Characterizing Buoy Wind Speed Error in Extreme Conditions with ASCAT and ERA5

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Are buoy winds biased low in high winds and seas?

**Large et al. 1996**

**Edson and Vandemark: Evaluating several key issues in satellite wind stress validation – OVWST 2018**
Research Questions

1. How do buoy winds from different anemometer heights (adjusted to a standard height) compare with each other under similar wind forcing and sea state?

2. Under what wind and sea state conditions do buoy winds strongly disagree with alternative sources (in our case, ASCAT)?
Outline

1. Dataset Description
2. Triple Collocation Calibration
3. Analysis of wind residuals (ASCAT – Calibrated Buoy Wind Speed) with Wave Parameters
4. Explanation of Results
Triple Collocation Data

Scatterometer Data (used as the reference dataset)

• COAPS Simplified Daily Satellite Swath Dataset (Coastal L2, 12.5 km)
  • ASCAT-A: 2009-2018 (KNMI, CMOD5.n)
  • ASCAT-B: 2012-2018 (KNMI, CMOD5.n)

Buoy Data

• Global Telecommunications System

• Only used moored buoys at least 25 km from shoreline and at least 100 m deep

ERA5 Reanalysis Data

• Used as an alternative source of wave information.

• Used ERA5 Model “First Guess” winds in the calibration
GTS Buoy Data
Methods: Height Adjustment

• Buoy winds were converted to \( U_{10S} \) for comparison.

\[
\bar{u}(z) - \bar{u}_s = \frac{u_\ast}{k} \left[ \ln \left( \frac{z-d}{z_0} + 1 \right) - \varphi(z, z_o, L) \right]
\]

• \( \bar{u}_s \): Copernicus Global Surface Currents (MULTIOBS_GLO_PHY_NRT_015_003)

• \( U_{10S} = U_{10N} \sqrt{\frac{\rho}{\langle \rho \rangle}}, \langle \rho \rangle = 1.225 \text{ kg m}^{-3} \)

\( \bar{u}_s \): Ocean Surface Velocity
\( u_\ast \): Friction Velocity
\( k \): Von Carman’s constant
\( z_0 \): Roughness Length
\( d \): Displacement Height
Triple Collocation Calibration

\[
\begin{align*}
x &= X + e_x \equiv T + e_x \\
y &= Y + e_y \equiv \alpha_1 + \beta_1 T + e_y \\
z &= Z + e_z \equiv \alpha_2 + \beta_2 T + e_z,
\end{align*}
\]

• Used triple collocation technique from Stoffelen 1998
• ERA5 FG and buoy \( U_{10SC} \) wind speed components \((u, v)\) were calibrated using ASCAT as the reference.
• Calibration was performed at the individual buoy level.
• 216 Buoys were used with at least 500 triplets.
Results

Relative Biases (Buoy − ASCAT (m s⁻¹))

ASCAT Wind Speed (m s⁻¹)

Buoy Raw Winds

Buoy U₁₀sc

Calibrated Buoy U₁₀sc

Wind Hgt. = 3m
Wind Hgt. = 4m
Wind Hgt. = 5m
Results

ERA5 Wave Separation

\[ \beta_i = 1.2 \times 28 \left( \frac{u_*}{C_p} \right) \cos(\theta - \varphi) \]

Wind Waves:
\[ \beta_i > 1, \ (\theta - \varphi) < \frac{\pi}{2} \]

Mixed Waves:
\[ \beta_i \leq 1, \ 0.25 \leq \frac{H_{swell}^2}{H_{wind}^2} < 4.0 \]

Swell:
\[ \beta_i \leq 1, \ \frac{H_{swell}^2}{H_{wind}^2} \geq 4.0 \]
Wind-Wave Conditions

Difference in Mean Residuals

A.) 5m − 4m

B.) 4m − 3m

(ASCAT – Cal. Buoy U10SC 5m) – (ASCAT – Cal. Buoy U10SC 4m)
Research Question

1. How do buoy winds from different anemometer heights (adjusted to a standard height) compare with each other under similar wind forcing and sea state?

   a. The buoy winds from 3, 4 and 5 m anemometer heights do follow a pattern where the wind speed from higher anemometer heights remain higher than lower anemometer heights for similar high wind speed and high wind-wave conditions.

   b. However, the paired uncertainty between the comparisons in high wind conditions is too high to confidently attribute this trend to wave sheltering of buoy winds.
Research Questions

2. Under what wind and sea state conditions do buoy strongly winds disagree with alternative sources (in our case, ASCAT)?
Results

\[ w_a = \frac{C_p}{u_*} \]
Results

• ASCAT winds are consistently above buoy $U_{10SC}$ in high $H_s$ and $W_a$ ranges

"*" indicate significant differences between the ASCAT and calibrated buoy U10SC values for the given $w_a$ and $H_s$ range, defined using Welch’s t-test at the 0.5% level.
Results (with binned buoy wind speed)
Possible Explanations: Wave Tilt Modulation

Stewart 1985: Methods of Satellite Oceanography
Possible Explanations: Wave Tilt Modulation

Correlation coefficients between $U_{10}$ residuals ($U_{10}^{\text{ASCAT}} - U_{10}^{\text{buoy}}$) and *in situ* buoy observations as a function of incidence angle.

Stopa et al. 2017: *Sea State Impacts on Wind Speed Retrievals From C-Band Radars*
Important Point

• ASCAT winds processed from CMOD5.n were used for this study. Substantial improvement to cross-track wind variability has improved with CMOD7. How different might these results be using ASCAT winds from CMOD7?
Summary

• For wind-wave dominant conditions, calibrated buoy $U_{10SC}$ is consistently above ASCAT. The opposite is true in swell conditions with ASCAT wind speed above calibrated buoy $U_{10SC}$ for all $H_s$ ranges.

• In cases of high swell waves, we observe increases of ASCAT winds over buoy $U_{10SC}$ with increasing $H_s$ and $w_a$.

• Choice of winds going into the calculation of $u_*$ affects the magnitude of the wind speed residual (calibrated buoy $U_{10SC}$ – ASCAT) differences with $w_a$, but the overall pattern remains consistent.

• If this is indeed a wave tilting issue with ASCAT wind retrievals, a correction including $H_s$, $w_a$ and incidence angle may be possible.
Questions?
Feel free to email me at:
ewright@coaps.fsu.edu
References

Edson and Vandemark: Evaluating several key issues in satellite wind stress validation – OVWST 2018. Available online at: https://mdc.coaps.fsu.edu/scatterometry/meeting/docs/2018/docs/WednesdayApril25/WednesdayMorning/vandmark_edson_OVW2018_talk.pptx


