Oceanic response to buoyancy, wind and tidal forcing in a Greenlandic glacial fjord

Dustin Carroll\textsuperscript{1}, David A. Sutherland\textsuperscript{1}, Emily L. Shroyer\textsuperscript{2}, and Jonathan D. Nash\textsuperscript{2}

\textsuperscript{1}University of Oregon, \textsuperscript{2}Oregon State University.

1. Introduction

The Greenland Ice Sheet is losing mass at an accelerating rate\textsuperscript{1}. This acceleration may in part be due to changes in ocean heat transport to marine-terminating outlet glaciers. Ocean heat transport to glaciers depends upon fjord dynamics, which include buoyancy-driven exchange flow, tides, internal waves, turbulent mixing, and connections to the continental shelf\textsuperscript{2}. Submarine melting may be a significant component of tidewater glacier mass loss, and additional observations are needed to constrain the sensitivity of glacial melt to both ocean and atmosphere forcings\textsuperscript{3}. This knowledge is critical for parameterizing the role of tidewater glaciers in future numerical models of ice-sheet dynamics.

2. The Problem

Direct observations of fjord circulation and heat transport towards the glacier face have been difficult to obtain due to the lack of sustained observations in Greenland's fjords\textsuperscript{4}. Recent numerical models of glacier/fjord systems have focused on the 2D circulation\textsuperscript{5}. We seek to investigate the following hypotheses in a newly developed 3D numerical model of Rink Isbræ fjord in west Greenland (Fig. 1):

- The mean exchange flow of the fjord is sensitive to changes in subglacial discharge rates.
- Bathymetric and rotational effects can strongly influence the buoyancy-driven circulation.
- Tides and wind-forcing cause significant variability in heat and freshwater transport to the glacier.

3. Model Setup

- Global 3D model domain bathymetry
- Initial T/S conditions from a July 2012 shipboard survey
- Fresh melt water (MIW) from is present near-surface. Cold, fresh polier water (PW) overlies relatively warm, salty subtropical water (STW).
  - Grid (rotated 30°)
  - 100 m horizontal resolution
  - 39 vertical z cells (10-200 m)
  - Hydrostatic
  - Horizontal Eddy Viscosity (0.5 - 1 m\textsuperscript{2} s\textsuperscript{-1})
  - K-Profile Parameterization
  - Nonlinear E.O.S
  - Tides: AOTIM-5
- Wind: Idealized zonal wind stress (0 - 1 N m\textsuperscript{-2})
- Initial Model T/S conditions
- Open Boundary Conditions: N,S,W,E
- N,S,W 100 km relaxation layer
- Relaxation time: Interior 5 days/ exterior 1 day
- Subglacial discharge forced at eastern glacial boundary at 500 m depth

4. Model Base Case: Buoyancy Forcing

- The spatial structure of the plume is sensitive to the rate of subglacial discharge.

5. Model Results with Wind and Tidal Forcing

Buoyancy driven results are forced with katabatic winds and tides to investigate the fjord/plume response and estimate the variability in heat and freshwater transport.

6. Summary

The estuarine circulation and plume structure is sensitive to the rate of subglacial discharge.

Bathymetry and rotational effects strongly influence the buoyancy-driven circulation.

Ocean and atmosphere forcing such as tides and wind can significantly modify the heat and freshwater flux towards the glacier.

Future work will include a coupled fjord model of two outlet glacier systems in close proximity to each other yet with different glacial mass balances (Rink Isbræ and Kangerdlugssup Semmersua). By investigating a region where the ocean and atmosphere forcing is expected to be similar, we can characterize the key ocean processes that may cause variability in glacier response.

References

\textsuperscript{1} Velicogna, 2009, GRL; Nick et al. 2012, Nature.
\textsuperscript{4} Sutherland and Straneo. 2012, Annals of Glaciology.
\textsuperscript{5} Straneo et al. 2012, JGR Oceans; Xu et al. 2012, GRL.