Long-distance radiation of barotropic Rossby waves from tropical instability waves

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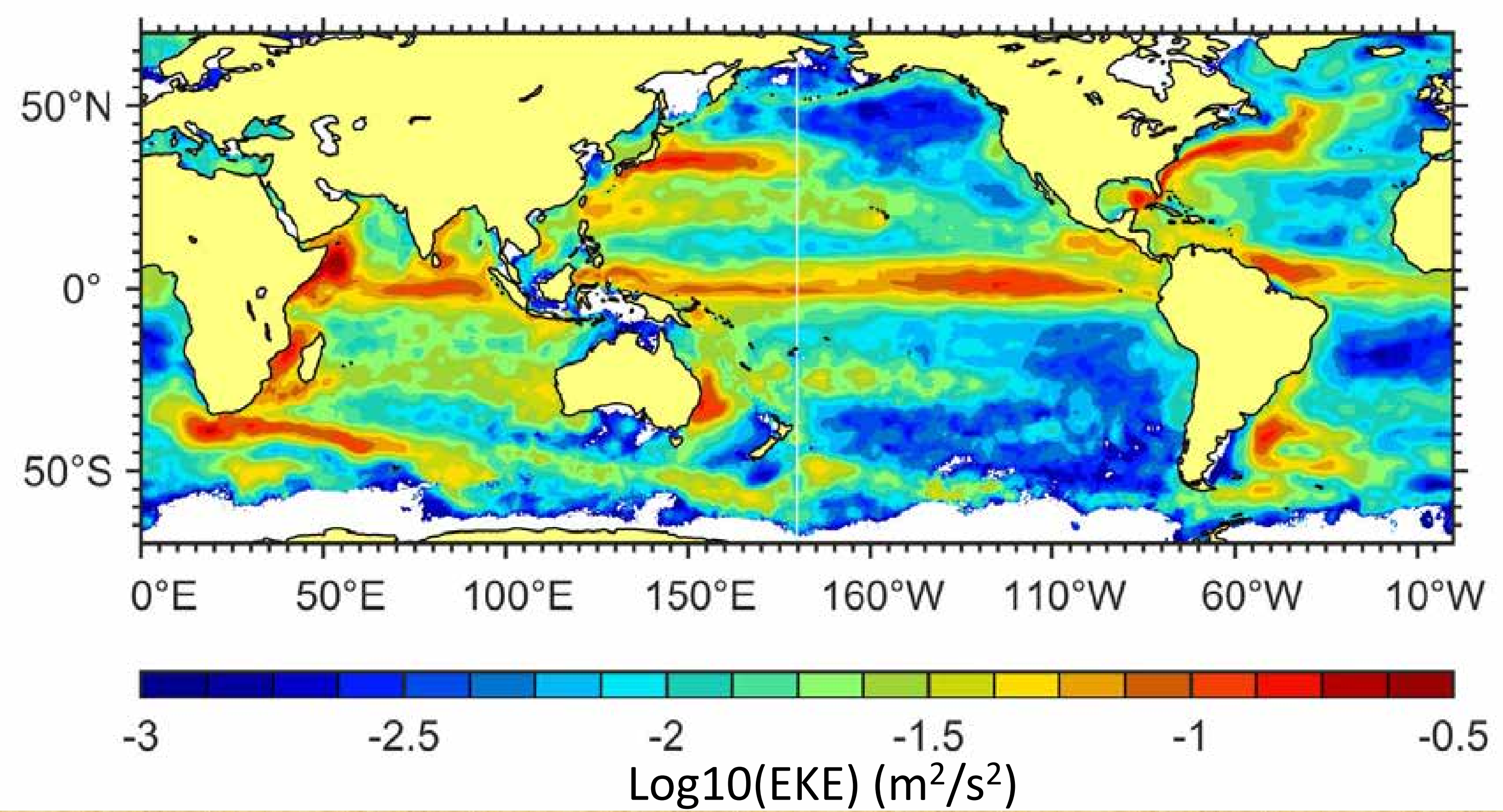
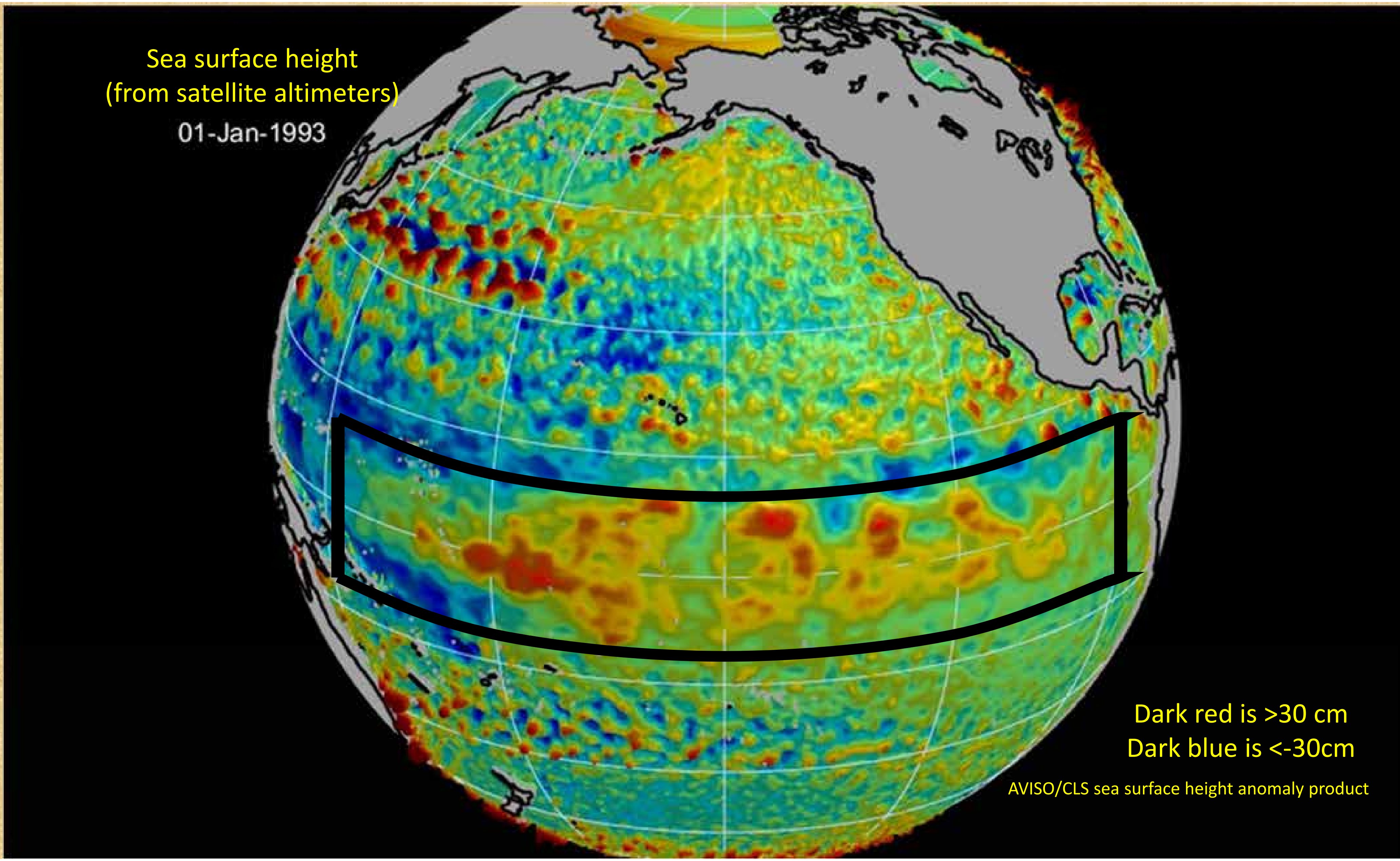
OSTST meeting, 25 October 2017

Eddy Kinetic Energy from drifters (Lumpkin and Johnson, 2013) → What's the source of the EKE away from strong currents?

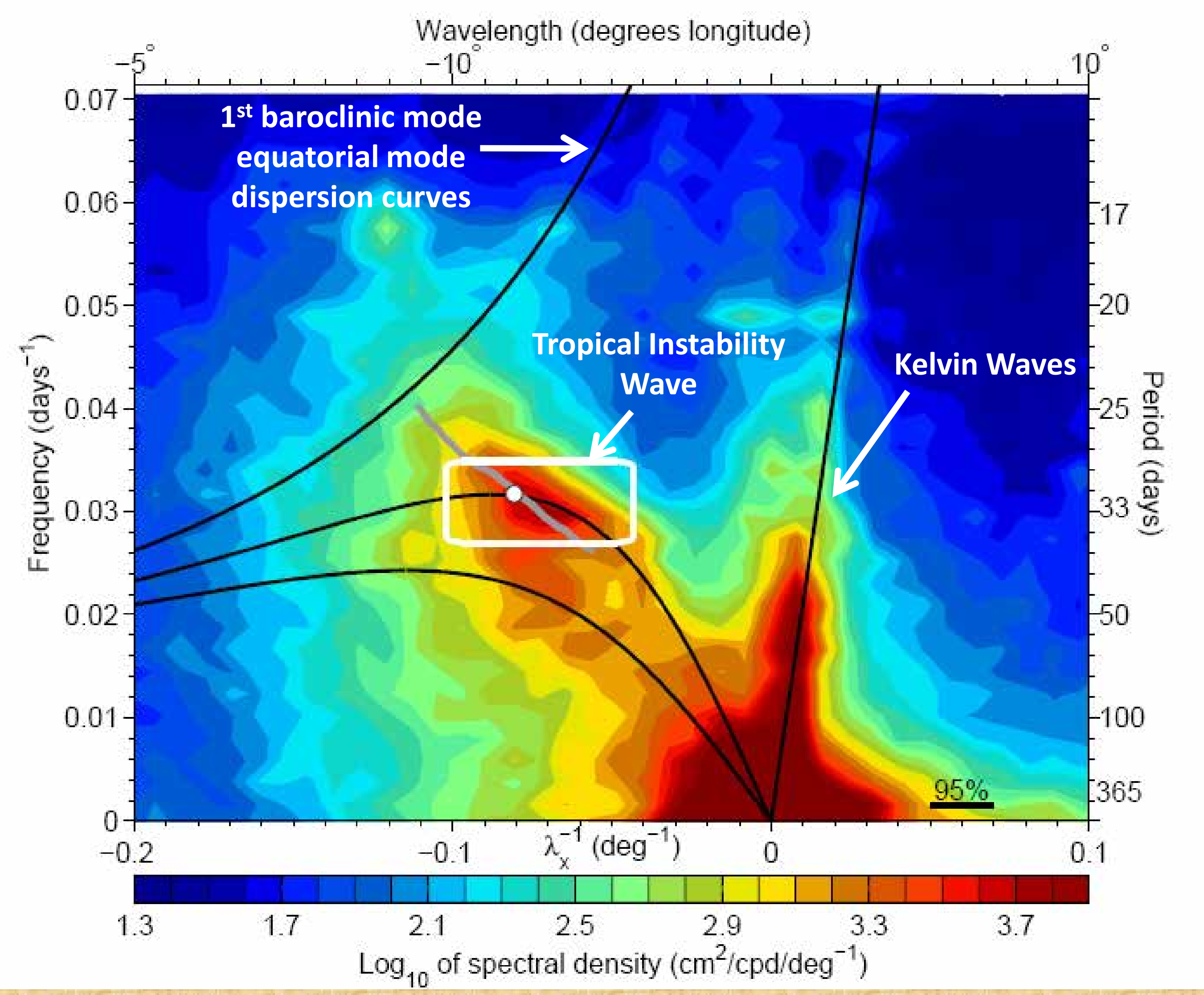
- Local instability of the large-scale flow field (e.g., Gill et al., 1974; Stammer, 1997; Smith, 2007; Ferrari and Wunsch, 2009; Tulloch et al., 2011)
- Radiation of wave energy from the vigorous and unstable jet-like current systems (e.g., Pedlosky, 1977; Harrison and Robinson, 1979; Hogg 1988; Bower and Hogg, 1992; Spall, 1992; Miller et al., 2007)




Sea surface height
(from satellite altimeters)
01-Jan-1993
Dark red is >30 cm
Dark blue is <-30cm
AVISO/CLS sea surface height anomaly product

Zonal-wavenumber/ frequency spectrum of sea surface height

(AVISO gridded product)
(average over 7°S-7°N)
(14 years of data)

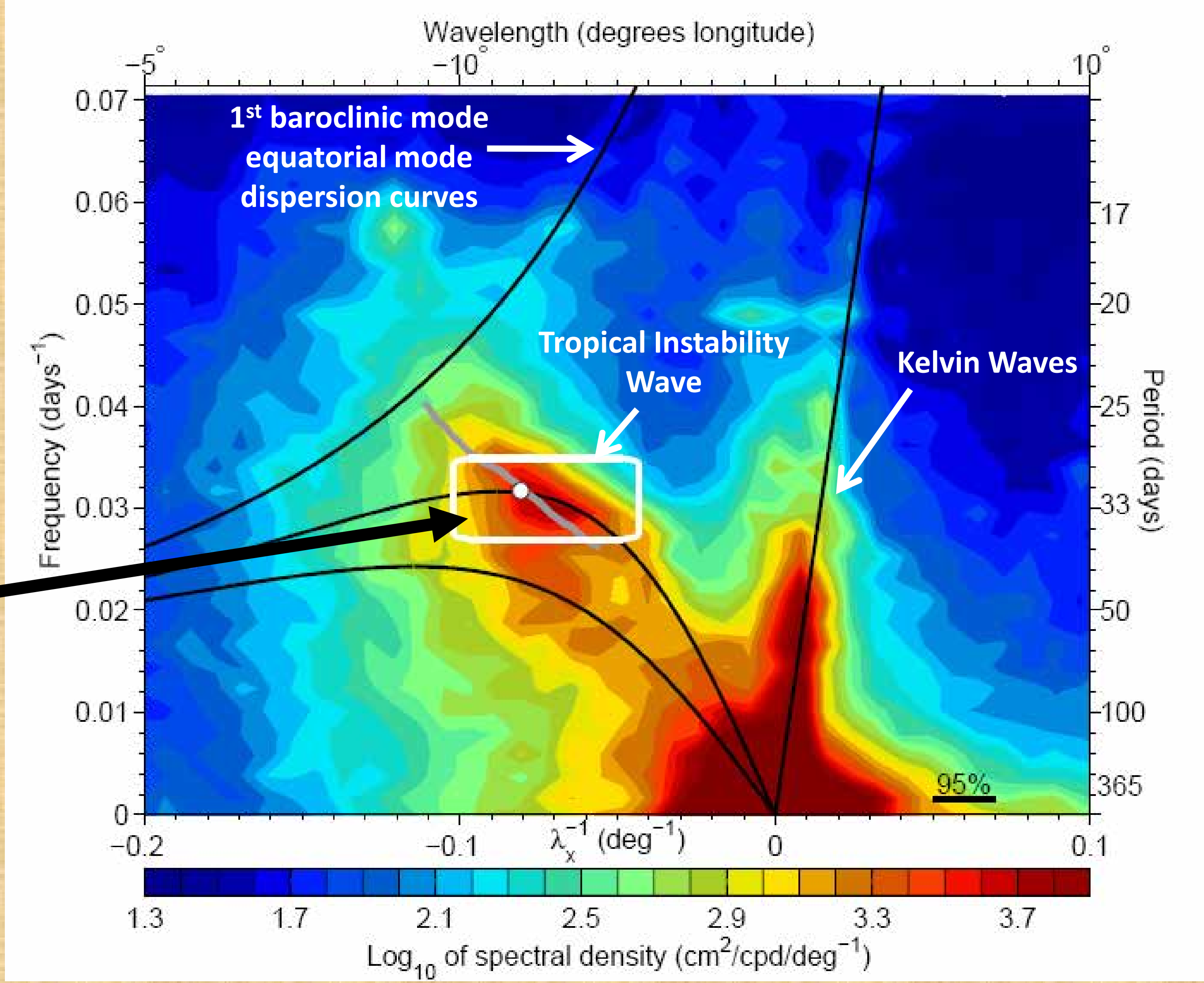


Farrar (2011, *Journal of Physical Oceanography*)

Zonal-wavenumber/ frequency spectrum of sea surface height

(AVISO gridded product)
(average over 7°S-7°N)
(14 years of data)

Let's examine SSH filtered for these wavenumbers and frequencies (Tropical Instability Waves)



Farrar (2011, *Journal of Physical Oceanography*)

Radiation of barotropic Rossby waves from tropical instability waves (Farrar, 2011)

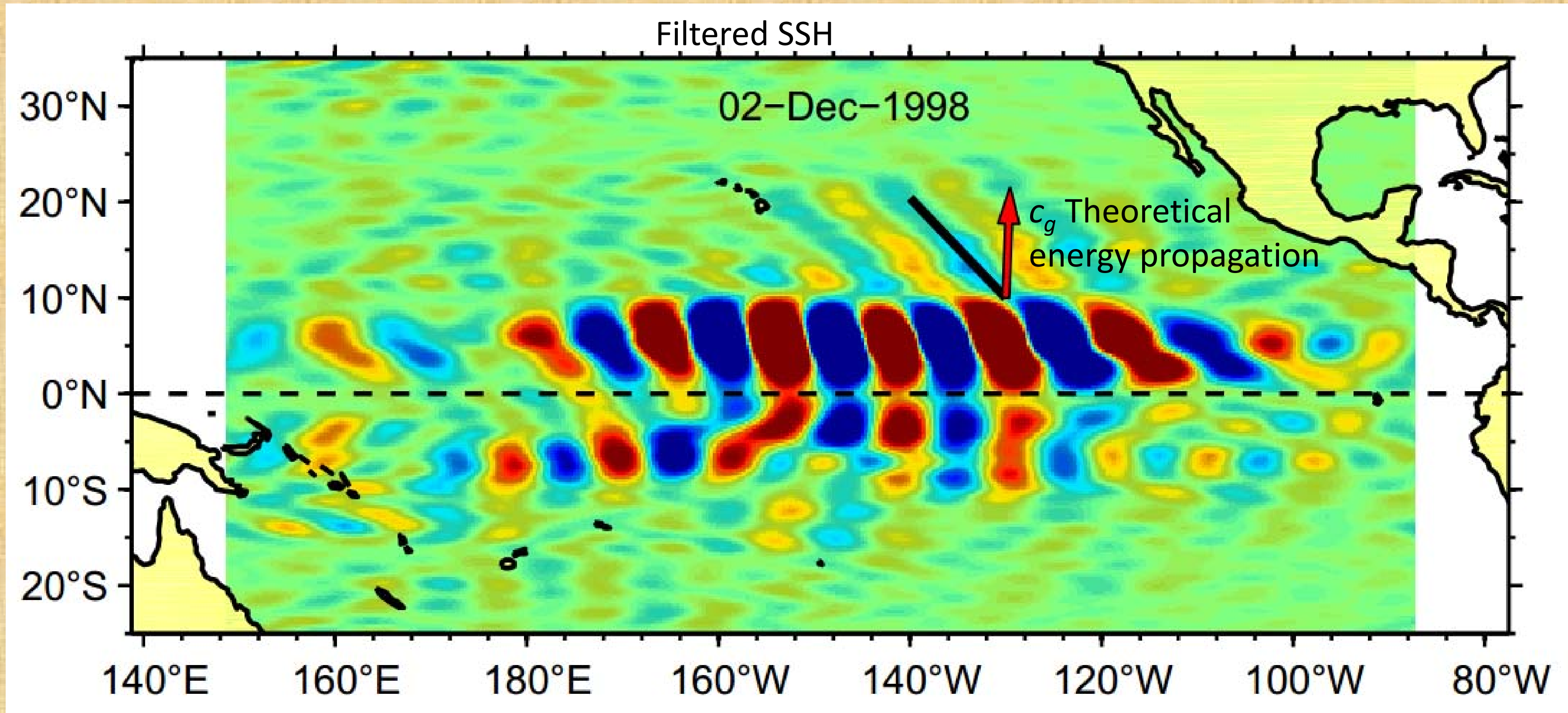
- Previous analysis examined 10-20°N. How far do these waves go? What happens to them?

Barotropic Rossby wave dispersion relation

$$\omega = \frac{-\beta k}{k^2 + l^2}$$

frequency

zonal/meridional wavenumbers



Farrar (2011, *Journal of Physical Oceanography*)

Spatial variation of temporal filtering in the Aviso product

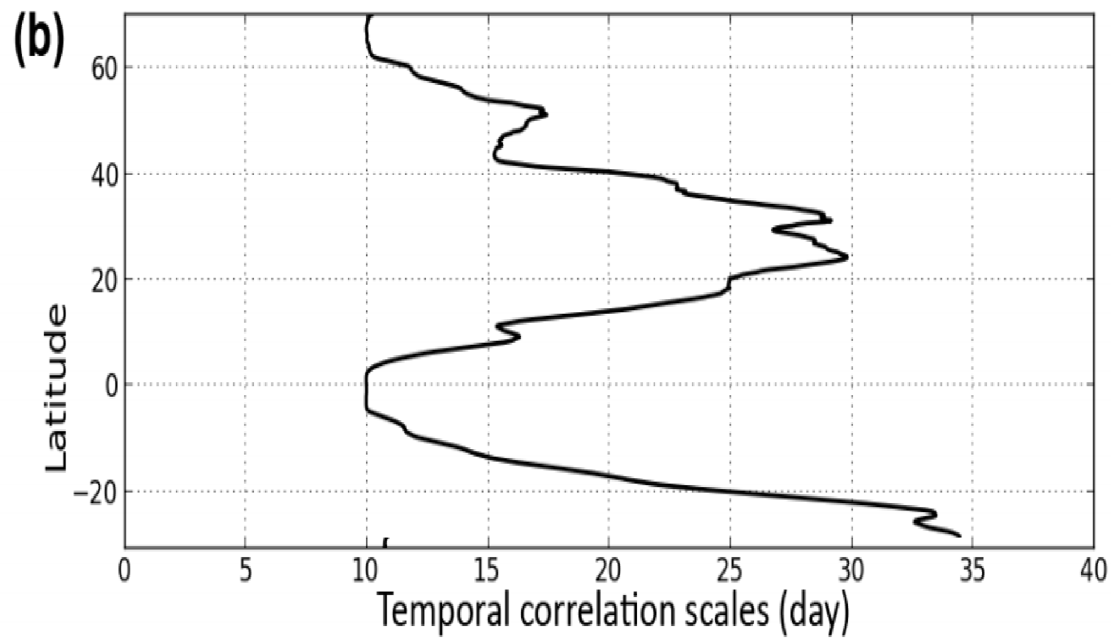
The filtering properties of Optimal Interpolation (or Gauss-Markov estimates) depend on:

(1) The assumed data and noise covariance functions

(2) The assumed signal-to-noise ratio

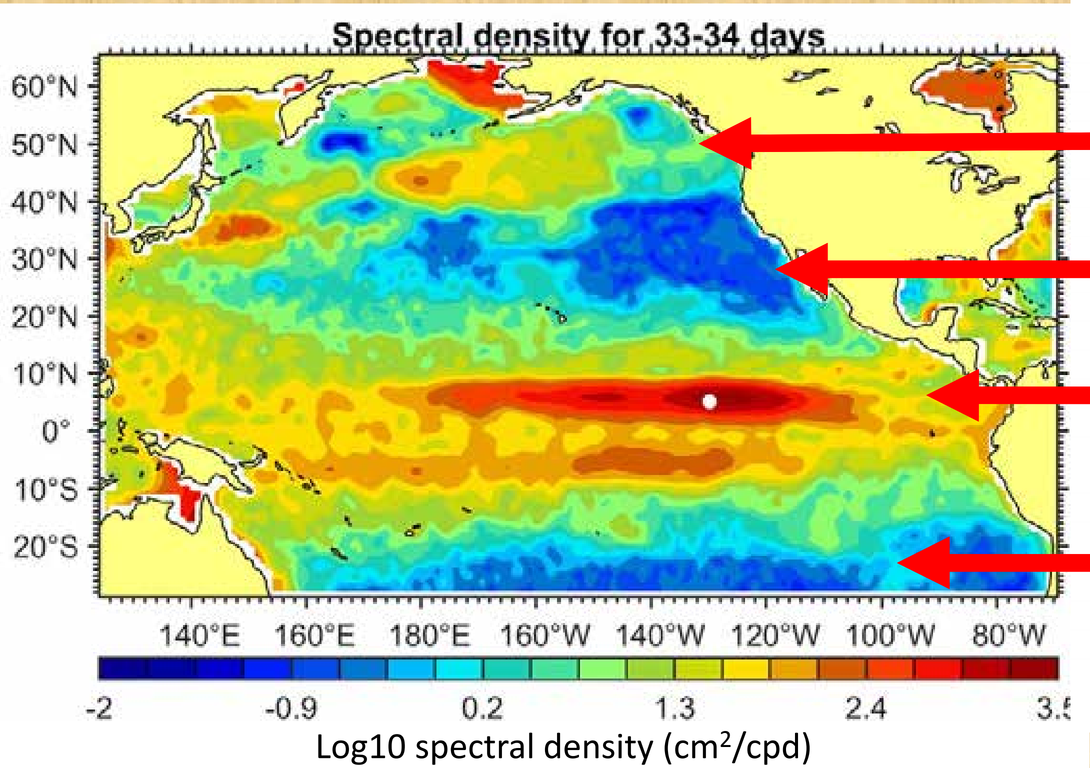
(3) The time-space sampling

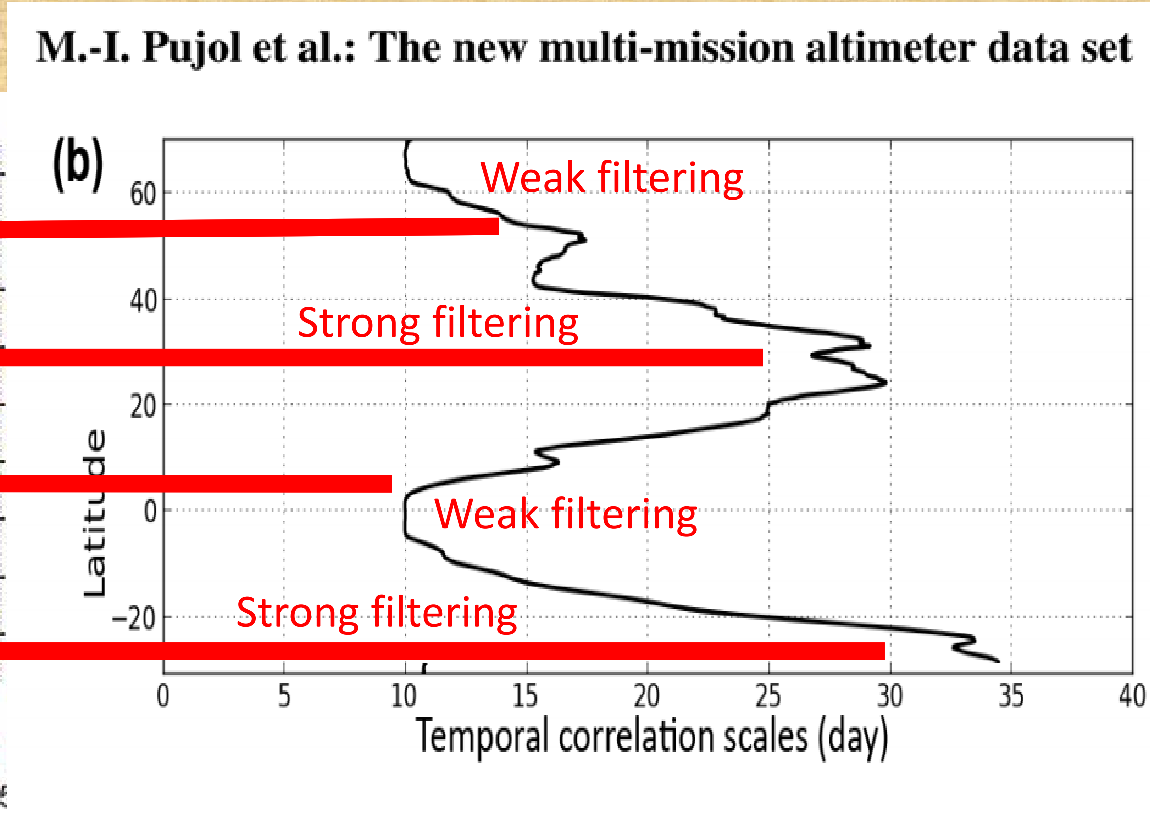
M.-I. Pujol et al.: The new multi-mission altimeter data set



Spatial variation of temporal filtering in the Aviso product

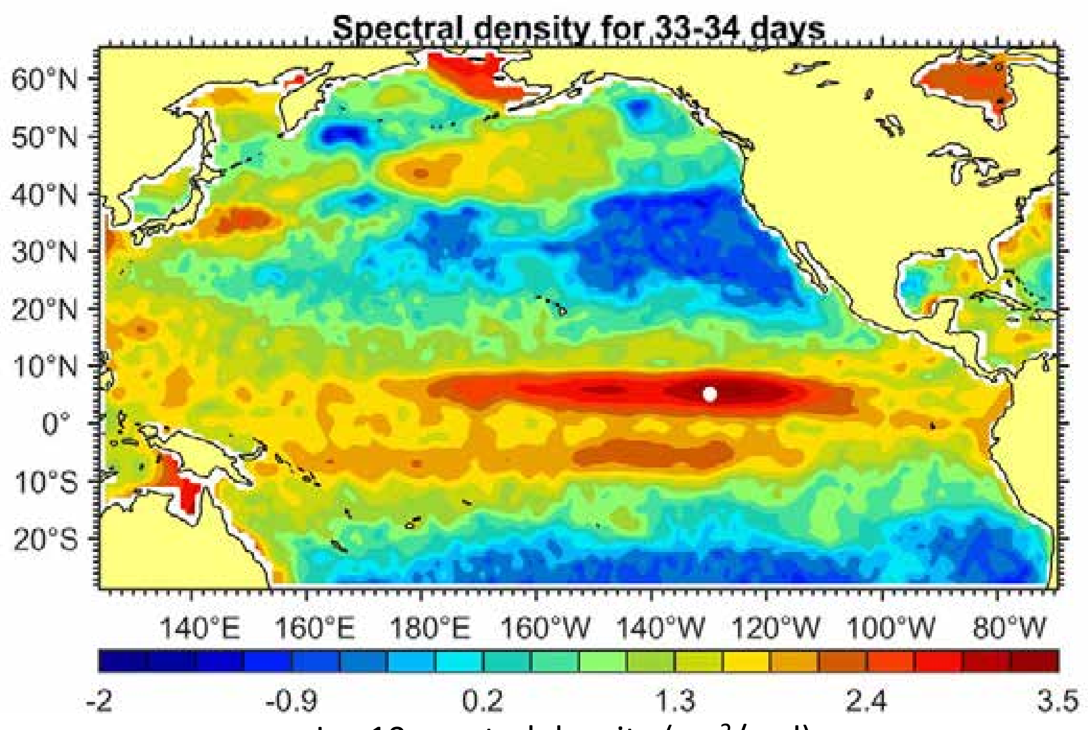
DUACS 2014 Aviso product





Spatial variation of temporal filtering in the Aviso product

DUACS 2014 Aviso product



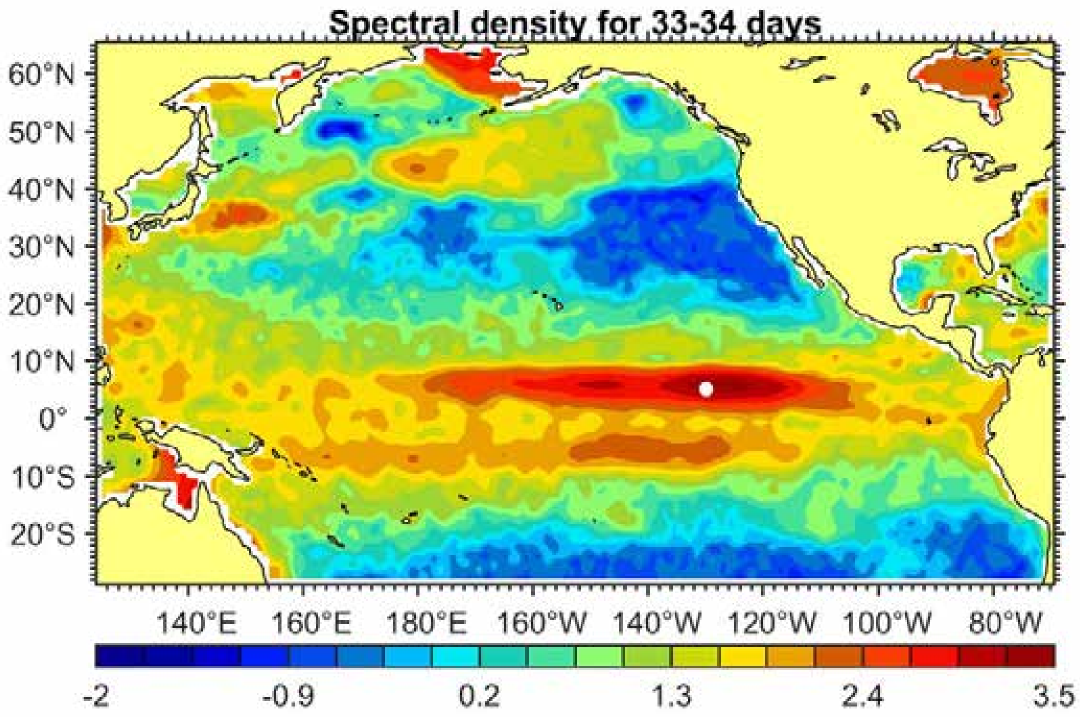
Log10 spectral density (cm^2/cpd)

Mapping with Gaussian weighted average
6°×6°×17-day half-power cutoff

The purpose of this is to ensure spatially uniform filtering properties so that the amplitude of the ~30-day waves is not distorted as they propagate

Spatial variation of temporal filtering in the Aviso product

DUACS 2014 Aviso product



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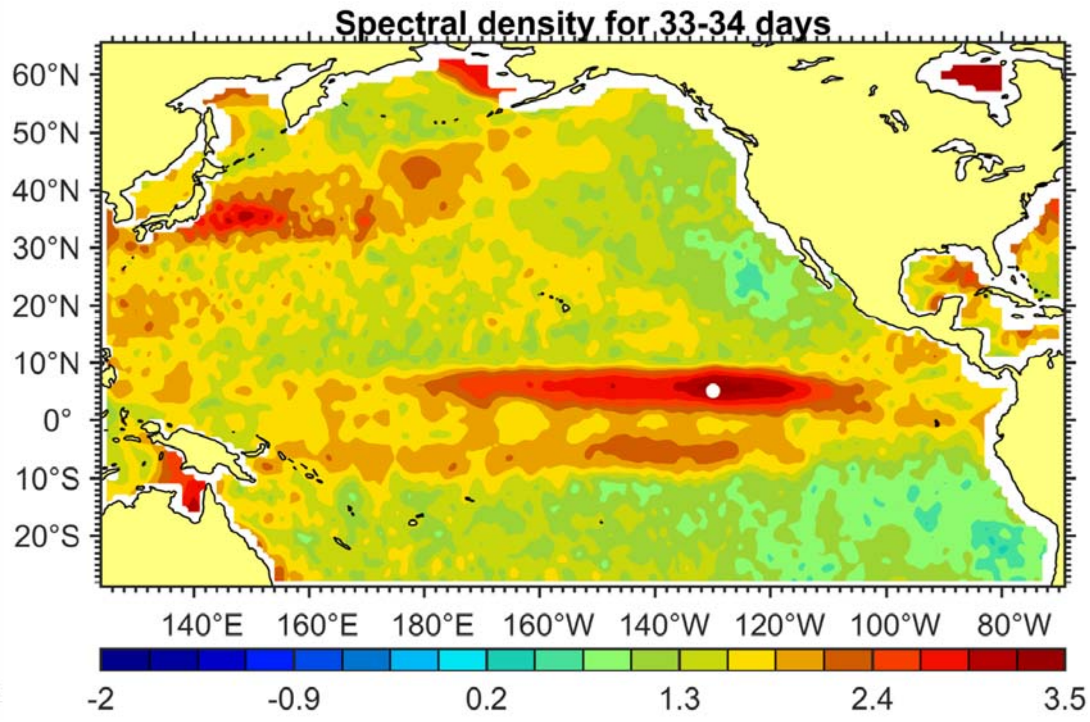

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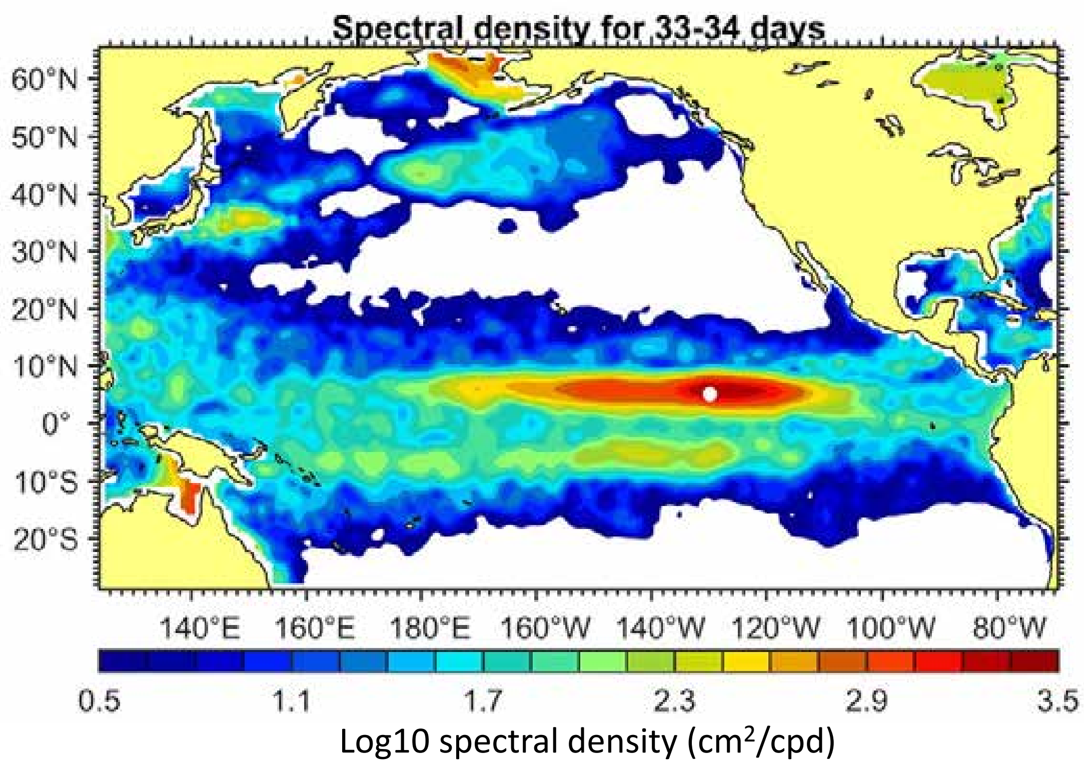
Spatial variation of temporal filtering in the Aviso product

DUACS 2014 Aviso product



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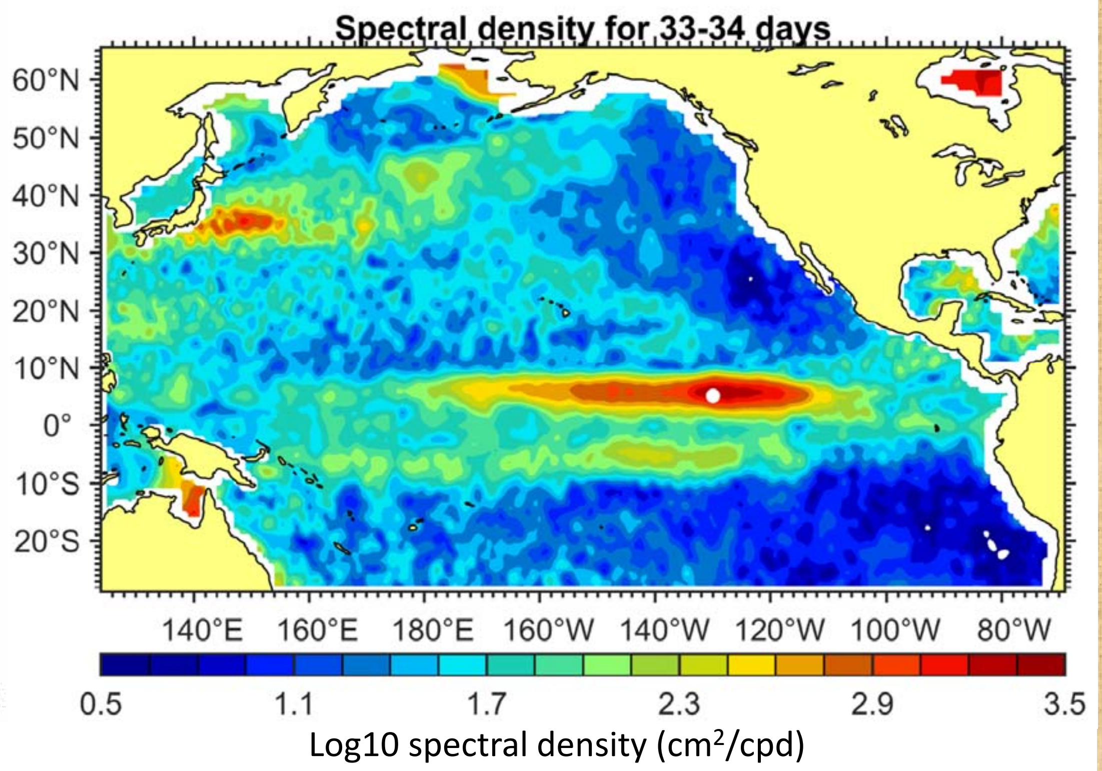
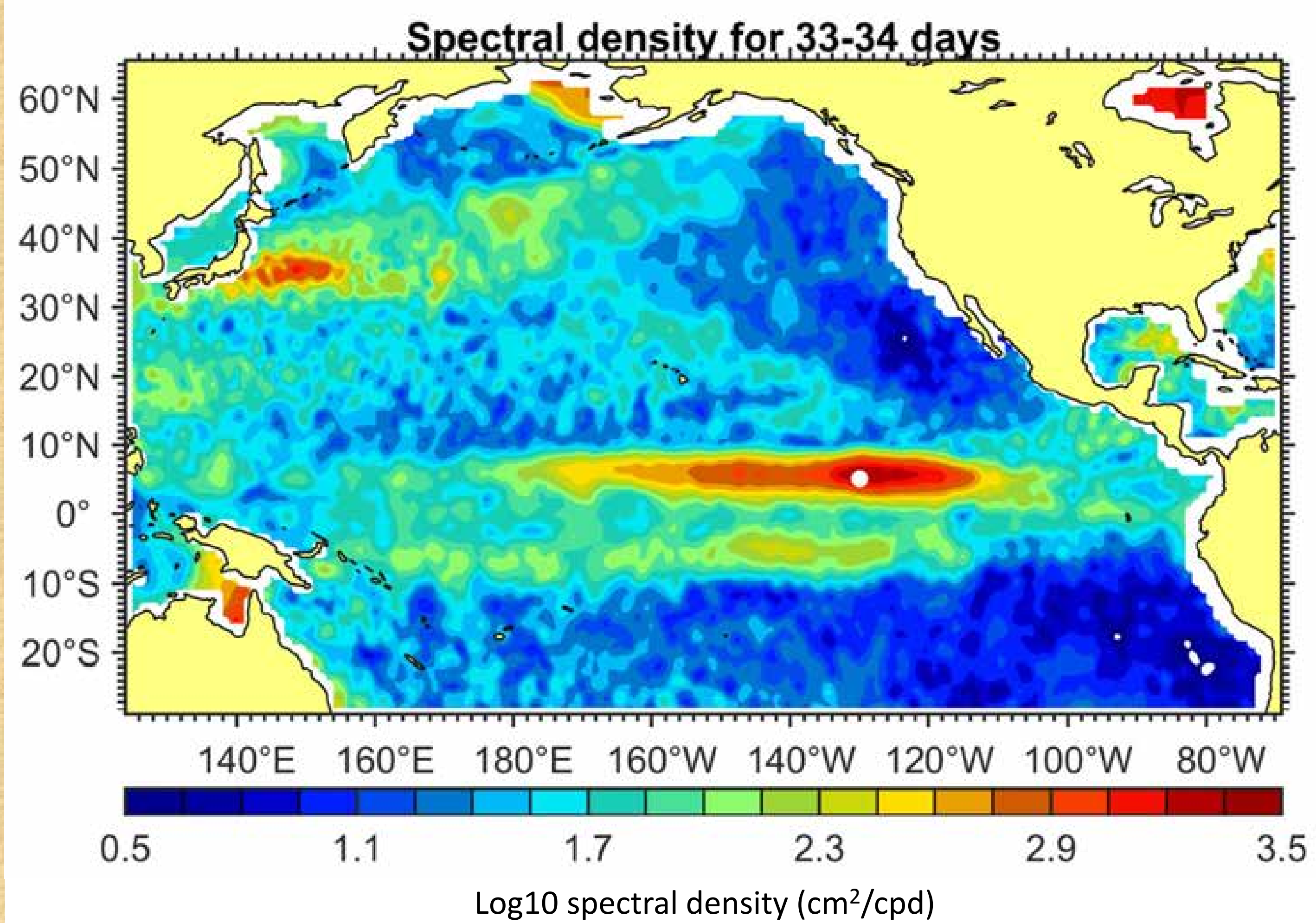


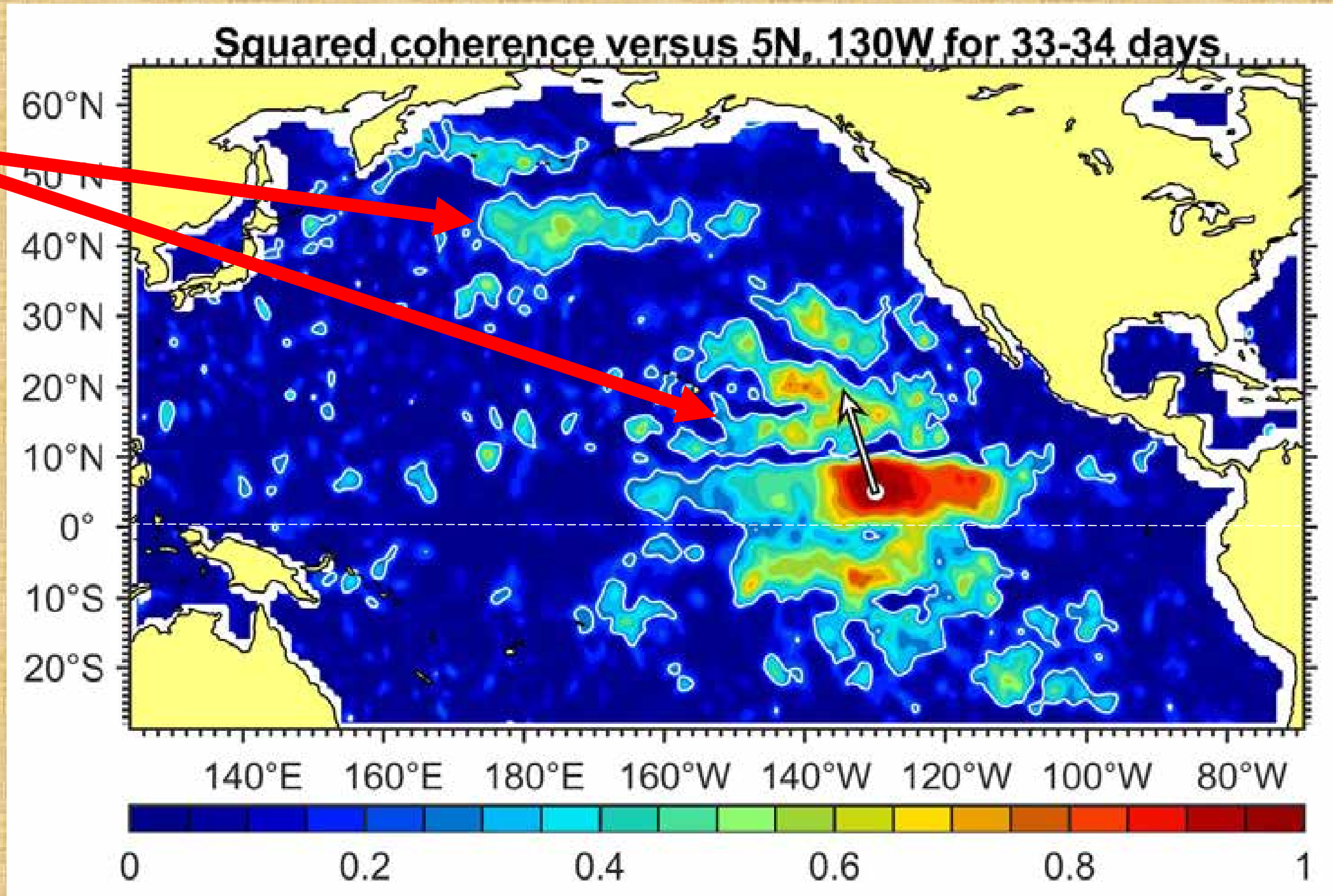
Approach to look for remote effects of radiating waves: examine coherence of SSH field against location of max TIW signal

- Focus on ~33-day period band with strongest TIW signal
- Compute coherence and associated quantities (gain, phase) against SSH at all other locations
- Made gridded SSH field with spatially uniform filtering properties (using Aviso along-track data)



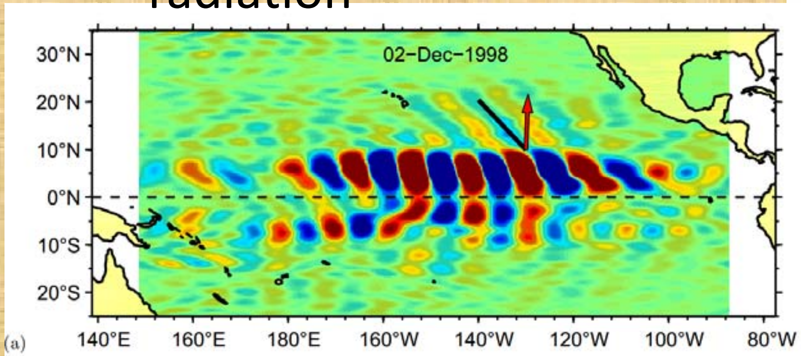
There is statistically significant coherence of SSH with the TIW signal at distant locations

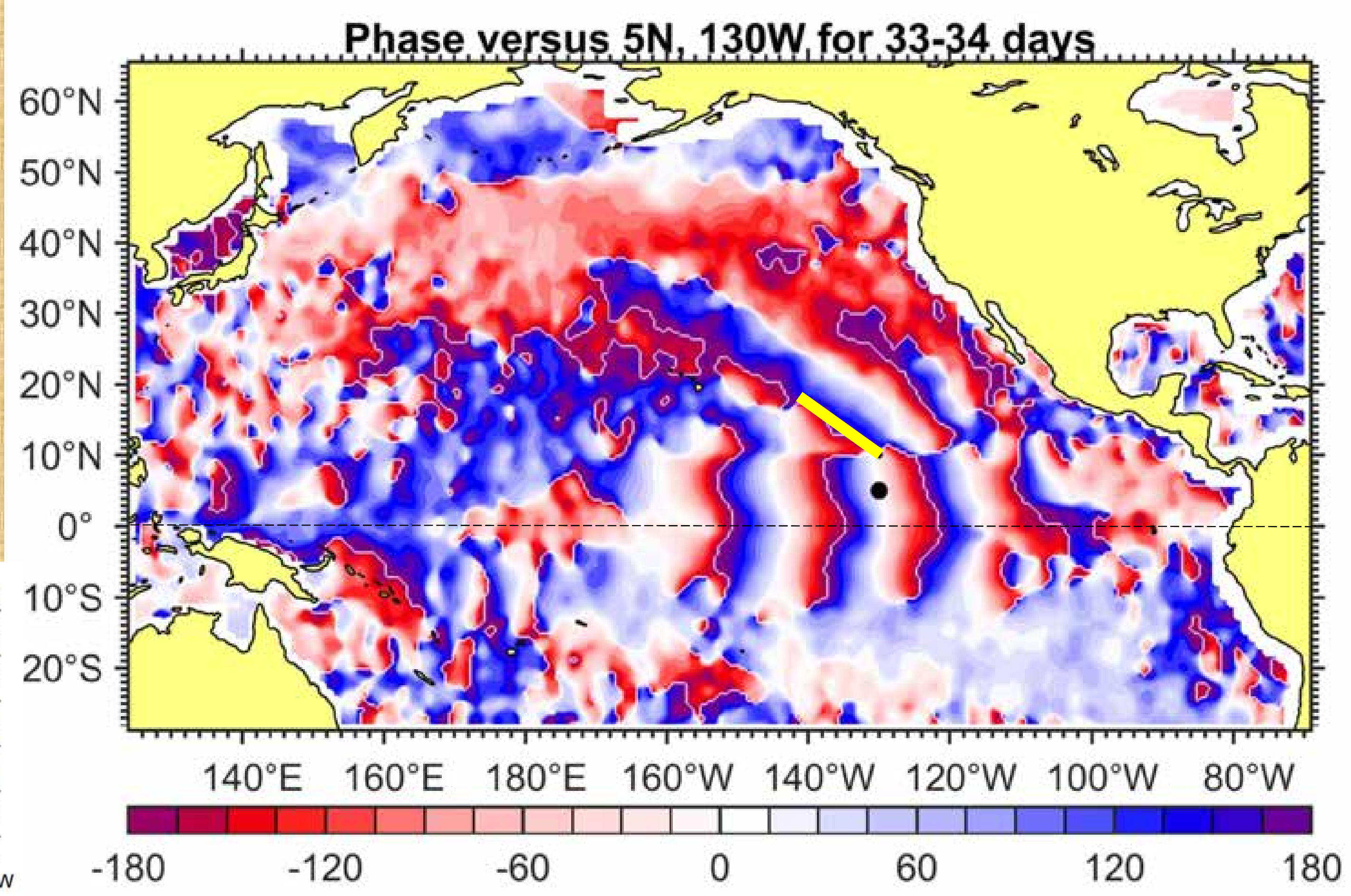
- The coherence amplitude is high (white contour is 95% significance level)



There is statistically significant coherence of SSH with the TIW signal at distant locations

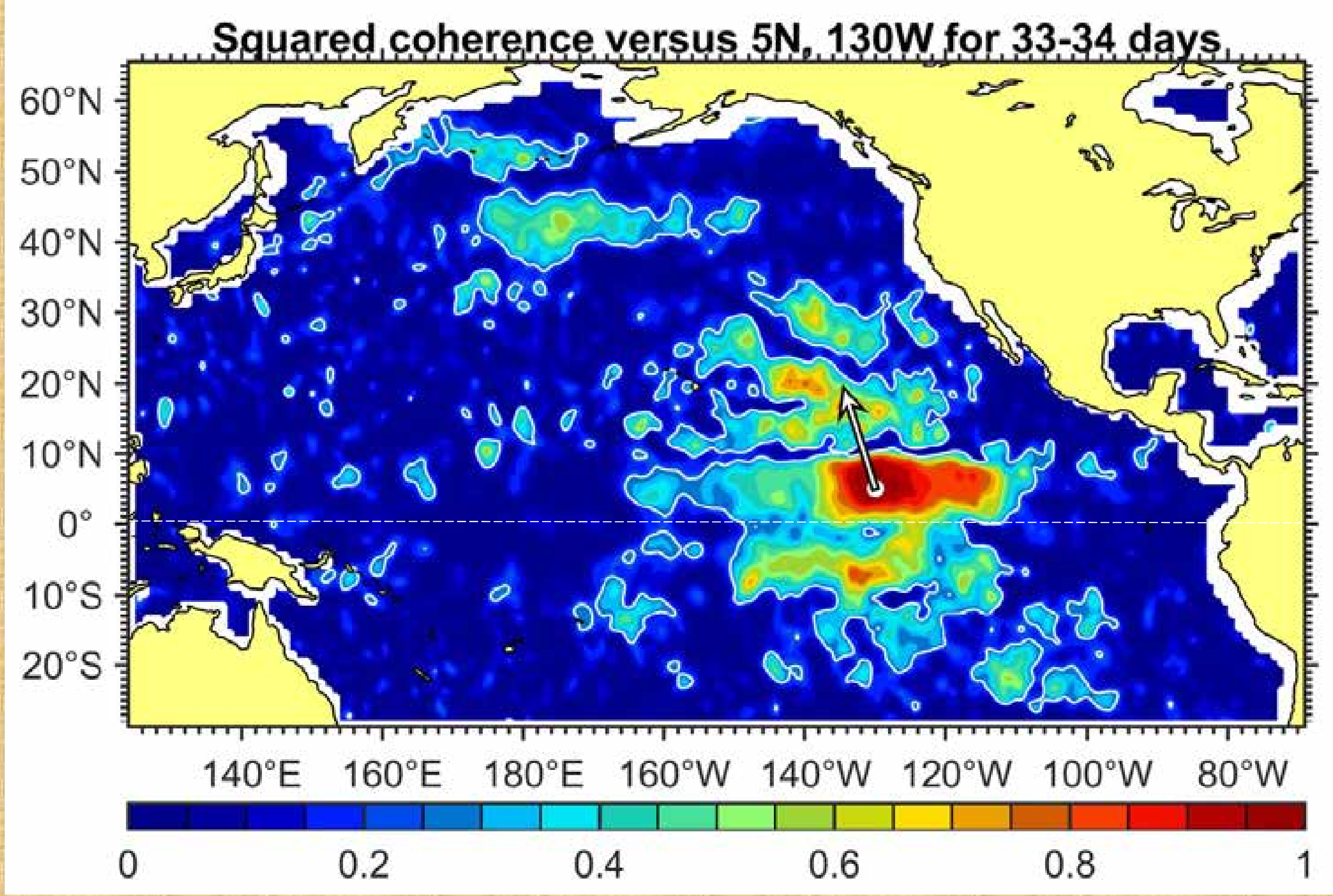
- The coherence amplitude is high (white contour is 95% significance level)
- In the "near field" (<2000km from source), the coherence phase is consistent with barotropic Rossby wave radiation





There is statistically significant coherence of SSH with the TIW signal at distant locations

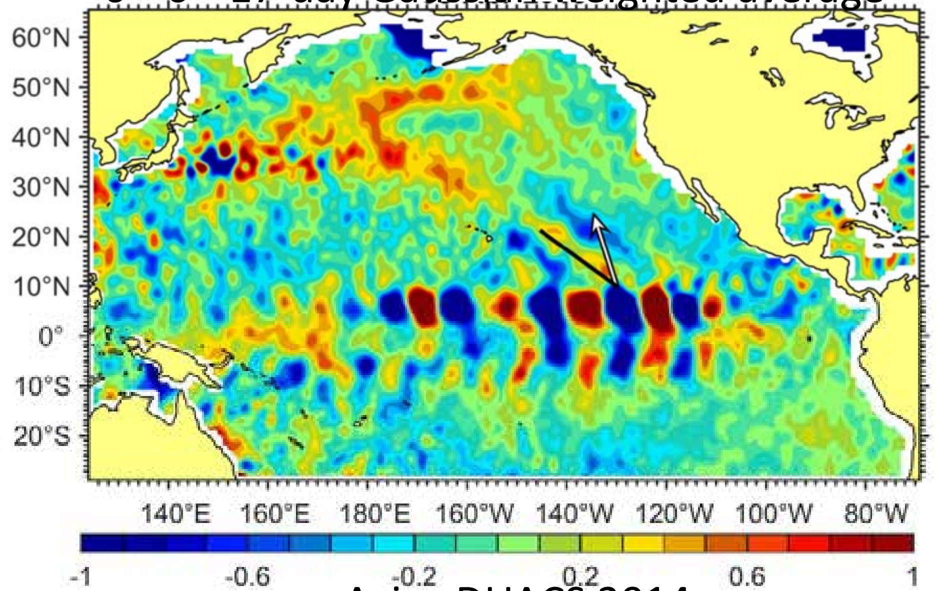
- The coherence amplitude is high (white contour is 95% significance level)
- In the “near field” (<2000km from source), the coherence phase is consistent with barotropic Rossby wave radiation
- The simplest interpretation of this is that the radiating waves are responsible



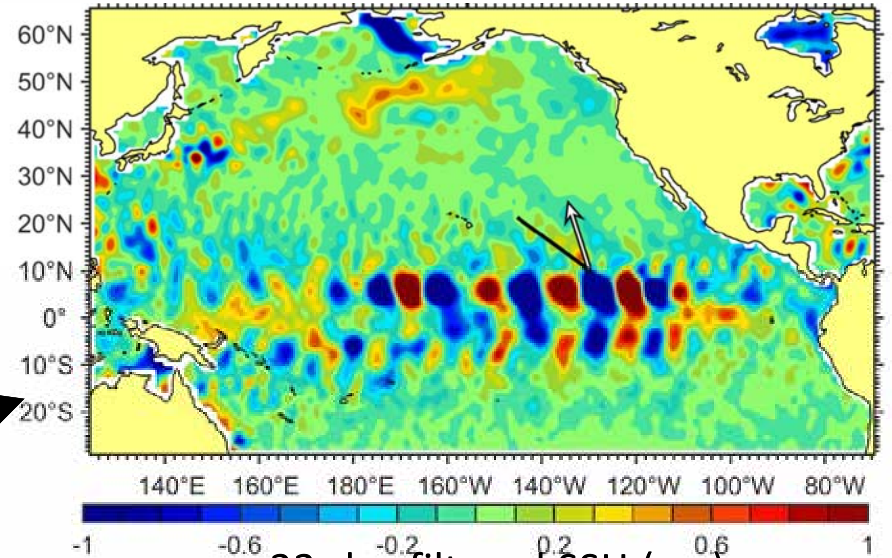
Conclusions

- SSH variability throughout much of the North Pacific is coherent with that of tropical instability waves.
- This variability can be interpreted as barotropic Rossby waves with northward energy propagation
- The waves clearly propagate from the equatorial region to at least 30°N
- This variability is not well represented in the gridded AVISO product. This is apparently a result of the assumed autocovariance function used for the objective mapping scheme

6°×6°×17-day Gaussian weighted average



Aviso DUACS 2014



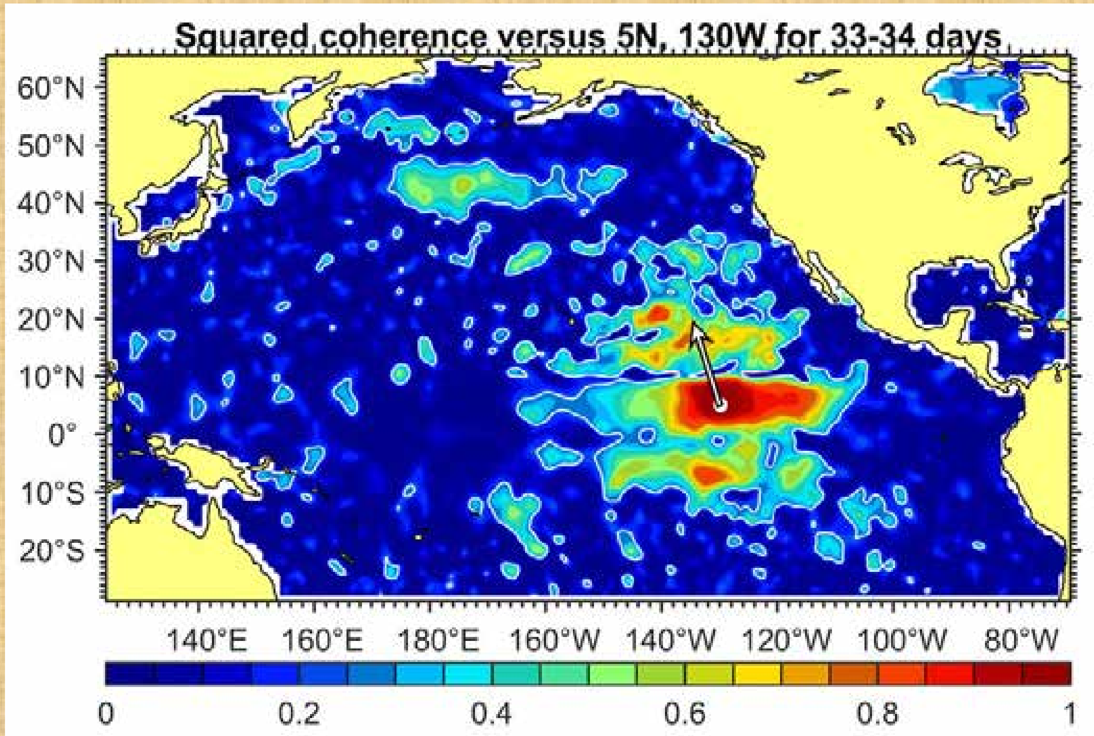
33-day filtered SSH (cm)

Snapshots of 33-day filtered fields

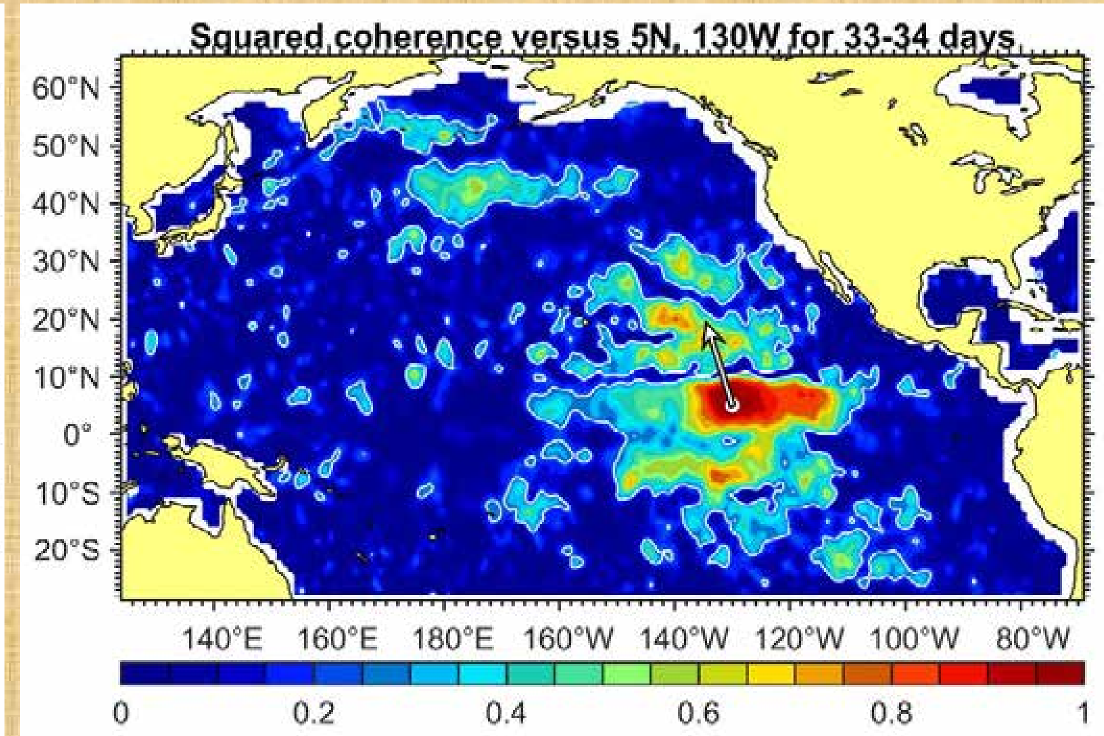
Back-up slides

Coherence calculations with two gridded products

DUACS 2014 Aviso product

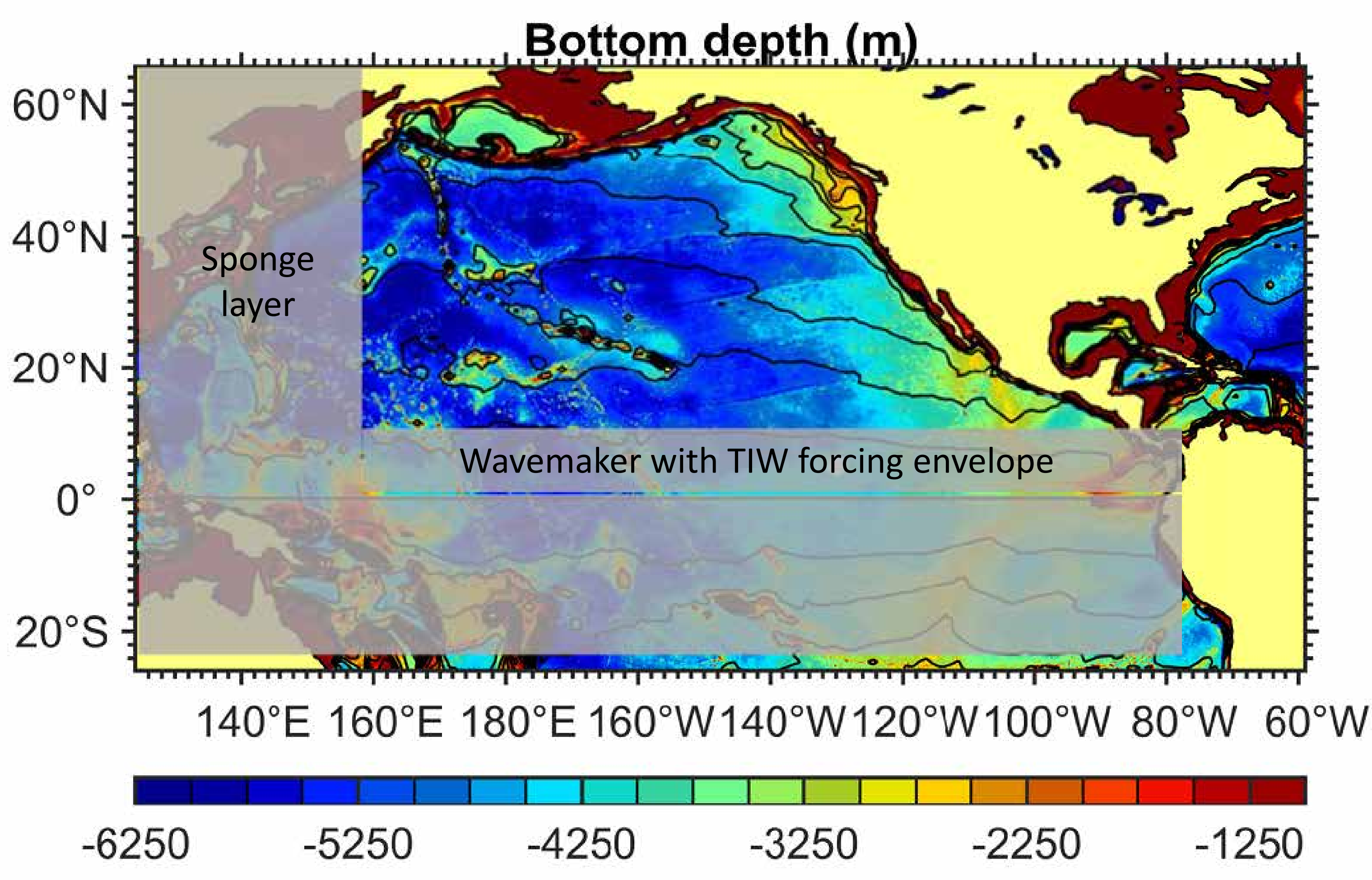


Mapped with Gaussian weighted average w/ 6°×6°×17-day half-power cutoff



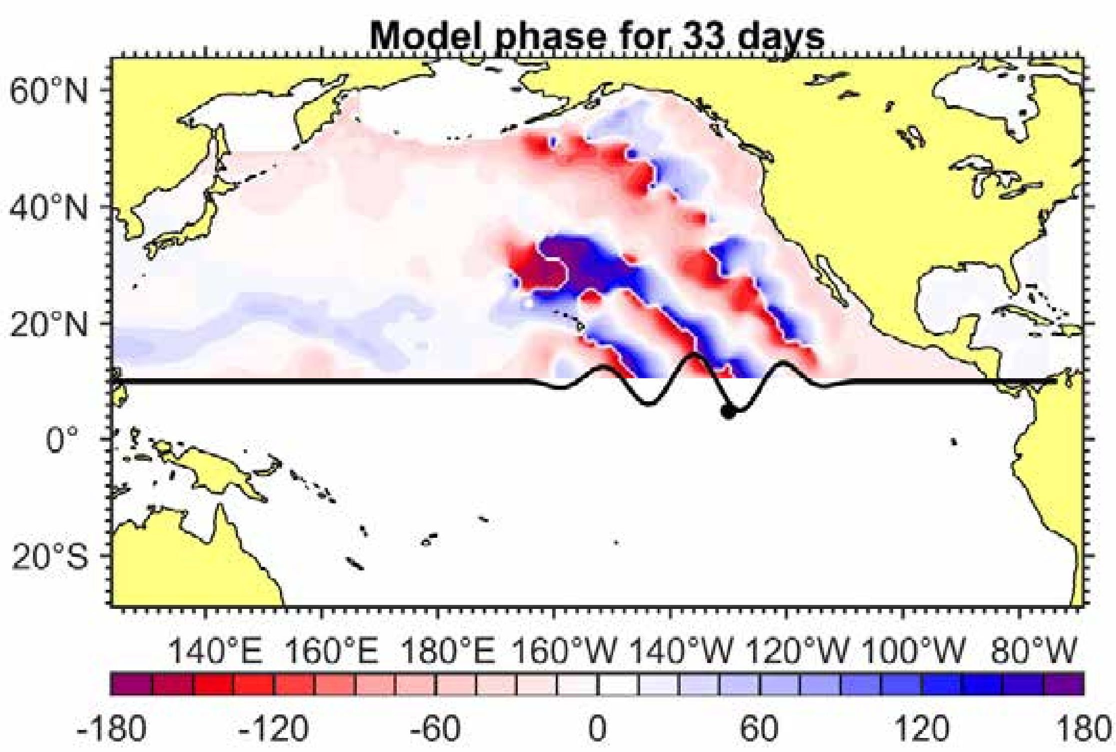
Interpretation as barotropic Rossby waves: numerical model

Using a primitive equation barotropic model with realistic topography

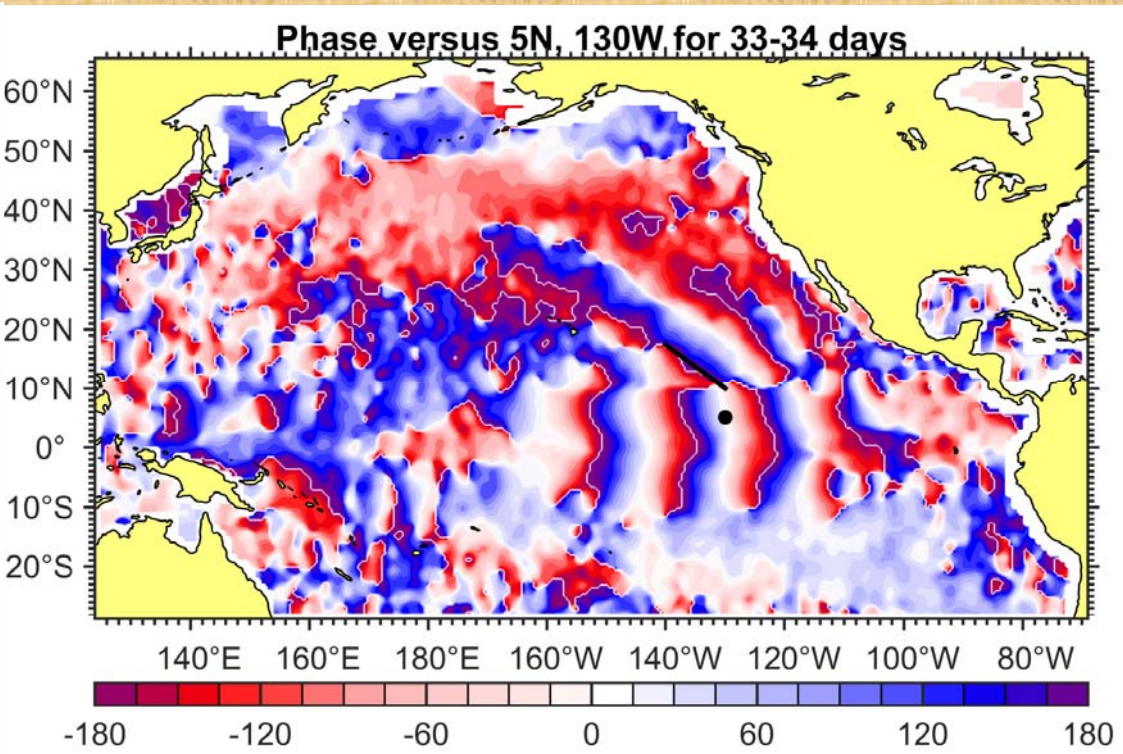


Interpretation as barotropic Rossby waves: numerical model

Model SSH (phase)



Observed SSH (phase)



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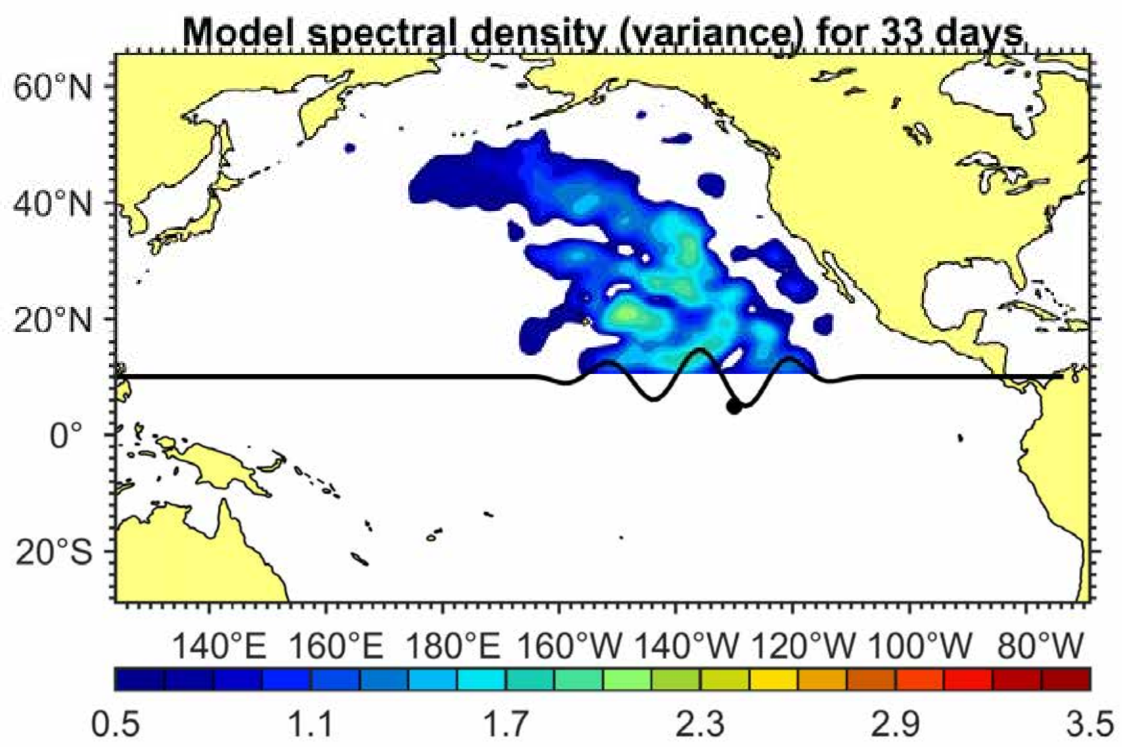
Model SSH (variance)



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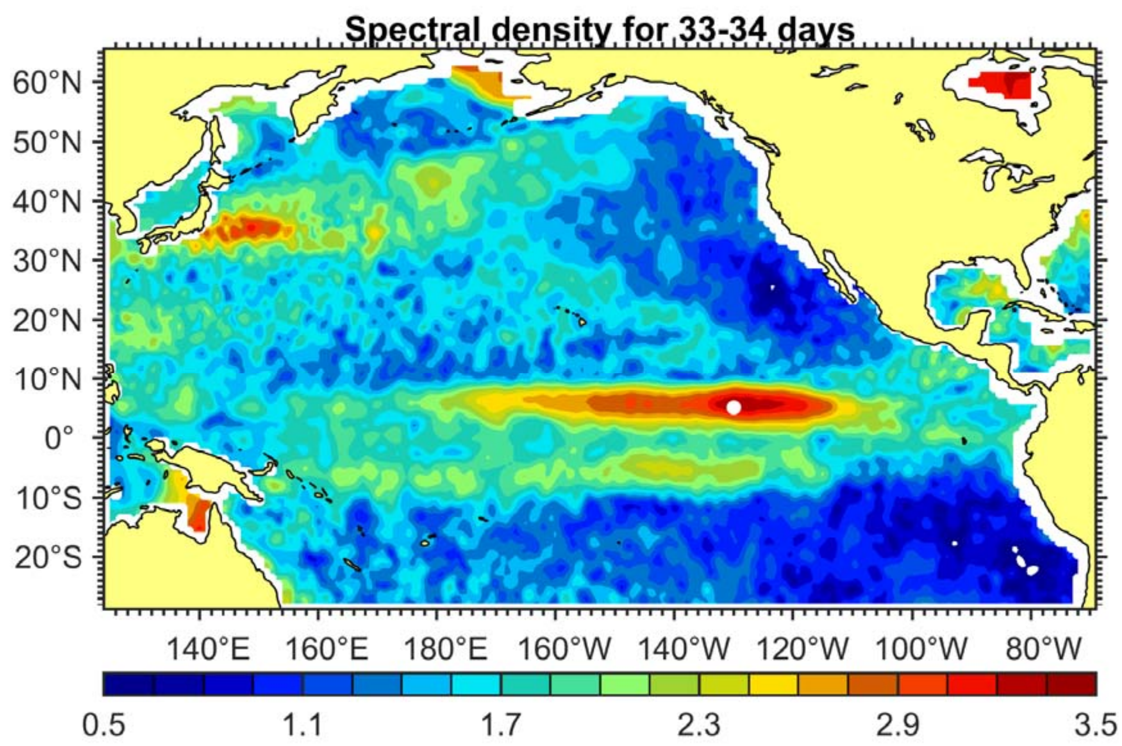

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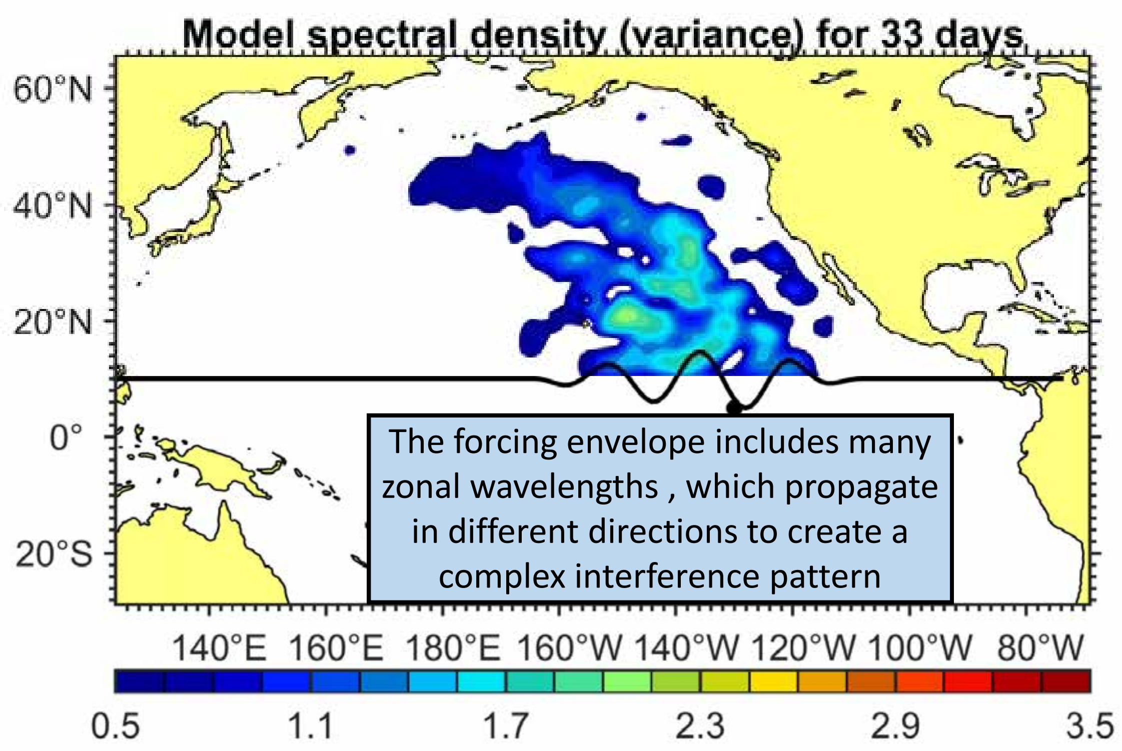
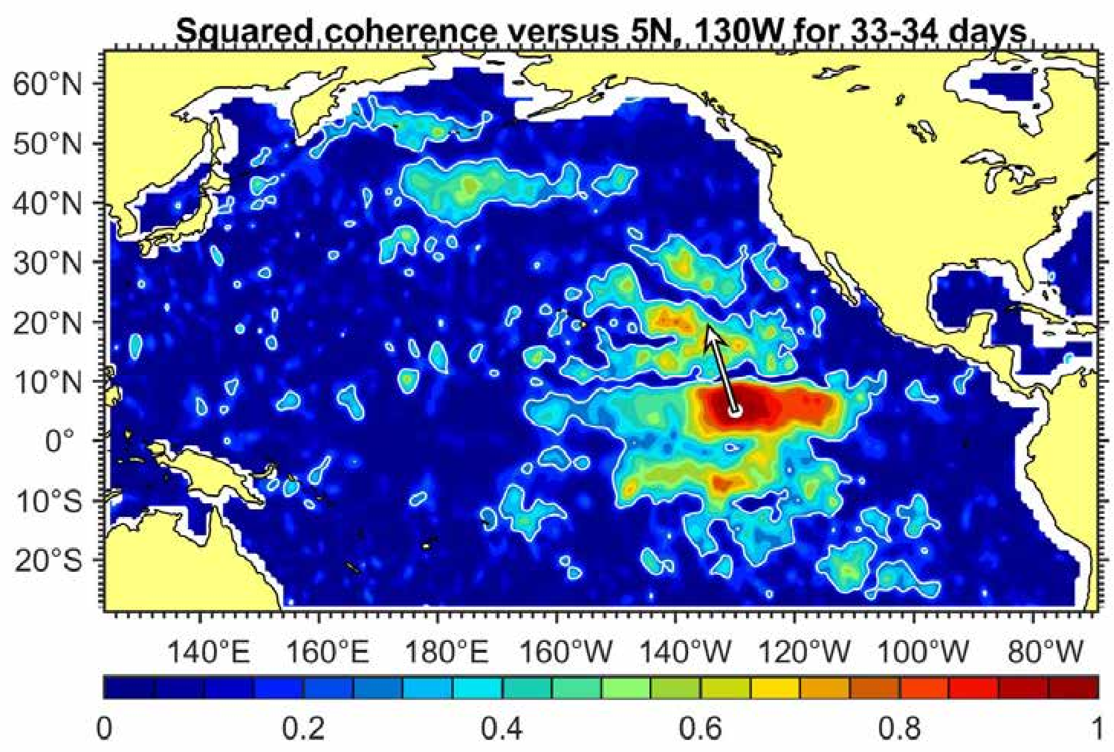


Observed SSH (squared coherence)



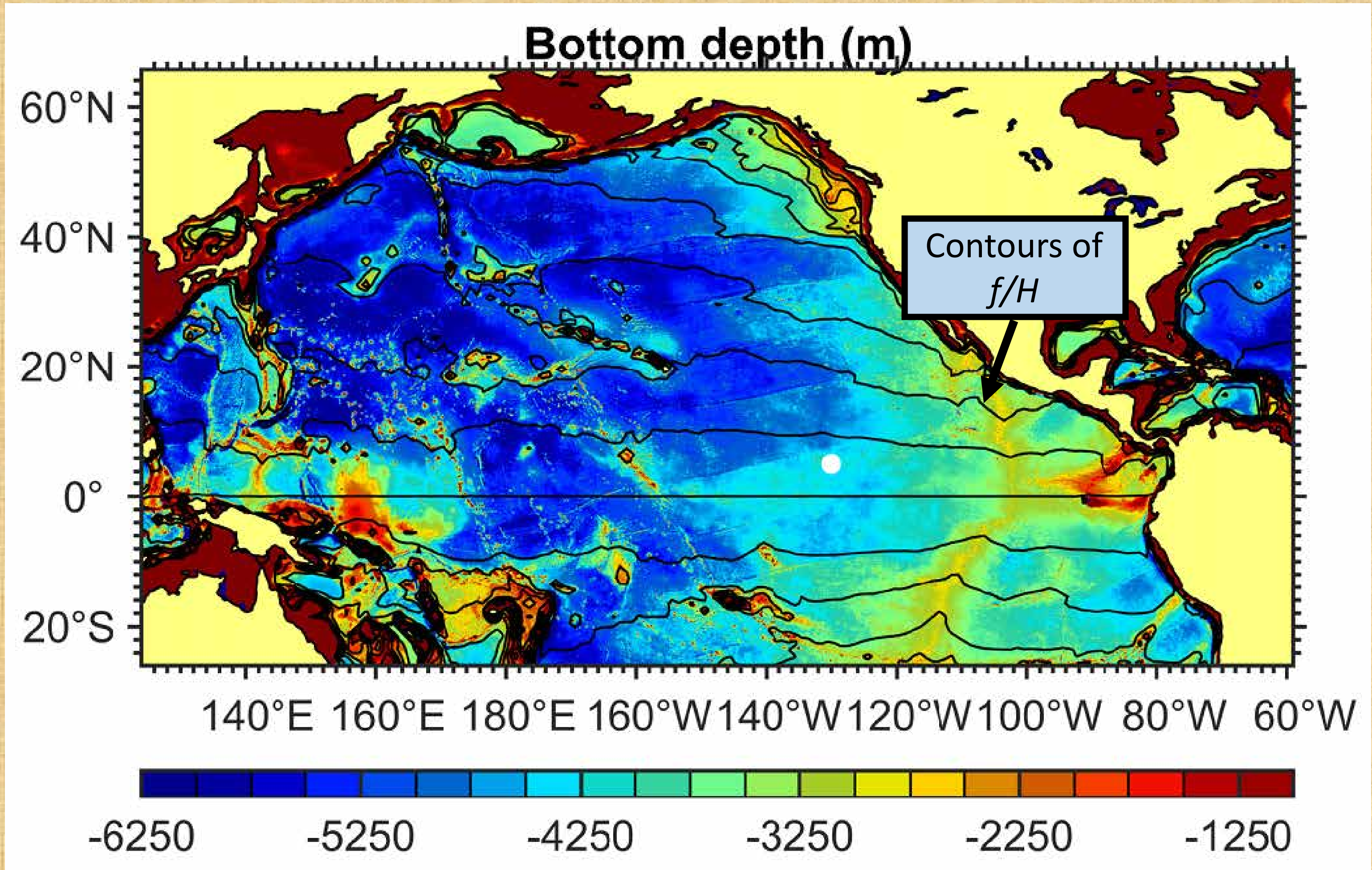
Interpretation as barotropic Rossby waves

Farrar (2011) interpretation of variability on 10-20°N was in terms of flat-bottom barotropic Rossby waves:

$$\omega = \frac{-\beta k}{k^2 + l^2}$$

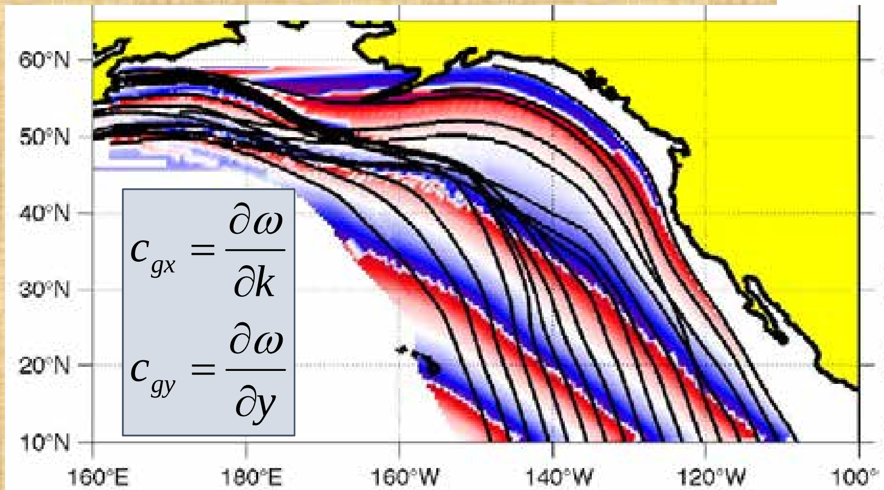
Barotropic Rossby waves with variable bottom depth:

$$\omega = \frac{-H\left(\vec{k} \times \nabla \frac{f}{H}\right)}{k^2 + l^2}$$



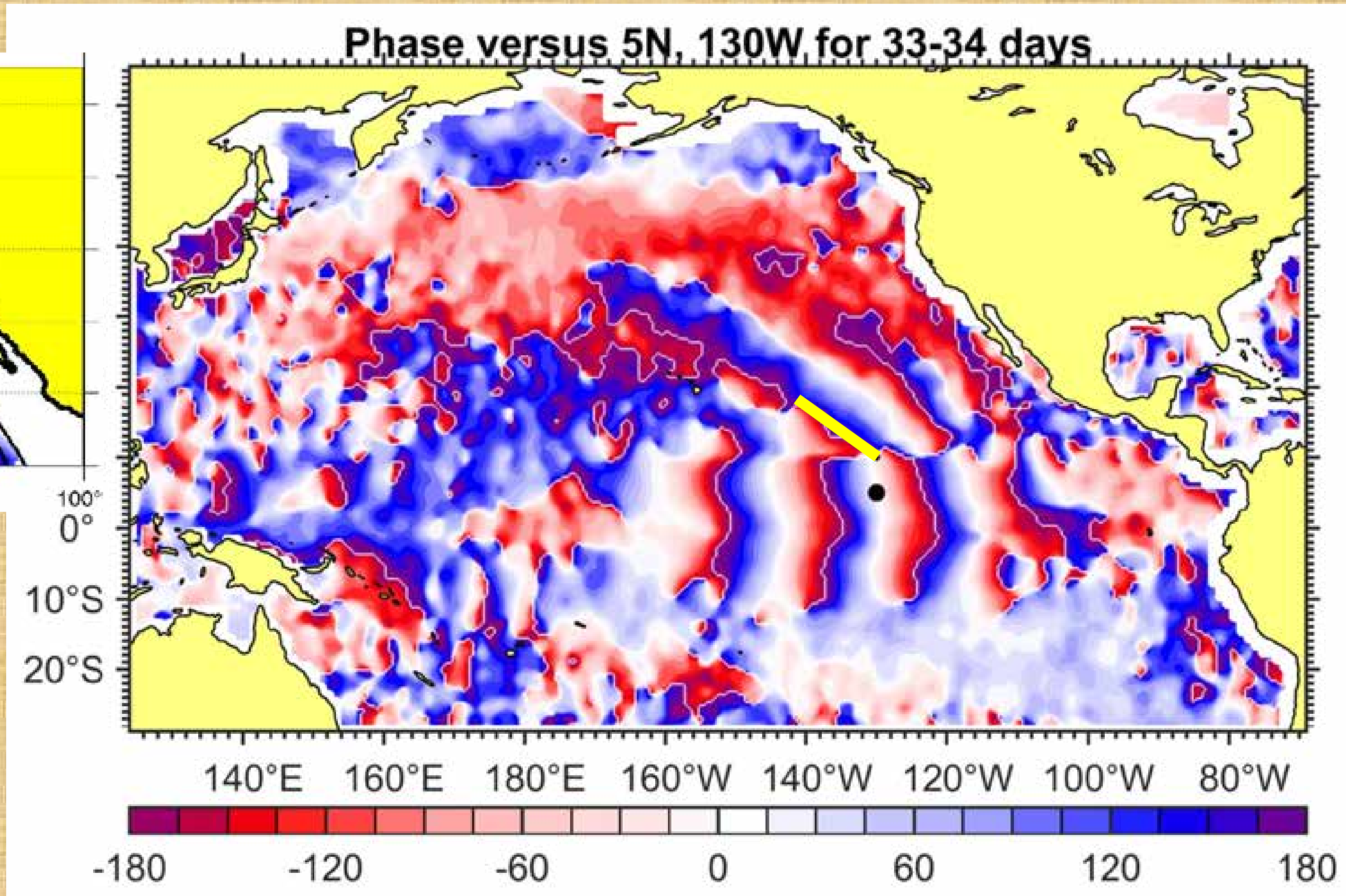
Interpretation as barotropic Rossby waves: ray tracing

Ray-tracing calculation



$$c_{gx} = \frac{\partial \omega}{\partial k}$$

$$c_{gy} = \frac{\partial \omega}{\partial y}$$



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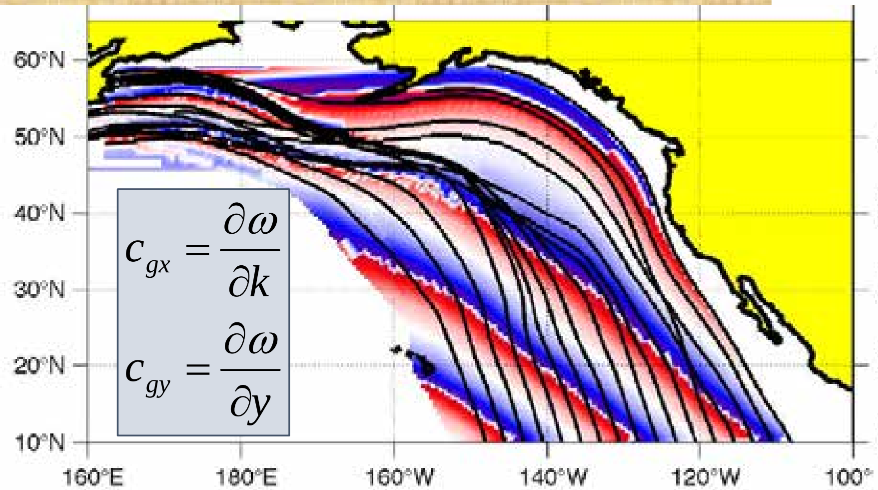

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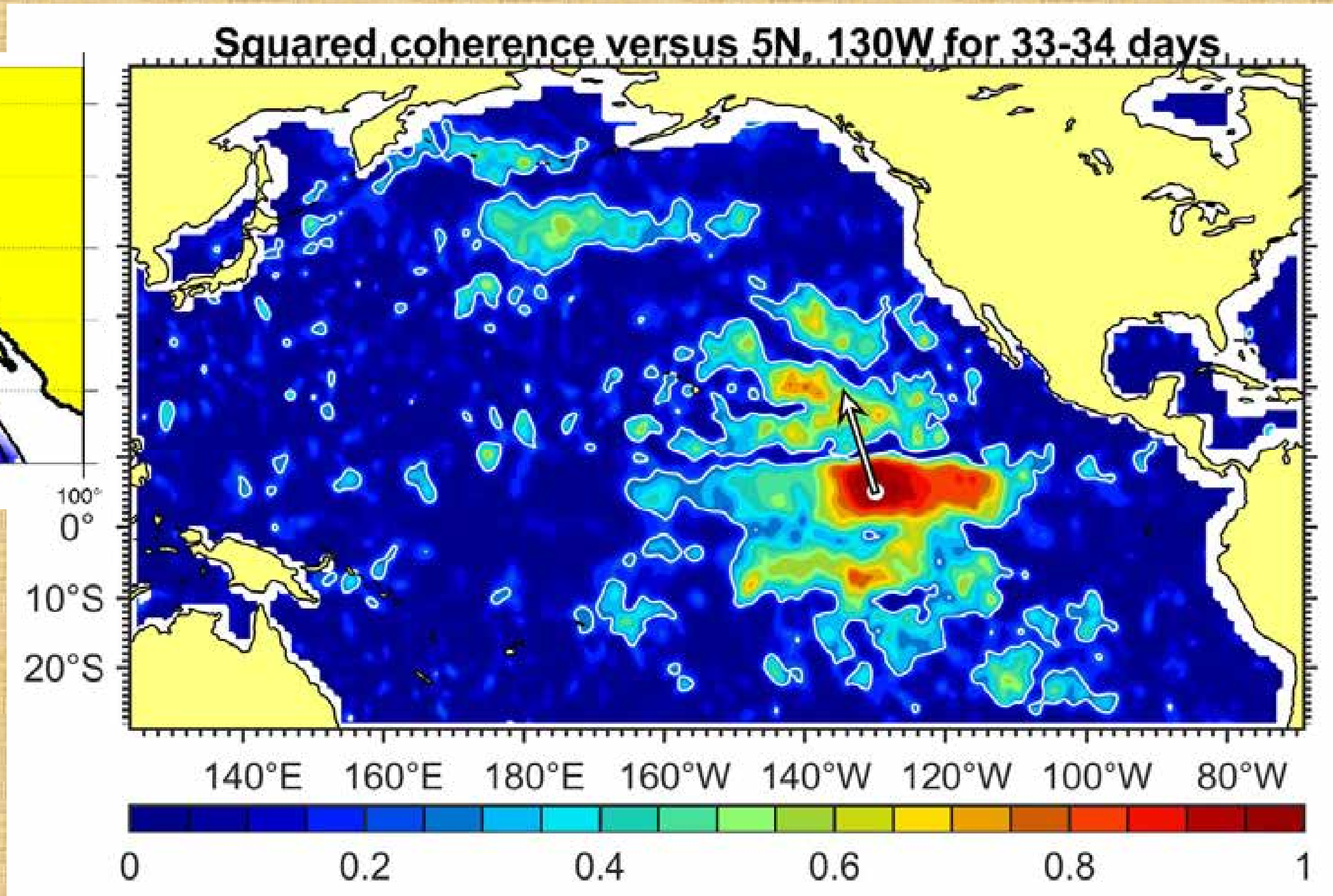

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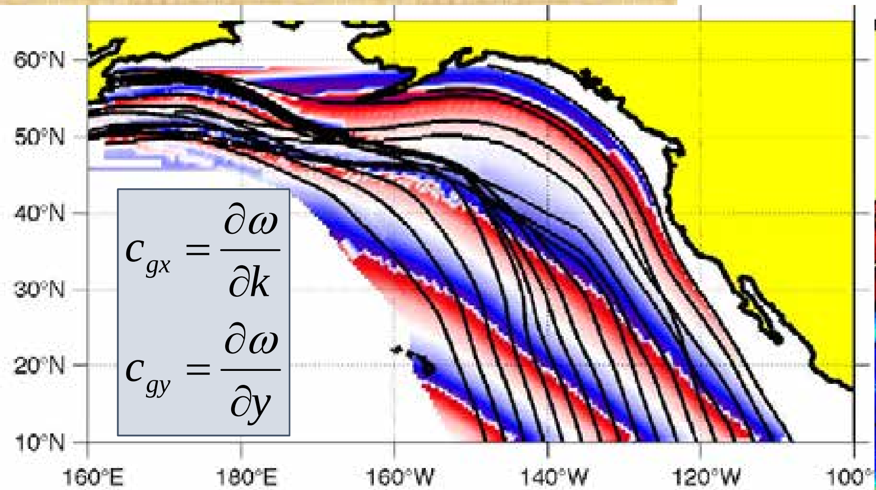

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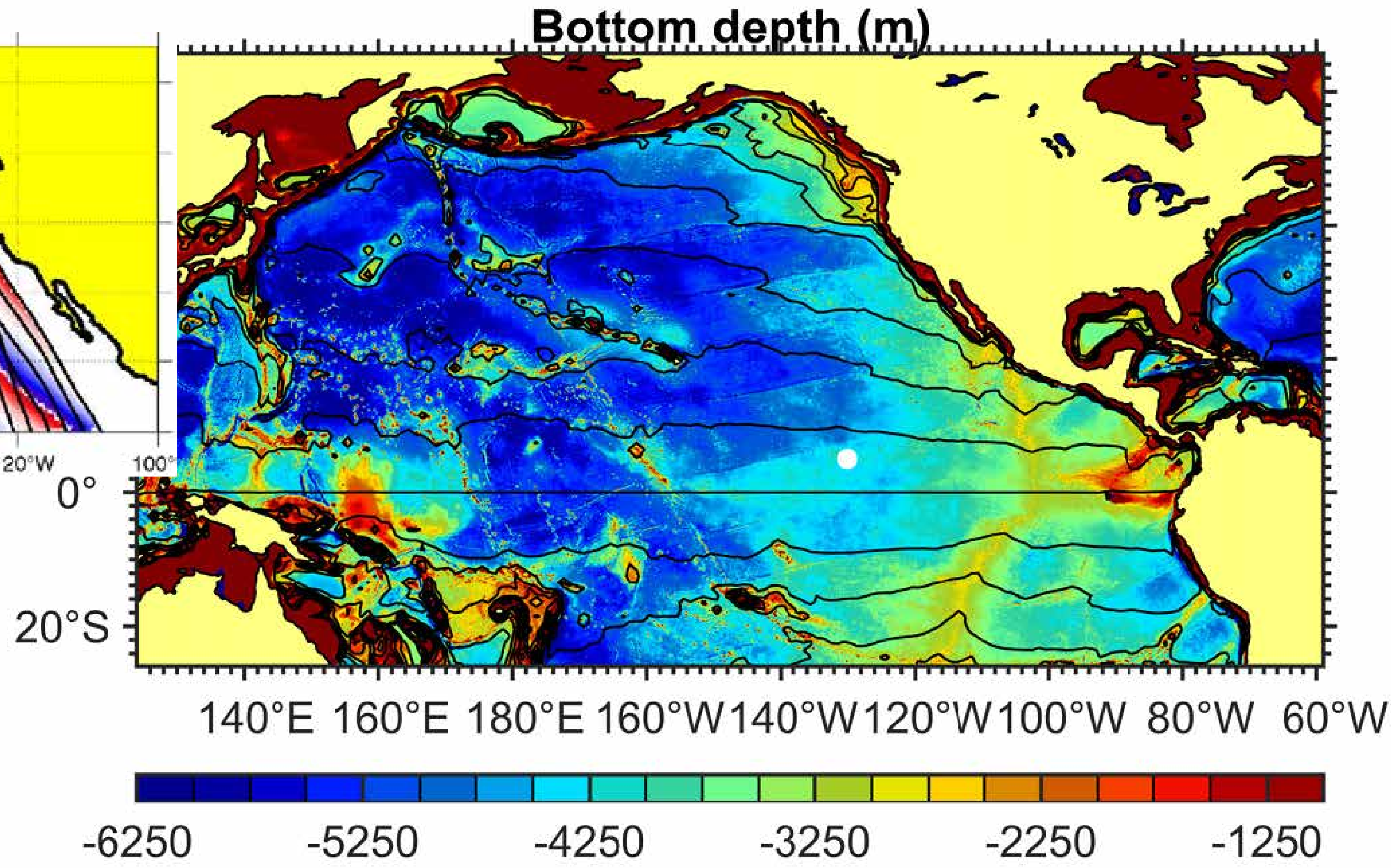
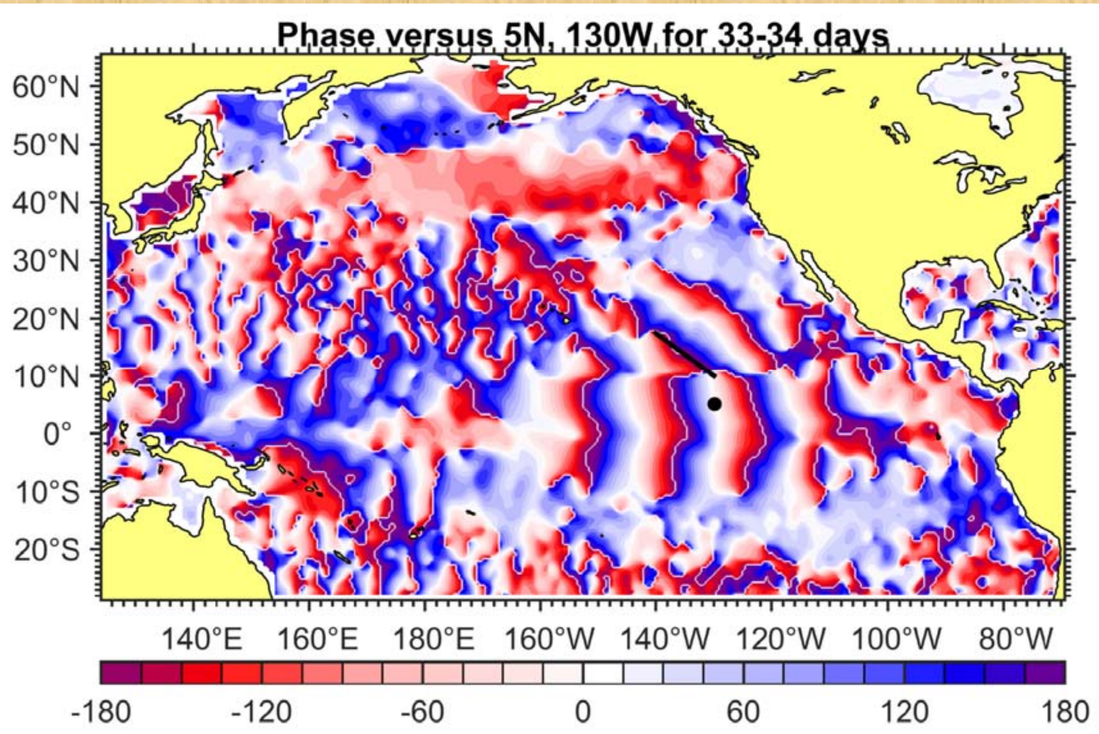
Ray tracing is too simple
(too much smoothing of topography)



Coherence calculations with two gridded products

DUACS 2014 Aviso product



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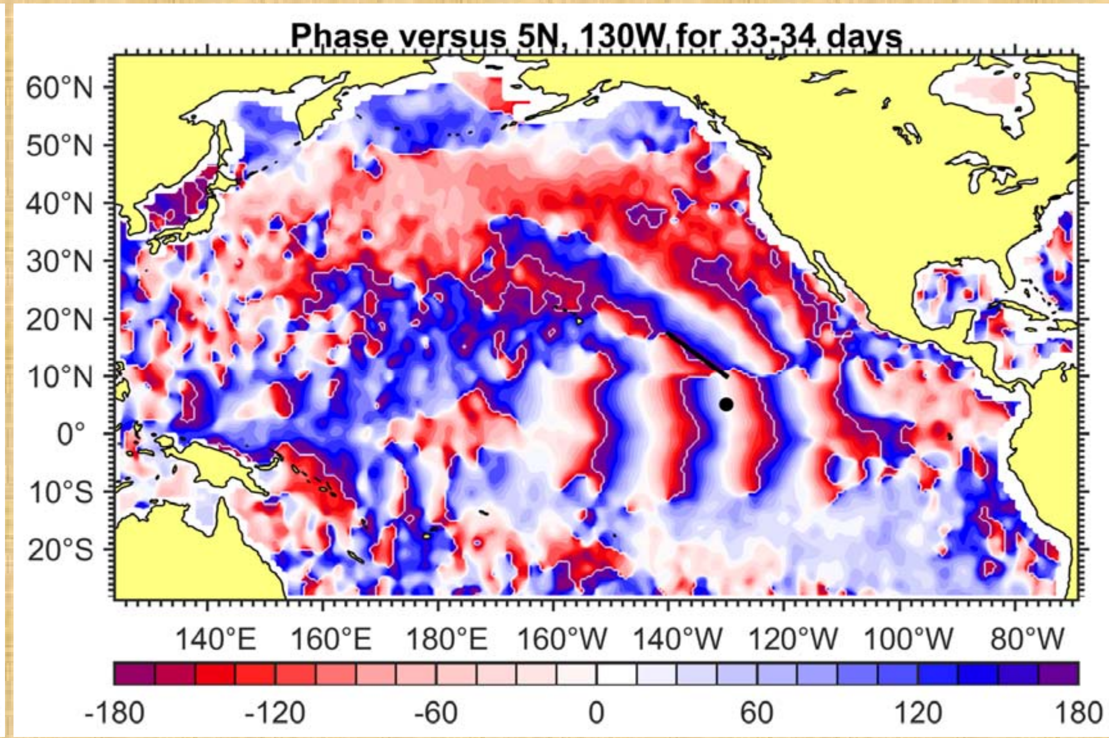

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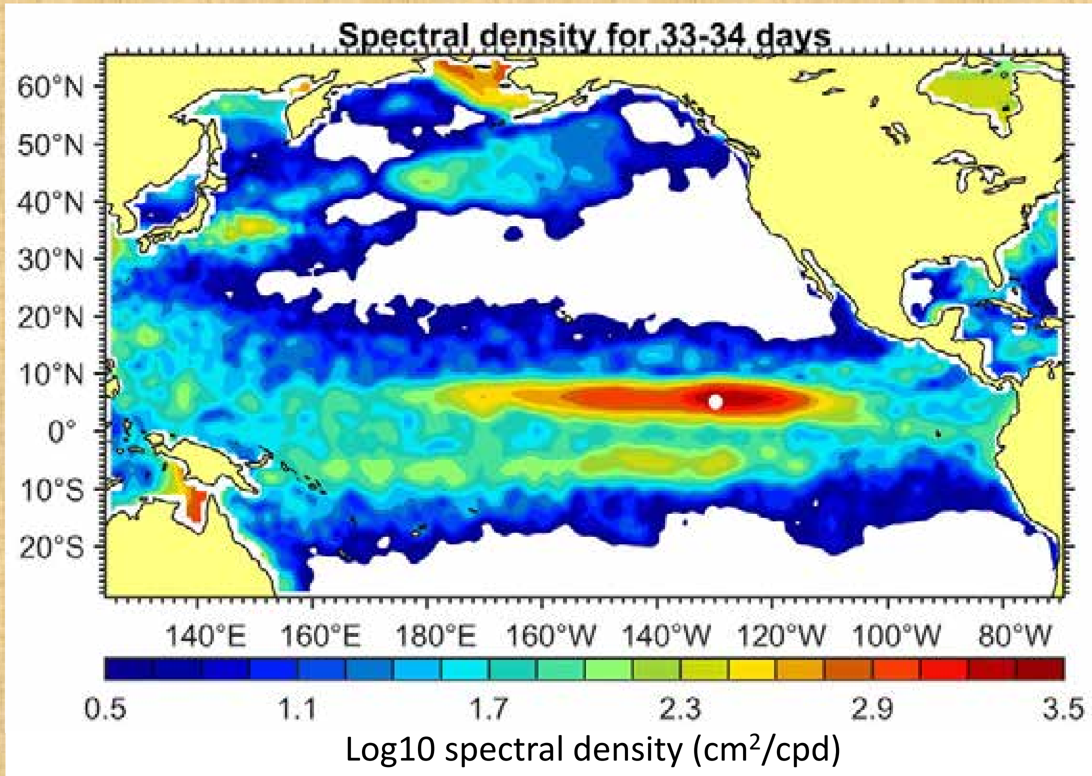

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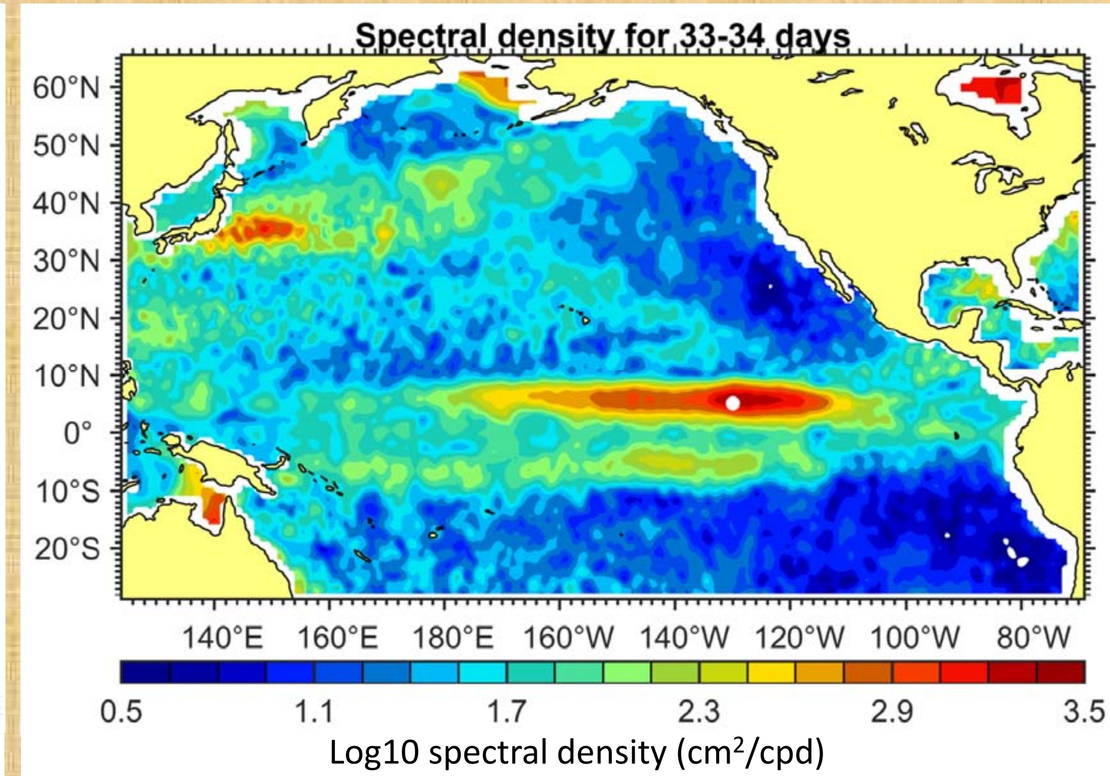

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