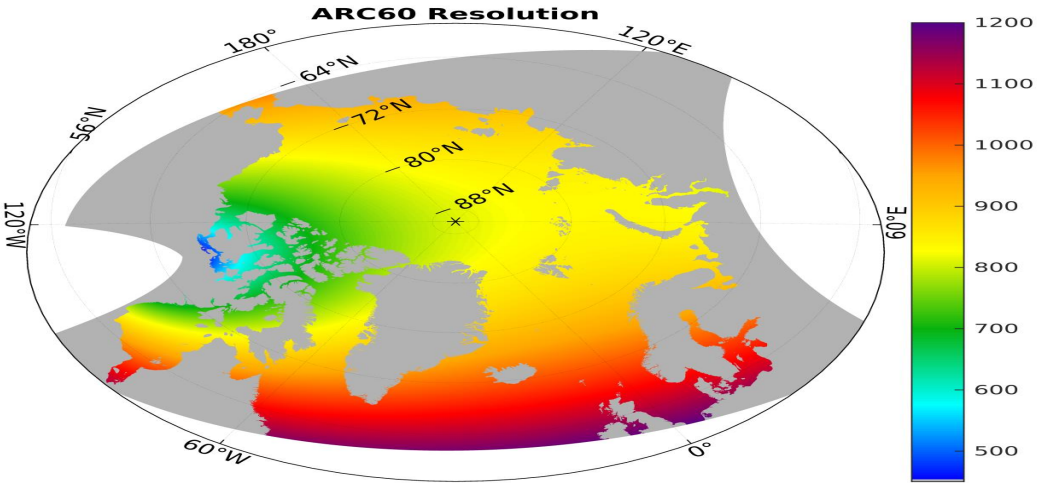
Sub-mesoscale modelling of the Arctic Ocean, including Baffin Bay



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Ventilation Interactions and Transports Across the Labrador Sea

MEOPAR

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ArcticNet

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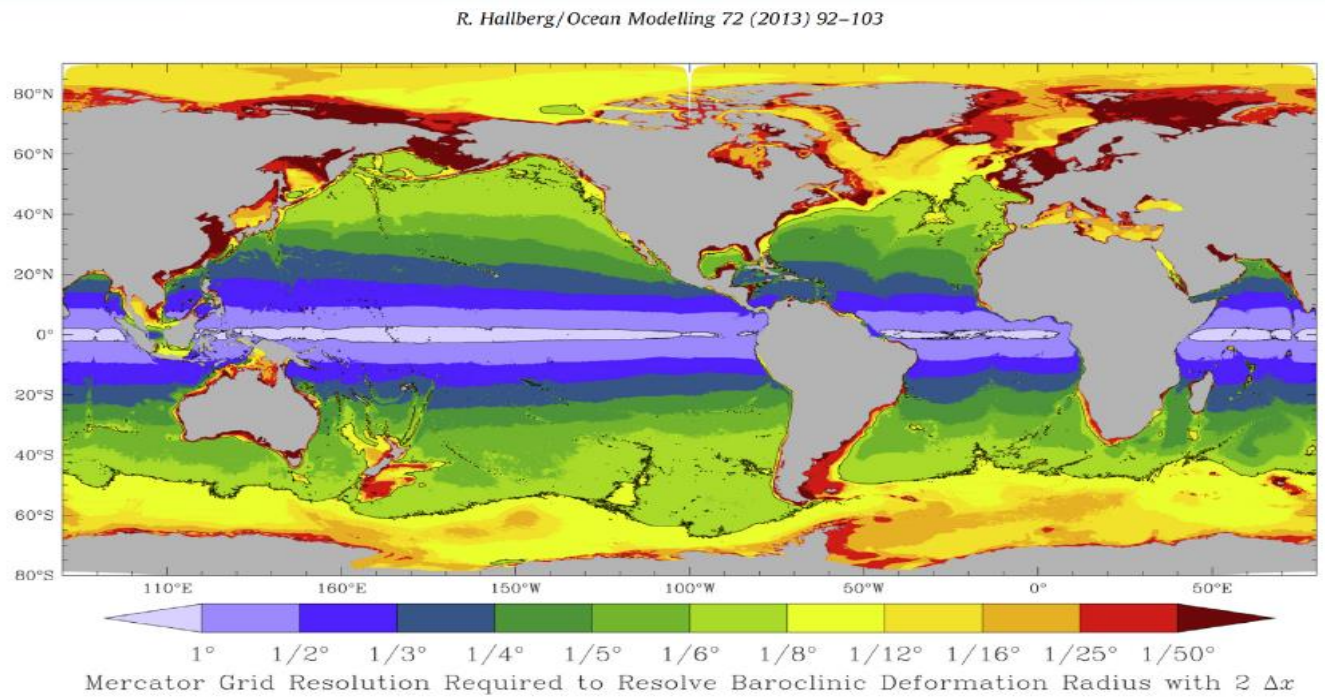
eas Earth & Atmospheric Sciences

Overview

- Challenges and needs for very high resolution modelling
- Previous work showing value of 1/60th degree simulations in the Labrador Sea
- Arctic60 Configuration
- Arctic eddies and freshwater content
- Baffin Bay processes related to Greenland melt
- Summary

Ocean Modelling Challenges

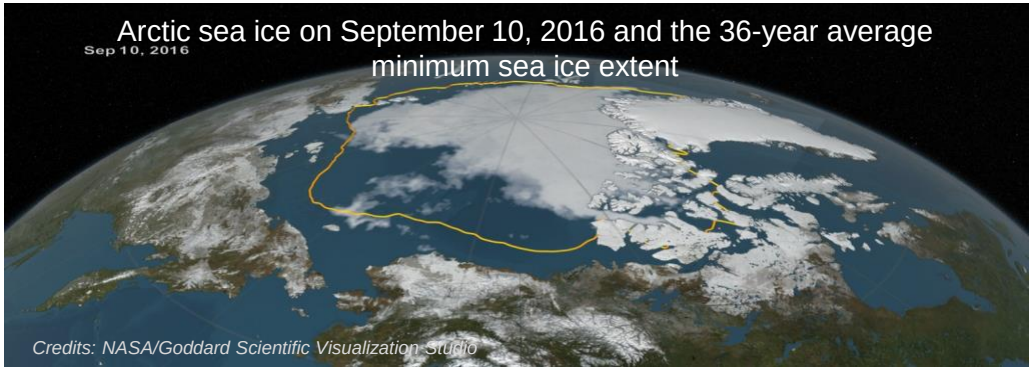


The density change from top to bottom is much smaller than the atmosphere – 1.02 to 1.04 gr/cm^3. This makes the Rossby radius much smaller – 100s to 10s km.

Changes in the Arctic Ocean Freshwater Budget

Changes in the 2000s compared to 1980-2000 ($x10^3$ km^3):

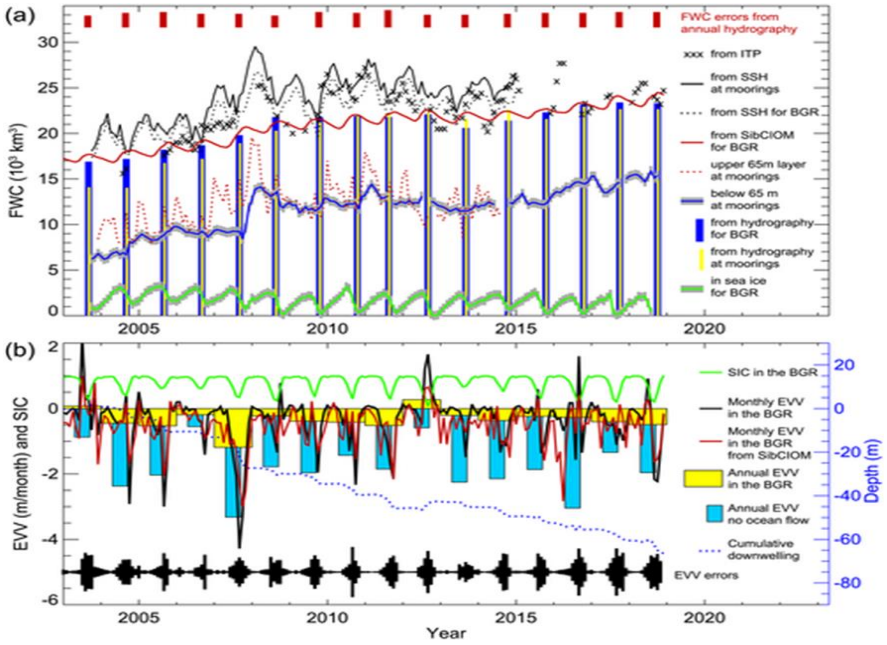
Liquid FW	(93➔101):	+9%
Beaufort Gyre	(16.9➔22.6):	+34%
Multiyear ice	(10.9➔ 7.4):	-33%
Seasonal ice	(13➔13.4):	+3%



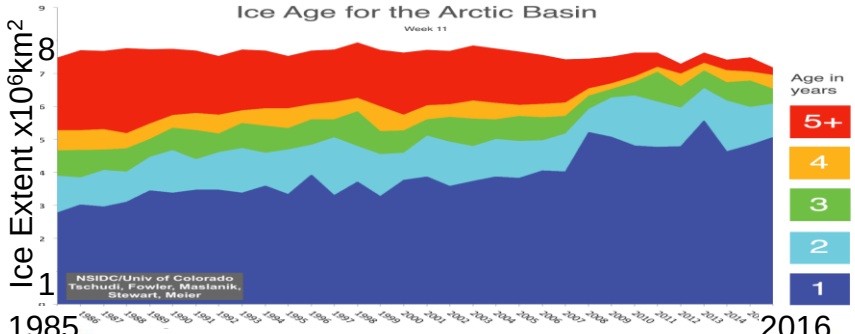
Fluxes ($x10^3$ km^3/yr):

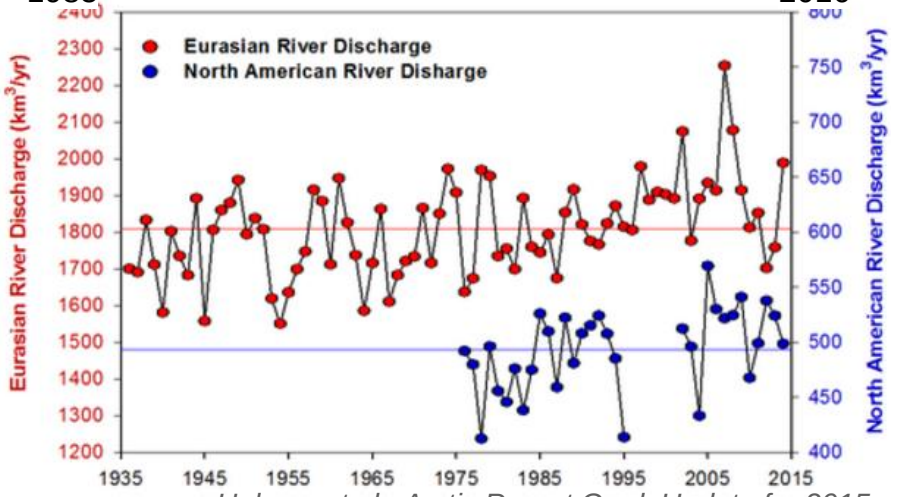
P-E	(2 ➔ 2.2):	+10%
Runoff	(3.6 ➔3.8):	+8%
Bering FW	(2-2.5 ➔3-3.5):	+4%
Net Ice Melt	(0.27 ➔0.29):	+8%

Haine et al., 2015; Shiklomanov, 2010; Woodgate et al., 2012; Proshutinsky et al., 2009.



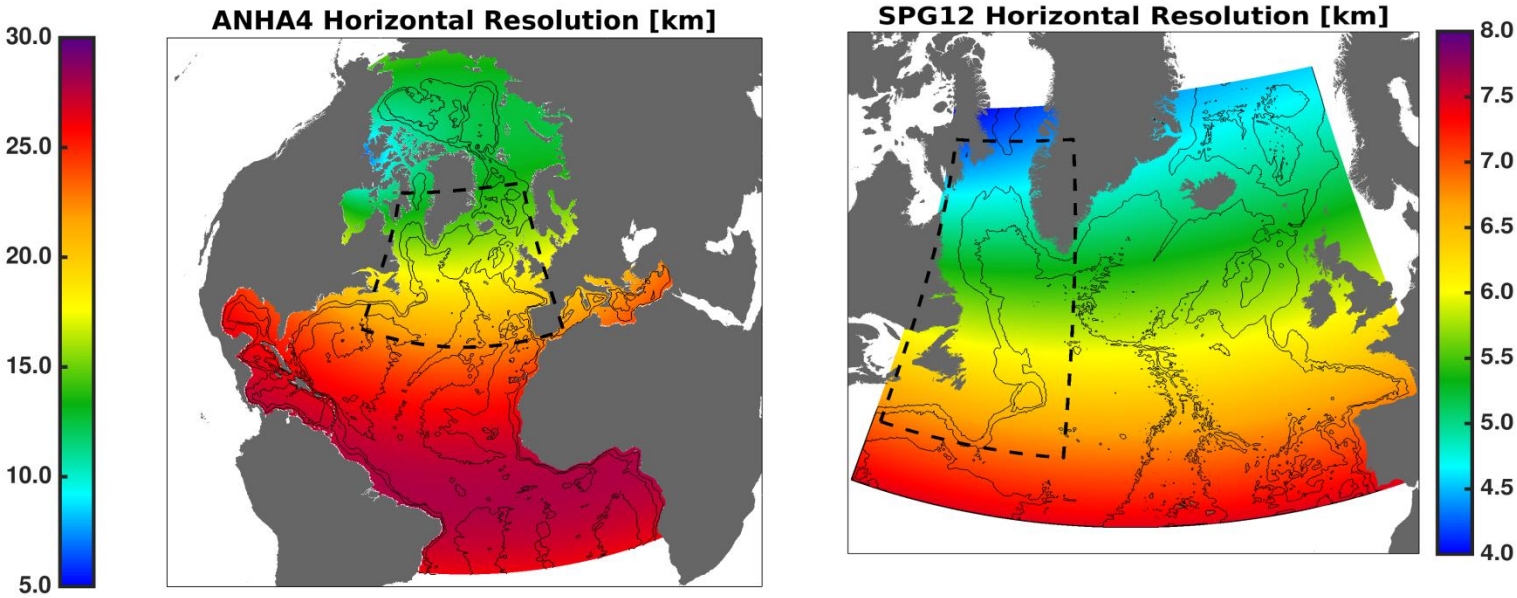
Proshutinsky et al., 2019

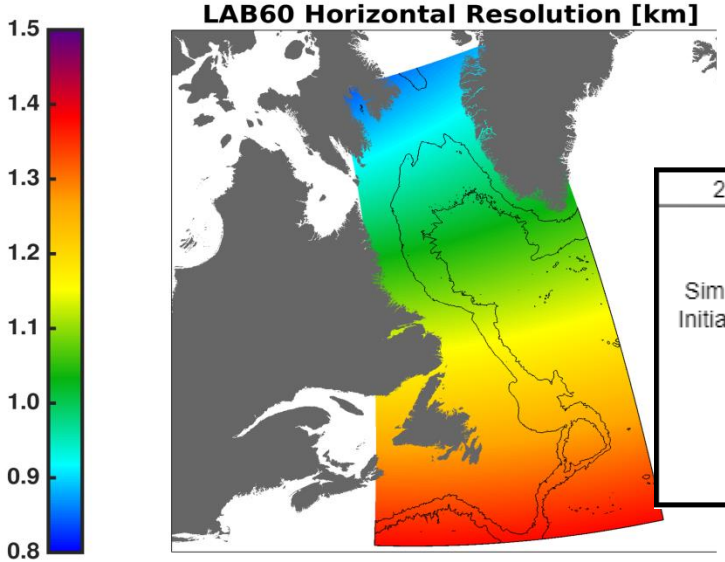


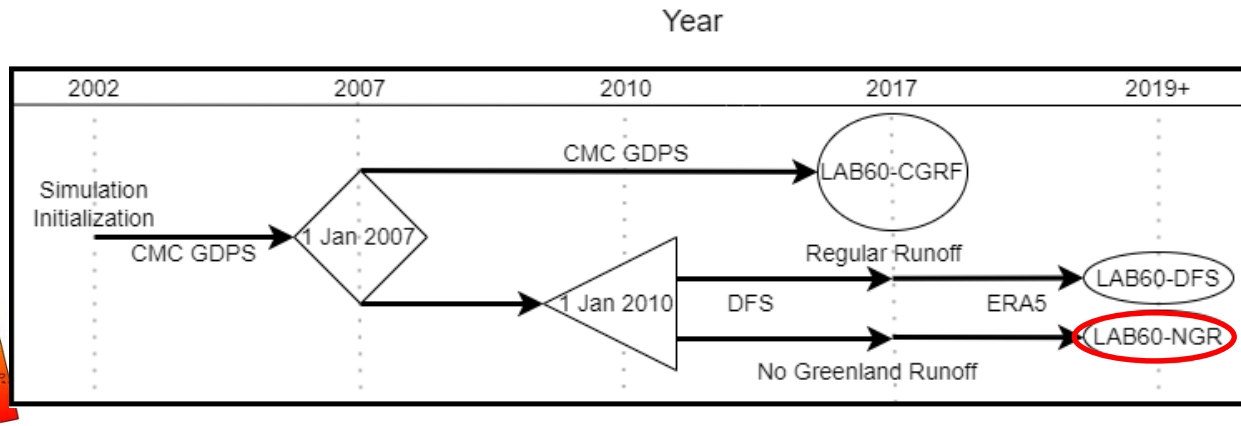


Holmes et al., Arctic Report Card: Update for 2015.

LAB60

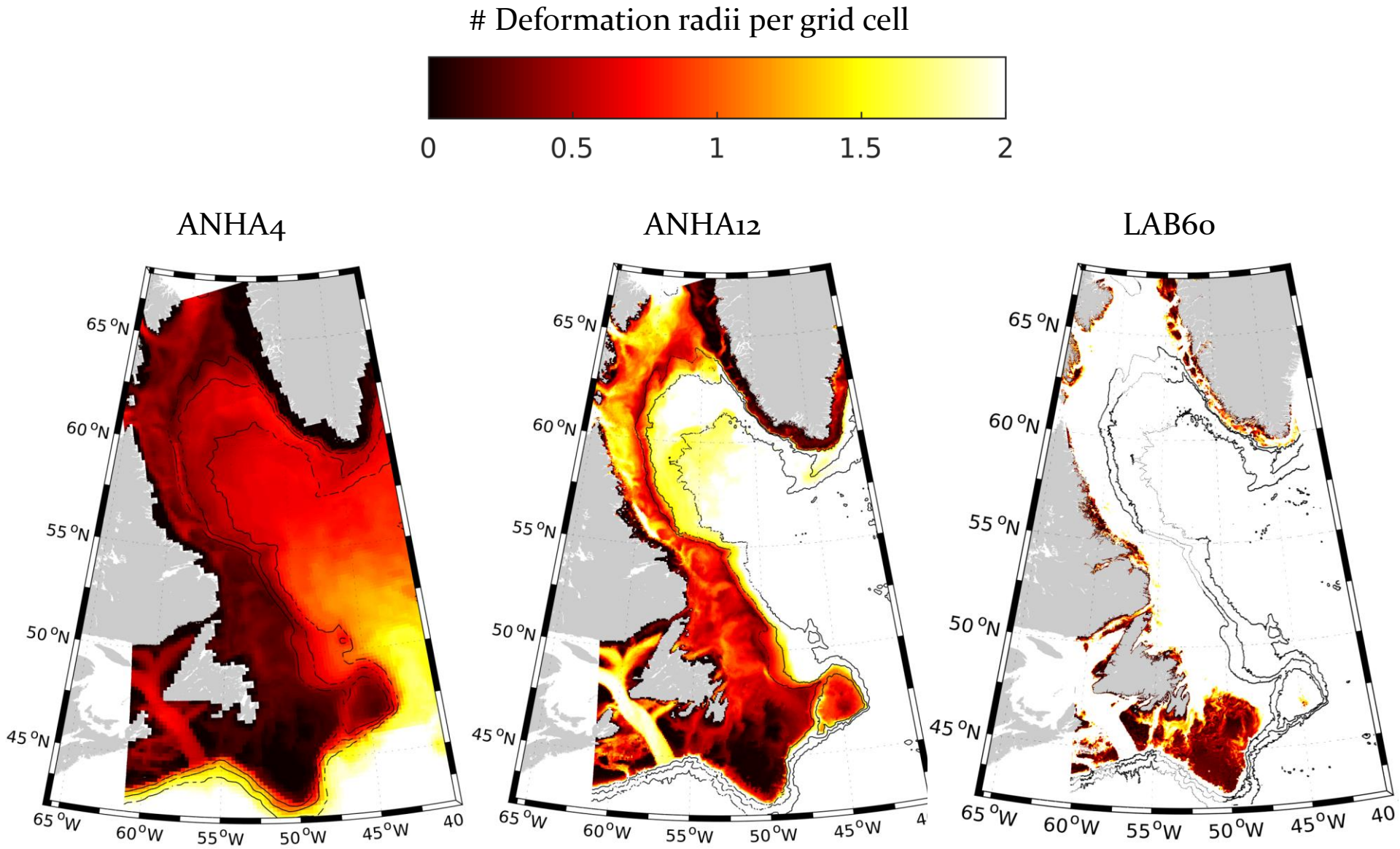

ANHA4 Horizontal Resolution [km]
30.0
25.0
20.0
15.0
10.0
5.0
SPG12 Horizontal Resolution [km]
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0


LAB60 Horizontal Resolution [km]
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8


Year
2002
2007
2010
2017
2019+
Simulation Initialization
CMC GDPS
1 Jan 2007
CMC GDPS
LAB60-CGRF
1 Jan 2010
Regular Runoff
DFS
LAB60-DFS
ERA5
LAB60-NGR
No Greenland Runoff

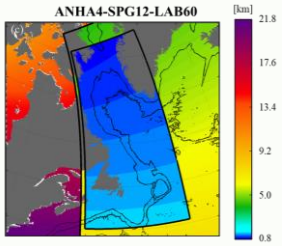
Eddy Resolving Power

Pennelly and Myers, 2020

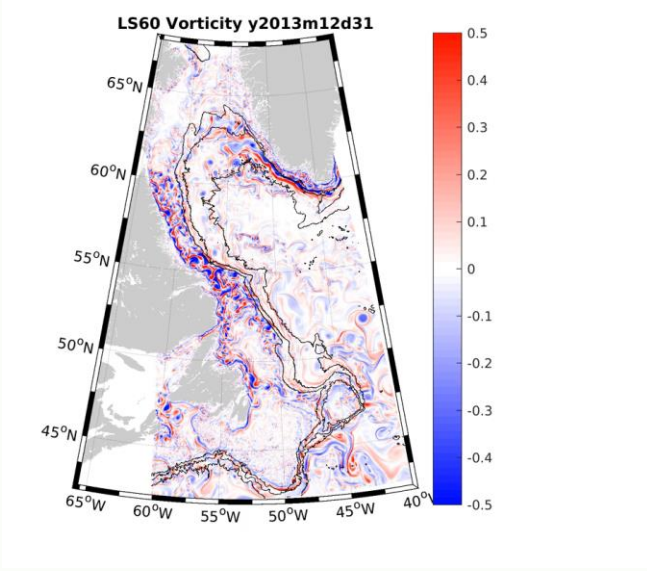


Motivation for Eddy Analysis

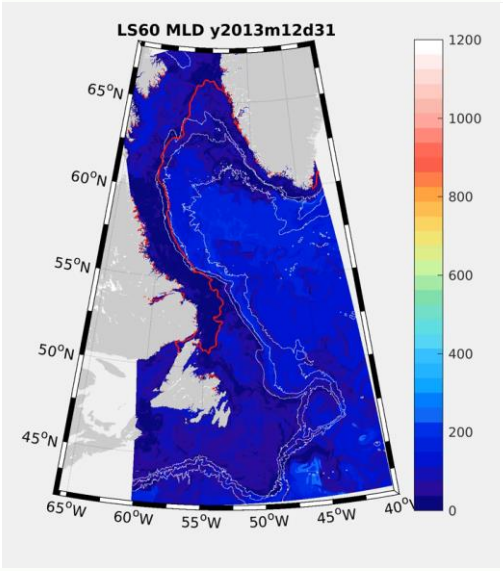
ANHA4-SPG12-LAB60-DFS/ERA5 Experiment



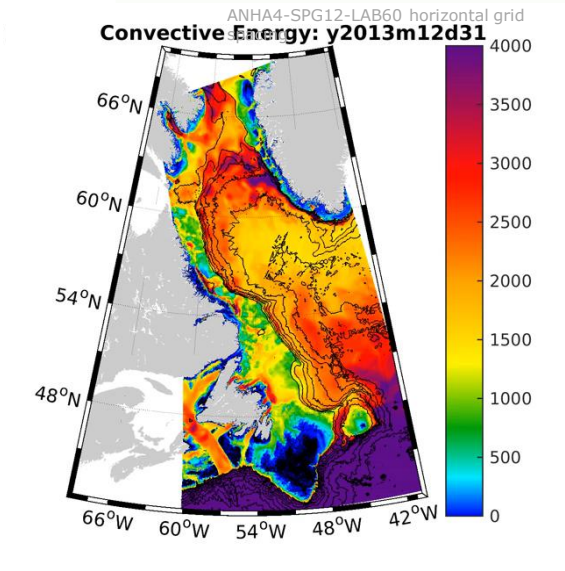
ANHA4-SPG12-LAB60 horizontal grid



Vorticity



Mixed Layer Depth [m]



Convective Energy [J/m^3]

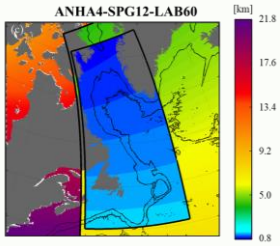
A high convective resistance value

A strongly stratified column of water

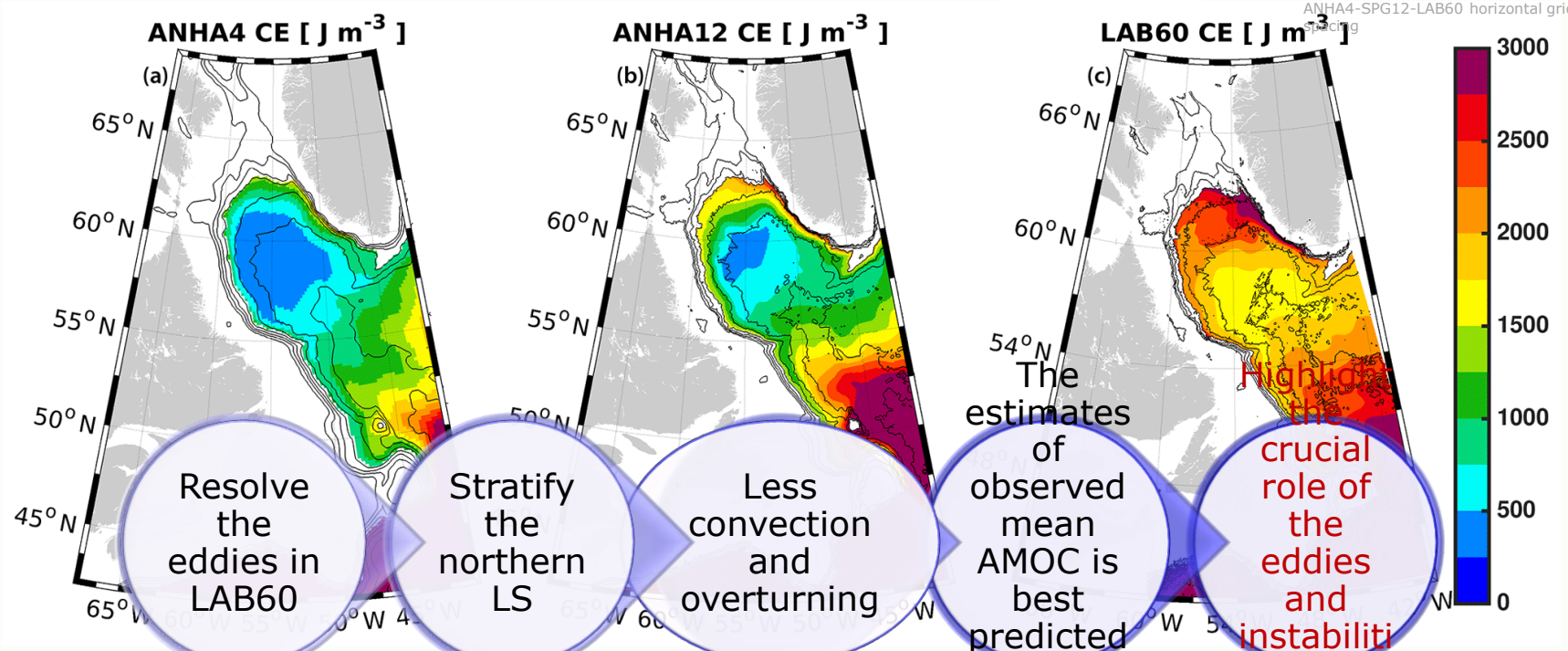
Pennelly et al. (2020)

Motivation for Eddy Analysis

Convective Energy [J/m^3]



ANHA4-SPG12-LAB60 horizontal grid spacing



Resolve the eddies in LAB60

Stratify the northern LS

Less convection and overturning

The estimates of observed mean AMOC is best predicted by LAB60 model

Highlight the crucial role of the eddies and instabilities in a model

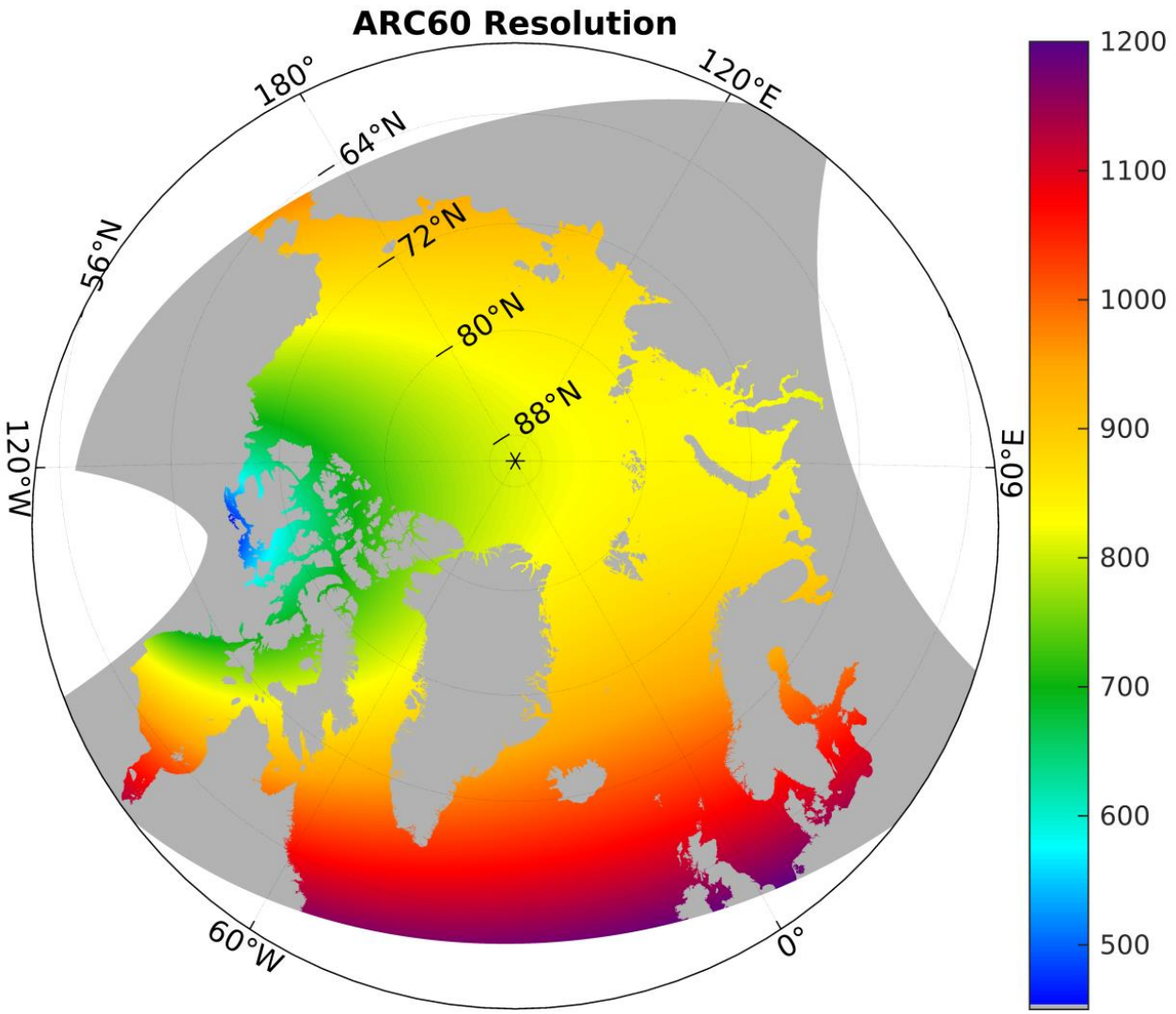
Pennelly et al. (2020)

Some Research Goals:

- Recirculation and propagation of Atlantic Water that drives tidewater glacier retreat.
- Understand watermass transformation in poorly studied regions.
- Eddy dynamics in ice covered waters
- Transpolar Drift, Freshwater Pathways, Transport, Storage
- Mesoscale and Submesoscale Activity

Requires an eddy enriched configuration and high resolution bathymetry

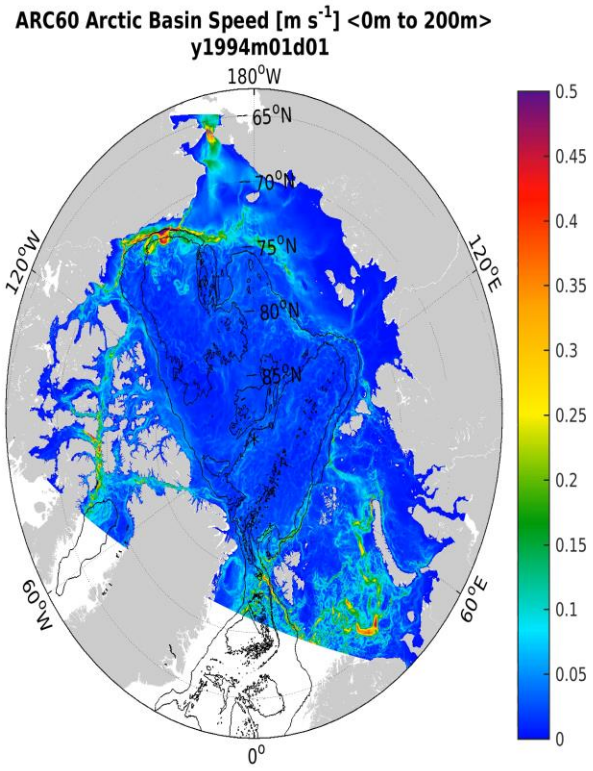
ARC60: our Arctic 1/60° configuration

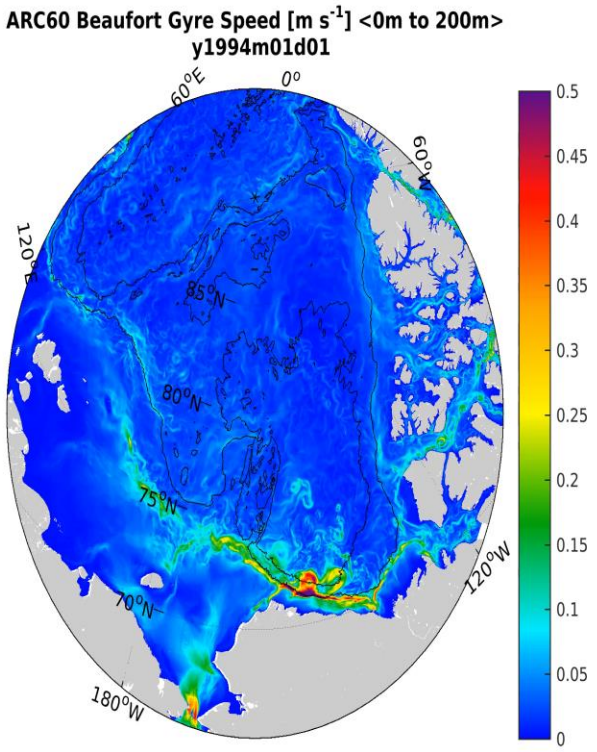


ARC60 Configuration:

Setting	ARC60 options
Numerical Models	NEMO 3.6, LIM2
Initial/Boundary Conditions	GLORYS2v4 ORAS ensemble member. BDY produced from our similarly forced ANHA12 simulation's output
Simulation Start/End	Jan 1993 through 2020 (currently in Jan 1999)
Spinup Phase	1993, no tides or icebergs (activated 1994). Started with a low timestep and adjusted it + eddy diffusivity/viscosity over 6 months to keep stable
Atmospheric Forcing	ERA5 (hourly)
Runoff (liquid and solid)	Dai and Trenberth + Bamber (Greenland; both are monthly).
Timestep	Stable at 30 seconds. Higher = instabilities near artificial north pole in shallow water, likely from tides
Domain Size	7500x 7025y 50z
CPUs required	3090
20 hour HPC submission	6 days of output=16 GB per day; 6TB per year
Horizontal Slippage	No Slip
Extra components	Greenland icebergs, 9 tidal constituents (TPXO)
Bathymetry	Primarily GEBCO 2021, and some SRTM15+, in-situ soundings, OpenStreetMap
AGRIF?	Nope! Too big a domain to rely on AGRIF. Wasn't going to be efficient

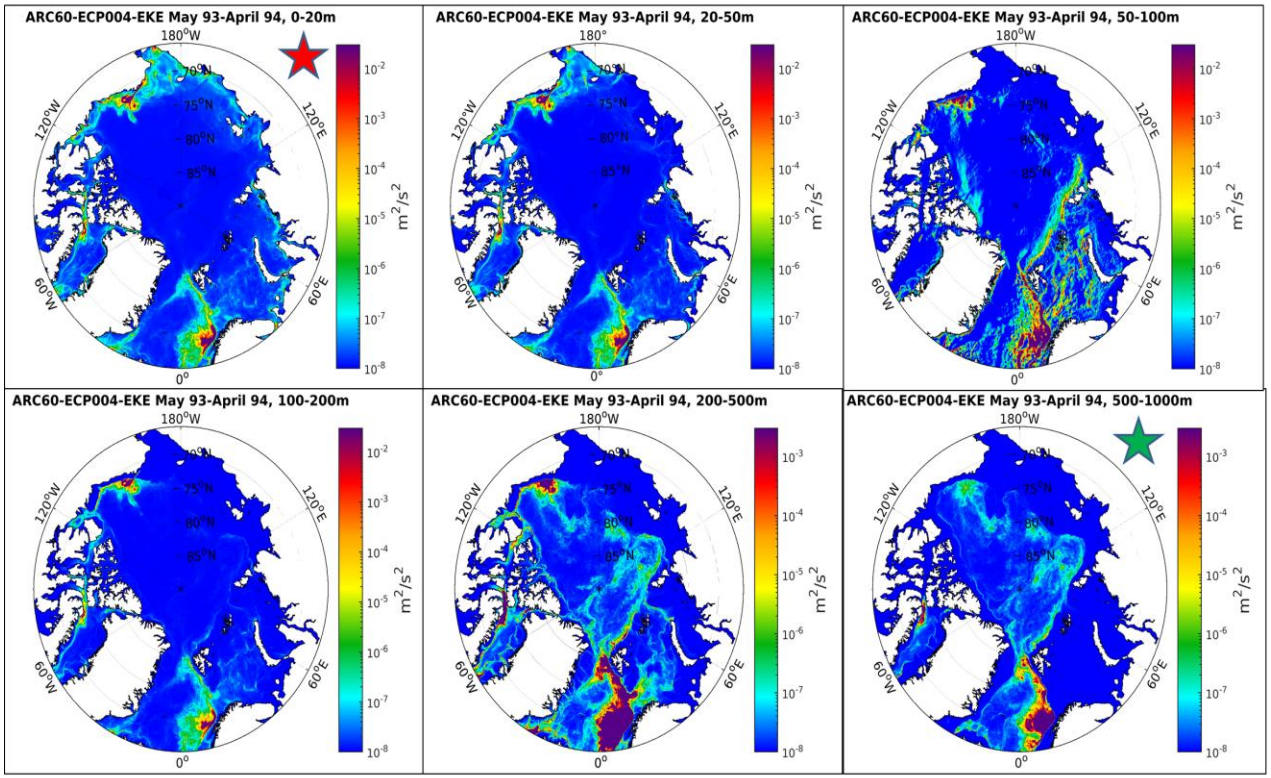
Arctic Eddies



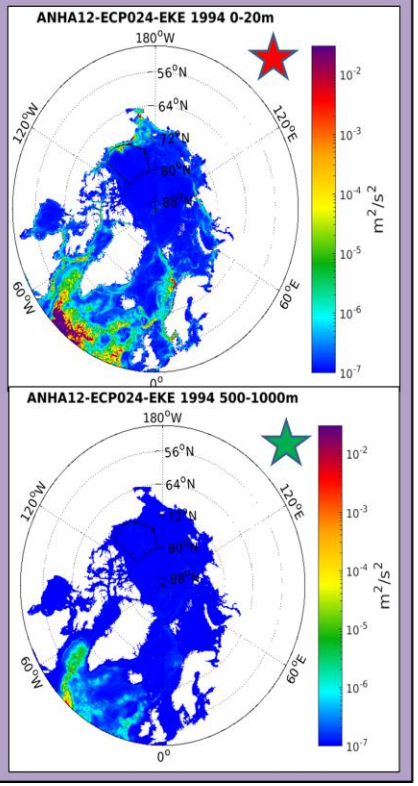


Enhanced Eddy Kinetic Energy

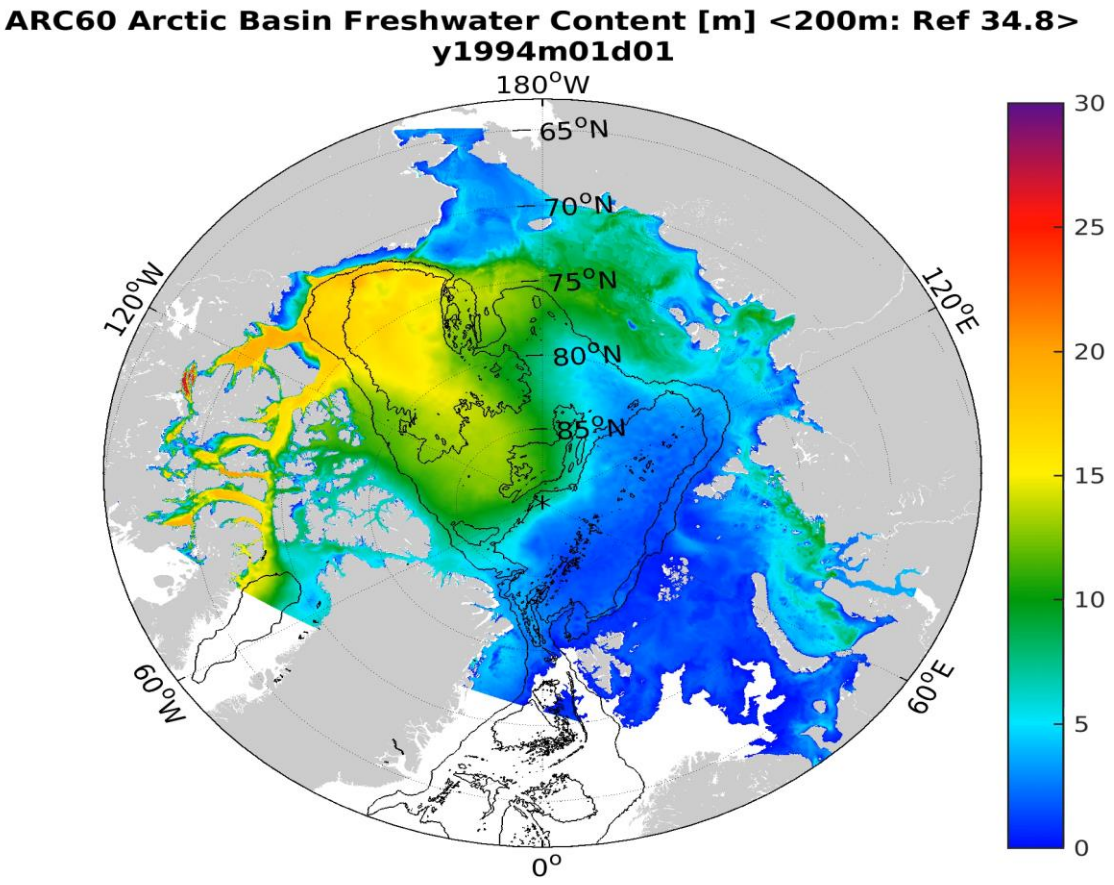
ARC60 EKE by depth



Comparison against ANHA 1/12°

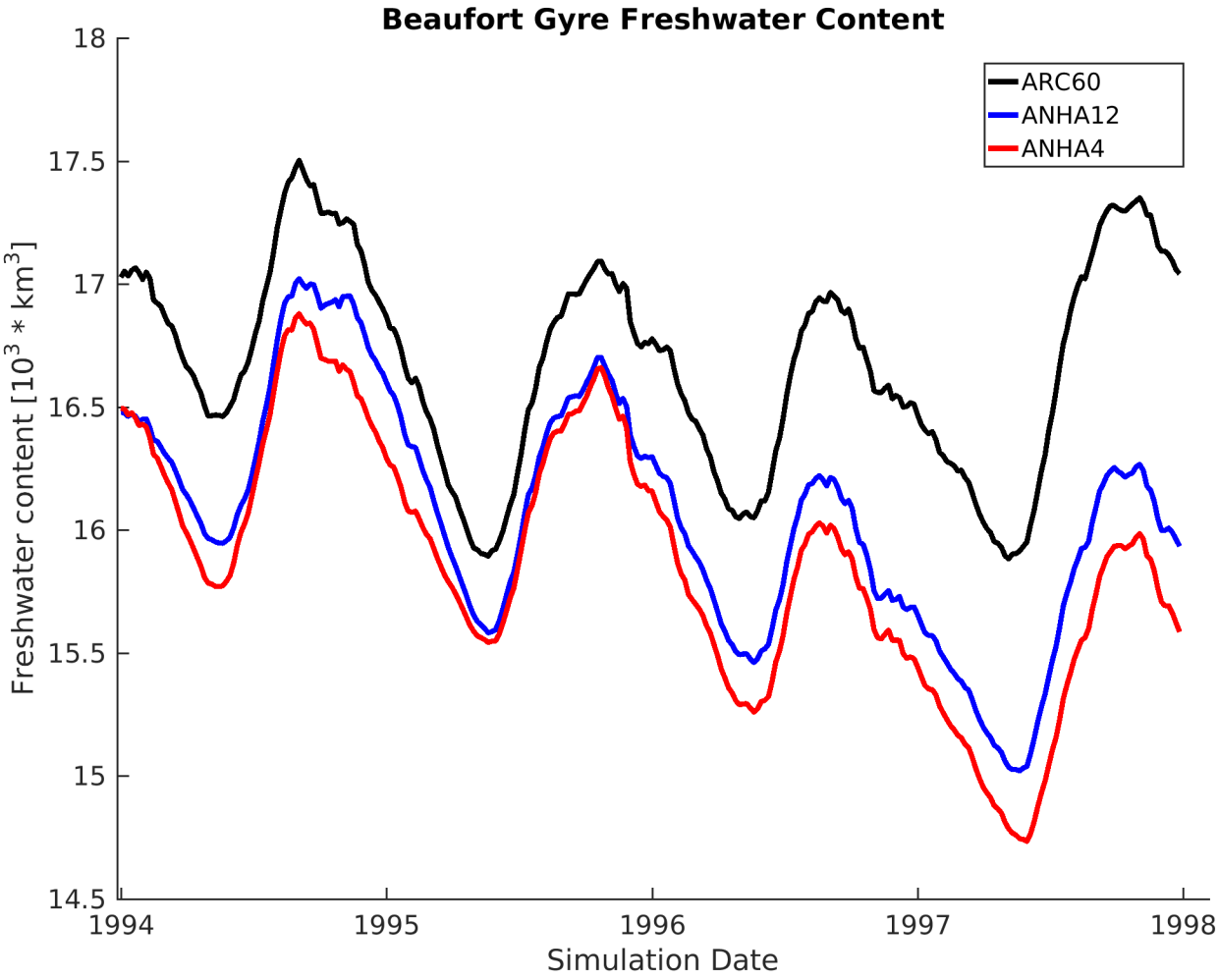


Arctic Freshwater Content



Beaufort Gyre Freshwater Content

Our lower resolution regional configurations have a Beaufort Gyre with much lower freshwater content than observations suggest. We are investigating how resolution, boundary conditions, and sea ice models play a role in this.

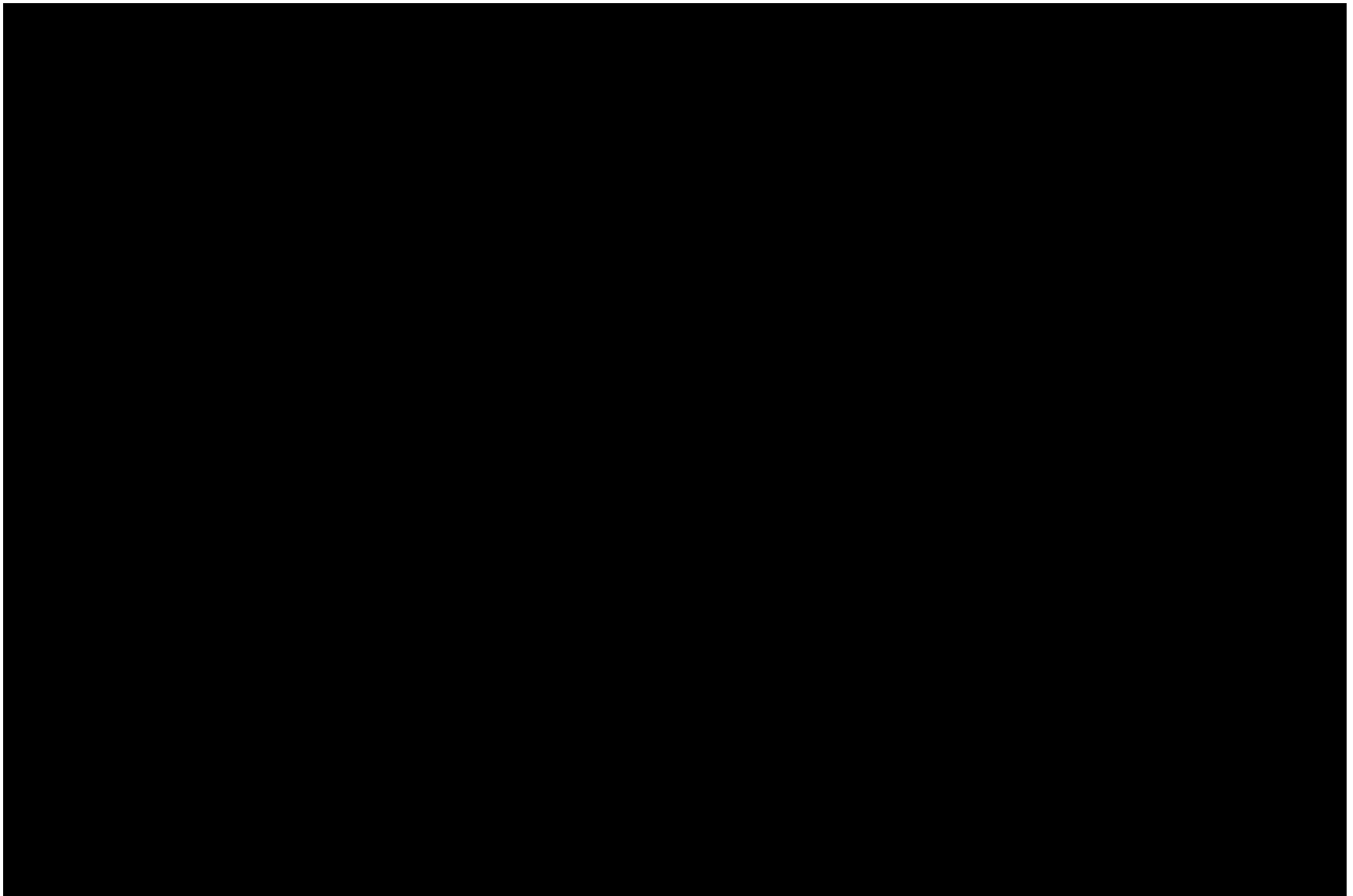


These ANHA12 and ANHA4 are identical to the ARC60 one, just at lower resolution.

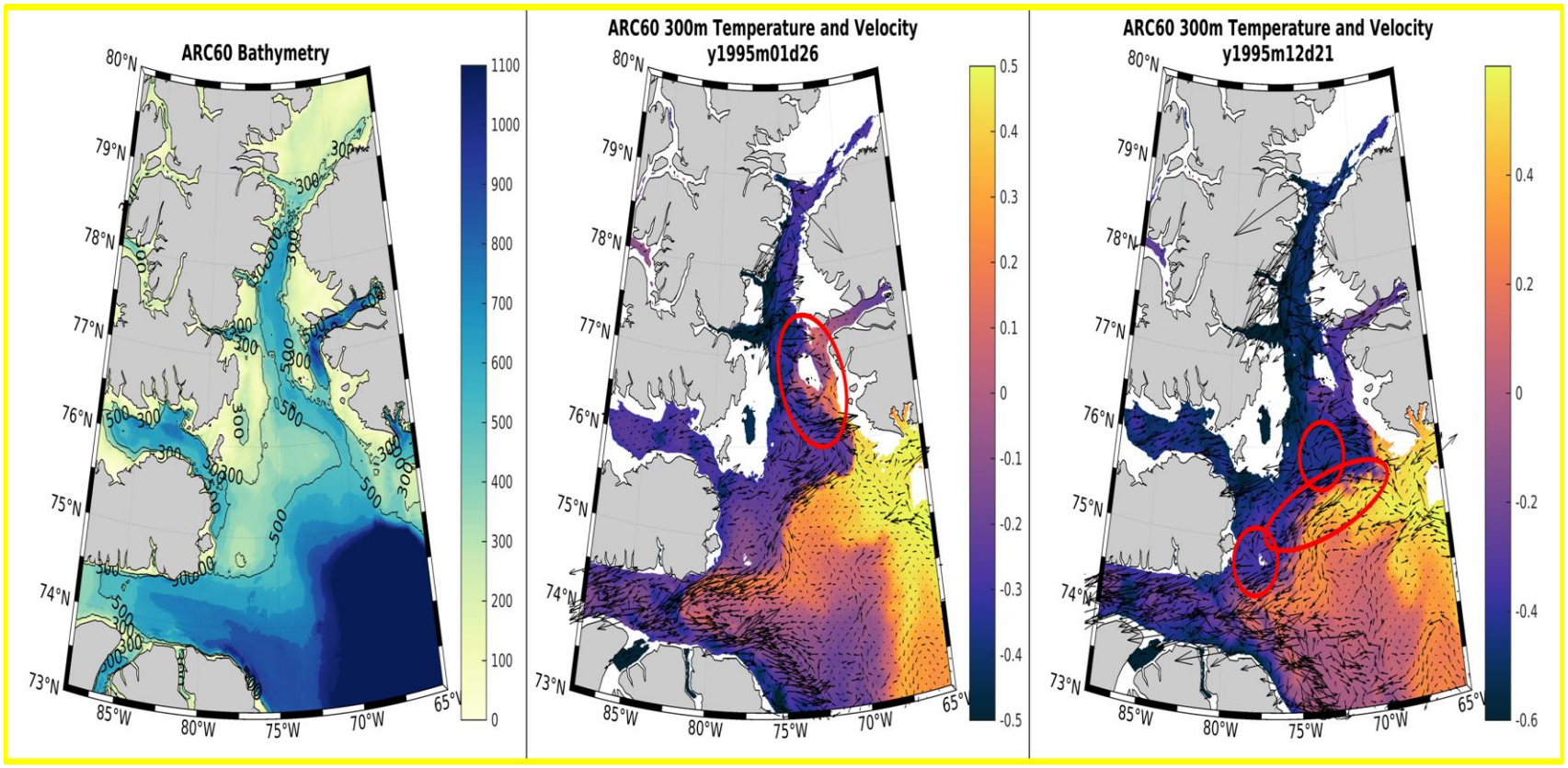
All simulations started in 1993 and we already see ARC60 is drifting less.

Observations for this region are around 20 *1000 km^3

Mesoscale and Submesoscale in Baffin Bay



Advantages of 1/60th Include



Far improved bathymetry within coastal regions and fjords than at 1/12 (not shown)

Propagation of Atlantic Water northward into Smith Sound, recirculation to west

Propagation of Atlantic Water to west, circulation features, eddies and shear instabilities

Summary

- Have developed a 1/60th degree pan-Arctic NEMO configuration
  - Includes tidal forcing and icebergs
  - Present run 1993-1999 and continuining
- Leads to significant increase in eddy activity in Arctic and sub-polar Oceans
  - Significant enhancement of EKE, leading to improved freshwater content in Beaufort Gyre
- Enhanced representation of sea-ice linear kinetic features
- Shows seasonal circulation features and eddy generation due to Greenland freshwater discharge, that was not previously simulated in detail
- Experiment and analysis ongoing