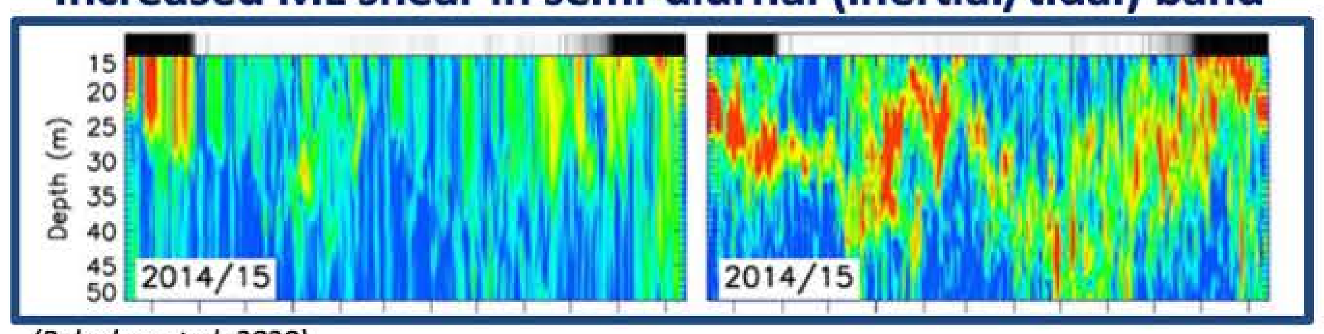
Effects of Surface Boundary Layer Mixing on Arctic Ocean Biogeochemistry

Katherine Smith and Luke van Roekel
Los Alamos National Laboratory (LANL), LA-UR-22-21148

Background/Motivation

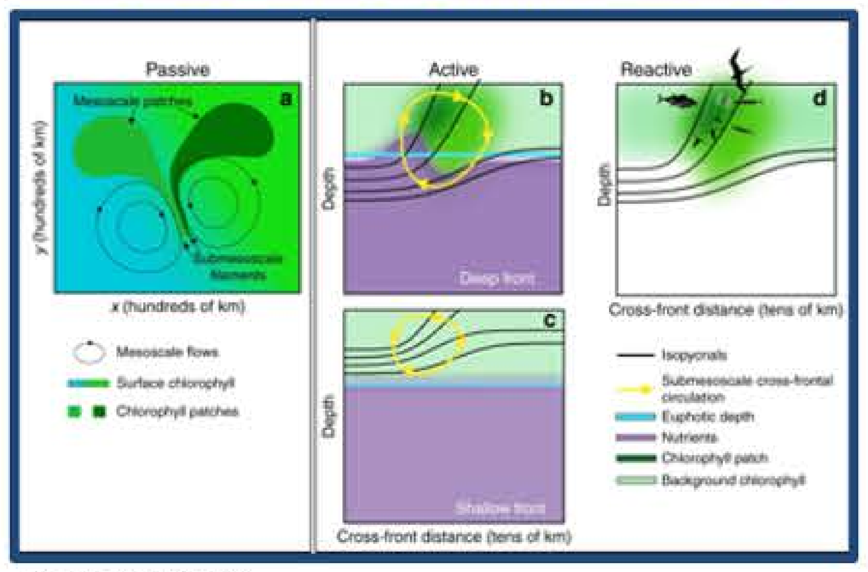
The Arctic Ocean's surface layer is important for many chemical *(CO_2/nutrient exchange)* and biological processes *(nutrient entrainment, bloom dynamics)* on regional and pan-Arctic scales

Increased ML shear in semi-diurnal (inertial/tidal) band



(Polyakov et al, 2020)

Submesoscale ML entrainment



(Levy et al, 2018)

Hypothesis: inertial oscillations, tidal mixing, and submesoscale currents are critical vertical mixing mechanisms for Arctic Ocean surface layer chemical and biological processes

- **What are the dominant mechanisms of vertical nutrient entrainment into the Arctic Ocean's surface layer? Are they universal across different Arctic regions?**
- **Are these mechanisms captured by parameterizations?**

Physical Model (Large Eddy Simulation)

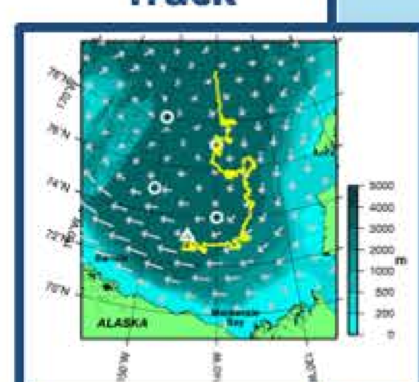
We use the Parallelized Large-Eddy Simulation Model (PALM), periodic horizontal boundaries, ITP and NABOS initial conditions, and constant surface forcing applied for 5-10 days

Inertial/Tidal Domain: 128 x 128 x -128m
Inertial/Tidal Computation Grid: 256^3
Inertial/Tidal Resolution: 0.5 m

Submesoscale Domain: 20km x 20km x -128m
Submesoscale Computation Grid: 512 x 512 x 128
Submesoscale Resolution: 40 x 40 x 0.5 m

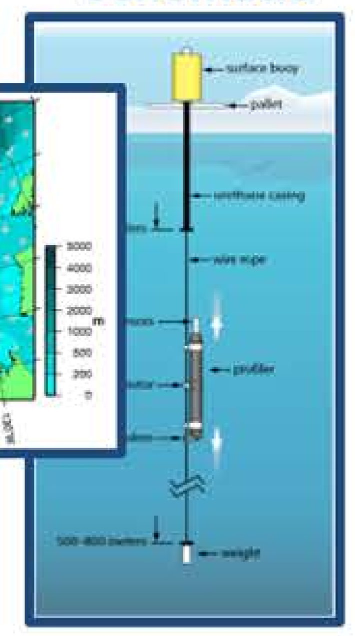
Initial/Boundary Conditions

ITP Drift Track

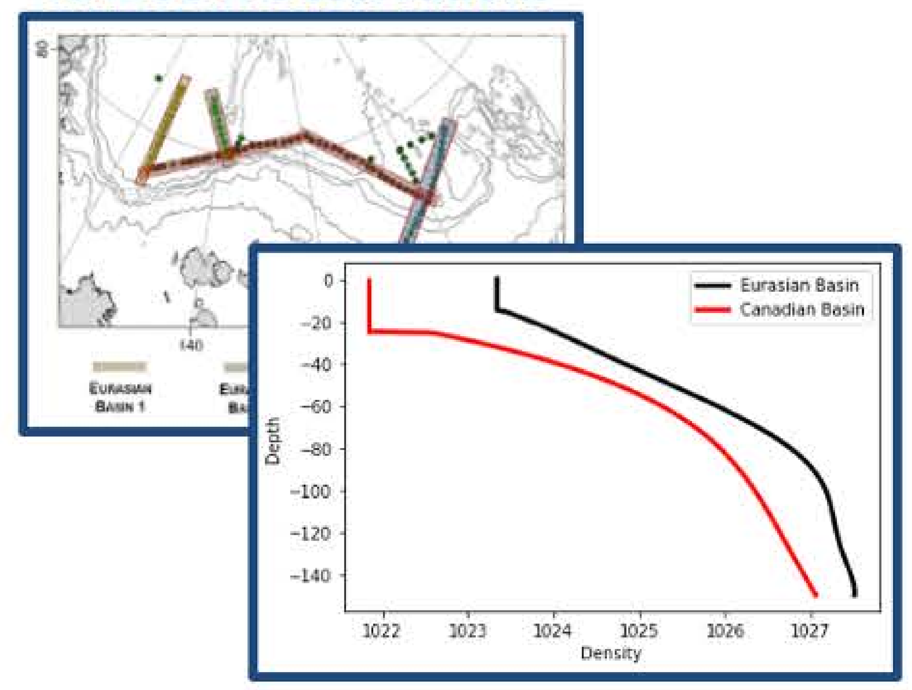


(Toole et al, 2011)

Ice-Tethered Profiler (ITP) Schematic

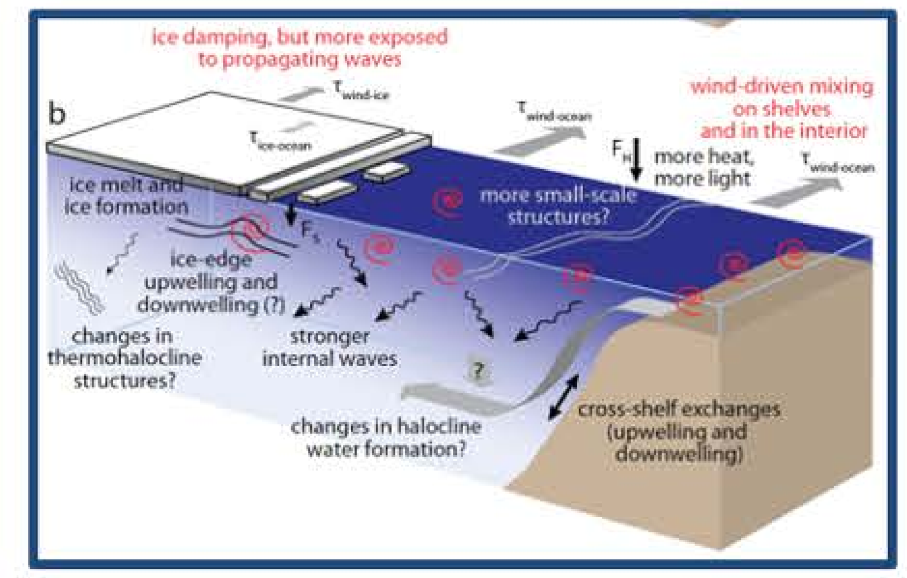


NABOS-II Observations



LES Initial Conditions From ITP and NABOS-II

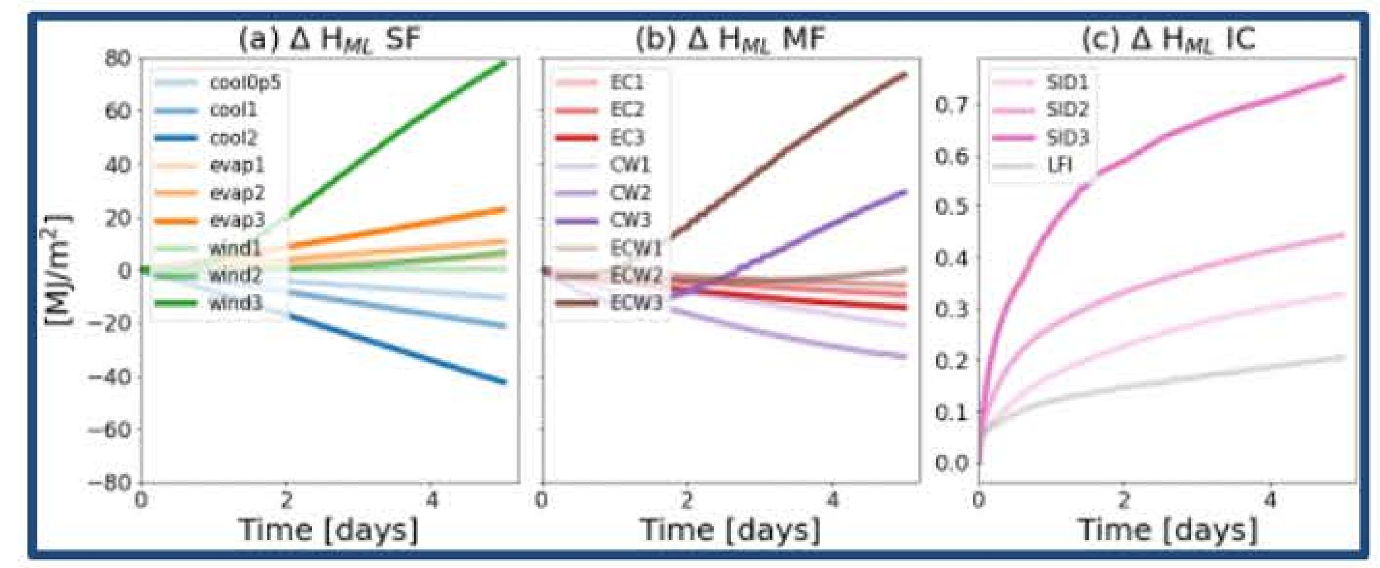
Previous Phase 1 InteRFACE Mixing Work



(Rainville et al, 2011)

What are the dominant mechanisms of vertical heat transport into the Arctic Ocean's surface layer?

Change in Mixed Layer Heat Content vs Time

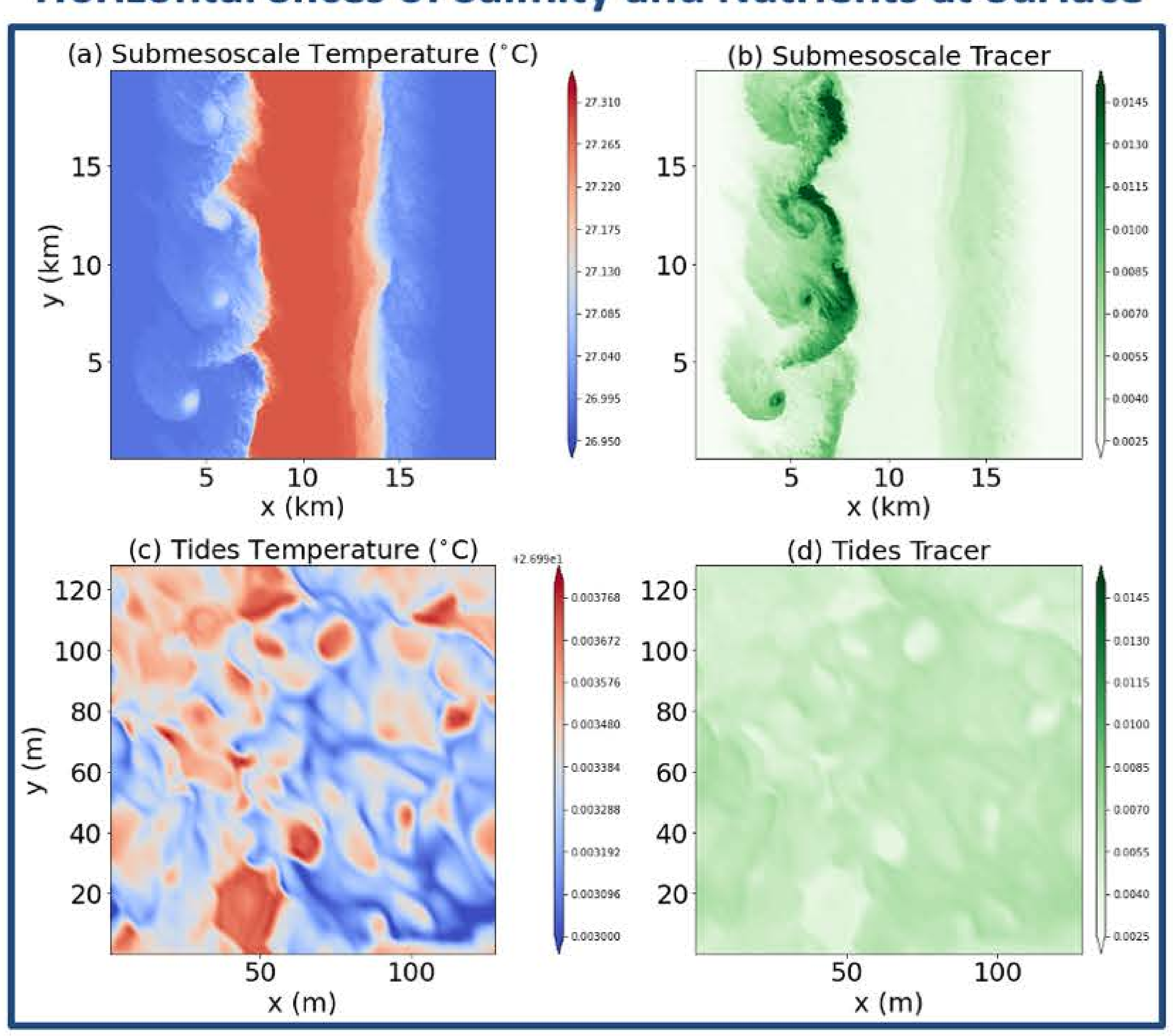


Wind erodes salinity stratification buffer → Drives heat into the mixed layer → More sea-ice loss/less sea-ice regrowth

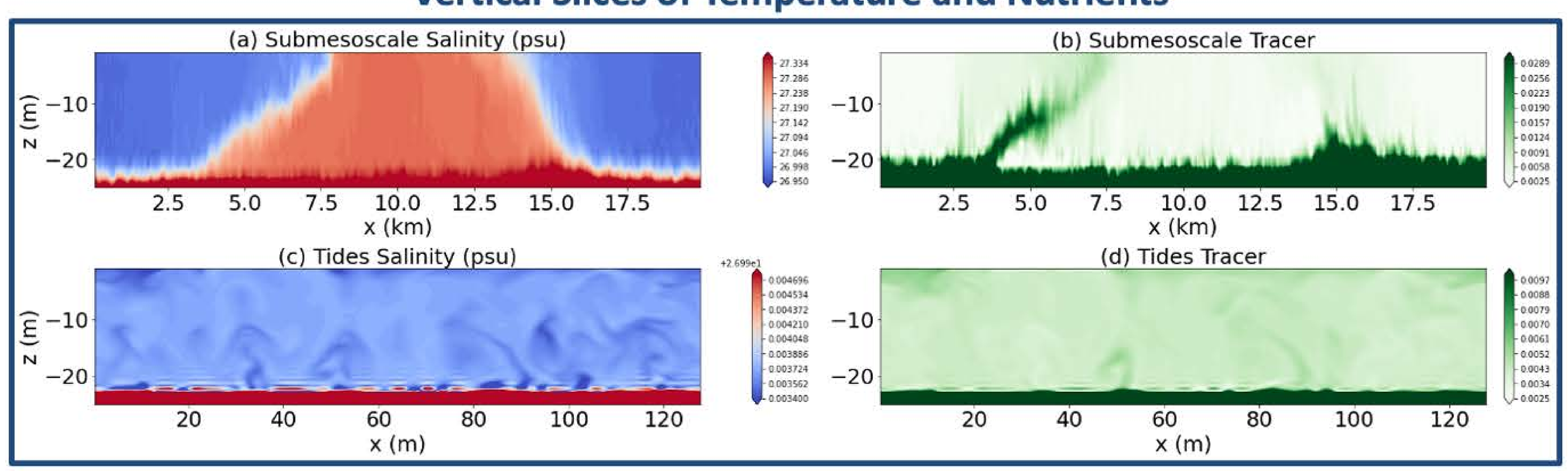
As the Arctic warms, will there be enough winter cooling?

Initial Results – Submesoscale and Tidal Forcing

Horizontal Slices of Salinity and Nutrients at Surface



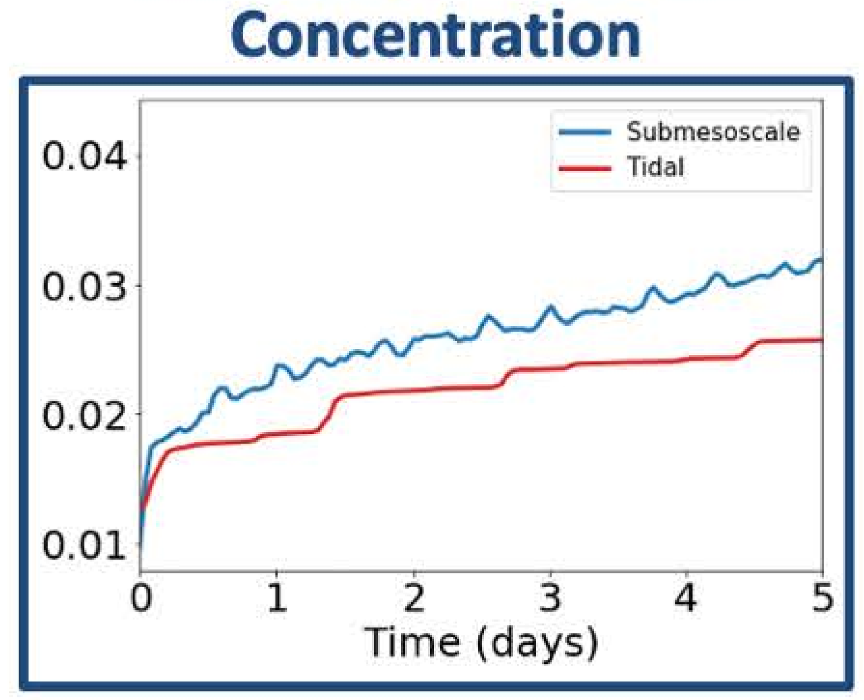
Vertical Slices of Temperature and Nutrients



Over 5 days, submesoscale currents entrain more nutrients into the mixed layer through upwelling along the unstable front

But do so in a more patchy distribution, while semi-diurnal tidal mixing is more well mixed

Mixed Layer Nutrient Concentration



Next Steps

- Compare Eurasian Basin vs Canadian Basin initial and forcing conditions (strong vs weak stratification)
- Examine wind-driven inertial oscillations (shares semi-diurnal band with tidal forcing)
- Explore role of ice-covered vs ice-free boundary conditions (current vs future scenarios)