에너지인력양성사업

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Several approaches to conduct quality assurance and quality control on the HFR radial velocity maps

Sung Yong Kim

Division of Ocean Systems Engineering

School of Mechanical, Aerospace & Systems Engineering

Korea Advanced Institute of Science and Technology (KAIST)

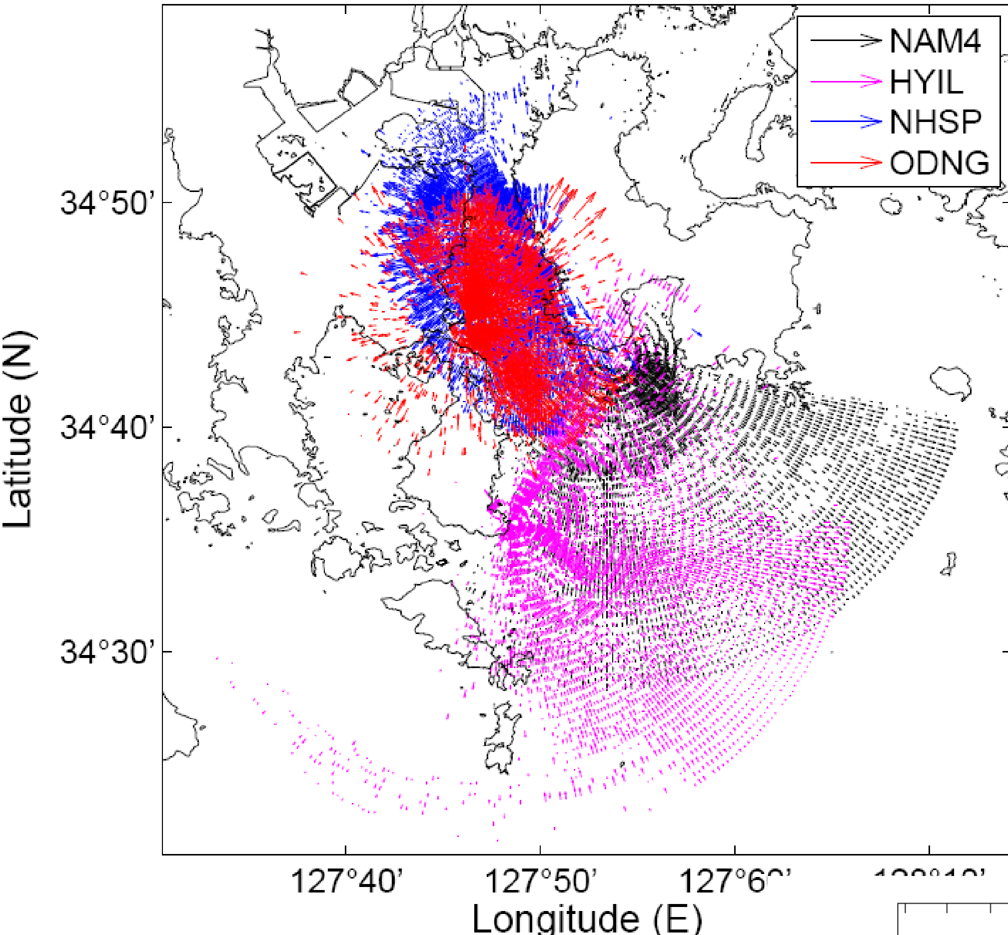
syongkim@kaist.ac.kr

Collaborators: S. H. Lee (Kunsan Nat'l Univ., Korea), KHOA, E. Terrill (SIO).

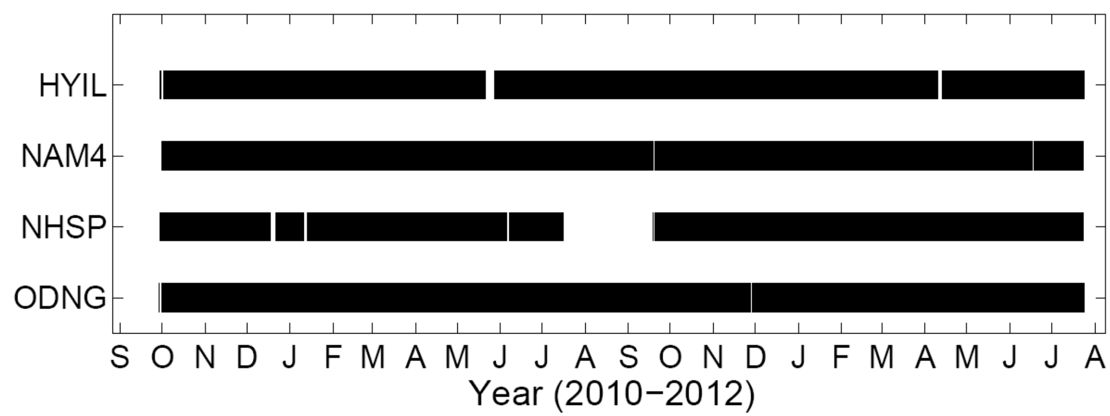
Outline

- QAQC of HF radar radial velocity maps (hindcast mode)
  - Spatial coverage of long term data
  - Correlation/covariance of pairs of radial velocities (RMS estimates)
  - 1 degree- vs 5 degree-azimuthal resolution?
  - RMS of difference of radial velocities (ideal vs. measured; CODAR only) $||r_{ideal} - r_{measured}||$
  - Geophysical signals
    - Energy spectra – tides, wind, inertial, and low-frequency forcing
    - Comparison with independent observations
  - Spatial coherence (correlation in a specific frequency band)
- Summary

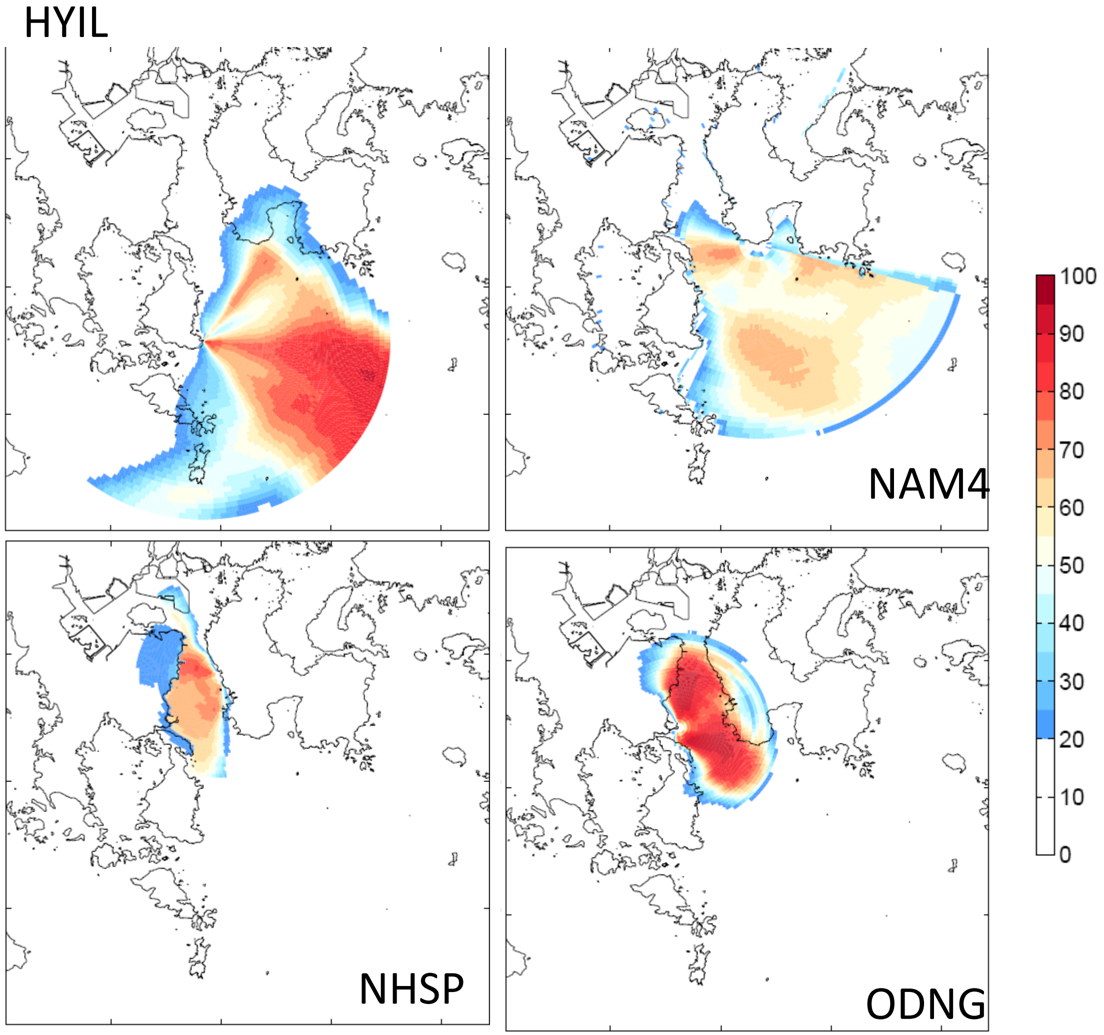
Radial velocity maps (Yeosu, Korea)



- 25MHz x 2; 42MHz x 2 (Yeosu, Korea)
- About two years hourly data



Spatial coverage of radial velocity maps (Yeosu, Korea)



- Long-term data coverage can provide the spatial consistency and influence/interference of coastline.

Correlation coefficients of pairs of radial velocities

$$r_1(t) = \mathbf{g}_1^{\mathrm{T}}\mathbf{u}_1(t) + \epsilon_1(t) = u_1(t)\cos\theta_1 + v_1(t)\sin\theta_1 + \epsilon_1(t),$$

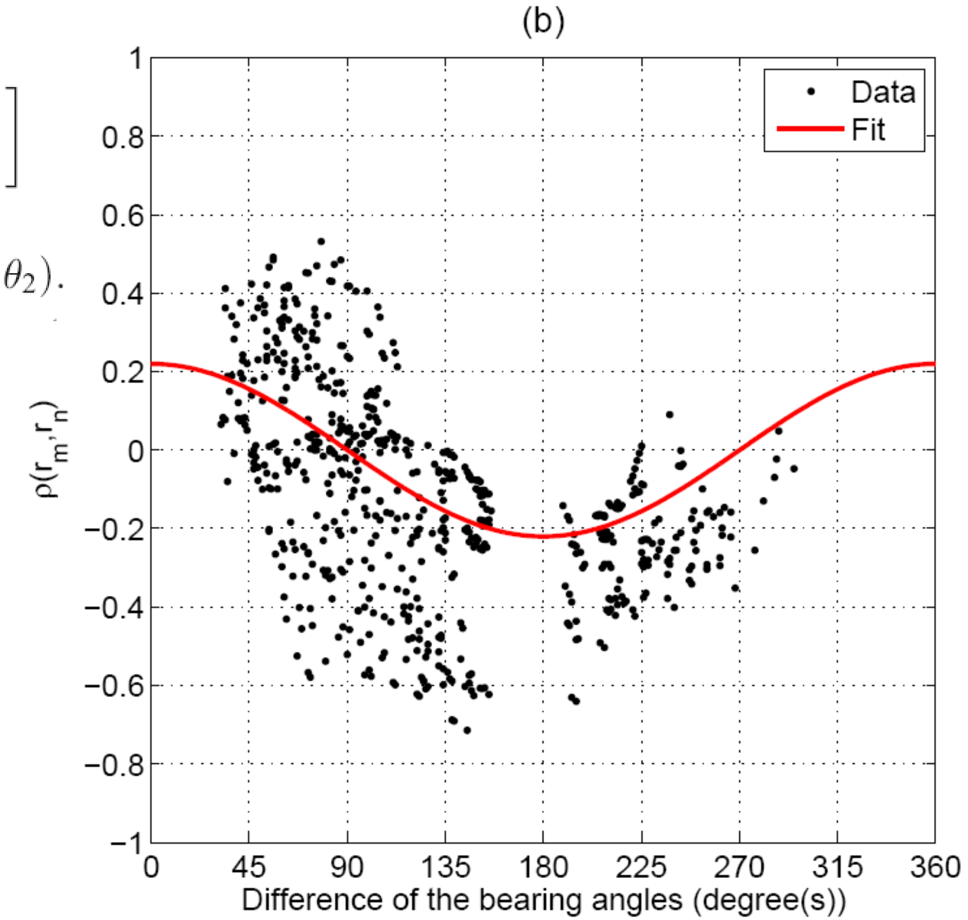
$$r_2(t) = \mathbf{g}_2^{\mathrm{T}}\mathbf{u}_2(t) + \epsilon_2(t) = u_2(t)\cos\theta_2 + v_2(t)\sin\theta_2 + \epsilon_2(t),$$

$$\langle r_1 r_2^{\mathrm{T}}\rangle = \mathbf{g}_1^{\mathrm{T}}\langle \mathbf{u}_1\mathbf{u}_2^{\mathrm{T}}\rangle \mathbf{g}_2 = [\cos\theta_1 \quad \sin\theta_1]\ \langle \mathbf{u}_1\mathbf{u}_2^{\mathrm{T}}\rangle \begin{bmatrix}\cos\theta_2 \\ \sin\theta_2\end{bmatrix}$$

$$\langle r_1 r_2^{\mathrm{T}}\rangle = \sigma^2(\cos\theta_1\cos\theta_2 + \sin\theta_1\sin\theta_2) = \sigma^2\cos(\theta_1 - \theta_2).$$

$$\rho(r_1, r_2) = \frac{\langle r_1 r_2^{\mathrm{T}}\rangle}{\sqrt{\langle r_1^2\rangle}\sqrt{\langle r_2^2\rangle}} = \frac{\sigma^2}{\sigma^2 + \gamma^2}\cos(\theta_1 - \theta_2),$$

where $\langle \mathrm{r}_1^2\rangle = \langle \mathrm{r}_2^2\rangle = \sigma^2 + \gamma^2$ and $\langle \epsilon_1^2\rangle = \langle \epsilon_2^2\rangle = \gamma^2$.



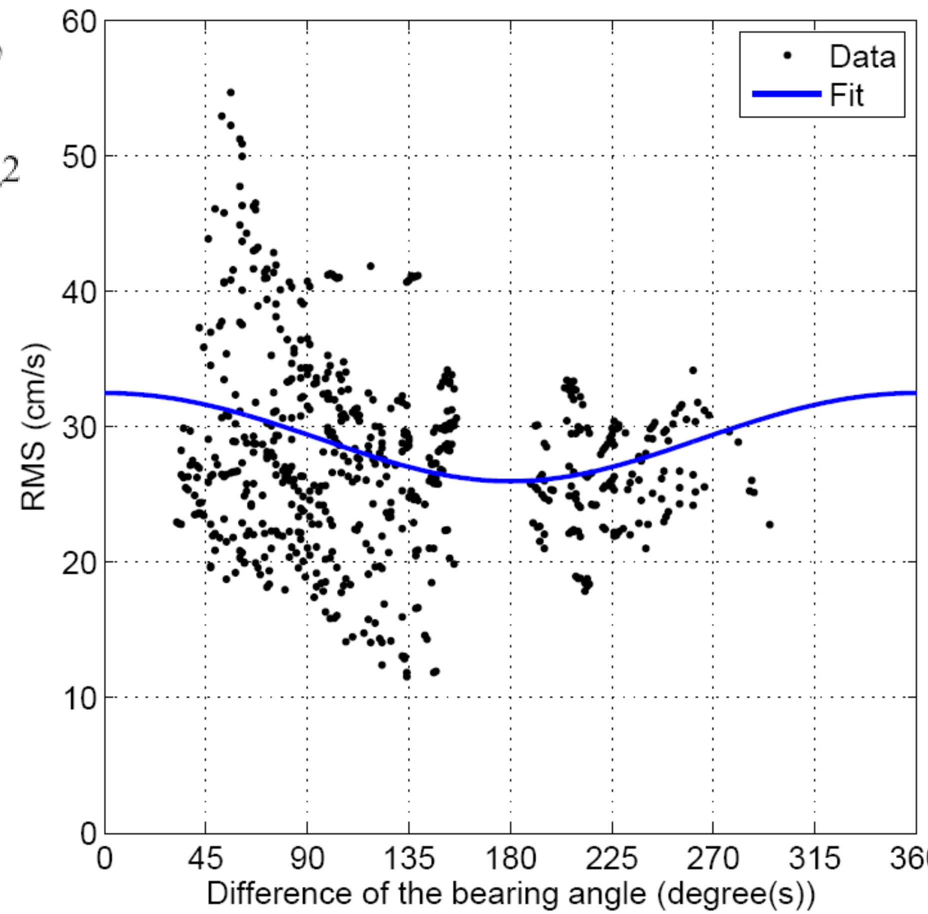
(Kim *et al*, JGR-C; 2010)

Covariance of pairs of radial velocities

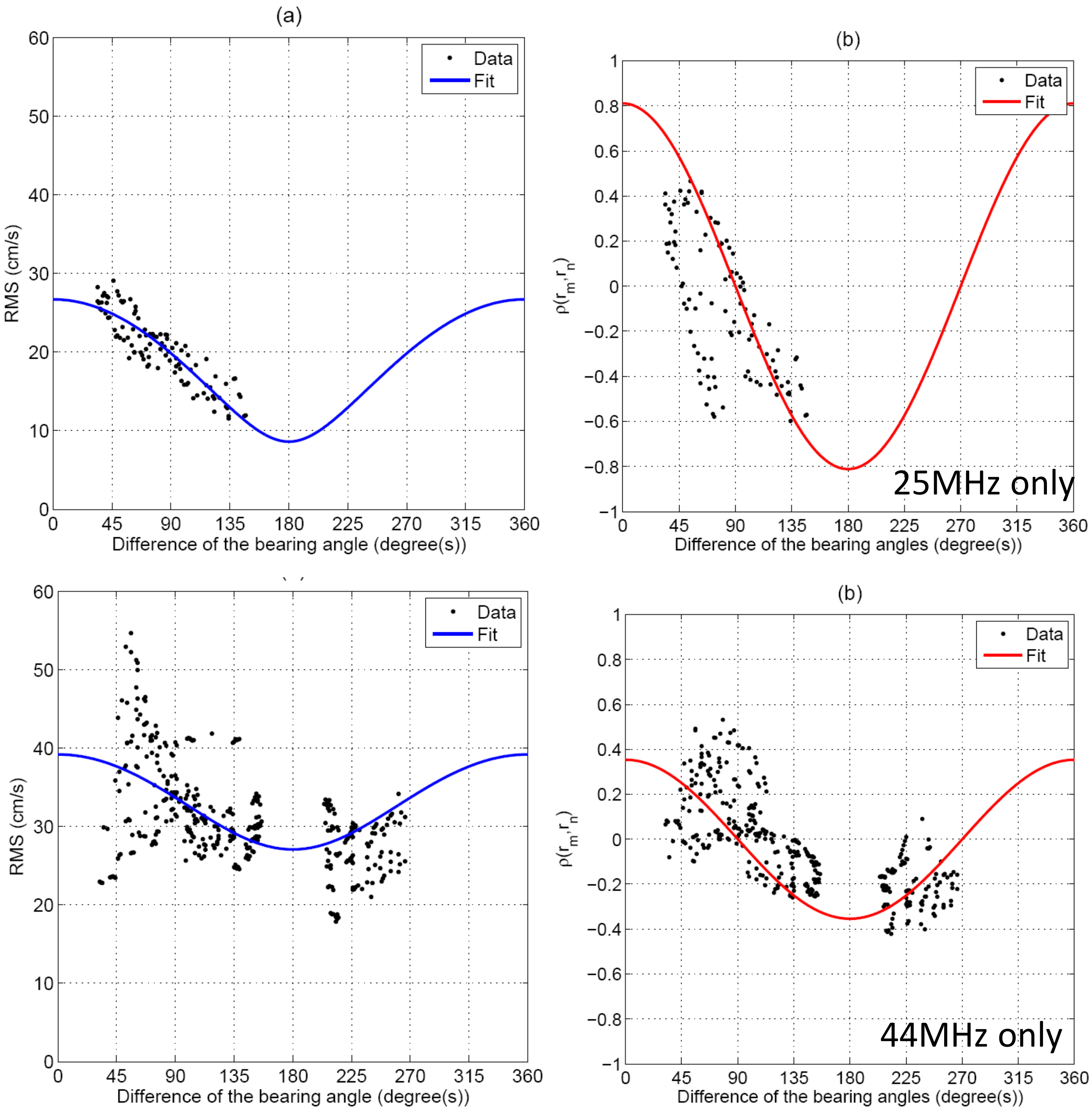
$$\langle (r_1 + r_2)^2 \rangle = \langle u^2 \rangle (\cos\theta_1 + \cos\theta_2)^2 + \langle v^2 \rangle (\sin\theta_1 + \sin\theta_2)^2 + \langle \epsilon_1^2 \rangle + \langle \epsilon_2^2 \rangle.$$

$$\langle u^2 \rangle = \langle v^2 \rangle = \sigma^2 \text{ and } \langle \epsilon_1^2 \rangle = \langle \epsilon_2^2 \rangle = \gamma^2,$$

$$\langle (r_1 + r_2)^2 \rangle = 4\,\sigma^2 \cos^2\left(\frac{\theta_1 - \theta_2}{2}\right) + 2\,\gamma^2$$

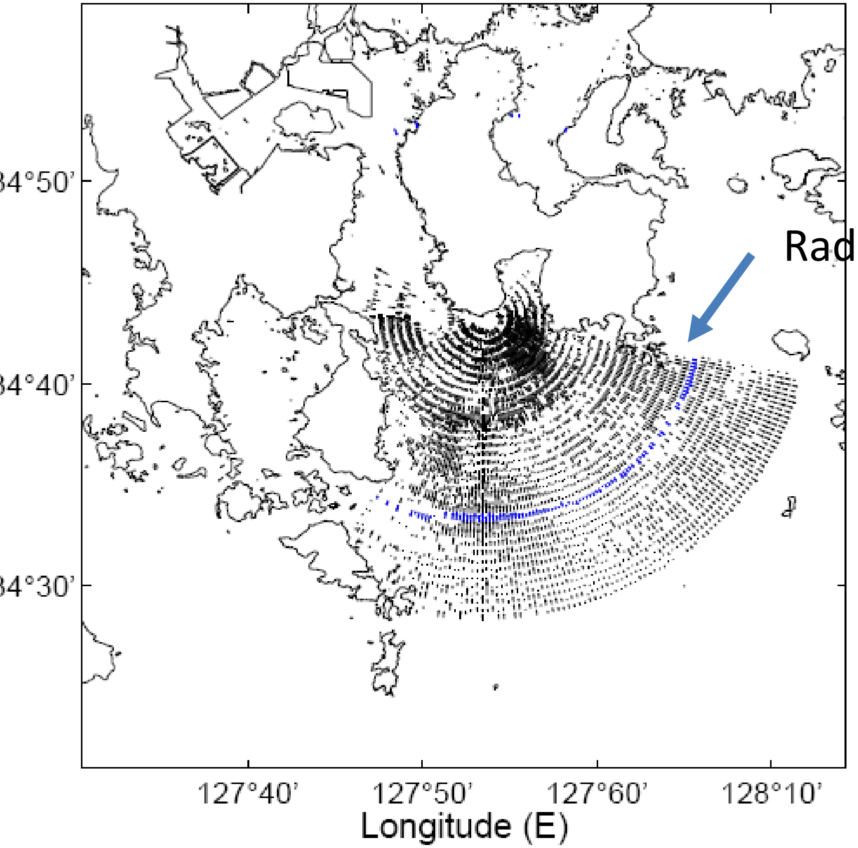


(Kim *et al*, JGR-C; 2010)

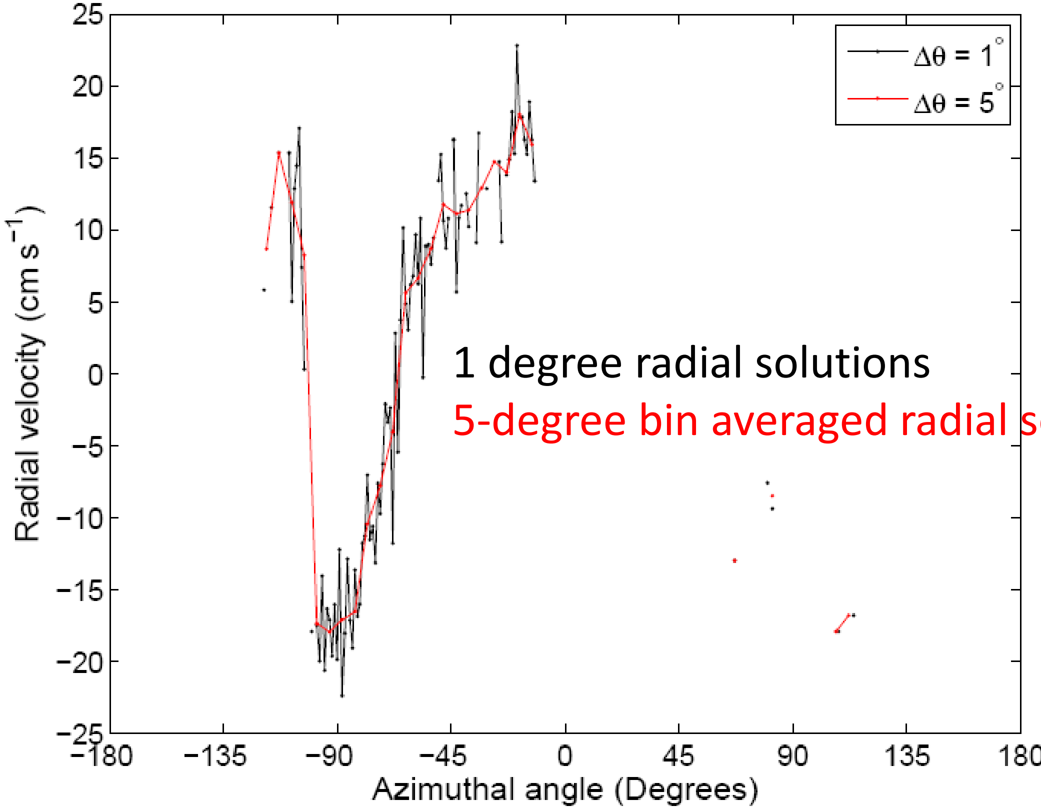


(a)
RMS (cm/s)
Difference of the bearing angle (degree(s))
Data
Fit
(b)
ρ(r_m,r_n)
Difference of the bearing angles (degree(s))
Data
Fit
25MHz only
RMS (cm/s)
Difference of the bearing angle (degree(s))
Data
Fit
(b)
ρ(r_m,r_n)
Difference of the bearing angles (degree(s))
Data
Fit
44MHz only

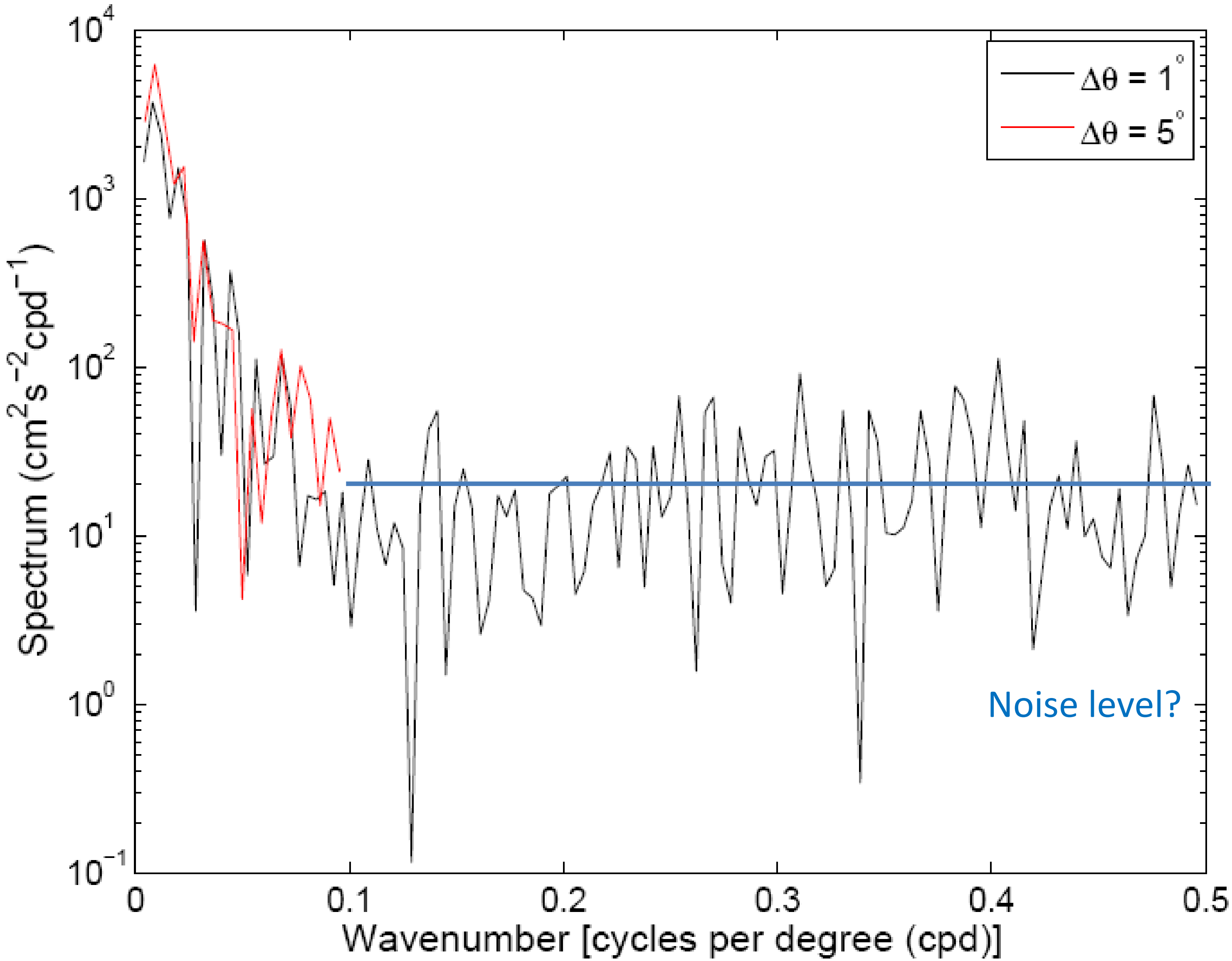
1- vs. 5-degree azimuthal resolution?



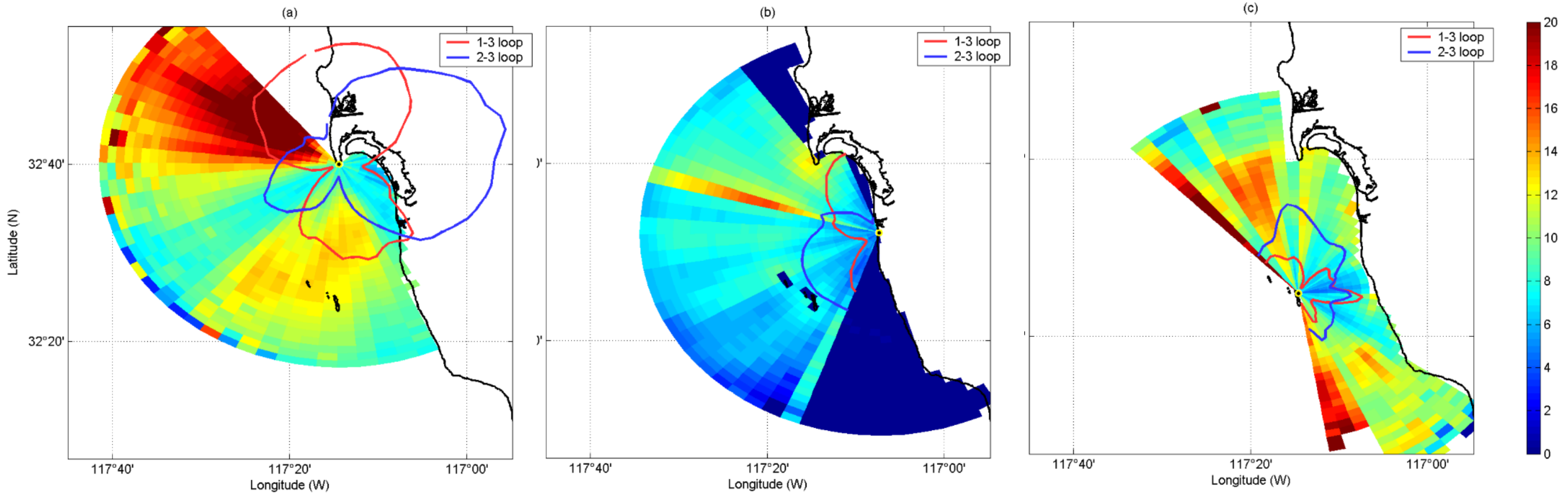
Radial velocities along a single range cell



1- vs. 5-degree azimuthal resolution?

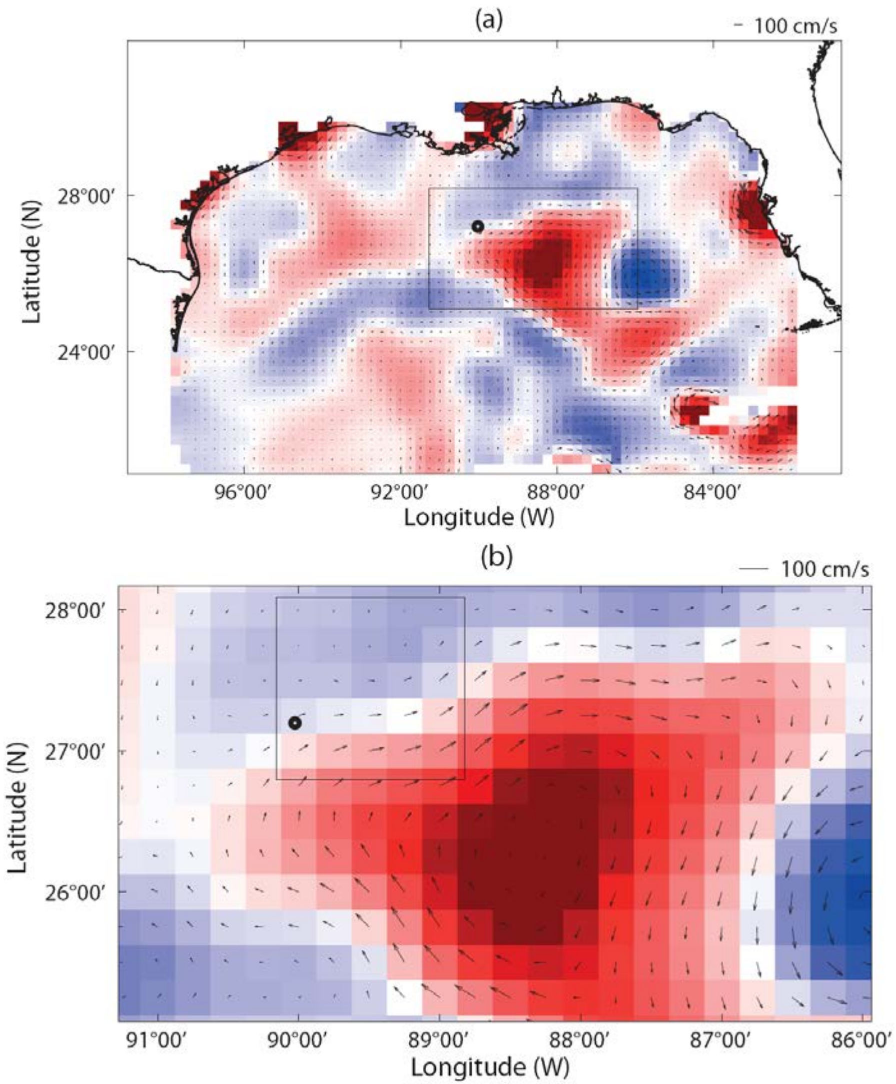


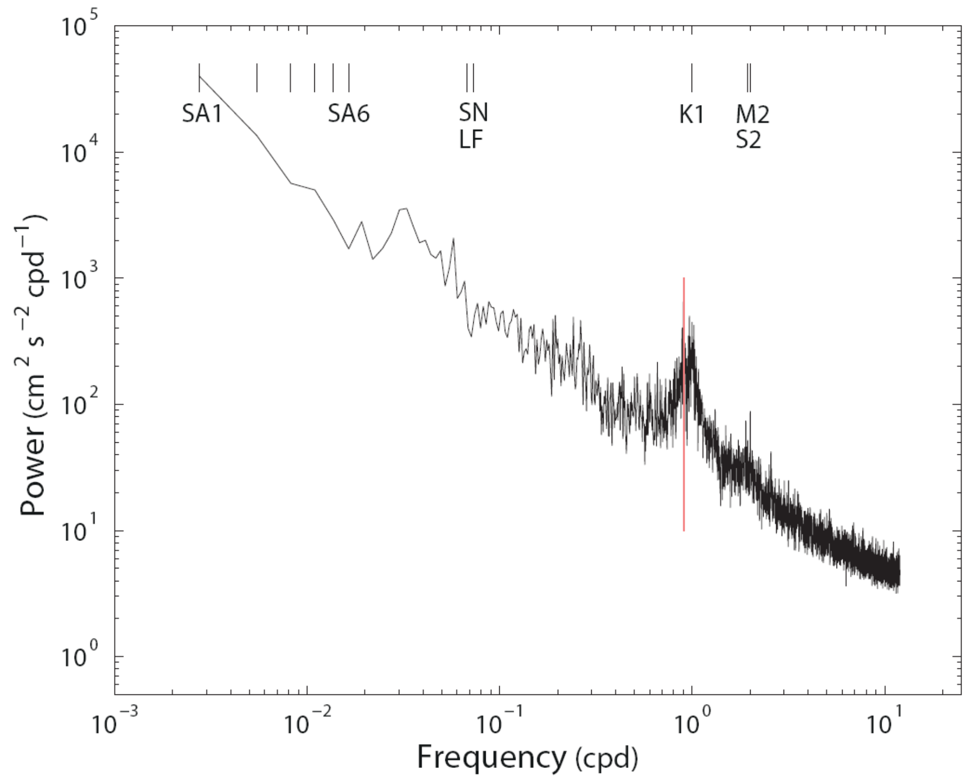
RMS of difference of radial velocity maps (ideal, measured)



- Overlaid with radar beam pattern and rms of difference of radial velocities
- Anomalous radial velocities in an azimuthal direction with a sharp peak of the beam pattern

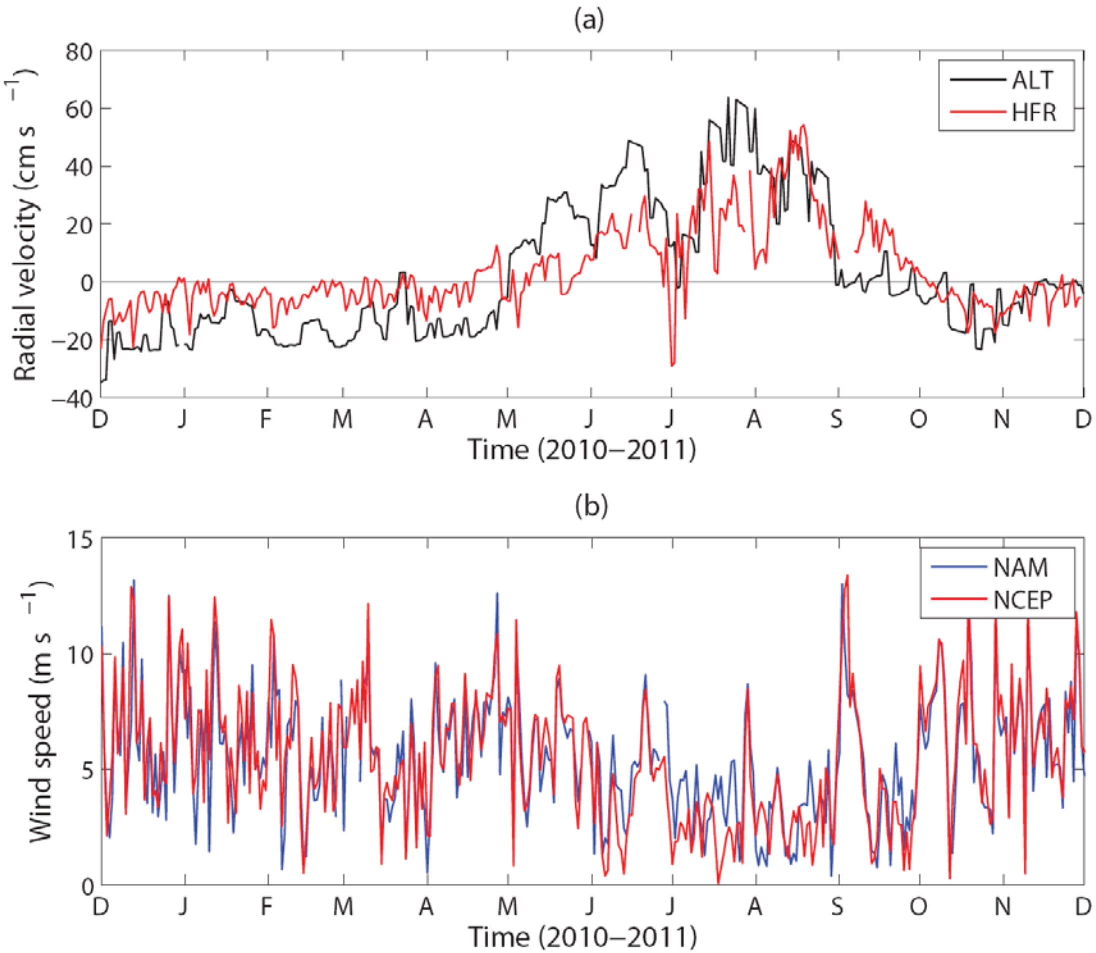
Geophysical signals: Energy spectra





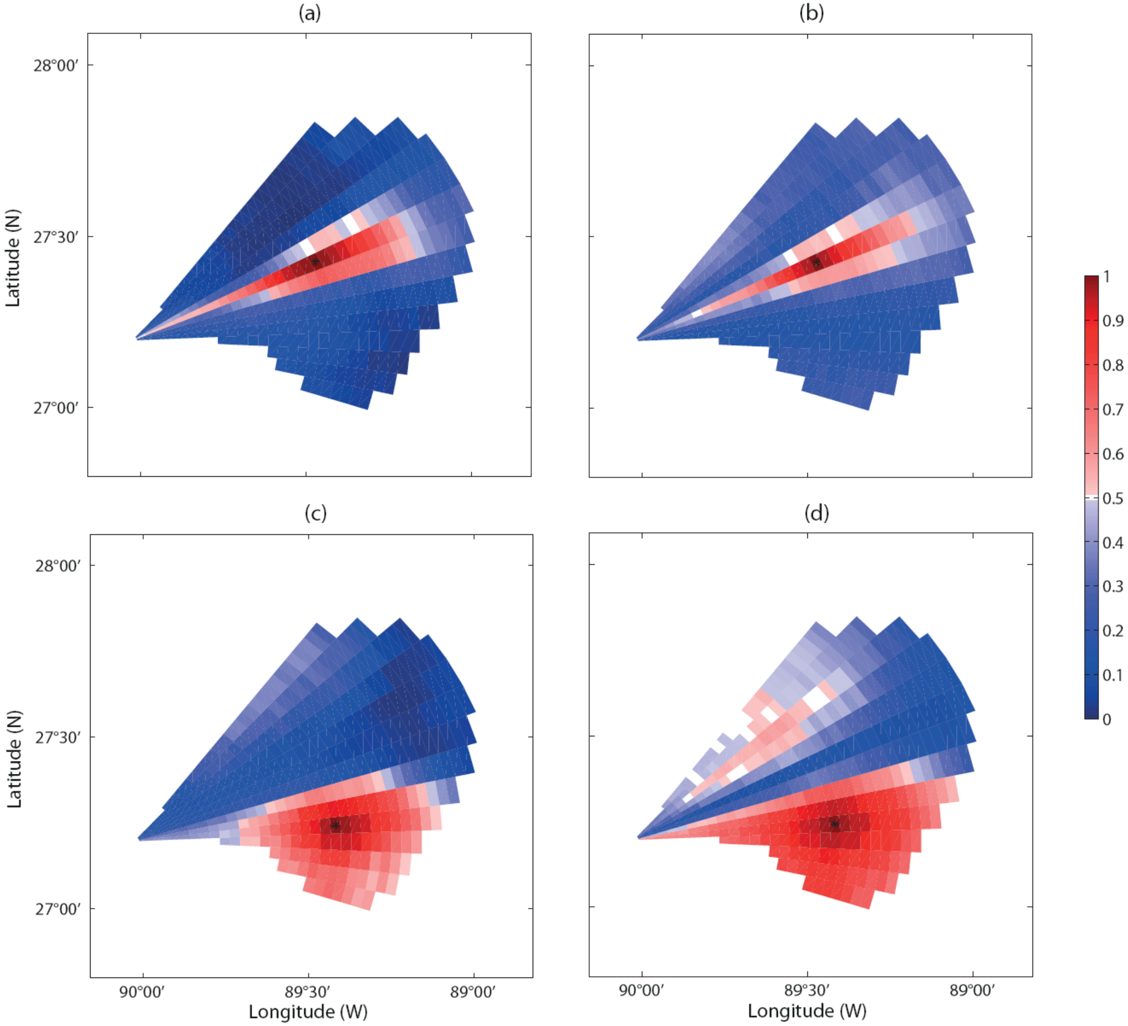
Courtesy: E. Terrill and T. Cook (SIO)

Geophysical signals: ageo-/geo-strophic currents



- CCAR/AVISO interpolated products are projected into the radial direction
- Coherent and incoherent with events; geostrophic components or potential errors

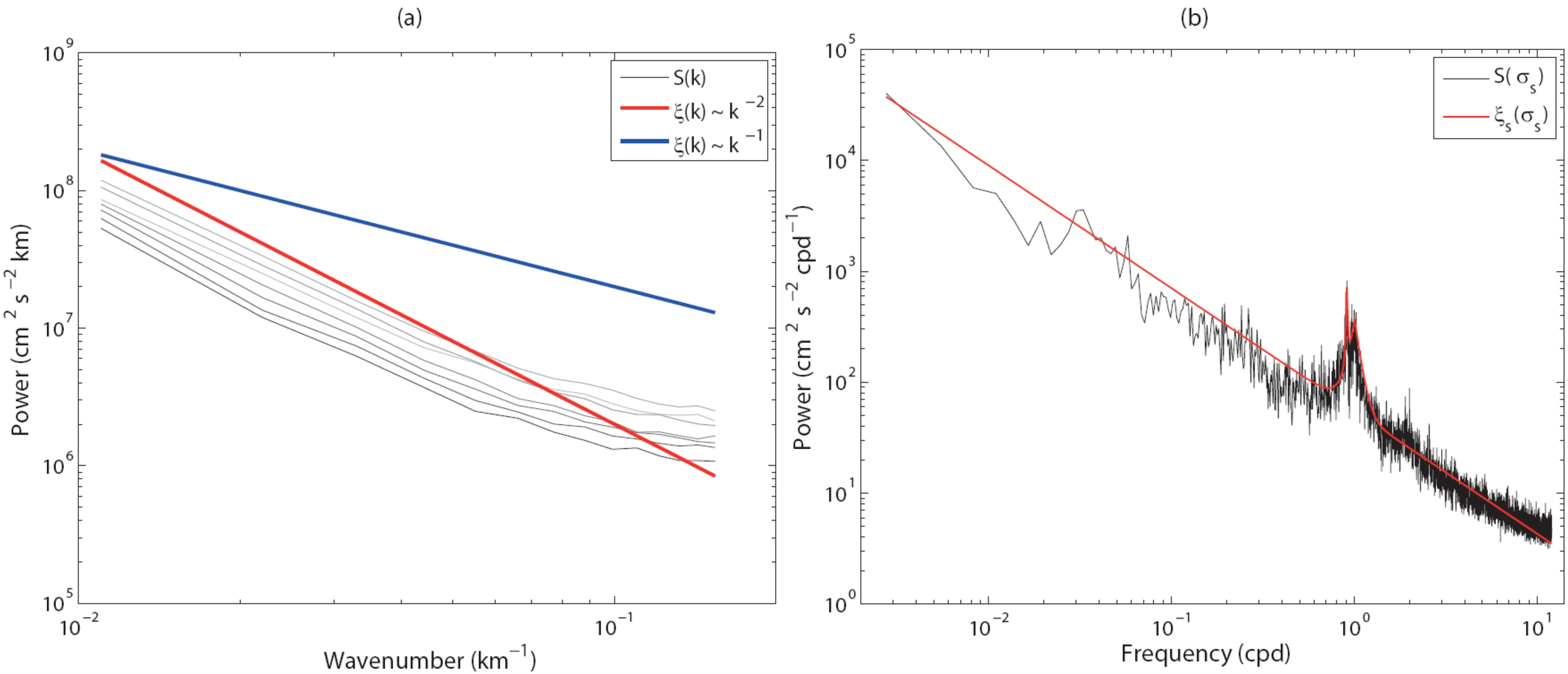
Spatial coherence: Correlation in a specific freq. band



- Spatial coherence of radial velocities in the near-inertial frequency ($|\sigma - fc| < 0.1\ fc$) and low frequency band ($\sigma < 0.2$ cpd).
- Expected O(100) km length scales for the offshore case.

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

Energy spectra of radial velocities in range and freq. domains



- Wavenumber spectra in the range direction
- Approximated energy spectra in the frequency domain

$$\xi_s(\sigma_s) = A\sigma_s^{-\alpha} + \sum_{n=1}^{N} B_n \exp\left(-\frac{|\sigma_s - \nu_n|}{(\lambda_t)_n}\right),$$

Summary

- Hindcast mode QAQC of HF radar radial velocities using statistics and geophysical consistency using long-term observations.
- Spatial coherence and energy spectra can be a first check
- Beam pattern issues may require the long-term data and reprocessing the data.
- Correlation and covariance of pairs of radial velocities can provide the noise of radar observations, which can be used in the optimal interpolation for vector current mapping.
- For real-time mode QAQC, the residual of the optimal interpolation can be a criteria to discern the outliers and spurious data.