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?

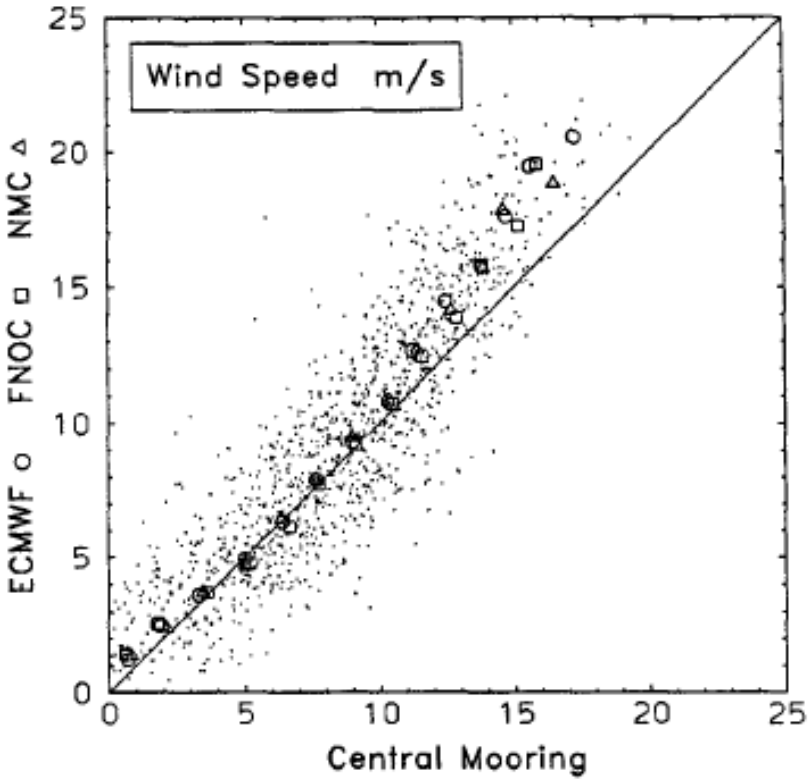
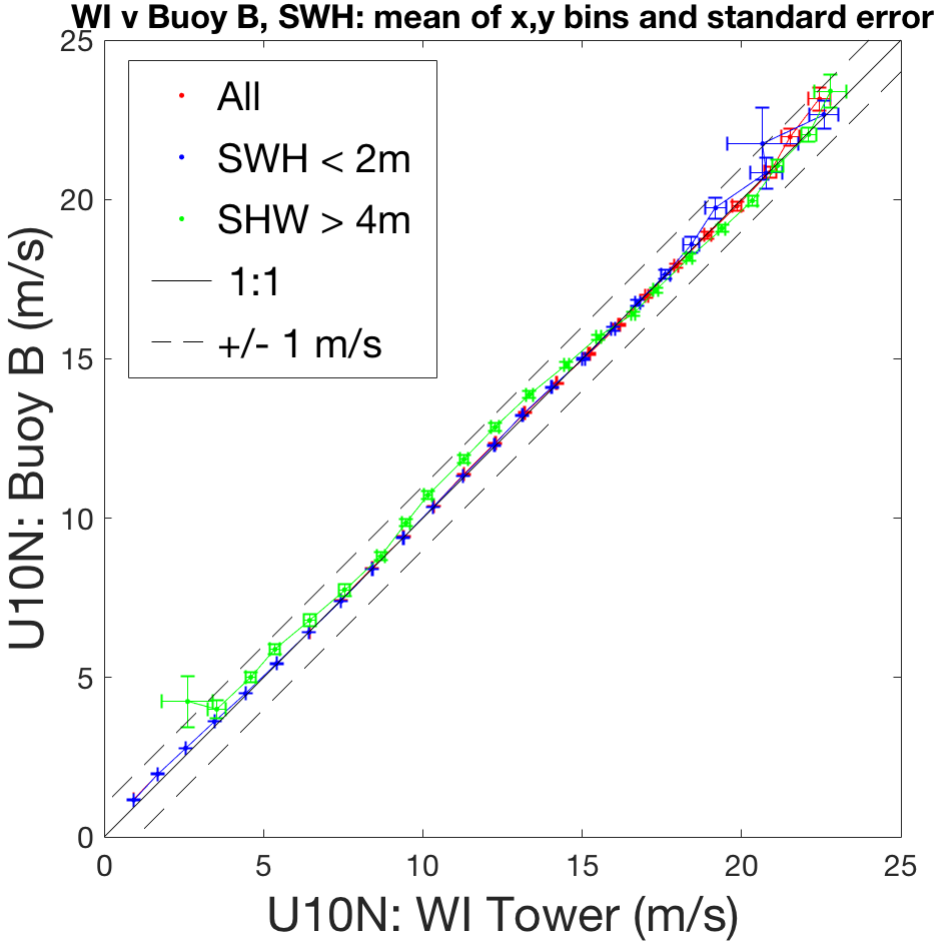


FIG. 4. Scatterplot of interpolated ECMWF wind speeds vs central mooring (S_C) speeds. Bin averages of these data are shown as open circles. Also shown are bin averages from NMC vs S_C (triangles) and FNOC vs S_C (squares) comparisons.

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)

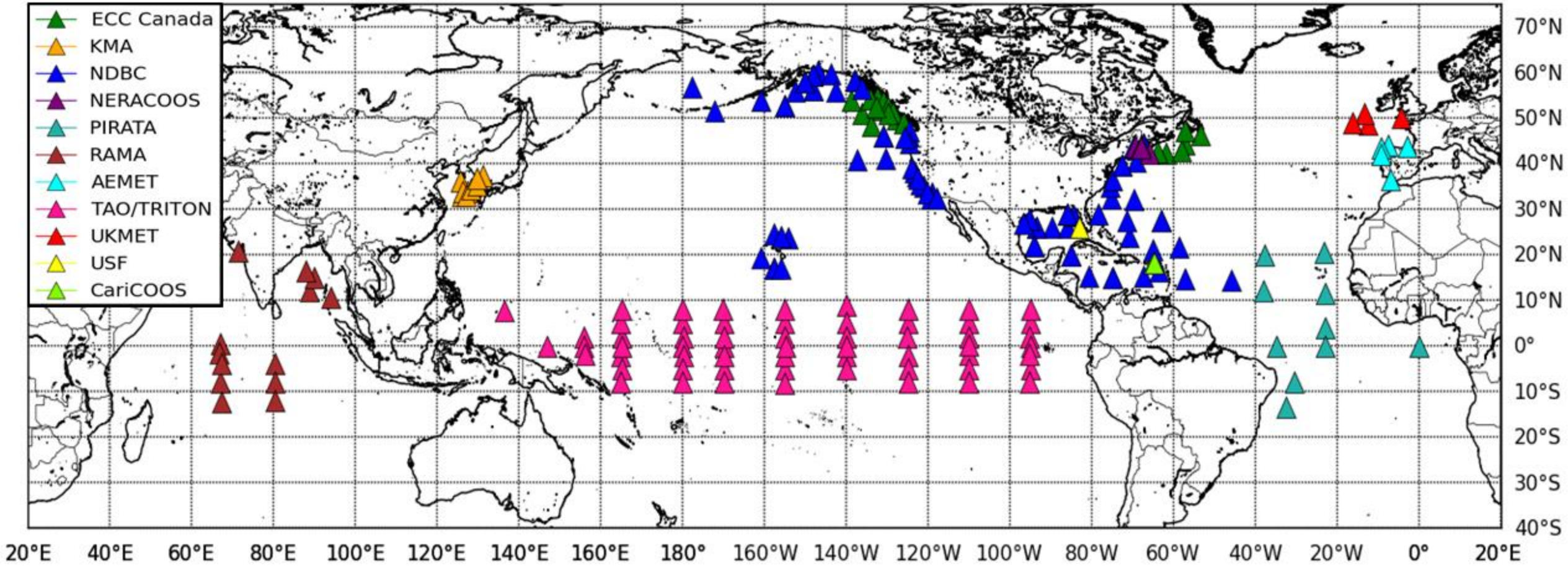
Buoy Data

- 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.

$$\overline{\mathbf{u}}(z) - \overline{\mathbf{u}}_s = \frac{\mathbf{u}_*}{k}\left[\ln\left(\frac{z-d}{z_o}+1\right) - \varphi(z, z_o, L)\right]$$

- $\overline{u}_s$: Copernicus Global Surface Currents (MULTIOBS_GLO_PHY_NRT_015_003)
- $U_{10S} = U_{10N}\sqrt{\frac{\rho}{\langle\rho\rangle}}, \langle\rho\rangle = 1.225\ kg\ m^{-3}$

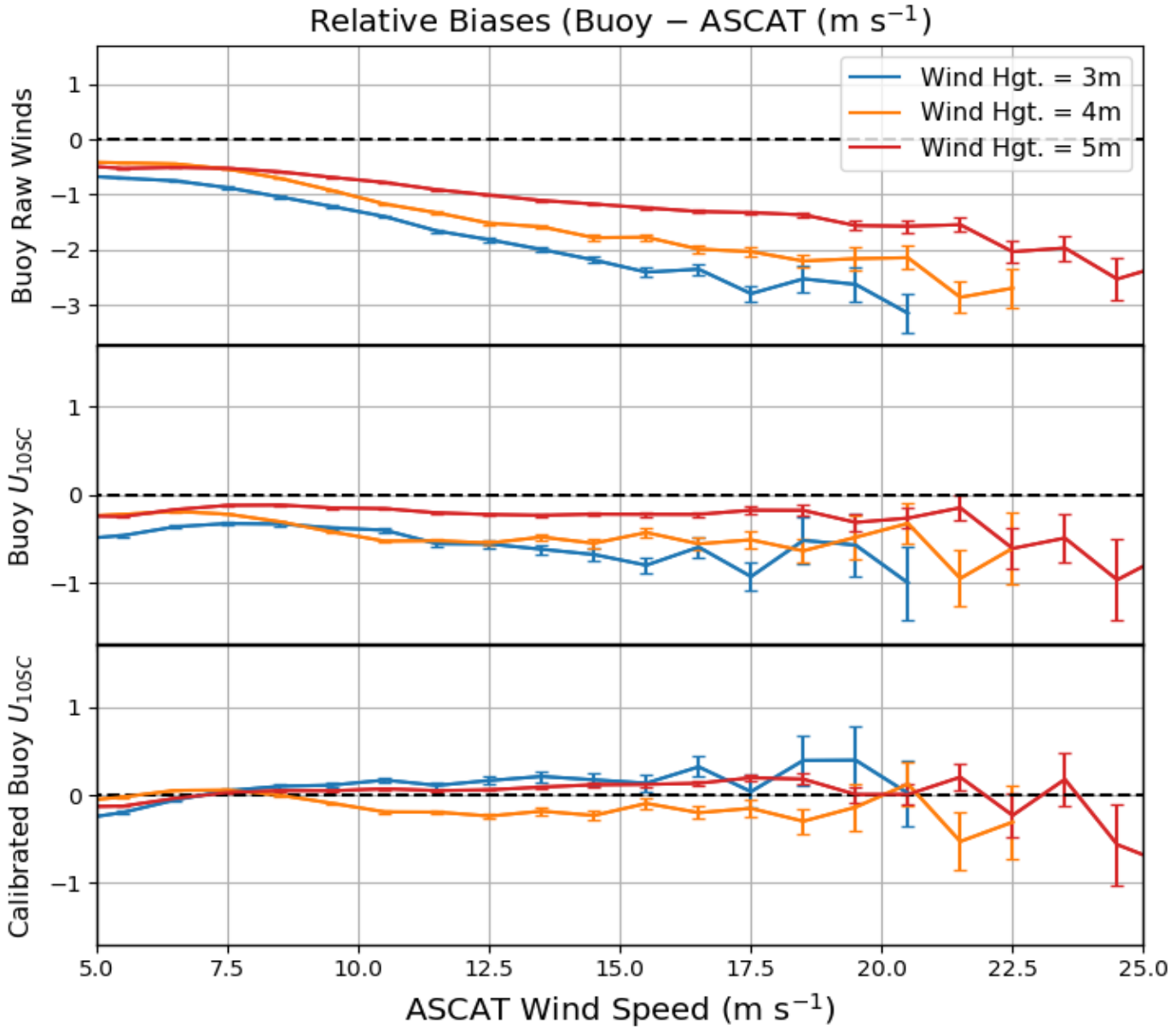
$\overline{u}_s$: Ocean Surface Velocity
u_* : Friction Velocity
k : Von Carman's constant
z_0 : Roughness Length
d : Displacement Height

Triple Collocation Calibration

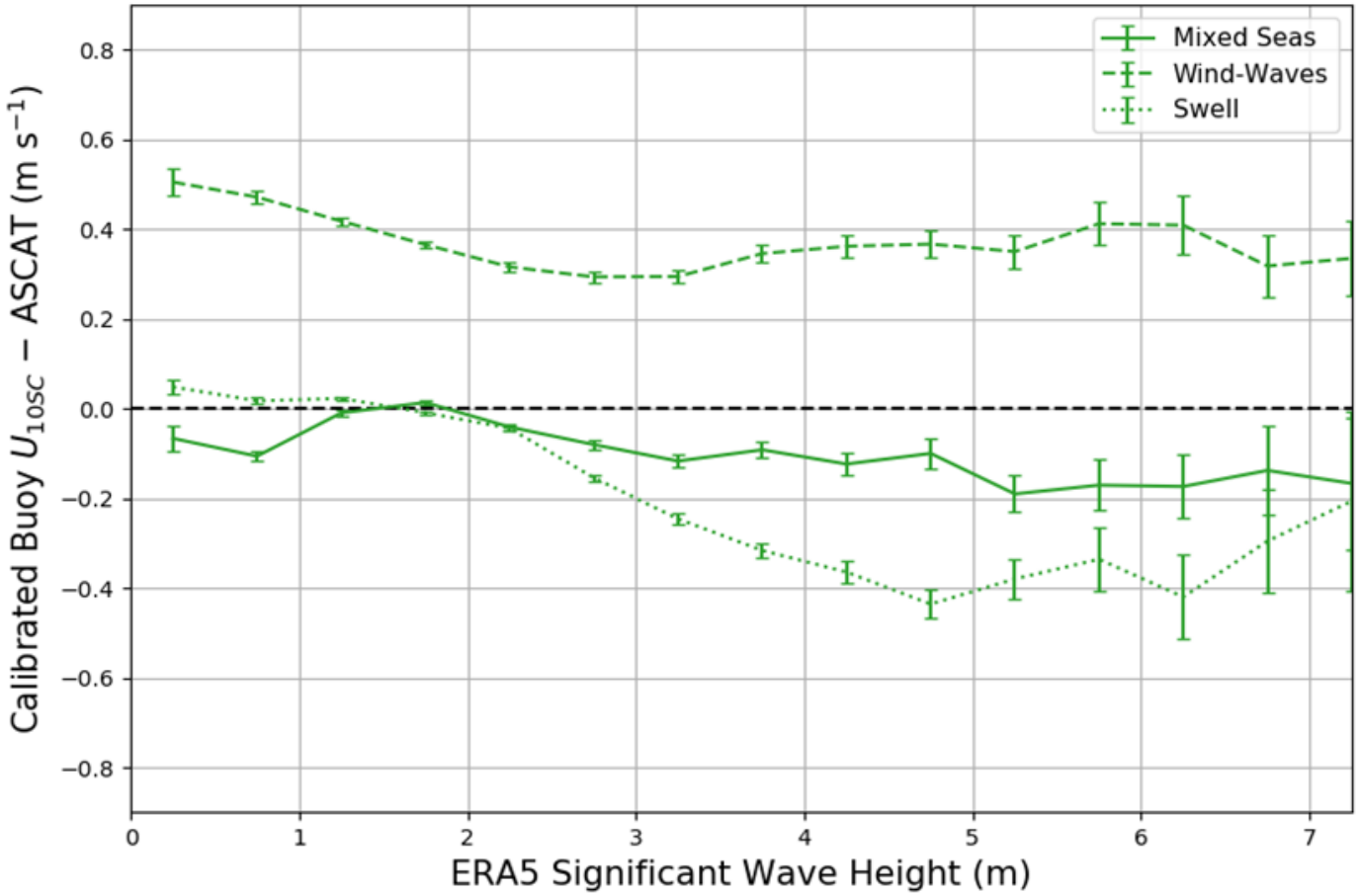
$$x = X + e_x \equiv T + e_x$$
$$y = Y + e_y \equiv \alpha_1 + \beta_1 T + e_y$$
$$z = Z + e_z \equiv \alpha_2 + \beta_2 T + e_z,$$

- 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})
Wind Hgt. = 3m
Wind Hgt. = 4m
Wind Hgt. = 5m
Buoy Raw Winds
Buoy U_{10SC}
Calibrated Buoy U_{10SC}
1
0
−1
−2
−3
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
ASCAT Wind Speed (m s^{-1})

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:

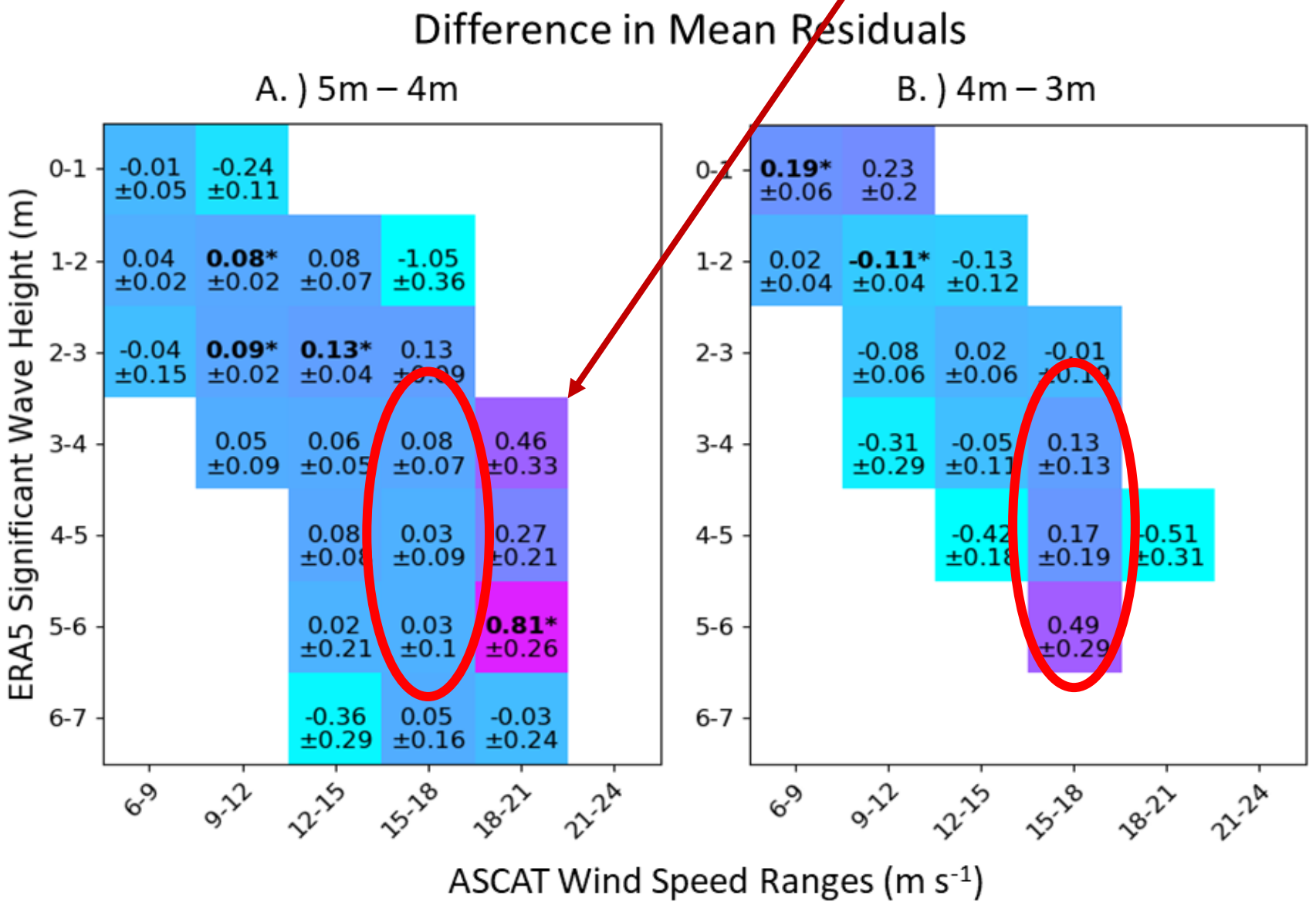
$$\beta_i \leq 1, 0.25 \leq \frac{H^2{}_{swell}}{H^2{}_{wind}} < 4.0$$

Swell:

$$\beta_i \leq 1, \frac{H^2{}_{swell}}{H^2{}_{wind}} \geq 4.0$$

Wind-Wave Conditions

(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?

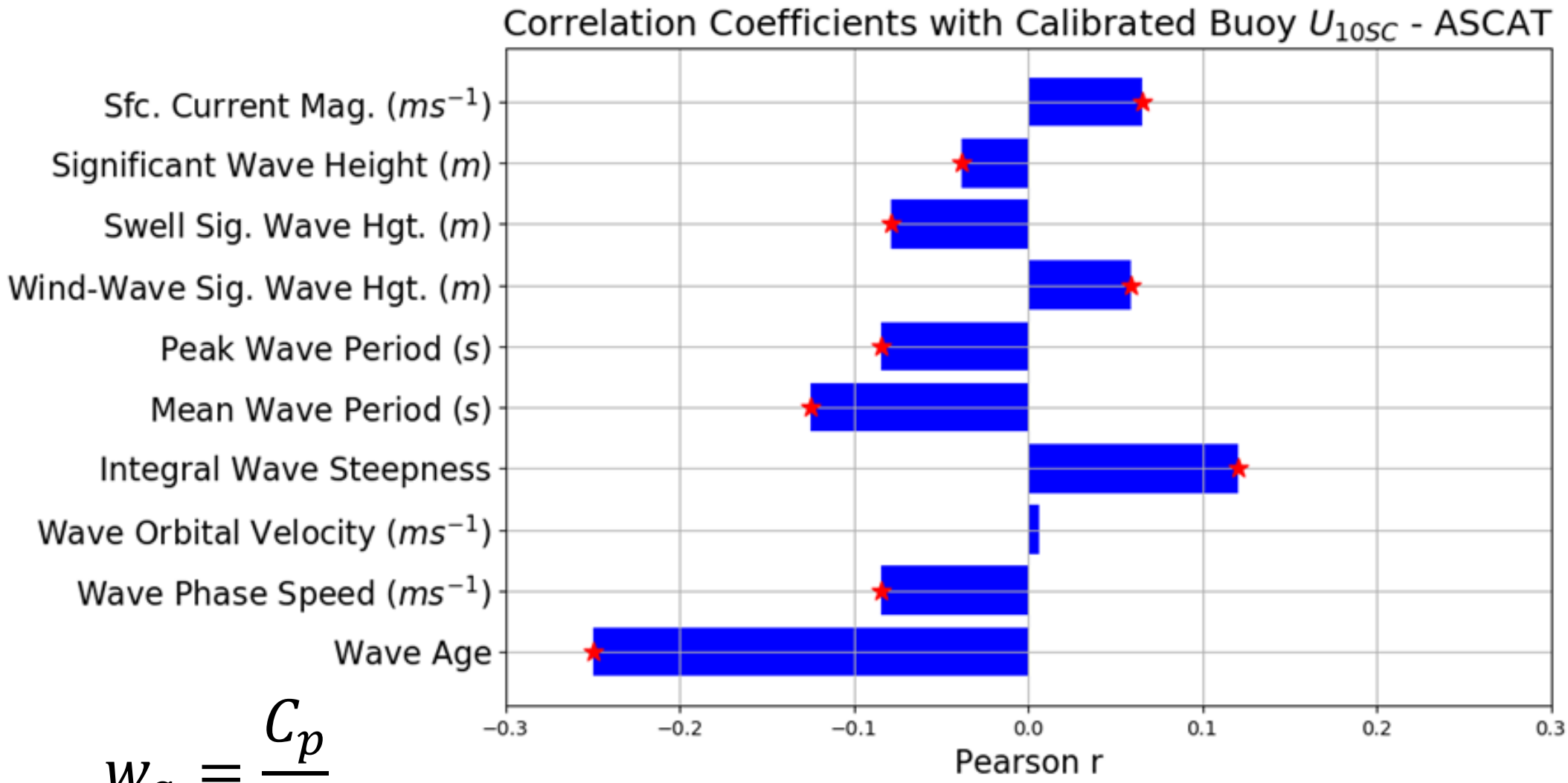
a. The buoy winds from 3, 4 and 5 m anemometer heights do follow a pattern where the wind speed from higher anemometer heights remain higher than lower anemometer heights for similar high wind speed and high wind-wave conditions.

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

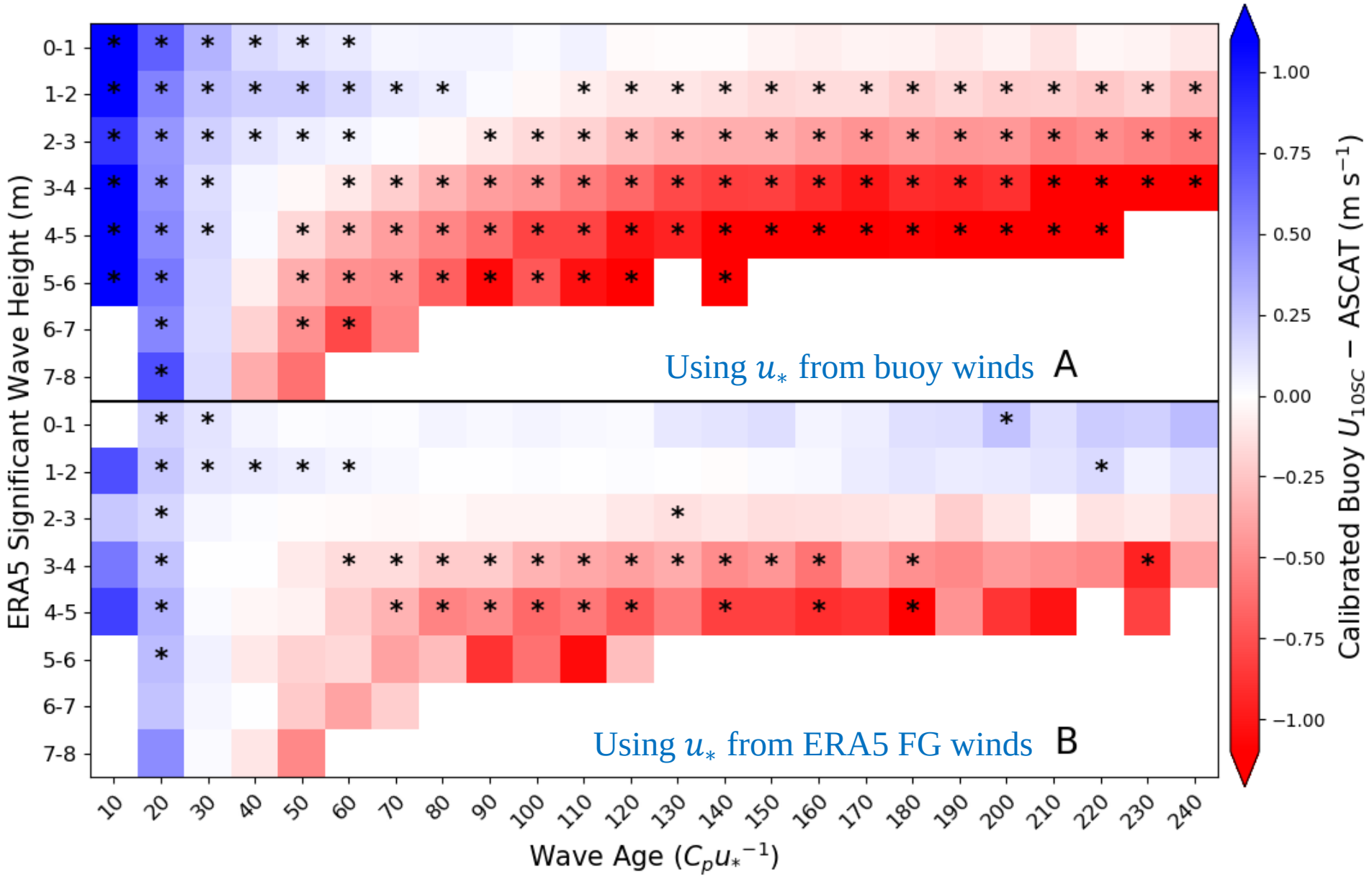
2. Under what wind and sea state conditions do buoy strongly winds disagree with alternative sources (in our case, ASCAT)?

Results



$$w_a = \frac{C_p}{u_*}$$

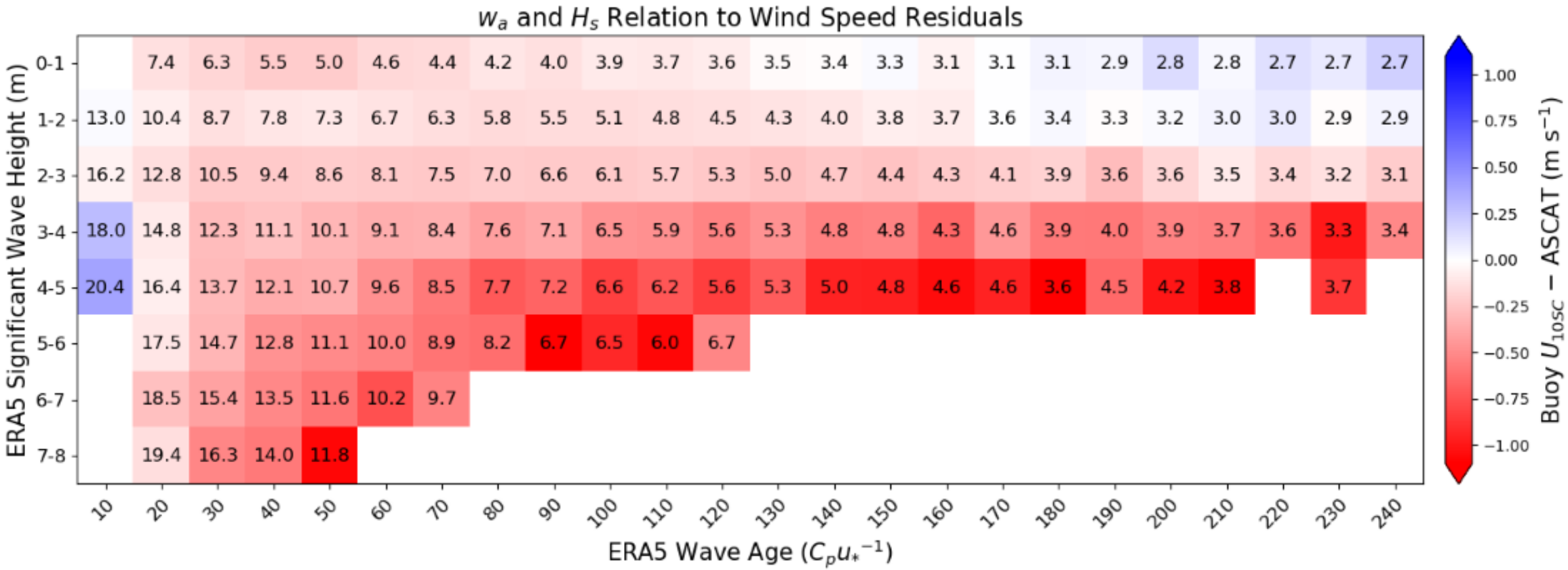
Results



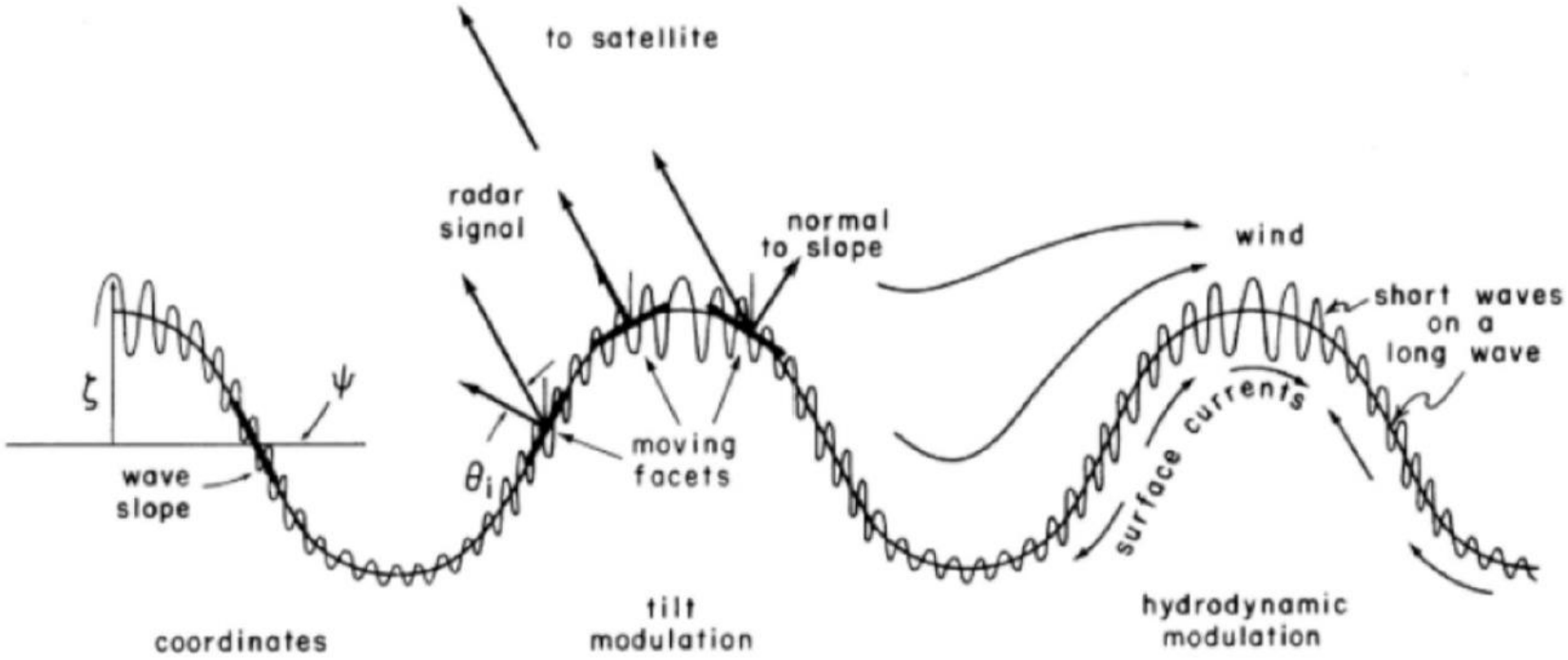
- ASCAT winds are consistently above buoy U_{10SC} in high H_s and W_a ranges

" * " 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*

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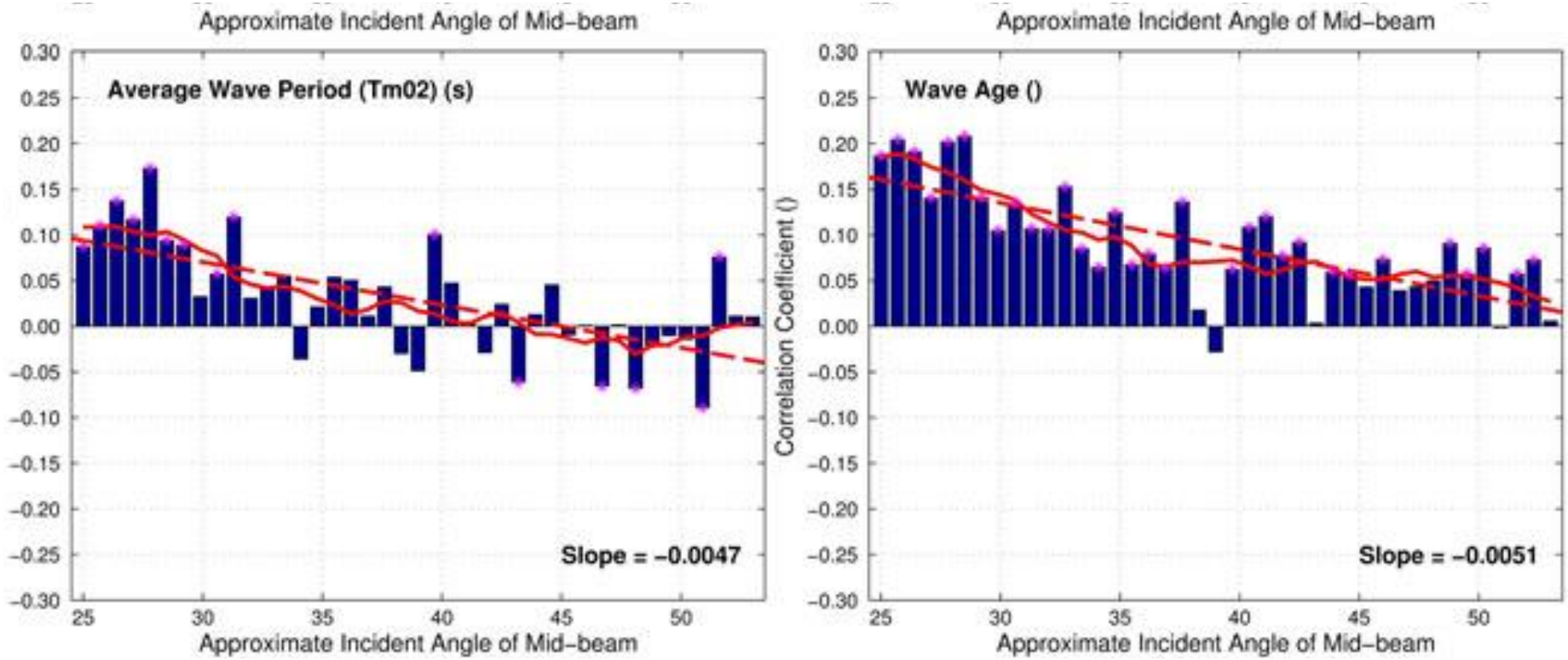

Correlation coefficients between U10 residuals ($U_{10ASCAT} - U_{10buoy}$) and *in situ* buoy observations as a function of incidence angle.

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:

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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/vandemark_edson_OVW2018_talk.pptx

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Stoffelen, A. Toward the True Near-Surface Wind Speed: Error Modeling and Calibration Using Triple Collocation. *J. Geophys. Res.* **1998**, *103*, 7755–7766, doi:10.1029/97JC03180.