Intercalibration of Visual Winds from VOS and Scatteromter Winds

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Motivation

The International Comprehensive Ocean-Atmosphere Data Set (ICOADS): The most complete and extensive archive available of historical in situ marine meteorological observations

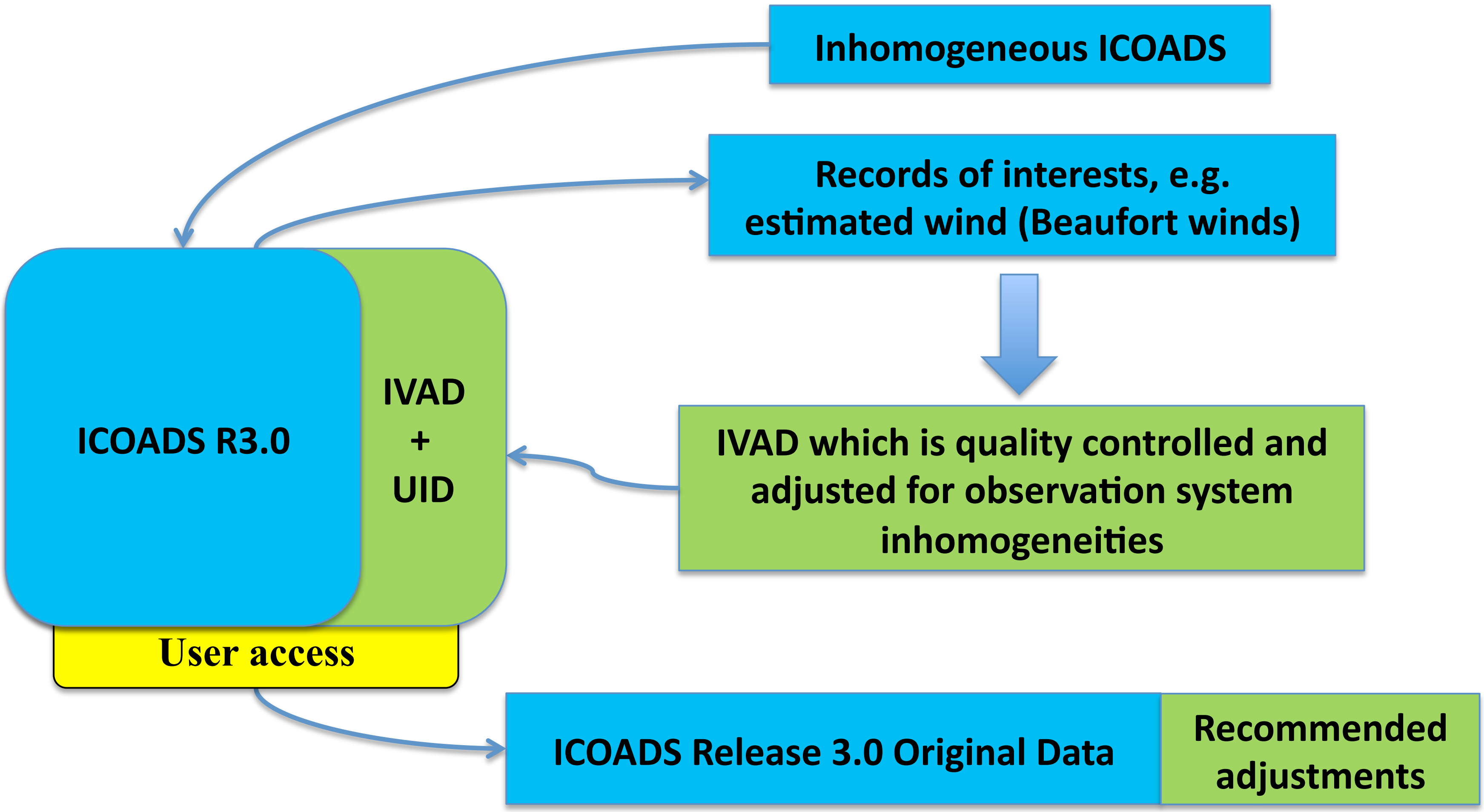
- Changing measurement technology (e.g. anemometer);
- Multiple archive sources (e.g. Ship logs, ship weather reporting forms, et.);
- Significant historical events (e.g. Digitized and quality-checked data);
- Other factors (Observer qualification)

ICOADS is inhomogeneous in data interpretation

- To enhance homogeneity and make ICOADS available to wider community

ICOADS value-added database (IVAD)

IVAD project (Big picture)



UID: Unique ID, map back into the full records of ICOADS.

Initial Estimated Wind IVAD

- During IVAD prototyping, FSU team applied Lindau (1995) correction to Beaufort estimated winds in ICOADS R2.5

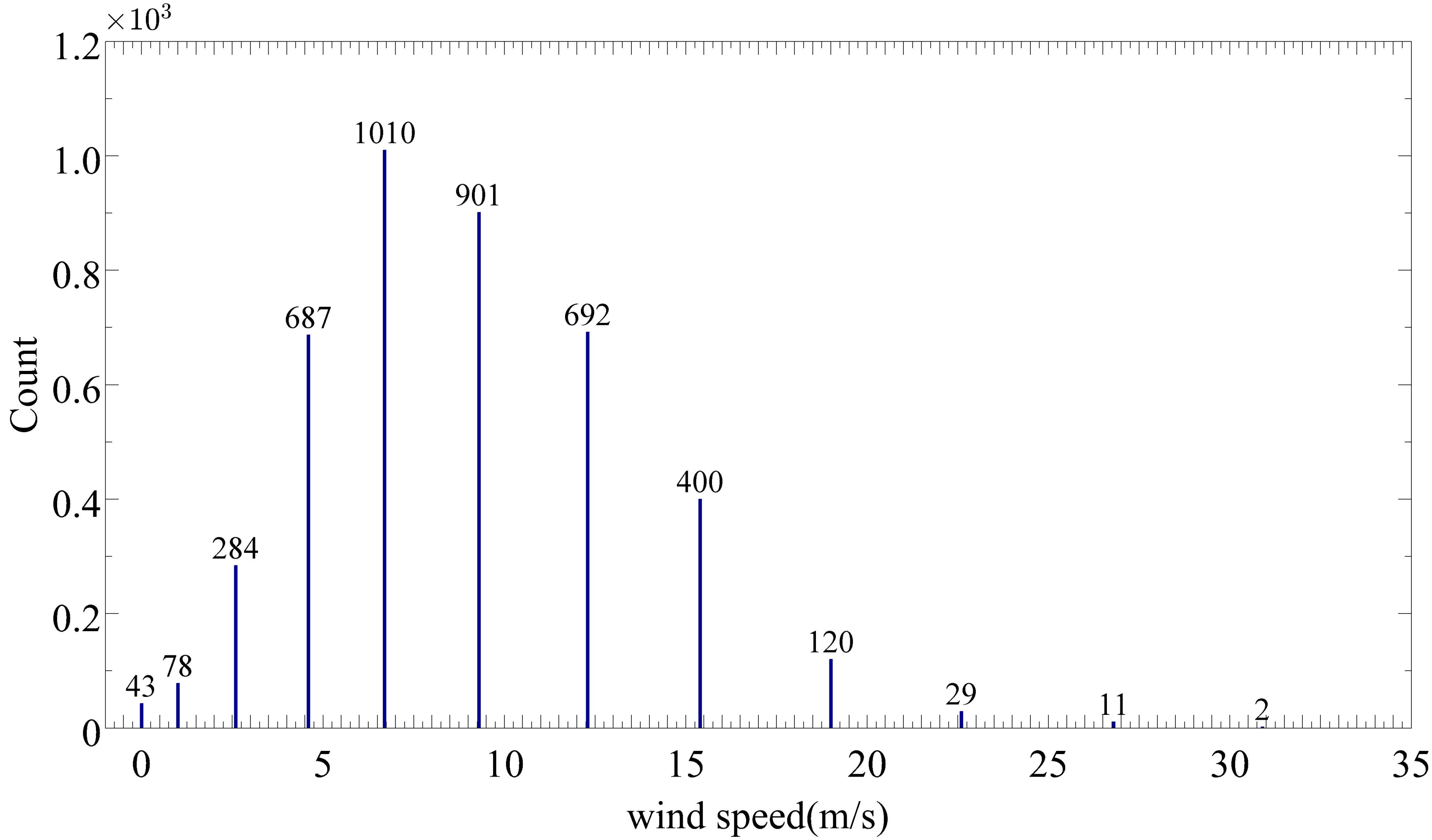
- Created for 1970 to 2007 to overlap with the marine air temperature IVAD developed by the National Oceanography Center (Berry et al., 2004)

- Problem: identifying estimated wind data in ICOADS exactly derived from Beaufort scale resulted in a limited set of wind records to apply the Lindau correction.

Table 1. Beaufort wind scale

Beaufort Number	Wind Speed (mph)	Description
0	< 1	Flat
1	1-3	Ripples without crests
2	4-7	Small wavelets.
3	8-12	Large wavelets
4	13-18	Small waves with breaking crests
5	19-24	Moderate waves of some length
6	25-31	Long waves begin to form
7	32-38	Sea heaps up
8	39-46	Moderately high waves with breaking crests
9	47-54	High waves whose crests sometimes roll over
10	55-63	Very high waves with overhanging crests
11	64-72	Exceptionally high waves
12	> 72	Huge waves.

Expected '13 value' Beaufort Distribution

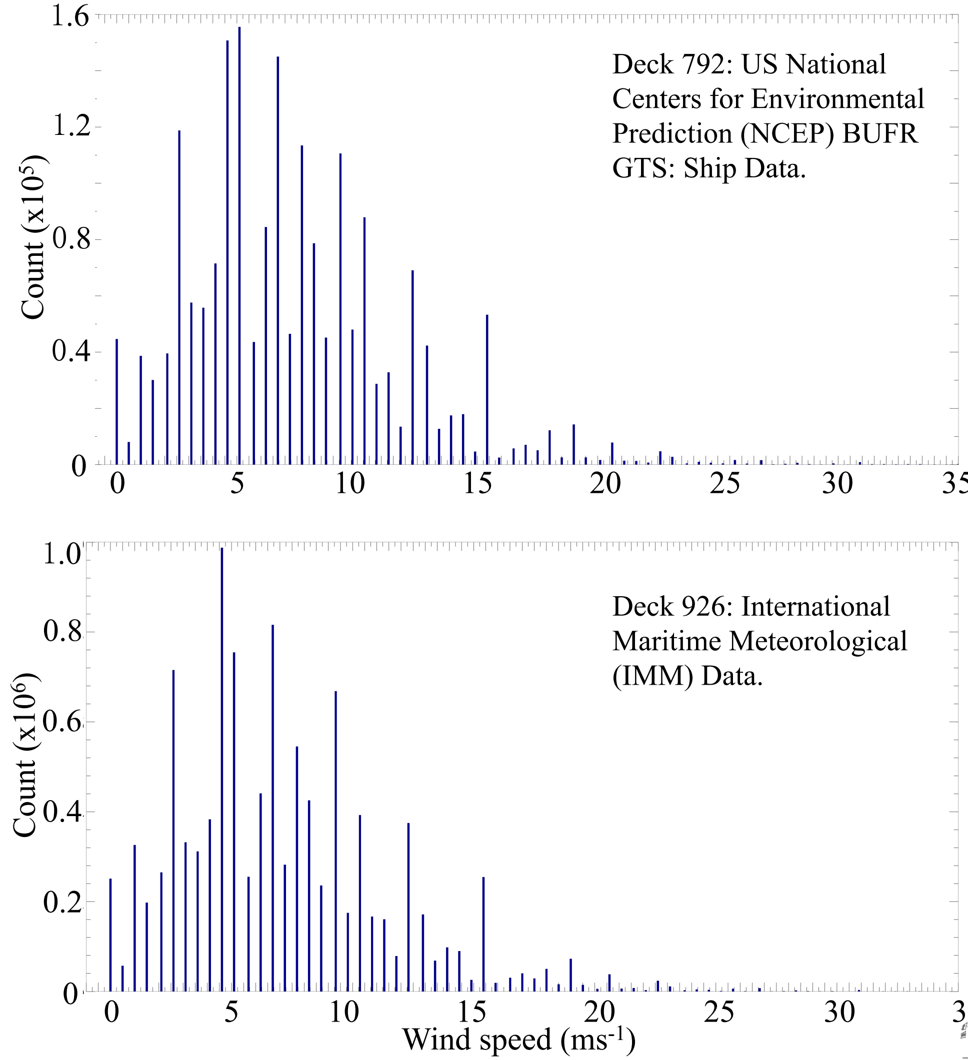


The histogram of estimated ship wind speed for WI=5 with deck 761(Japanese Whaling Ship Data [CDMP/MIT digitization, 1946-1984]) for the period 1970-2007.

Other Estimated Winds in ICOADS

- For wind indicators in ICOADS not directly noted as Beaufort, but still listed as estimated, wind distributions do not show expected 13 Beaufort wind bins.

- This lead us to rethink applying the Lindau (1995) correction in favor of developing a new correction based on collocated satellite to ICOADS estimated wind speeds.



Data for Collocation

- Satellite scatterometer winds
  - Version 3 JPL QuickSCAT scatterometer wind speeds: Nov. 1999-Oct. 2009
  - Excluded all rain flagged data
- Visually estimated winds
  - R.2.5 ICOADS: Nov. 1999-Oct. 2009
  - Used only winds from ships removing values with WNC (wind) flag = 'Erroneous'

- ***Assumption***: visually-estimated ship winds are similar to satellite scatterometer winds
  - Satellite scatterometer winds calibrated to equivalent neutral winds (Liu and Tang, 1996; Verschell et al., 1999; Mears et al., 2001).
  - Visual winds: Stress-like rather than wind-like (similar to satellite scatterometer equivalent neutral wind).
  - ***Assume the visually estimated winds as equivalent neutral winds***
    - i.e., winds that can accurately be converted to a stress using a neutral drag coefficient rather than a stability dependent drag coefficient

Collocation

- Thresholds to define satellite to ship collocation are:

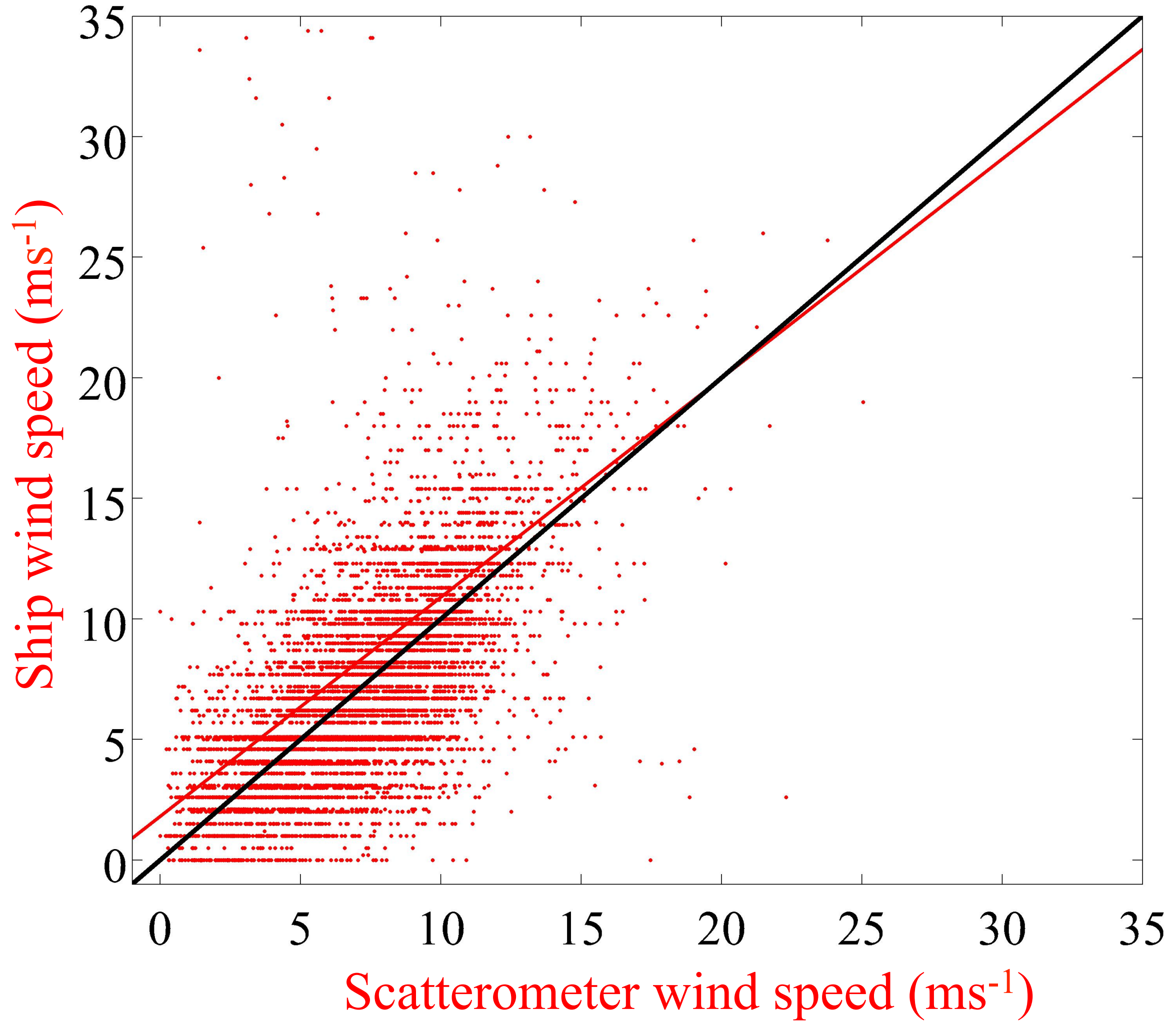
  1) Time: 30min (1800s)

  2) Distance: 25km

- Steps to identify collocated values:

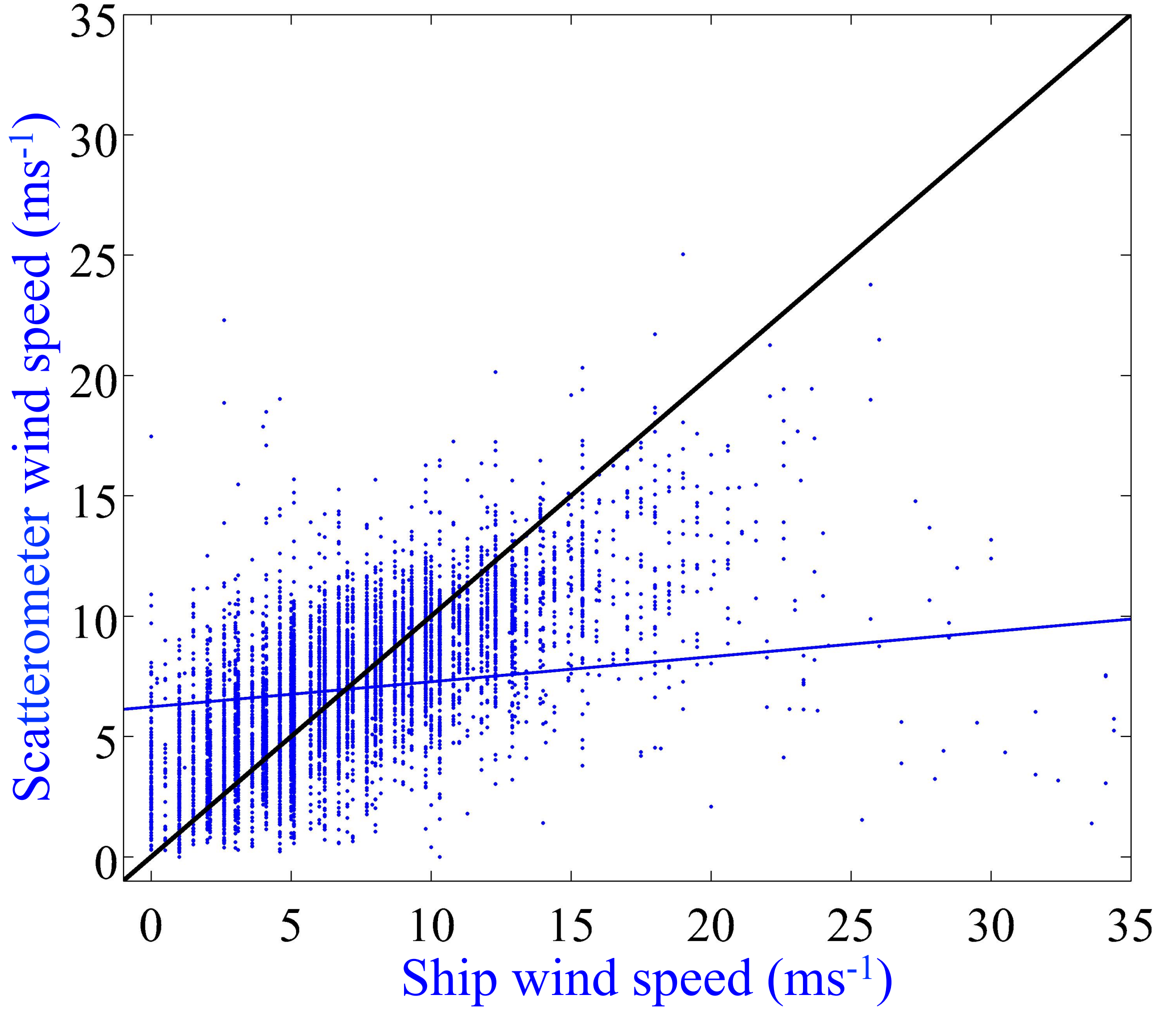
  1) Find all data matches within 30 minutes of each other
  2) Of the data matches from step 1, find which ones match in space within 25km
  3) Of the data matches from step 2, find the closest match in space

Error assessment



Red line is linear fit for collocated data. Black line is the reference line

Error assessment



Blue scatter plot: ship winds and scatterometer winds are plotted on the horizontal axis and vertical axis, respectively. Blue line is linear fit for blue scatter plot. Black line is the reference line

Error assessment

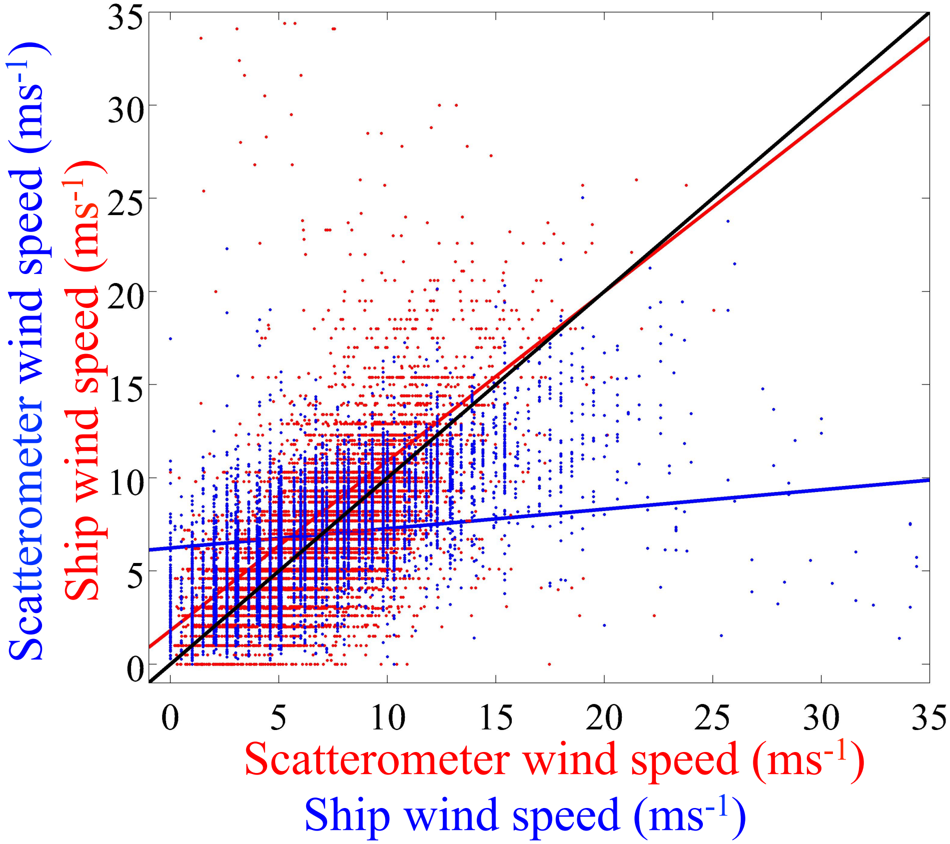


Figure 11. Plot the two figures of figure 8 into one plot

- Collocation matches: 6782 pairs
- Observed wind speed:

$$w_{obs} = w_t + \varepsilon$$

- w_{obs} : Observed wind speed. w_t: True wind speed. ε : Noise
  - Scatterometer winds:

$$Var(w_{scat}) = Var(w_t) + Var(\varepsilon_{scat})$$

  - Ship winds:

$$Var(w_{ship}) = Var(w_t) + Var(\varepsilon_{ship})$$

$$slope_{scat} = \frac{Cov[w_{scat}, w_{ship}]}{Var(w_{scat})} > slope_{ship} = \frac{Cov[w_{ship}, w_{scat}]}{Var(w_{ship})}$$

$$\Downarrow$$

$$Var(\varepsilon_{ship}) > Var(\varepsilon_{scat})$$

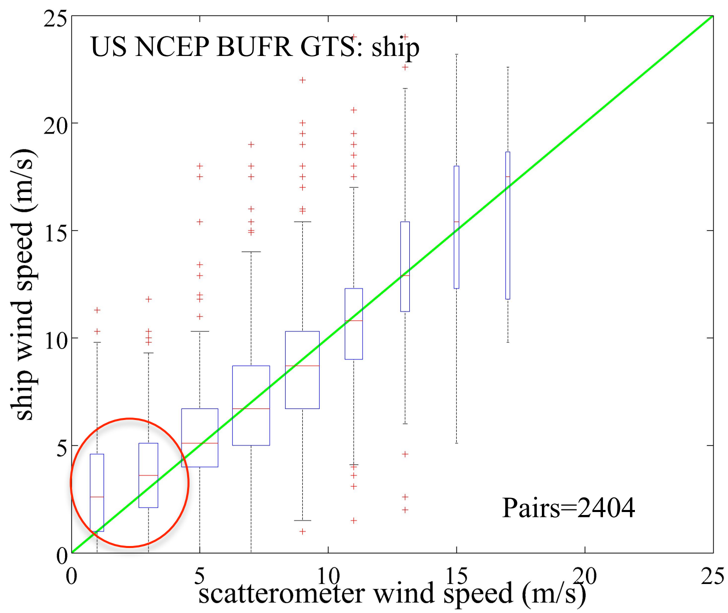
- Satellite scatterometer wind speed data is much more accurate!

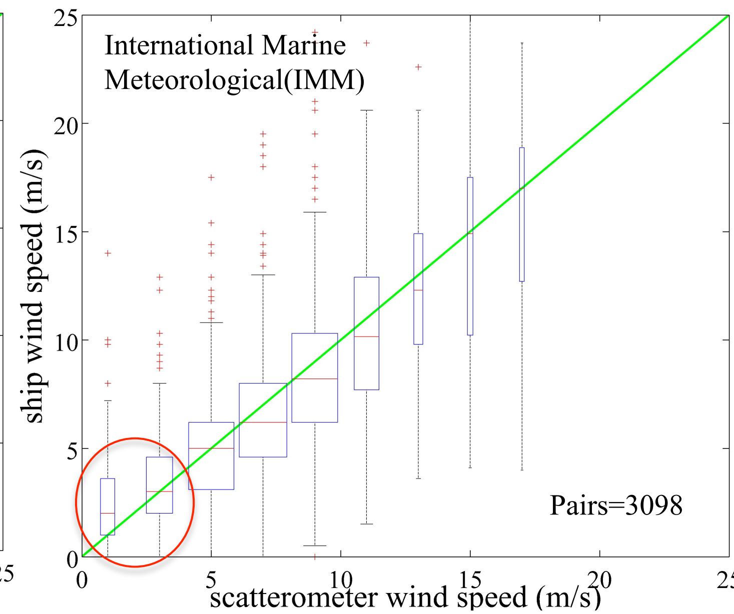
- ***Asymmetry implies data sets have different amounts of noise***
- ***Noise alters the best fit slope – unless equal for both data sets***
  - Scatterometer uncertainty: ~ 0.9 m/s; Ship uncert. ~3 m/s

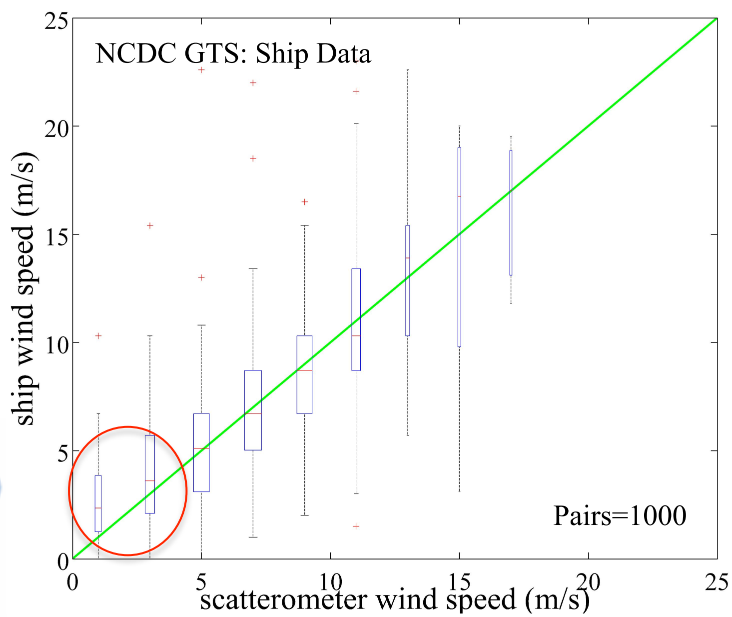
IVAD ICOADS Value Added Database

ICOADS

Binning collocated data by scatterometer wind speed







- For three different decks in ICOADS
  - Box medians follow one-to-one line for mid-range speeds
  - Notable differences at low wind speeds
    - Believed to be statistical artifact.

Determine whether statistical artifact exists

- Freilich (1997): Comparison between scatterometer winds (plotted on y) and buoy winds (plotted on x)
- Random vector component error are often manifested as systematic calibration error in speed, particularly for low wind speeds.
- Apparent insensitivity of the scatterometer data to buoy data for these conditional means (low wind speeds)
    - in other words, such comparisons show an overestimation of scatterometer data relative to buoy data.
    - Freilich and Dunbar (1999) and Freilich (1997): numerical simulation by treating buoy data as error-free data and add noise to match scatterometer data.
    - This appearance of a bias is purely artificial.
- This technique allows us to calculate the artificial effect of the random component error on biases at the low vector wind speed.

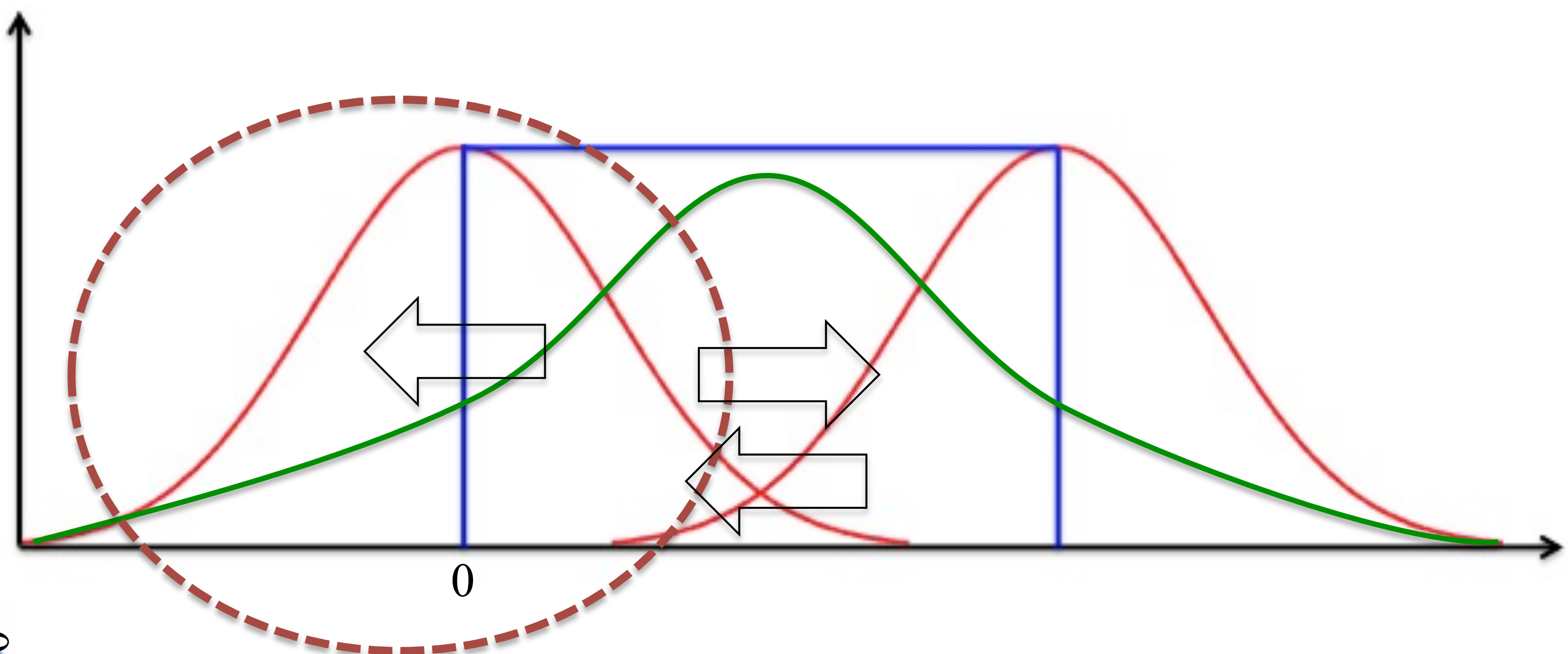
Determine whether statistical artifact exists

- Freilich and Dunbar (1999) and Freilich (1997):

Noisy vector wind speed = Error-free observation + Random noise added to each vector component.

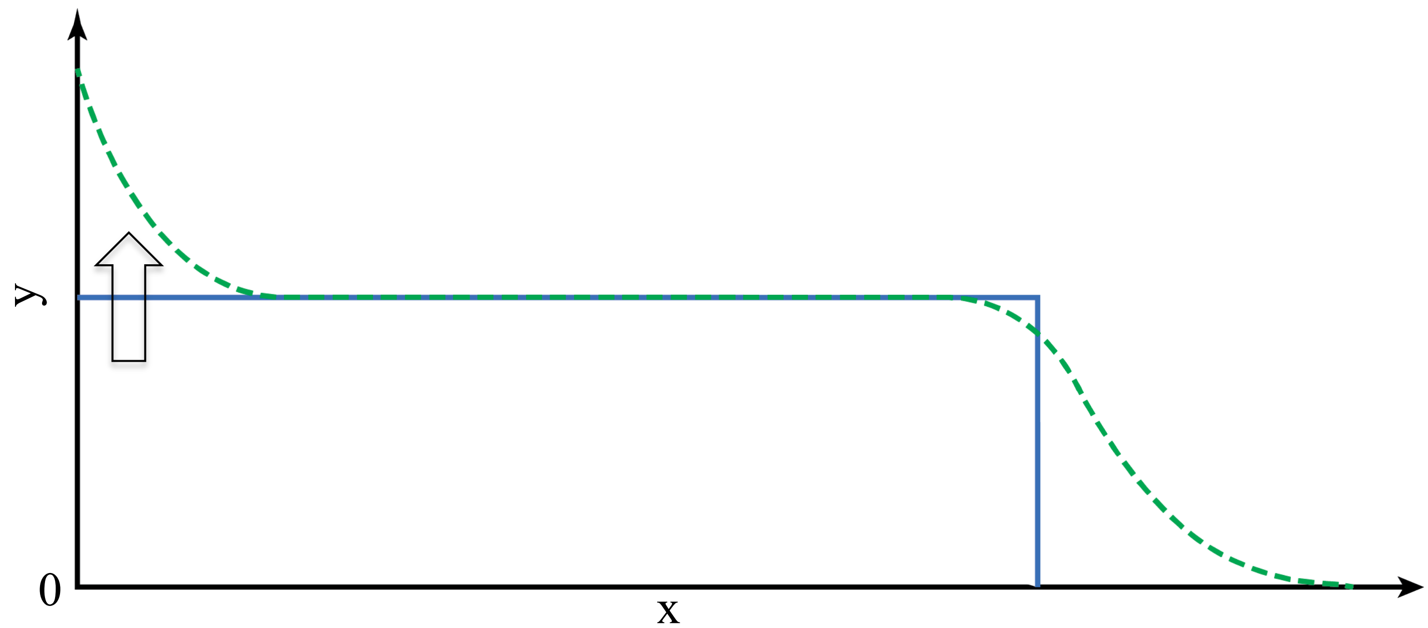
$$S_{ni} = [(S_i \sin\theta_i + \delta u_i)^2 + (S_i \cos\theta_i + \delta v_i)^2]^{1/2}$$

- Where δu and δv are Gaussian distributed random noise and θ is uniformly distributed wind direction. S_{ni} is i^{th} the noisy wind speed. S_i is the i^{th} noise-free wind speed.



Random error changes the data distribution

Determine whether statistical artifact exists

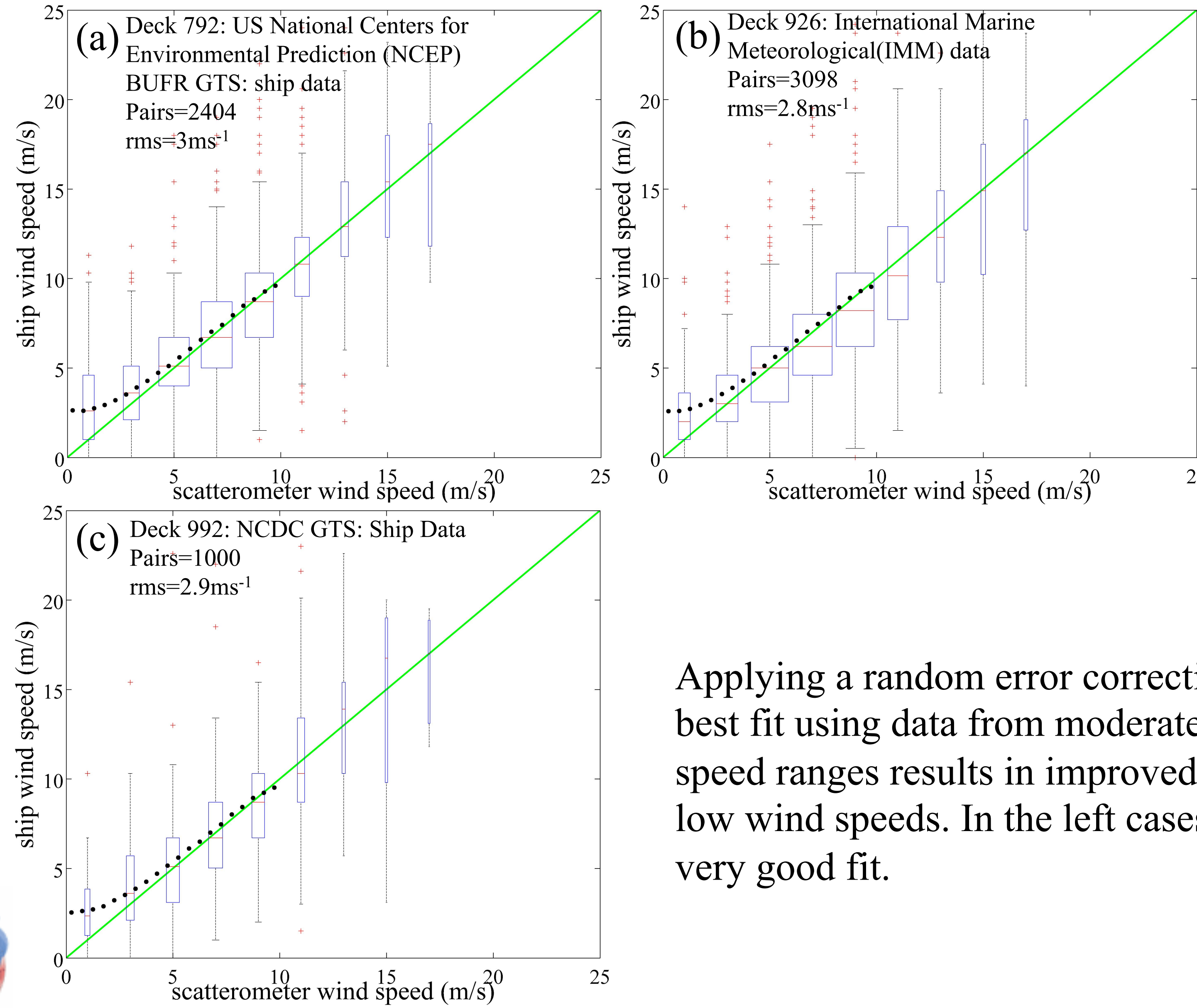


Blue line represents the data distribution before adding noise.
Green line represent the data distribution after adding the noise.

Wind speed distribution does not allow negative values

Negative values → Positive values → Artificial bias

Artifact error test at low wind speed



Applying a random error correction to best fit using data from moderate wind speed ranges results in improved fit at low wind speeds. In the left cases, a very good fit.

A new bias correction: LMS

- The correction for real biases can be addressed by the difference between satellite winds and ship winds with artifact biases removed.

$$bias = \left(w_{ship} - error_{artifact}\right) - w_{scat}$$

- w_{ship} denotes the median of ship winds in each bin of satellite winds (larger effect of outlier on mean rather than median); $error_{artifact}$ denotes the artifact difference, w_{scat} denotes the mean for each bin of satellite winds.

- LMS (Li, Mark, and Shawn) correction: weighted averaged by the number of observations with two major decks (792 and 926)

Significance test (t-test)

Wind speed range (ms^{-1})	P-value		Wind speed range (ms^{-1})	P-value	
	Deck 792	Deck 992		Deck 792	Deck 992
0.0-0.5	0.210	0.049	10.0-10.5	0.595	0.026
0.5-1.0	0.993	0.896	10.5-11.0	0.112	0.136
1.0-1.5	0.843	0.430	11.0-11.5	0.032	0.646
1.5-2.0	0.268	0.070	11.5-12.0	0.451	0.667
2.0-2.5	0.042	0.622	12.0-12.5	0.893	0.884
2.5-3.0	<0.001	<0.001	12.5-13.0	0.764	0.275
3.0-3.5	0.923	0.235	13.0-13.5	0.230	0.100
3.5-4.0	0.321	<0.001	13.5-14.0	0.451	0.919
4.0-4.5	0.592	0.674	14.0-14.5	0.583	0.702
4.5-5.0	0.356	0.002	14.5-15.0	0.759	0.058
5.0-5.5	0.019	0.007	15.0-15.5	0.389	0.059
5.5-6.0	0.661	<0.001	15.5-16.0	0.197	0.152
6.0-6.5	0.614	<0.001	16.0-16.5	0.235	0.203
6.5-7.0	0.110	0.069	16.5-17.0	0.511	0.024
7.0-7.5	0.002	0.028	17.0-17.5	0.935	N/A
7.5-8.0	0.261	0.002	17.5-18.0	N/A	0.953
8.0-8.5	0.160	0.039	18.0-18.5	0.640	0.895
8.5-9.0	0.005	0.594	18.5-19.0	0.261	N/A
9.0-9.5	0.012	<0.001			
9.5-10.0	0.527	0.021			

Table 6. Significance test for each bin of $0.5ms^{-1}$ of scatterometer wind speed

Two-tailed t-statistic, which follows a t-distribution
$\alpha=0.01$

- $<$ 0.01: Apply the bias correction
- $\geq$0.01: No bias adjustment needed.

Question: *Is the difference between the bin of artificial error-free ship winds and satellite winds large enough to confidently be identified as a bias?*

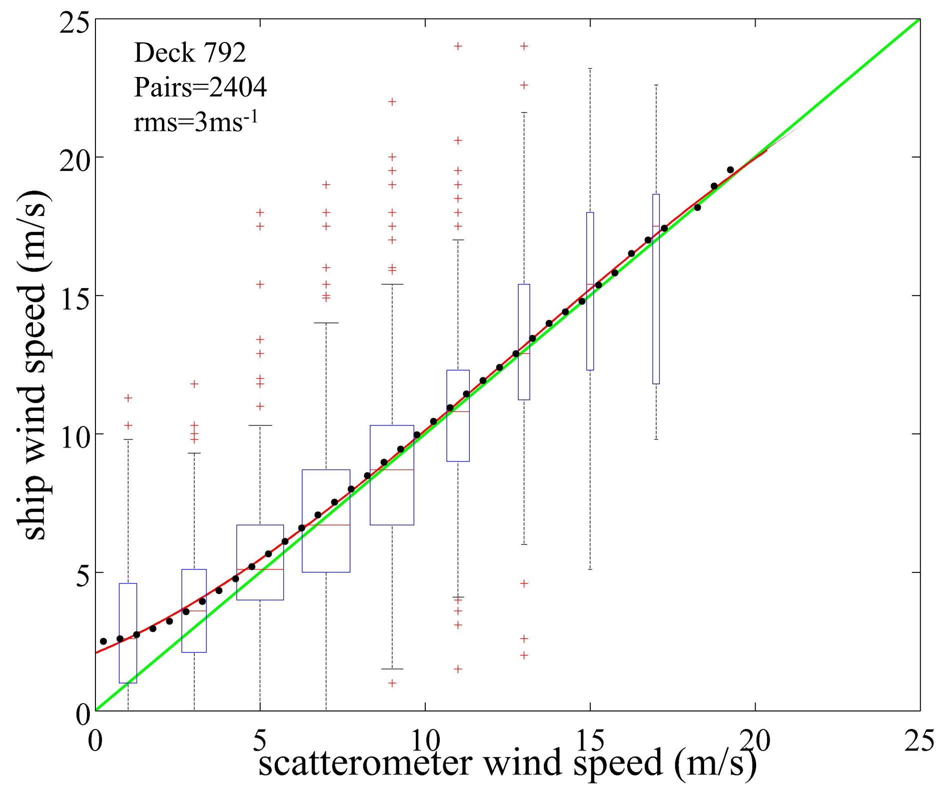
Comparison between Lindau (1995) correction and LMS correction

Beaufort Force	Lindau's (1995) correction	LMS correction value (ms^{-1})
0	0.0	-0.2
1	0.2	0.2
2	0.1	0.6
3	0.0	0.6
4	0.5	0.4
5	0.4	-0.1
6	-0.2	-0.4
7	-0.8	0.1
8	-1.8	--
9	-2.4	--
10	-3.4	--
11	-3.8	--
12	--	--

- Note: the global averaged bias of $0.2ms^{-1}$ between equivalent neutral winds (larger) and actual winds
  - The slightly larger corrections are expected if the target is equivalent neutral winds

Conclusions and future work

- VOS visual winds from 1999 to 2009 are adjusted to satellite winds
  - The adjustments are minor, suggesting that the VOS visual winds have been height adjusted
- The new adjustment is to equivalent neutral winds (satellite winds), and shows
  - a remarkable similarity in calibration between VOS and satellite winds (presumably after height adjustment)
  - Much greater noise in the visual winds (roughly 3.3 times that of scatterometer winds)
- Vastly more satellite data are available to improve the accuracy of this adjustment
- This suggests that a satellite-like data record could be extended back in time to decades prior to satellite observations



The black dots are associated with conditional sample mean of each 0.5ms-1 bin of scatterometer winds generated by Monte Carlo approach. Red line is the cubic fitting for those black dots.

Thank You

This work is funded by NASA Ocean Vector Winds Science Team (OVWST) &
ICOADS Value Added Dataset development from NOAA/COD

IVAD project at FSU

- The adjustments could include the following:
  - Temperature errors due to ship (buoy, etc.) heating.
  - Beaufort wind adjustments.
  - Height adjustments (e.g., anemometer).
  - Platform mixture issues (ship, buoy, profile, etc.).
  - Adjustments for known instrument variations (e.g., bucket vs. intake vs. drifting buoy SST).
  - Improved QC procedures (e.g., adaptive QC, track checking, platform-type checks).
- Address biases correction in the conversion of visually estimated (e.g., Beaufort force) winds to Geophysical numeric wind values, building onprevious work by Lindau (1995) and Kent and Taylor (1997).

- ***Goal***: Improve the conversion of Beaufort winds to geophysical values with scientific units (ms^{-1} in this case). Focus on the adjustments to visually observed estimated (Beaufort winds) winds.

Lindau's (1995) correction

BFT	0	1	2	3	4	5	6	7	8	9	10	11	12
WI=5, Deck 761 (ms^{-1})	0.0	1.0	2.6	4.6	6.7	9.3	12.3	15.4	19.0	22.6	26.8	30.9	--
Lindau (1995; ms^{-1})	0.0	1.2	2.7	4.6	7.2	9.7	12.1	14.6	17.2	20.2	23.4	27.1	31.4
Lindau's (1995) correction (ms^{-1})	0.0	0.2	0.1	0.0	0.5	0.4	-0.2	-0.8	-1.8	-2.4	-3.4	-3.8	--

Table 4. Lindau (1995) correction, class 13 is not shown.

- WI=5 : Beaufort wind. It is known to be Beaufort winds, the conversion is based on the WMO 1100 scale.