Intercomparison and Validation of Winds from Scatsat-1 and in situ Buoys

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1. Introduction

- Scatterometers are one of the few sources of reliable high-resolution wind vector data with almost global coverage.
  - Scatterometer wind data when assimilated into numerical weather prediction models, greatly increases the accuracy of forecasts (Stoffelen et al., 1998).
  - It can also be interpreted directly to analyze important oceanographic phenomenon like upwelling and for the observation of tropical and extratropical cyclones (Smitha et al., 2014).

- To maintain the continuity of missions as well as ascertain the quality of data obtained from satellites, it is essential to validate them with *in situ,* model and/or other existing satellite observations.

Scatterometer	Comparison with	Source
SeaWinds	Global buoy networks, North Indian Ocean buoys, research vessel wind observations	Ebuchi et al., 2002, Satheesan et al., 2007, Bourassa et al., 2003
ASCAT	QuikSCAT, Global buoy networks, ECMWF model	Bentamy et al., 2012, Bentamy et al., 2008, Bentamy and Croizé-Fillon, 2012
OSCAT	Global buoy networks & ASCAT	Kumar et al, 2013; Rani and Gupta, 2013; Sudha and Prasada Rao, 2013;
ScatSat-1	North Indian Ocean buoys, ECMWF reanalysis winds, and ASCAT	Mandal et al. 2018

2. Data

Period of analysis: 1st Nov. 2016 to 30th Jun. 2018

Study region: Global

SCATSAT-1 Level 2B (L2B) data

- Orbit-wise 10 m height WS and WD and at 25 km spatial resolutions
- Provides the time of data acquisition in the 'WVC_row_time' dataset
- Wind Vector Cell (WVC) quality flags provided: rain flag, ambiguity filtering, coastline.

Quality 1 L2B data used for validation

GTMBA data

- Composed of three networks; TAO/TRITON in the Pacific, PIRATA in the Atlantic and RAMA in the Indian Ocean.

NDBC data

- Spread along the coast of USA. In the Western North Atlantic and the North Pacific.

OMNI buoys

- Present in open waters of the Bay of Bengal and the Arabian Sea

All the buoy datasets are quality controlled and the highest quality of data is used.

3. Methodology

Buoy winds reported at 3m and 4m are converted to the equivalent neutral wind at 10 m height following the empirical logarithmic wind profile formulation (Peixoto and Oort, 1992).

$$U_{10} = U_o \frac{\log \frac{z}{z_o}}{\log \frac{z_{ref}}{z_o}}$$

(U_o) represents the WS at a height of 3 m or 4 m, (z_{ref}) represents the equivalent neutral wind at 10 m and Z is 10 m. The roughness length is assumed to be 1.52 x 10-4 m following (Rani and Gupta, 2013).

Collocation

Window centered on SCATSAT-1 pass.

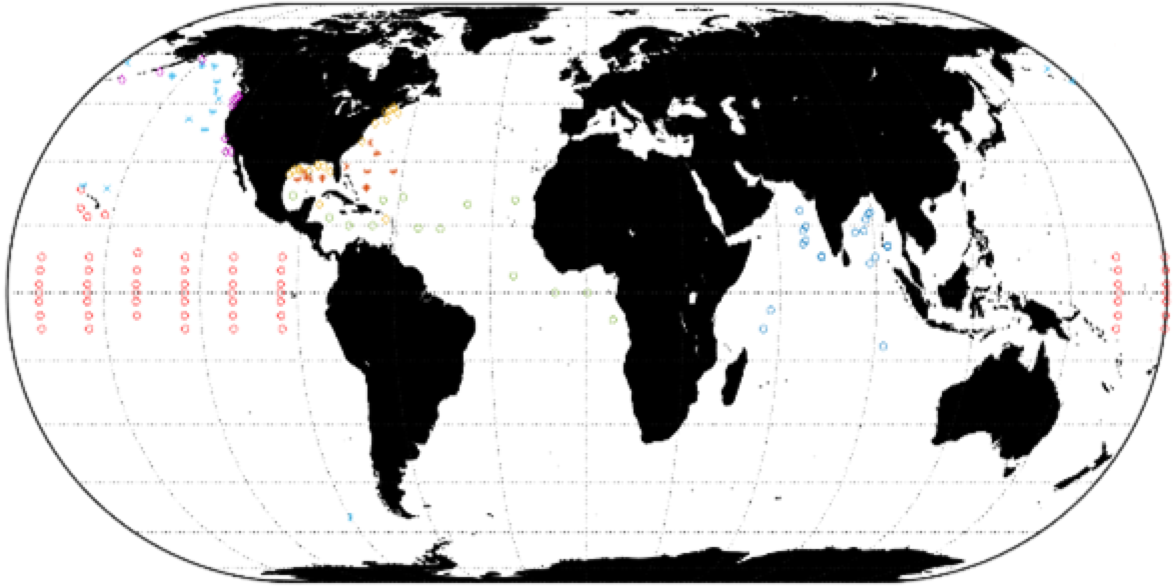
Spatial extent: 0.25° by 0.25°

Temporal extent: ±10 minutes for GTMBA and NDBC
±1 hour for the OMNI buoys

Classification

Region	Number of Collocated Data Points
Tropical Pacific	53,035
Extra-tropical Pacific	16,953
Coastal Pacific	7,445
Tropical Atlantic	9,556
Extra-tropical Atlantic	10,912
Coastal Atlantic	13,422
Tropical Indian	6,296

Tropical: GTMBA
+ OMNI
Other: NDBC

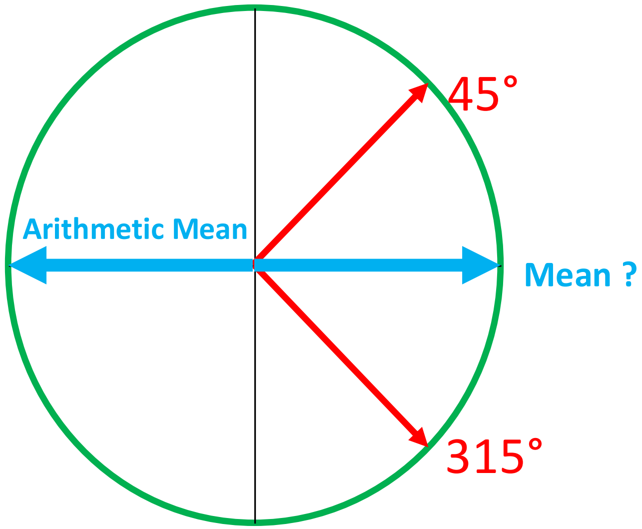


Directional Data: Directional data arise naturally in many scientific fields where observations are recorded as directions or angles relative to a system with a fixed orientation. Examples of circular data include wind directions, wave directions and time measures such as time of day.

Statistics of Directional data: Directional Statistics/ Circular Statistics

Circular Mean

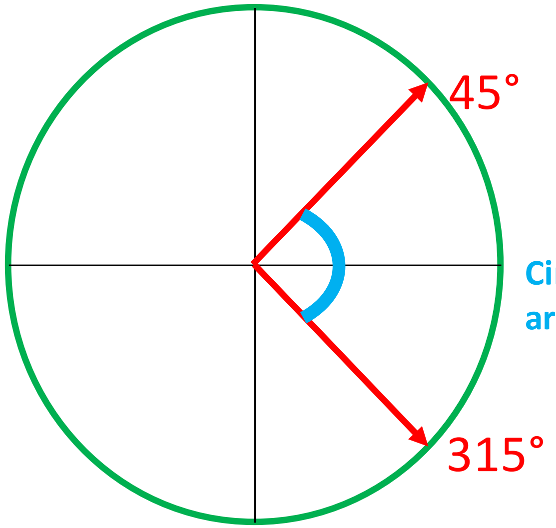
$$\left(\sum_{i=1}^{n} \cos\alpha_i,\ \sum_{i=1}^{n} \sin\alpha_i\right) = (C,\ S)$$



$$\bar{\alpha}_0 = arctan^*(S/C),$$

where

$$\bar{\alpha}_0 = arctan^*(S/C) = \begin{cases} arctan(S/C), & \text{if } C > 0,\ S \geq 0, \\ \pi/2, & \text{if } C = 0,\ S > 0, \\ arctan(S/C) + \pi, & \text{if } C < 0, \\ arctan(S/C) + 2\pi & \text{if } C \geq 0,\ S < 0, \\ \text{undefined}, & \text{if } C = 0,\ S = 0. \end{cases}$$



Circular Distance – shorter arc between two directions

Circular Distance

$$d_0(\alpha,\beta) = \min(\alpha-\beta, 2\pi-(\alpha-\beta)) = \pi - |\, \pi - |\, \alpha-\beta \,||\, .$$

Circular-Circular Correlation Coefficient

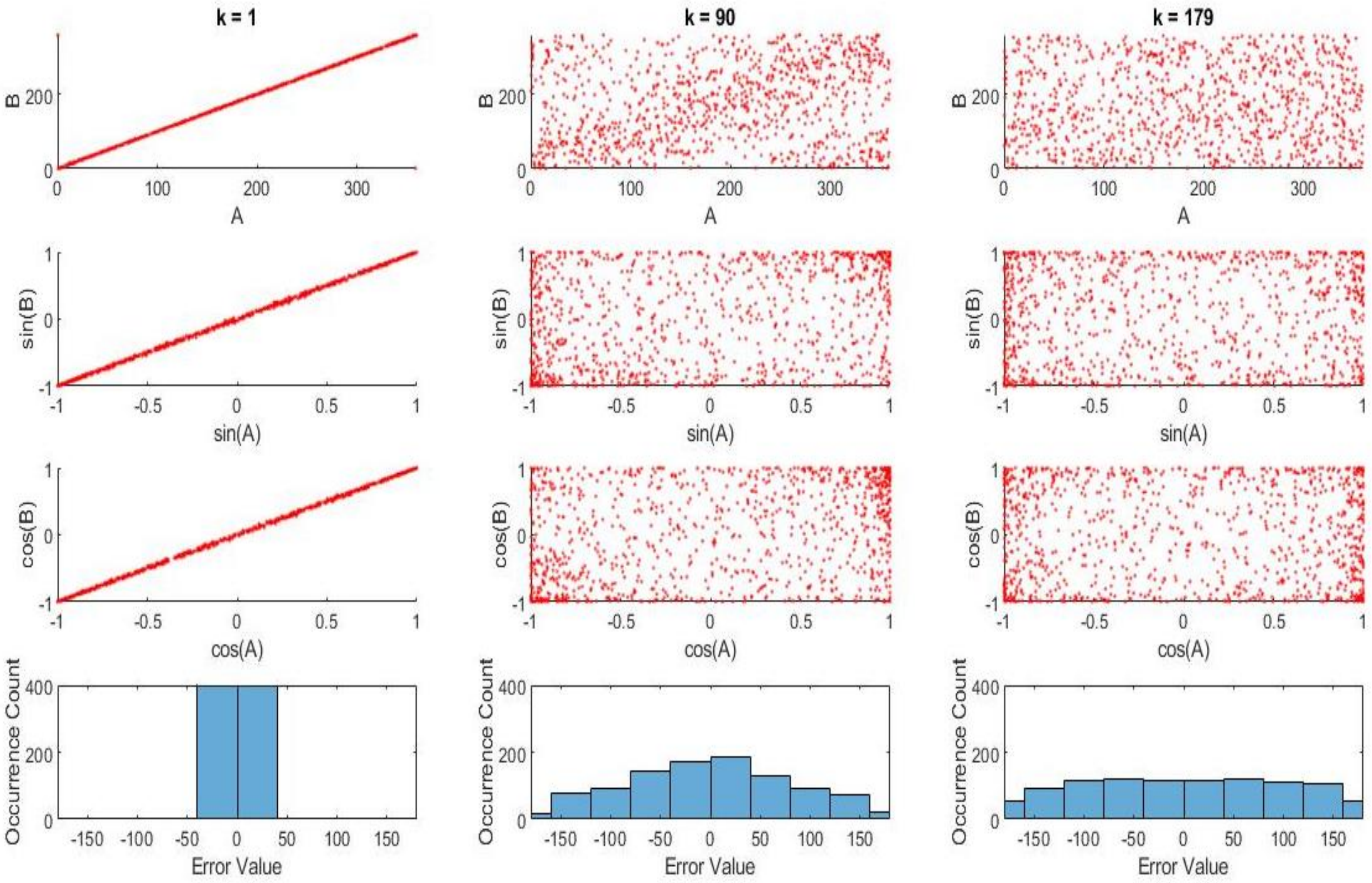
$$r_{cc} = \frac{\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} \sin(\theta_i-\theta_j)\sin(\varphi_i-\varphi_j)}{\sqrt{\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sin^2(\theta_i-\theta_j)\ \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sin^2(\varphi_i-\varphi_j)}}$$

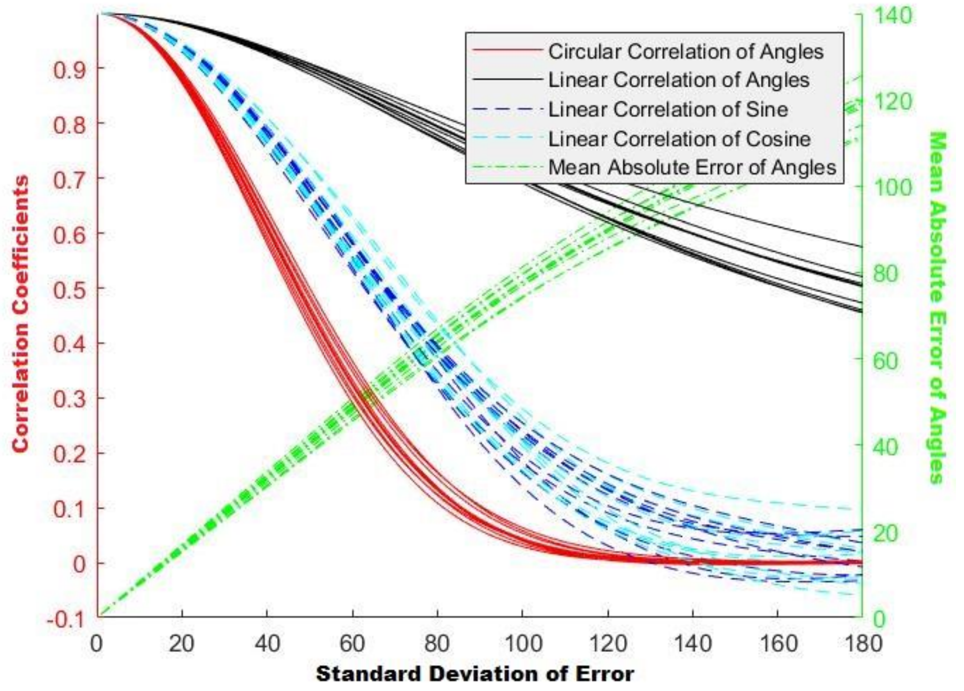
Linear Correlation Coefficient

$$r_{xy} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}}$$

Circular-Circular Correlation Coefficient

$$r_{cc} = \frac{\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} \sin(\theta_i - \theta_j)\sin(\varphi_i - \varphi_j)}{\sqrt{\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sin^2(\theta_i - \theta_j)\ \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sin^2(\varphi_i - \varphi_j)}}$$





4. Results and Discussions

Statistical Parameters	Wind Speed			Wind Direction		
	MAE (m/s)	Bias (m/s)	r	MAE (°)	Bias (°)	r_{cc}
Tropical Pacific	0.825	-0.010	0.869	11.882	1.677	0.838
Extratropical Pacific	1.133	-0.238	0.894	14.532	7.512	0.786
Coastal Pacific	1.359	-0.472	0.858	21.563	5.444	0.628
Tropical Atlantic	0.732	-0.053	0.904	10.864	-1.752	0.854
Extratropical Atlantic	1.018	-0.047	0.878	15.293	3.572	0.803
Coastal Atlantic	1.105	-0.339	0.890	17.883	4.338	0.734
Tropical Indian	1.019	-0.484	0.844	18.451	3.530	0.713

Statistical Parameters	U-wind			V-wind		
	MAE (m/s)	Bias (m/s)	R	MAE (m/s)	Bias (m/s)	R
Tropical Pacific	1.064	-0.038	0.859	1.017	-0.107	0.902
Extratropical Pacific	1.739	-0.027	0.892	1.602	0.079	0.899
Coastal Pacific	1.960	-0.058	0.787	1.749	0.060	0.861
Tropical Atlantic	0.903	-0.111	0.911	1.225	0.230	0.875
Extratropical Atlantic	1.453	0.053	0.885	1.359	-0.188	0.910
Coastal Atlantic	1.854	0.044	0.855	1.725	0.102	0.880
Tropical Indian	1.429	0.208	0.845	1.286	0.190	0.895

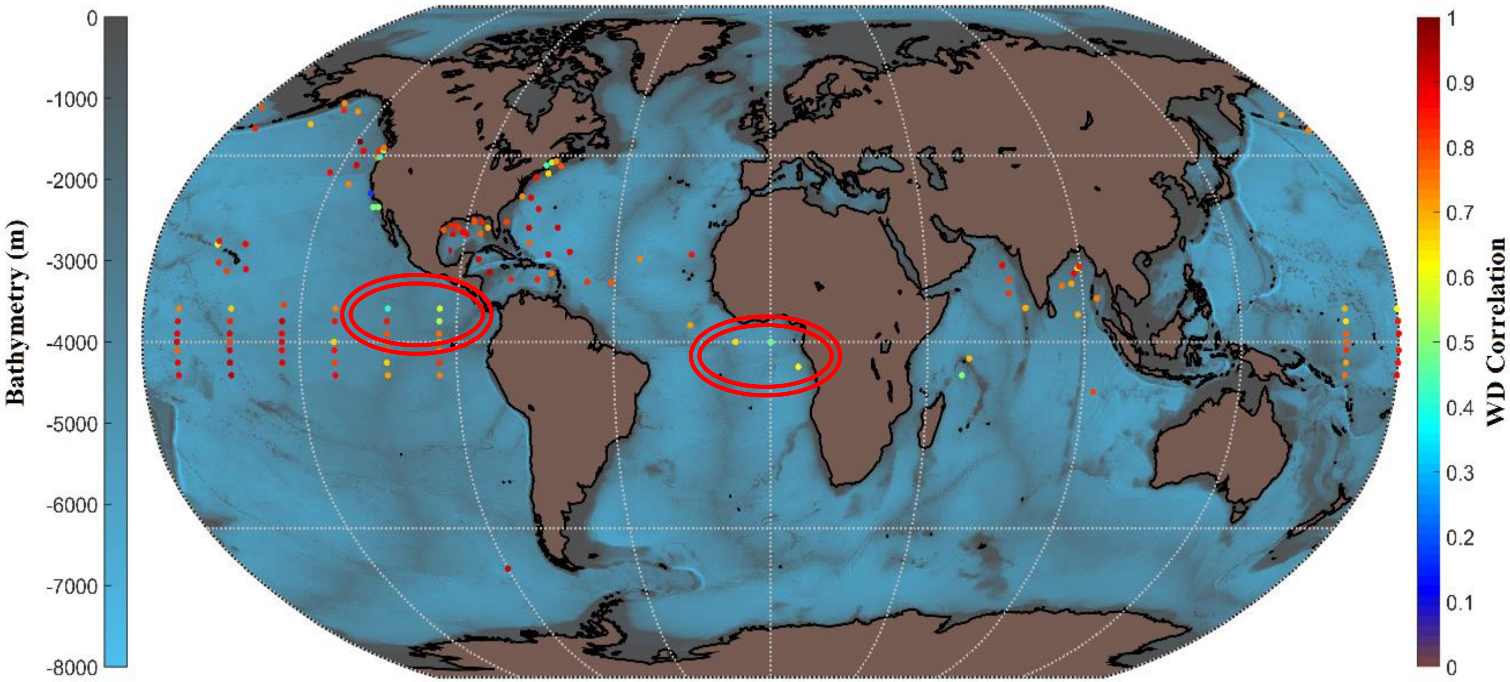
WS, U, V MAE < 2.0 m/s
WS, U, V Bias < 0.5 m/s
WS, U, V correlation > 0.8
WD MAE < 22° (≤ 15° in open waters)
WD bias < 6°
WD correlation > 0.6

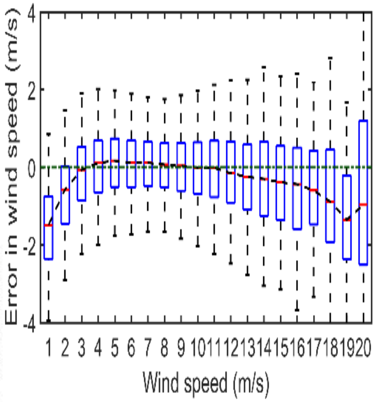
Coastal Pacific shows the worst performance especially for WD. Coastal Atlantic is much better.

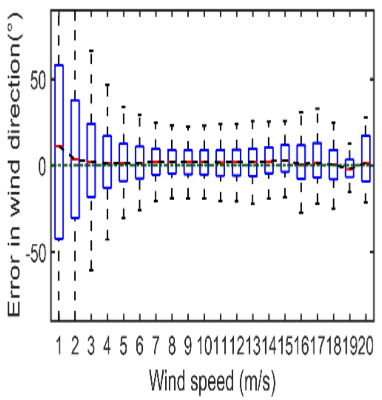
- ☐ Shallow waters + low WS

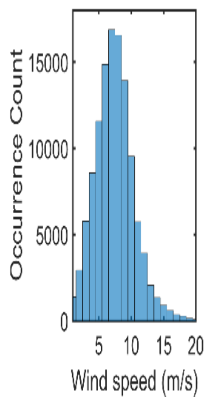
Indian Ocean shows highest WS bias

- ☐ Low WS
- ☐ Fewest collocated observations

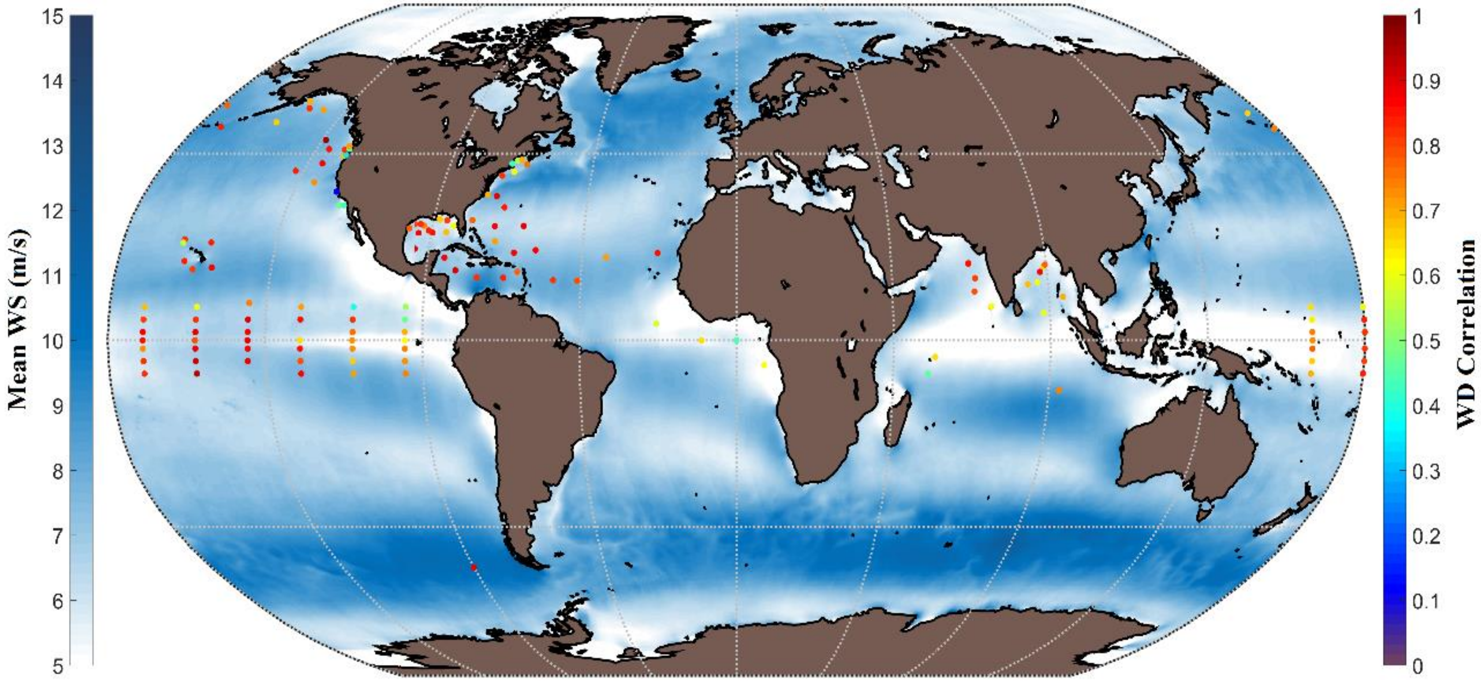






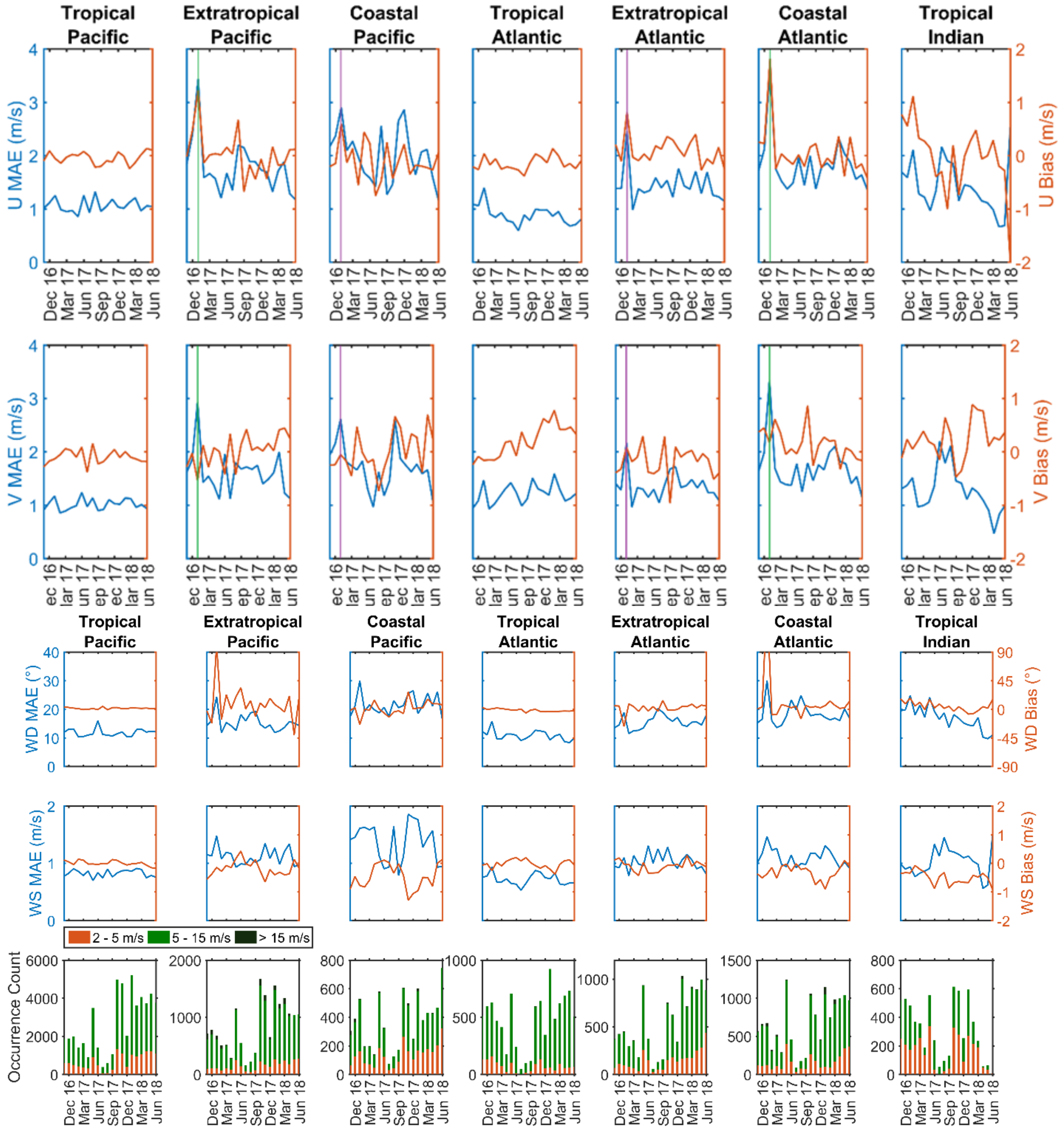


Low WS (< 3 m/s)	High WS (> 15 m/s)
• WS overestimated	• WS overestimated
• WD underestimated	• Large WS error
• Large WD error	



Clusters of open water buoys with low WD correlation: Equatorial Atlantic and off Panama

Possibly due to low WS



MAE of WS and the magnitude of its bias are less than 2 m/s for all regions throughout the entire study period. WS MAE and magnitude of WS bias are less than 1 m/s for the tropical oceans.

This suggests that large errors in U and V are associated with highly biased errors in WD.

Largest observed WD bias is for January 2017 for the coastal Atlantic; 173°

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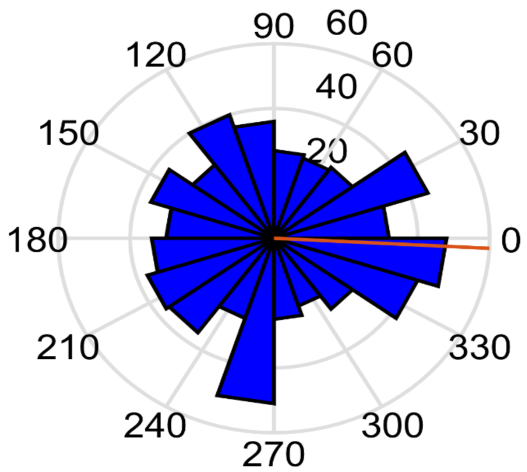
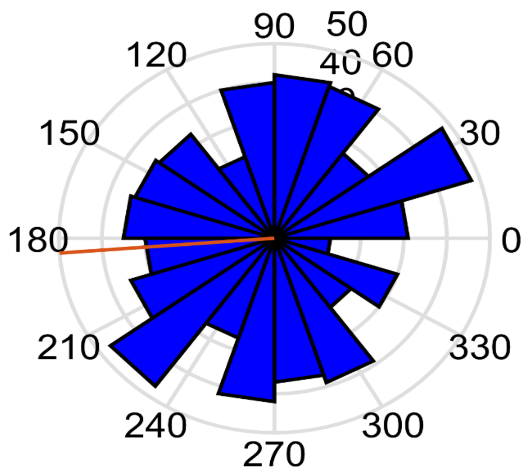
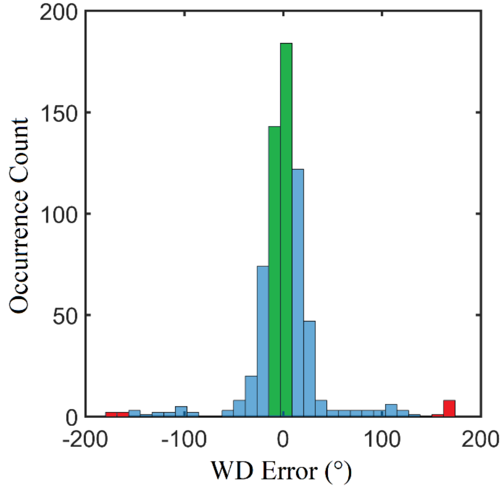


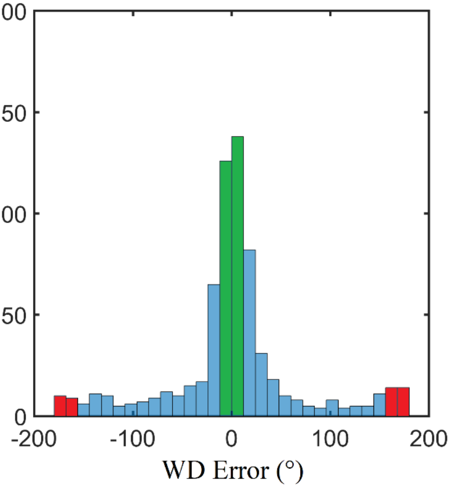
Scatsat-1 Wind Direction
Mean direction: 357°



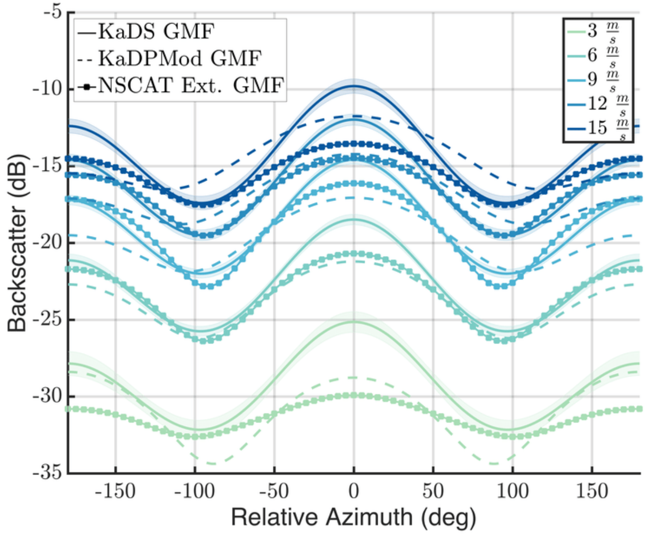
Buoy Wind Direction
Mean direction: 184°

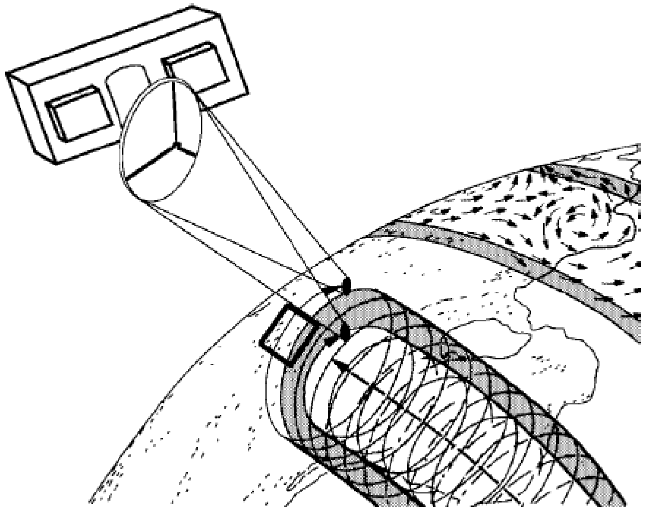


December, 2016
n = 662
WD Bias: 3.5°



January, 2017
n = 675
WD Bias: 173°





Directional ambiguity is a common scatterometer problem resulting from the near symmetry of the GMF at 180° azimuthal separation.

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