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

(a) t = 17544h
(b) t = 00003h
(c) t = 00002h
(d) t = 00001h

Month (2007 – 2008)

Day (Jan., 2008)

SDBP

Latitude (N)
Longitude (W)

Latitude (N)
Longitude (W)

SDBP

Month (2007 – 2008)
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

<table>
<thead>
<tr>
<th>Reference grid point</th>
<th>Nearshore (A)</th>
<th>Nearshore (A)</th>
<th>Offshore (B)</th>
<th>Offshore (B)</th>
</tr>
</thead>
</table>

**Figure:**

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

\[
c(\Delta x, \sigma) = \frac{\langle \hat{r}(x, \sigma) \hat{r}^\dagger(x + \Delta x, \sigma) \rangle}{\sqrt{\langle |\hat{r}(x, \sigma)|^2 \rangle} \sqrt{\langle |\hat{r}(x + \Delta x, \sigma)|^2 \rangle}}
\]
Tidal amplitudes and phases

\[
\begin{align*}
 r_A &= u \cos \theta_A + v \sin \theta_A, \\
 &= \text{Re}[(u + iv)(\cos \theta_A - i \sin \theta_A)], \\
 &= \text{Re}[ue^{-i\theta_A}].
\end{align*}
\]

\[
 r_B = u \cos \theta_B + v \sin \theta_B = \text{Re}[ue^{-i\theta_B}],
\]

\[
 \hat{r}_A = \hat{r}_B e^{-i(\theta_B - \theta_A)}
\]
Wind transfer functions of radials

$$H(x, \sigma) = \frac{\langle \hat{i}(x, \sigma) \hat{\tau}^\dagger(x, \sigma) \rangle}{\langle \hat{\tau}(x, \sigma) \hat{\tau}^\dagger(x, \sigma) \rangle + \langle \varepsilon \varepsilon^\dagger \rangle}$$
Uncertainty of radial observations

\[ r_A = u \cos \theta_A + v \sin \theta_A + \epsilon_A \]

\[ r_B = u \cos \theta_B + v \sin \theta_B + \epsilon_B \]

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

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

Correlations of paired radials

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.