S3-12394 2018 PTA Symposium @La Paz

Fine-scale variability of isopycnal salinity in the California Current System

Sachi Itoh (AORI, U Tokyo) &
Daniel L. Rudnick (SIO, UCSD)

Spray
Underwater
Glider

Ref. Itoh & Rudnick (2017, JGR)

Outline

1. **Variability of California Current System: observations with various resolution (brief review)**

   - Shipboard, satellite, drifter and spray observations at/ around CalCOFI stations

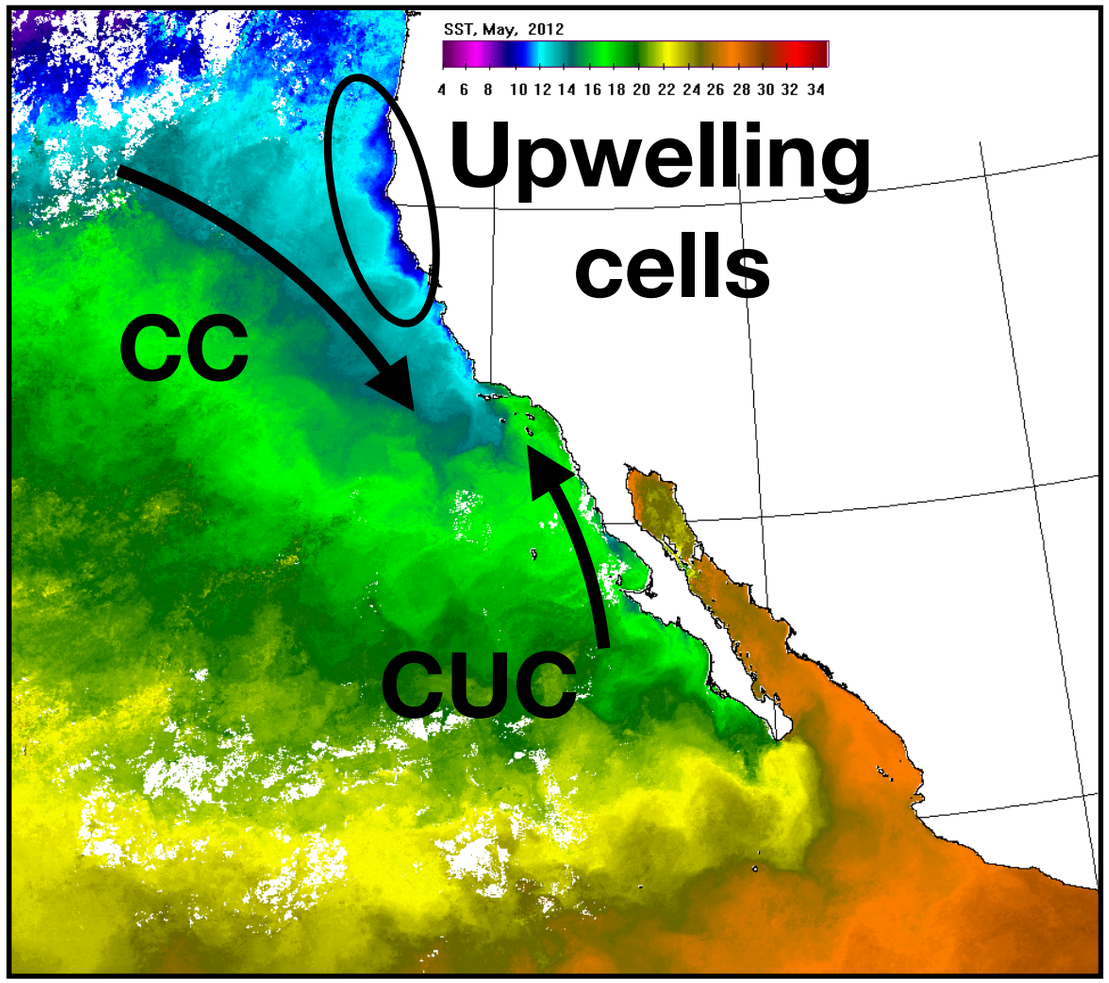
2. **Seasonal fluctuations of the fine-scale structure (Itoh & Rudnick 2017, JGR)**

   - Analysis of glider data obtained in 2007–2013

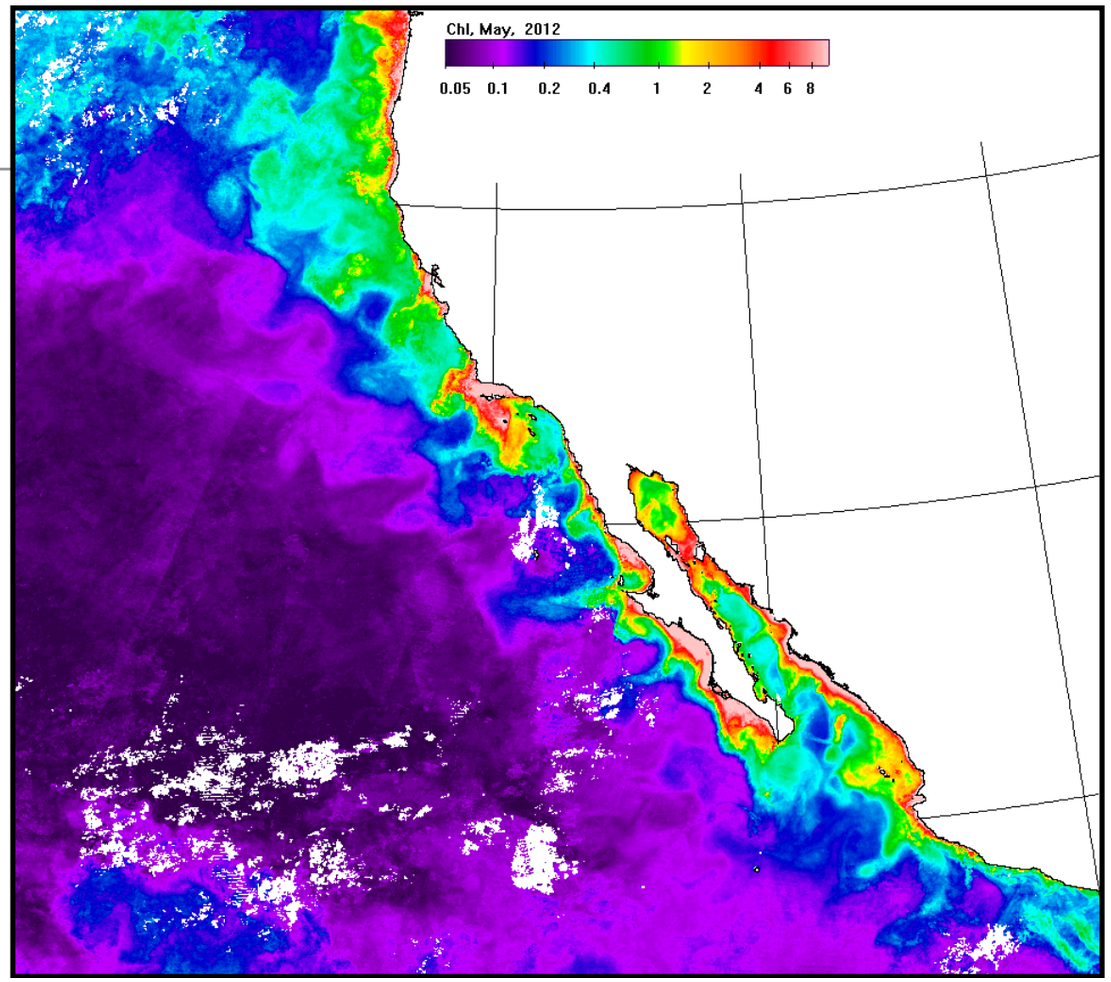
✓ Summary

California Current System

SST in May 2012



Chlorophyll *a* in May 2012



Downloaded from https://spg.ucsd.edu/Satellite_Projects/CAL/Full_res_sat_time_series_California.htm
(Kahru et al. 2012)

CC: California Current

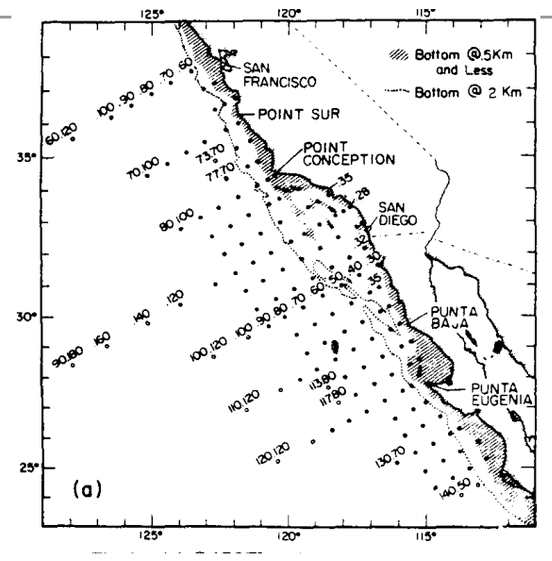
CUC: California Under Current

Exploring the variability of the CCS

- **CalCOFI Station data**

  $\Delta x \sim 50–100$ km, $\Delta t \sim 50–100$ d

(Lynn & Simpson 1987)



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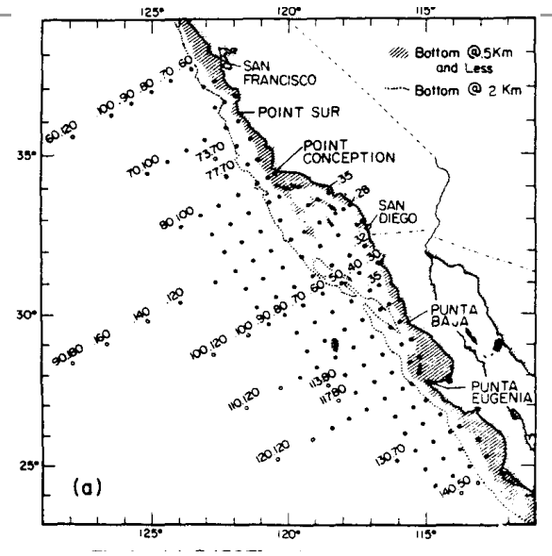

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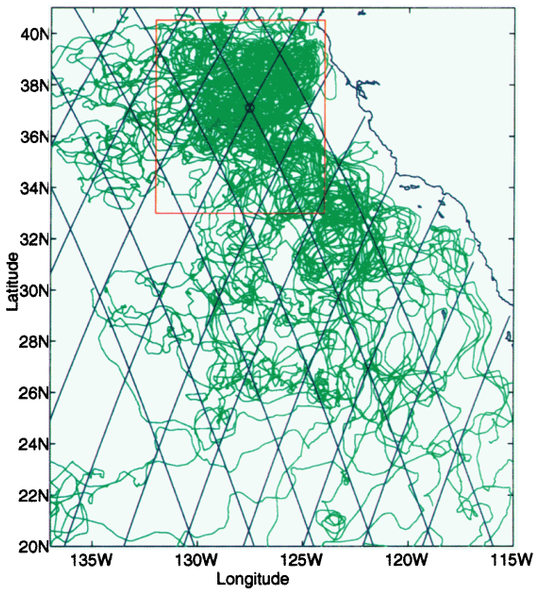

- **Surface drifter & satellite altimetry**

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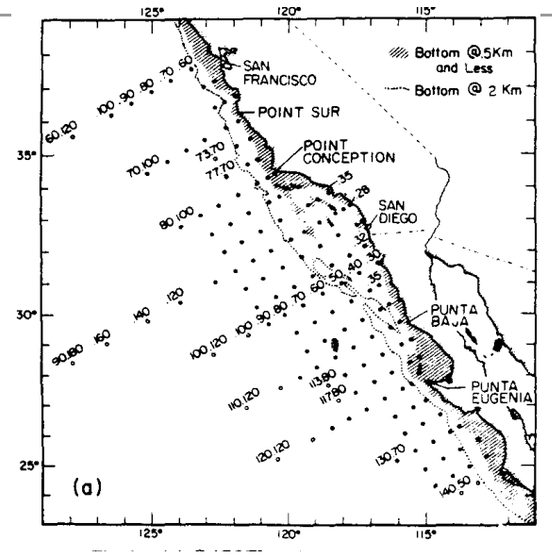

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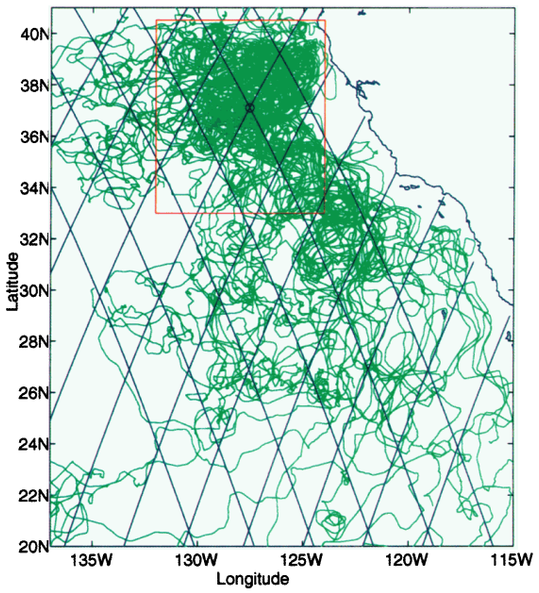

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Only for the surface

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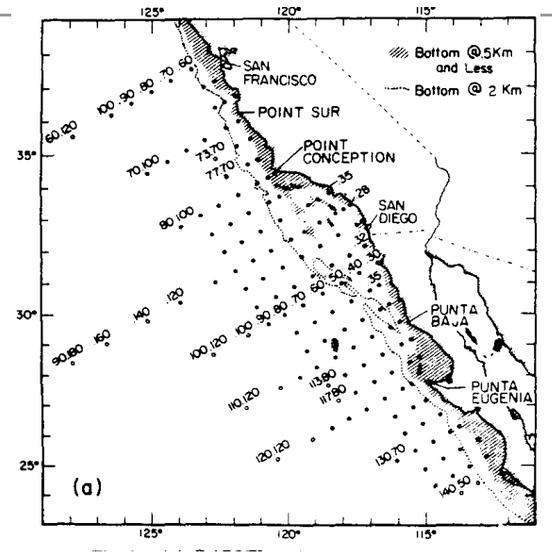

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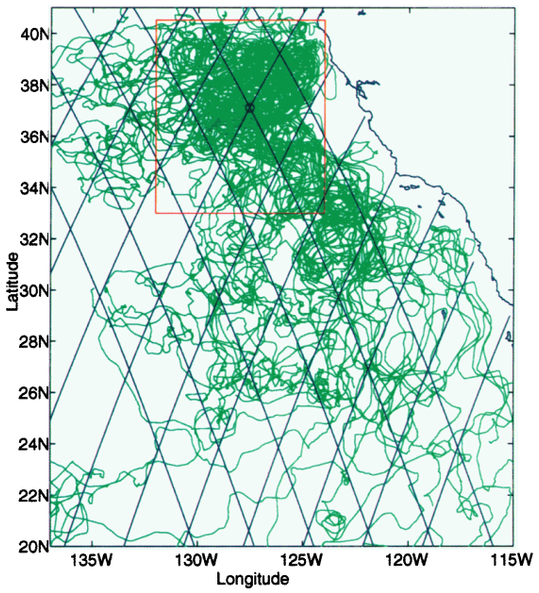

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Models revealed fine-scale & baroclinic fluctuations in the CCS

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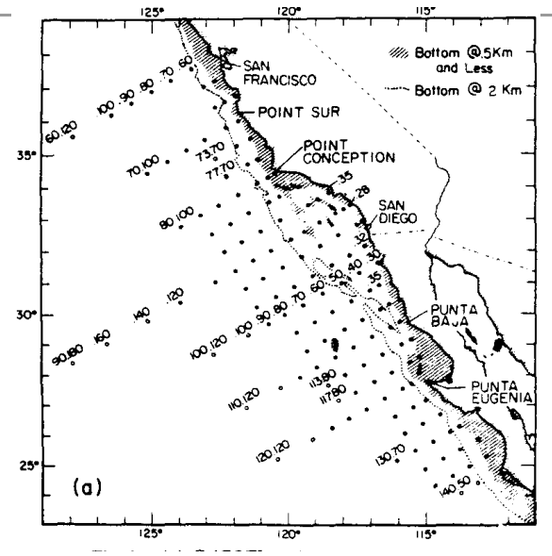

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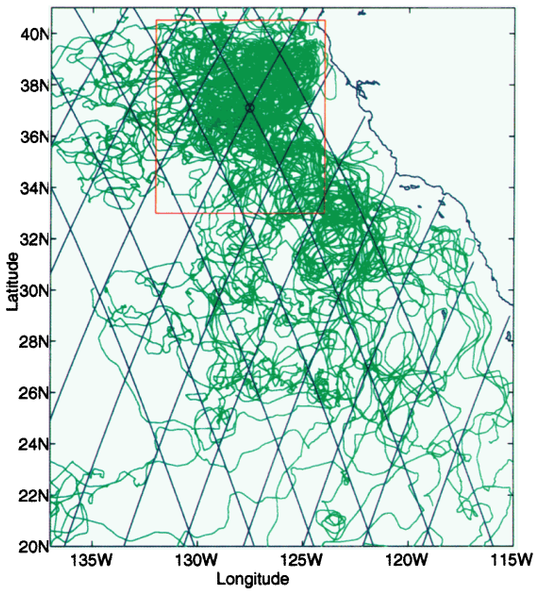

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Only for the surface

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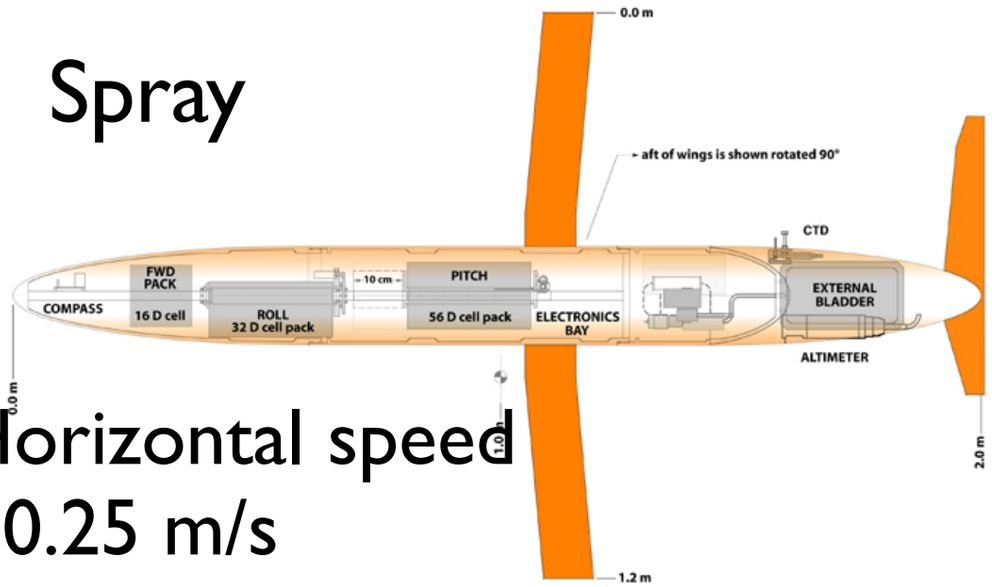
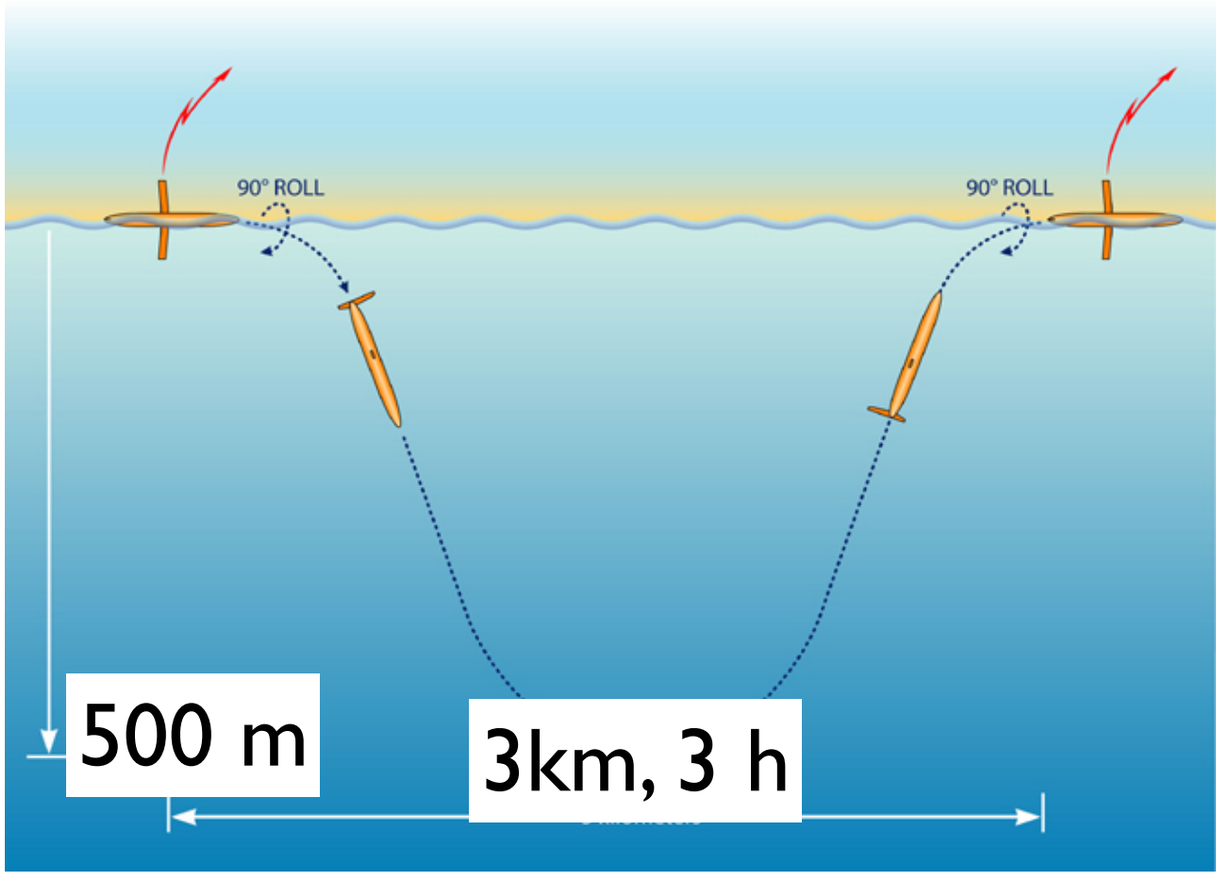
Needs for fine-horizontal-spacing & frequent vertical profiles

California Underwater Glider Network (CUGN: 2006–)

Spray



Horizontal speed
~0.25 m/s



http://spray.ucsd.edu/

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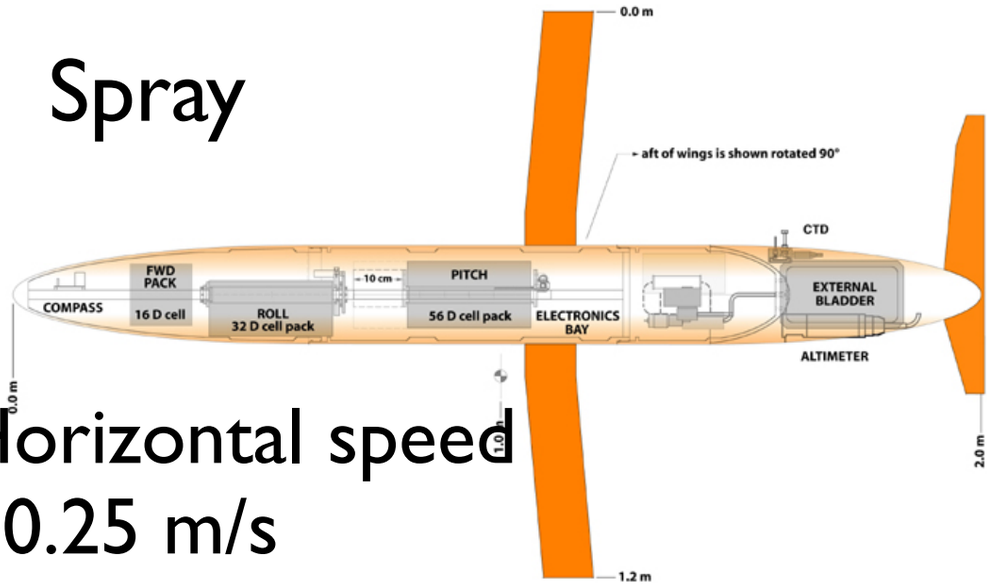

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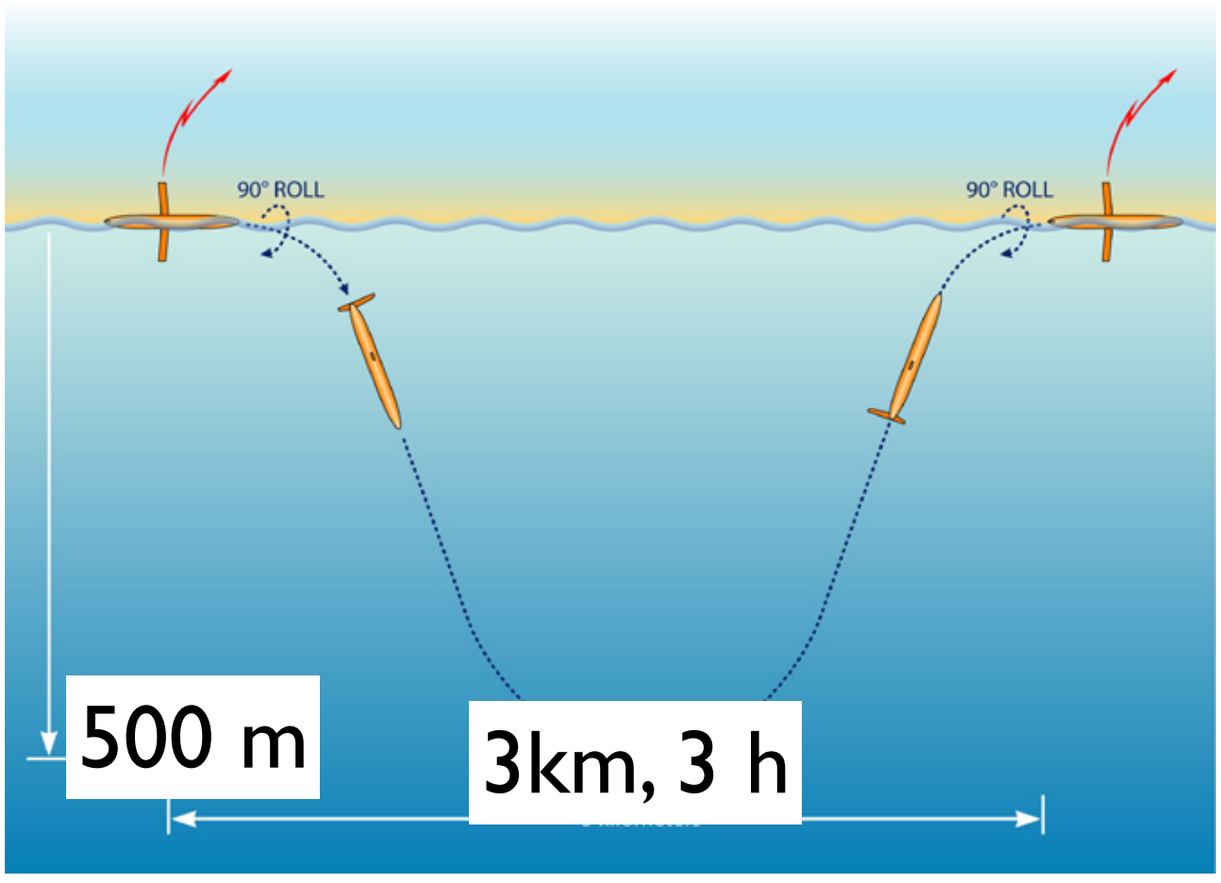
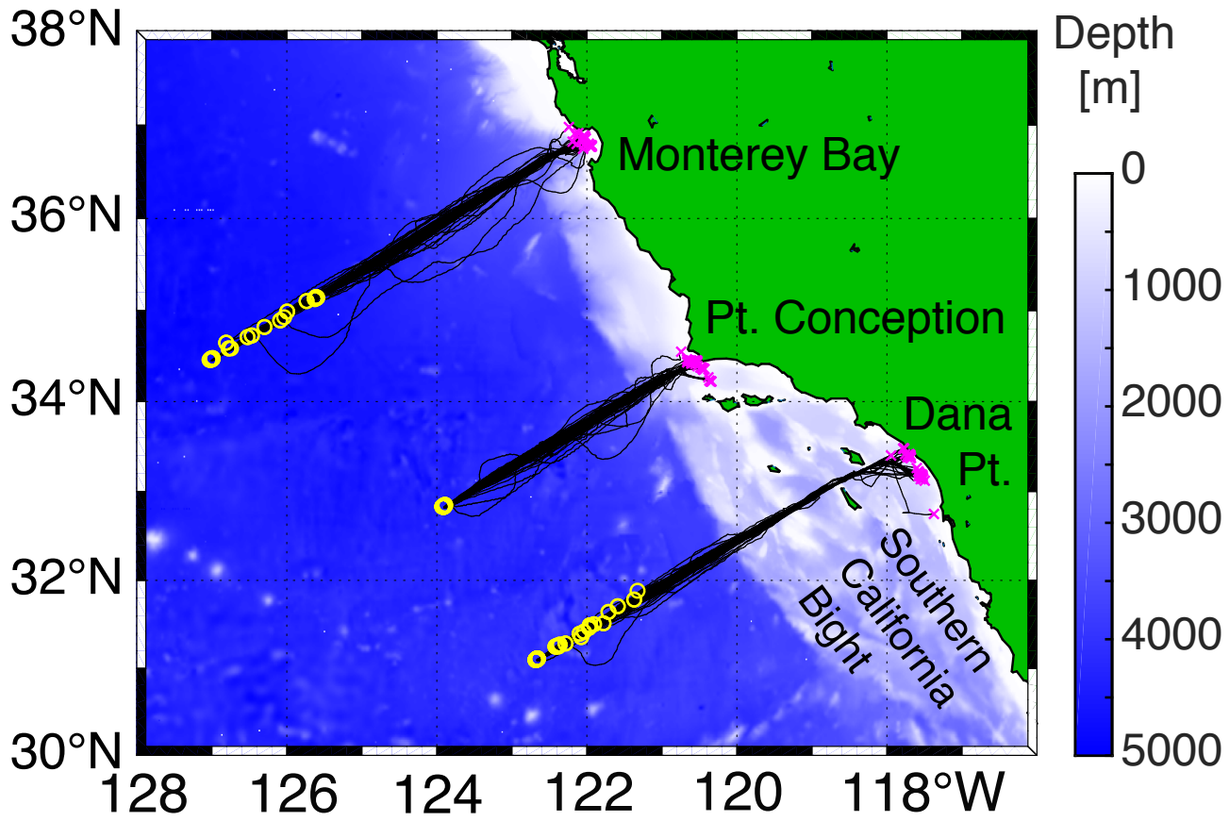




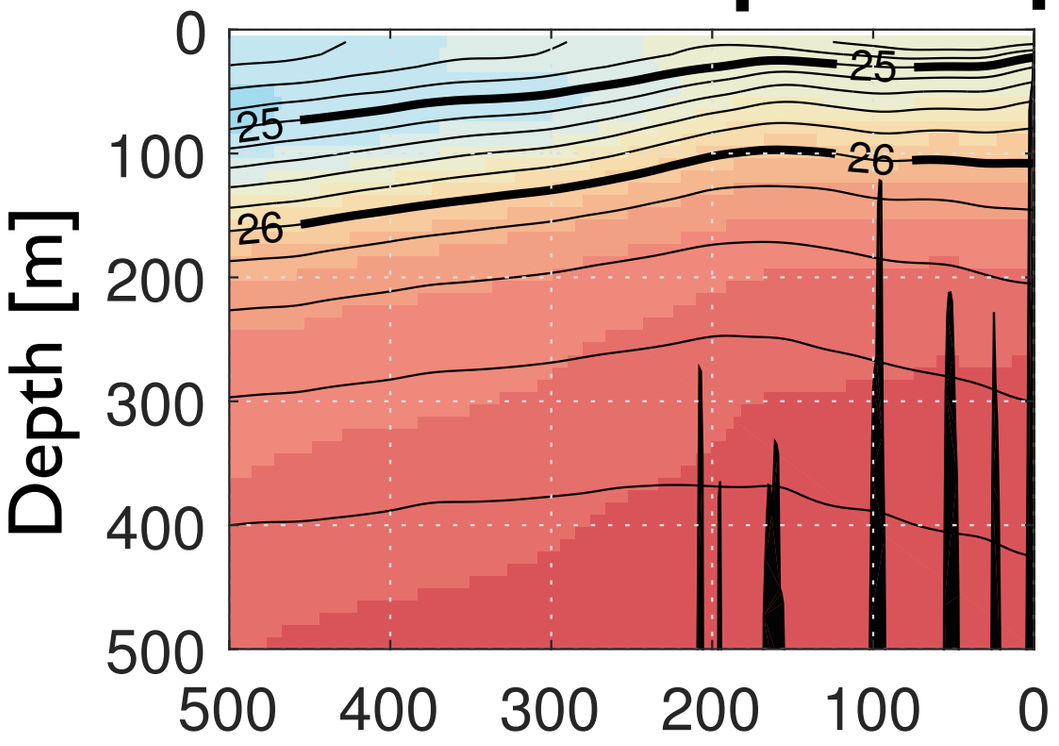
Monitoring 3 CalCOFI lines
with a cycle of 2–3 weeks

http://spray.ucsd.edu/

Climatology: examples of salinity along L90

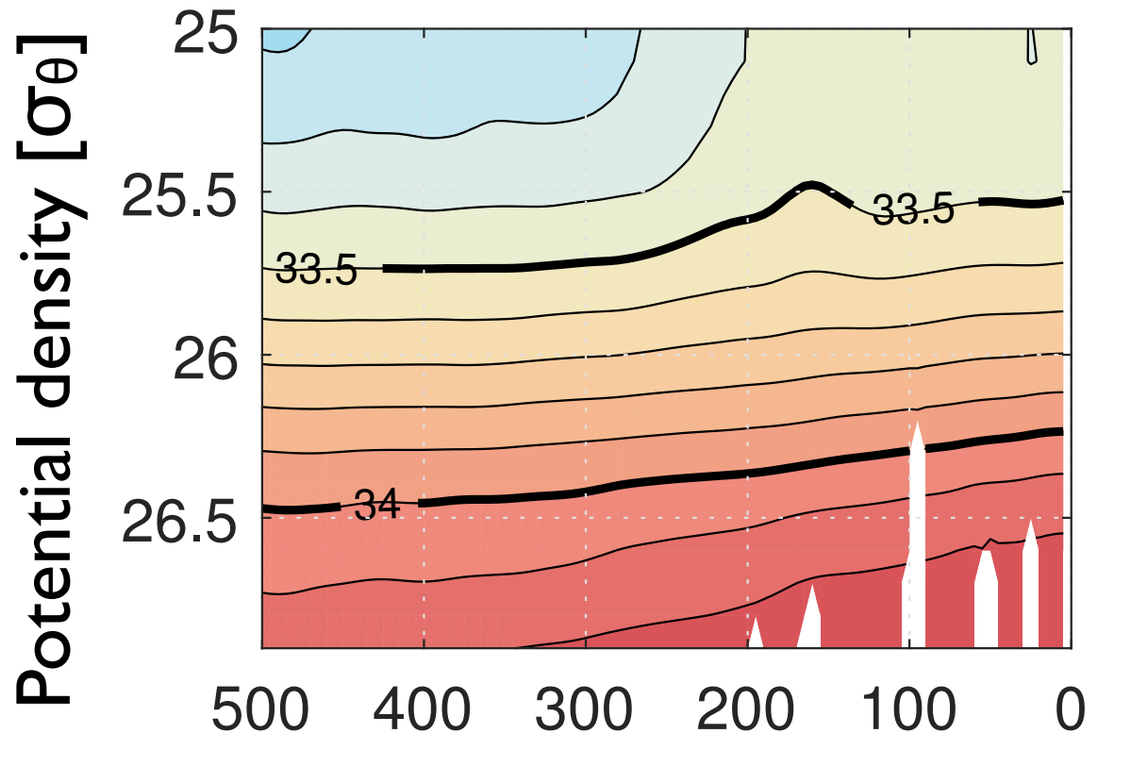
(Data from Rudnick et al. 2016)

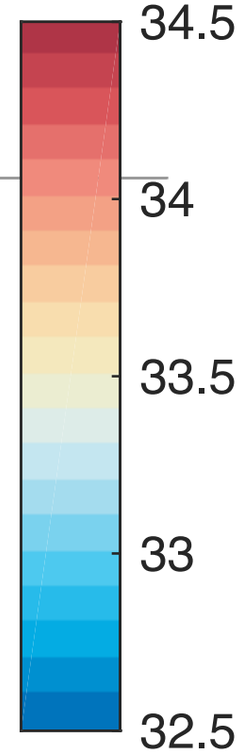
Southern California Bight



Annual mean isobaric salinity (color) and potential density (contour) along L90

Annual mean isopycnal salinity along L90

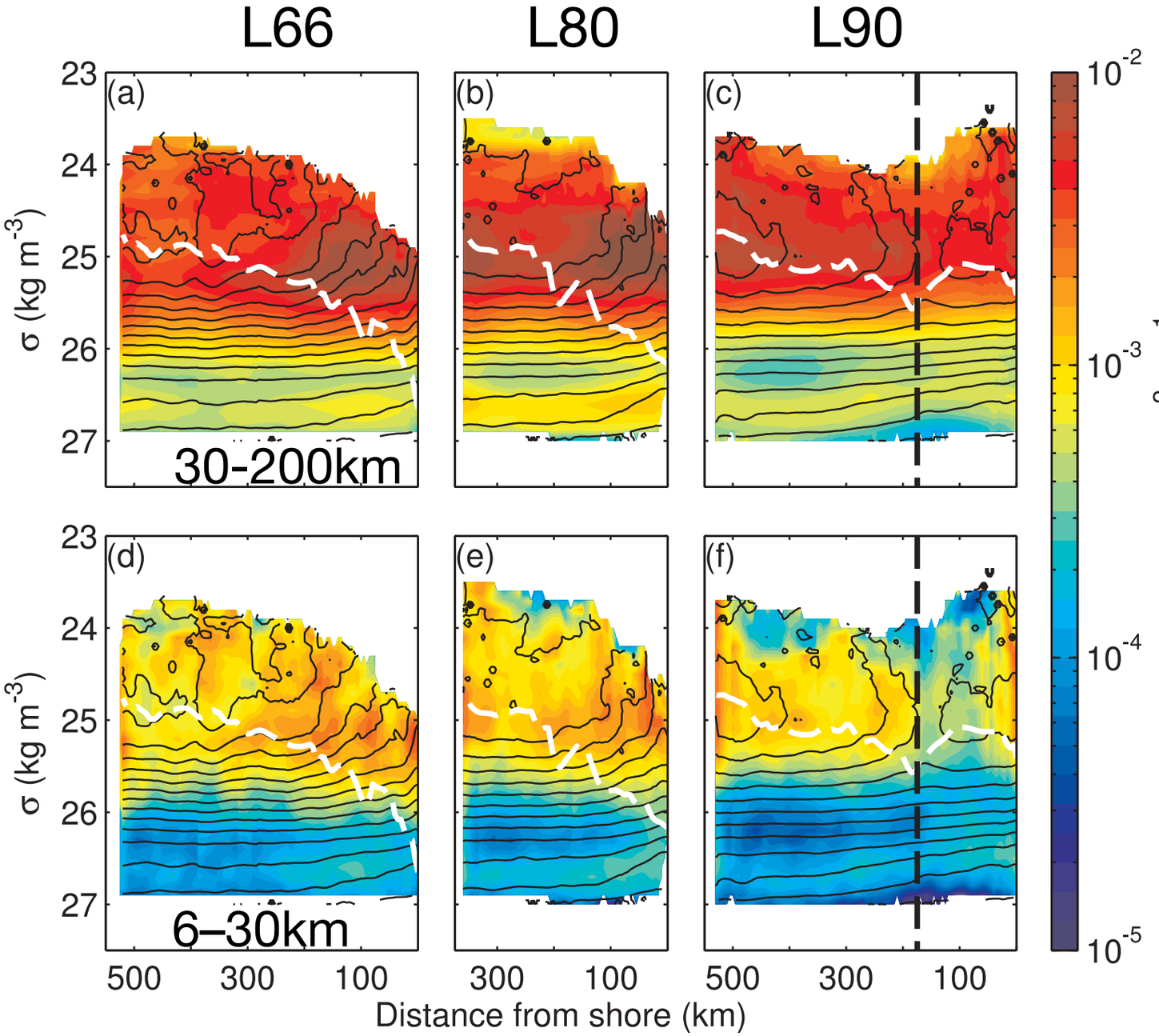




Spatial variability (From 2006–2010 CUGN data)

Todd et al. (2012)

- Maximum: within the remnant mixed layer
- Minimum: around 26.3 kg m^{-3}
- Spectral curve $P(k)$ for $S \sim k^{-2}$ (for $\partial S/dx \sim k^0$)



Annual Isopycnal salinity variance

White dashed line: densest outcropping isopycnal

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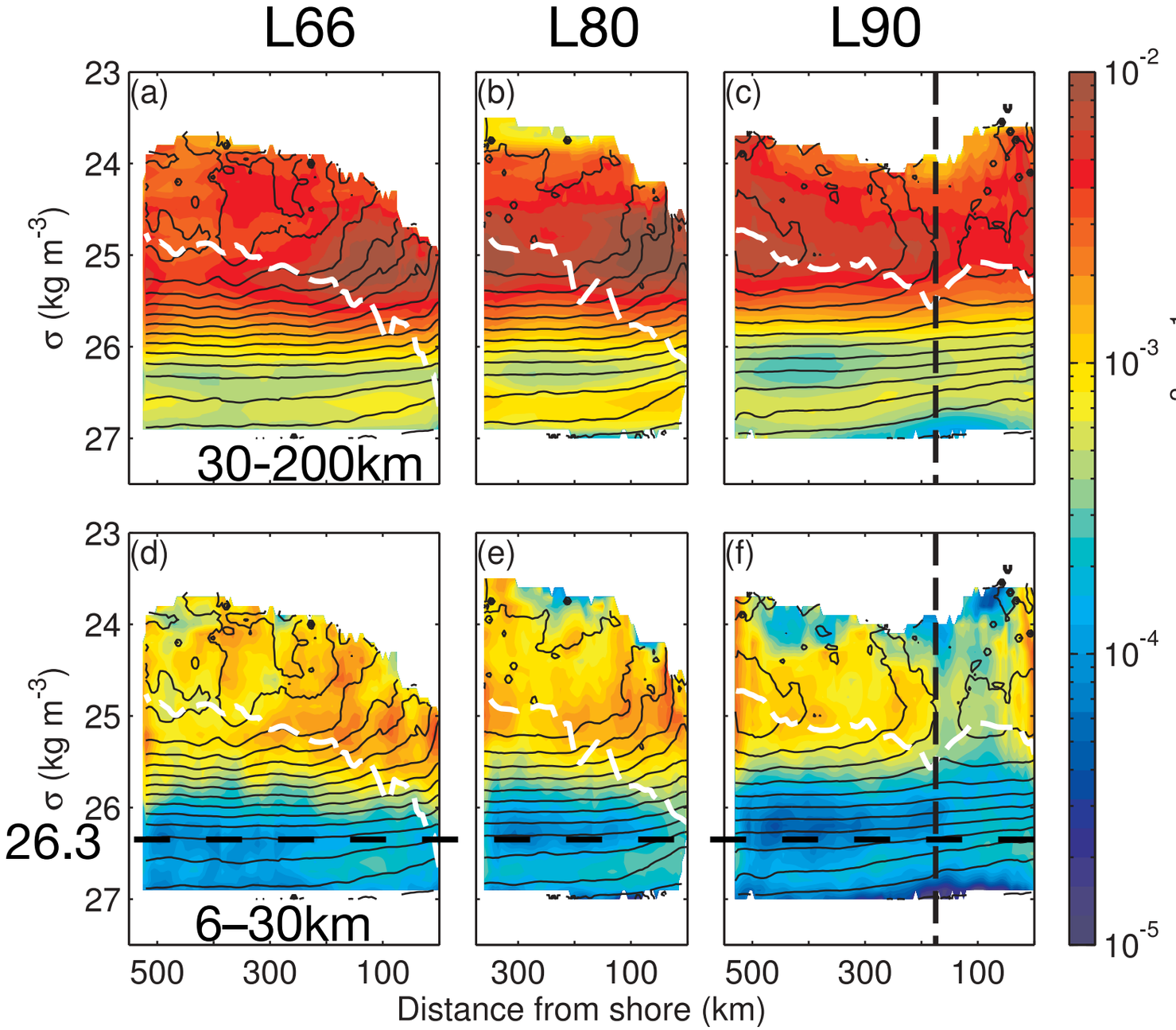

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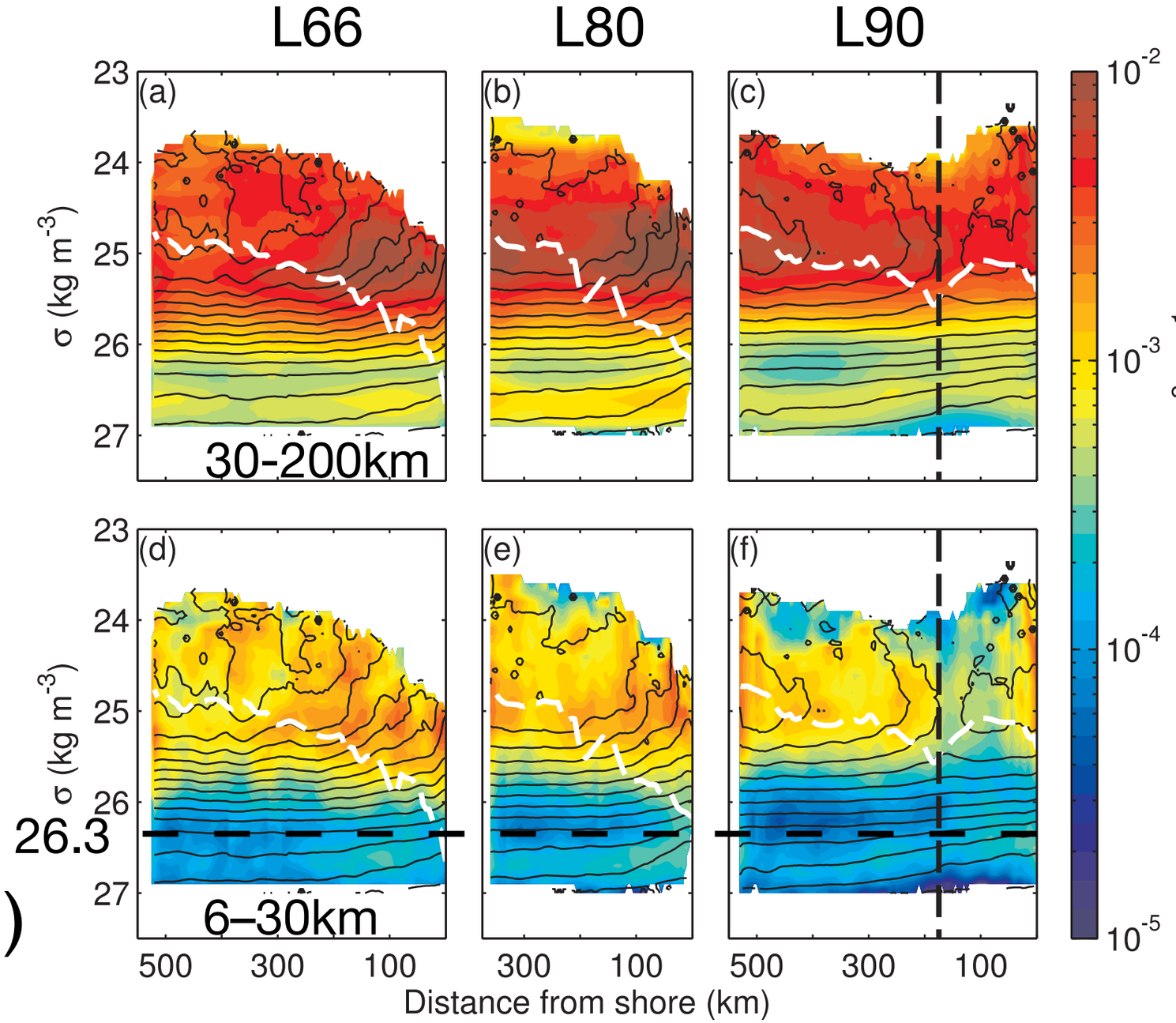
k^0 slope:
<u>different from</u> theory (k^{+1})
for enstrophy inertial range of QG flow



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~170 transects until 2010 → Annual mean (Todd et al. 2012)

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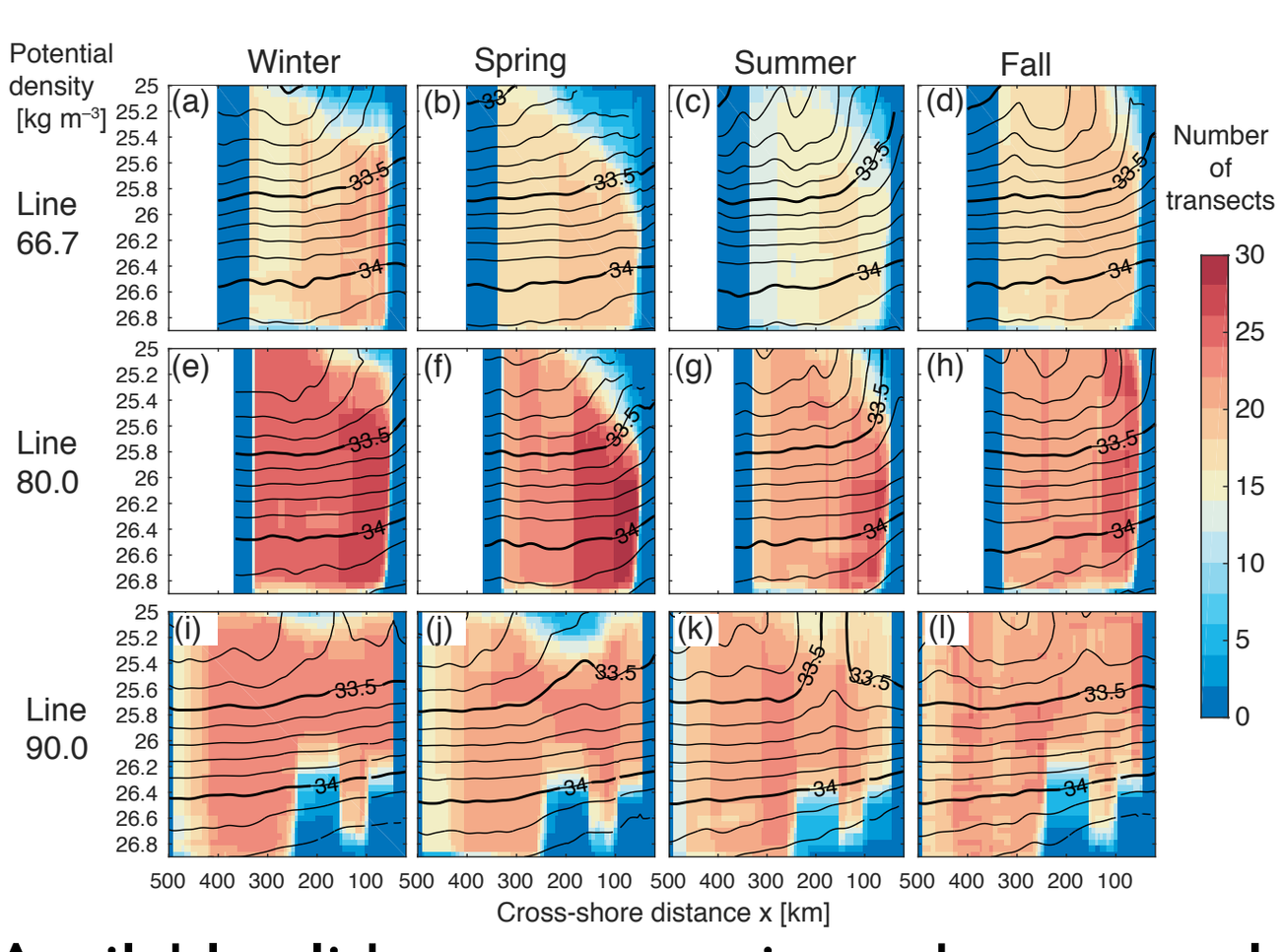


Available glider transects in each season along each line

Focus

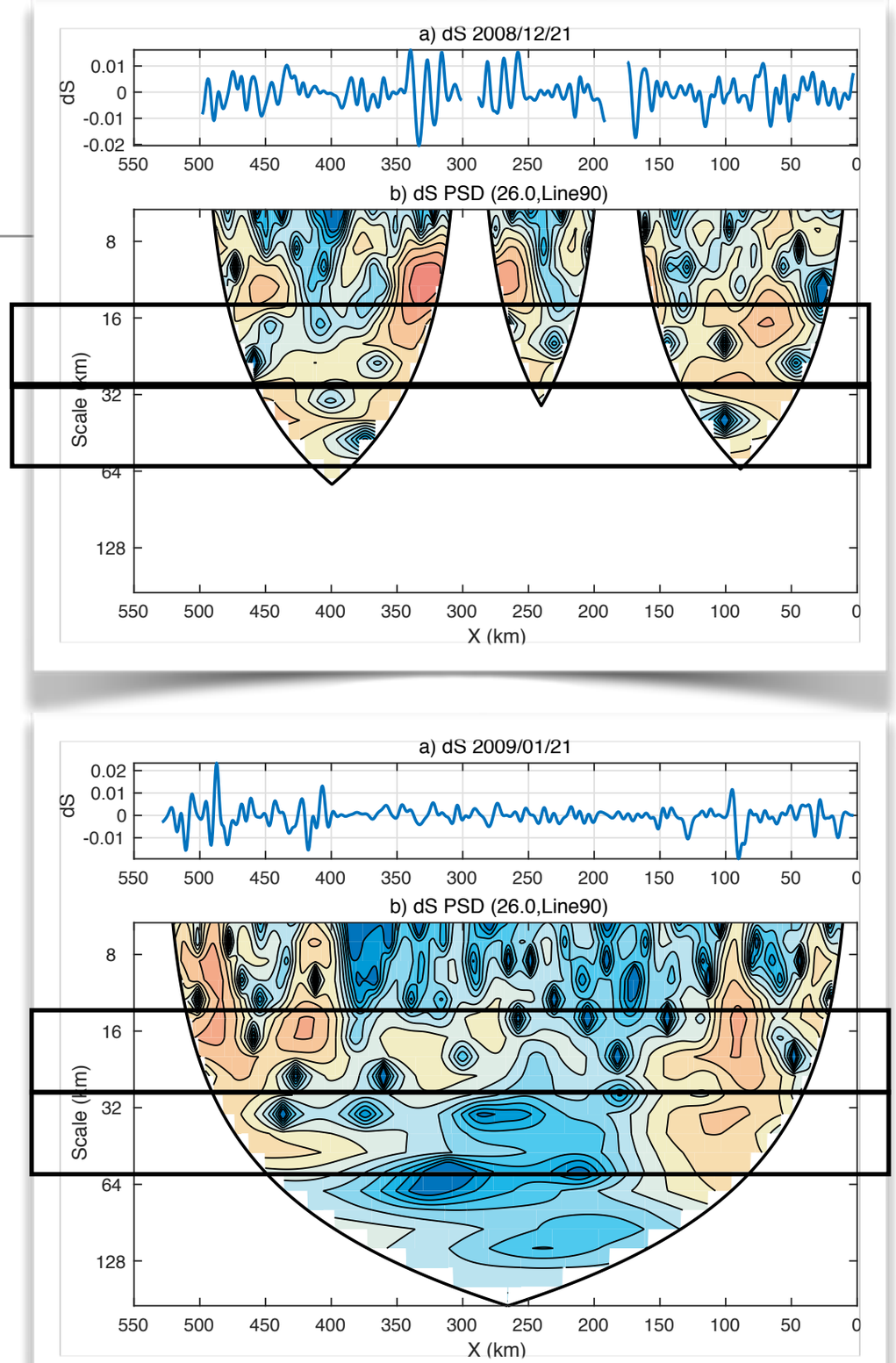
On fine-scale structure, especially,

- Seasonal fluctuation
- Lateral structure
- Spatial distributions of spectral curves

Itoh & Rudnick (2017)

Wavelet analysis

- Wavelet analysis on **isopycnal salinity**



Examples of $\partial S/dx$ & wavelet power spectra for an isopycnal data

Itoh & Rudnick (2017)

Wavelet analysis

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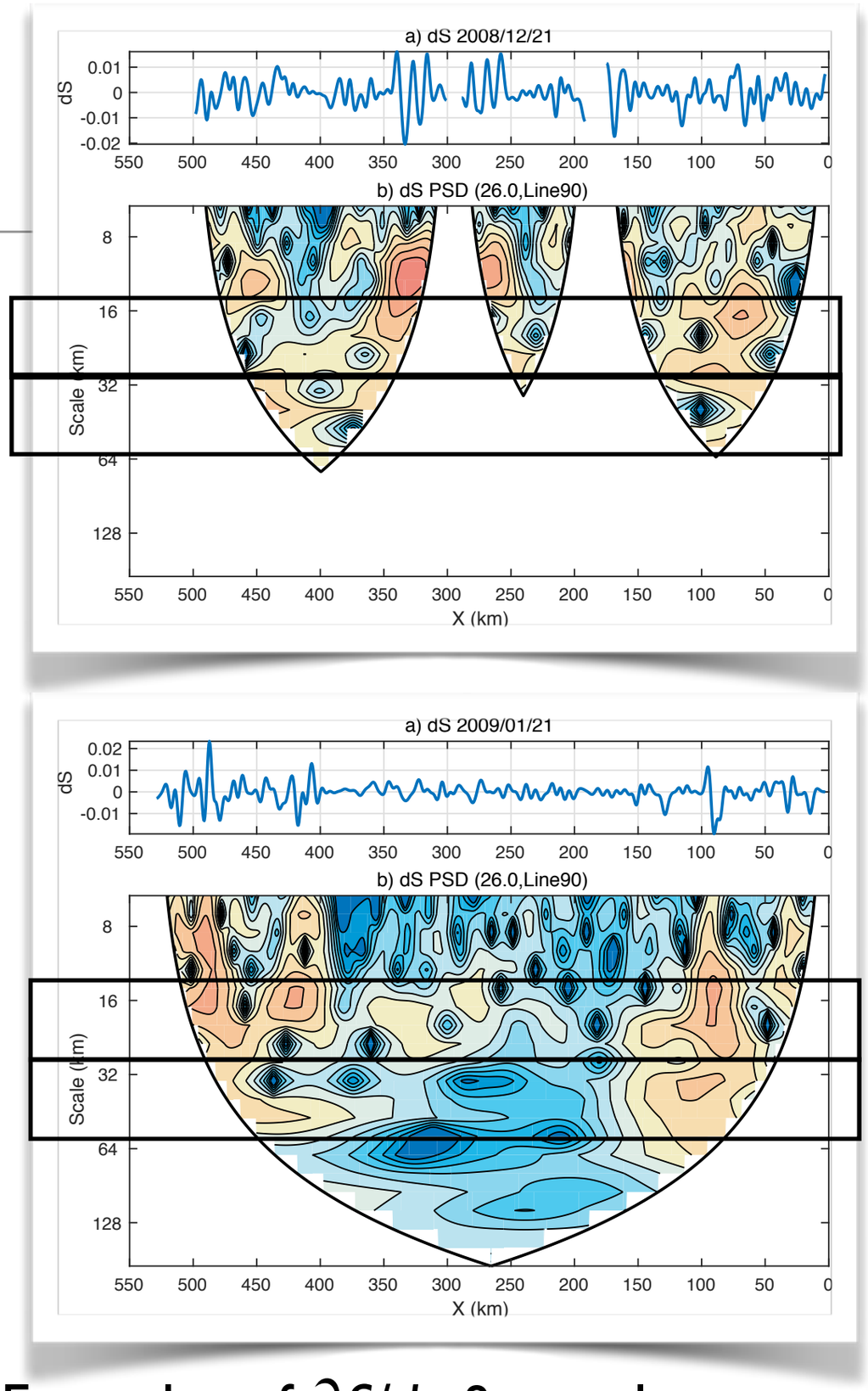
- Integration of wavelet power over **“meso” (30–60 km)** & **“submeso” (12–30 km)** bands



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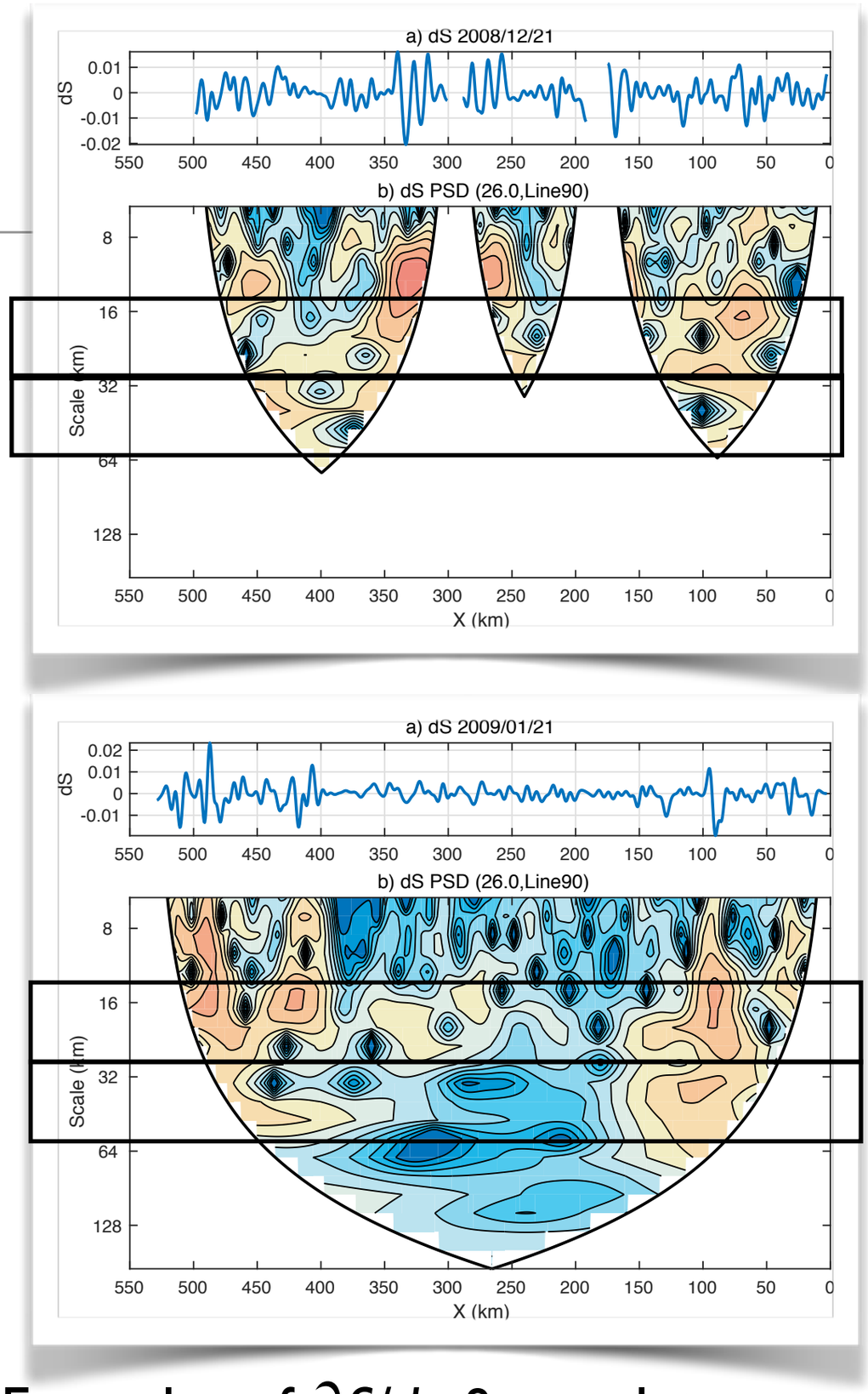

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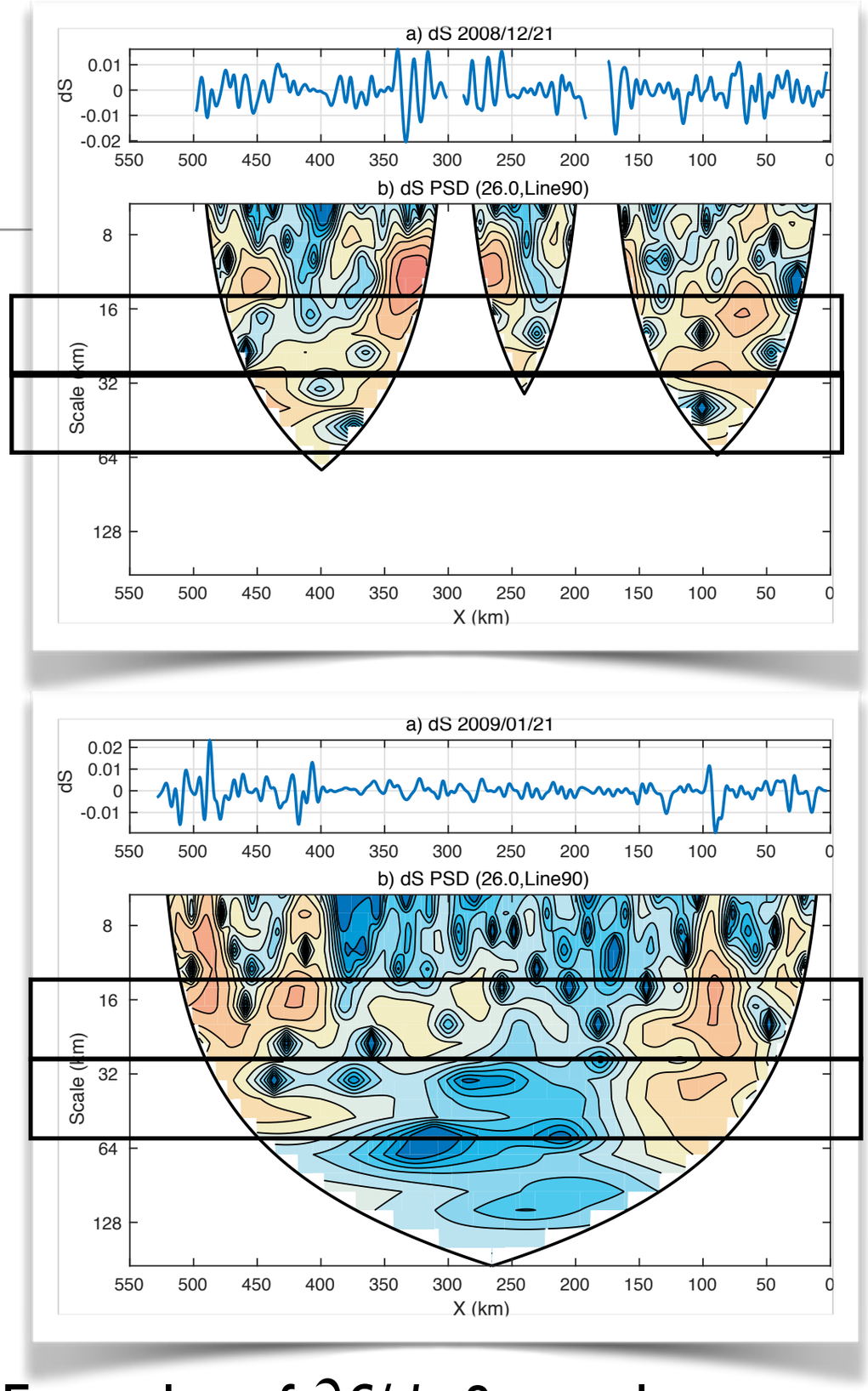
- Estimate **spectral slope *b***

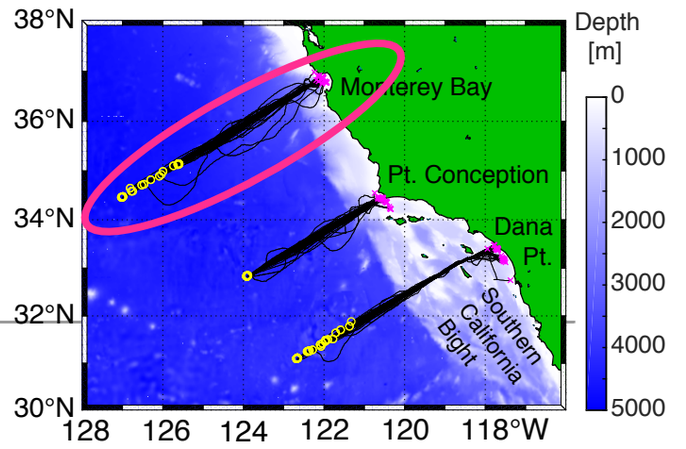


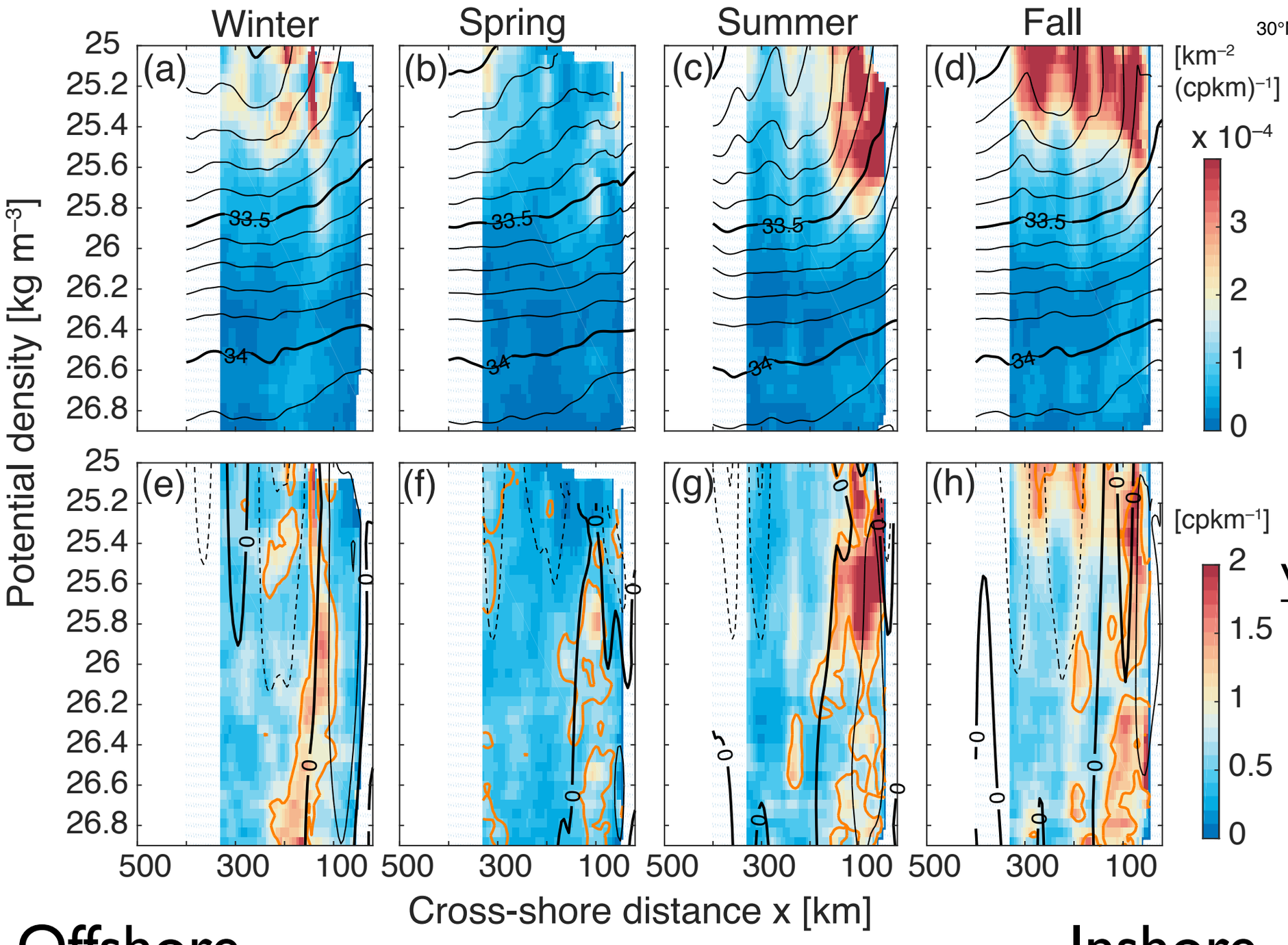
Examples of $\partial S/dx$ & wavelet power spectra for an isopycnal data

Itoh & Rudnick (2017)

Submesoscale variability:

1. off Monterey Bay (Line 66.7)





Scale (12–30 km) -averaged wavelet power

Variance-normalized scale (12–30 km) -averaged wavelet power

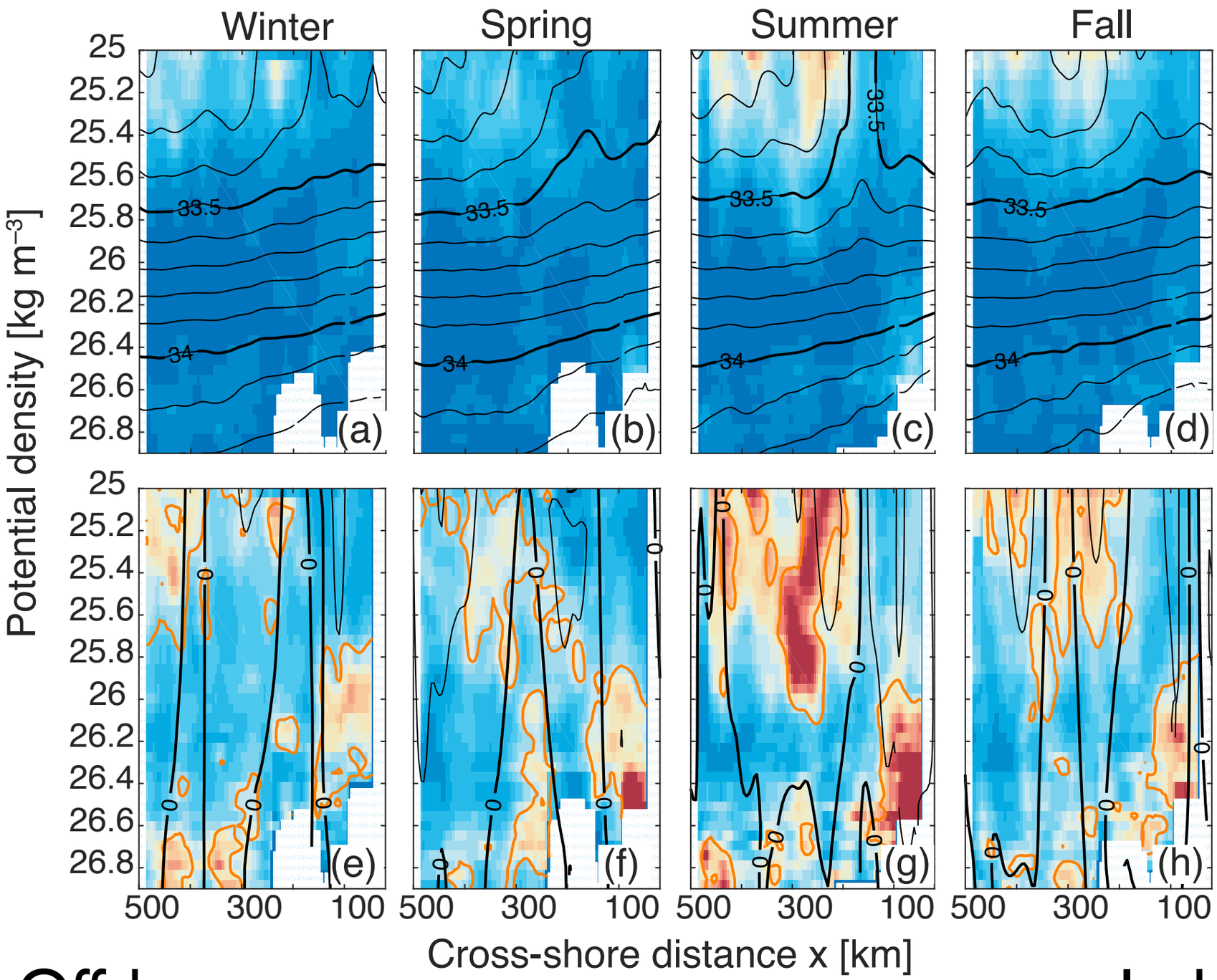
Offshore

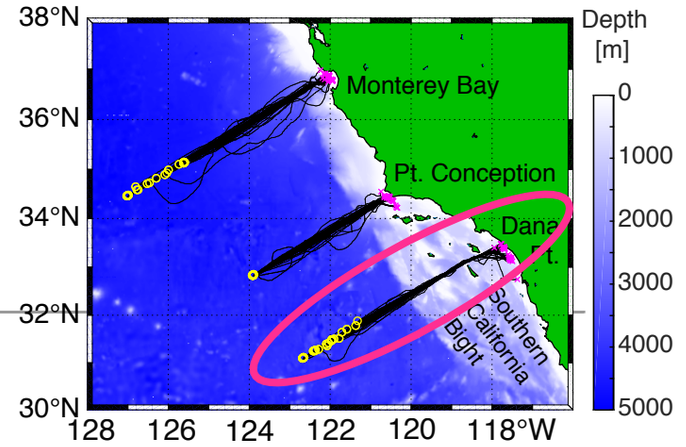
Inshore

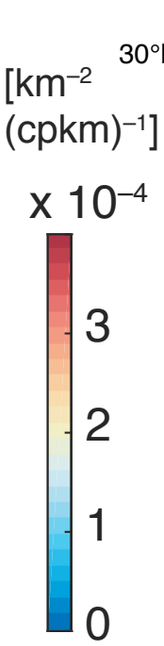
Itoh & Rudnick (2017)

Submesoscale variability:

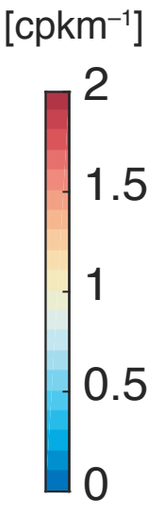
2. off San Diego (Line 90.0)







Scale (12–30 km) -averaged wavelet power



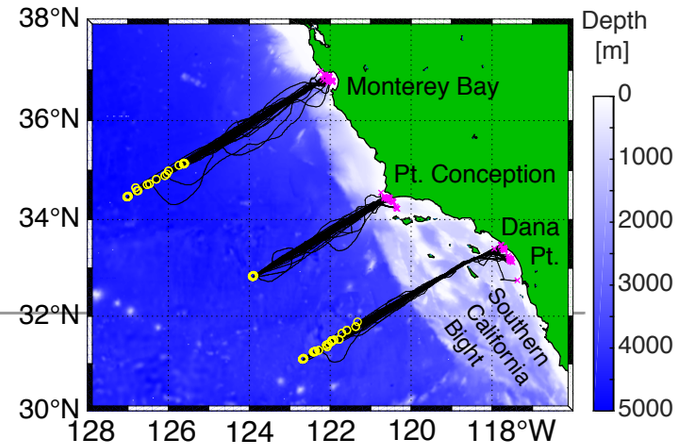
Variance-normalized scale (12–30 km) -averaged wavelet power

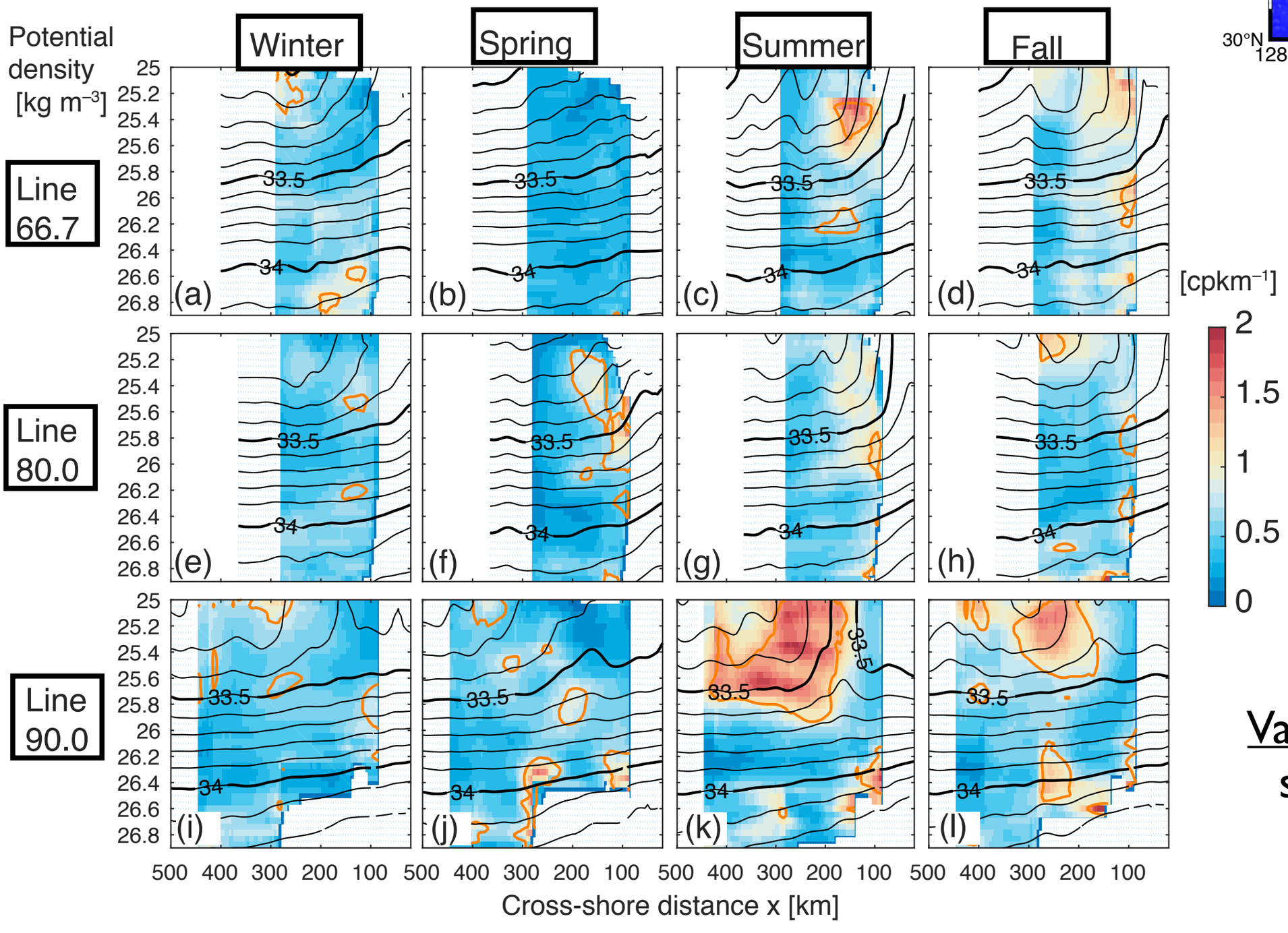
Offshore

Inshore

Itoh & Rudnick (2017)

Mesoscale variability

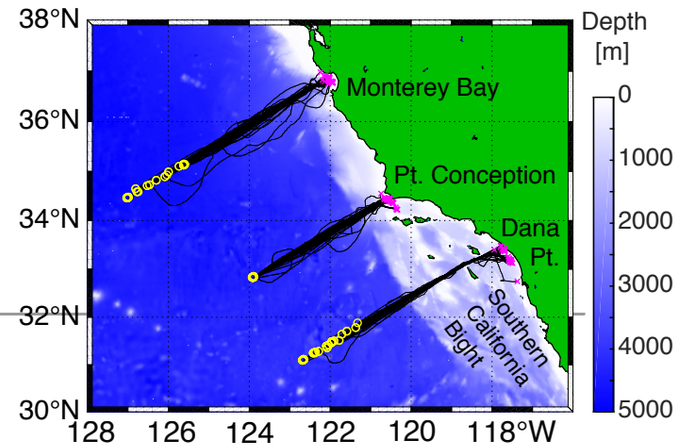


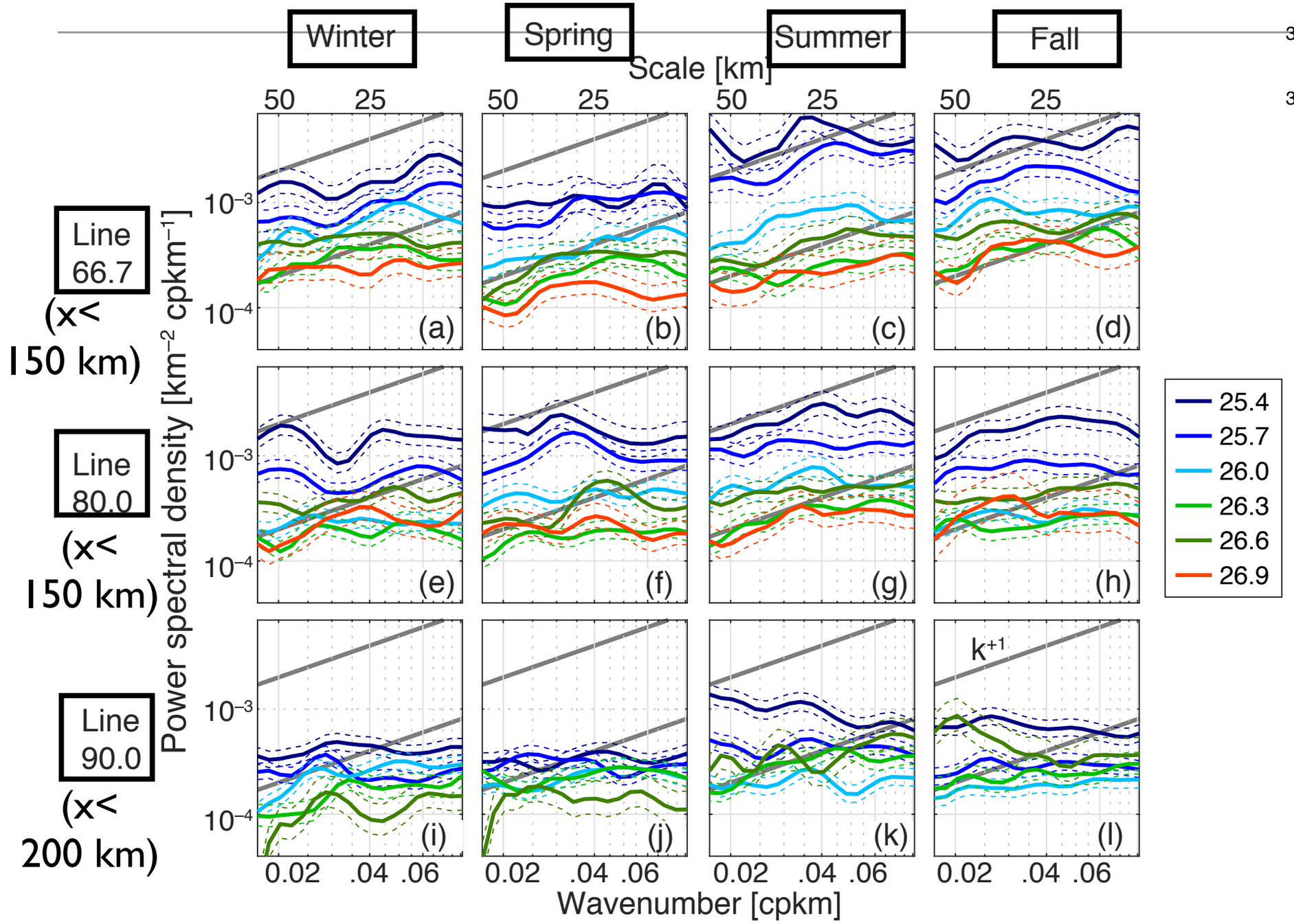


Variance-normalized scale (30–60 km) -averaged wavelet power

Itoh & Rudnick (2017)

Spectrum: 1. Inshore side





Not along k^{+1} on average but sharper than k^0

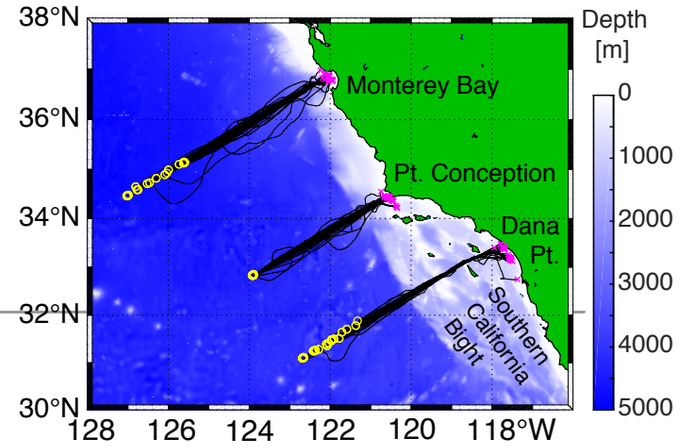
Mean ± std of the slope:

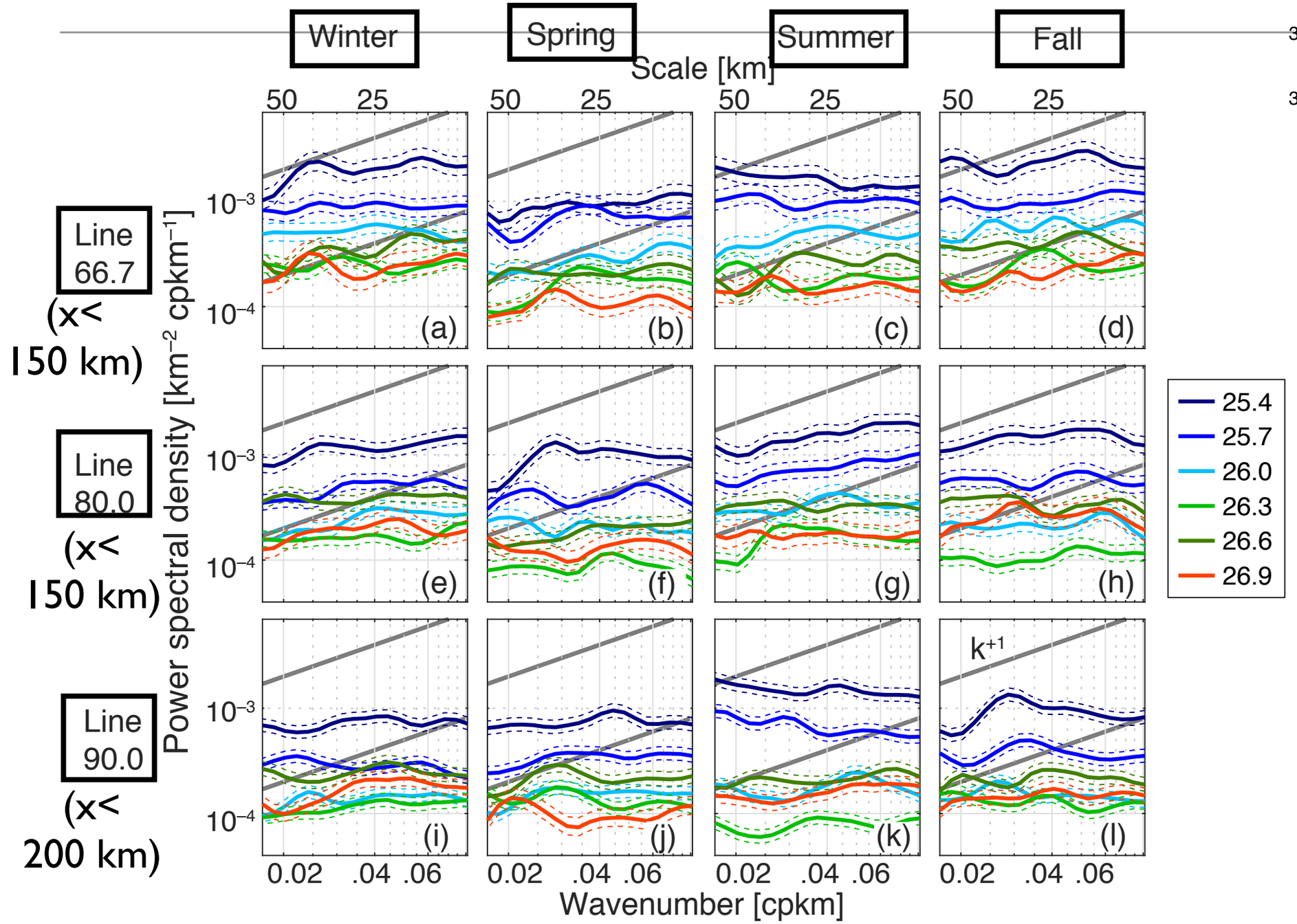
0.25 ± 0.32

Mean spectrum averaged over the inshore side

Itoh & Rudnick (2017)

Spectrum: 2. Offshore side





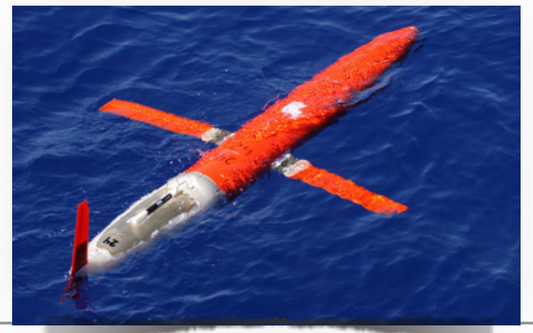
Not along k^{+1} on average but sharper than k^0

Mean ± std of the slope:

0.14 ± 0.19

Mean spectrum averaged over the offshore side

Summary



Spray Underwater Glider

Frequent (2–3 weeks) & **high-resolution** (~3 km) operation of underwater gliders in the CCS

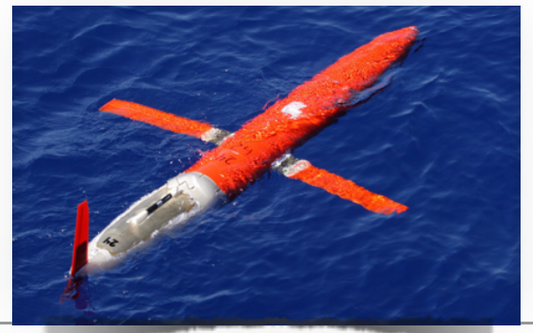
- High-resolution climatology of T, S & V distributions (Rudnick et al. 2017)
- Annual isopycnal salinity variability (Todd et al. 2012)

Further data accumulation (Itoh et al. 2017)

- Seasonal fluctuation
- Lateral structure
- Spatial distributions of spectral curves

For more detail: Itoh & Rudnick (2017, JGR)

Summary



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- Elevated variance around the salinity front during summer
- Offshore spreading in fall-winter

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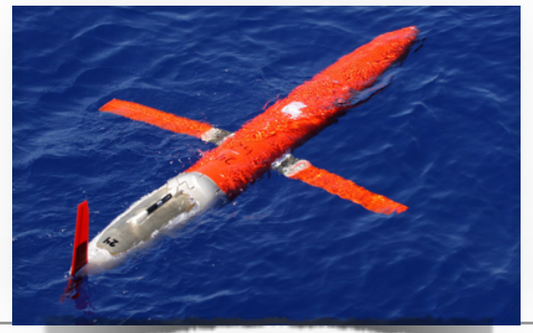

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Flatter than k^{+1} but greater than k^{0}

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Acknowledgements

CUGN Climatology
Katherine Zaba
Robert Todd
Russ Davis

SIO IDG
Jeff Sherman
Brent Jones
Evan Randall-Goodwin
Derek Vana

Funding
NOAA, NSF

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Dan Rudnick (host)
AORI
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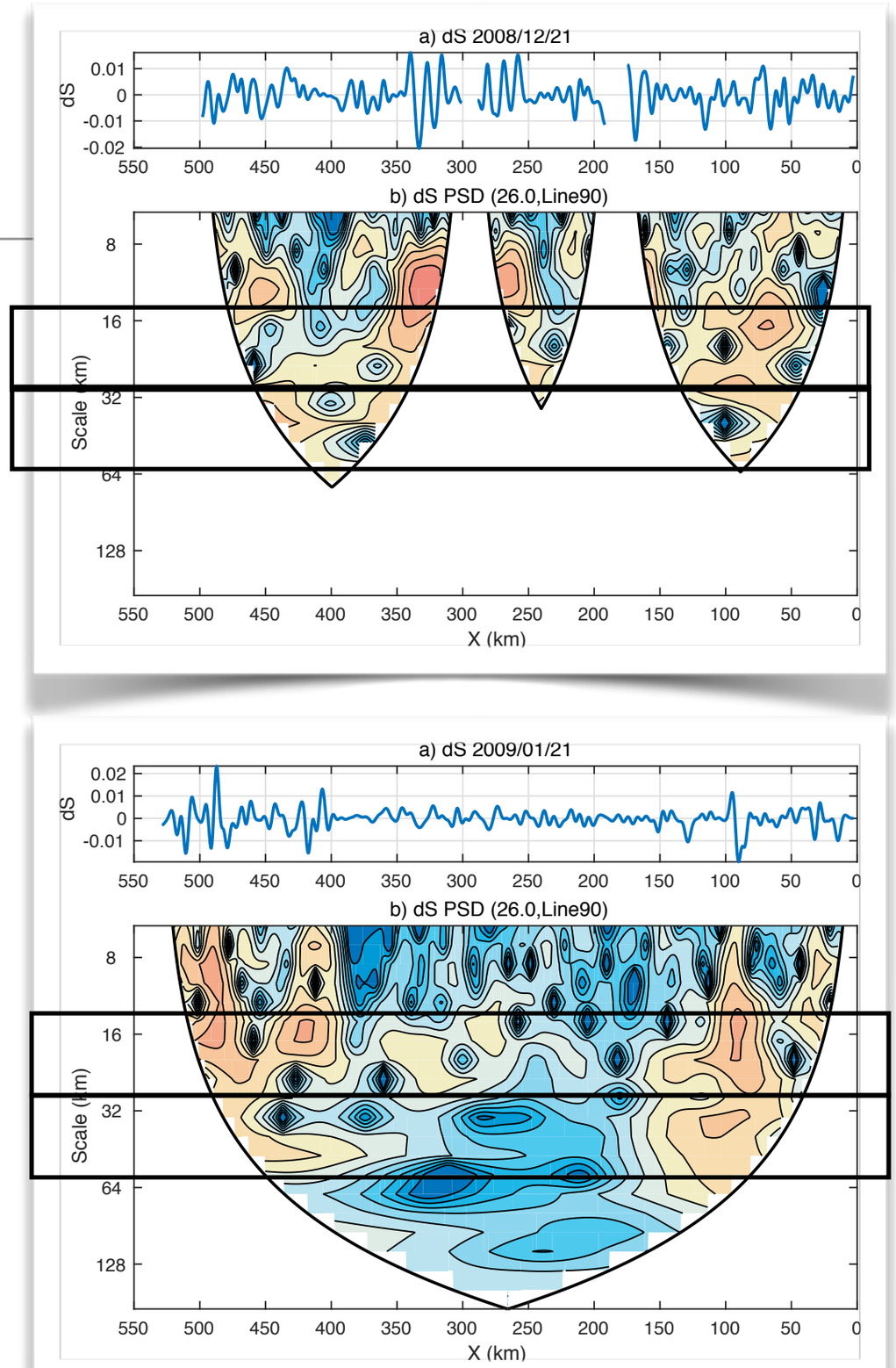
Itoh & Rudnick (2017)

Wavelet analysis



Examples of $\partial S/dx$ & wavelet power spectra for an isopycnal data

Itoh & Rudnick (2017)

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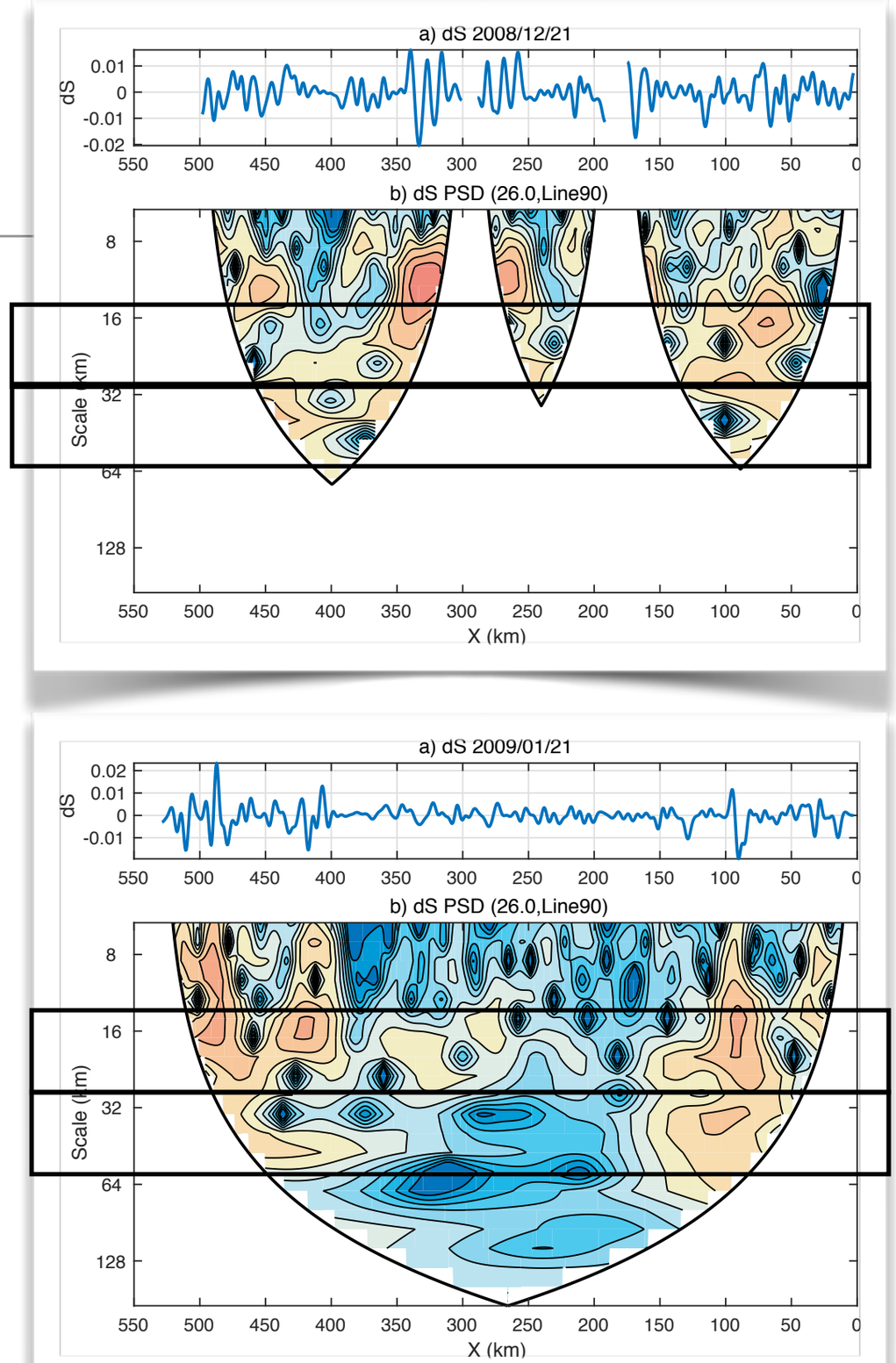
- Wavelet analysis on **isopycnal salinity**



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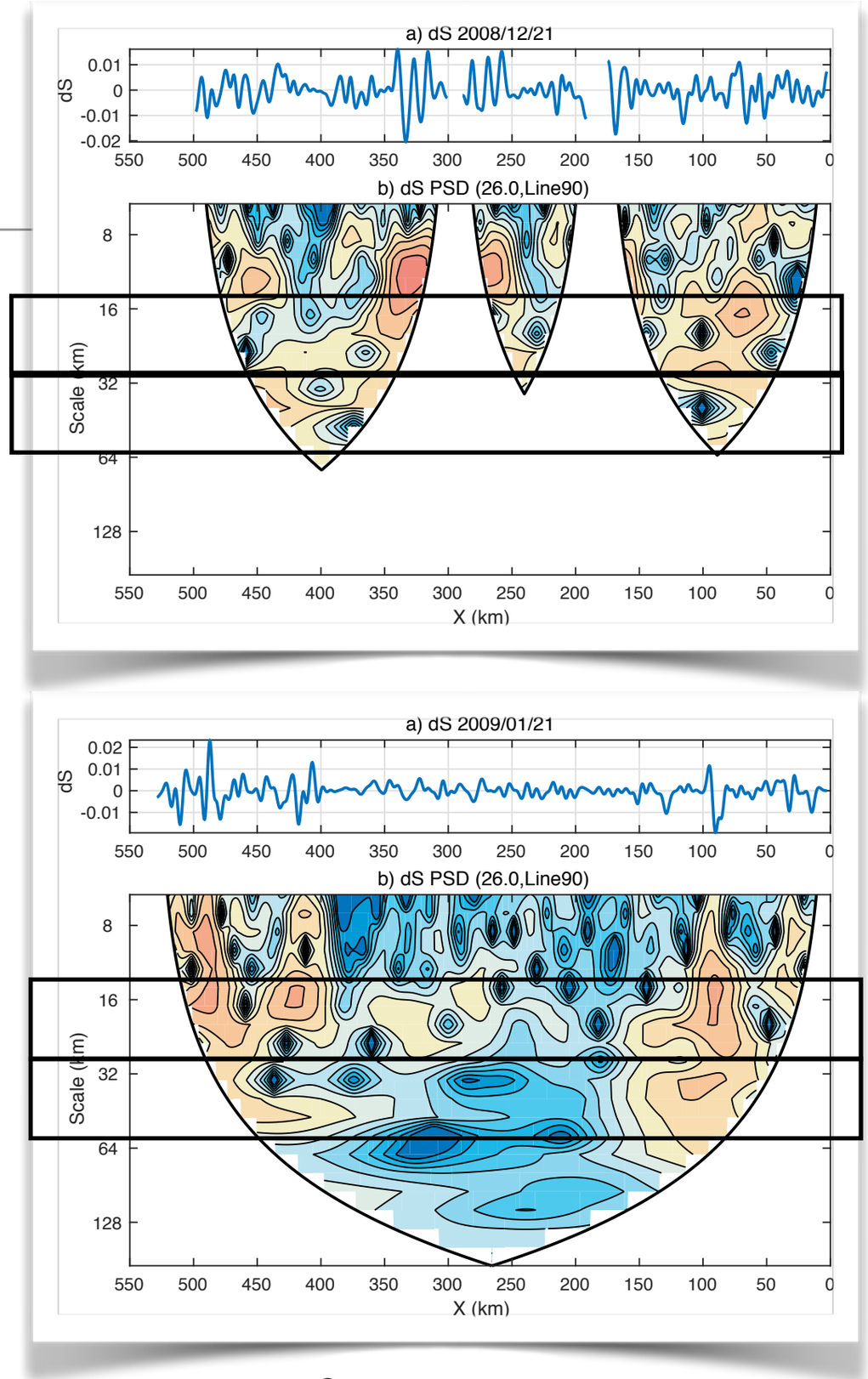

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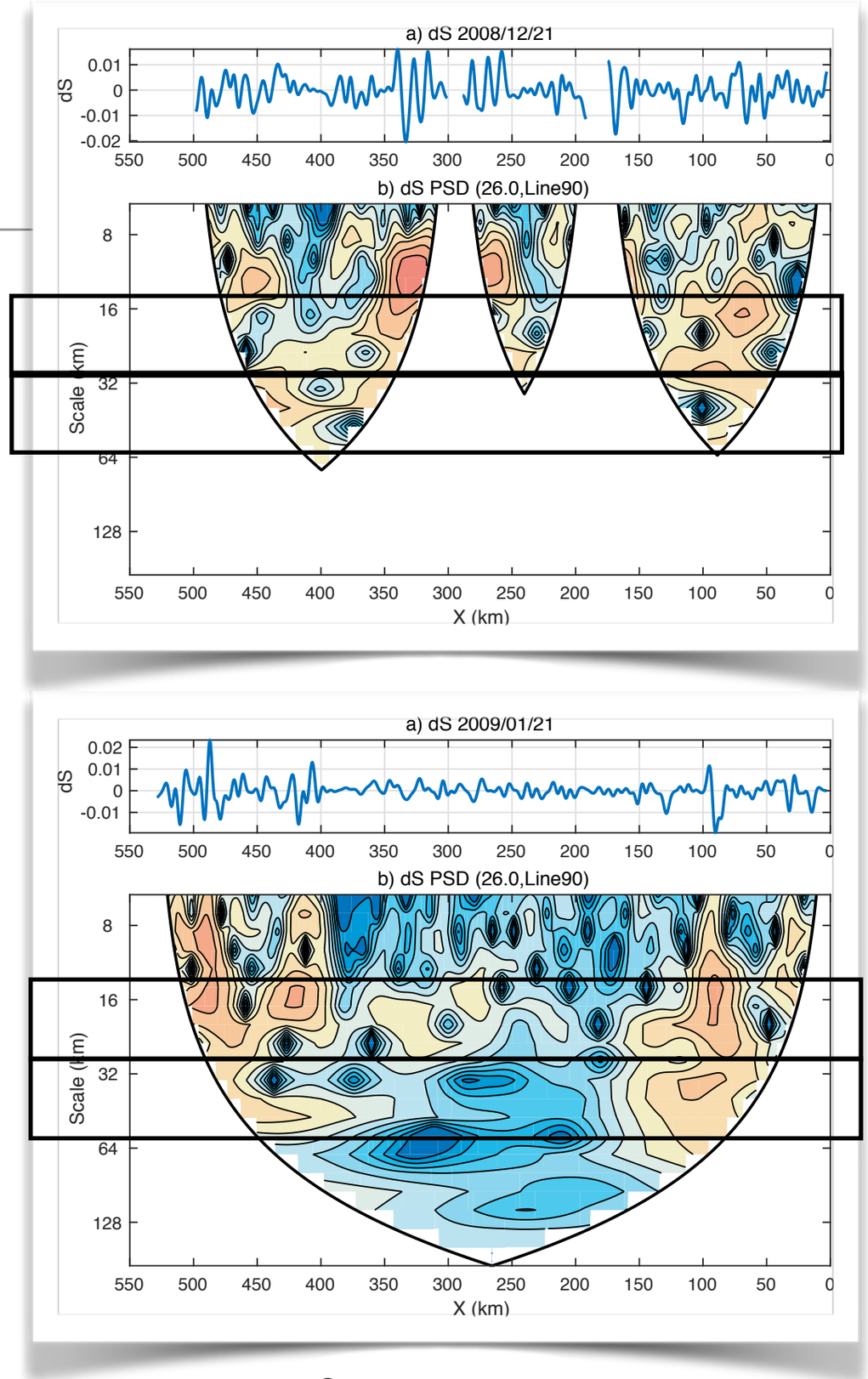

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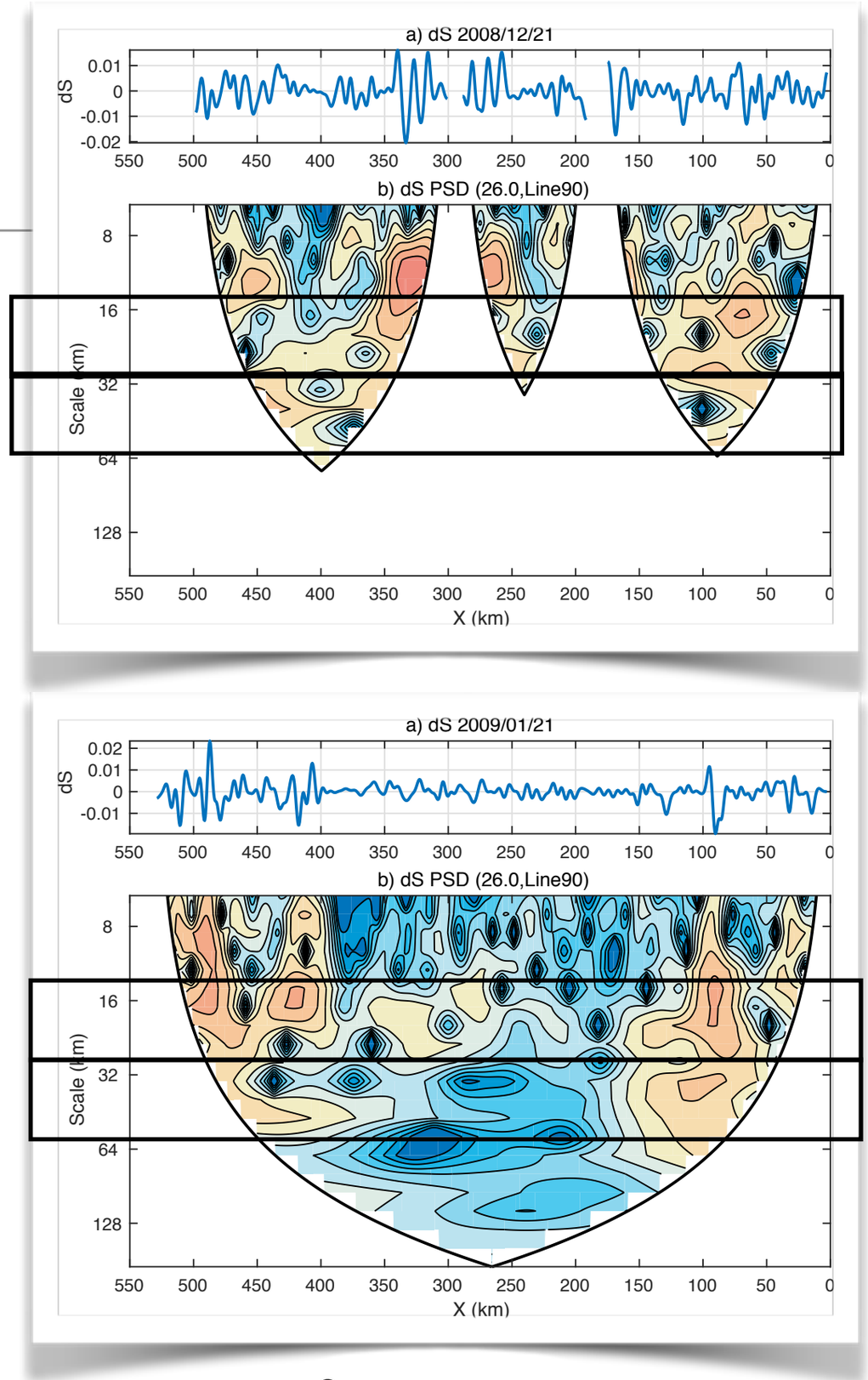

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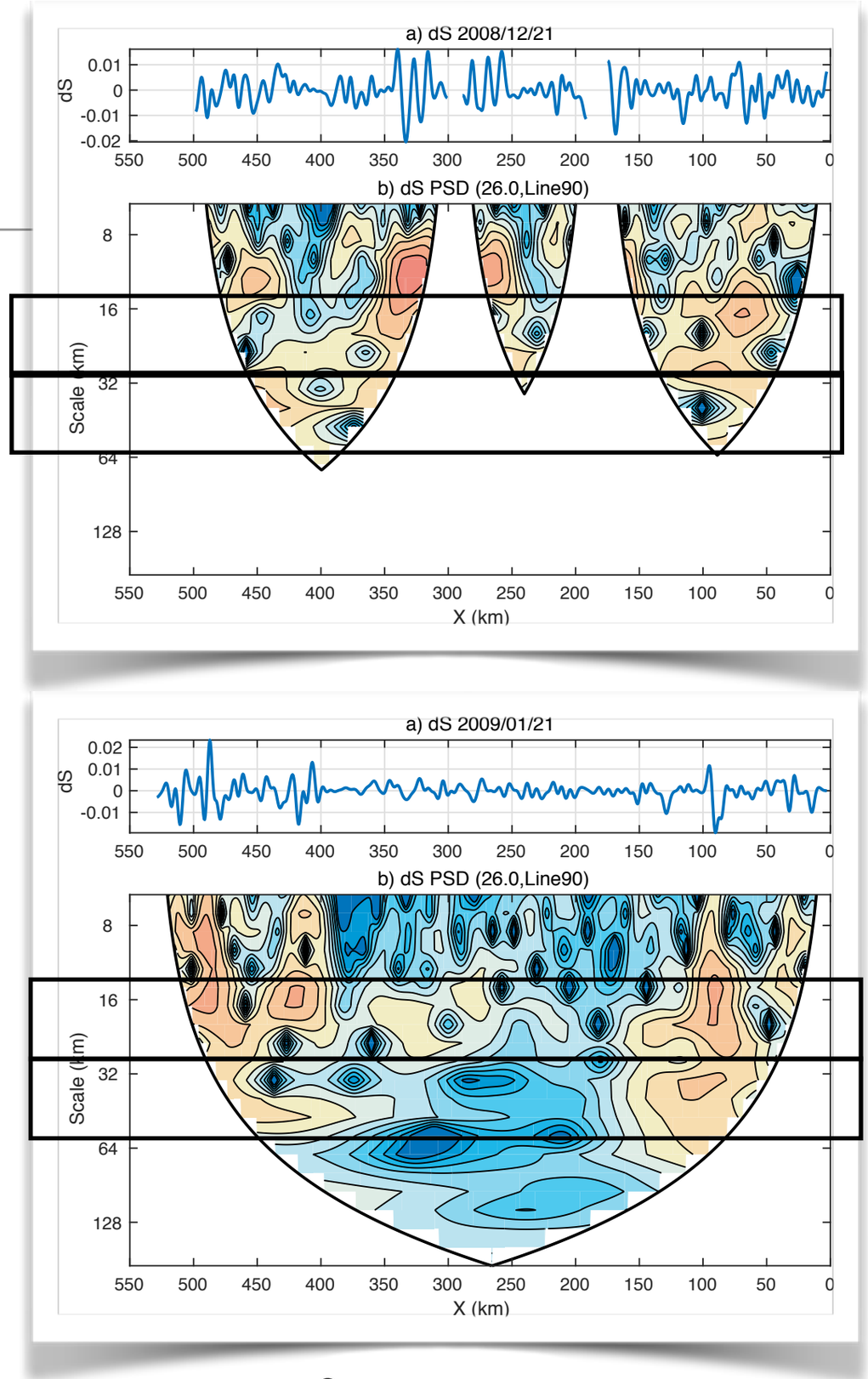
$$P(k) = a \times k^{b} \qquad \text{k: wavenumber}$$



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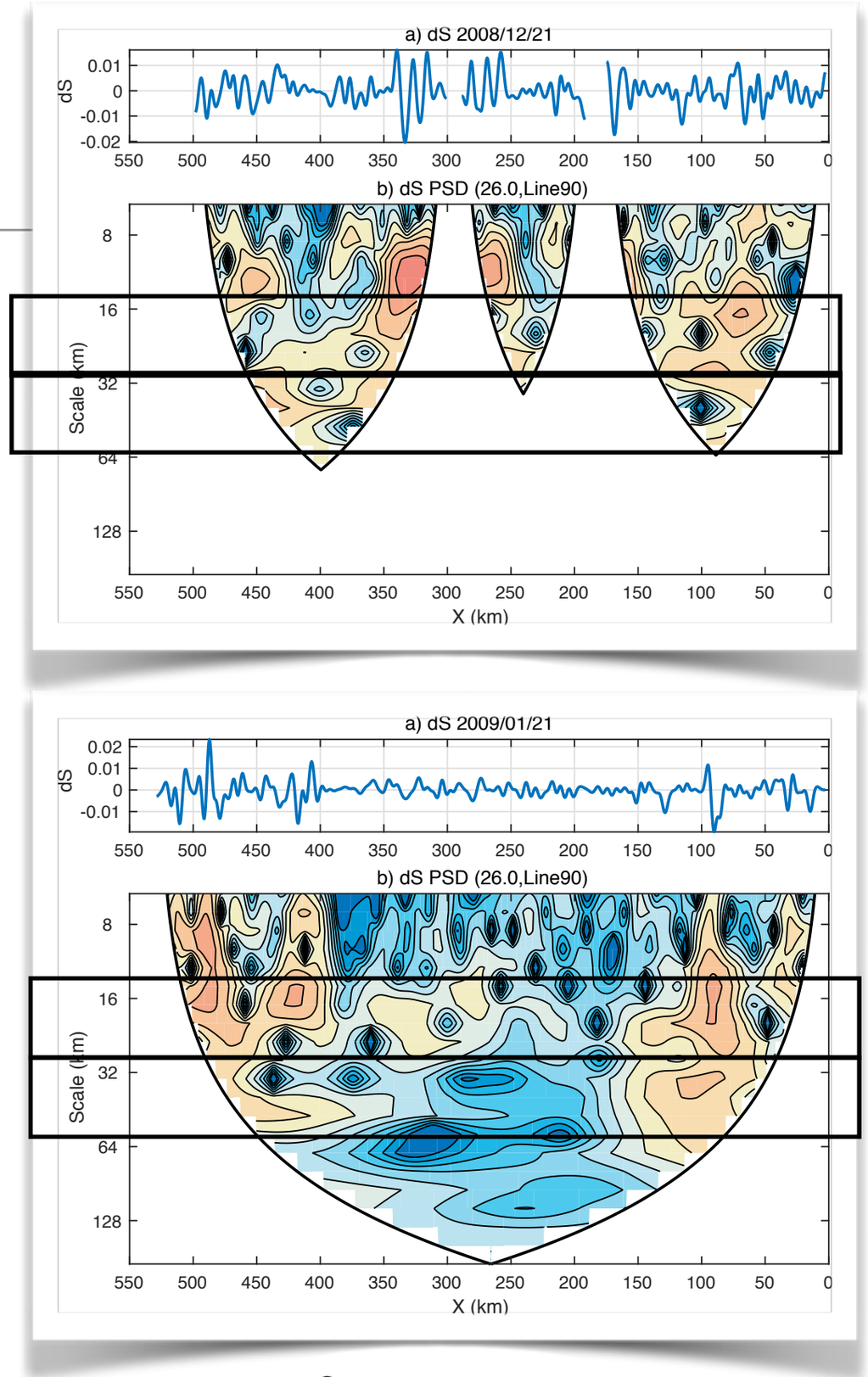
$$P(k) = a \times k^{b} \qquad \text{k: wavenumber}$$

$$b = \frac{\log\left(P_1 / P_2\right)}{\log\left(k_1 / k_2\right)}$$



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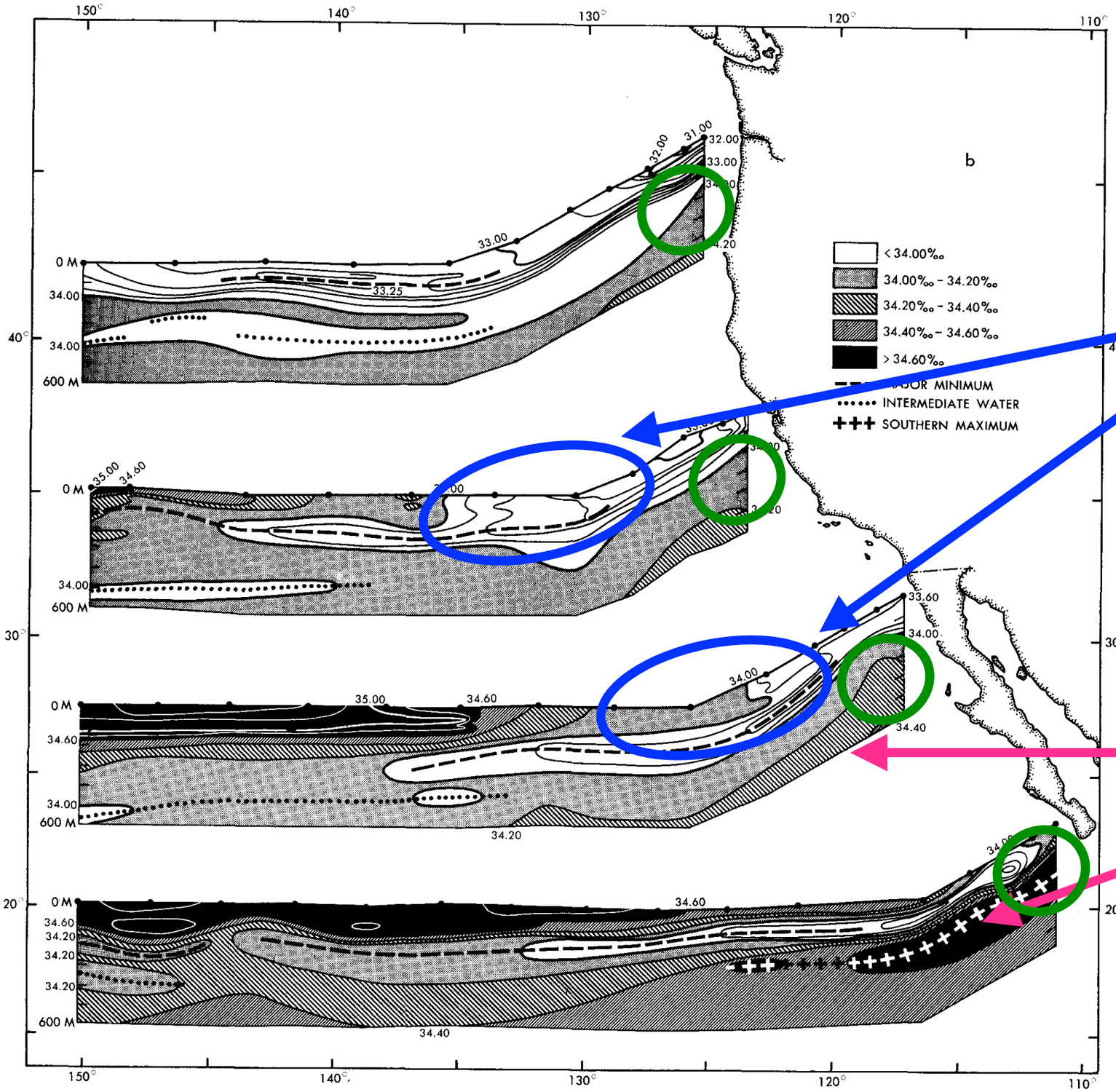
CalCOFI Surveys (1949–)

Reid et al. (1958)



Salinity distribution in August 1955

Fresh (& cold) CC

Coastal upwelling

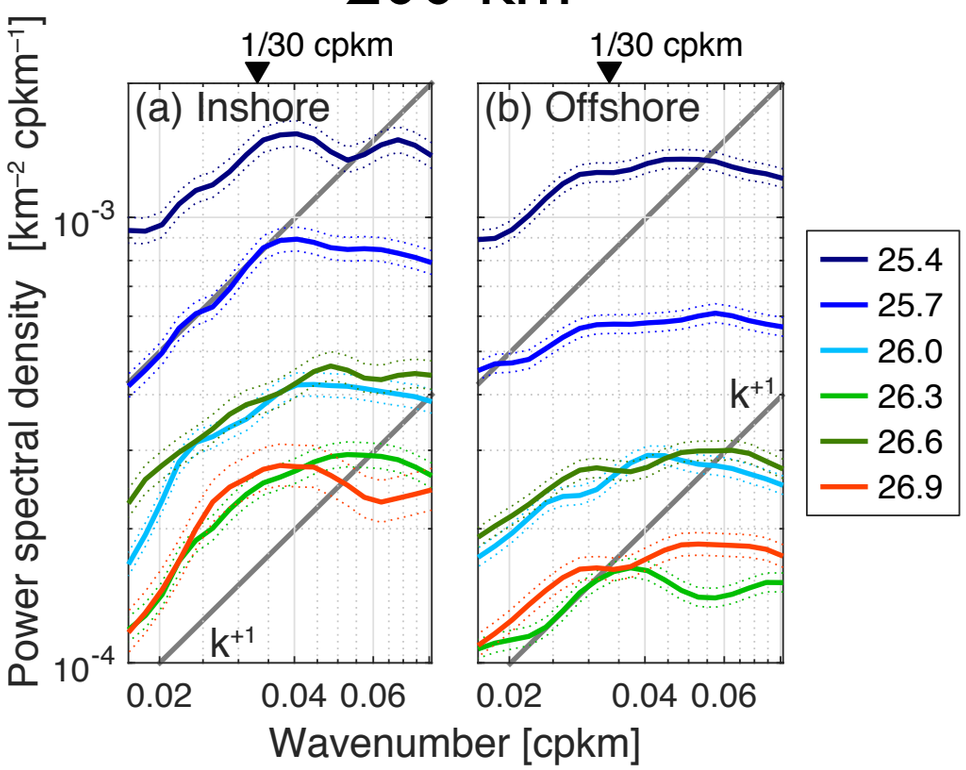
Salty (& warm) CUC

Spectral slope over submeso & meso range (12–60 km)

Inshore

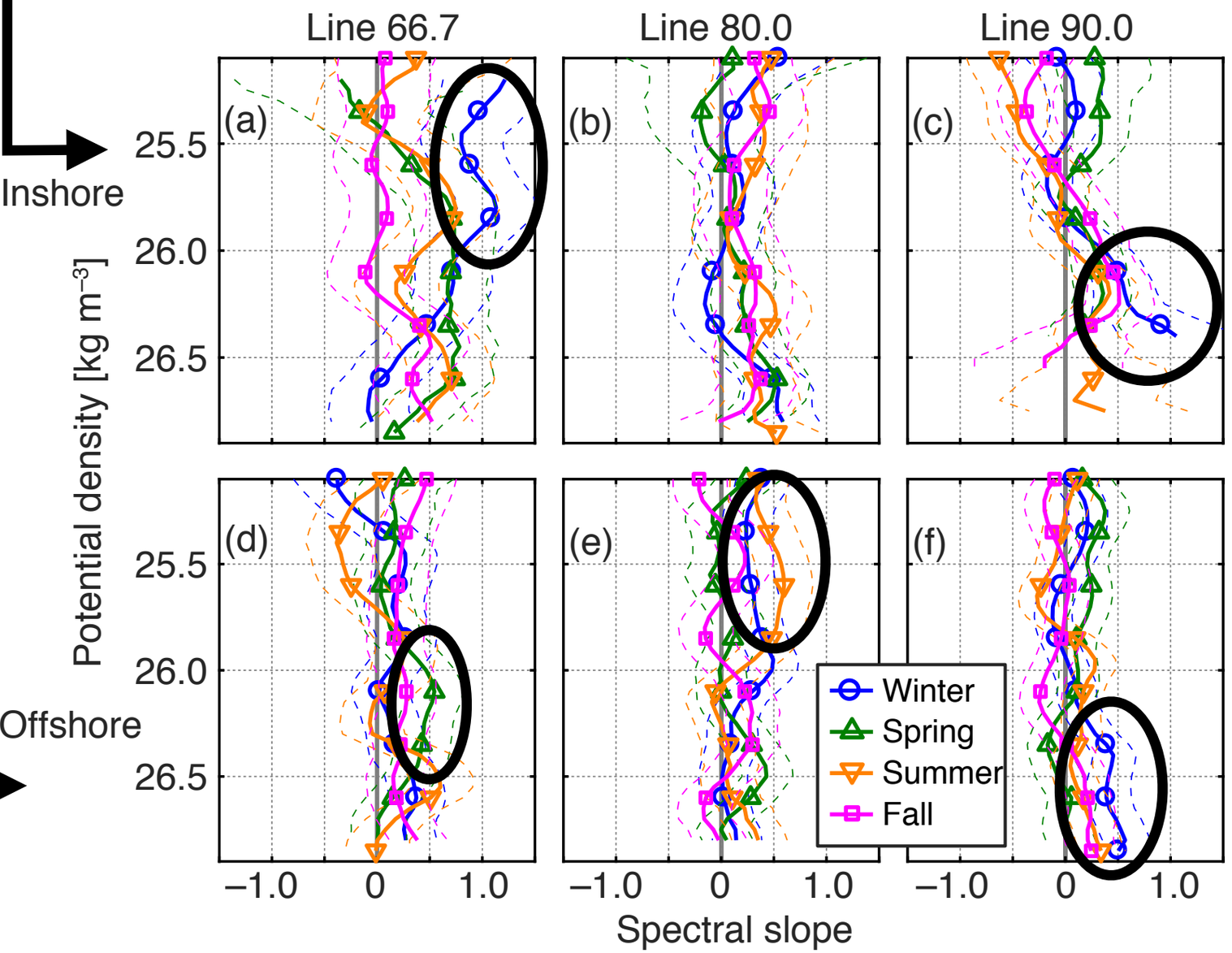
Offshore

$x <$ 150 km 200 km $< x$



Offshore side

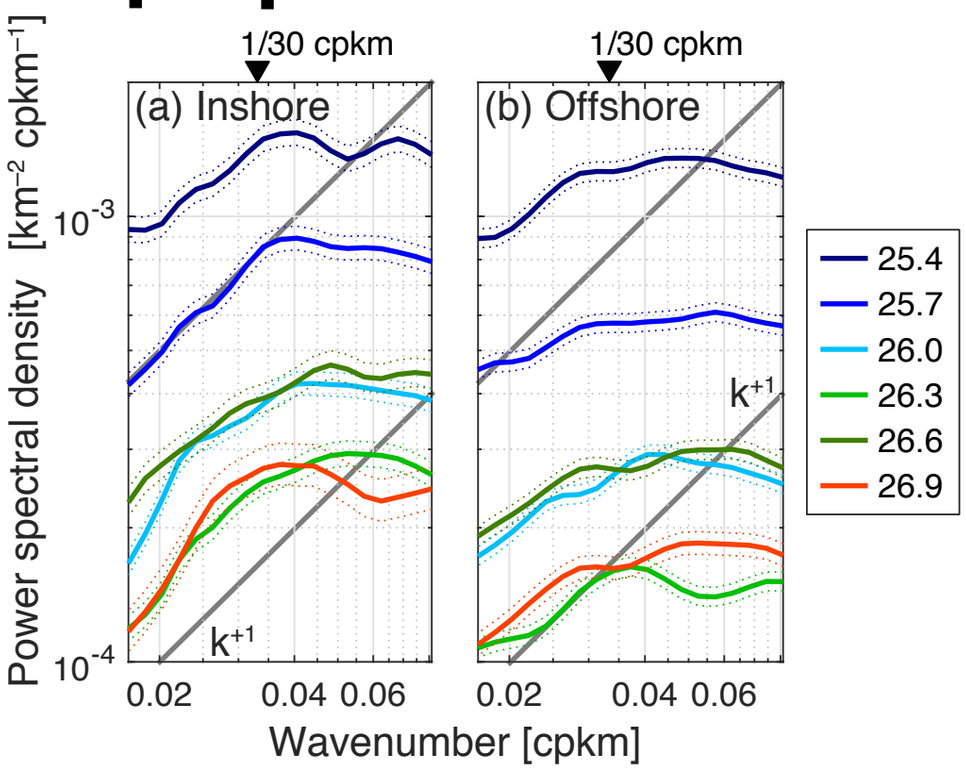
Averaged over 12–60 km range but separated by each line/season (inshore)



Spectral slope over submeso range (12–30 km)

Inshore

Offshore



Offshore side

Averaged over 12–30 km range but separated by each line/season (inshore)