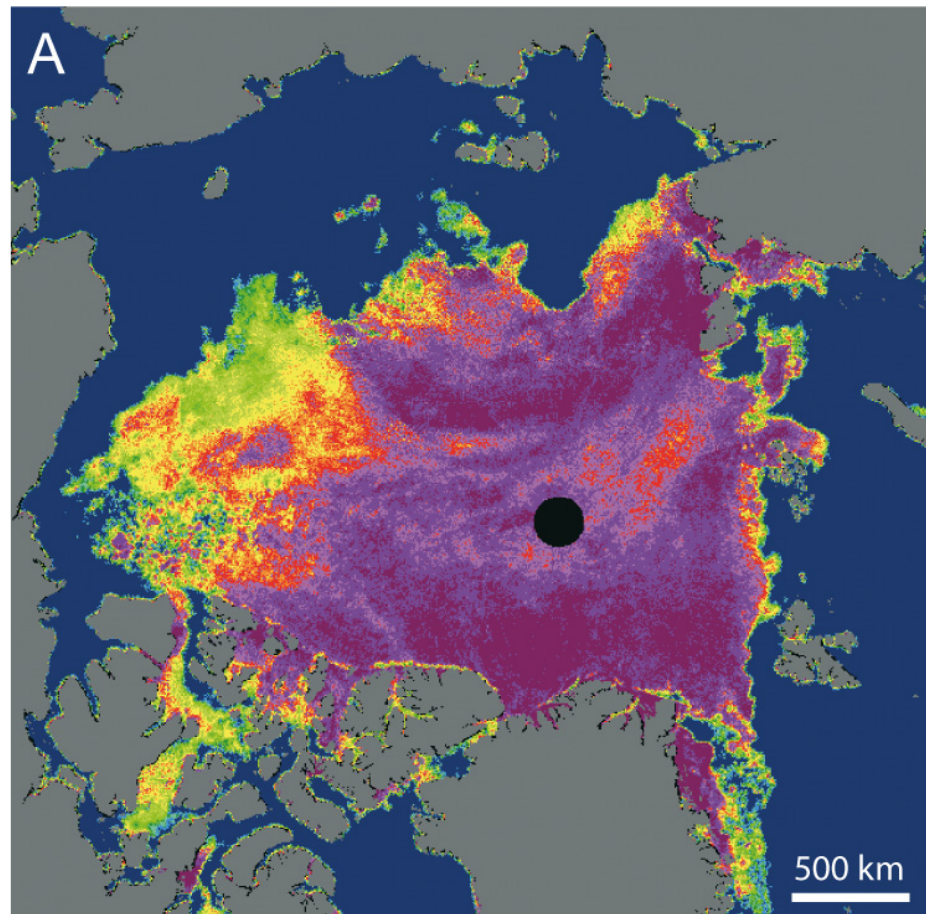


Acquisition of aero-geophysical data - Spring 2009

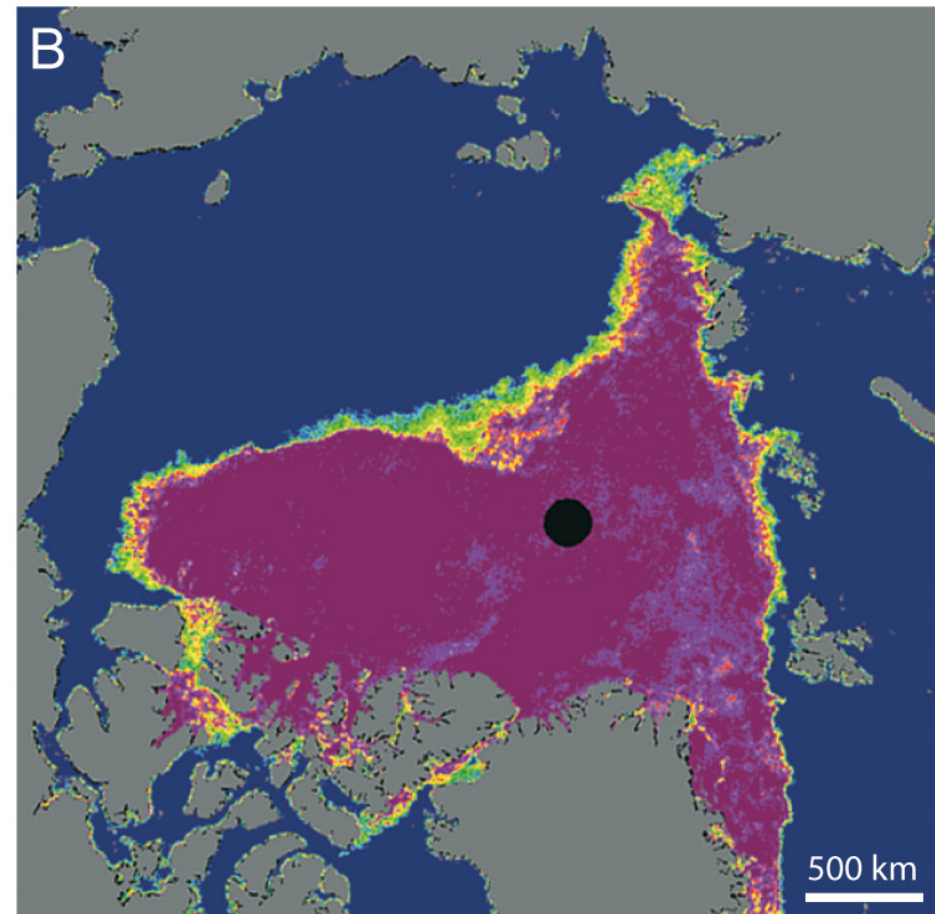
A joint Danish – Canadian project to acquire supporting data on both sides of the Lomonosov Ridge using a DC3T.

Magnetic data will be included in the World Digital Magnetic Anomaly Map (WDAM) and the gravity data in the Arctic Gravity Project (ArcGP).

Ice conditions in the Arctic Ocean - August 2007



August 1



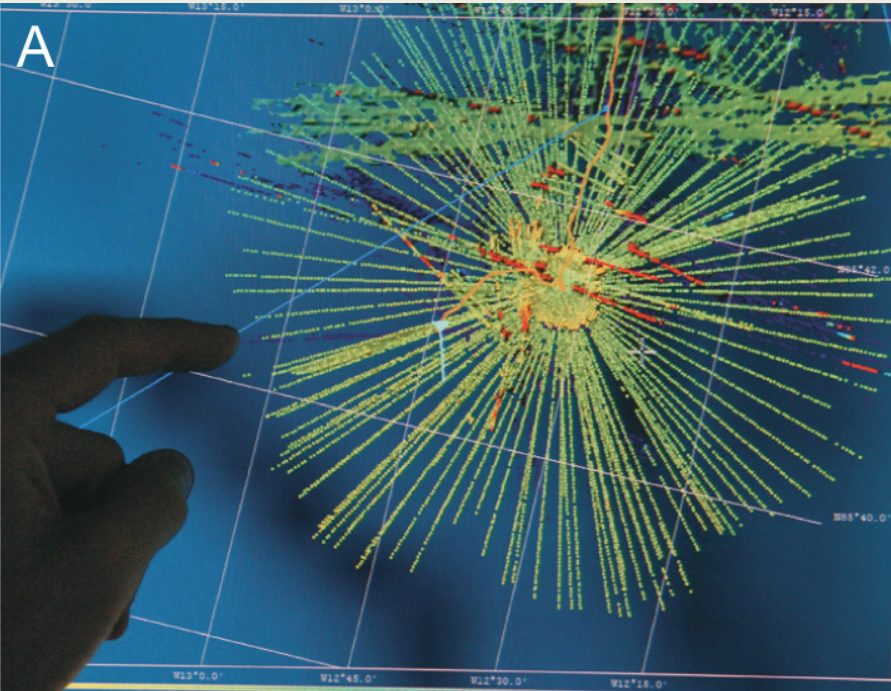
September 30

Source: AMSR-E sea ice map - IUP University of Bremen

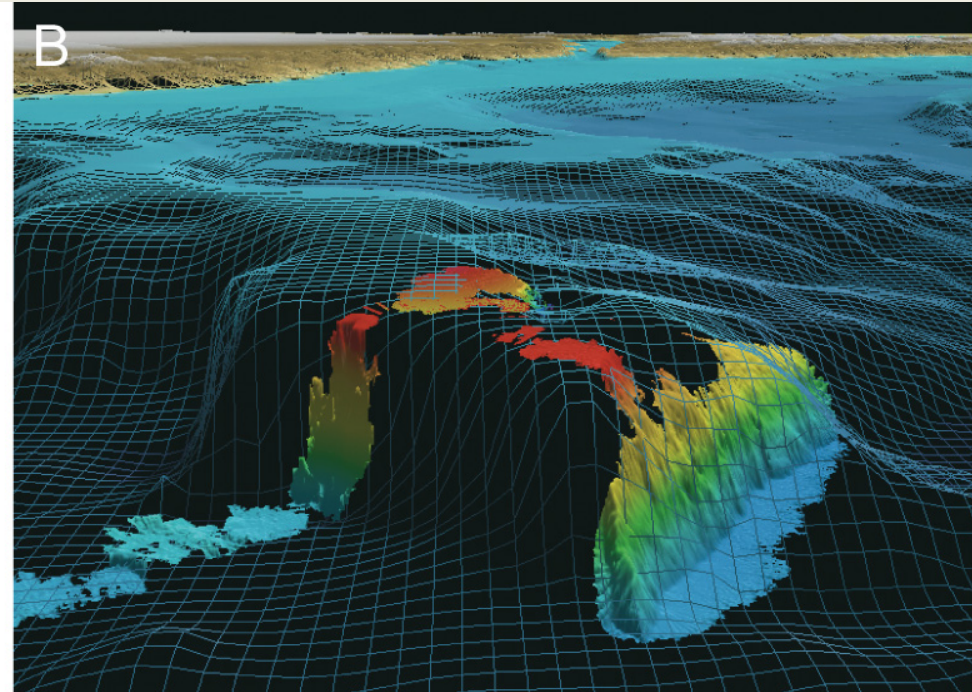


Photo: Martin Jakobsson

LOMROG I & II: Multi beam acquisition

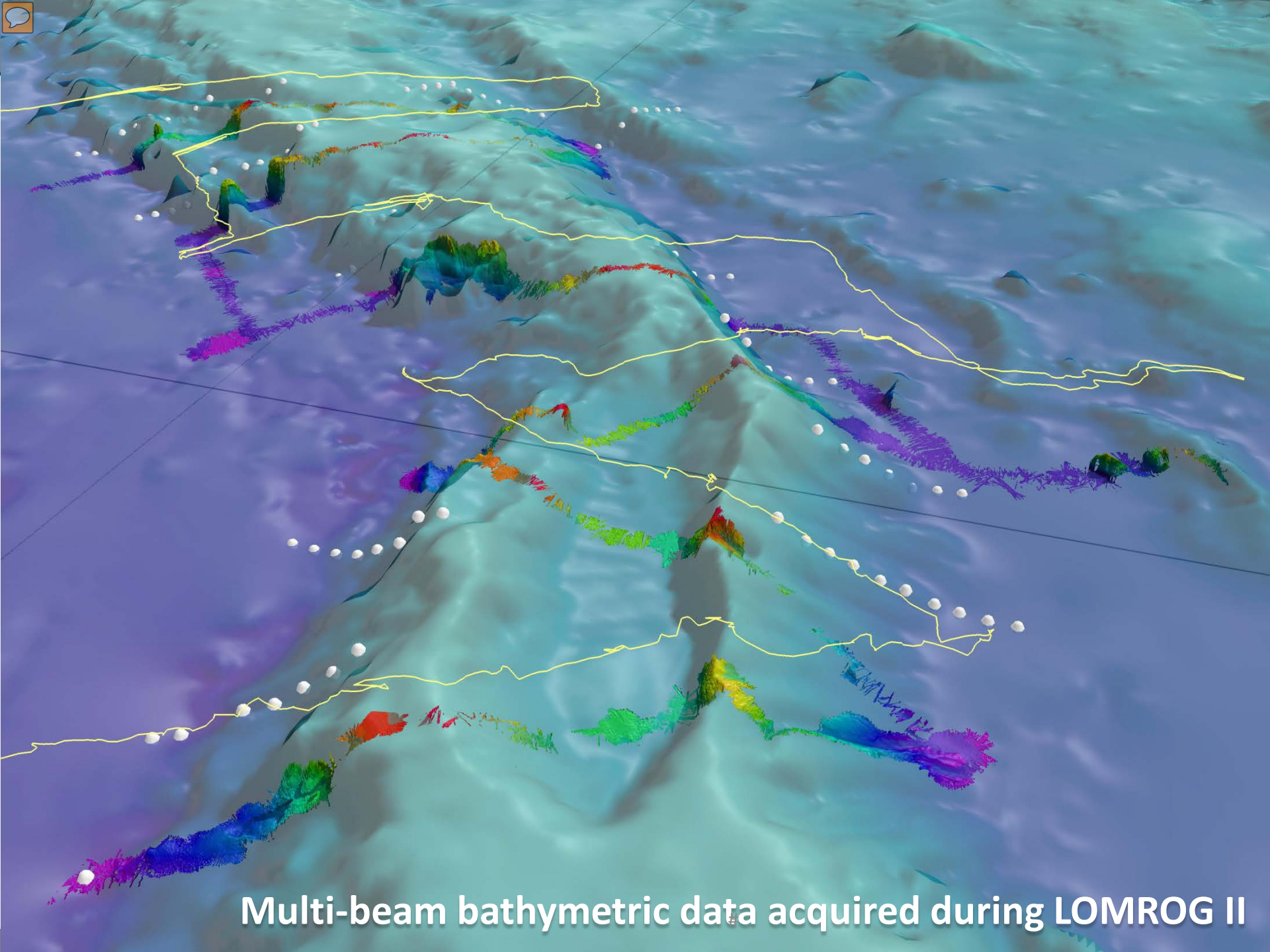


“Pirouette surveying”



3D-view of the multi-beam mapped Morris Jesup Rise north of Greenland (LOMROG I)

Courtesy: Martin Jakobsson



Multi-beam bathymetric data acquired during LOMROG II

Acquisition of seismic data in Arctic sea ice

- The streamer is considerably shorter than in open water. For the LOMROG II cruise we used a 250 meter long streamer. With a 250 meter streamer, we are able to deploy and recover the streamer with the ship at a standstill without risk of damage.
- The seismic source is considerably smaller and therefore also more compact than for open water surveys.
- Both the streamer and guns are towed at a depth of approximately 20 meters, which is more than twice as deep as normal (“survival depth”).
- Both the airguns and streamer are connected with only one cable to the ship (the “umbilical”).

Seismic equipment develop for acquisition in sea ice



Airgun

Seismic streamer



Winch

Recording container

Acquisition of seismic data in Arctic sea ice

Oden's normal mode of operation under heavy ice conditions, is to break ice at as high a speed as possible. If the ship gets stuck in the ice, it would normally back and ram as many times as necessary to pass the obstacle. However neither high speed nor backing and ramming are possible with seismic gear deployed behind the ship:

- High speed would create an unacceptable noise level behind the ship and the seismic gear is not designed to withstand a high speed.
- As the ship travels faster, the towed gear gets pulled toward the surface, risking damage by ice.
- Oden can not back due to the risk of getting the seismic gear tangled in the propellers.



Photo: Thomas Funck



Photo: Thomas Funck

Acquisition of seismic data in Arctic sea ice

- In light ice conditions, where Oden can break ice continuously at 3 to 4 knots along a pre-planned heading, seismic data of reasonable data quality can be acquired. Ice conditions often prevent Oden from being able to acquire data where needed.
- A second option is to have Oden break a 25 nautical mile long lead or track along a pre-planned line, going back along the same lead to make it wider, and finally to acquire the seismic data while passing through the lead a third time.
- A third option is to use two icebreakers for collection of seismic data in ice filled waters. A lead icebreaker – as powerful as possible – breaks a lead along a pre-planned line, possibly several times in order to prepare as wide a lead as possible. Oden trails behind acquiring seismic data. This concept has been used by Russia and Canada/USA.



Photo: Thomas Funck

LOMROG I: Ice Escort – *50 Let Pobedy* and *Oden*





Acquisition of bathymetric and seismic data 2007 and 2009

Russian nuclear icebreaker as lead icebreaker in areas with [extreme ice conditions](#).



2010: *Akademik Fedorov* trailing behind *Yamal* during multibeam bathymetric data acquisition



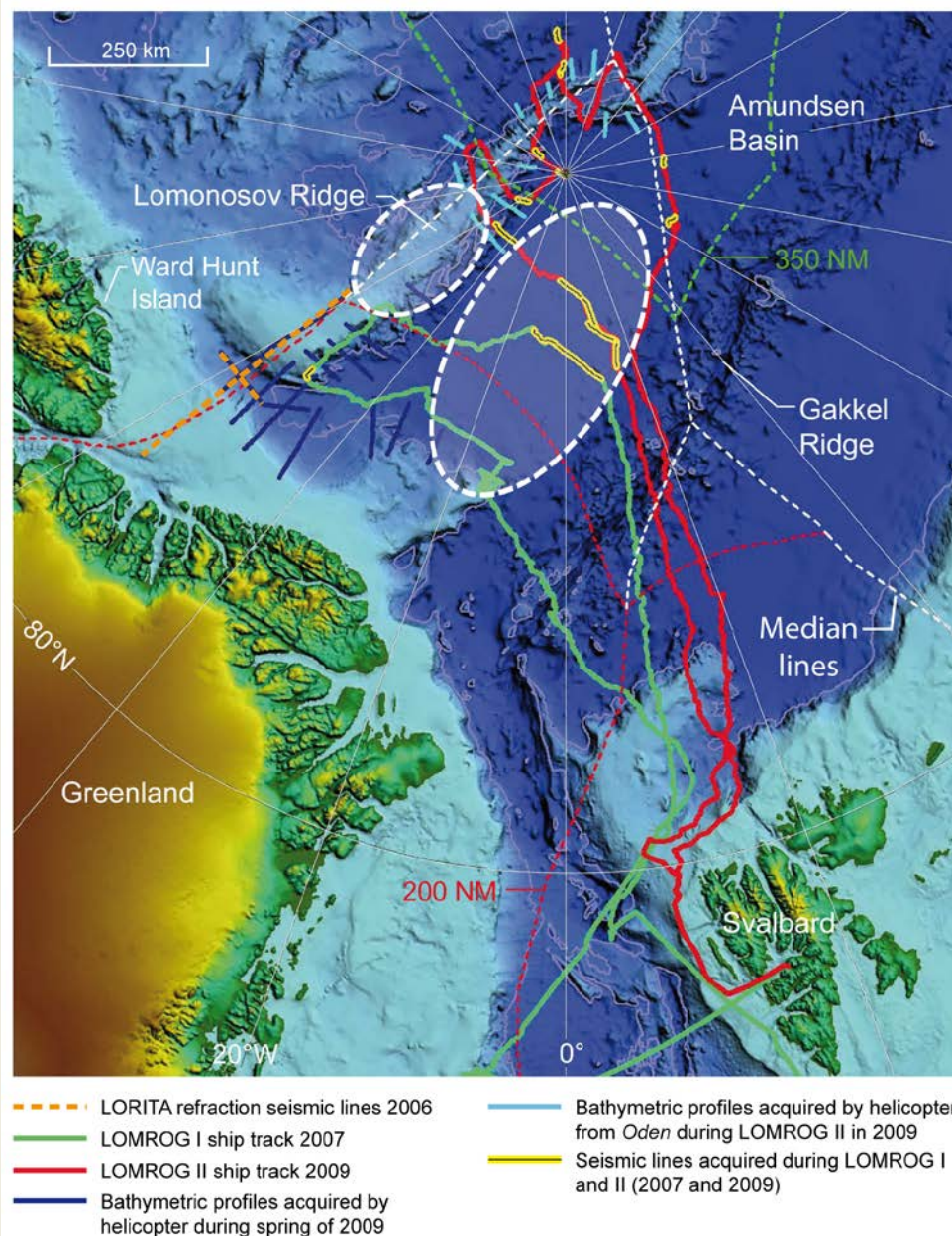
Louis St Laurent and Healy in 2011



AUV used for bathymetry



Track as of September 09, 2011



Continental shelf project of the Kingdom of Denmark

Field work north of Greenland from 2006 to 2009

Focus on the acquisition of bathymetric and seismic data.

The white ellipses show work areas planned for the LOMROG III cruise in 2012. with *Oden*.

White stippled lines – unofficial median lines.



International cooperation



Canadian and Danish geophysicists - 2006



Photo: Martin Jakobsson

Russian and Swedish icebreakers working for the Danish project - 2007



Photo: Jon Biggar

Canadian and US icebreakers - 2008



Photo: Janice Lang, NRCan/DRDC

Canadian and Danish hydrographers - 2009

More flags at the North Pole - 2009



Photo: Adam Jeppesen



Foto: Ludvig Löwemark

Thank you for your attention!

More information www.a76.dk