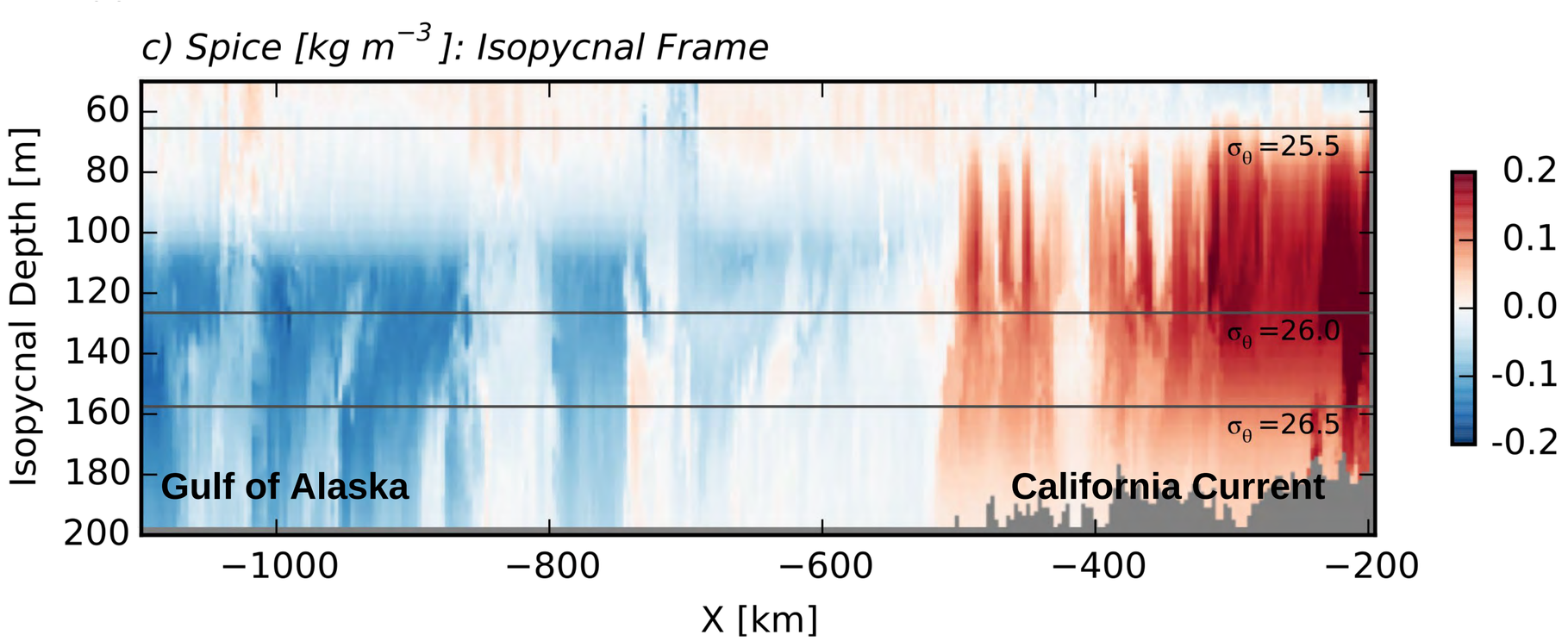
Submesoscale observations in the Northeast Pacific

Jody Klymak
University of Victoria



Ocean Physics Group

Why lateral mixing?

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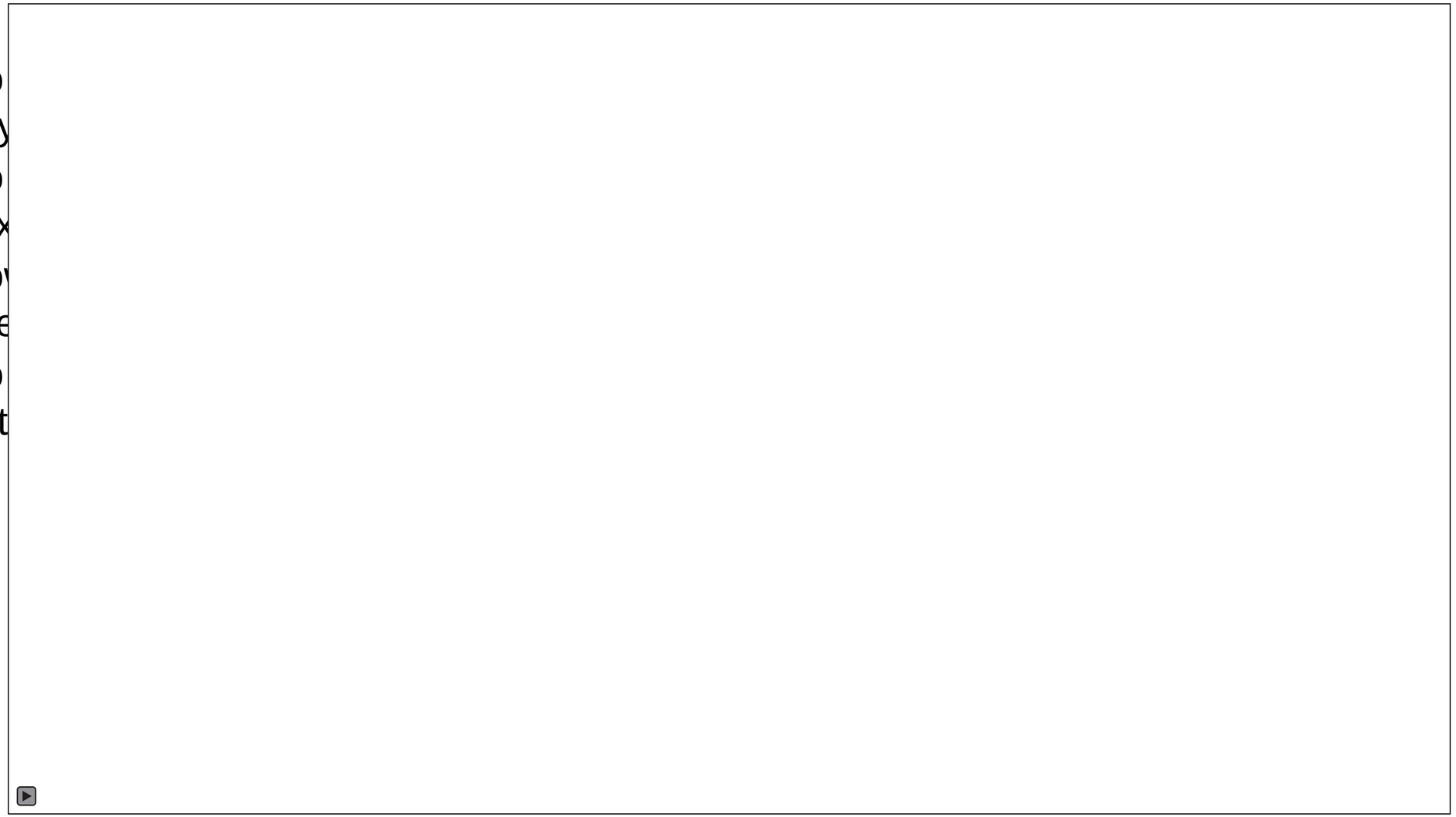
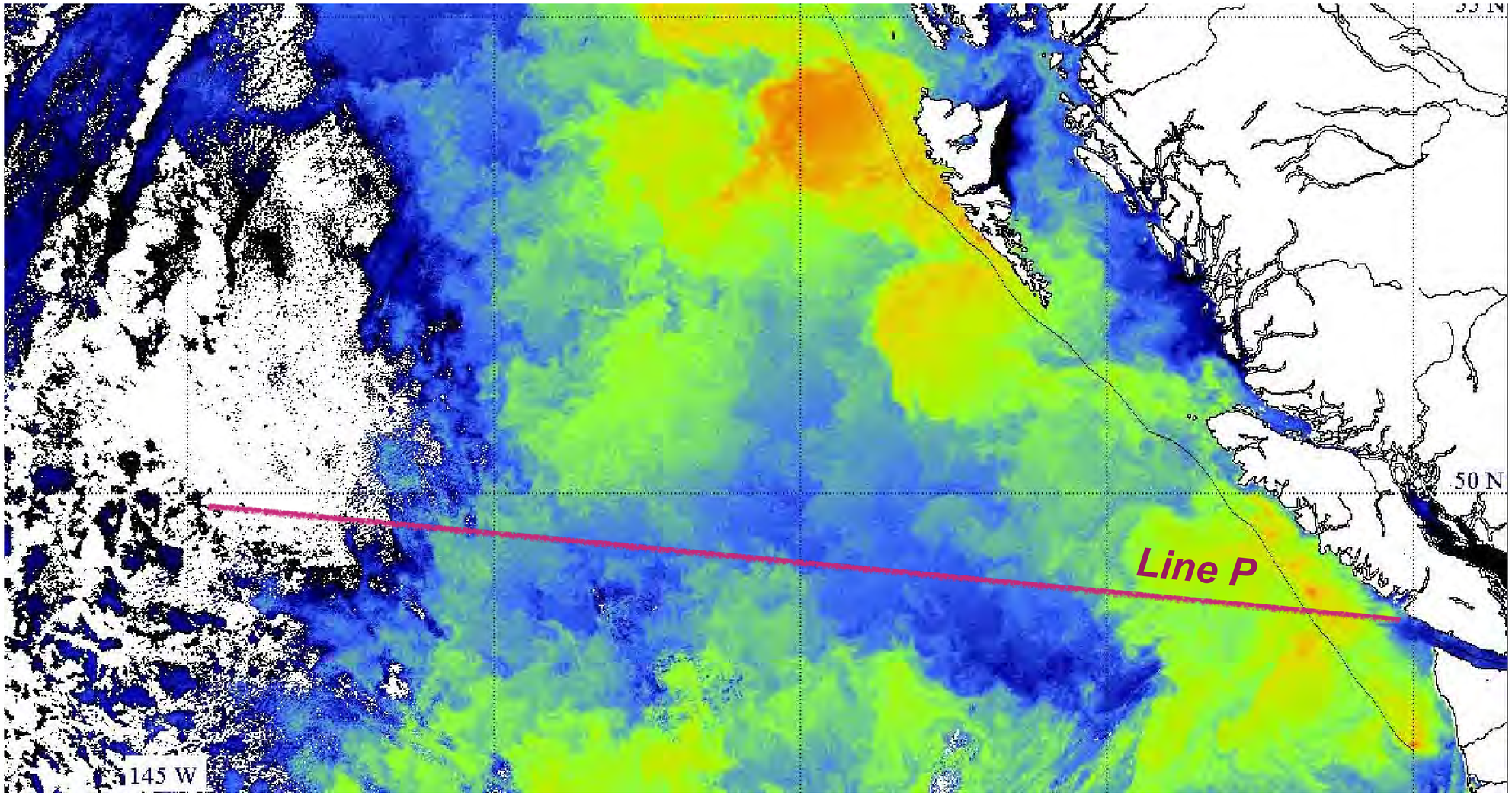


MEOM group

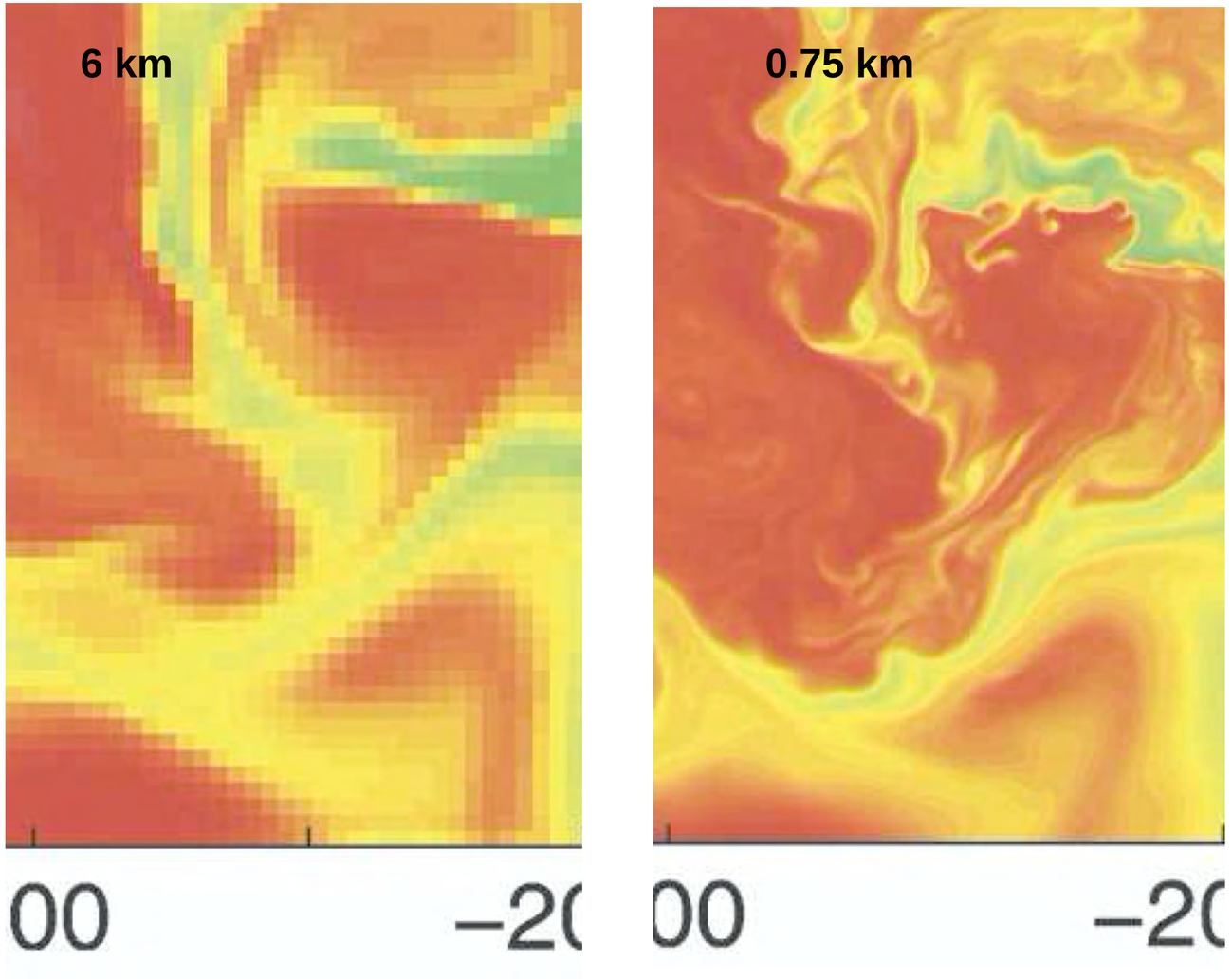
Why lateral mixing?



Frank Whitney, IOS

Parameterizing small scale?

- Does it matter?
  - data assimilation can always correct for bad flux parameterizations…
  - …for variables that we have lots of data for
  - can’t data assimilate hard things like gases, nutrients, biology
  - dynamics might be wrong, and data assimilation not fast enough to correct (timing spring bloom)

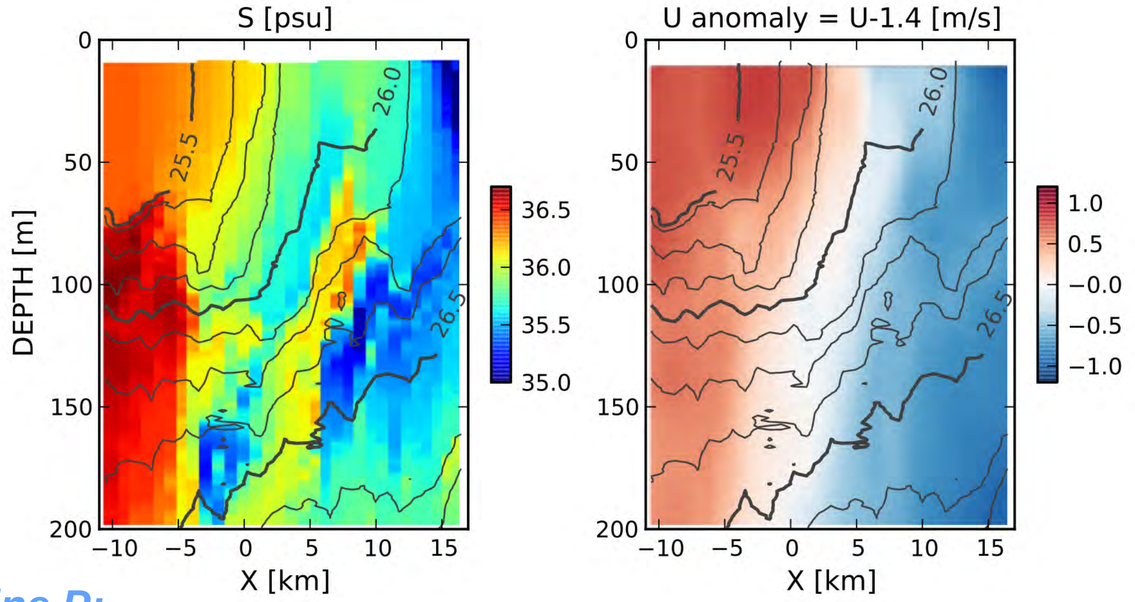


Capet et al 2008a

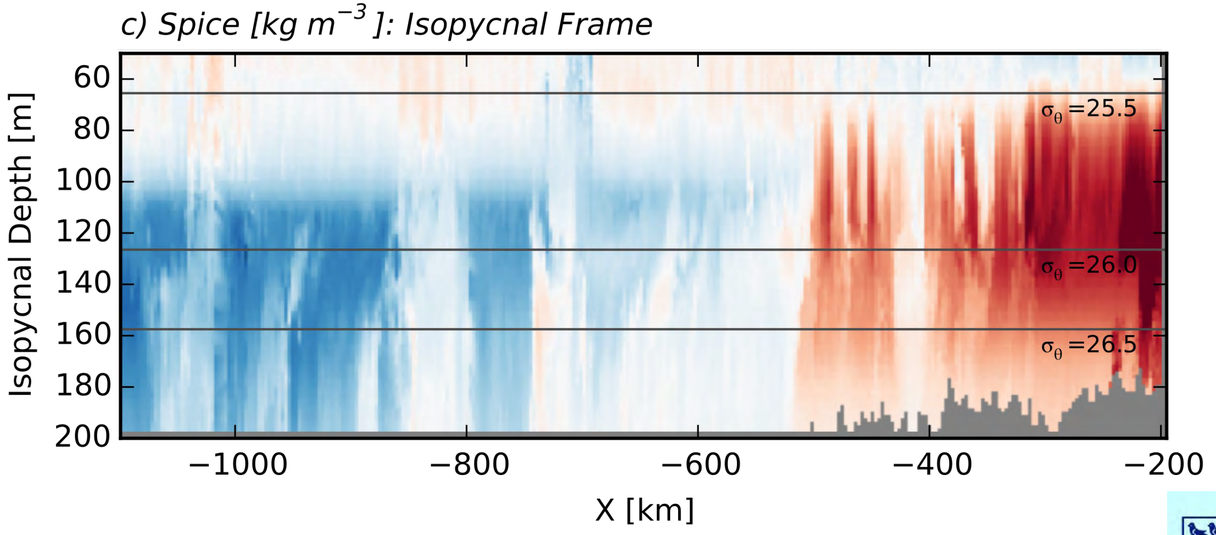
Steps to parameterize

1. Characterize:
   A. phenomenology
   B. statistics
2. Suggest Parameterization
3. Test versus data
4. Repeat…

Gulf Stream:

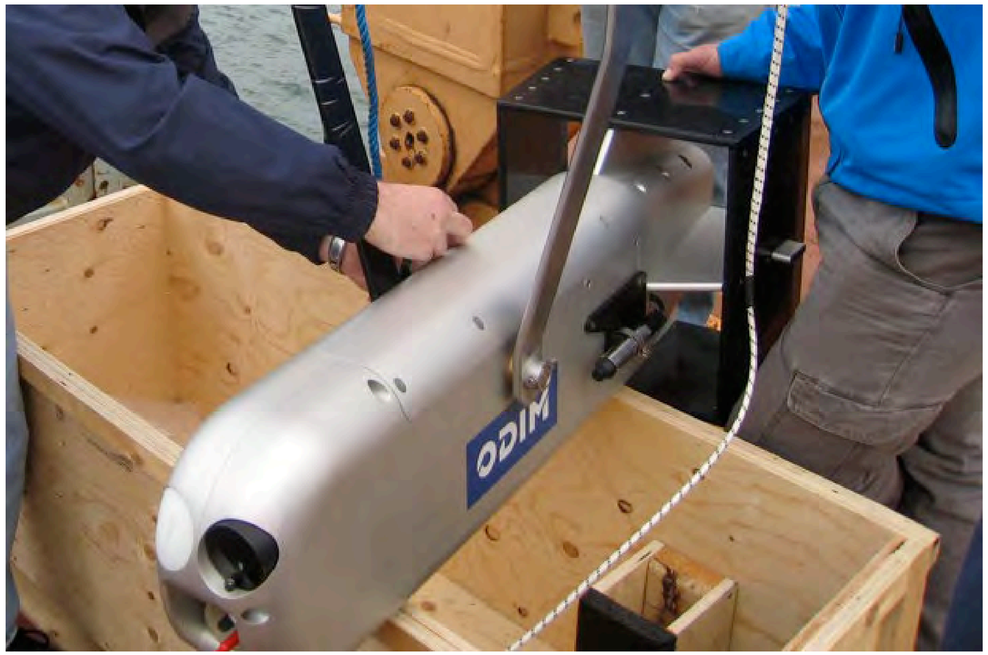


Line P:



Methodology

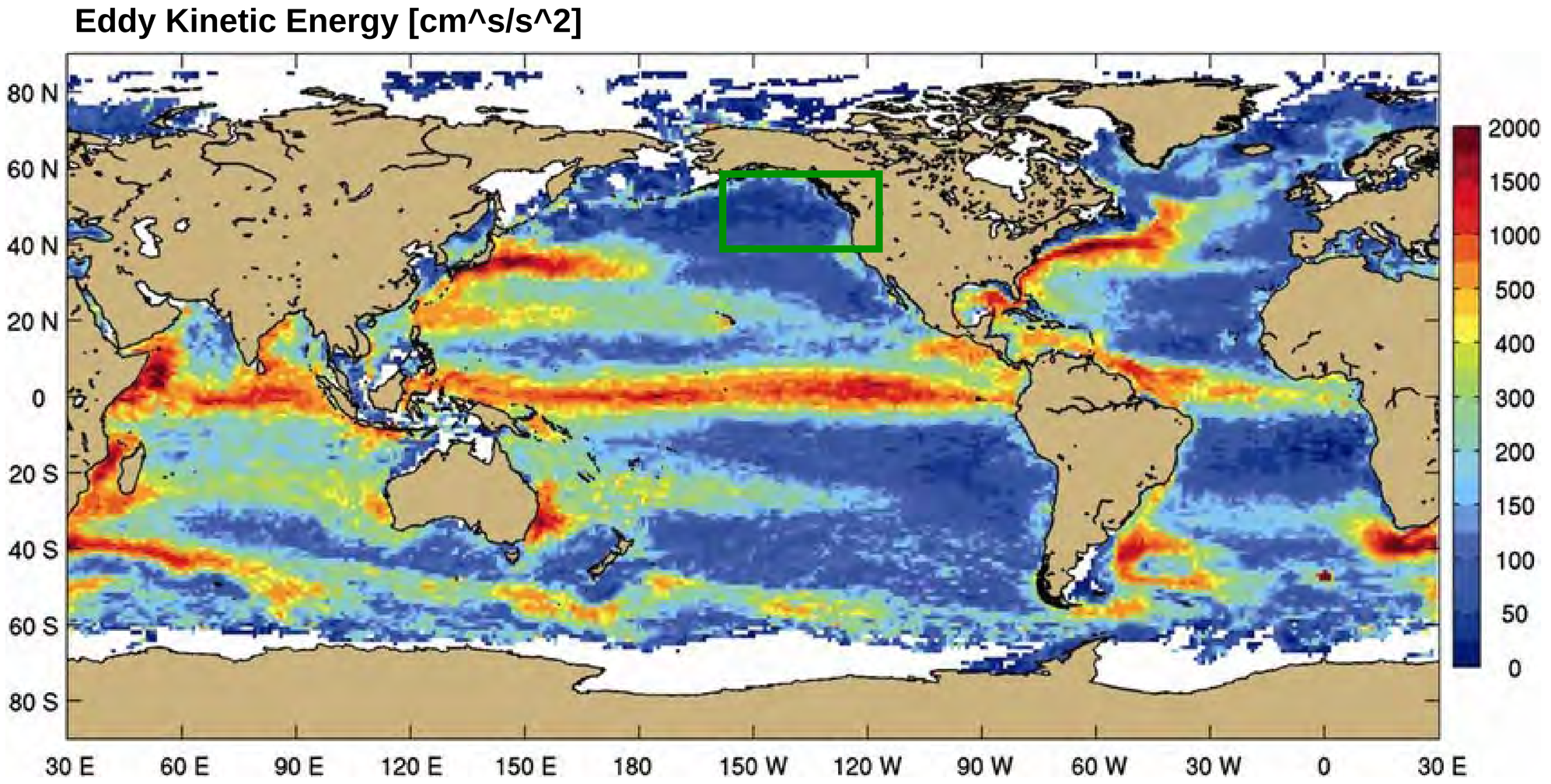
Moving Vessel Profiler



- Ship cruises 6-10 kts
- Casts to 200 m depth
- Spacing 700-1200 m

- CTD sensor
- O2 or Fluorometer

Line P spice and kinetic energy



Maximenko et al 13

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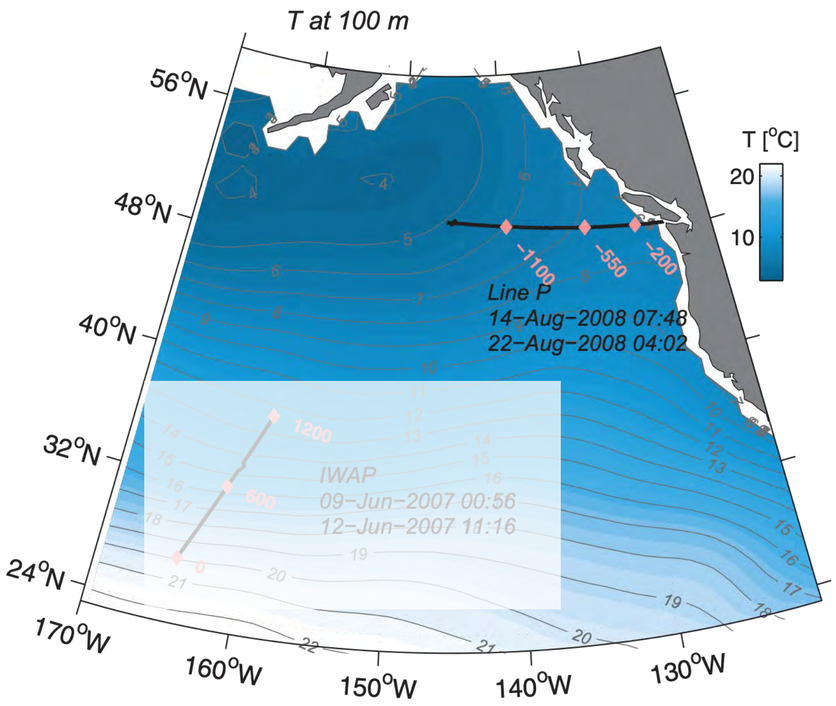
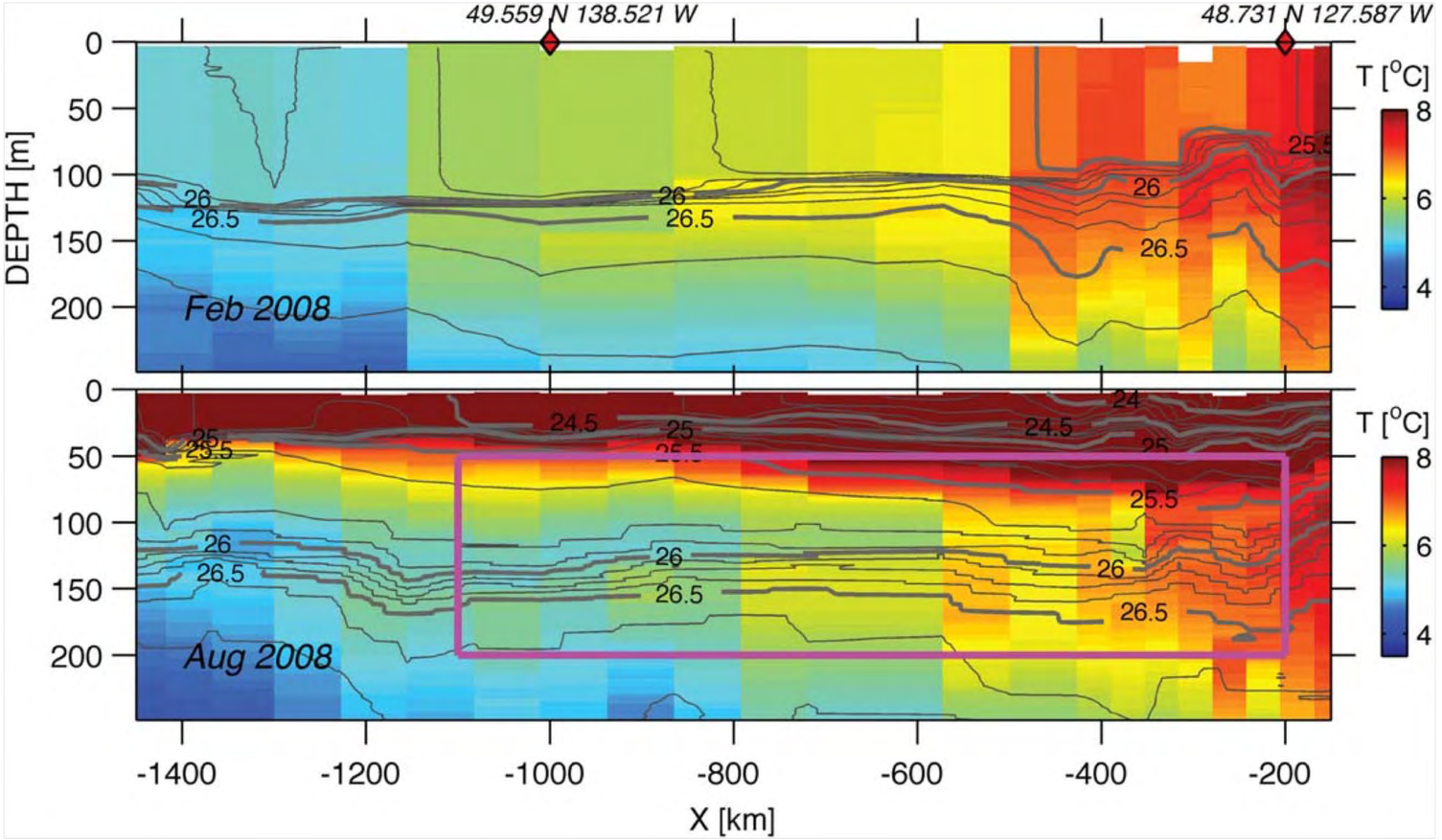
Line P





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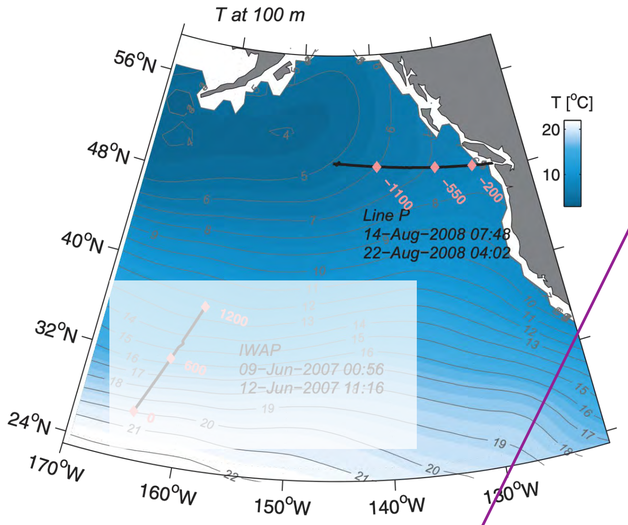
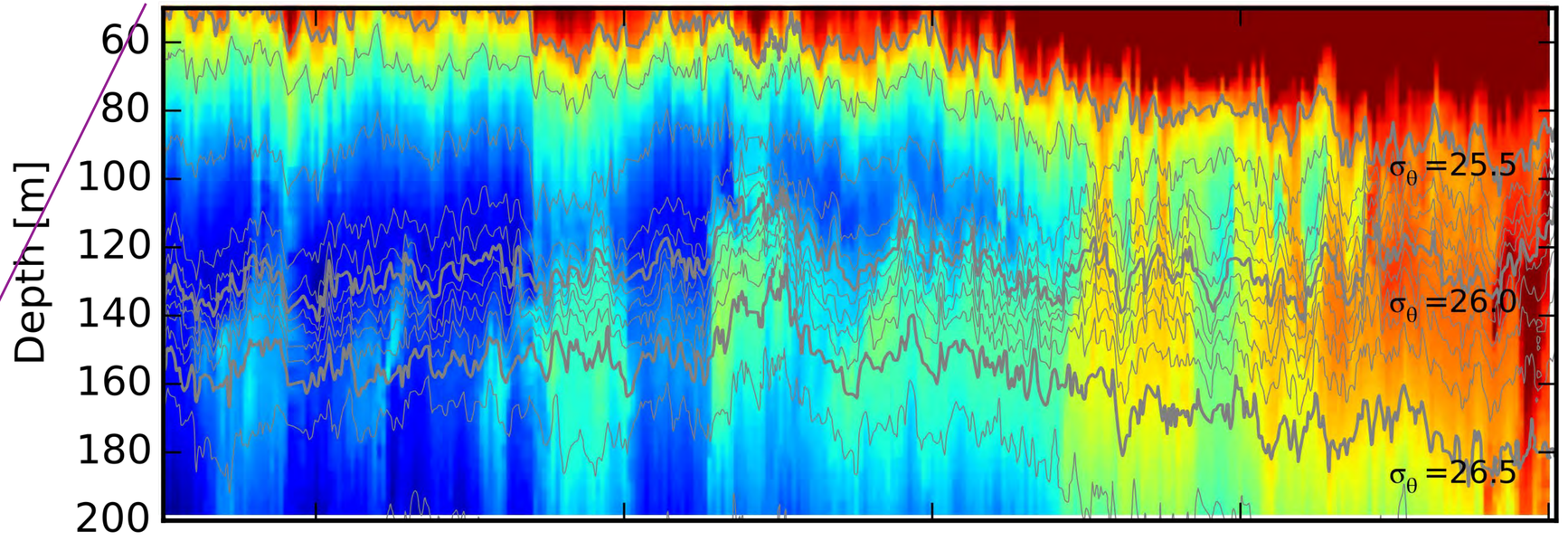
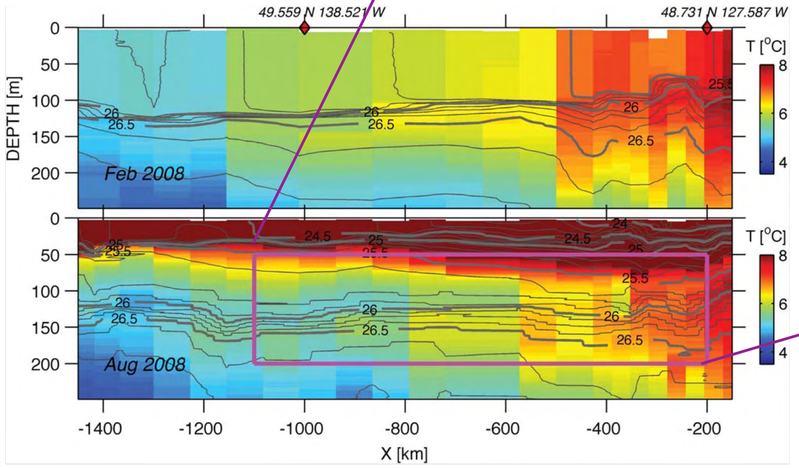
Line P



a) Potential Temperature [^{o} C]: Observed Field – Line P





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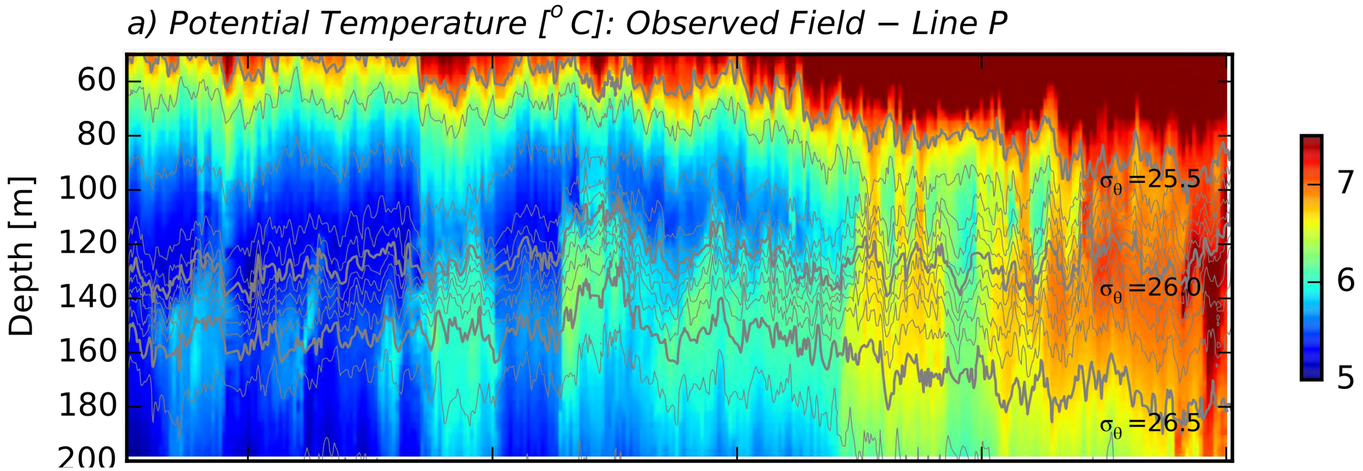
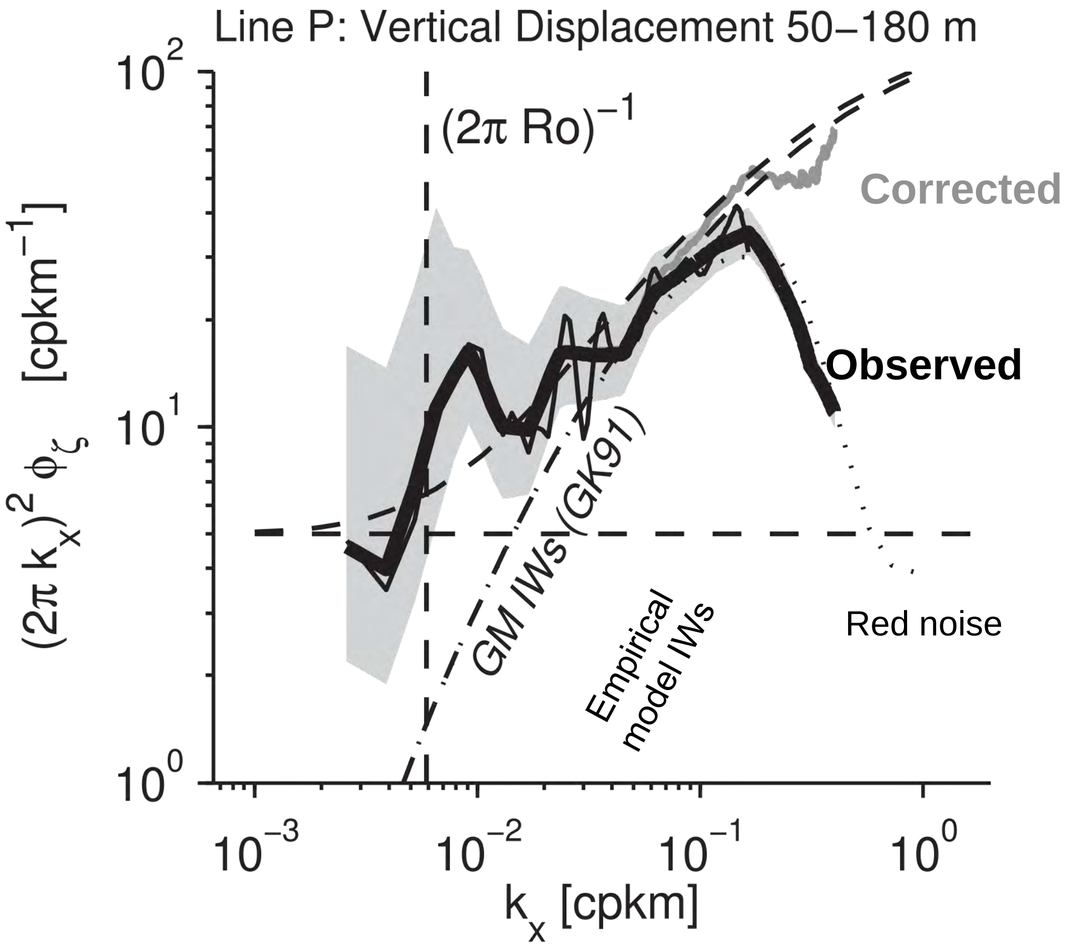
Line P



Internal waves:



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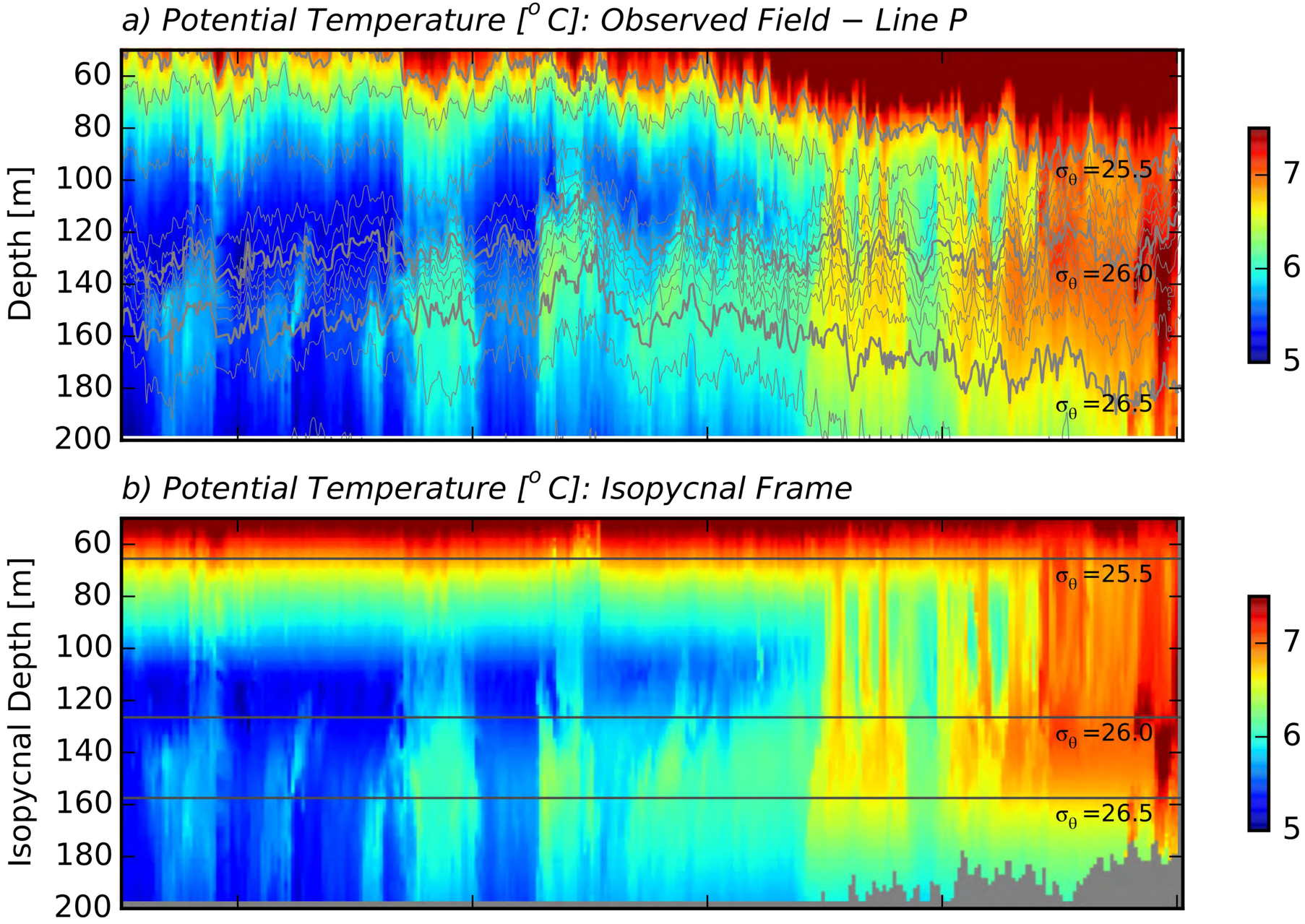
Line P



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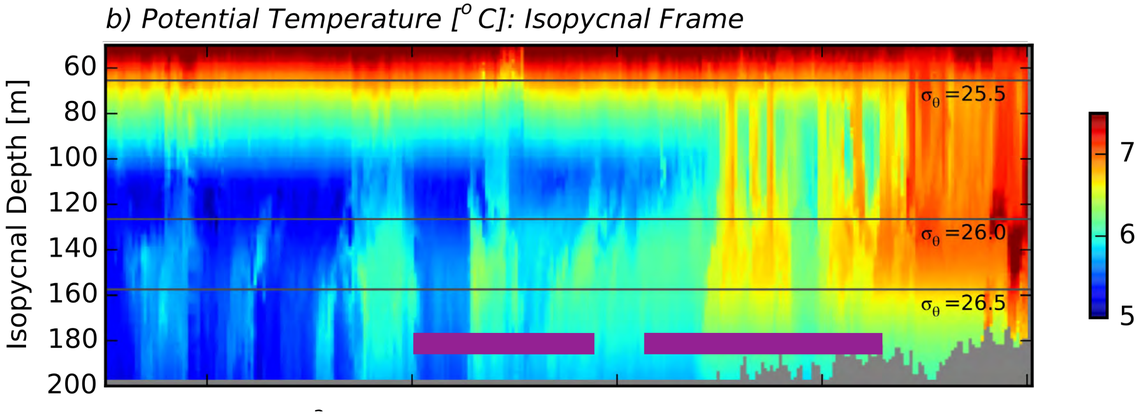
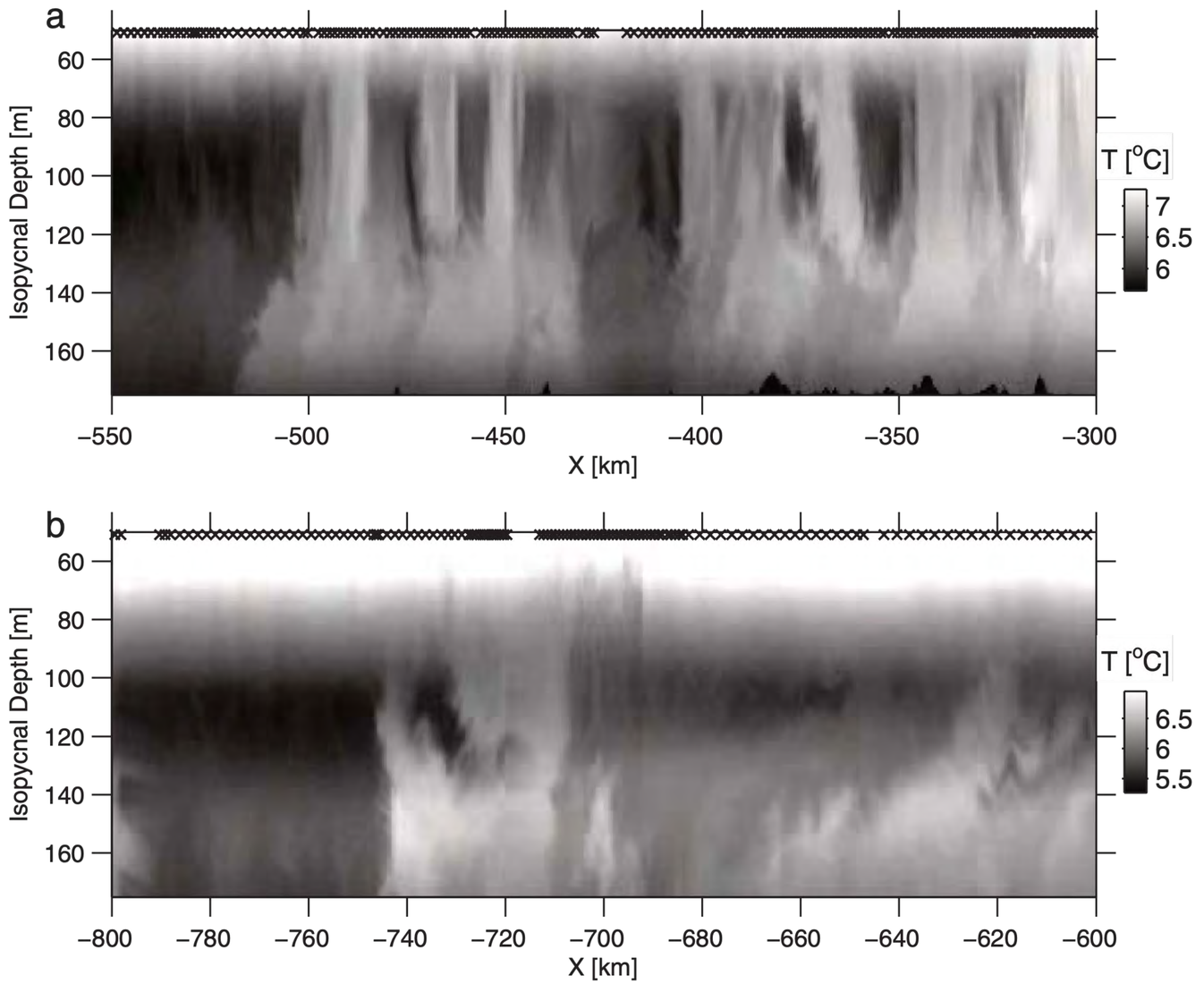


Lateral stirring:



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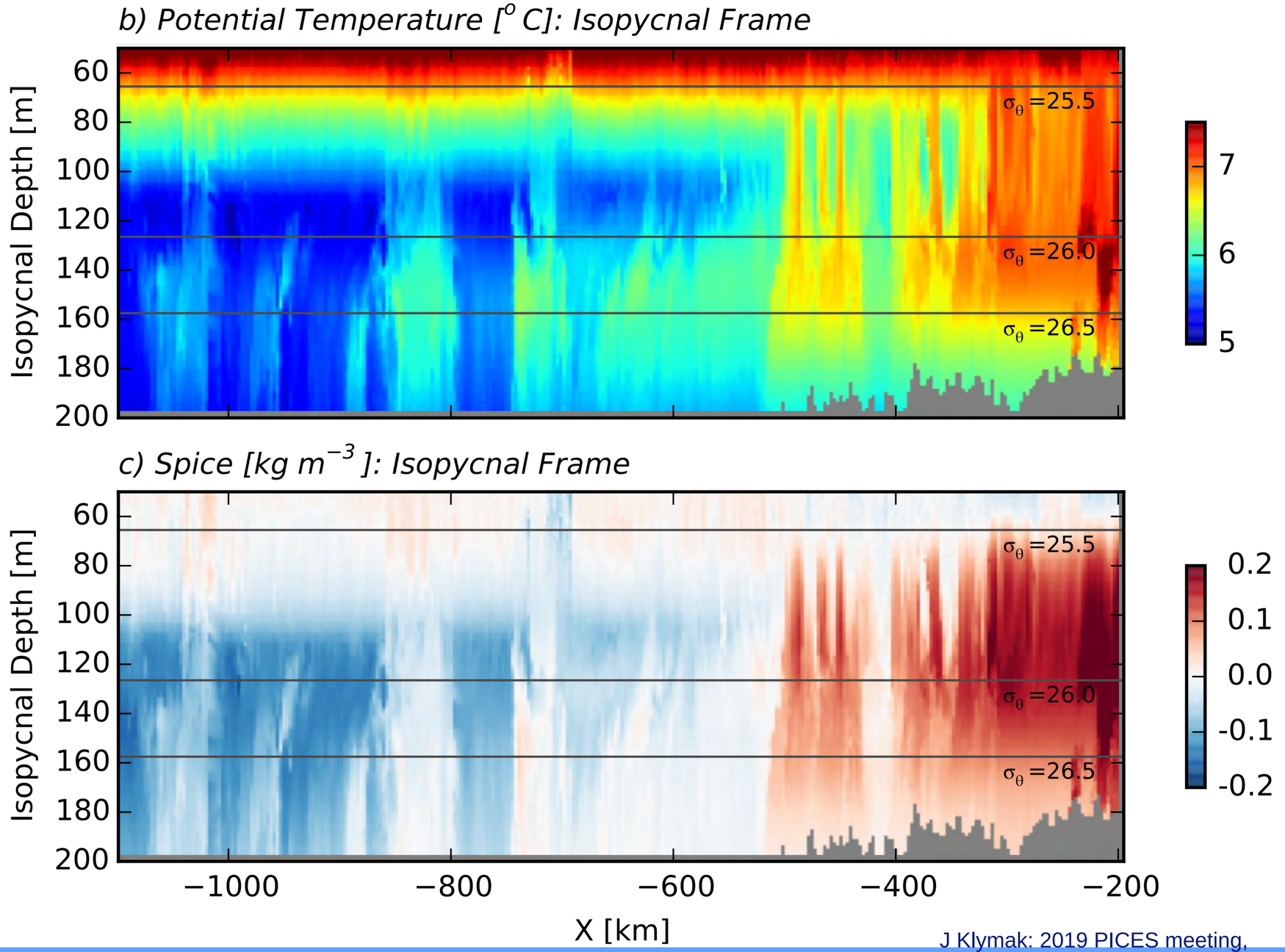
Line P



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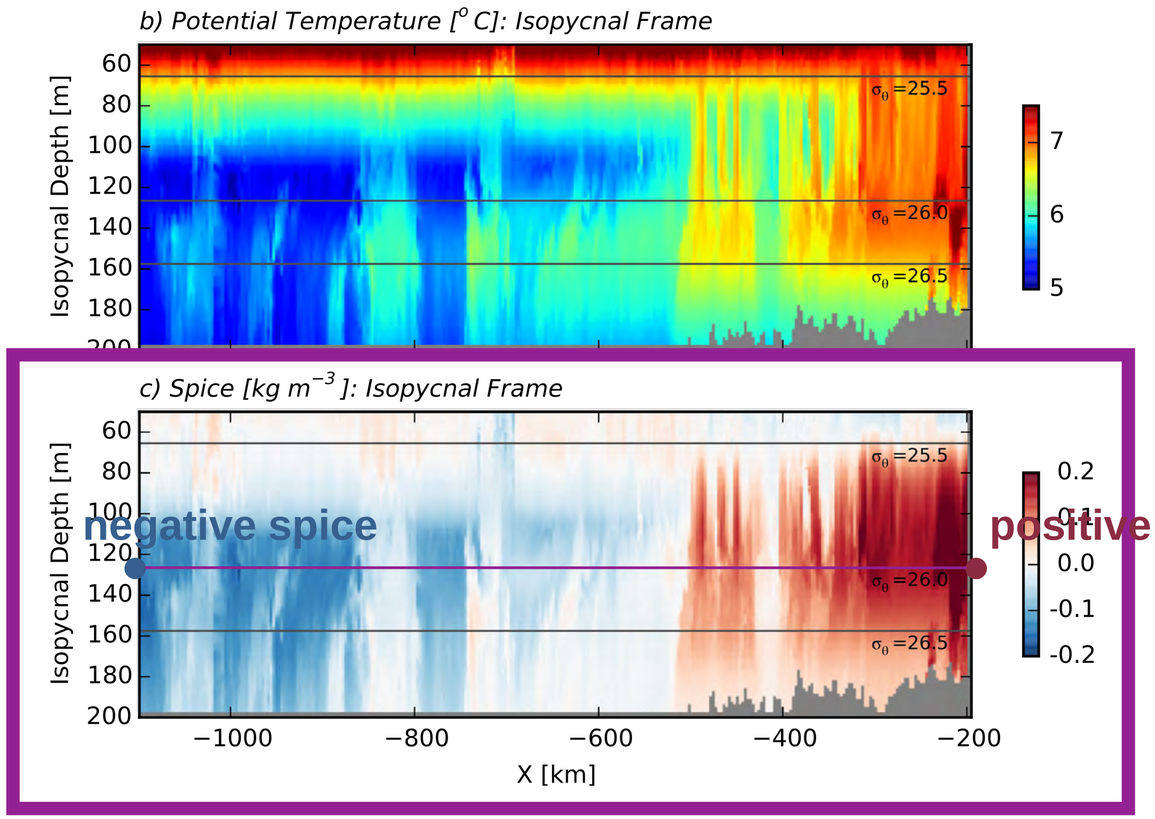
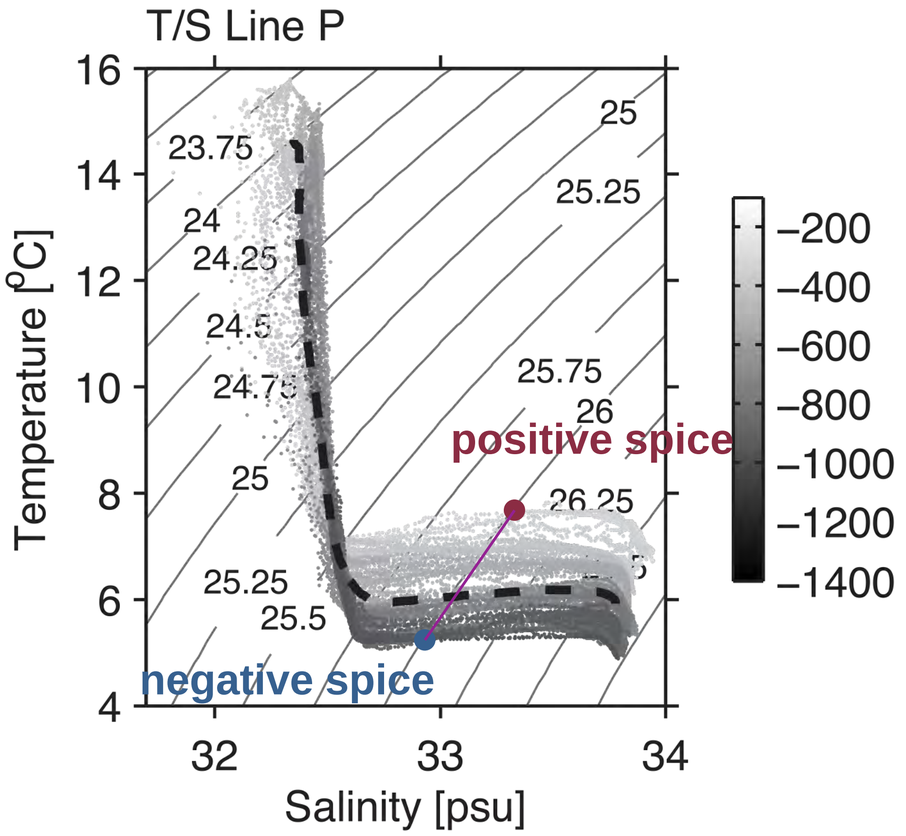
Line P

Lateral stirring: Spice



Spice: T anomaly along isopycnal



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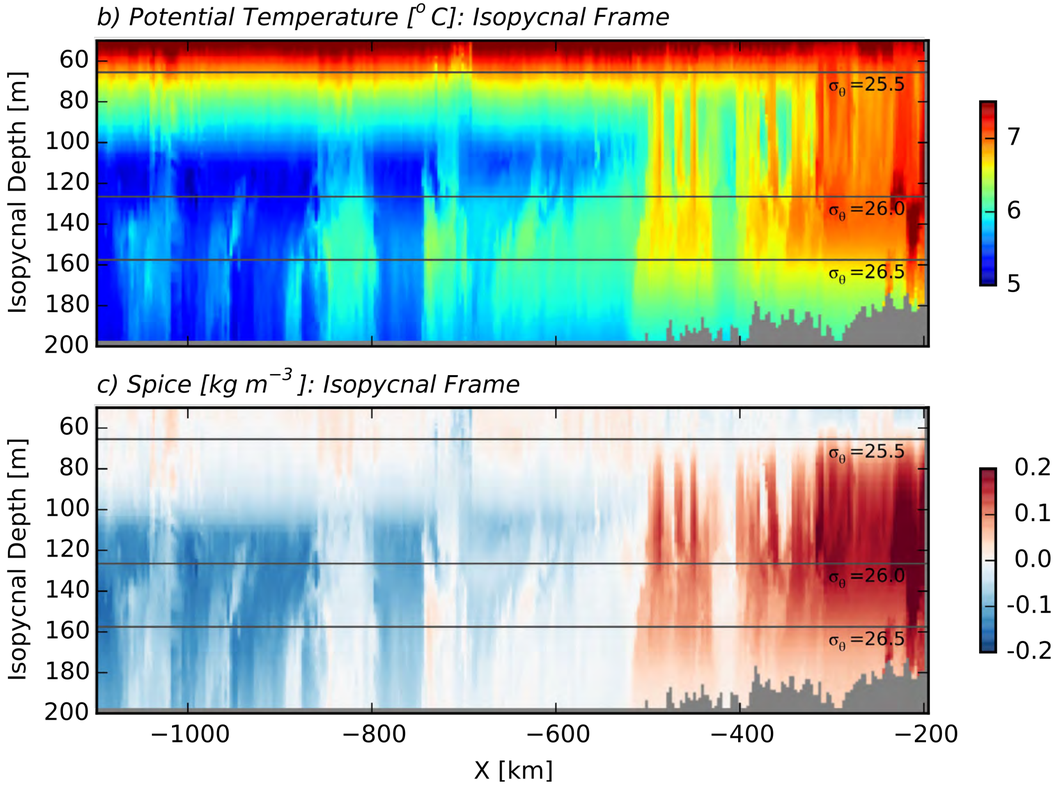
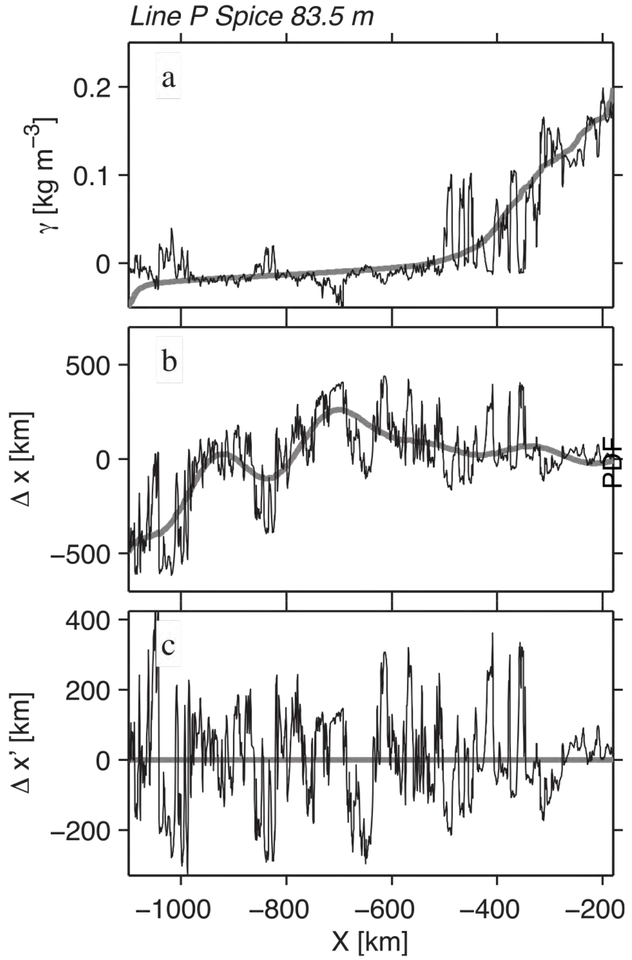
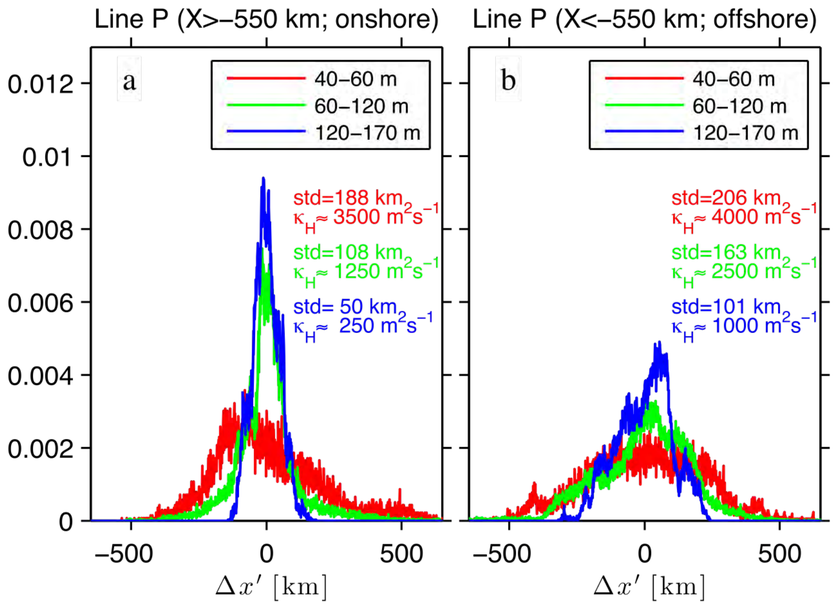
Line P

Lateral stirring: lateral displacement statistics







Submesoscale high-pass

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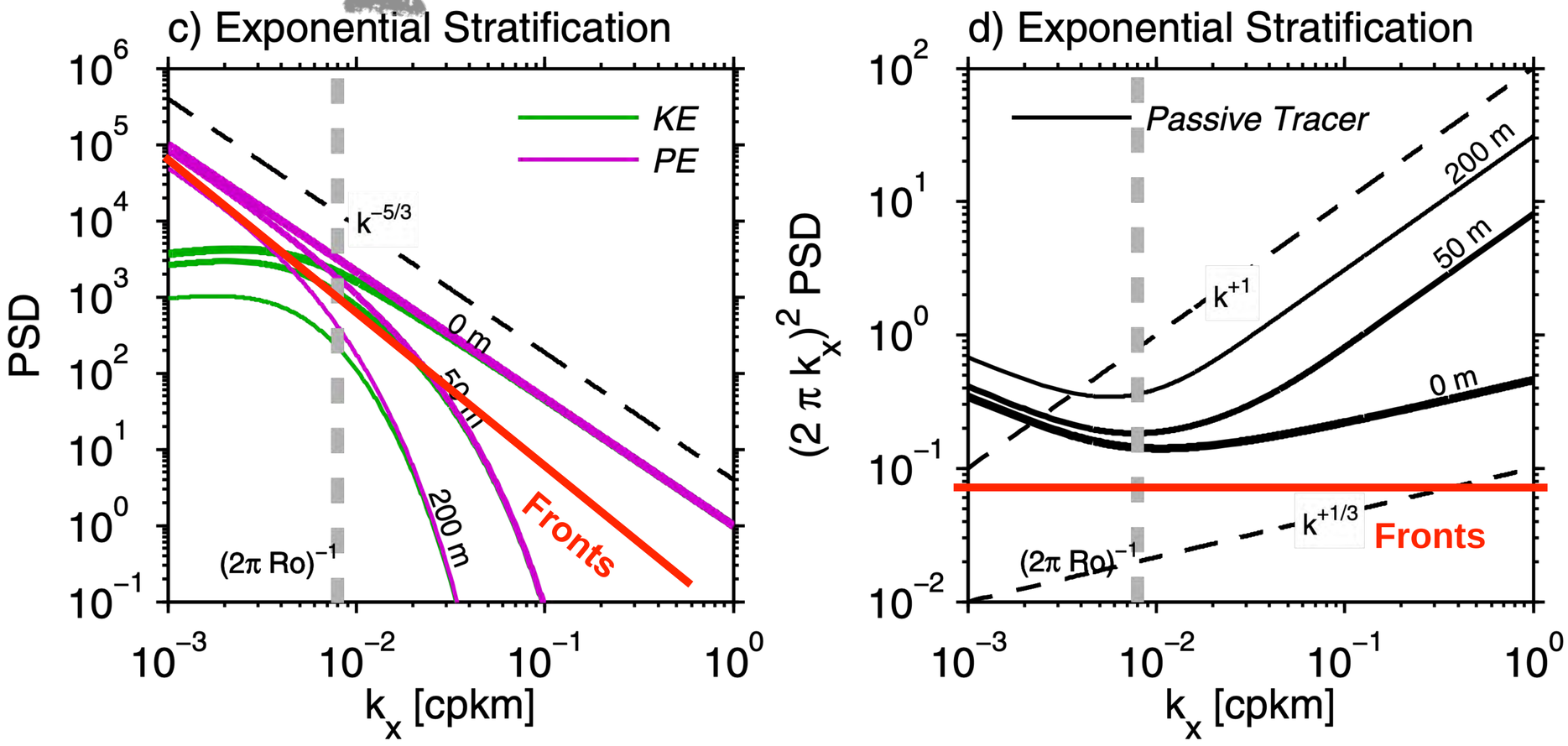
Line P

Lateral stirring: lateral displacement statistics

Surface quasi-geostrophy:

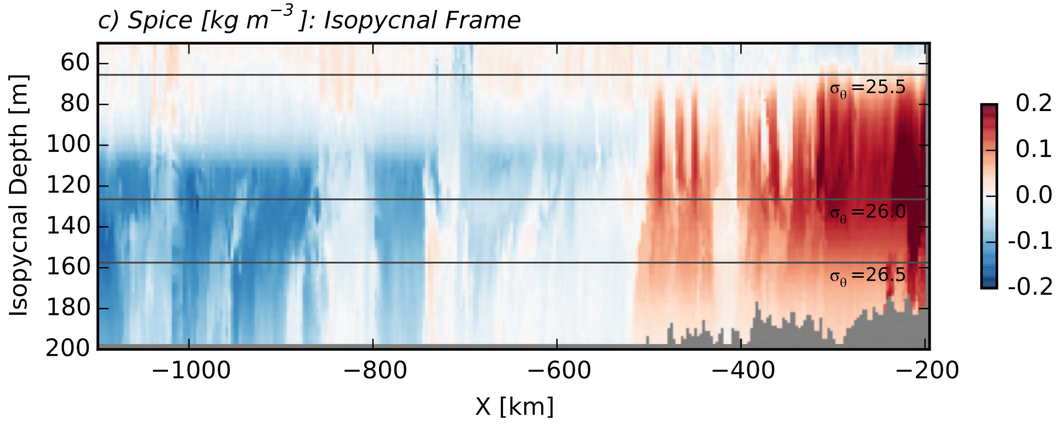
Vorticity input

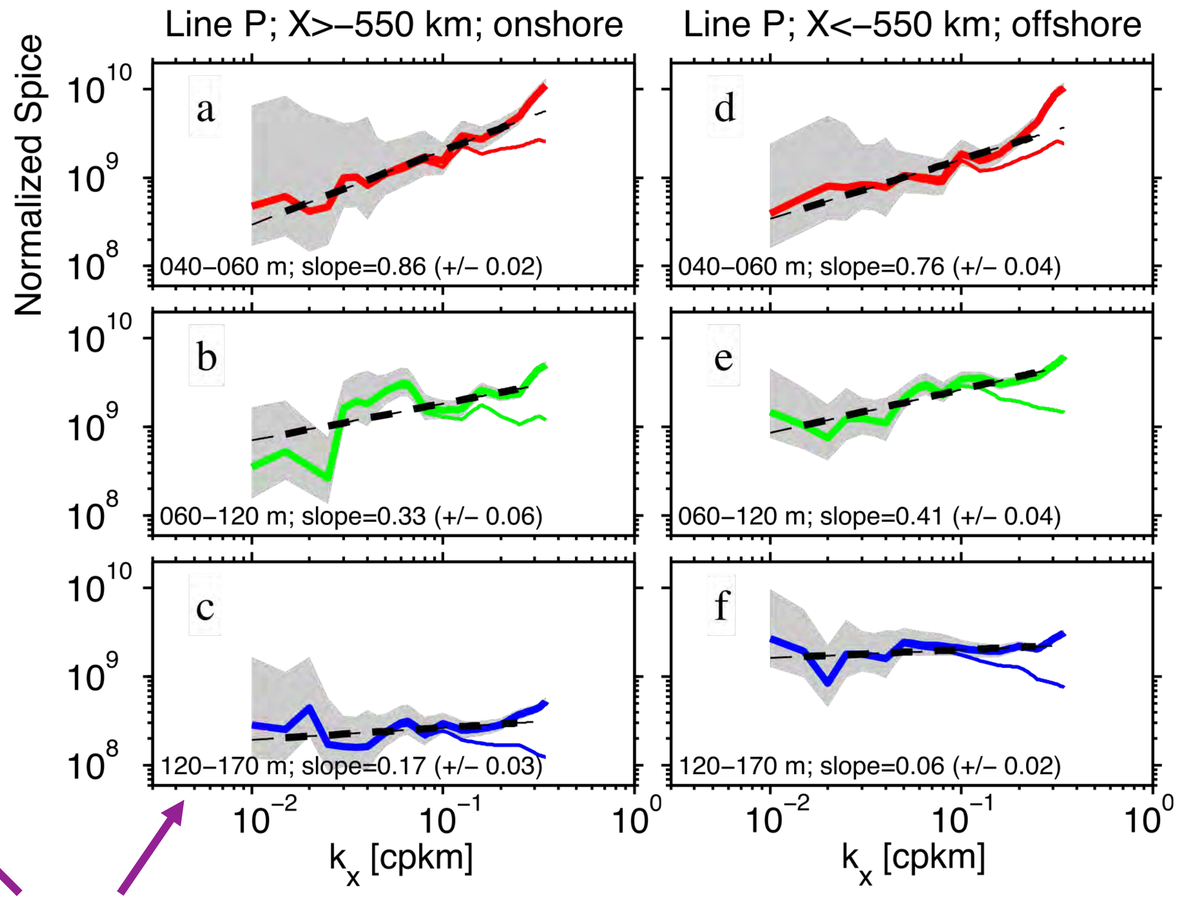


after Callies and Ferrari , 2013

Line P

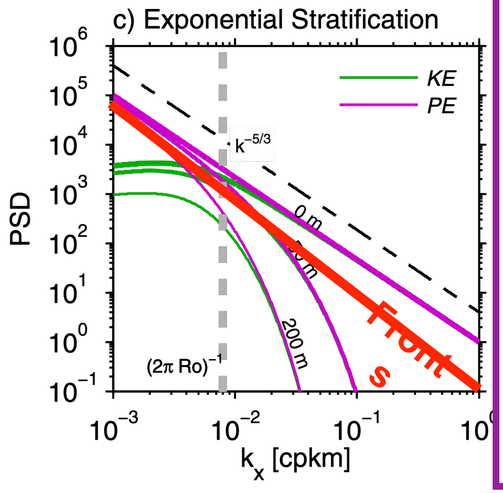
Lateral stirring: lateral displacement statistics

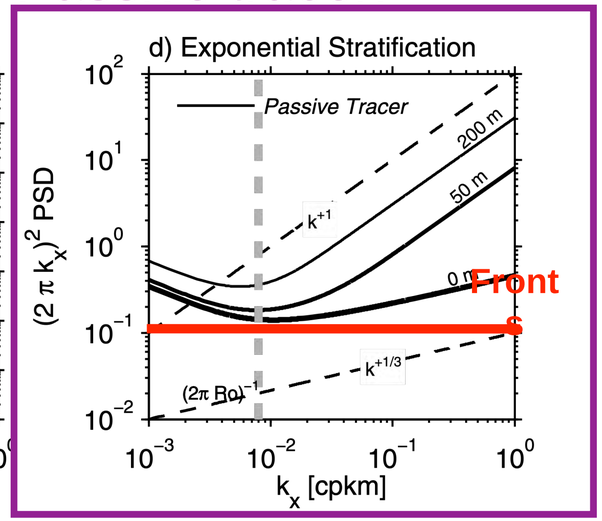




Surface quasi-geostrophy:

Passive tracer:





Opposite depth trend!

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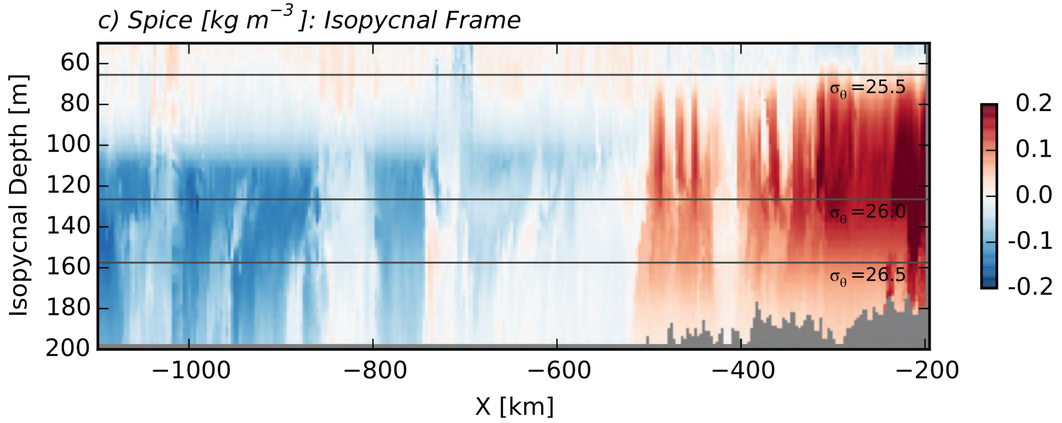
Line P

Lateral stirring: lateral displacement statistics



Surface quasi-geostrophy:

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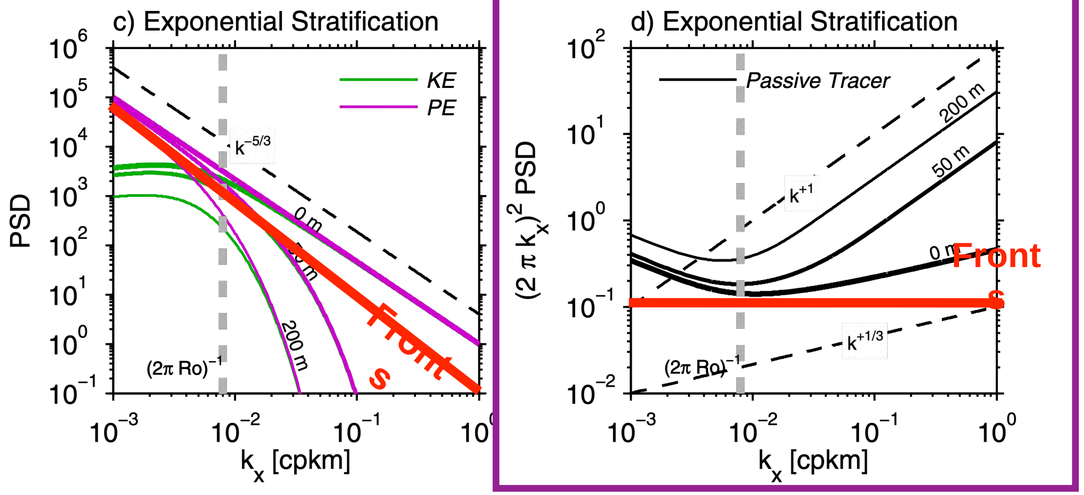
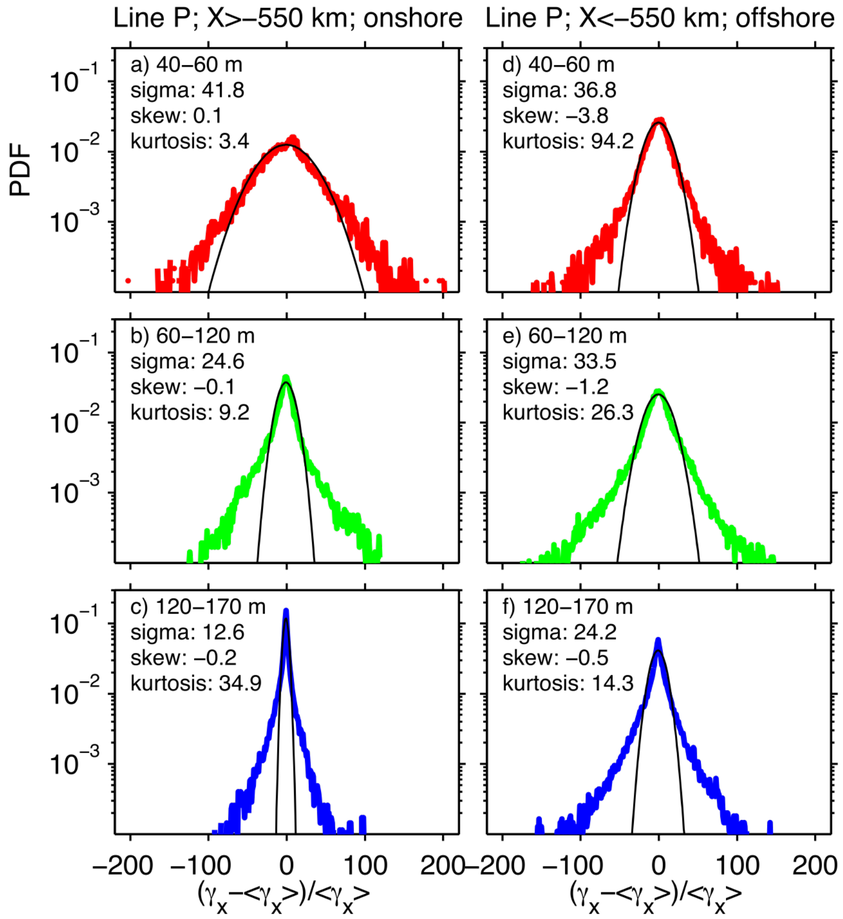


Spice derivative PDFs



High kurtosis (tails) means data more like fronts

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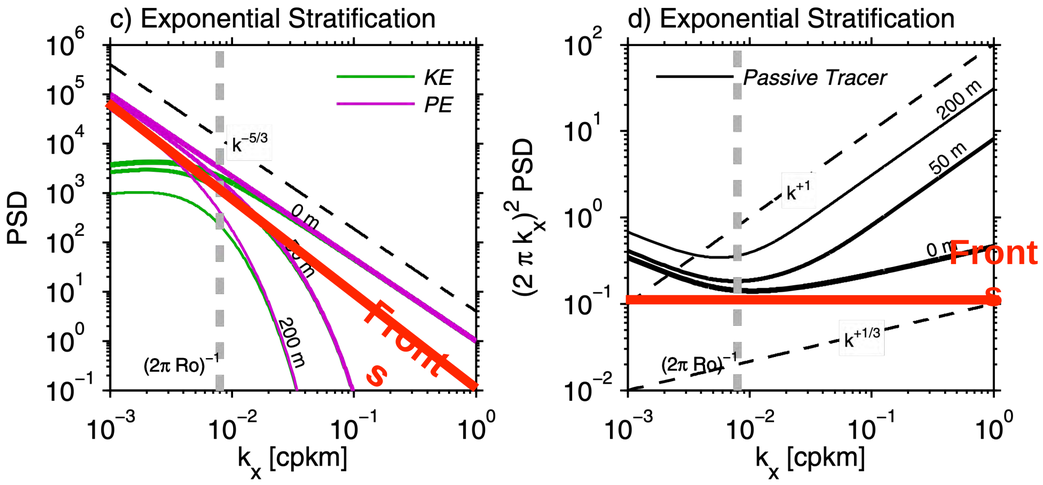
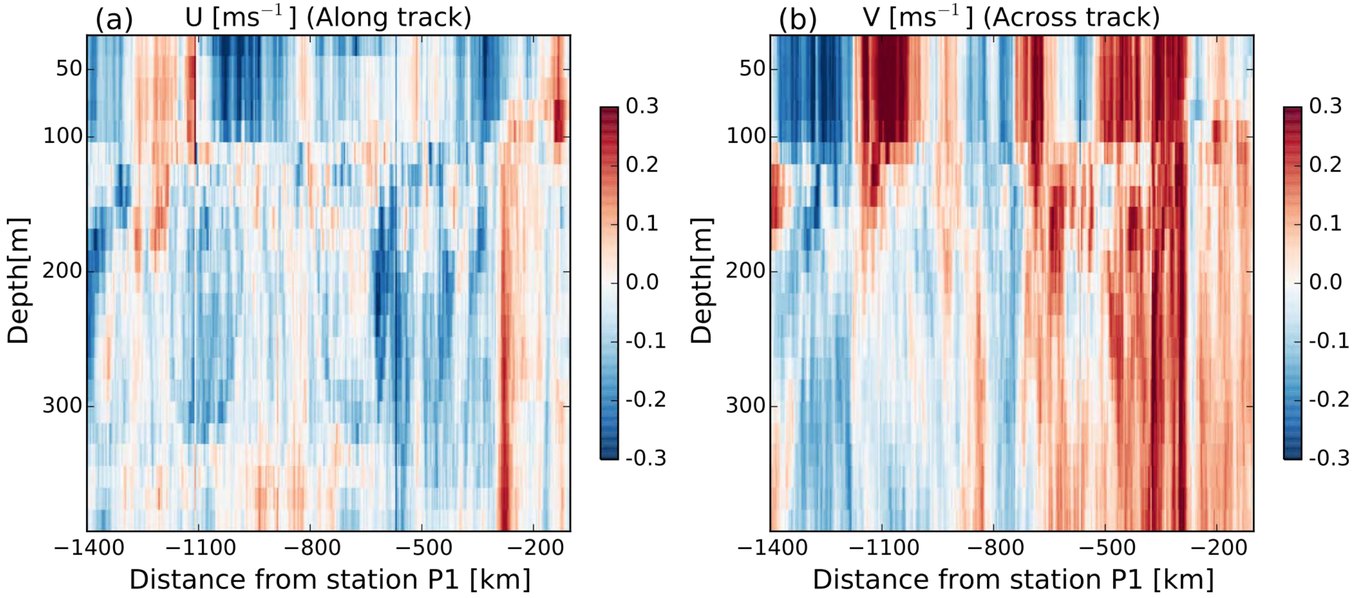
Line P

Lateral stirring: Velocity statistics

MSc: Manman Wang, 2016

Surface quasi-geostrophy:





ADCP data along Line P: Feb and June cruises 3 years

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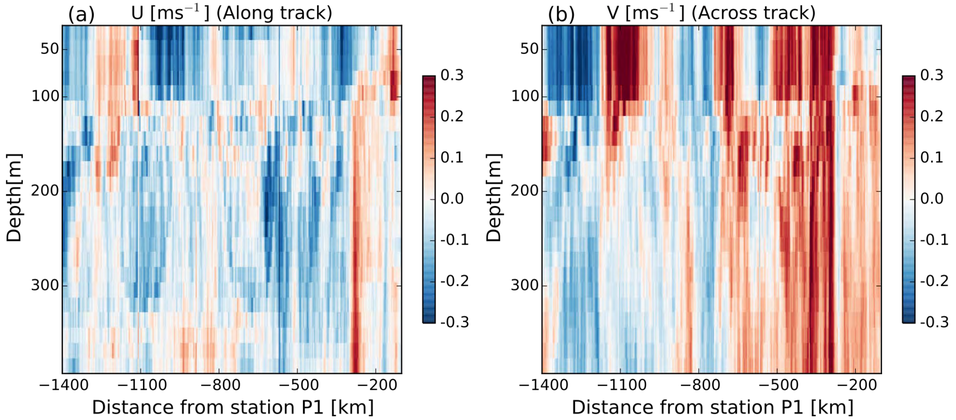
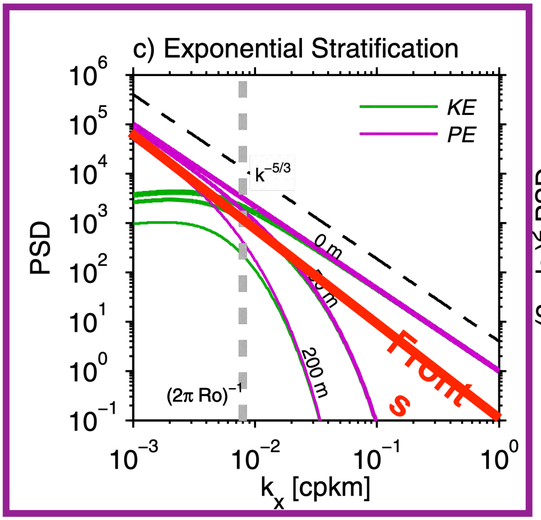
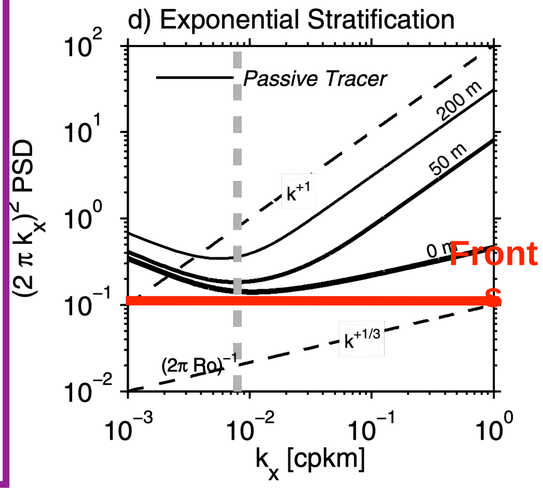
Line P



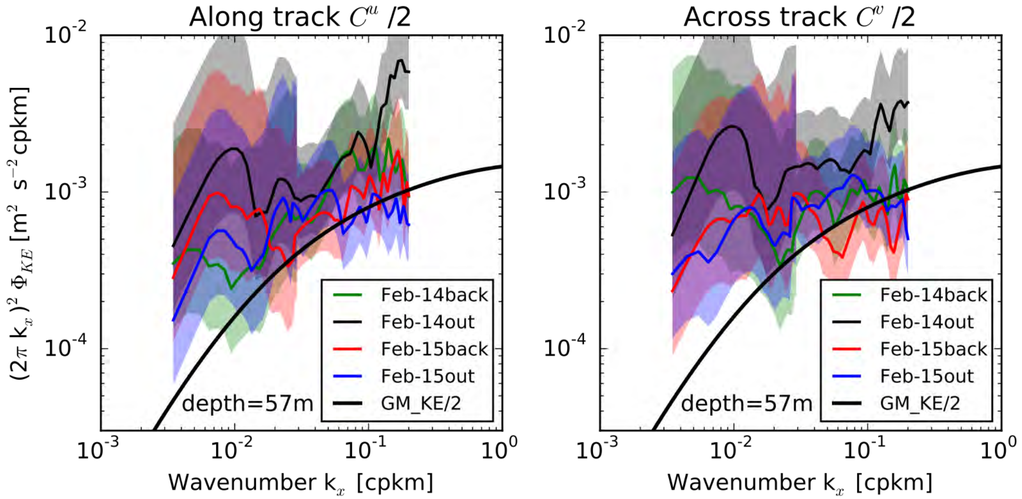
Surface quasi-geostrophy:





Lateral stirring: Velocity statistics

MSc: Manman Wang, 2016



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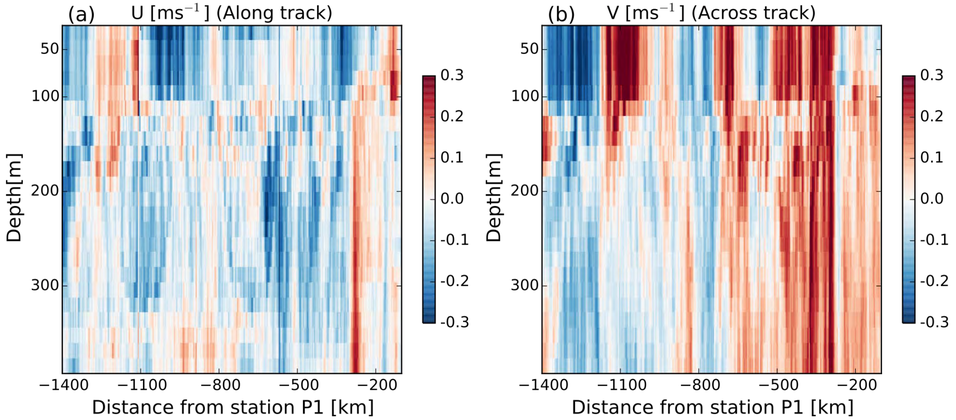
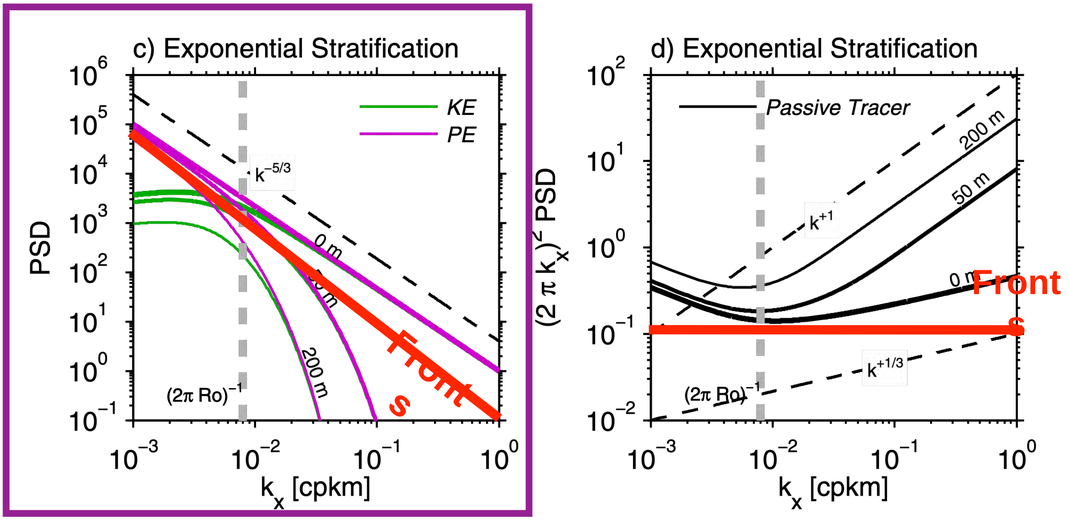
Line P



Surface quasi-geostrophy:



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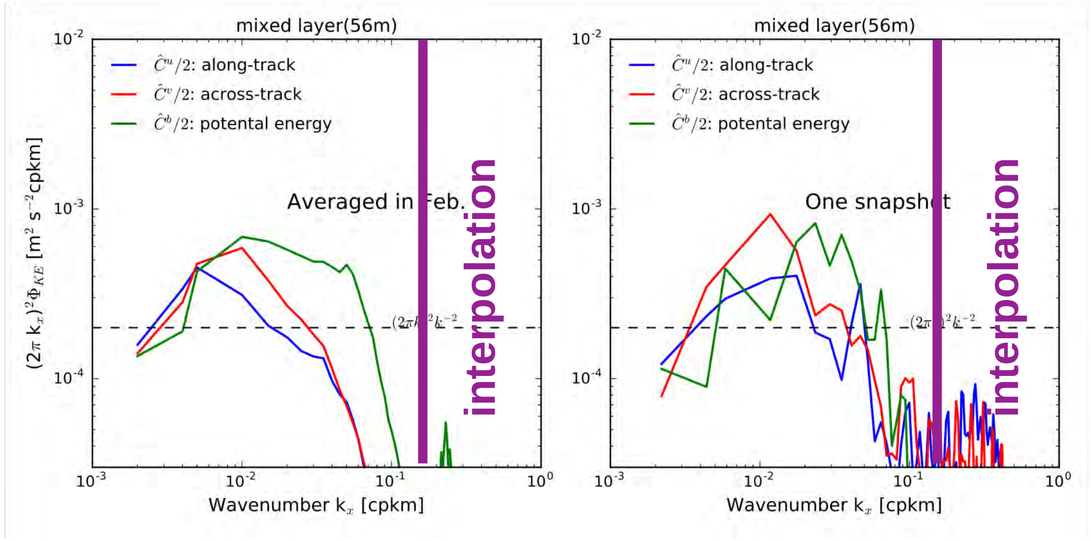

NEMO data (a few years ago) 1/32nd degree

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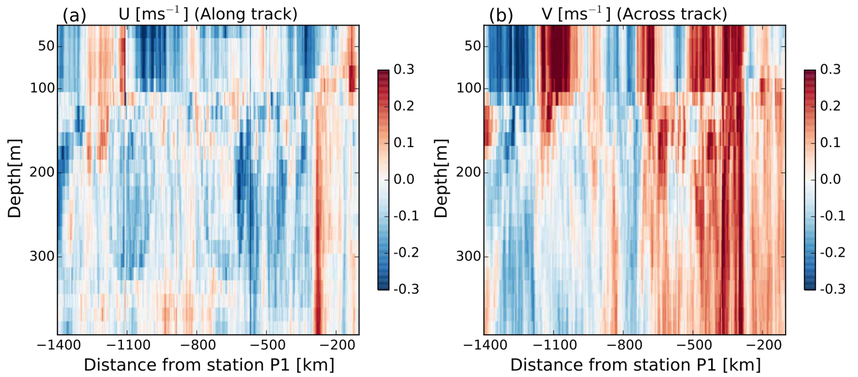
Line P

Lateral stirring: Velocity statistics

MSc: Manman Wang, 2016



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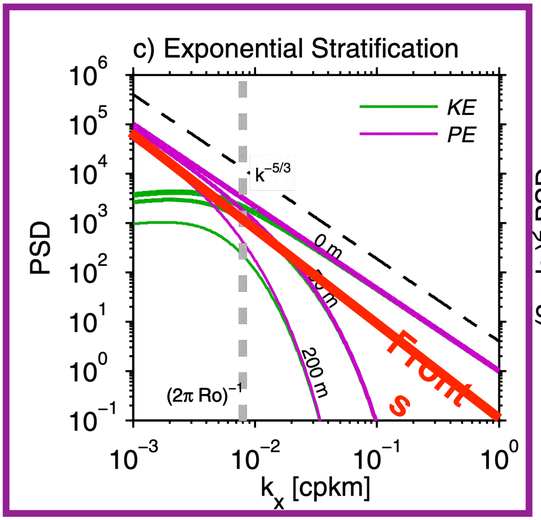

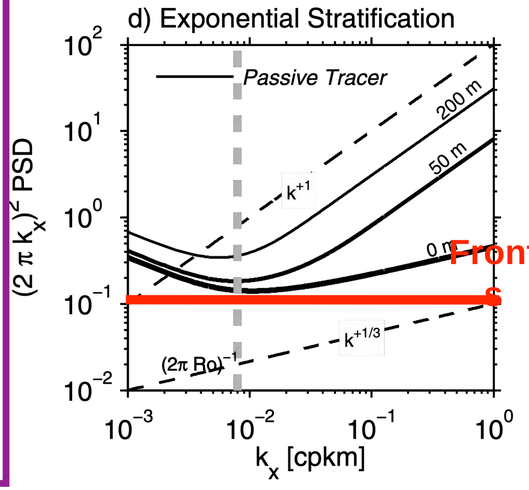

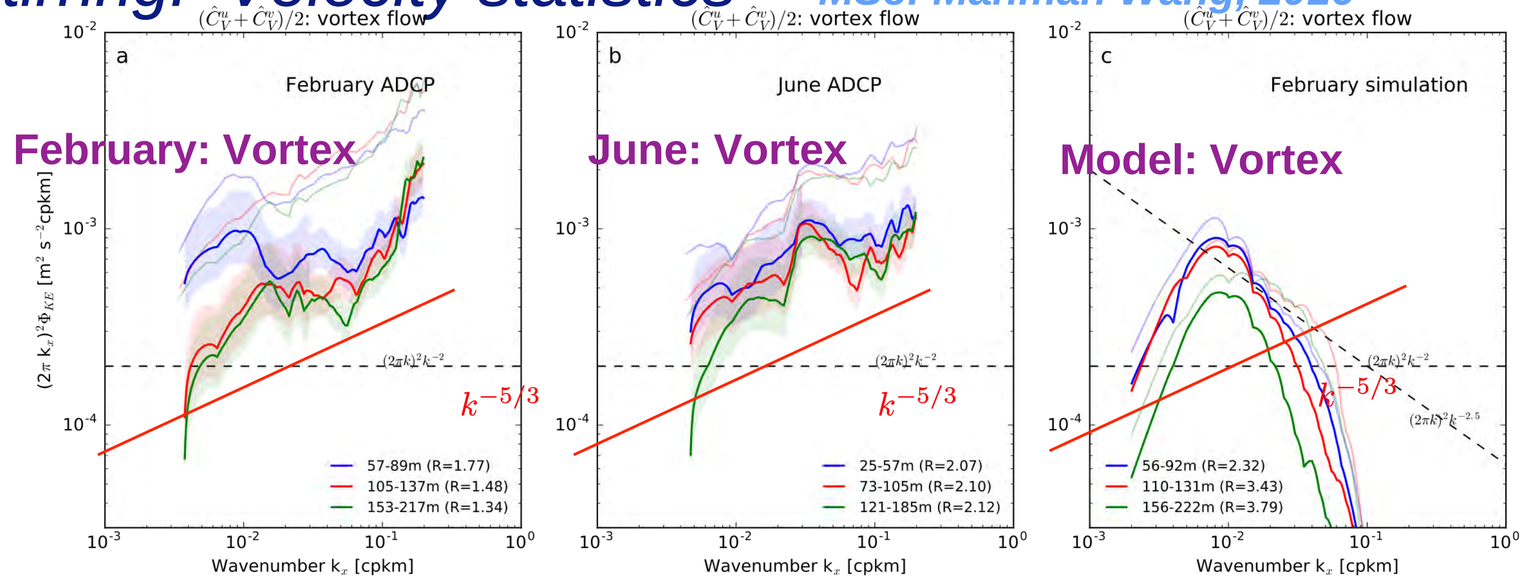

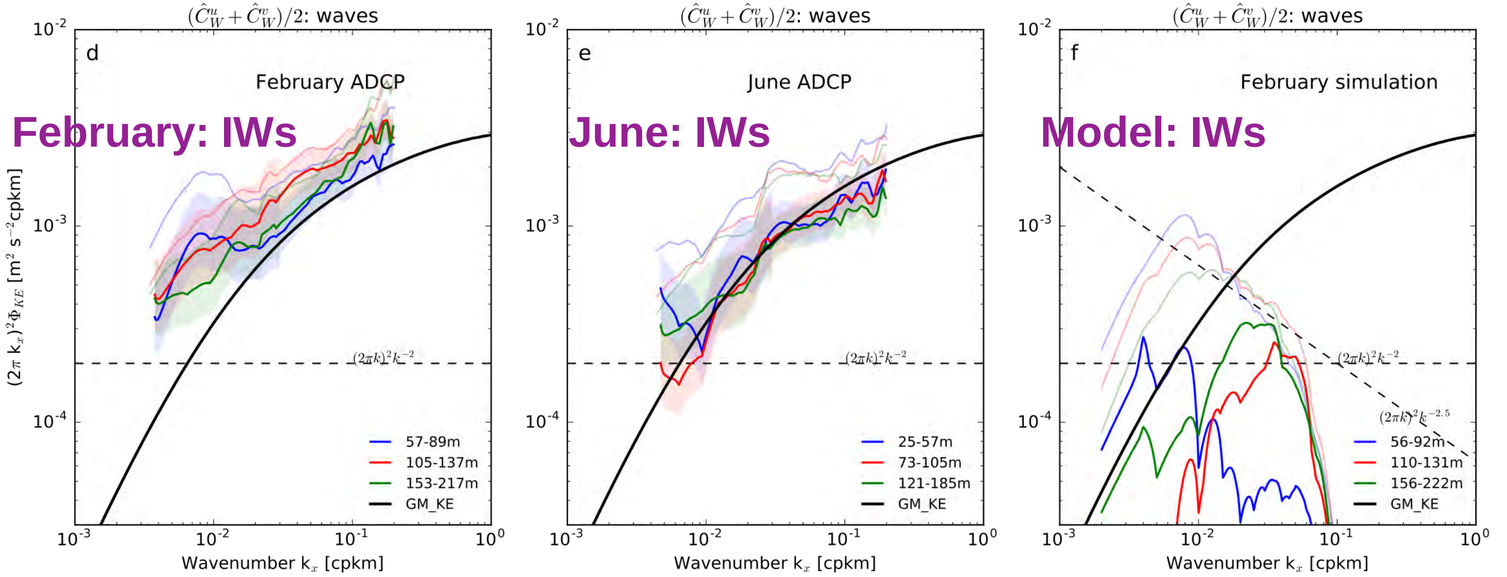

Decompose motions: IWs + Vortex flows (Buhler et al 14)

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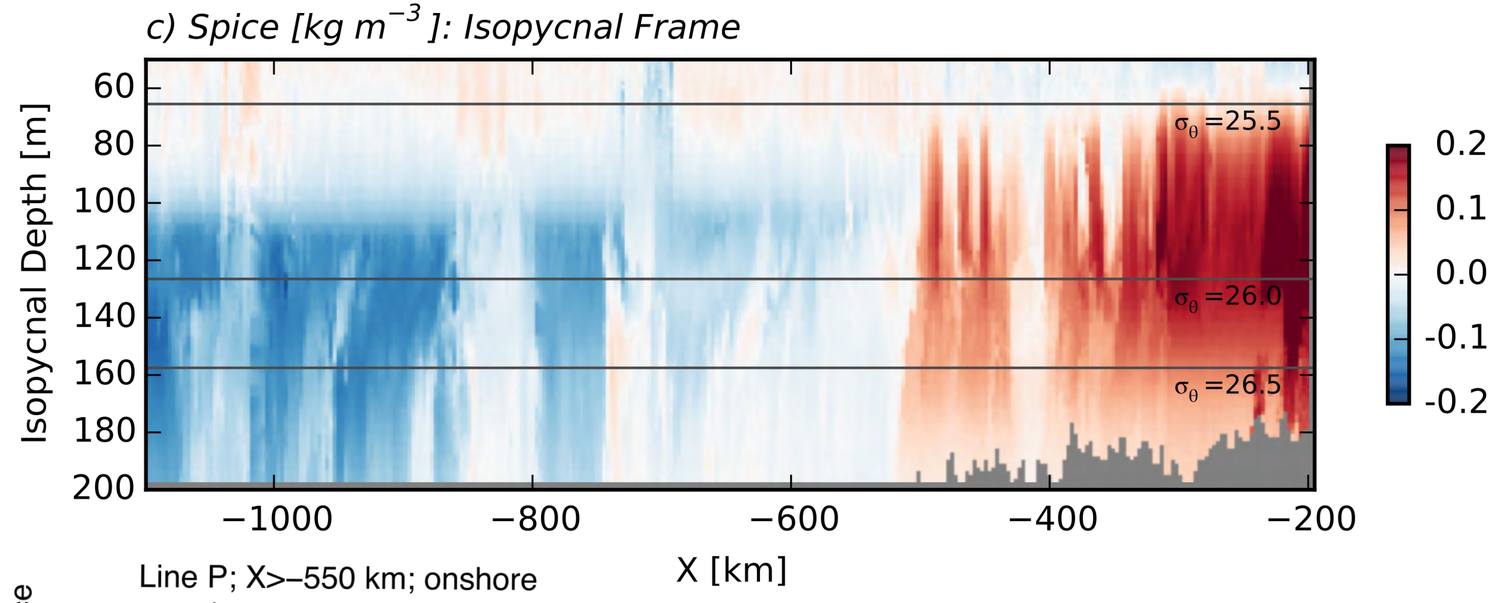
Line P

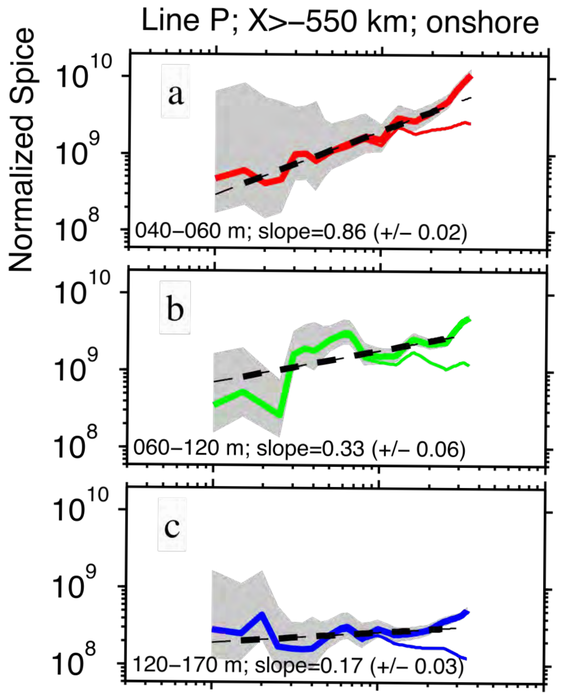
Summary

- *Tracer*:
  - Lateral stirring on scales of +/- 200-km
  - Two different regimes - near shore and offshore.
  - Less small scale variance than Surface Quasi-geostrophy
  - Opposite depth dependence

- *Kinetic energy*:
  - Internal waves
  - Inertial subrange at all depths

- *Models*:
  - don’t capture internal waves
  - more consistent with QG theory: Similar to ACC and Gulf Stream





Implications

QG/SQG theories not directly applicable

Mid-depth vorticity source?

Time history matters?

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Plans

- Submesoscale sampling important to characterize lateral stirring and to test models.
  - Continue work from ships:
    - combine ADCP and MVP (better KE decomposition, APE estimates, and more spice statistics)
    - repeat different seasons (Line P regular cruises)

Moving Vessel Profiler

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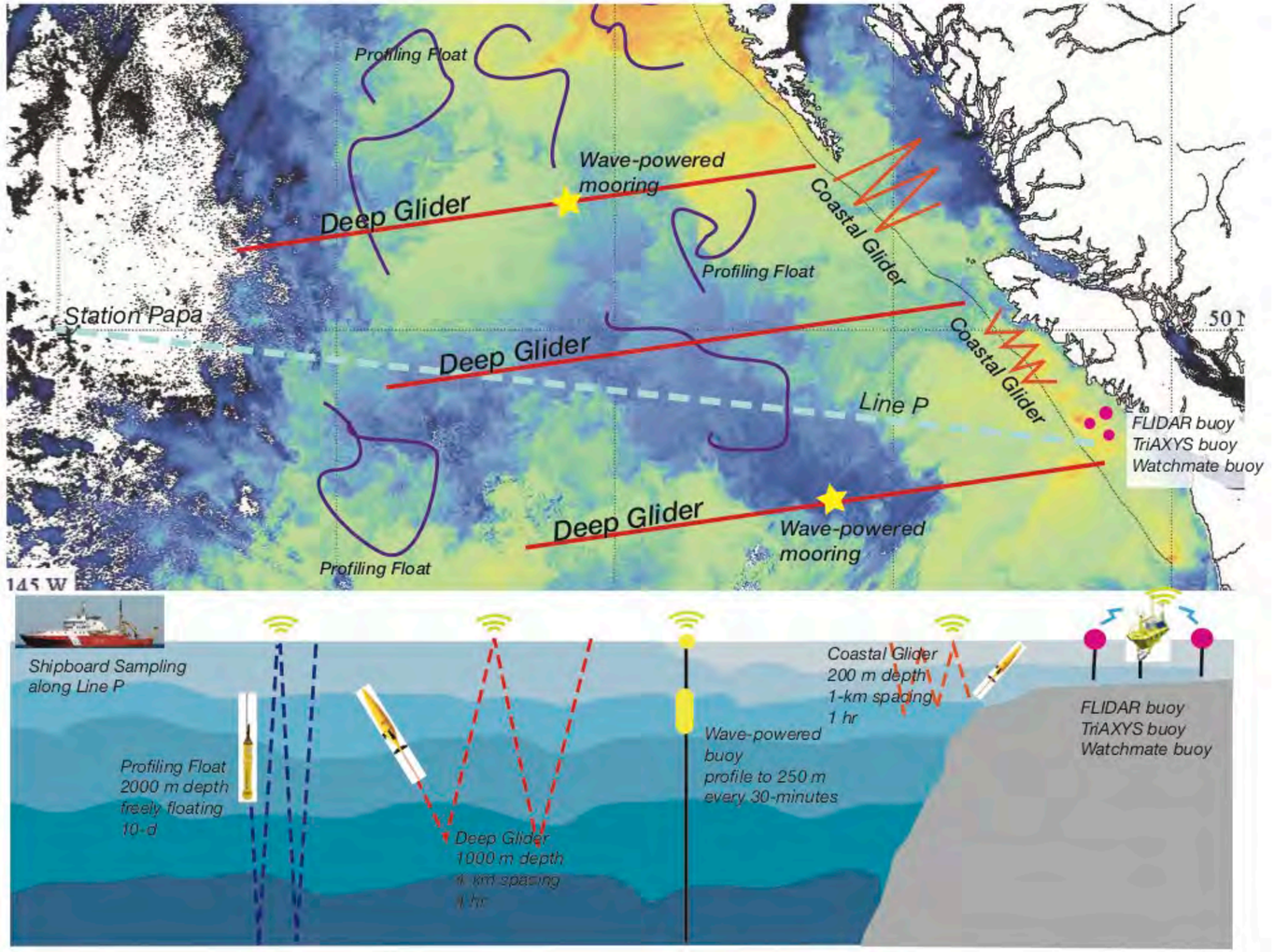
  - Continue work from ships:
    - combine ADCP and MVP (better KE decomposition, APE estimates, and more spice statistics)
    - repeat different seasons (Line P regular cruises)
  - Autonomous sampling:
    - gliders for lateral variability all seasons
    - moorings for temporal anchor
    - multiple lines for correlation statistics, seeing signals propagate

C-PROOF *(T. Ross, S. Waterman, et al)*



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C-PROOF: http://cproof.uvic.ca

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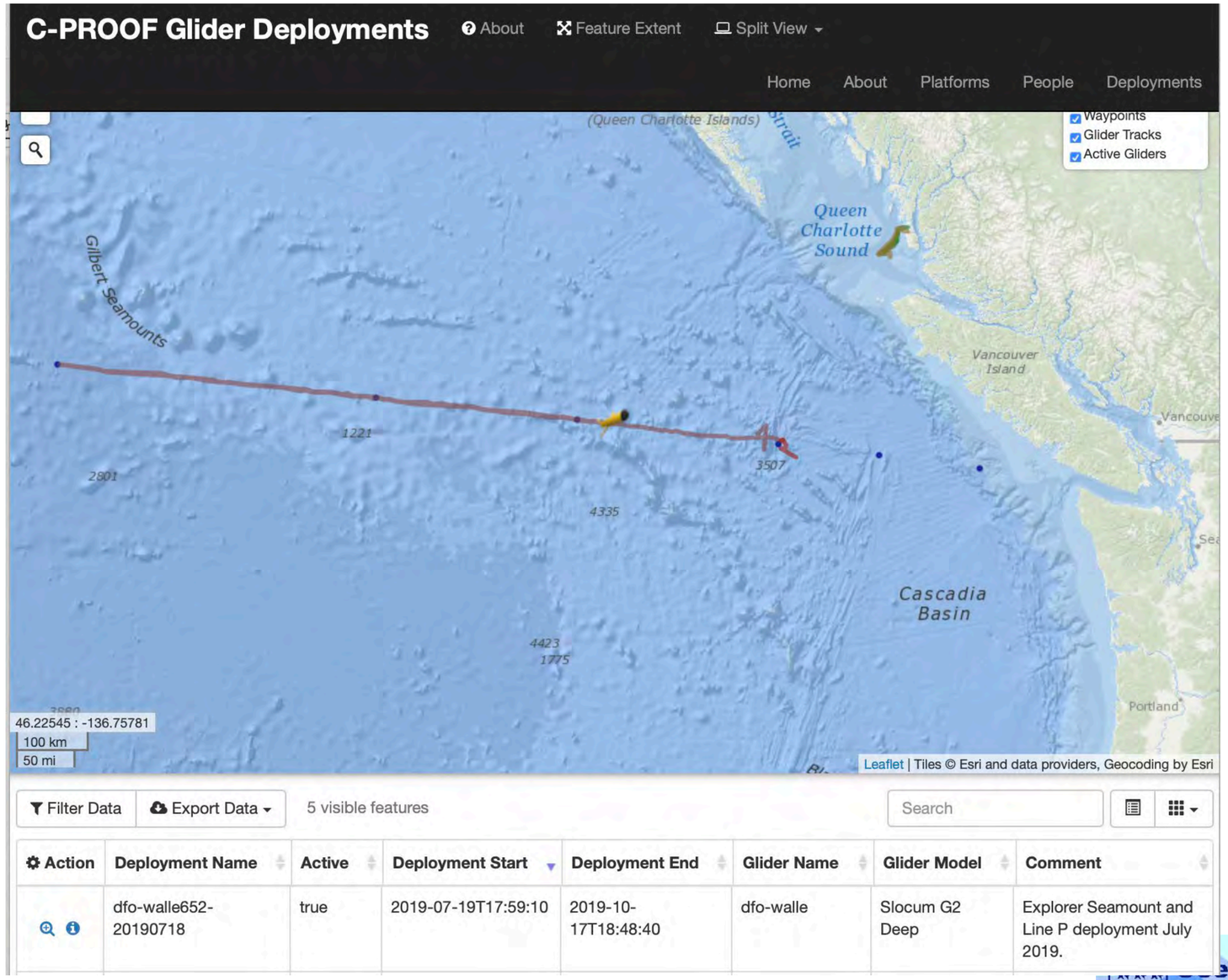

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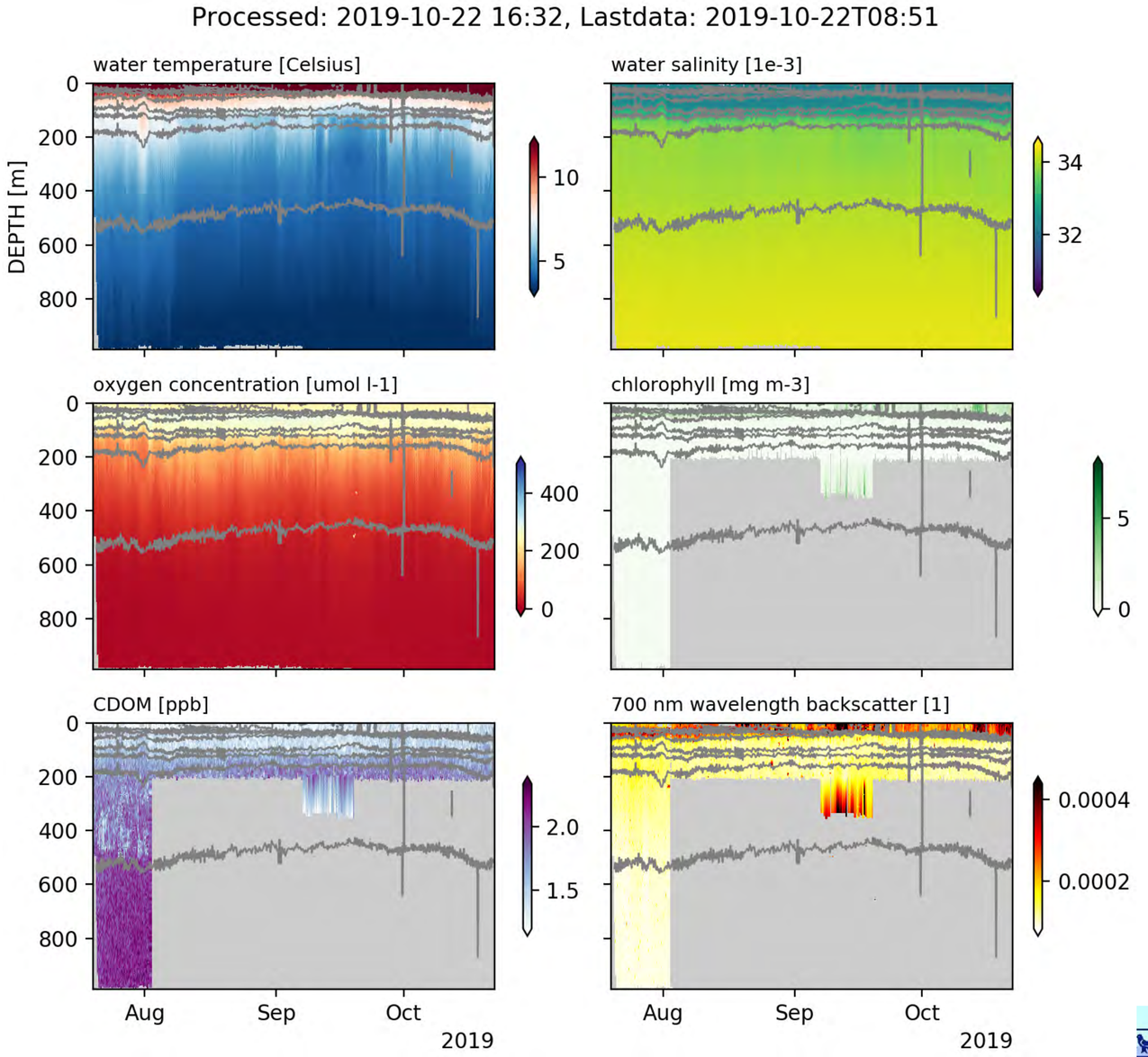


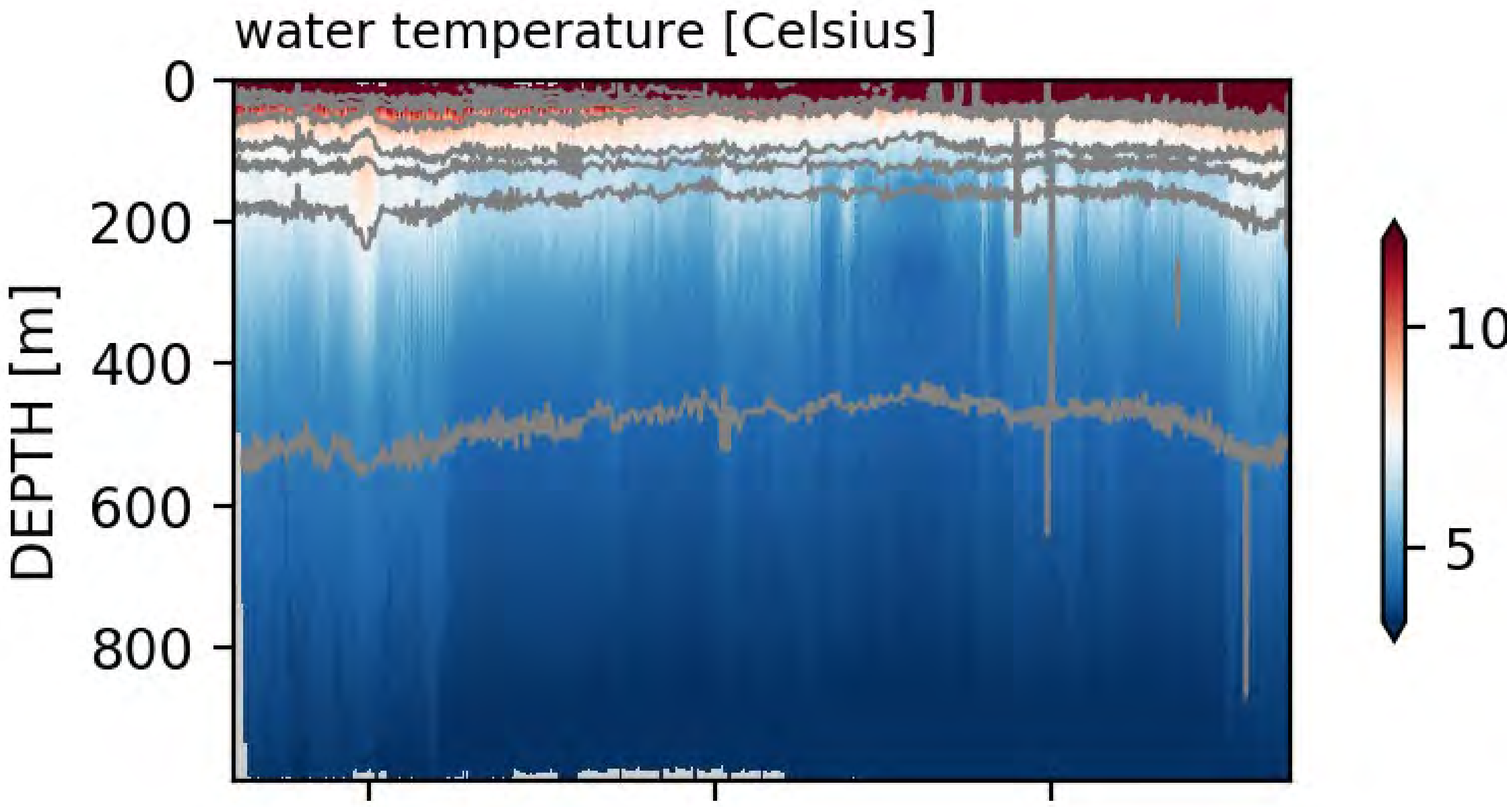
J Klymak: 2019 PICES meeting, Victoria

Ocean Physics Group

Plans

C-PROOF: http://cproof.uvic.ca

- Submesoscale sampling important to characterize lateral stirring and to test models.
  - Continue work from ships:
    - combine ADCP and MVP (better KE decomposition, APE estimates, and more spice statistics)
    - repeat different seasons (Line P regular cruises)
  - Autonomous sampling:
    - gliders for lateral variability all seasons
    - moorings for temporal anchor
    - multiple lines for correlation statistics, seeing signals propagate



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Plans

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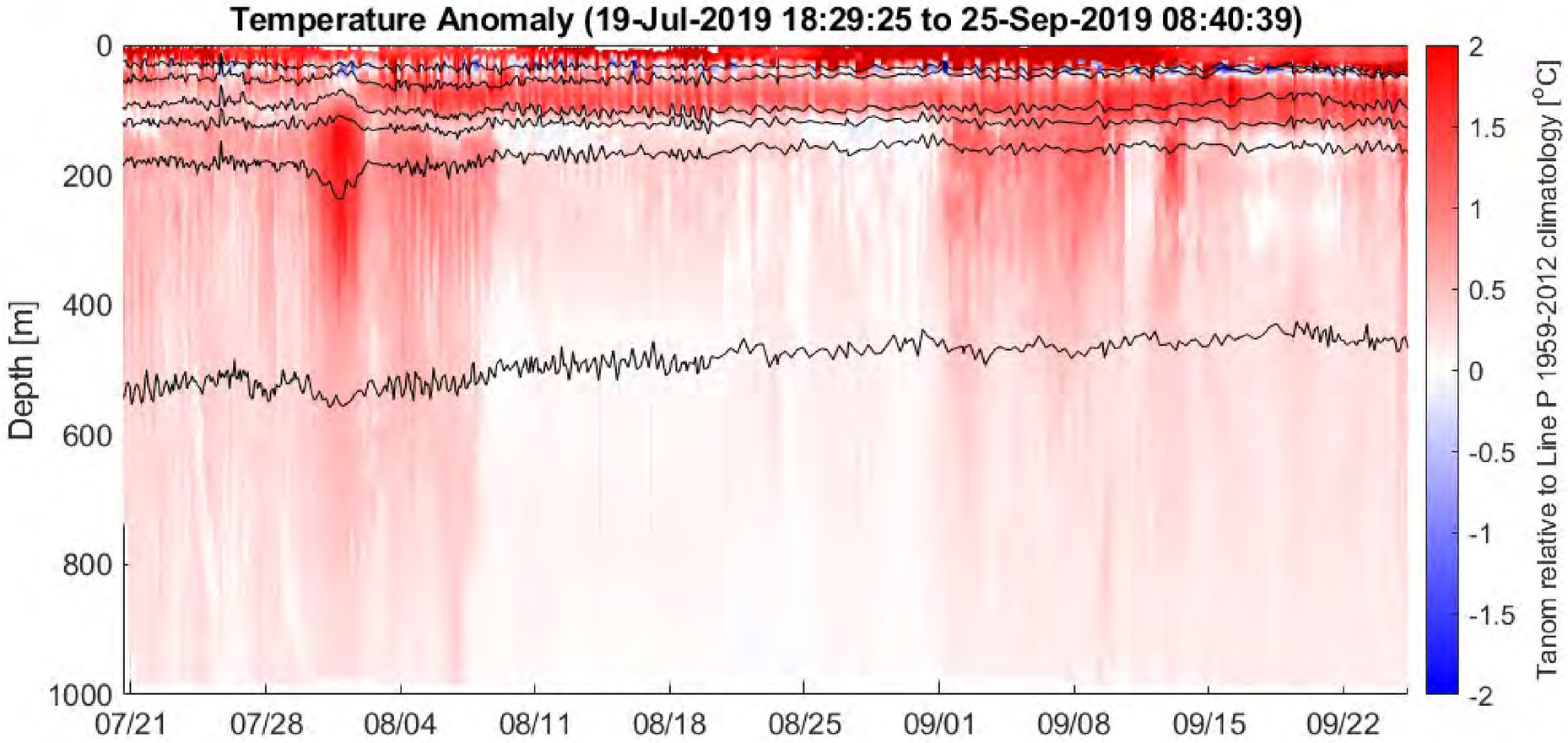

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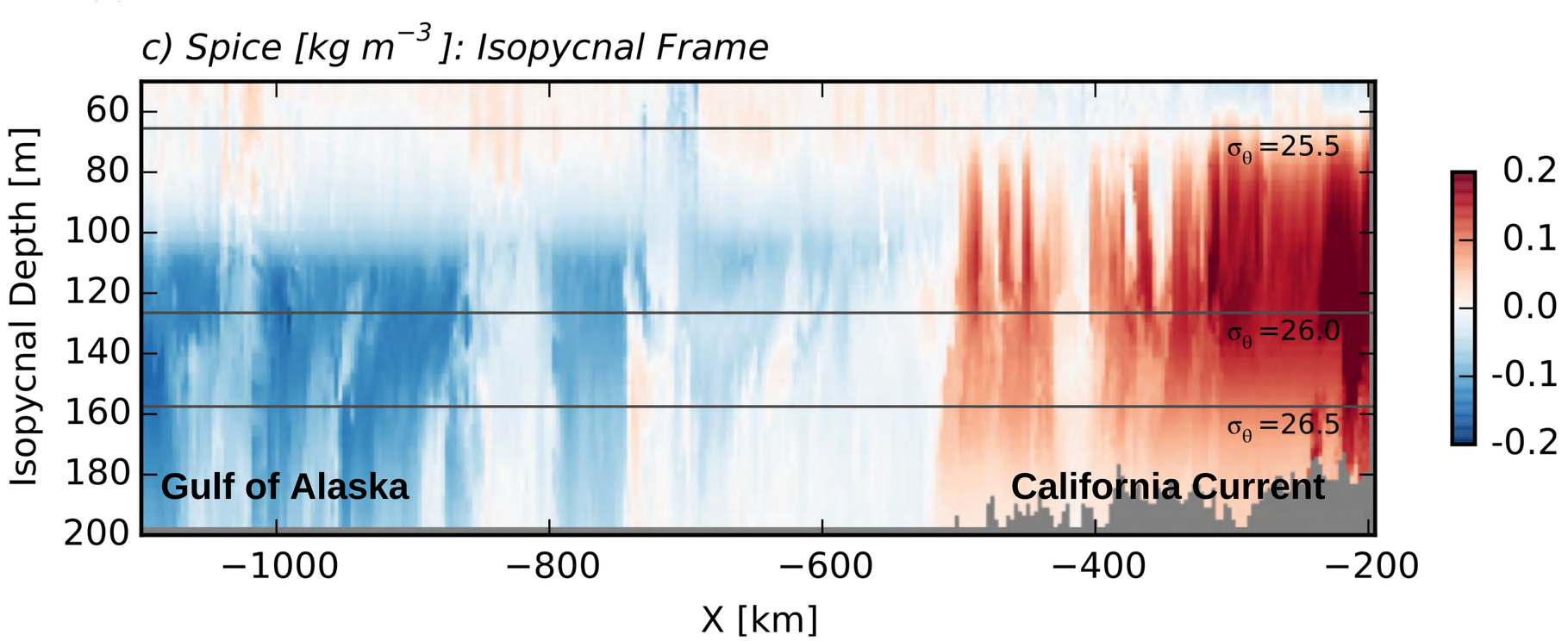
Submesoscale observations in the Northeast Pacific

Jody Klymak
University of Victoria



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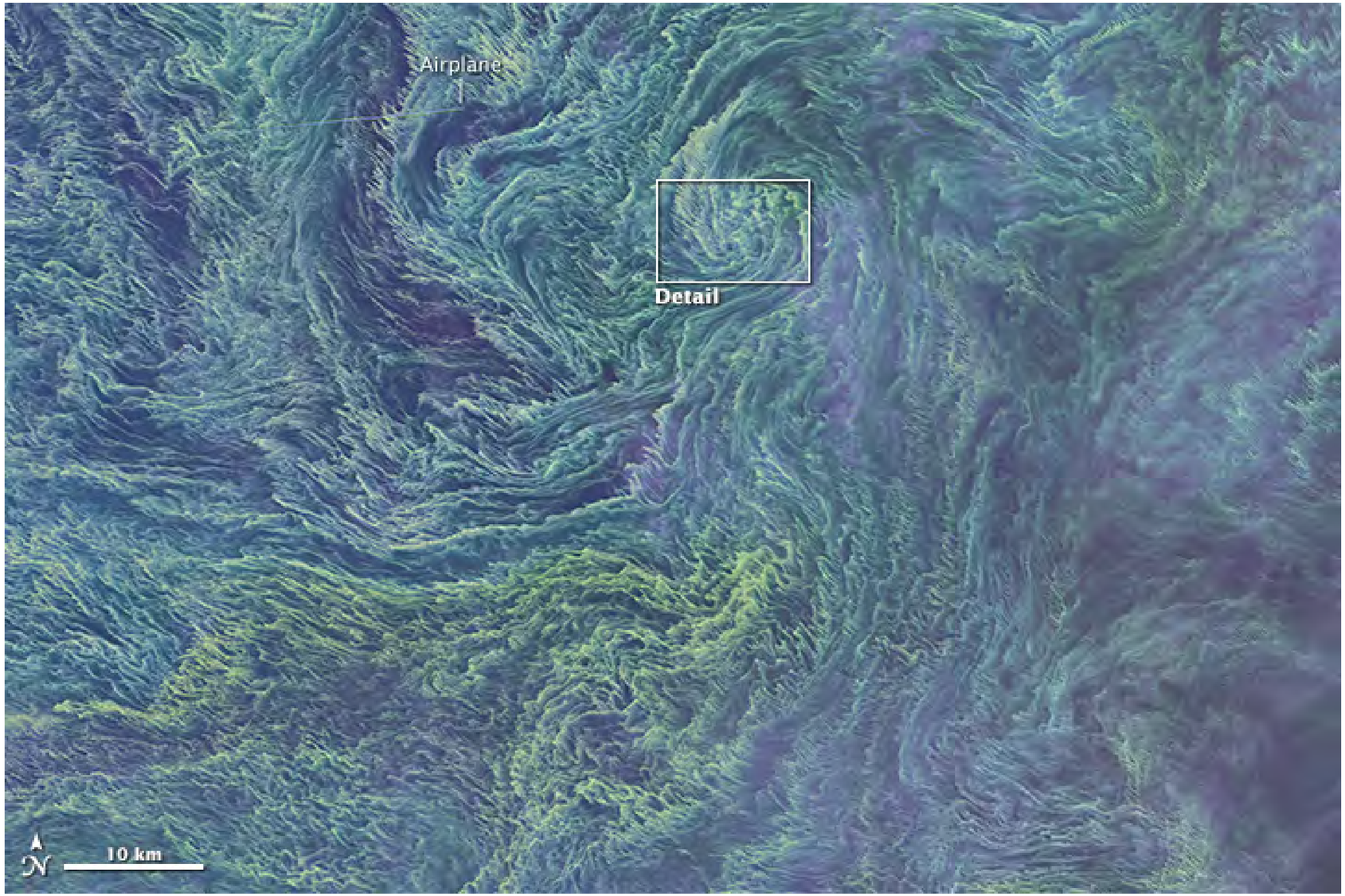
Why lateral mixing?



Cyanobacteria
Baltic Sea

NASA, Earth Observatory

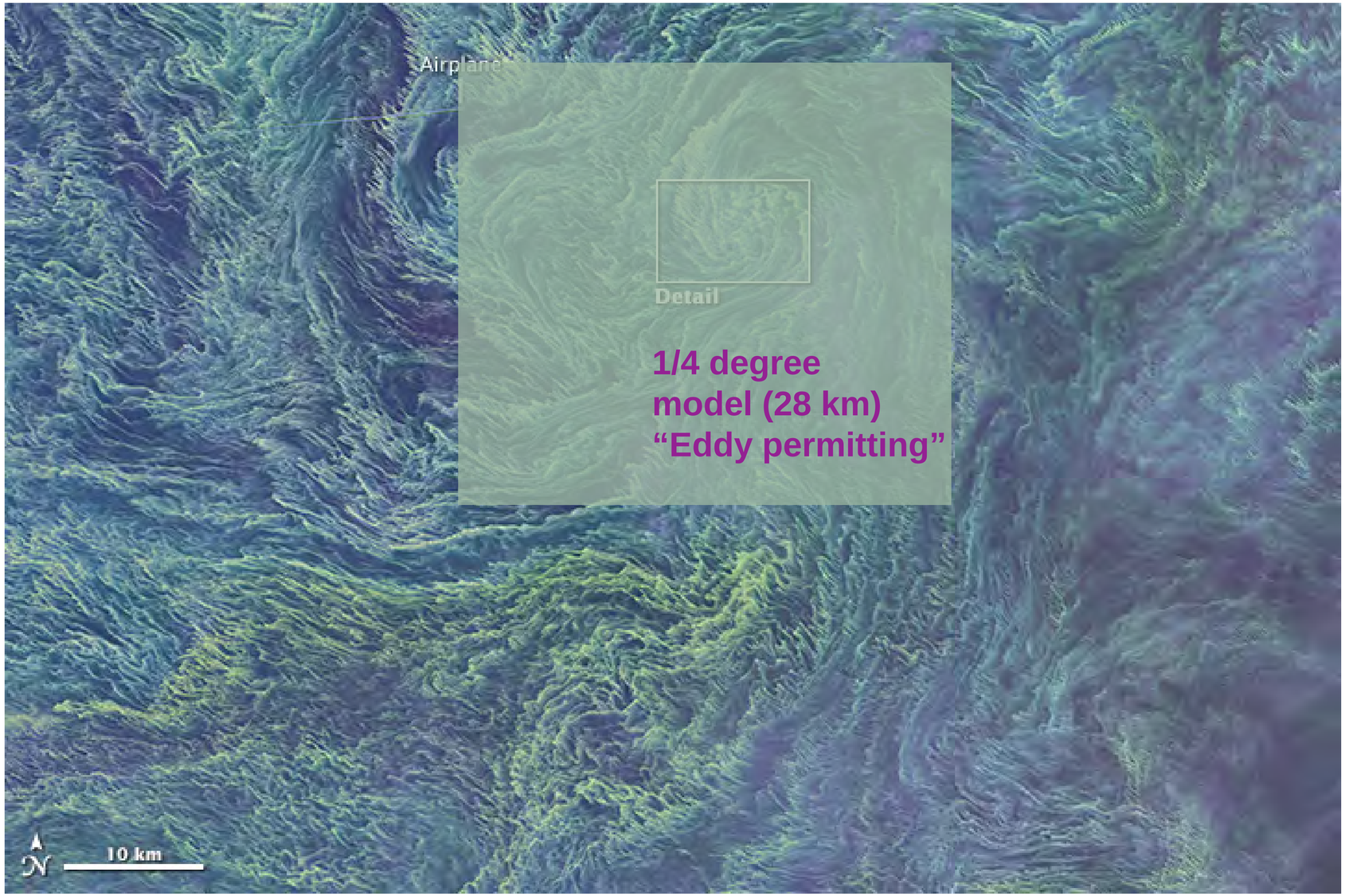
Why lateral mixing?

Cyanobacteria
Baltic Sea

1/2 degree
model (55 km)

NASA, Earth Observatory

Why lateral mixing?



Cyanobacteria
Baltic Sea

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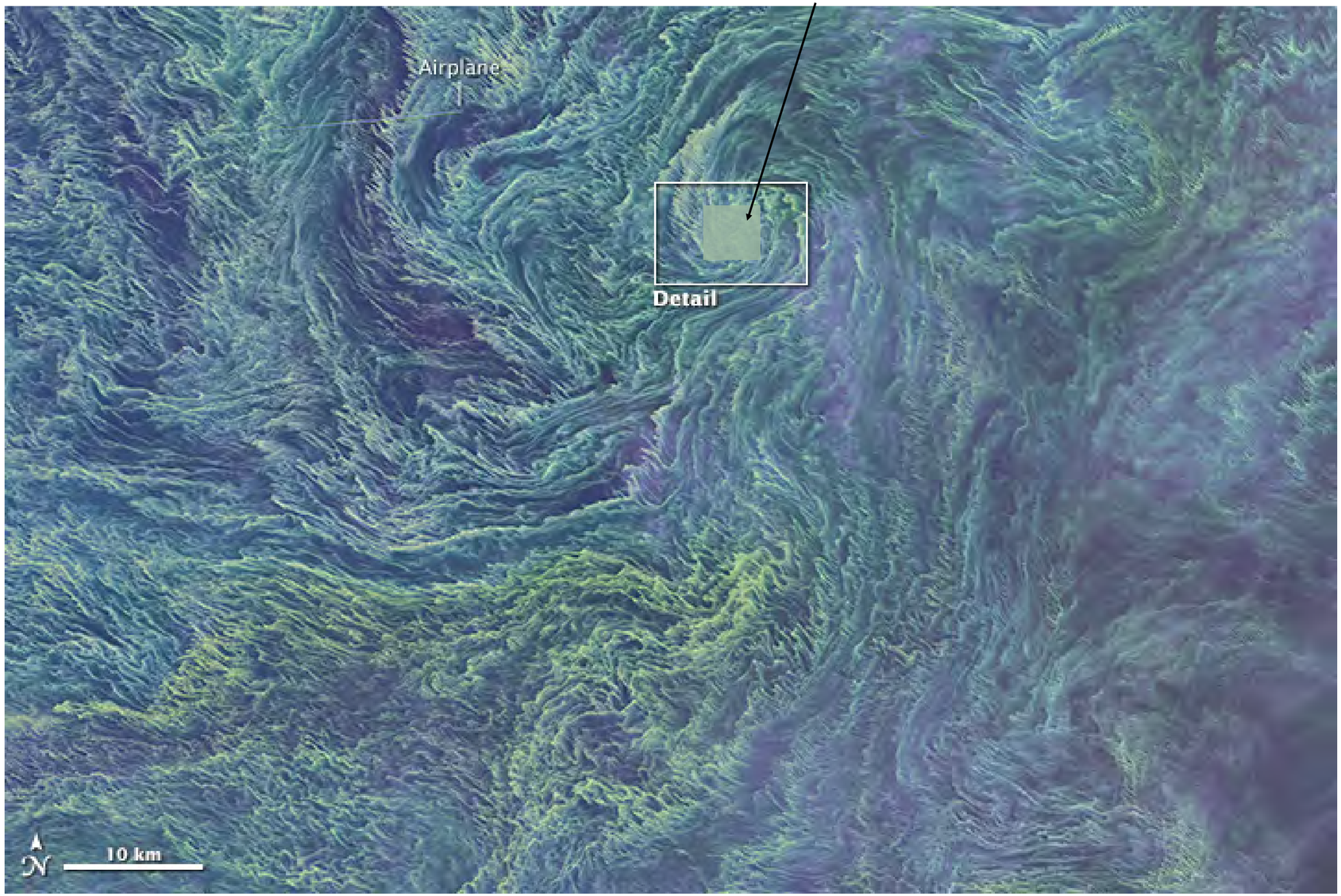
Why lateral mixing?

1/32 degree model: Eddy resolving



Cyanobacteria
Baltic Sea

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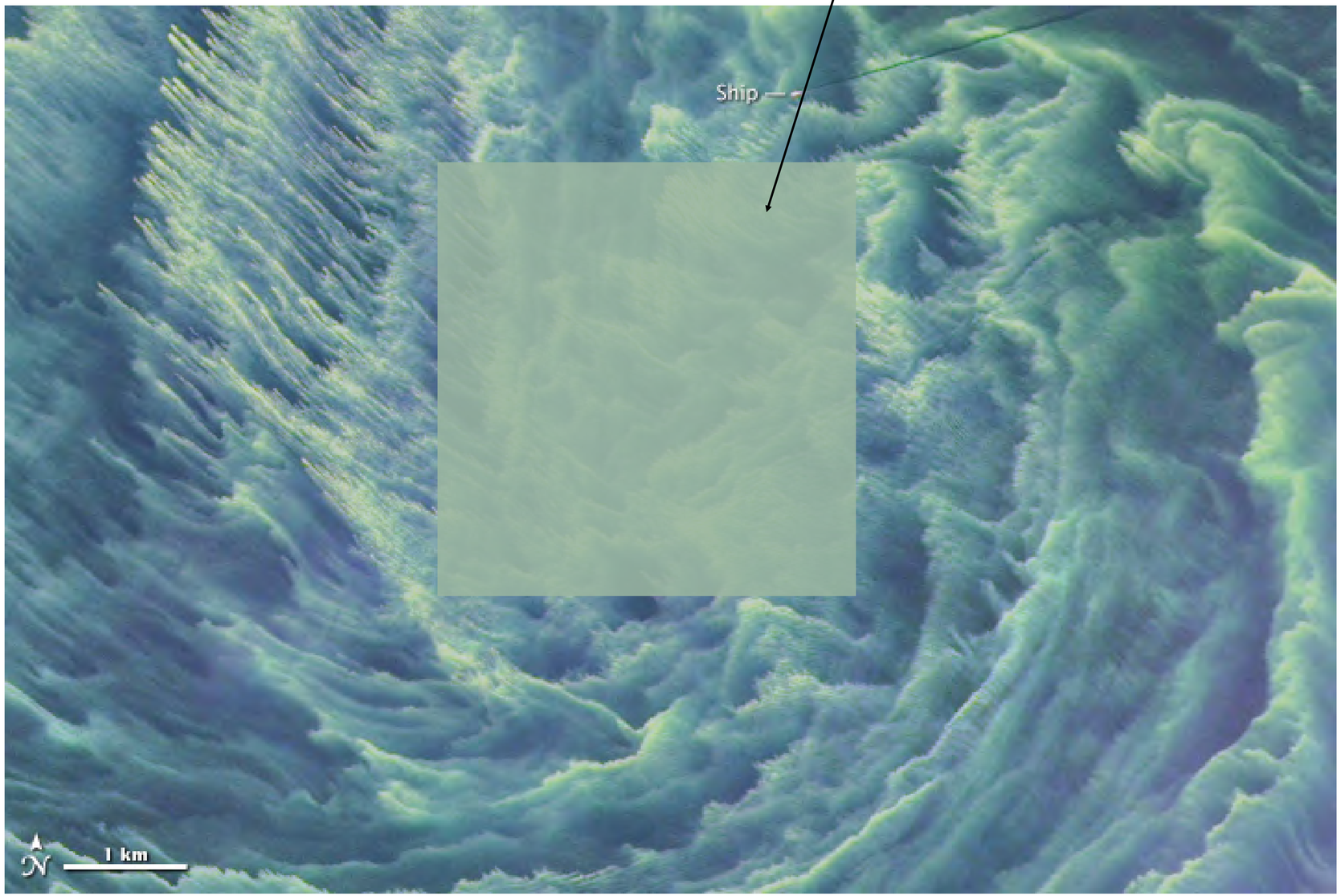
Why lateral mixing?

1/32 degree model



Cyanobacteria
Baltic Sea

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