Changes to exchange across the Southwest Greenland shelf break in response to surface and vertically distributed meltwater forcings in a mesoscale-eddy resolving ocean model

Theresa Morrison¹, Julie McClean¹, Sarah Gille¹, Mathew Maltrud², Detelina Ivanova³

¹ Scripps institution of Oceanography
² Los Alamos National Laboratory
³ Climformatics
Motivation

Accelerated mass loss from the Greenland Ice Sheet is expected to contribute more to than the Antarctic Ice Sheet up to in the next 100 years.

Land ice modeling and ice-ocean interactions are leading sources of uncertainties in sea level rise projections.

Combined Greenland and Antarctic Ice Sheet contributions to global sea level rise from IMBIE satellite record (black), and the high (marron), middle (orange) and low (yellow).


Runoff and solid ice discharge have from the Greenland Ice Sheet have increased since the 1990s.

Freshwater enters the North Atlantic in a critical region for deep water formation.

FWF: Total Freshwater Flux
D: Solid Discharge (Icebergs)
RGIS: Greenland ice sheet runoff
RGLC: Glacier and ice cap runoff
RT: Tundra runoff on non-glaciated land

Mixing within fjord

Many hosing or Greenland freshwater perturbation experiments do not account for the mixing within fjords.

Observations show the dilution of meltwater before it reaches the continental shelf.
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How does the vertical distribution of meltwater from the Greenland Ice Sheet change its pathways in the Labrador Sea?
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When comparing the meltwater perturbation experiments we consider:

- Changes in the cross-shelf exchange and along-shelf currents in the West Greenland Current
- Changes in shelf heat-content and the potential for increased ocean driven melting
- Does vertically diluting meltwater make the simulations closer to observations? Is the resulting difference from the two forcings statistically significant?
What does the meltwater forcing look like vertically and horizontally?

- Remapped point-by-point from Bamber et al. 2018 reanalysis of Greenland Runoff
- Linearly interpolated in time from monthly data
- 0.25° at 60N Gaussian Filter, but exclude areas deeper than 400m
- Added either to the surface layer of the model (10m thickness)
- OR vertically distributed over the top 200m
Model Description: Ultra-High 8 to 2

- Global
- POP2/CICE5
- CORE 2 - IAF
- Spin up from 1975 with no meltwater
- 60 vertical levels

**Meltwater:**
- **Greenland:** From Bamber et al. 2018 reconstruction, spatially and time varying
- **Southern Ocean:** From Hammond et al. 2016 climatology of Antarctic ice sheet freshwater fluxes

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Ice Sheet Meltwater?</th>
<th>Time period</th>
</tr>
</thead>
<tbody>
<tr>
<td>UH8to2 - Control</td>
<td>No</td>
<td>1990-1992</td>
</tr>
<tr>
<td>UH8to2 - Surface</td>
<td>Surface layer only</td>
<td>1990-1992</td>
</tr>
<tr>
<td>UH8to2 - Spread</td>
<td>Distributed vertically in top 200 m</td>
<td>1990-1997</td>
</tr>
</tbody>
</table>
Observations: AVISO

UH8to2 Simulation
Eddy Kinetic Energy in the West Greenland Current: Comparison of 0.1° and UH8to2 Simulations
Comparison to T and S along AR07 line 1993-1996

Model data is samples at the closest model point and in the same month as the AR07 observations.
Results

First use the meltwater tracer to show the horizontal and vertical pathways through the Labrador Sea.

Second show how meltwater is connected to changes in isopycnal slope at the shelf break.
1. Meltwater Tracer in Surface and Spread Cases: 1992-12
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Time Series of Meltwater Dye Tracer and Salinity: What dynamics cause this difference in Meltwater concentration?

Surrounding Shelf is the yellow and green regions. Labrador Sea is the orange region.
Shelf-Current Structure in the West Greenland Eddy Shedding Region

Increased EKE in spread case along shelf break

Both meltwater forced cases show increased EKE in the Labrador Sea

What mechanism causes this change? Is it connected to the meltwater forcing?
Changes in cross-slope salinity: 1992-03

- Line cuts across high EKE zone
- Isopycnals: 27.4, 27.6, 27.7 (dashed) and 27.5 (solid)
- Slope of isopycnals is similar in control and surface run
- 27.5 isopycnal does not outcrop in the surface case
Changes in cross-slope salinity: 1992-03

- Salinity differences
- More freshening off the shelf in the spread case (compared to the control)
- Can this be attributed to the meltwater forcing?
Changes in cross-slope salinity: 1992-03
Main Take Away:

- Isopycnals are flatter in the spread case
- This corresponds to freshening across the shelf break
- The freshening is in the same location as the meltwater tracer
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While the freshwater perturbation associated with meltwater is small, how it is added can drive changes in cross shelf exchange.
Question: How does the vertical distribution of meltwater from the Greenland Ice Sheet change its pathways in the Labrador Sea?

- What mechanism is causing the change in cross shelf exchange?
- What are the implications for freshening in the Labrador Sea and potential warming on the continental shelf?
- Does vertically diluting meltwater make the simulations closer to observations?
Summary and Ongoing work

Question: How does the vertical distribution of meltwater from the Greenland Ice Sheet change its pathways in the Labrador Sea?

- What mechanism is causing the change in cross-shelf exchange?
- What are the implications for freshening in the Labrador Sea and potential warming on the continental shelf?
- Does vertically diluting meltwater make the simulations closer to observations?

Ocean Sciences Meeting:
HL08 The physics and biogeochemistry of melting coastal margins: Interactions between glaciers, permafrost, circulation, sea ice, elemental cycling, and ecosystems
Thursday March 3, 2022
Assessing the Impacts of the Vertical Distribution of Meltwater from the Greenland Ice Sheet on Cross-shelf Exchange in Southern Greenland Using a Meso-scale Eddy Resolving Ocean Model