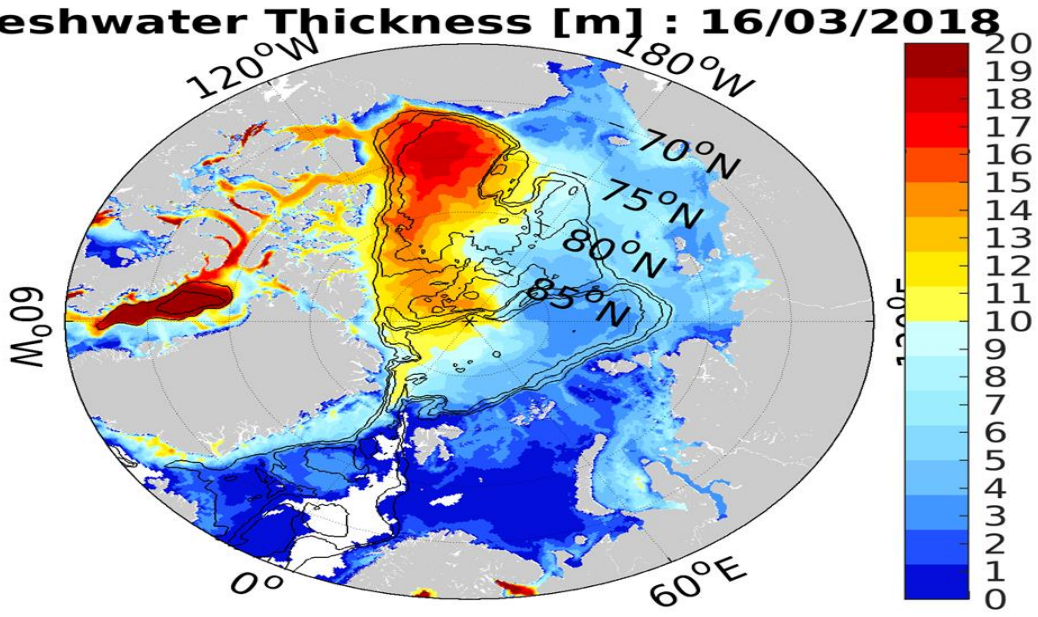
An examination of the freshwater content of the Beaufort Gyre in a suite of NEMO model simulations



Paul G. Myers, Clark Pennelly, Tanisha Garg, Chuanshuai Fu, Carlos Ramos Portalatino and Tahya Weiss-Gibbons and many other students who have contributed to our ocean models and their analysis
Department of Earth and Atmospheric Sciences
University of Alberta

Ventilation Interactions and Transports Across the Labrador Sea

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eas Earth & Atmospheric Sciences

Outline

- Introduction
- Beaufort Gyre
  - Freshwater content
  - Vertical Salinity Structure
  - Bering Strait Inflow
  - Global eORCA025 simulations
- ARC60

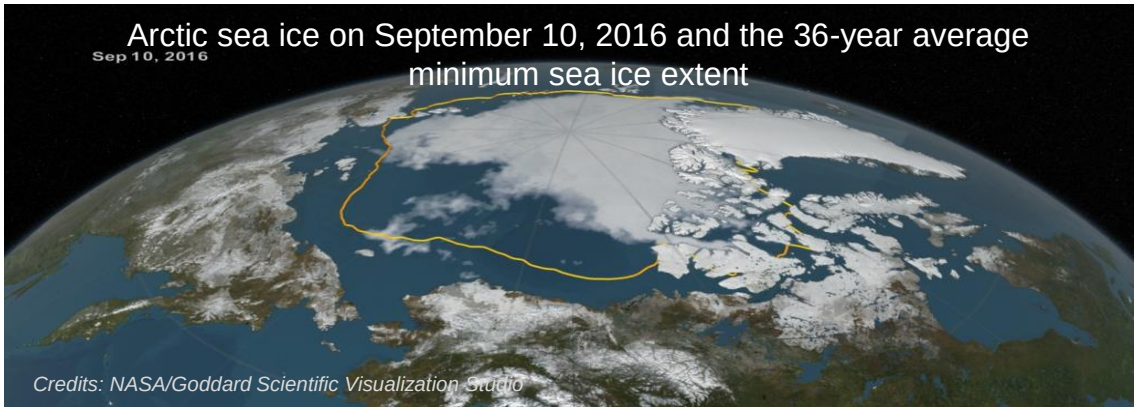
Changes in the Arctic Ocean Freshwater Budget

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

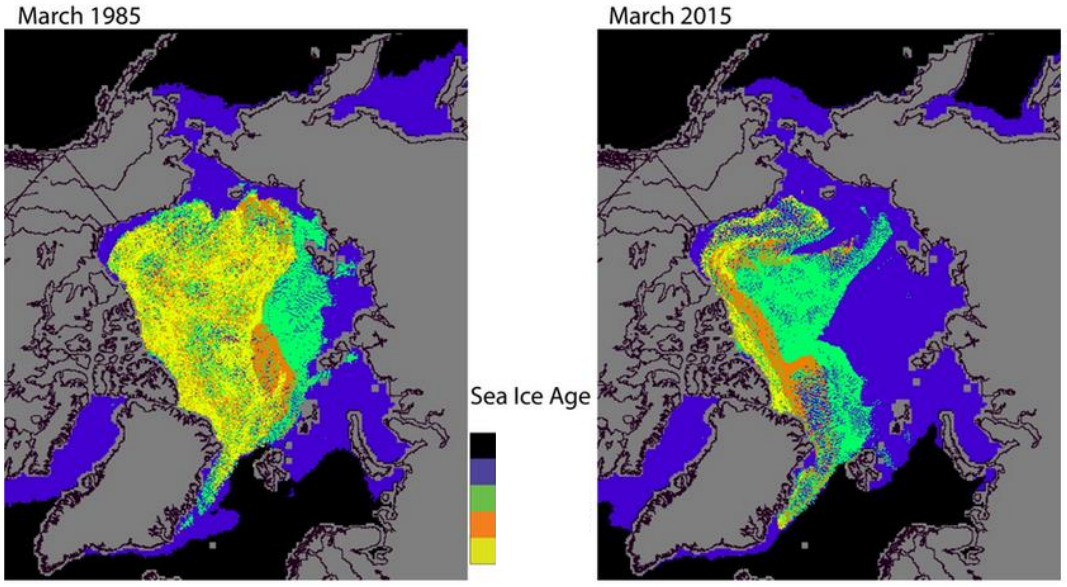
Liquid FW	(93➔101):	+9%
Beaufort Gyre	(16.9➔22.6):	+34%
Multiyear ice	(10.9➔ 7.4):	-33%
Seasonal ice	(13➔13.4):	+3%

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

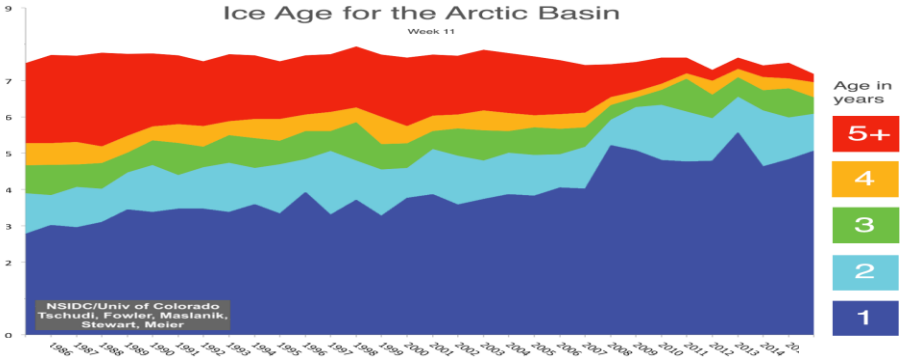
P-E	(2 ➔ 2.2):	+10%
Runoff	(3.6 ➔3.8):	+8%
Bering FW	(2-2.5 ➔3-3.5):	+4%
Net Ice Melt	(0.27 ➔0.29):	+8%

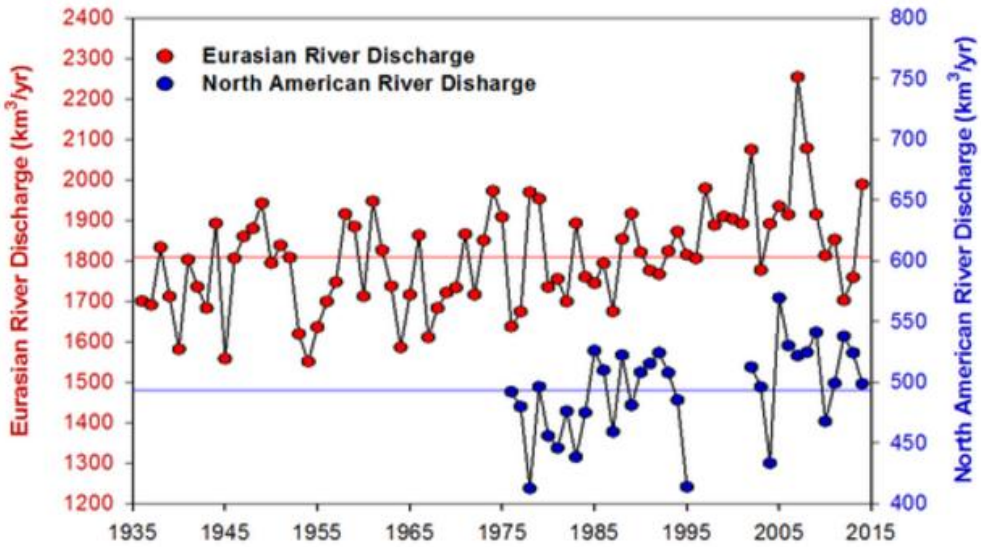


Haine et al., 2015; Shiklomanov, 2010; Woodgate et al., 2012; Proshutinsky et al., 2009.



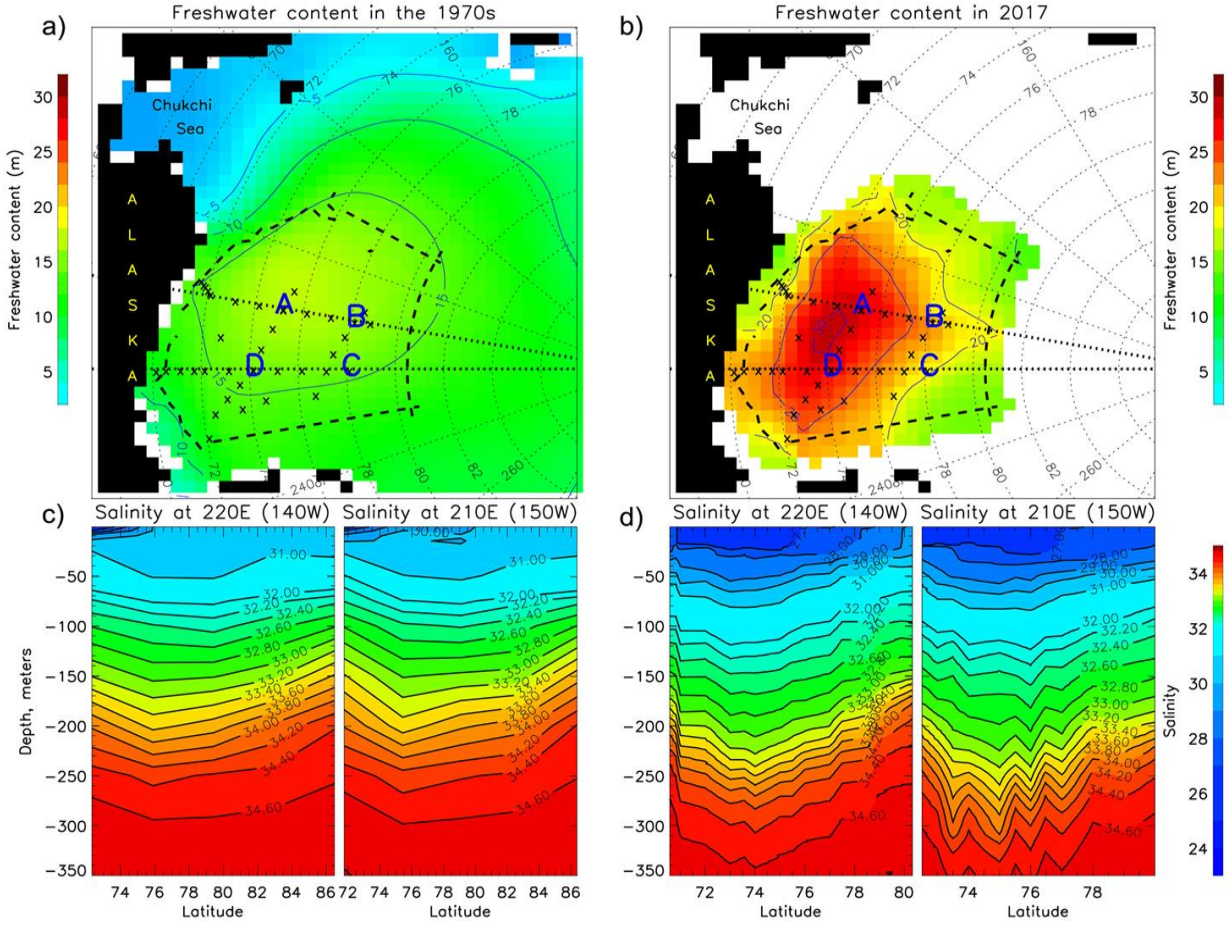
Perovich et al., Arctic Report Card: Update for 2015.

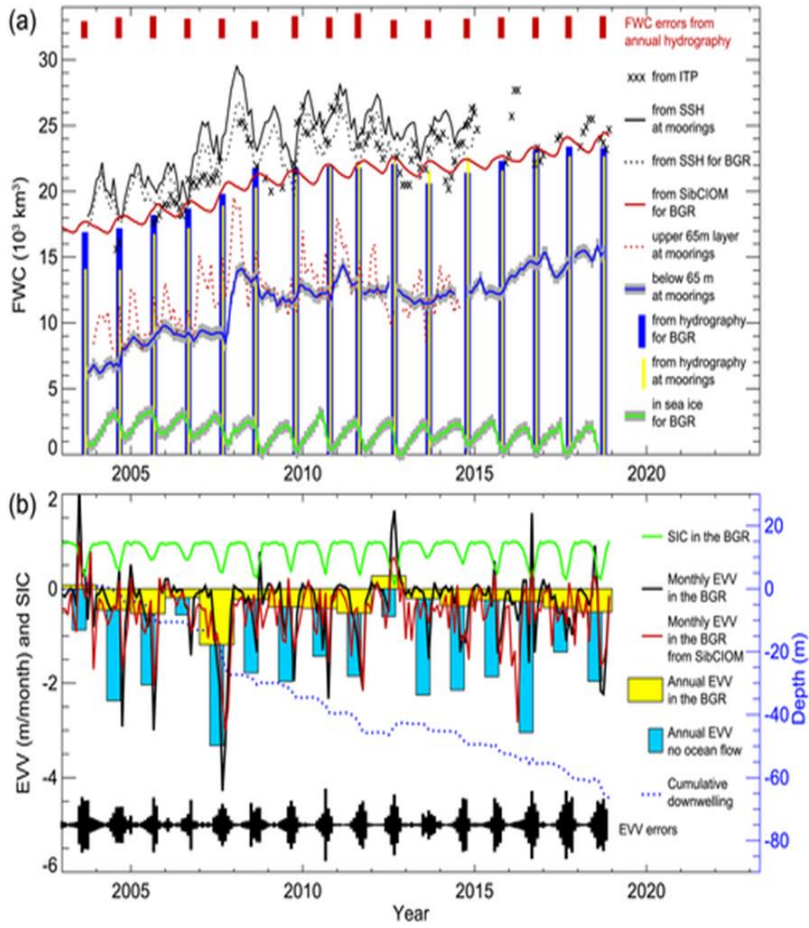




Holmes et al., Arctic Report Card: Update for 2015.

BG has been getting fresher





Proshutinsky et al., 2019

ANHA: Arctic and Northern Hemisphere Atlantic

ANHA12 & ANHA4

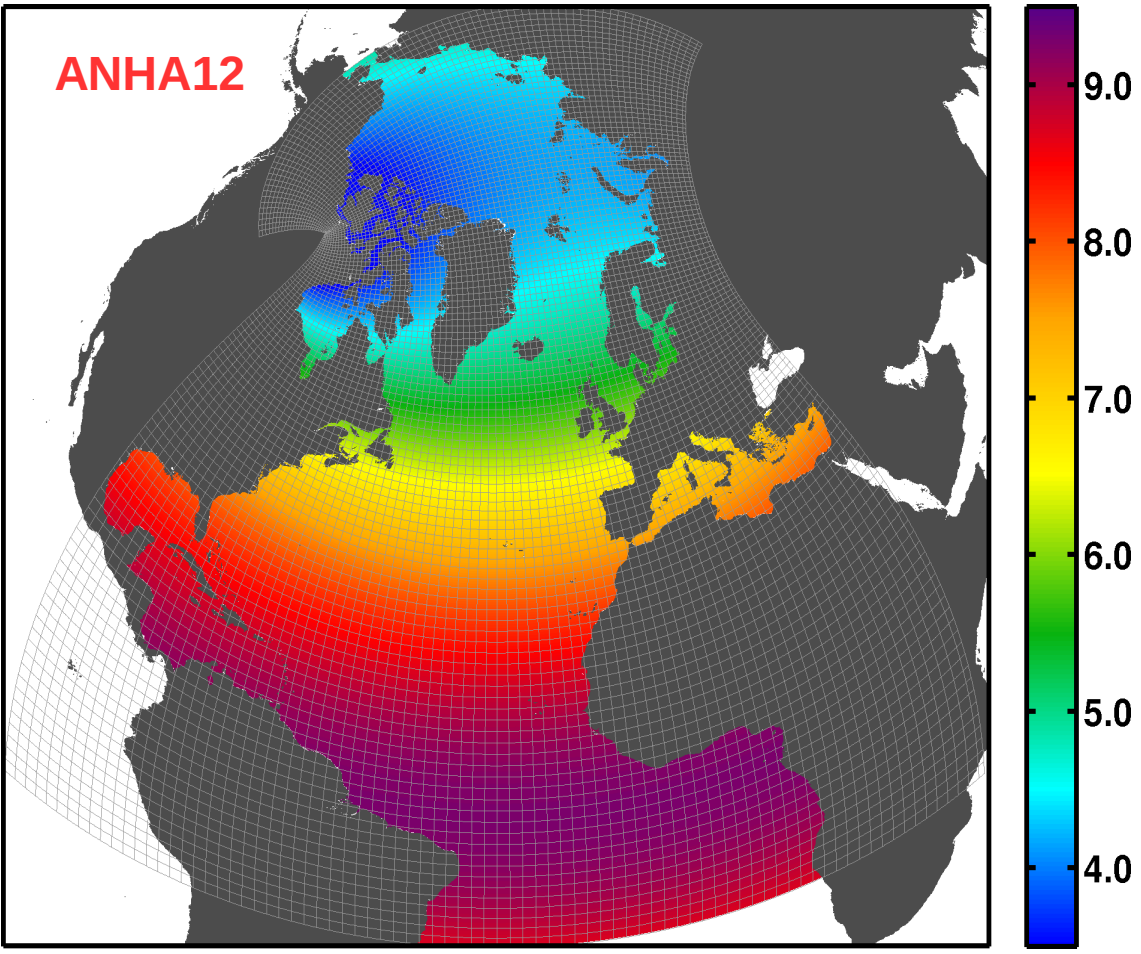
Model : NEMO 3.4
LIM2 + EVP

Resolution : 1/12 degree
¼ degree

Mesh : 1632 x 2400
544 x 800
50 levels

LS : ~ 5 km
~ 15 km

CAA : ~ 4 km
~10 km



Initialization:

3D T, S, U and V (GLORYS2v3, Jan02)
Sea Ice

Atmospheric forcing:

T2, Q2, U10, V10
Precipitation
Radiation (SW & LW)

CGRF or ERA5

Snow: Calculated from precipitation

Runoff: DT or HYPE Hydrological
Greenland Mass Loss (Bamber)
+ Iceberg Module

OBC: U, V, T and S (GLORYS2v3)

NO temperature & salinity restoring

Jan 2002 – Dec 2021

Newer runs: Explicit Tides
– 9 Constituents

CGRF: CMC GDPS reforecasts

GDPS: Global Deterministic Prediction System

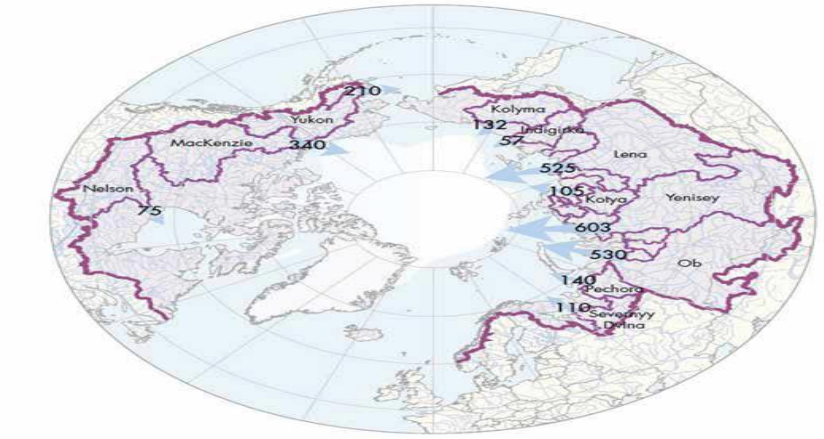
CMC: Canadian Meteorological Centre

GLORYS: GLobal Ocean ReanalYses and Simulations

Model Changes and Updates

- Previous results shown in Hu et al., 2014, 2019
  - Look at role of resolution and PW pathways
  - But limited as BG FWT less than observations
- So want to explore in newer suite of experiments
  - Improved river runoff
  - Greenland melt (and icebergs)
  - Explicit tides (9 constituents)
  - Also consider global experiments to avoid fixed inflow condition at Bering Strait

Sensitivity to River Runoff

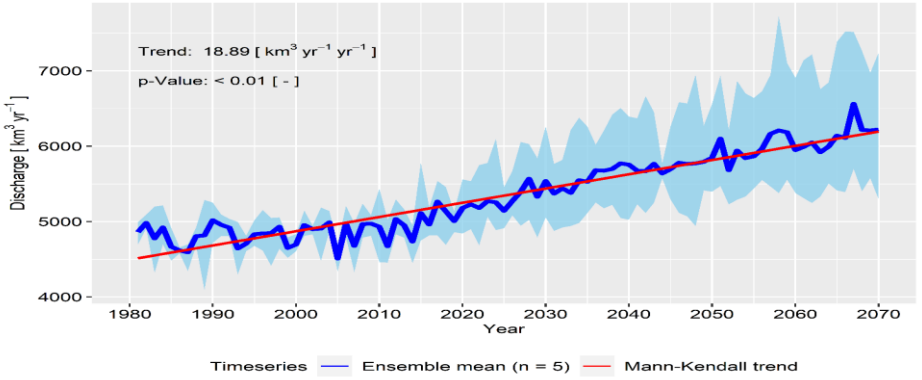


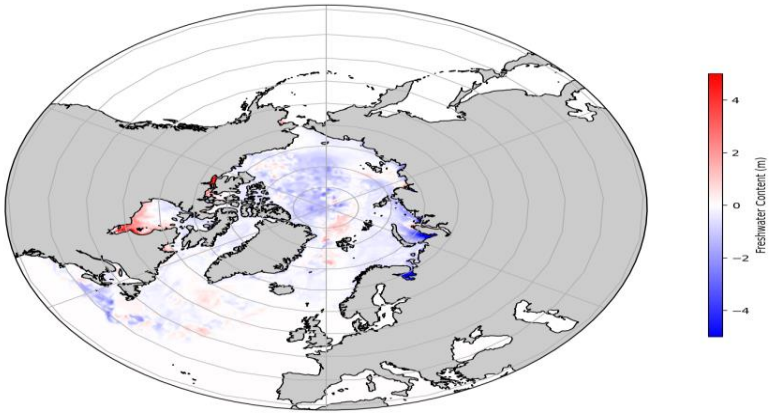
Catchment area of the Arctic Ocean, showing the annual discharge (cubic kilometers) of major rivers (Source: CAFFs Arctic Flora & Fauna - 2001)

Hydrological model A-HYPE used to simulate pan-Arctic hydrology

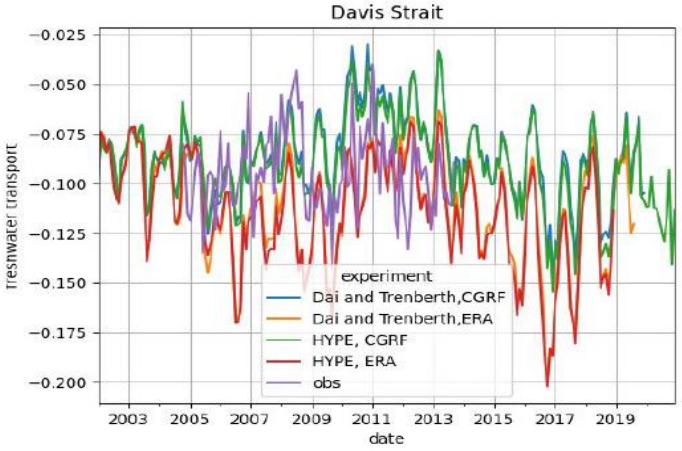
Compared to Dai and Trenbeth climatology of major rivers

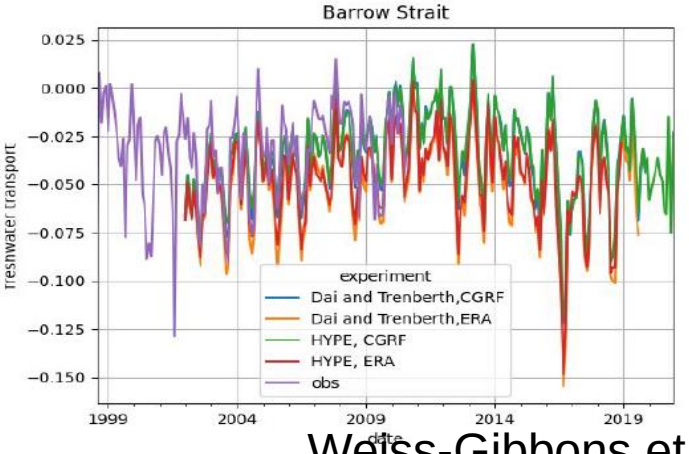
2018 HYPE – DT FWT above 34.8





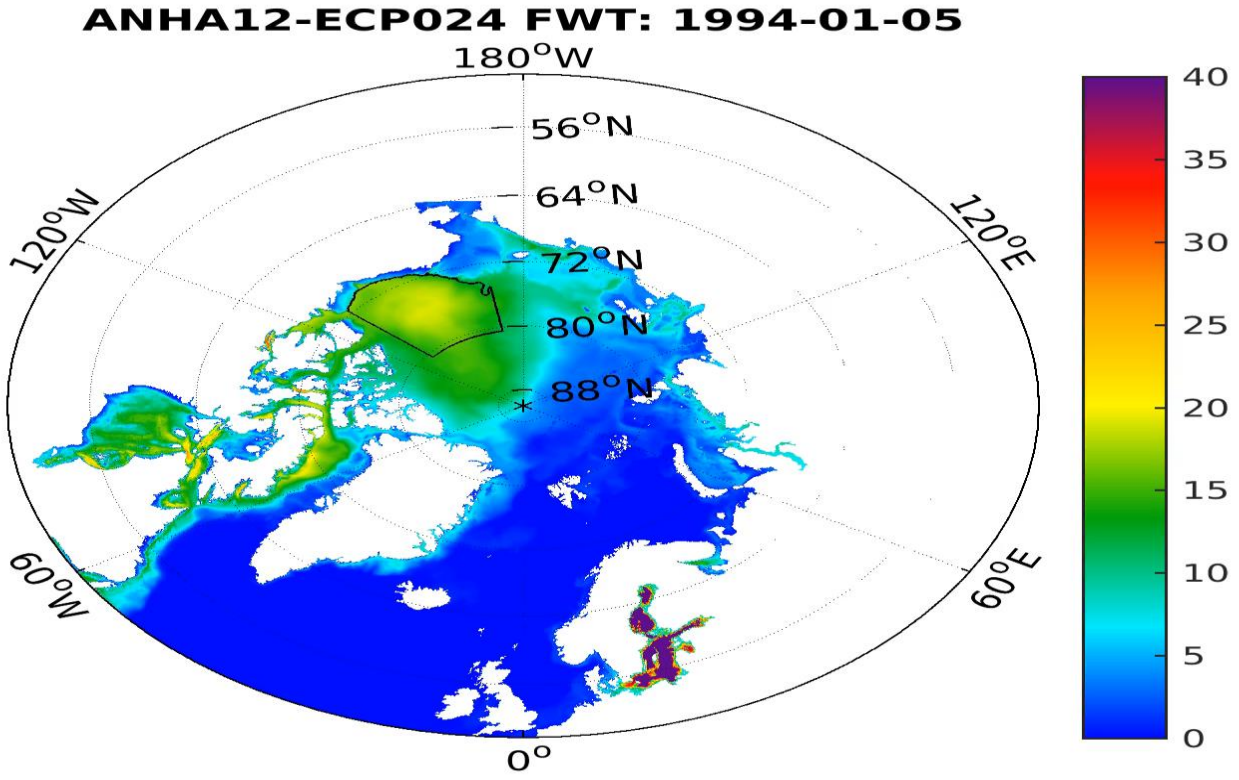
Stadnyk et al., 2021, Elementa



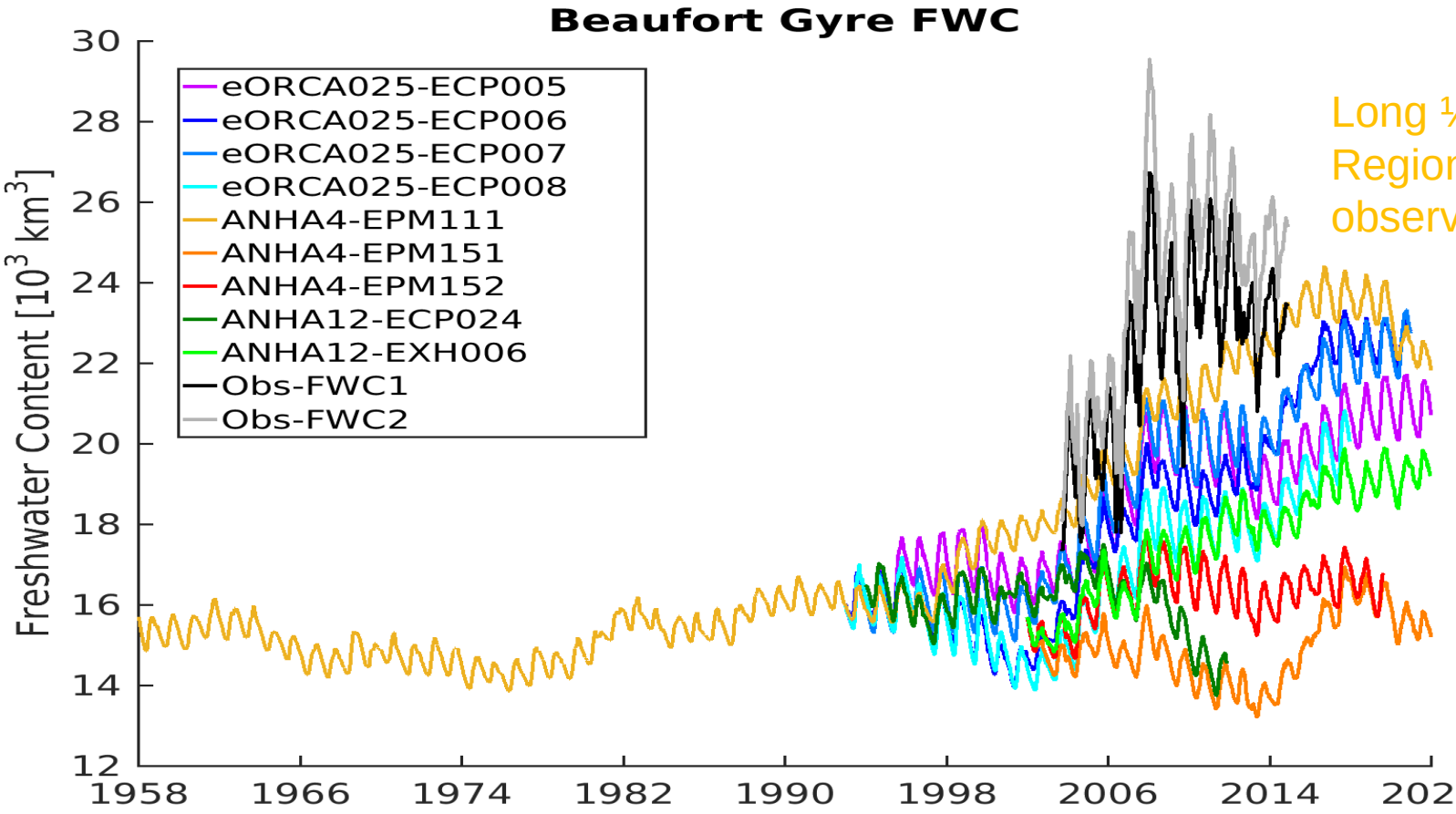


Weiss-Gibbons et al, 2024, submitted

Arctic FW Thickness (above 34.8 isohaline, and relative to 34.8)
ANHA12 – GDPS Forcing, HYPE Runoff, Explicit Tides (1993-2008)



Average FWT(above 34.8 isohaline, and relative to 34.8) – BG Box



Long ¼ Regional has observed incr.

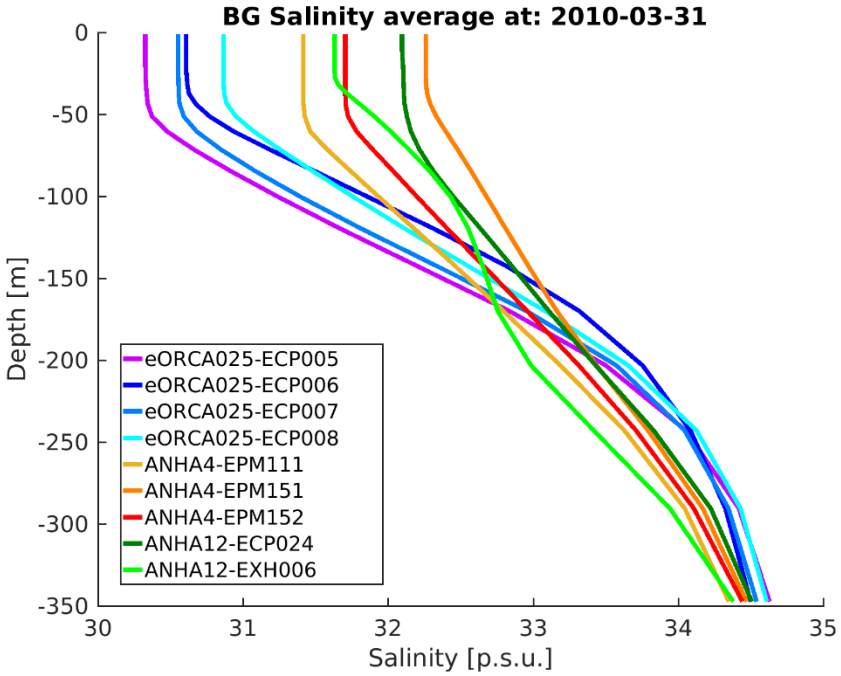
Global ¼ degree closer to Obs.

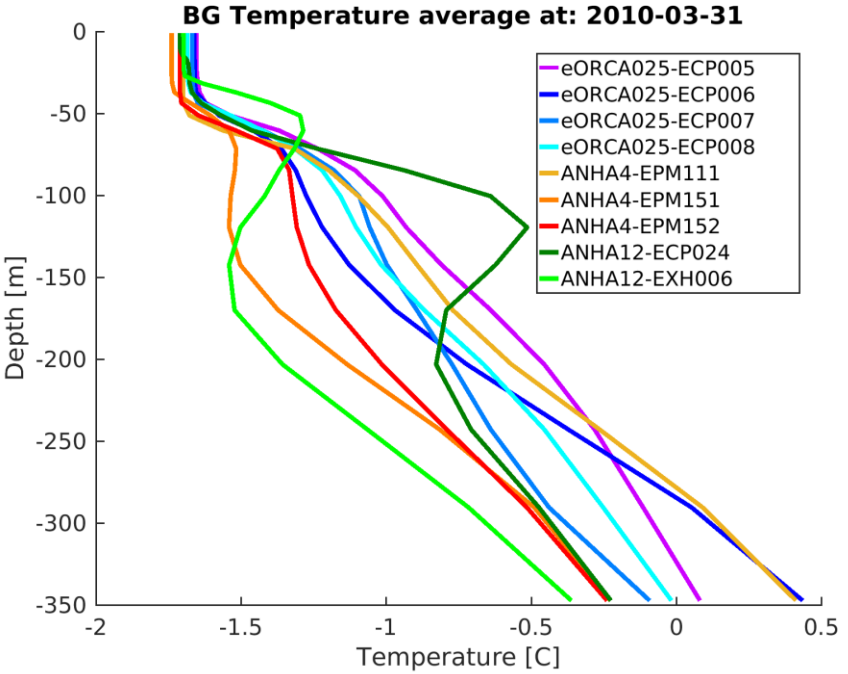
1/12 Regional Better

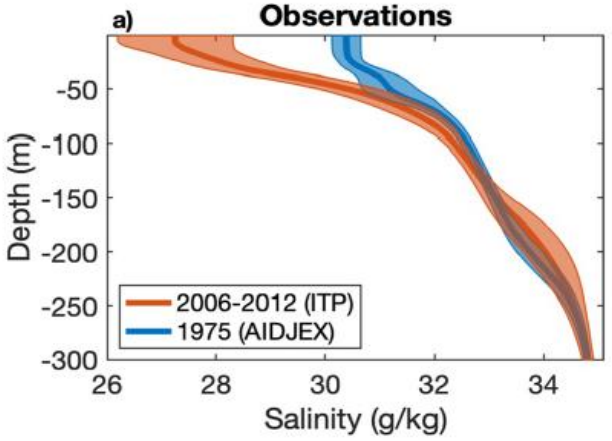
¼ Degree Regional – Very low

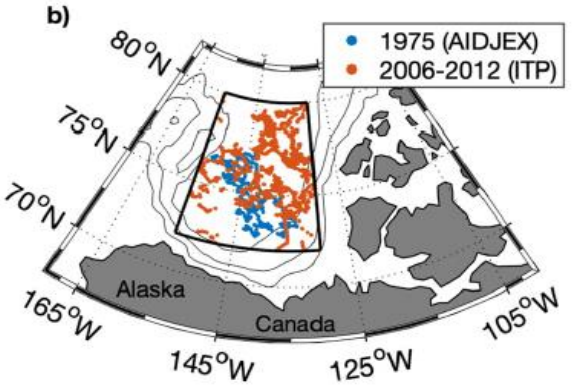
But newer 1/12 Regional FWT Declines?

BG Average T and S Profiles



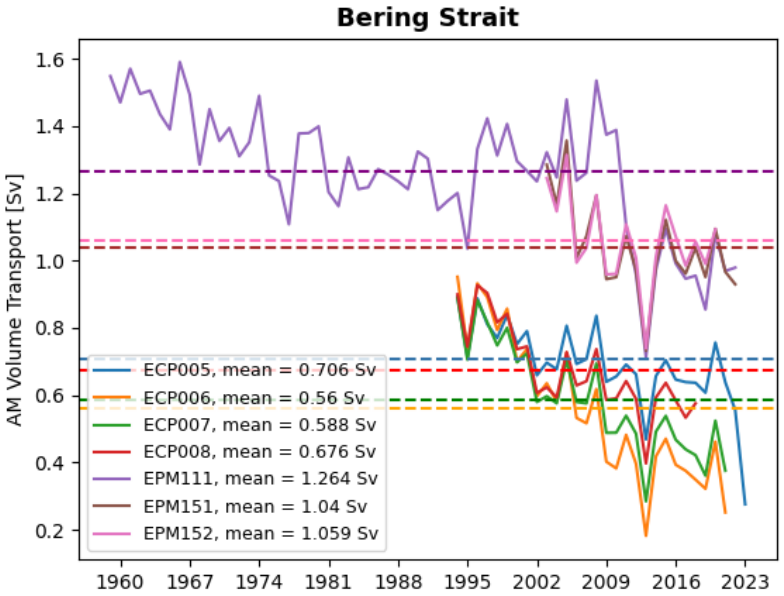


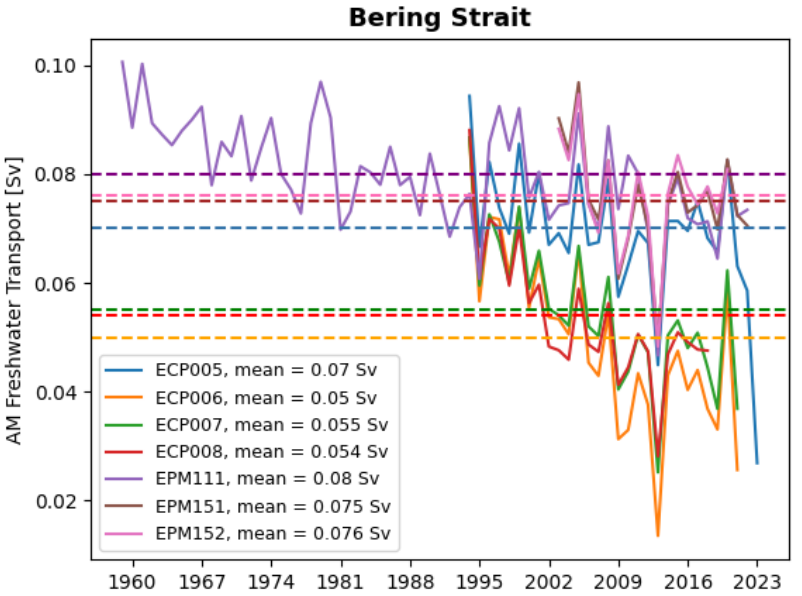




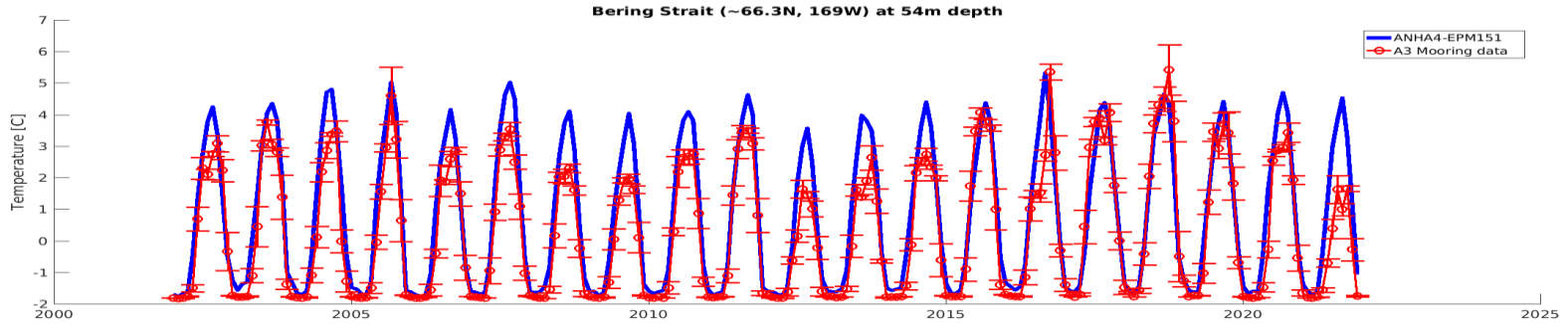
From Rosenblum et al., 2021

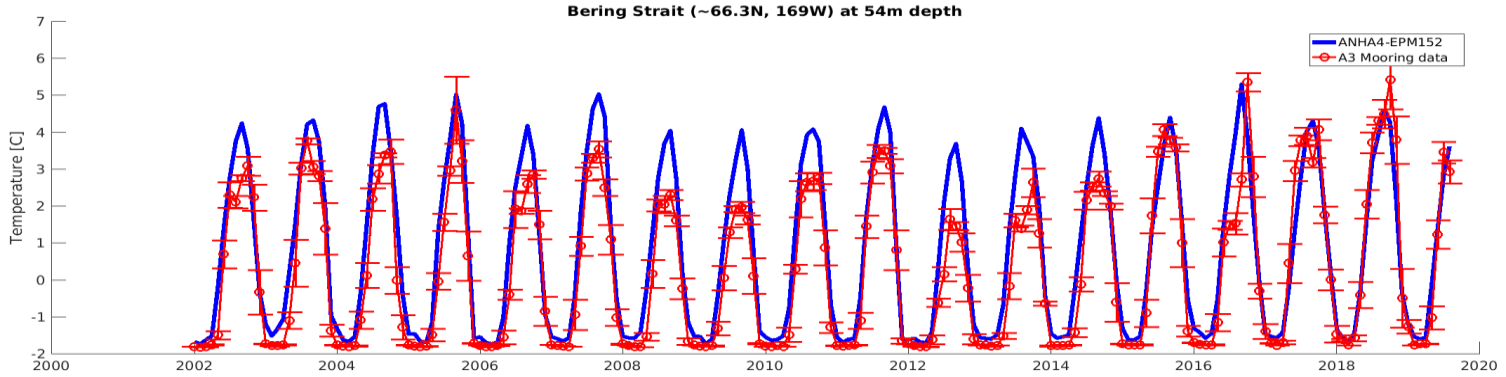
Bering Strait Transports



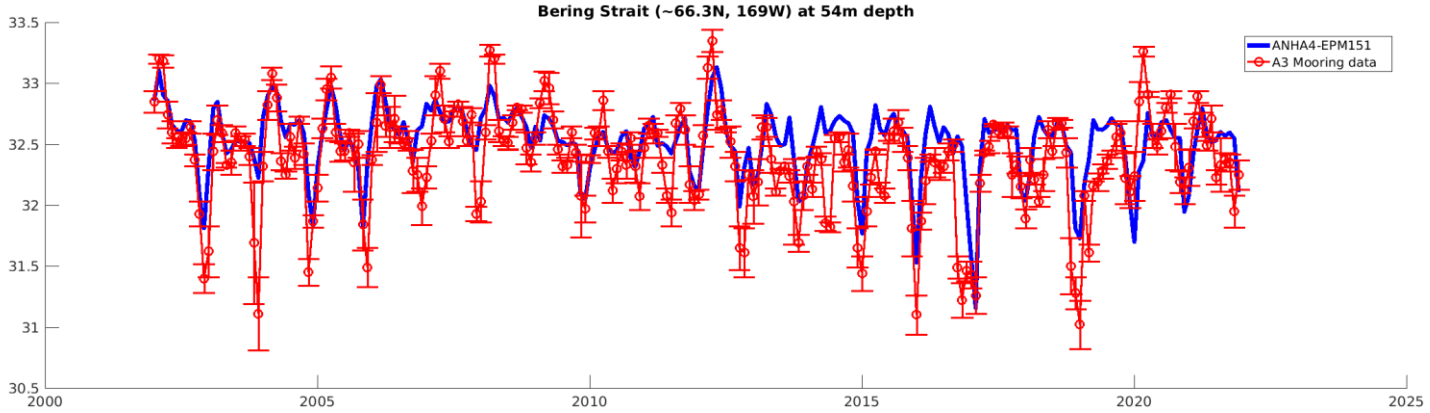


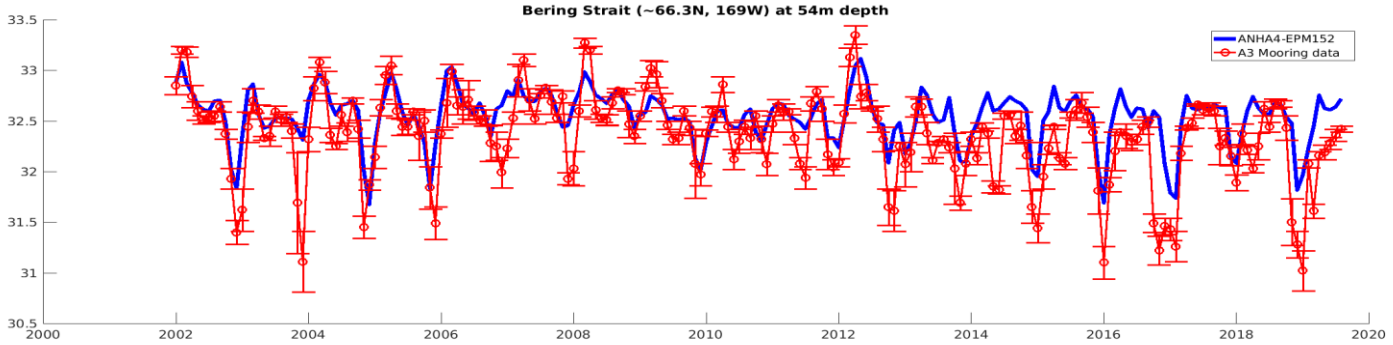
Bering Strait 54m Model vs Obs Comparison



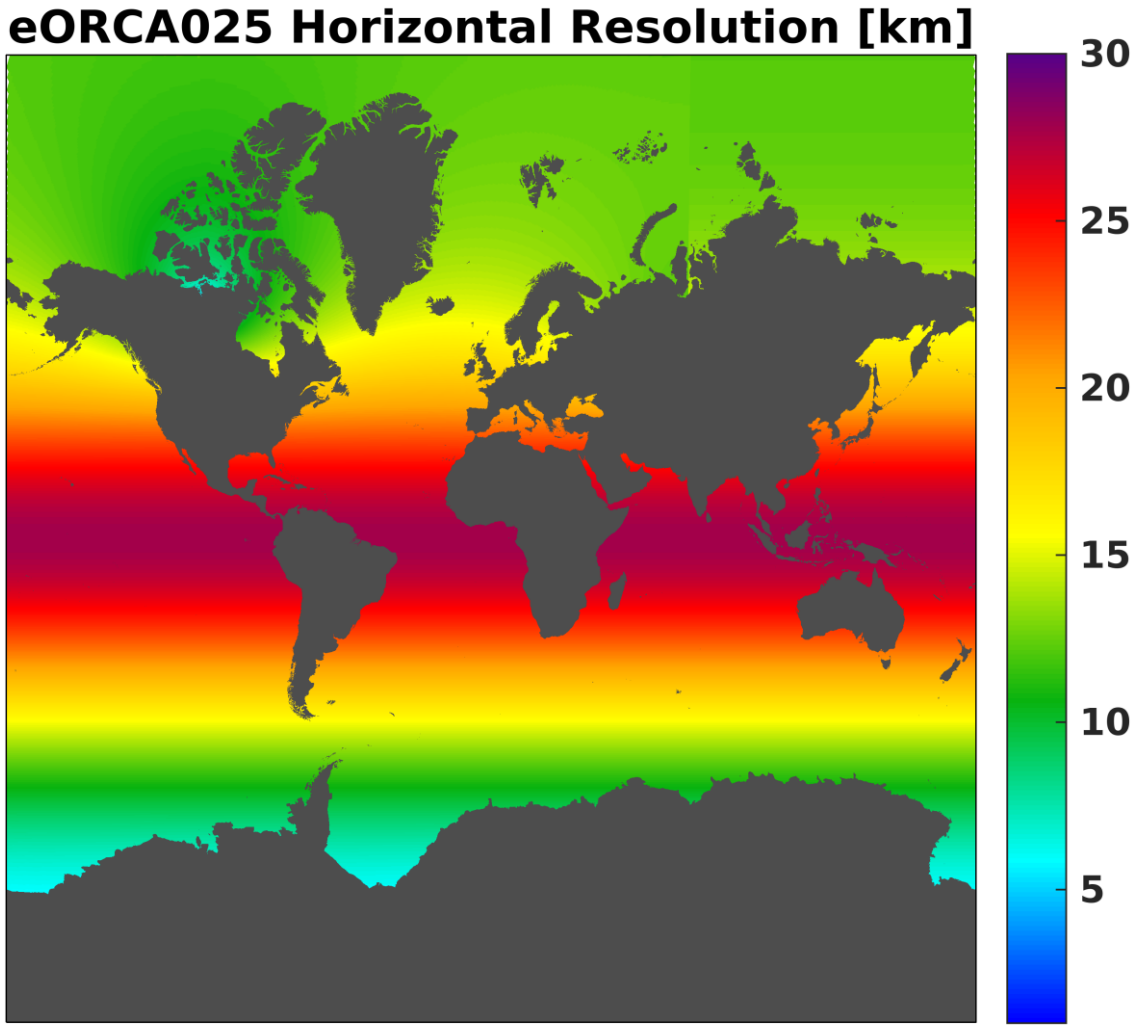


Bering Strait 54m Model vs Obs Comparison





eORCA025



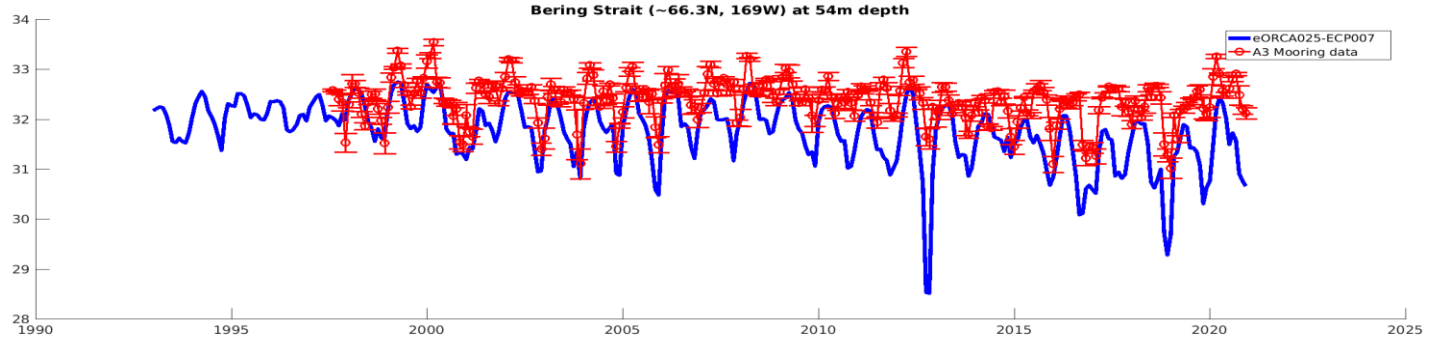
We've finally gone global!

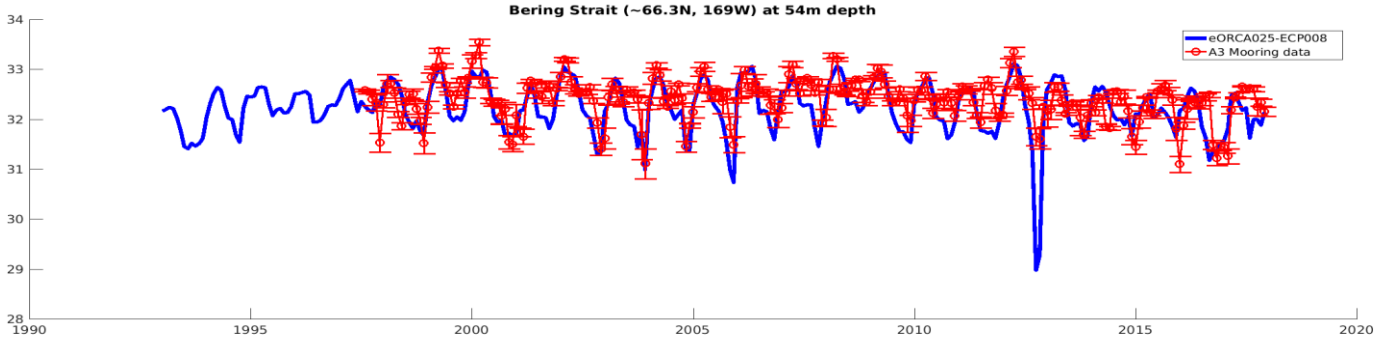
- NEMO 3.6 (4.2 is a work in progress)
- ¼ degree
- 50 vertical levels
- 1993 start from Glorys2v4

- Sensitivity runs:
  - Runoff (HYPE versus DT/Bamber)
  - Atmospheric Forcing (ERA5/JRA55)
  - Icebergs (with/without)
  - Sea Ice Model (LIM2/LIM3)

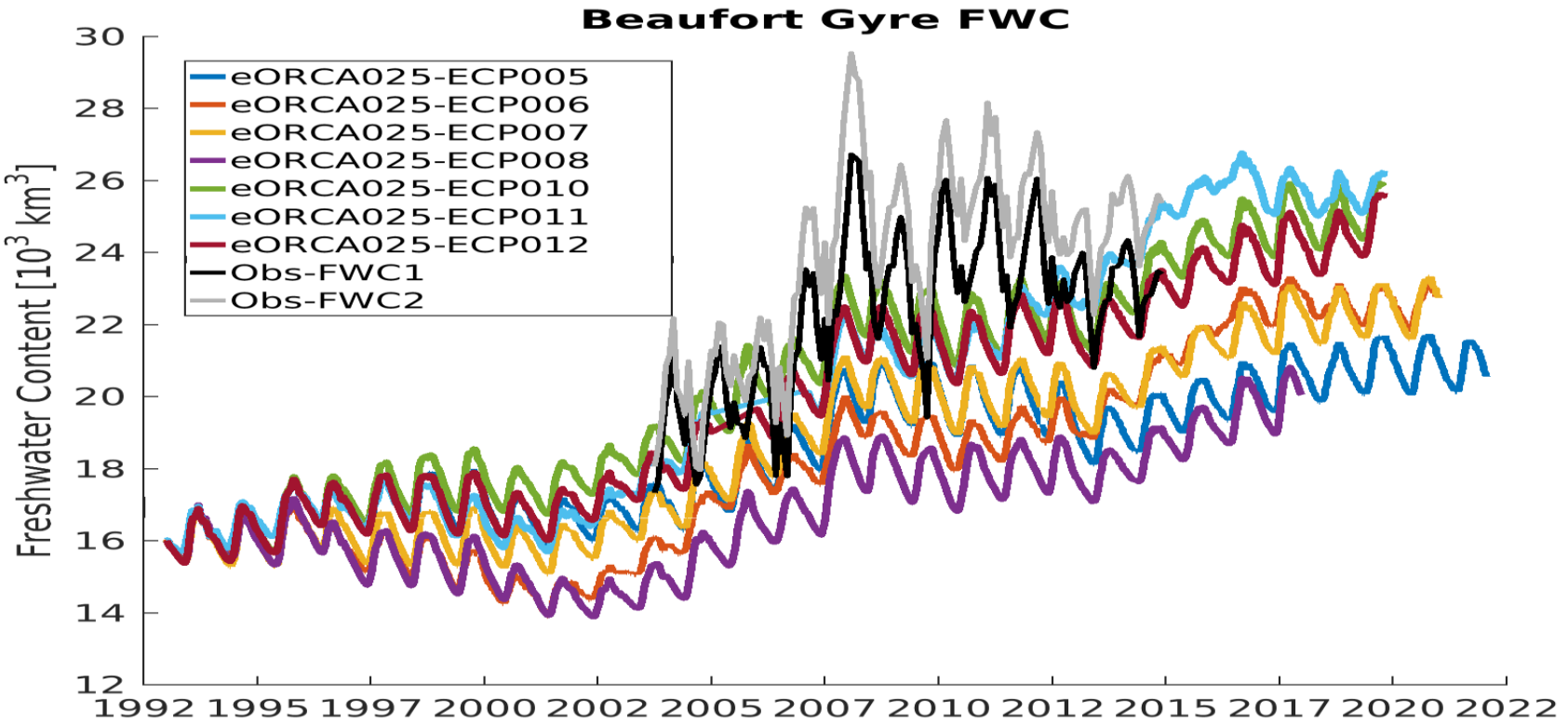
- To add:
  - Tides
  - BLING (biogeochemical model)
  - Carry into NEMO 4.2

Bering Strait 54m Model vs Obs Comparison

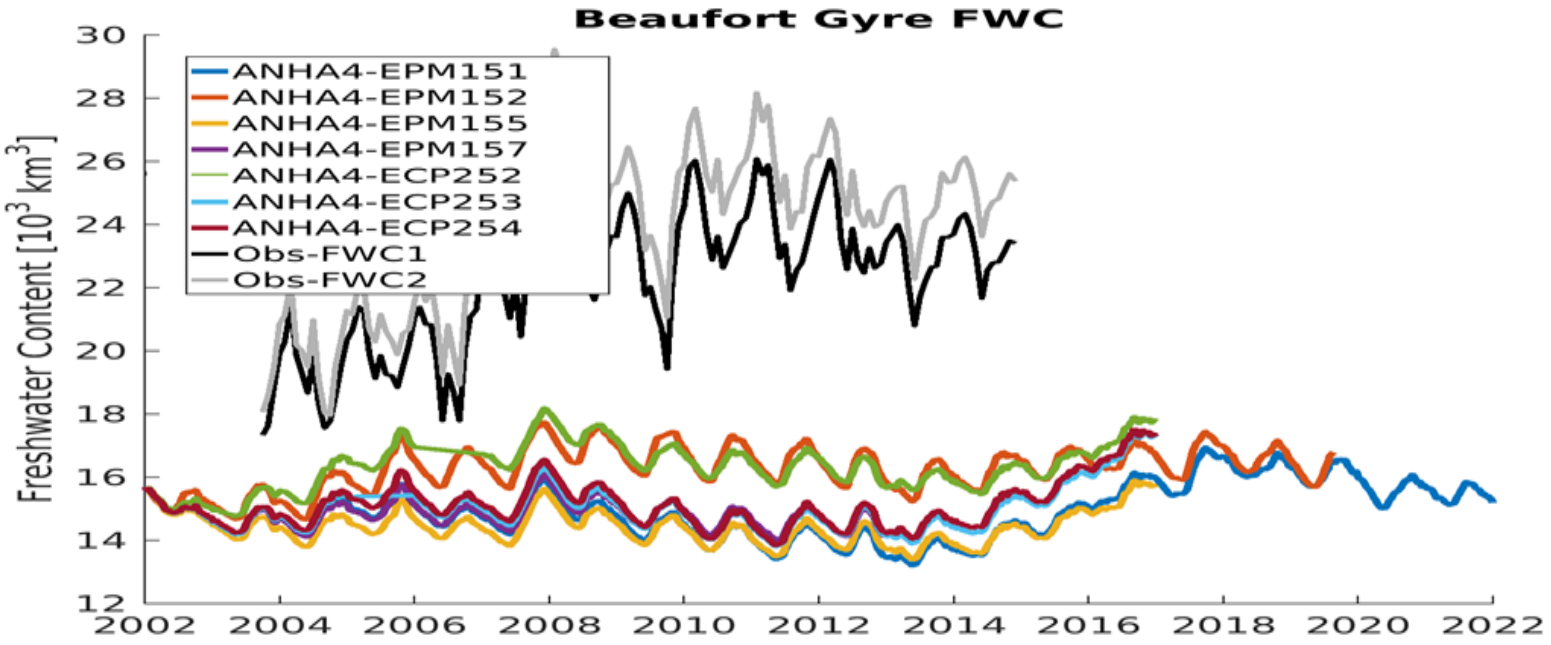




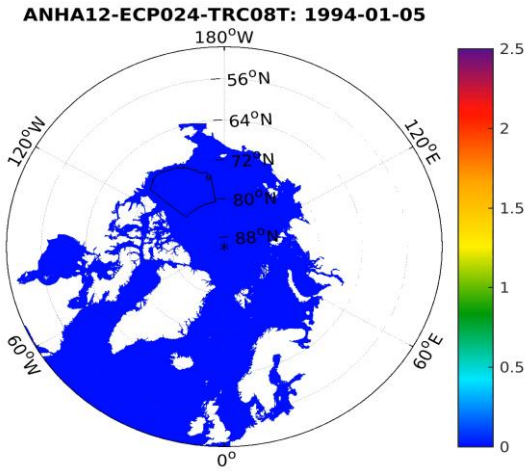
Updated eORCA025 with runoff from Hydrological Model



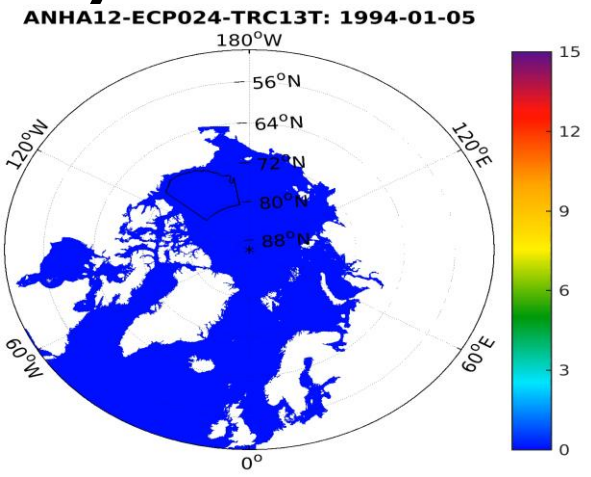
But driving the regional model with BCs from the Global model doesn't change much



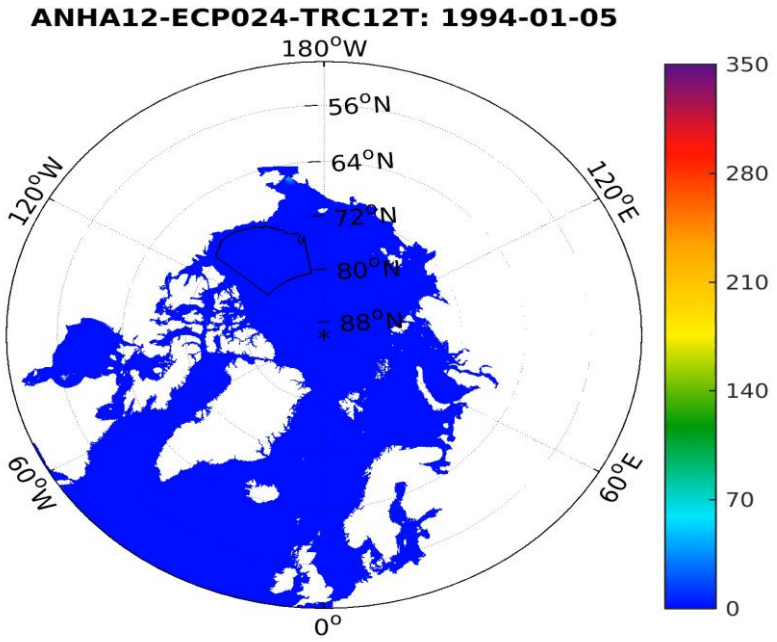
River and Bering Strait Tracers (1993-2011)



N. American Rivers

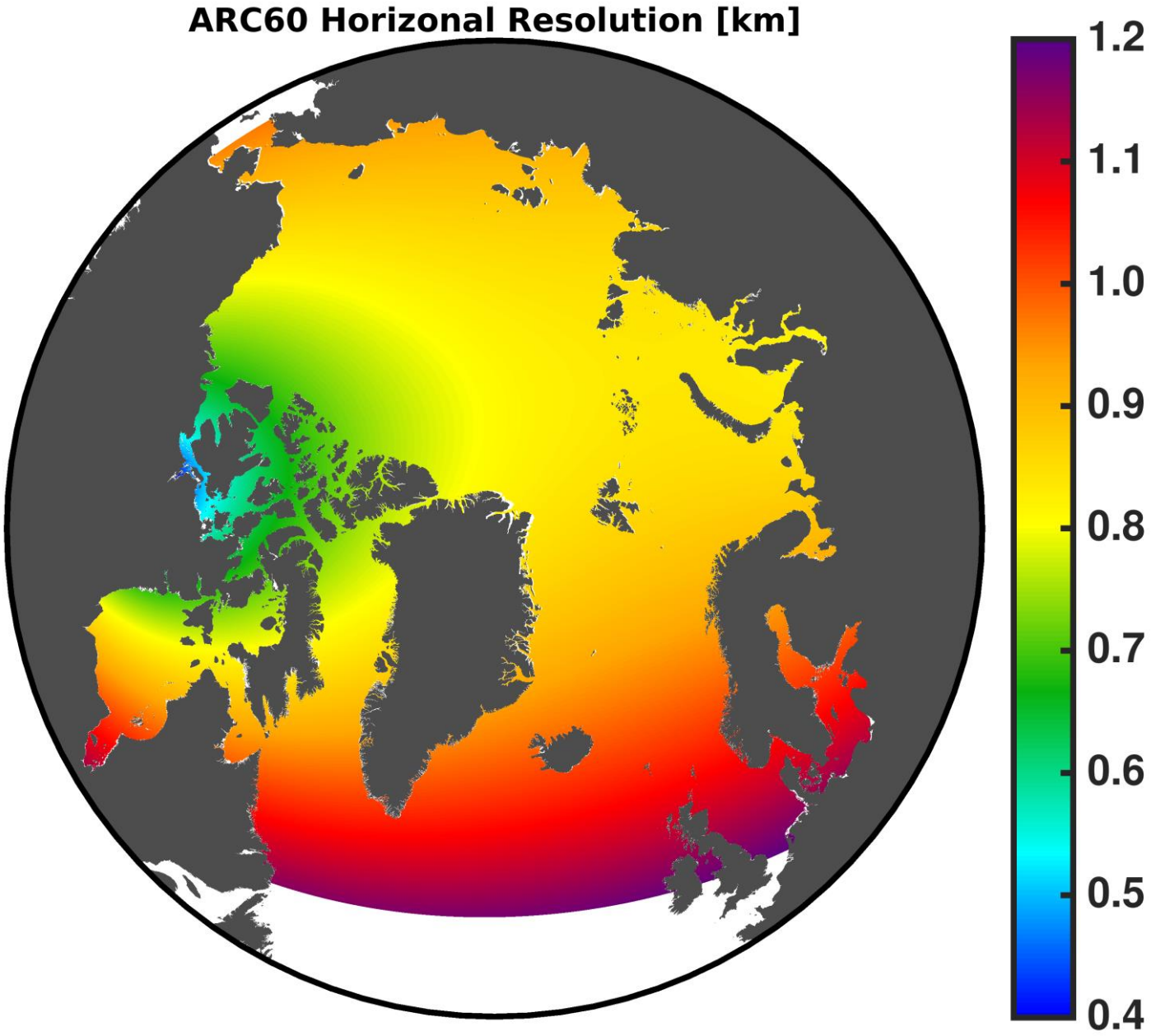


Eurasian Rivers



Bering Strait Inflow

ARC60

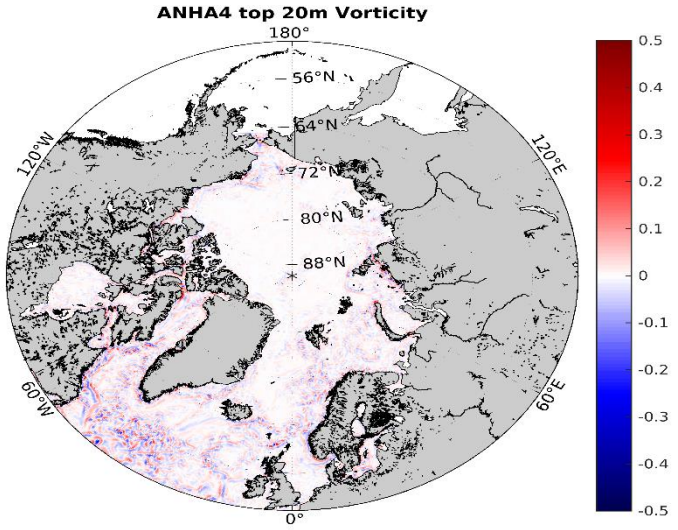


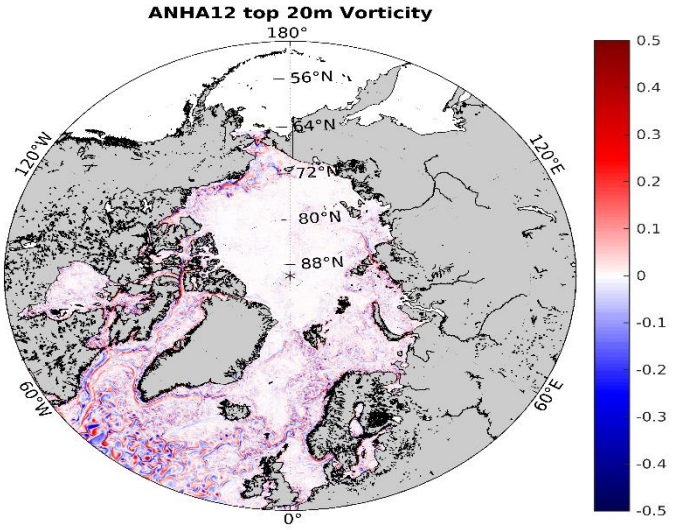
Our first ARC60 simulation:

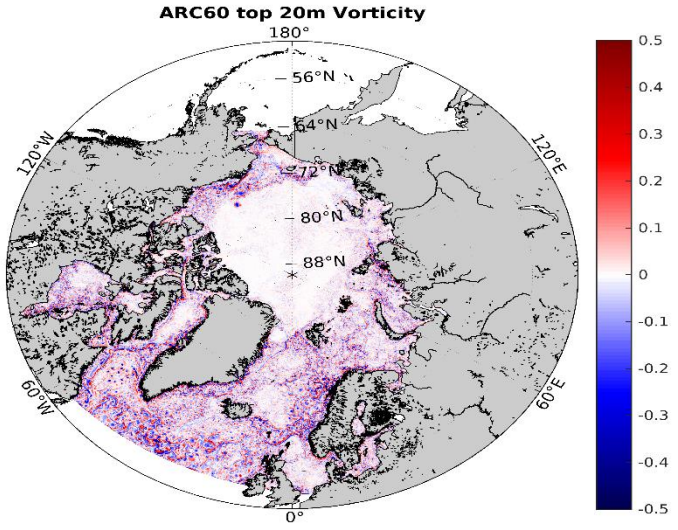
- 1993 GLORYS2v4 IC
- ERA5 forced
- 50 vertical levels
- Tides/diaharm/vvl
- Greenland icebergs
- 3 Passive Tracers
- ANHA12 BDY condition
- No-slip lateral conditions
- 8000+ cores required

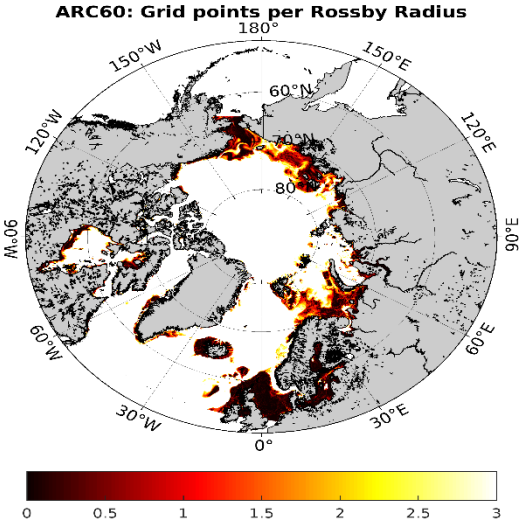
Still in spinup – nearly 1 year output at present

Resolution for Arctic Modelling

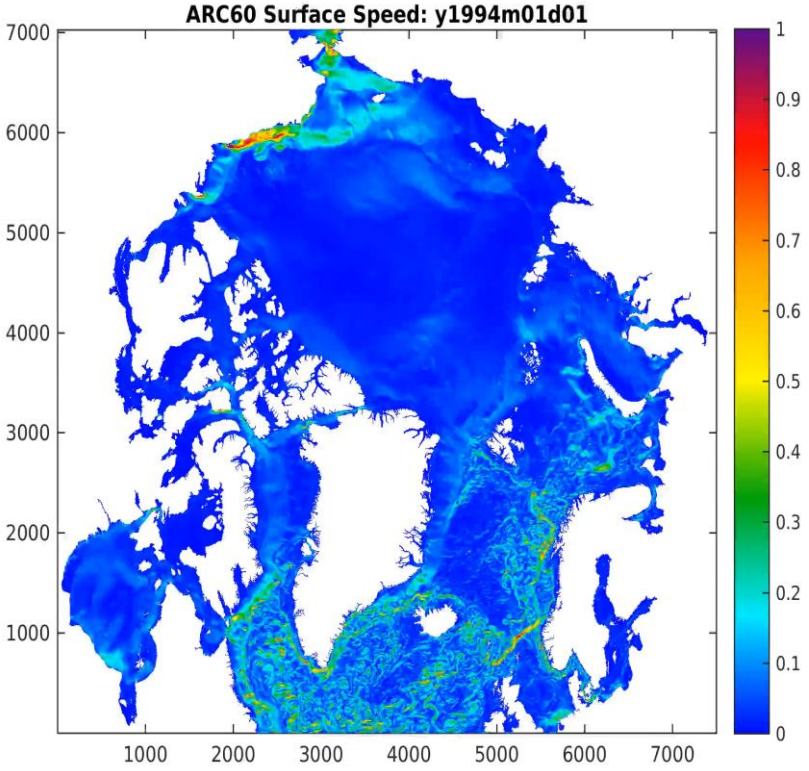


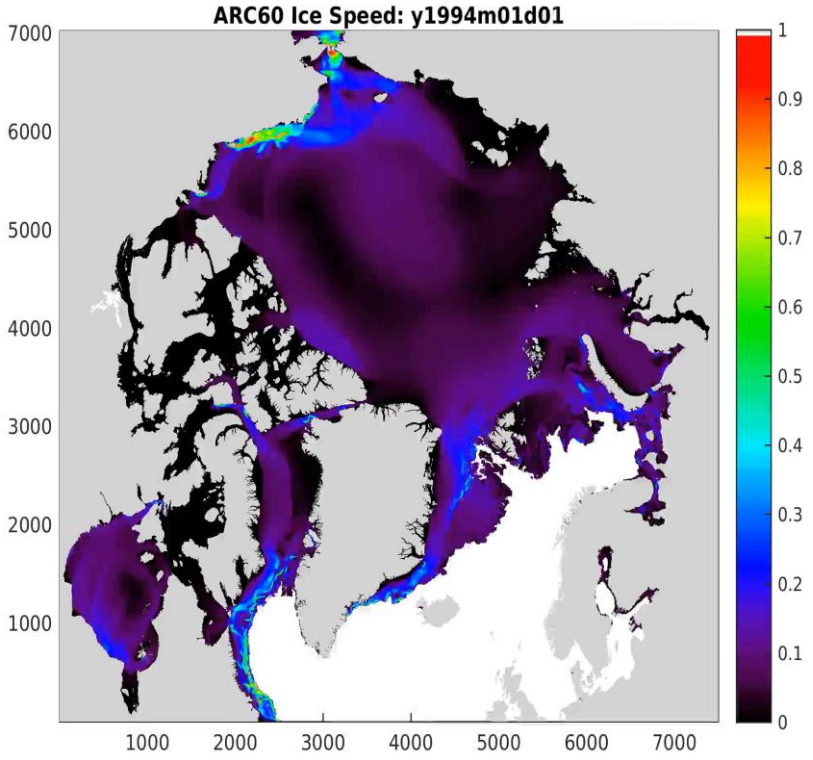






ARC60 – Velocity (ocean and ice) Magnitude





Summary

- BG Freshwater generally under-represented in a suite of simulations
  - And the ‘closest’ result is for the ‘wrong’ reasons
  - Too little low salinity freshwater at surface
  - Regional models underestimate the inflow from Bering Strait
  - Comparing with Bering Strait moorings show
    - Good comparison in temperature
    - Significant underestimate in Salinity
  - Global models have much better FWC and salinity compared to Bering Strait moorings
    - But can’t just use the such runs as boundary conditions for inflow at Bering Strait in regional model
  - Need to examine in detail pathways from Bering Strait, off the shelves and into the BG, in detail, and with time