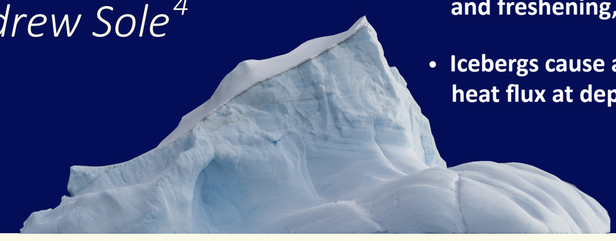
Iceberg melting substantially modifies oceanic heat flux towards Greenland's tidewater glaciers

Ben Davison[1] (bd41@st-andrews.ac.uk), Tom Cowton[1], Finlo Cottier[2,3] and Andrew Sole[4]

[1]School of Geography and Sustainable Development, University of St Andrews, UK
[2]Scottish Association for Marine Science, Scottish Marine Institute, Argyll, UK
[3]Department of Arctic and Marine Biology, UiT The Arctic University of Norway, Tromso
[4]Department of Geography, University of Sheffield, UK



Key points:

- **We simulate submarine iceberg melting in two major iceberg-congested Greenlandic fjords**
- **Iceberg melting causes significant along-fjord cooling and freshening, and invigorates fjord circulation**
- **Icebergs cause a 20-40% increase in up-fjord oceanic heat flux at depths critical to glacier stability**

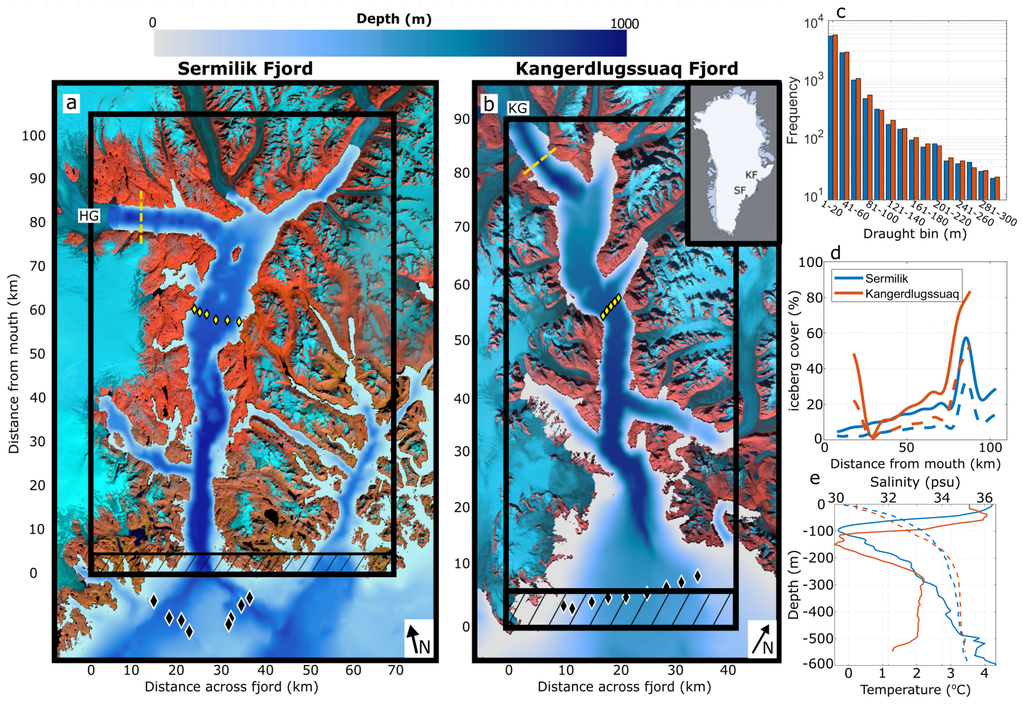
1. Introduction and Aims

- Freshwater release from submarine iceberg melting is a key component of the freshwater budget of iceberg-congested Greenlandic fjords[1,2]
- However, how submarine iceberg melting affects fjord water properties, fjord circulation and, ultimately, oceanic heat delivery to tidewater glaciers remains unknown.

We aim to:

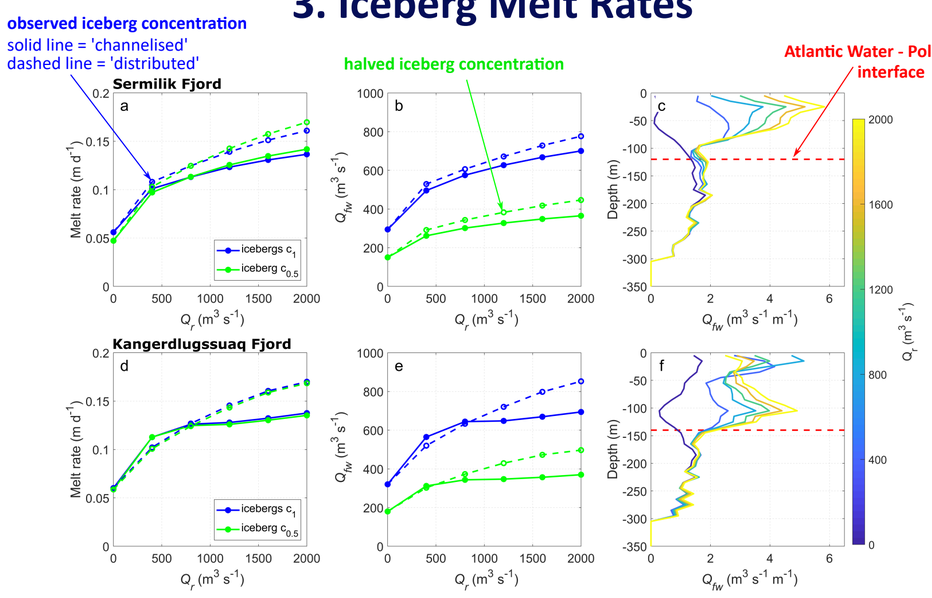
1. Simulate submarine iceberg melting in MITgcm[3]
2. Quantify the impact of iceberg melting on fjord properties, circulation and up-fjord oceanic heat flux

2. Study Area and Model Setup

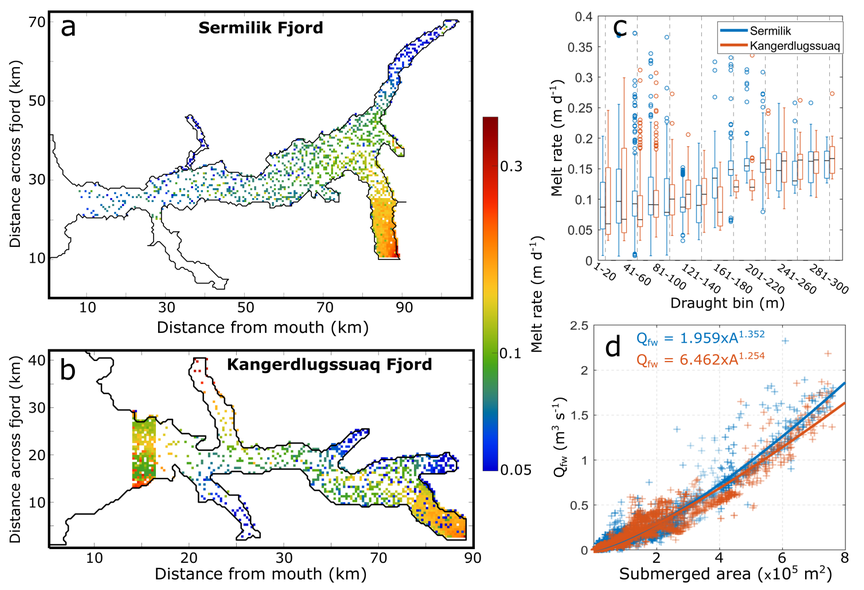


- We generate high-fidelty model domains of Kangerdlugssuaq Fjord and Sermilik Fjord, based on BedMachine bathymetry[4] and observed iceberg distributions[1,5,6]
- We examine the effect of varying runoff[7] on iceberg-ocean interaction using two end-member subglacial drainage system configurations
- We use observed temperature and salinity conditions at the fjord mouth to bound our model domains

3. Iceberg Melt Rates



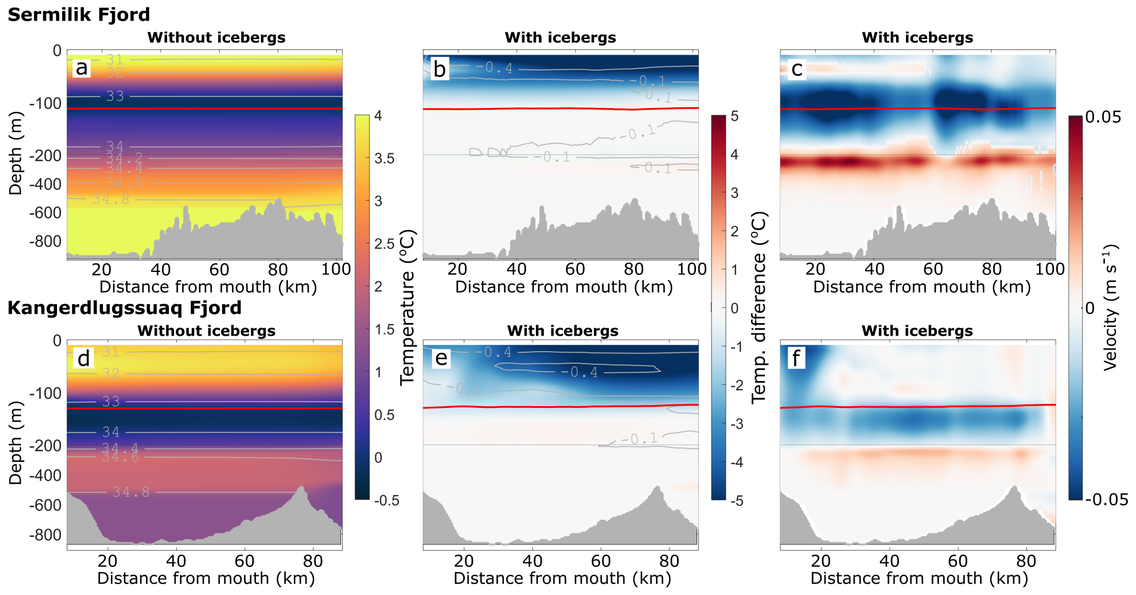
- Submarine iceberg melt rates increase with runoff raised to the power 0.1-0.2
- During 'summer', freshwater release from icebergs was 89% (Sermilik Fjord) and 142% (Kangerdlugssuaq Fjord) of the average annual runoff during 1990-2012
- On average, 48.8% (Sermilik Fjord) and 36.4% (Kangerdlugssuaq Fjord) of iceberg freshwater production occurred below the Atlantic Water - Polar Water interface



- Iceberg melt rates greatest for large icebergs, and more variable for small icebergs
- Freshwater production scales with submerged surface area

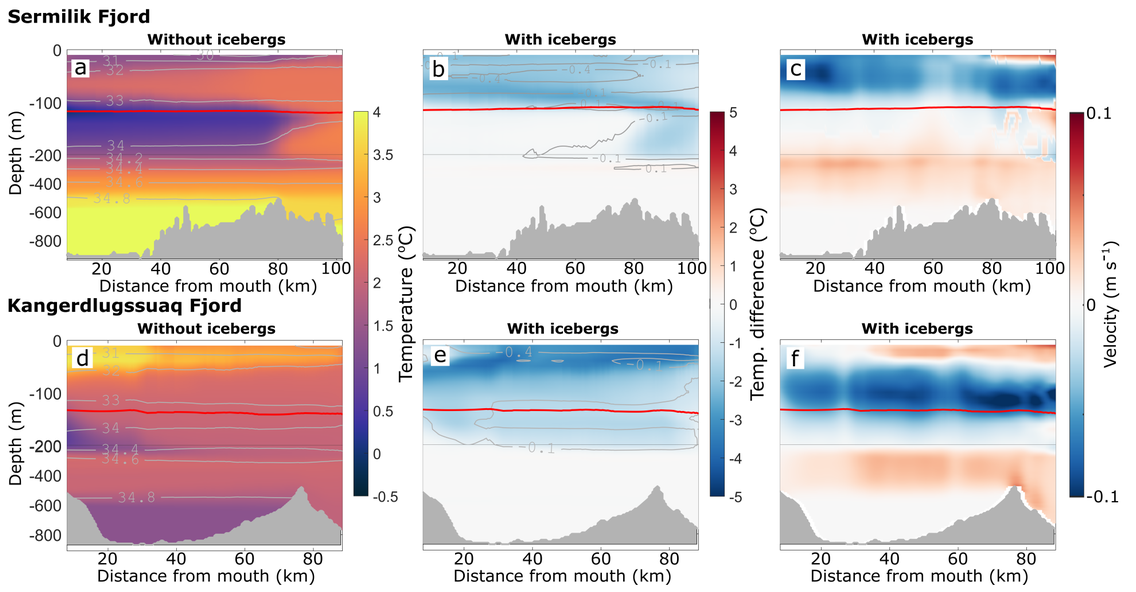
4. Effect on Fjord Properties and circulation

No-runoff scenario



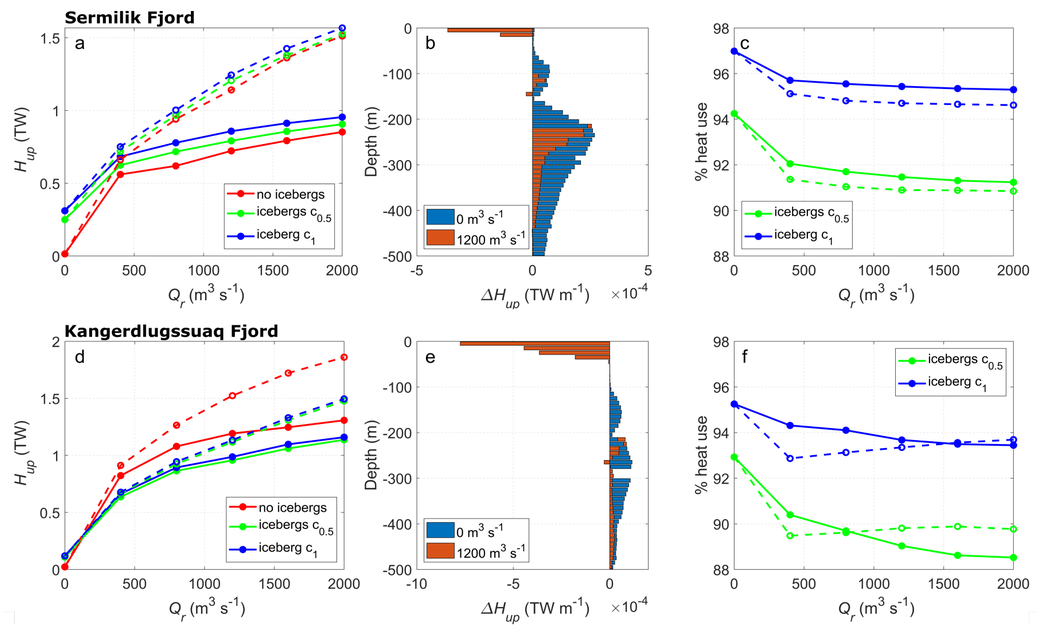
- Iceberg melting causes cooling and freshening in the upper 200 m by ~5°C and ~0.5 psu, and creates along-fjord gradients of temperature and salinity, comparable to observations[7,8]
- Submarine iceberg melting generates a weak overturning circulation, even in the absence of runoff

Summer runoff forcing scenario



- Cooling is less pronounced, but more homogeneous, in experiments with runoff
- The iceberg-driven circulation increases export of fjord water by 30% (Sermilik Fjord) and 7.6% (Kangerdlugssuaq Fjord)

6. Effect on Up-fjord Heat Flux



- Icebergs result in a 40-70% reduction in up-fjord heat flux between 0 and 50 m, but a 20-40% increase between 50 and 500 m
- Of the heat used for ice melt within these fjords, iceberg melting accounts for over ~90%

7. Summary

- We adapt an ocean model (MITgcm) to simulate submarine iceberg melting in two major glacial fjords
- We find melt rates of 0.05-1.2 m d^{-1} and freshwater release of 180-850 m^3 s^{-1} - similar to annual ice sheet runoff into these fjords - up to half of which is released below the Atlantic Water-Polar Water interface
- Iceberg melting causes cooling of ~5°C and freshening of ~0.5 psu, creating along-fjord gradients in temperature and salinity that are similar to observations, and augments the runoff-driven circulation
- These changes result in a 20-40% increase in up-fjord oceanic heat flux at depths thought to be critical to glacier stability
- Iceberg melting is a major heat sink in these fjords

References
We would like to thank D. A. Sutherland, F. Straneo & R. Jackson for providing conductivity, temperature, depth data in Sermilik Fjord; J. Dowdeswell, K. Heywood & M. Inall for collecting and sharing CTD data and bathymetric data for Kangerdlugssuaq Fjord. This work was funded by a PhD studentship to B.J.D, provided by SAGES and the University of St Andrews.

University of St Andrews
FIORD Forum for Ice-Ocean Research Development
SAGES Scottish Alliance for Geoscience, Environment and Society
St Andrews Glaciology
SAMS
The University Of Sheffield.

References
[1]Enderlin et al. (2016), *GRL*; [2]Moon et al. (2018), *Nat Geo.*; [3]Marshall et al. (1997), *JGR*; [4]Morlighem et al. (2017), *GRL*; [5]Sulak et al. (2017), *Ann. Glac.*; [6]Dowdeswell et al. (1992), *JGR*; [7]Sutherland et al. (2014), *JGR*; [8]Inall et al. (2014), *JGR*