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Sub-Mesoscale Modelling of the Labrador Sea

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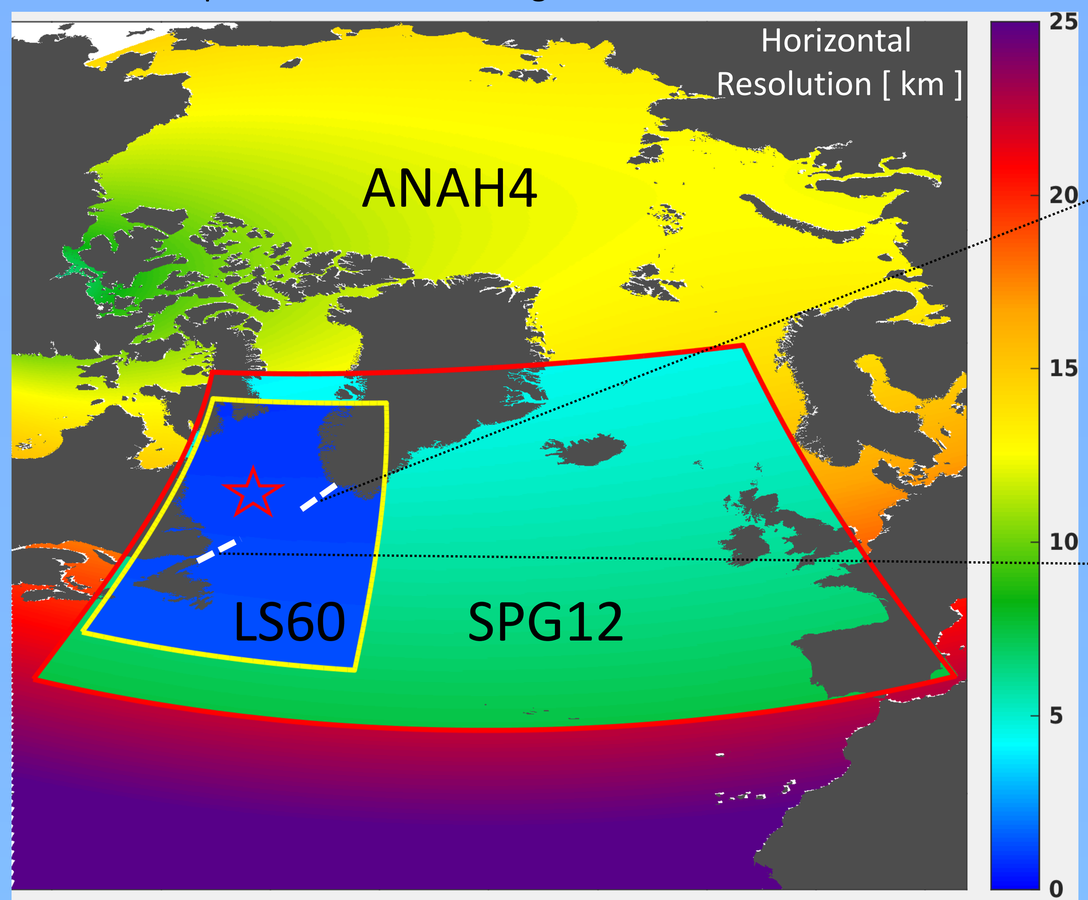
Motivation

- The Labrador Sea contains a region of deep convection ☆
- The result of deep convection is a newly ventilated water mass: Labrador Sea Water
- Labrador Sea Water is one component of the Meridional Overturning Circulation
- Small-scale features, including eddies, play an important role controlling deep convection
- Mesoscale simulations may poorly resolve these features, misrepresenting convection
- Boundary currents may also be misrepresented at lower resolution
- Thus the volume, variability, and export pathway of Labrador Sea Water may affect on sub-mesoscale features

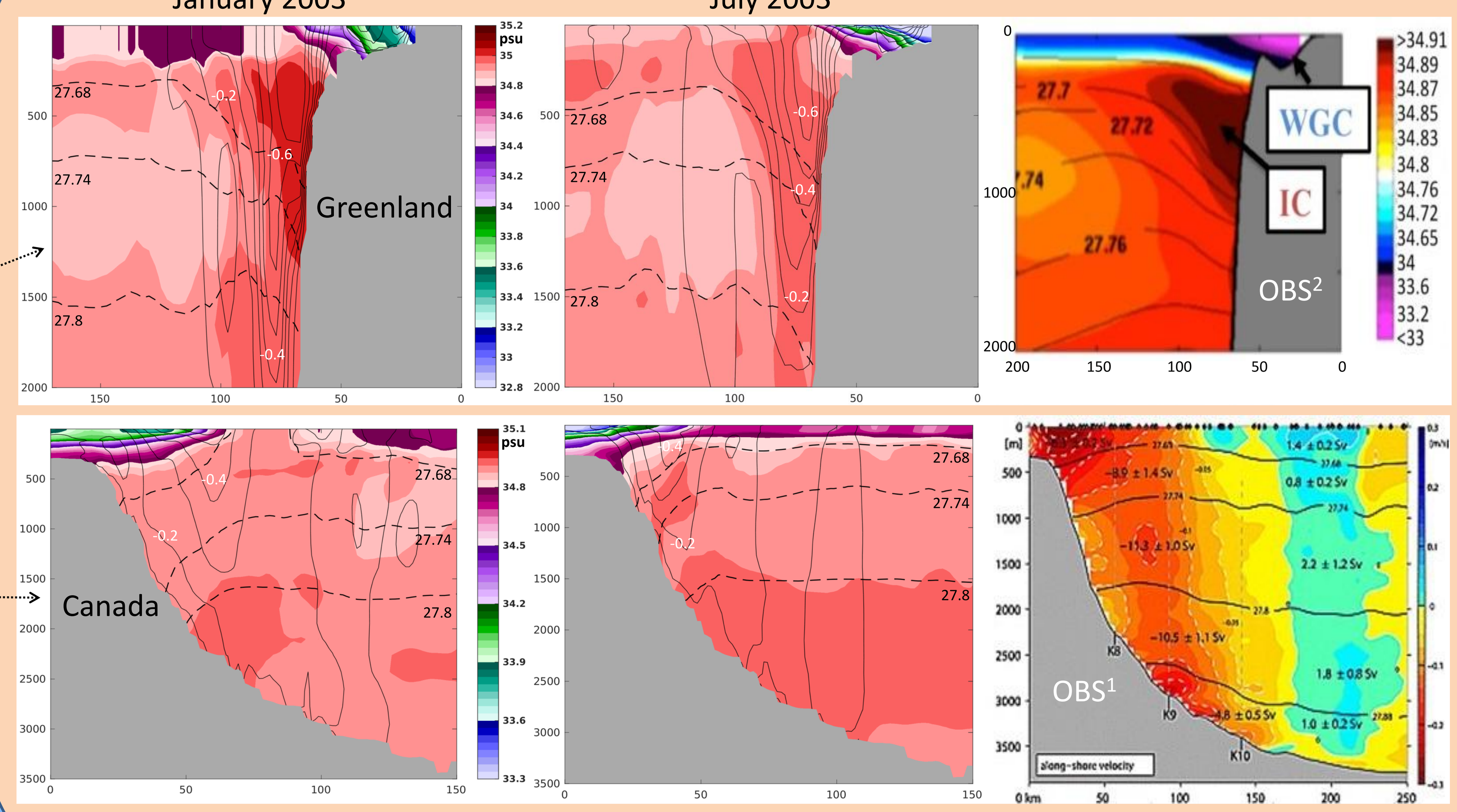
Model Plan

- We simulate the Labrador Sea at 1/60° and explore the crucial role of sub-mesoscale activity
- We compare against our traditional ¼° and 1/12° simulations as well as observations
- The simulations is currently underway from 2002-2017: only 2 years are finished

Domain setup:
1/4° regional configuration (ANHA4)
1/12° nest in the Sub Polar Gyre (SPG12)
1/60° inner nest in the Labrador Sea (LS60)
Open Boundaries: Bering Strait and 20° S latitude

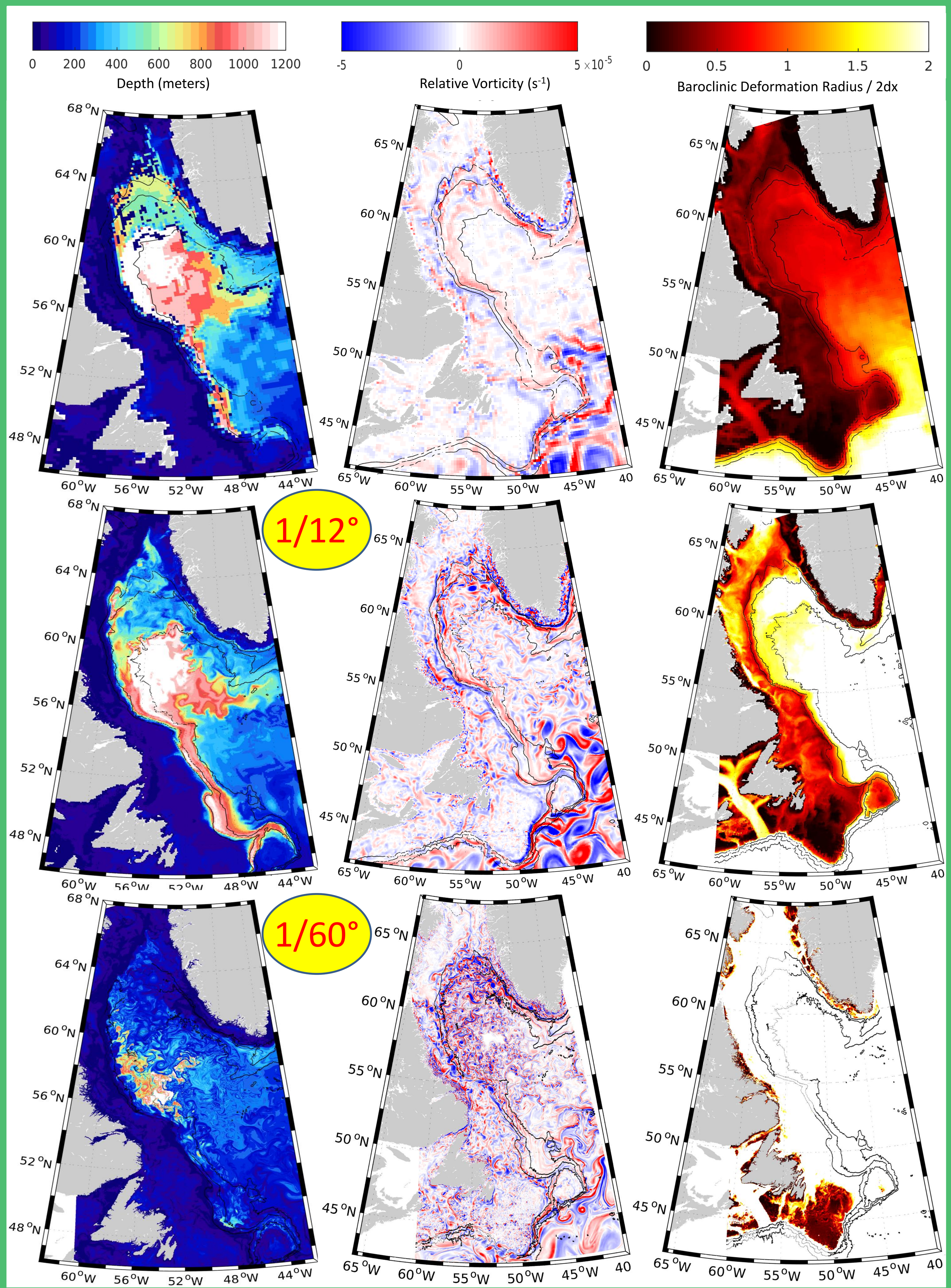


Cross Sections



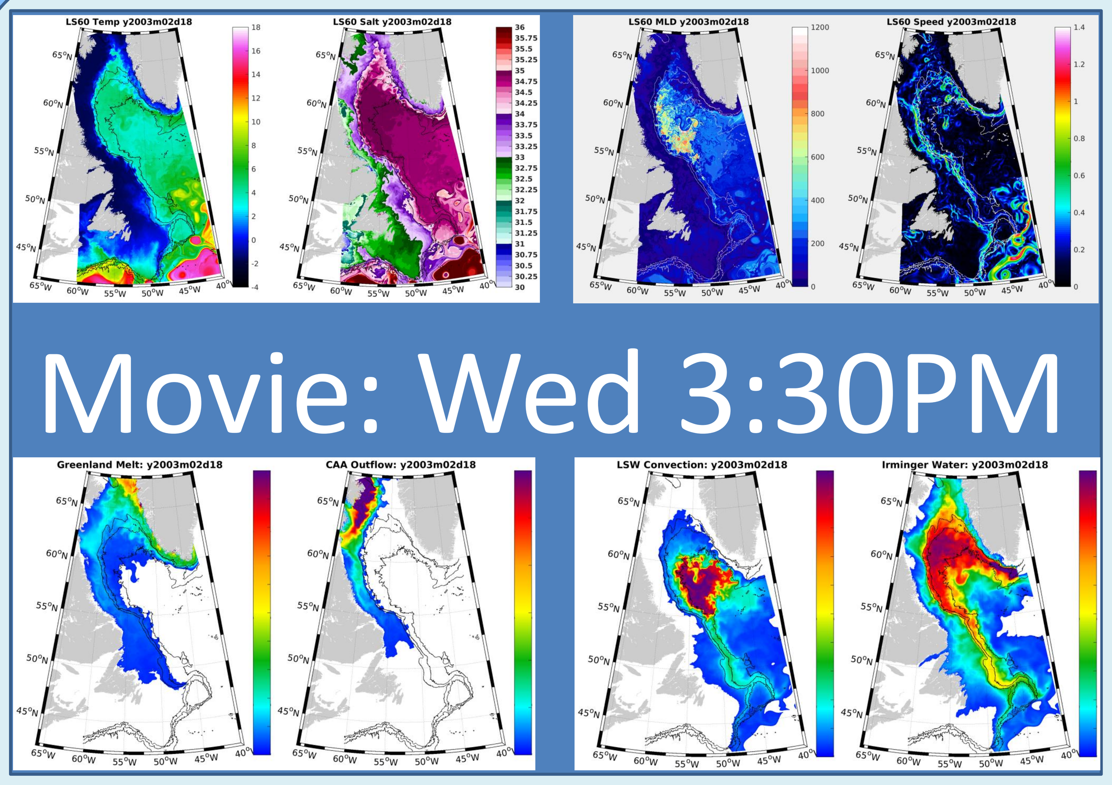
Through-section speed (solid contours) has units of m s^{-1}, while potential density (dashed contours) is kg m^{-3}

Impact of Model Resolution



- LS60 has a dramatically reduced region which experiences deep mixing
- Much closer in spatial extent and location to observations than at 1/12° and 1/4 °
- Vorticity shows varying levels of sub-mesoscale features resolved
- Most of the LS60 simulation has finer spatial spacing than the deformation radius

Movie Highlights



Salinity (50m):
- Fresh core of Irminger Rings visible

Mixed Layer Depth:
- Localized region of convection
- Close to Labrador coast

Speed (50m):
- Highly coherent eddies/Irminger Rings
- Eddies persist for many months
- Swift boundary currents

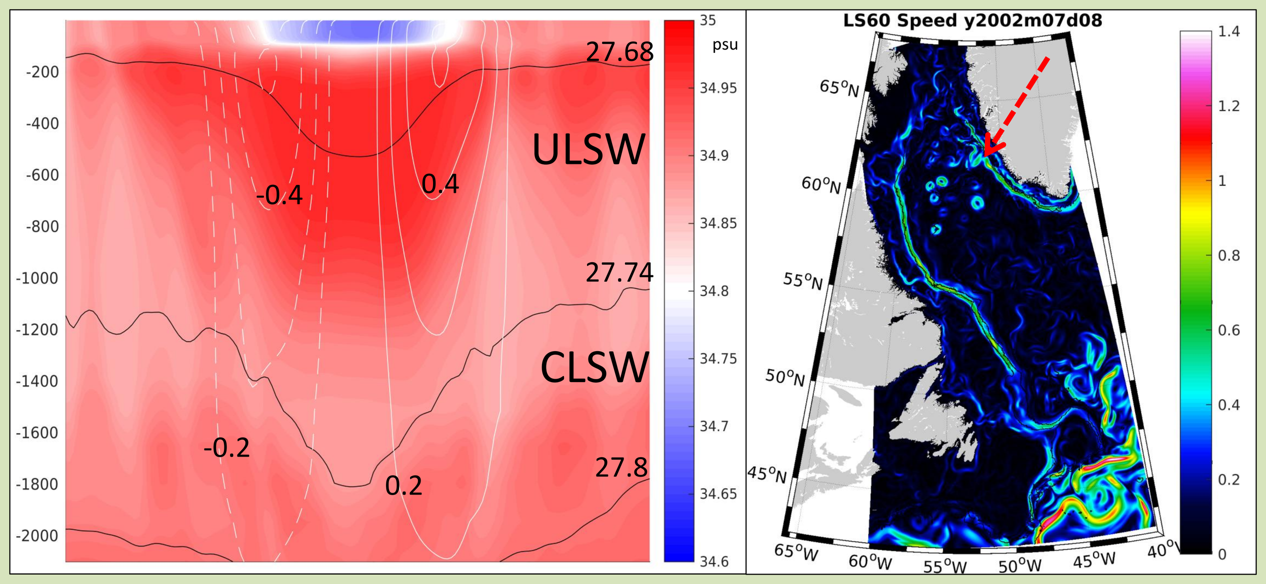
Greenland Melt:
- Large flux towards interior of LS via Greenland
- Large outflow from Baffin Bay
- Stays along Labrador shelf-break

CAA outflow Tracer:
- Stays on Labrador shelf

LSW convection Tracer:
- Small scale onset of convection
- Slowly spreads eastward, quickly spreads along Labrador Coast

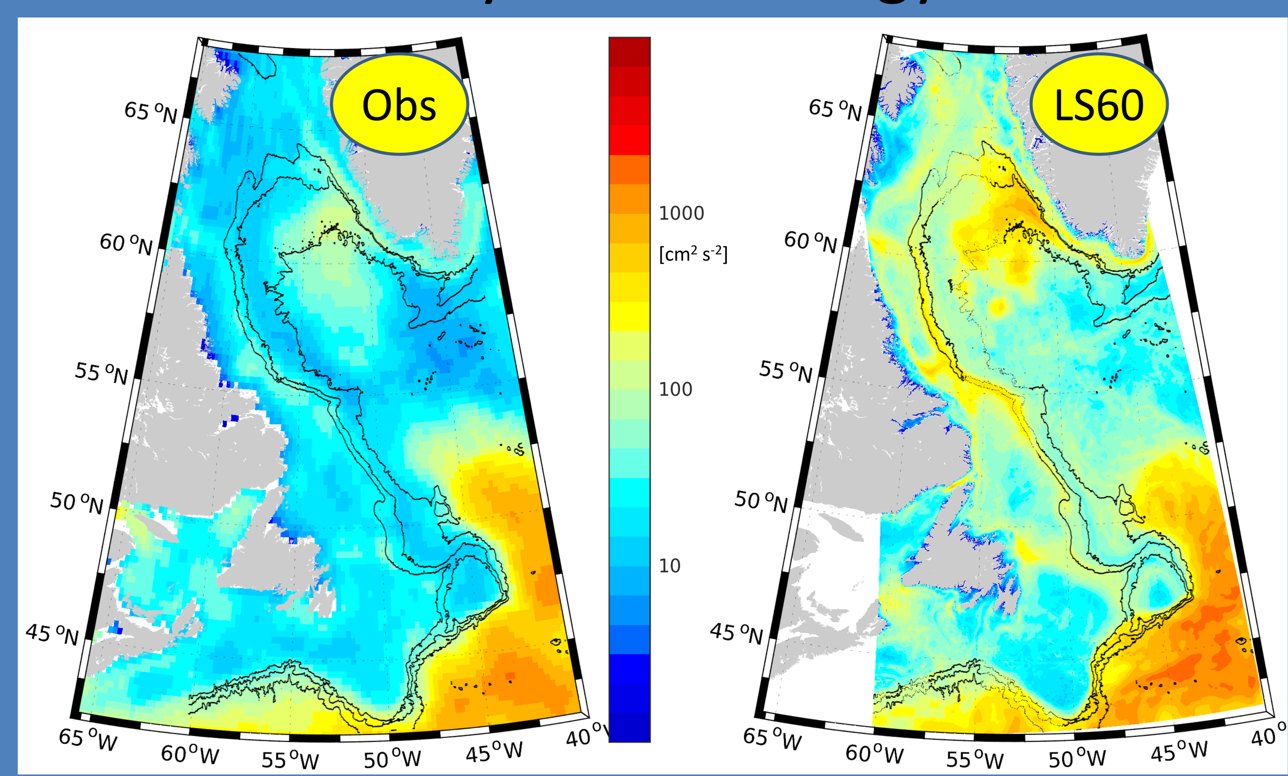
Irminger Water Tracer:
- Recirculation at Cape Farwell
- Crosses Labrador Sea between 2000 and 3000m isobaths

Inside an Irminger Ring



East-west section through the center of an Irminger Ring
White contours are north-south speed [m s^{-1}], black contours are potential density
- Well contained freshwater core (West Greenland Current) within top 100m
- Salty Irminger core extends down to 500m
- Well deformed isopycnals shows clear contrast between Irminger Ring and ambient water

Eddy Kinetic Energy



- Very good agreement on location of strong eddy activity
- LS60 has stronger EKE within Labrador Sea, probably from short averaging period
- North Atlantic Current + Northwest corner are very well simulated

Simulation Expense

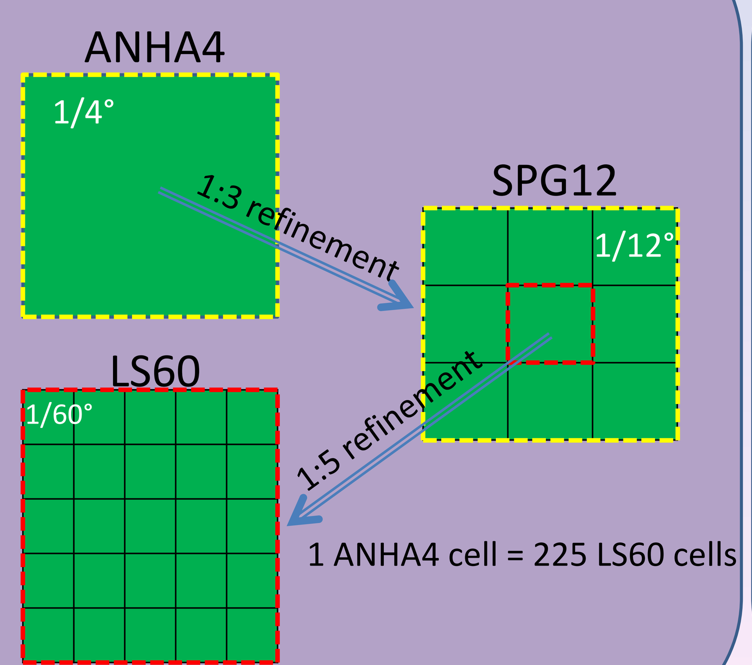
Configuration	ANHA4	ANHA12	LS60
Time step	1080s	180s	40s
Horizontal Resolution	1/4°	1/12°	1/60°
Horizontal Grids	544x 800y	1632x 2400y	1180x 2660y
Vertical Level	50	50	75
CPUs used	64	256	672
Cost in core years	0.3 yr^{-1}	25 yr^{-1}	65 yr^{-1}
Output frequency	5 day	5 day	1 day
Storage	15 Gb yr^{-1}	130 Gb yr^{-1}	1.2 Tb yr^{-1}

[1] Fischer et al., 2010: Interanual to Decadal Variability of Outflow From the Labrador Sea, *Geophys. Res. Lett*. 37
[2] Rykova et al., 2015: Seasonal and Interanual Variability of the West Greenland Current System in the Labrador Sea, 1993-2008, *J. Geophys. Oceans,* 120, 1318-1332
[3] Madec and the NEMO team, 2008: NEMO ocean engine, Technical Note, Institut Pierre-Simon Laplace, France
[4] Debreu, Laurent, Christophe Vouland, and Eric Blayo. "AGRIF: Adaptive grid refinement in Fortran." *Computers & Geosciences* 34.1 (2008): 8-13
[5] Smith et al., 2014: A new atmospheric dataset for forcing ice-ocean models: Evaluation of reforecasts using the Canadian global deterministic prediction system, *Quarterly Journal of the Royal Meteorological Society*, 140.680, 881-894

Configuration Settings

Setting	LS60 Simulation	Notes
Numerical Model	NEMO[3]	Version 3.6
Sea-Ice model	LIM2	Lim3 not fully compatible with AGRIF
Nesting Software	AGRIF	1:3 ratio between ANHA4 and SPG12 1:5 ratio between SPG12 and LS60
Atmospheric forcing	CGRF[5]	Hourly, 33km resolution
Initial Conditions	GLORYS1v1	T/S/U/V/SSH
Boundary Conditions	GLORYS1v1	T/S/U/V/SSH/Ice
Passive Tracers	4	Greenland melt, Irminger Water, CAA outflow, LSW formation
Simulation Period	2002-2017+	Same period as CGRF forcing
Sea Surface Restoring	None	

AGRIF[4]



Key Points

- Higher resolution presents significant differences
- Area of convection has been reduced and confined to be more reasonable
- Well resolved mesoscale and sub-mesoscale activity across the domain
- Freshwater primarily enters the Labrador Sea interior via west Greenland

Research Goals

Examine the influence of sub-mesoscale features on:
- Stratification within the Labrador Sea and LSW formation
- Contribution of convective eddies on restratification
- Air-sea fluxes
- Cross-shelf exchange of freshwater
- Water mass pathways determined by passive tracers