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

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Abstract

ISRO's Scatsat-1 scatterometer, launched on 26th September 2016, supports the OSCAT-2 scatterometer as a continuation and enhancement of the OSCAT onboard the OceanSat-2. This paper carries out a detailed inter-comparison between the swath-wise level 2B (L2B) data from Scatsat-1 with *in situ* wind velocity data derived from three different moored buoy arrays: the Global Tropical Moored Buoy Array (GTMBA,) National Data Buoy Center (NDBC), and the Ocean Moored buoy Network for northern Indian Ocean (OMNI.) While the three arrays collectively span most of the ocean basins, they are primarily concentrated in the tropical regions and the coast of North America; therefore, to facilitate an assessment of the agreement between the satellite and in situ data in different regions, the comparison is split between tropical, extra-tropical and coastal regions for each ocean basin. The statistics thus derived are however biased towards buoys with a greater number of collocated observations and therefore the agreement between the two wind vector datasets are also estimated at each buoy location.As wind direction is a circular variable, circular/directional statistics has been used to compute the relevant parameters for wind direction. A temporal analysis of the agreement between WS and WD has also been carried out and it indicates that months with high WD bias contain a relatively greater number of observations with errors close to 180°.

1 Introduction

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

ISRO's Scatsat-1, launched on 26th September 2016, supports the OSCAT-2 scatterometer as a continuation and enhancement of the OSCAT onboard the OceanSat-2 which ceased to operate in April 2014. OSCAT-2 is a Ku-band pencil beam scatterometer operating at 13.515GHz with two beams; the inner with a 1400 km swath,48.9°incidence angle and HH polarization and the outer with a swath of 1400 – 1840 km,57.6°incidence angle and VV polarization. It is placed on a sun-synchronous orbit of altitude 720 km and an inclination of 98.1degrees with a repeat period of 2 days (14.5 orbits per day.) (ScatSat-1 wind Product User Manual, 2018).

This paper presents a global comparison between SCATSAT-1 and buoy WS and WD across various regions and an analysis of the spatial and temporal variation of the agreement of SCATSAT winds with the corresponding buoy data.

2 Data

Four different wind datasets, spanning the period from 1st Nov 2016 upto 30th Jun 2018, have been used in this comparative analysis: scatterometer wind data from SCATSAT-1 and in-situ wind data from the Global Tropical Moored Buoy Array (GTMBA,) National Data Buoy Center (NDBC), and the Ocean Moored buoy Network for northern Indian Ocean (OMNI).

In the present work, SCATSAT-1 Level 2B (L2B) data (available at https://www.mosdac.gov.in/) consisting of orbit-wise Wind Speed (WS) and Wind Direction (WD) at 10 m height at 25 km resolutions have been used. The GTMBA moorings support several types of sensors, the WS and WD accuracy for the T-flex mooring sensors and next-generation ATLAS sensors are ±2% and 1°, and ±0.3 m/s or 3% and 5° - 7.8°, respectively and the range for WS for the T-flex mooring sensors and next-generation ATLAS sensors are 0-60 m/s, and 1-20 m/s, respectively (Payne, 2002). The minimum WS and WD accuracy requirement met by all the NDBC systems is ± 1.0 m/s or ±10% (whichever is greater) and ± 10.0 deg, respectively although field comparisons suggest higher accuracies (Gilhousen, 1987). For OMNI buoys, the accuracy of measurement of WS is 1.5% FS or 0.9 m/s and that of WD is 3.6°. OMNI buoys are capable of measuring WS over the range of 0-60 m/s. WS and WD data with a quality flag value of 1, corresponding to the highest quality available, has been used for the present analysis (Tiwari, 2009).

3 Methodology

To carry out a detailed validation exercise of the Scatsat-1 wind products, first the winds from Scatsat-1 and the buoys were collocated following a fixed spatio-temporal window. Since, the buoy winds are at different heights from the ocean surface (3 m & 4 m) unlike the Scatsat-1 winds which are at 10 m, all *in situ* winds products were converted to the equivalent neutral wind at 10 m height following the empirical logarithmic profile where the roughness length z_0 is assumed to be 1.52×10^4 m following (Rani, 2013).

The SCATSAT-1 wind observations are collocated with wind observations from each of the three sets of buoys mentioned in the previous section. A spatial collocation window 0.25° by 0.25° width centred on each buoy was considered for collocating the SCATSAT-1 WS and WD and a temporal window of ±10 minutes of Scatsat-1 pass for GTMBA and NDBC buoy wind data within a temporal window of 10min and ±1 hour for the OMNI buoys. The collocated data points are then classified as tropical, extratropical (with respect to the 23.5° latitude lines) and coastal (deeper than 50 m but within a distance of 2° from the coast) for each ocean basin (Atlantic Ocean, Indian Ocean, and Pacific Ocean) where available.

Linear statistical analysis has been used for WS, u and v validation, while we have utilized circular/directional statistics for WD which is expected to allow a better comparison as the distance between two given angles (say d_1 and d_2) for a circular variable like wind direction is *min* $(d_1 - d_2, 360° - (d_1 - d_2))$ and not simply the difference $(d_1 - d_2)$. The mean direction $\bar{\theta}$ is computed following (Jammalamadaka, 2001) while the circular-circular correlation coefficient is calculated following (Zar, 1999.)

4 Results and Discussion

The mean absolute error (MAE), bias and correlation coefficient (R) for WS and WD are presented in Table 1. The largest MAE and bias for WS, (and WD) are 1.35 m/s and -0.47 m/s, and (21.56° and 7.51°,) respectively. The smallest CC for WS, (and WD) are 0.84, and (0.63,) respectively. The poorest parameter values mostly occur in the Coastal Pacific Ocean (for WS, WD, U, and V); this can be explained in terms of the inherently poor performance of scatterometers close to the coast, however the Coastal Atlantic has significantly better parameter values. This asymmetry between the two coasts may be attributed to the higher mean WS on the Atlantic coast.

The region-wise statistical parameters are biased towards buoys with higher numbers of collocated samples and therefore are not suitable for a spatial analysis of the accuracy of scatterometer winds. Therefore, to analyse these spatial variations, the correlation coefficient for WD at each buoy location has been presented in figure 4 against the bathymetry ('The GEBCO_2014 Grid, version 20150318, http://www.gebco.net) and in figure 5 against the mean absolute WS (obtained from the SCATSAT-1 L4AW product). The correlation coefficient for WD is chosen for this analysis as it has the greatest spatial variation.

Table 2: Statistics of comparisons between Scatsat-1 and buoy wind speed and wind direction

	WS			WD		
	MAE	Bias	R	MAE	Bias	R
Tropical Pacific	0.82	-0.01	0.86	11.88	1.67	0.83
Extratropical Pacific	1.13	-0.23	0.89	14.53	7.51	0.78
Coastal Pacific	1.35	-0.47	0.85	21.56	5.44	0.62
Tropical Atlantic	0.73	-0.05	0.90	10.86	-1.75	0.85
Extratropical Atlantic	1.01	-0.04	0.87	15.29	3.57	0.80
Coastal Atlantic	1.10	-0.33	0.89	17.88	4.33	0.73
Tropical Indian	1.01	-0.48	0.84	18.45	3.53	0.71

An analysis of the spatial distribution reveals that the majority of buoys with a low value of WD correlation are in regions of shallow bathymetry and/or low wind speed. The low correlation of the buoys in the western pacific, the coastal buoys in the Atlantic and the Pacific may be attributed to the shallow bathymetry while the low correlation for the buoys in the Arabian sea, the equatorial Atlantic and the East Pacific may be associated with the low wind speeds.

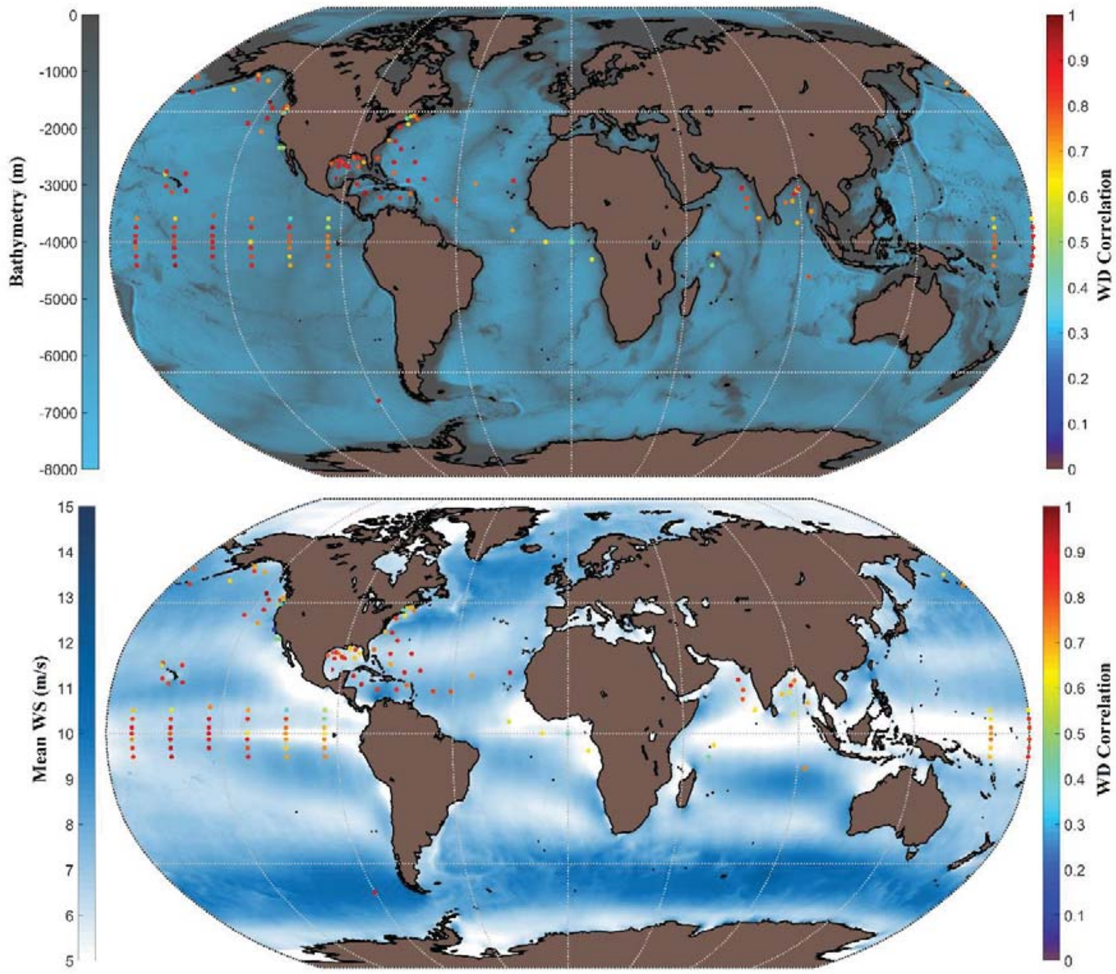

Figure 1: Spatial distribution of WD correlation with bathymetry (top) and mean WS (bottom)

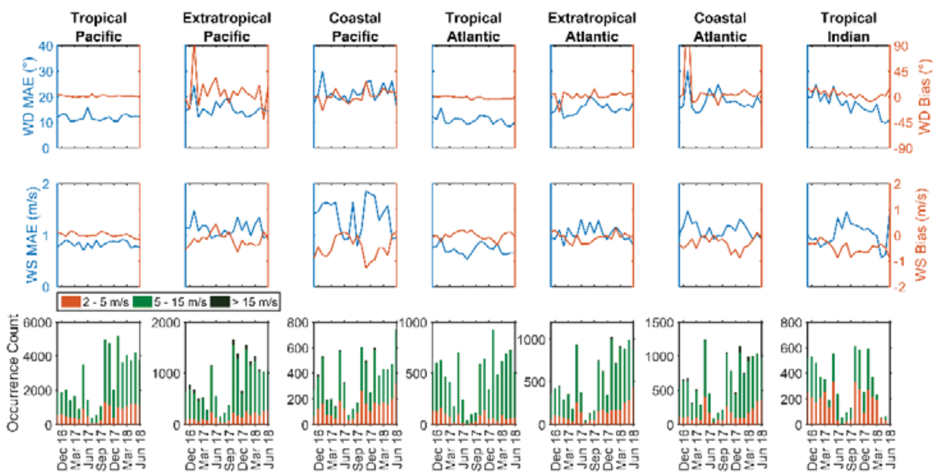

Figure 2: Temporal variation of WD (top row) and WS (middle row) MAE and bias with corresponding occurrence count (bottom row)

A temporal analysis of the MAE and bias of WS and WD (figure 5) further illustrates that the tropical buoys, the ones farthest from the coast, have lower errors and biases in comparison to their coastal counterparts in all three ocean basins. The WD bias for January 2017 for the coastal Atlantic is approximately 180° (173°) and this instance is further investigated by comparing the polar histogram of satellite and in situ WD observations and a histogram of the WD errors. It is evident from this analysis that January, 2017 indeed has a greater prevalence of observations with high direction errors including errors close to ±180° (which is possibly a failure to correctly resolve the directional ambiguity.)

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