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15.	**Abstract:** Wind velocity, Wind stress and Wind Stress Curl global products have been computed from 2-Day wind composites, generated using SCATSAT L3 wind data. In the process of wind stress computation, Large and Pond (1981) drag coefficients are used. While wind stress curl has been estimated using cross directional differential of wind stress. In the process, MATLAB tools are used to compute and map in standard formats with 50 km and 25 km resolution. In this report, we summarize the computation of products of Wind velocity, Wind Stress and Wind Stress Curl and generation of 'png' images and Netcdf data files of these derived parameters. **Key Words:** SCATSAT, *Scatterometer, Wind Stress, Wind Stress Curl, DIVA and MATLAB.*			

Contents

1. Abstract 3

2. Introduction 3

3. Product Evolution 6

4. Sample Products 9

6. Validation 12

7. Conclusion 13

1. Abstract

Wind velocity, Wind stress and Wind Stress Curl global products have been computed from 2-Day wind composites, generated using SCATSAT L3 wind data. In the process of wind stress computation, Large and Pond (1981) drag coefficients are used. While wind stress curl has been estimated using cross directional differential of wind stress. In the process, MATLAB tools are used to compute and map in standard formats with 50 km and 25 km resolution. In this report, we summarize the computation of products of Wind velocity, Wind Stress and Wind Stress Curl and generation of 'png' images and Netcdf data files of these derived parameters.

2. Introduction

The Earth and Climate Science Area (ECSA) of National Remote Sensing Centre (NRSC), at the Indian Space Research Organisation (ISRO) is engaged in the process of generating scientific long term geophysical parameter from the space based sensors to study climate variability under National Information System for Climate and Environment Studies (NICES). In this regard, it is planned to create a database of wind velocity, wind stress and wind stress curl from scatterometer wind fields to support the climatic studies. The objective of the present document is to provide details of the above products of SCATSAT to the user community for their further utilization in the ocean and atmospheric studies, including climatic database.

2.1 SCATSAT

SCATSAT-1 is an OceanSat-2 follow-up mission, actually a gap-filler mission between OceanSat-2 and 3, at ISRO. It is launched in September 2016, with the objective to continue the global ocean wind vector data acquisition started by the OSCAT (OceanSat-2 Scanning Scatterometer). The information of global ocean surface winds is an important ingredient for weather forecast.

- **SCATSAT Scatterometer** – SCATSAT, ku-band (13.515 GHz) scatterometer, is a conically scanning pencil beam scatterometer which is designed and developed at ISRO/Space Apllication Centre (SAC), Ahmedabad. SCATSAT covers a continuous swath of 1400 km for inner beam and 1840 km outer beam respectively, and provides a ground resolution of 25 × 25 km. SCATSAT provides global ocean coverage with a revisit time of 2 days.

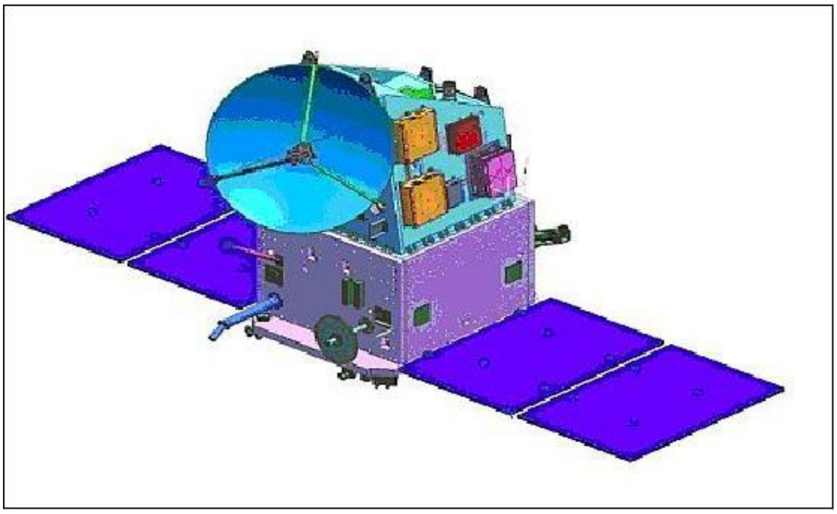


Figure 1: Image view of SCATSAT.

The details of SCATSAT data and their format can be acquired from ISRO with respective web sites of SAC and NRSC, Hyderabad and also the product handbook [Ref. 1].

2.2 Scatterometer Wind

A radar scatterometer is designed to determine the normalized radar cross-section (σ^0) of the surface, by transmitting microwave pulses and measuring the backscattered power. Since the atmospheric effect is least on radiation emitted and received by the radar signal, scatterometer helps in measuring wind velocity over the ocean. Wind stress over the ocean generates ripples (small waves), which makes the sea surface rough. This rough sea surface modifies the radar cross-section (σ^0) of the ocean surface and hence, the magnitude of backscattered power.

Surface winds over oceans play vital role in several operational oceanographic, atmospheric climatological studies for improved numerical weather prediction, forecast, monsoon and cyclones related studies. Winds are one of the basic forcing parameter in driving the upper ocean circulation. Wind velocity, Wind stress and wind stress curl information is required in the major ocean circulation models, and these are computed from the sea surface wind field.

The force of the wind, parallel to the surface, exerted on the sea surface is called the wind stress. It is the vertical transfer of horizontal momentum. Thus momentum is transferred from the atmosphere to the ocean by the wind stress. Wind stress is computed using bulk formulae based on the standard meteorological data. Scatterometer wind data provide high-resolution surface forcing information for the analysis of global ocean-atmosphere processes.

The Wind Stress Curl (WSC) is the rotational motion of winds at the sea surface. For reference, imagining strong wind blowing northward at one location and weaker wind right to it. The water at the first location moves to right, and it does so faster than the water at the second location. The water converges at the second location, pushing the water downward. This is how the curl of the wind stress is related to water convergence and hence being water pushed up or down. Positive WSC pulls the water up and negative WSC pushes it down. Its fluctuations influences the sea surface temperature (SST) such as cooling the sea surface during positive wind stress curl and warming during negative wind stress curl and relaxation periods [Ref. 2].This relationship between WSC and SST is strongly correlated to the upwelling and down-welling [Ref. 3].In the present study wind vector fields from scatterometer on-board SCATSAT Satellite are utilized. Our goal is to provide global wind velocity, wind stress and wind stress curl composites on daily basis.

There are three levels of data products available from SCATSAT: Level-1B (Raw data), Level-2 (Along-track data) and Level-3 (Global gridded data).

The SCATSAT data from NRSC website is available in HDF (.h5) file format. For our computation, we have used 2-Days composites of wind vector fields as generated using DIVA (Data Interpolation and Variational Analysis) techniques on SCATSAT L3 products.

3. Products Evolution

For the computation of wind stress and wind stress curl, 2-Days composite (using DIVA) of SCATSAT wind products have been used. The products are generated for the Global Ocean at the spatial resolution of $0.25^{o}\times 0.25^{o}$ and $0.50^{o}\times 0.50^{o}$. In this section, an elaborate description of wind, wind stress and its curl data products and methodology is provided.

The output data files are available in NETCDF (.nc) format. The images are provided in PNG image format. Figure 2 presents the flow diagram of the procedure followed for generation of daily composites of SCATSAT wind fields, wind stress and wind stress curl.

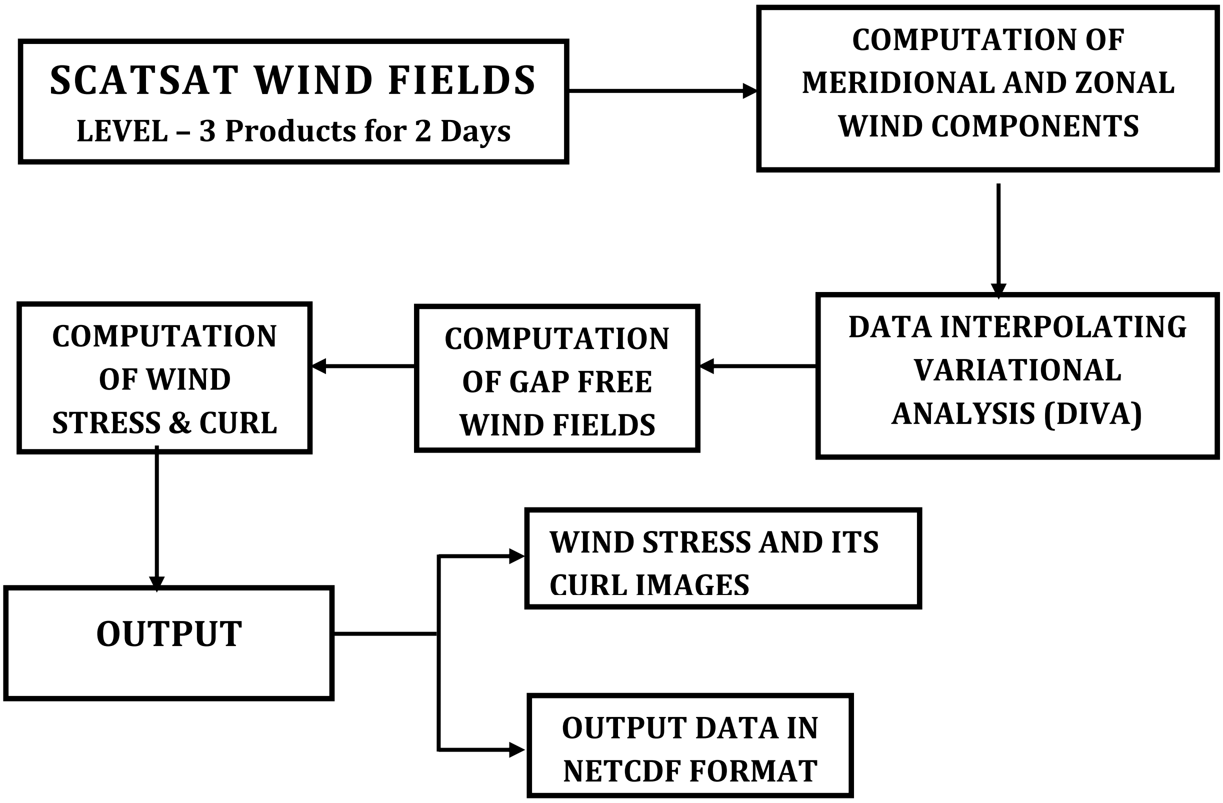


Figure 2: Flow diagram of the Wind Stress and Wind Stress Curl computation using SCATSAT data.

3.1 Methodology

All the Wind velocity, Wind Stress and its curl products are generated for the Global Ocean with the spatial resolution of $0.25^o \times 0.25^o$ and $0.5^o \times 0.5^o$. MATLAB tools have been used for the computation and generation of output products [Ref. 4]. The following steps have been adopted for the derivation of products:

<u>STEP 1- Using DIVA for estimating 2-days wind composites</u>: 2-days wind composites have been generated by interpolating SCATSAT L3 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 [Ref. 7].**It is recommended to use wind fields with error values less than 0.3.**

<u>STEP 2- Computation of Wind Stress components</u>: For the computation of wind stress, a non-linear drag coefficient (C_D) based on [Ref. 5], modified for low wind speeds [Ref. 6] is used. It is defined as:

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

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 → Zonal Wind Stress

τ_y → Meridional Wind Stress

ρ_{air} → Density of air (~1.2 Kg/m^3)

W → Wind Speed

U → Zonal Wind component

V → Meridional Wind component

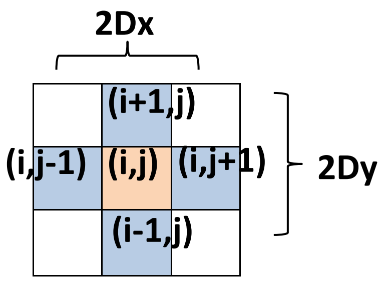
For the computation of wind stress, error fields are not taken into consideration (i.e. wind stress has also been computed for wind fields with error values more than 0.3). Zonal and meridional wind stress components have been provided in the output netcdf data file.

STEP 3- Computation of Wind Stress Curl: The stress curl, ***curl (τ)*** at each 0.25°×0.25°grid cell is then evaluated from the resultant wind stress fields as follows:

$$curl(\tau) = \frac{\tau y(i,j+1) - \tau y(i,j-1)}{2Dx} - \frac{\tau x(i+1,j) - \tau x(i-1,j)}{2Dy}$$

Where, **τx** and **τy** 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. (as shown in figure)
- **Dx** and **Dy** are the width (parallel to longitude) and height (parallel to latitude) of the current grid cell.



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

4. 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 $0.25^{o}\times0.25^{o}$ and $0.5^{o}\times0.5^{o}$. The title of the image consists of following parameters:

I. SCATSAT
II. Wind parameter shown. (Wind Velocity [Fig. 3], Wind stress[Fig. 4] / wind stress curl[Fig. 5])
III. Units and scale. (m/s, N/m^2or 10^{-6} N/m^3)
IV. Observation dates.

The above products have been generated from the start day of dissemination of SCATSAT data (October 16, 2016) till date.

4.1 2-Days Composite Products

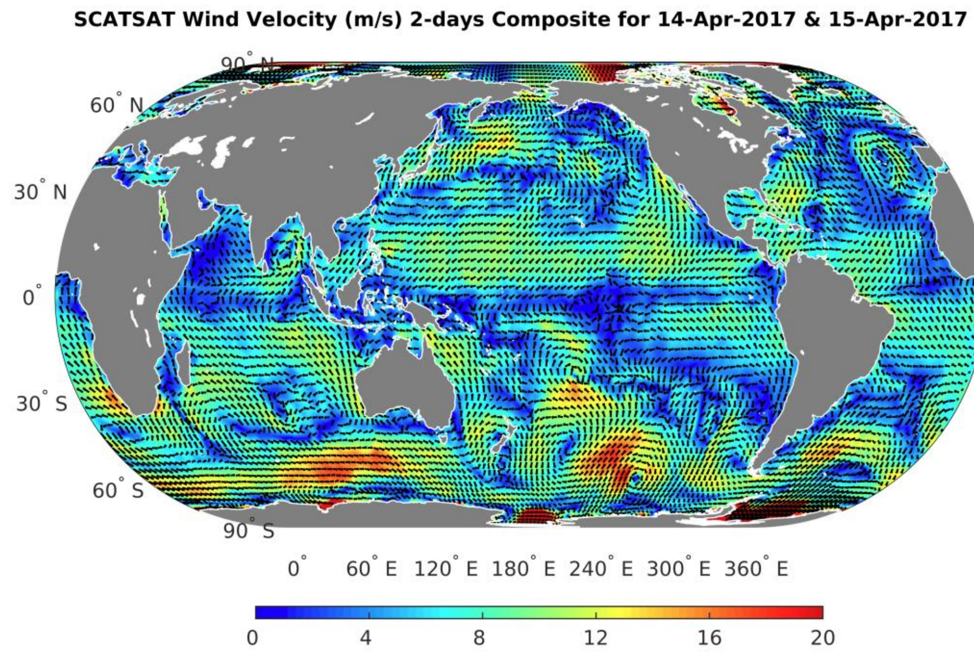


Figure 3: Image of wind velocity composite.

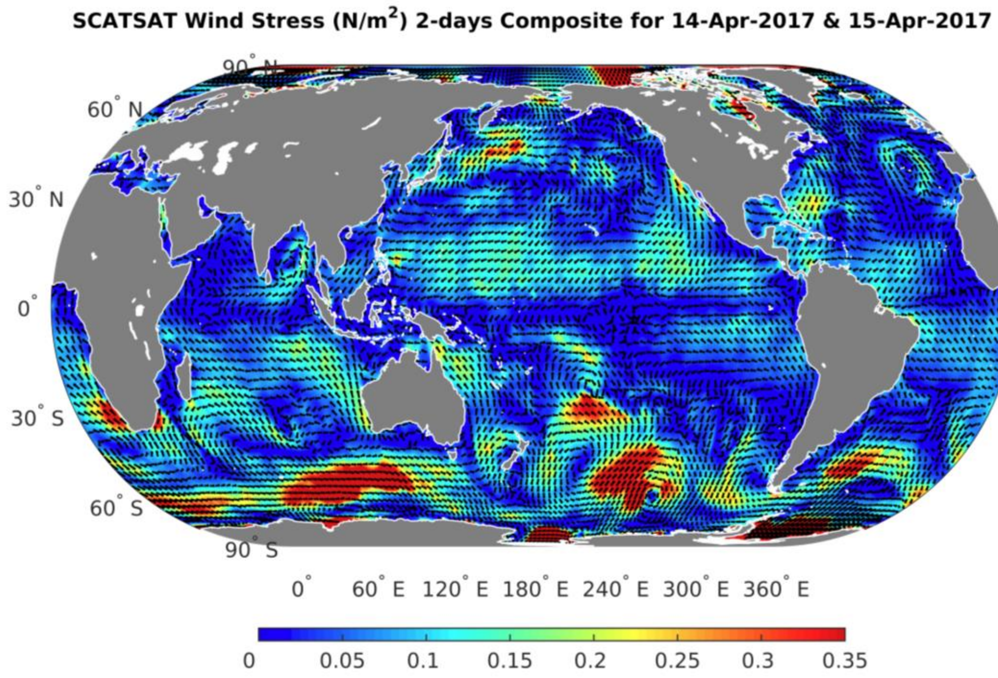


Figure 4: Image of wind stress composite.

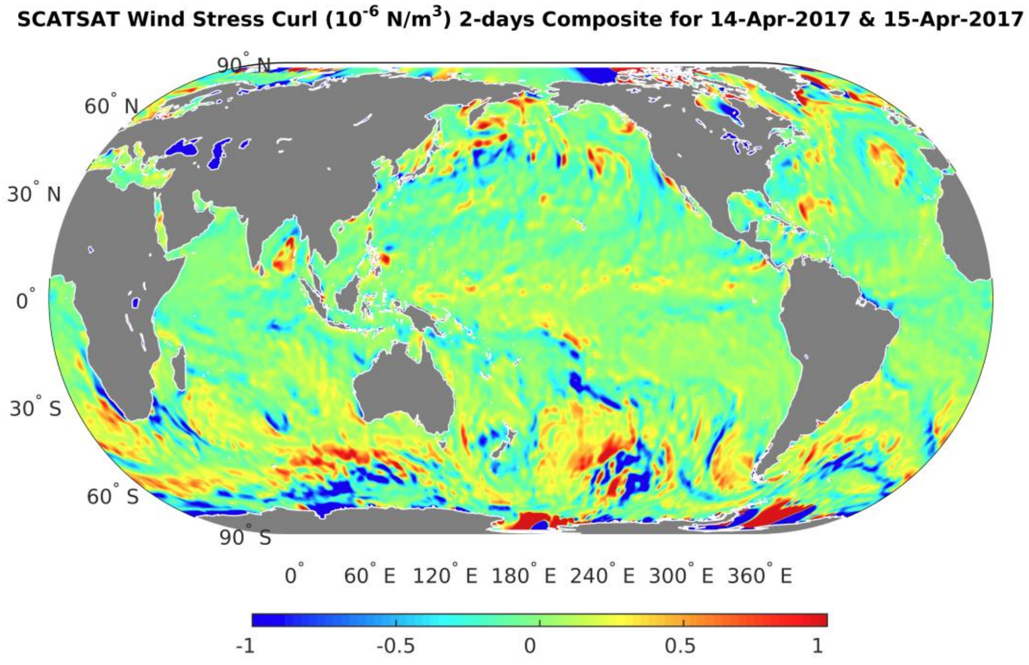


Figure 5: Image of wind stress curl composite

4.2 Naming Convention

Input and output file naming conventions are mentioned below:

Input file:

- Level 3WW : S1L3WWYYYYDDD_25.h5
- Level 3WW : S1L3WWYYYYDDD_50.h5

Output data file:

- Daily Composite : S1L3WSCYYYYMMDD_25.nc
- Daily Composite : S1L3WSCYYYYMMDD_50.nc

Output images:

- Daily Composite : S1L3TTTYYYYMMDD_25.png
- Daily Composite : S1L3TTTYYYYMMDD_50.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 → Surface winds, WST → Wind Stress, WSC → Wind Stress Curl).

5. Validation

Early comparison and validation of SCATSAT products has been done with NCEP reanalysis winds and INCOIS buoys for the month of October 2016 over North Indian Ocean (NIO).

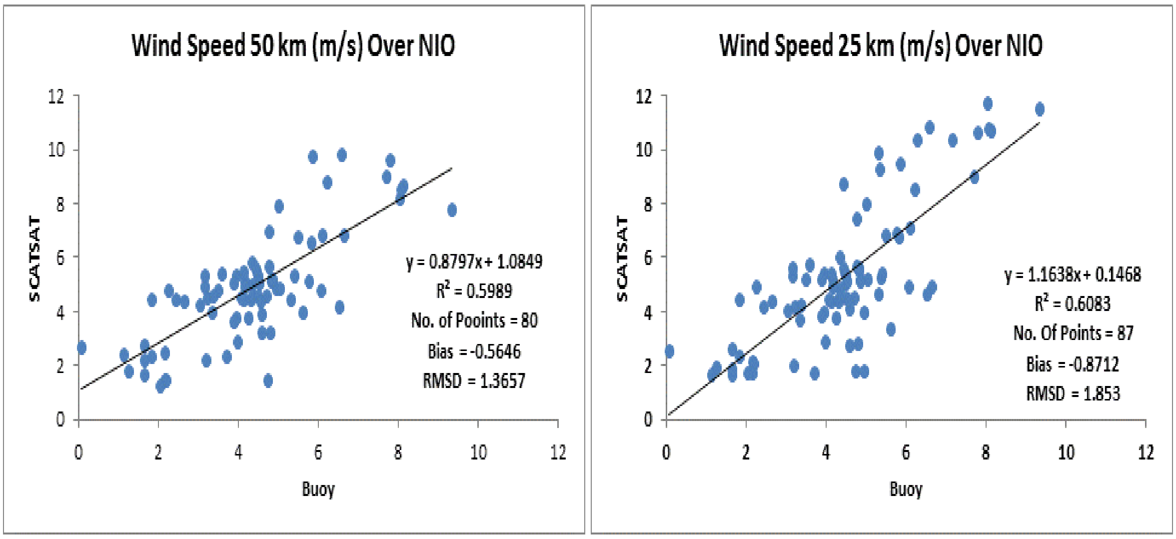


Figure 6: SCATSAT Wind Speed comparison with INCOIS buoys.

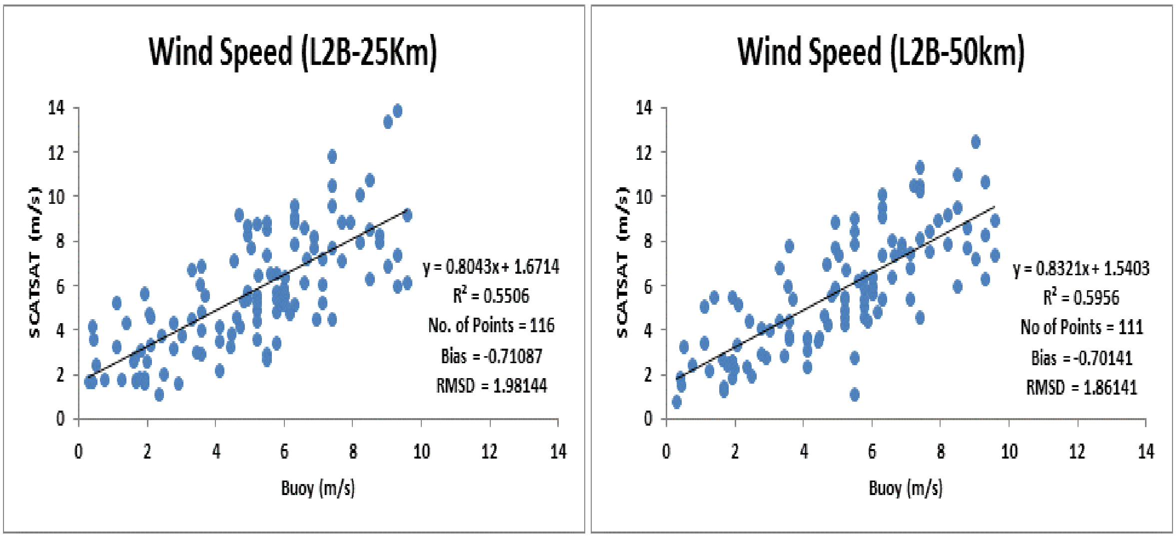


Figure 7: SCATSAT Wind Speed comparison with INCOIS buoys (L2B-pass data of SCATSAT).

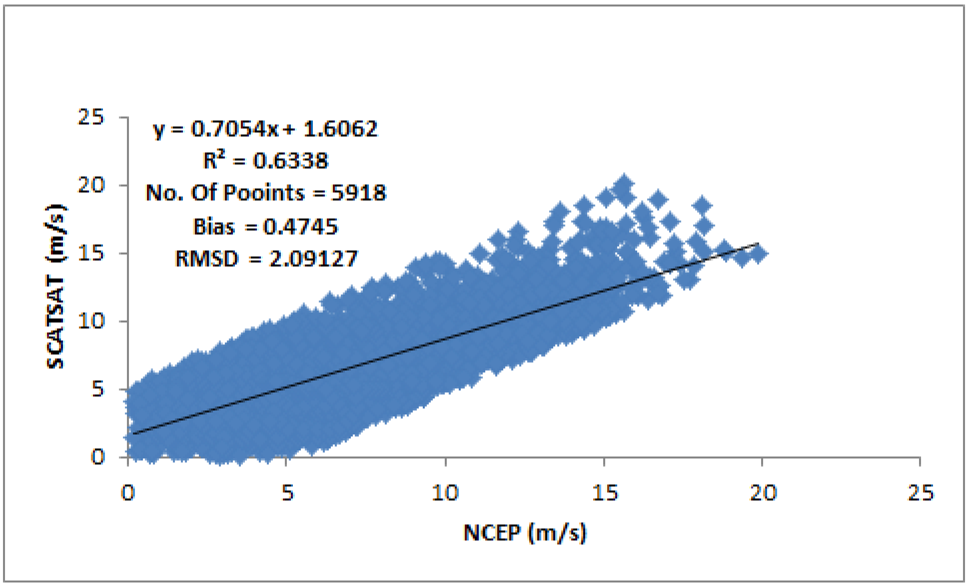


Figure 8: SCATSAT Wind Speed comparison with NCEP reanalyses wind.

Early comparisons with buoy data show good correlation of around 0.6 for both the resolution products since the data sample is small. Initial result shows SCATSAT underestimation at higher velocities and overestimation at lower velocities in both the pass and interpolated products of wind velocity. Further validation is under progress.

6. Conclusion

The curl of wind stress is helpful in identifying areas of cyclogenesis and their propagation, besides the mass movement and productive zones. The products of Wind Stress and Wind Stress Curl composite have been generated using SCATSAT wind data and DIVA method. These data products are available at the NICES portal of Bhuvan.

Acknowledgements: We take it as a deemed privelege to express our sincere thanks to all concerned who have contributed either directly or indirectly for the successful completion of wind products computation and product generation using SCATSAT scatterometer data.

7. References

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