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Comparison of Oceansat-2 Winds with RAMA buoy Measurements in the Indian Ocean

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Abstract

The oceans are the potential sources of food, fuel and minerals which can support our future generations on this planet earth. They play an important role in regulating the weather and climate. Our dependence on oceans shall continue to increase in many ways. Therefore, the study of our oceans and their dynamic behaviour from space borne sensors which provides useful and widespread information to the scientific community are essential for research and development. In this regard, Oceansat-2 is the second in the series of Indian Remote Sensing (IRS) Satellite which was launched on 23 September 2009 by the Indian Space Research Organisation (ISRO), Department of Space (DOS), Government of India is currently providing wind speed and direction data (www.nrsc.gov.in) over the globe with two days repeativity. In this study, a sample Oceansat-2 winds have been compared and correlated with a selected RAMA (The Research Moored Array for African-Asian- Australian Monsoon Analysis and Prediction) buoy measurements (www.pmel.noaa.gov) in the Indian Ocean by colocating both the data in space and time. The results are quite encouraging. Such comparisons of satellite measurements with the sea truth from available locations are highly essential for validating the space borne measurements which are required for understanding the physics of the oceans, spatio-temporal variability over the oceans and predicting the atmospheric weather as well as the ocean environment, besides various other research and civilian applications.

Keywords: Oceansat-2, RAMA buoy, validation of satellite winds

Introduction

Oceans, cover 71% of our planet earth (water planet) often called as the world ocean. We have been directly or indirectly influenced by the oceans. The ocean serve us as the source of food, fuel and valuable minerals, as a vast highway for commerce, and provide a place for recreation. They are also source of energy such as wave, tidal and thermal energy which are becoming important as the demand on energy requirements is growing exponentially. Ocean water is processed to extract commercially viable drinking water, minerals such as salt, bromine, and magnesium. Although, nearly 60 valuable chemical elements have been found dissolved in ocean water, most are in dilute concentrations that their extraction is gradually becoming possible at present. Therefore, our dependance on the oceans need not be over emphasized.

The ocean and the atmosphere together control the weather and climate which we encounter in our daily life. In India, we have two important national institutes such as Indian National Centre for Ocean Information Services (INCOIS, Hyderabad) and National Centre for Medium Range Weather Forecasting (NCMRWF, Delhi) who have been entrusted with the tasks of regional ocean and weather prediction respectively. In addition, the study of the ocean and its dynamic behaviour has been an important area of research by the practitioners /scientists of earth, ocean and climate sciences in India. However, the measurement of the oceanic and marine meteorological parameters need a lot of human effort and a costly affair. Among them, wind is one of the important parameters which has a host of applications. The present day satellites are capable of providing information on ocean surface parameters on global scale. In this regard, Oceansat-2 (figure 1) is the second in the series of Indian Remote Sensing (IRS) satellite which was launched on 23 September 2009 by the Indian Space Research Organisation (ISRO), Department of Space (DOS), Government of India which is currently providing wind speed and direction data (www.nrsc.gov.in) over the globe with two days repeativity. The scatterometer onboard Oceansat-2 provides the wind information and the Ocean Color Monitor (OCM) provides color images along the satellite track. However, the data collected by the satellite need to be validated by comparing with sea truth measurements before they are accepted for research and operational applications. In this study, a sample of Oceansat-2 winds have been compared and correlated with the RAMA[1] (The Research Moored Array for African-Asian- Australian Monsoon Analysis and Prediction, figure 1) buoy measurements (www.pmel.noaa.gov) in the Indian Ocean.

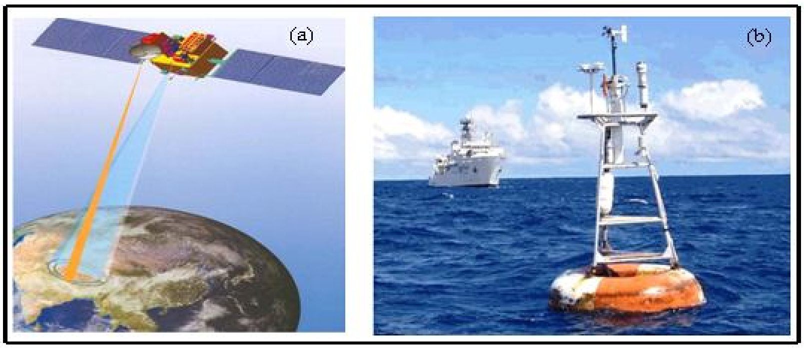

Figure 1. Photographs of (a) Indian Remote Sensing Satellite Oceansat-2 and (b) RAMA buoy deployed in the Indian Ocean.

Data and Methods

The samples of wind data from Oceansat-2 and the RAMA buoy utilised in this study have been downloaded from the internet as sited above. It may be noted that, ISRO had announced for the opportunities to carry out scientific research for the utilization of Oceansat-2 data[2] (ISRO, March 2008) which includes the validation of satellite products as one of the important area of research presently undertaken by the Indian scientists and co-ordinated by Space Application Centre (SAC, Ahmedabad). Hence, this is one of the attemps in which the available data for the period of January 2010 have been utilised for the comparison between the sea truth from one of the RAMA[1] buoy (4.0 S, 80.5 E) and the Oceansat-2 measurements. Figure 2 shows the data locations of available Oceansat-2 measurements for 2nd January 2010 which includes both ascending and descending tracks. Figure 3 shows the other locations of RAMA buoys in the Indian Ocean as of December 2008[1]. The details on Oceansat-2 and its data repeativity etc. may be seen from ISRO site[2].

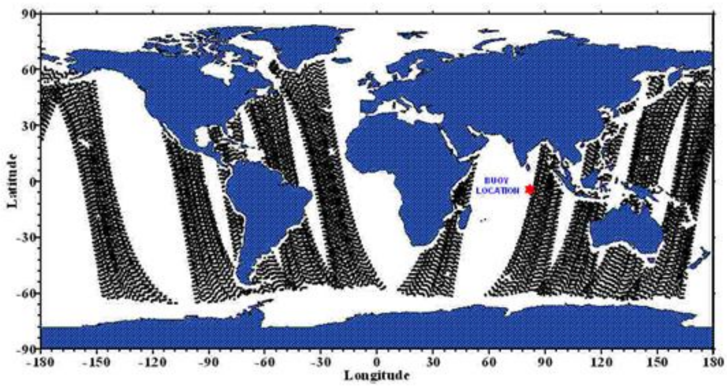

Figure 2. Global coverage of Oceansat-2 wind data (shown with black solid circles which appear as satellite tracks) for 2nd January 2010 which includes both ascending and descending tracks. Some tracks/data are missing. The RAMA buoy location is shown with a red star (4.0 S, 80.5 E).

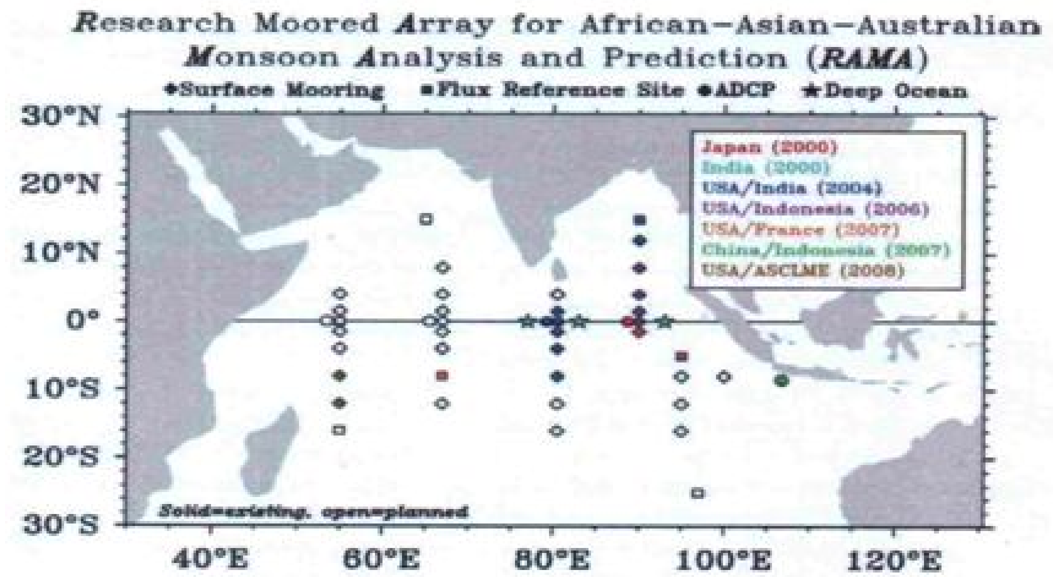

Figure 3. Schematic of RAMA buoy deployment locations shown with different shapes over the oceanic region (McPhaden et. al., 2009).

The selected RAMA buoy wind data for the month of January 2010 is available every 10 minutes as the continuous time-series with no data points missing. The time-series of winds from the buoy considered for comparison with Oceansat-2 data is plotted in figure 4 (total number of data points 4465). The same data is plotted as histogram (only wind speed) and wind rose diagram (both wind speed and direction) for analysis. Although, the buoy data is available continuously, the Oceansat-2 satellite measured wind (at 10m height) is available only once in a day and the data repeativity is once in two days. However, wind data (speed and direction) have been co-located in time and space (nearest time and nearest distance for all days) using a FORTRAN programme downloaded from internet (free source). The resultant wind data of RAMA buoy (corrected to 10m) and Oceansat-2 along with date, time and position information are shown in table-1. There were total 25 observations which have been shorted for comparison. The time and position information of Oceansat-2 wind data is only indicated in the table since buoy position is fixed and its measurements are in rounded 10 minutes during each hour. Accuracy of wind measurements[3] by RAMA buoy are given below in table-1. The comparisons of wind speed and direction for the co-located observations for buoy and satellite measurements are plotted in figure 6. The scatter plot and the linear fit between the satellite observed and sea truth are shown in figure 7.

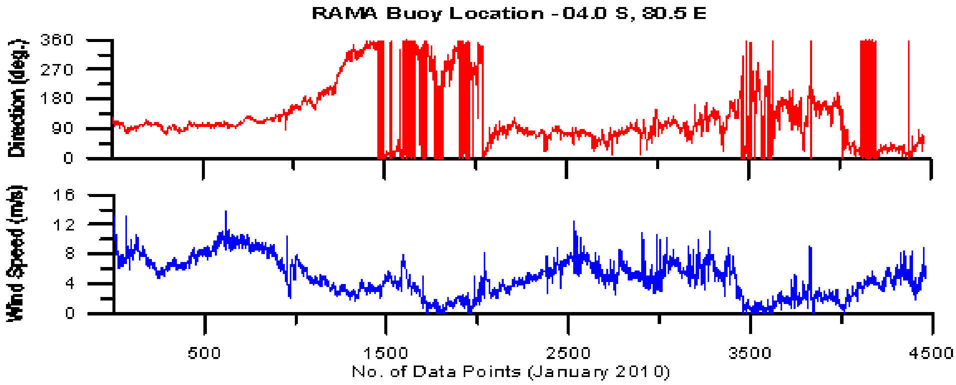

Figure 4. The observed wind variations at the buoy site for the month of January 2010.

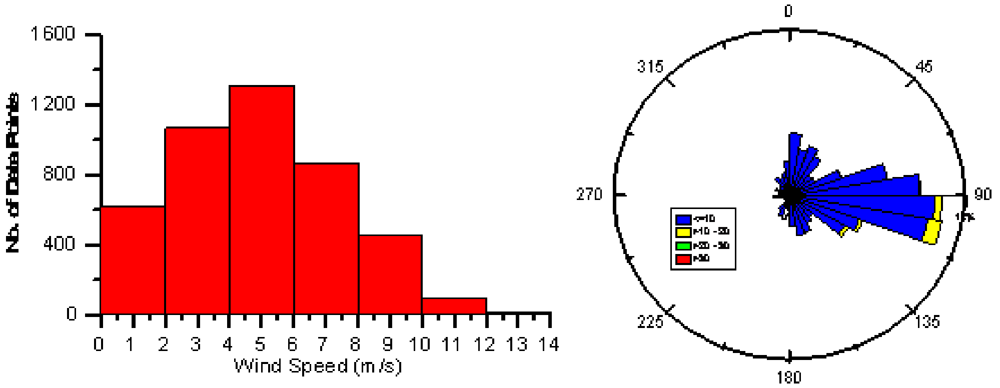

Figure 5. Histogram showing number of occurrences for different wind intervals (left) and the wind rose diagram (right) show directional distribution of wind (polar scale in degrees).

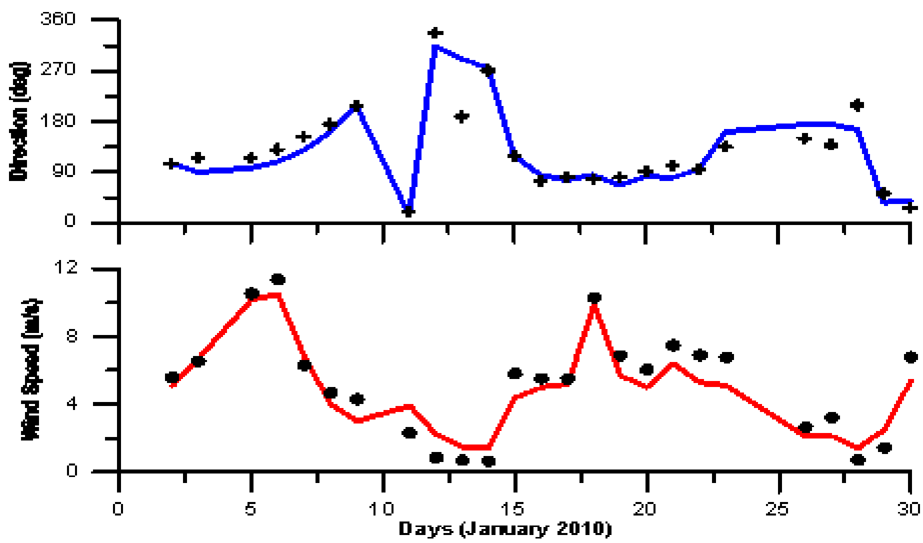

Figure 6. Comparison of daily observed RAMA buoy winds (continuous line) with the Oceansat-2 satellite winds (shown with symbols) during January 2010.

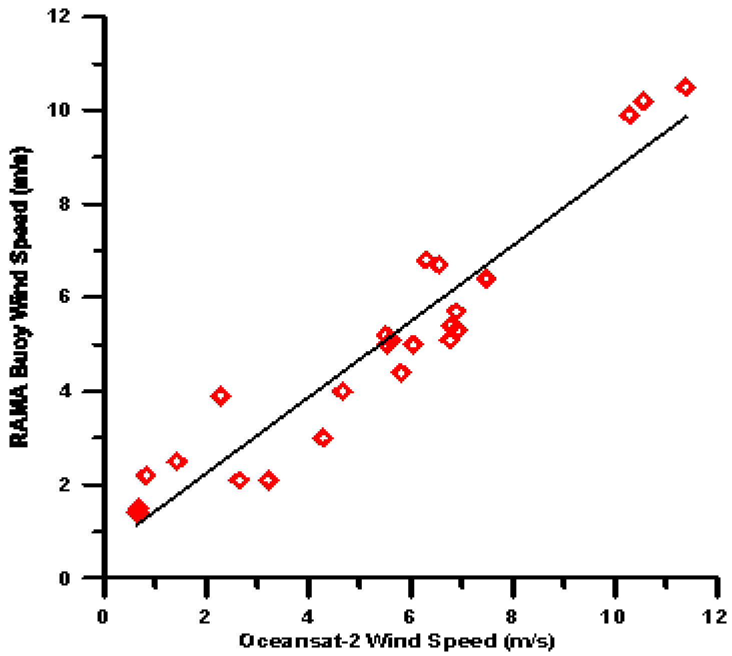

Figure 7. Scatter diagram of Oceansat-2 winds versus RAMA buoy winds and the thick straight line is the best fit for the data.

Table 1. Co-located satellite wind speed and directions for RAMA buoy (4.0 S, 80.5 E)

Sl. No.	Date	Satellite Wind Time & Location			Wind Speed (m/s)		Wind Direction (deg.)	
	YYYYMMDD	HHMM	LAT	LONG	Buoy	Oceansat2	Buoy	Oceansat2
1	20100102	1701	-4.32	80.79	5.1	5.6	105.6	104.2
2	20100103	0615	-3.81	80.24	6.7	6.6	90.0	115.4
3	20100105	0617	-3.79	80.23	10.2	10.6	97.2	114.3
4	20100106	1702	-4.30	80.74	10.5	11.4	108.0	130.1
5	20100107	0615	-3.86	80.21	6.8	6.3	128.8	152.2
6	20100008	1702	-4.29	80.73	4.0	4. 7	160.3	174.6
7	20100109	0615	-3.80	80.23	3.0	4.3	208.7	208.2
8	20100111	0615	-3.52	80.29	3.9	2.3	14.0	19.2
9	20100112	1702	-4.30	80.73	2.2	0.8	313.8	336.6
10	20100113	0615	-3.83	80.22	1.5	0.7	291.6	189.1
11	20100114	1702	-4.32	80.71	1.4	0.6	274.5	270.4
12	20100115	0615	-3.80	80.23	4.4	5.8	119.2	118.5
13	20100016	1702	-4.28	80.72	5.0	5.5	85.0	74.3
14	20100117	1728	-4.37	80.84	5.2	5.5	76.3	81.2
15	20100118	1702	-4.34	80.73	9.9	10.3	85.0	77.4
16	20100119	0615	-3.84	80.21	5.7	6.9	66.6	80.1
17	20100120	1702	-4.32	80.72	5.0	6.1	82.7	91.5

18	20100121	0615	-3.87	80.17	6.4	7.5	79.8	102.3
19	20100122	1702	-4.29	80.72	5.3	6.9	95.9	95.3
20	20100123	0615	-3.85	80.20	5.1	6.8	161.5	135.1
21	20100126	1703	-4.34	80.71	2.1	2.6	175.0	150.5
22	20100127	0615	-3.80	80.20	2.1	3.2	175.0	138.1
23	20100128	1702	-4.36	80.76	1.4	0.7	165.5	208.9
24	20100129	0618	-3.58	80.25	2.5	1.4	36.6	52.3
25	20100130	1702	-4.32	80.76	5.4	6.8	38.2	27.4

Note: RAMA buoy, wind speed: accuracy 0.3 m/s in the range 0-20 m/s, direction: accuracy ± 5 degrees. YYYY–year, HH–hour, MM–minute, LAT–latitude, LONG–longitude.

Results and Discussion

Considerable progress has been achieved in India in demonstrating the utility of satellite based remote sensing data and products for oceanographic research and applications[4]. Remote sensing of the oceans using space borne platforms is proven to be a feasible alternative for obtaining the ocean surface information in real-time for operational utilization[5]. However, as we launch a new satellite, the data and products need validation before their use by the user community. The following discussion below will deal with the analysis of observed RAMA[1] buoy winds and their use for validation of oceansat-2 winds subsequently.

The observed winds at the RAMA buoy site (4.0 S, 80.5 E) during January 2010 varied between 0 to 10 m/s (figure 4) while the wind direction varied from north to around east. Figure 4 clearly reveals that, winds were relatively steady in their direction continuously for 10 to 12 days period. The histogram (figure 5) indicates most predominant winds from 2 to 8 m/s and mean wind speed around 5 m/s. Most of the cases, winds are from around east for 70% of the time and rest of the time from around north.

The comparisons between the RAMA buoy (sea truth) and the Oceansat-2 winds as shown in figure 6 appear quite encouraging. It may be noted that, the spikes in the wind speed and direction (spurious data) as shown in figure 4 have been removed for the co-located observations considered for analysis. The estimated mean percentage error for wind speed is 12.5% and it is 8.0% for the wind direction. It may be concluded that, the satellite observed winds are quite good as they compare well with the buoy measurements.

A linear best-fit line for the data (figure 7) show a definite trend in the data distribution as they are more or less distributed evenly around the fitted line. The correlation coefficient between the RAMA[1] buoy observations and the Oceansat-2 measurements is 0.91 which is a significant finding of this study. The best fit linear equation and the associated parameters are given in table-2.

Table 2. Results of Linear Fit to data (satellite observed and buoy wind speed in m/s)

1	Equation	Equation Y = 0.62 + 0.81 * X (satellite wind – X and buoy wind – Y)
2	Parameters	Number of data points used = 25 Average X = 5.19 Average Y = 4.83 Residual sum of squares = 14.73 Regression sum of squares = 150.41 Coefficient of correlation = 0.91 Residual mean square = 0.64

Conclusions

The observed winds at the RAMA buoy site (4.0 S, 80.5 E) during the month of January 2010 varied between 0 to 12 m/s while the wind direction varied from north to east. The mean wind speed was 5.0 m/s and the most predominant wind direction was east. The estimated mean percentage error for wind speed and direction are 12.5% and 8.0% respectively. The coefficient of correlation between the RAMA buoy observations and the Oceansat-2 measurements is 0.91 which is quite significant. Such comparisons of satellite measurements with the sea truth from all available sources are highly essential for validating the space borne measurements as the high quality satellite measurements are required for research, operational and engineering applications.

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