Dynamic and Thermodynamic Renewal Processes in Greenland's Fjords

Ken X. Zhao, Andrew L. Stewart, and James C. McWilliams

Department of Atmospheric and Oceanic Sciences, UCLA

Contact Information

- Email: kzhao@atmos.ucla.edu
- Web: https://dept.atmos.ucla.edu/kenzhao/
- Addr: 9277 Boelter Hall, UCLA, Los Angeles

Research Overview

- Goal is to understand the sensitivity of Greenland fjord warm water supply/renewal (which impacts glacial melt rates) to dynamic and thermodynamic controls extending from the fjord to the continental shelf.
- Use MITgcm and layered-model (BEOM) in idealized setup to explore a broad parameter regime including:

(a) Geometric controls
(b) Surface wind strength and direction
(c) External conditions and shelf variability
(d) Subglacial discharge

Ilulissat/Disko Bay (Motivation)

- Jakobshavn Glacier terminates in Ilulissat Icefjord (IIf) and is renewed by Disko Bay waters
- 2-layer stratification consisting of Atlantic Water (warmer, saltier, and denser) and Polar Water (colder, fresher, and lighter) masses enter the bay and are mixed with the IIf glacially-modified water within the bay and the fjord.[2]
- Gap in understanding: **How do external processes and variability translate to changes/variability in fjord renewal, and how are they are modulated by fjord/bay geometry?**

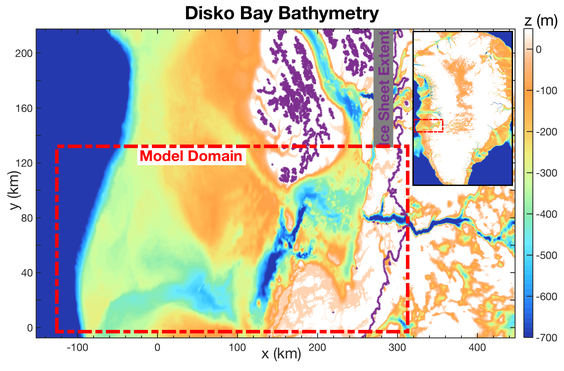

Figure 1: Disko Bay location and bathymetry. Credit: Bedmachine V3.[1]

MITgcm Reference Case

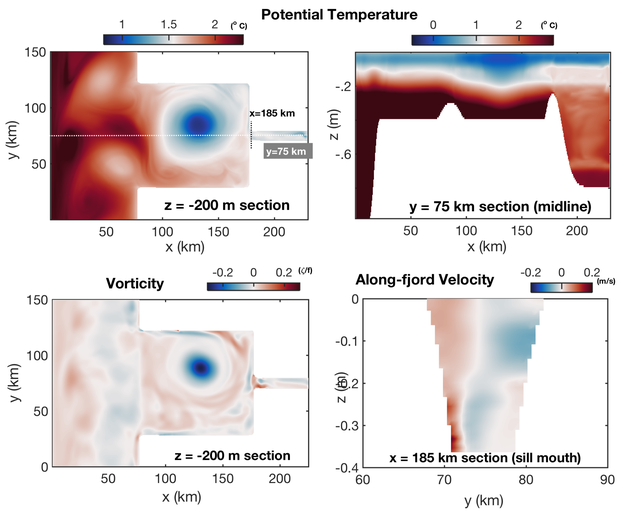

Figure 2: Time-averaged (days 700-800) potential temperature, vorticity, and along-fjord velocity cross-sections.

Layered-Model Configuration

- Back of the Envelope Ocean Model (BEOM) is a hydrostatic shallow-water isopycnal model that simulates rotating basins with layer-outcropping.[3]
- Use a thickness nudging at western boundary (using hydrographic data) and eastern boundary (motivated by plume theory under certain assumptions).[2]

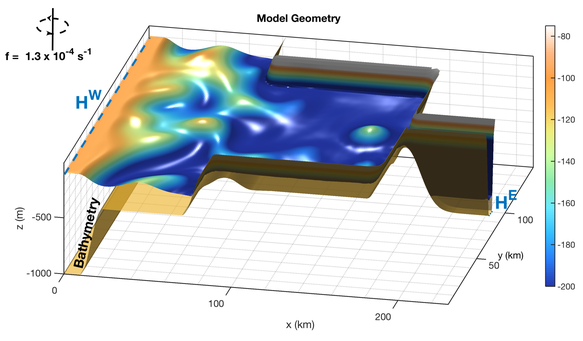

Figure 3: Representative geometry of IIf configuration with snapshot of interface depth (η).

Parameter Sensitivity

- **Critical thresholds in each parameter exist for the complete shutoff of warm water mass renewal in the fjord interior, but are more sensitive to winds and inner sill height.**

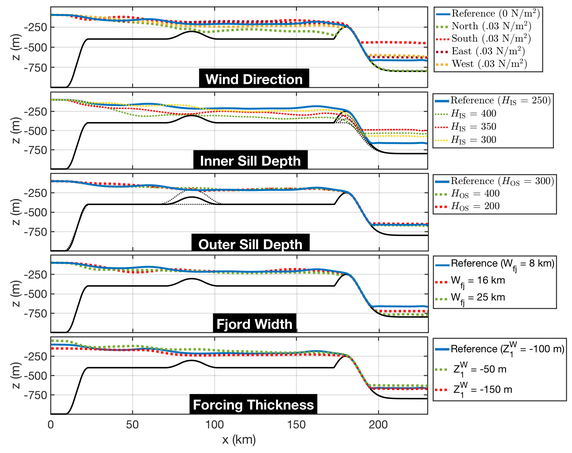

Figure 4: Sensitivity of zonal cross-section interface depth (η) over selected parameters.

Overturning Circulation (Renewal Rate)

- Overturning strength approximately geostrophic (sum of pressure head, bathymetric form stress, and interfacial form stress terms) with minimal eddy contribution.[4]

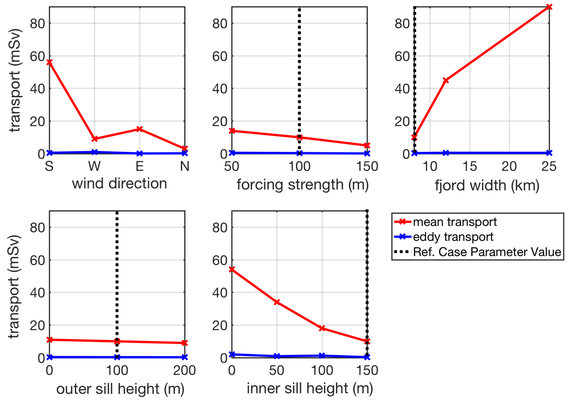

Figure 5: Time-averaged (days 700-800) mean and RMSD transport from our numerical simulations measured at the inner sill maximum.

Connectivity and Renewal

- Inner sill controls connectivity of the shelf-to-bay region; with sill, fjord overturning circulation decreases by factor of 5 and recirculation by factor of 2.

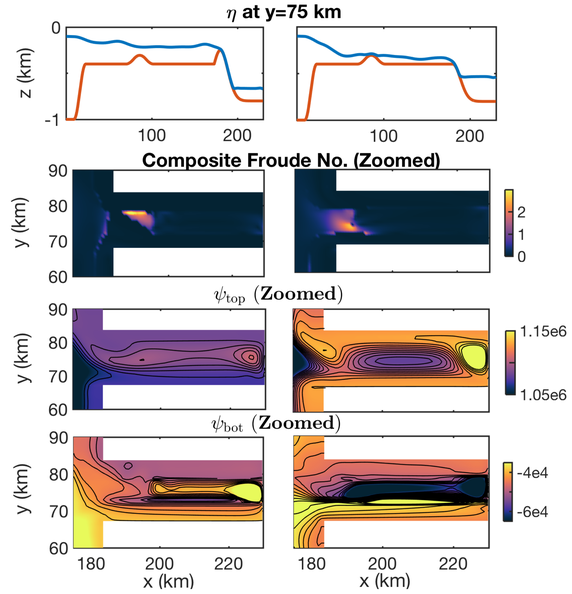

Figure 6: Time-averaged (days 700-800) BEOM output comparing interface depth and streamfunction for $H_{IS} = 250$ (left) and $H_{IS} = 400$ (right).

Summary and Future Work

- Fjord renewal is influenced by a complex interaction of drivers and controls of the overturning circulation including geometry, winds, eddies, and subglacial discharge. **Geometric effects suggest a hydraulically controlled state for Ilulissat renewal.**
- **Intrinsic variability external and internal to the fjord is significant, but does not substantially enhance renewal** - suggests forcing variability is most important for understanding renewal variability.
- Further work will explore the distribution of mixing within the shelf-to-fjord system and how it influences fjord renewal.

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References: [1] Morlighem, M. et al. 2017. IceBridge BedMachine Greenland, Version 3. Bathymetry Dataset. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/2CIX82HUV88Y. Date Accessed: 05/01/2018. [2] Gladish, C.V., D.M. Holland, A. Rosing-Asvid, J.W. Behrens, and J. Boje, 2015: Oceanic Boundary Conditions for Jakobshavn Glacier. Part I: Variability and Renewal of Ilulissat Icefjord Waters, 2001–14. J. Phys. Oceanogr., 45, 3–32, https://doi.org/10.1175/JPO-D-14-0044.1 [3] St-Laurent, Pierre. Back of the Envelope Ocean Model (BEOM). Source code available under copyleft license: http://www.nordet.net/beom.html [4] Zhao K.X., A.L. Stewart, and J.C. McWilliams. Sill-Influenced Exchange Flows in Ice Shelf Cavities. J. Phys. Oceanogr., In Press, https://doi.org/10.1175/JPO-D-18-0076.1