COMPARISON OF OCEAN SURFACE WINDS FROM SCATSAT-1 SCATTEROMETER WITH BUOYS MEASUREMENTS

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KEY WORDS: Scatterometer, Root Mean Square Error, TAO Buoys.

ABSTRACT: The Scatsat-1 was launched by Indian Space Research Organization (ISRO) on September 26; 2016.Scatsat-1 is a continuity mission for Oceansat-2 Scatterometer to provide wind vector data products over global oceans for weather forecasting, cyclone detection and tracking services to the users. This paper describes the validation of ocean surface winds derived from Scatsat-1 Scatterometer using global moored buoy observations. Sea surface winds from SCATSAT-1 over global oceans are evaluated against the data from global in situ buoys by TAO (Tropical Atmosphere Ocean) project for the period of 9 months. The root mean square differences in the wind speed and wind direction are 1.14 ms^{-1}, and 20.7^{o} respectively. The accuracies of SCATSAT-1 wind products in speed and direction are 1.8 ms^{-1}(or 10% whichever is higher) and 20^{0}. The RMSE (Root mean square error) values are well within the requested SCATSAT-1 accuracy only.

INTRODUCTION:

Space-based scatterometer measurements of wind speed and direction are of utmost importance for studies on oceanic processes and helps in improving weather forecasting through data assimilation for operational weather prediction models. Sea surface winds are the main driving force for the ocean circulation as well as generation of ocean currents and surface waves. Although space-based radar altimeters are also used for measuring winds, scatterometer allow measurement of both wind speed and direction. Owing to its importance in both meteorology and physical oceanography, measurements of ocean surface winds from scatterometer data is an area of increasing focus in recent years.

For the last three decades, ocean surface wind vectors are regularly retrieved on synoptic scales from various scatterometers onboard polar orbiting satellites. In the placement of international missions of scatterometers, the latest one is orbiting onboard SCATSAT-1. It is a continuity mission for Oceansat-2 scatterometer to provide wind vector data products for weather forecasting, cyclone detection and tracking services to the users. The satellite carries Ku-band scatterometer similar to the one flown onboard Oceansat-2. It was launched by the Indian Space Research Organization (ISRO) on September 26, 2016 carrying a Ku-band (13.51 GHz) pencil-beam scatterometer into a near-polar sun-synchronous orbit of 720-km altitude, inclination 98.28^{o}.The sensor conically scans the surface of the earth in two polarizations i.e. one vertical (outer beam) and one horizontal (inner beam) polarizations at two different incidence angles. The sensor measures each point on the surface of the earth from four view angles i.e. Inner Fore, Inner Aft, Outer Fore and Outer Aft. The satellite scanning geometry is shown in the figure 1.

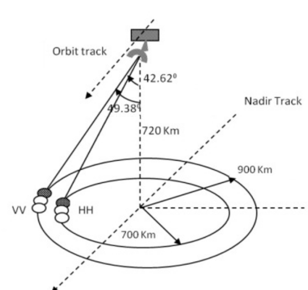

Figure 1: Satellite scanning geometry

It covers 90% of the globe in single day and entire globe in two days. The specifications of the scatterometer sensor are as follows.

Table 1: SCATSAT-1 scatterometer sensor specifications

Parameter	**Specification**	
Altitude	720km	
Frequency	13.515 GHz	
Scanning rate	20.5 rpm	
Nominal PRF	193 Hz	
	Inner beam	**Outer beam**
Polarization	HH	VV
Swath	1400 km	1800 km
Beam width (Az x El)	1.47^0 x 1.63^0	1.39^0 x 1.72^0
Footprint	27km x 46 km	30 km x 70 km
Wind vector cell size	50 km x 50 km, 25 km x 25 km	
Wind speed range	3 to 30 m/s	
Wind direction range	0^0 to 360^0	
Wind speed accuracy	1.8 m/s or 10% whichever is higher	
Wind direction accuracy	20^0 rms.	

Scatterometer works on the principle of back scattering. It actively transmits electromagnetic pulses to the earth's surface and measures back scattered response. Sigma-0 is derived from the back scattered response using radar equation. The intensity of the back scatter response depends on the roughness and dielectric properties of the target. The ocean surface roughness changes according to wind velocity and correspondingly the received back scattered power. The back scattered power is measured from different azimuth angles and it is four in this case. The wind speed and direction are estimated with these observations using GMF (Geo physical model function) that relates back scatter and wind vector. The wind vector retrieval process uses model winds derived from ECMWF.

Development of the Tropical Atmosphere Ocean (TAO) buoys array was motivated by the 1982-1983 El Nino event, the strongest of the century up to that time, which was neither predicted nor detected until nearly at its peak. The event highlighted the need for real-time data from the tropical Pacific for both monitoring, prediction and improved understanding of El Nino. The TAO consists of approximately 70 moorings in the Tropical Pacific Ocean, telemetering oceanographic and meteorological data to shore in real-time via the Argos satellite system. The operationally supported measurements of the TAO/TRITON array consist of winds, sea surface temperature, relative humidity, air temperature and subsurface temperature at 10 depths in the upper 500 m. TAO buoys data can be downloaded from the web or via anonymous FTP. Details of the buoys, instruments, and stations were described in the NDBC (National Data Buoy Center) website (http://www.ndbc.noaa.gov).

SCAT wind measurements, like all Scatterometer measurements, require a validation procedure to verify consistency with in situ data and assess the quality of the winds obtained from the satellite measurements. Several studies with regard to the validation of Scatterometer derived wind with the in situ measurements have been carried out, such as the validation of active microwave instrument [2], Advanced earth observing satellite/NASA Scatterometer [3], SeaSat/European remote sensing satellite 1 [4], and QSCAT/Sea Winds [5]. Few studies are also performed with OSCAT derived winds utilizing data over the global oceans (Singh *et al.*2012).

This study is restricted to wind parameters comparison and statistical analysis. On the basis of this it is possible to draw firm conclusions on the quality of the SCATSAT-1 25-km wind vectors. Comparison of Scatterometer wind products with independent buoy measurements is a proven method. This study was carried for nine months of SCATSAT-1 data with buoys data. However, a large number of buoy data are needed over a period of more years in order to obtain good statistics.

DATA:

In the present study, operational wind data (Level-2B, version 1.1.2) of SCATSAT-1 is compared with buoys data. These data are available from NRSC (National Remote Sensing Centre), India (www.nrsc.gov.in).Wind data have been retrieved with the SCATSAT-1 geophysical model function. The spatial resolution of the data is 25km, and the reference height of the wind vectors is 10m above the sea surface. The Ku-band scatterometer measurements are subjected to rain contamination and so is the derived wind. Appropriate flagging for such rain contaminations is implemented in the data sets. In the present study rain free data for nine months (NOV-2016 to JUL-2017) was taken to evaluate the sensor performance.

In order to compare with the SCATSAT-1 wind data, we collected buoy observations from 49 buoys by the TAO (Tropical Atmosphere Ocean) project. The TAO buoy locations are shown in Fig. 2. Only the buoys moored offshore and in deep water were selected.

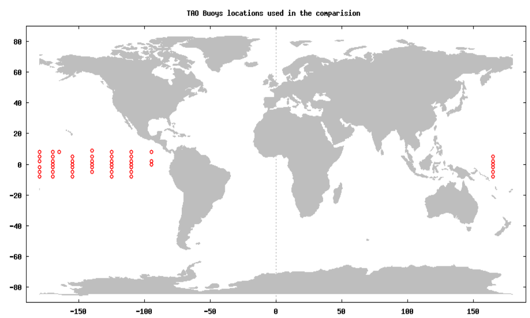

Fig .2 Location of the TAO buoys used in the inter comparisons

VALIDATION METHOD AND RESULTS:

Ocean surface wind vectors derived from SCATSAT-1 are compared with global moored TAO buoys during the period from November 1, 2016 to July 31, 2017. In this period rain free data was segregated by using rain contamination quality flag information provided in the data products. All the rain free data is used for comparison with TAO buoys observations. TAO buoys provide wind observations at 10-minutes interval. The collocated observations of SCATSAT-1 and TAO buoys are considered for comparison. The observations are considered to be collocated if the temporal difference and spatial separation between the SCATSAT-1 and buoy observations were limited to less than 30 minutes and 25km respectively. SCATSAT-1 provides wind measurements at 10m above the sea surface, but buoys measures winds from different heights above the sea surface. So the wind speeds measured by the buoys at various heights above the sea surface is converted to equivalent neutral wind speed at a height of 10 m using the log profile model as follows[1]

$$U_{10} = 8.87403 \times U_z / \ln (z/0.0016) \qquad (1)$$

Where z is the observation height in meters, U_z is the wind speed, and U_{10} is the 10mwind speed.

During the study period 4378 collocated pairs of observations are obtained. The scatter plots of wind speed and direction for all wind speed ranges (0-30 m/s) are shown in Fig.3. Similarly, the scatter plots for the wind speed range of 3-30m/s and 0-3 m/s are shown in Fig.4 and Fig.5.

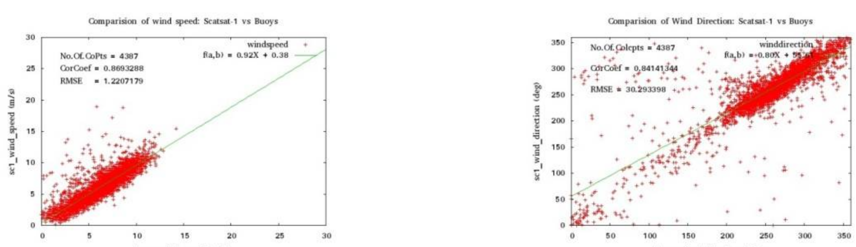

Fig. 3. Comparison ofSC1 and TAO buoys wind speed (left) and wind direction (right) for the entire speed range (0-30 m/s).

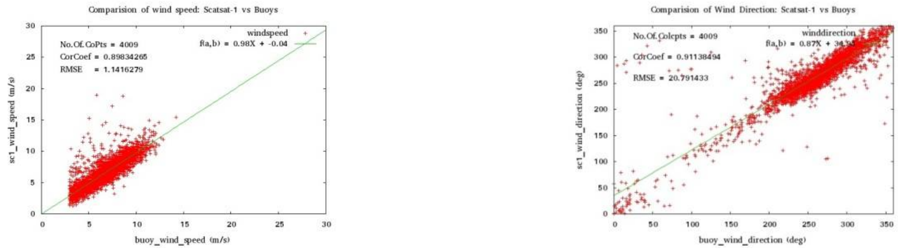

Fig. 4.Comparison of SC1 and TAO buoys wind speed (left) and wind direction (right) for the speed range (3-30 m/s).

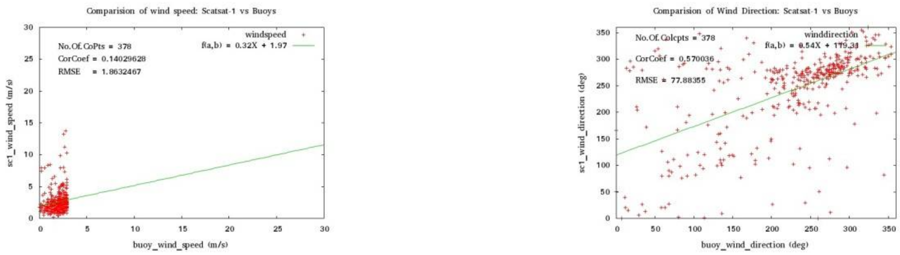

Fig. 5.Scatter plots for SC1 and TAO buoys wind speed (left) and wind direction (right) for the speed range (0 to < 3 m/s).

The RMSE (root-mean-square error) values in wind speed and direction for all wind speed ranges (0-30 m/s) are 1.22 m/s and 30.29^{o} respectively. The RMSE values for the wind speed range of 3–30 m/s are 1.14 m/s and 20.79^{o}. The SCATSAT-1 mission requirement of RMSE values in wind speed and direction are 1.8 m/s and 20^{o}for the wind speed range of 3–30 m/s. For wind speed range of 3-30 m/s SCATSAT-1 data agrees well with buoys observations. From the Fig.5 it is observer that for lower winds (<3m/s) SCATSAT-1 winds are slightly over estimated as compared with buoys. All these statistics are shown in Table I and indicate that the mission requirements for wind speed and direction are successfully met.

Table 2: Comparison of SCATSAT-1 and buoys observations (1-Nov-2016 to 31-JUL-2017)

	Wind speed range(m/s)	**SCTASAT-1 / TAO Buoys**		
		N	**RMSE**	**Correlation. Coef.**
Wind speed (m/s)	**ALL**	**4387**	**1.22**	**0.869**
	3-30	**4009**	**1.14**	**0.898**
	0-3	**378**	**1.86**	**0.14**
Wind direction (deg)	**ALL**	**4387**	**30.29**	**0.841**
	3-30	**4009**	**20.79**	**0.911**
	0-3	**378**	**77.88**	**0.57**

CONCLUSION:

The SCATSAT-1 provides ocean surface wind vectors regularly over global oceans with resolution 25km. The retrieved winds vectors from SCATSAT-1 are being assimilated in numerical weather prediction, forecast models and used in various atmospheric and oceanic models on operational basis. In order to provide an assurance of the quality of the operational SCATSAT-1 derived winds to the global user community, validation of SCATSAT-1 derived wind vectors over global ocean is performed against in situ wind observations from TAO buoys. Only off-shore buoys are considered, and their data are converted to produce 10-m equivalent neutral wind vectors. Sea surface winds from SCATSAT-1 over global oceans are evaluated against the TAO buoy winds during the period Nov-2016 to Jul-2017. The root mean square differences in the wind speed and wind direction are approximately in the range of 1.14 ms^{-1}, and 20.79^{o}respectively. The accuracies of SCATSAT-1 wind products in speed and direction are 1.8 ms^{-1}(or 10% whichever is higher) and 20^{0}. The RMS values of wind speed and direction are well within the requested SCATSAT-1 accuracies only. These statistics shows the potentiality of SCATSAT-1 to provide wind data products for the global community usage.

FEATURE COURSE OF ACTION:

In this scope of the validation study SCATAST-1 data with buoys data is not validated for inter annual climate oscillations and also over different individual global oceans how the wind accuracies are changing. This study is planned with sufficient period of SCATSAT-1 data. Time series of SCATSAT-1 data is also planned for climate variability and changes.

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