Quality assessment techniques applied to surface radial velocity maps obtained from high-frequency radars

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Motivation & outline

- An overview of radial data analysis
  - Summary of how to handle huge radial data sets easily and to QAQC them.
  - Beneficial to potential end users including HFR users and operators
  - Applicable to both compact and phase array radars

- QAQC of radial velocity maps
  - Data availability in time and space & grid spacing
  - Statistical approaches (e.g., coherence, correlation)
  - Spatial consistency with
    - Radials at other sites (e.g., rms difference of paired radials at any angles)
    - Independent observations (e.g., winds and tides)

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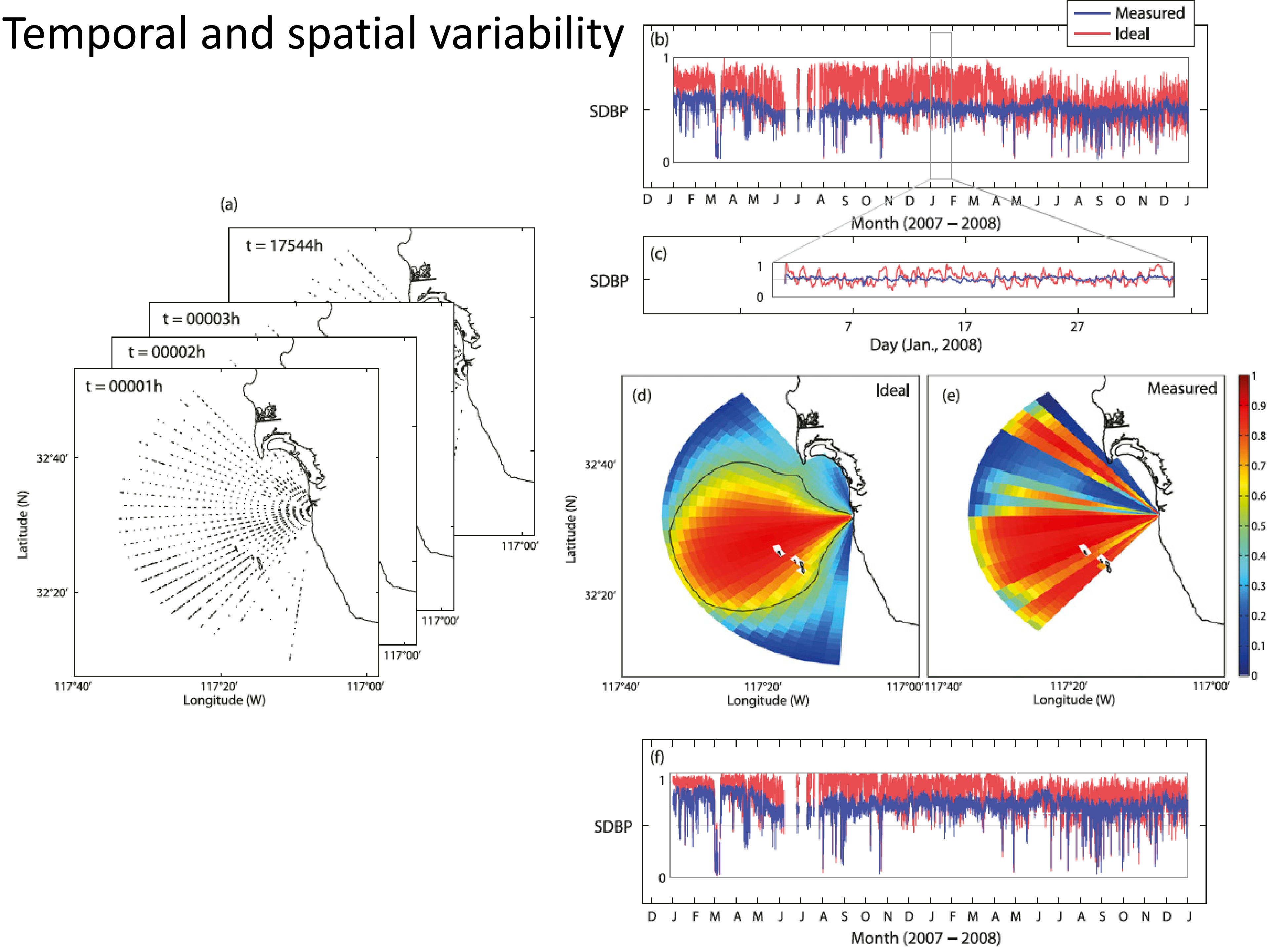
QAQC of radials based on (expected) spatial structure

Temporal and spatial variability

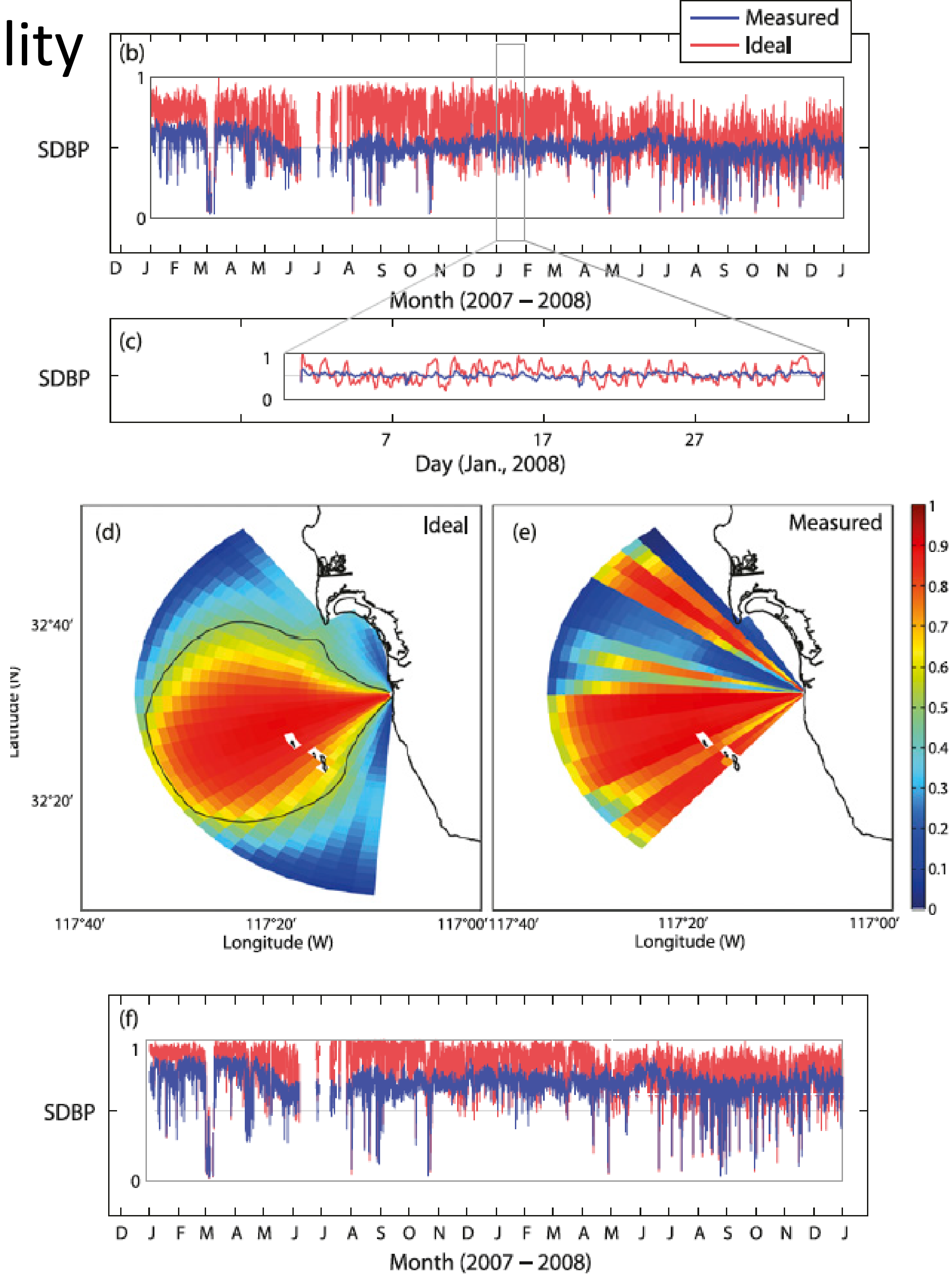


Temporal and spatial variability

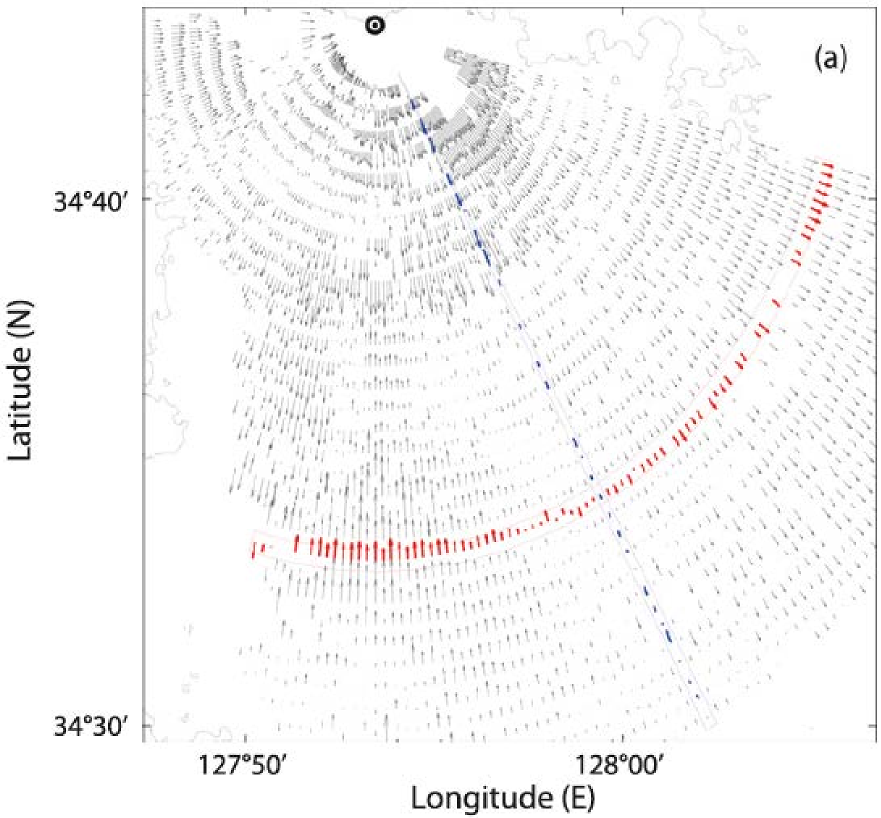
$$d_t(t) = \frac{\sum_{m} \sum_{\theta} N(m,\theta,t)}{\max\left| \sum_{m} \sum_{\theta} N(m,\theta,t) \right|},$$

$$d_s(m,\theta) = \frac{1}{E_t} \sum_{t} N(m,\theta,t)$$

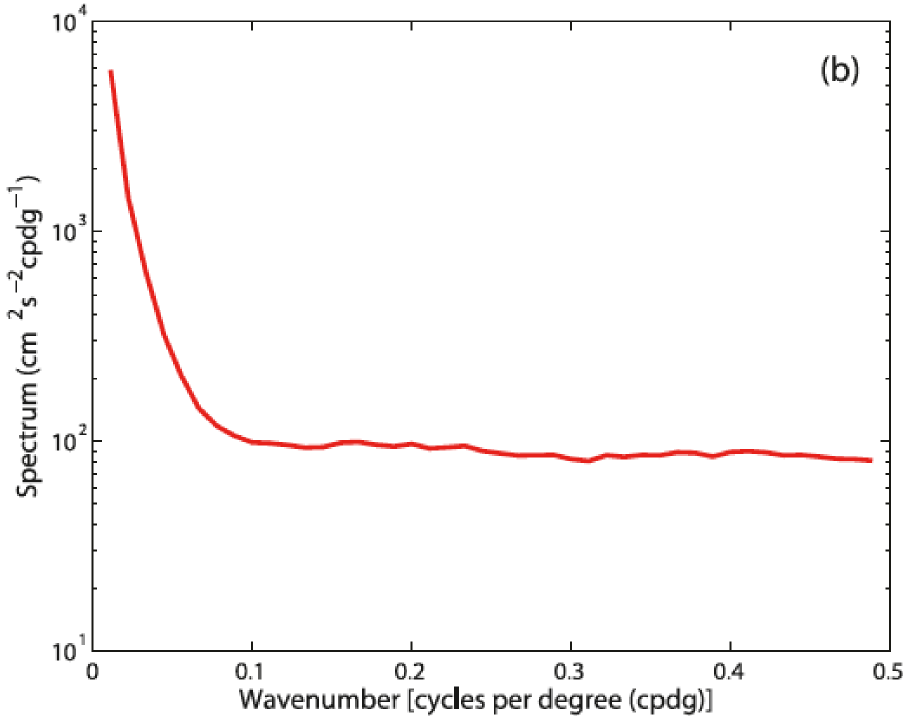
$$d_g(t;\alpha) = \frac{1}{E_g} \sum_{m_g} \sum_{\theta_g} N(m,\theta,t)$$

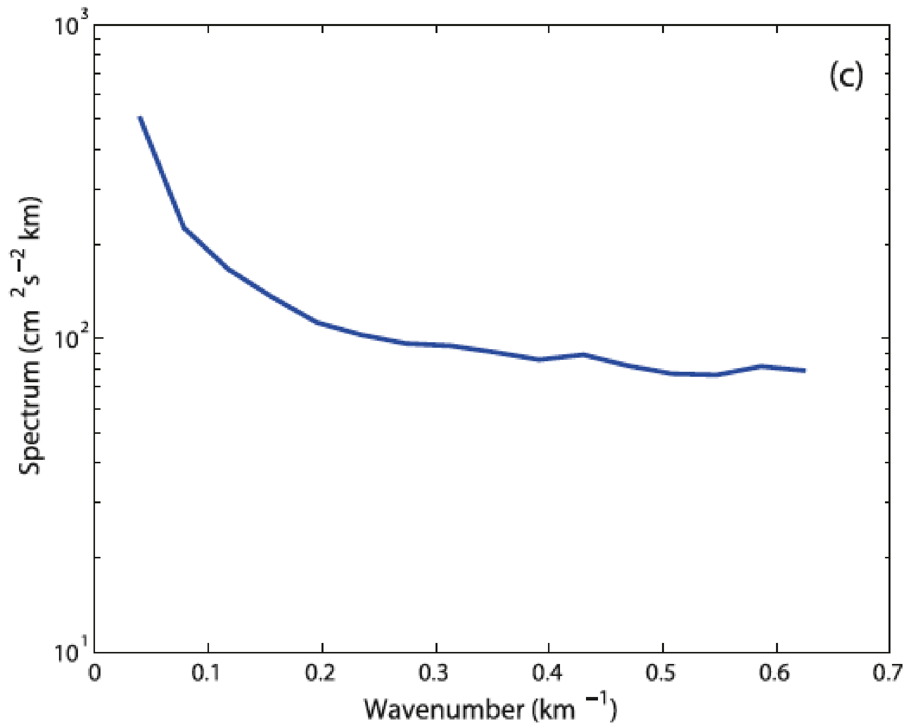


Radial grid spacing



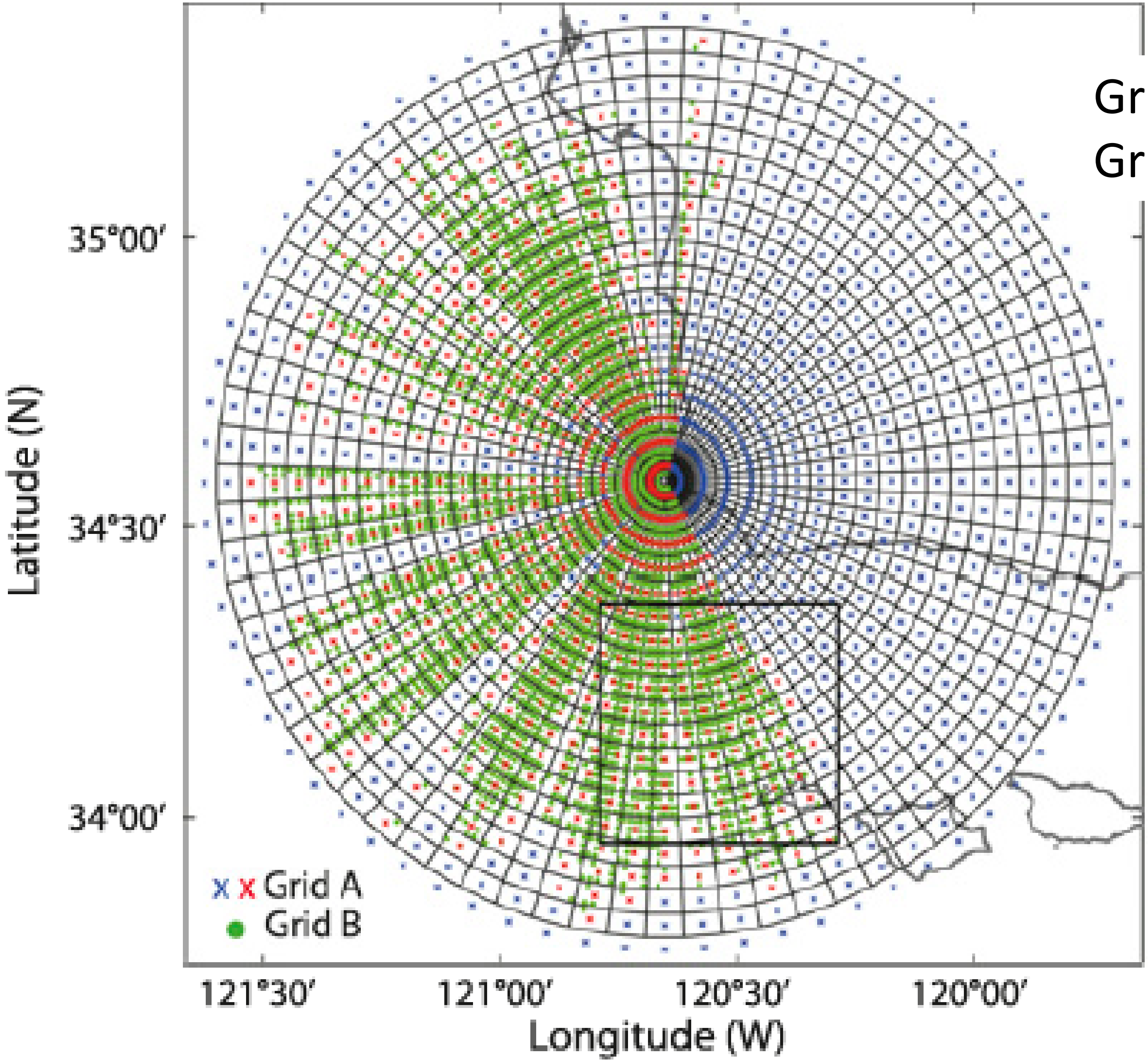
Yeosu (Korea) 1.5 km x 1 deg.





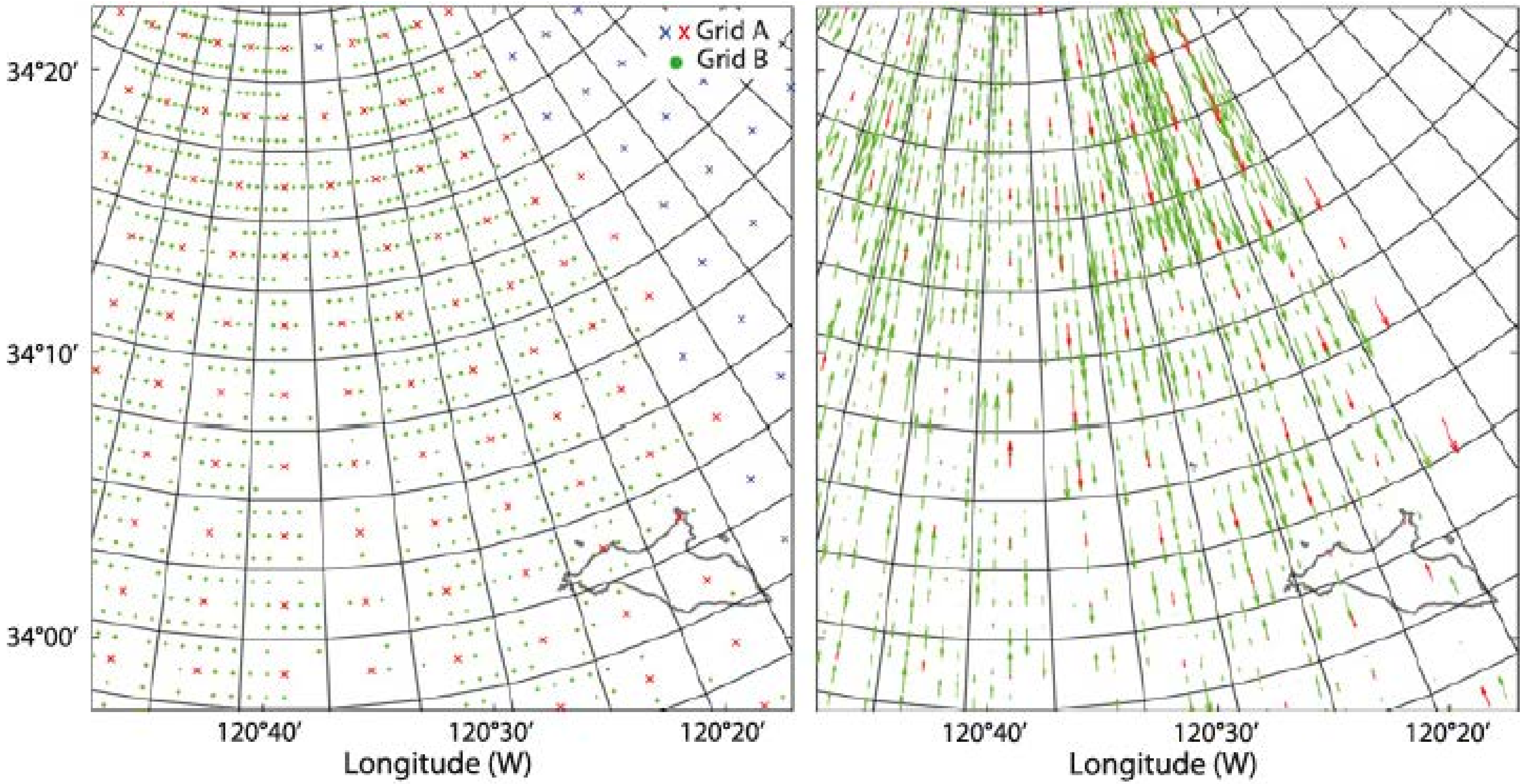
- Saturation of spectral energy of radial velocities in the range and azimuthal direction(s)

Radial grid spacing

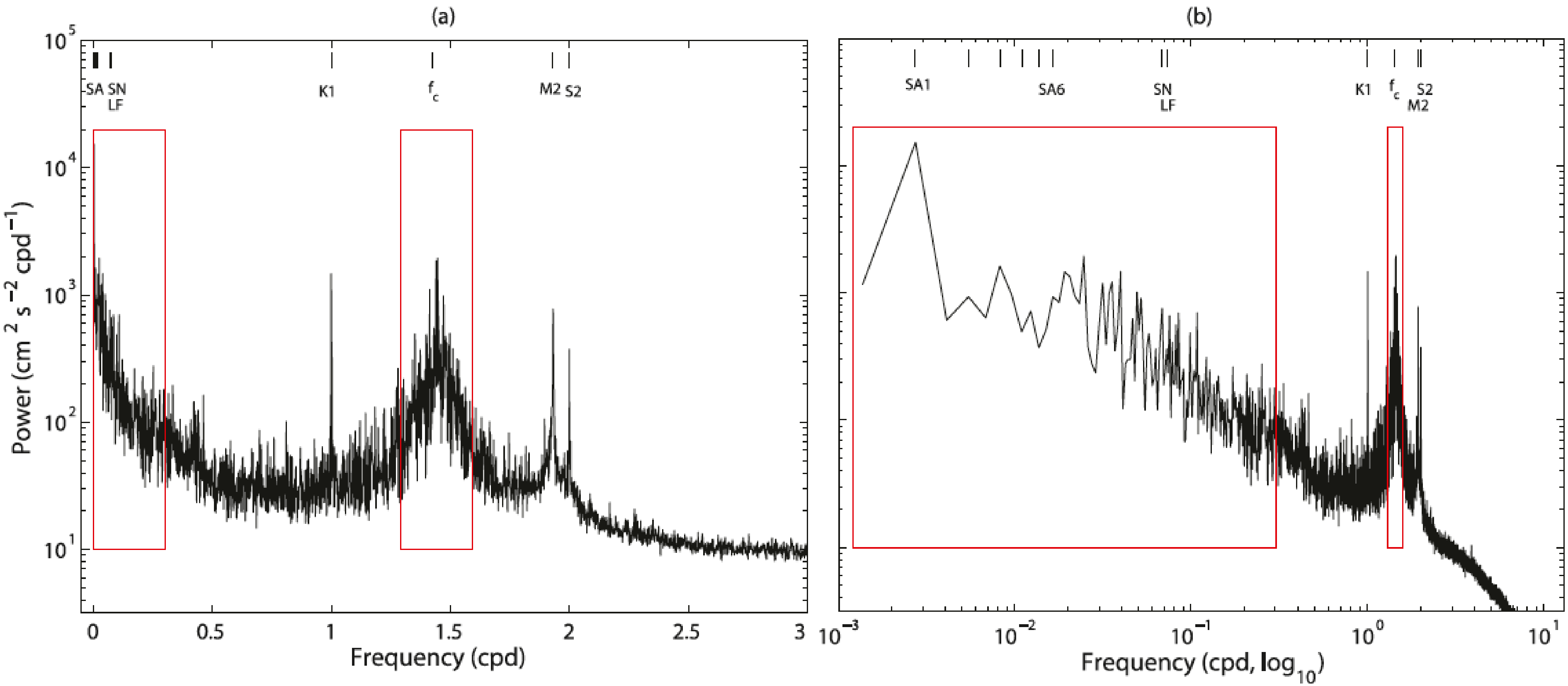


Grid A: 4.5 km x 5 deg.
Grid B: 1.5 km x 1 deg.

Radial grid spacing

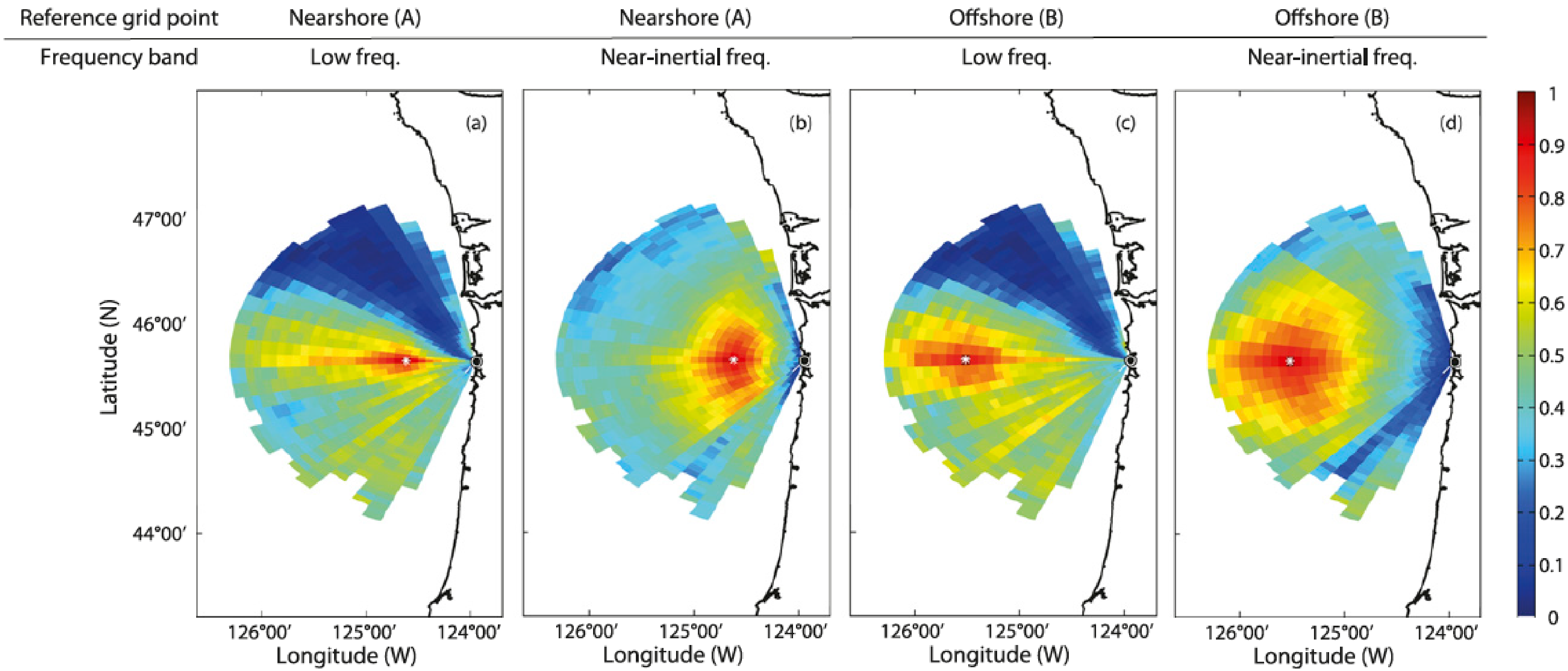


Variance of radial velocity time series



- Dominant variance in clockwise near-inertial frequency band and low frequency band
- Linear and log scale in the x-axis

Spatial coherence of radials



$$c(\Delta \mathbf{x}, \overline{\sigma}) = \frac{\langle \hat{r}(\mathbf{x}, \overline{\sigma}) \hat{r}^{\dagger}(\mathbf{x} + \Delta \mathbf{x}, \overline{\sigma}) \rangle}{\sqrt{\langle |\hat{r}(\mathbf{x}, \overline{\sigma})|^2 \rangle} \sqrt{\langle |\hat{r}(\mathbf{x} + \Delta \mathbf{x}, \overline{\sigma})|^2 \rangle}}$$

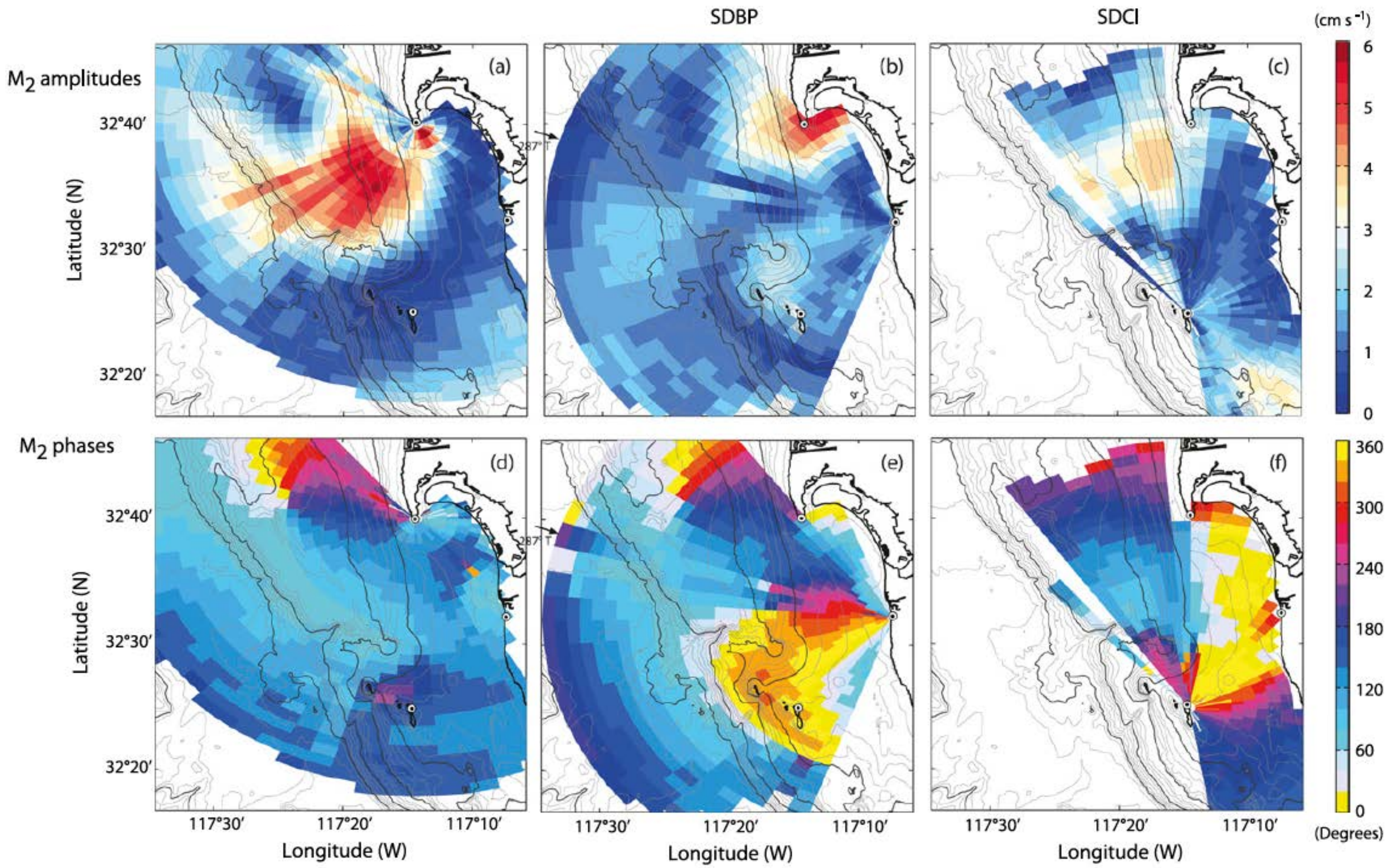
- Spatial coherence in low frequency and NI frequency bands in terms of offshore and near-shore locations
- Expected spatial structure and decorrelation length scales

Tidal amplitudes and phases

$$r_A = u\cos\theta_A + v\sin\theta_A,$$
$$= \mathrm{Re}[(u + iv)(\cos\theta_A - i\sin\theta_A)],$$
$$= \mathrm{Re}[\mathbf{u}e^{-i\theta_A}].$$

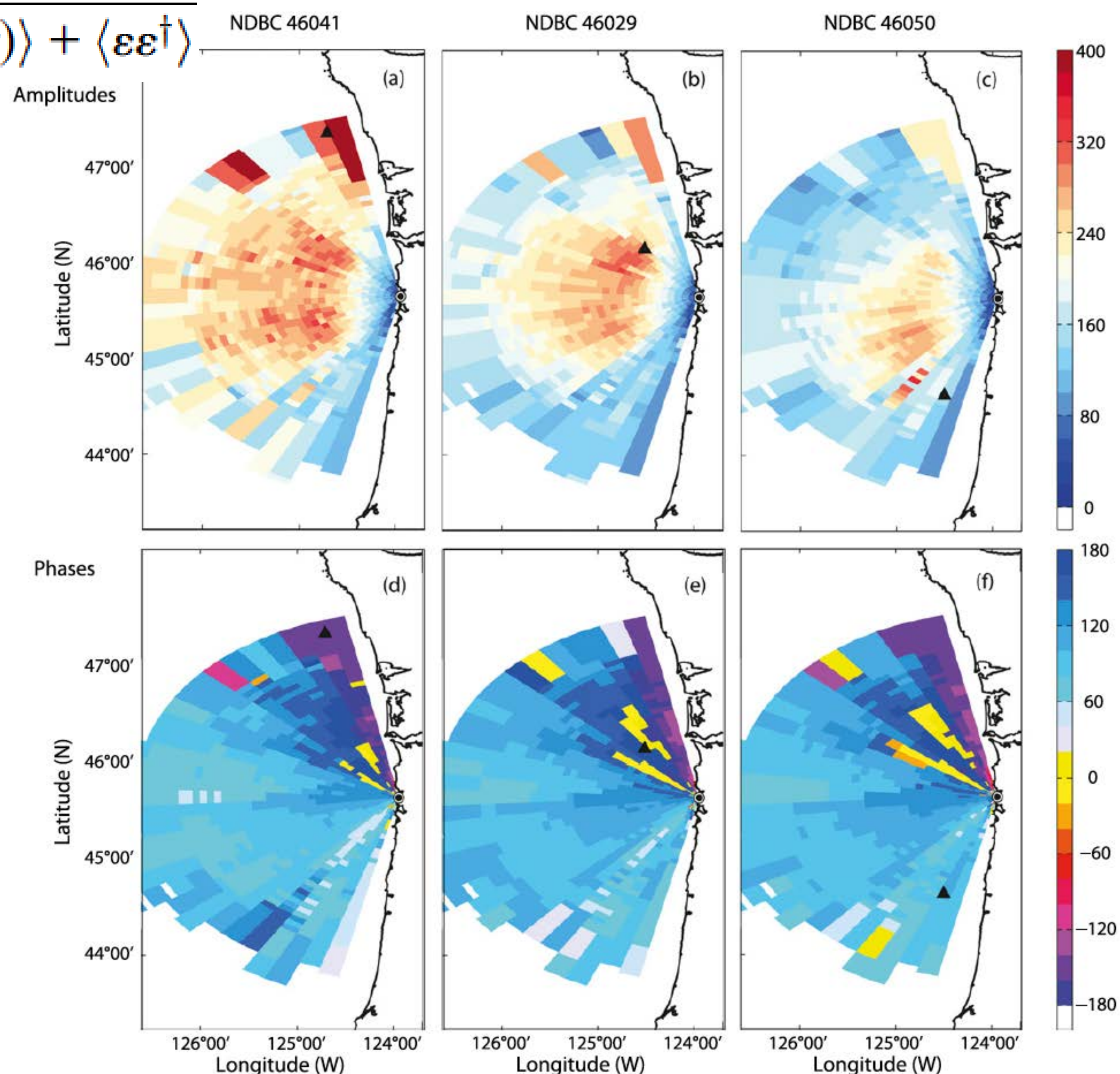
$$r_B = u\cos\theta_B + v\sin\theta_B = \mathrm{Re}[\mathbf{u}e^{-i\theta_B}]$$

$$\hat{r}_A = \hat{r}_B e^{-i(\theta_B - \theta_A)}$$



Wind transfer functions of radials

$$\mathbf{H}(\mathbf{x},\sigma) = \frac{\langle \hat{r}(\mathbf{x},\sigma)\hat{\boldsymbol{\tau}}^{\dagger}(\mathbf{x},\sigma)\rangle}{\langle \hat{\boldsymbol{\tau}}(\mathbf{x},\sigma)\hat{\boldsymbol{\tau}}^{\dagger}(\mathbf{x},\sigma)\rangle + \langle \varepsilon\varepsilon^{\dagger}\rangle}$$



Uncertainty of radial observations

$$r_A = u\cos\theta_A + v\sin\theta_A + \varepsilon_A$$
$$r_B = u\cos\theta_B + v\sin\theta_B + \varepsilon_B$$

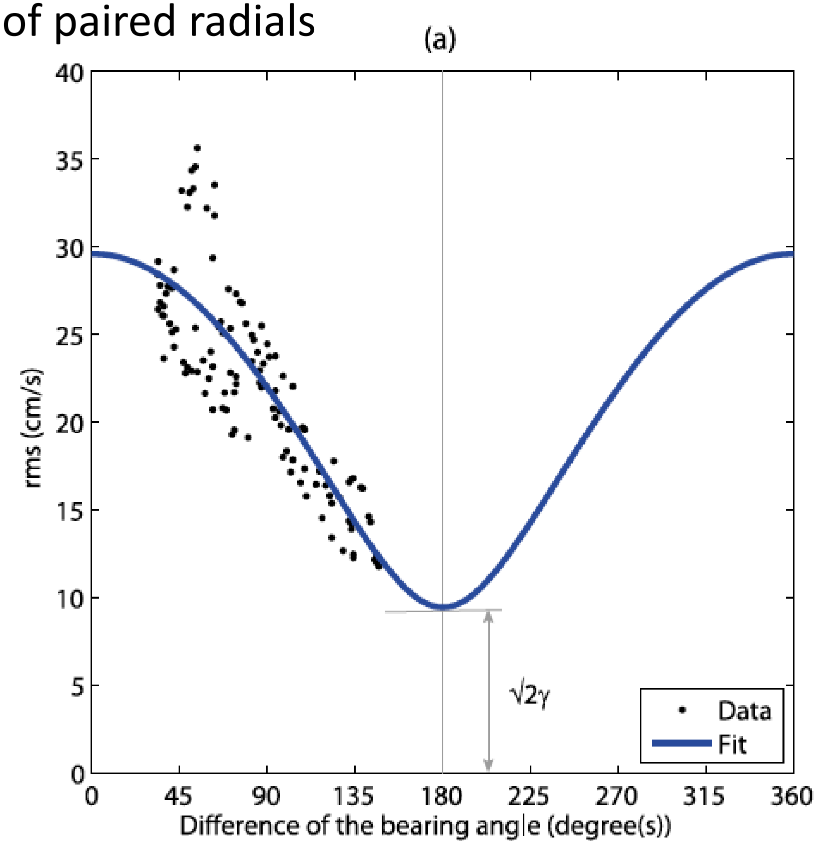
$$\rho = \frac{\langle r_A r_B^\dagger \rangle}{\sqrt{\langle r_A^2 \rangle}\sqrt{\langle r_B^2 \rangle}} = \kappa\cos\delta$$

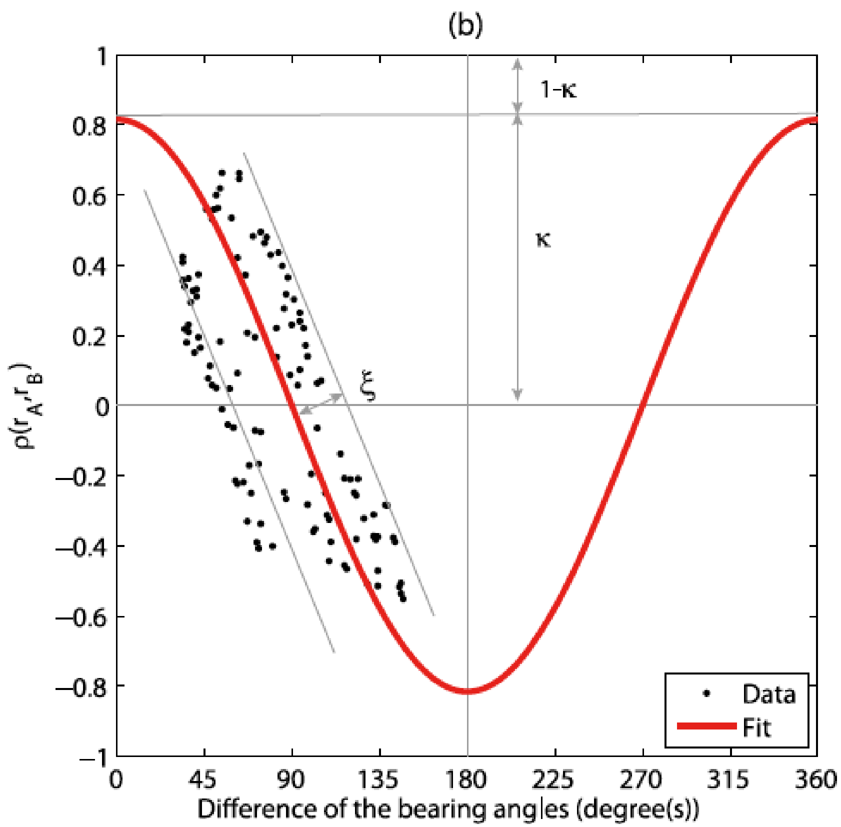
correlations of paired radials

$$\lambda = \sqrt{\langle (r_A + r_B)^2 \rangle} = \sqrt{4\sigma^2\cos^2\frac{\delta}{2} + 2\gamma^2}$$

rms of paired radials

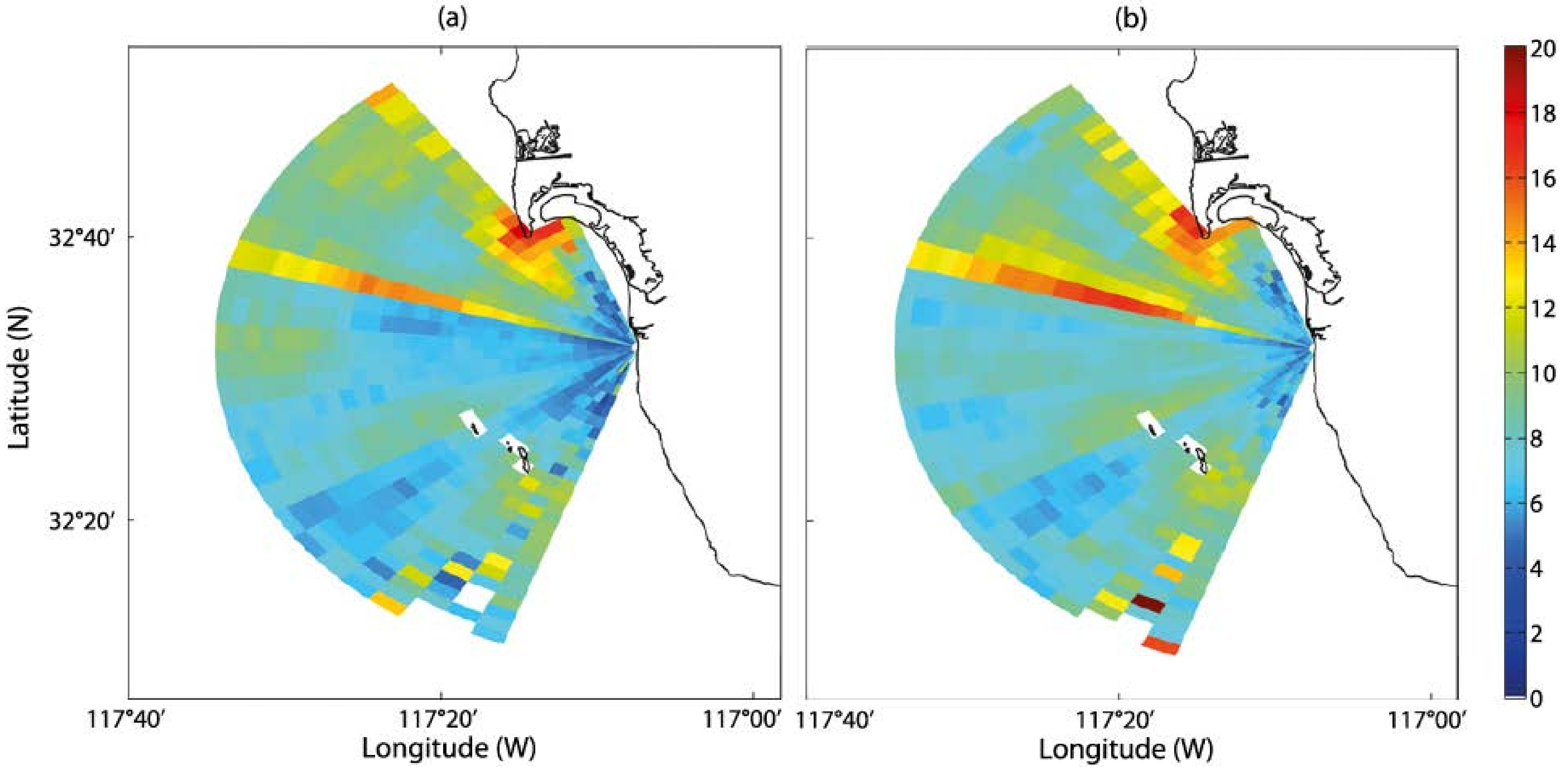
SNR $$\chi = \frac{\sigma^2}{\gamma^2} = \frac{\rho}{\cos\delta - \rho}$$





RMS of radial differences (beam patterns)

$$\zeta(m,\theta) = \sqrt{\langle |r^I(m,\theta) - r^M(m,\theta)|^2 \rangle}$$



Summary

- Several approaches to QAQC based on long-term radial observations (e.g., at least one year hourly records) were discussed.
- They include routines to sort radial spatial maps and to validate the data themselves or with independent observations.
- It will be beneficial to HFR end users and those who are interested in analyzing the HFR data.