Observations of near-inertial surface currents off Oregon: Decorrelation length and time scales

Sung Yong Kim[1] and P. Michael Kosro[2]

[1]Division of Ocean Systems Engineering,
Korea Advanced Institute of Science and Technology (KAIST),
Daejeon, Republic of Korea

[2]College of Earth, Ocean, and Atmospheric Sciences,
Oregon State University, Corvallis, Oregon, USA

Questions?

- Vertical observations have been already used to examine the near-inertial energy. However, the observations of high-resolution currents in the horizontal space are sparse and limited…..

- How we quantify the decorrelation scales [space & time] of near-inertial (surface) currents?

- How was the propagation of NI signals in the super-inertial and sub-inertial frequency bands?

- Is visible ‘coastal inhibition’ of near-inertial motions?

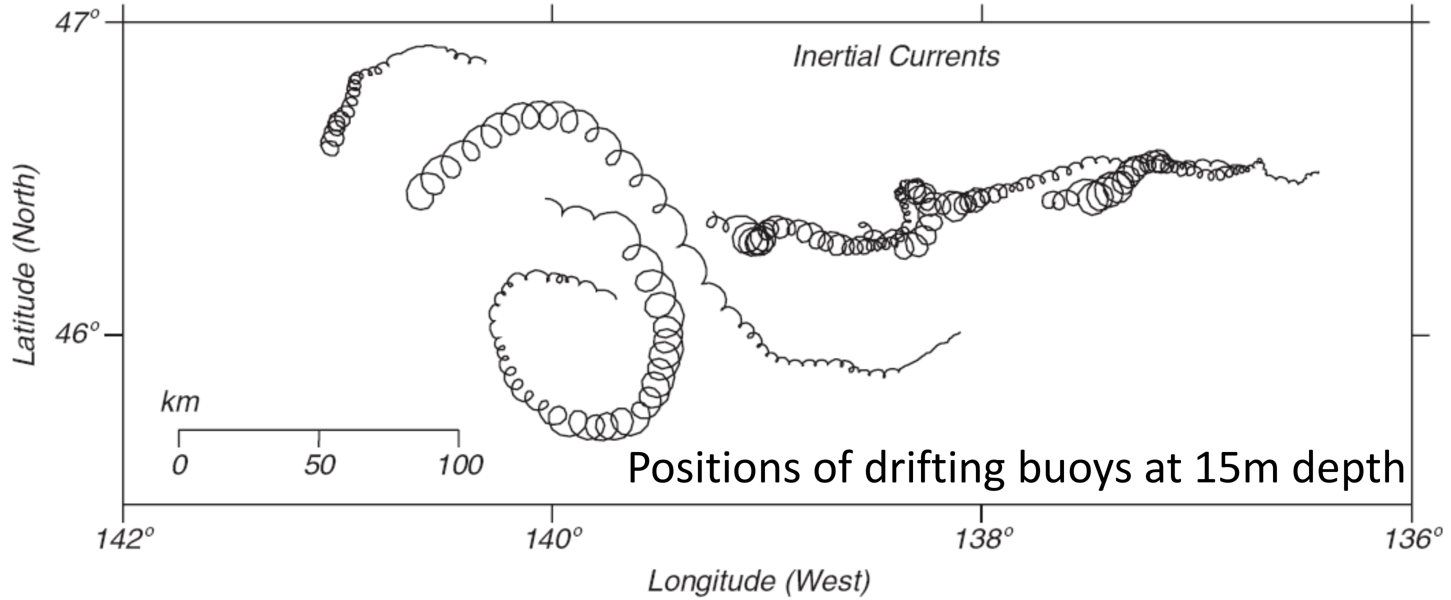
Near-inertial (NI) motions

Physical Oceanography 101 (R. Stewart)

- Oscillations near the local inertial frequency due to wind stress (moving wind storms or fronts with time scale of 1-2 days)

$$\frac{du}{dt} = 2\Omega\, v \sin\varphi = f v$$

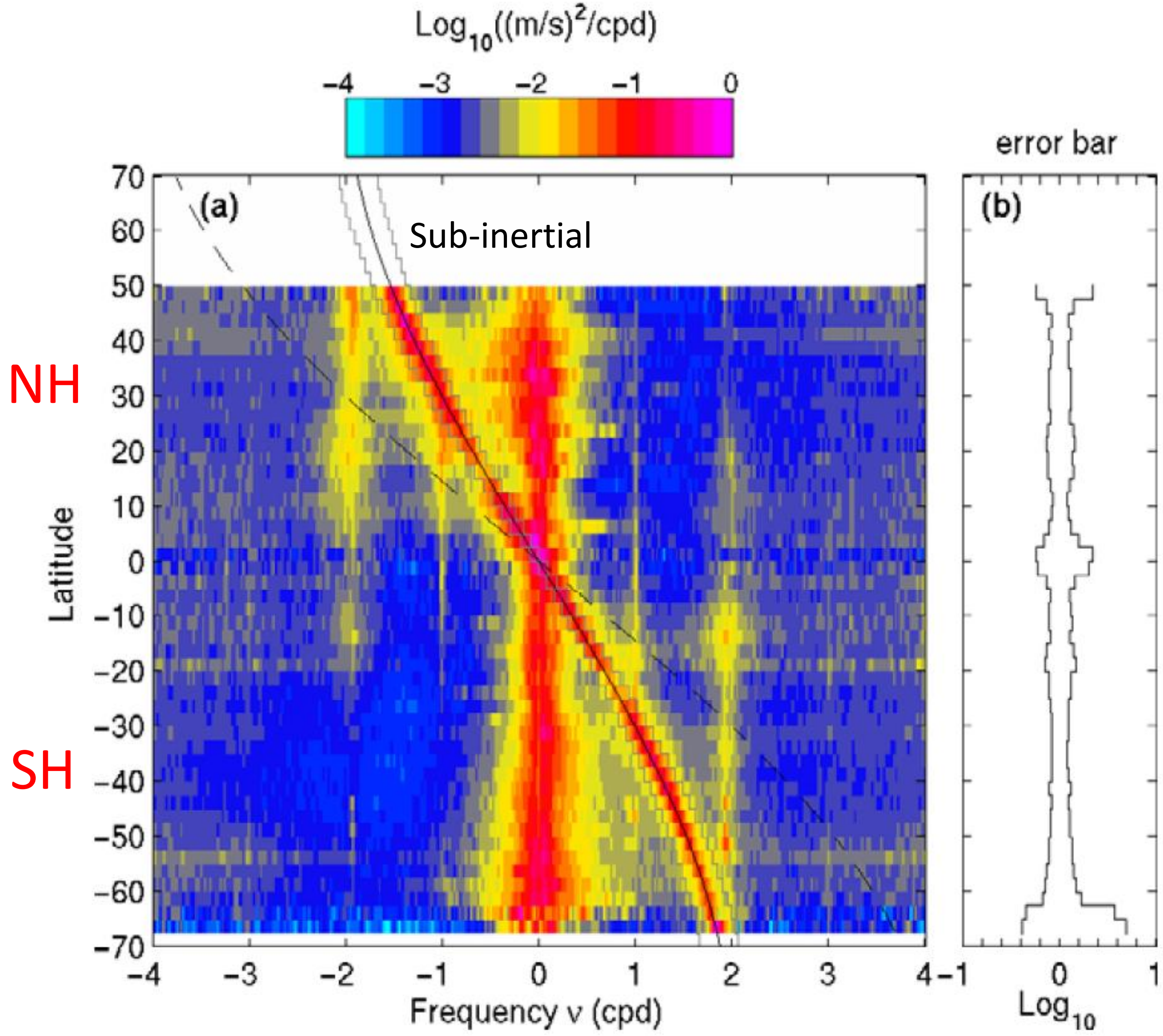
$$\frac{dv}{dt} = -2\Omega\, u \sin\varphi = -f u$$

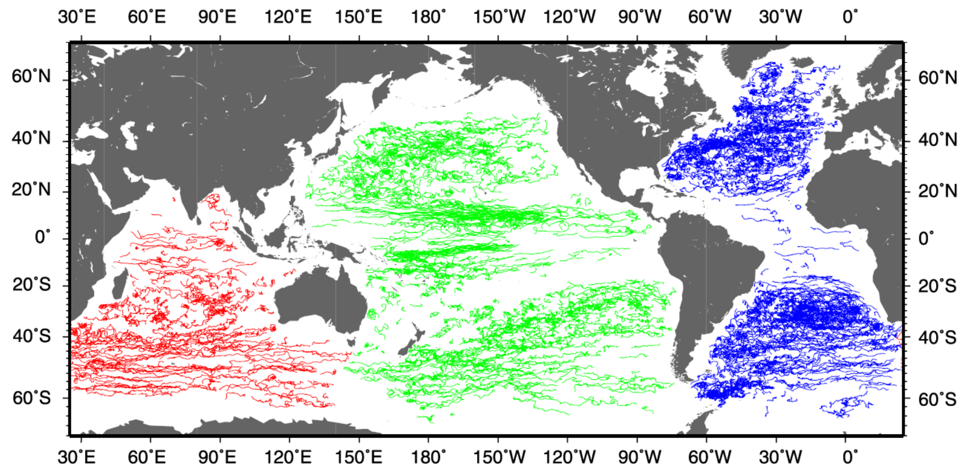


Positions of drifting buoys at 15m depth

- Everywhere in the ocean.
- Reduced amplitudes of NI motions near the coast (coastal inhibition).
- Effective inertial frequency = local inertial frequency + background vorticity (variance spreading).
- Meridional propagation is asymmetric and dominantly equatorward.
- Poleward propagation appears with superinertial motions.

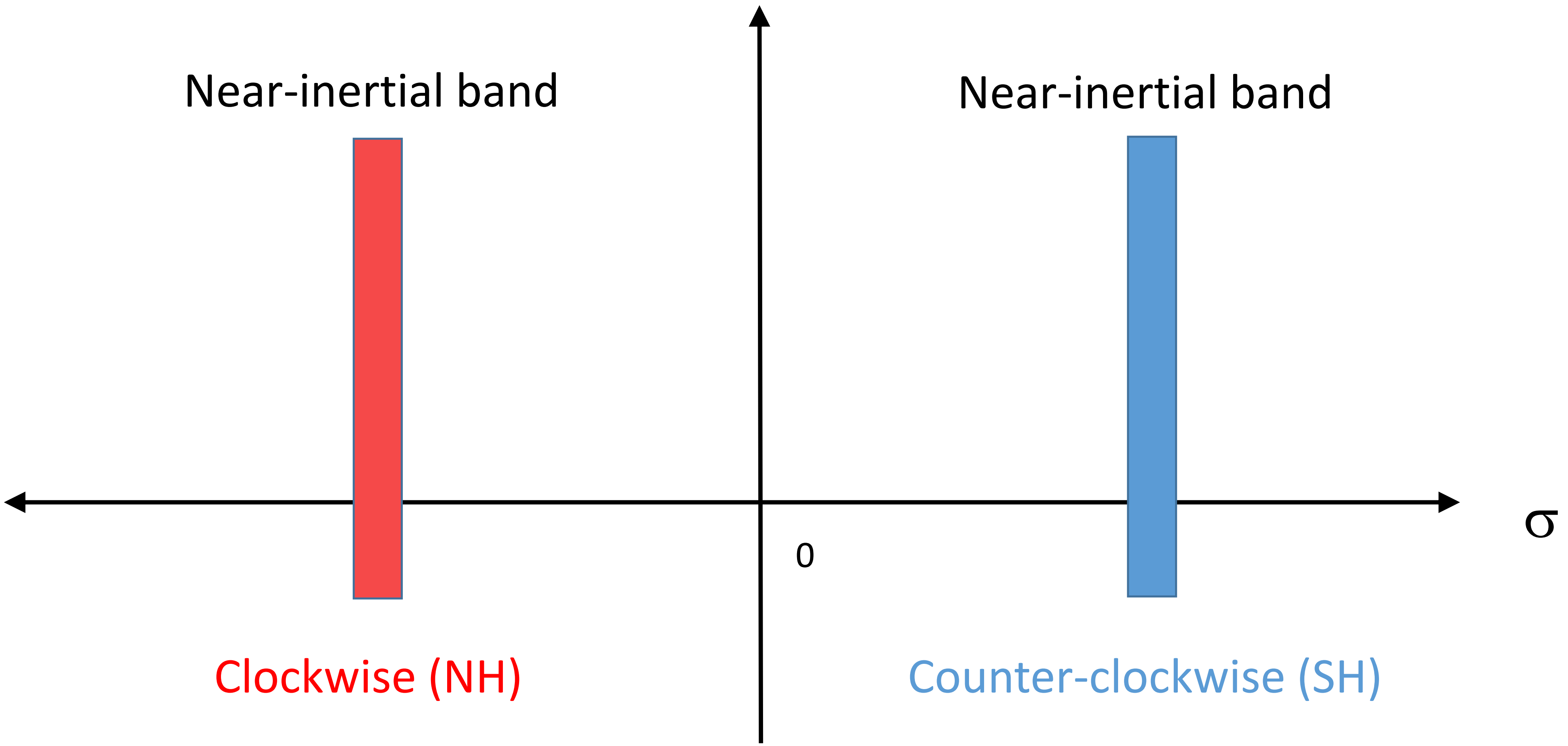
NI variance distribution



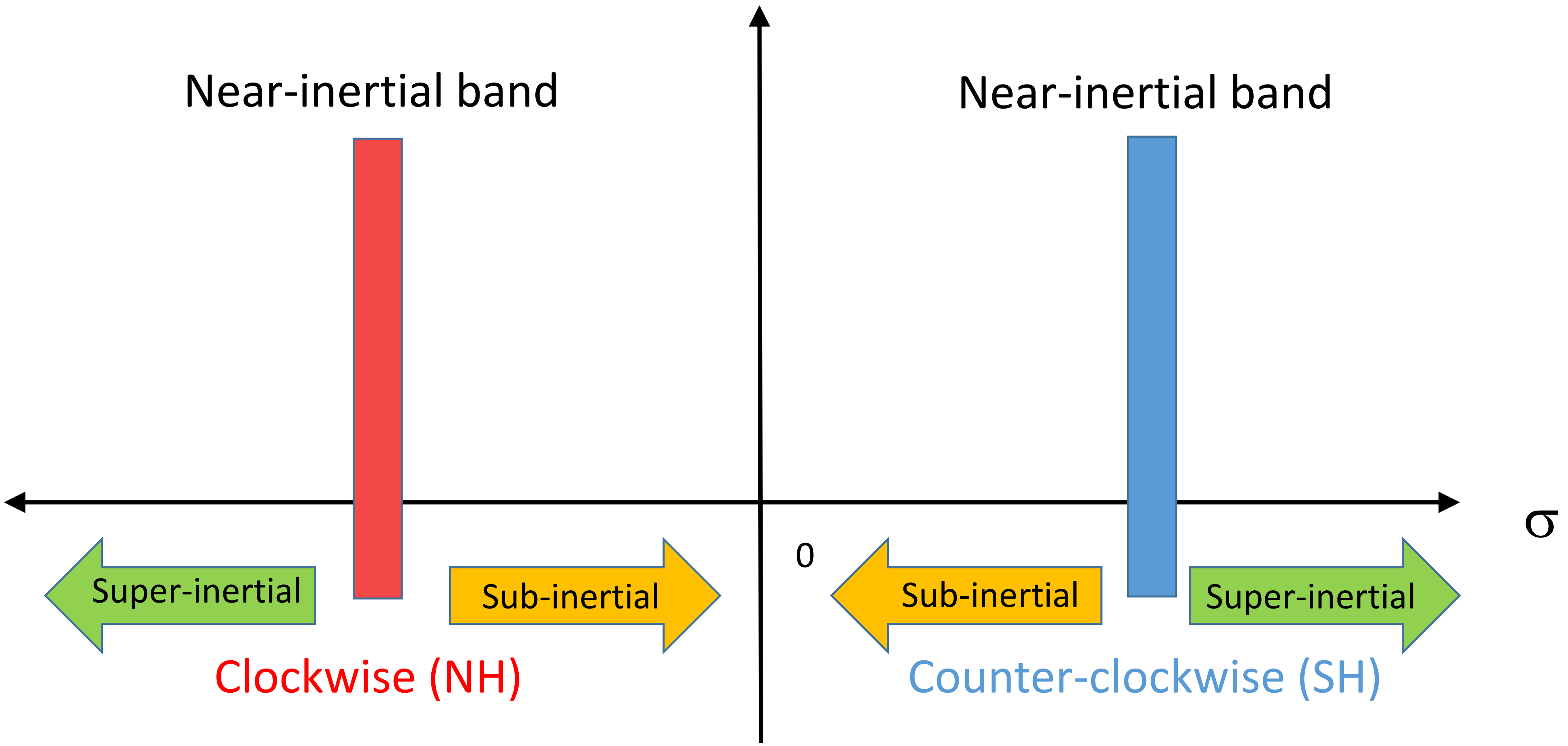


Elipot and Lumpkin (GRL 2008)

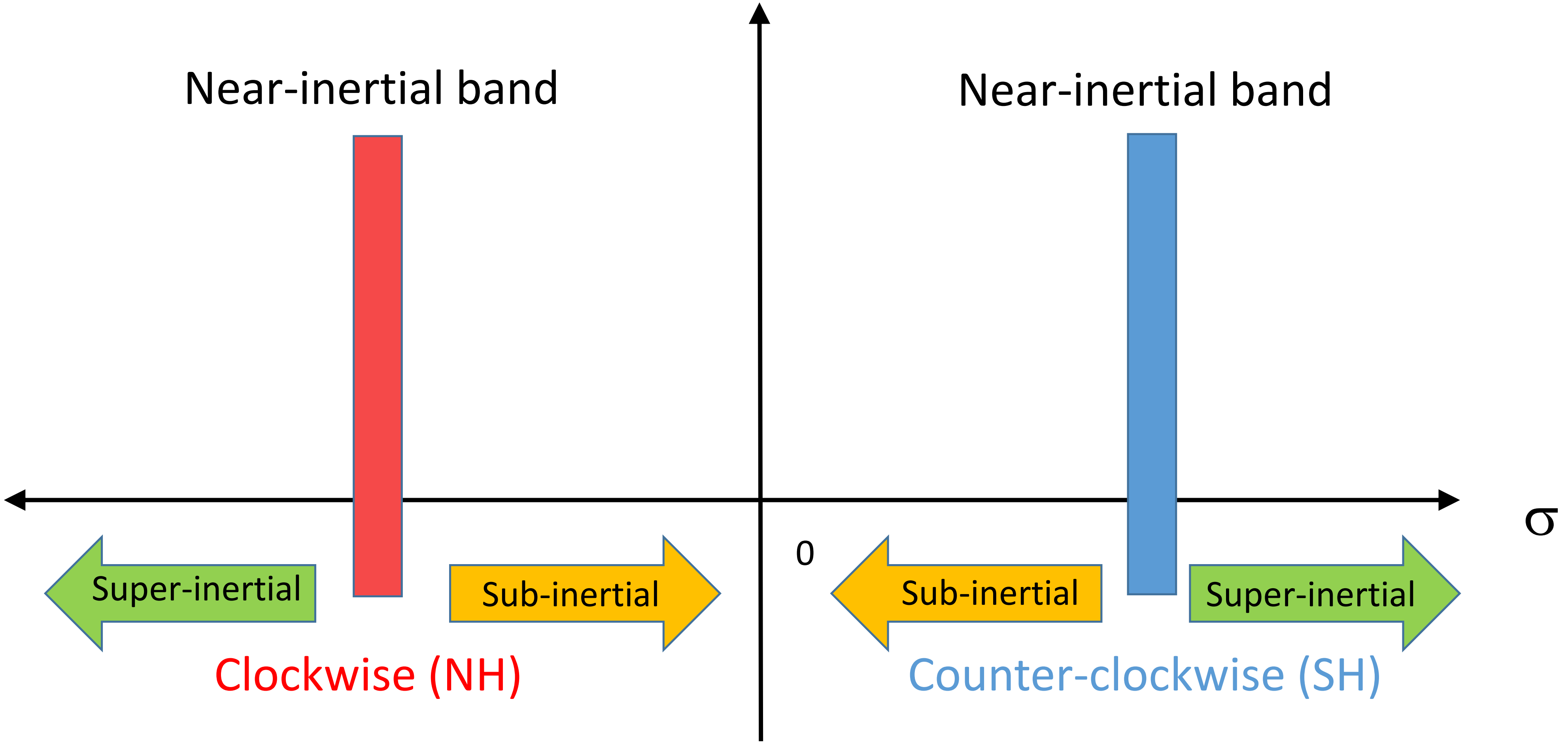
Subinertial & superinertial motions



Subinertial & superinertial motions



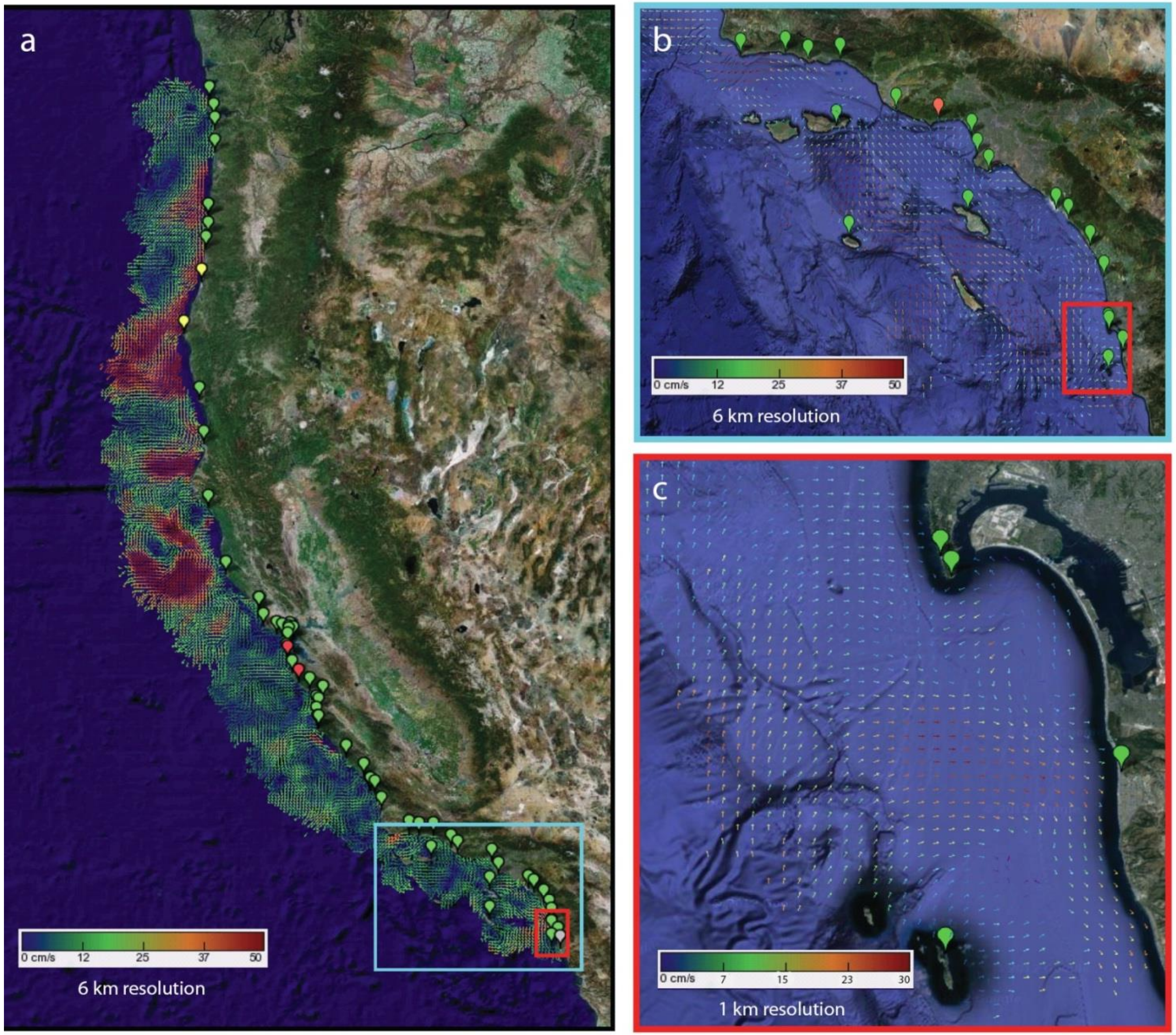
Subinertial & superinertial motions



Sub-inertial = Clockwise (NH) NI band + (+) vorticity

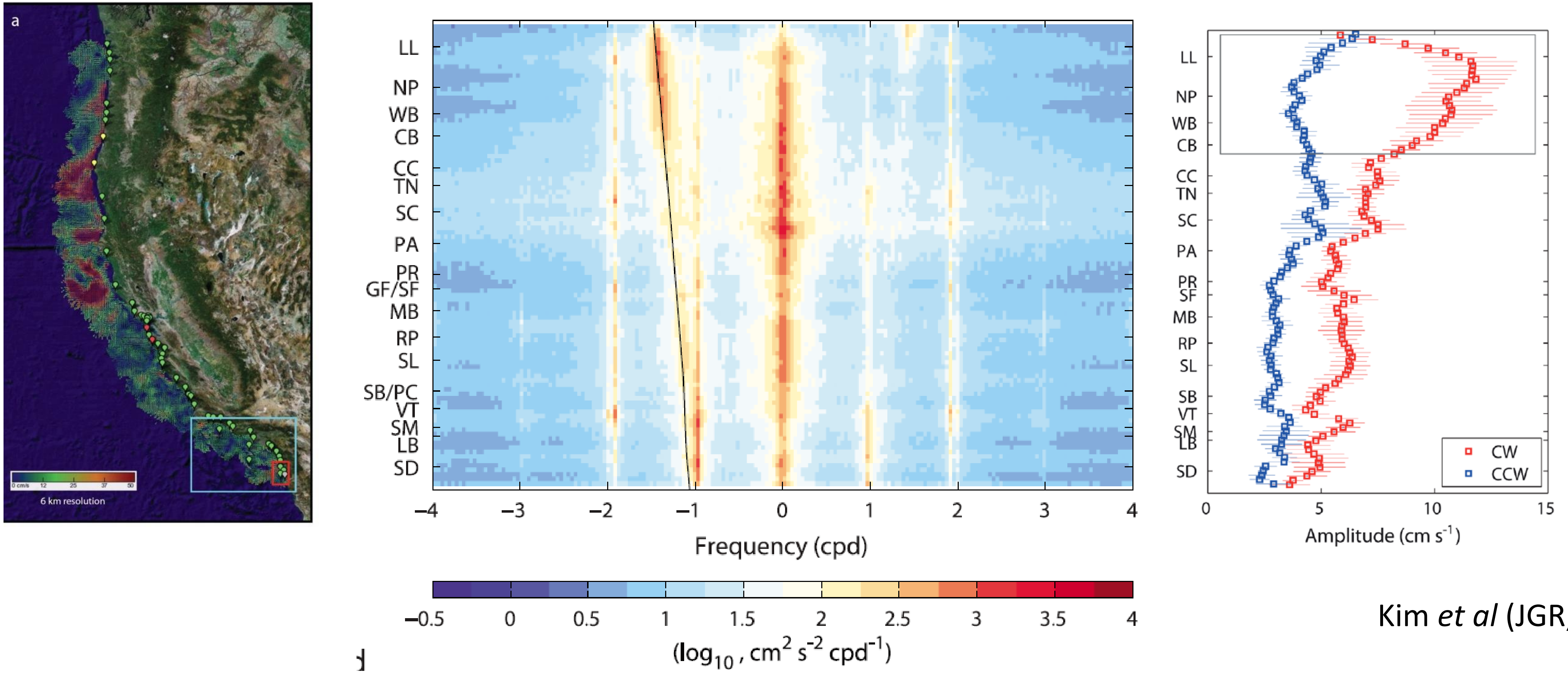
= Counter-clockwise (SH) NI band + (-) vorticity

High-frequency radar-derived 'surface currents'



- A network of high-frequency radars (HFRs) along the coast over 2500 km of US West Coast provides km resolution and hourly surface current maps which cover about 150 km offshore from shoreline.

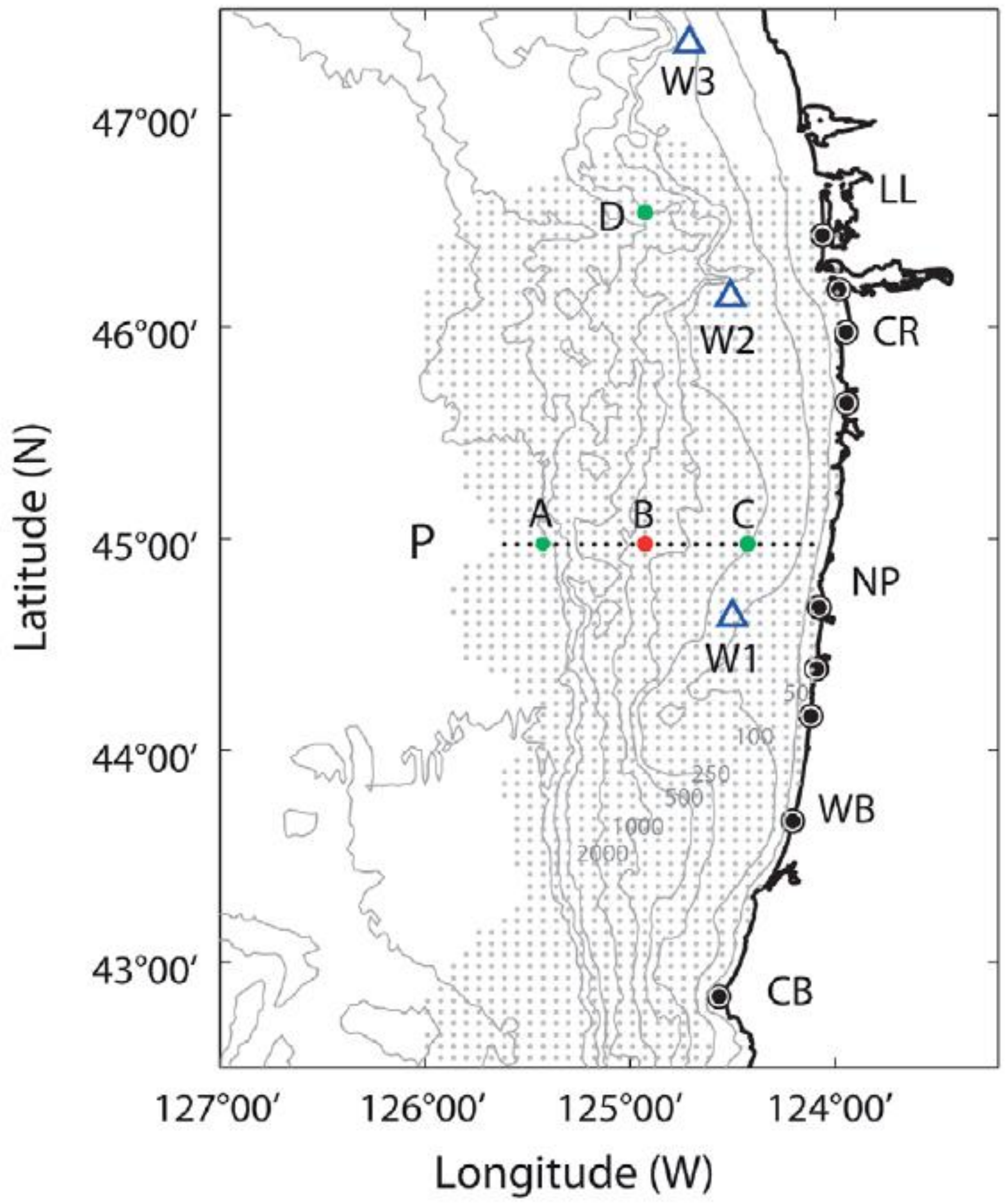
Study domain: Oregon coast

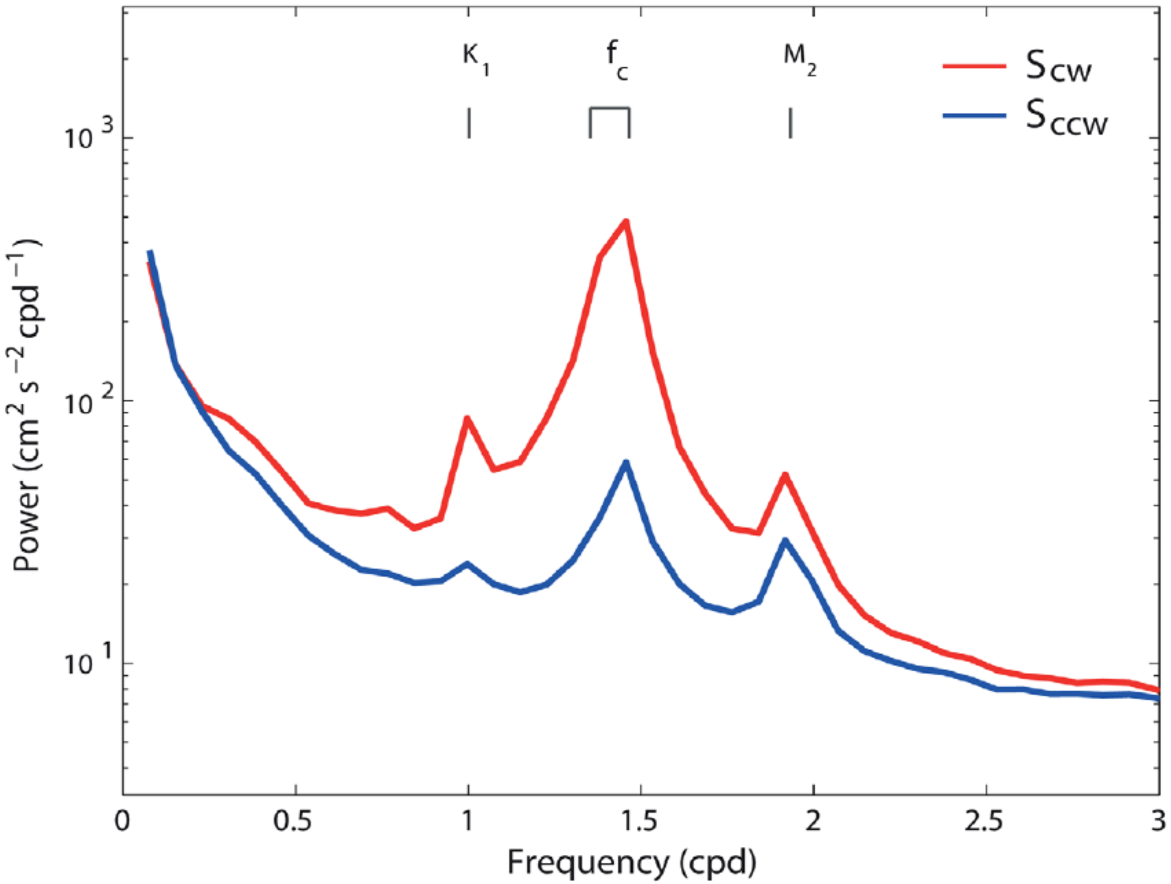


Kim *et al* (JGR, 2011)

- Wind- and tide-coherent, low-frequency variance, and inertial variance
- Enhanced near-inertial (NI) variance off Oregon
- Spatial and temporal structures of NI surface currents?

Study domain

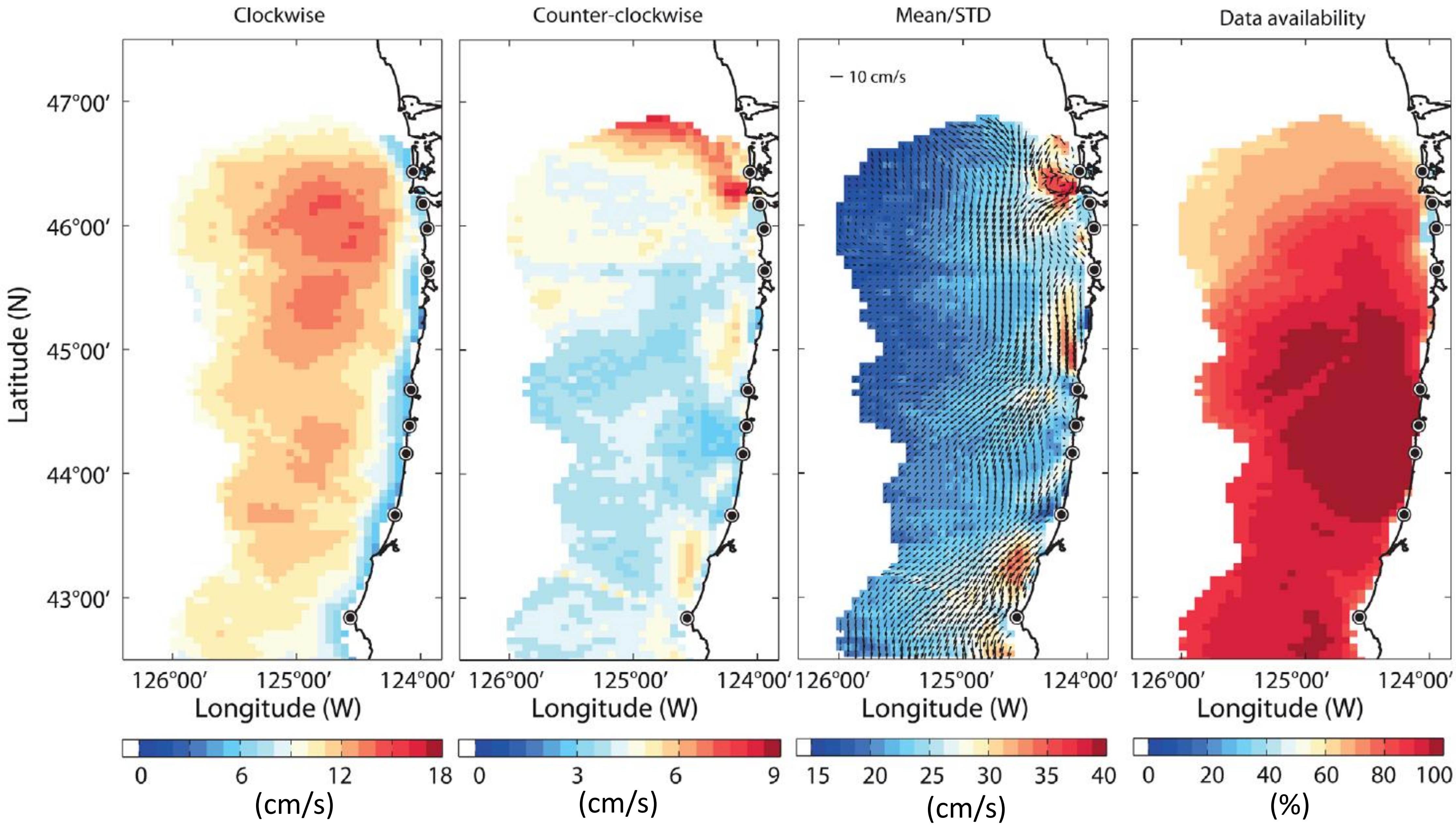




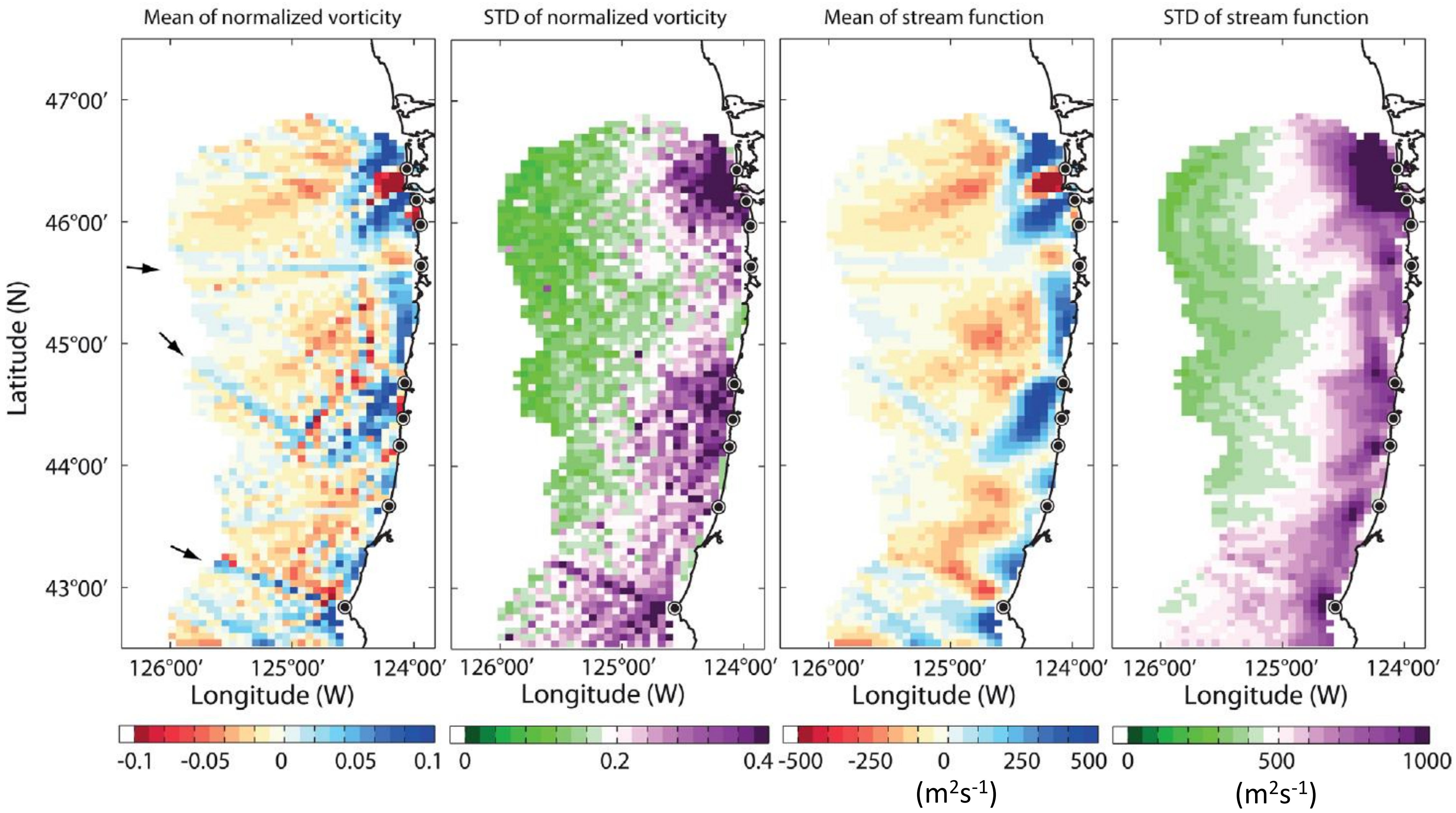
- Detided surface currents; Enhanced clockwise near-inertial variance
- Hourly HFR surface currents; wind data at 3 NDBC buoys (W1-W3)
- A-D points were chosen to examine NI spatial structures

Kim and Kosro (JGR, 2013)

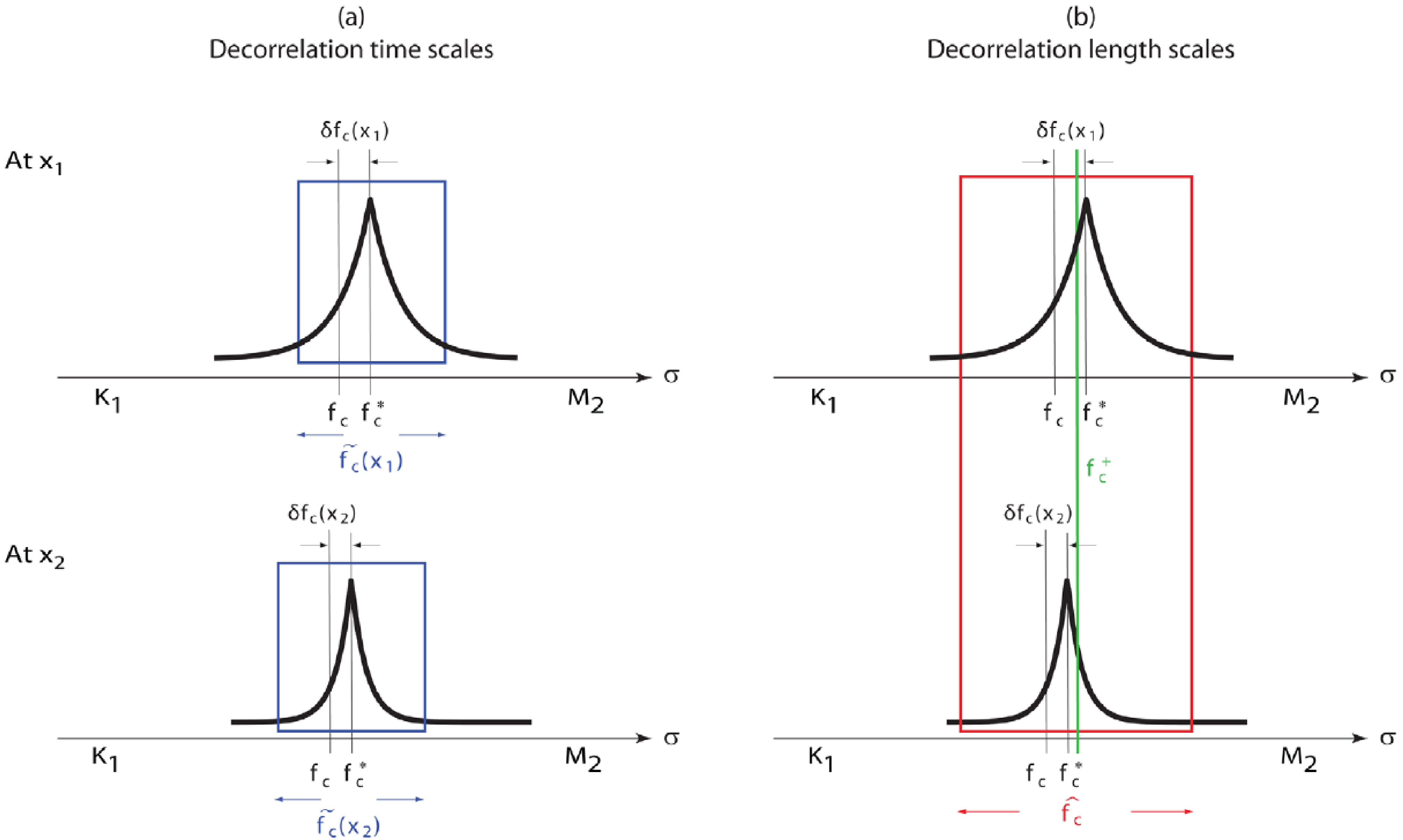
Amplitudes of NI surface currents, mean/STD



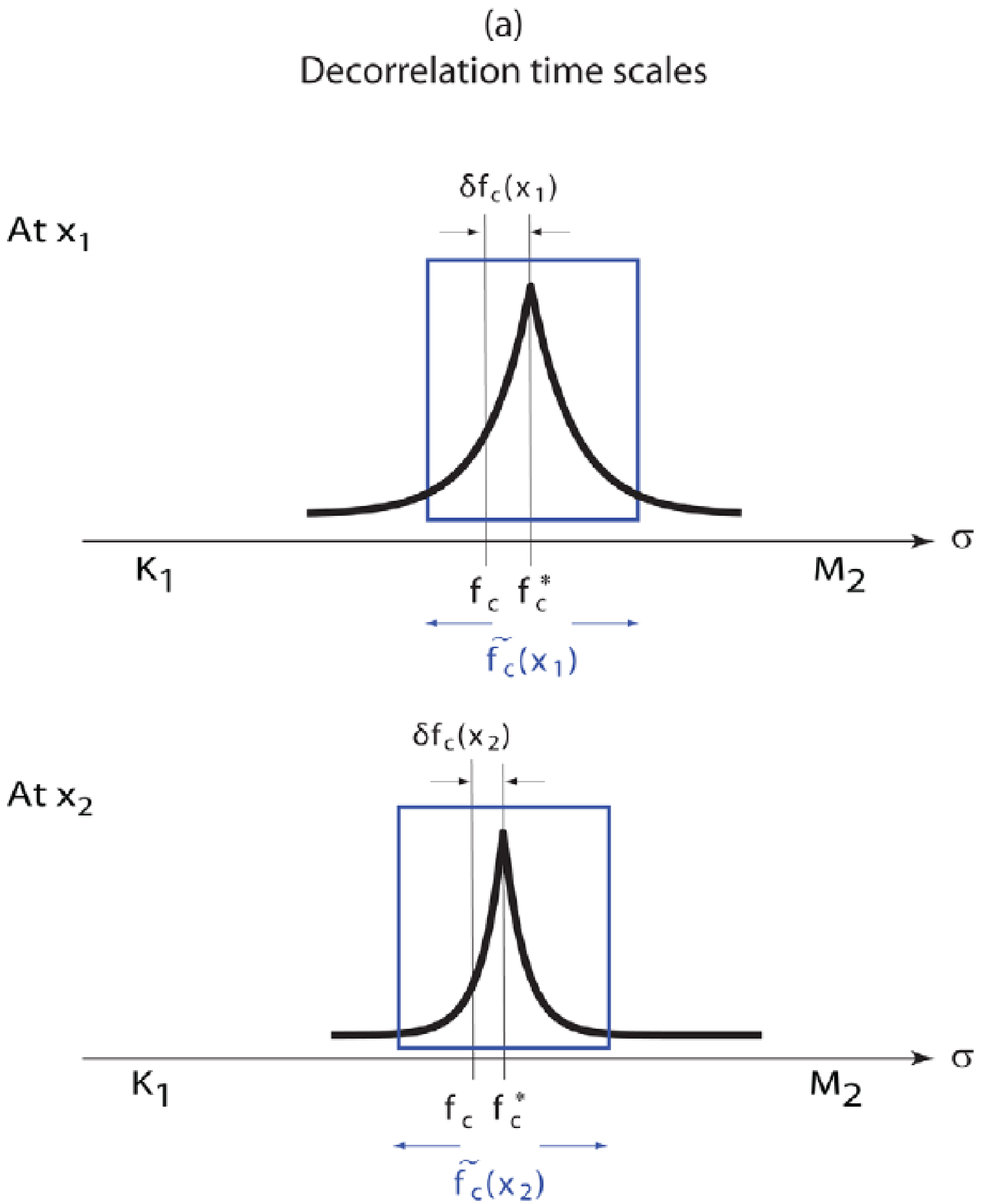
Normalized vorticity and stream function



Estimates of decorrelation time and length scales



Estimates of decorrelation time scales



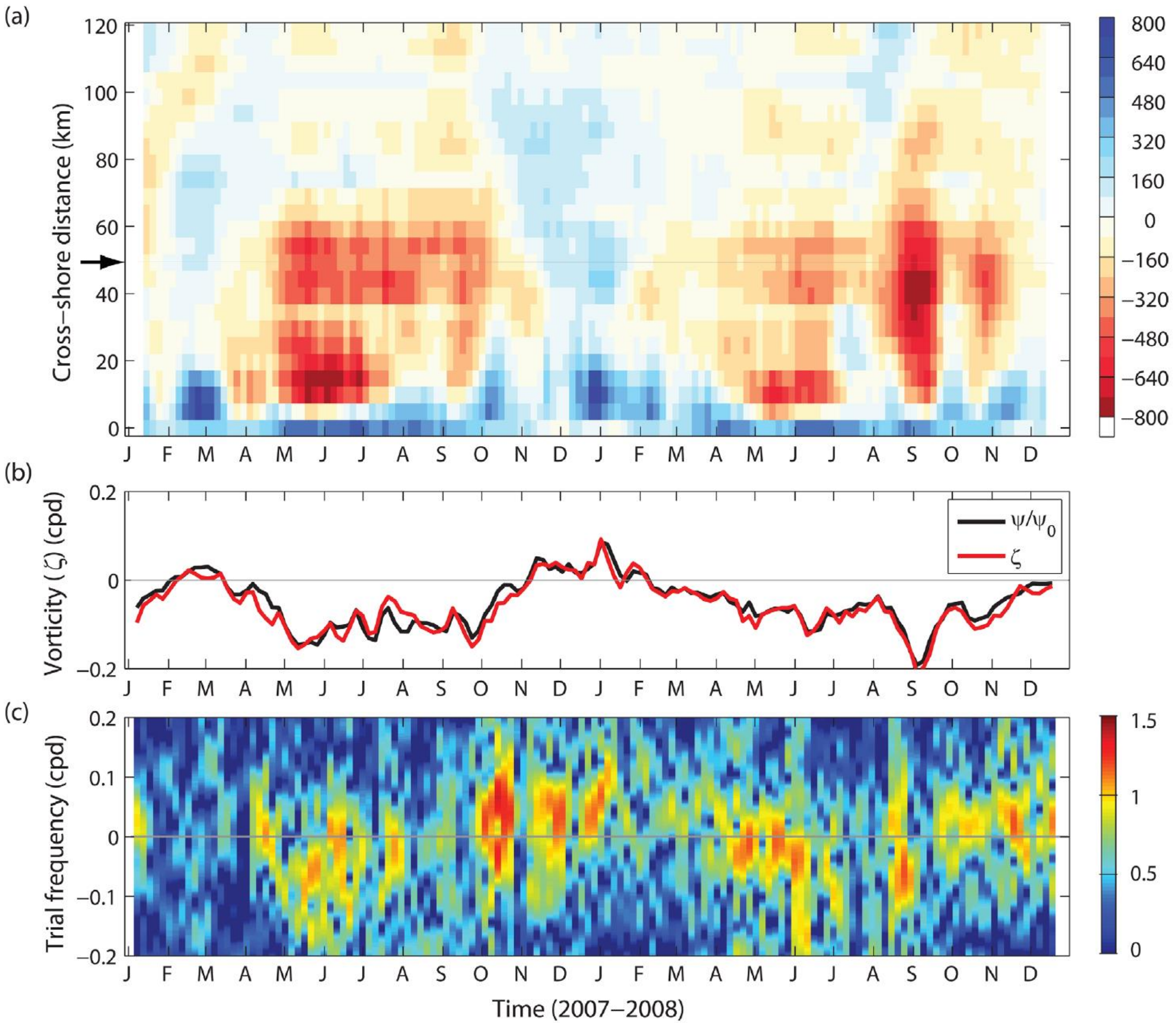
- A NI peak of the power spectrum at each vector time series is fitted with a function, an exact Fourier transformed time series of NI motions.

$$S(\sigma) = \frac{A^2\lambda^2}{1+\lambda^2\left(\sigma+f_c^*\right)^2},$$

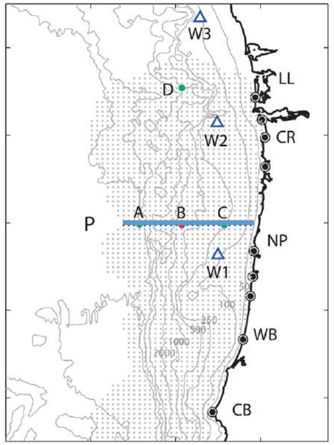
$$c(t) = Ae^{-if_c^* t}e^{-\frac{t}{\lambda}}, t \geq 0$$

- λ is the decay time scale.
- f_c^* is the local inertial frequency with a peak shifted.

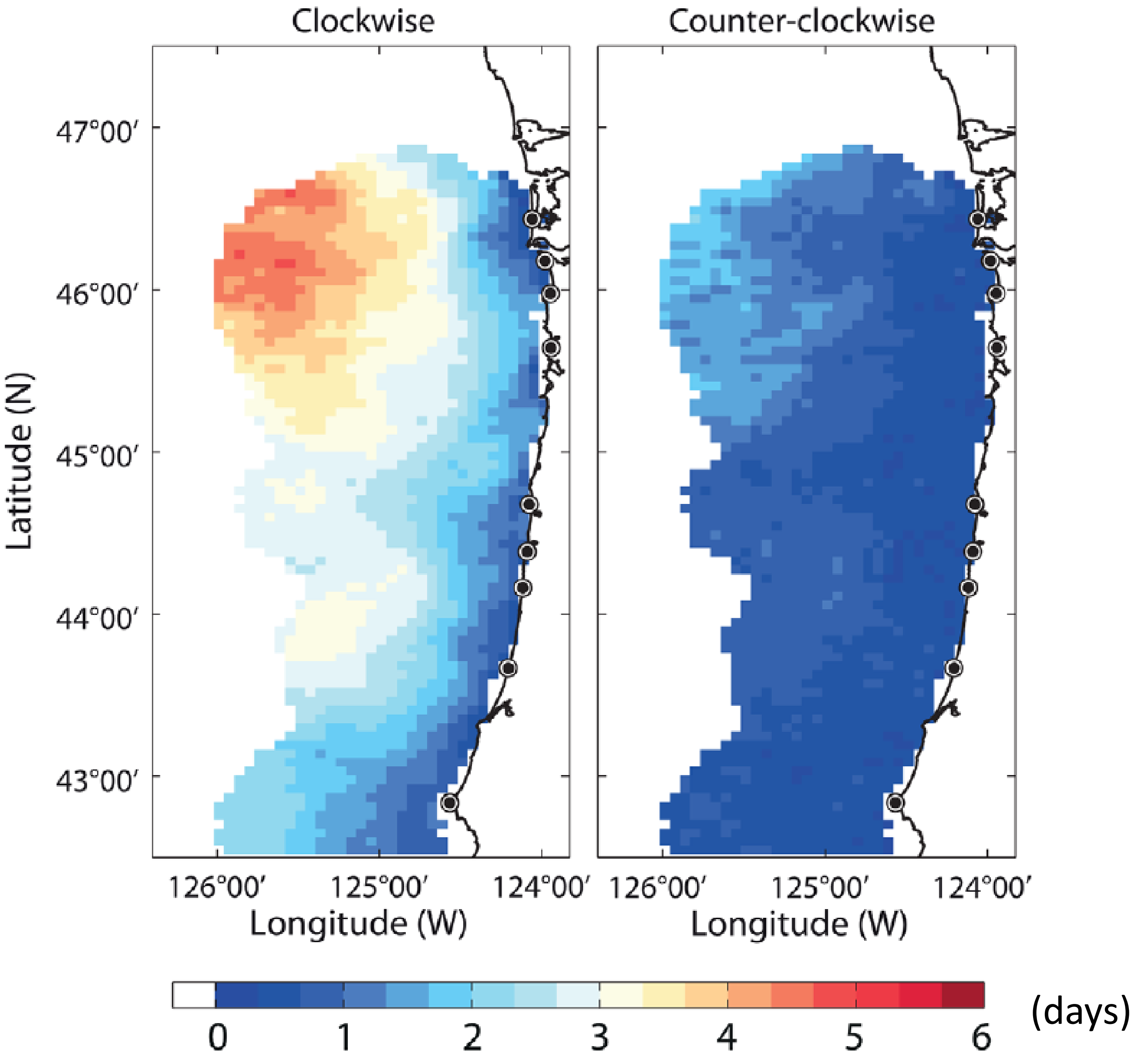
Shifted near-inertial peak due to vorticity?



- Vorticity time series in a cross-shore direction contain seasonal circulation.
- Vorticity and normalized stream function (at a grid point) are consistent.
- Superinertial!
- A NI peak can be located using a least-squares fit with a set of trial frequencies.



Decorrelation time scales



- Cross-shore variation of decay time scales of NI CW motions shows longer offshore [6 days] than nearshore [2 days], presenting the effects of bathymetry and coast (coastal inhibition).
- NI motions are restricted with coastline and bathymetry.
- NI CCW motions are limited (required more investigation)

$$S(\sigma) = \frac{A^2\lambda^2}{1+\lambda^2\left(\sigma+f_c^*\right)^2},$$

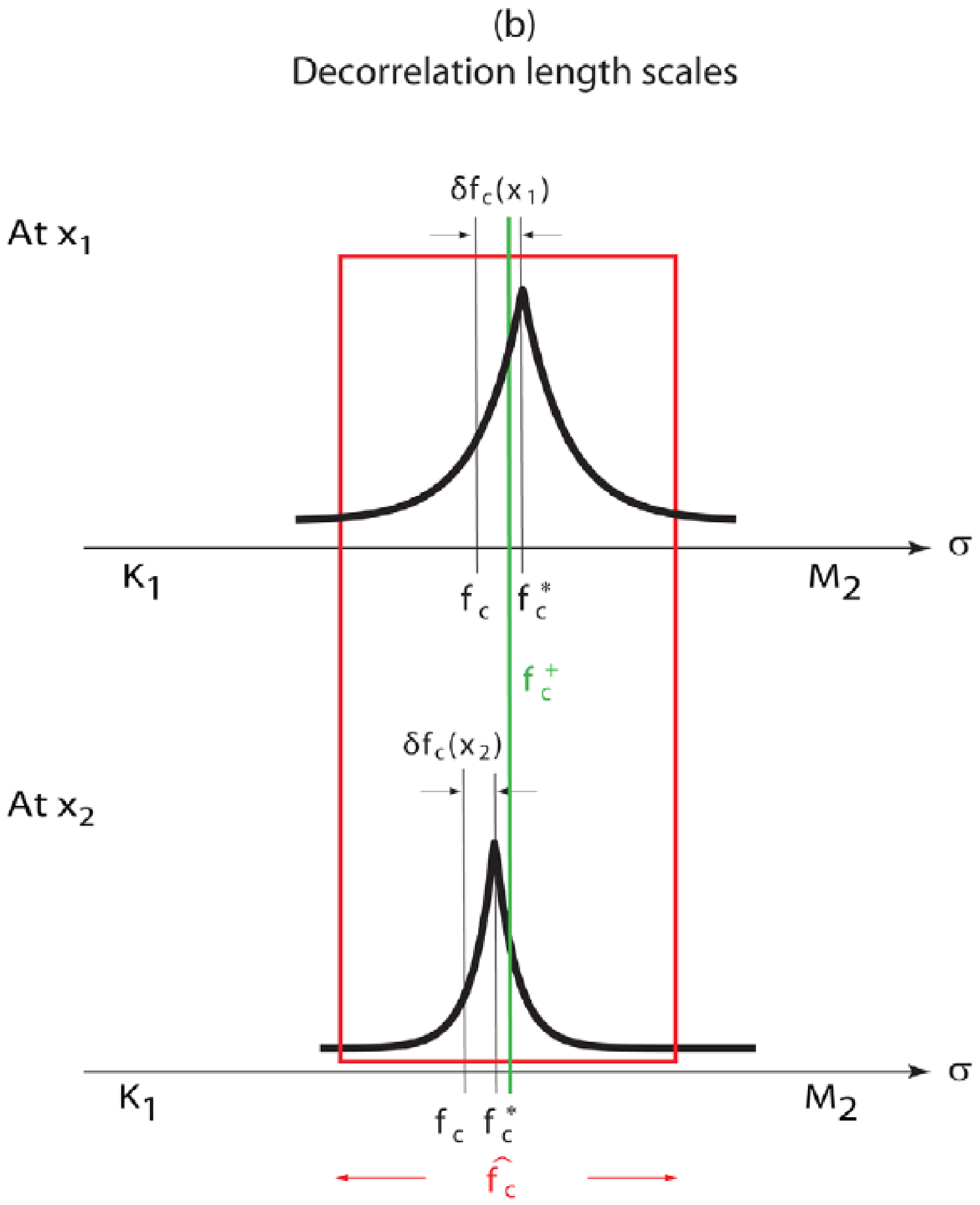
$$c(t) = Ae^{-if_c^* t}e^{-\frac{t}{\lambda}}, t \geq 0$$

Estimates of decorrelation length scales

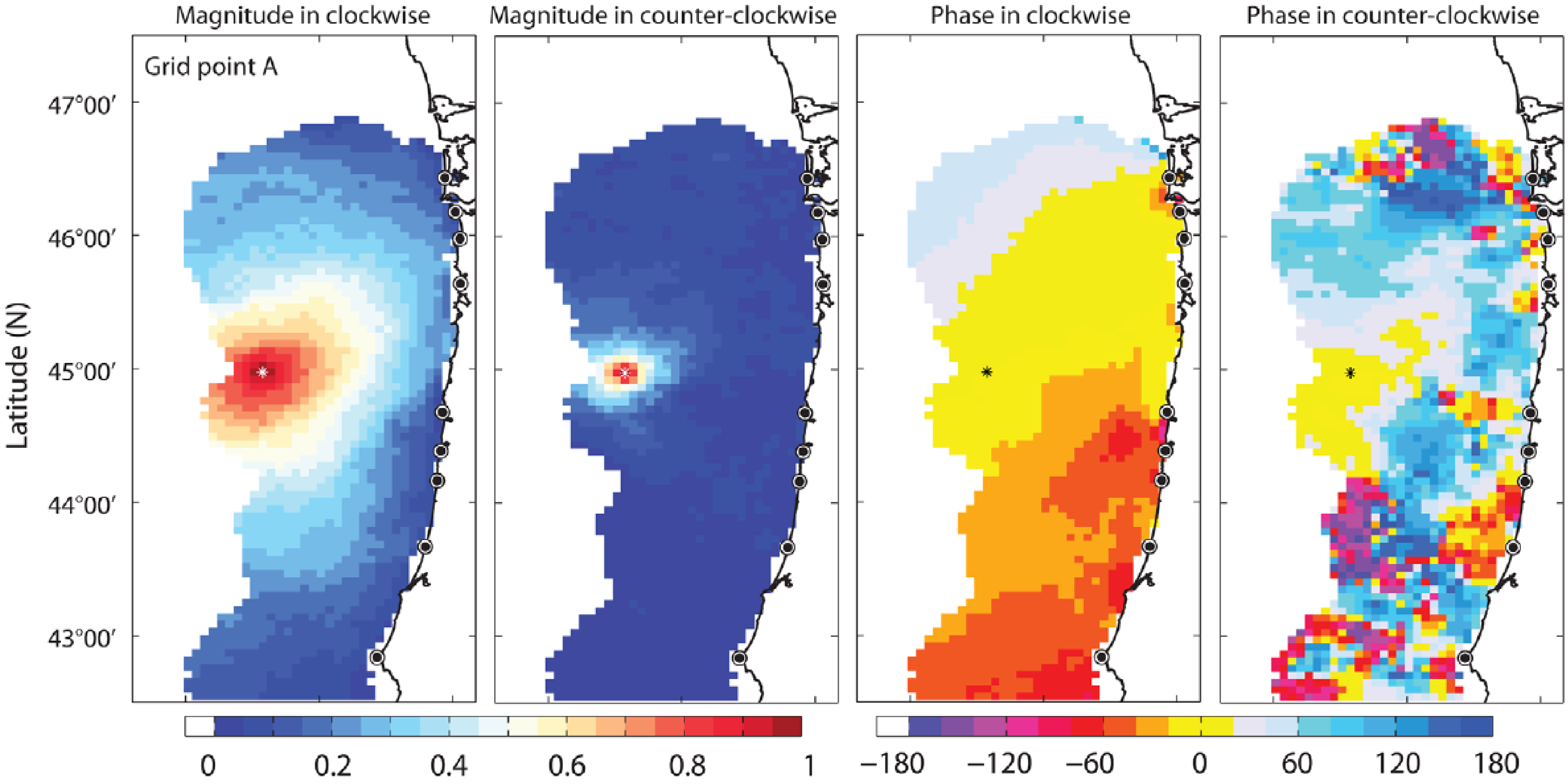
- Coherence, a correlation in a specific frequency band (NI band here), is computed with vector current time series at two locations (x_1 and x_2).

$$\hat{c}(\Delta \mathbf{x}, \hat{f}_c) = \frac{\langle \hat{\mathbf{u}}(\mathbf{x}, \hat{f}_c)\ \hat{\mathbf{u}}^{\dagger}(\mathbf{x} + \Delta \mathbf{x}, \hat{f}_c) \rangle}{\sqrt{\langle |\hat{\mathbf{u}}(\mathbf{x}, \hat{f}_c)|^2 \rangle} \sqrt{\langle |\hat{\mathbf{u}}(\mathbf{x} + \Delta \mathbf{x}, \hat{f}_c)|^2 \rangle}},$$

- Spatial coherent map is fitted with an exponential function (why?) to estimate the decorrelation length scale.

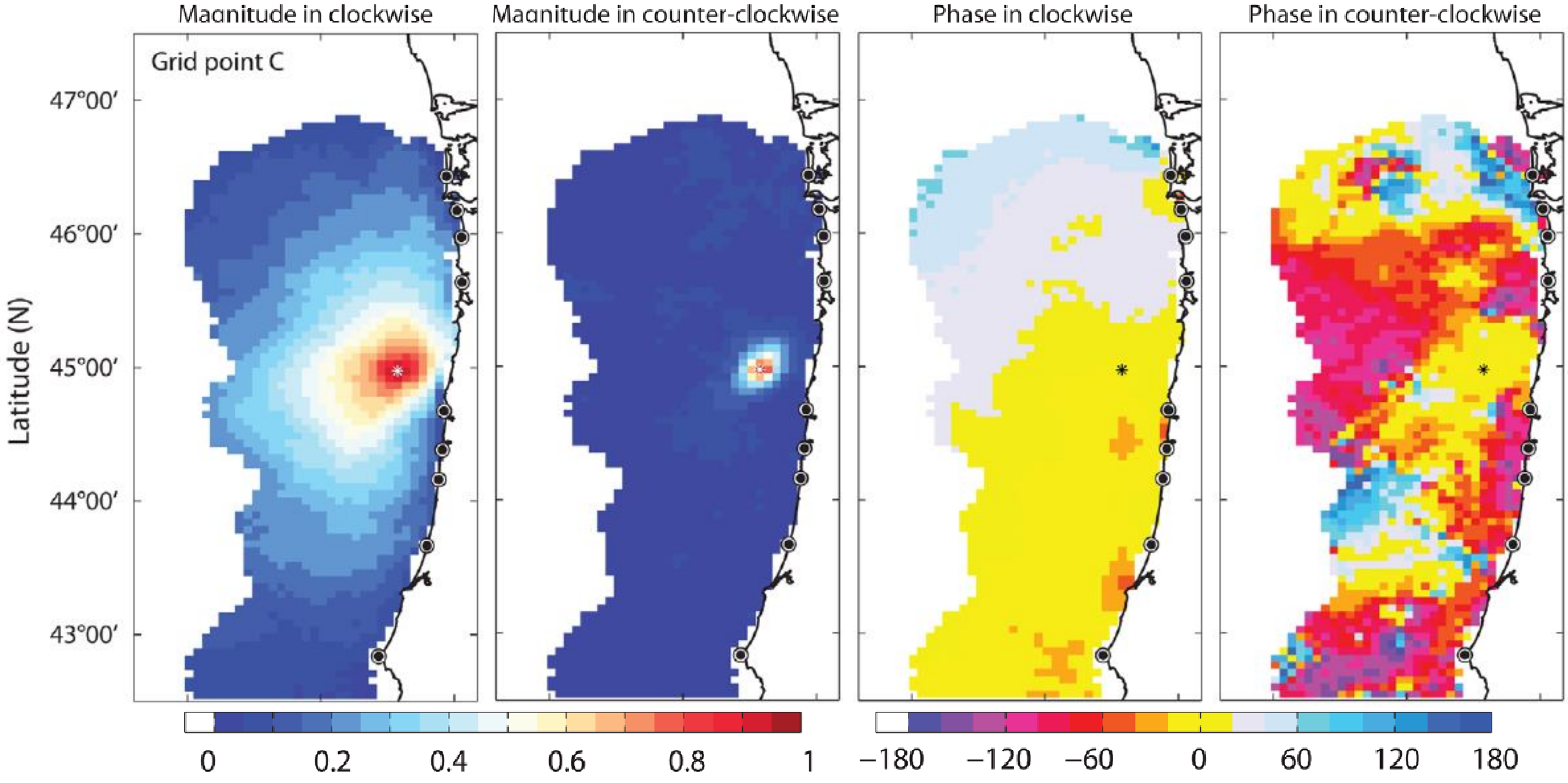


Spatial coherence and phase at grid pt. A

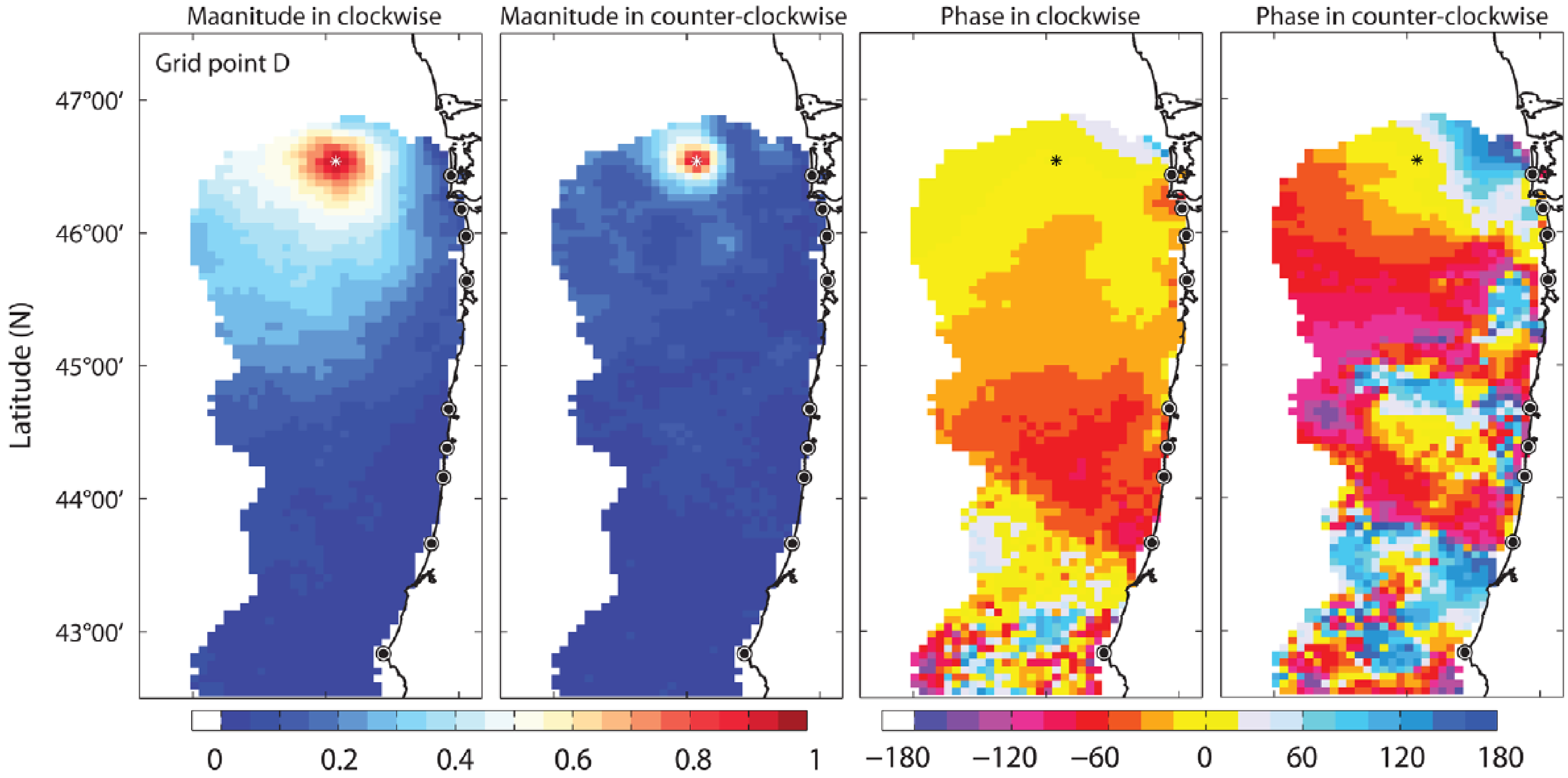


- Spatial coherence; CW vs. CCW; Well-organized phase map
- Poleward phase increase; superinertial NI motions due to negative ζ

Spatial coherence and phase at grid pt. C

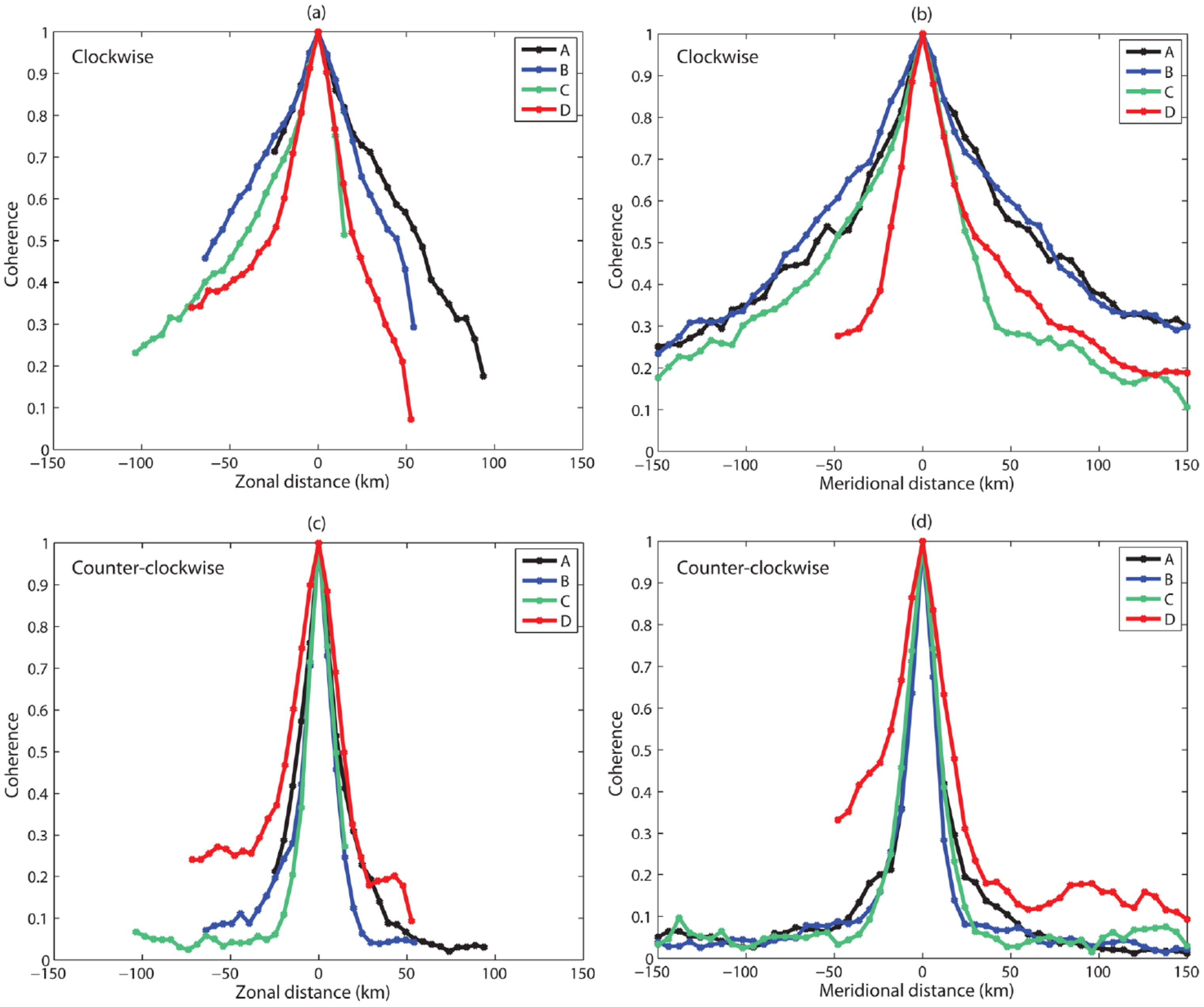


Spatial coherence and phase at grid pt. D



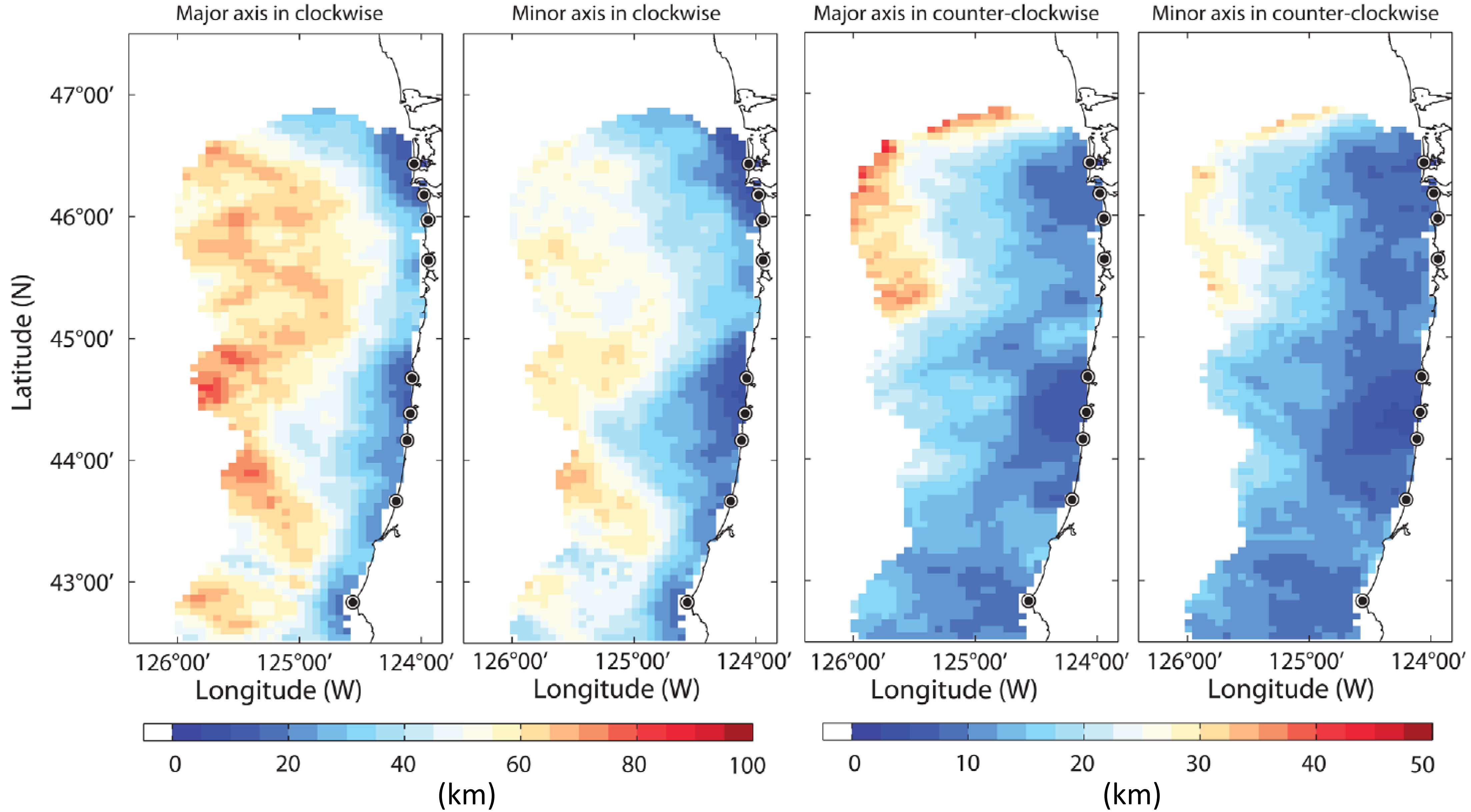
- Wavelength from phase maps: CW (1000-1200 km) CCW (300-400 km)

Sliced coherence in x- and y-directions



- Sliced coherenece shows the exponentially decay spatial function.
- The local composite mean of coherence provides a smooth structure.

Decorrelation length scales



Summary and future works

- Decorrelation time and length scales of near-inertial (NI) surface currents off Oregon are estimated with two year observations of HFR-drived surface current maps (hourly and 6 km resolution).
- The time scales of CW NI motions increase from nearshore to offshore from 2 to 6 days. A similar spatial tendency on the length scales of NI surface currents appears -- from 30 to 90 km.
- Poleward phase propagation of CW NI motions appears due to negative vorticity (superinertial due to CW background flow).
- The estimate time and length scales exhibit the coastal inhibition of near-inertial motions.

- Direct and indirect wind forced near-inertial motions will be examined with the wind-transfer function analysis.