Stability of Freshwater Runoff in East Greenland Currents

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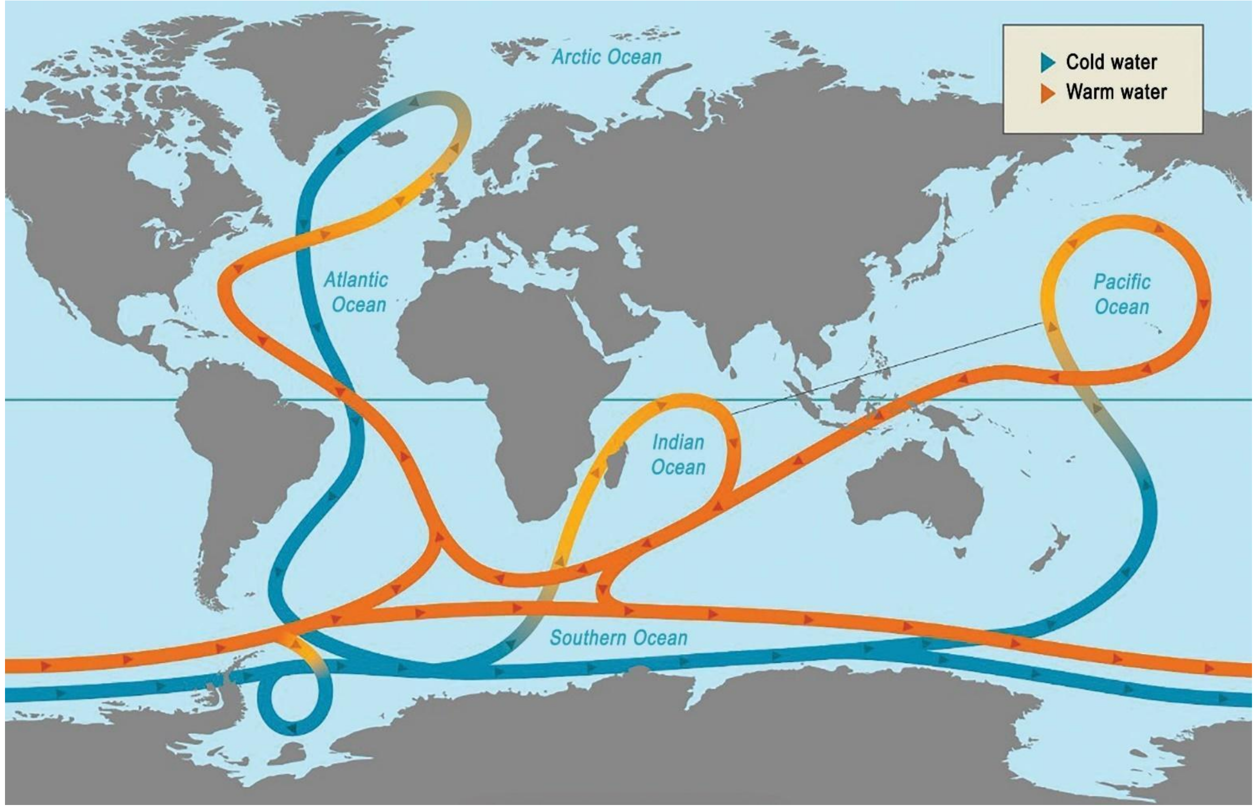
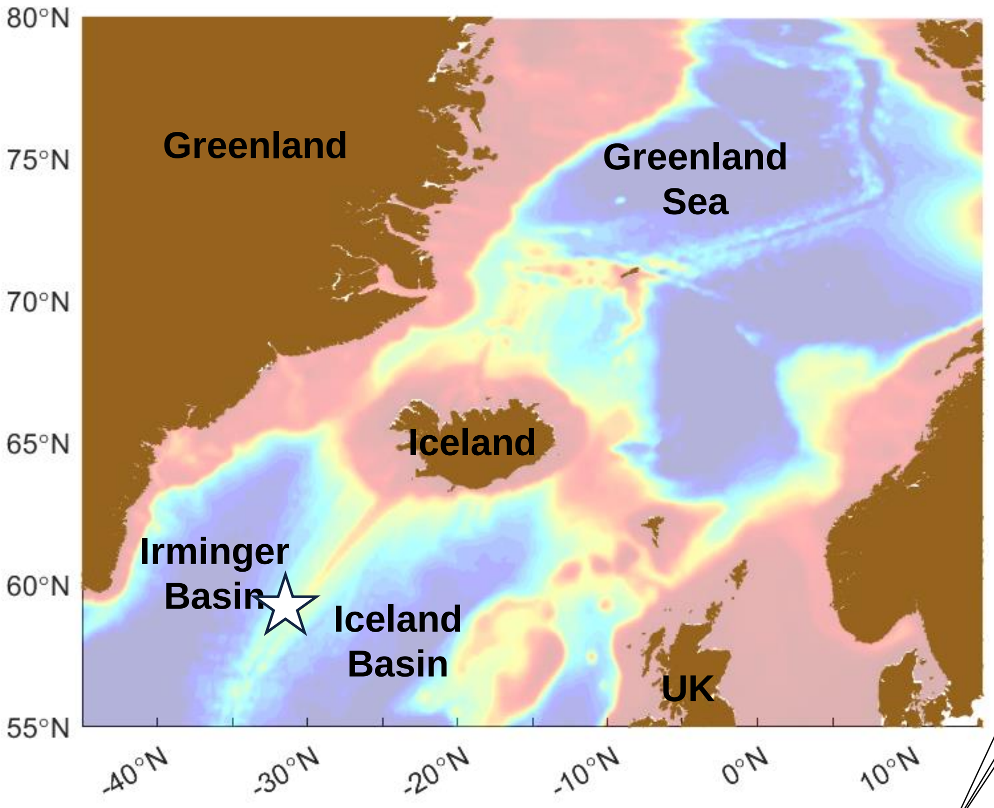
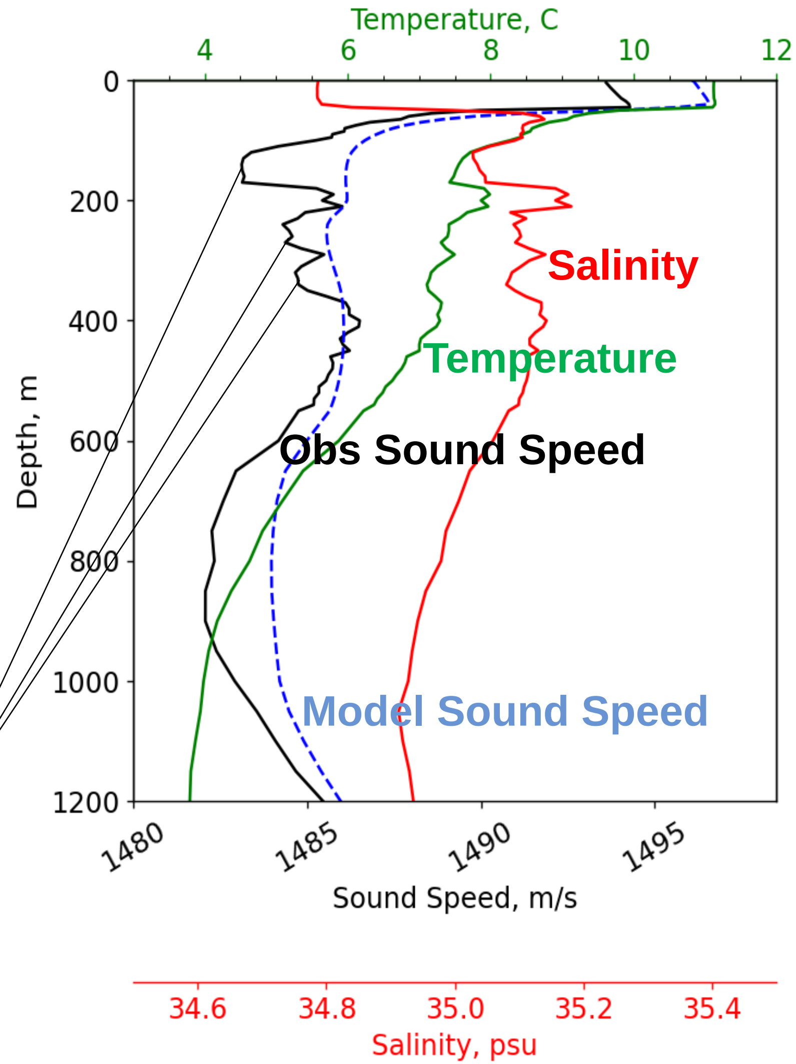
1. Climate is changing more rapidly at high latitudes
   - Warm Atlantic Ocean waters intrude further into the Arctic Ocean
   - Melting of the Greenland Ice Sheet provides increasing freshwater and ice runoff into the ocean
2. High North Atlantic is where deep water is formed
   - The location of deep convection has moved southward



Motivation

- High resolution ocean modeling to understand the dynamic mechanisms causing cold/dense water mass formation and intrusions in the tactically relevant Irminger and Iceland Basins (GIUK Gap).





- water-mass intrusions cause exploitable subsurface acoustic sound channels.

Subsurface acoustic sound channels are defined by sound speed minima

Motivation

Average Transports (Sverdrup)

Sverdrup = 1 million m^3/s

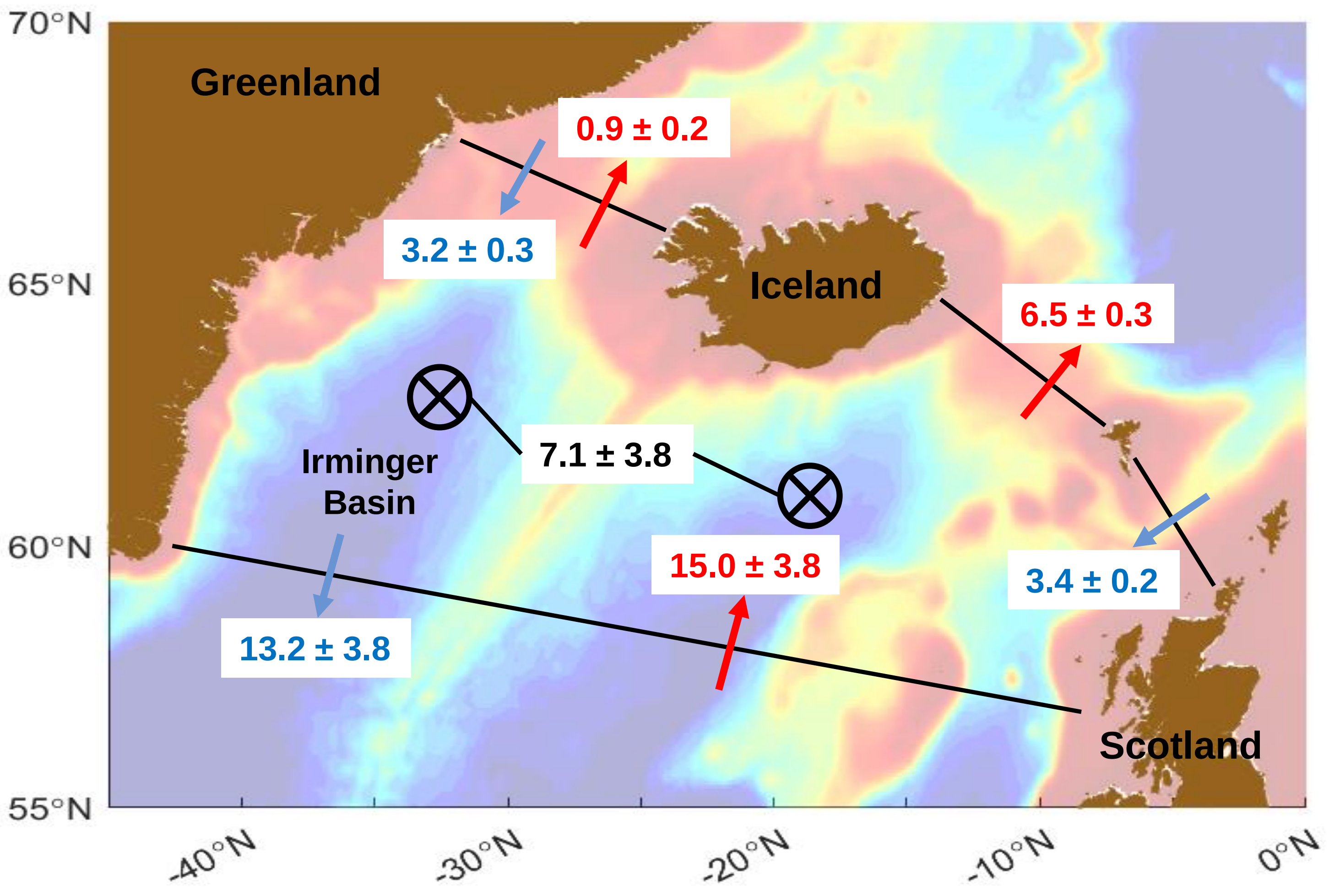
(Aug 2014 – May 2016)

= transport of upper ocean

= transport of deep ocean

⊗ = transport from upper to deep

What are the potential mechanisms causing deep water convection to shift southward?

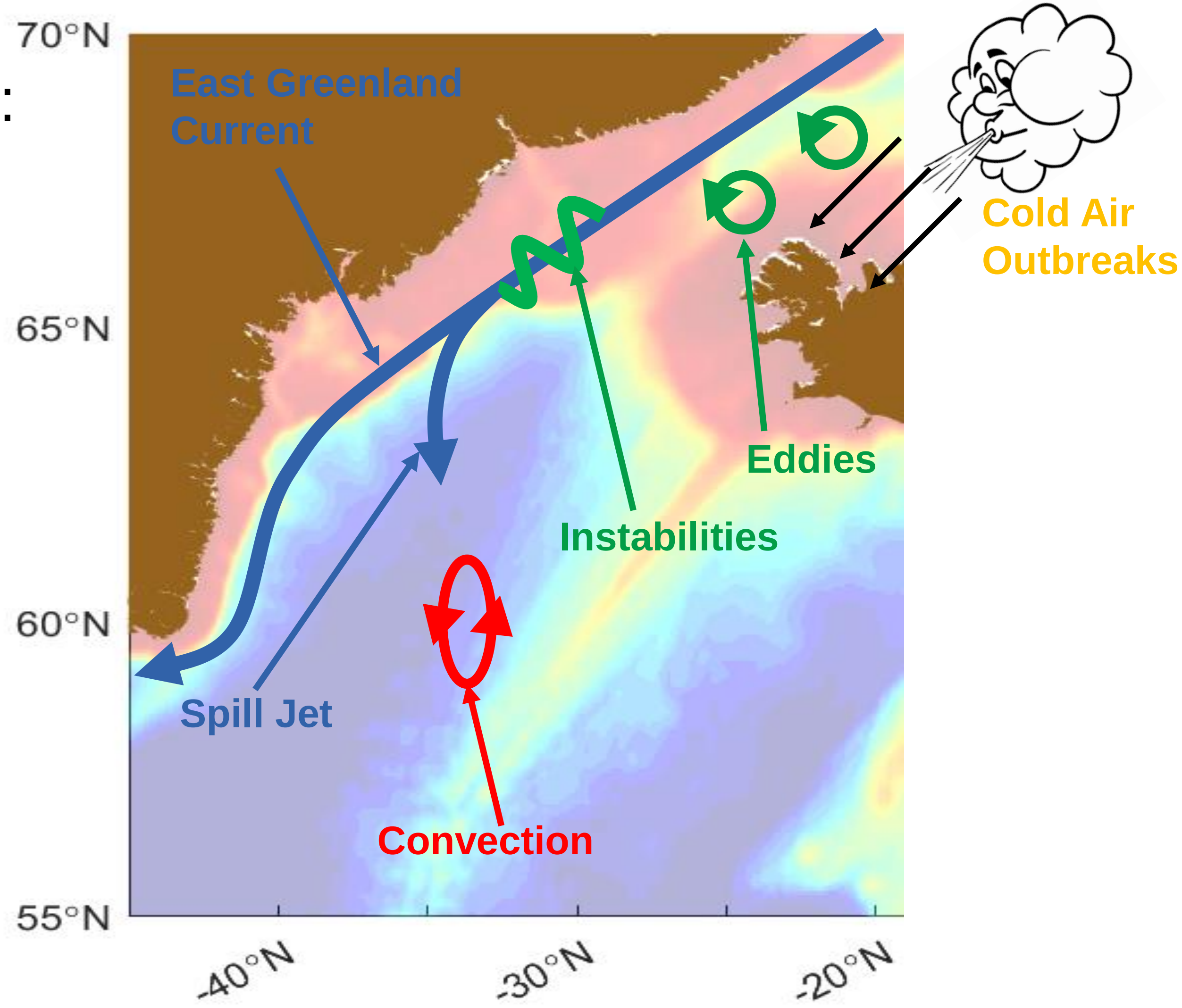


Adapted from Petit et. al., 2020

Motivation

Potential mechanisms causing convection:

1. Small scale dynamic features causing Spill Jet from the East Greenland Current
   a) Instability perturbations
   b) Cyclonic eddies in the shelf break front
2. Cold-air-outbreaks
3. Sea ice coverage
4. Fresh water runoff



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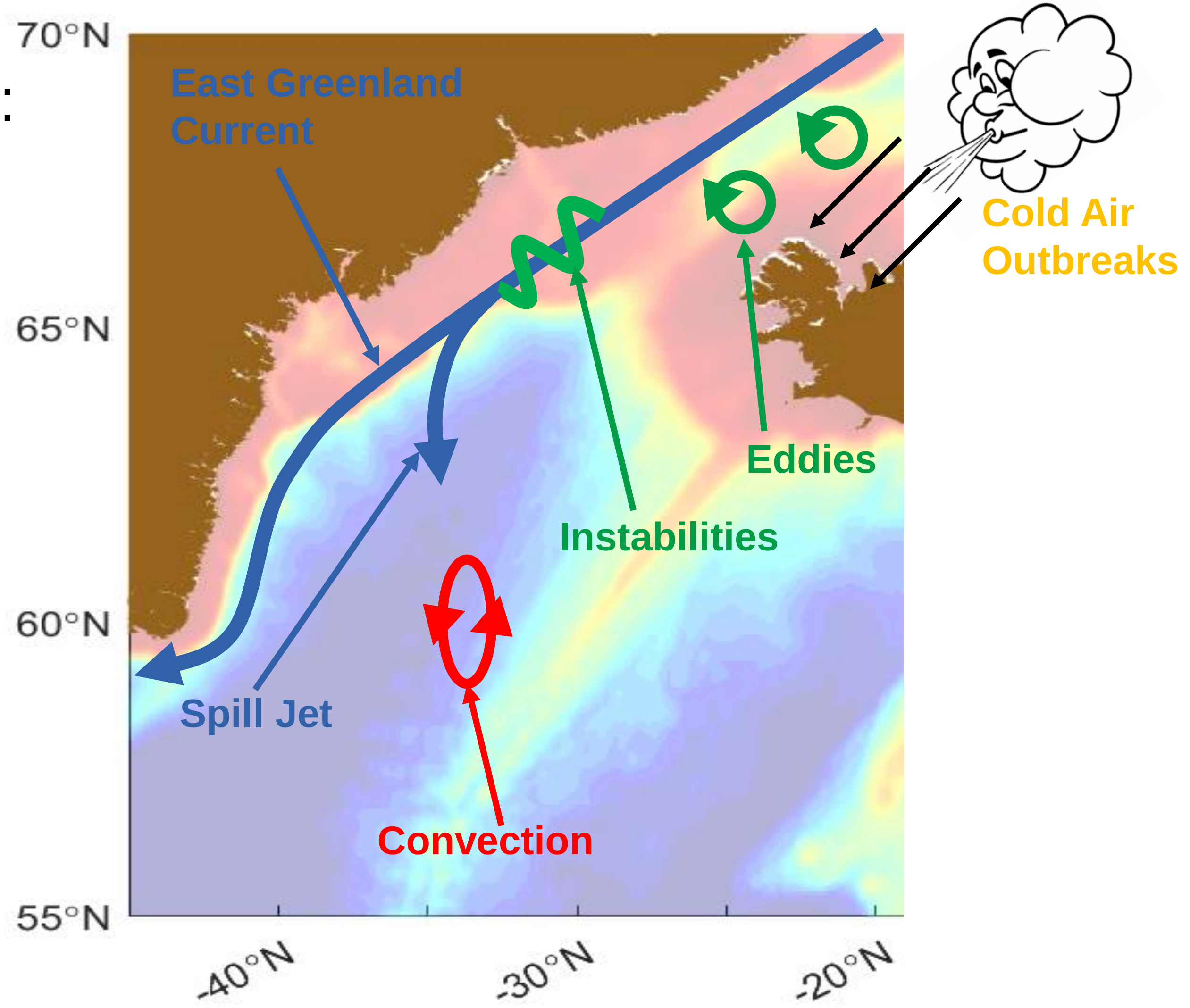


Coarse Navy Coastal Ocean Model

Coarse Navy Coastal Ocean Model (NCOM):

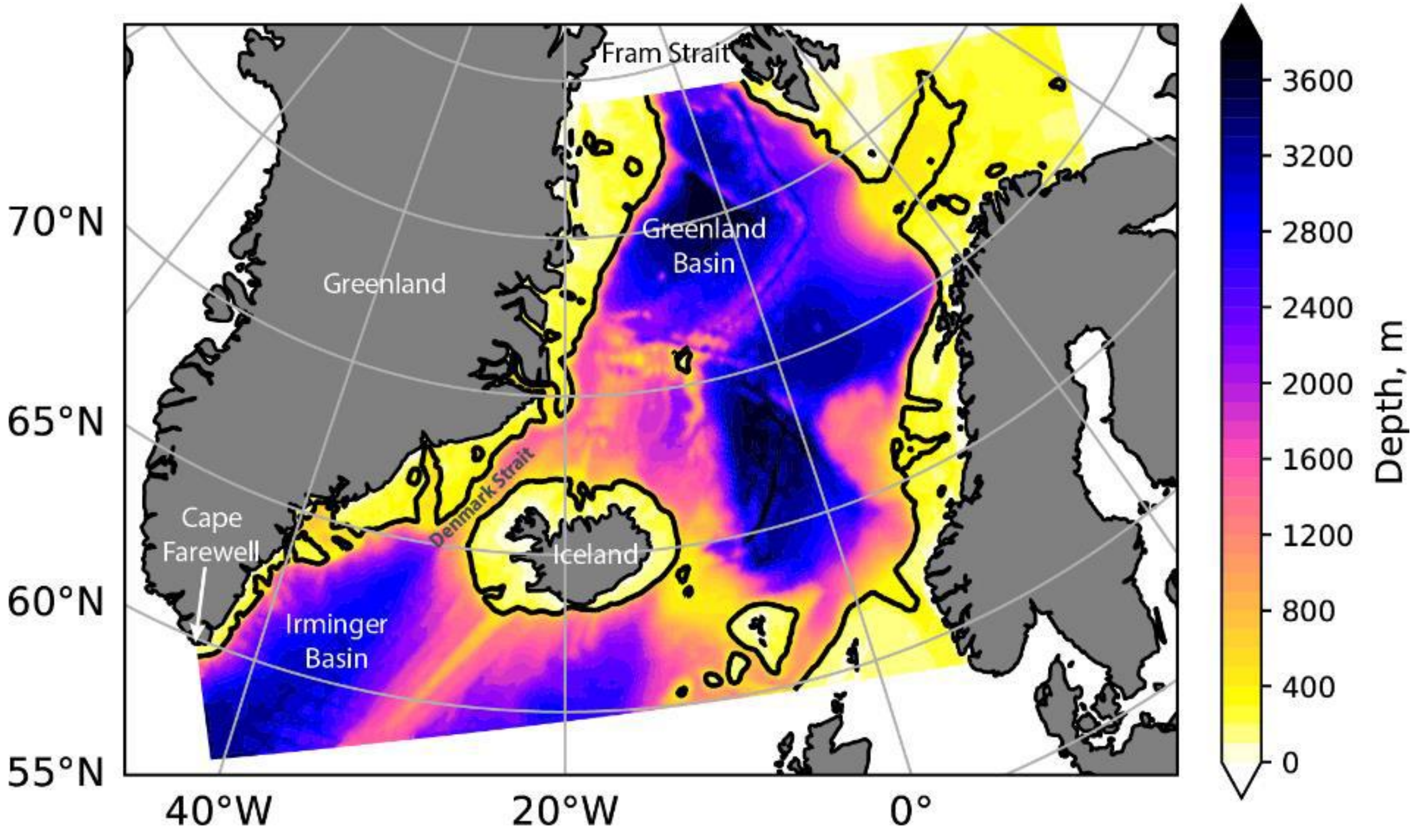
Formulation: primitive equation, hydrostatic, Boussinesq ,free-surface sigma/z-level coordinate

Tides: barotropic surface pressure, barotropic height converted to velocities at the boundary

Resolution: 4km horizontal (801 x 485 gridpoints), 100 vertical level, Lambert Conformal Grid

Boundary conditions: Navy Global Ocean Forecasting System (HYCOM), res. 1/12, 41 levels

Surface Forcing: Navy Global Environmental (Atmospheric) Model (NAVGEM) 1.4, 37 km res., 50 levels, spectral model



NCOM: 100 fixed sigma/z-levels at 4 km horizontal resolution with tides

Fine Nested Navy Coastal Ocean Model

Fine Navy Coastal Ocean Model (NCOM):

Formulation: primitive equation, hydrostatic, Boussinesq ,free-surface sigma/z-level coordinate

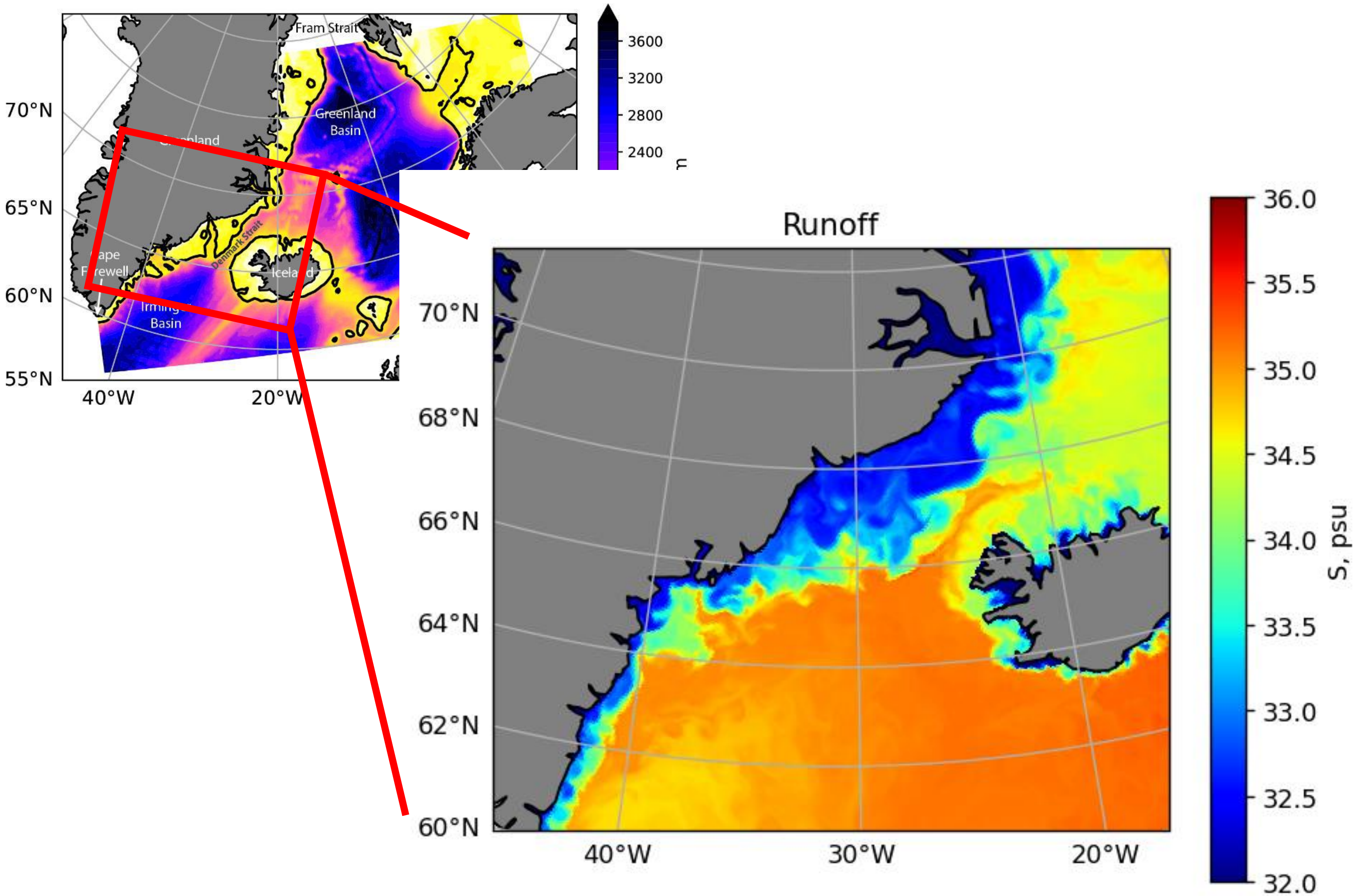
Tides: barotropic surface pressure, barotropic height converted to velocities at the boundary

Resolution: 1km horizontal (1730 x 1910 gridpoints), 100 vertical level, Lambert Conformal Grid

Boundary conditions: **Coarse resolution NCOM**

Surface Forcing: Navy Global Environmental (Atmospheric) Model (NAVGEM) 1.4, 37 km res., 50 levels, spectral model

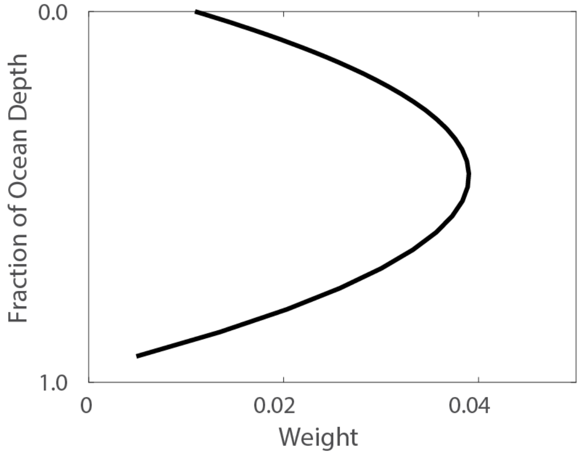
Processing: 192 processors on Narwhal.



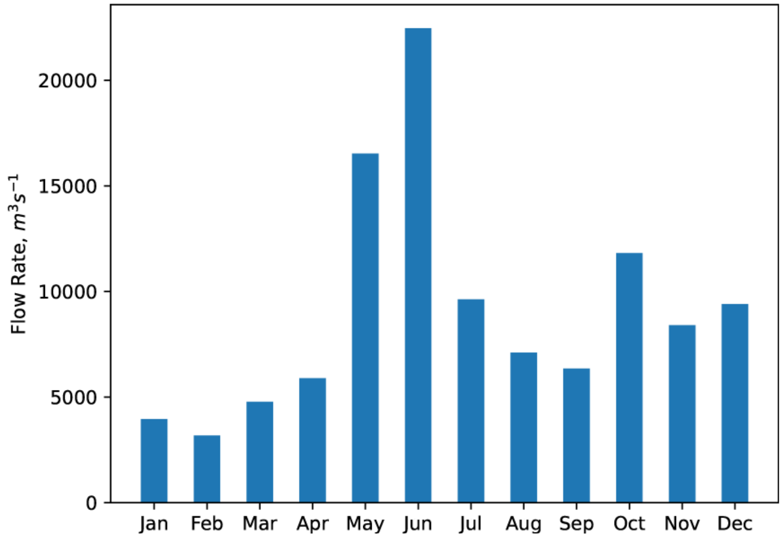
NCOM: 100 fixed sigma/z-levels at 1 km horizontal resolution with tides

Greenland Freshwater Runoff

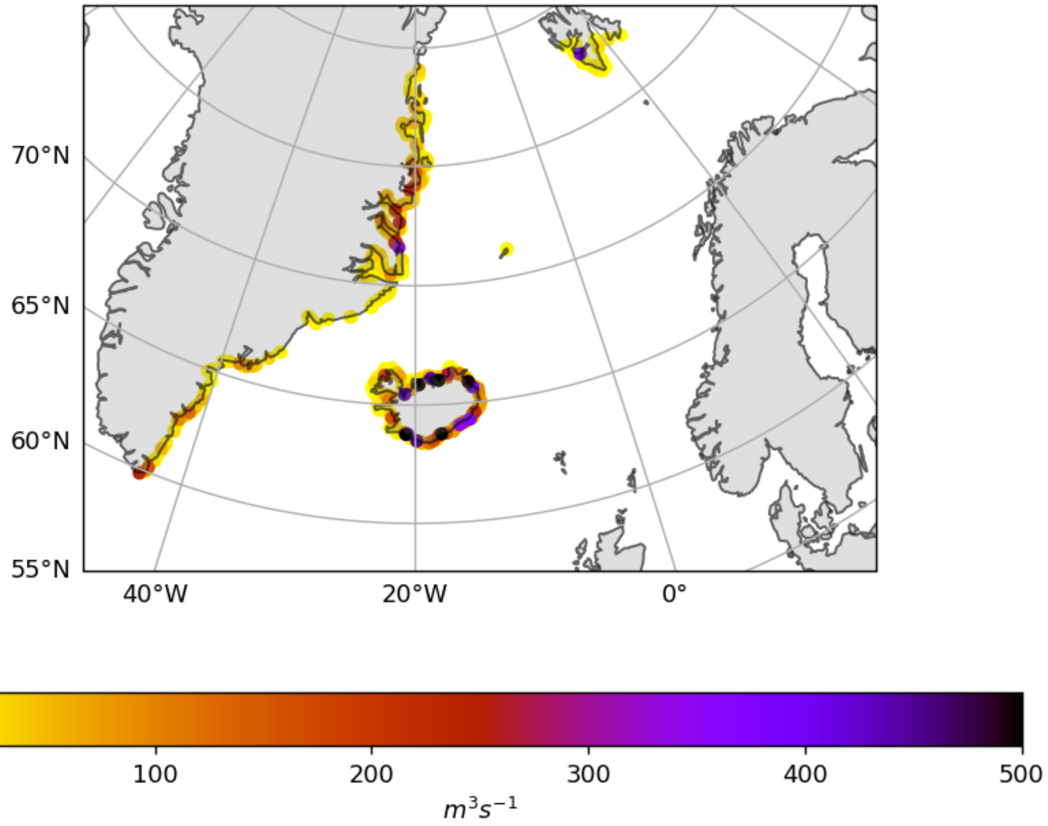
River Input Profile



Freshwater Runoff for 2016



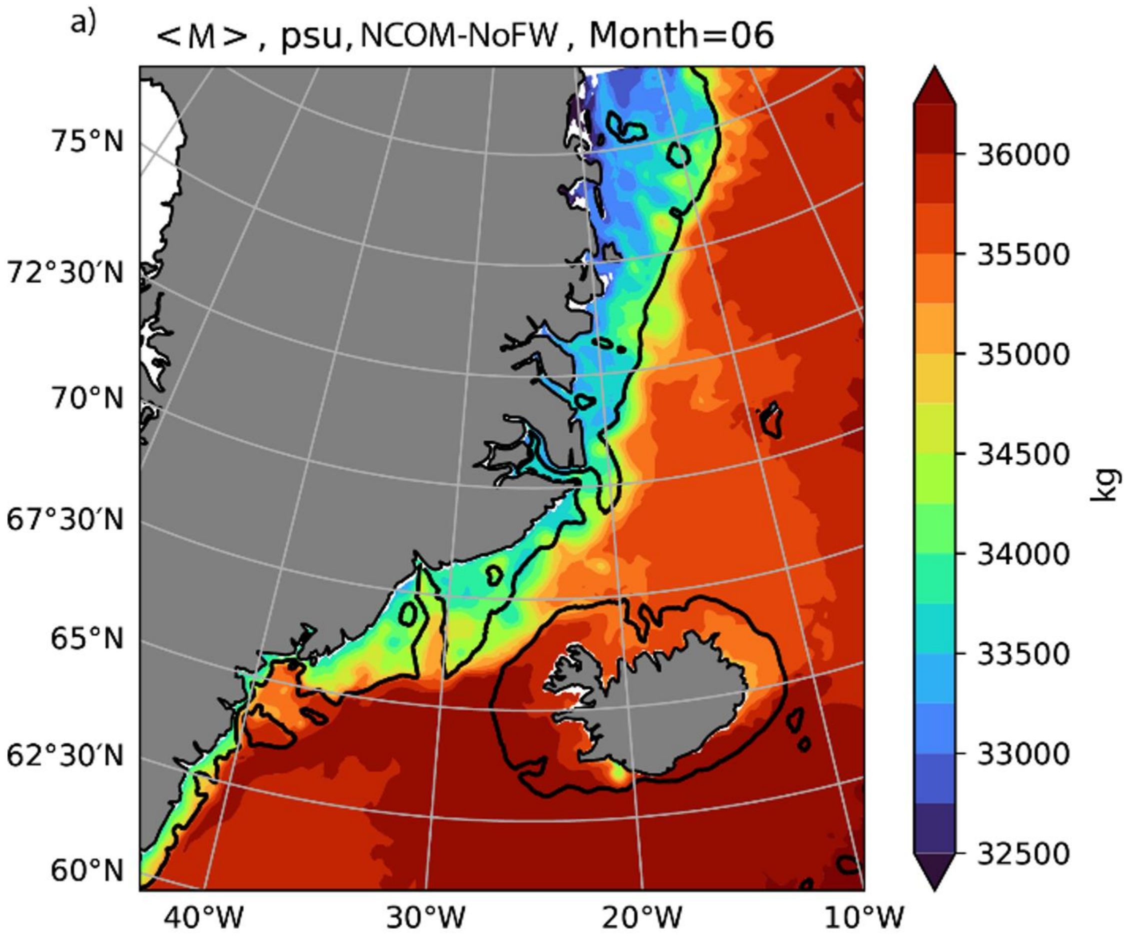
Tundra and Ice Runoff, June



- NCOM includes freshwater volume flux from river sources, but not from ice melt.
- 625 ‘river sources’ were added to NCOM to include the ice and tundra runoff from Greenland, Iceland, and Svalbard.
- Runoff is 0ºC and 0 PSU.

Bamber, J. L., et al. (2018). "Land Ice Freshwater Budget of the Arctic and North Atlantic Oceans: 1. Data, Methods, and Results." Journal of Geophysical Research-Oceans 123(3): 1827-1837.

Water Column Salt Mass of Coarse NCOM



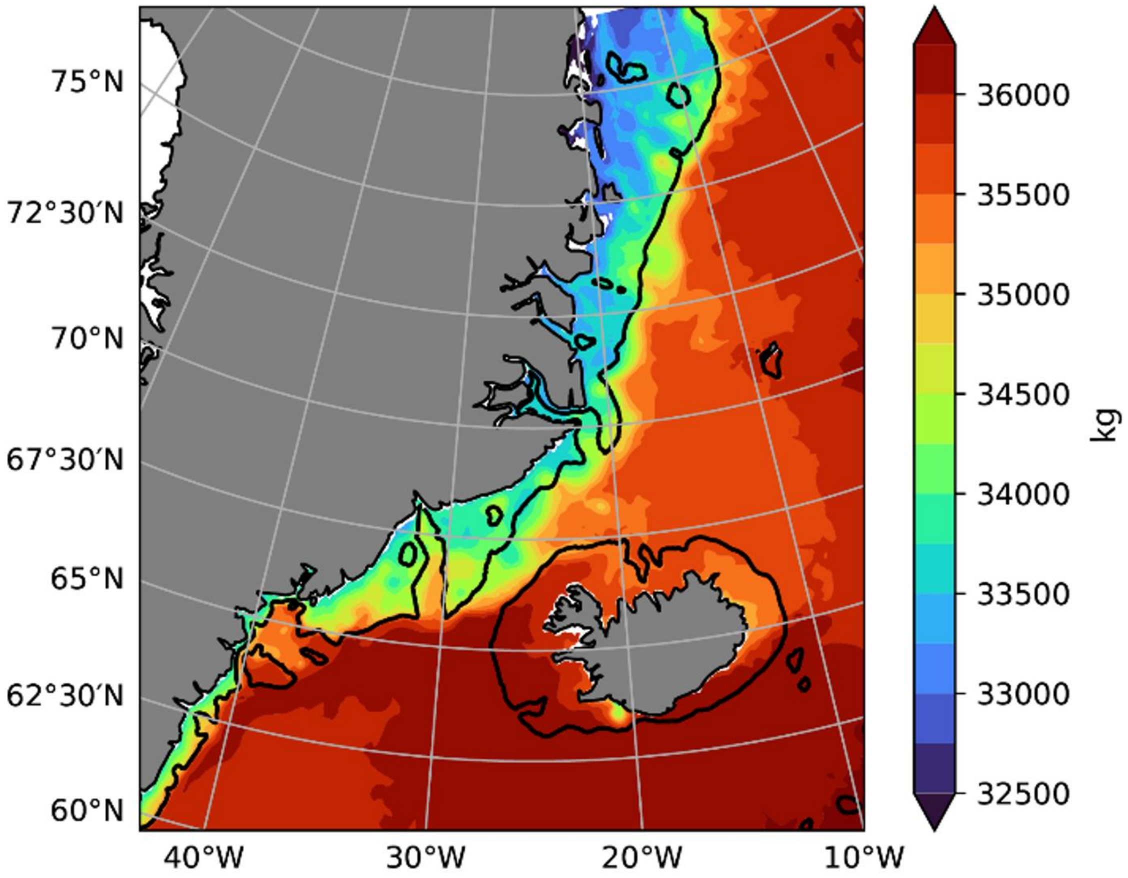
The salt mass in kg, averaged over the month of June for the standard experiment.

Water Column Salt Mass

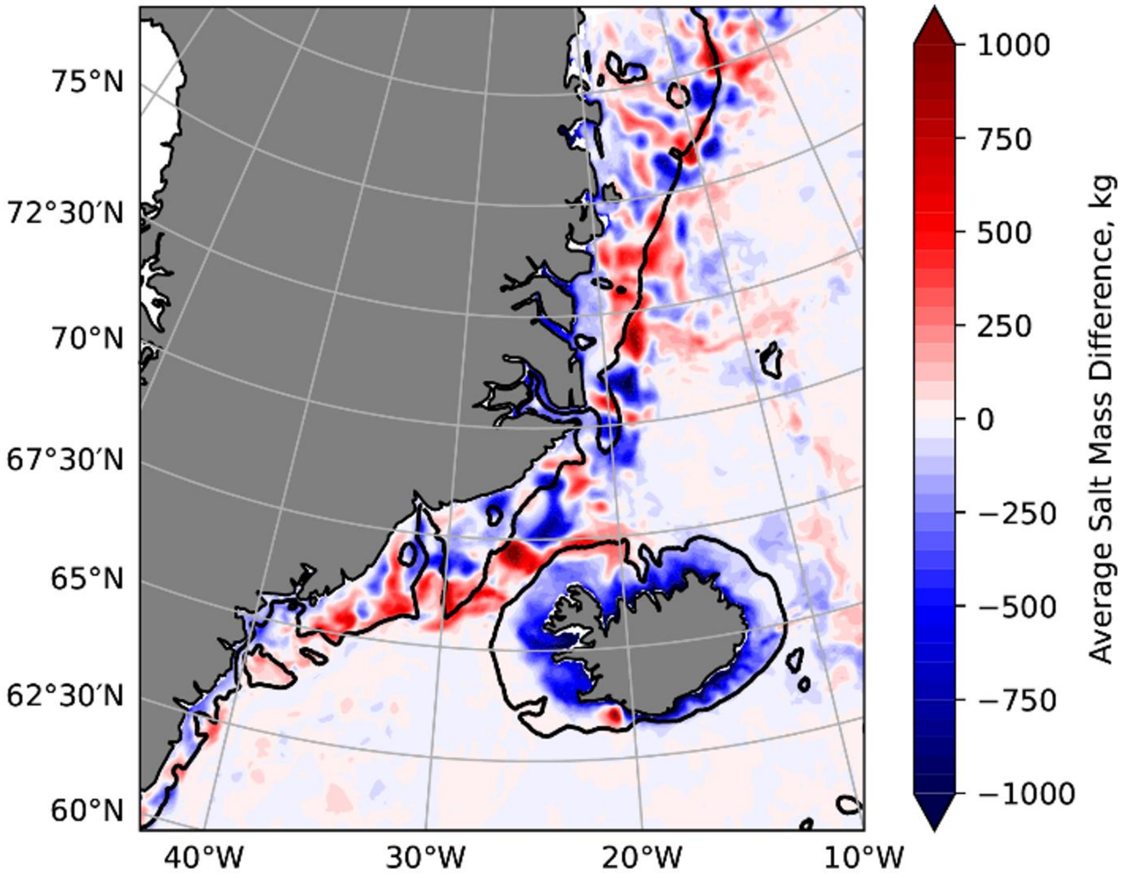
$$\bar{M}_{ij} = \sum_{k=1}^{k=nz_{ij}} \rho_{ijk} S_{ijk} \Delta v_{ijk}$$

Water Column Salt Mass of Coarse NCOM

Salt Mass of Standard Exp (June)

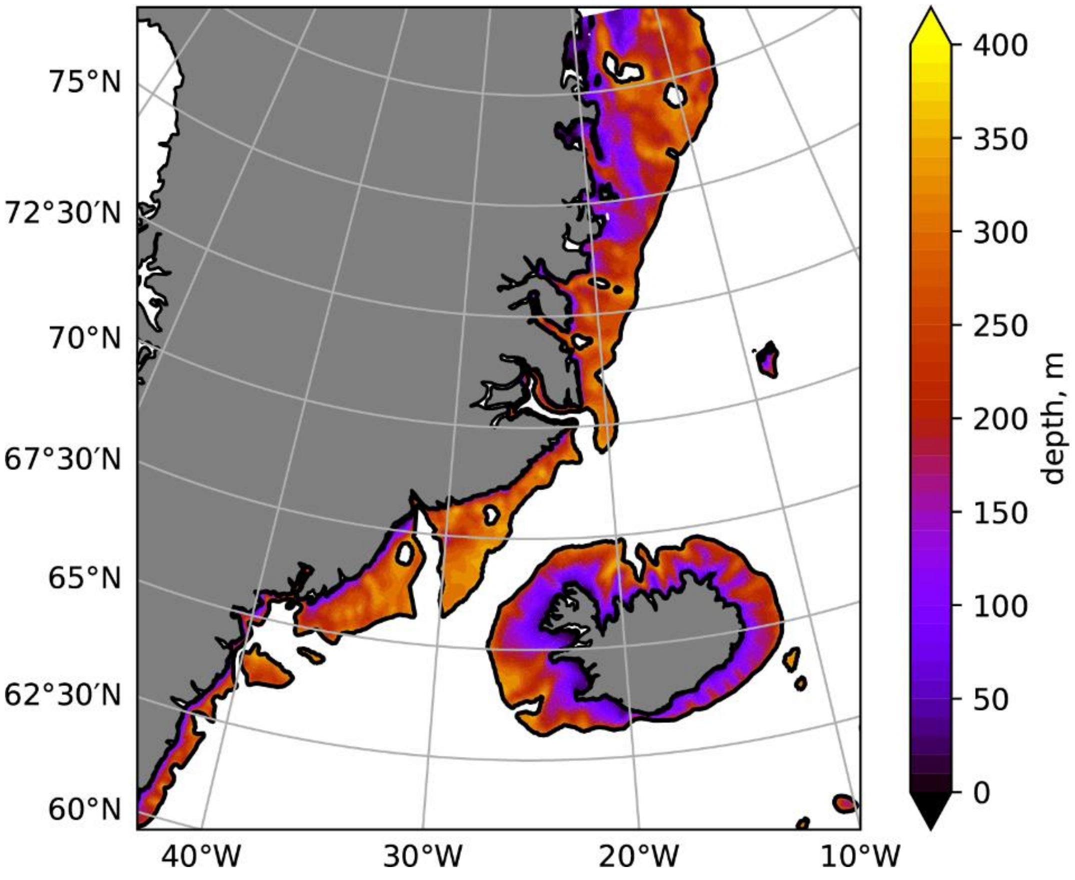


Salt Mass Diff (Runoff - Standard)

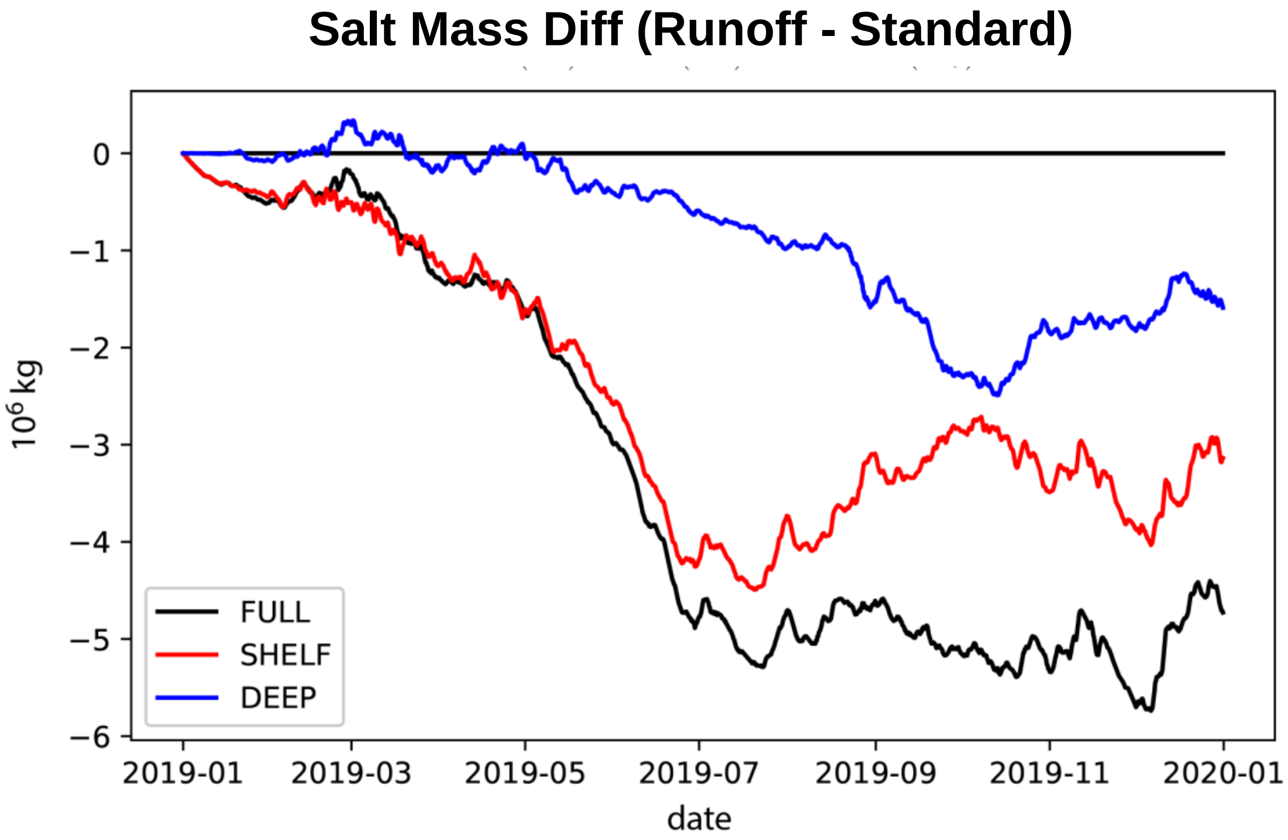


The runoff experiment is fresher near the coast and there is a lot of variability along the shelf break

Water Column Salt Mass Change of Coarse NCOM



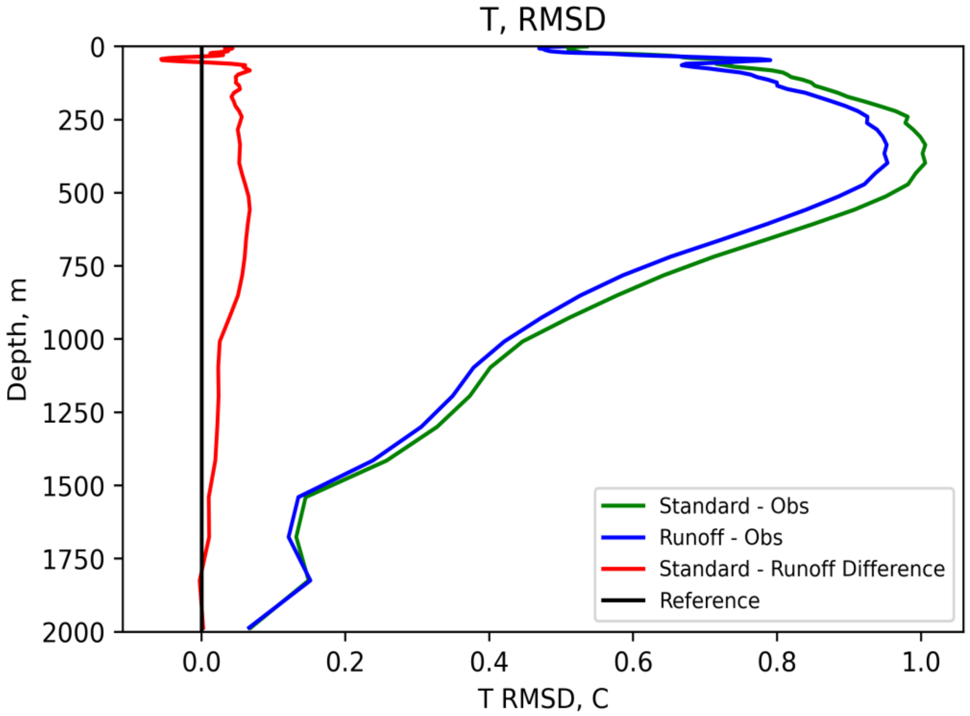
Shaded regions are the shelf areas

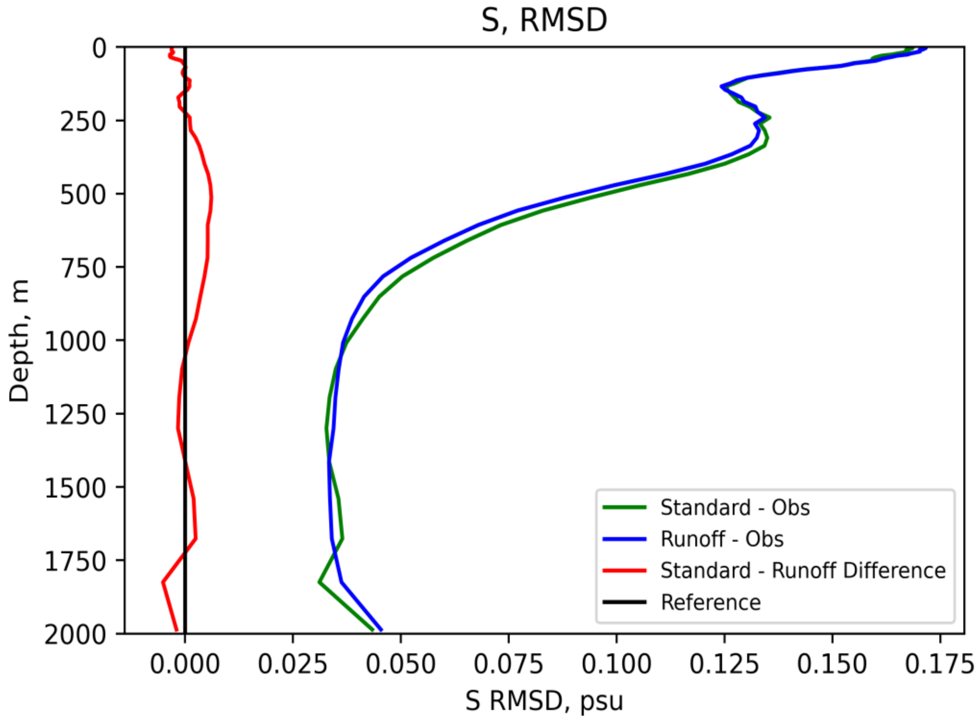


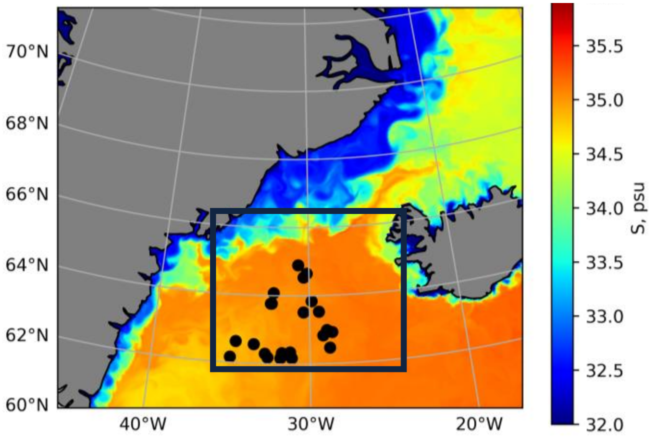
The change in salt mass for the full domain (black), the deep ocean (blue) and the shelf (red) regions.

Freshwater tends to stay on the shelf until July, and then begins leaking into deep

Coarse NCOM Compared to Observations





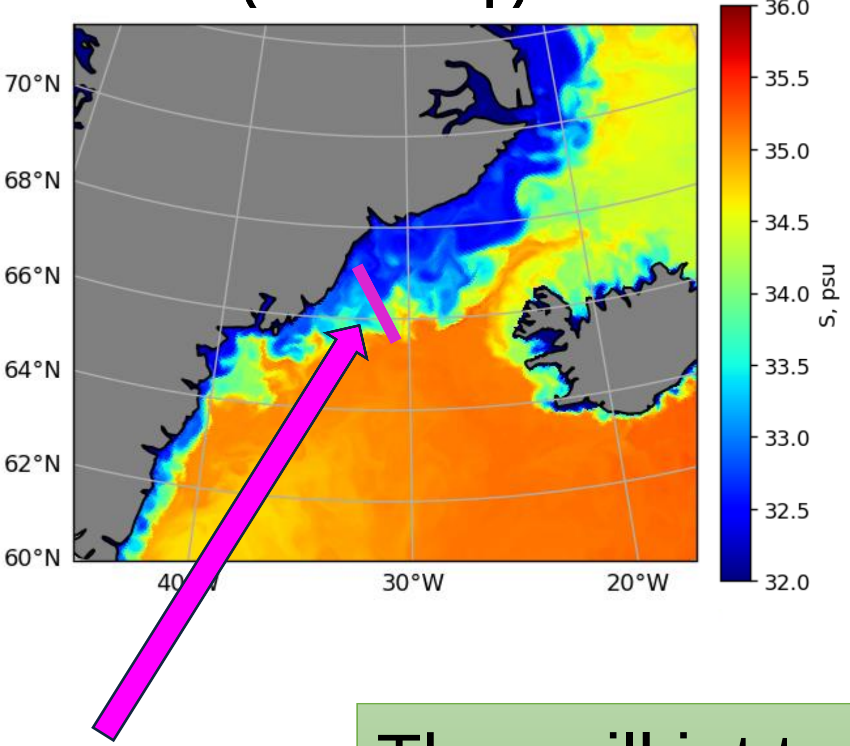


- Profile observations of temperature and salinity are compared to Coarse NCOM with and without freshwater runoff for all of 2019.

Freshwater runoff experiment is more accurate than the standard experiment for both temperature and salinity

Spill Jet Location

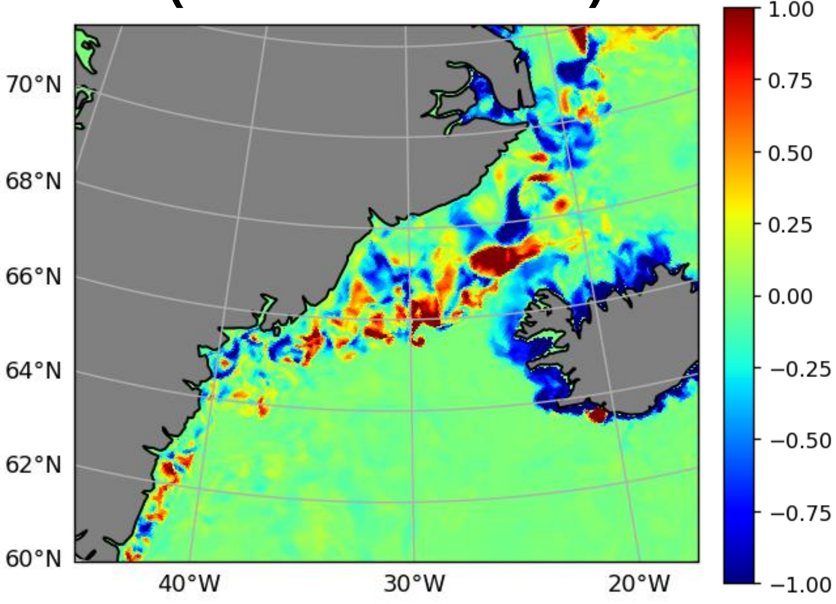
Surface Salinity (Runoff Exp)



Spill Jet

Coarse Resolution NCOM

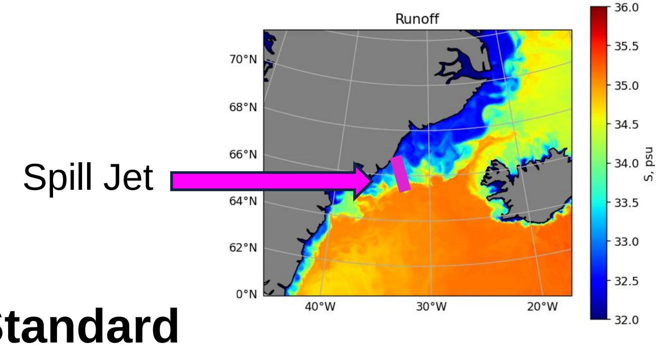
Surface Salinity Difference (Runoff - Standard)



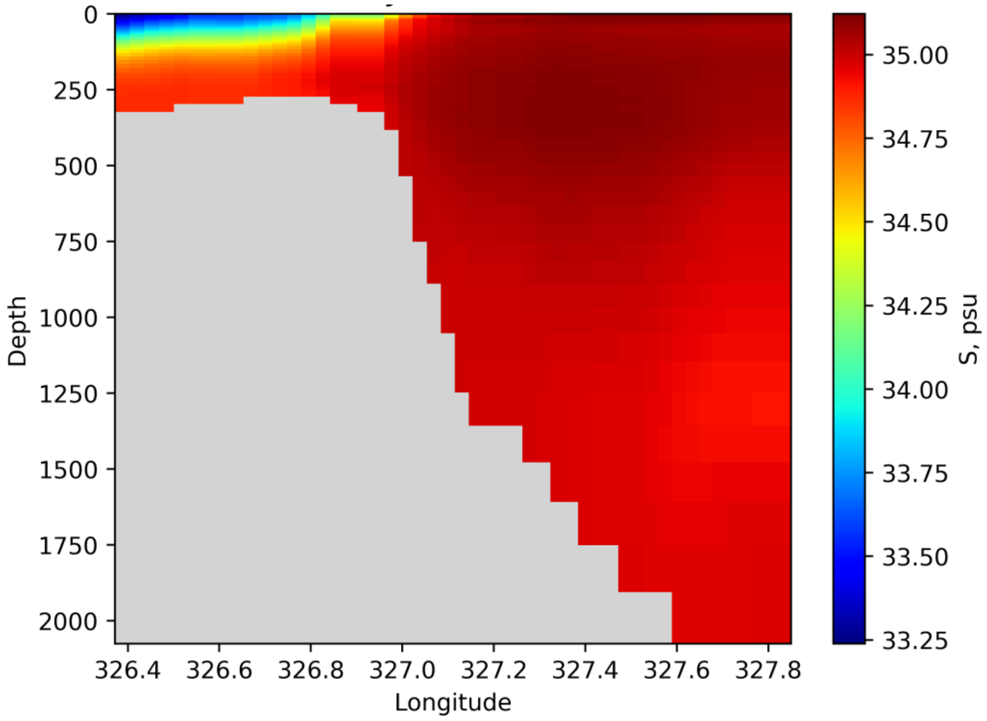
The spill jet transect is an important location because water tends to come off the shelf here

Transect of Salinity along Spill Jet

The runoff experiment is saltier on the shelf

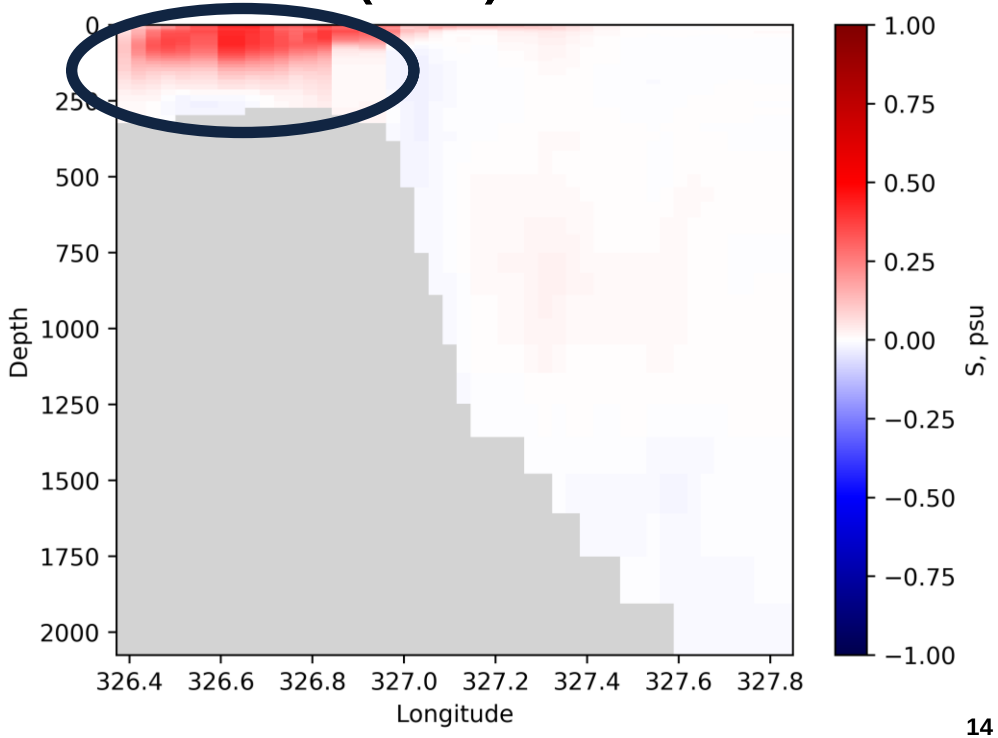


Mean Salinity of Runoff Exp (June)



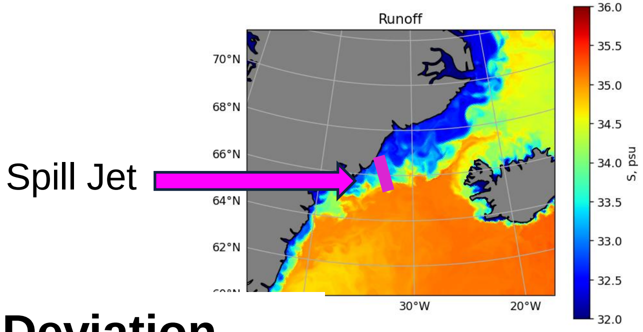
Coarse Resolution NCOM

Runoff - Standard (June)

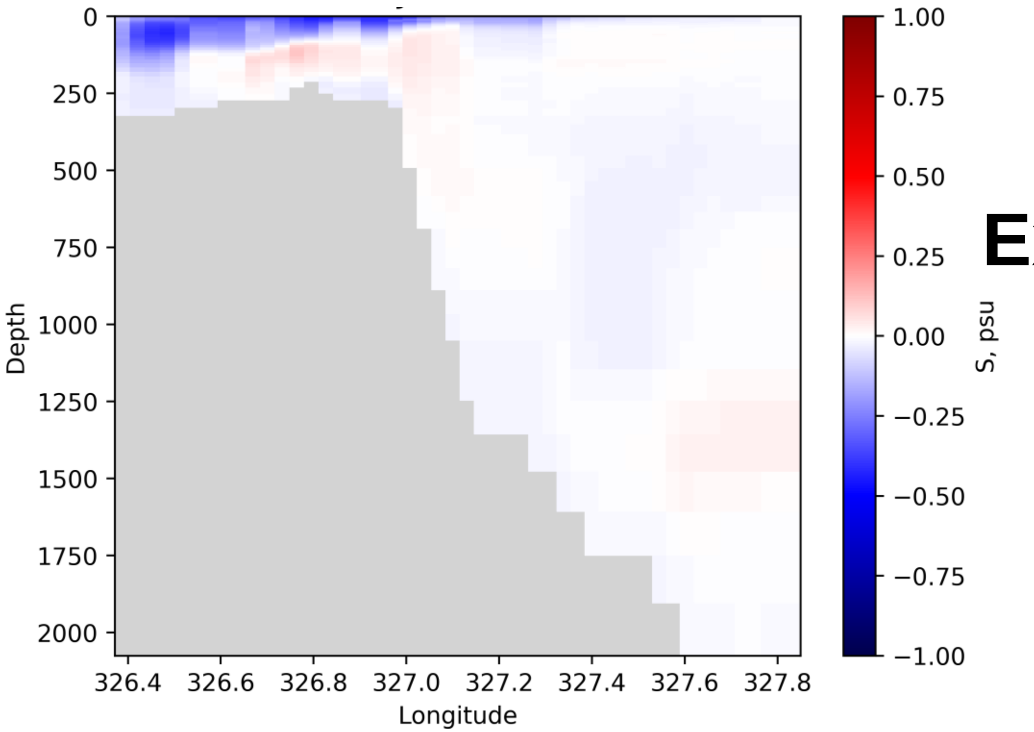


Comparison of Coarse and Fine Resolution

The fine resolution experiment is fresher and more variable on the surface of the shelf and is diffusing into the deep faster

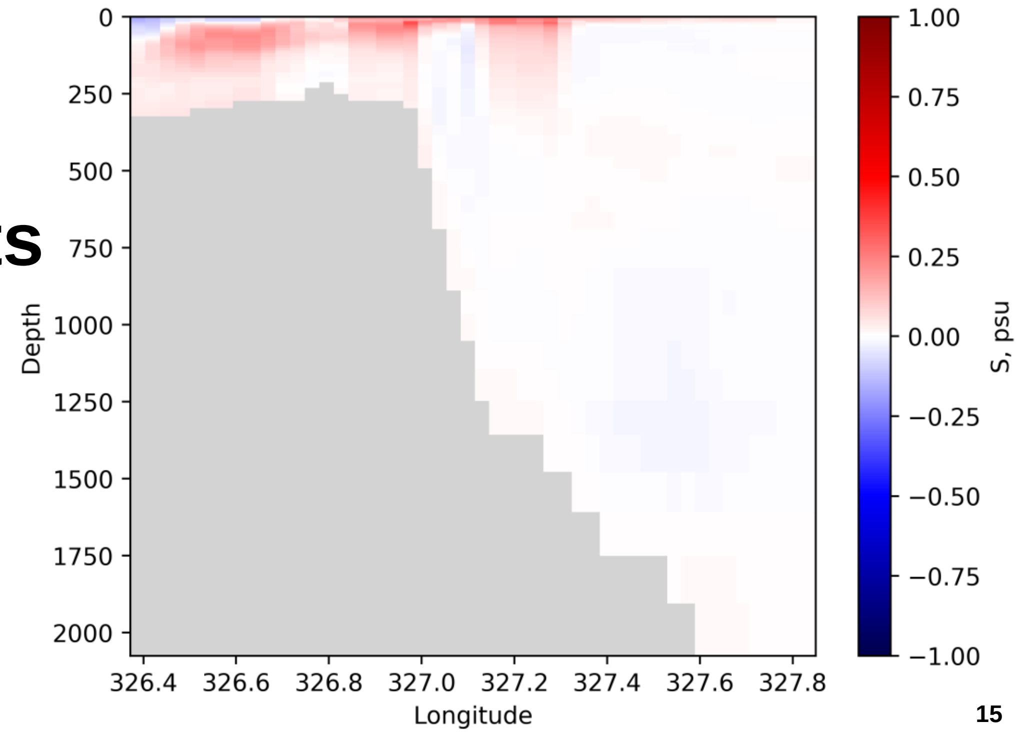


Salinity Difference (Fine - Coarse)



Runoff Experiments (June)

Standard Deviation (Fine - Coarse)



Conclusions

- Adding runoff to the coarse experiment created fresher water near the coast and pockets of saltier water in areas of high instability, such as along the shelf break
- Freshwater tended to stay on the shelf for the first half of the year, then it began to leak into the deep
- The runoff experiment is more accurate than the standard experiment for both temperature and salinity
- The fine resolution experiment is fresher and more variable on the surface of the shelf and diffuses into the deep faster