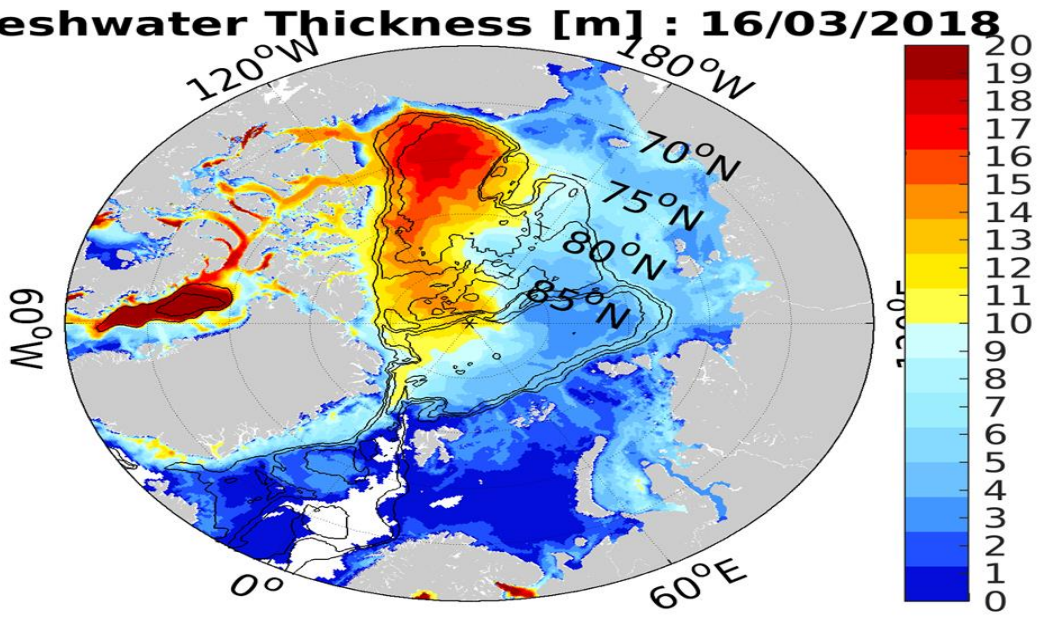
An examination of the freshwater content of the Beaufort Gyre and Arctic shelves in a suite of NEMO model simulations



Paul G. Myers, Clark Pennelly, Tahya Weiss-Gibbons, Chuanshuai Fu and Carlos Ramos Portalatino
Department of Earth and Atmospheric Sciences
University of Alberta

Ventilation Interactions and Transports Across the Labrador Sea

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Outline

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

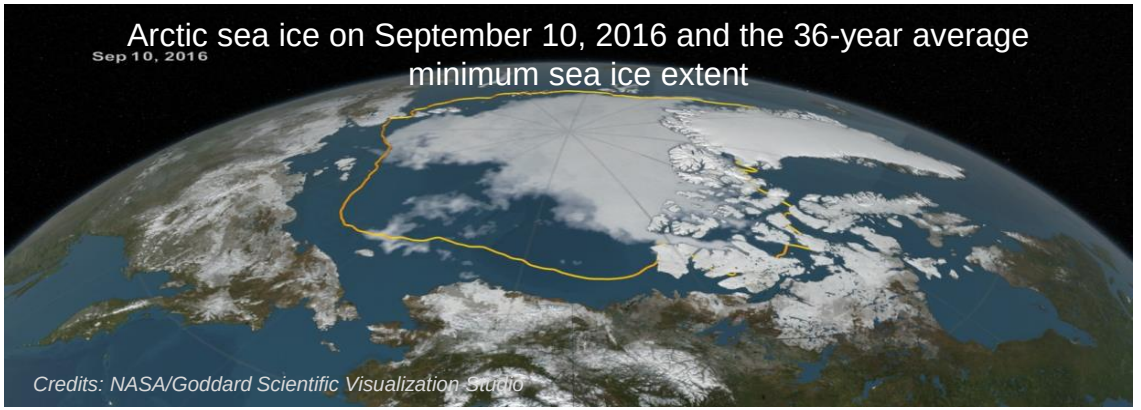
Changes in the Arctic Ocean Freshwater Budget

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

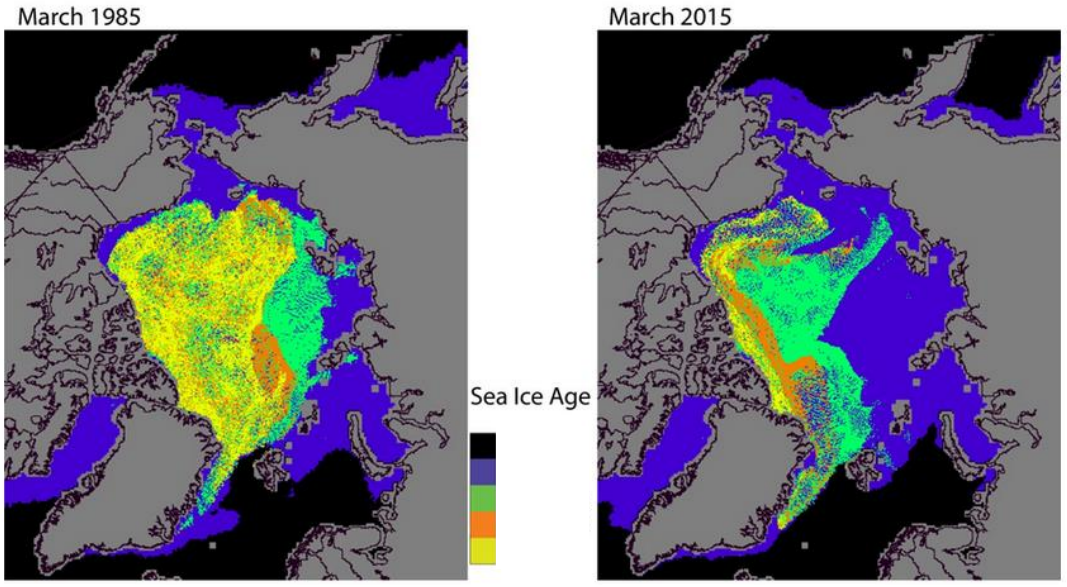
Liquid FW	(93➔101):	+9%
Beaufort Gyre	(16.9➔22.6):	+34%
Multiyear ice	(10.9➔ 7.4):	-33%
Seasonal ice	(13➔13.4):	+3%

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

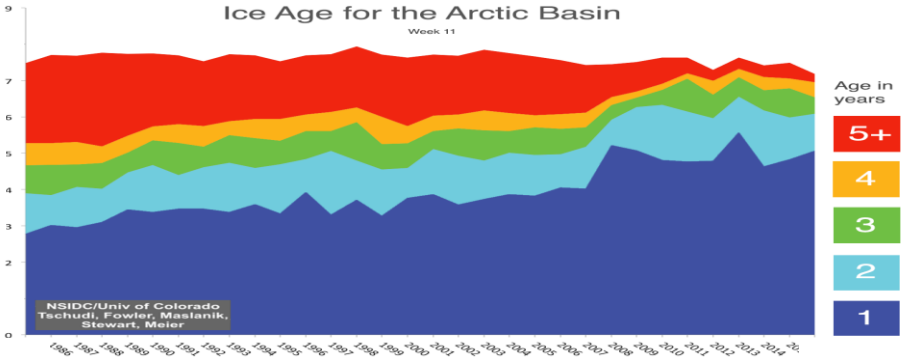
P-E	(2 ➔ 2.2):	+10%
Runoff	(3.6 ➔3.8):	+8%
Bering FW	(2-2.5 ➔3-3.5):	+4%
Net Ice Melt	(0.27 ➔0.29):	+8%

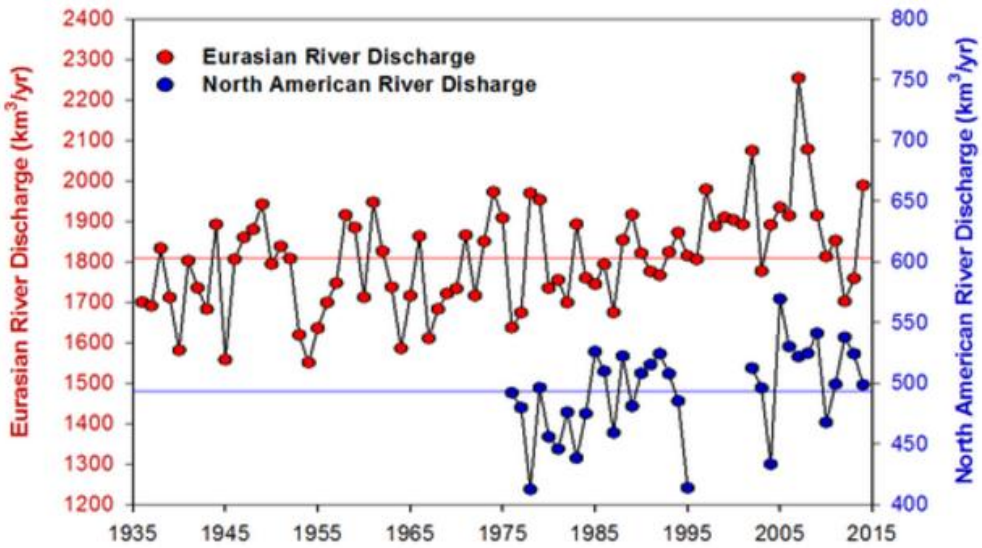


Haine et al., 2015; Shiklomanov, 2010; Woodgate et al., 2012; Proshutinsky et al., 2009.



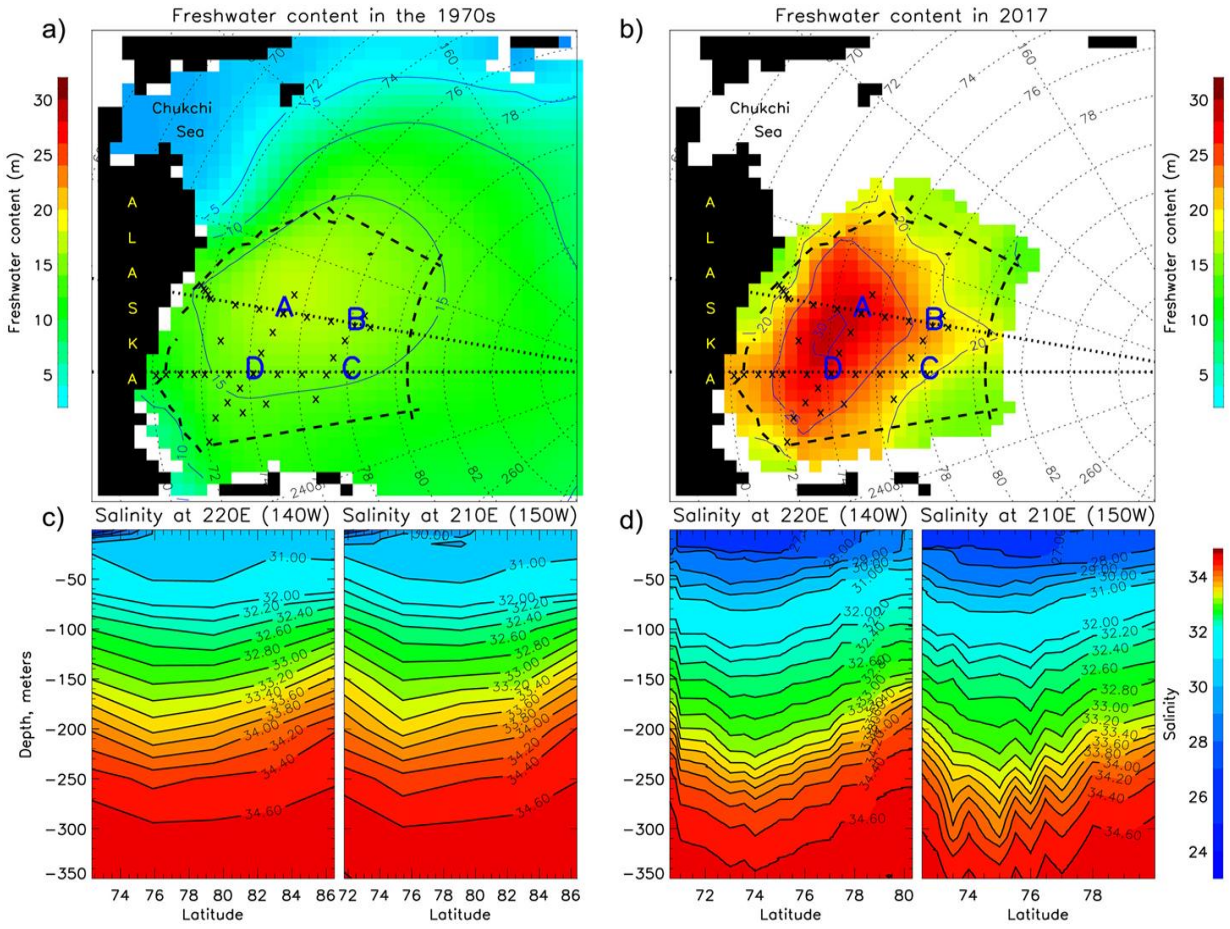
Perovich et al., Arctic Report Card: Update for 2015.

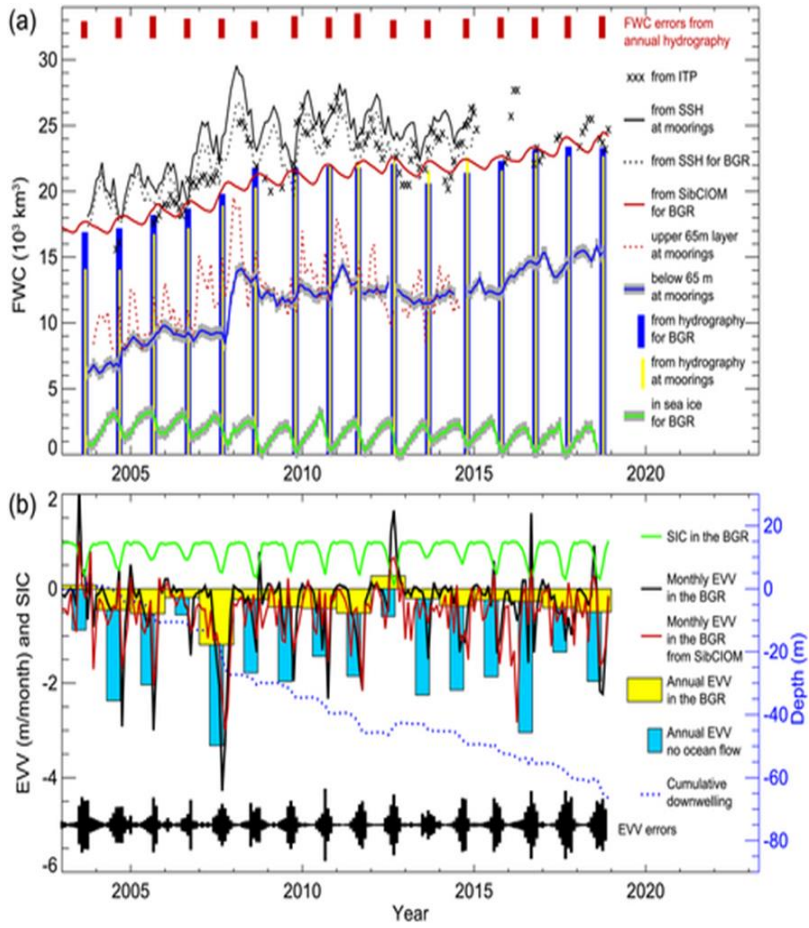




Holmes et al., Arctic Report Card: Update for 2015.

BG has been getting fresher





Proshutinsky et al., 2019

ANHA: Arctic and Northern Hemisphere Atlantic

ANHA12 & ANHA4

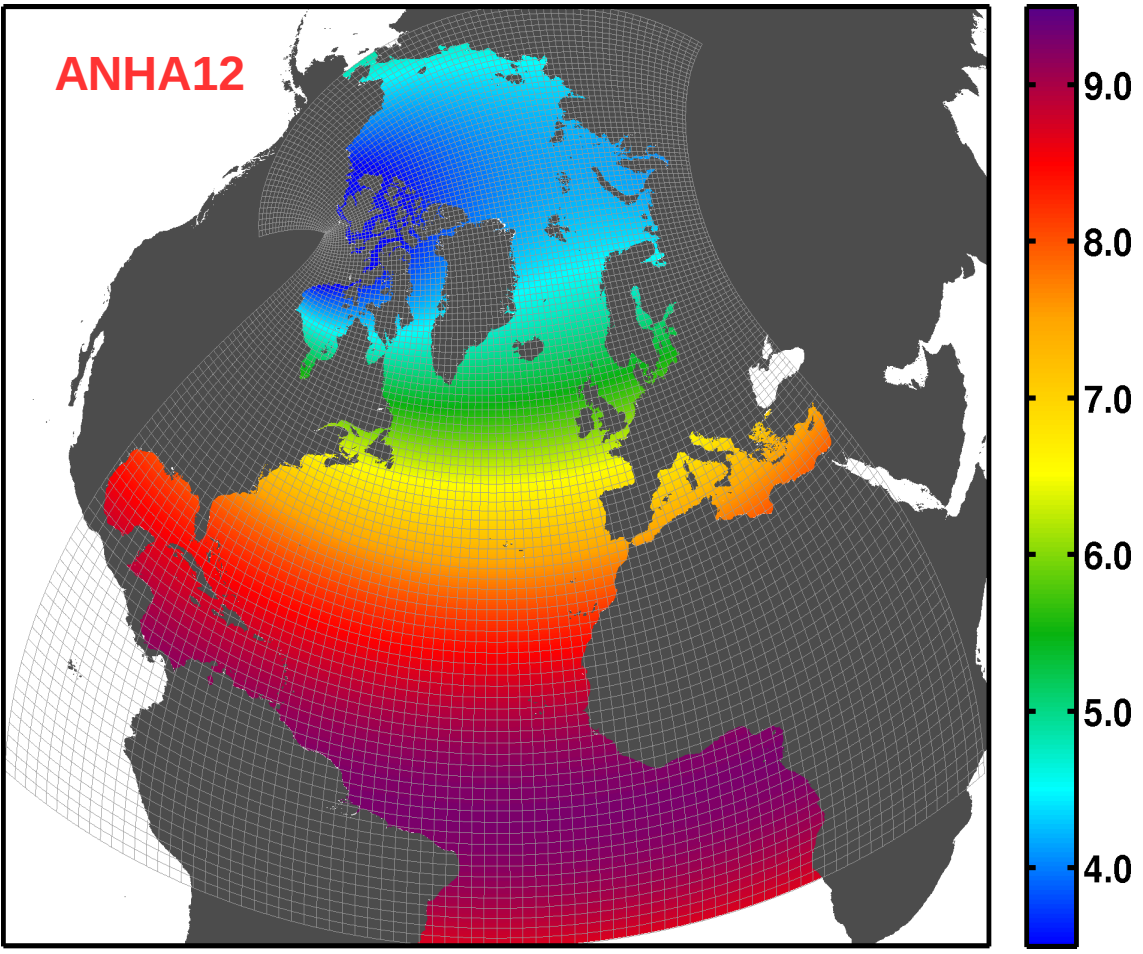
Model : NEMO 3.4
LIM2 + EVP

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

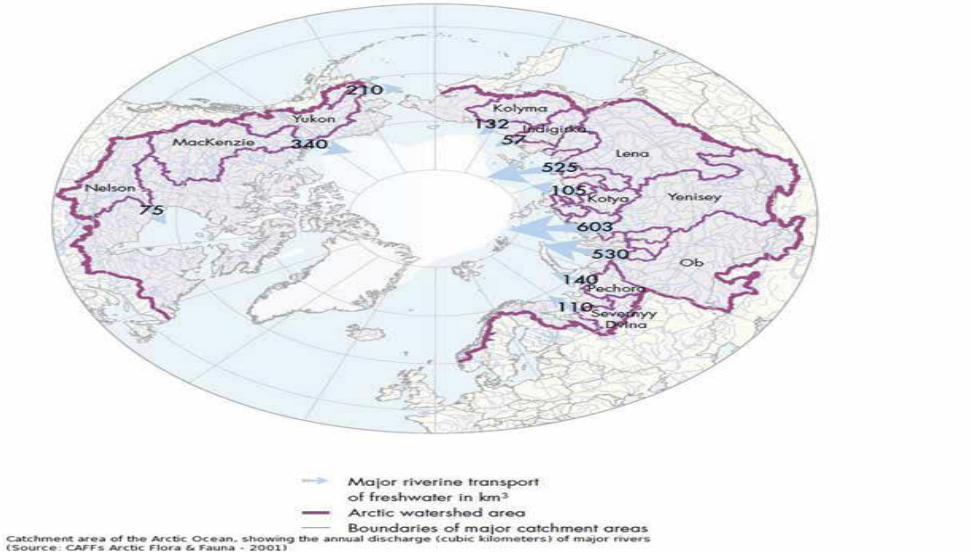
CMC: Canadian Meteorological Centre

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

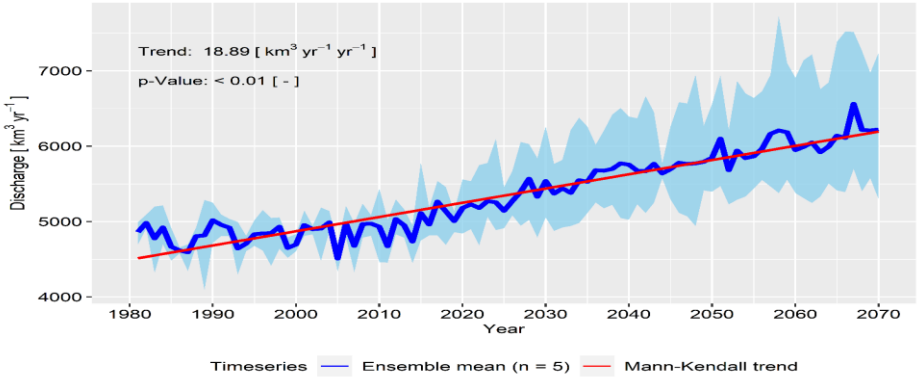


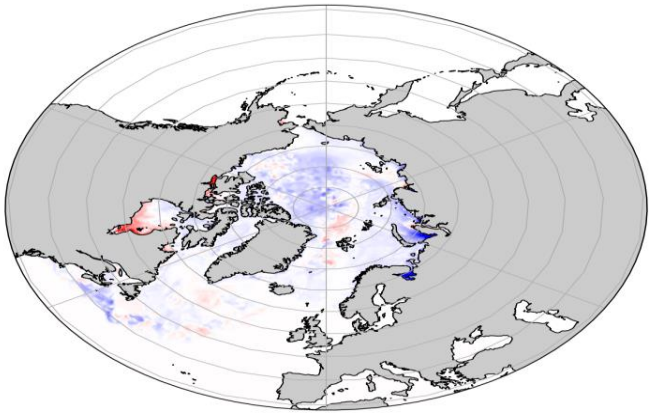
Catchment area of the Arctic Ocean, showing the annual discharge (cubic kilometers) of major rivers (Source: CAFFs Arctic Flora & Fauna - 2001)

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

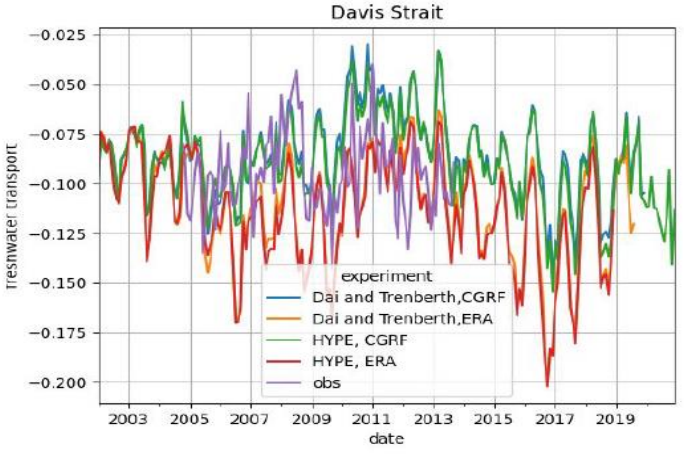
Compared to Dai and Trenbeth climatology of major rivers

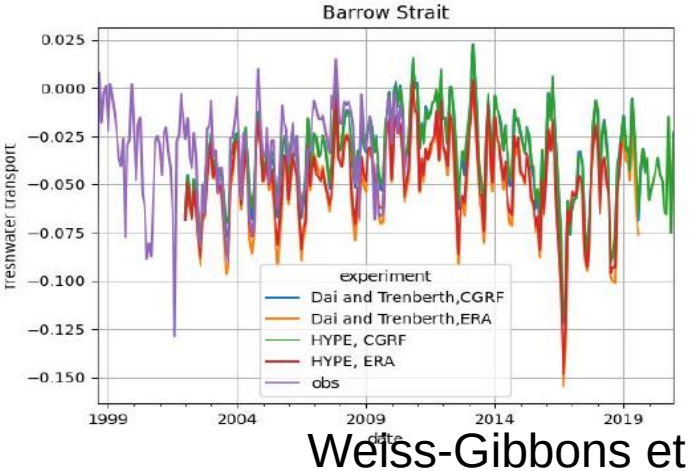
2018 HYPE – DT FWT above 34.8





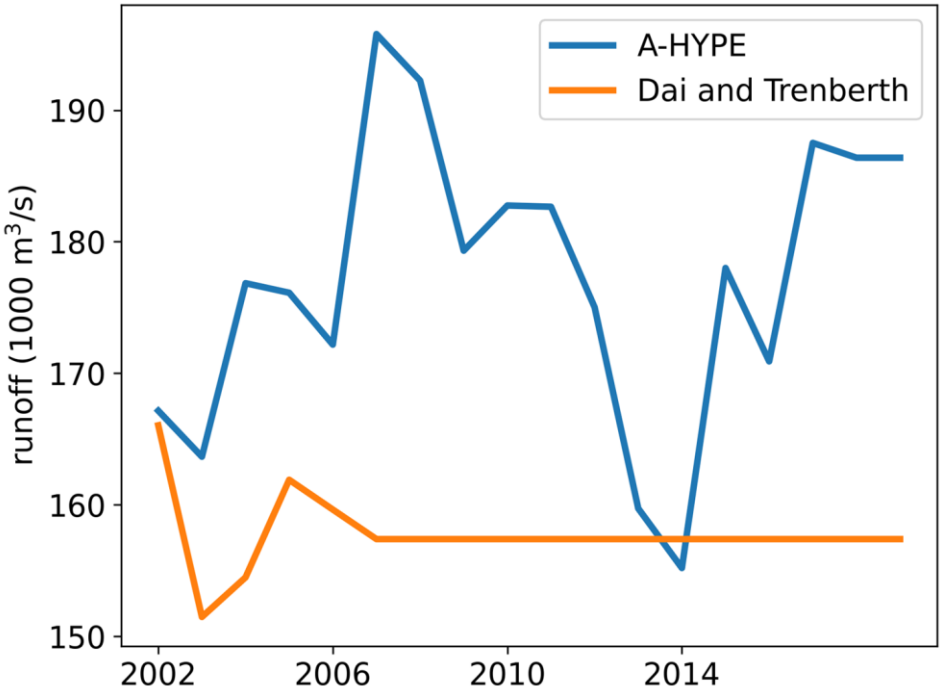
Stadnyk et al., 2021, Elementa



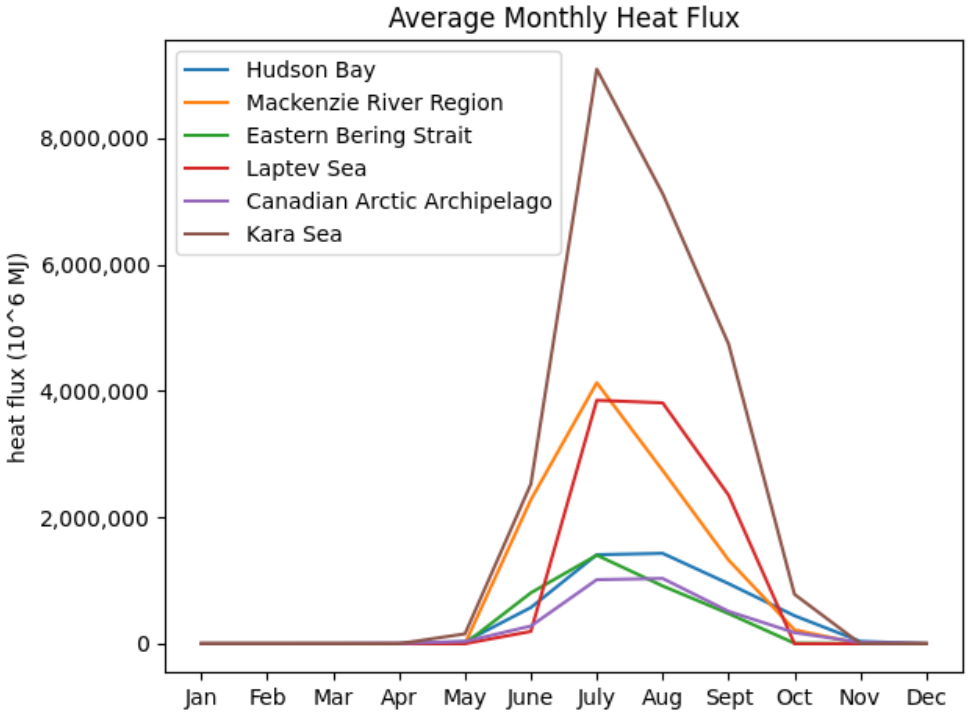


Weiss-Gibbons et al, 2024, submitted

Combining Hydrological Model Output with Ocean Model Simulations

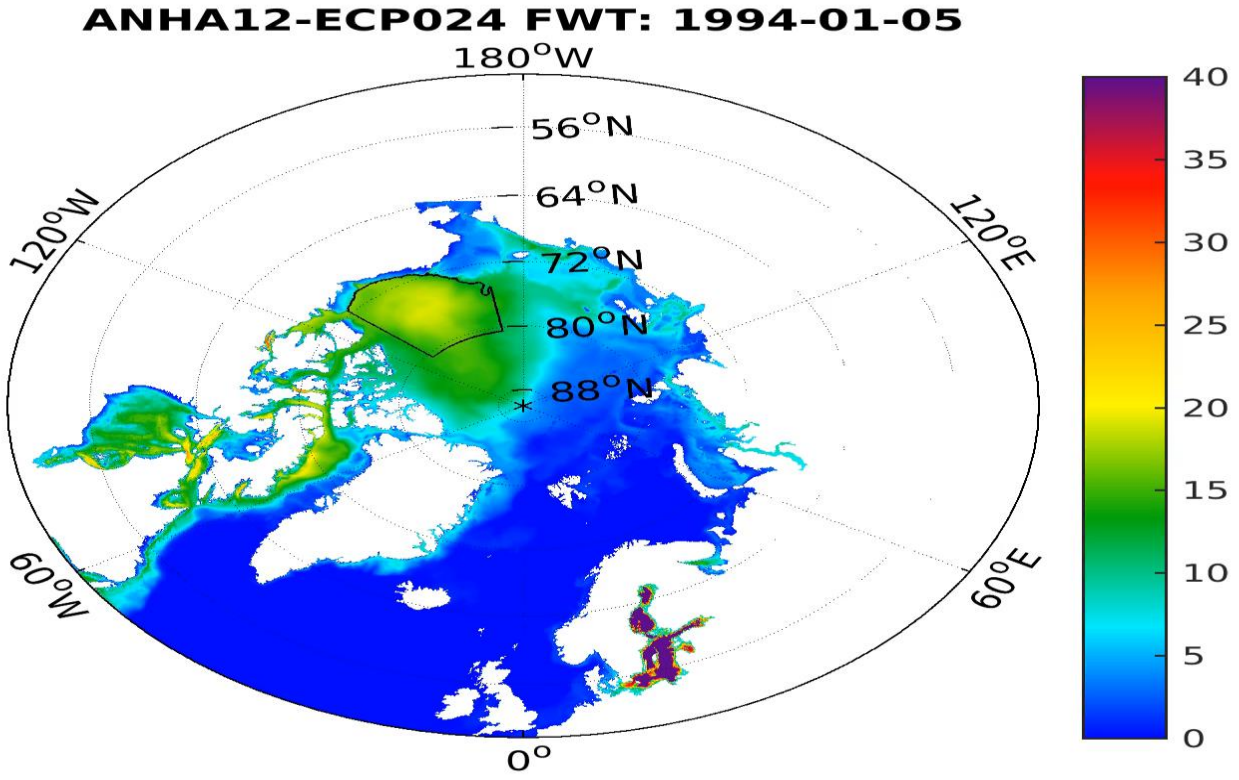


The annual average runoff from A-HYPE provides inter annually varying data, consistent with climate trends

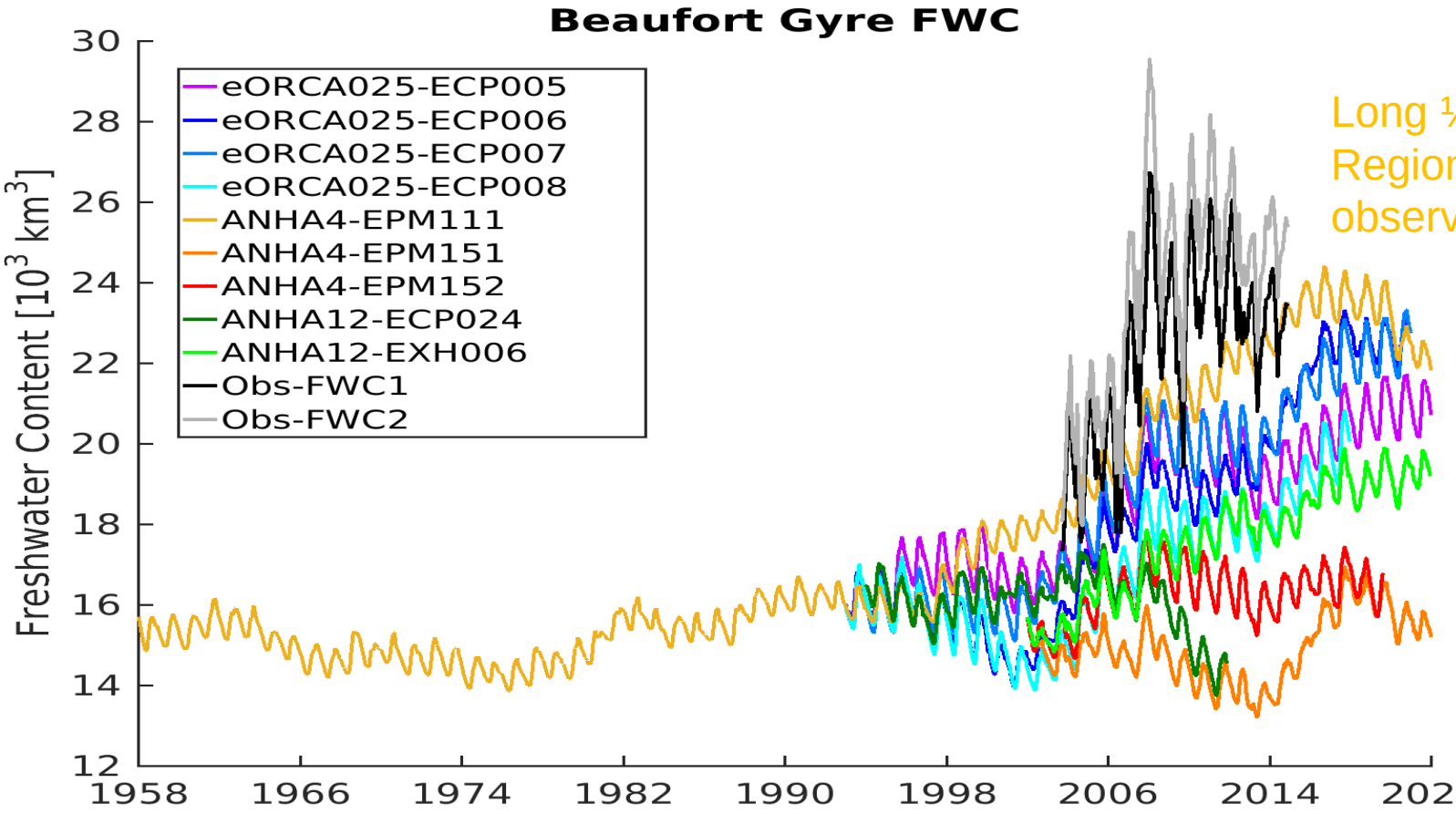


Can also use hydrological data to provide river water temperature information to the ocean model

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.

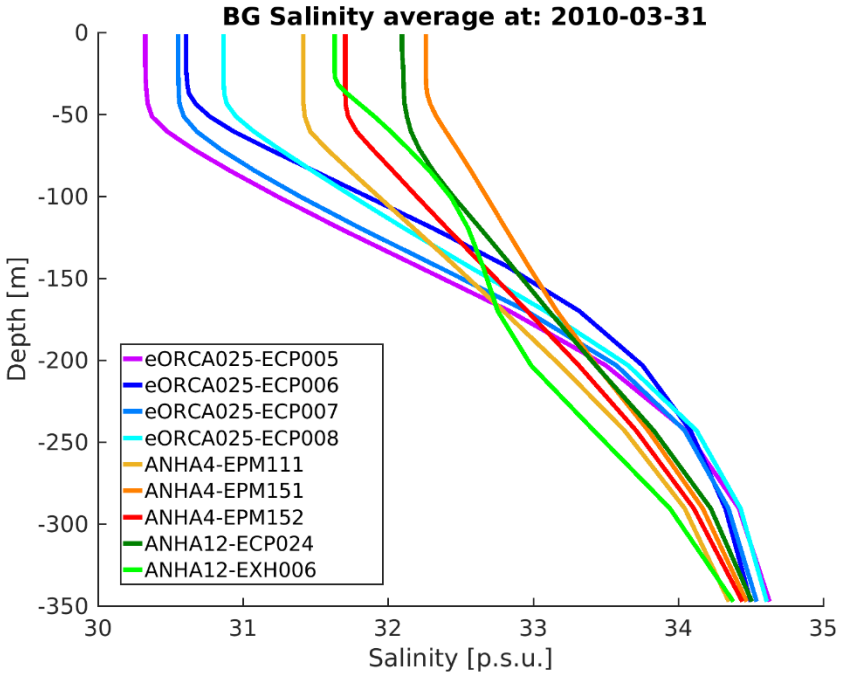
Global ¼ degree closer to Obs.

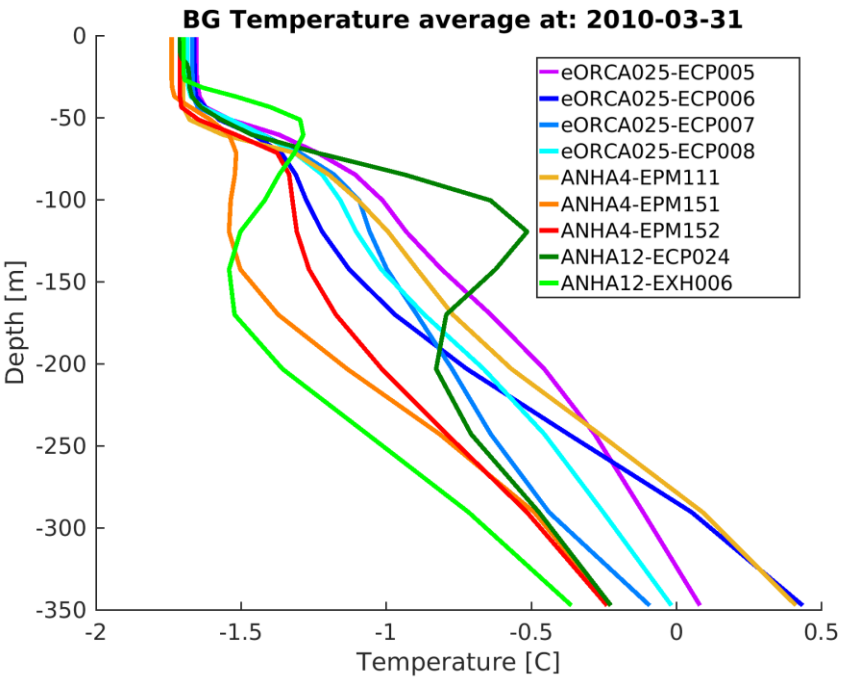
1/12 Regional Better

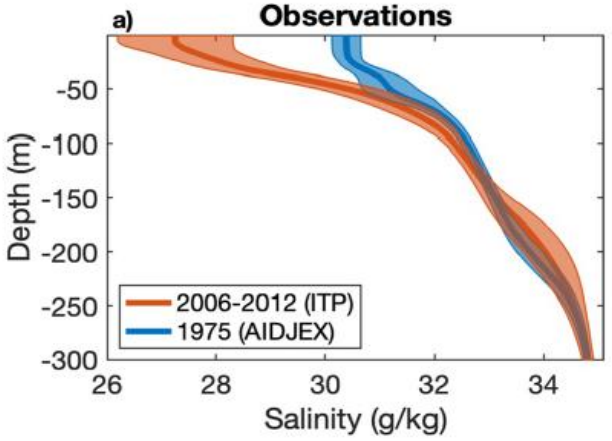
¼ Degree Regional – Very low

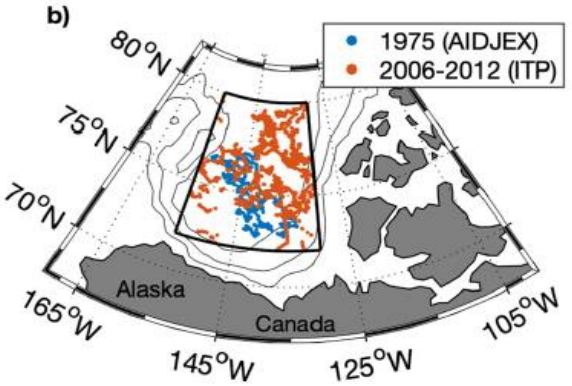
But newer 1/12 Regional FWT Declines?

BG Average T and S Profiles



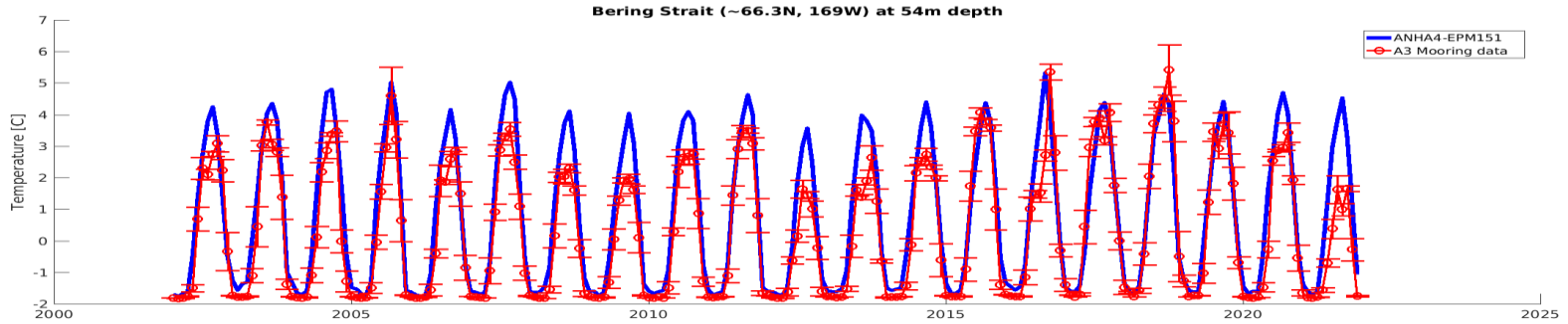


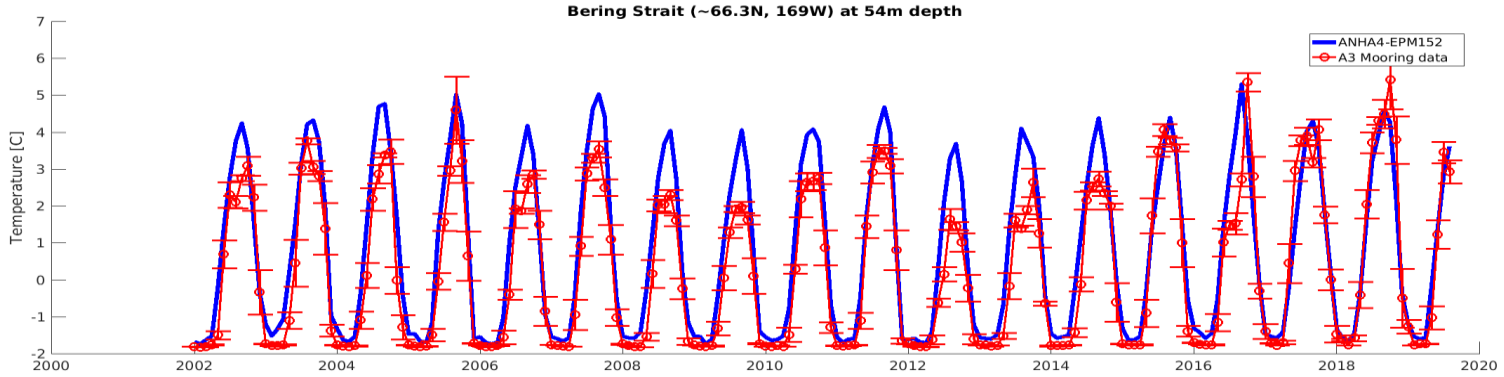




From Rosenblum et al., 2021

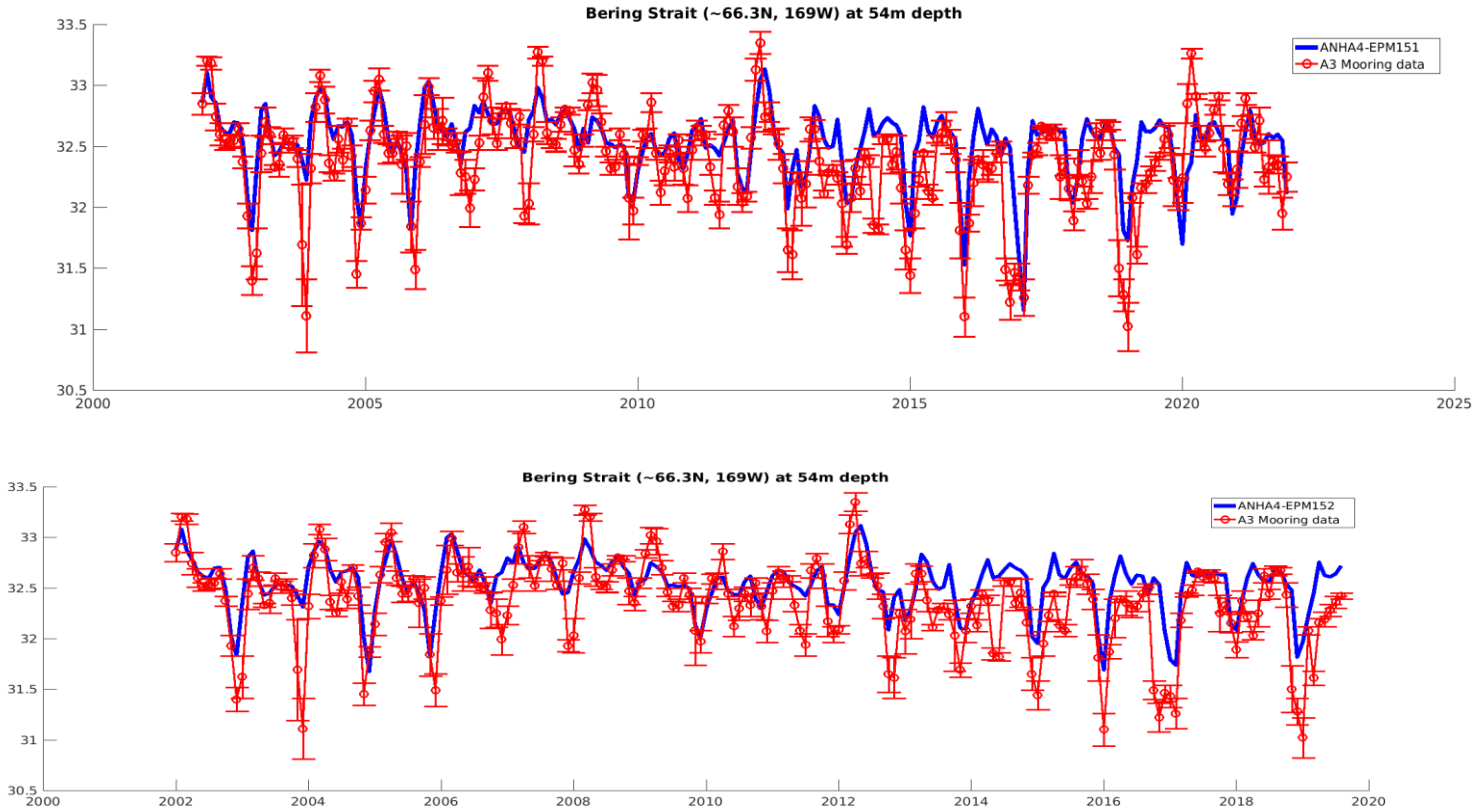
Bering Strait 54m Model vs Obs Comparison





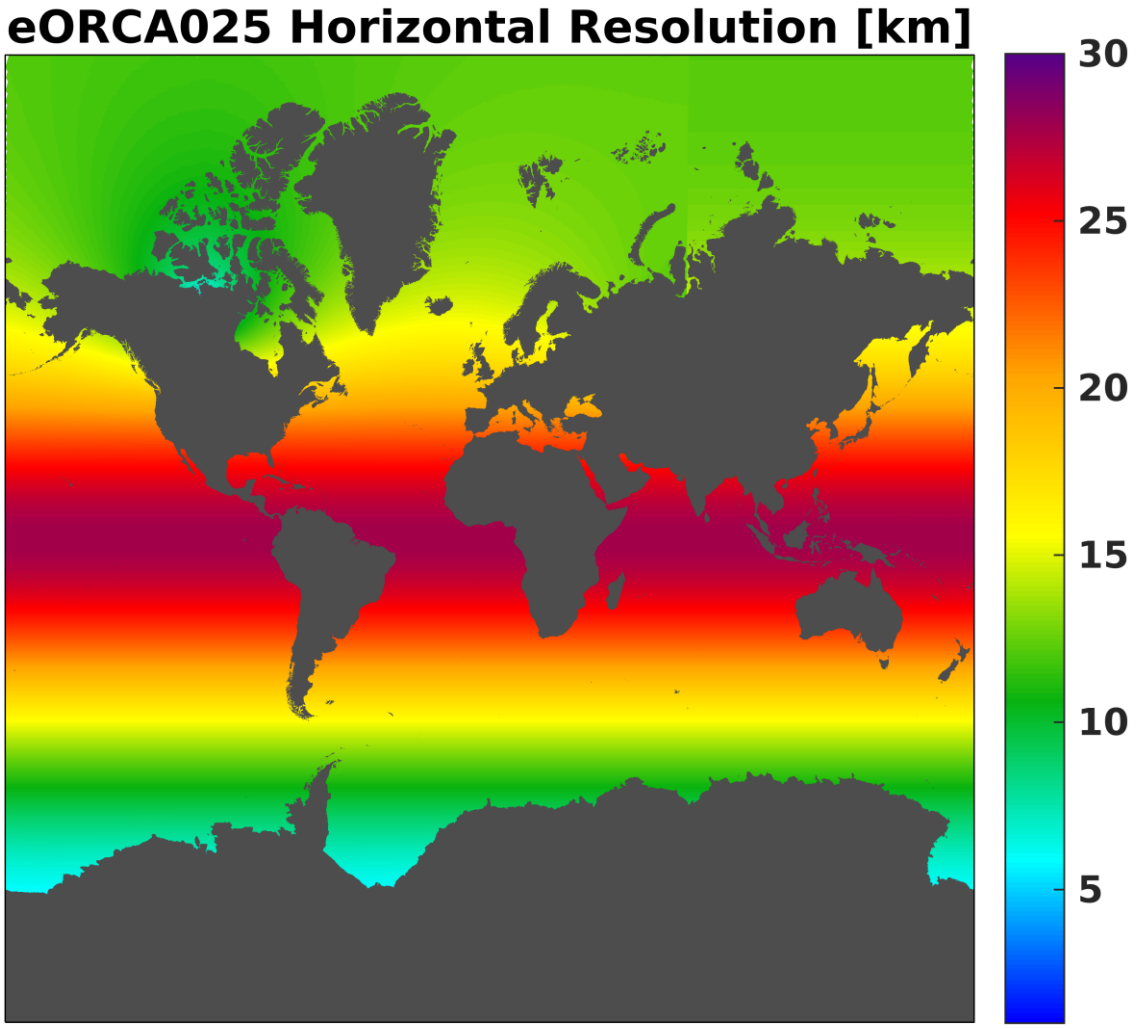
Rebecca: These are comparisons of our ¼ degree model with your mooring – I was very pleasantly surprised with the temperature comparison, some issues with the summer maximum, but otherwise good agreement – Difference between the runs is atmospheric forcing – GDPS vs ERA

Bering Strait 54m Model vs Obs Comparison



Rebecca: And now the salinity comparisons – no where near as nice as the temperature – both experiments miss all the low salinity fluctuations, with the model having a smaller annual range – similar issues in our other regional runs, suggested in may be a function of what we use for the open boundary conditions

eORCA025



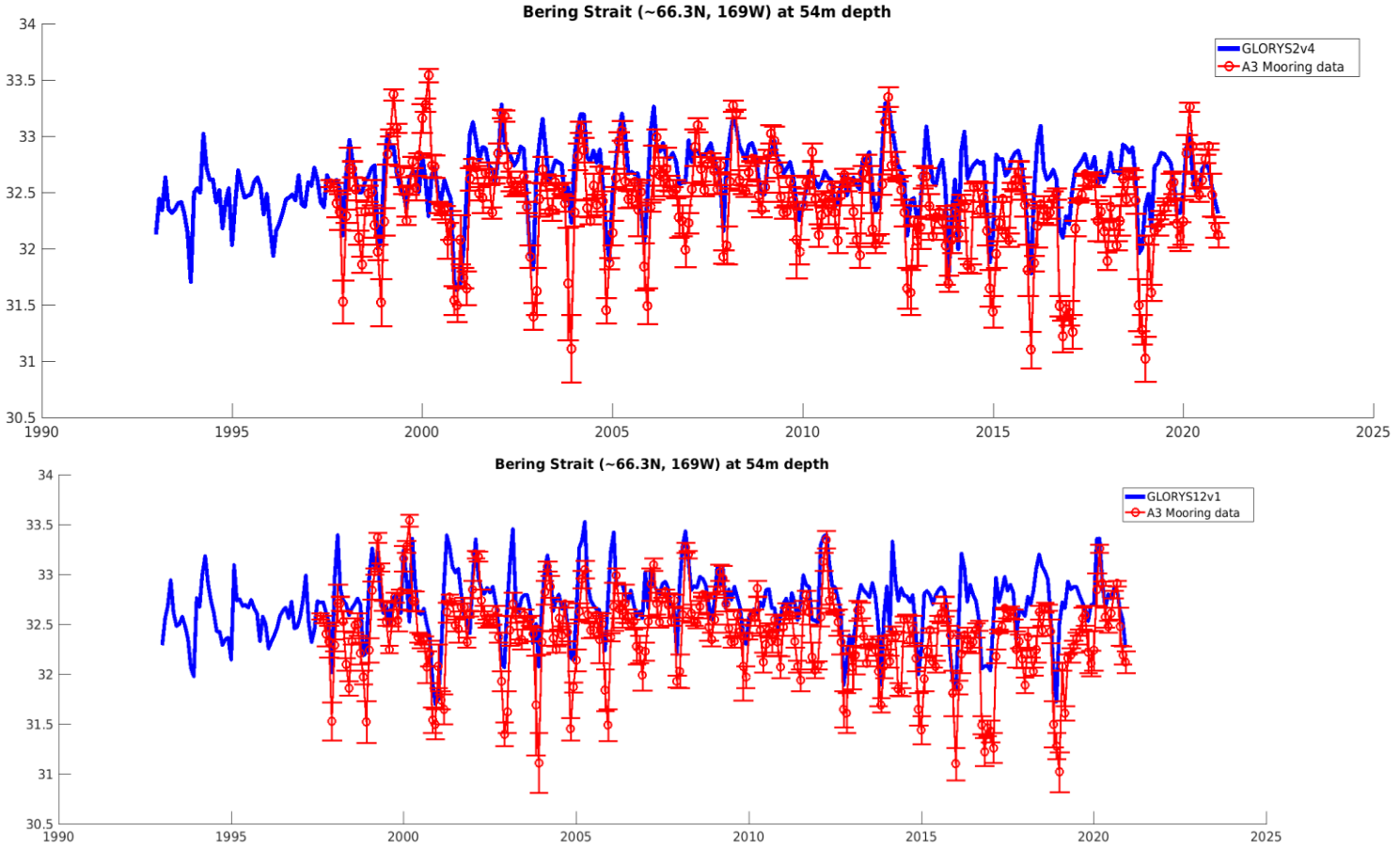
We've finally gone global!

- 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)

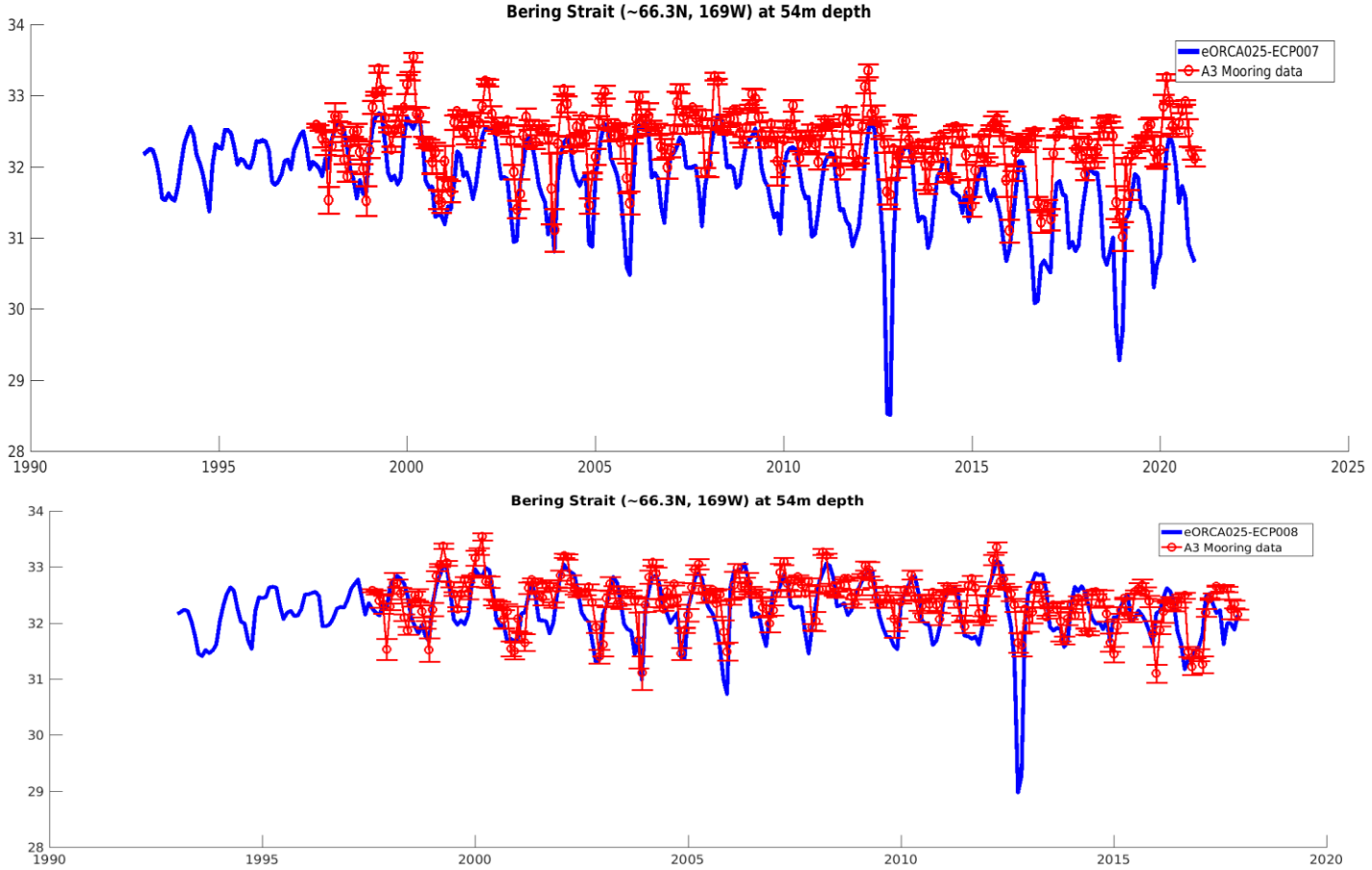
- To add:
  - Tides
  - BLING (biogeochemical model)
  - Carry into NEMO 4.2

Bering Strait 54m Model vs Obs Comparison



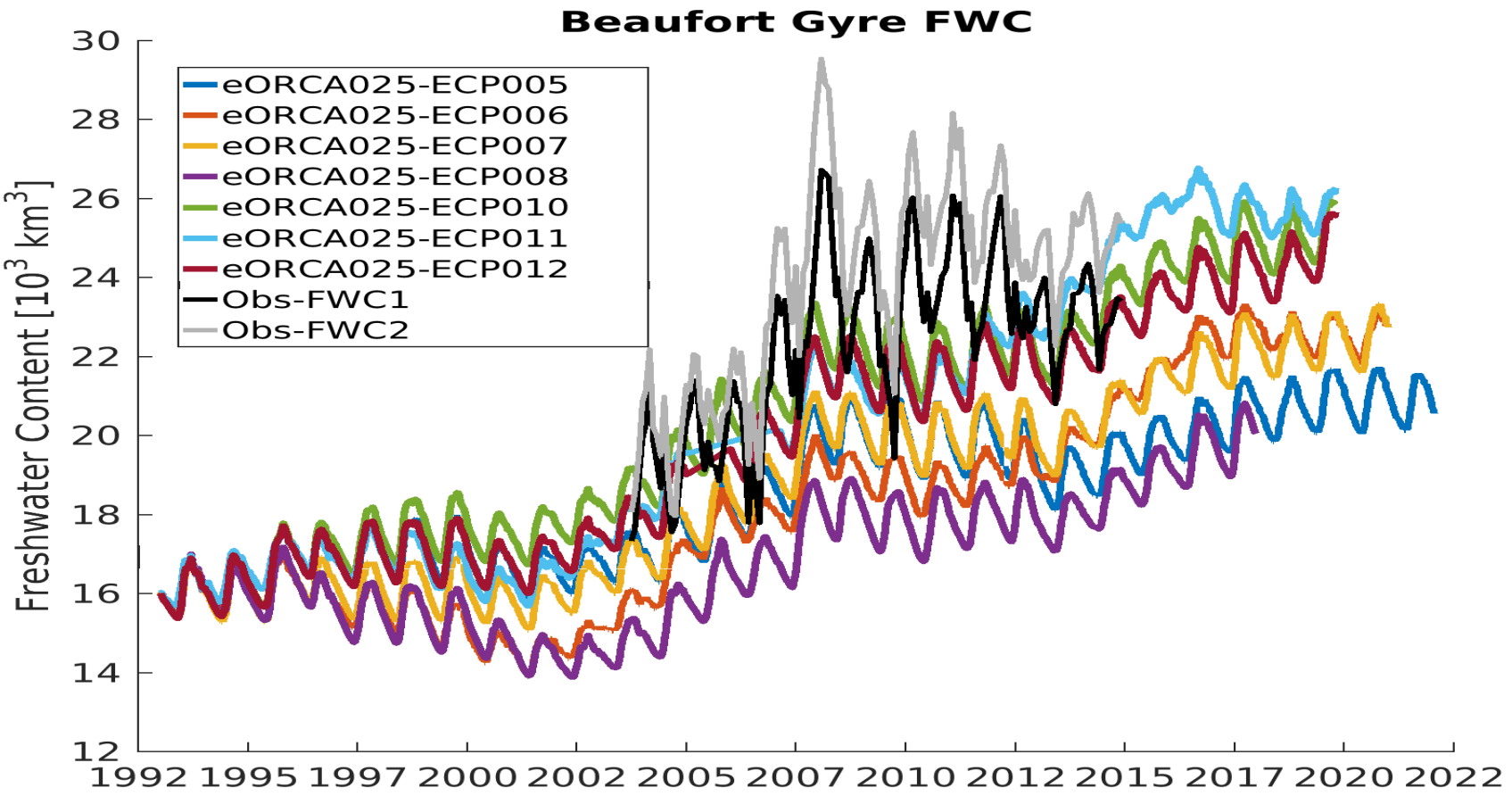
Rebecca – And same comparison with the the GLORYS reanalysis product we use for our OBCs (and which many people use to study the Arctic) – Neither product good, no better than the prognostic models

Bering Strait 54m Model vs Obs Comparison



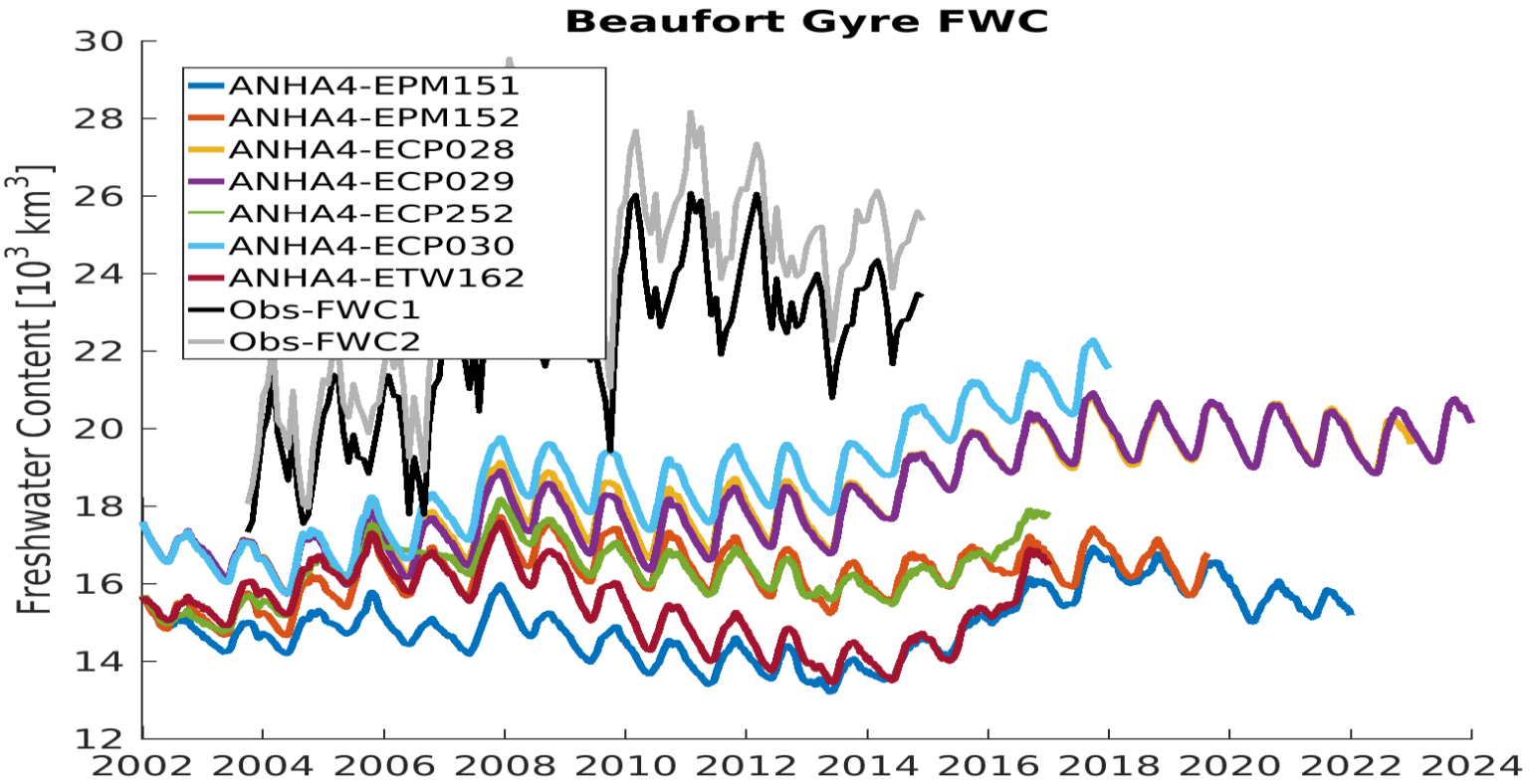
Rebecca – Now we do the same comparison with a global model! So no open boundary conditions, and allows Arctic-Pacific feedbacks. 2 different runs – Top one is interestingly fresher than the observations – But the second (which has a more advanced ice model, tides and ERA forcing) compares much more closely to your observations – So it is possible!

Updated eORCA025 with runoff from Hydrological Model



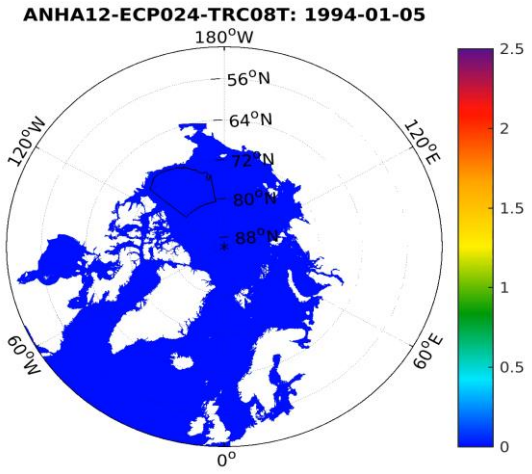
Rebecca – So the global ones, that are fresher at Bering Strait, also do better in the Beaufort Gyre – still low, but not nearly as much – the Cyan run, ECP012 is the one that compared the best with your mooring data on the previous slide

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

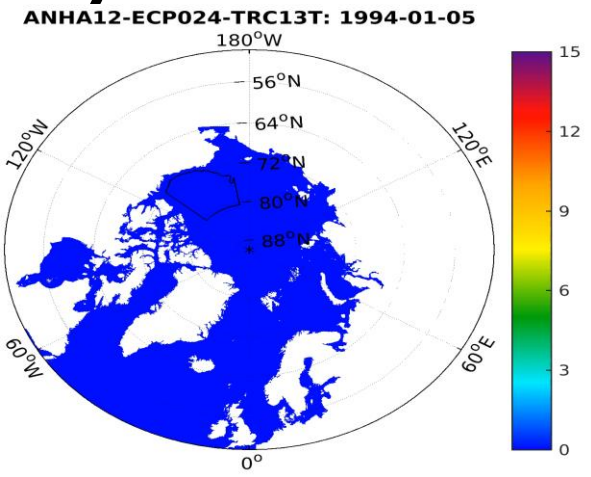


Rebecca – so we tried using the output from the that global run that compared best as the new OBCs for the regional model – ran 3 different ¼ regional experiments with slightly different set ups helped (ECP028 in yellow, ECP029 in purple, ECP030 in cyan) – they helped, but still regional model quite low compared to the observations – so that is where we are at present

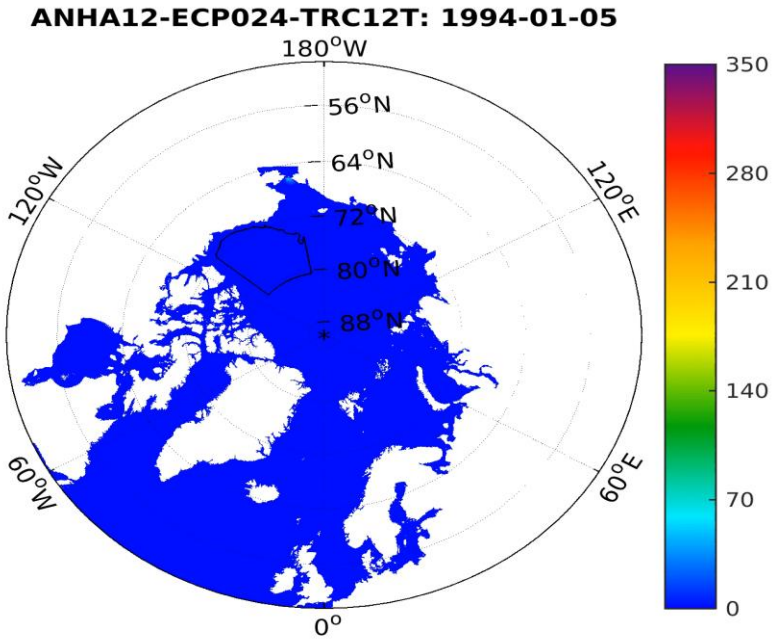
River and Bering Strait Tracers (1993-2011)



N. American Rivers

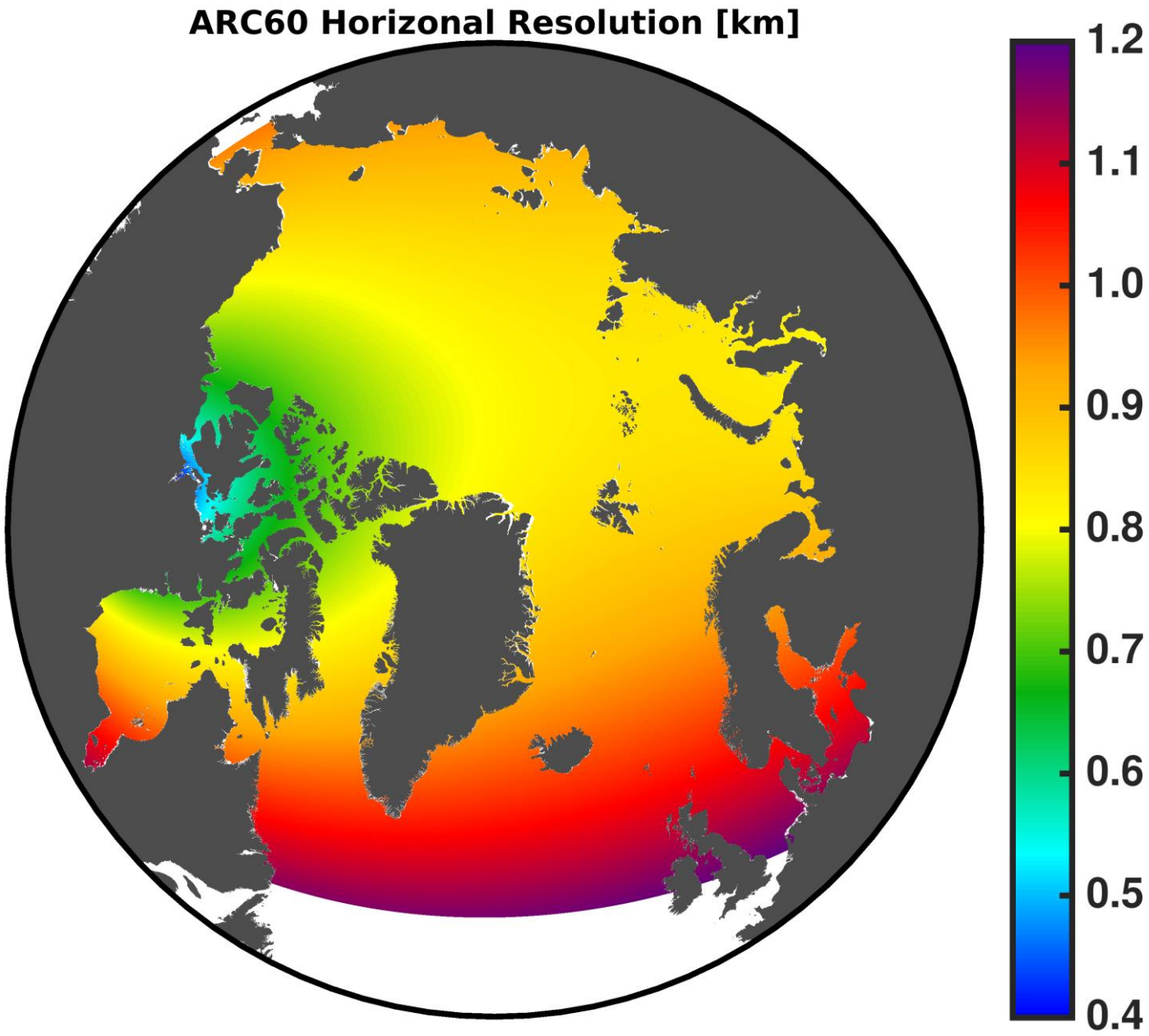


Eurasian Rivers



Bering Strait Inflow

ARC60

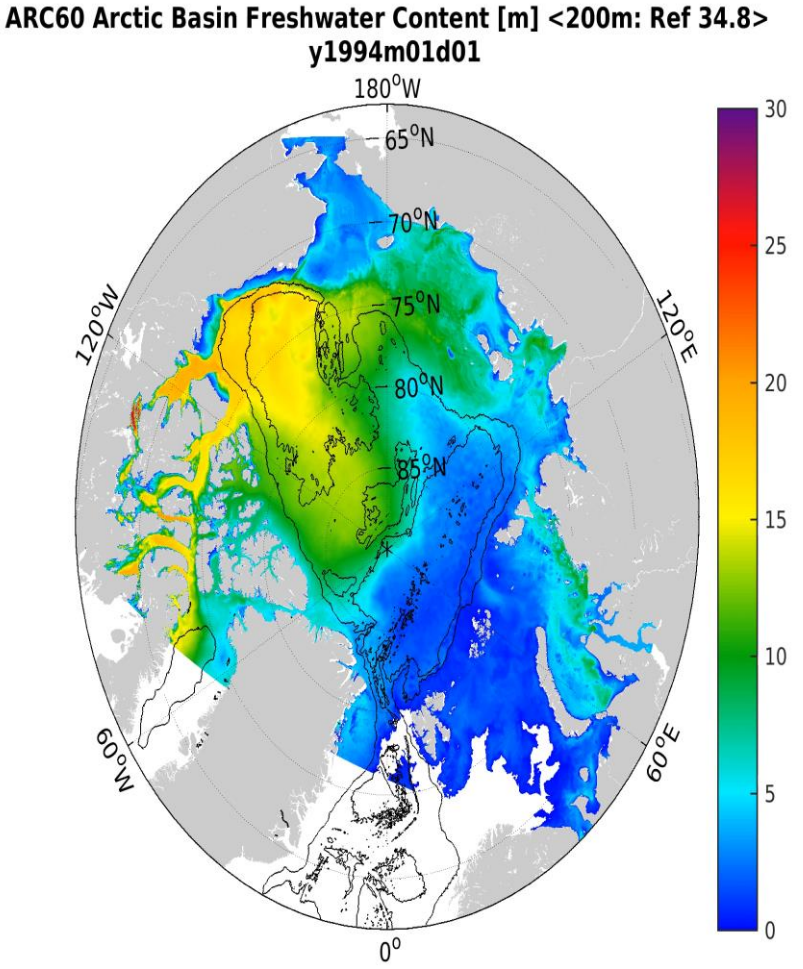


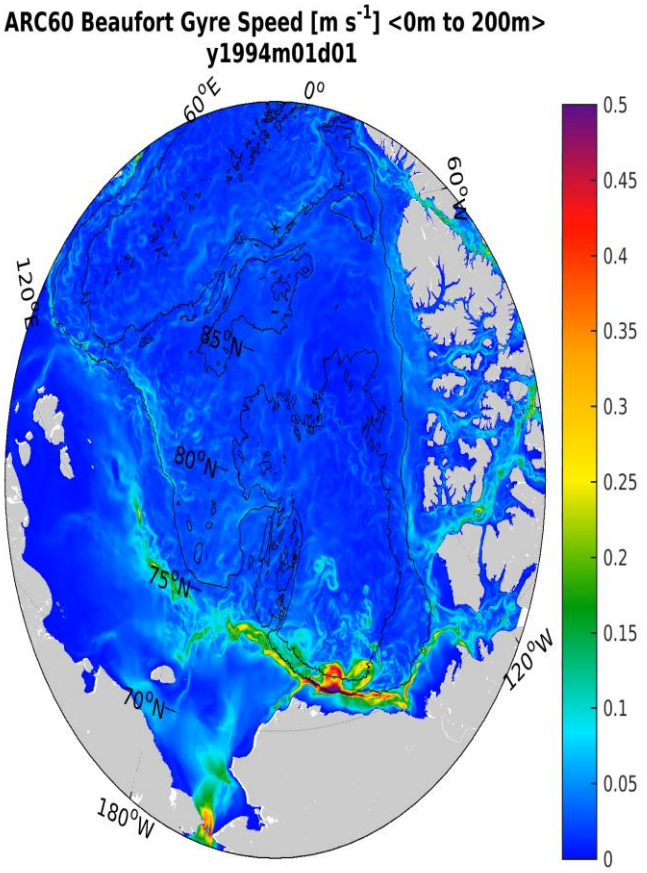
Our first ARC60 simulation:

- 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

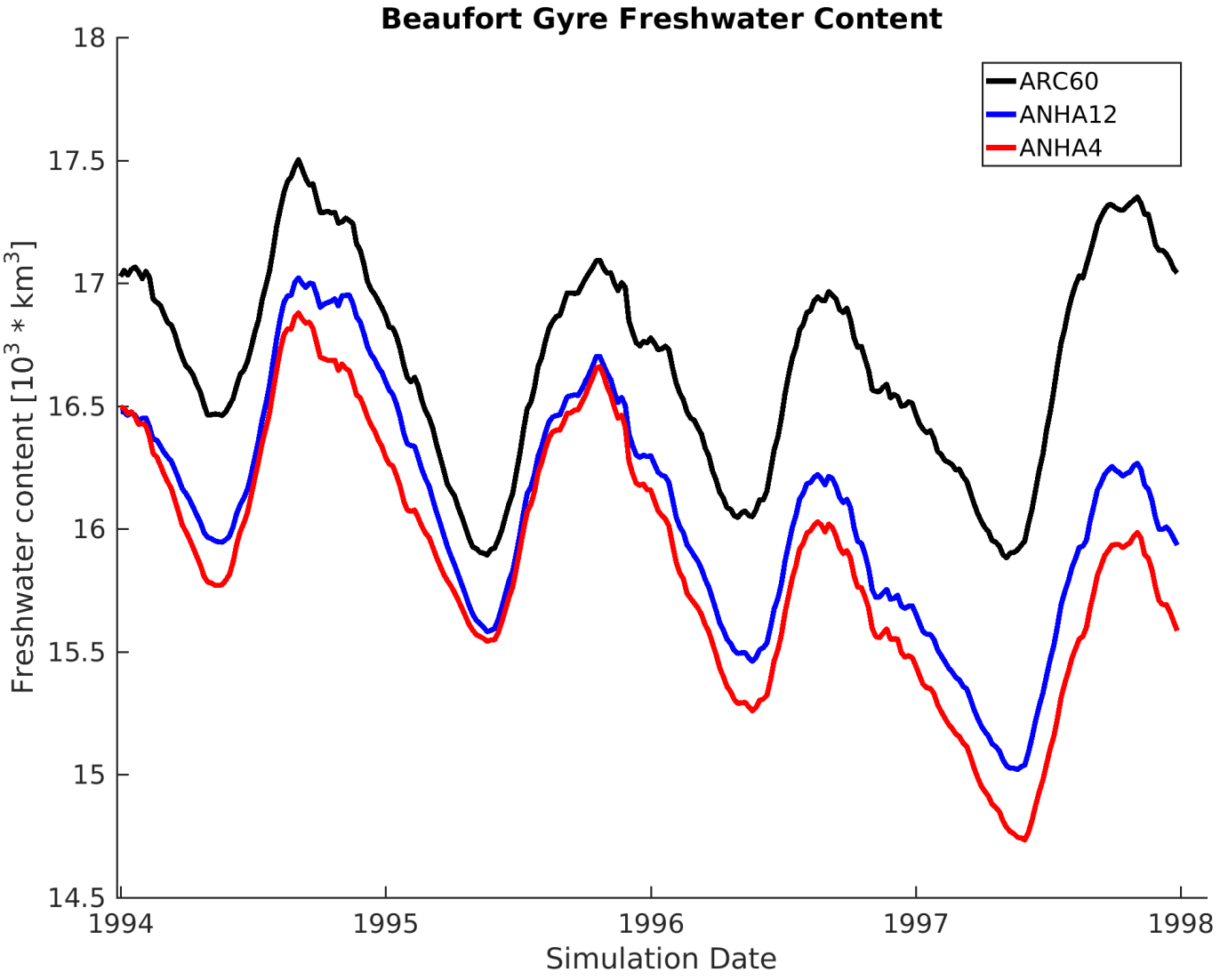
Arctic Freshwater Content





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

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