

Atlantic water access and the break-up of the C.H. Ostenfeld Gletsjer ice tongue, Northwest Greenland

Supplementary information

Group author: “GEOEO 2024 Scientific Party”:

Camille Hayatte Akhoudas^{a,b}, Nai-Chen Chen^{a,c}, Love Dalén^{d,e,f}, Björn Eriksson^a, George Geier^g, Björn Gunnarson^h, Anders Götherström^{d,i}, Sophie ten Hietbrink^{a,b}, Marcus Karlsson^{a,b}, Hans W. Linderholm^j, Wilma Ljungberg^k, Julie Lattaud^{b,l}, Blanda Matzenbacher^{a,b}, Rezwan Mohammad^{a,b}, John Prytherch^{m,n}, Sarath Pullyottum Kavil^{a,b}, Niklas Rolleberg^o, Katharina Schwarzkopf^{a,b}, Mikkel-Holger S. Sinding^p, Flor Vermassen^{a,b}, Tirza Weitkamp^{a,b}, Julia Weissenbach^q, Flore Wijnands^{a,b,d}

^aDepartment of Geological Sciences, Stockholm University, 10691 Stockholm, Sweden, camille.akhoudas@geo.su.se ; bjorn.eriksson@geo.su.se ; blanda.matzenbacher@geo.su.se ; marcus.karlsson@geo.su.se ; rezwan.mohammad@su.se ; sarath.pullyottum.kavil@geo.su.se ; katharina.schwarzkopf@geo.su.se ; flor.vermassen@geo.su.se ; tirza.weitkamp@geo.su.se ; sophie.ten.hietbrink@geo.su.se ; flore.wijnands@geo.su.se

^bBolin Centre for Climate Research, Stockholm University, Stockholm, Sweden

^cDepartment of Geochemistry, Geological Survey of Denmark and Greenland (GEUS), Denmark, nache@geus.dk

^dCentre for Palaeogenetics, Stockholm, Sweden

^eDepartment of Bioinformatics and Genetics, Swedish Museum of Natural History, Stockholm, Sweden

^fDepartment of Zoology, Stockholm University, Stockholm, Sweden, love.dalen@zoologi.su.se

^gDepartment of Earth and Planetary Sciences, Dartmouth College, Hanover, NH 03755, USA, george.r.geier.gr@dartmouth.edu

^hDepartment of Physical Geography, Stockholm University, Sweden, bjorn.gunnarson@natgeo.su.se

ⁱDepartment of Archaeology and Classical Studies, Stockholm University, Stockholm, Sweden, anders.gotherstrom@arklab.su.se ;

^jDepartment of Earth Sciences, University of Gothenburg, Sweden, hansl@gvc.gu.se

^kDepartment of Marine Sciences, University of Gothenburg, Sweden, wilma.ljungberg@gu.se

^lDepartment of Environmental Science, Stockholm University, Sweden, julie.lattaud@aces.su.se

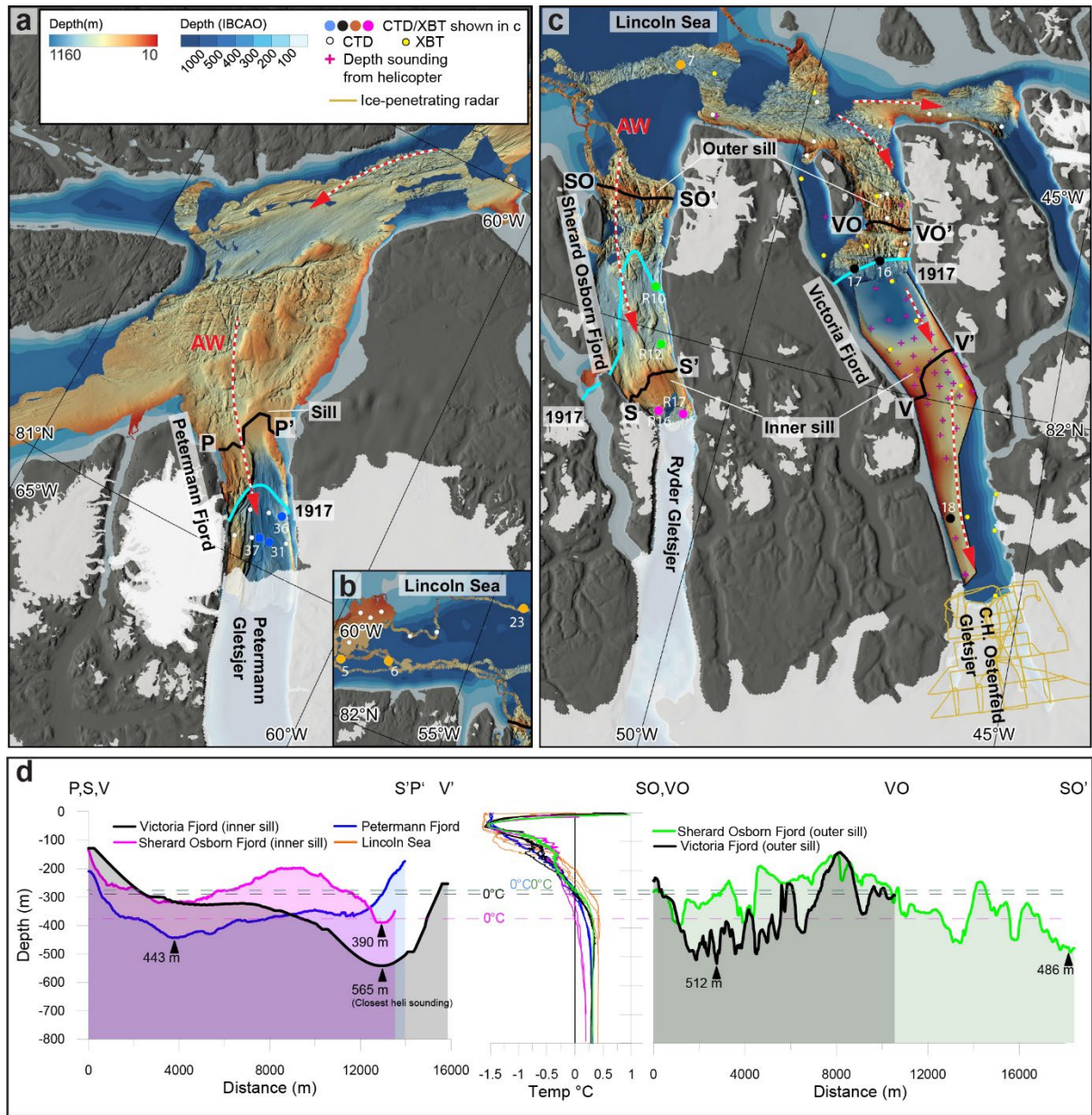
^mDepartment of Meteorology, Stockholm University, Stockholm, Sweden

ⁿDepartment of Earth Sciences, Uppsala University, Uppsala, Sweden john.prytherch@geo.uu.se

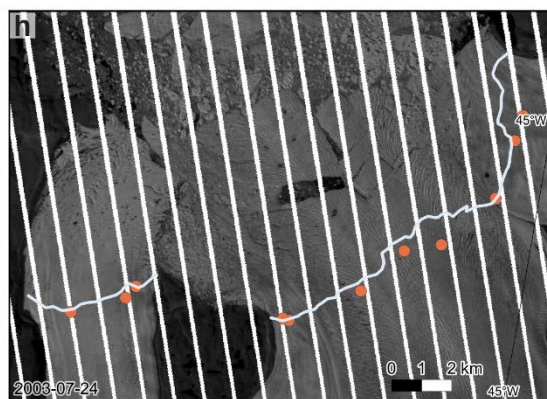
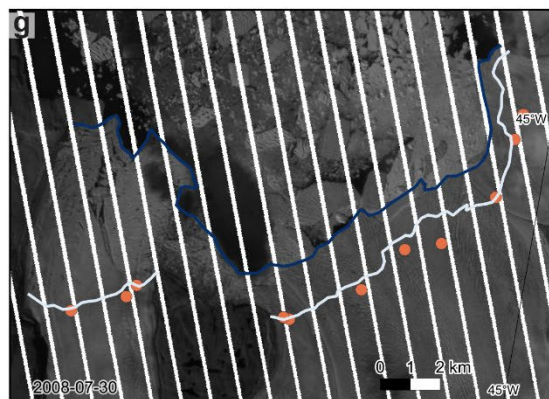
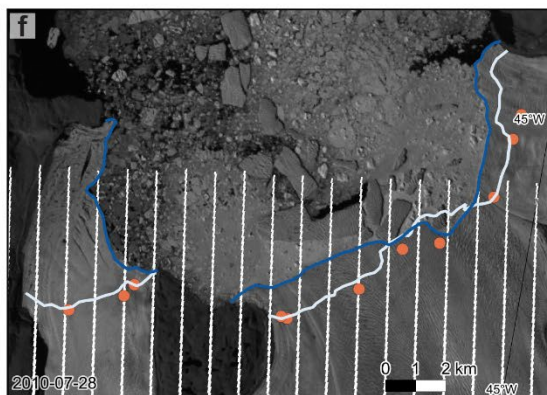
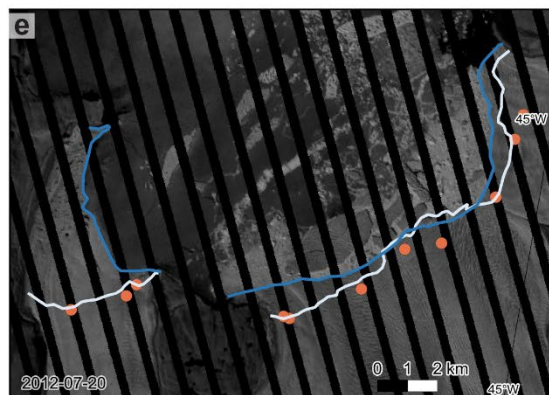
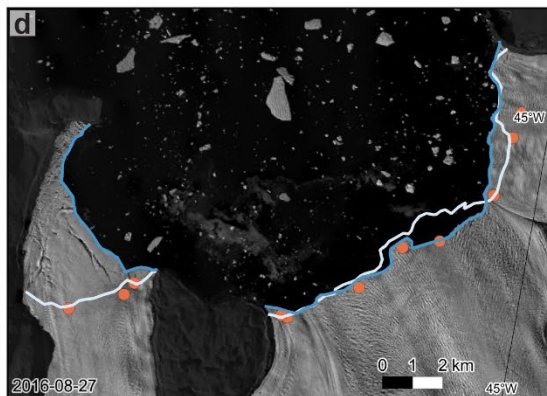
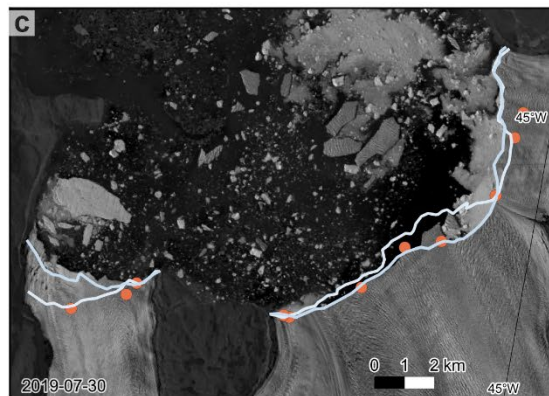
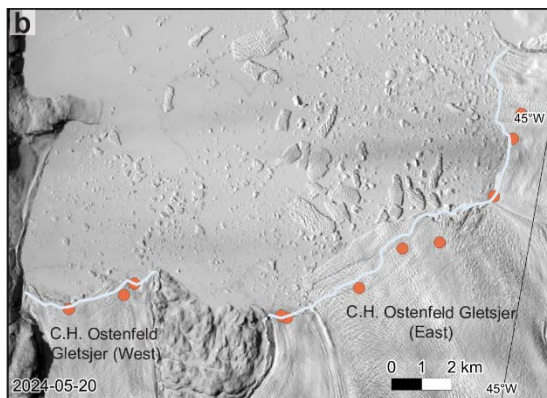
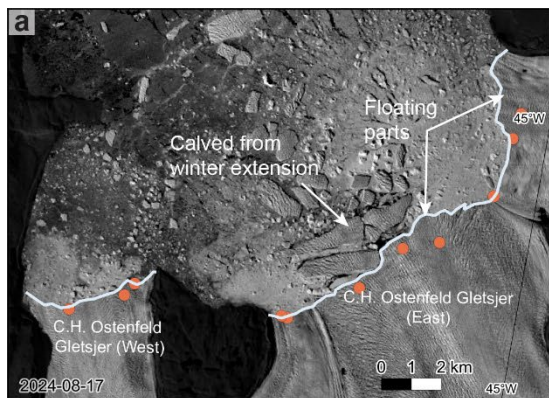
^oKTH Royal Institute of Technology, Stockholm, Sweden, nrol@kth.se

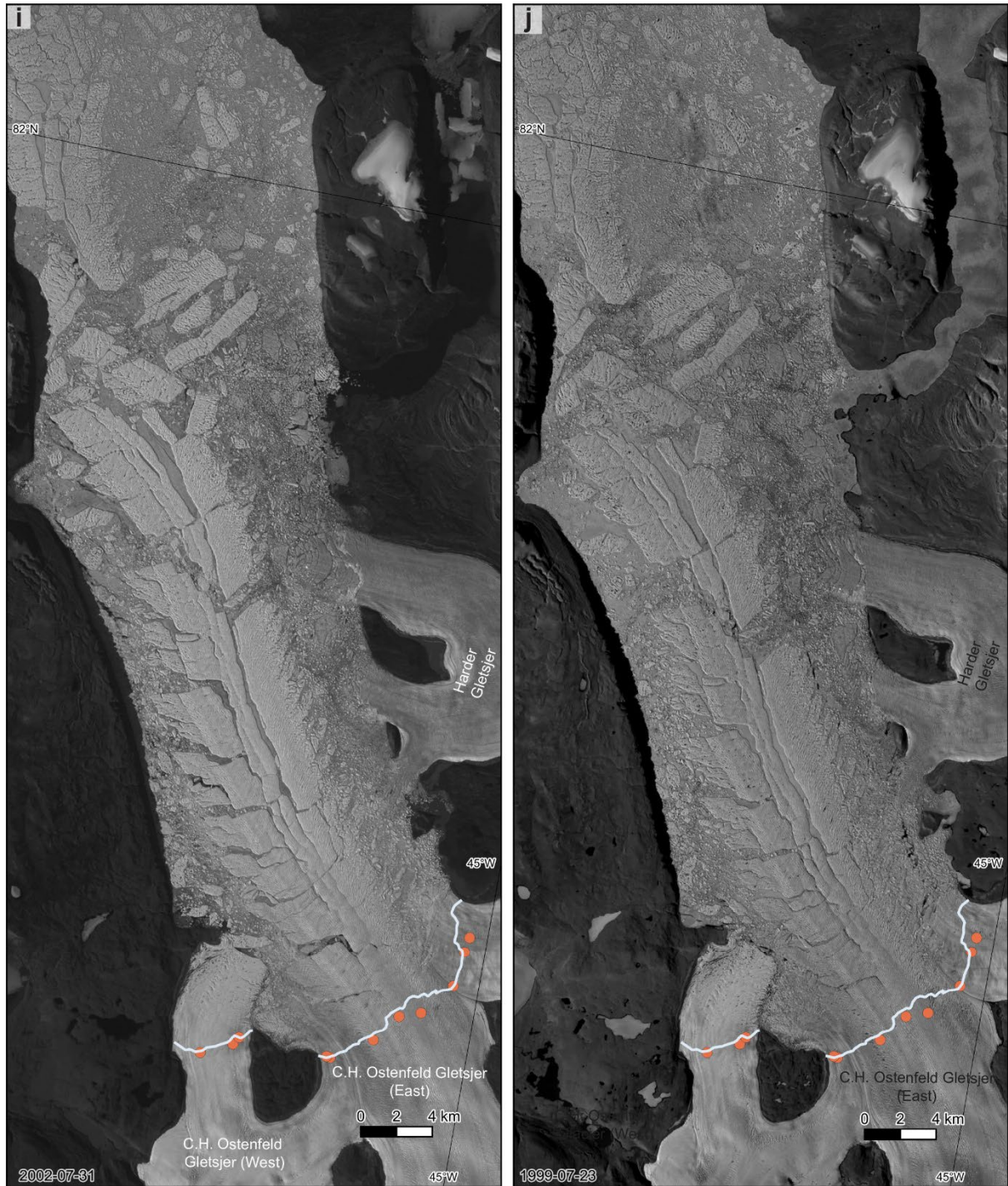
^pDepartment of Biology, University of Copenhagen, Copenhagen, Denmark, mikkel.sinding@sund.ku.dk

^qDepartment of Biology and Environmental Science, Centre for Ecology and Evolution in Microbial Model Systems (EEMiS), Linnaeus University, Kalmar, Sweden, julia.weissenbach@lnu.se



Supplementary figure 1. Detailed bathymetric maps and data from Petermann, Sherard Osborn and Victoria fjords for comparison. **(a-c)** Maps showing seafloor bathymetry from multibeam mapping and spot soundings (pink crosses). The background bathymetry, shown in a blue colour scheme, is based on the International Bathymetric Chart of the Arctic Ocean (IBCAO) Version 5.0¹, updated in this study with the new depth data acquired during the GEOEO 2024 Expedition. Locations of temperature profiles acquired with CTD and XBT instruments are marked with filled circles. The 1917 ice-tongue margins mapped by Lauge Koch² are shown for all three glaciers in turquoise. Schematic subsurface AW flow inferred from temperature profiles is indicated by red arrows. **(d)** Color-coded bathymetric profiles across mapped sills and temperature profiles. The bathymetric profile locations are shown in **(a-c)** with black lines. Black arrows mark the approximate deepest passages across the sills, along with their depths. Temperature profiles are color-coded according to their locations on the maps and marked with white numbers denoting the station (R mark stations from Ryder 2019 expedition³). The approximate vertical position of the 0 °C isotherm is inferred from the temperature data using the same colour coding as for the temperature profiles.

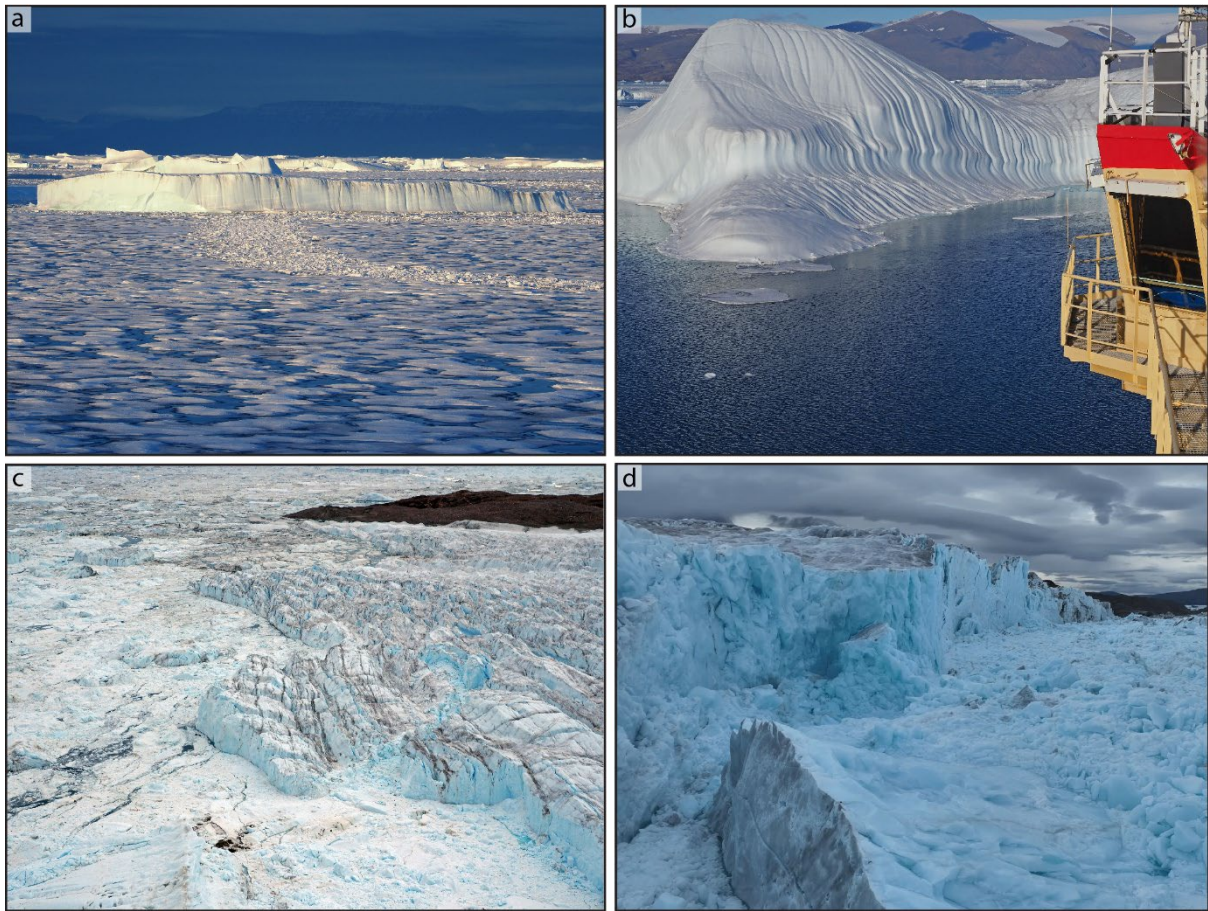




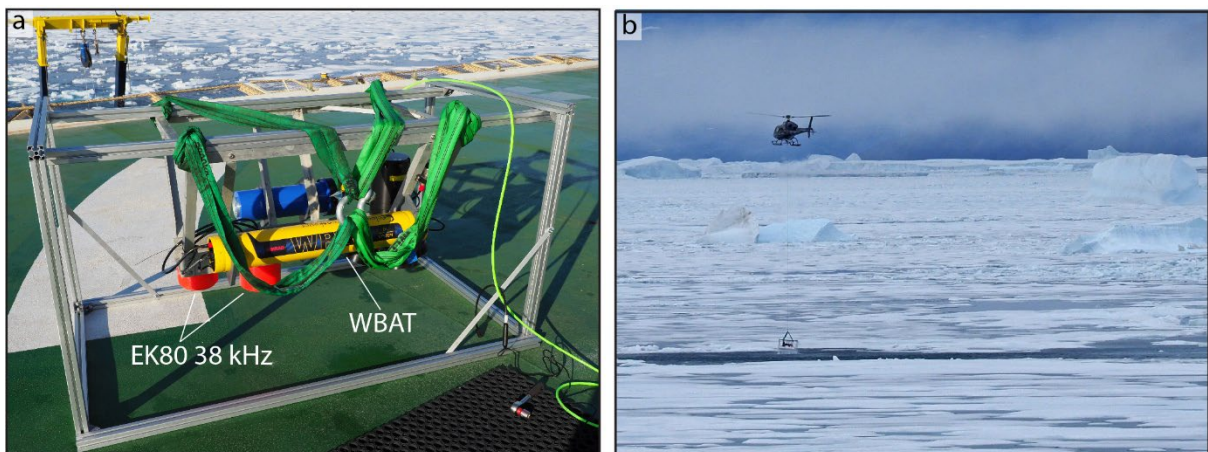
Supplementary figure 2. Landsat images⁴ of the C.H. Ostenfeld Gletsjer showing the break-up and evolution of the ice tongue from 1999 to 2024 at selected snapshots in time. Panels a-j correspond to images from 1999-07-23, 2002-07-31, 2003-07-24, 2008-07-30, 2010-07-28, 2012-07-20, 2016-08-27, 2019-07-30, 2024-05-20, and 2024-08-17. The ice margin from 17 August 2024 is shown in white as a reference in all images, while the margin at the time of each image is shown in blue. Grounding-line positions inferred from radio-echo sounding profiles are indicated by orange-filled circles. The names of the glaciers are shown only in (a). Panels i and j show the full longitudinal extent of the ice tongue prior to and during the main break-up phase, allowing comparison with its later reduced state. By 2003, only a few kilometres of floating ice tongue remained attached to the outlet glacier. The stripes in panels e-h are due to errors from the Scan Line Corrector in Landsat-7 data.



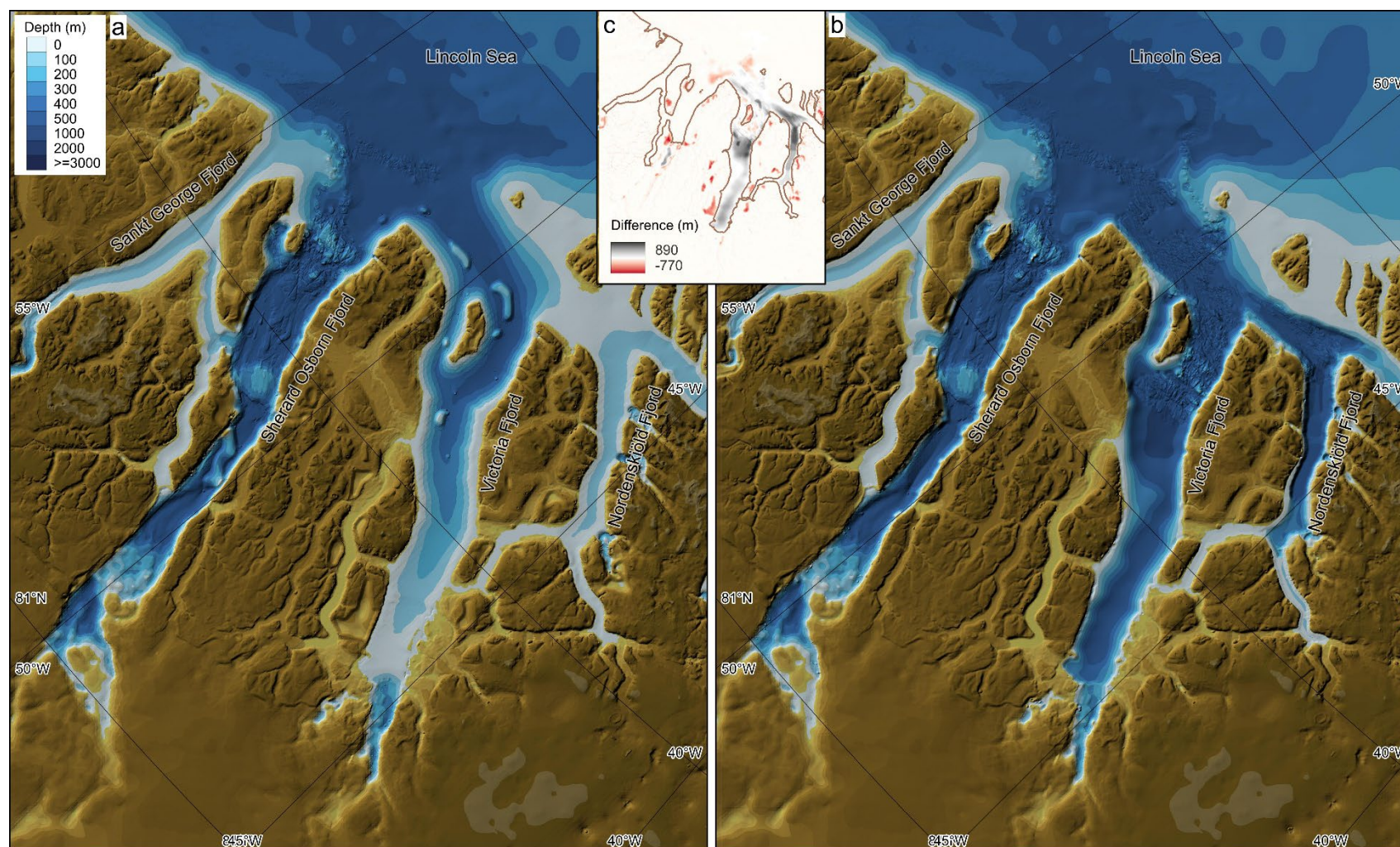
Supplementary figure 3. Satellite image from 2025-09-05 showing how the ice-tongue margin of Petermann Gletsjer advanced beyond its positions following the big calving events in 2010 and 2012, with 6 km and 16 km respectively. However, there are large cracks propagating through the ice tongue, of which the innermost is located up to > 3 km landward of the ice-tongue margin after the 2012 calving.



Supplementary figure 4. Icebergs in Victoria Fjord and the ice-tongue margin of the C.H. Ostenfeld Gletsjer. (a, b) Icebergs at about the location reached by IB Oden in Victoria Fjord. (c, d) The ice margin of the C.H. Ostenfeld Gletsjer; (d) shows a snapshot from drone footage. Photos a-c, Martin Jakobsson; Snapshot of drone footage, Jamie Barnett and Felicity Holmes.



Supplementary figure.5. Setup and deployment of the EK80 echosounder. (a) The EK80 system mounted in a frame assembly designed to be deployed from a helicopter. Two 38 kHz transducers were mounted, although one served as a spare. The echosounder's electronics are housed inside the WBAT tube. (b) The EK80 echosounder being deployed from a helicopter to acquire depth soundings in an opening in the sea ice. Photos a and b, Martin Jakobsson.



Supplementary figure 6. IBCAO bathymetry of the area around Sherard Osborn and Victoria fjords before and after updating with multibeam bathymetry and depth soundings acquired during the GEOEO 2024 Expedition. **(A)** IBCAO version 5.0¹. **(B)** IBCAO 5.0 updated using multibeam bathymetry, spot soundings, and manually inferred contours to constrain gridding in areas with only sparse spot soundings (see Methods). **(C)** Difference between IBCAO 5.0 and the new updated grid. IBCAO 5.0 makes use of BedMachine Version 5⁵ for the under-ice topography and inner fjords.

Supplementary references

1. Jakobsson, M. *et al.* The International Bathymetric Chart of the Arctic Ocean Version 5.0. *Sci Data* **11**, 1420 (2024).
2. Koch, L. Nord-Grönland fra 81° til 83° 25' nordlig bredde og 38° til 56° vestlig længde. (1922).
3. Jakobsson, M. *et al.* Ryder Glacier in northwest Greenland is shielded from warm Atlantic water by a bathymetric sill. *Communications Earth & Environment* **1**, 45 (2020).
4. USGS EROS Archive - Landsat Archives - Landsat 7 ETM Plus Collection 2 Level-2 Science Products | U.S. Geological Survey. <https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-archives-landsat-7-etm-plus-collection-2-level-2> (2022).
5. Morlighem, M. IceBridge BedMachine Greenland, Version 5. NASA National Snow and Ice Data Center Distributed Active Archive Center <https://doi.org/10.5067/GMEVBWFLWA7X> (2022).

