Evaluating several key issues in satellite wind stress validation – OVWST 2018

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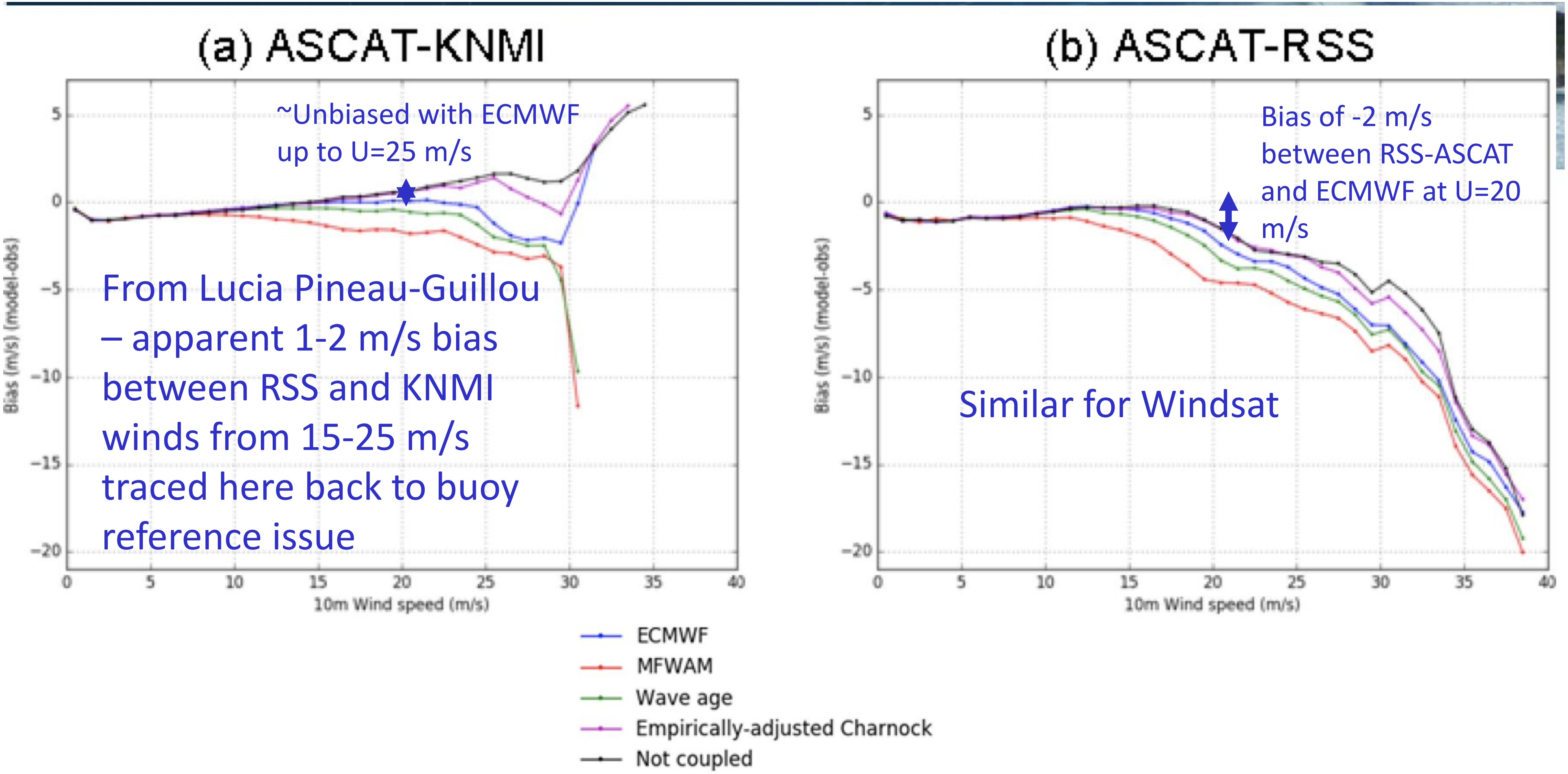
Overview: Issues of concern in high(er) wind validation

Four points being addressed with CDR objectives:

1. Tower vs. buoy winds – who to trust above U=15?
2. Drag coefficient choice/ambiguities – Edson this meeting
3. Possible flow distortion corrections on flux buoys
4. New/expanding *in situ* wind stress datasets

Issue: Are buoy winds biased low?



Issue: Are buoy winds biased low?

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Platform Motion; Vector vs. scalar averaging

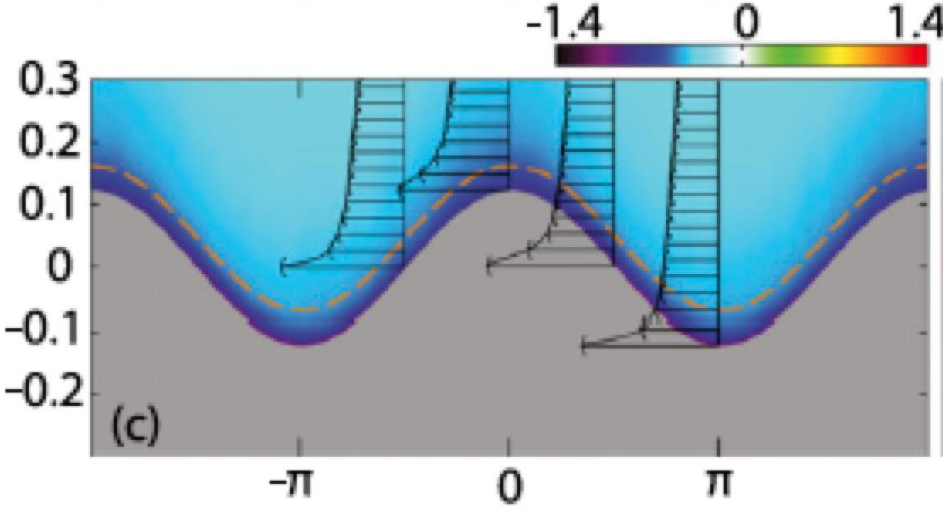
Thomas and Swail (2011) Buoy wind inhomogeneities..., Intl J. Climatology

Anemometer Types; Vane issues

Howden et al.(2008). Hurricane Katrina Winds Measured By a Buoy-Mounted Sonic Anemometer. Journal of Atmospheric and Oceanic Technology

Wave Sheltering/ wave boundary layer

Hara & Sullivan 2015, LES eval....



Flow distortion - platform specific

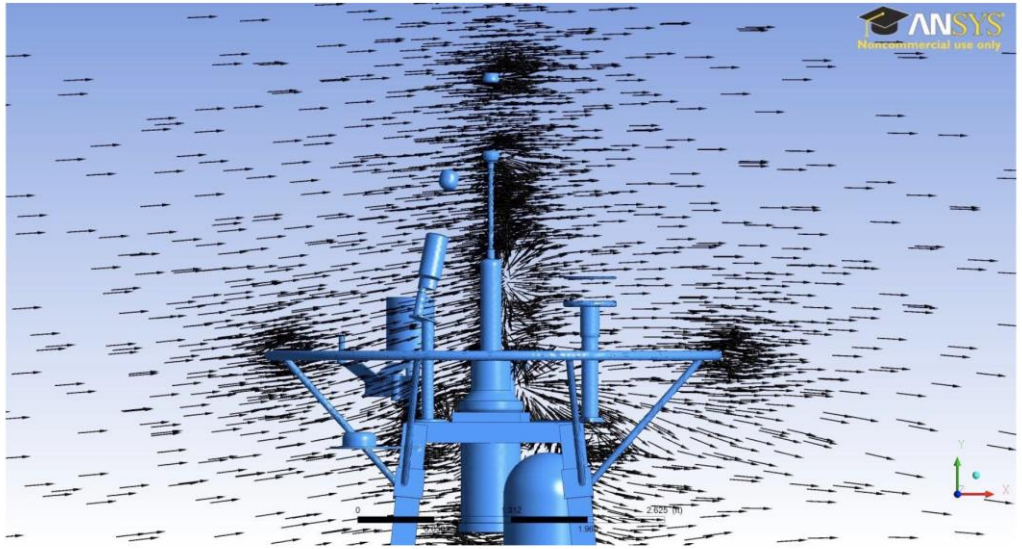


Figure U-1e UNH 0 deg. inflow angle run

Key citation used to support possible buoy wind biases below true value for U > 10-15 m/s;

Also Zeng and Brown (1998) Using UWPBL

ACCOUNTING FOR SURFACE-WAVE DISTORTION OF THE MARINE WIND-PROFILE IN LOW-LEVEL OCEAN STORMS WIND MEASUREMENTS

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Abstract

Marine wind measurement at three heights (3.0, 4.5, and 5.0 m) from both moored and drifting buoys during the Ocean Storms Experiment are described. These winds are compared with each other, with winds from ships, from subsurface ambient acoustic noise, and from the analyses of three numerical weather prediction centers. In the mean, wind directions generally differ by only a small constant offset of a few degrees. No wave influence on the wind direction is evident, because the differences are not systematic and with few exceptions, they are less than the expected error. After correcting for some apparent calibration and instrument bias, the Ocean Storms wind speeds display similar behavior when compared to the analyzed wind products. There is excellent agreement up to a transition wind speed between 7 and 10 m s(-1), above which all me measured winds tend to be relatively low. The transition speed is found to increase with anemometer height, so this behavior is interpreted as being due to the distortion of the wind profile by surface waves. The wave effects are shown to be profound. By increasing the stress by 40% or more in high winds, the corrections are shown to be essential for numerical models to simulate the oceanic response to storm events. The Ocean Storms corrections are used to construct functions describing wave influence on both the vertical wind shear and the mean wind speed profile. These functions can only be regarded as crude approximations because the Ocean Storms data are far from ideal for determining them. However, they can be used to assess potential influences of surface waves on any low-level wind measurement.

Keywords

KeyWords Plus: DISPLACEMENT HEIGHT; STRESS; MOORINGS; MODELS; LAYER; ARRAY

Typical citation-support for the high wind buoy wind error issue/disclaimer

(Peterson et al., 2017): "The wind speed, wind gust and wind direction were measured at 4 m height with a Gill WindSonic wind sensor (Fugro OCEANOR AS, 2007). **It has been shown that during rough seas, due to sheltering effects and elevation changes, wind measurement by buoys can be negatively biased** (e.g. **Large et al., 1995**; Zeng and Brown, 1998). Here, no attempt is made to compensate for a potential bias in the data set; that is left to the user. "

A few Large et al. 1995 study details:

- Key reference platform is a special Storm Central buoy – vector-averaged, 8.5 min per hour)
- ECMWF assumed to be the ground truth because all buoys showing low biases
- Timeframe is Aug. 1987-June 1988
- Model comparisons with in situ are with 6 hour averaging of buoy winds
- Their conclusion: They assume that the WBL extends to 7 m (their z_1), this height is independent of SWH, and then assert that extreme wind field distortion leads to strong buoy wind underestimates as winds go above U=7-8 m/s

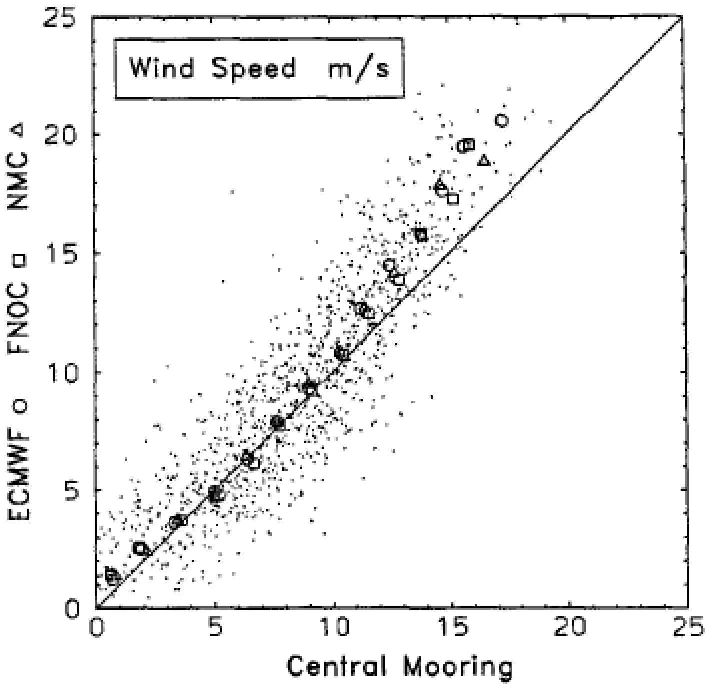

FIG. 4. Scatterplot of interpolated ECMWF wind speeds vs central mooring (S_C) speeds. Bin averages of these data are shown as open circles. Also shown are bin averages from NMC vs S_C (triangles) and FNOC vs S_C (squares) comparisons.

$$
\begin{aligned}
U_{10} &= U_M \quad U_M \leqslant U^T \\
&= AU_M + B \quad U_M > U^T, \qquad (11)
\end{aligned}
$$

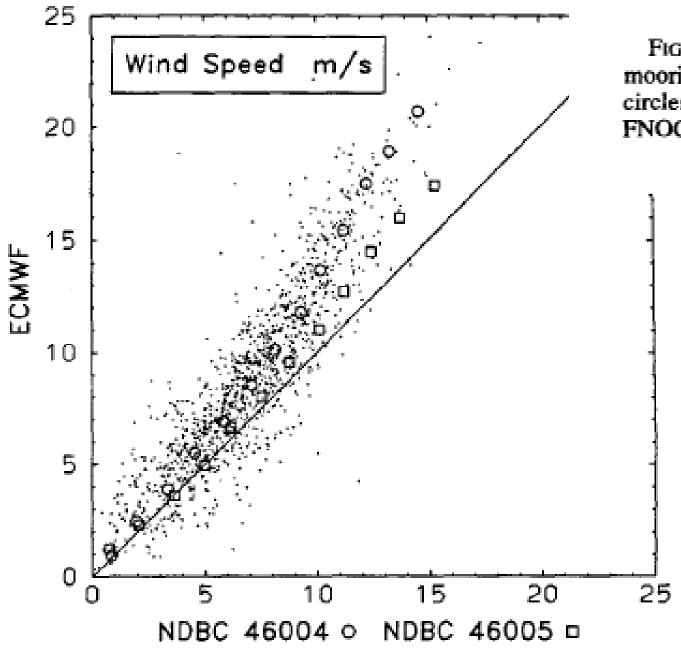

FIG. 6. Scatterplot of interpolated ECMWF wind speeds vs NDBC mooring N_4. Bin averages of these data are shown as open circles.

Buoys were biased low by 8-10% starting at U=10 m/s

FF 2018 - We still lack of independent, trusted and calibrated data > 15 m/s

Approach: CMAN tower vs. discus buoy (32m vs. 3 m)

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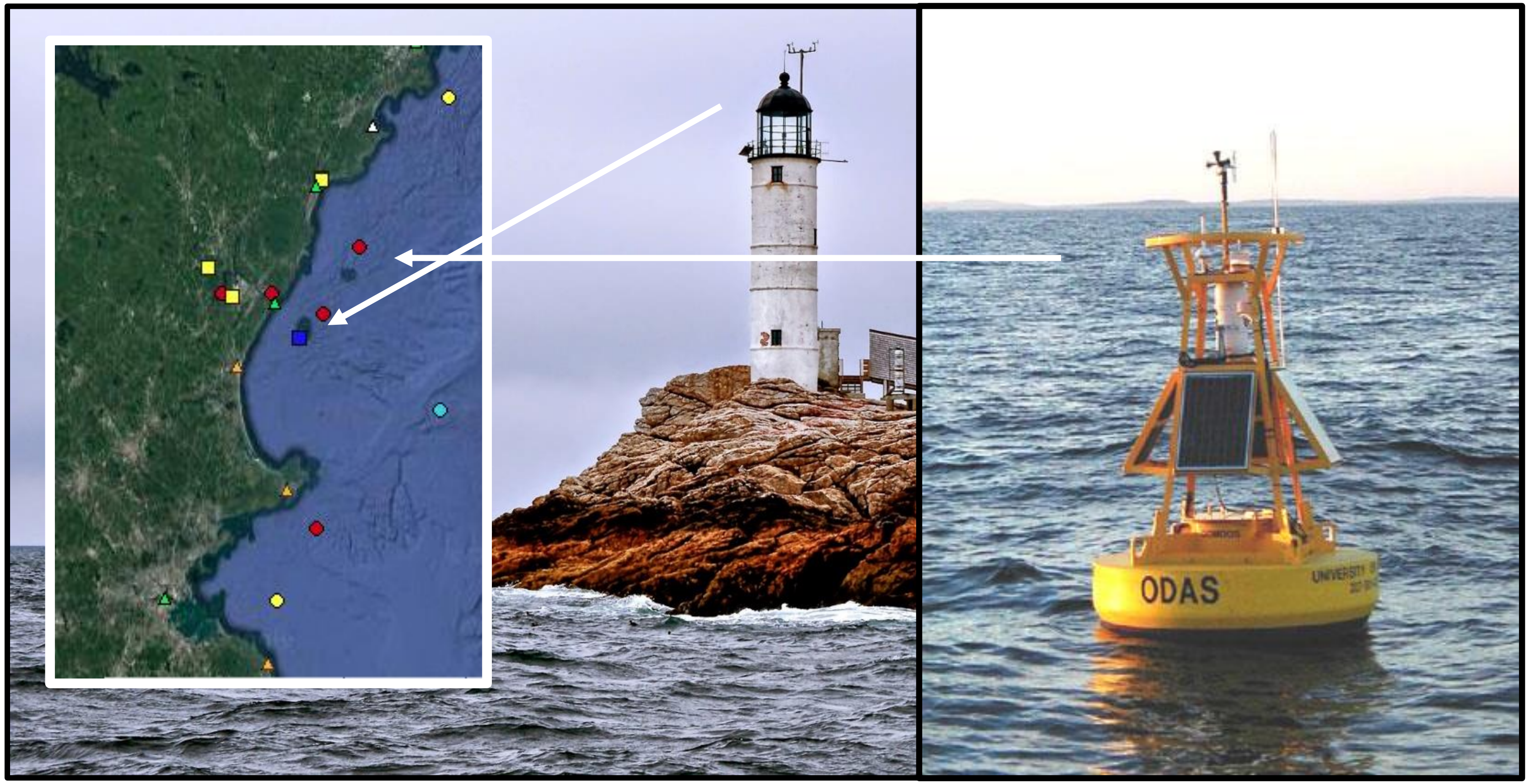

NERACOOS Buoy B
3 m buoy winds
24 km from tower

NDBC IOSN3
CMAN station
32.3 m tower
winds

- 2001-2017
- 8.5 min avg. @ 10 min
- 24 km separation
- Scalar-averaged (atten. motion)
- Vanes early on, then sonics
- Coare3.5 to adjust to 10m N

Results: CMAN tower wind distribution

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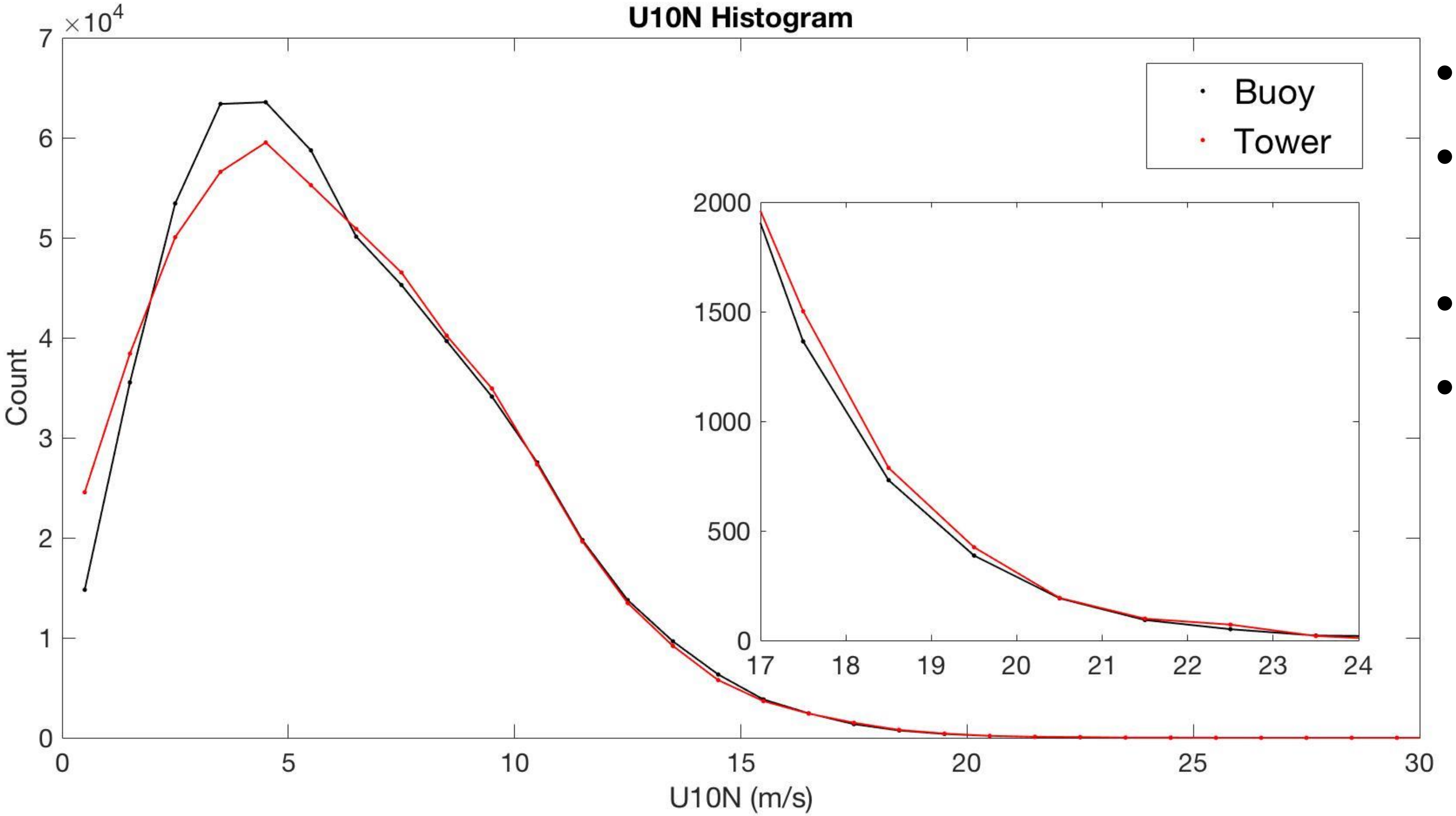

- N=544k
- N = 3100 for U > 17 m/s
- 10k for U > 15
- Gilhousen (1987) had N=1 for U > 17 m/s in one of few tower/buoy evals.

Results: 10 m neutral winds compared

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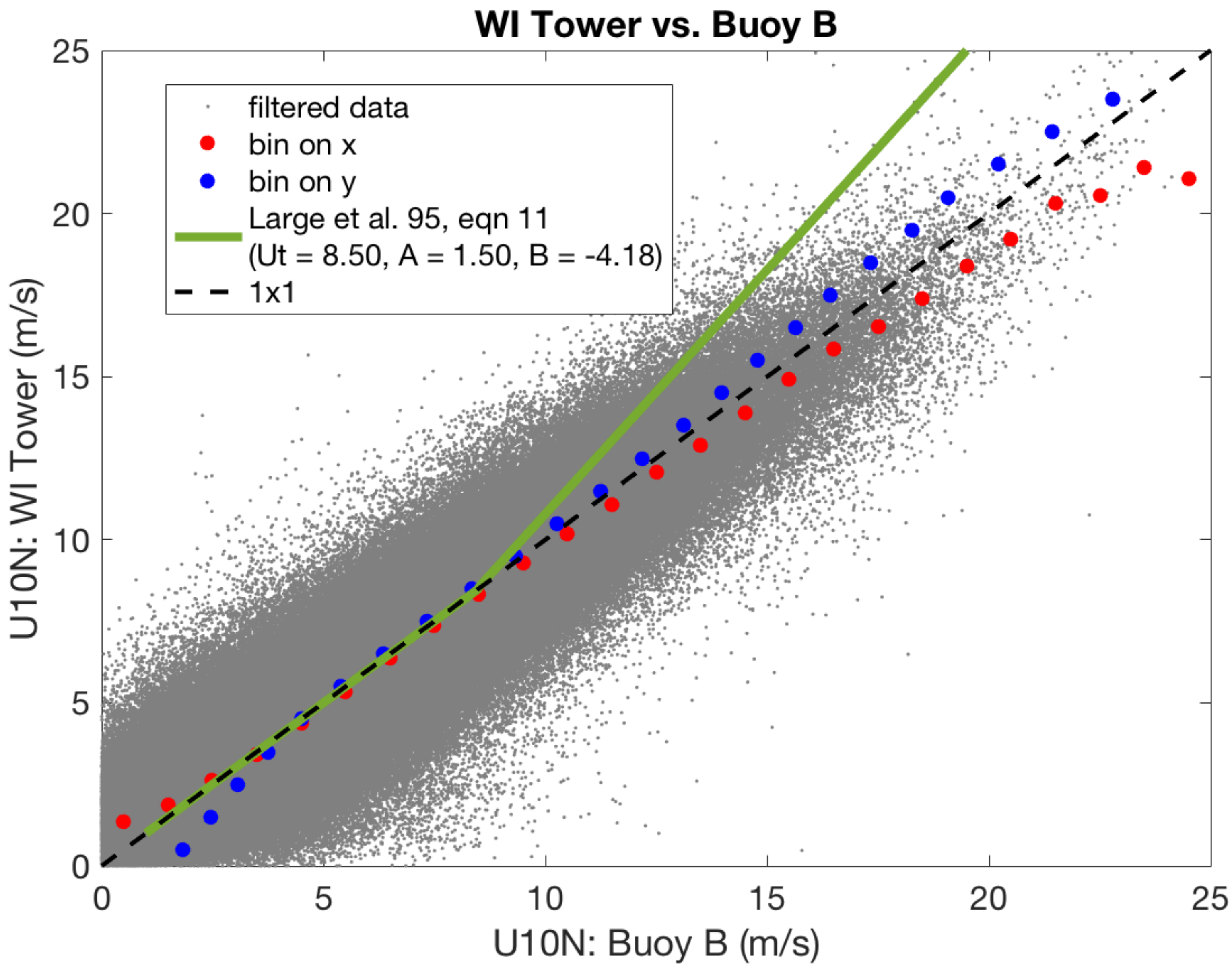

Orthogonal (TLS) fits

All winds

y = 0.97x +0.27 ; R = 0.92

Winds > 10

y = 0.99x + 0.14 ; R = 0.81

Filtering applied on dU/dt per Gilhousen, 1987

Results: 10 m neutral winds compared vs. SWH

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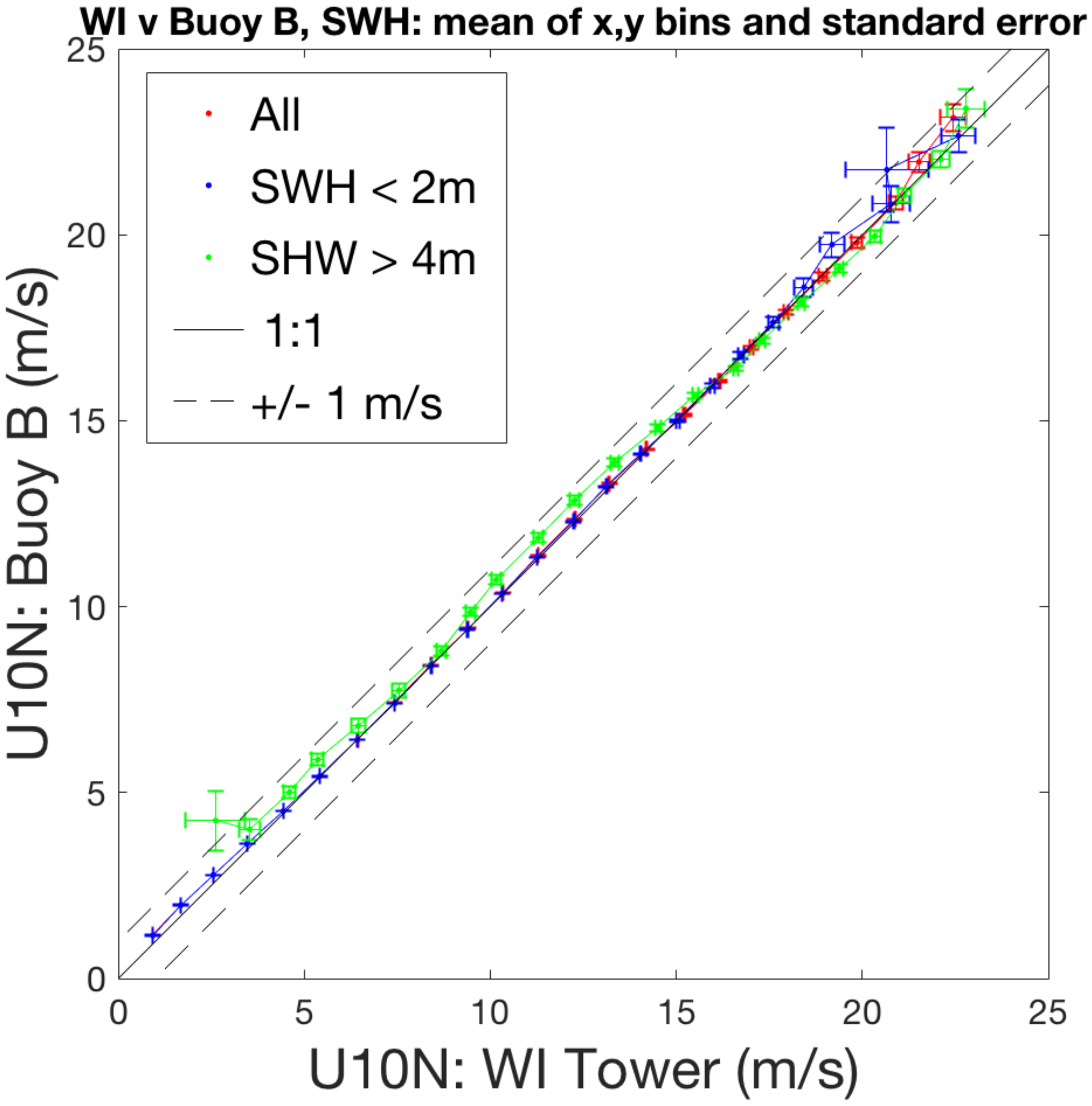

- No significant negative buoy bias seen vs. SWH increase
- Small (0.2-0.4 m/s) positive bias for high vs. low seas at U=7-15 m/s
- Rare to have large swell in Gulf of Maine, thus avg. steepness is higher than Pacific for SWH > 4 m – stronger possible sheltering

Conclusions

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- Results indicate U10N agreement to better than 0.3 m/s between the pitching buoy winds at 3m and fixed lighthouse 32m up to 22-23 m/s;
- No negative buoy wind speed bias observed due to wave sheltering from 8-22 m/s (in fact, slightly positive)
- Filtering data to "steady state" winds was critical for U> 12 m/s due to the 24 km separation distance
- Possible small negative bias for tower/lighthouse due to flow distortion under certain directions at highest winds (not shown here)
- **One Implication:** NDBC buoys (NOMAD, Discus) have cleaner platforms and 4-5 m anemometer heights, so expect equivalent or better results (if scalar averaging), **and Caution:** Historical datasets have mixture of scalar vs. vector avg., so care required
- Possibly a few other sites in NDBC network for similar evaluation; plus 1 more GoM buoy

Questions?

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Extra: vs. wind directions

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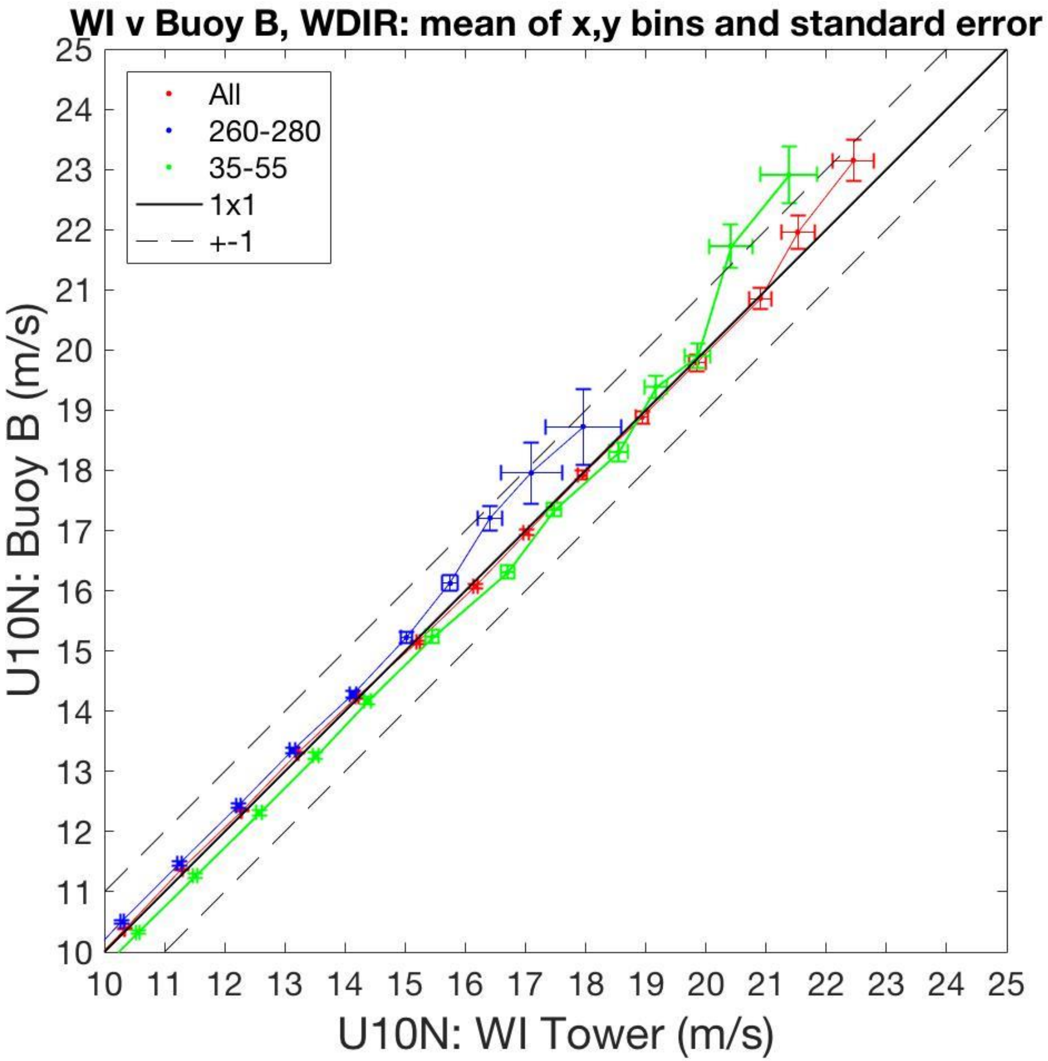

- Wind directions of storms/gales often from W or NE
- Both cases have buoy > tower
- Possible cause flow blocking/distortion at light house

Supporting information: Buoy wind biases

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- Issues include vector vs. scalar avg (Gilhousen, 1987)
- Timing inside of 30 min – often quite unclear – it matters more for high wind (can demonstrate)
- Spatial differences – again it matters much more for high winds
- Flow distortion vs. direction – it can matter for fixed or unveined buoy platforms.
- Stoffelan's 1998 point that high kurtosis PDFs at high winds may lead to bin avg biases (fig. 3.3 in CHEFS document)

- Large et al 1995 is one touchstone (85 citations)
- Gilhousen one of few tower vs. buoy – 1 data pt above 18 m/s
- Recent Ireland Sea buoy/tower study
- Lucia's P-G study
- CHEFS document (It cites latest 2017 CMOD 7 and CMOD_stress_Kloe_2017 papers)
- CHEFS says U >25 m/s buoys for sure have issues..and maybe > 15
- Pond, 1968; Buoy motion predicted effects
- See also Zeng and Brown (1998) for succinct typical issues

Supporting information: Buoy winds biases

University of New Hampshire

- Issues include vector vs. scalar avg (Gilhousen 1987)
- Lack of independent and calibrated data > 15 m/s
- Timing inside of 30 min – often quite unclear – it matters more for high wind (demo)
- Spatial differences – again it matters more for high winds; filter to steady conditions
- Flow distortion change vs. direction – it can matter for fixed towers or unveined buoy platforms.
- Sonic vs. prop. vane anemometers (Thomas 2011) - thorough
- Sea state – WBL change or motion-induced errors (former should change with sensor height) (Skey?)
- Recent Irish Sea tower study –
- Gustiness corrections needed?
- CHEFS
- Bigorre?