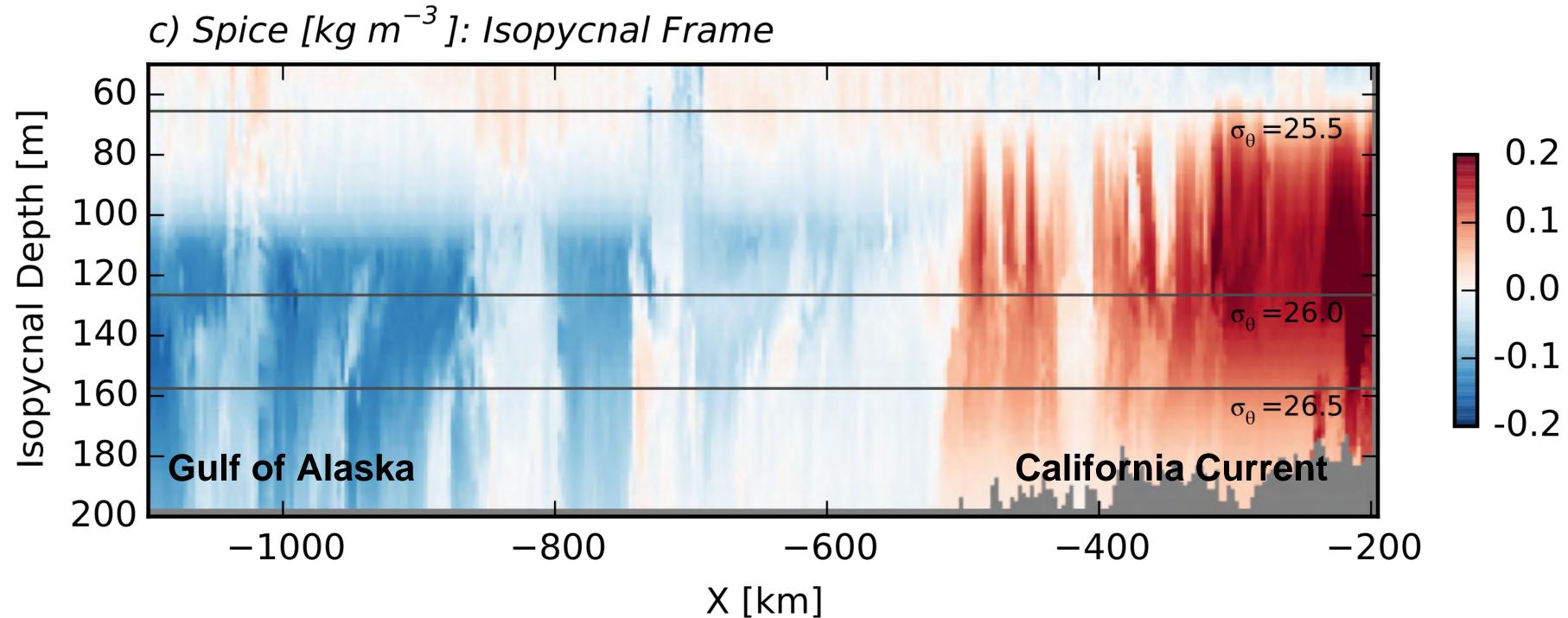
Submesoscale observations in the Northeast Pacific

Jody Klymak **University of Victoria**







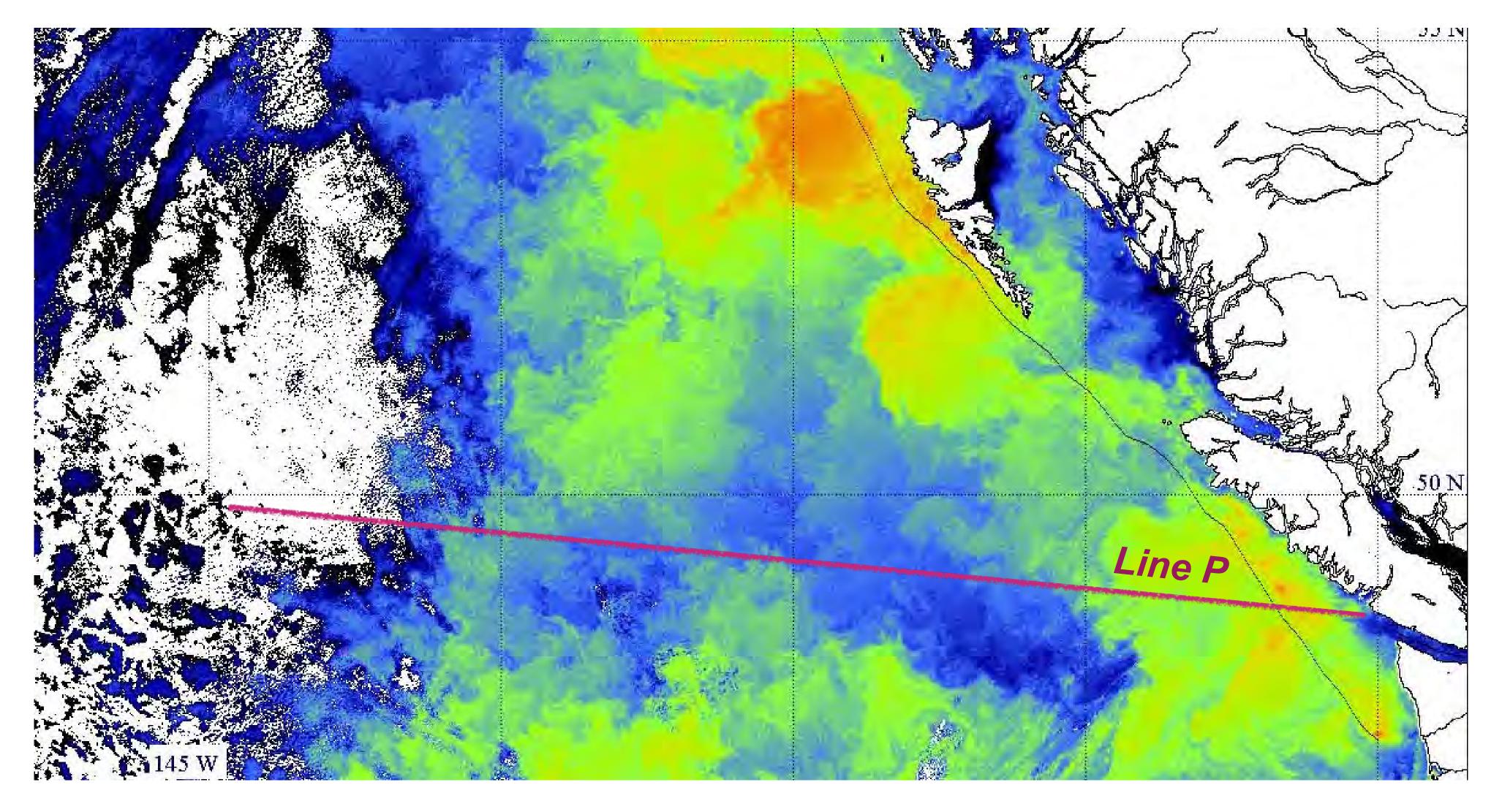
Physics Group

Do phy Do flux Ho late Do of t

MEOM group



J Klymak: 2019 PICES meeting, Victoria



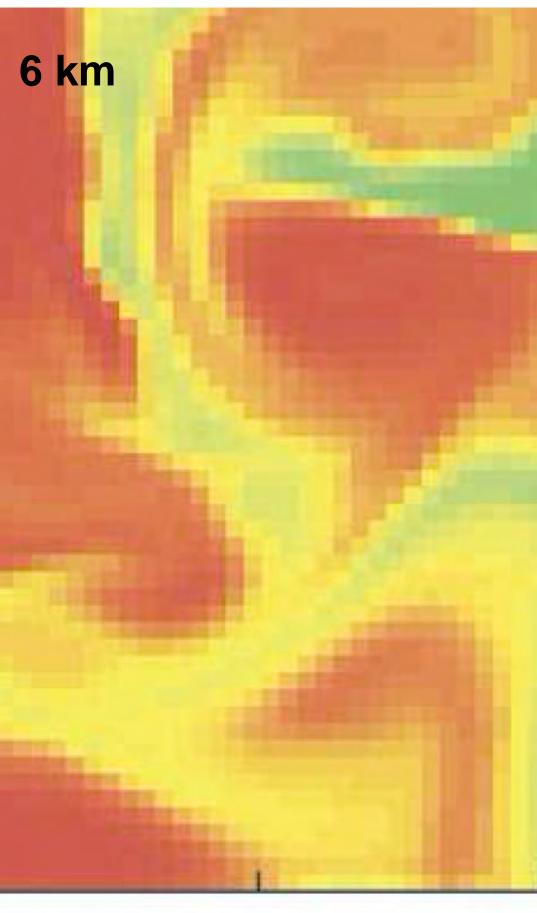
Frank Whitney, IOS

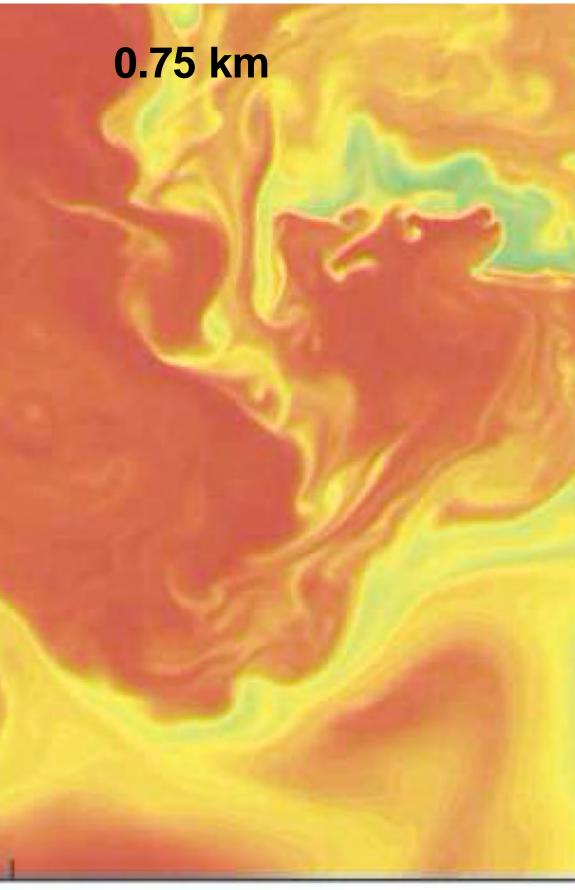


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Parameterizing small scale?

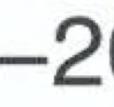
- Does it matter?
 - data assimilation can always correct for bad flux parameterizations...
 - ... for variables that we have lots of data for
 - can't data assimilate hard things like gases, nutrients, biology
 - dynamics might be wrong, and data assimilation not fast enough to correct (timing spring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













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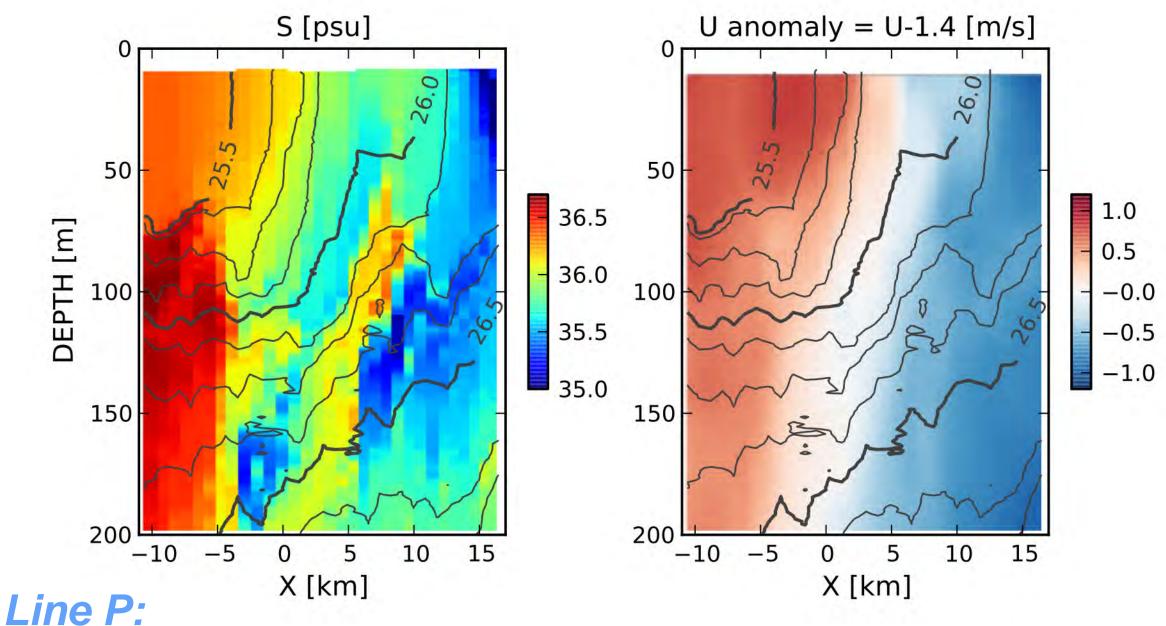
法法法 Ocean **Physics**

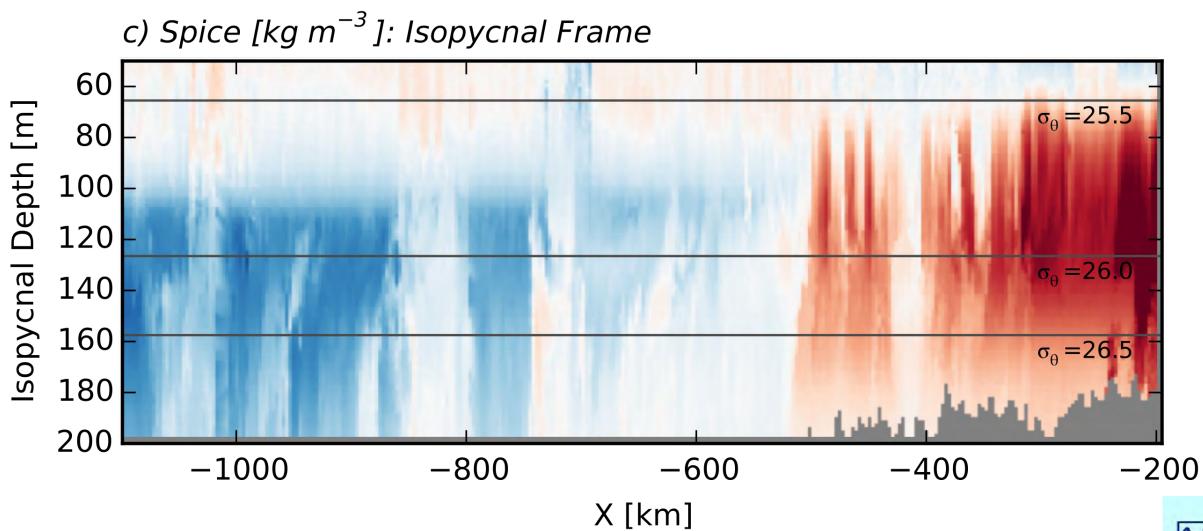
Group

Steps to parameterize

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





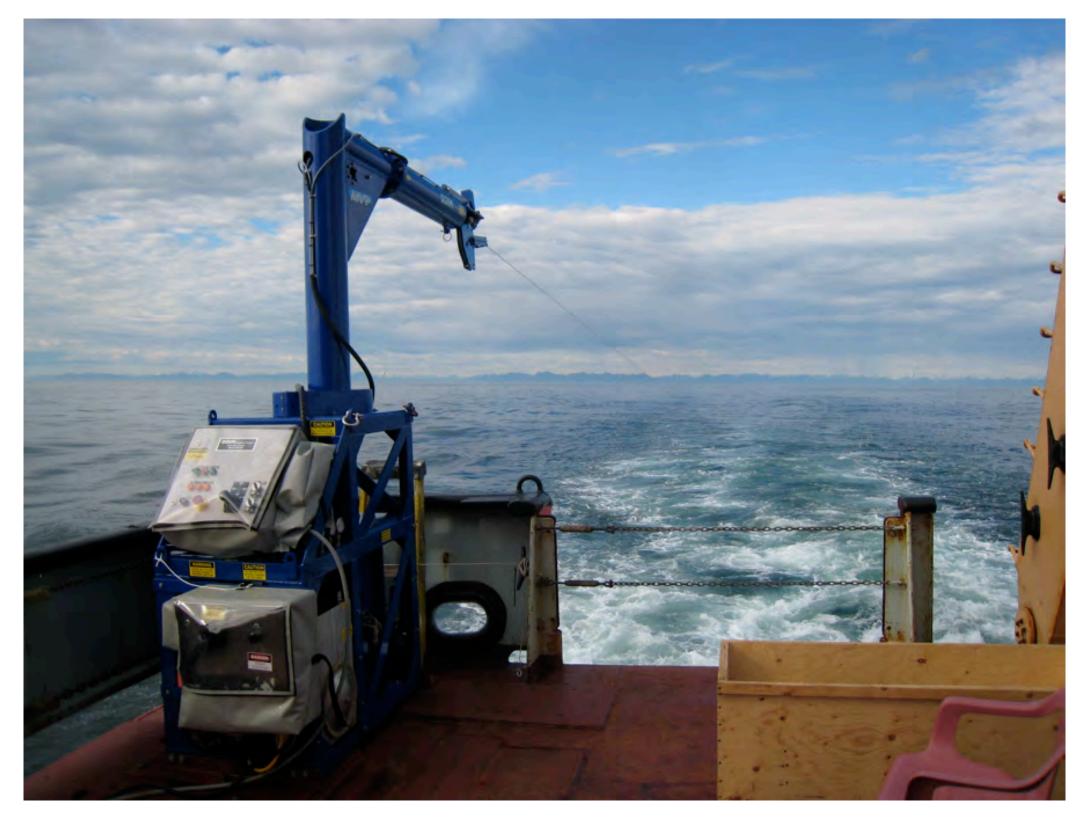


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Methodology

Moving Vessel Profiler



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

Line P Outlook Introduction



 CTD sensor • O2 or Fluorometer

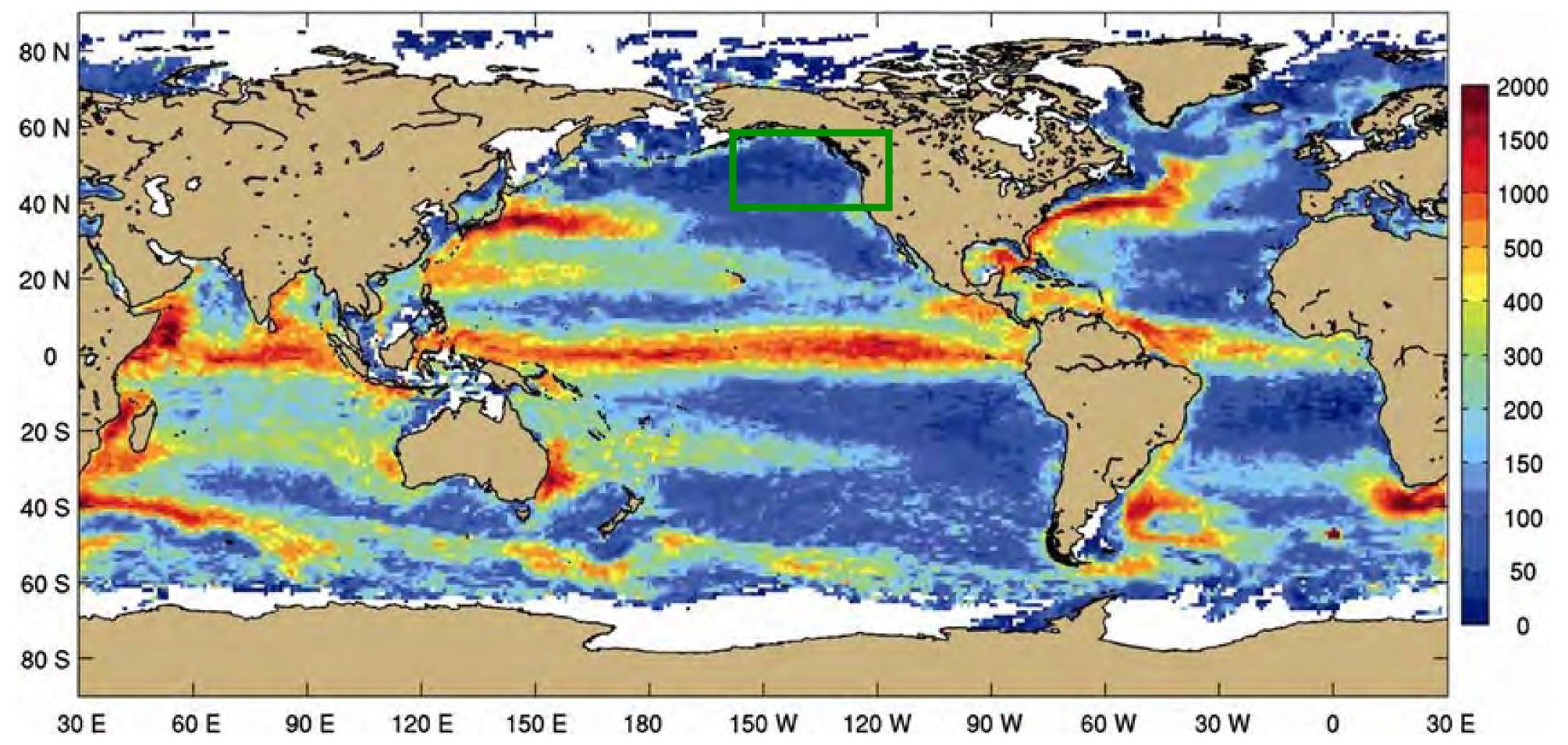


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Line P spice and kinetic energy

Eddy Kinetic Energy [cm^s/s^2]



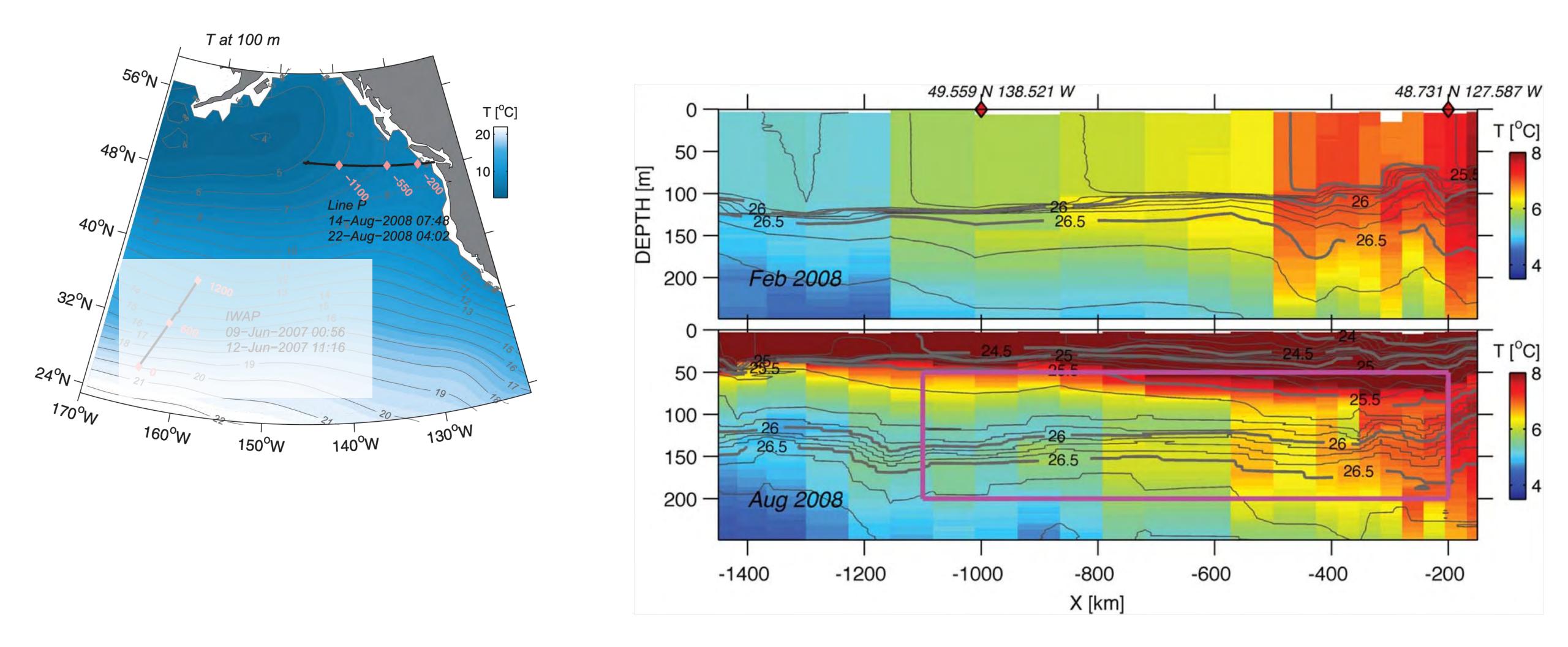


Maximenko et al 13

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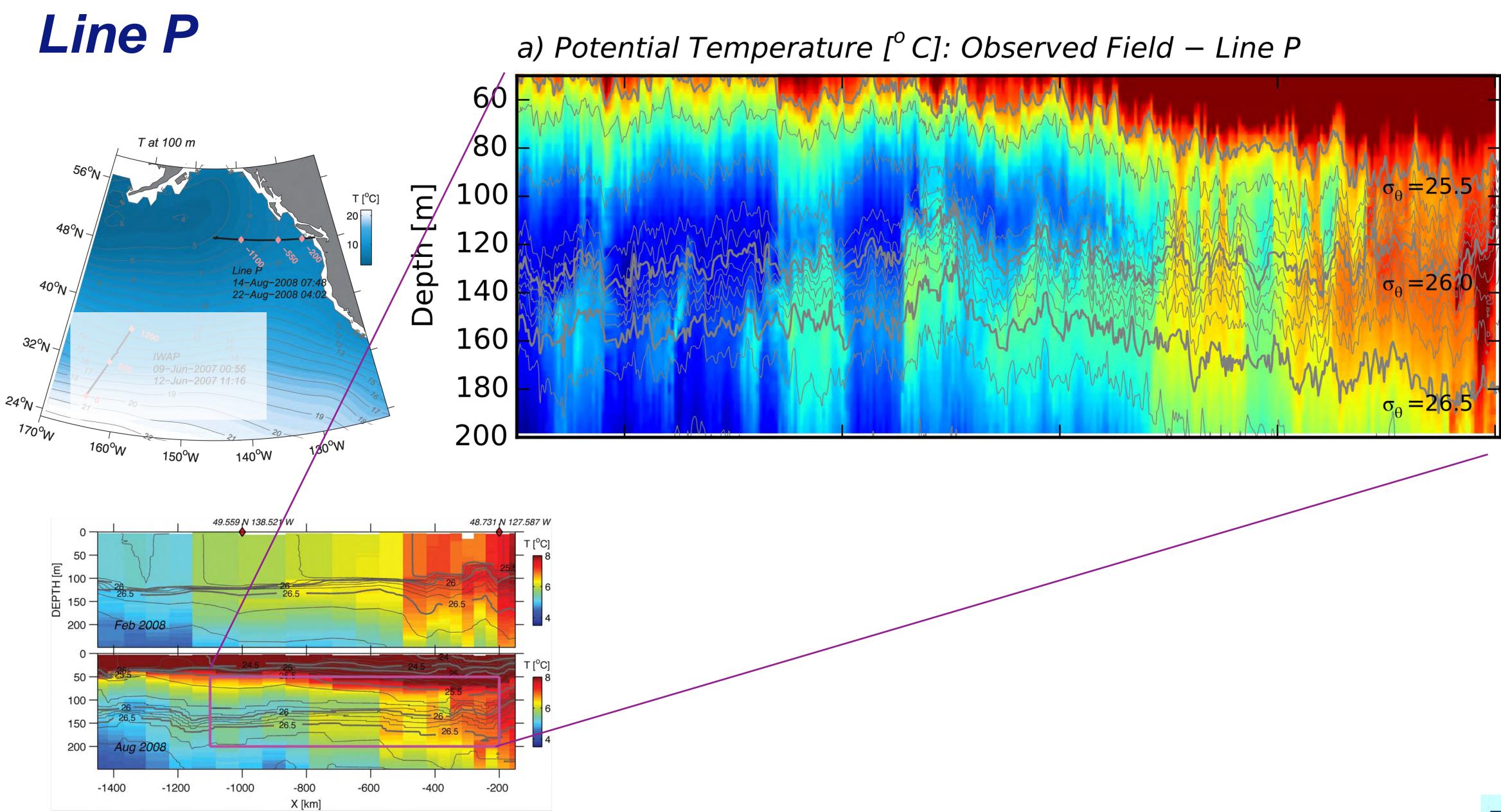


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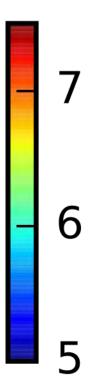


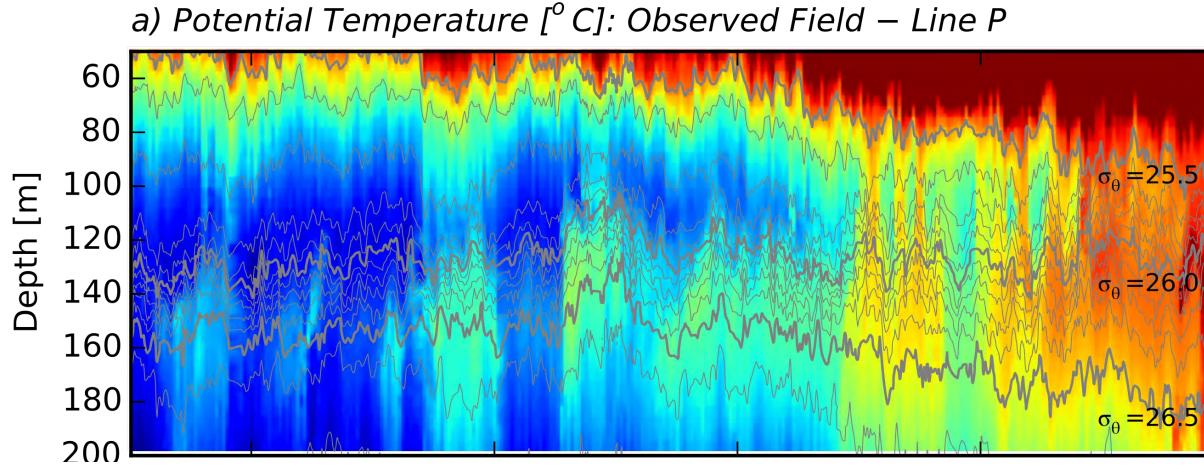
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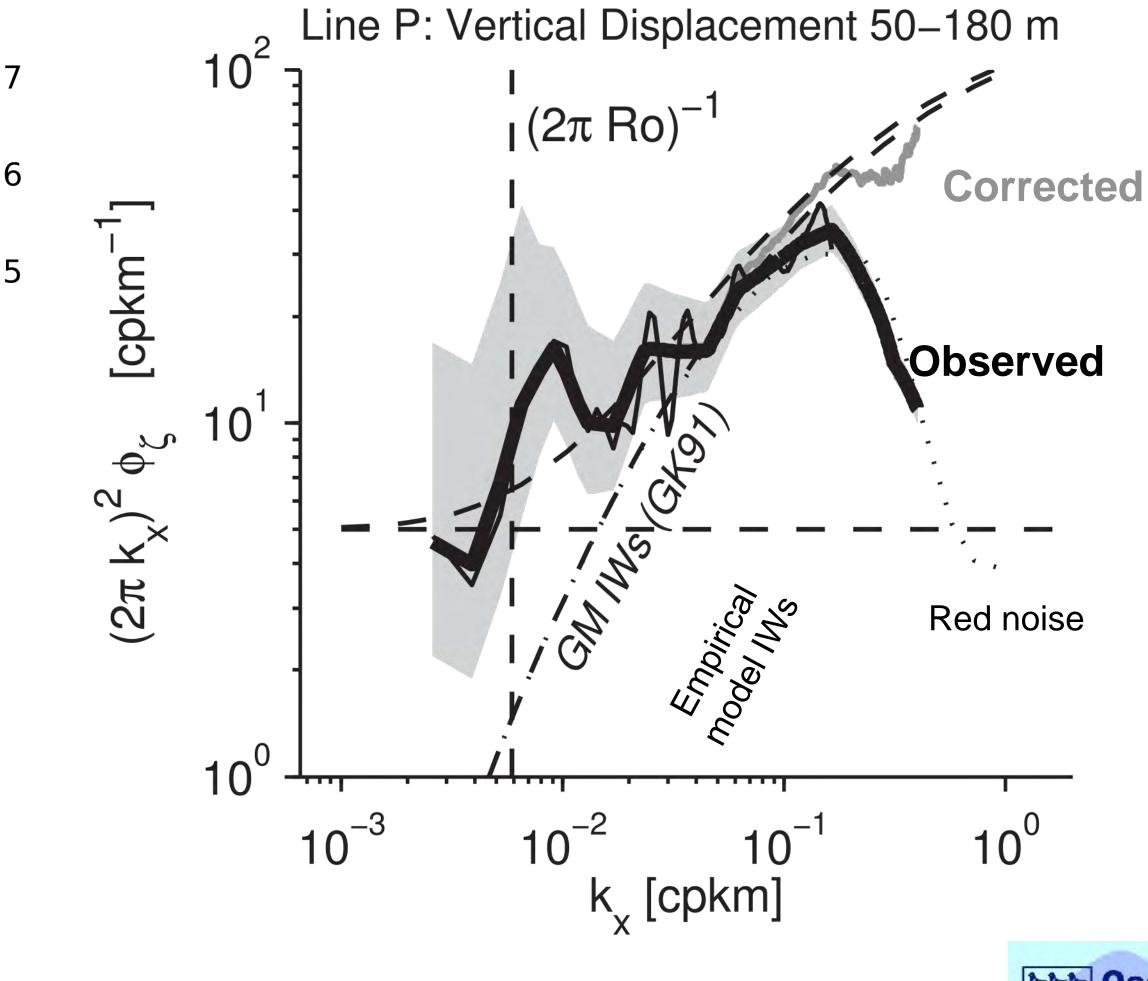
Internal waves:



7

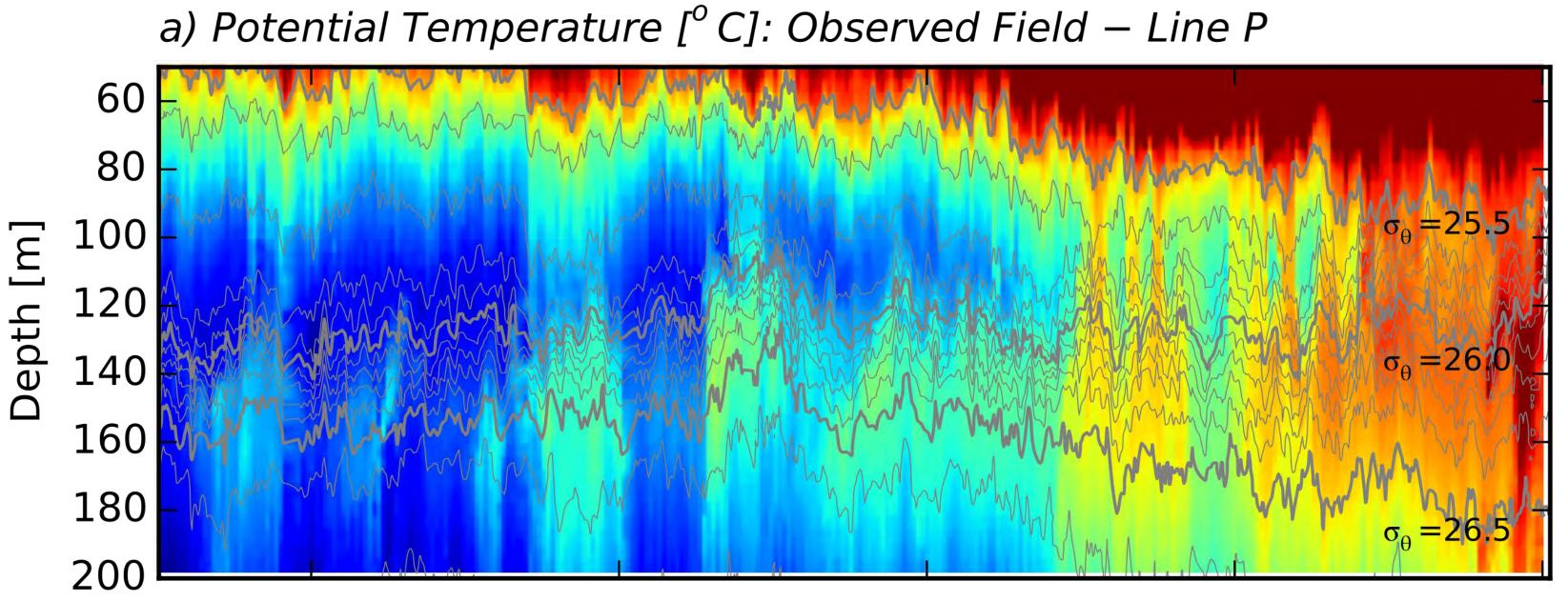
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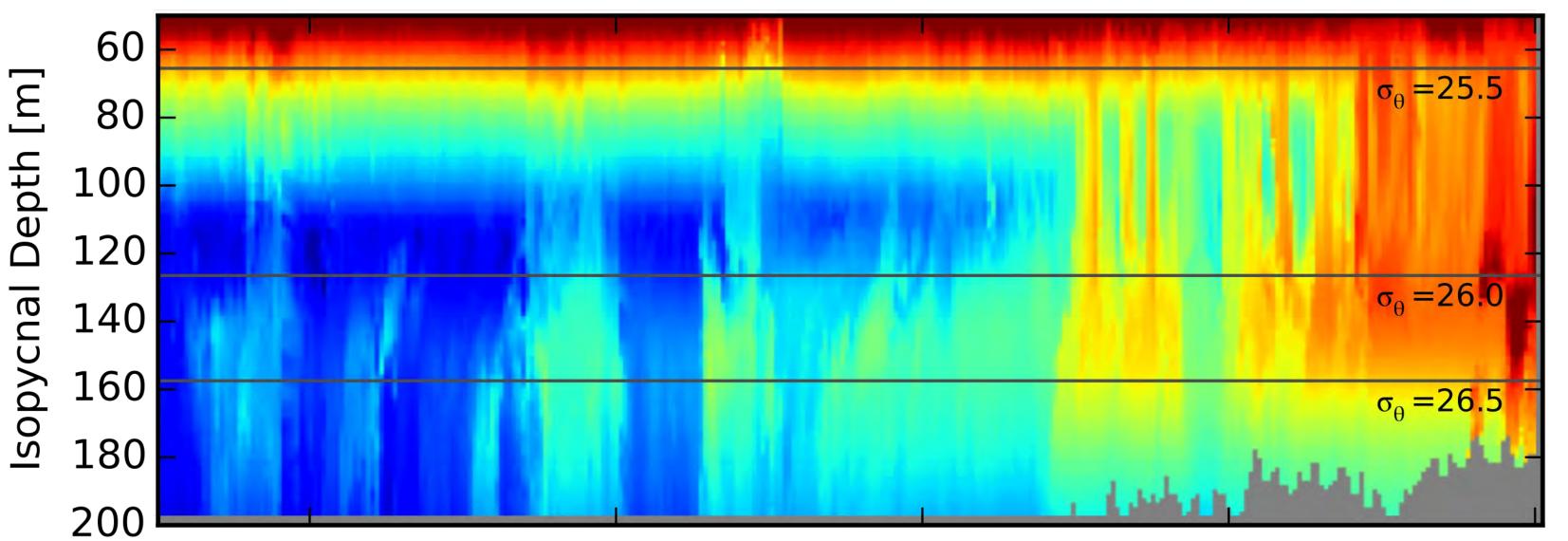


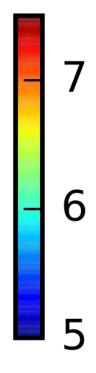
J Klymak: 2019 PICES meeting, Victoria

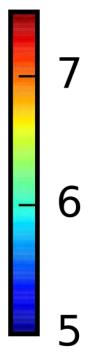






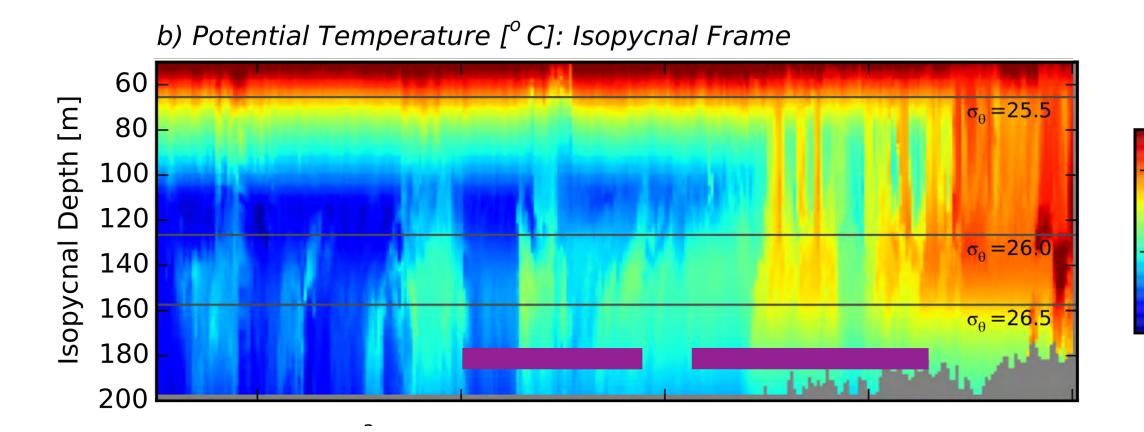






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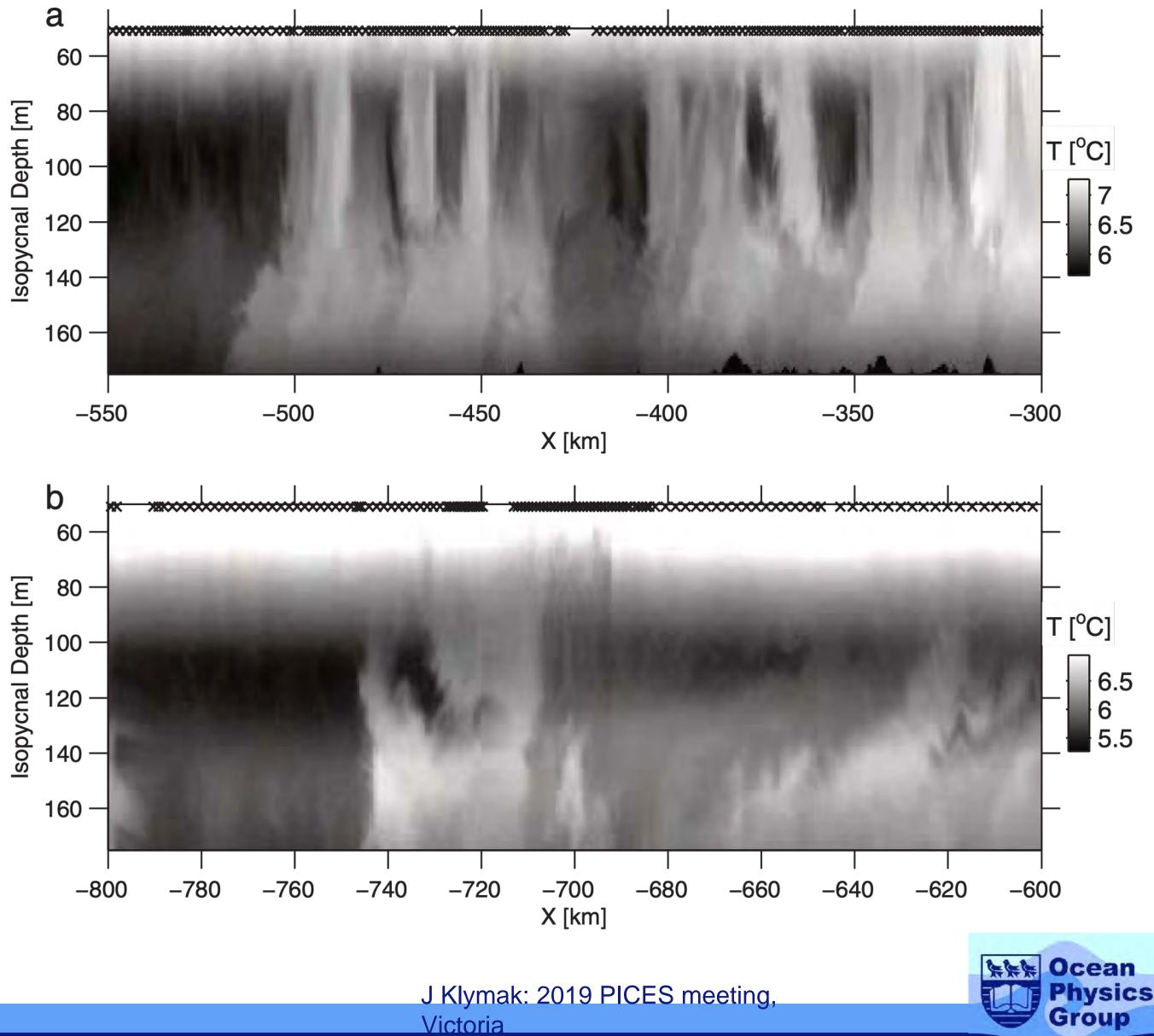


Lateral stirring:

7

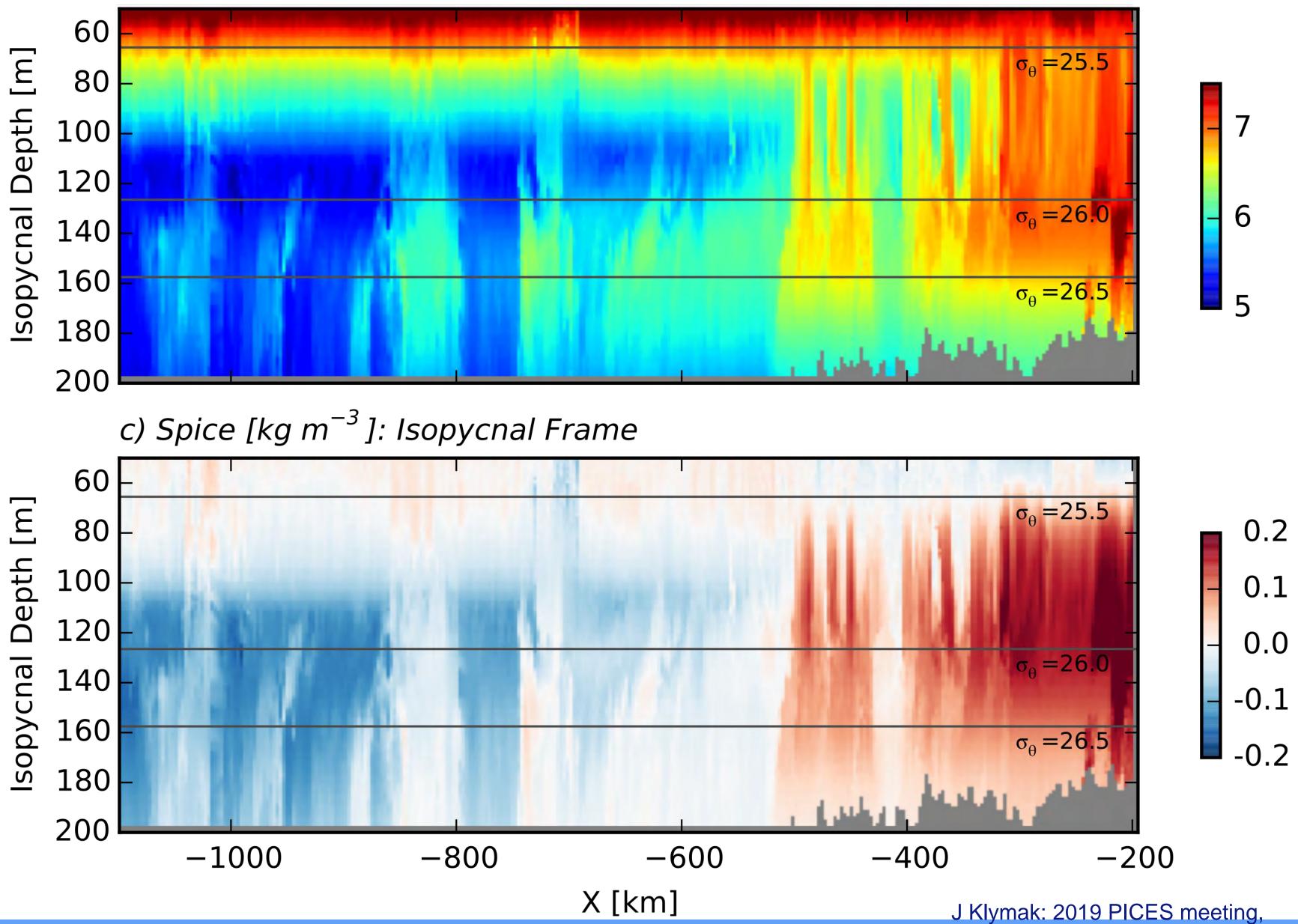
6

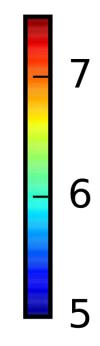
5







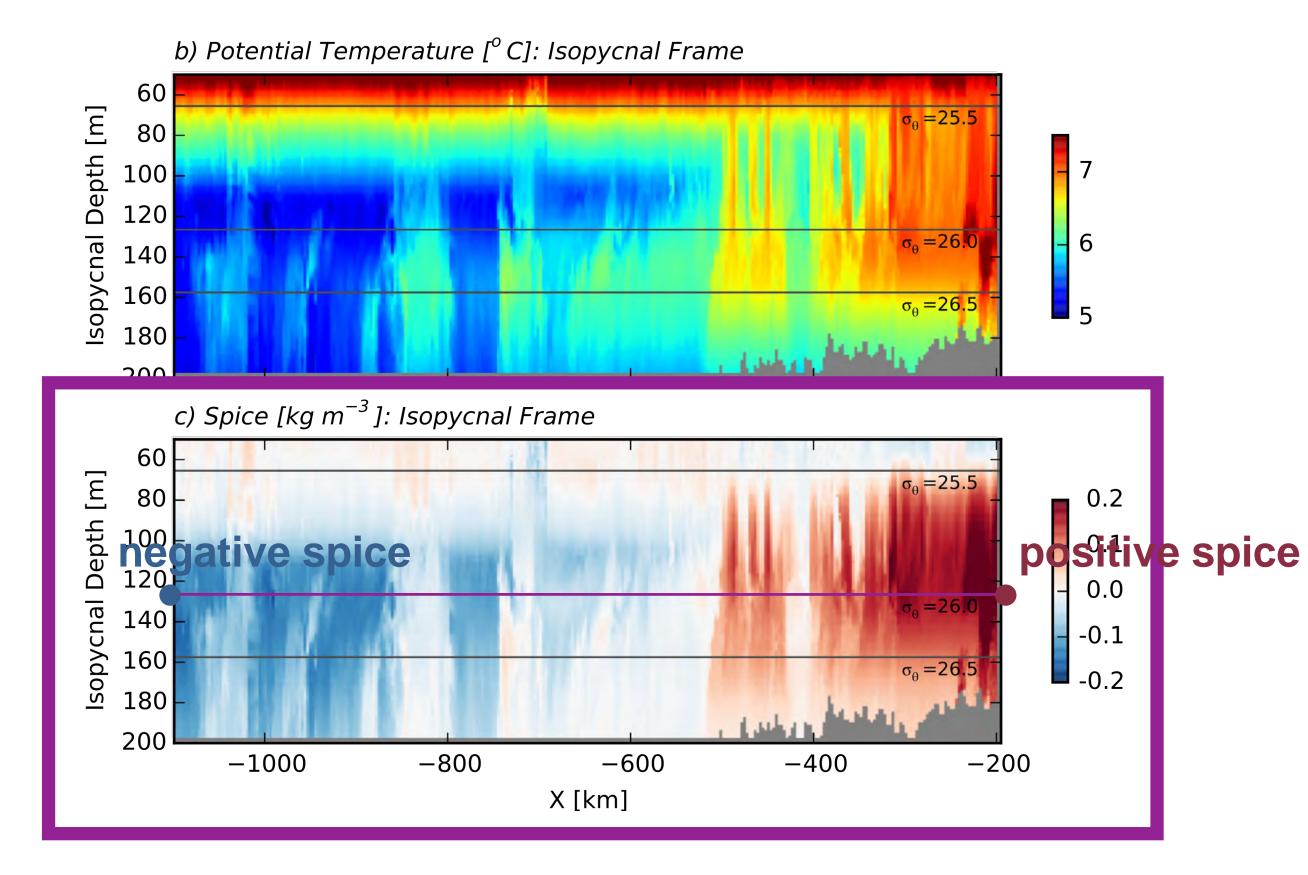




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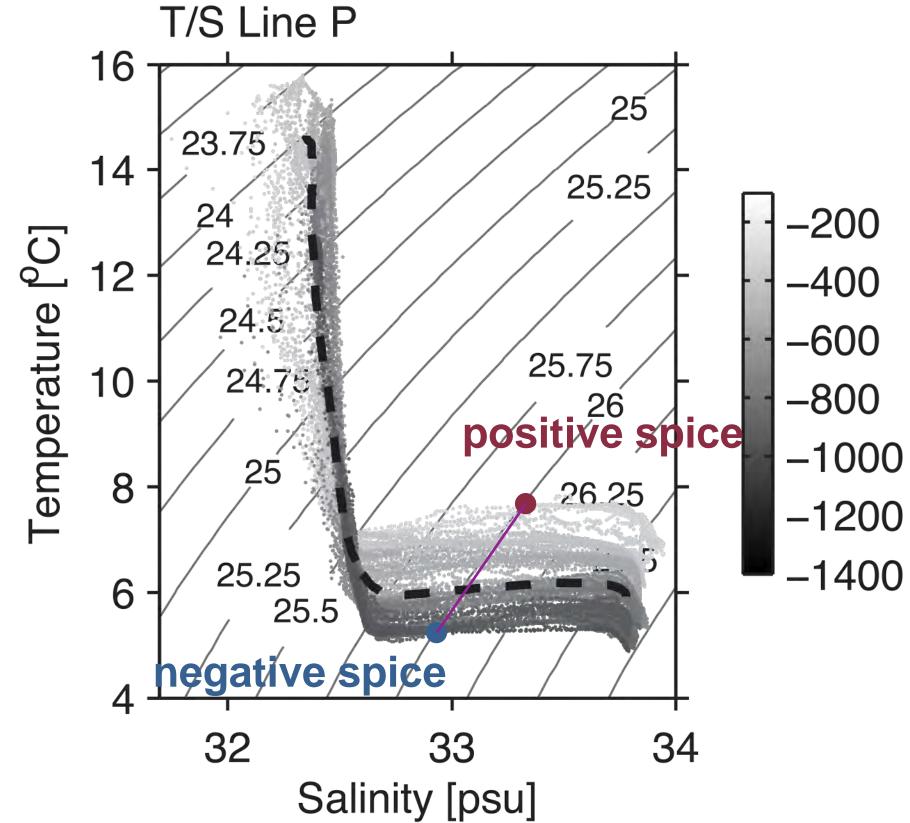






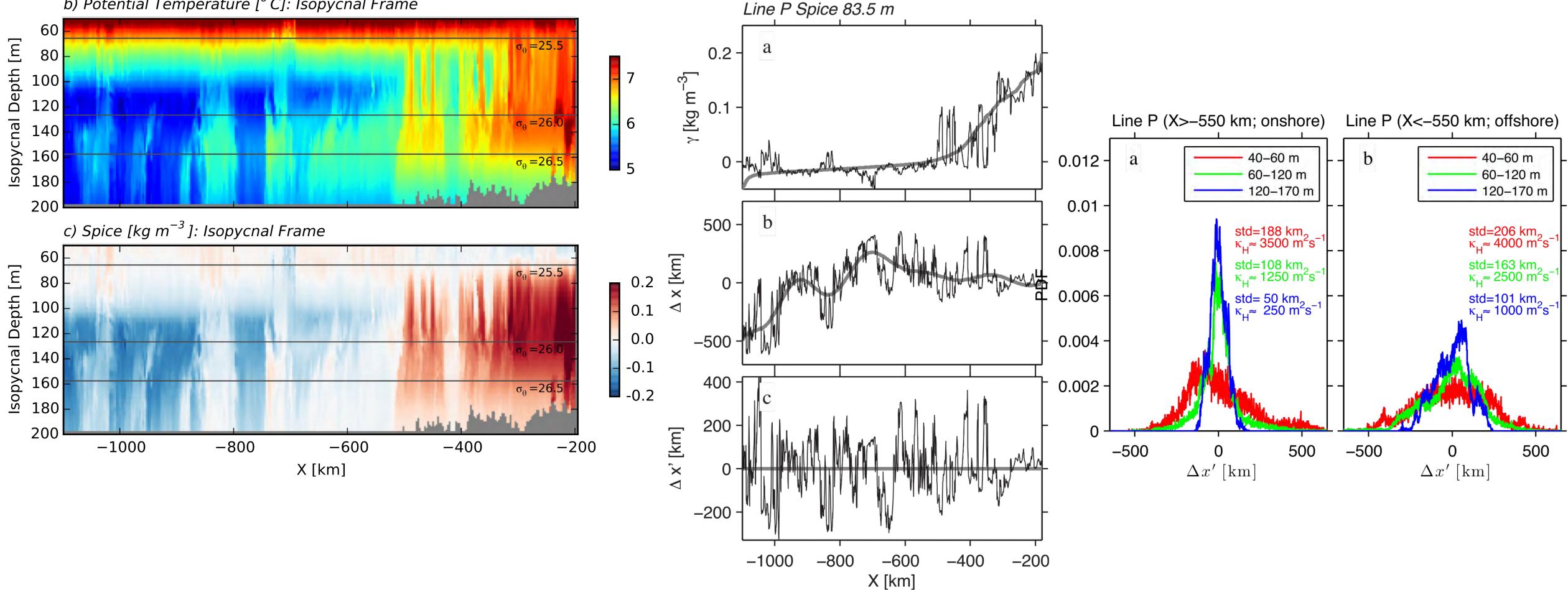
Lateral stirring: Spice

Spice: T anomaly along isopycnal



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Lateral stirring: lateral displacement statistics

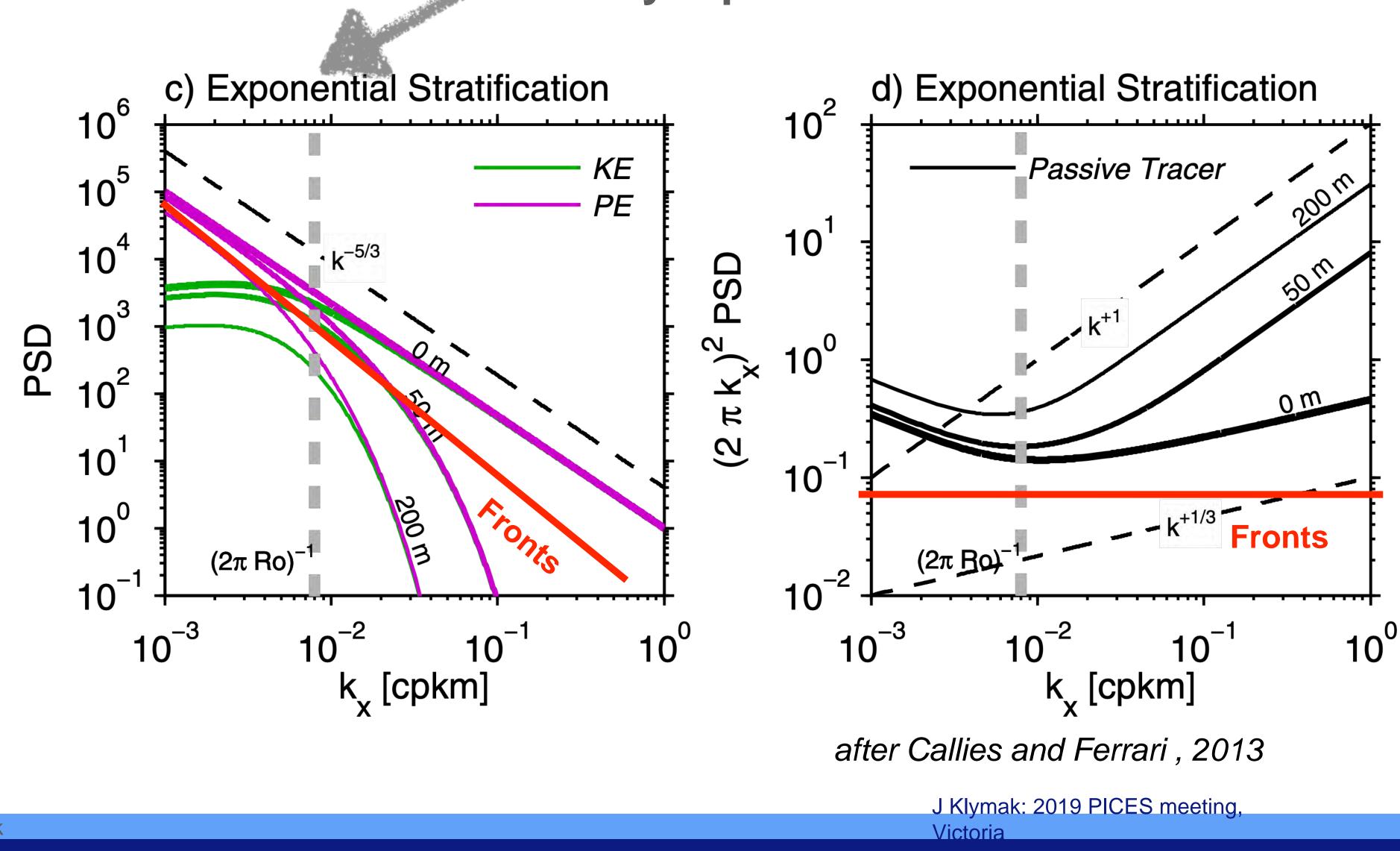






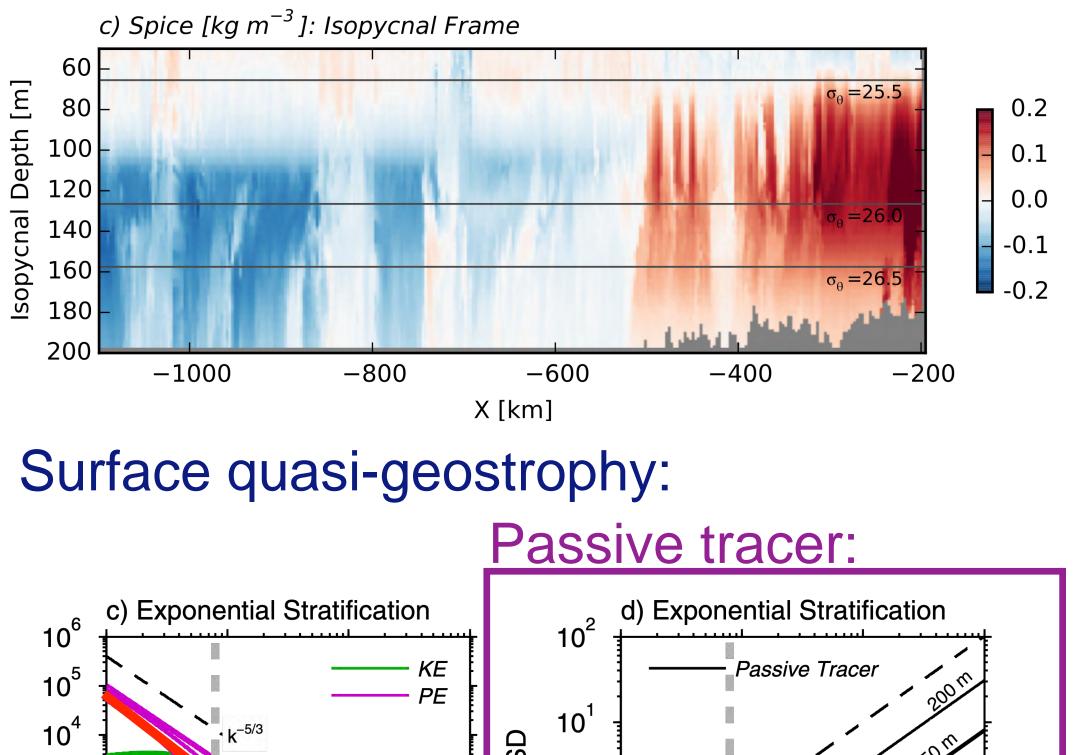
Lateral stirring: lateral displacement statistics **Vorticity input**

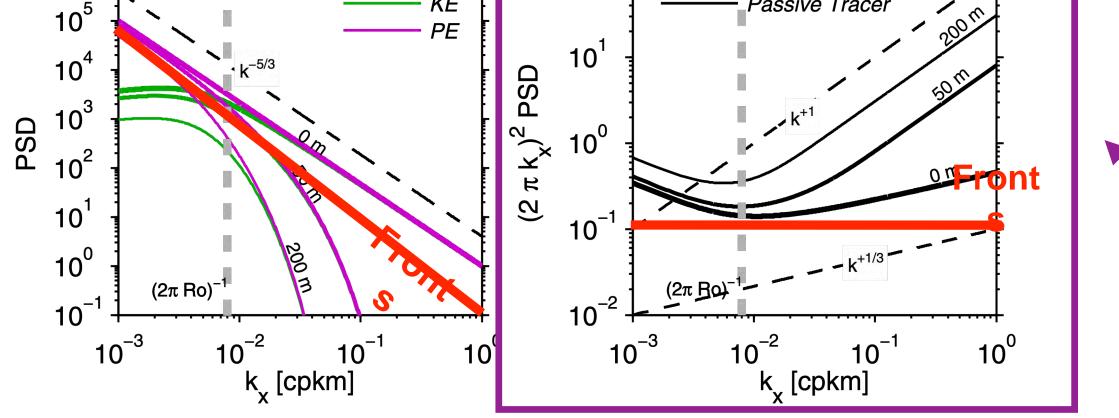
Surface quasi-geostrophy:



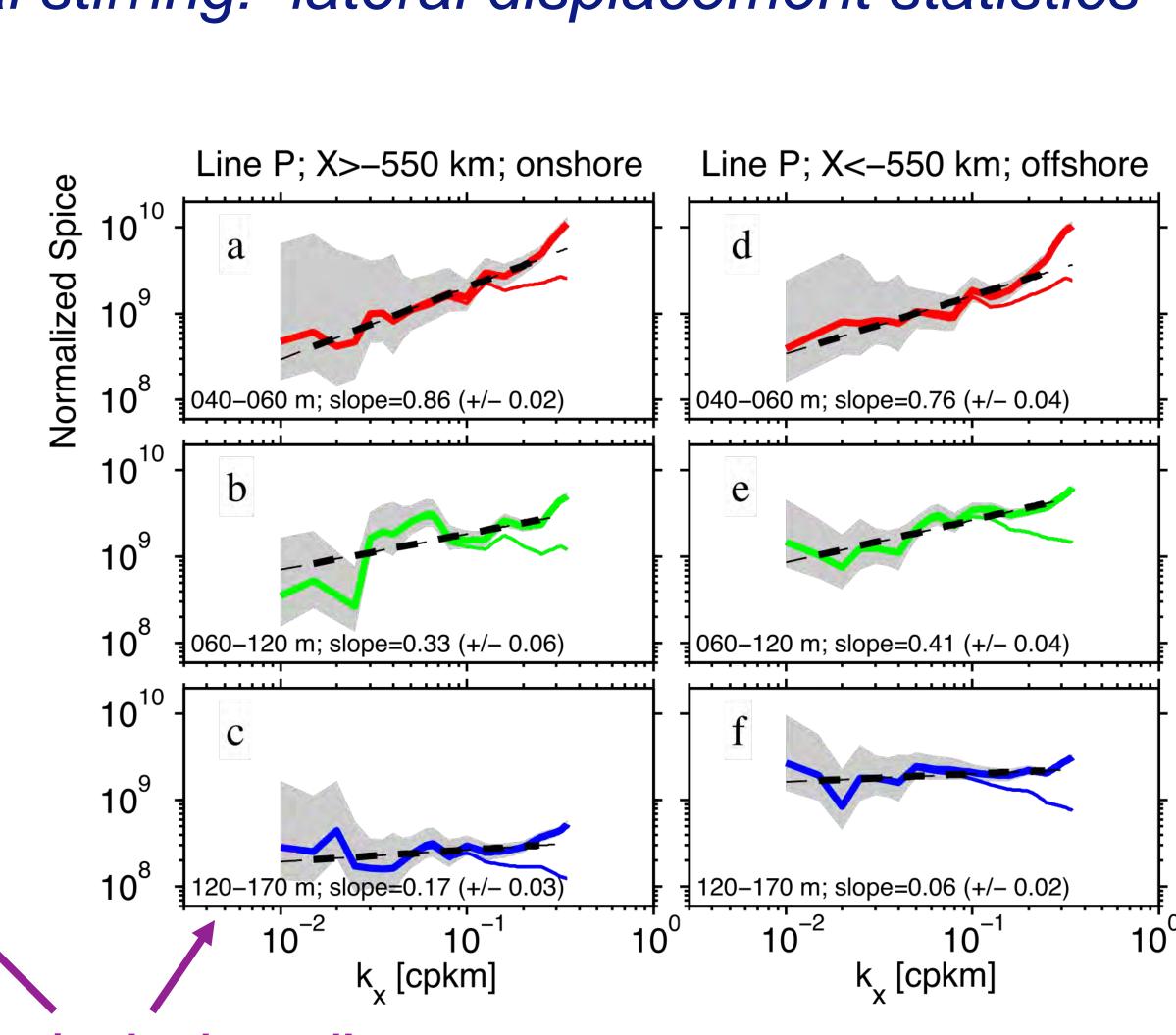


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Lateral stirring: lateral displacement statistics



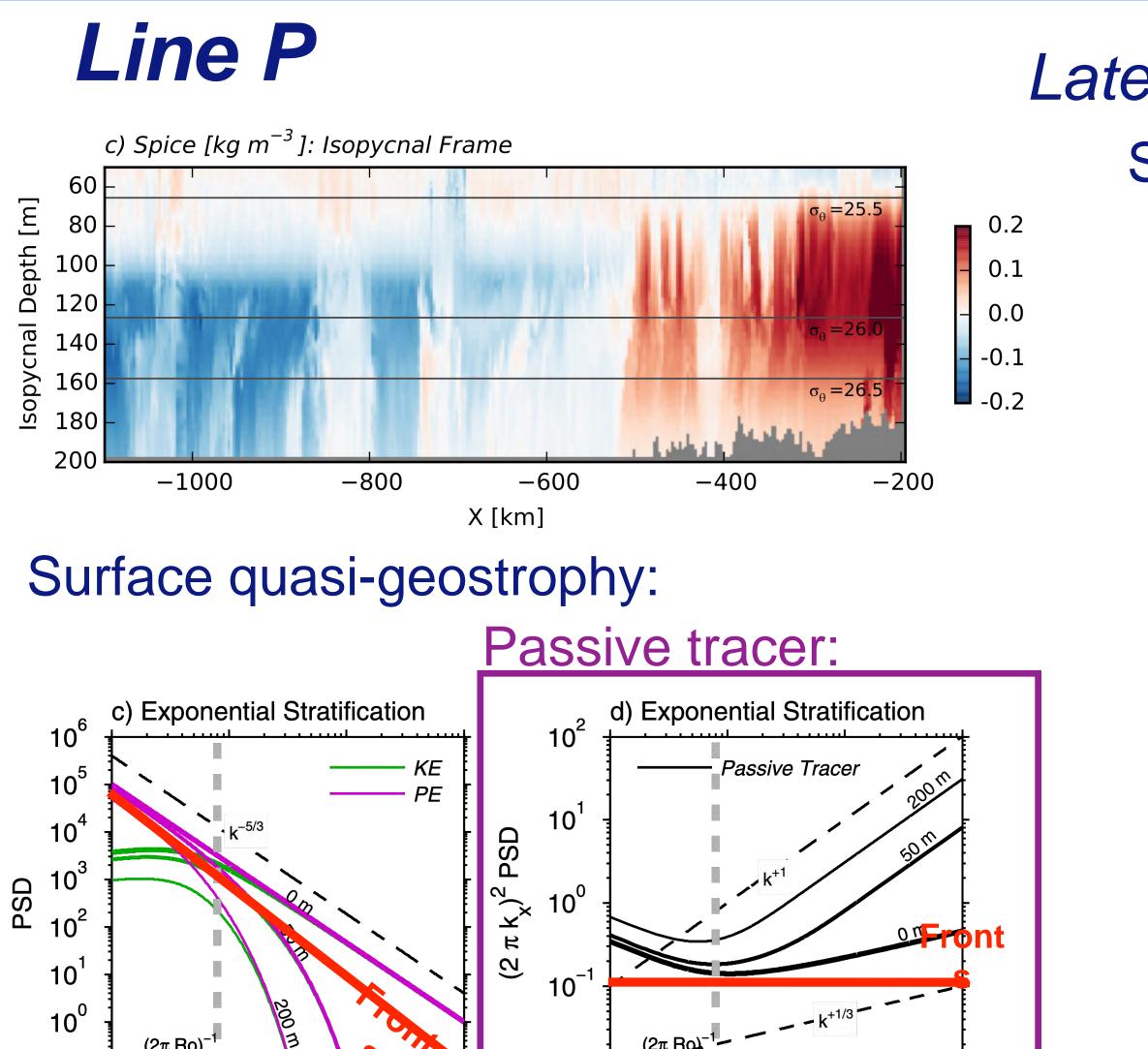
Opposite depth trend!

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(2π <u>B</u>0)-1-

10

10

k_x [cpkm]

10

10⁻²

10

10

10

10

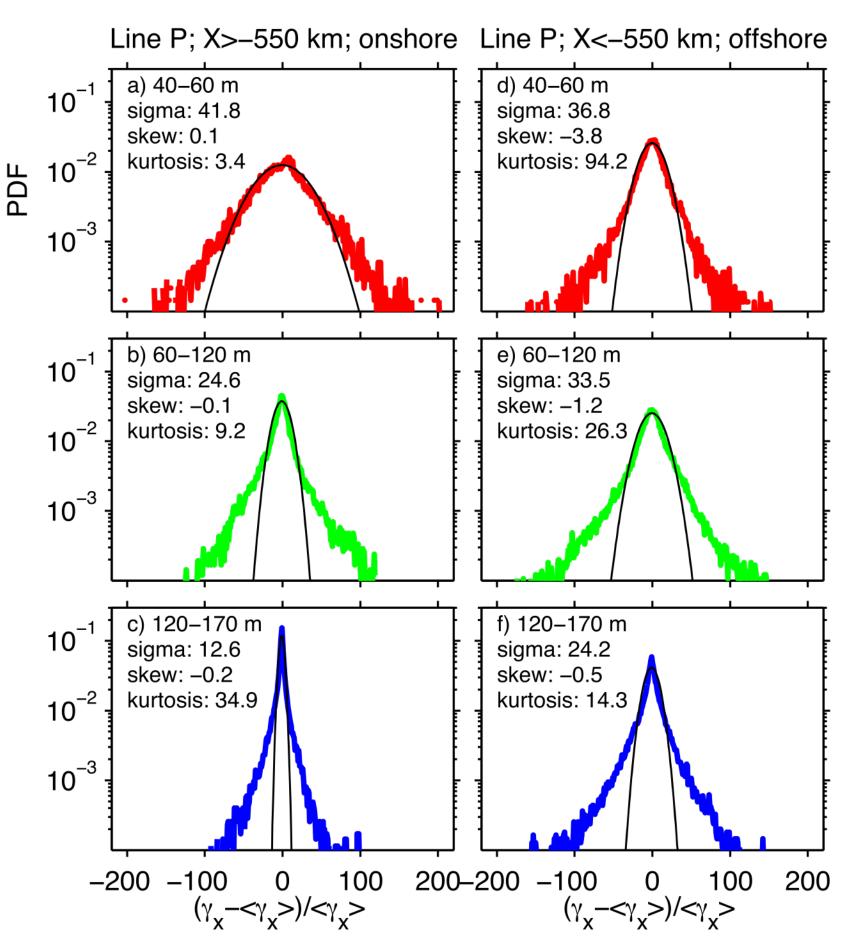
k_x [cpkm]

 $(2\pi \text{ Ro})^{-1}$

10

10

Lateral stirring: lateral displacement statistics Spice derivative PDFs



High kurtosis (tails) means data more like fronts



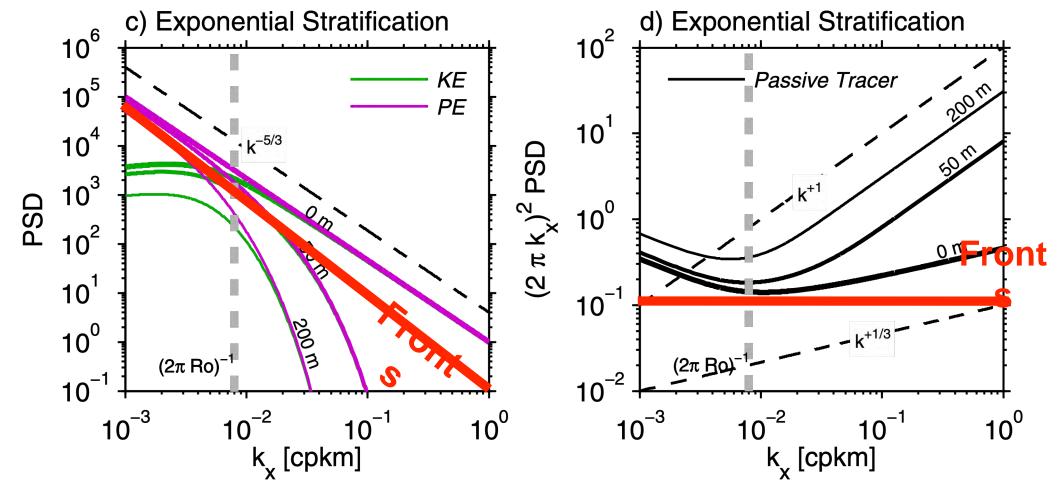
J Klymak: 2019 PICES meeting, Victoria



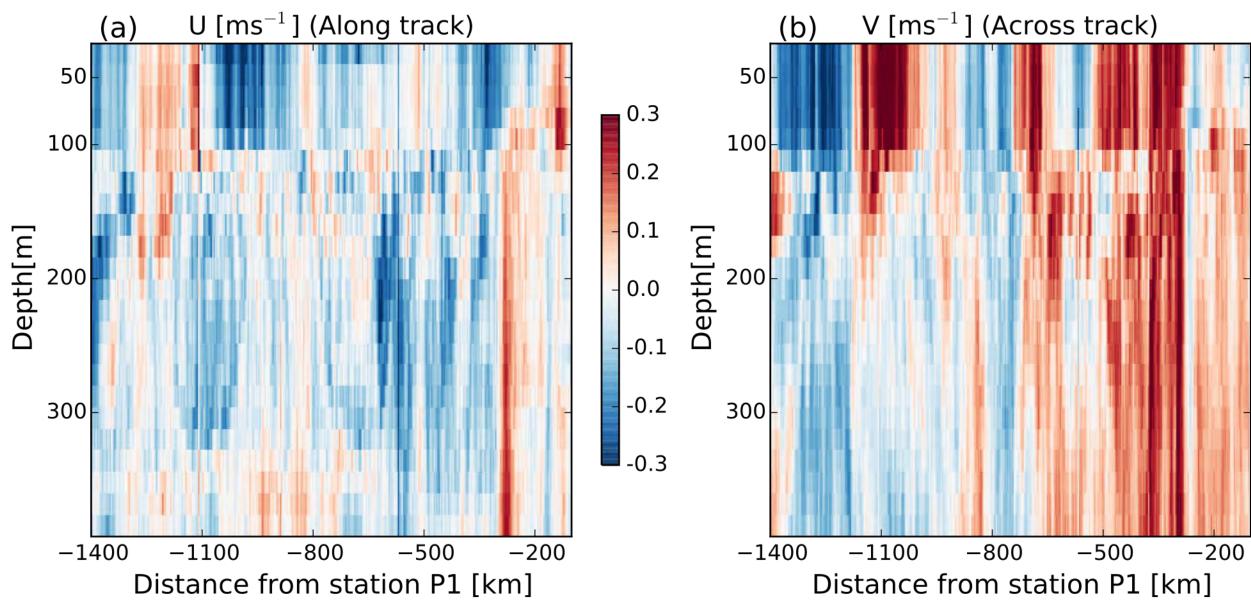
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Surface quasi-geostrophy:



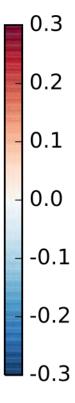
Lateral stirring: Velocity statistics MSc: Manman Wang, 2016

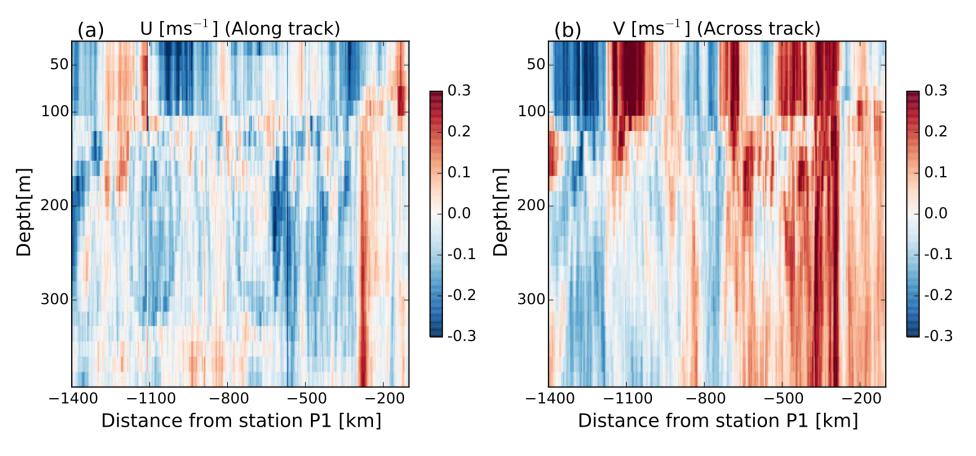


ADCP data along Line P: Feb and June cruises 3 years



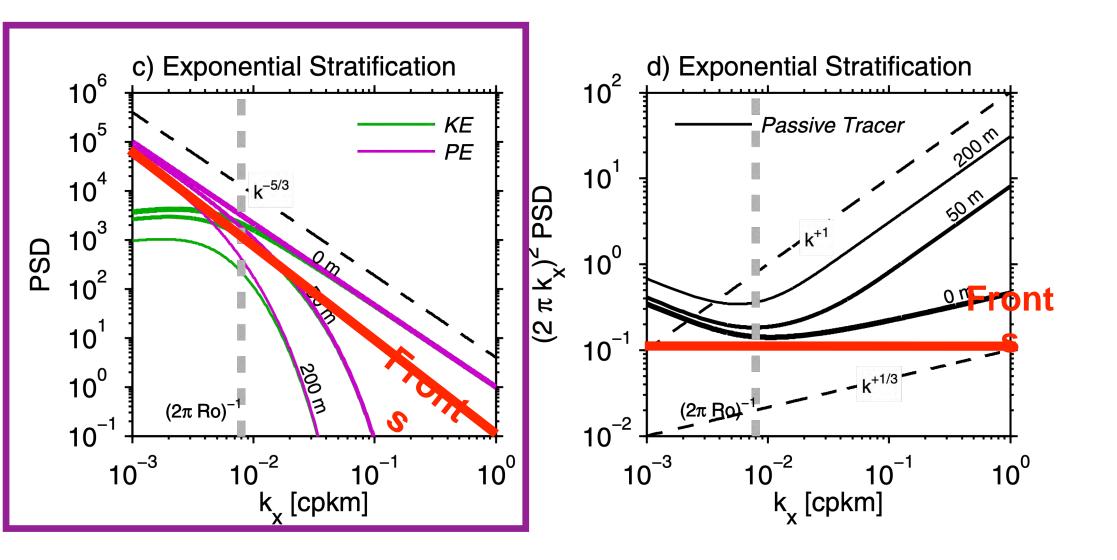
J Klymak: 2019 PICES meeting, Victoria



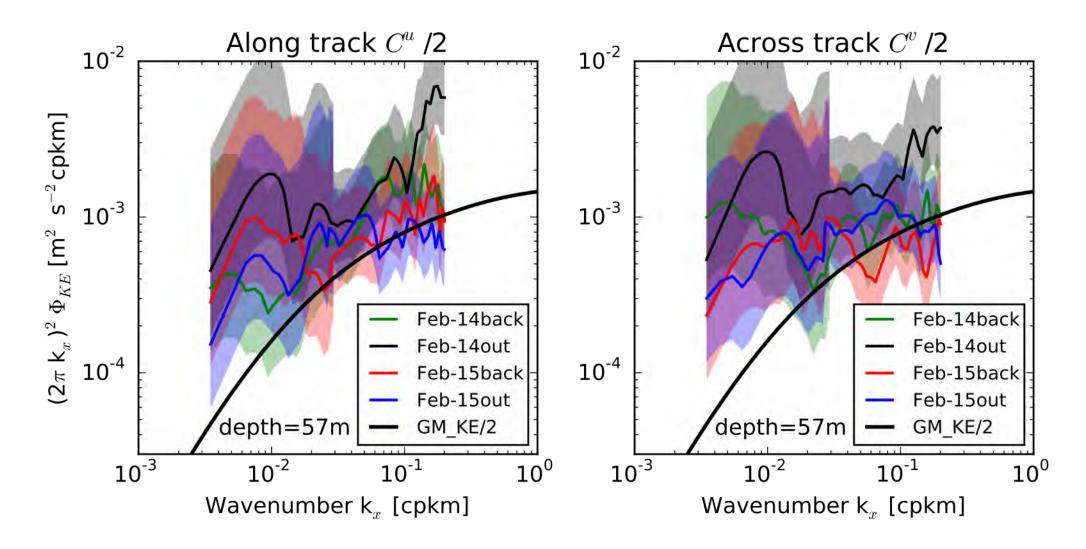


Lateral stirring: Velocity statistics

Surface quasi-geostrophy:



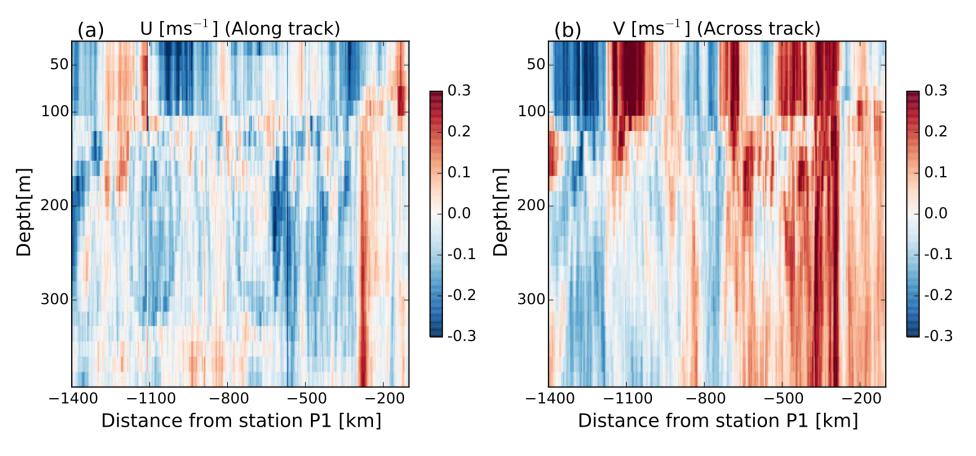
MSc: Manman Wang, 2016





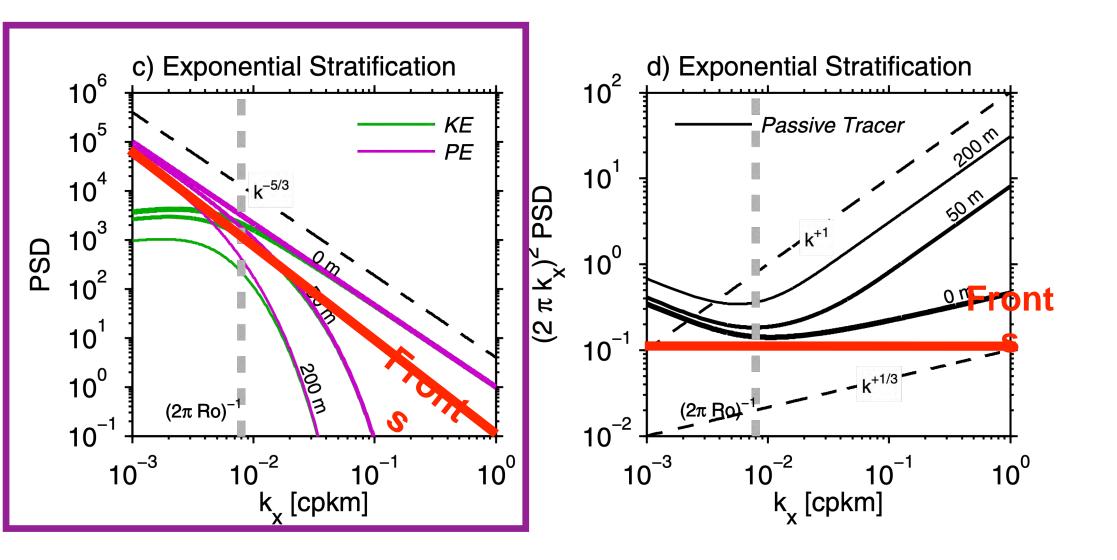
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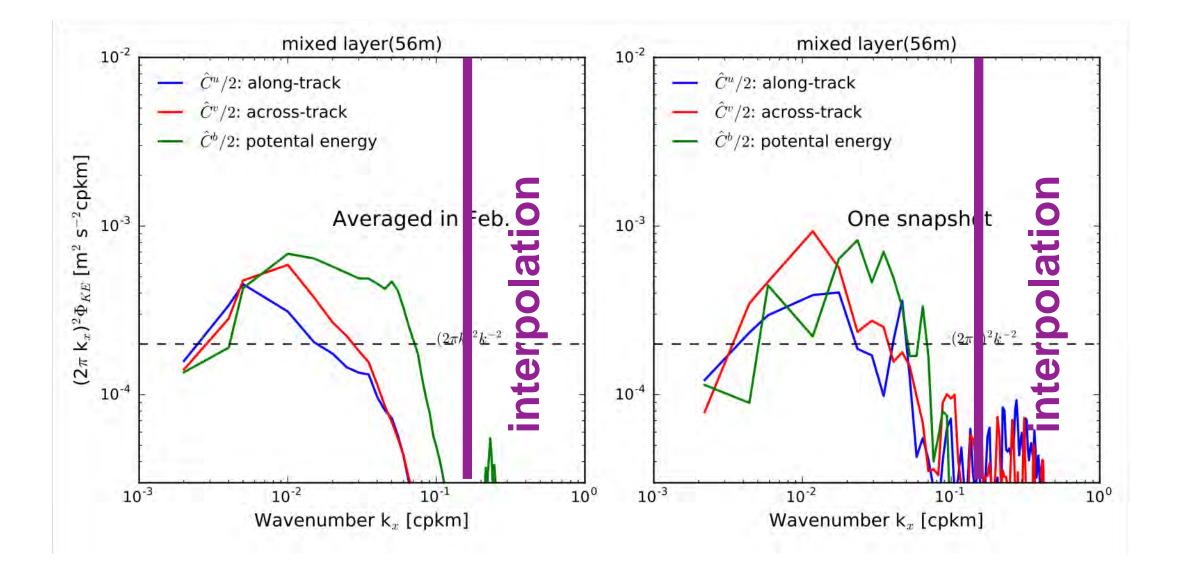
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Lateral stirring: Velocity statistics MSc: Manman Wang, 2016

Surface quasi-geostrophy:



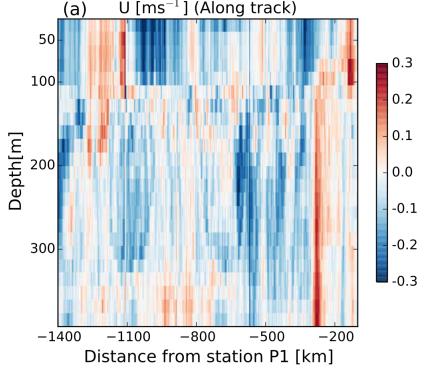


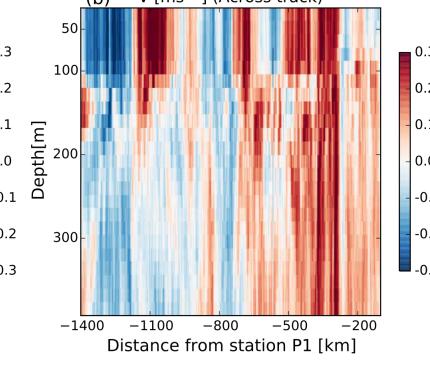
NEMO data (a few years ago) 1/32nd degree

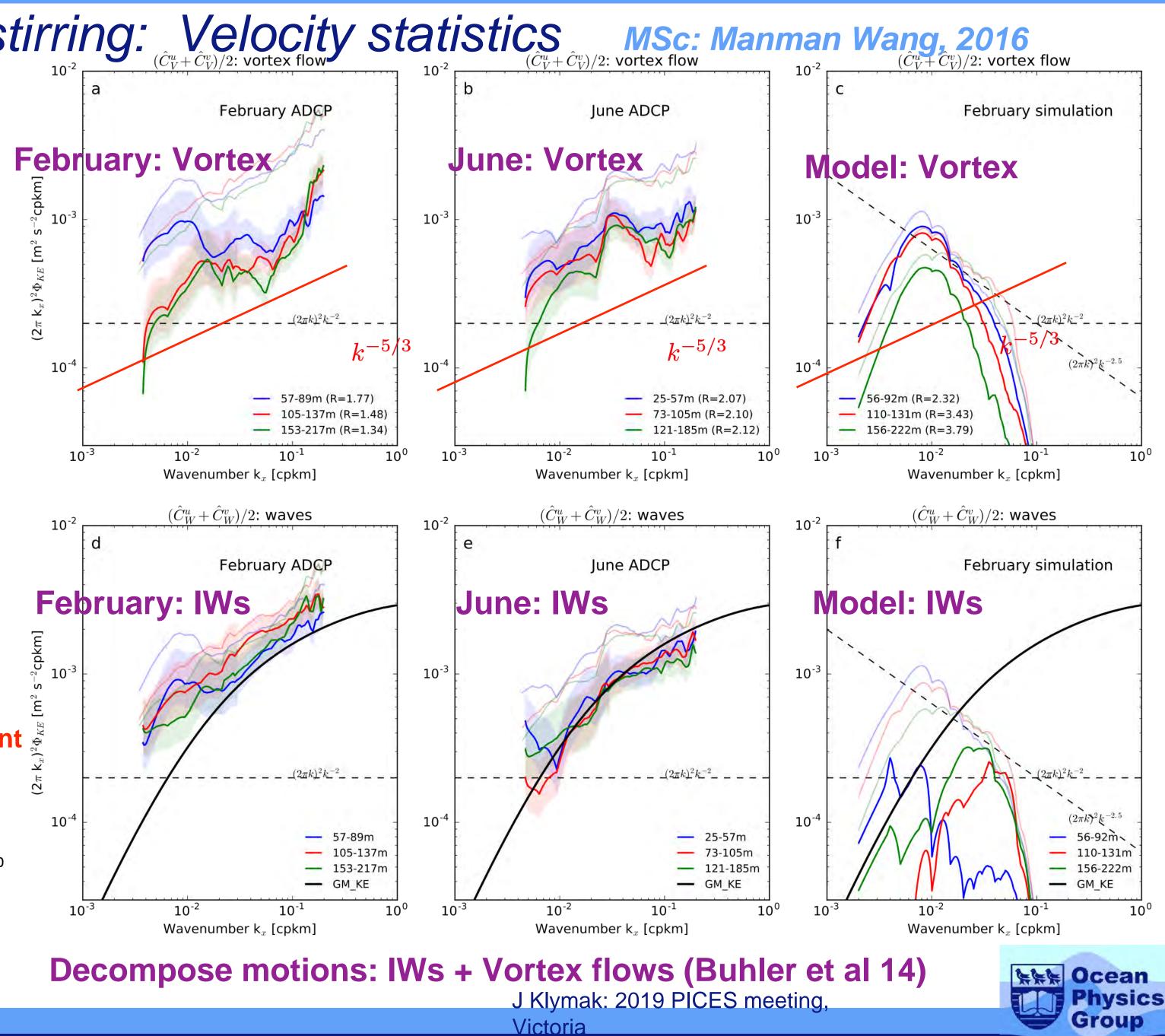


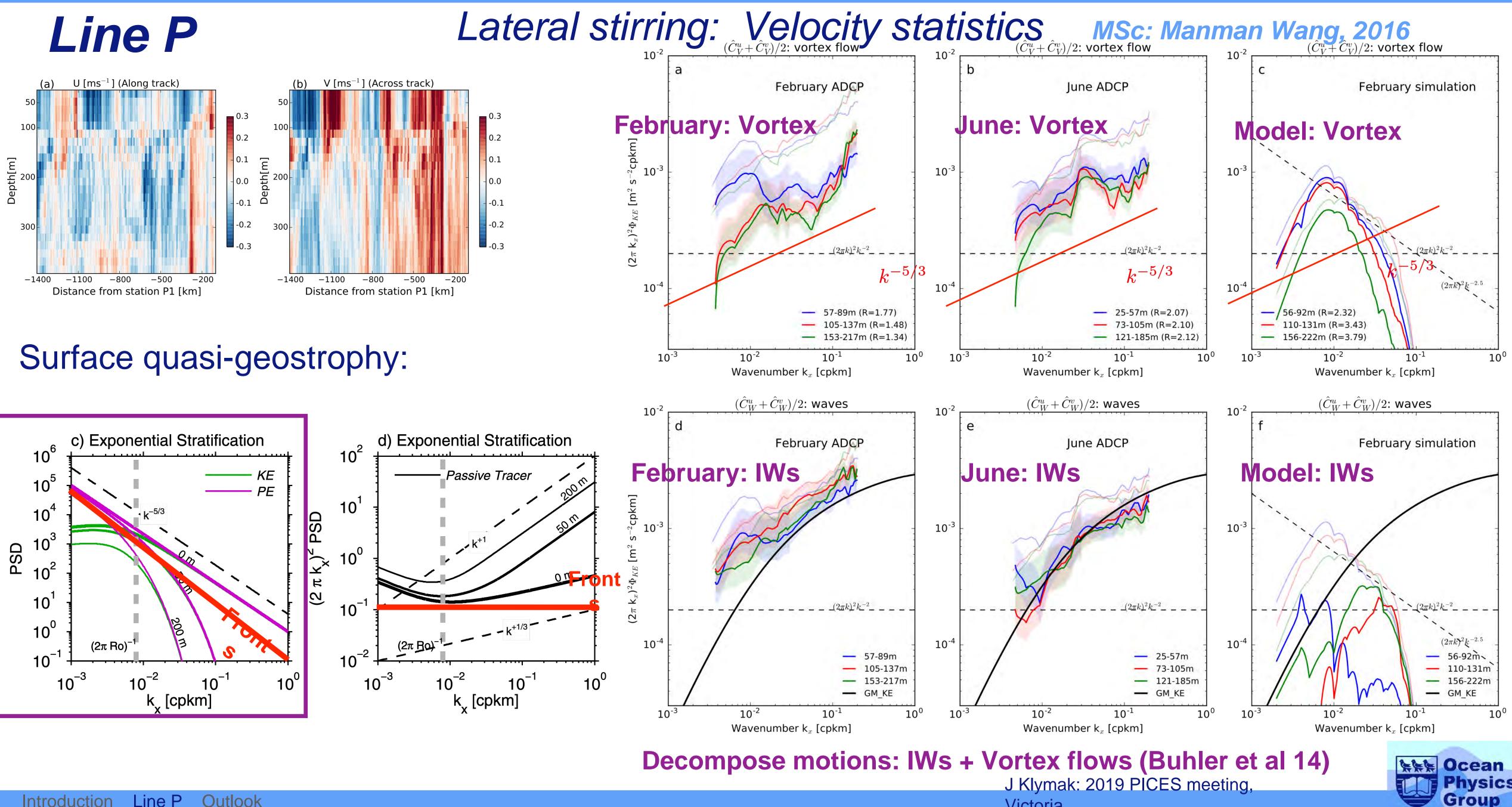
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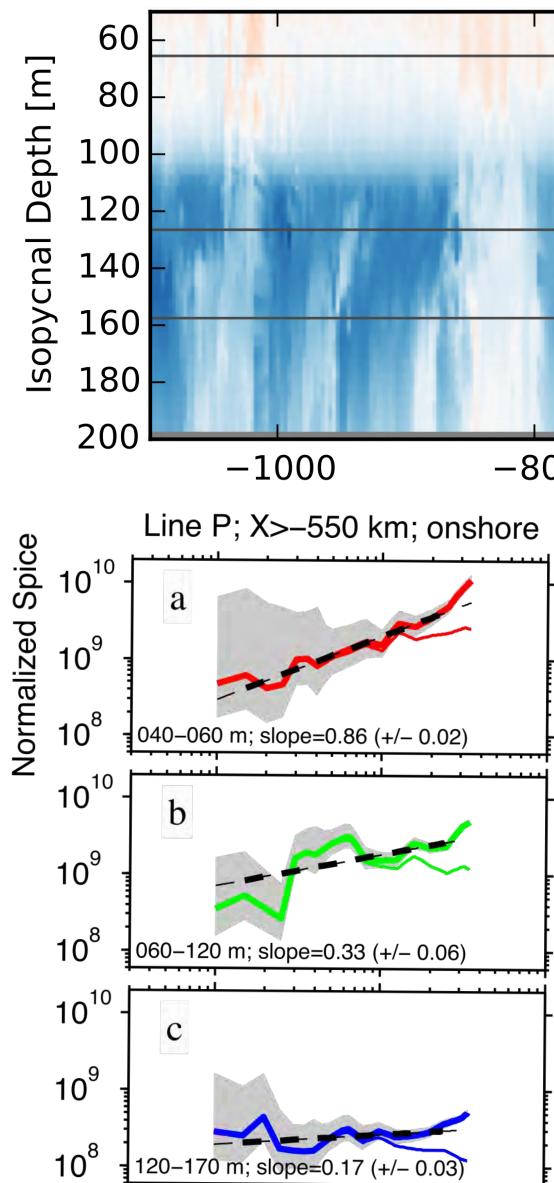




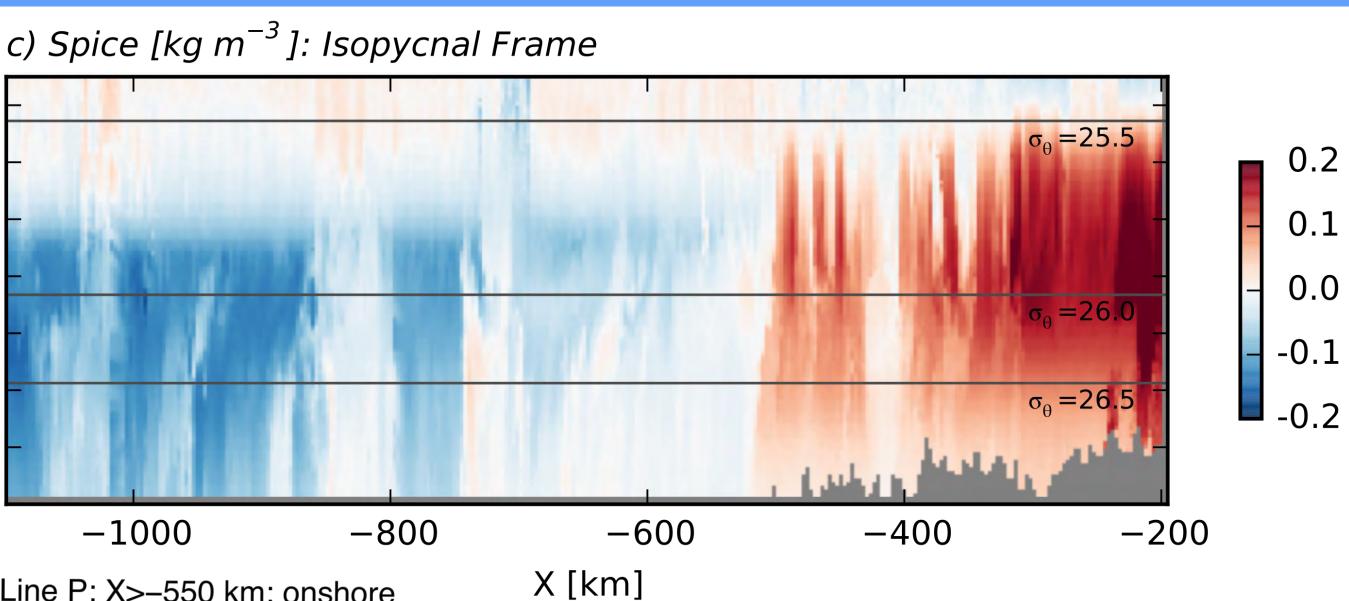


Line P Summary

- 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



Outlook



Implications

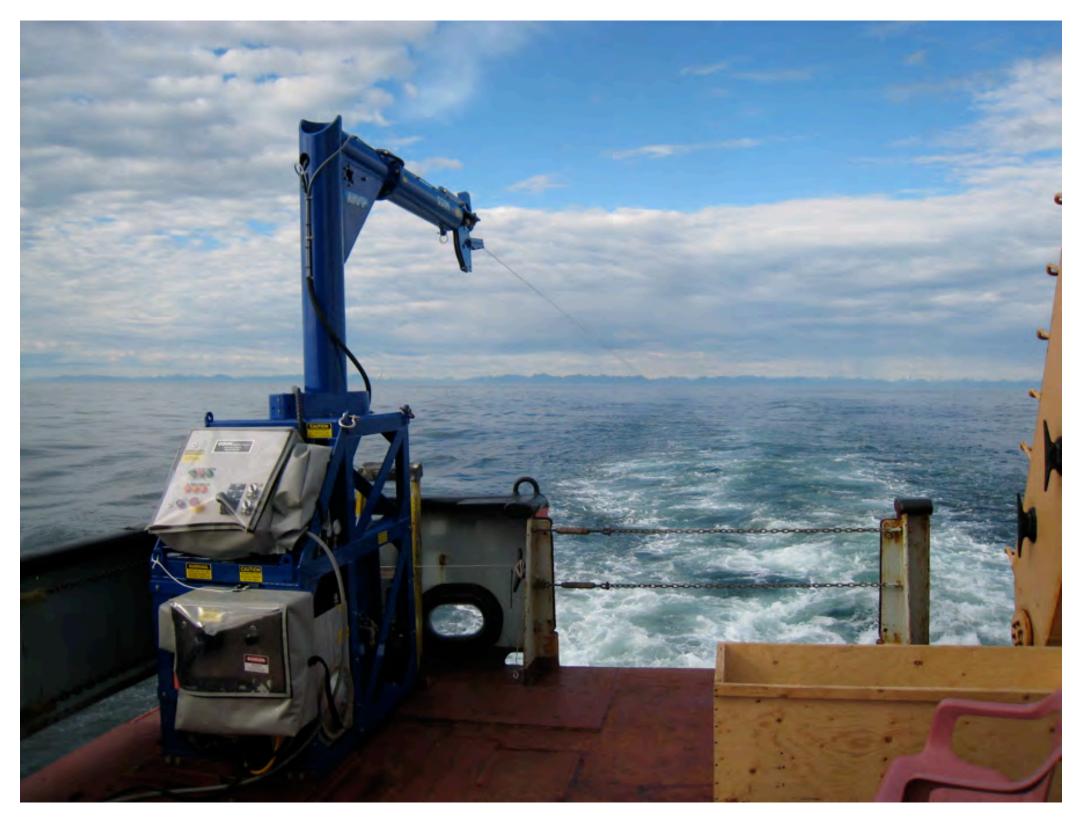
QG/SQG theories not directly applicable Mid-depth vorticity source? Time history matters?



Physics Group

- 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



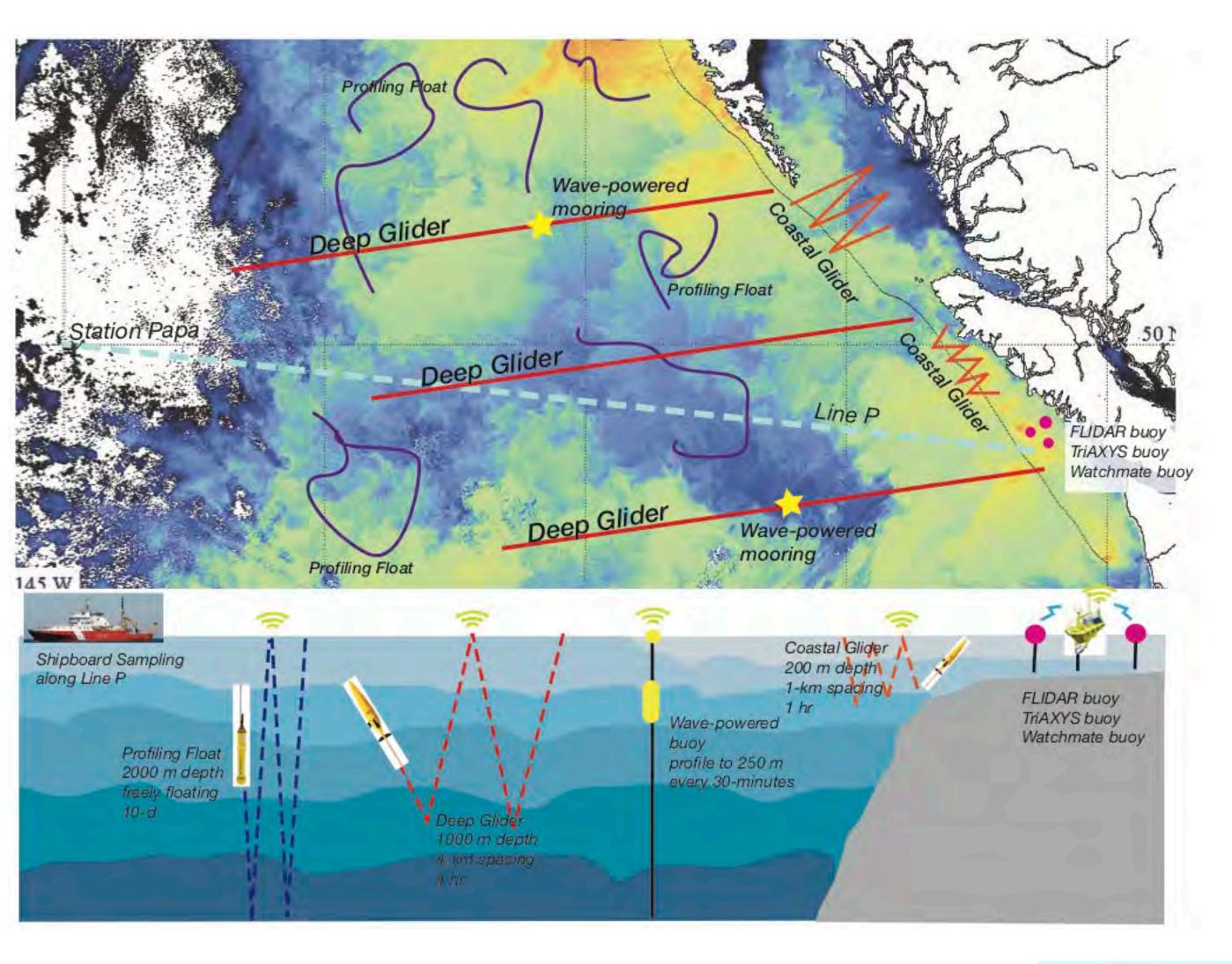


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kkk Ocean **Physics** Group

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 - 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)

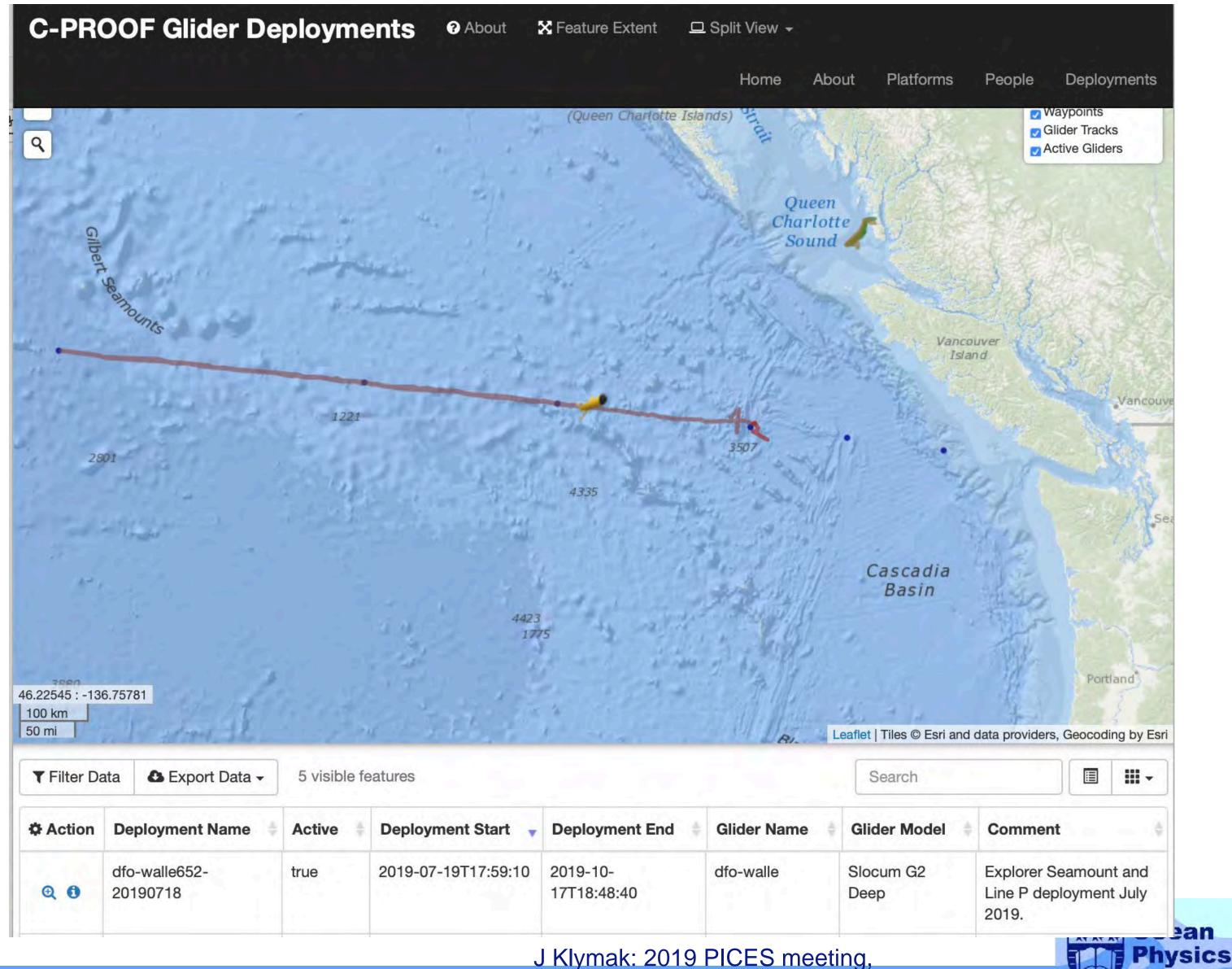




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C-PROOF: <u>http://cproof.uvic.ca</u>

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2019.		true	2019-07-19T17:59:10		dfo-walle		Explorer Seamount Line P deployment 2019.

Victoria

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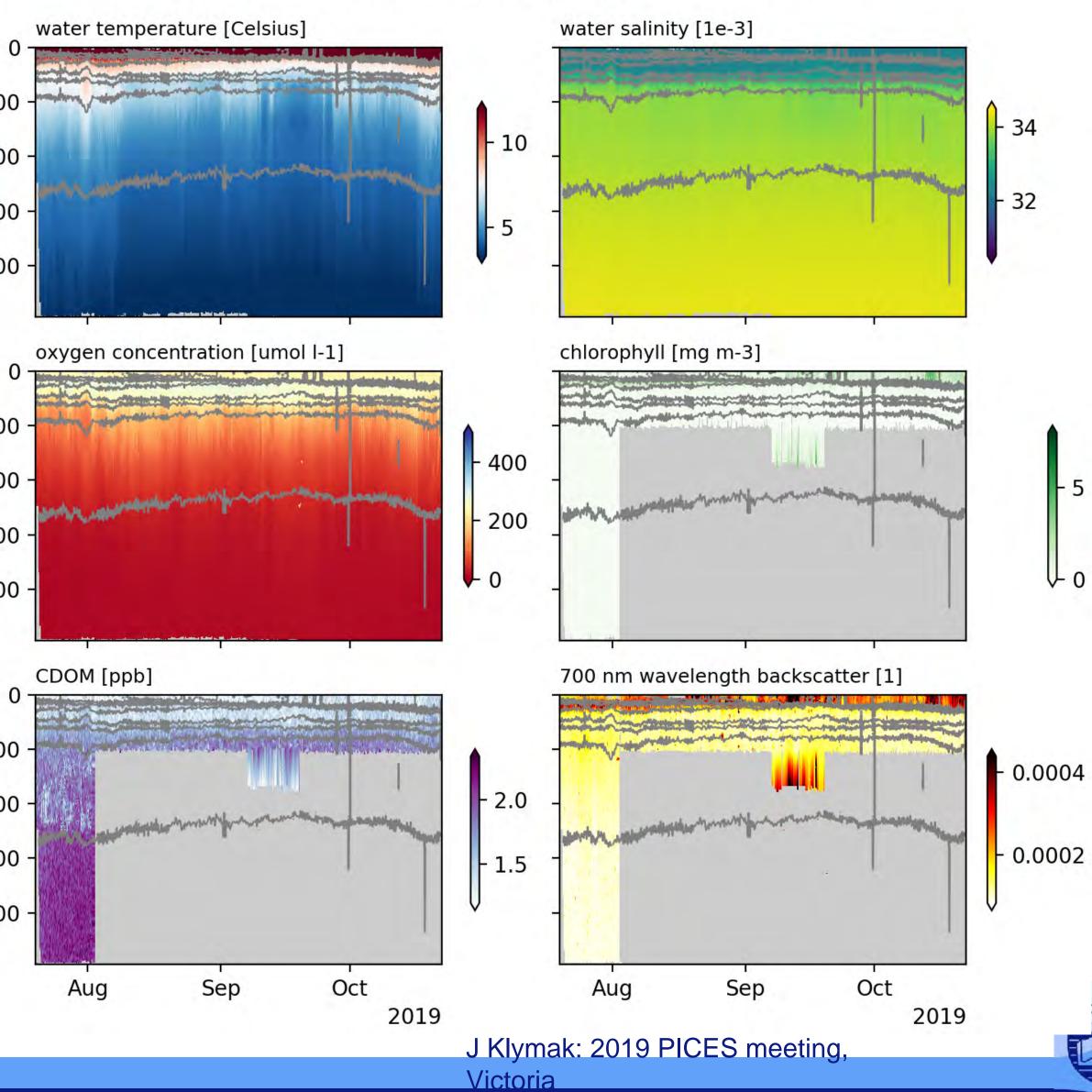
Group



 Submesoscale sampling important to 	20
characterize lateral stirring and to test	
models.	[m] 40 60
Continue work from ships:	H 60 C 80 80
• combine ADCP and MVP (better	80
KE decomposition, APE estimates,	
and more spice statistics)	20
repeat different seasons (Line P	40
regular cruises)	60
• Autonomous sampling:	80
gliders for lateral variability all	
seasons	
• moorings for temporal anchor	20
	40
 multiple lines for correlation 	60
statistics, seeing signals propagate	80

C-PROOF: <u>http://cproof.uvic.ca</u>

Processed: 2019-10-22 16:32, Lastdata: 2019-10-22T08:51



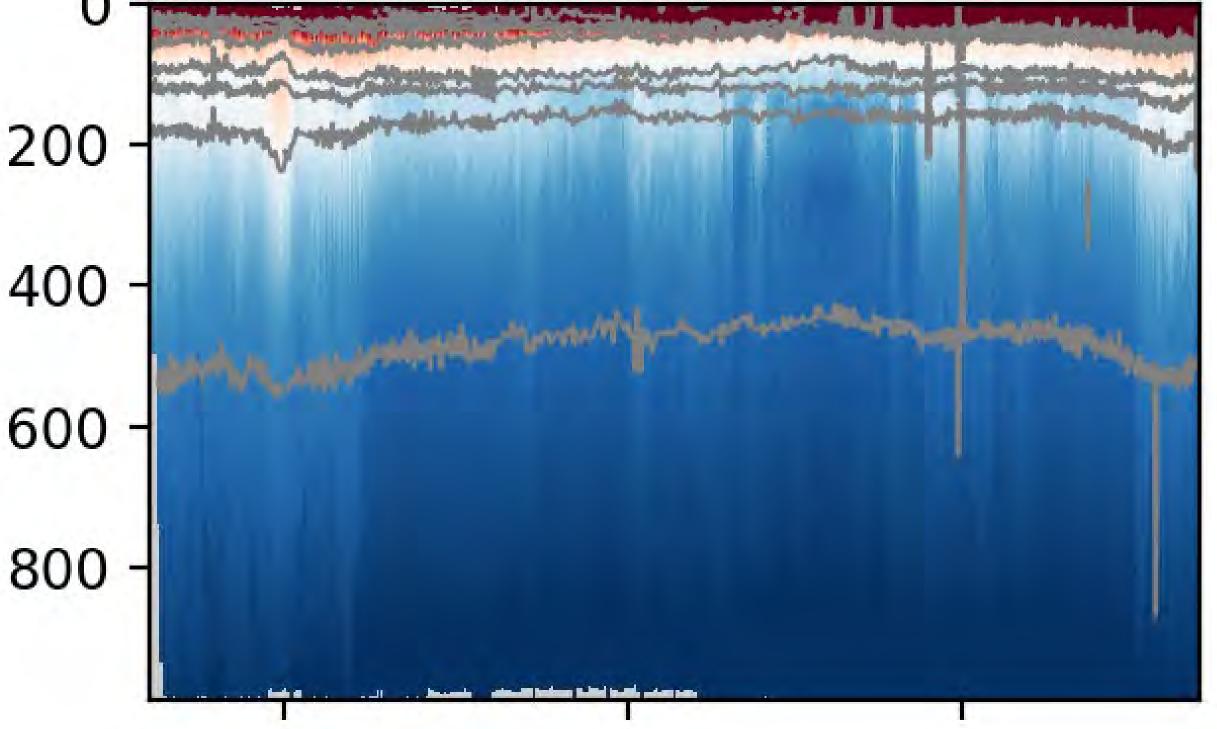
Submesoscale sampling important to characterize lateral stirring and to test models.

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Plans

C-PROOF: <u>http://cproof.uvic.ca</u>

water temperature [Celsius]

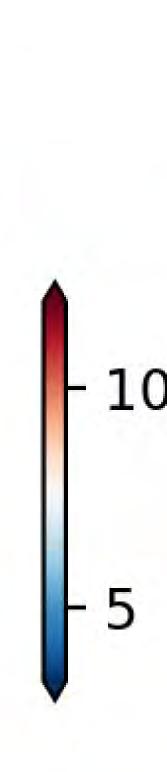




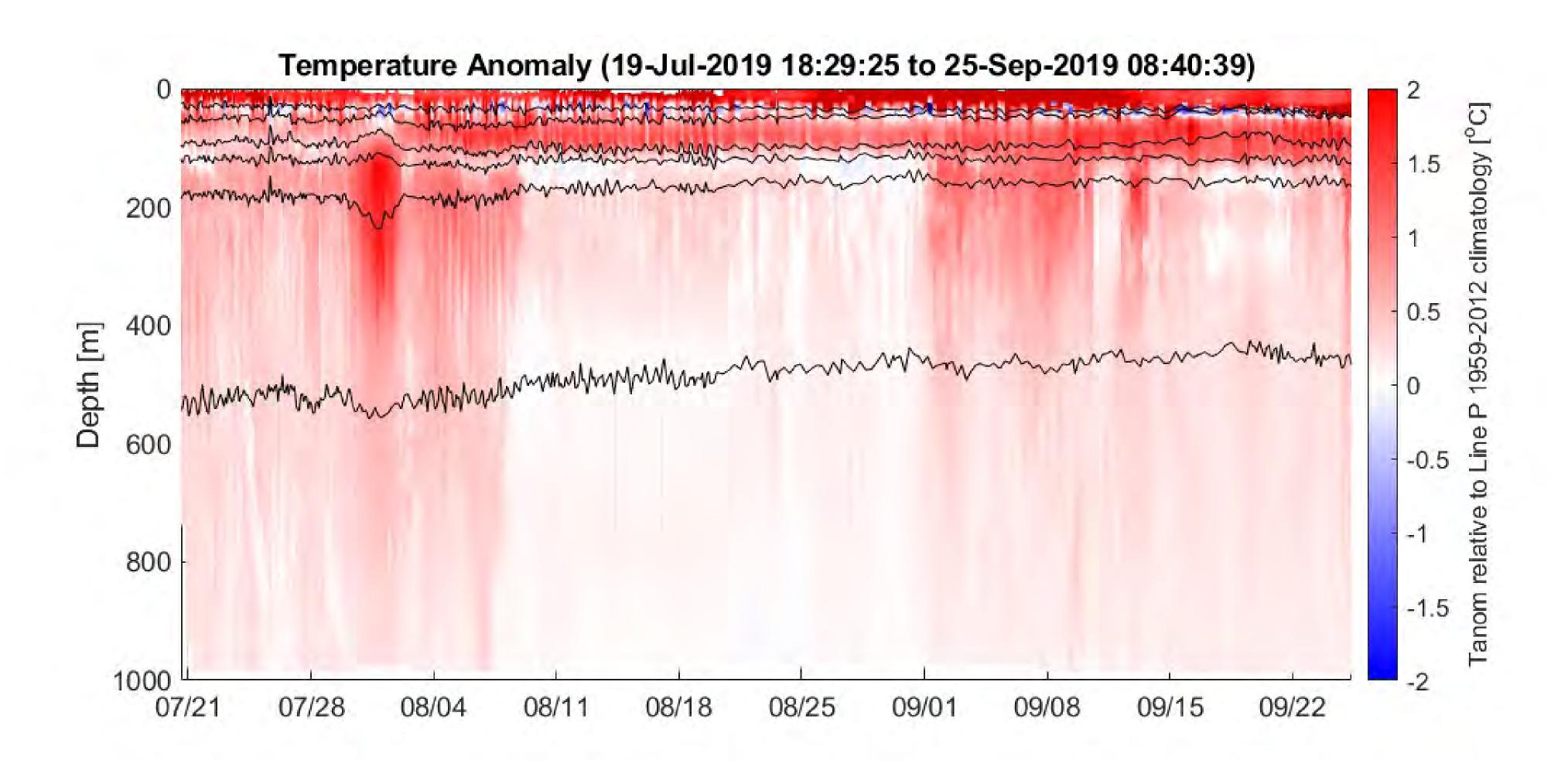


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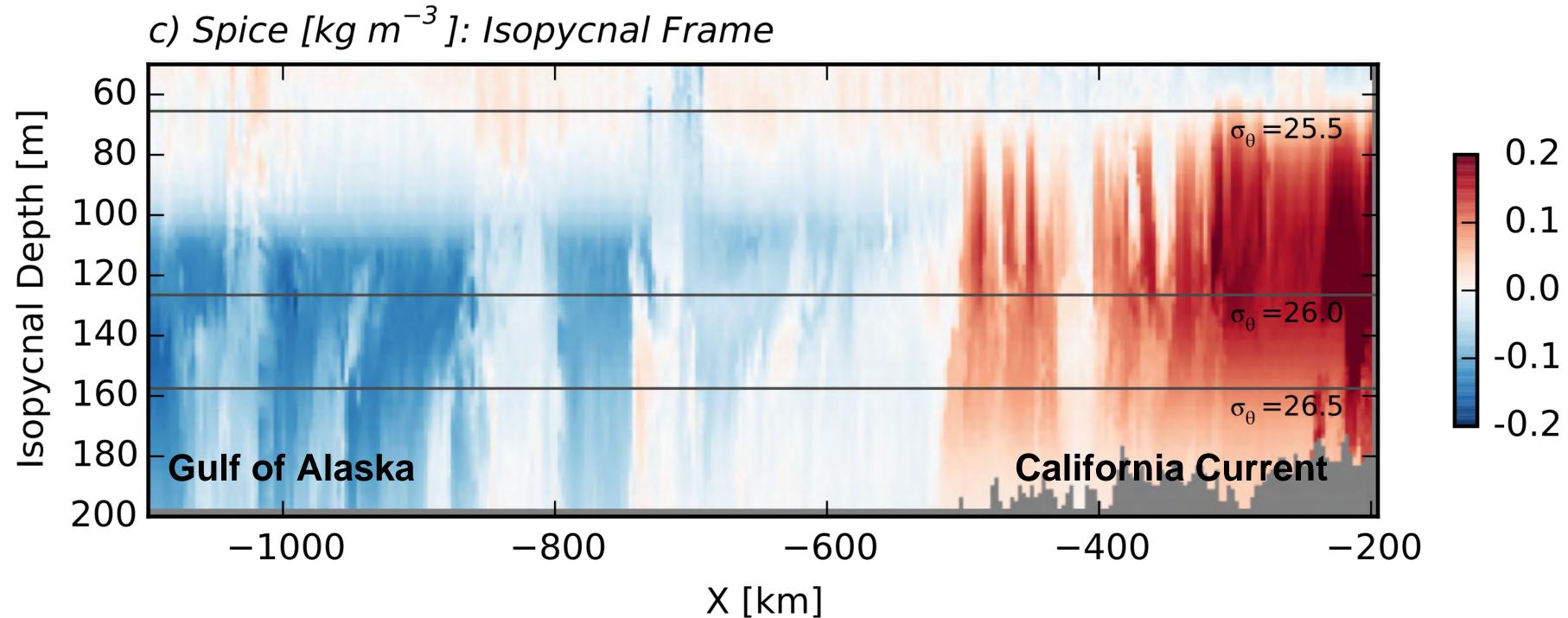


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Submesoscale observations in the Northeast Pacific

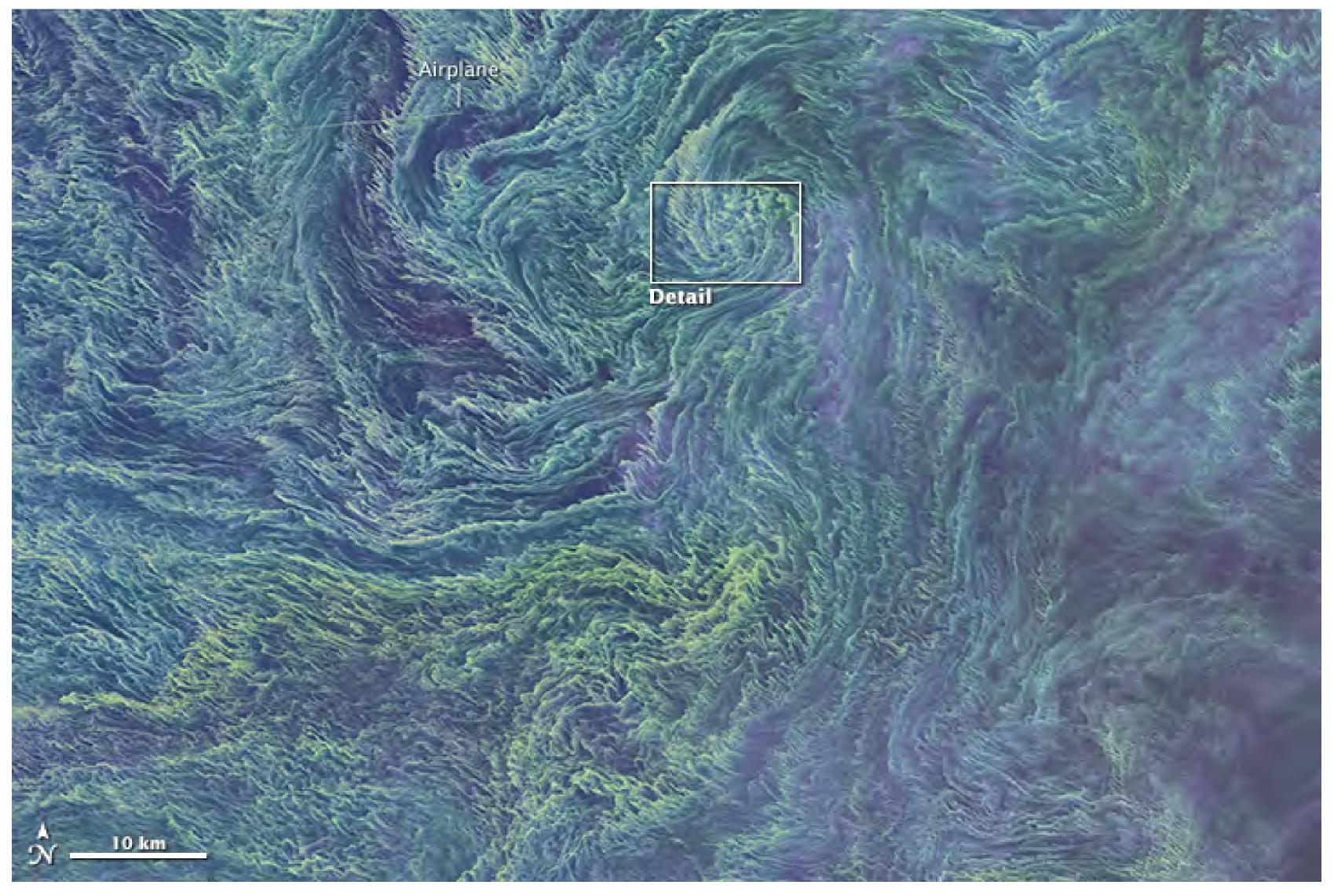
Jody Klymak **University of Victoria**







Physics Group



Cyanobacteria **Baltic Sea**

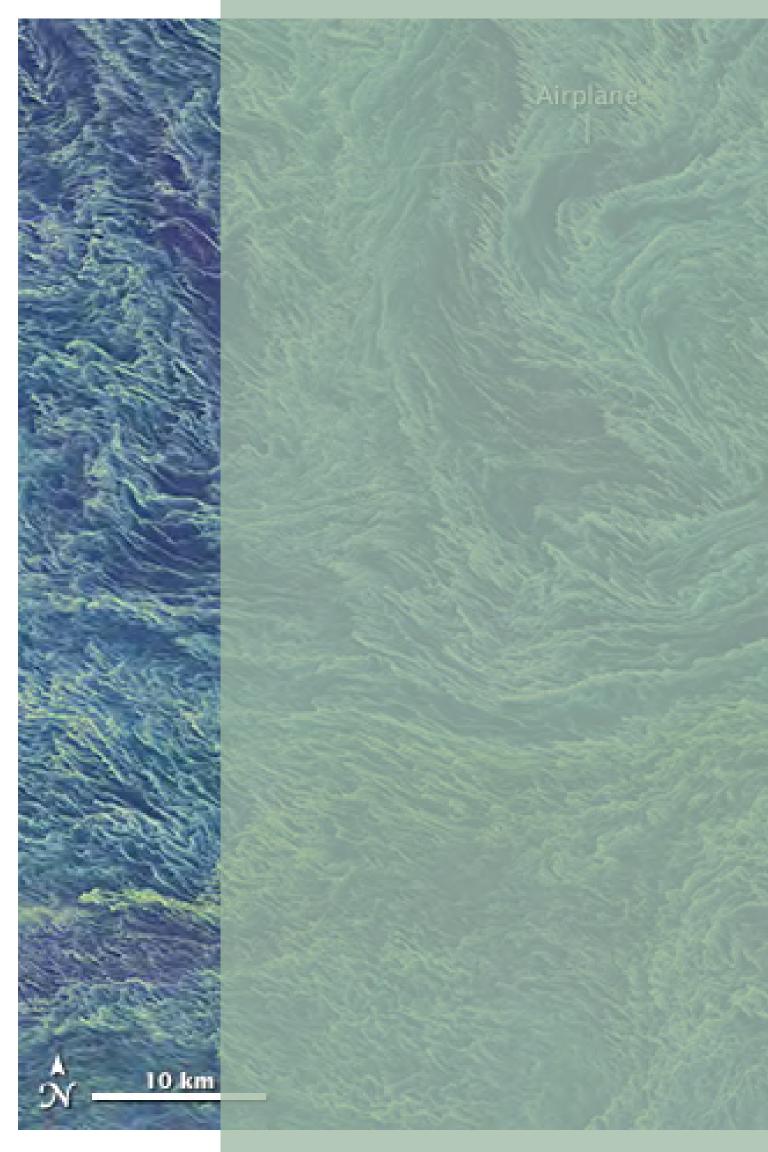
NASA, Earth Observatory

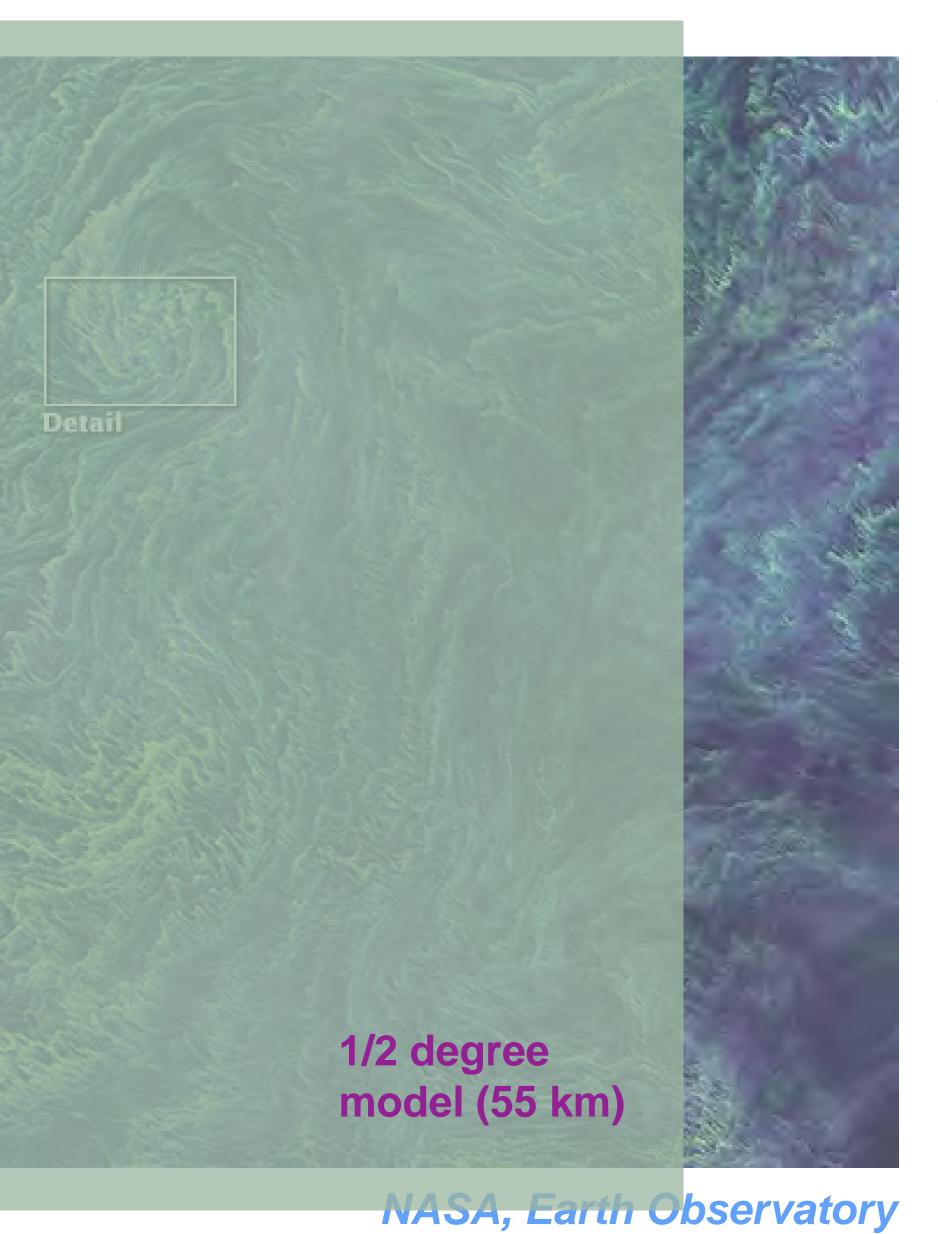


J Klymak: 2019 PICES meeting, Victoria







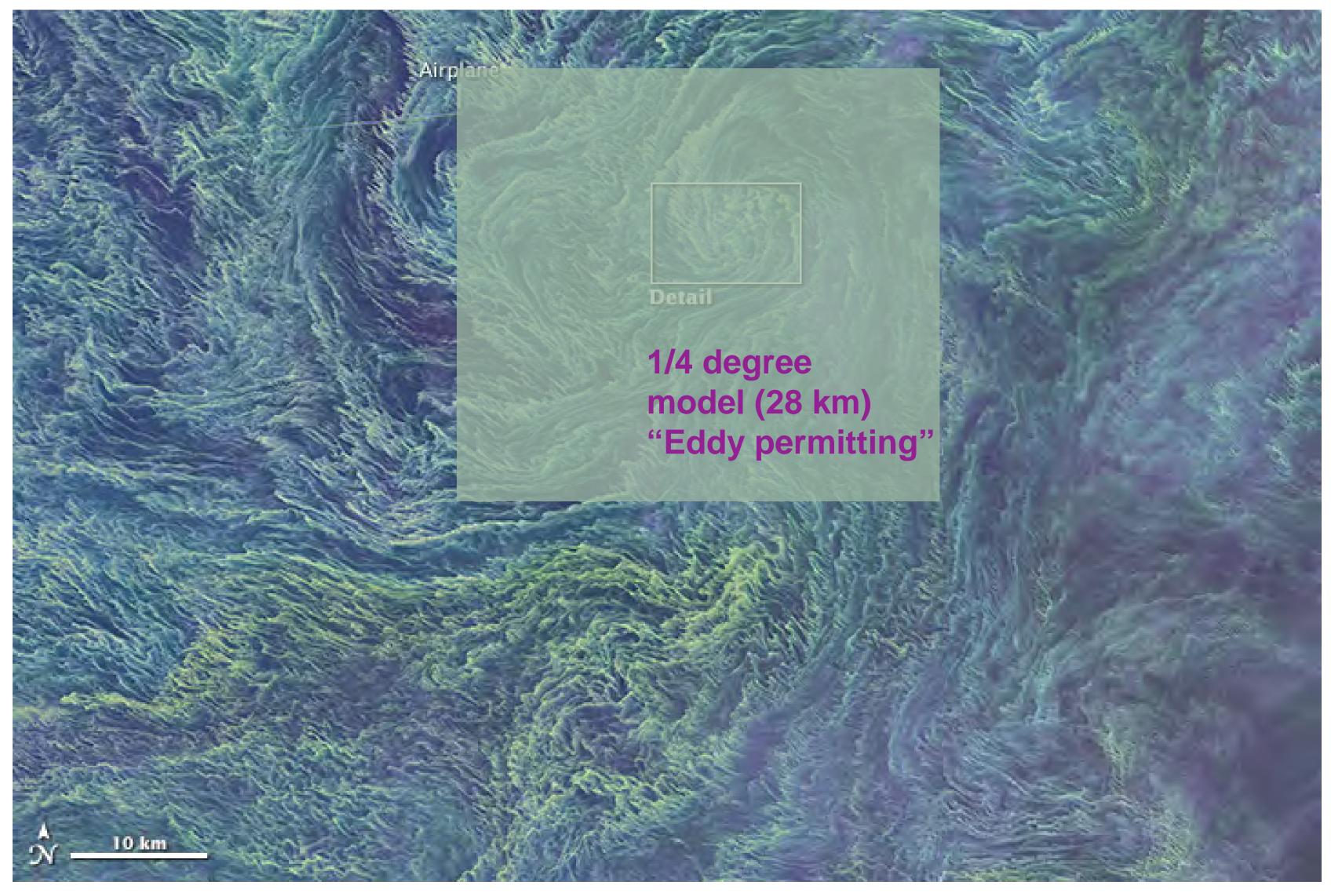


Cyanobacteria **Baltic Sea**

J Klymak: 2019 PICES meeting, Victoria







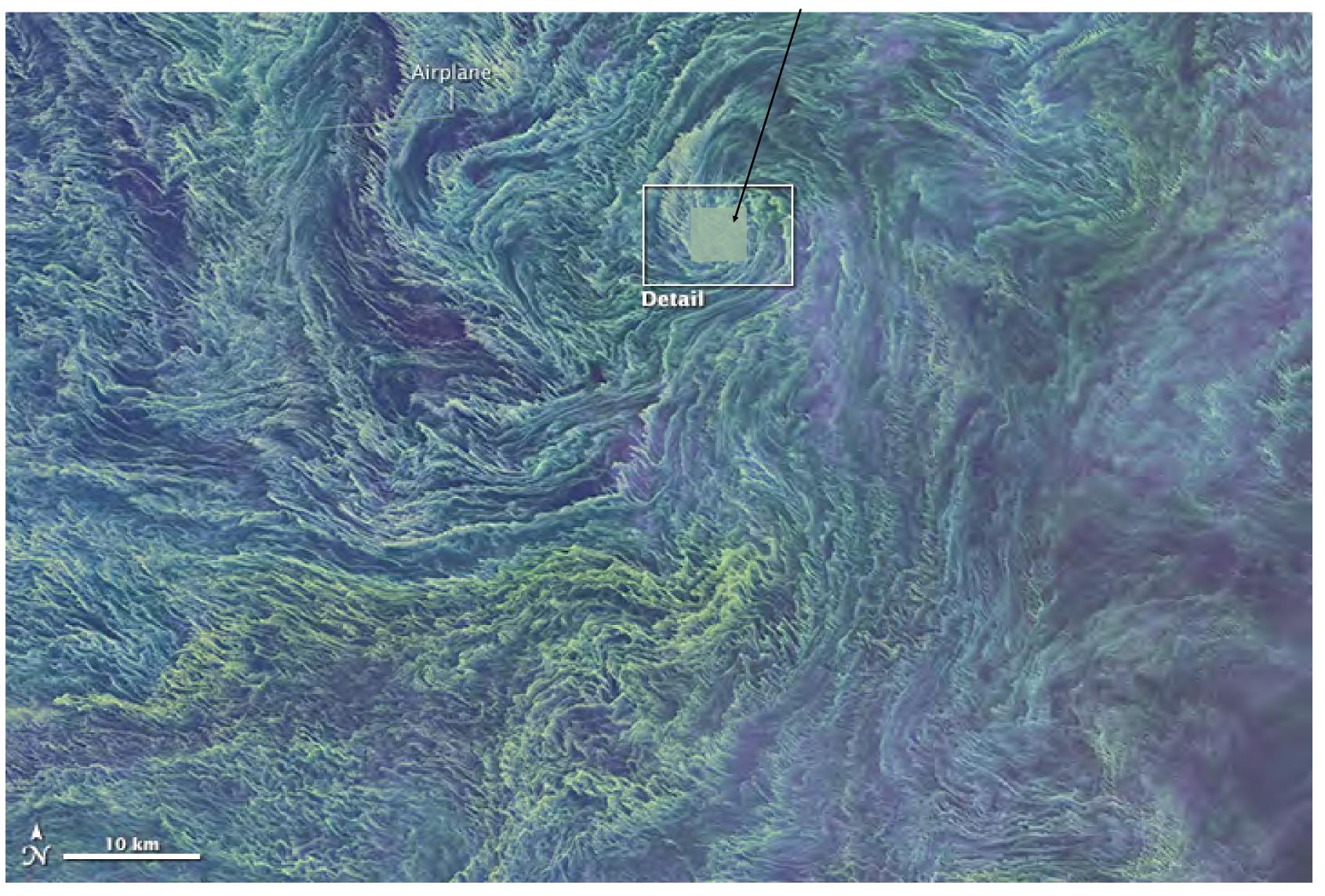
Cyanobacteria **Baltic Sea**

NASA, Earth Observatory



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1/32 degree model: Eddy resolving

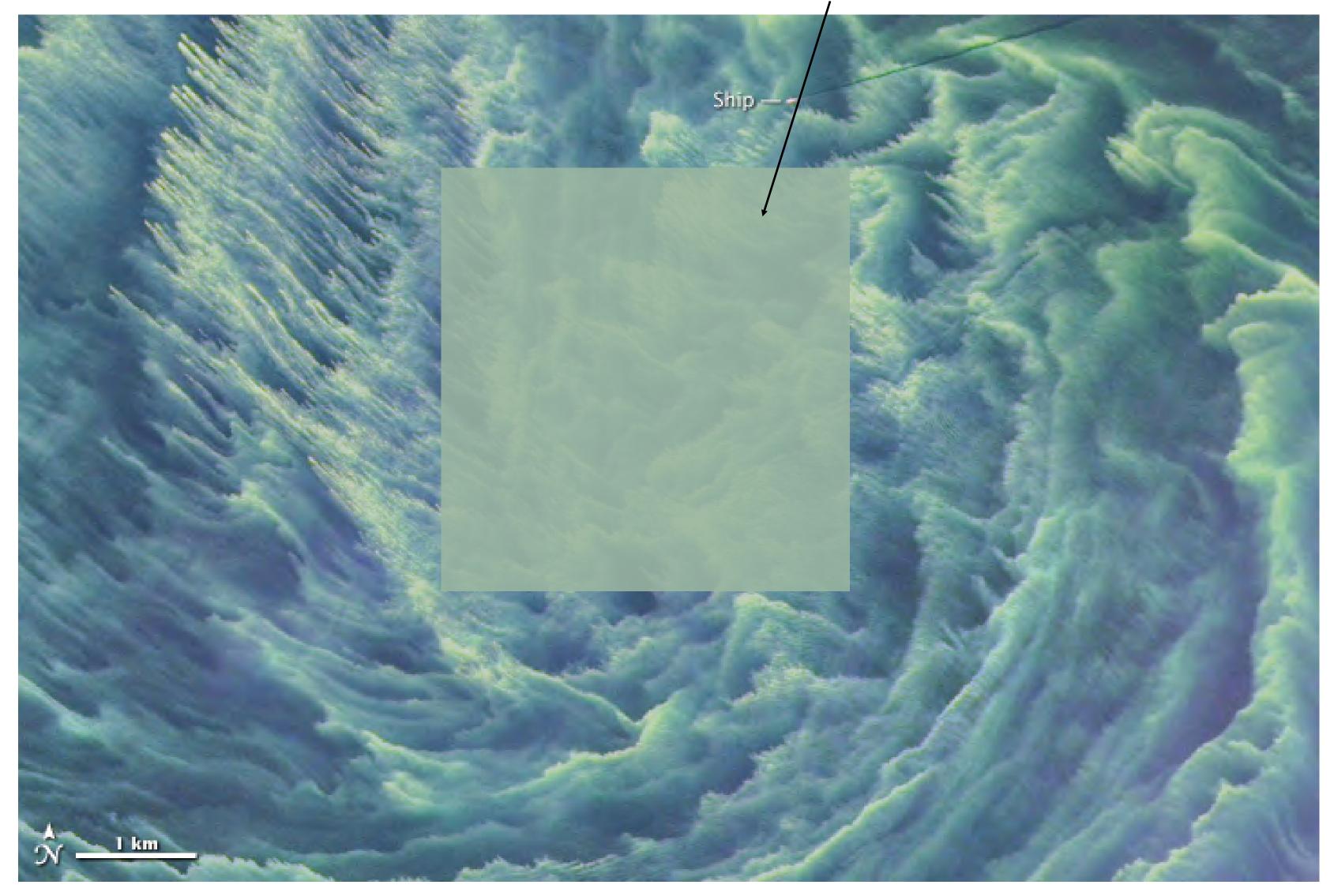
Cyanobacteria **Baltic Sea**

NASA, Earth Observatory



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1/32 degree model

Cyanobacteria **Baltic Sea**

NASA, Earth Observatory



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