Effects of Greenland's Runoff in a Regional Arctic System Model

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Introduction

The Regional Arctic System Model (RASM) is a high resolution (1/12°) coupled regional model capable of simulating past, present and future states of the Arctic climate system. We seek to evaluate the role of freshwater in the evolution of the ocean state by providing freshwater runoff from land sources, including ice discharge from the Greenland Ice Sheet and other ice caps or tidewater glaciers. In this focused study, our model configuration utilizes a more restrictive component set of the fully coupled RASM model by only allowing ocean (Parallel Ocean Program, POP) and and sea ice (CICE) models to be actively coupled. This ocean-ice configuration is forced by atmospheric reanalyses given from the Coordinated Ocean-ice Reference Experiments[1] (CORE2) data set. The land ice model is unused and kept as a stub, while the land model is used in data-mode only so that the freshwater forcing can be provided to the ocean.

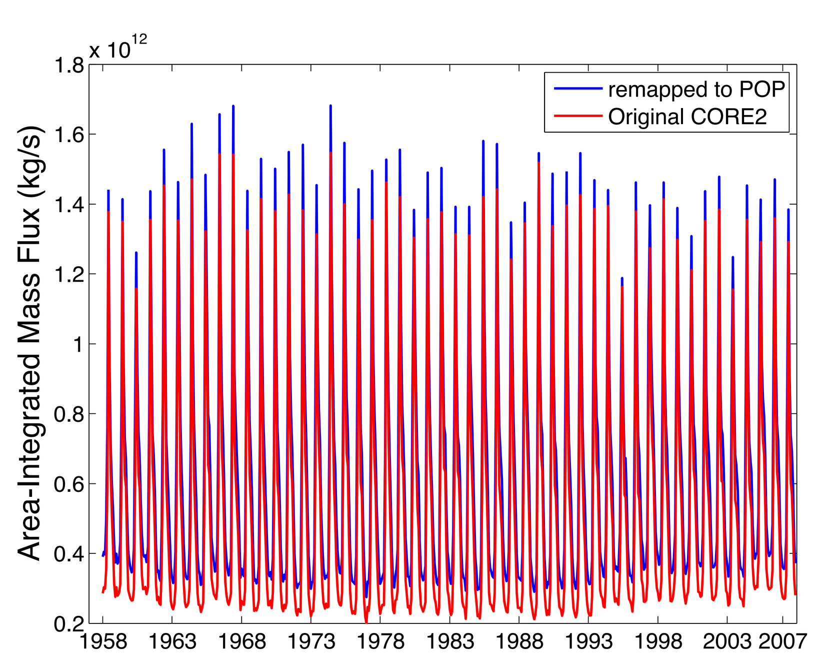
With this more realistically forced ocean, we evaluate the impact runoff has in the ocean currents around Greenland, where significant variability in ice discharge rates may result in critical feedbacks in the ocean dynamics. In this preliminary evaluation of results, we focus on the role the freshwater forcing has in the West Greenland Current, a current that is maintained, in part, by bouyancy flow.

Freshwater Forcing

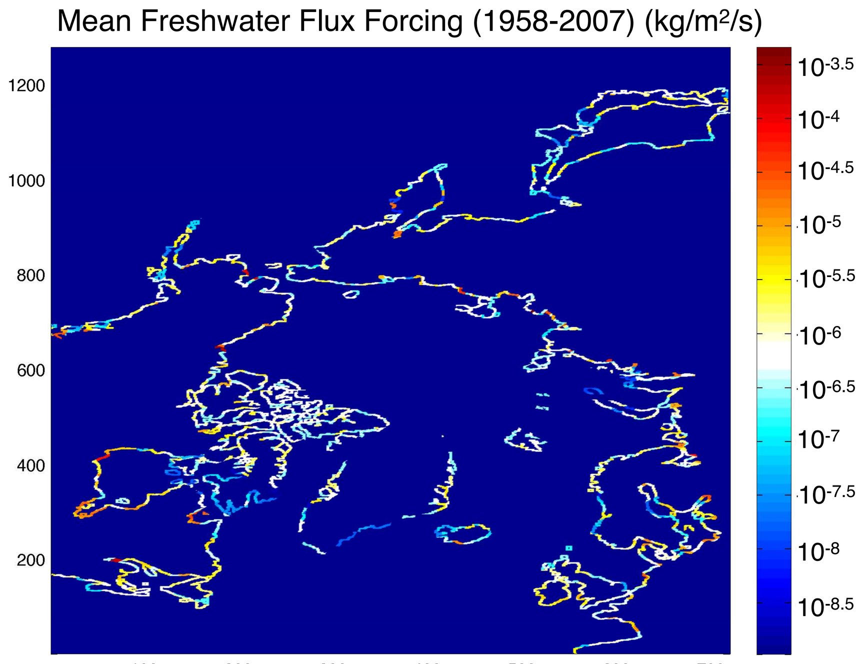
We provide a realistic runoff, or freshwater flux, into POP at a monthly resolution throughout the entire length of the model run, from 1958-2007. This freshwater forcing is based on the runoff given by the CORE2[1] data sets, which includes an evaluation of ice discharge. A remapping scheme is employed to transfer the runoff in CORE2's Arctic region onto the POP domain used in RASM. This forcing is provided to the surface level (5 m thick) grid point along the swath of 3-4 coastal grid cells that extend from the land.

Given that the mapping projections and resolutions differ between CORE2 and RASM's domain, care was taken to accurately remap the runoff values (kg/m²/s) from CORE2 onto the POP domain in RASM. First, a coastline grid was created within POP's ocean domain in RASM to designate coastal points that extend 3-4 grid cells away from the land. Then, for each of these cells, we find the nearest grid cell in the CORE2 domain, according to their latitudes and longitudes. Finally, the original runoff value given by CORE2 is divided by 10 before being designated to the POP coastal grid. Because the CORE2 resolution is on the order of 100km whereas RASM's POP domain is on the order of 10km, the POP domain grid cell may be nearest to a land domain cell of CORE2 because of the coarser resolution. To avoid this and to create a continuous runoff map, if the algorithm determines a runoff value of zero for the POP domain grid cell, then it searches in all of the adjacent CORE2 cells for, again, the nearest non-zero runoff.

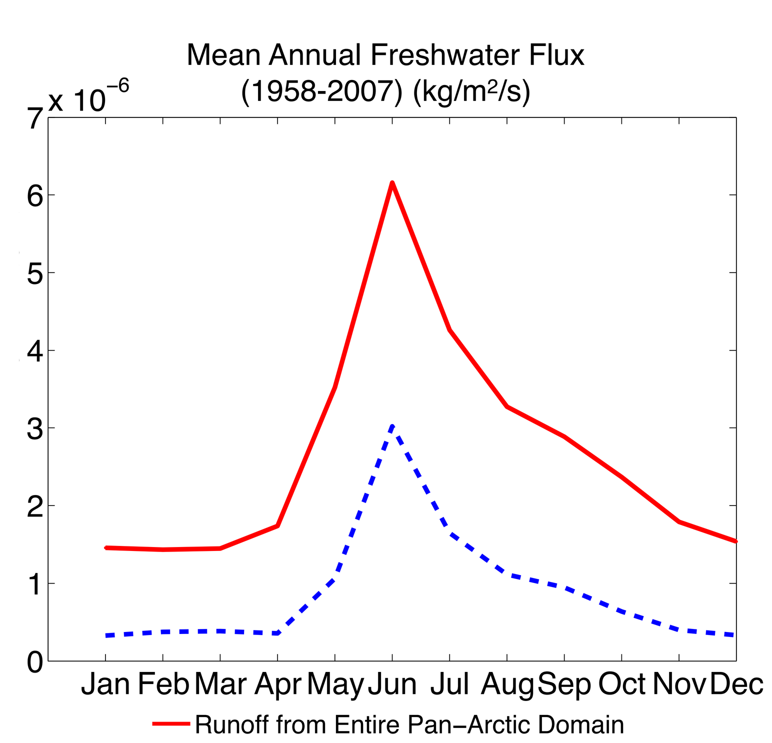
The above method relies on a factor of 1/10 when converting CORE2 runoff values onto the higher resolution POP domain, and searching in adjacent cells when a runoff value of zero is reached. This approach does not conserve mass, and produces ~20% more freshwater flux from 1958-2007 in the POP domain. This discrepancy is shown in Figure (1) below. However, despite this over saturation of mass compared to the CORE2 data, we still used this forcing for the 50 year simulation presented here. A display of the resulting freshwater fluxes are given in the bottom figures.



◀ **Figure (1)** The evolution of the area-integrated runoff flux from the original CORE2 data's Arctic region (red line) and the total flux fed into our model simulations after implementation of the remapping scheme described above (blue line). The total flux entering into our model simulations are consistently higher than the original CORE2 mass flux and produces an overall 20% larger mass flux.



▲**Figure (2)** This map shows the time-averaged runoff flux (kg/m²/s) prescribed to the ocean domain in our G-case model run.

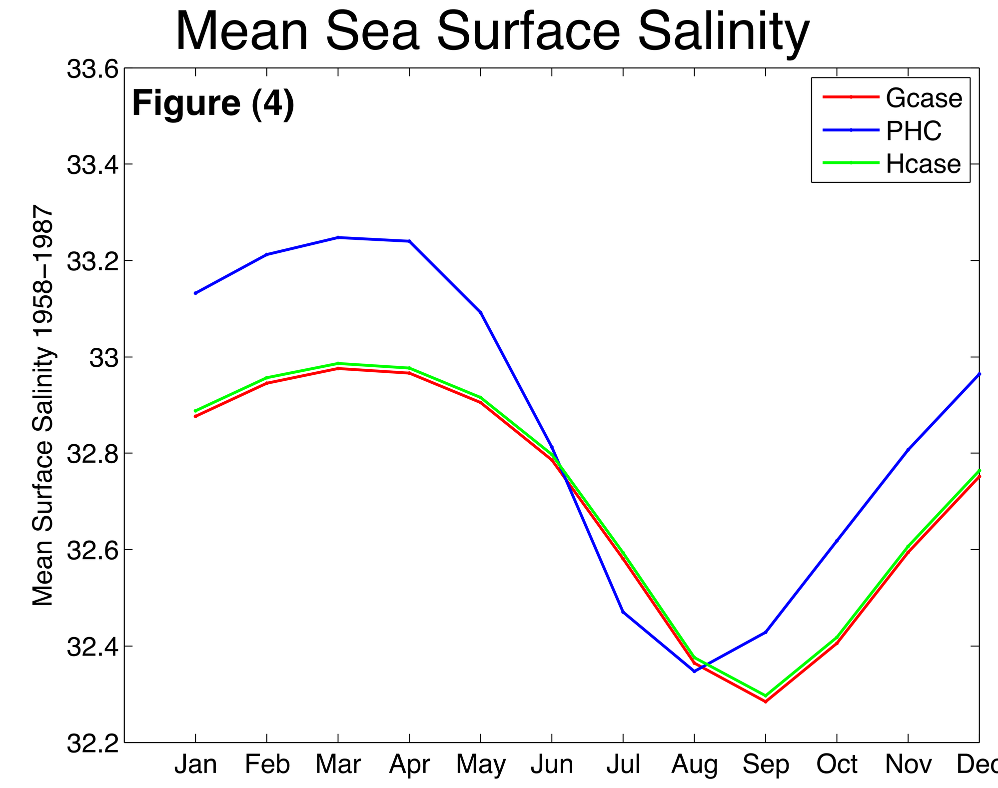


▲**Figure (3)** Annual average runoff flux forcing used in our G-case run for the entire domain and for Greenland only.

Evaluation of Simulations

1. Comparison to Observations

We present two RASM simulations that focus on the role of freshwater runoff in the oceanography around Greenland. The two simulations are exactly the same except that the first (Gcase in Figure (4)) is forced by an evolving runoff flux, whereas the second simulation (Hcase in Figure(4)) is given no runoff flux and does not undergo any surface salinity restoring. The simulations began with identical initial states and were allowed to evolve for 50 years (1958-2007). We determined that the model configuration with freshwater forcing was performing technically as expected by noting that the mean surface salinity across the entire Arctic domain of POP was slightly below the Hcase simulation (without freshwater forcing). We also compared these results with sea surface salinities from the Polar Center Hydrographic Climatology 3.0[2] (PHC in Figure (4)) which are based on observations. ▶



2. Heat and Volume Transport of Flow along Western Greenland

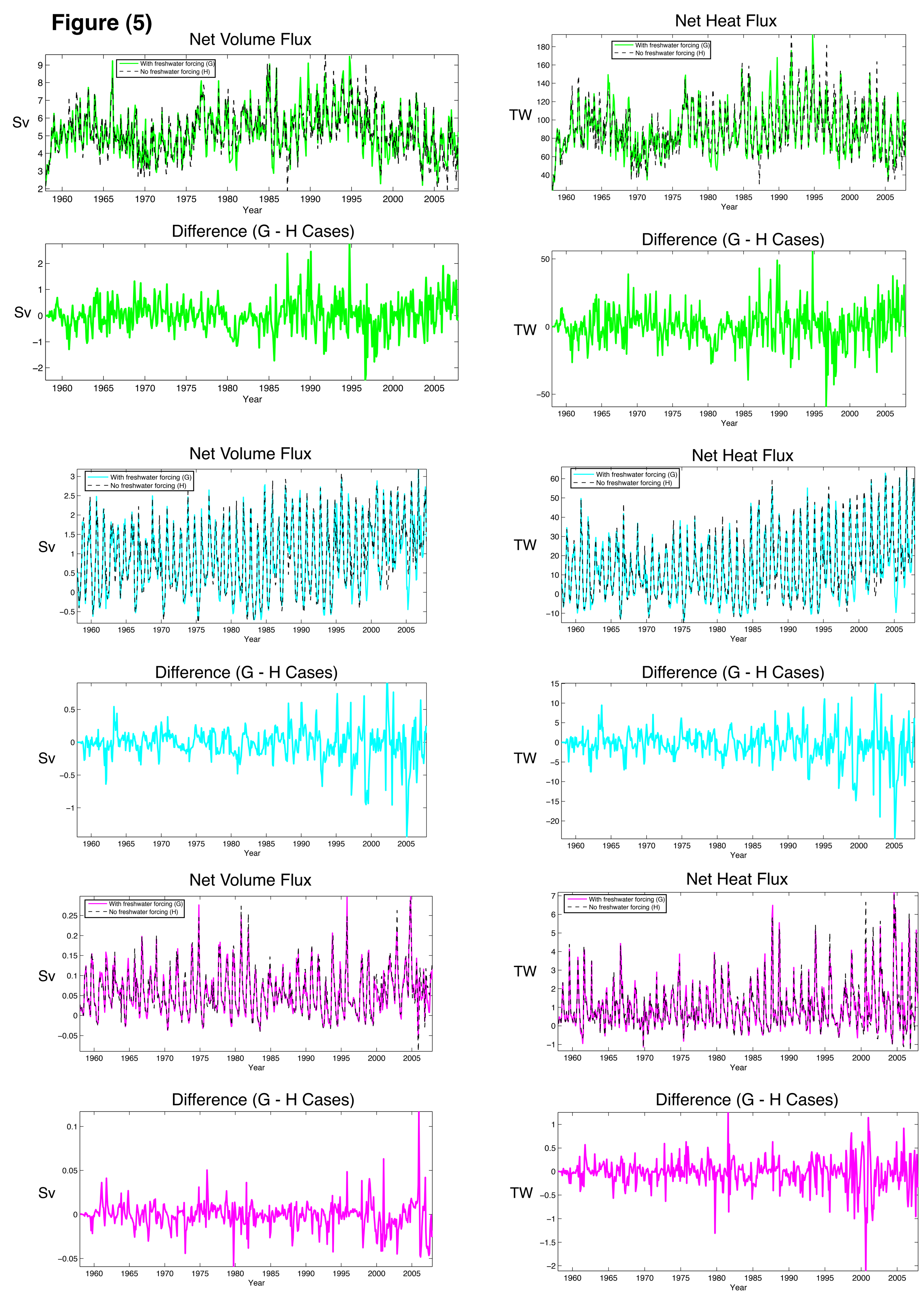
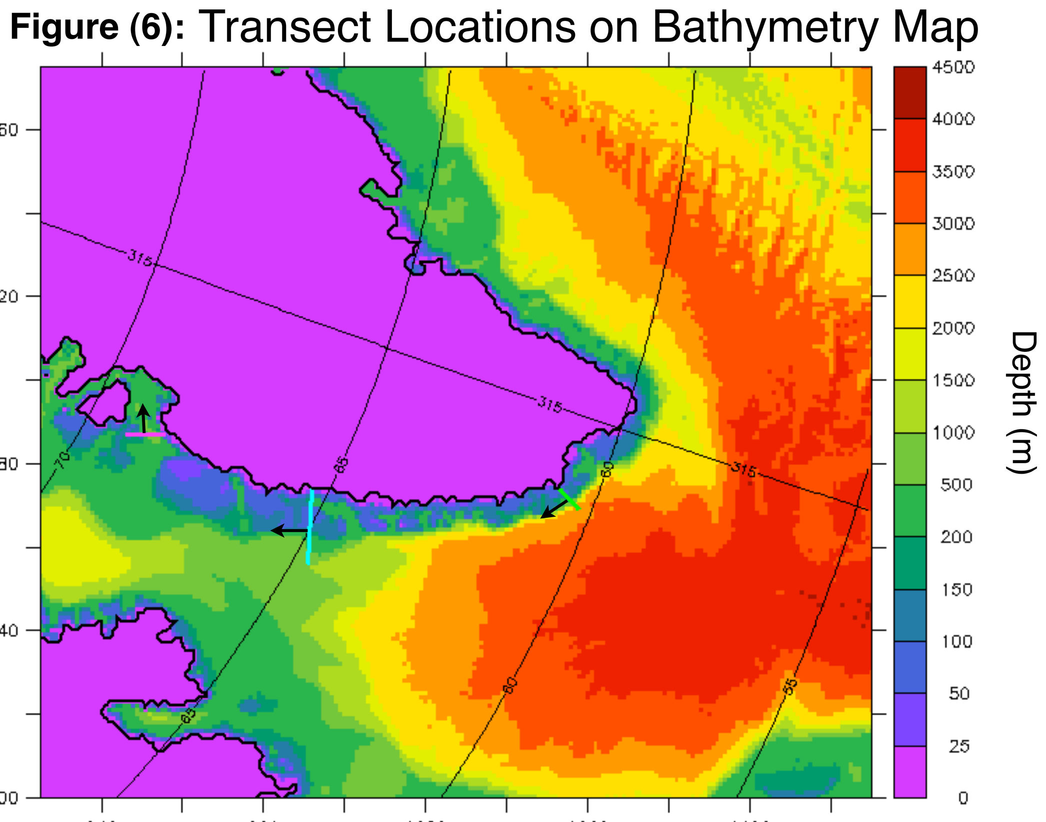


Figure (6): Transect Locations on Bathymetry Map

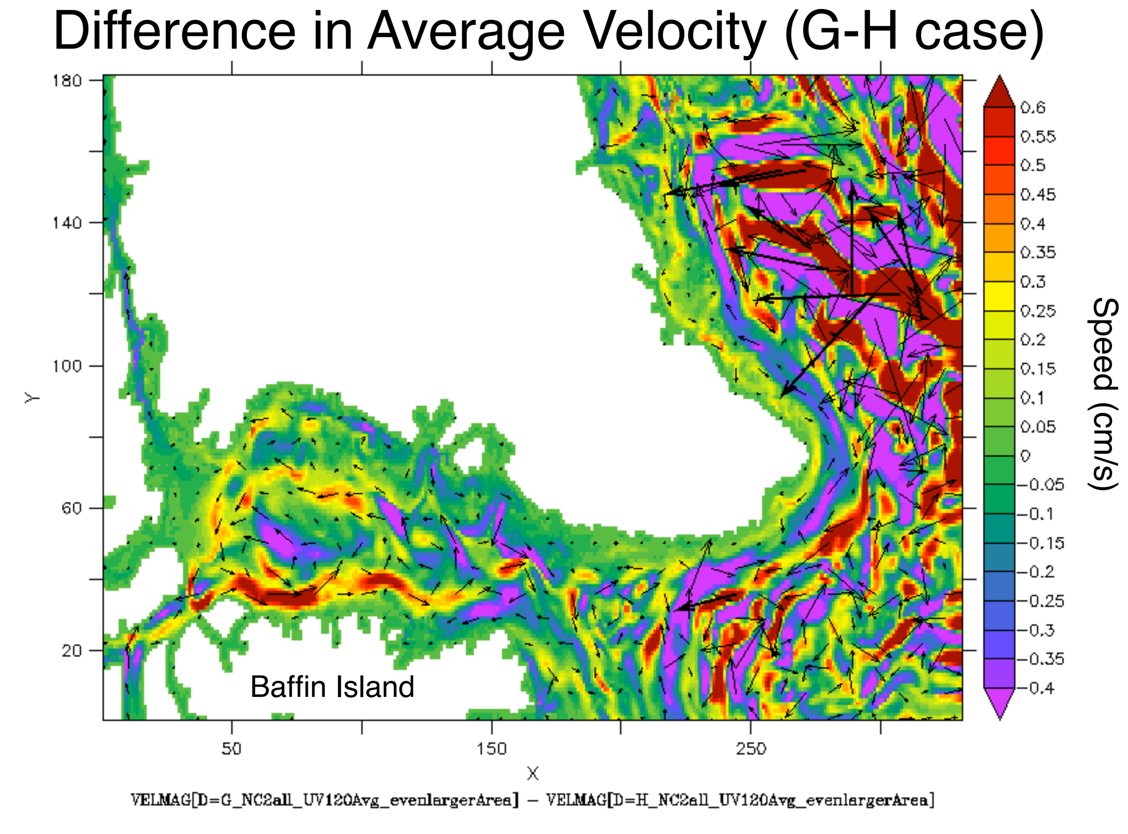


▲**Figure (6)** This map of the bathymetry of the ocean basins around Greenland contains three lines indicating the locations of vertical transects through which net volume and heat fluxes were calculated and shown in Figure (5) (left). The black arrows indicate the direction of positive net flow.

◀**Figure (5)** These plots depict the net volume and heat fluxes through each of the vertical sections indicated in Figure (6) for both the G case (with freshwater forcing, solid colored line) and the H case (without freshwater forcing, dashed black line). Below each of these plots is a difference between the two runs.

3. Surface Flow Evolution Differences

Difference in Average Velocity (G-H case)



▲**Figure (7)** Here we show the difference in the mean velocities of the surface ~120 m water layer throughout the 50 year run (1958-2007) between the run with freshwater (G case) forcing and without (H case). There is a slight enhancement of the flow along the boundary currents around Greenland, especially along the East Greenland Coastal Current compared the West Greenland Current. The most pronounced enhancement of the flow in the G-case occurs as the boundary current rounds the northern-most extent of Baffin Bay and flows south along the coast of Baffin Island.

Future Directions

We will further analyze these model results, focusing on how freshwater may alter ocean dynamics, especially around Greenland. With these two model simulations, we will better explore shorter time scale features in the ocean dynamics to understand if a realistically forced freshwater flux can enhance boundary current flow, especially in the West Greenland Current. Similarly, warm eddies emerging from intermediate Irminger waters could be affected by the bouyancy flow, and we will investigate how the simulations perform compared to observations.

While remapping CORE2 runoff values onto the POP domain for RASM runs, the factor of 1/10 was chosen by trial-and-error for its approximate agreement between the original freshwater mass flux and the remapped flux, but in a future run a more accurate transformation of the fluxes due to the correct proportion of each cell's area will be conducted.

References

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Steele, M., R. Morley, and W. Ermold. PHC: A global ocean hydrography with a high quality Arctic Ocean. Journal of Climate. 14, 2079-2087, 2001.