Arctic Monitoring Forecasting Center
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Freshwater modelling in the Arctic

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Ocean models and freshwater

Freshwater or salinity?

- Oceans contain a lot more water than salt.
- Accounting of freshwater in the oceans is ill-posed from the start (Schauer and Losch 2019), better track salt.
- The present literature:
  - Freshwater defined against an arbitrary reference salinity (mostly 34.8 psu)
  - Sea ice is accounted as freshwater (~6 psu)

The future: double accountancy of freshwater and salt fluxes until the literature becomes sufficient for stable salt budgets.

Ocean models and freshwater

Models are all designed for conservation, but of what?

Two options for **water**

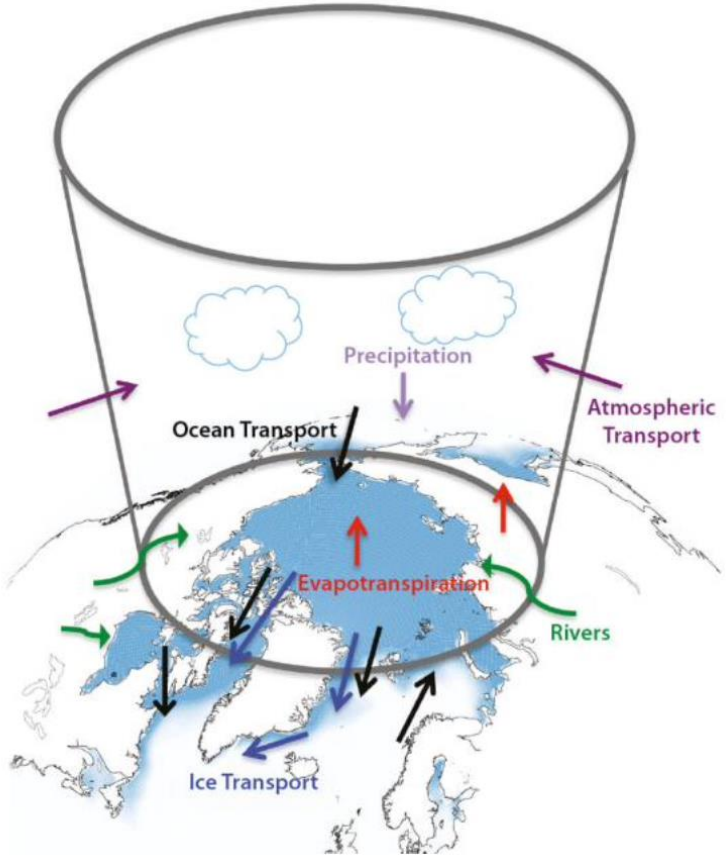
- Volume conservation (z-levels or terrain following models)
  - NEMO, MOM5, MITgcm, ROMS, MPAS.
  - Sea level rise diagnosed empirically
- Mass conservation (isopycnic coordinates)
  - MICOM, HYCOM, MOM6, BLOM.
  - Something else is not constrained

Conservation of **salt**, with some caveats

- Data assimilation increments are not conservative
- Inherently with numerical diffusion
- Computing fluxes from model output is a sensitive topic (due to numerical noise)
- Initial salinities from World Ocean Atlas are vastly incorrect

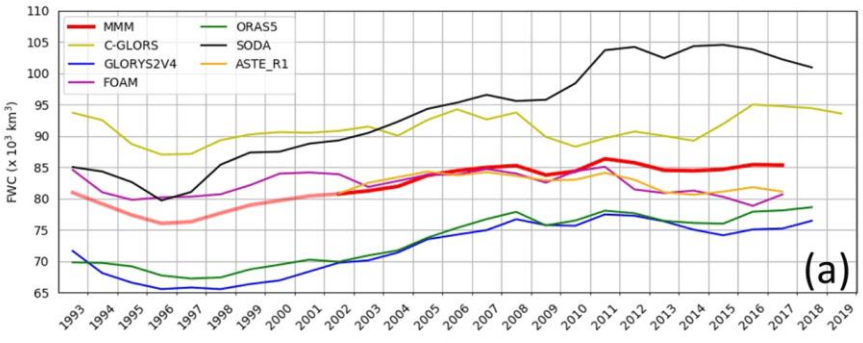
Freshwater from where?

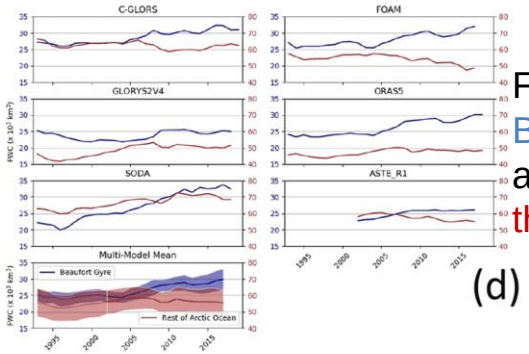
- Pacific (Bering Strait)
  - Moorings: 0.8 Sv, increasing (Woodgate et al. 2018)
  - Often 1.4 Sv in models
- Rivers (2000 km3 / yr)
  - Increasing …
- Glacial melt
  - Lacks streamflow measurements
  - Mostly going to North Atlantic, not Central Arctic
- Sea ice melt (300 km3 / yr, Edel et al. 2024)
  - Reduced ice thickness abruptly in 2007
    - Lacks snow depths obs.
  - Export in Fram Strait reducing
- Precipitations – evaporation
  - Increase moisture flux (follows AO)
  - Reduced evaporation
  - Lacks observations of snow fall à la Edel et al. 2020.



Freshwater going where?

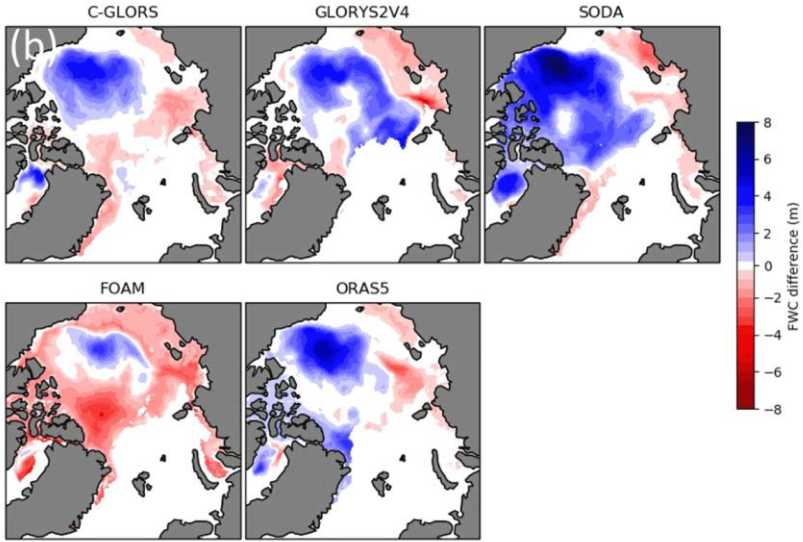
FWCs

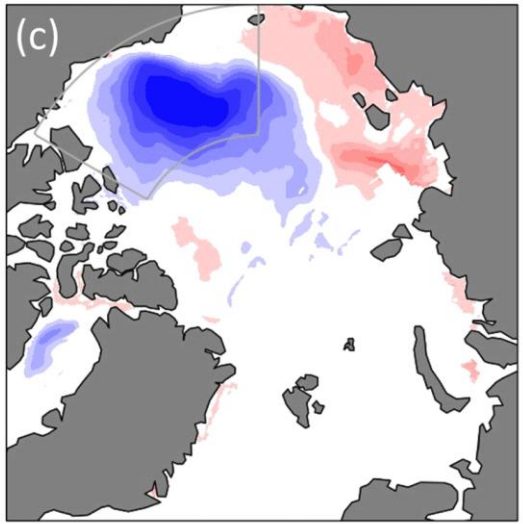




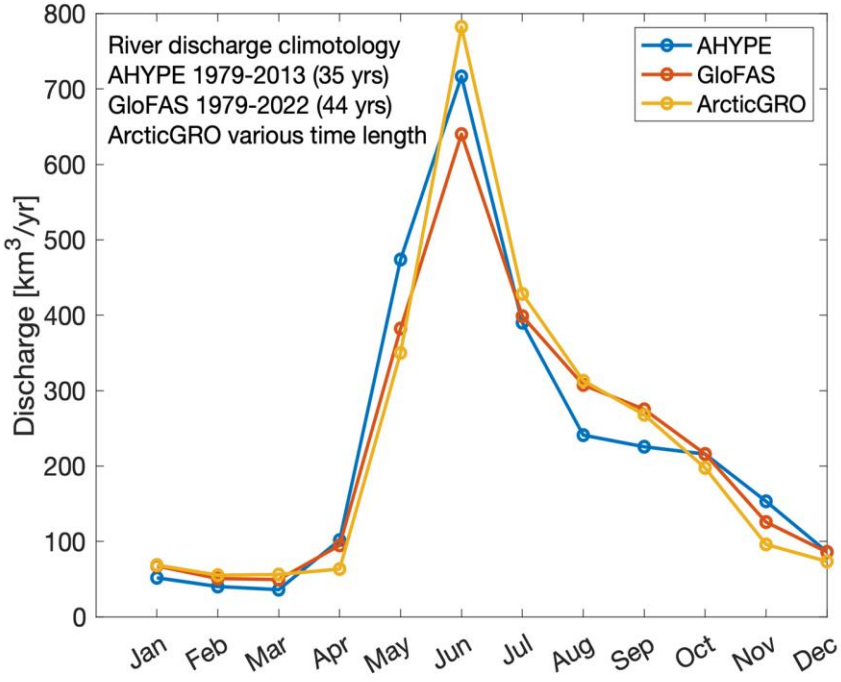
FWC in Beaufort Gyre and the rest of the Arctic

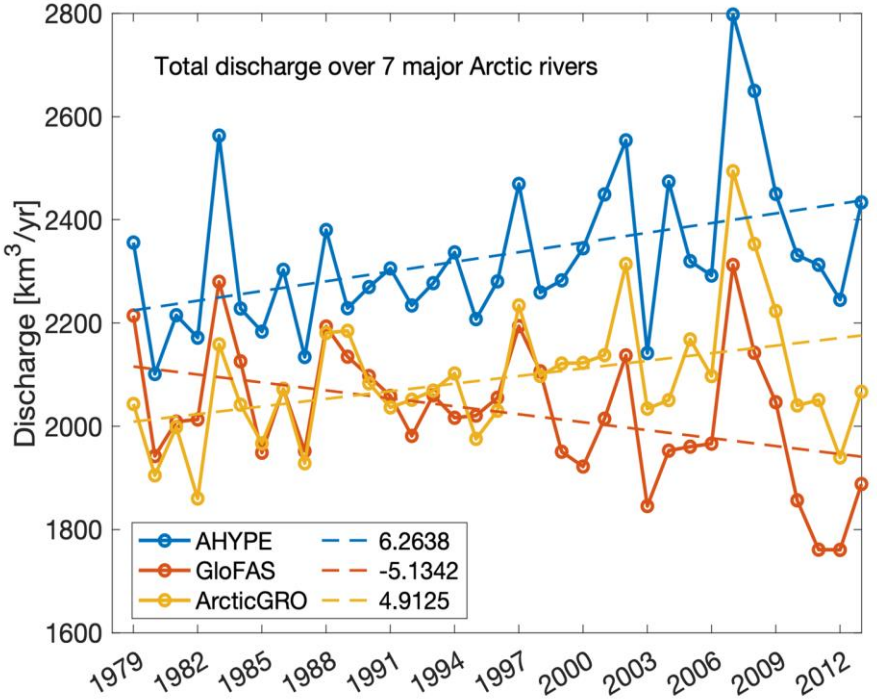
Change from 2000-2010 to 2010-2017





For improvement: river discharge





Large interannual variability

Both GloFAS and Arctic-HYPE can be corrected to respect the total discharge and trends.

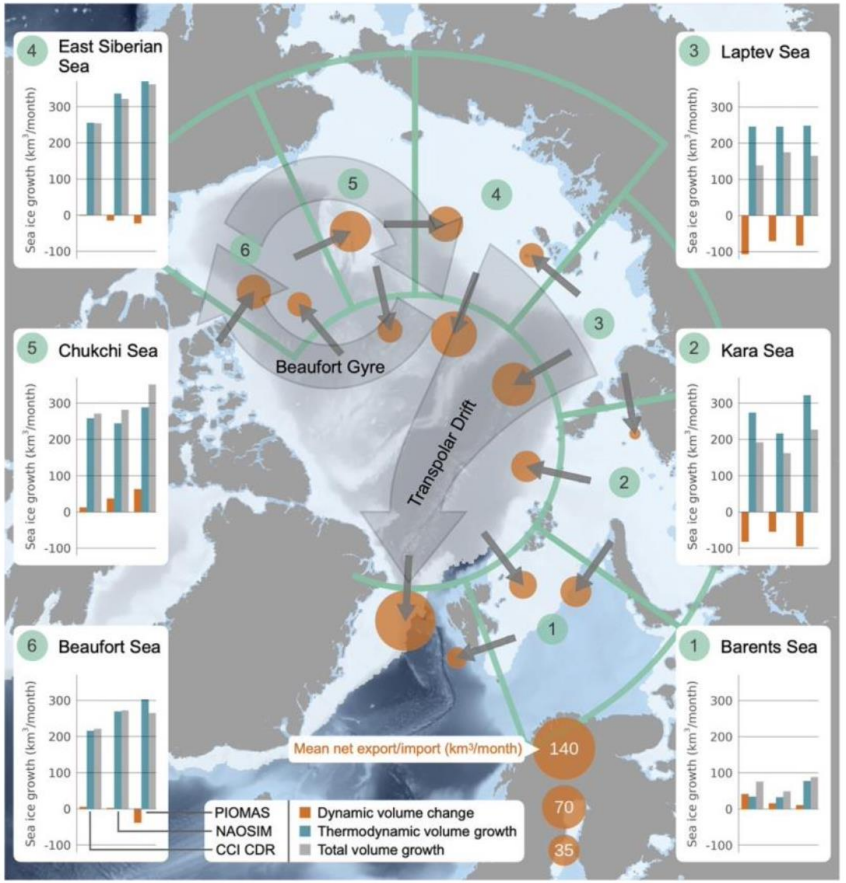
Key points from Solomon et al. 2021

What has changed between the 2000s and the 2010?

1. the Arctic Oscillation and moisture transport into the Arctic are in-phase and have a positive trend;
2. the sea ice cover has transitioned to be increasingly seasonal and mobile; the impacts of this variability on the Arctic Ocean and atmosphere are still being debated;
3. mass loss from the Greenland Ice Sheet and other Arctic glaciers has increased, including in the northern region that drains directly into the Arctic Ocean; But represents a smaller freshwater source
4. vertical mixing of Atlantic water into the deep Arctic has increased in the eastern Eurasian Basin where imported warm Atlantic waters have shoaled and the halocline has weakened.

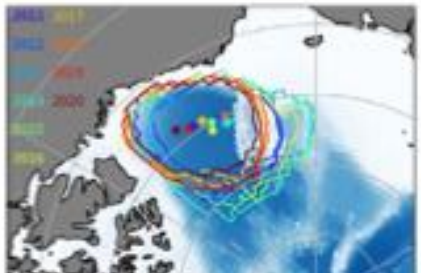
ARCFRESH project plans

- Consider boxes in the Arctic
  - à la Ricker et al. 2021)
- Compute FW fluxes between the boxes
  - ocean and sea ice
- Compute FW fluxes to the bottom
  - The remainder
- Evaluate sensitivity to main FW sources
  - Pacific water
  - Rivers
  - Precipitations



Recommendations

- What observations do we need / need to improve?
  - Ocean salinity
  - In situ observations of mixed layer depths (Ice-tethered profilers)
  - Sea ice thickness
  - Snow depths
  - Sea level in leads (see below)
  - Solid precipitations à la CloudSat
  - Greenland ice sheet



Interannual variability in the spatial extent of the Beaufort Gyre. The star symbol indicates the center location of the BG.
Raj et al. 2022, CryoTempo, follow-up at BEC

- Low-hanging fruits to improve models:
  - Interannual river discharge
  - Assimilate sea level in leads
  - Include Greenland mass loss
- Fruits on a different tree
  - Improve winds from atmospheric models (account for sea ice roughness)
  - Get authorisation and ingest historical Russian profiles.
    - Improve the Arctic climatology


Thank you!