Impact of assimilation of SCATSAT-1 wind data on simulation of tropical cyclones over Bay of Bengal

K. Vijaya Kumari[1], V. Yesubabu[2], Sabique Langodan[3], Hariprasad D[3] and S. Vijaya Baskara Rao[1]

1. Department of Physics, S.V. University, Tirupati - 517502, India.
2. National Atmospheric Research Laboratory, Gadanki
3. King Abdullah University of Science and Technology, Thuwal, Saudi Arabia

vijayakattamanchi@gmail.com

Abstract: ***The impact of assimilating SCATterometer SATellite-1(SCATSAT-1) winds with operationally available NCEP PrepBUFR data has been assessed for predicting the two tropical cyclones (VARDAH and GAJA) over Bay of Bengal using WRF model. Before assimilated the SCATSAT data, we have examined the quality of scatterometer fields and the validation of SCATSAT-1 using the buoy data from INCOIS during the period 01 December 2016 to 31 March 2019 suggests that the SCATSAT-1 winds exhibit a high skill with minimum errors in term of RMSE, bias and good correlation with the buoy data. The results of the three numerical experiments conducted namely CONTROL, PREPBUFR, SCATSAT suggests that significant improvements in the intensity simulation after assimilating the SCATSAT winds. Comparison of with observed datasets suggests that the assimilation of SCATSAT data has also improved the simulation of track, translation speed, surface winds, cloud band structure, rainfall and radius-height cross sections etc.***

1 Introduction

Tropical cyclone is one of the deadliest weather phenomena which produce high intensity winds, torrential rainfall, storm surge and rough sea etc [1]. Accurate prediction of the cyclone in terms of intensity, track and associated wind along with its rainfall is very essential to save the public life and reduce the potential infrastructure damage. Conventional observational studies suggest that low level disturbance (cyclonic vorticity) is other responsible factor for a cyclone to form along with many other and there is a strong correlation among the winds, low-level convergence and the movement of the cyclones [2]. Accurate wind information is essential to get know about cyclone structure which includes eye, eye wall, spiral bands organisation etc and its propagation, it is necessary to accurately build up the wind information in the initial conditions to the models. The vortices of TCs at the starting phase can be easily resolved by accurate knowledge of surface winds which is a difficult task for numerical model. But due to the lack of observations over ocean at the time of model initialization, the active region of the cyclone formation is difficult to notice and hence limits the prediction. Therefore assimilating the available synoptic and satellite data is the best option to provide precise representation initial cyclonic vortex and to predict the track of the cyclones accurately. Two recent tropical cyclones formed over Bay of Bengal during post-monsoon season in 2016 and 2018 are selected i.e., VARDAH and GAJA for present analysis. The main objective of the study is to examine the initial changes brought by surface wind assimilation of SCATSAT data and how afar it impacts the representation of cyclonic vortices and changes in simulated intensities and structure of the storm.

2 Validation of SCATSAT, WRF Model configuration and experimental details

2.1 Validation of SCATSAT

In the present study, SCATSAT-1 winds are validated using the in-situ moored buoy data from National Institute of Ocean Technology (NIOT) and INCOIS Hyderabad during the period 01 December 2016 to 31 March 2019. For this, the SCATSAT wind data are interpolated to the closest grid point of selected BUOY locations. The agreement between SCATSAT and BOUY has been assessed for both zonal (U) and meridional (V) wind components in the form of scatter plot as shown in Figure 1.

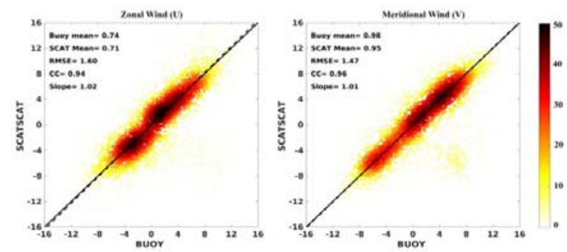

Figure 1 Scatter plots for SCATSAT 10m U and V winds against BUOY data

Scatter plots suggests that SCATSAT exhibit a good in agreement with the observed buoy data. The correlation coefficients show that the SCATSAT wind data is in consistent with the BUOY data. However, a slight over estimation of SCATSAT winds is noticed for the zonal wind. Similar kind of pattern is also noticed in the case of meridional wind. Our results (figure not shown) suggest that the SCATSAT are overestimated by 1 m/s when compare to the BUOY during the southwest monsoon and underestimated during northeast monsoon. The SCATSAT winds on an average are consistent with the BUOY data with slight variations with the seasonal variations and with the intensity estimations.

2.2 WRF Configurations and experiments

WRF-ARW and its data assimilation module (WRFDA) are used to study the impact of assimilating SCATSAT winds to the operationally available National Centres for Environmental Prediction (NCEP) PrepBUFR data. The domains considered and model physics options selected to conduct the experiments are considered from [6]. Three numerical experiments are conducted namely (1) control run (CTL) in which model is initialized using NCEP-Global Forecasting System (GFS) analysis, (2) PREPBUFR – a single cycle variational data assimilation experiment using NCEP PrepBUFR observations with WRF four-dimensional variational assimilation (4D-Var) system (3) SCATSAT- a similar PREPBUFR experiment with assimilating the SCATSAT-1 derived winds to the PrepBUFR observations.

3 Results and Discussions

3.1 Vector Track positions and Intensity Predictions

The predicted track positions of the VARDAH and GAJA cyclone are compared with the corresponding IMD best track estimates (Figure2). The impact of assimilating SCATSAT is clearly shown from the maturity phase of both the storms. As the forecast length increases, the track error reduced gradually. The translation speeds are high compared to IMD suggesting that the movement of cyclone is faster with all the experiments (Figure not shown). As a result, there is an early landfall i.e., 12 hours before is noticed. The time series of Central Sea level pressure (CSLP) and maximum sustained winds (MSW) for the three experiments are compared with the IMD estimates and presented in Figure 3 for GAJA. Though there is a higher translation speed noticed with SCATSAT, the stages of the cyclones i.e developing, rapid intensification, mature and weaking phases are well reproduced when compared to observation. The intensity is slightly over estimated.

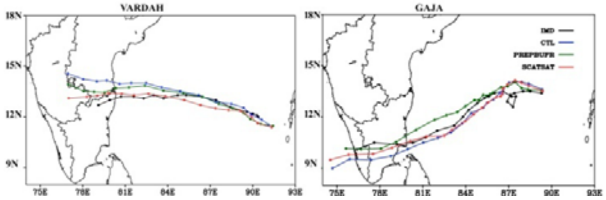

Figure 2 Vector track positions of VARDAH and GAJA

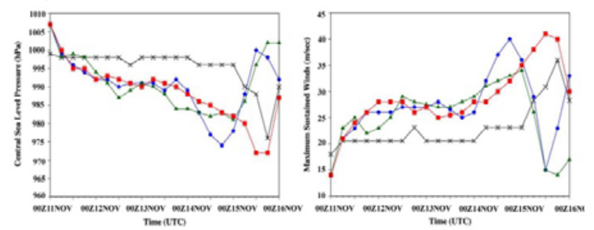

Figure 3 Comparison of CSLP and MSW predictions with IMD estimates for GAJA

3.2. Surface Winds

The simulated surface winds are analyzed by comparing with the multiplatform winds from CIRA during the mature period of the cyclonic storm as shown in Figure 4. Top panel is for VARDAH cyclone and lower panel is for GAJA cyclone. In VARDAH case, the closed isotach structure and the strong surface winds of magnitude 50 knots are well simulated in the SCATSAT experiment. Also the organization of the wind structure agrees well with the observations. The isotachs are close to each other with the SCATSAT experiment in GAJA case which depicts a well organized stronger storm. Though there is a temporal and intensity variation, a well-organized cyclonic structure is obtained using assimilation of wind information from SCASAT-1. From the simulations of surface winds, the positive impact of assimilating scatterometer winds is clearly shown for both the cyclone cases.

3.3 Rainfall

In order to overcome the temporal differences between the simulations and observation, 48 hours accumulated rainfall is considered and presented in Figure 5 along the tracks (top panel -VARDAH and bottom panel - GAJA). The precipitation pattern appears to be closer to the observations with the experiment assimilated SCATSAT data, especially after the landfall in the case of VARDAH. In case of GAJA, the rainfall distribution is well estimated with the exact landfall location. Also, the rainfall intensity is reduced after the landfall. When the system entered into the Kerala region, the rainfall intensity increased due to the re-intensification of the storm which is realistic.

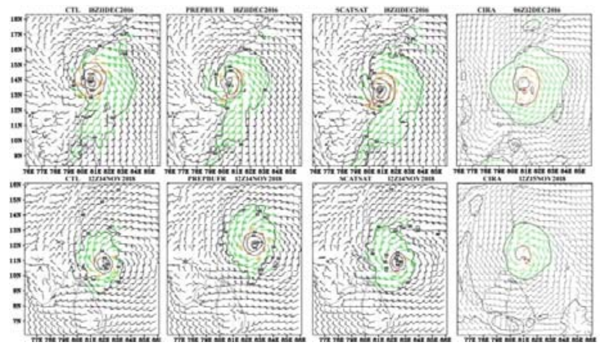

Figure 4 Comparison of surface winds from experiments with the CIRA observations for both cyclones

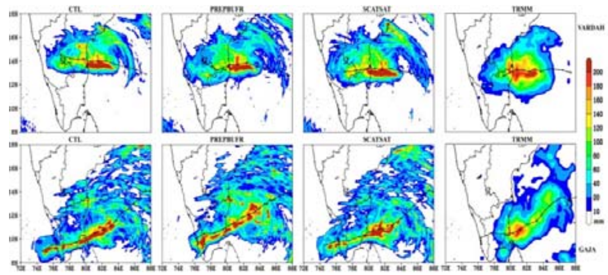

Figure 5 Comparison of Rainfall predictions during landfall

4. Conclusions

From the validation study, it depicts that the SCATSAT winds has a good correlation with the in-situ Buoy data. Assimilation of the surface winds in the initial conditions better represented the vortex of the storm and has shown improvements in the prediction of tracks and intensity of the cyclones. Also, better representation of secondary circulation is noticed and there is a positive impact in simulating the convective clouds organization for both the cyclone cases which is a good sign of better rainfall prediction.

Acknowledgement

The presenting author acknowledges ISRO RESPOND project for financial support, UGC-SVU for computing facilities, INCOIS and NIOT for providing the buoy data.

References

1. Samala et al 2013 Study of the Indian summer monsoon using the WRF–ROMS regional coupled model simulations. Atmospheric Science Letters, 14, 20–27.

2.George and Gray 1976, Tropical cyclone motion and surrounding parameter relationships, *J. Appl. Meteor*., 15, 1252-1264.

3. Bao et al, 2000, Numerical simulation of air–sea interaction under high wind conditions using coupled model: A study of hurricane development. *Mon. Wea. Rev.,* 128, 2190–2210.

4. Atlas, R. and R.N. Hoffman, 2000, The use of satellite surface wind data to improve weather analysis and forecasting. Elsevier Oceanography Series.

6. Srinivas, C.V et al 2013 Tropical cyclone predictions over the Bay of Bengal using the high-resolution Advanced Research Weather Research and Forecasting (ARW) model. *Q J R Met Society*, 139(676), 1810–1825.