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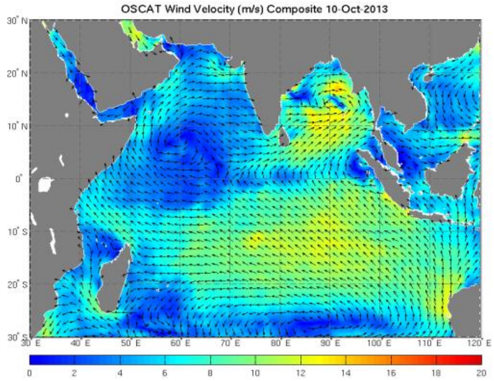
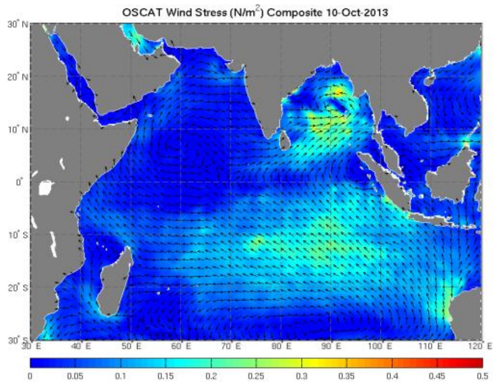
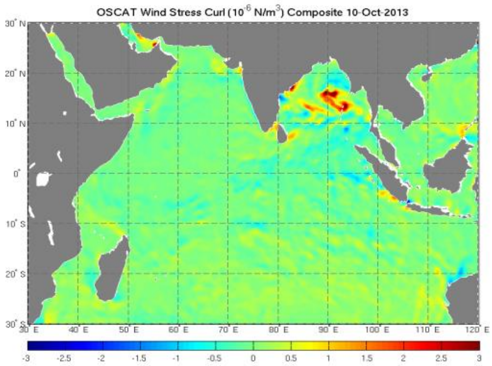
Generation and evaluation of Oceansat-2 OSCAT 25km wind fields







Ocean Sciences Group
Earth and Climate Science Area
NATIONAL REMOTE SENSING CENTRE
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15	Gridded, gap-free two-day moving average Wind fields, Wind stress and Wind Stress Curl for Indian Ocean have been generated at $25km$ resolution from Oceansat-2 scatterometer wind data products using DIVA interpolation procedures for the period of 2010 - 2013. Since OSCAT is currently not in operation, this exercise is carried out to provide good quality data for the entire operational period of OSCAT (2010 – 2013) and can serve as a precursor for future scatterometer missions of ISRO. Intercomparison of this product with ASCAT data for 2013 has been conducted daily, weekly, monthly and annually with correlation values around 0.72 in all cases. It compares well in both annual and seasonal time scales. Validation with RAMA buoy for six different locations has been done and RMSErr value is around $1.5ms^{-1}$ for all cases. *Key words:* Variational analysis, OSCAT, ASCAT, DIVA	

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Generation and Evaluation of Oceansat-2 OSCAT 25km Wind Fields

1 Abstract

Gridded, gap-free two-day moving average Wind fields, Wind stress and Wind Stress Curl for Indian Oceanhave been generated at $25km$ resolution from Oceansat-2 scatterometer wind data products using DIVA interpolation procedures for the period of 2010 - 2013. Since OSCAT is currently not in operation, this exercise is carried out to provide good quality data for the entire operational period of OSCAT (2010 – 2013) and can serve as a precursor for future scatterometer missions of ISRO. Intercomparison of this product with ASCAT data for 2013 has been conducted daily, weekly, monthly and annually with correlation values around 0.72 in all cases. It compares well in both annual and seasonal time scales. Validation with RAMA buoy for six different locations has been done and RMSErr value is around $1.5ms^{-1}$ for all cases.

2 Introduction

Surface winds over global oceans drive heat and momentum transfer between the ocean and atmosphere, thereby forcing the surface circulation of the oceans. Sea surface wind is one of the main inputs for operational oceanography as well as climate studies in terms of improving weather forecasting using numerical weather prediction models (*Bentamy and Fillon et. al., (2012)* [1]; *Mathew et al., (2012)* [2]). Over a period of time, with the improvement in sensor technology, surface winds over the oceans are being measured by employing different sensors starting from wind anemometers fixed on moored buoys and ships to Radars and space based scatterometers. OSCAT is a scatterometer onboard ISRO's Oceansat-2 mission. The scatterometer was operational till February 2014 providing ocean surface wind speed and direction for the period of its operation i.e., September 2009 - February 2014.

Wind stress distribution over the ocean surface is an important factor for identifying areas of upwelling/downwelling (*R.M. Castelao and J.A. Barth et. al., (2006)* [3]). The curl of wind stress is helpful in identifying areas of cyclogenesis (*Neeru Jaiswal and C.M. Kishtawal et. al., (2006)* [4]) and their propagation and useful in several operational oceanographic applications such as water mass transport, mapping of PFZ (*V.N. Agostini and Andrew Bakun et. al., (2002)* [5]).

3 Data and Methodology

3.1 Satellite Data

OSCAT daily global data of wind speed and direction (Version 1.4) for L3W products with a spatial resolution of $25km \times 25km$, is obtained from the Oceansat-2 data portal of National Remote Sensing Centre (NRSC) [www.nrsc.gov.in] for the period 2010 - 2013. OSCAT has a repeat cycle of two days with the equatorial crossing time of 12 PM $\pm$ 10 minutes orbiting at an altitude of $720km$ and inclination of $98.25°$. Wind speed and direction are converted to u and v components of the wind vector for this study.

3.2 DIVA

GeoHydrodynamic and Environmental Research (GHER) under the SeaDataNet project of the European Union had developed DIVA (*Troupin et al. (2010)* [6]). DIVA is equipped with automatic coastline detection based on the numerical coast which is independent of the number of observations. Outliers are detected by comparing data residual with the standard deviation (SD) of the resultant data (*Troupin et al. (2010)* [6]). The error component within the output is generated for each grid cell and can be used based on the limits set by the user which is usually less than 0.3. During the study period (2010 – 2013), computing the two day moving average, if the data is missing for one of the days, then data for the set of those two days is not generated.

The input file for diva contains three columns namely latitude, longitude and zonal/meridonial component of wind velocity. Parameter file is initiated at 30.125° E and 29.875° S with a step distance of 0.25° in each direction. The correlation length L is taken to be 3 while signal to noise ratio is 0.3.

3.3 Method

3.3.1 Wind Stress

The horizontal force of the wind on the sea surface is called the wind stress, denoted by τ. It can also be defined as the tangential (drag) force per unit area exerted on the surface of the ocean (earth) by the adjacent layer of moving air.

To estimate surface wind stress (τ) for each scatterometer wind value, the following relation based on (*Catelao et. al., (2006)*) has been used:

$$\tau = C_D W^2$$

Zonal and Meridional wind stress components are computed as:

$$\tau_x = \rho_{air} C_D W^2 sin\rho \qquad \tau_y = \rho_{air} C_D W^2 cos\rho$$

Where,
ρ is the density of air ($1.2 kgm^{-3}$).
C_D is a dimensionless coefficient called drag coefficient.
W is the wind speed.
θ is the angle of the wind vector from true north.

Drag coefficient depends on the roughness of the surface and the lapse rate. The drag coefficient C_D for the ocean surface has a non-linear relation with the wind speed, which generally increases with wind speed.

3.3.2 Wind Stress Curl

The curl is a measure of the rotation of a vector fiels. Wind Stress Curl (WSC) is the measure of the rotation of the wind stress (or ocean surface circulation).

WSC is computed using the following basic relation :

$$\nabla \times \tau = \frac{\partial \tau_y}{\partial x} - \frac{\partial \tau_x}{\partial y}$$

Where,
τ_x is the Zonal wind stress.
τ_y is the meridional wind stress.

WSC is a vector quantity with its direction pointing parallel to the z-axis. Following right-hand rule, positive value of curl implies counter-clockwise circulation, and negative curl is for clockwise circulation. Cyclones in the northern hemisphere have positive curl, whereas cyclones in the southern hemisphere have negative curl.

All the Wind Stress and its curl products are generated for the Indian Ocean with the spatial resolution of 0.25° × 0.25°. MATLAB tools have been used for the computation and generation of output products. Two-day moving average has been taken for the computation of fields on a particular day. Like calculation for 4^{th} July would consider two-day moving average of 3^{rd} and 4^{th} July. The following steps have been adopted for the derivation of products:

STEP 1 - Using DIVA for estimating two-day wind composites:
Two-day wind composites (moving average) have been generated by interpolating OSCAT L3W wind data using Variational Inverse Method (VIM, in-built in DIVA). Zonal and meridional wind components with their respective error fields have been estimated and provided in the output NetCDF data files. For error estimation, Clever poor man error estimation method has been used (*Mathew et. al., (2012)* [2]). It is recommended to use wind fields with error values less than 0.3.

STEP 2 - Computation of Wind Stress components:
For the computation of wind stress, a non-linear drag coefficient (C_D) based on (*Large and Ponds et. al., (1981)* [7]), modified for low wind speeds is used. It is defined as:

$$C_D = \begin{cases} 0.00218, & W(\text{wind speed}) \leq 1ms^{-1} \\ (0.62 + 1.56/W) \times 0.001, & 1ms^{-1} < W < 3ms^{-1} \\ 0.00114, & 3ms^{-1} < W < 10ms^{-1} \\ (0.49 + 0.065W) \times 0.001, & W \geq 10ms^{-1} \end{cases}$$

And the wind stress components have been computed as:

$$\tau_x = \rho_{air} C_D W * U \qquad \tau_y = \rho_{air} C_D W * V$$

Where;
τ_x is Zonal wind stress
τ_y is Meridional wind stress
ρ_{air} is Density of air ($1.2kgm^{-3}$)
W is Wind speed
U is Zonal wind component
V is Meridional wind component

For the computation of wind stress, error fields are not taken into consideration (i.e. wind stress has also been computed for wind fields with error values more than 0.3). Zonal and meridional wind stress components have been provided in the output NetCDF data file.

STEP 3 - Computation of Wind Stress Curl:
The stress curl, $\nabla \times \tau$ at each 0.25×0.25 grid cell is then estimated from the resultant wind stress fields as follows:

$$\nabla \times \tau = \frac{\tau_y(i, j+1) - \tau_y(i, j-1)}{2D_x} - \frac{\tau_x(i+1, j) - \tau_x(i-1, j)}{2D_y}$$

Where,
$\tau_x$and τ_y are the zonal and meridional components of the wind stress vector.
i and j are the row and column index of the current grid cell.

D_x and D_y are the width (parallel to longitude) and height (parallel to latitude) of the current grid cell. ($D_y = 27,780m$).

In the output images, the scale of the colorbar for wind stress and wind stress curl varies from 0 to $0.35Nm^{-2}$ and -1 to $1 \times 10^{-6}Nm^{-3}$ respectively. The latitude-longitude values defined in the output file are the centre of the grid cells.

4 Products Information

For the computation of wind stress and wind stress curl, two-day composite (using DIVA) of OSCAT wind products have been used. The products are generated for the Indian Ocean at the spatial resolution of 0.25×0.25. In this section, an elaborate description of wind stress curl data products and methodology is provided.

4.1 Flow Chart of Algorithm

The output data files are available in NetCDF (.nc) format. The images are provided in PNG image format. Figure 1 presents the flow diagram of the procedure followed for generation of daily composites of OSCAT wind fields, wind stress and wind stress curl.

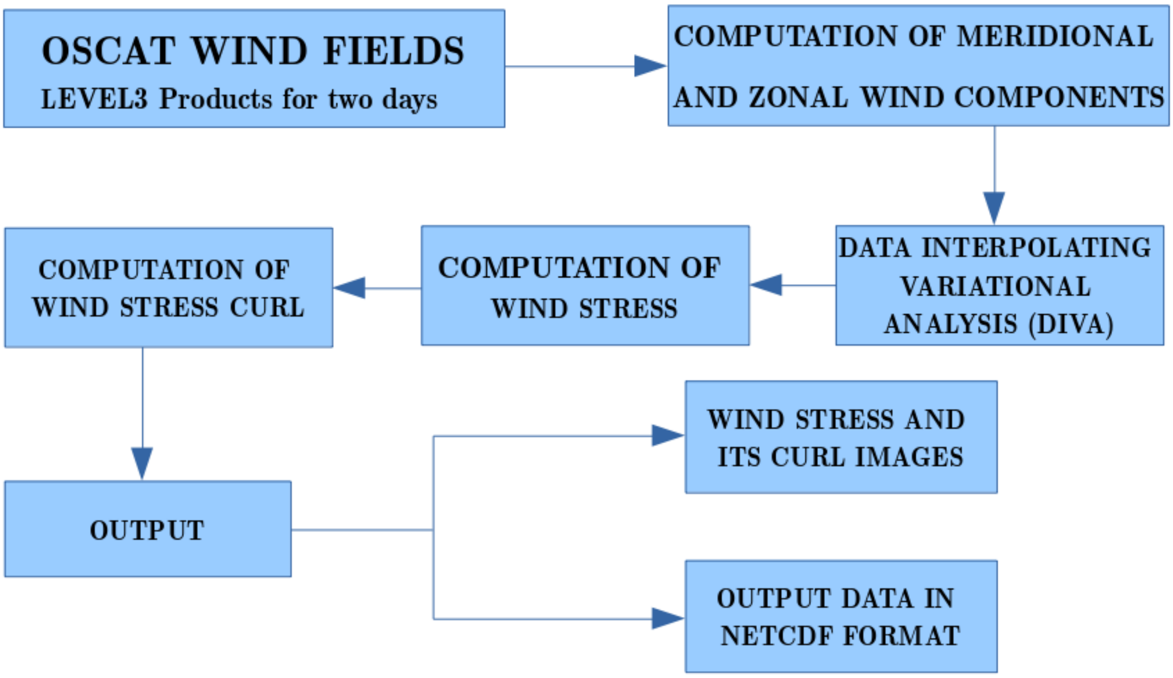

Figure 1: Flow diagram of the Wind Stress and Wind Stress Curl computation using OSCAT data.

4.2 Naming Convention

Input and output file naming conventions are mentioned below:

Input file:
Level 3WW : S1L3WWYYYYDDD.h5

Output data file:
Daily Composite : S1L3WSCYYYYMMDD_25.nc

Output images:
Daily Composite : S1L3TTTYYYYMMDD_25.png

Where,
YYYY : The calendar year when data was acquired.
MM : The month when data was acquired.
DD : The day of the month when data was acquired.
DDD : The day of the year when data was acquired.
TTT : Product Type (WSW $\rightarrow$ Surface winds, WST $\rightarrow$ Wind Stress, WSC $\rightarrow$ Wind Stress Curl).

For input file, the date 1^{st} January 2013 corresponds to day number 001, and 31^{st} December 2013 corresponds to day number 365. For more information on OSCAT-2 products, visit http://www.nrsc.gov.in/

5 Sample Products

In this section, different output products have been discussed using sample images. In the following images, Eckert IV projection of the world map has been used. The grid cell size is 0.25×0.25. The title of the image consists of following parameters:

1. OSCAT – Oceansat-2 Scatterometer.
2. Wind parameter shown. (Wind Velocity, Wind Stress or Wind Stress Curl)
3. Observation dates.

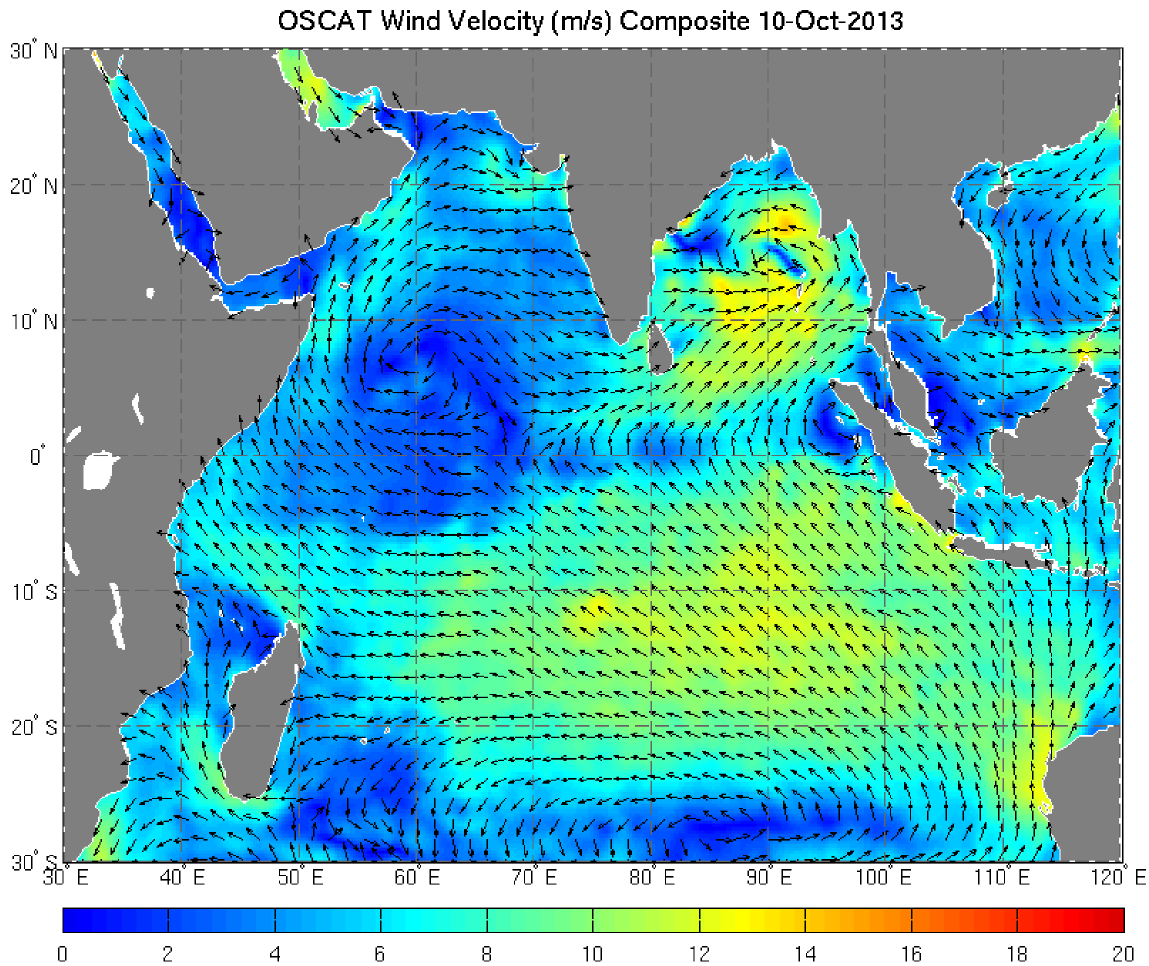

Figure 2: Image of wind velocity composite for 9^{th} and 10^{th} October, 2013 during Cyclone Phailin.

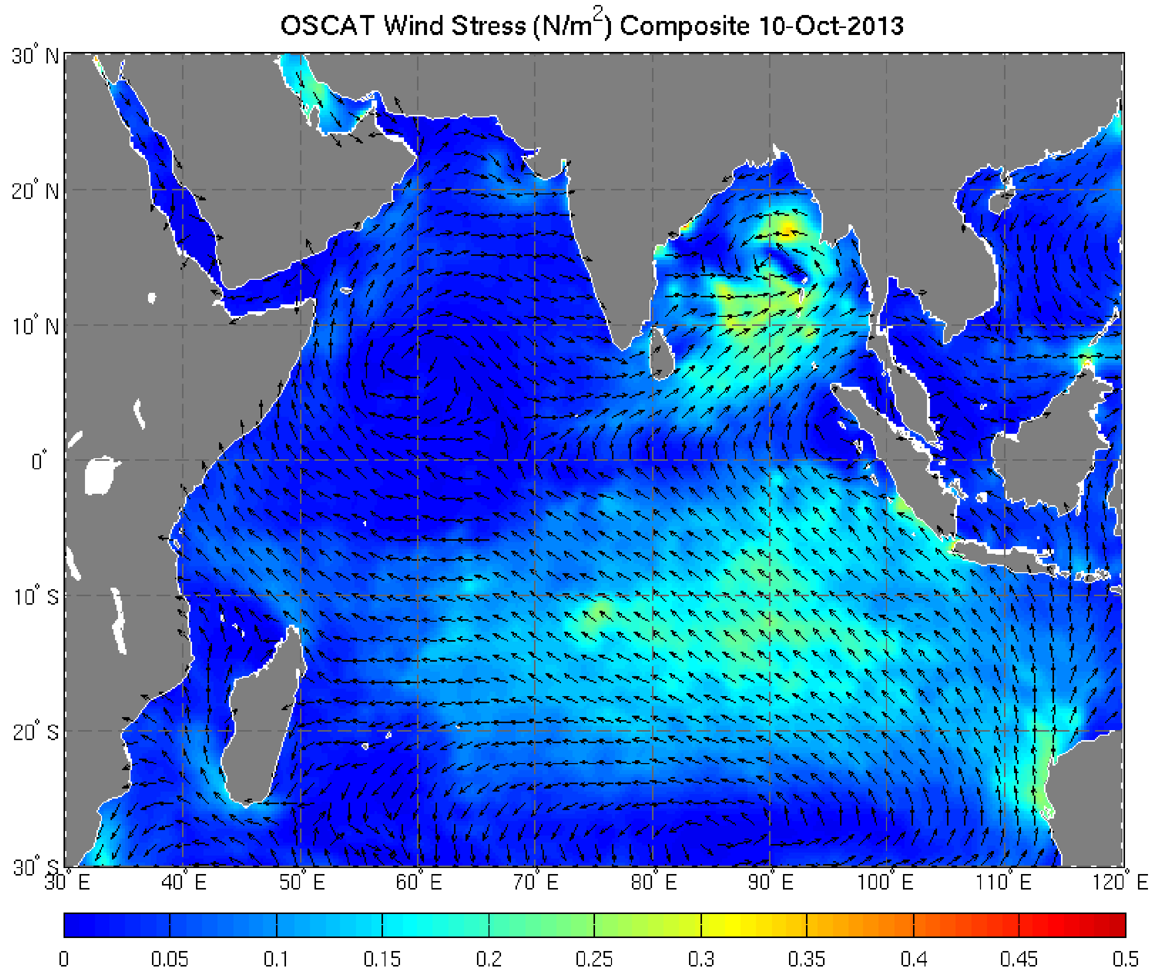

Figure 3: Image of wind stress composite for 9^{th} and 10^{th} October, 2013 during Cyclone Phailin.

Originating from an area of low pressure over the Gulf of Thailand on October 4, 2014, Cyclone Phailin travelled through the Bay of Bengal and made landfall in the Odisha coast on October 12 as a very severe Cyclonic Storm with peak winds of 260 $km\,hr^{-1}$. The images show the wind field, wind stress and wind stress curl composites for Cyclone Phailin as observed by OSCAT. The inner parts of the cyclone (see Figure 3 and 4) indicate high stress and curl of about $0.4Nm^{-2}$ and $2.5 \times 10^{-6}Nm^{-3}$ respectively.

6 Validation and Intercomparison with in-situ data and ASCAT

Wind velocity from OSCAT, 2013 was compared to ASCAT, 2013 (both calculated using DIVA).

2013(mode)	r_u	r_v	r_w	Bias$_u$	Bias$_v$	Bias$_w$	RMSErr$_u$	RMSErr$_v$	RMSErr$_w$
Annualy	0.761	0.759	0.727	−0.193	−0.008	−0.147	2.3	1.55	2.03
Monthly	0.758	0.753	0.72	−0.194	−0.012	−0.136	2.3	1.61	2.08
15 day	0.764	0.76	0.727	−0.205	−0.013	−0.163	2.34	1.46	1.99
Weekly	0.764	0.759	0.727	−0.204	−0.012	−0.163	2.34	1.46	1.99

Comparison statistics between ASCAT and the two-day composite of OSCAT is carried out to evaluate the quality of two-day composite winds. The correlation shows that both the datasets

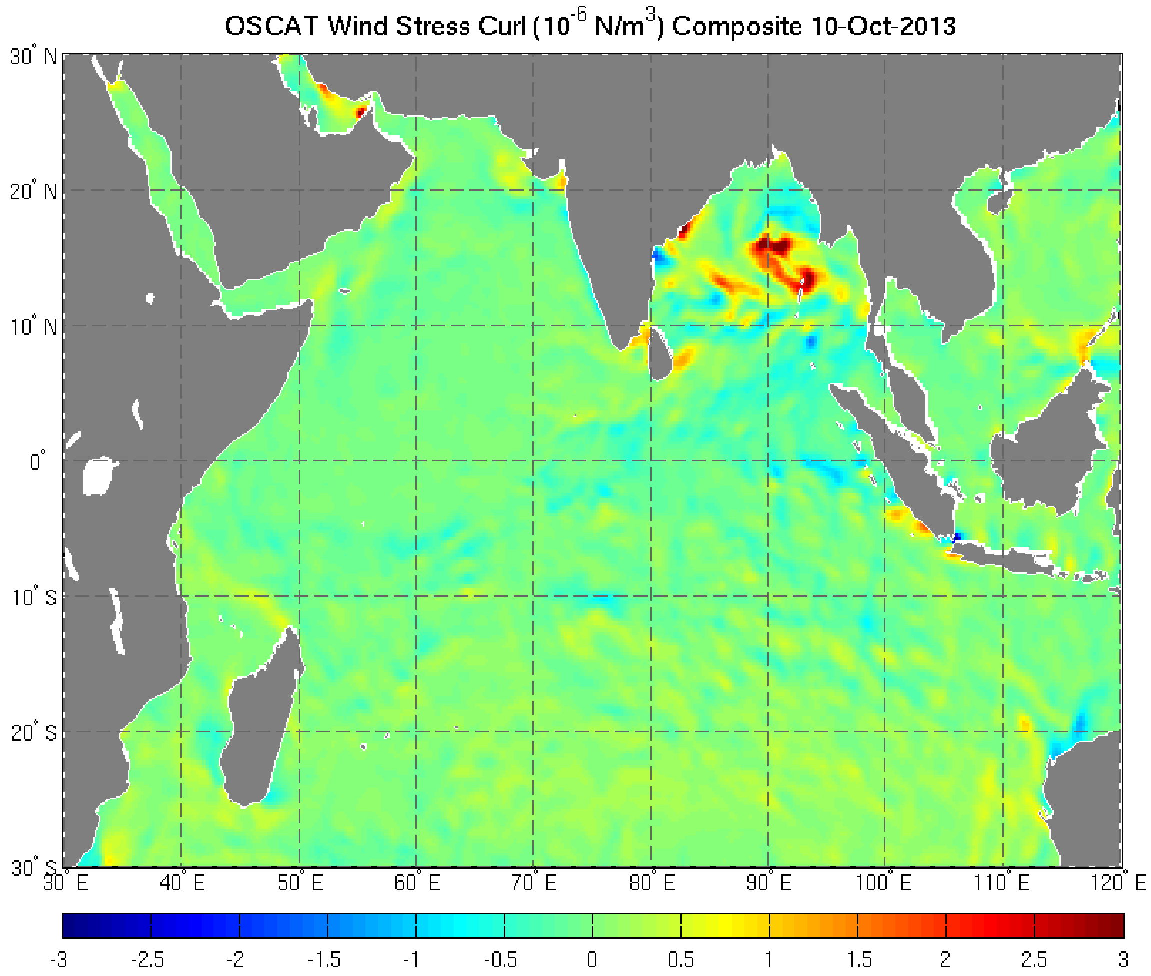

Figure 4: Image of wind stress curl composite for 9^{th} and 10^{th} October, 2013 during Cyclone Phailin.

match well with each other. From the negative bias value for u and v, it is understood that the interpolated OSCAT product is overestimated compared to ASCAT. Root Mean Square Error (RMSErr) in all the cases is around or equal to $2ms^{-1}$.

Wind velocity data generated using DIVA method for 2011 is compared with in-situ observations (RAMA buoy data). Zonal and meridional components of winds are compared at six different locations and RMSErr in almost all the cases is found out to be around $1.5ms^{-1}$. From the scatter plot (Figure 5 and 6), it is observed that the DIVA interpolated OSCAT data and the in situ observations are in good correlation with each other.

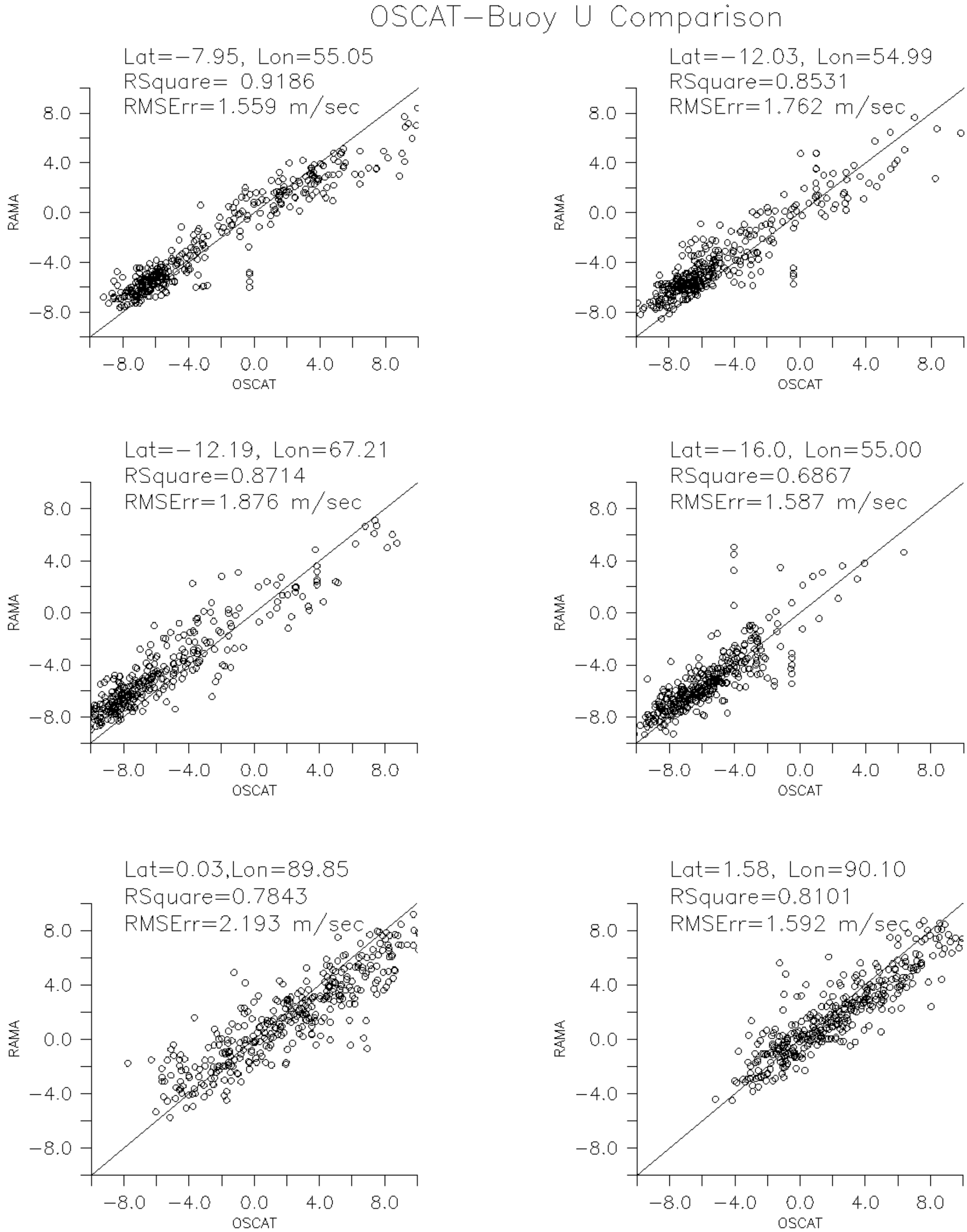

Figure 5: Scatter diagram between Buoy and OSCAT observations of Zonal winds.

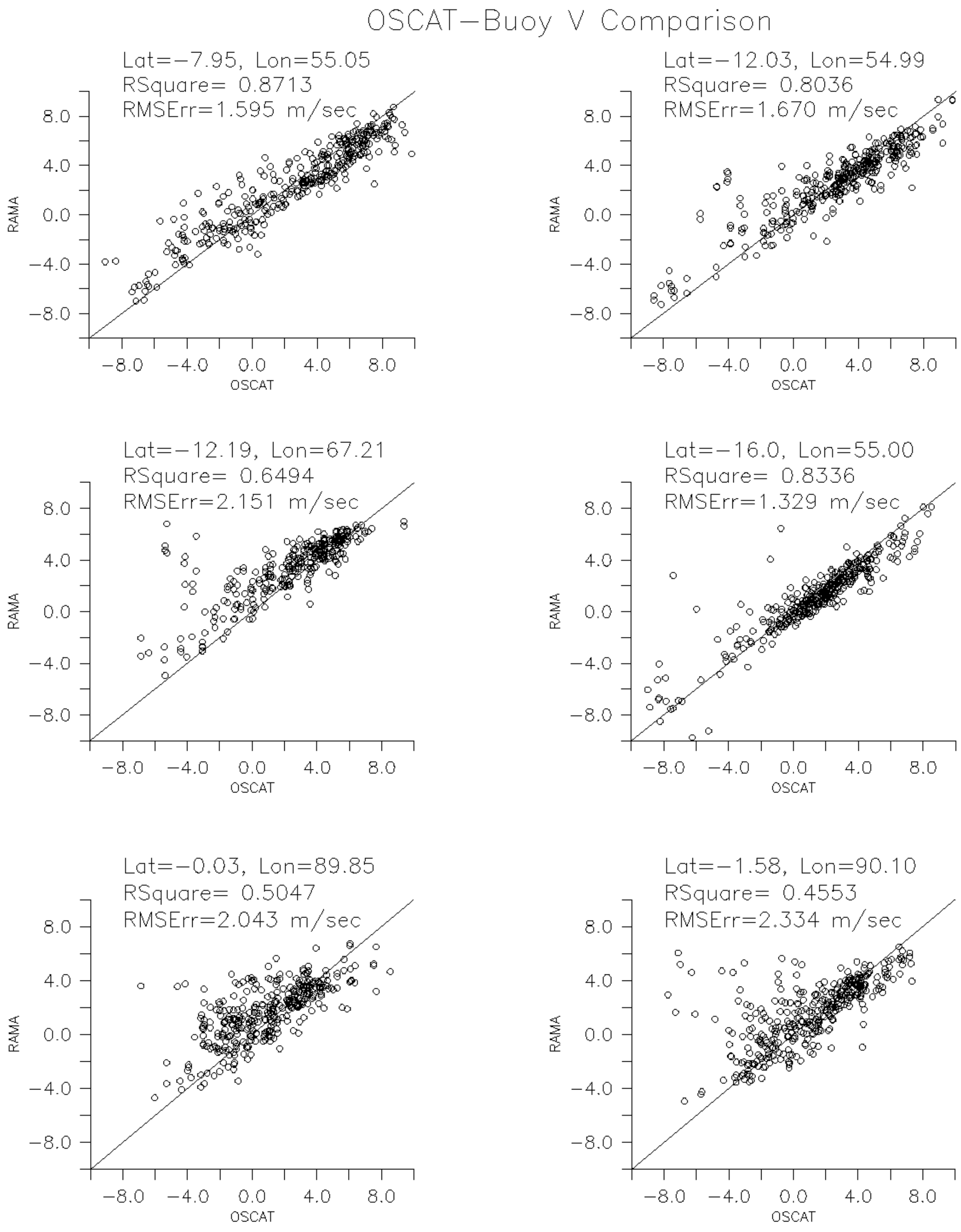

Figure 6: Scatter diagram between Buoy and OSCAT observations of Meridional winds.

7 Conclusion

The products of Wind fields, Wind Stress and Wind Stress Curl composite have been generated using OSCAT wind data ($25km$ resolution) and Data-Interpolating Variational Analysis (DIVA) method. These data products have been processed for the period of four years (January 2010 to December 2013).

8 Acknowledgement

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References

[1] Bentamy A. and Croize-Fillon D. Gridded surface wind fields from Metop/ASCAT measurements. *International Journal of Remote Sensing*, 33:1729–1754, 2012.

[2] Mathew T. Chakraborty A. Sarkar A. and Raj Kumar. Comparison of oceanic winds measured by space-borne scatterometers and altimeters. *Remote Sensing Letters*, 3:715–720, 2012.

[3] Castelao R.M. and Barth J.A. Upwelling around Cabo Frio, Brazil: The importance of wind stress curl. *Geophysical Research Letters*, 33(3), 2006.

[4] Neeru Jaiswal and Kishtawal C.M. Prediction of Tropical Cyclogenesis Using Scatterometer Data. *IEEE transactions on Geoscience and Remote Sensing*, 49(12), 2006.

[5] Agostini V.N. and Bakun A. Ocean triads' in the Mediterranean Sea: Physical mechanisms potentially structuring reproductive habitat suitability. *Fisheries Oceanography*, 11(3):129–142, 2002.

[6] Troupin C. Machin F. Ouberdous M. Sirjacobs D. Barth A. and Beckers J.M. High resolution climatology of the northeast Atlantic using Data Interpolating Variational Analysis (DIVA). *Journal of Geophysical Research*, 115, 2010.

[7] Large W.G. and Pond S. Open Ocean Measurements in Moderate to Strong Winds. *Journal of Physical Oceonography*, 11:324–326, 1981.

Ocean Sciences Group

Earth and Climate Sciences Area

National Remote Sensing Centre

Indian Space Research Organisation

Department of Space

Government of India

Balanagar, Hyderabad-500037, INDIA