Quantifying the impact of submesoscale dynamics on the evolution of Arctic freshwater fronts

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vEGU21 - Arctic changes – processes and feedbacks in climate, ocean and cryosphere (CL4.7)

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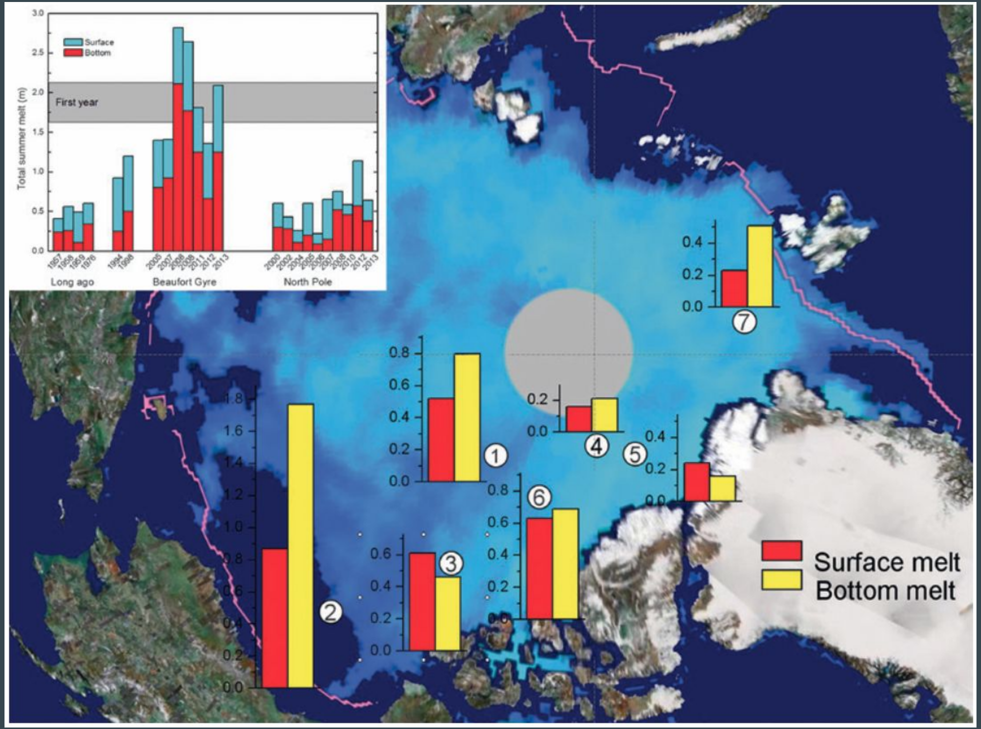
An Evolving Arctic Summer Mixed Layer

Seasonal cycle of freshwater flux due to sea ice melt.

Summer 2008 sea ice melt [m]



Carmack et al (2015), Perovich (2011)

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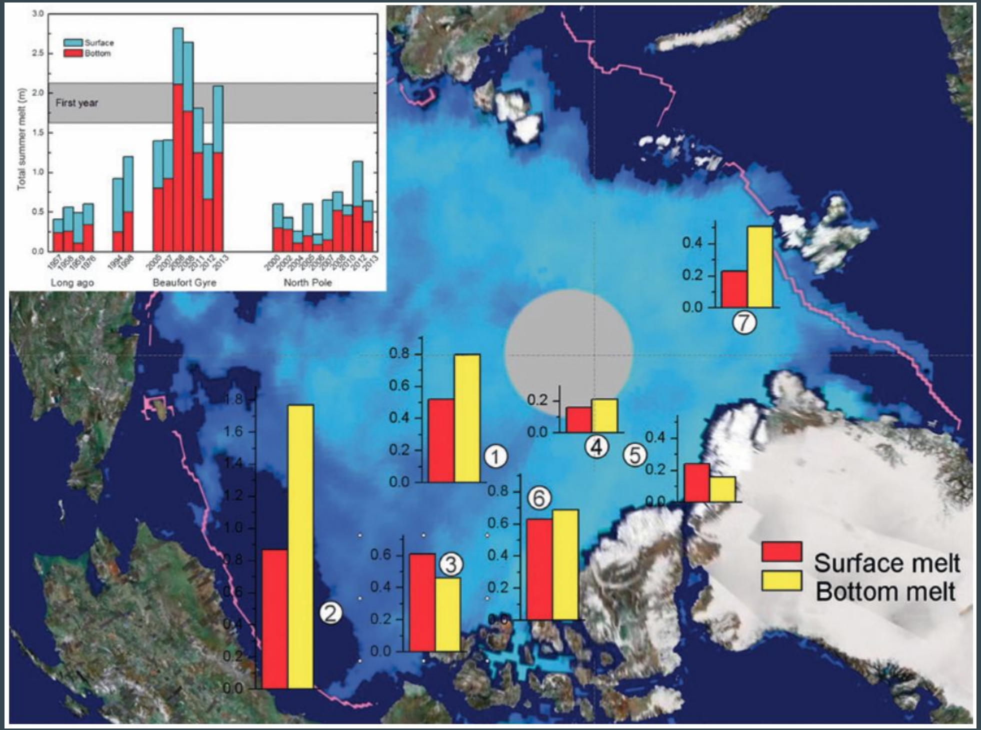

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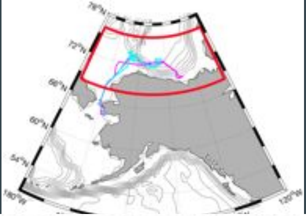

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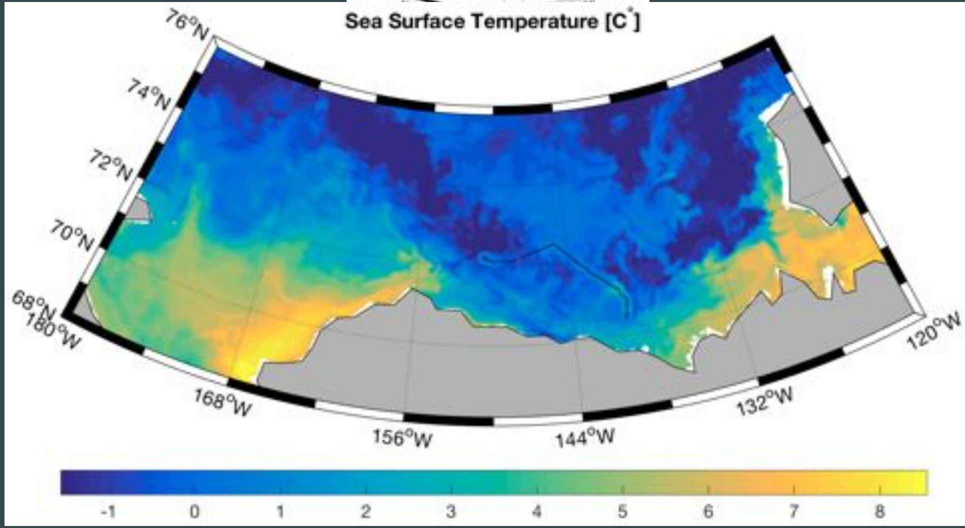
This source of freshwater is inherently patchy.



Hycom reanalysis, September 2015

An Evolving Arctic Summer Mixed Layer

Seasonal cycle of freshwater flux due to sea ice melt.

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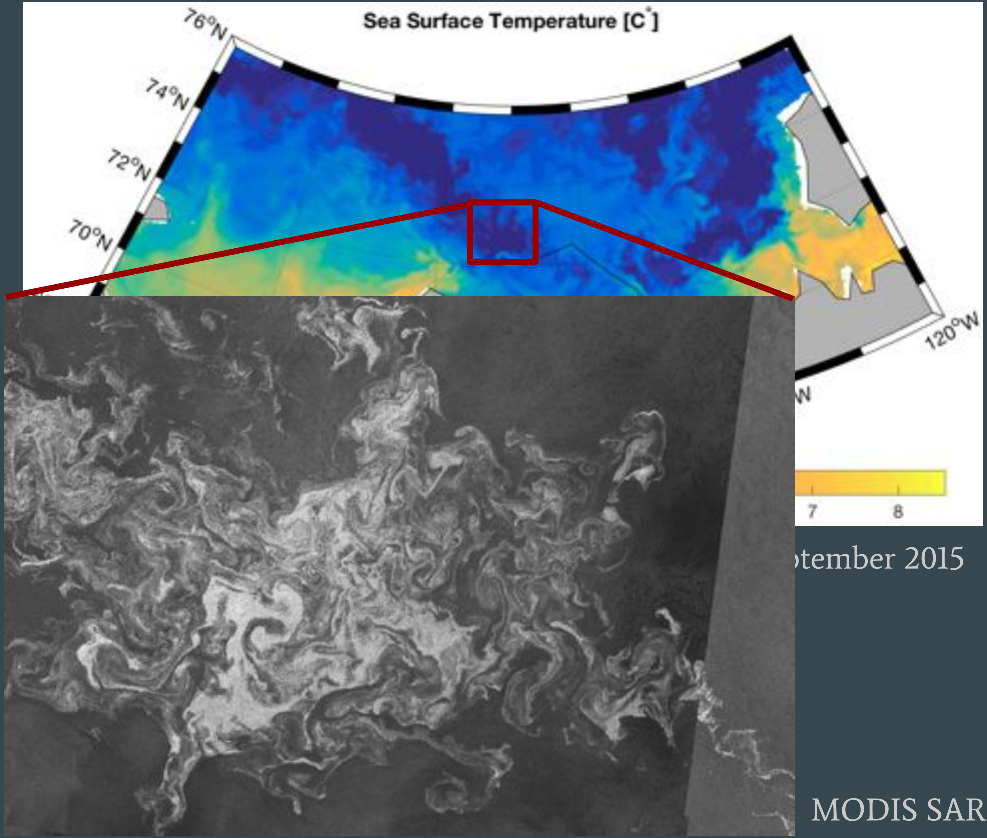
The resulting fronts are stirred and strained by eddies and are observed to have Rossby numbers O(1).



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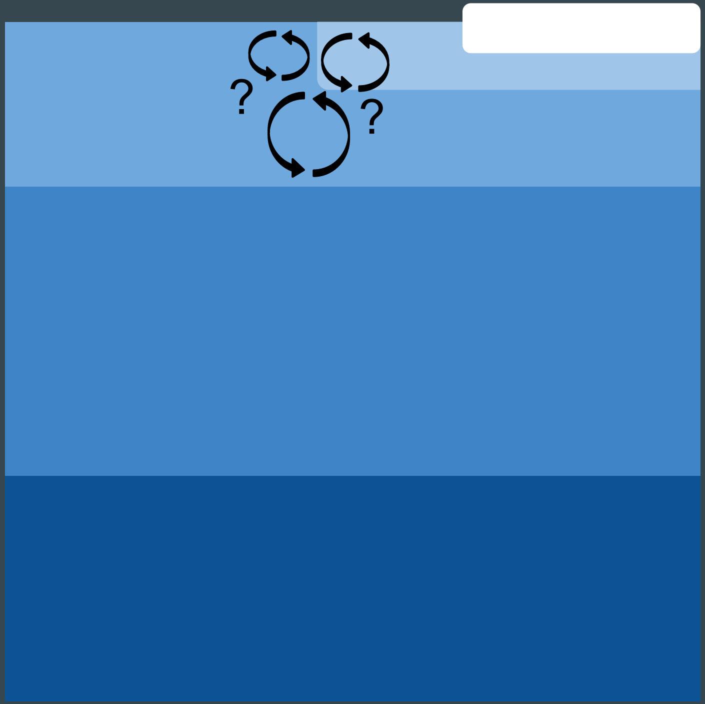
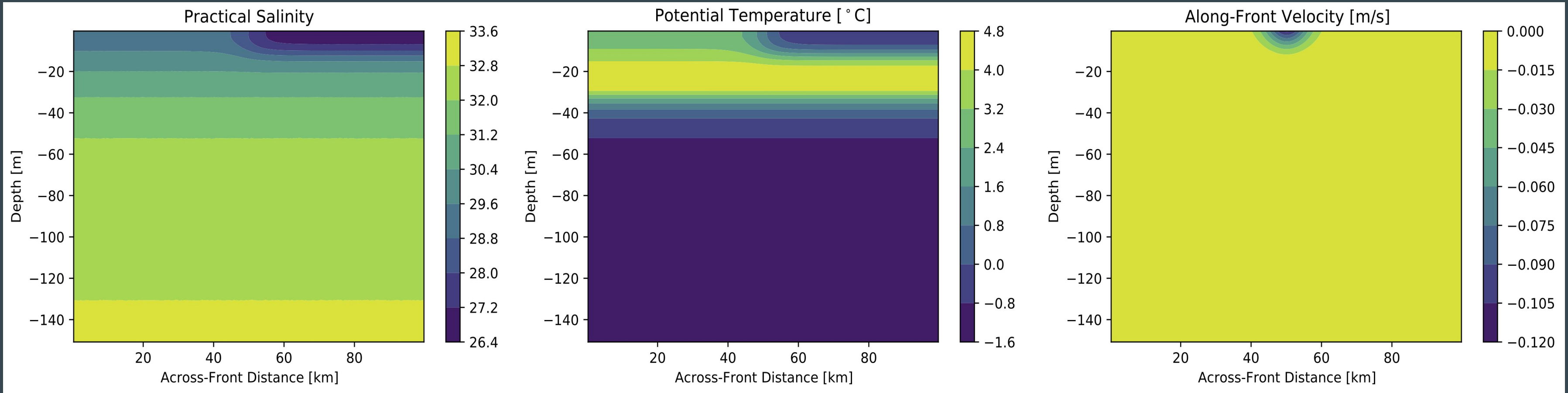
MODIS SAR

Questions



- What processes control the evolution of these freshwater fronts?
- What is the importance of submesoscale processes for the lateral and vertical exchange of heat and salt?

Model Setup



Vertical profiles and frontal length scales based on in-situ observations with a geostrophically balanced jet centered at the front. Salinity field seeded with white noise.

MITgcm, channel configuration, 25 vertical layers (100 km x 100 km x 150 m)

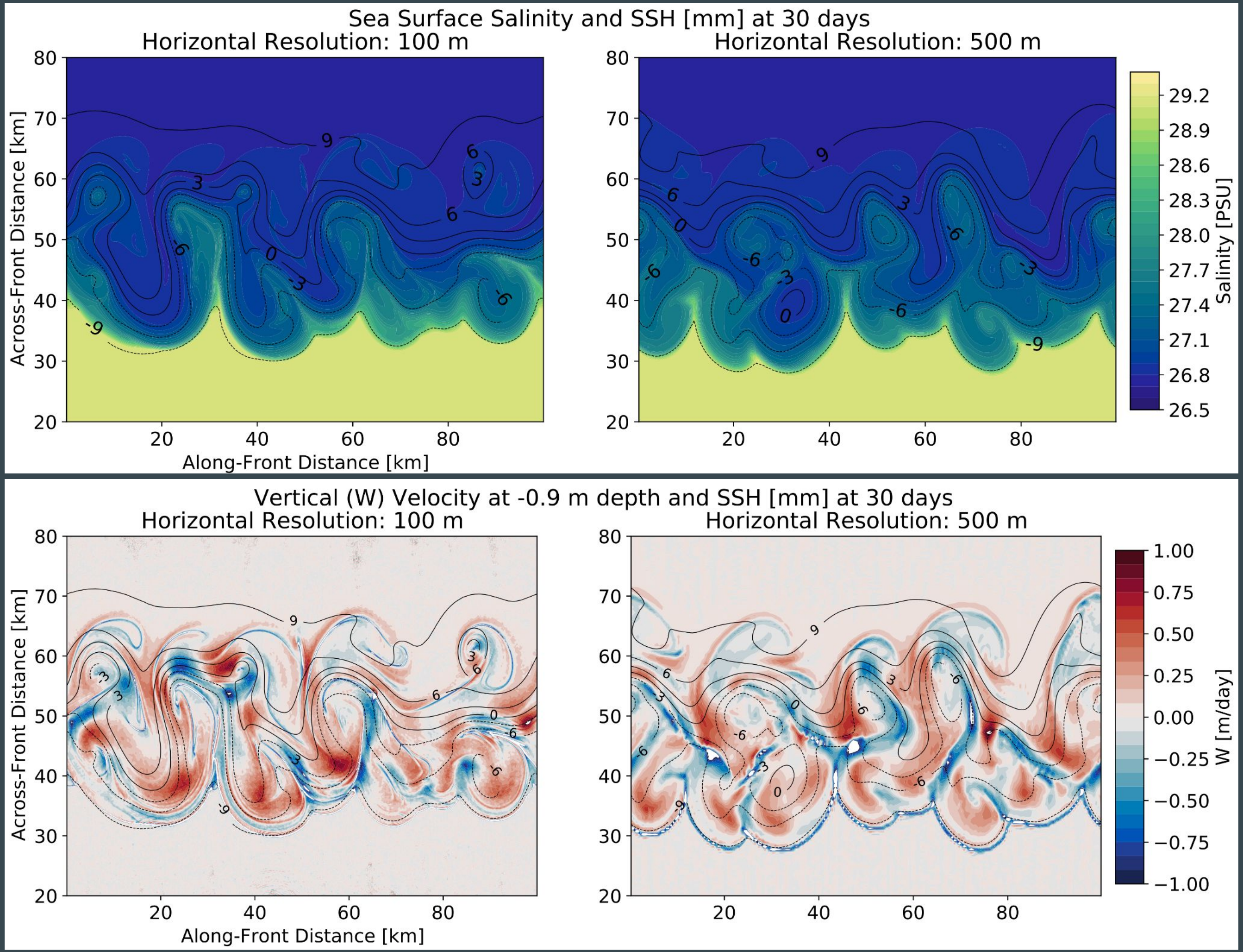
Mixed layer baroclinic Rossby radius is ~2 km for configuration. Employ a high (dx = 100 m) and low (dx = 500 m) lateral resolution simulations.

kappa_T = 1e-6 m^2/s, nu = 1e-4 m^2/s

Front Evolution

Formation of baroclinic instabilities, jet meanders, and isopycnals slump and flatten.

Warm, salty intrusions into the cold, fresh side of the front oppose the tracer transport of the overturning.



Upper ocean temperature budget

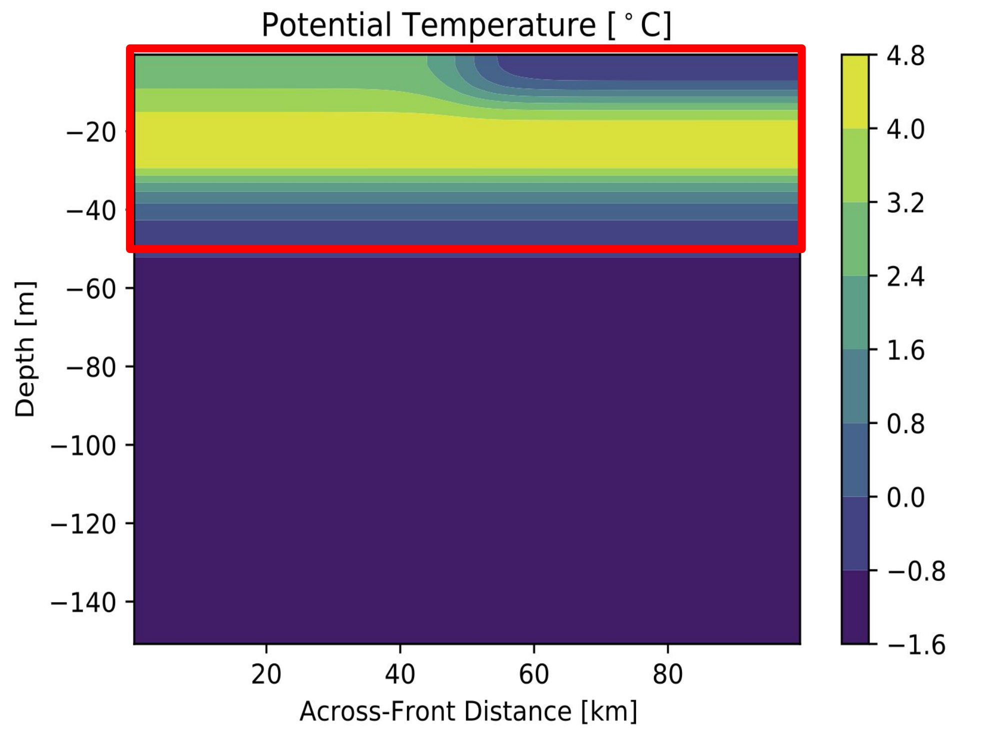
$$\frac{\partial T}{\partial t} = -\frac{\partial(u_G T)}{\partial x} - \frac{\partial(u_A T)}{\partial x} - \frac{\partial(v_G T)}{\partial y} - \frac{\partial(v_A T)}{\partial y} - \frac{\partial(wT)}{\partial z} + \kappa_H \frac{\partial^2 T}{\partial x^2} + \kappa_H \frac{\partial^2 T}{\partial y^2} + \kappa_R \frac{\partial^2 T}{\partial z^2}$$

Horizontal velocities are decomposed into geostrophic and ageostrophic components.

Integrate in time to day 60, vertically from the surface to 50 m depth, and over the domain in the along-front direction.

x - along-front direction

y - across-front direction



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x - along-front direction

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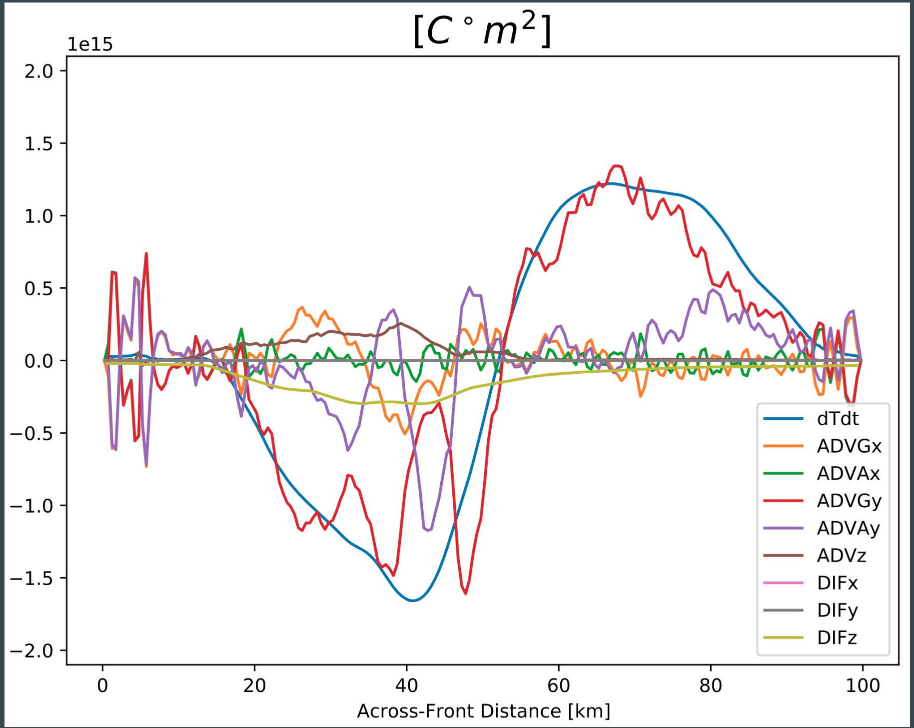
Temperature tendency is dominated by across-front geostrophic motions with across-front ageostrophic motions having greater influence on the salty side of the front.



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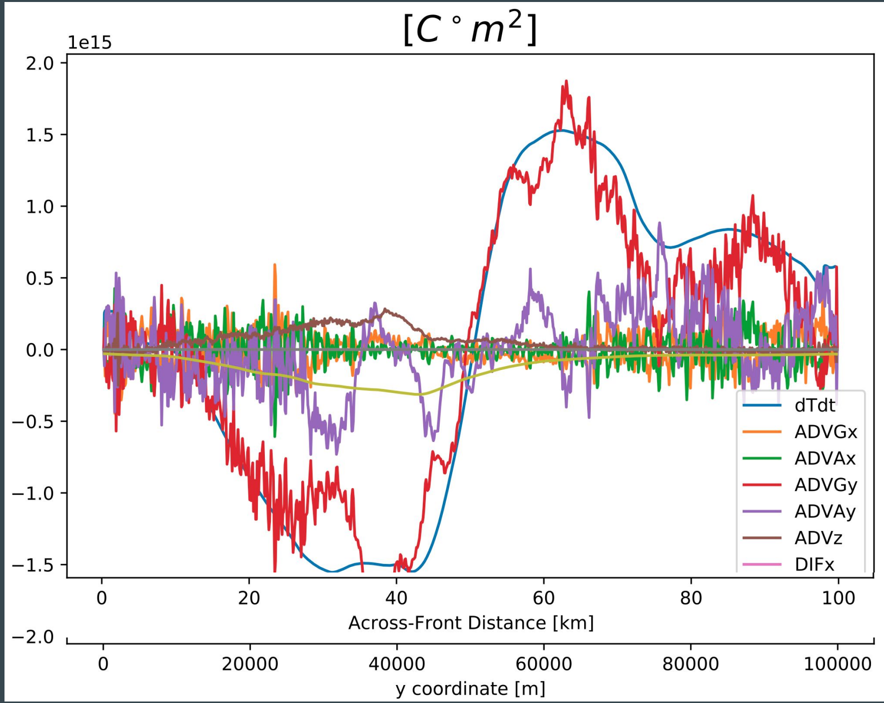
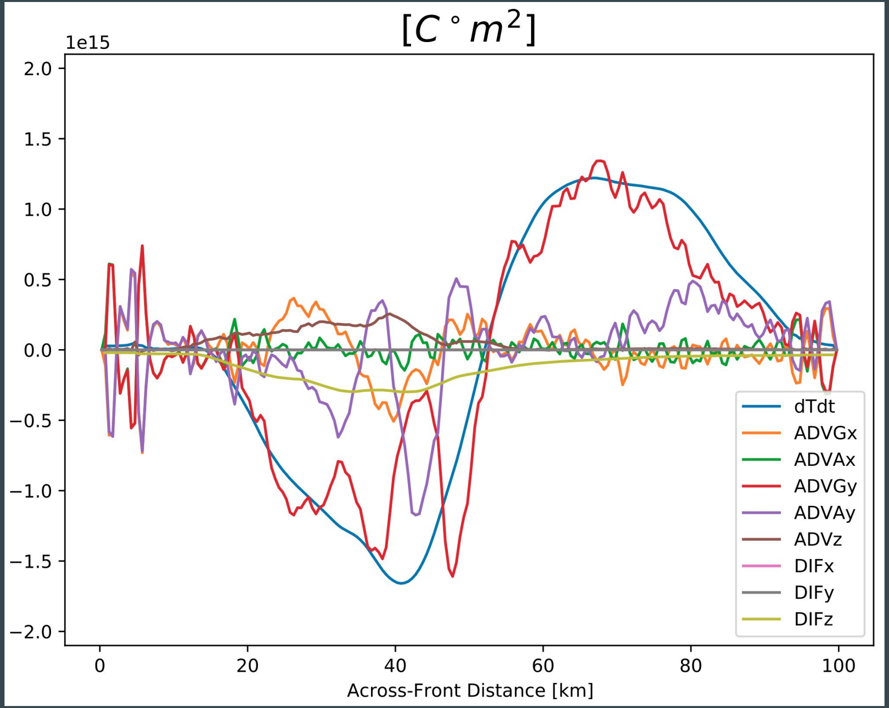


High resolution (100 m)

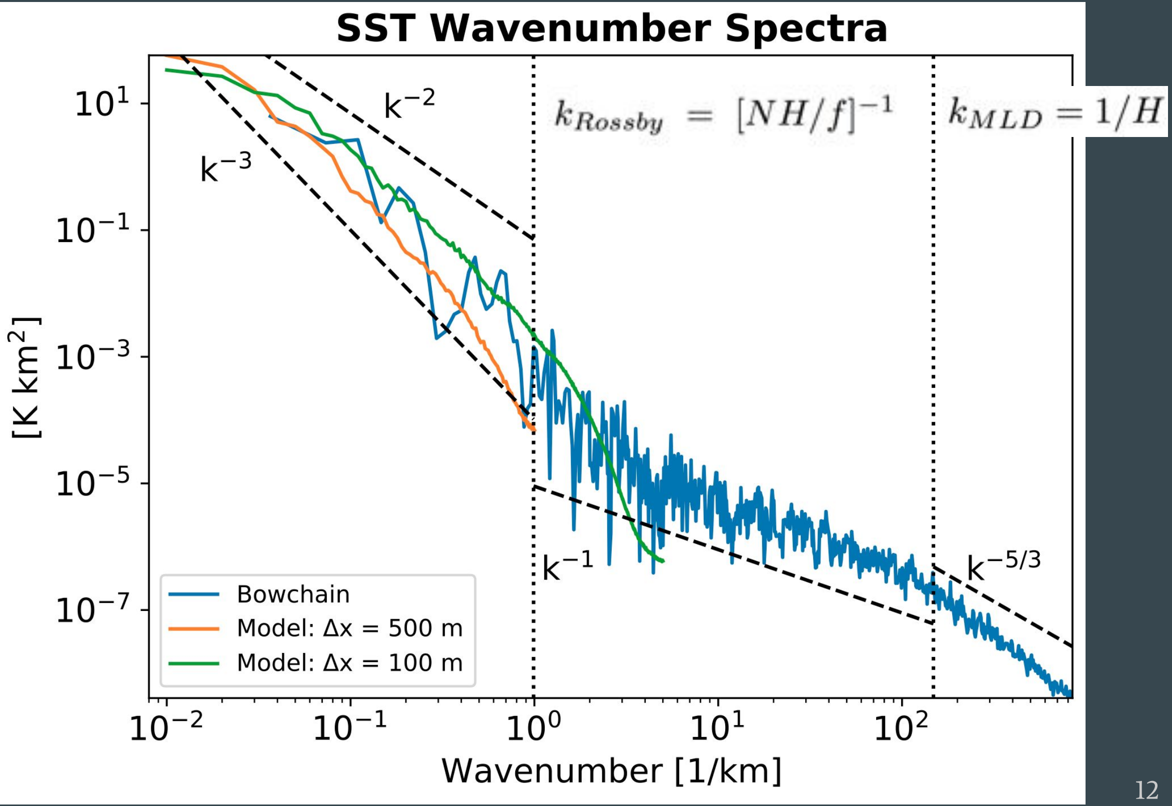


Low Resolution (500 m)

Comparison with observations

Simulations envelope the observations over the mesoscale range.

Still not quite resolving the first decade of the submesoscale range.



Takeaways

1. Across-front geostrophic motions enhance lateral transport of heat across Arctic surface mixed layer fronts.
2. Permitting a larger range of dynamics further increases the extent over which geostrophic motions drive lateral heat fluxes and increase the total temperature tendency.
3. Both simulations reproduce relatively steep spectral slopes observed over the mesoscale range but still can’t capture full submesoscale range.

Thank you

Please feel free to send me your questions ahead of time at malberty@princeton.edu

I look forward to talking with you during the CL4.7 breakout sessions on Wednesday, 28 April 2021, 09:30-10:30 CEST.