

**Bolin Centre for
Climate Research**

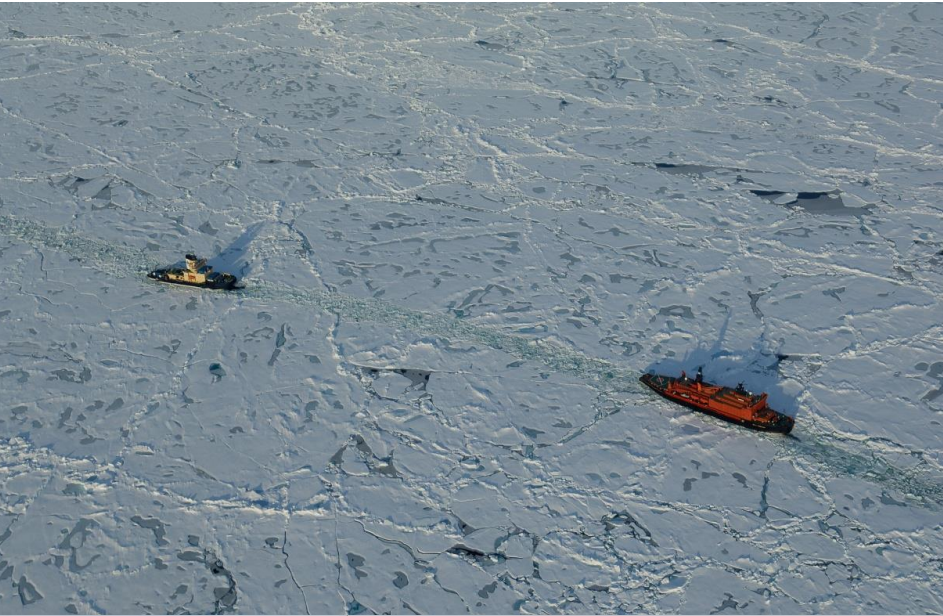


**Stockholm
University**

Arctic Ocean Bathymetric Mapping: Scientific discoveries and future challenges

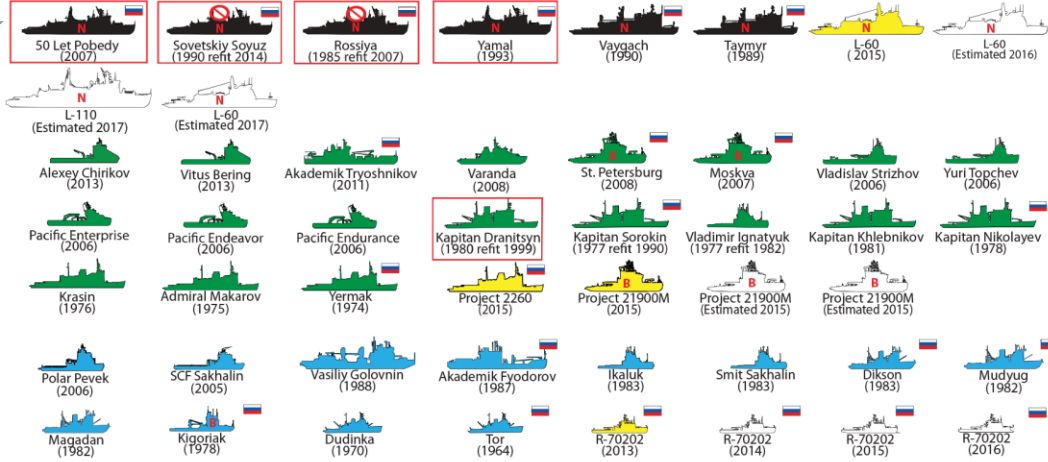
Martin Jakobsson
Department of Geological Sciences
Stockholm University

Mapping in Arctic Ocean Sea Ice



MAJOR ICEBREAKERS OF THE WORLD

RUSSIA
(37)
+ 4 under construction
+ 8 planned



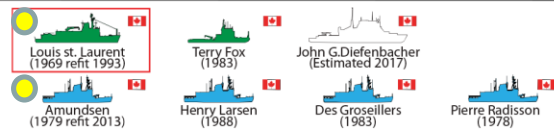
SWEDEN
(7)



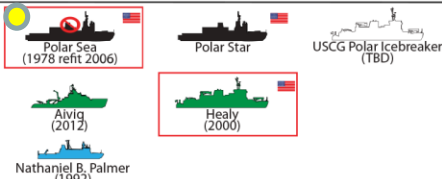
FINLAND
(7)



CANADA
(6)
+ 1 planned



USA
(5)
+ 1 planned



DENMARK
(4)



CHINA
(1)
+ 1 planned



ARGENTINA
(1)



AUSTRALIA
(1)



CHILE
(1)



ESTONIA
(2)



GERMANY
(1)
+ 1 planned



JAPAN
(1)



SOUTH KOREA
(1)



SOUTH AFRICA
(1)




LATVIA
(1)



NORWAY
(1)
+ 1 planned

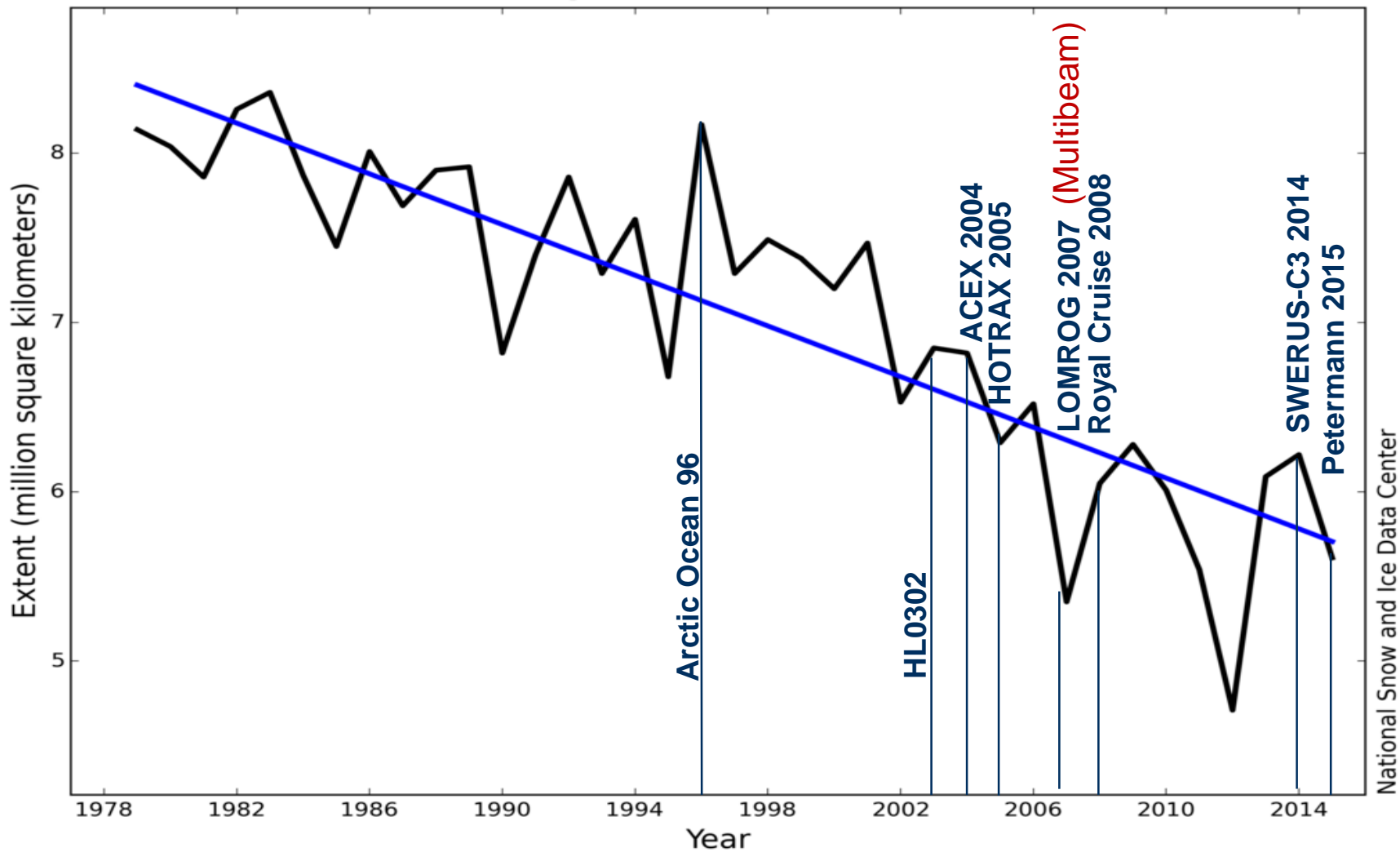


 Been to the North Pole

 Been North of Greenland

 Multibeam

Average Monthly Arctic Sea Ice Extent August 1979 - 2015



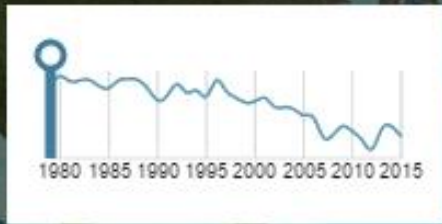


Ice concentration chart

Toggle on/off

September 1979

Ice area 7.22 million km²



Drag the blue bar to select a year

Sea Ice concentration charts are based on satellite measurements and are provided by the [National Snow and Ice Data Center](#)

IB Oden multibeam

EM 122, 12 kHz, 1°x1°



IB Oden sub-bottom profiler

SBP 120, 2-7 kHz, 3°x3°

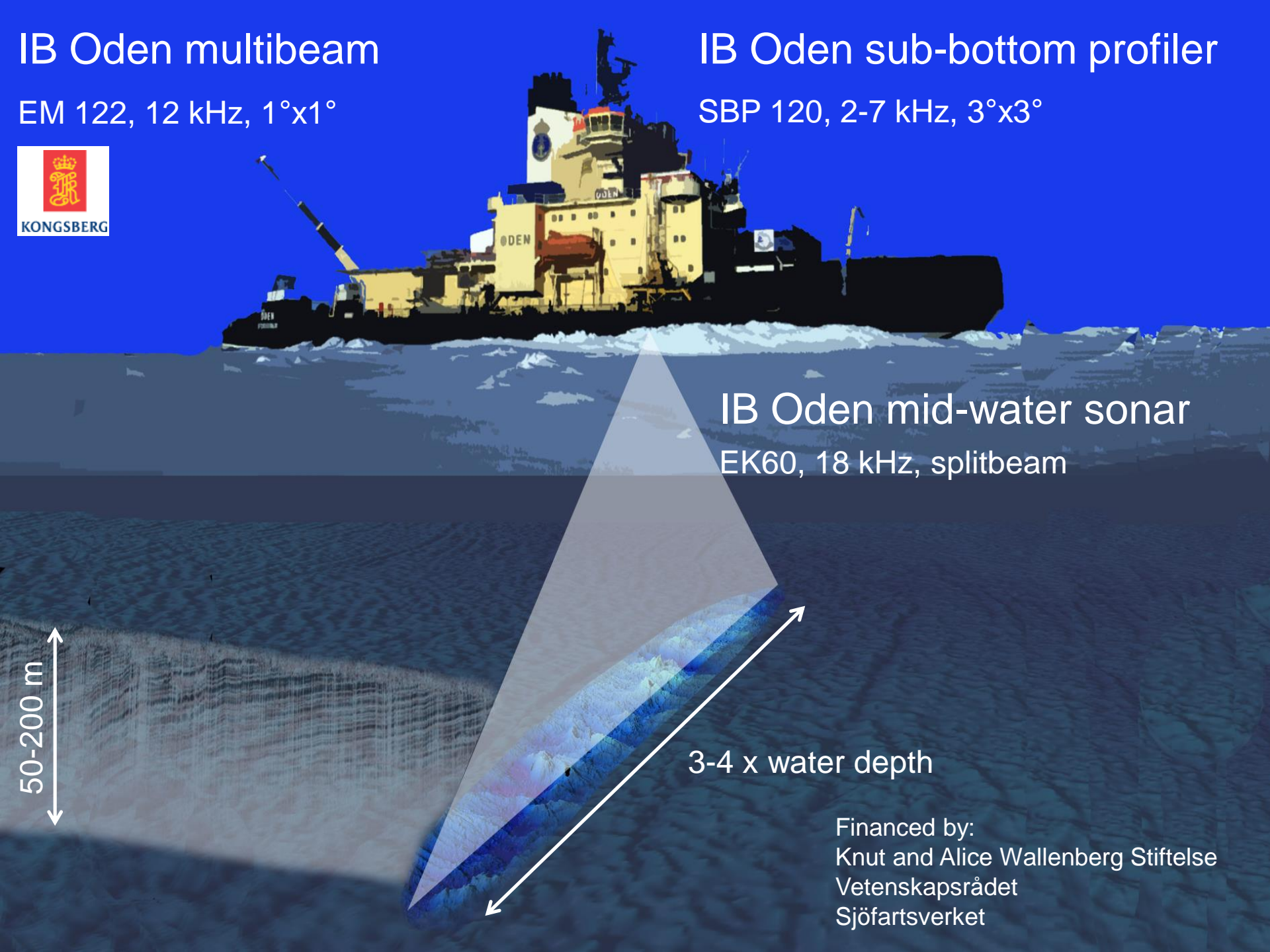
IB Oden mid-water sonar

EK60, 18 kHz, splitbeam

50-200 m

3-4 x water depth

Financed by:
Knut and Alice Wallenberg Stiftelse
Vetenskapsrådet
Sjöfartsverket



RV Skidbladner

Equipment:

Multibeam: EM2040, 200/300/400 kHz, 1°x1°

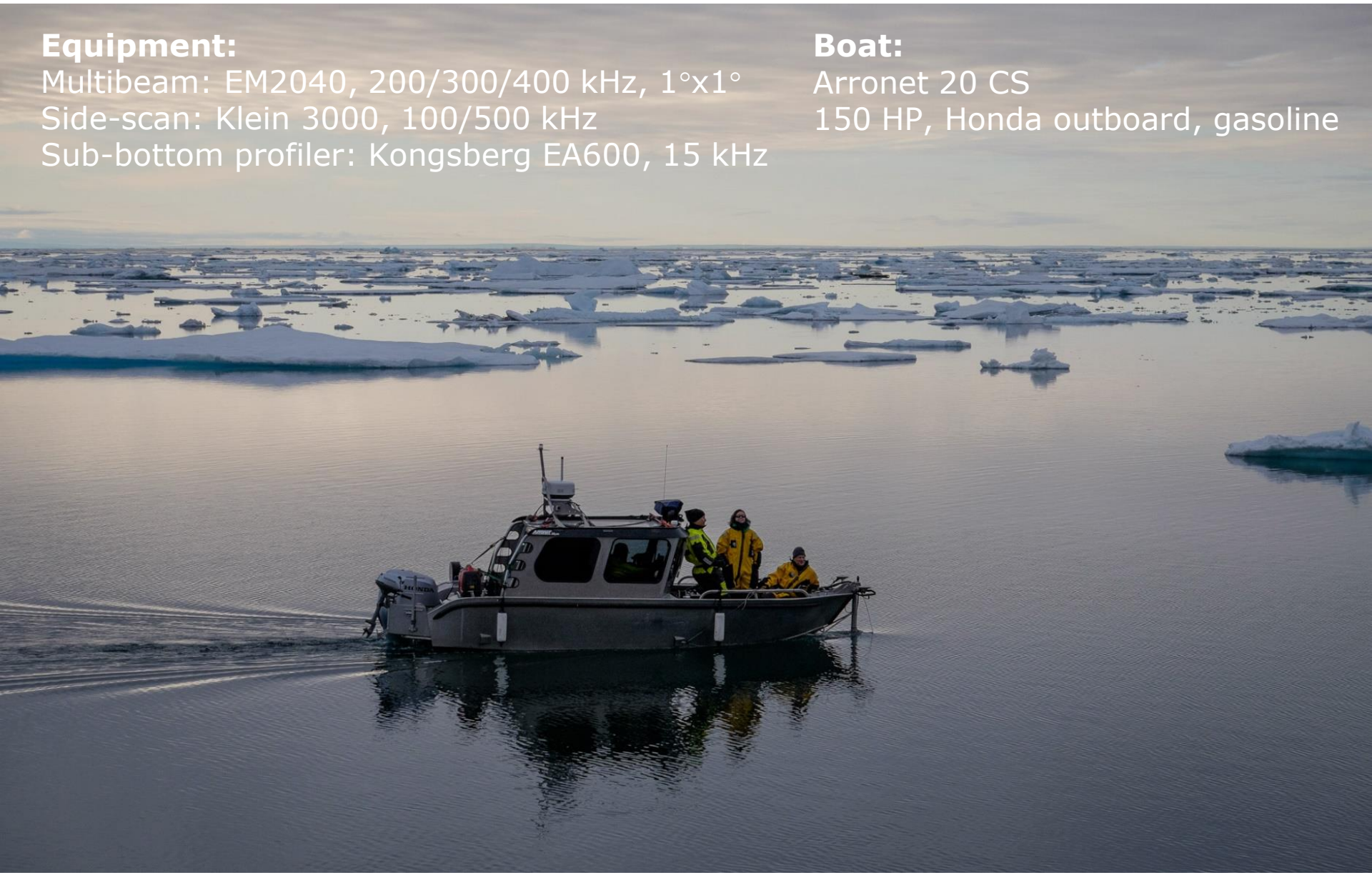
Side-scan: Klein 3000, 100/500 kHz

Sub-bottom profiler: Kongsberg EA600, 15 kHz

Boat:

Arronet 20 CS

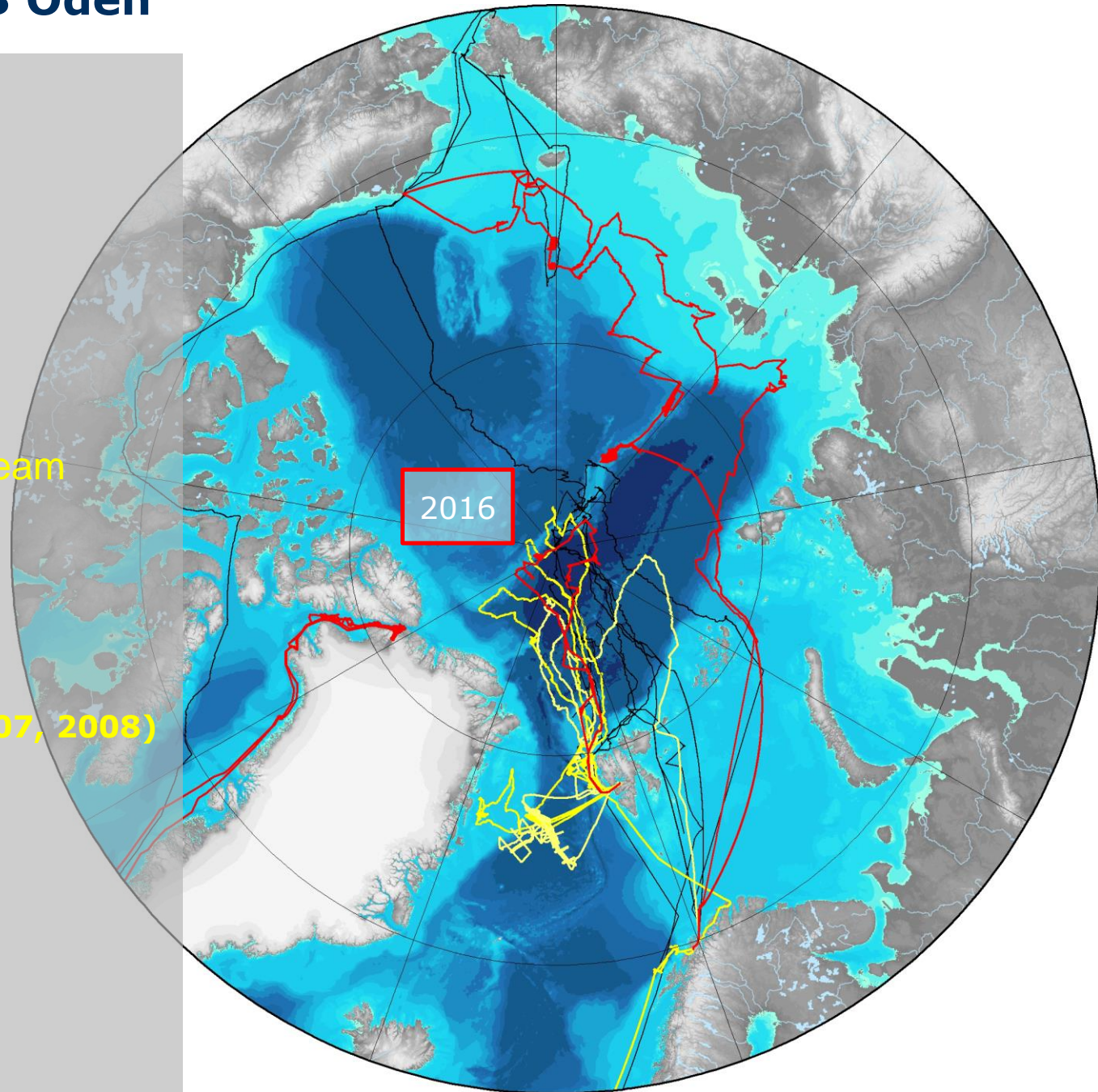
150 HP, Honda outboard, gasoline



Mapping with IB Oden

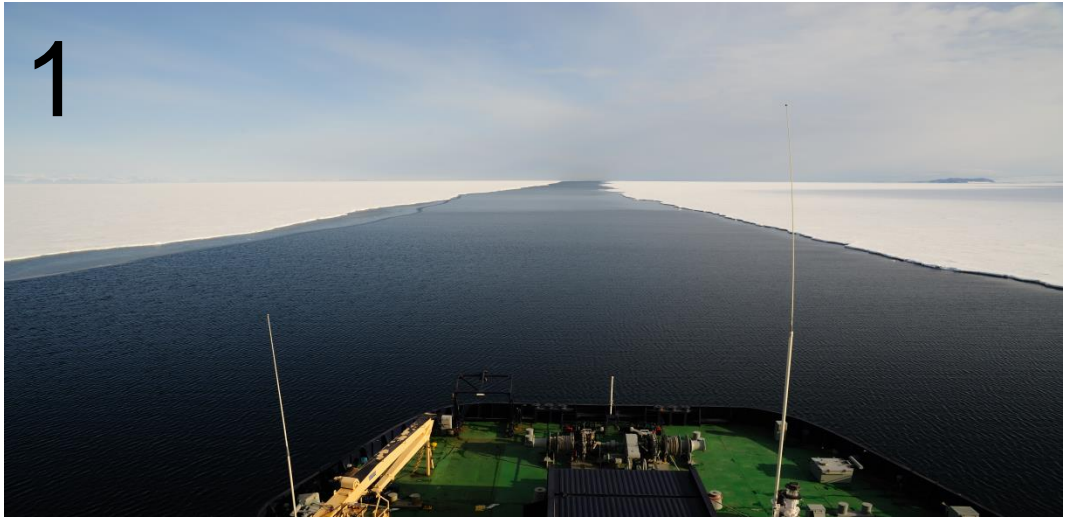
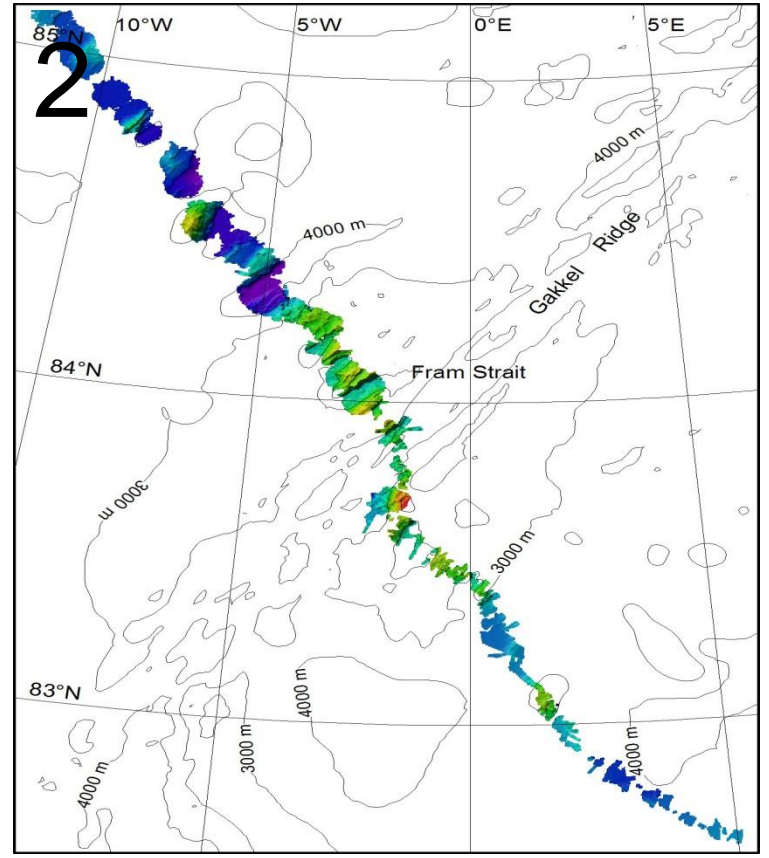
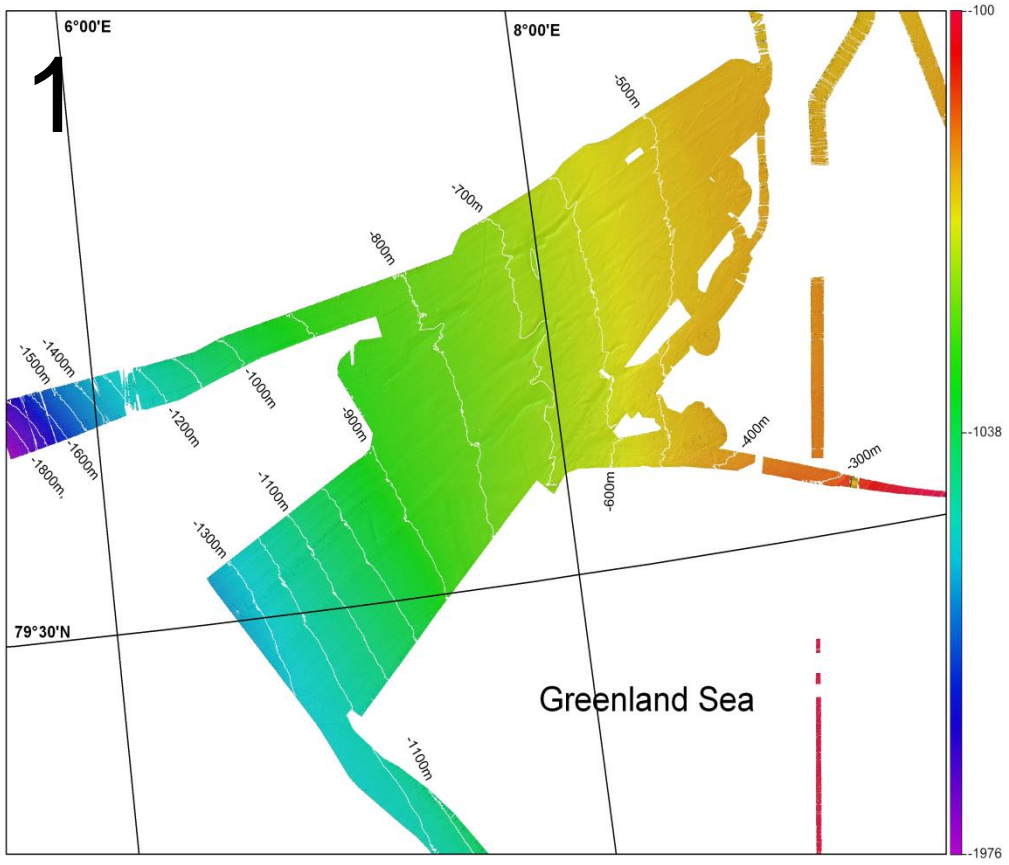
- Arctic Ocean 1991
- Arctic Ocean 1996
- Arctic Ocean 2001
- Arctic Ocean 2002
- ACEX – 2004
- Beringia 2005
- **AGAVE 2007**
- **LOMROG 2007**
- **ASCOS 2008**
- **Multibeam SAT (2007, 2008)**
- **LOMROG 2009**
- **EAGER 2011**
- **LOMROG 2012**
- **SWERUS-C3 (2014)**
- **Petermann (2015)**

Multibeam



Different polar survey modes in polar waters





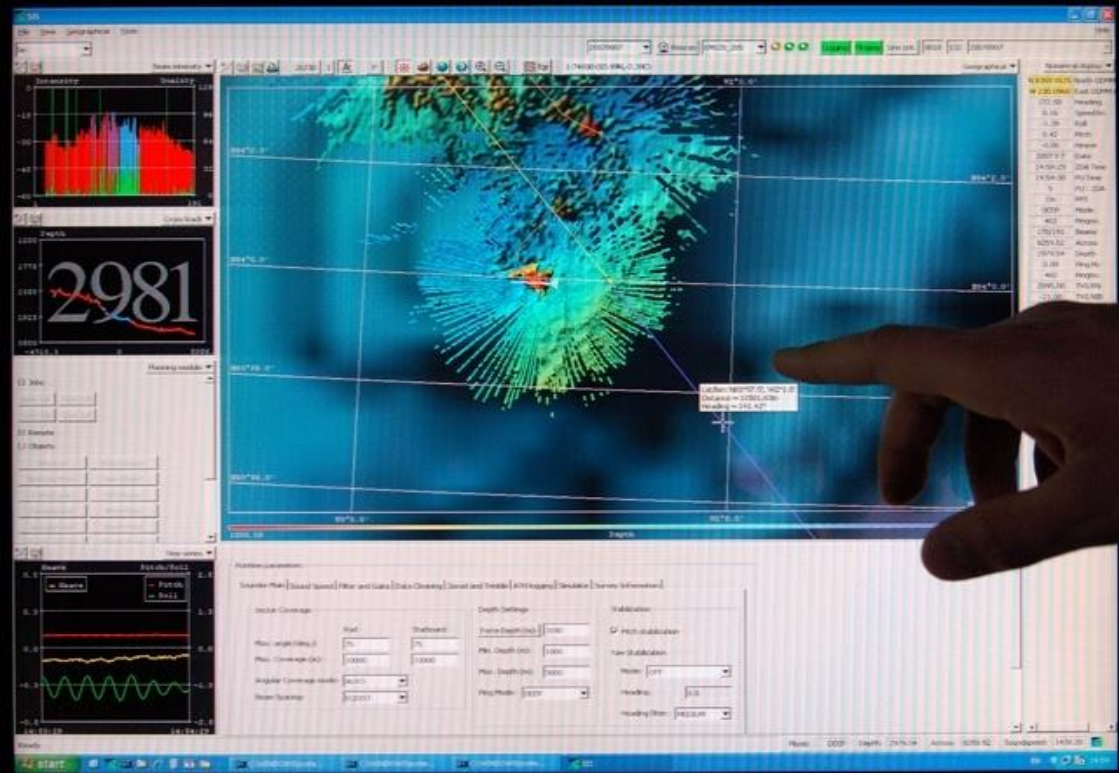
3 10/10 ice conditions

"Pirouette Survey"



Finding or breaking up an opening large enough to spin the icebreaker around 360°.

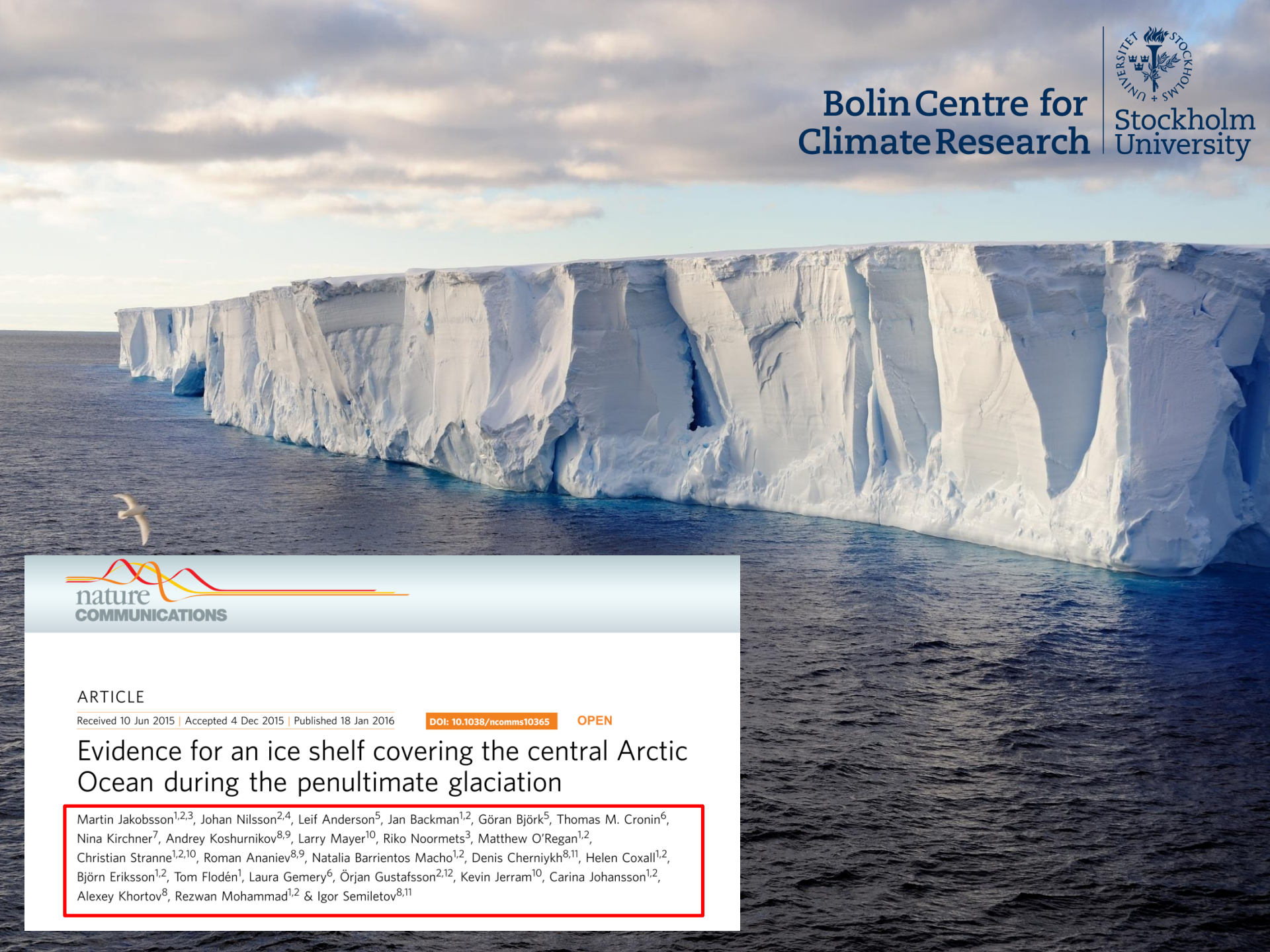
Results: Worked superbly in 10/10, 4 m thick, ice conditions. Data can be difficult to process.





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Scientific discoveries



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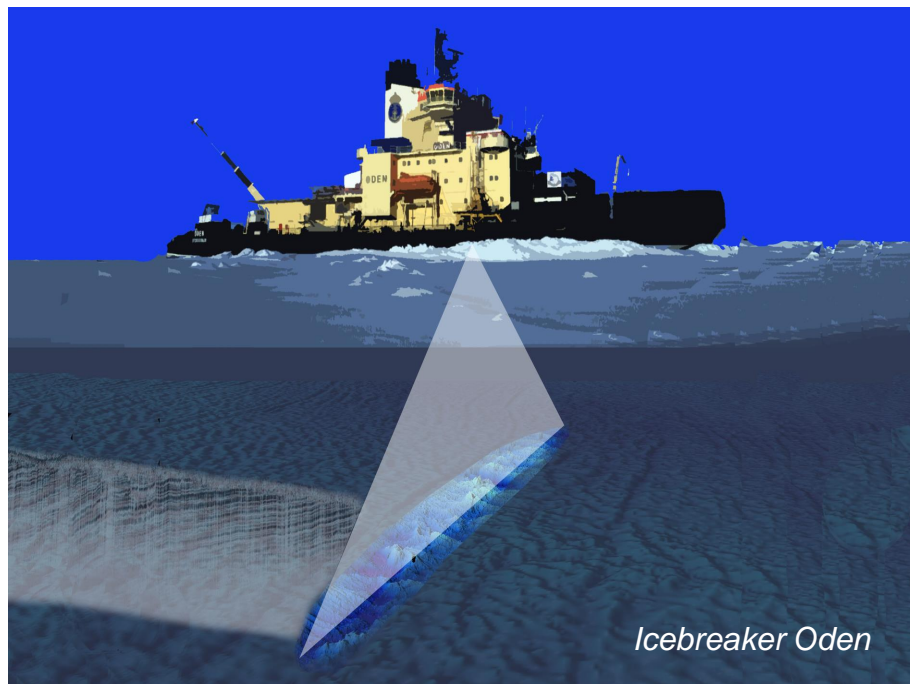
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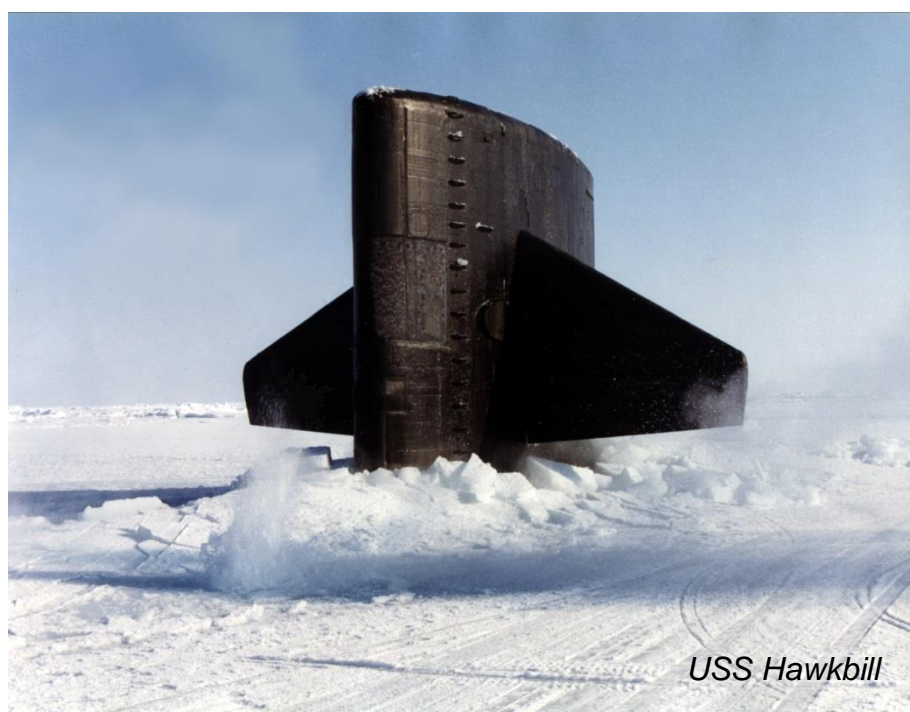
OPEN

Evidence for an ice shelf covering the central Arctic Ocean during the penultimate glaciation

Martin Jakobsson^{1,2,3}, Johan Nilsson^{2,4}, Leif Anderson⁵, Jan Backman^{1,2}, Göran Björk⁵, Thomas M. Cronin⁶, Nina Kirchner⁷, Andrey Koshurnikov^{8,9}, Larry Mayer¹⁰, Riko Noormets³, Matthew O'Regan^{1,2}, Christian Stranne^{1,2,10}, Roman Ananiev^{8,9}, Natalia Barrientos Macho^{1,2}, Denis Cherniykh^{8,11}, Helen Coxall^{1,2}, Björn Eriksson^{1,2}, Tom Flodén¹, Laura Gemery⁶, Örjan Gustafsson^{2,12}, Kevin Jerram¹⁰, Carina Johansson^{1,2}, Alexey Khortov⁸, Rezwan Mohammad^{1,2} & Igor Semiletov^{8,11}



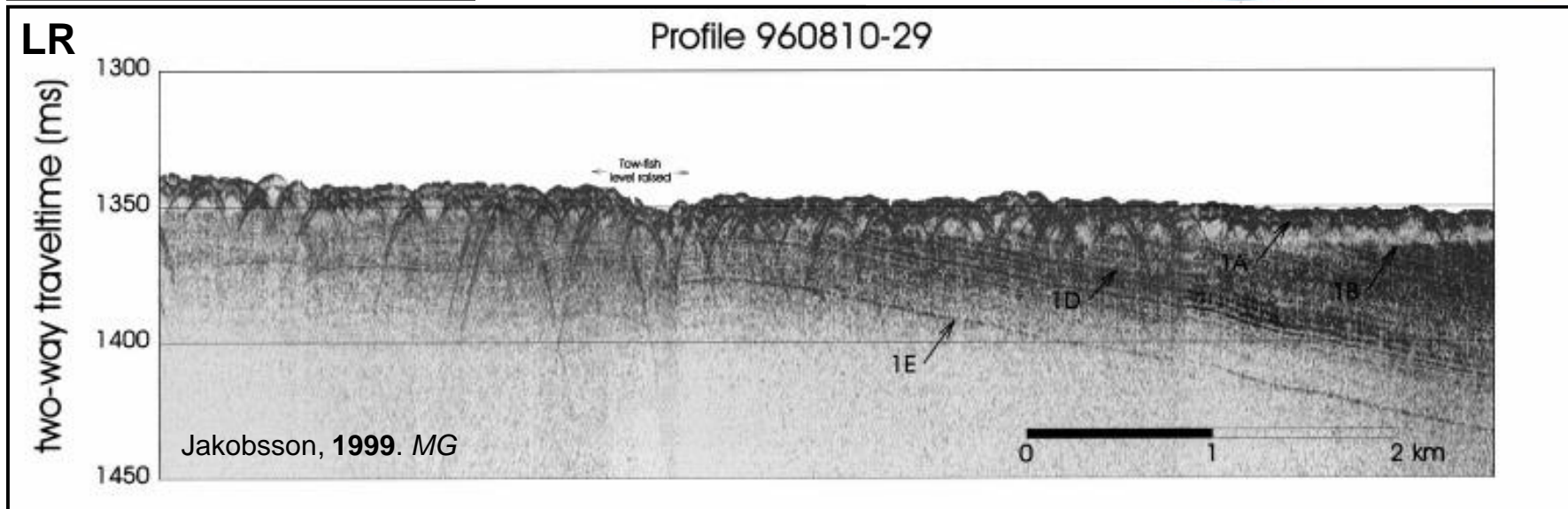
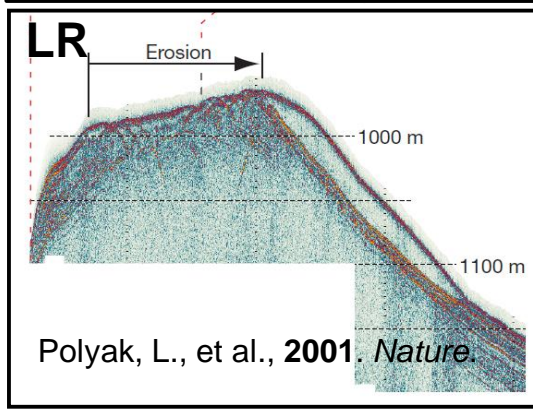
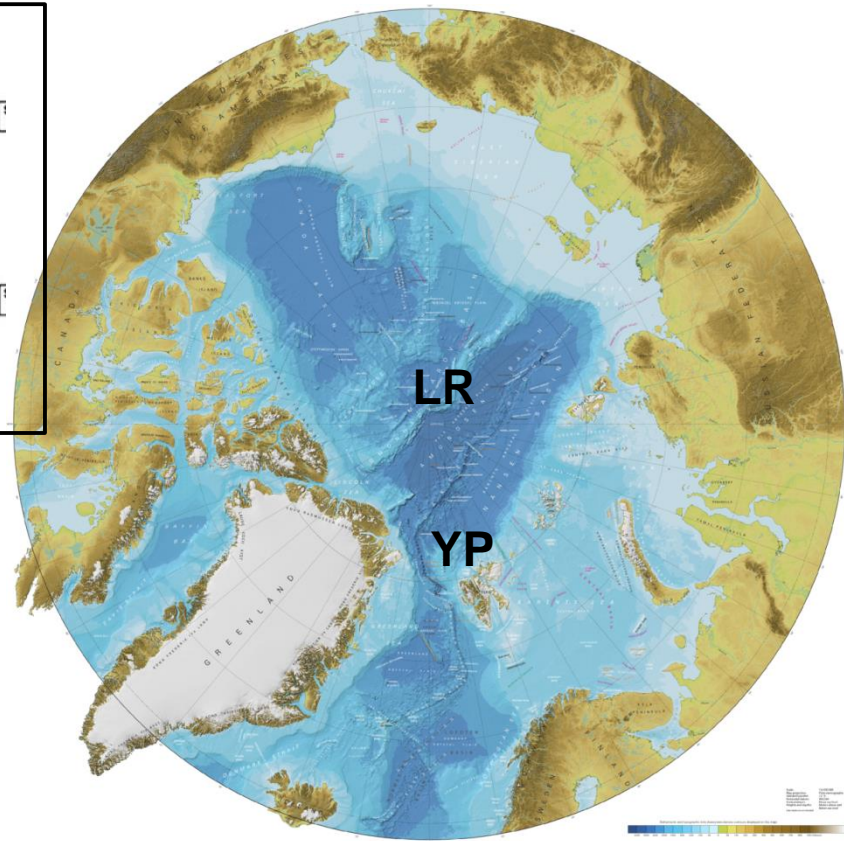
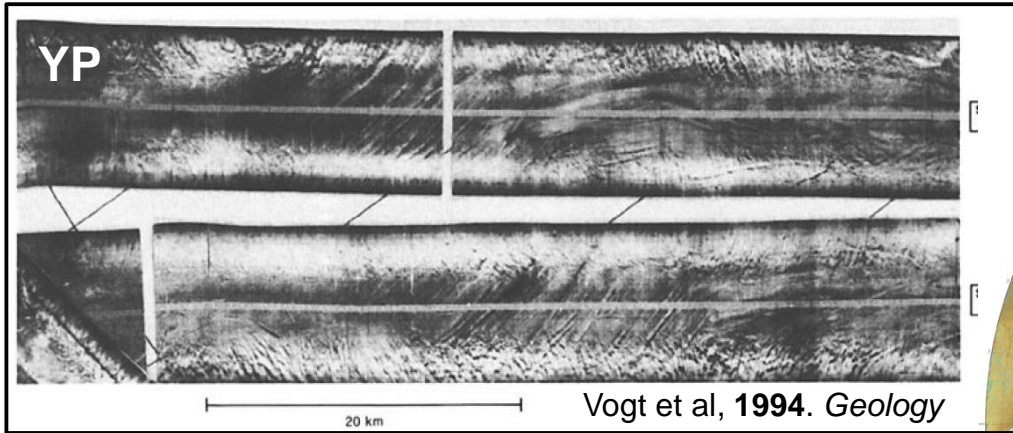
Icebreaker Oden



USS Hawkbill



SCAMP Phase II installation on the Hawkbill started in Pearl Harbor on April 8, 1998. Image: LDEO.



Discovery deep ice grounding



Vogt, P.R., Crane, K., Sundvor, E., **1994**. Deep Pleistocene iceberg plowmarks on the Yermak Plateau: sidescan and 3.5 kHz evidence for thick calving ice fronts and a possible marine ice sheet in the Arctic Ocean. *Geology* 22, 403-406.

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Polyak, L., Edwards, M.H., Coakley, B.J., Jakobsson, M., **2001**. Ice shelves in the Pleistocene Arctic Ocean inferred from glaciogenic deep-sea bedforms. *Nature* 410, 453 - 459.

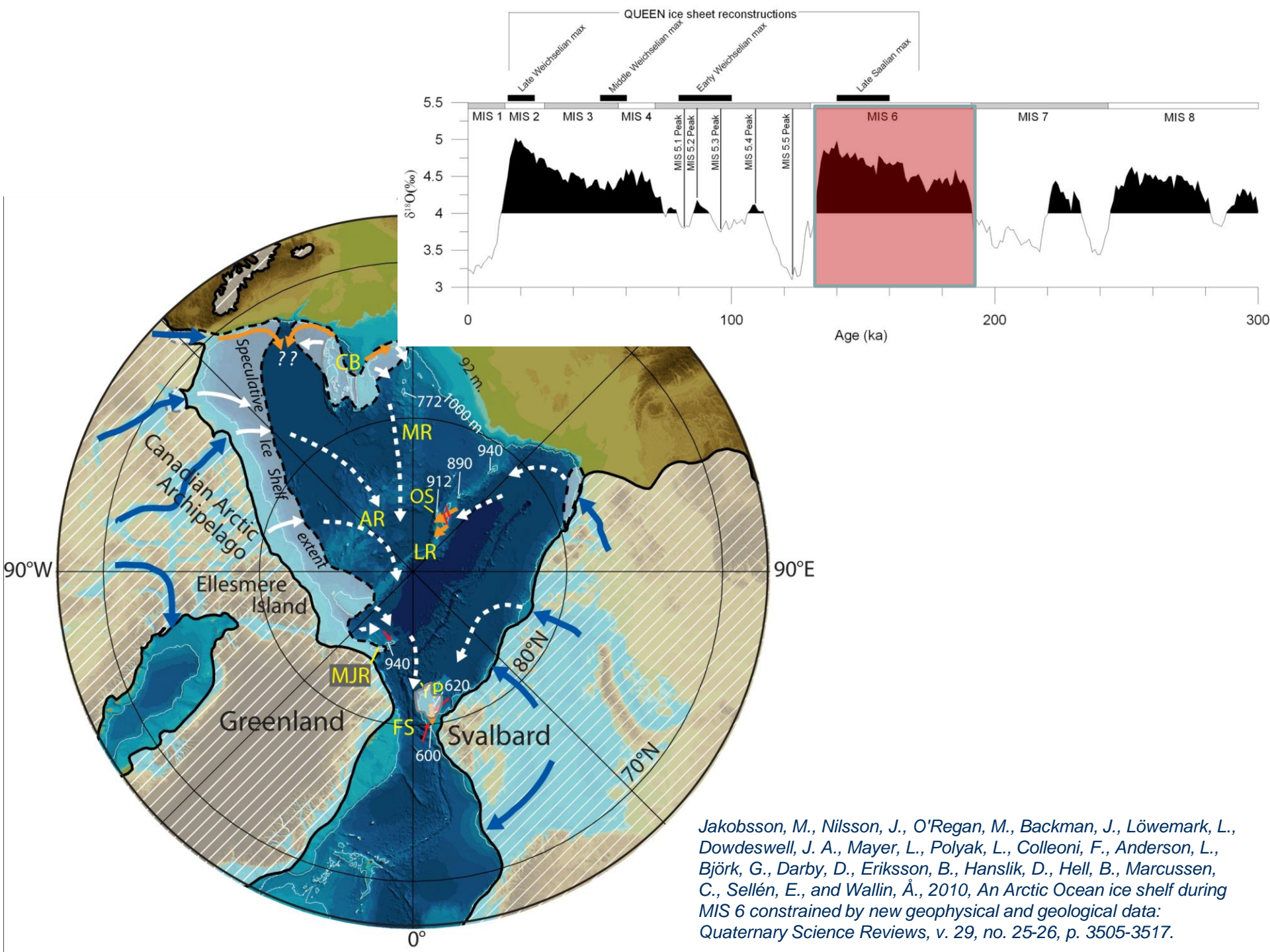
Jakobsson, M., Armstrong, A., Calder, B., Huff, L., Mayer, L., Ward, L., **2005**. On the use of Historical Bathymetric Data to Determine Changes in Bathymetry: An Analysis of Errors and Application to Great Bay Estuary, New Hampshire. *International Hydrographic Review* 6, 1-17.

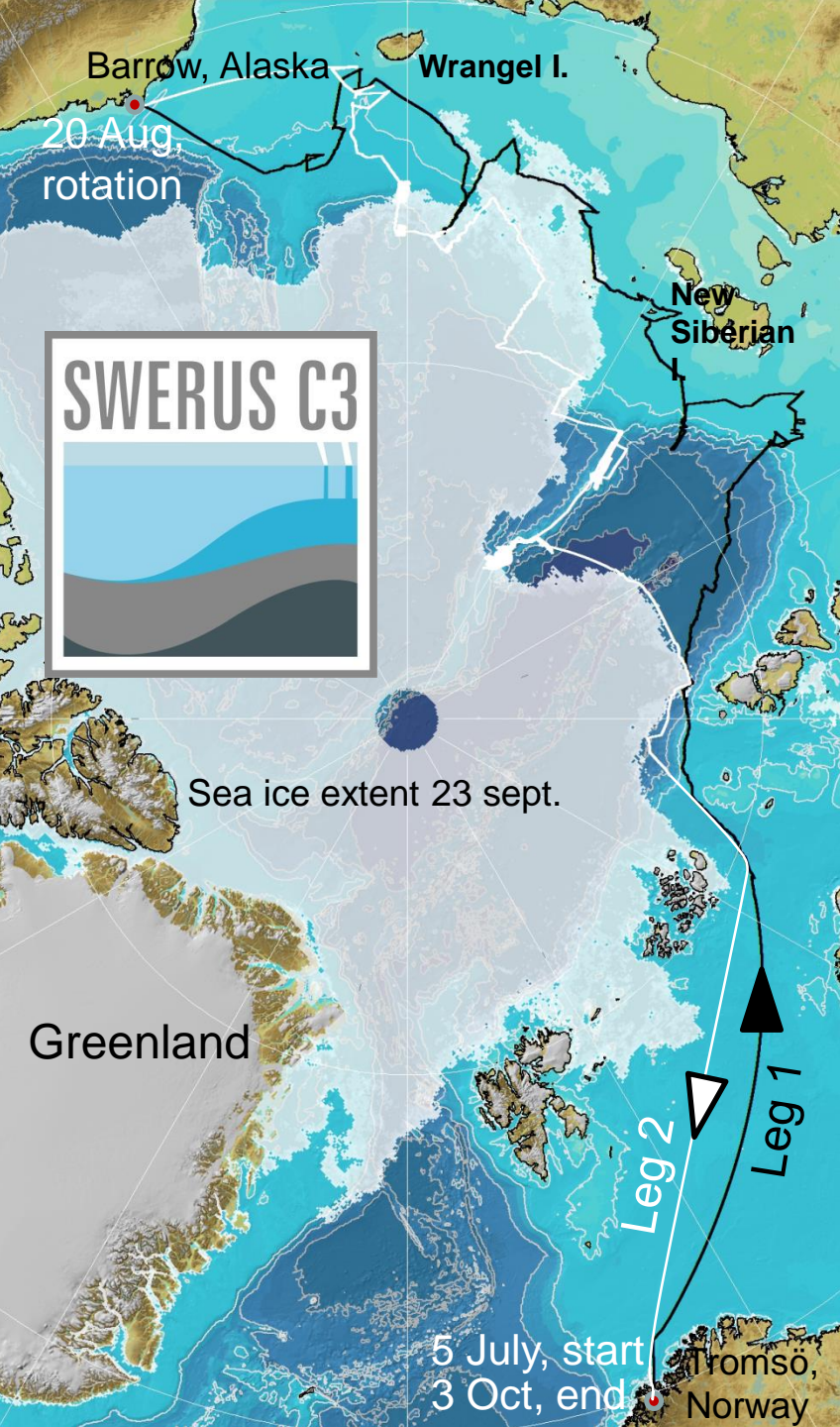
Jakobsson, M., Polyak, L., Edwards, M., Kleman, J., Coakley, B., **2008**. Glacial geomorphology of the Central Arctic Ocean: the Chukchi Borderland and the Lomonosov Ridge. *Earth Surface Processes and Landforms* 33, 526-545.

Jakobsson, M., Nilsson, J., O'Regan, M., Backman, J., Löwemark, L., Dowdeswell, J.A., Mayer, L., Polyak, L., Colleoni, F., Anderson, L., Björk, G., Darby, D., Eriksson, B., Hanslik, D., Hell, B., Marcussen, C., Sellén, E., Wallin, Å., **2010**. An Arctic Ocean ice shelf during MIS 6 constrained by new geophysical and geological data. *Quaternary Science Reviews* 29, 3505-3517.

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Arndt, J.E., Niessen, F., Jokat, W., Dorschel, B., **2014**. Deep water paleo-iceberg scouring on top of Hovgaard Ridge—Arctic Ocean. *Geophysical Research Letters* 41, 2014GL060267.





Oden in Barrow, Alaska



SWERUS 2014

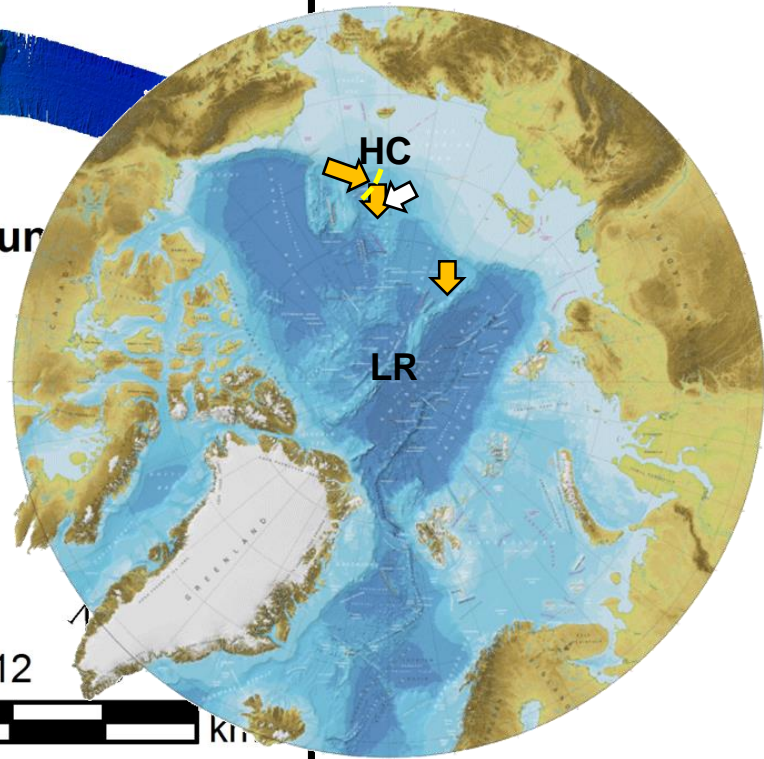
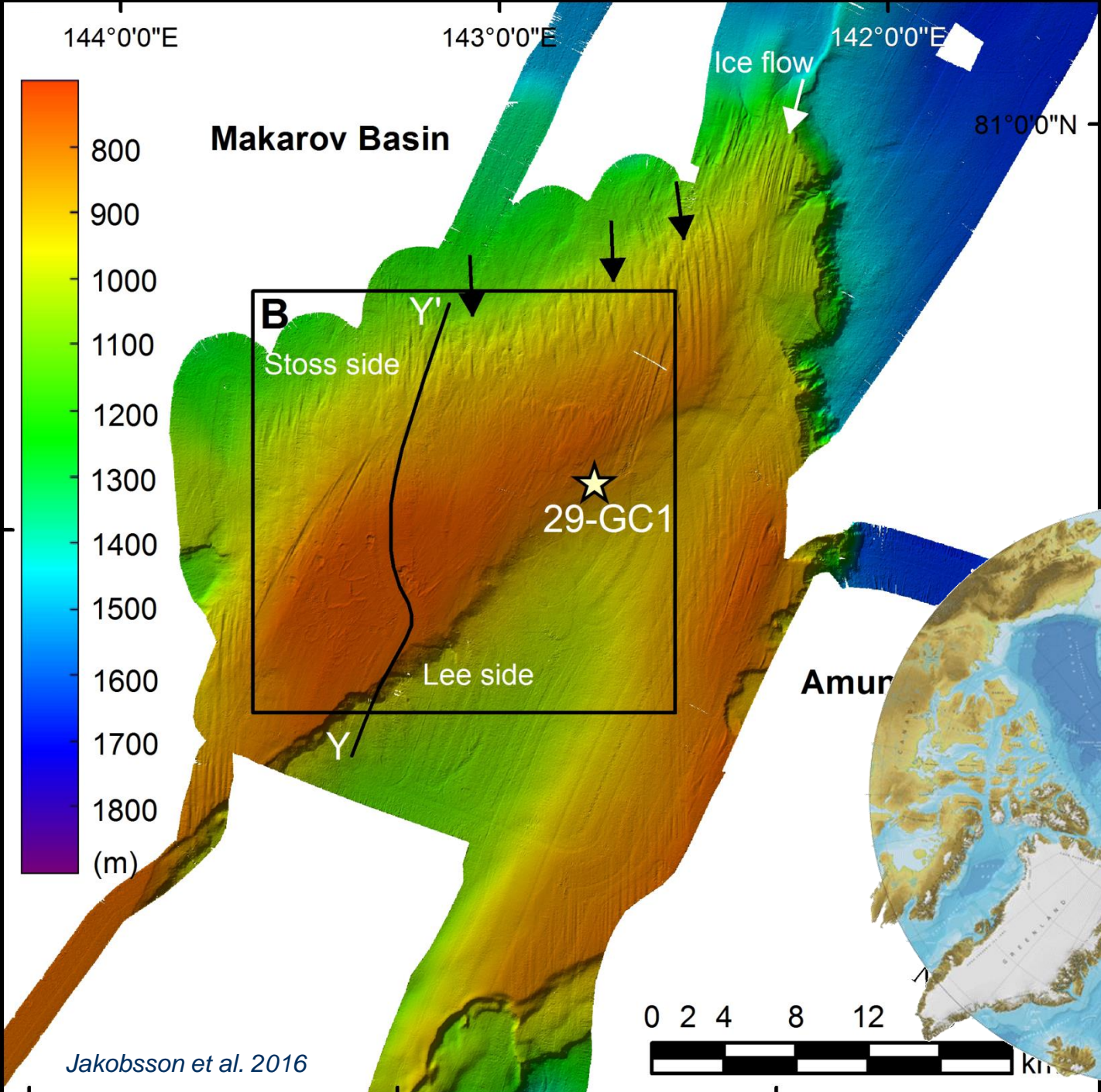
Tromsø-Barrow-Tromsø on 90 days

Oden in Tromsø, Norway





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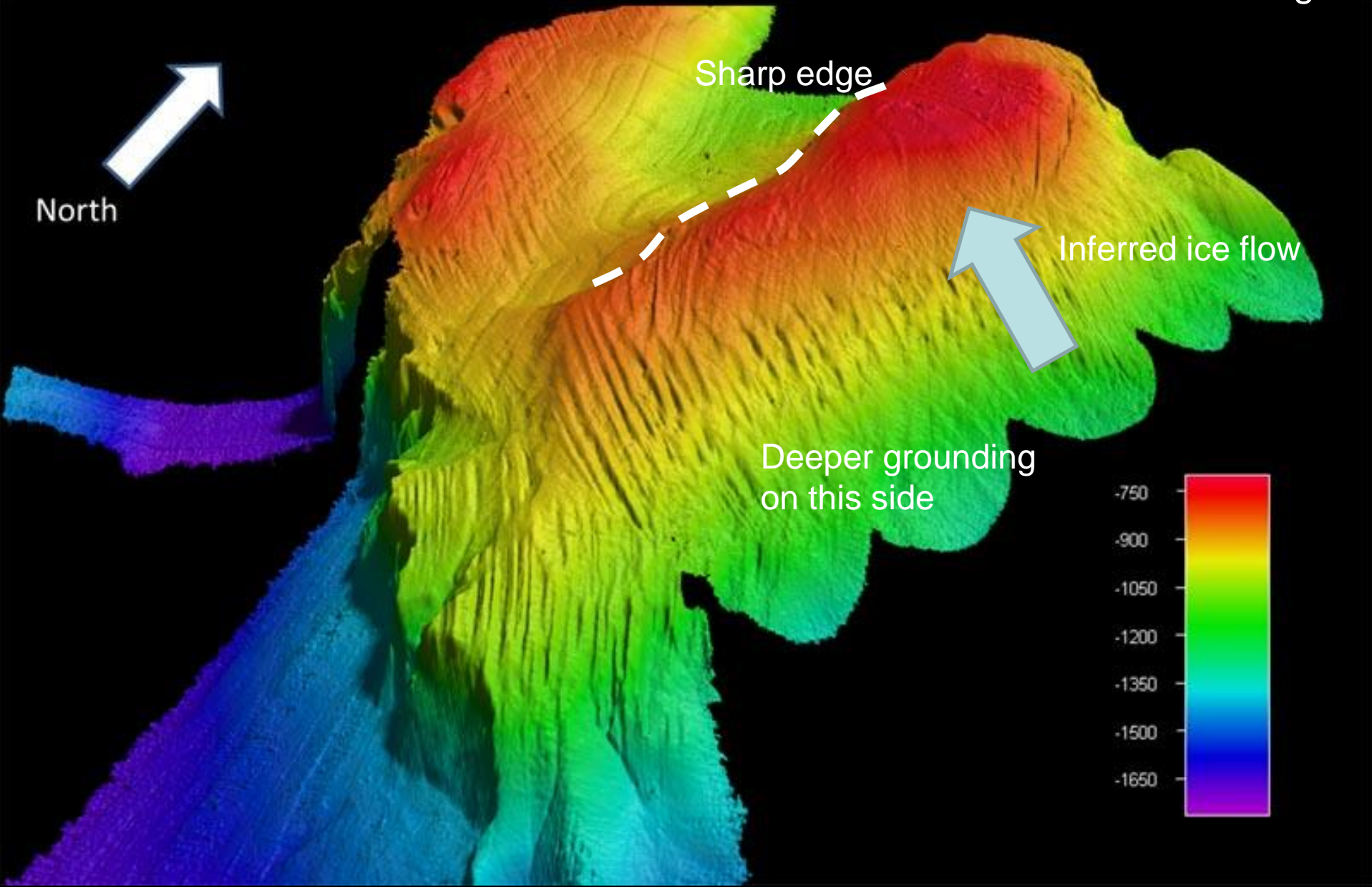
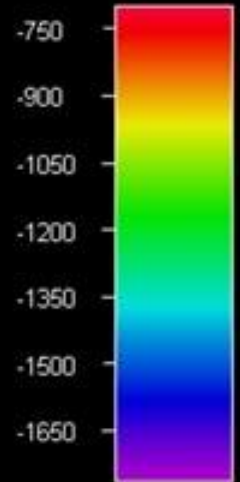
Southern Lomonosov Ridge

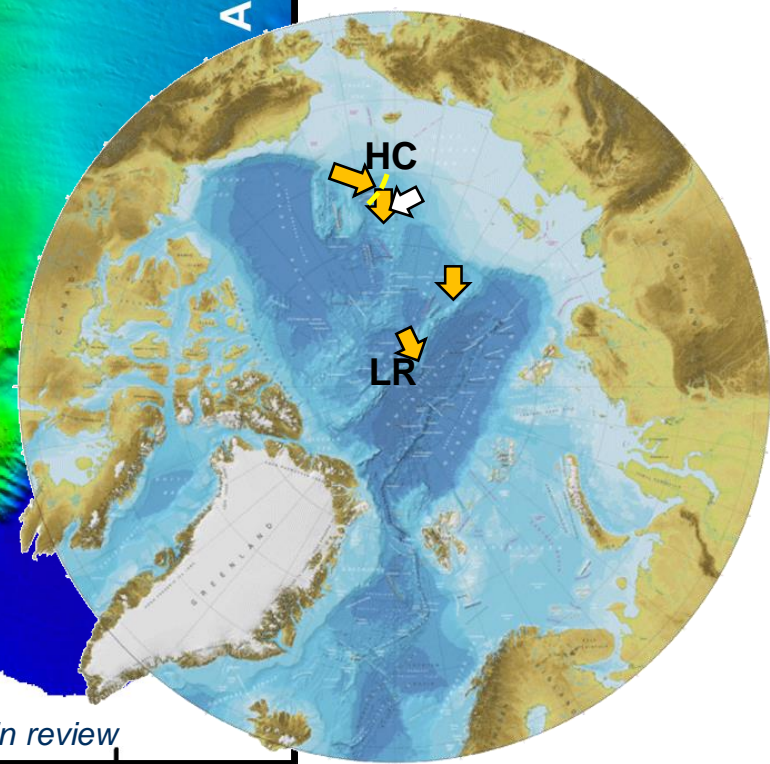
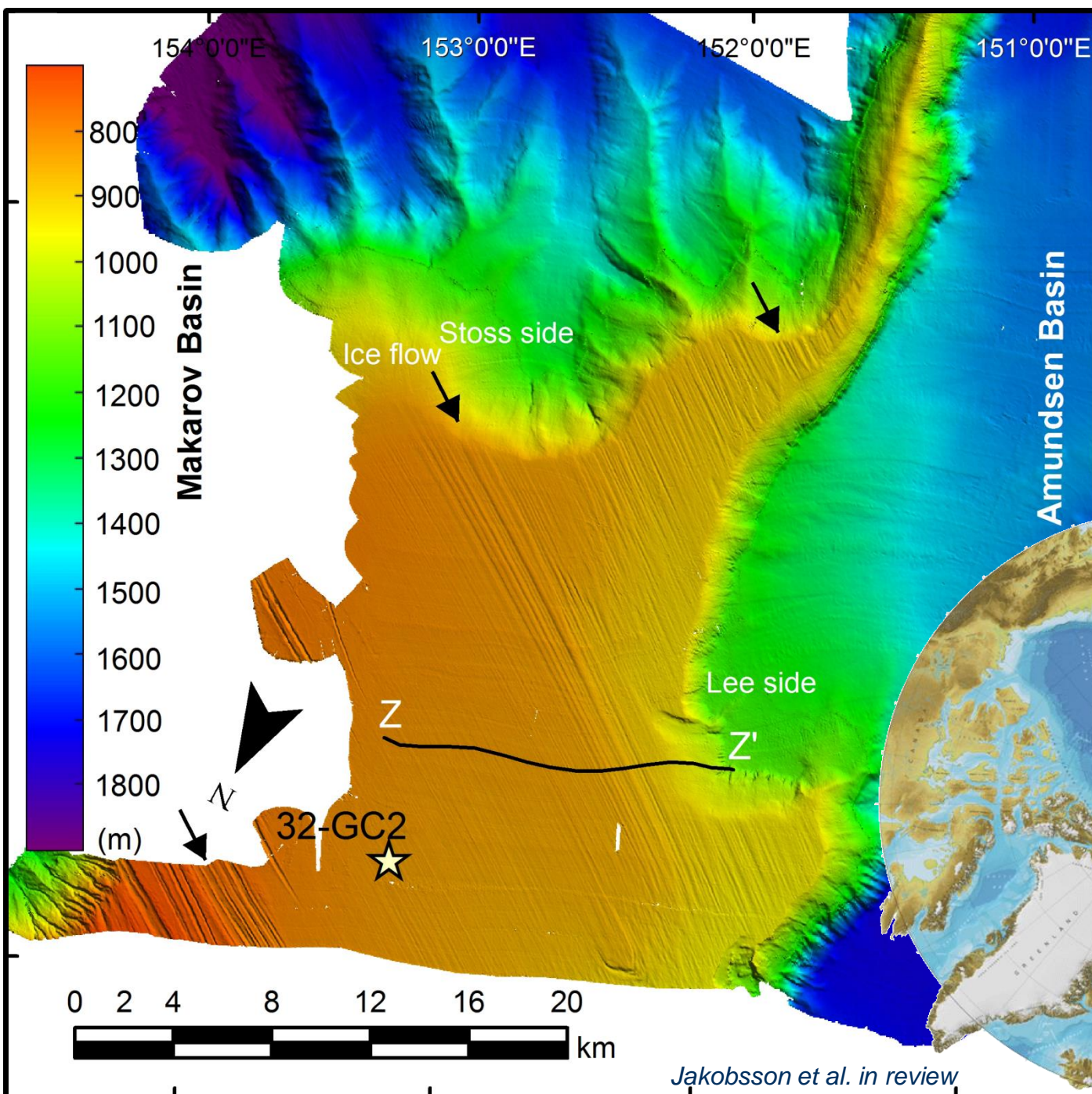


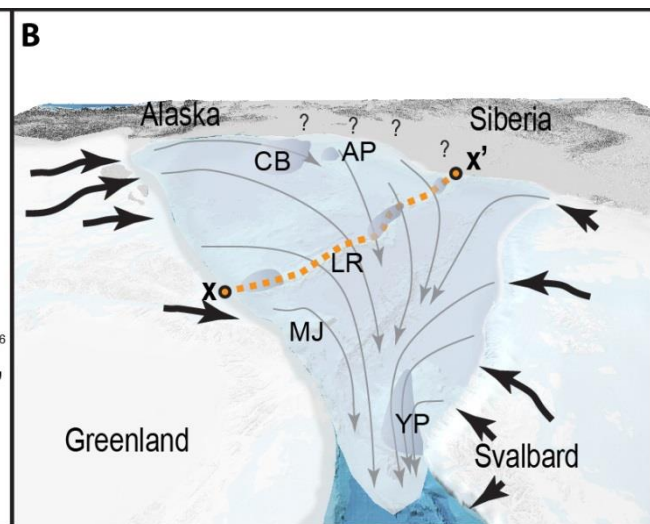
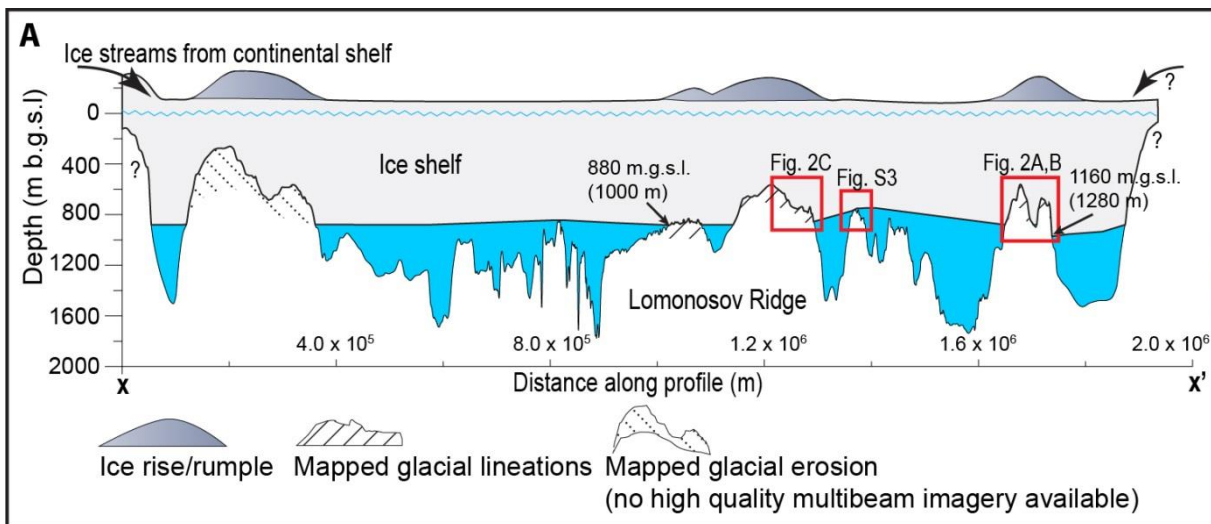
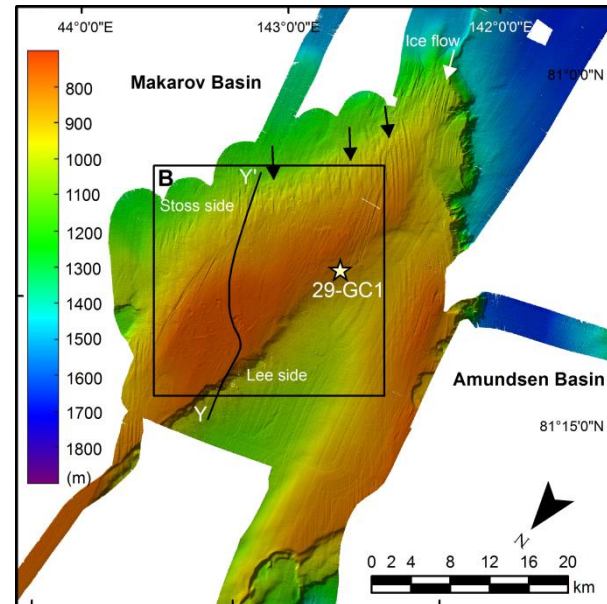
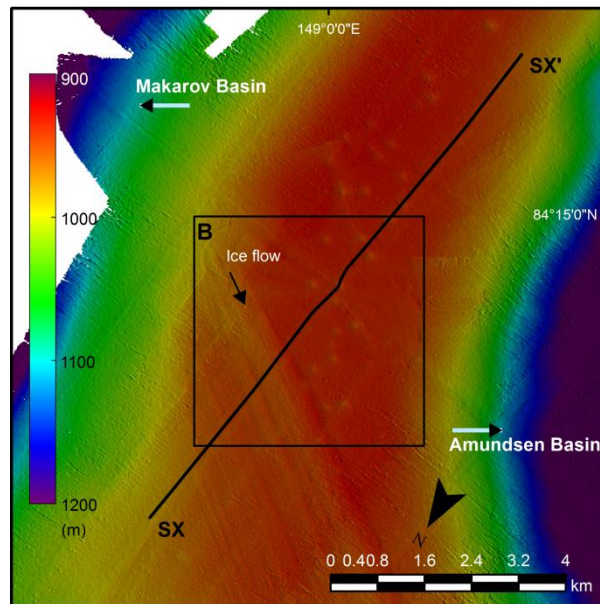
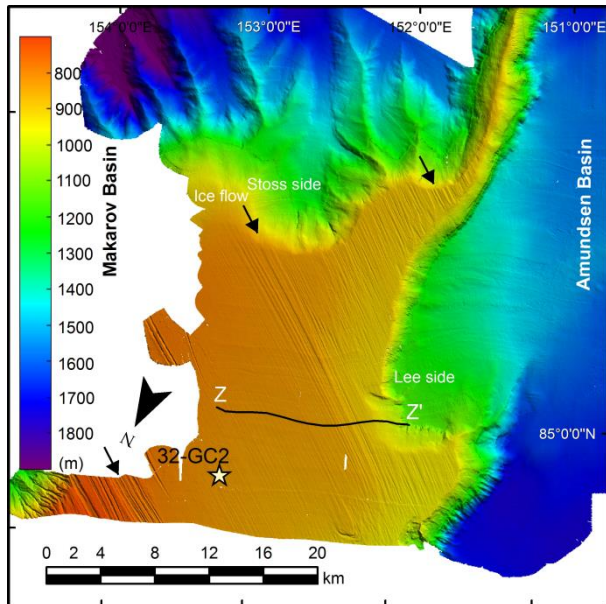
Sharp edge

Inferred ice flow

Deeper grounding
on this side









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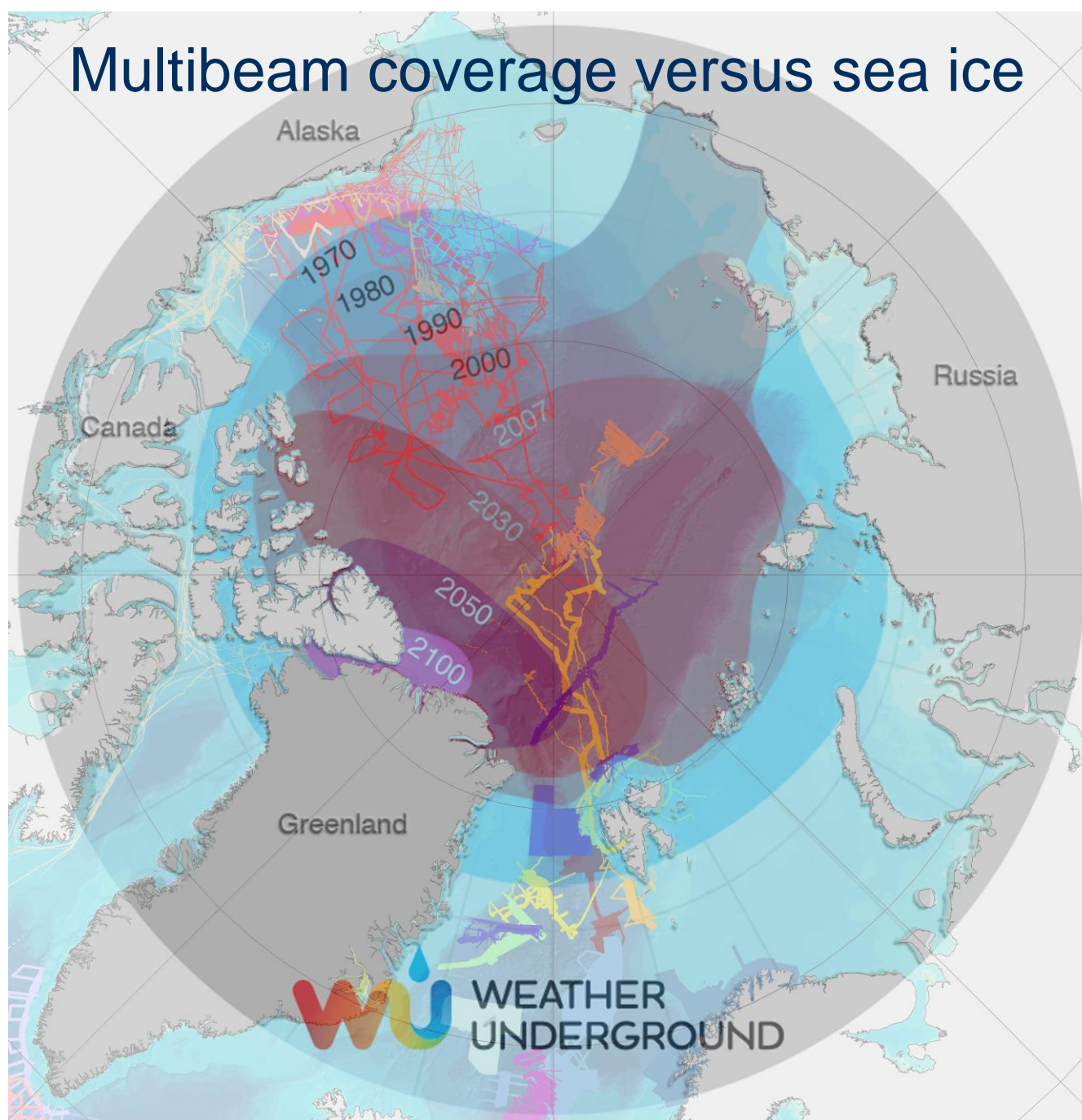
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Future challenges

Multibeam coverage versus sea ice



Multibeam data used in IBCAO Version 3.0 and sea-ice extent observations from 1970-2007) and forecasted 2030-2100. The data source is from the NOAA GFDL sea-ice model. The yearly extent represents an average 80% sea ice concentration. The sea-ice map is based on an illustration by Weather Underground.