Intercalibration of Visual Winds from Volunteer Observing Ships and Scatterometer Winds

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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.

If found to be consistent with satellite winds, a satellite-like (in value, but not in sampling) wind record back in time. This will be of value in the areas of good coverage, which include most of the North Atlantic Ocean and major shipping routes.

Traditional calibrations have been to actual wind speed. Here we attempt to calibrate to equivalent neutral wind speeds. We expect this approach to have smaller regional and seasonable biases because visual estimates are based on sea state, which is a function of stress. Scatterometer respond to stress event though the main product is an equivalent neutral wind. Our initial assumption is that visual winds are equivalent neutral winds (after conversion to wind speed at a height of 10m), and we will determine biases and random errors.

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.

Beaufort #0 Beaufort #6 Beaufort #12

The Beaufort scale and description (upper left) and examples of the sea state at three Beaufort numbers.

Visually Estimated Ship Wind Data

Release 2.5 of ICOADS (available at http://rda.ucar.edu/datasets/ds540.0/)

- R.2.5 ICOADS has 261 million records in the International Maritime Meteorological Archive (IMMA) format covering 1662–2014.
- Focus on the time period from 1970 to 2007 (overlap with the marine air temperature adjustments that were developed by the National Oceanography Center (NOC; Berry et al., 2004)

Platform Type	Description	Platform Type	Description
0	US Navy or 'deck' log, or unknown	11	Mechanical/digital/micro bathythermograph (MBT)
1	Merchant ships or foreign military	12	Expendable bathythermograph (XBT)
2	Ocean station vessels, off station or station proximity unknown	13	Coastal-Marine Automated Network (C-MAN) (NDBC operated)
3	Ocean station vessels, on station	14	Other coastal/island station
4	Lightships	15	Fixed ocean platform
5	Ships	16	Tide gauge
6	Moored buoy	17	High-resolution Conductivity-Temp. -Depth (CTD)/Expendable CTD (XCTD)
7	Drifting buoy	18	Profiling float
8	Ice buoy	19	Undulating oceanographic recorder
9	Ice station (manned, including ships overwintering in ice)	20	Autonomous pinneped bathythermograph
10	Oceanographic station data (bottle and low-resolution CTF/XCTD data)	21	Glider

Marine Meteorological data comes from many types of platforms (e.g., ships, buoys, towers). We focus on winds from ships. ICOADS uses the 'platform type' variable to allow the platform to be identified.

Similarly, there are different ways in which wind were measure and different units in the original record. ICOADS uses the 'wind speed indicator '(WI) to identify the observational method (measured or visually estimated) and the original units. Visually estimated winds are indicated in red.

WI	Description	Grouping for analysis
0	Meter per second, estimated	Estimated
1	Meter per second, measured	Measured
2	Estimated (original units unknown)	Estimated
3	Knot, estimated	Estimated
4	Knot, measured	Measured
5	Beaufort force (conversion of original data, or based on documentation, WMO 1100)	Estimated
6	Estimated (original units unknown) OR unknown method	Estimated
7	Measured (original units unknown)	Measured
8	High resolution measurement (e.g. hundredths of a meter per second)	Measured
Missing	Wind indicator blank so method and units unknown	Not used

Table 3. Wind indicator flag meaning

Previous conversions to geophysical units

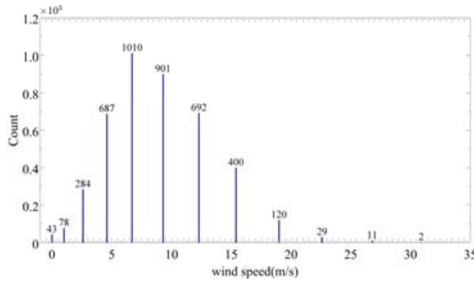
Kent and Taylor (1997) examined the following conversions.

WMO 1100 (WMO, 1970), CMMIV (WMO, 1970), UWM (daSilva et al., 1995), Lindau (1995), Isemer (1992), Kaufeld (1981), Cardone (1969).

Lindau (1995) was found to be best. This adjustment was determined based on consistency with observation-based pressure gradients. It also benefited from a two-way regression.

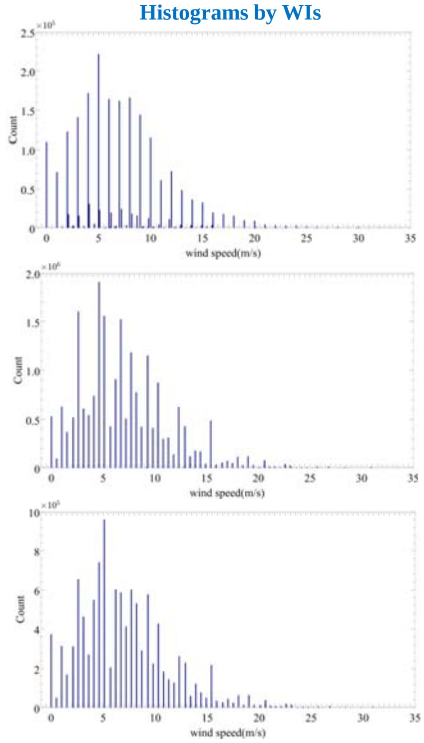
- WMO 1100 commonly used in ICOADS is biased.
- The Lindau (1995) scale gives the closest distribution to the anemometer winds.

'13 value' Expected 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. This is the only collection of ship winds that have only the 13 expected wind speeds.

Histograms by WIs



Histogram of Wind speed with: (a) WI=0; (b) WI=3; (c) WI=6.

Quality control (QC)

Satellite scatterometer wind speed dataset:

- The Ku-band scatterometer can be sensitive to rain contamination (Weissman, 2012).
- ***All rain flagged scatterometer data are removed.***

Visually estimated ship wind speed dataset:

- ICOADS R2.5 contains an *Icoads* attachment, which contains one of QC elements denoted as 'WNC' flags.
- ***Remove records with WNC flag denoted as 'Erroneous'.***

Value	Coded	Weight	Meaning	Reason
R	1	0	Correct	--
A	2	1	Correctable	Legality
B	3	1	Correctable	Internal consistency
J	4	2	Suspect	Internal consistency
K	5	2	Suspect	Time
L	6	2	Suspect	Extreme (outside)
M	7	3	Erroneous	Legality
N	8	3	Erroneous	Internal consistency
Q	9	3	Erroneous	Extreme
S	10	3	Missing	--

ICOADS WNC flag meaning

Data for Collocation

Satellite scatterometer winds:

- Version 3 JPL QuickSCAT scatterometer wind speed dataset (Nov. 1999-Oct. 2009).
- Satellite scatterometer winds calibrated to equivalent neutral winds (Liu and Tang, 1996; Verschell et al., 1999; Mears et al., 2001).

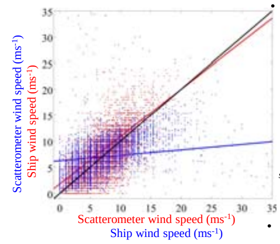
R.2.5 ICOADS covering the time period Nov. 1999-Oct. 2009.

- Visual winds: Strees-like rather than wind-like (similar to satellite scatterometer equivalent neutral wind).
- Lack information of stability-related modifications to the adjustment from the surface to 10m

Assumptions: visually estimated ship winds has a similar calibration to satellite scatterometer winds

- *Treat the visually estimated winds as equivalent neutral winds*
- Initially, we use Lindau (1995) conversion of Beaufort winds
- Visually estimated ship winds: R.2.5 ICOADS covering the time period Nov. 1999-Oct. 2009

Assessment of Systematic and Random Errors



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

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

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

- Satellite scatterometer wind speed data are much more accurate!

Scatter Plot of **scatterometer wind vs. visual wind speed**, and **visual wind speed vs. scatterometer wind**. The differences in slope indicate that ship data are much noisier. This noise has several impacts on calibration.

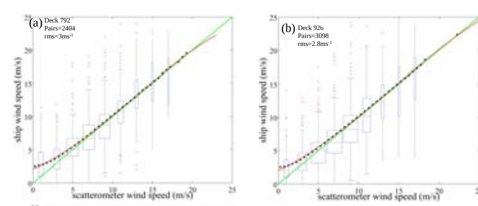
Modification of the calibration due to statistical artifacts

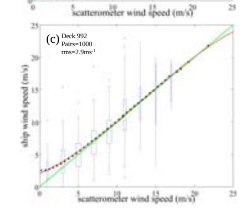
- Freilich (1997): Comparison between scatterometer winds (plotted on y) and buoy winds (plotted on x)
- Random vector component error are often manifested as systematic calibration error in speed.
  - Particularly near a boundary in the range of the data (e.g., zero wind speed
  - This appearance of a bias is purely artificial.
- Apparent insensitivity of the scatterometer data to buoy data for theses 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.
  - Investigate conditional mean of the scatterometer winds.
- This technique allows us to calculate the artificial effect of the random component error on biases at the low vector wind speed.

Artificial bias test by Monte Carlo simulation at higher wind speed

- Since the distribution of realistic winds does not follow the uniform distribution and there are relatively few observations for high wind speeds it is not clear that the assumption of a uniform distribution is useful
  - We try something that has not been done before, to account for the actual distribution of data
  - This also lets us explore artificial biases for the high value side of the distribution
- To work with a realistic distribution, we randomly select the wind speed associated with every 0.1 percentile of satellite scatterometer winds in order to generate a new satellite wind speed dataset
  - Monte Carlo simulation as the noise-free dataset.
  - At high wind speed we see a small fall off the reference line.
  - The estimate of the artificial bias for low wind speeds is slightly difference.

Results of Artifact error test at high wind speed





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.

(a)Deck 792: US National Centers for Environmental Prediction (NCEP) BUFR GTS: ship data

(b)Deck 926: International Marine Meteorological(IMM) data

(c)Deck 992: NCDC GTS: Ship Data

Conclusions and future work

- Based on Freilich and Dunbar (1999), we use a new approach to account the actual wind speed distribution to test the effect of artificial error on the lower wind speed ($0ms^{-1}$-$5ms^{-1}$) and higher wind speed ($15ms^{-1}$ to $17ms^{-1}$): A significant effect at lower wind speed and small impact at higher wind speed.
- A new bias correction, LMS correction, is developed by the weighted average of bias correction values of two major decks (792 and 992)
- Bias corrects were small, suggesting that the assumption of visual winds being treated as equivalent neutral winds is a good assumptions.

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	--	--

- However, the LMS correction is limited up to 17m/s of wind speed. Satellite winds and collocated ship winds that met severe quality control requirements, very few matches of temporal and spatial are found in the higher wind speed area.
- The future work will focus on the bias correction for Beaufort scale 8, 9, 10, 11, 12. This will require different quality control assumptions.