A Nested High-Resolution Simulation of Circulation in Sermilik Fjord, Greenland

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Introduction

The melting of Helheim Glacier at the head of Sermilik Fjord in southeast Greenland has been hypothesized to be strongly influenced by the exposure of the glacier terminating wall to warm, saline Atlantic Water (AW) (Straneo et al[1]; Sutherland and Straneo[2]). To examine the transport of AW from offshore, its transport and modication within the fjord and its interaction with the terminating glacier, a high-resolution numerical model study of the region is being carried out.

Methods

A three-level nested simulation of the region, shown in Fig 1, is being conducted using the Coupled-Ocean-Atmosphere-Wave-Sediment Transport (COAWST)[3] model that has been extended to include a Coupled Regional sea Ice Model (CRIM)[4] and ice-ocean interaction with ice shelves. The extended version of COAWST is denoted Polar COAWST (PCOAWST). Only the ocean model, based on the Regional Ocean Modelling System (ROMS)[5], CRIM and the ice shelf module are employed in this study.

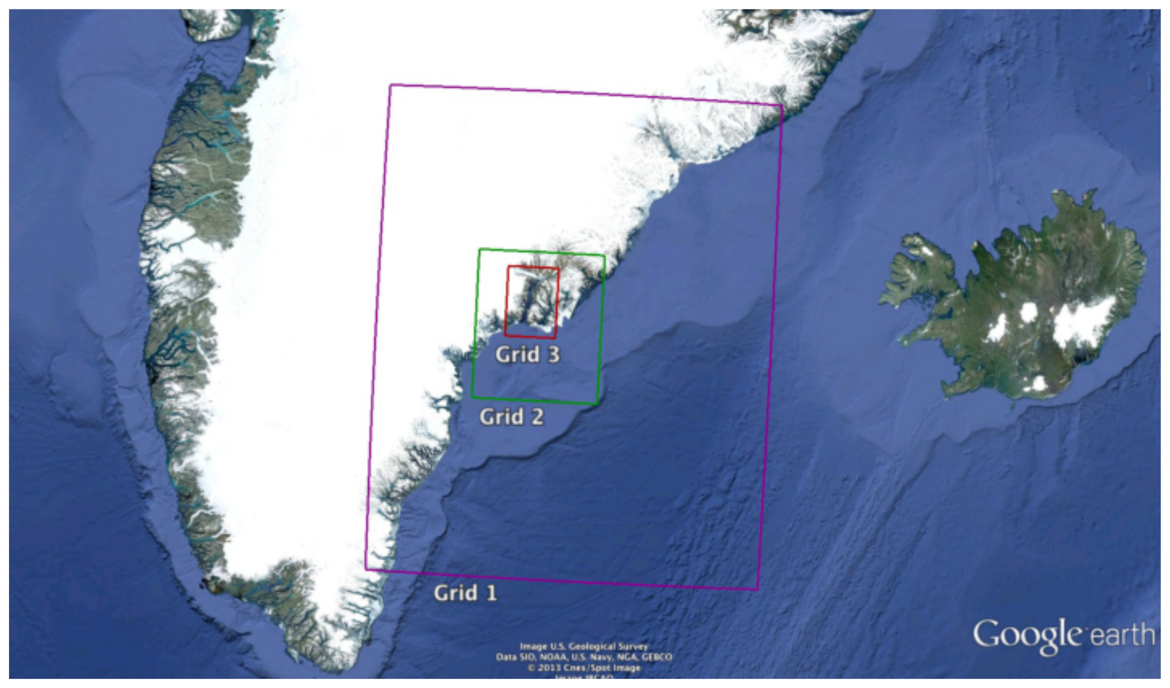


Fig 1. Nested PCOAWST grids.

One-way nesting is used with grid sizes of 2250 m ➔ 750 m ➔ 250 m. The vertical discretization is a 40-level generalized topography-following (s-coordinate) system. Boundary forcing on the outer grid is from the Simple Ocean Data Assimilation (SODA)[6] monthly-mean data set. Tides, with 8 constituents (K_2, S_2, M_2, N_2, K_1, P_1, O_1,Q_1) from the TPXO-7.2[7]data set are applied at the open boundary of outer grid. Atmospheric forcing was from the Climate Forecast System Reanalysis (CFSR)[8]. The melange at the head of the fjord at the 3 terminating glaciers was taken to be a 20 m thick ice shelf.

First, a simulation with just Grid 1 was carried out. The simulation was initialized with SODA and started at Jan. 1, 2008. The simulation was conducted for one year. Then a 3-level nested simulation, initialized from the Grid 1 fields was conducted from Oct. 20 – Nov. 29, 2008.

Results

A transect was sampled from the thalweg (black line) of the fjord in the level 3 nested model (Fig 2). The 40-day mean temperature and salinity distribution along the thalweg are shown in Figs 2 and 3. It can be seen that AW is transported up the fjord in the lower layer. At the cross-section (red line) mid-way up the fjord, it can be seen that the northward component of the mean current has considerable lateral structure. As reported by Sutherland and Straneo[2], the dynamics are dominated by a 2-layer baroclinic flow that is coherent over ~70 km in the lower fjord. The first mode EOF captures 68.4% of the variance in v at the cross-section

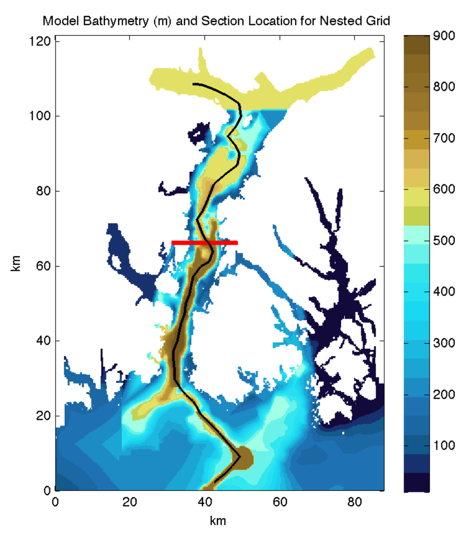


Fig 2. Section locations

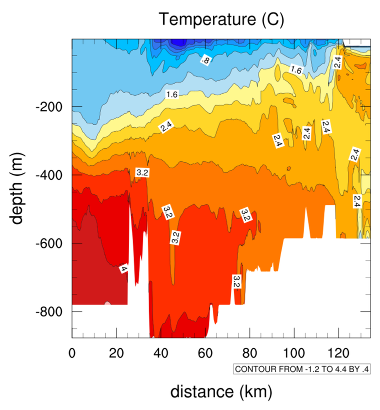


Fig 3. Thalweg T.

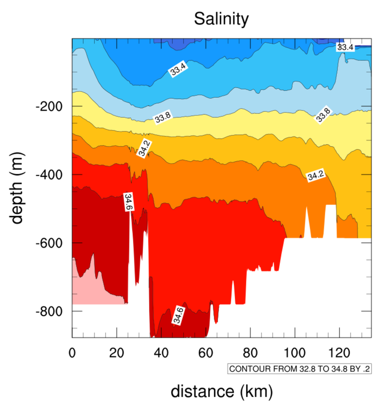


Fig 4. Thalweg S.

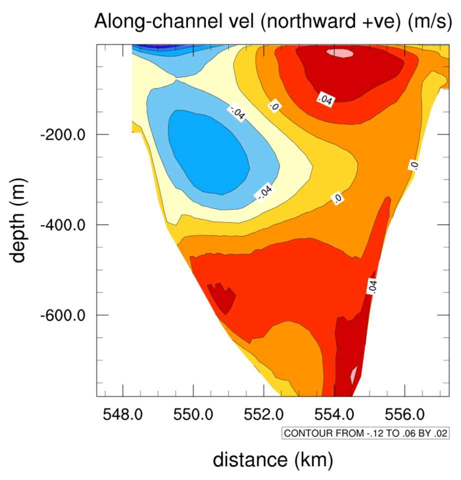


Fig 5. Mean v at cross-section

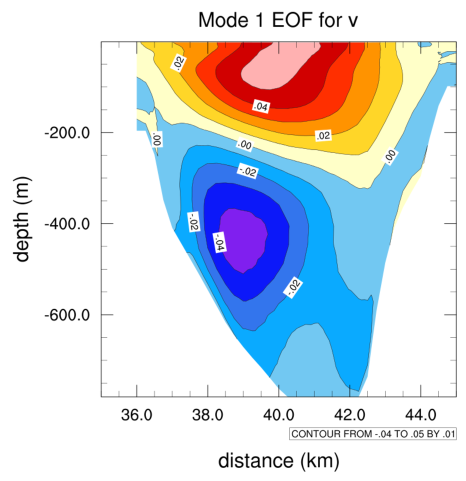


Fig 6. Mode 1 v-EOF at section.

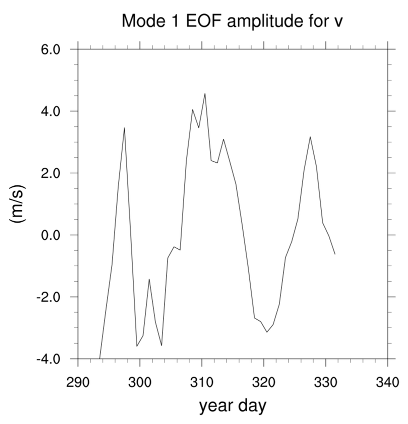


Fig 7. Amp. of EOF mode 1.

(Fig 6), with a reversal of the 2-layer circulation on 10-20 day time scales. To examine the influence of remote forcing, the results from the coarse model (Grid 1) were used. A real vector EOF analysis of (u,v) vertical profiles at the station locations in Fig 8 was carried out. The first 3 modes accounted for 68% of the total variance. Since the time scale of the EOF amplitudes was in the 10-20 day meteorological band, an EOF analysis of sea level pressure from CFSR was performed. The ocean velocity field at the stations was then reconstructed through the use of a Canonical Correlation Analysis (CCA) between the model velocity EOFs and CFSR SLP EOFs. For one station near the mouth of the fjord, the model v-

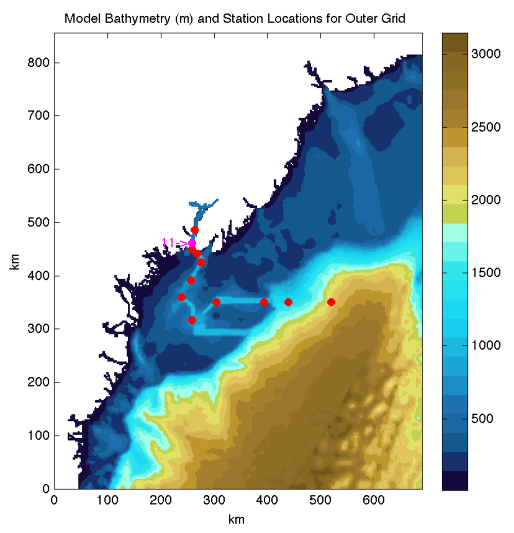


Fig 8. Station locations in Grid 1 model. Time series shown at magenta marker (denoted 11).

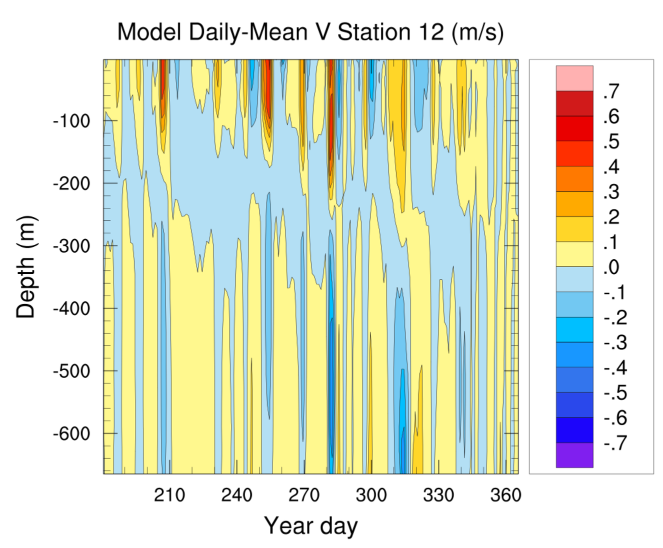


Fig 9. Hovmüller diagram of v-component at station 12 (denoted 11 in Fig 8).

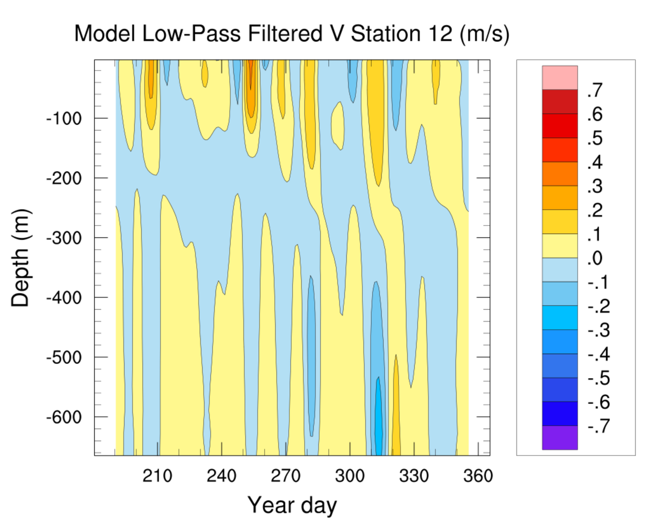


Fig 10. Same as Fig 9, but for low-pass filtered v with ½ power point at 10 days.

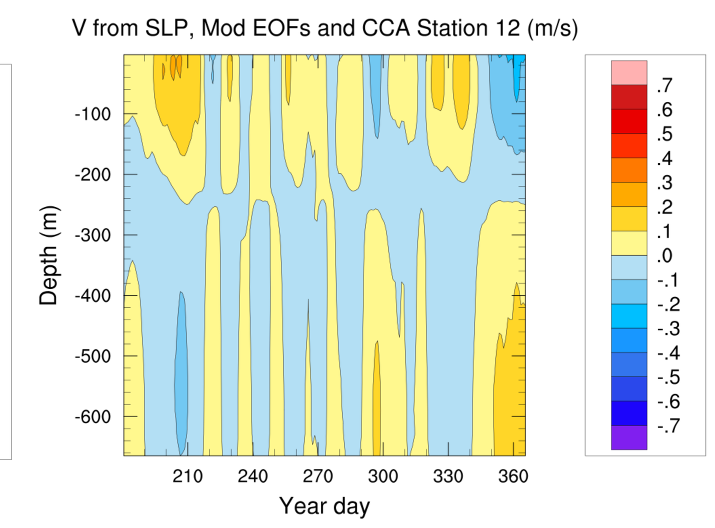
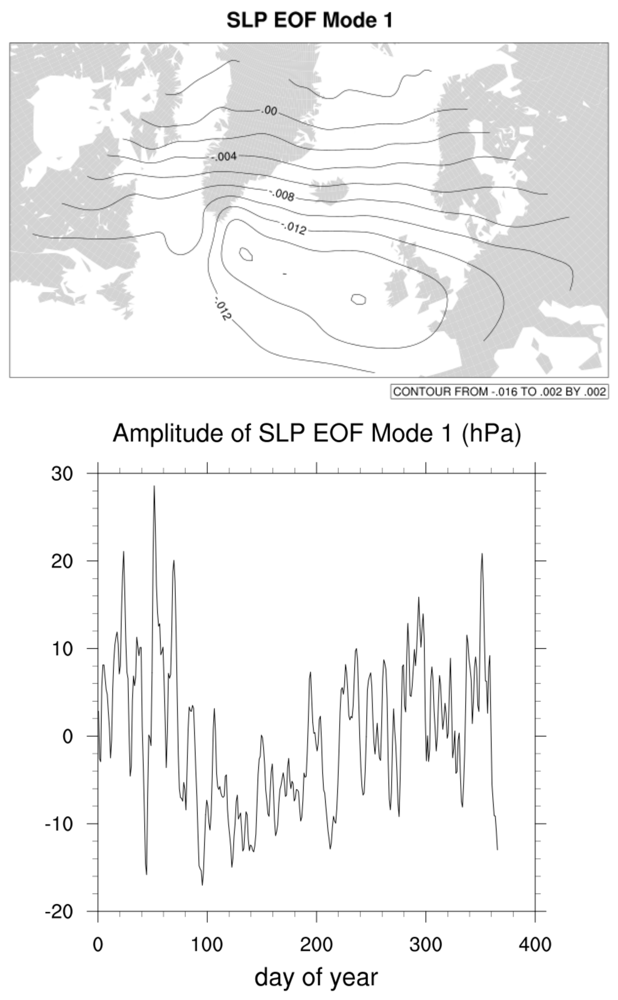


Fig 11. Same as Fig 9, but for v reconstructed from EOFs of (u,v) station data and CCA with EOFs from SLP.

component of velocity, the low-pass filtered v-component and the EOF/CCA reconstruction of the v-component are shown in Figs 8, 9, and 10, respectively. The structure of the first 3 SLP EOF modes and the amplitude time series of mode 1 are shown in Fig 12. Intensification of the Icelandic Low is positively correlated with inflow to the fjord near the bottom and outflow from the fjord near the surface. While there is a correspondence



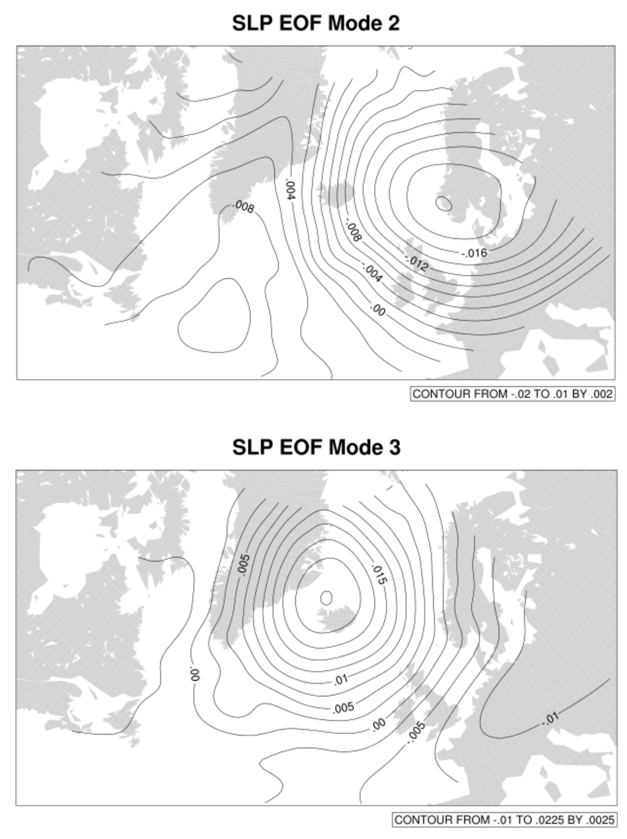


Fig 12. Structure of 1st 3 SLP EOFs. Amplitude time series of mode 1.

between the occurrence of reversal events in Figs 10 and 11, the reconstructed current amplitudes are too weak and there are systematic phase errors. The reconstructed v-component accounted for only 12.7% of the variance of the filtered model result at station 12. This would suggest that variability in the North Atlantic atmospheric circulation on 10-20 day time scales are generating variability in the East Greenland Current, the Irminger Current and the North Icelandic-Irminger Current that could produce fluctuations in AW inflow/Polar Water outflow.

Conclusions

These are very preliminary results from a simulation that is still underway. In order to generate robust estimates for the mean circulation, the nested model will need to be run for at least a year. These early results suggest there is a relationship between large-scale atmospheric variability in the region and Sermilik Fjord baroclinic exchange processes, but most likely the the fjord exchanges are primarily caused by atmospherically-induced variability in the regional current systems. This possibility will be examined in the next stage of the study. Not shown here is the encouraging result that the first mode EOF amplitude time series from the outer and innermost nested models are nearly identical for v-profiles at the same location in the two models. The fine (250 m) grid model provides much more horizontal structure. This gives us some hope that the nesting approach used here could be a useful means of downscaling climate model results to the fjord-scale, in particular to forge a link between regional ocean circulation and glacial melting processes.

Bibliography

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