SUPPLEMENTING OSCAT WINDS WITH SARAL ALTIKa OBSERVATIONS FOR CYCLONE STUDIES

K.Niharika*, H.S.V. Usha Sundari, A.V.V. Prasad, E.V.S. Sita Kumari, V.K.Dadhwal, M.M.Ali

National Remote Sensing Centre, Indian Space Research Organisation, Hyderabad, India.
niharika_k@nrsc.gov.in*, ushasundari_hsv@nrsc.gov.in, prasad_avv@nrsc.gov.in, sitakumari_evs@nrsc.gov.in, dadhwalvk@hotmail.com, mmali110@gmail.com

Commission VIII, WG VIII/9

KEYWORDS: Oceansat-2, Scatterometer **(**OSCAT), SARAL, AltiKa, Wind speed, Cyclones, RMW

ABSTRACT:

Accurate prediction of life cycle of cyclone is very critical to the disaster management practices. Since the cyclones originate over the oceans where in situ observations are limited, we have to resort to the remote sensing techniques. Both optical and microwave sensors help studying the cyclones. While scatterometer provide wind vectors, altimeters can give only wind speed. In this paper we present how altimeter measurements can supplement the scatterometer observations in determining the radius of maximum winds (RMW). Sustained maximum winds, indicator for the intensity of the cyclone, are within the eye wall of a cyclone at a distance of RMW. This parameter is also useful in predicting right time of the storm surge. In this paper we used the wind speed estimations from AltiKa, an altimeter operating at Ka band.

1. INTRODUCTION

A cyclone is a low pressure area in the atmosphere in which winds spiral upward. Cyclones are one of the most violent weather manifestations that cause devastation along the coastal regions. Cyclones evolve through a life cycle of genesis to dissipation. Cyclone genesis, intensity, track and landfall have to be predicted with accuracy throughout the life cycle for a better disaster management in planning the mitigation efforts to save loss of human life and property.

Cyclones can be studied through in-situ measurements and satellite observations. The temporal and spatial coverage of the cyclone area is the greatest limitation of the in-situ measurements (Nagamani et.al., 2012). Because of these limitations in in-situ measurements, satellite observations have been a key component of cyclone monitoring, and research.

Optical sensors on the geostationary satellites have been the only source of information for cyclone studies for a long period of time. It is well known that visible/infrared sensors cannot provide all the information required for monitoring cyclones.
The development of advanced sensor technology and the availability of a variety of satellites orbiting the earth, it has been possible to use multi-spectral, multi-sensor combination to improve the understanding of the physics of the tropical cyclones for a better and accurate forecasting. (Joshi et.al., 2009). Thus a combination of visible and infrared data from the geostationary satellites and active and passive microwave data from atmospheric sounders, scatterometers and altimeters has improved the cyclone prediction capability skills.

The centre or eye of a tropical cyclone is at the area of lowest pressure and is characterised by little or no wind and often a cloudless sky. This centre can be easily identified in the visible channel for a matured cyclone. The radius of maximum wind (RMW) is a parameter in atmospheric dynamics and tropical cyclone forecasting (Hsu and Babin, 2005). It is the distance between the centre of a cyclone with a band of strongest winds, near the eye wall. Winds at this location are used to estimate the sustained winds and to denote the strength of a cyclone. The highest rainfall rates occur near the RMW of tropical cyclones. It is one of the most critical parameter that determines the tropical cyclone wind structure. This information is required to assess the area of damage after the landfall of the cyclone and to predict the storm surge. The extent of a cyclone's storm surge and its maximum potential intensity can be determined using the RMW. As maximum sustained winds increase, the RMW decreases. The radius of maximum winds is normally small compared to the size of the cyclone, which can vary depending up the circumstances.

The RMW is traditionally measured by reconnaissance aircraft in the Atlantic basin (Hsu and Babin, 2005). It can also be determined on weather maps as the distance between the cyclone centre and the system's greatest pressure gradient (Blanchard and Hsu, 2006). Another approach is in finding the distance between the coldest cloud top temperature and the warmest temperature in infrared satellite imagery. The reason why this method has merit is that the strongest winds within tropical cyclones tend to be located under the deepest convection, which is seen on satellite imagery as the coldest cloud tops (Hsu and Babin, 2005). Use of velocity data from Doppler weather radar can also be used to determine this quantity, both for tornadoes and tropical cyclones near the coast.

Scatterometer, a satellite radar instrument, observes surface backscatter radiance and thereby provides a measure of vector wind at 10m (at the height of the ship deck). These winds are one of the crucial observations over the data sparse ocean region for accurate analysis of flow patterns. With Scatterometer observations of ocean surface wind vectors over global oceans, the strength and movement of cyclones can be monitored right from early stages of its formation till its landfall. However, unless the eye of the cyclone is at least 2 pixels larger than the spatial resolution (25/50 km) of the cyclone, it is difficult to be identified in a scatterometer data. On the other hand it can be easily identified in an altimeter observation due to its better resolution of ~7 km, provided a pass over the cyclone exists. In this study we demonstrate the application of an AltiKa onboard SARAL (**S**atellite for **AR**gos and **AL**tiKa) mission, a joint venture of ISRO/CNES, in supplementing the Oceansat-2 Scatterometer (OSCAT) wind vectors. Oceansat-2 is ISRO's second satellite in the series of Indian Remote Sensing (IRS) satellites dedicated to ocean research, launched on 23rd September 2009. Oceansat-2 has a repetivity of 2 days.

SARAL was launched successfully on 25th Feb 2013 and reached its final orbit on March 13th, 2013. The satellite has three payloads namely AltiKa, ARGOS and Solid State C-band Transponder (SCBT). The prime payload of the SARAL mission is AltiKa, the altimeter which is the first spaceborne altimeter to operate at Ka band (35.75 GHz). The Ka band altimeter with enhanced bandwidth will have the advantage of negligible ionospheric effect and better vertical resolution. The wideband altimeter offers higher performance both in terms of spatial and vertical resolution (~ 7km with 1Hz sampling rate) (SARAL/AltiKa Product Handbook, 2013). The reduction of effective footprint and increase in along track resolution offers SARAL/AltiKa a clear advantage over previous altimeters with respect to coastal monitoring. But the measurements from this altimeter are more sensitive to integrated liquid water (LW) and the water vapour (WV). However, the onboard radiometer helps correcting these two parameters. Ka –band is highly sensitive to rainy and cloudy conditions compared to Ku band, although, even in the tropics, actual data loss is only expected to be 5-10% (Tournadre et.al, 2009).

AltiKa provides information on significant wave height, sea surface height and wind speed over the ocean surface. We used both OSCAT and AltiKa observations to study the following cyclones. Our main emphasis has been to estimate the RMW.

2. CYCLONES STUDIED

2.1 Hudhud Cyclone

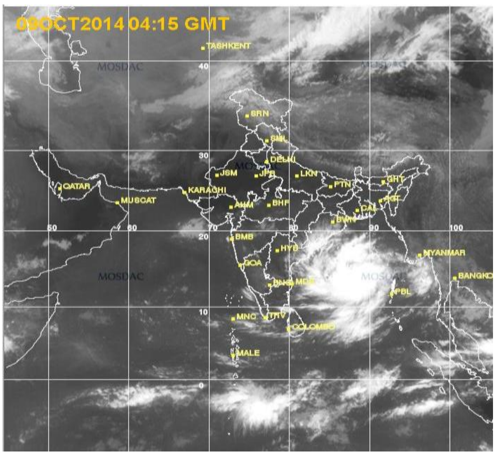

Figure 1. Kalpana image showing Hudhud Cyclone (Curtsey: www.mosdac.gov.in)

Very severe cyclone storm Hudhud (Figure. 1) formed on 7th Oct 2014 in Andaman Sea with landfall on 12th October in Visakhapatnam and dissipated on 14th Oct 2014. (IMD website) . The track of the cyclone is given in Figure. 2. On 10th Oct 2014, SARAL passed over the centre of this cyclone (cycle no 17 and pass no 438).

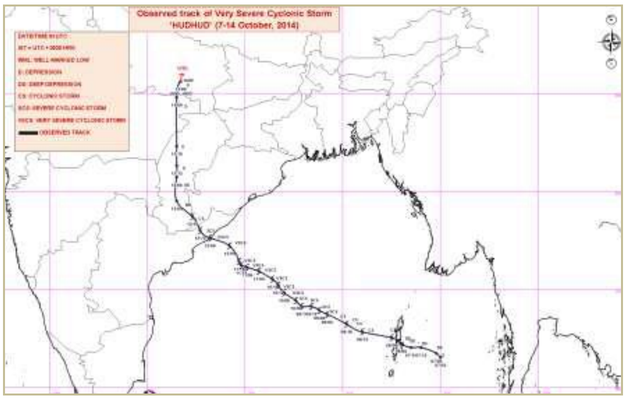

Figure 2. Track of hudhud cyclone (Curtsey: www.imd.gov.in).

2.2 Wipha Cyclone

Figure 3. Typhoon Wipha (Curtesy: news.softpedia.com)

Wipha (Figure. 3) was a large typhoon that originated from a tropical depression well to the east of Guam, Japan on 8th Oct 2013, reached its peak intensity on 14th October and dissipated on 16th Oct 2013. On 15th Oct 2013, SARAL had passed through the centre of cyclone with cycle no 7 and pass no 148. Besides, OSCAT with revolution numbers 21494(14th Oct 2013) and 21509 (15th Oct 2013) covered the cyclone.

3. DATA AND METHODOLOGY

Information on the location, intensity and track of the cyclones is taken from Joint Typhoon Warning Centre (JTWC) for the above two cyclones. While AltiKa data is available for both cyclones, OSCAT observations are available only for Wipha. The centre of the cyclone has been taken from JTWC. The satellites data used for these studies are from SARAL/AltiKa and OSCAT.

3.1 SARAL AltiKa

Since Jason-2 algorithm has been applied to AltiKa, the estimated wind speeds given in CNES site are not very accurate. (Abdhalla, 2014). Hence, (Ali et.al., 2014) used an artificial neural network model function (AMF) to estimate the winds from AltiKa. SARAL AltiKa data has been selected whenever it passed over the two cyclones. The variation of wind speed along the AltiKa track has been studied and the RMW has been estimated as a mean of distance between centre of the cyclone and the two peaks in the wind speed.

3.2 Oceansat-2 Scatterometer

Similarly, OSCAT data over Wipha have been used (OSCAT was not available during the Hudhud cyclone).

From the centre of cyclone position (taken from JTWC) zonal and meridional profiles have been analysed to know the wind speed variation along the latitudes and longitudes. The zonal variation has been studied by cyclone central latitude and varying the longitude. Similarly meridional profile has been analysed by cyclone central longitude and varying the latitude. Distance has been calculated from the centre of cyclone to each measurement of both profiles. RMW has been calculated using both the profiles and average value has been taken.

Software has been developed in house which has capability to do the extraction of data, displaying, plotting and calculating RMW for AltiKa and OSCAT data products.

4. RESULTS AND ANALYSIS

4.1 Hudhud Cyclone

Wind speed from SARAL track with cycle no 17 pass no 438 of 10th Oct 2014 pass over the Hudhud cyclone (Figure 4) is ranging from 9-19 m/s (in red) along 10 to 20degree latitude.

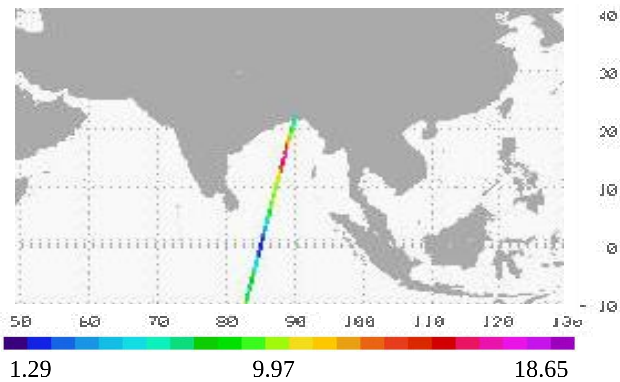

Figure 4. Wind speed values (m/s) for cycle no. 17, pass no. 438 of SARAL AltiKa on 10th Oct 2014.

Wind speed increases from the centre of a cyclone, reaches to the maximum at the eye wall of cyclone or at RMW and then again decreases. The variation of winds from AltiKa over cyclone Hudhud (Figure. 5) has a peak, a dip and a second peak. The two peaks correspondence to the winds at RMW and the dip represents the winds at the eye of the cyclone. The maximum winds are about 17.3 m/s. Due to the limitation of the AMF, the actual winds could not be reproduced in the AltiKa derived winds. However, the wind magnitudes from AltiKa are comparable with those from OSCAT. From the Table 1, the average RMW is 117.46 km.

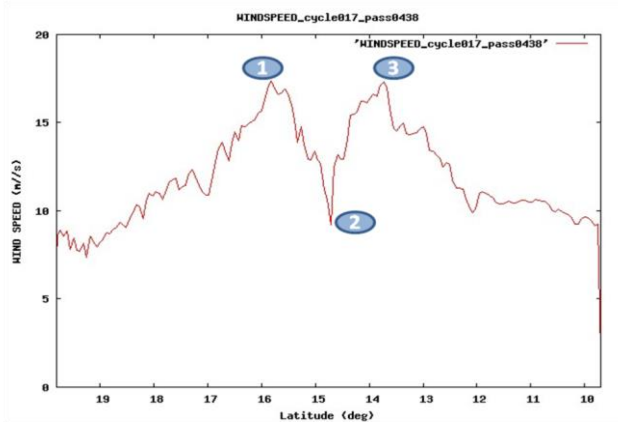

Figure 5. Wind speed Vs. Latitude for cycle no. 17, pass no. 438 of SARAL/AltiKa on 10th Oct 2014.

Point No	Wind Speed (m/s)	Latitude, Longitude (deg)	Distance From The Centre (km)
1	17.35	15.82N, 88.42E	124.39
2	9.22	14.72N, 88.17E	Centre of cyclone eye
3	17.3	13.73N, 87.94E	110.53

Table 1. Maximum wind speed values and positions in cyclone area for cycle no. 17, pass no. 438 of SARAL AltiKa on 10th Oct 2014.

Since OSCAT data are not available for this cyclone, Cyclone Wipha has been analysed so that both AltiKa and OSCAT results can be compared.

4.2 Wipha cyclone

4.2.1. SARAL AltiKa: Same analysis has been carried out for Wipha cyclone with cycle no 7, pass no 148 of 15th Oct 2013. Figure 6 shows the variation of wind speed on the SARAL track covering from 25 to 35deg. latitude. High wind speeds of 7 to 30 m/s (in red) are reported by AltiKa. As in the previous case these winds from AltiKa do not compare with the actual winds. The wind speeds along the track have peaks of 24.2 m/s and 27.3 m/s at the RMW of 62 km (Figure. 7 and Table 2). JTWC reported a RMW of 55.62 km.

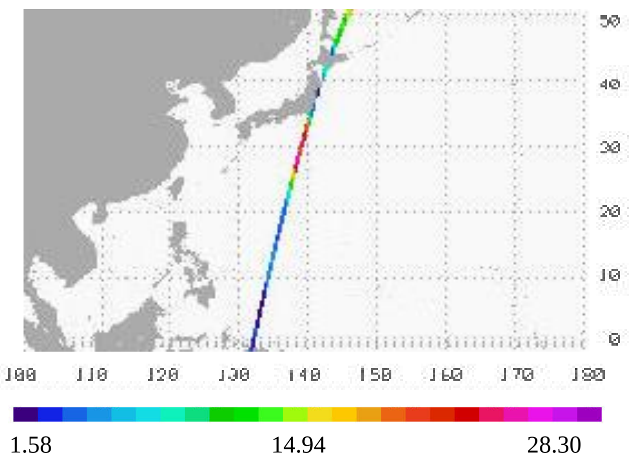

Figure 6. Wind speed values (m/s) for cycle no. 7, pass no. 148 of SARAL AltiKa on 15th Oct 2013.

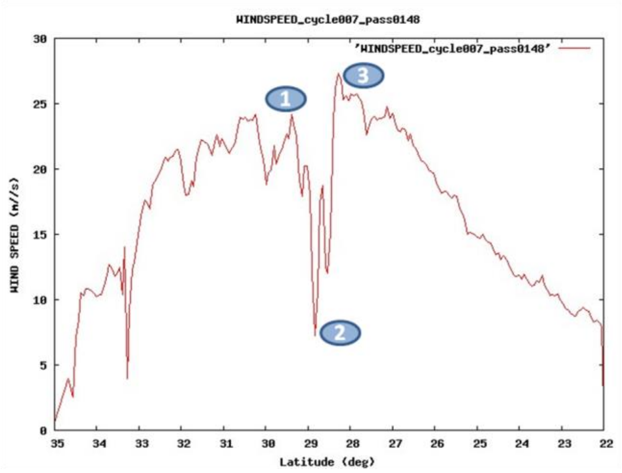

Figure 7. Wind speed Vs. Latitude for cycle no. 7, pass no. 148 of SARAL/Altika on 15th Oct 2013.

Point No	Wind Speed (m/s)	Latitude, Longitude (deg)	Distance From The Centre (km)
1	24.20	29.38 N, 138.56E	62.2
2	7.22	28.83N, 138.41E	Centre of cyclone eye
3	27.29	28.28N, 138.27E	62.1

Table 2. Maximum wind speed values and their positions (shown in Figure 7) in cyclone area for cycle no. 7, pass no. 148 of SARAL Altika on 15th Oct 2013.

4.2.1. Oceansat-2 Scatterometer: The wind speed values are extracted from OSCAT for cyclone Wipha from Level-2B, 25 km wind products.

4.2.1.1 Revolution number 21494: The wind speed variation of OSCAT with revolution number 21494 on 14th Oct 2013 is given in Figure 8.

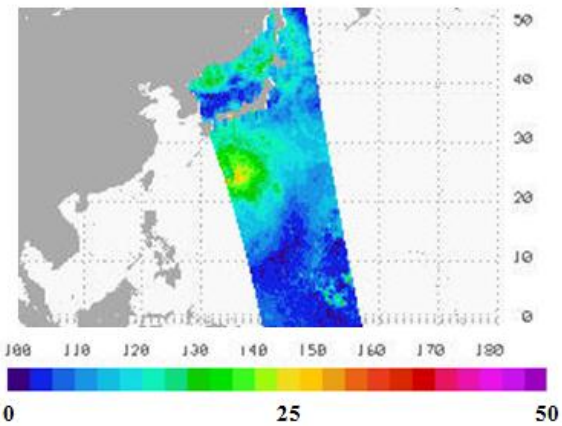

Figure 8. Wind speed magnitudes (m/s) of OSCAT 25 km resolution data for revolution no. 21494 on 14th Oct 2013.

Zonal and meridional profiles passing through the centre of the cyclone (25.25 N, 134.75E) taken from JTWC have been analysed for identifying the maximum wind speed positions in the cyclone area which are shown in Figures 9 and 10.

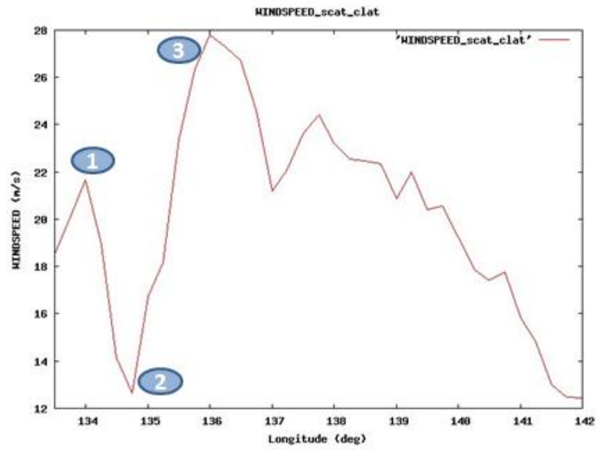

Figure 9. Zonal profile of wind speed along 25.25 deg latitude for revolution no. 21494 of OSCAT on 14th Oct 2013.

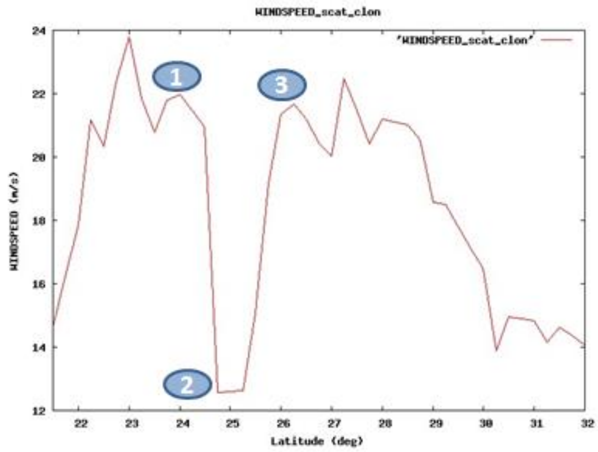

Figure 10. Meridional profile of wind speed along 134.75 deg longitude for revolution no. 21494 on 14thOct 2013 of OSCAT.

The maximum wind speed values and their latitude, longitude and distance from the centre of the cyclone are given in the Table 3 (zonal) and Table 4 (meridional).

Point No	Wind Speed (m/s)	Latitude, Longitude in deg	Distance From The Centre In km
1	21.68	25.25 N, 134 E	74.62
2	12.64	25.25 N, 134.75E	Centre of cyclone eye
3	27.79	25.25 N, 136 E	124.36

Table 3. Maximum wind speed values and their positions in the zonal direction for revolution no. 21494 on 14th Oct 2013 of OSCAT.

Point No	Wind Speed (m/s)	Latitude, Longitude in deg	Distance From The Centre In km
1	21.96	24 N, 134.75 E	137.5
2	12.64	25.25 N, 134.75E	Centre of cyclone eye
3	21.67	26.25 N, 134.75 E	110

Table 4. Maximum wind speed values and their positions in the meridional direction for revolution no. 21494 on 14th Oct 2013 of OSCAT.

From these profiles, distances from maximum wind speed positions to the centre of the cyclone have been calculated and averaged to get RMW of 111.62 km.

4.2.1.2 Revolution number 21509: Same analysis has been carried out on revolution number 21509 of 15th Oct 2013. The wind speed magnitudes for 21509 in cyclone area were shown in Figure 11.

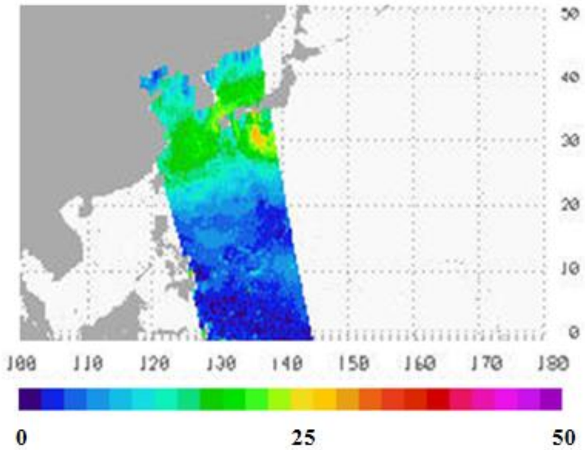

Figure 11. Wind speed magnitudes (m/s) of OSCAT for revolution no. 21509 on 15th Oct 2013.

Zonal and meridional profiles have been analysed for the revolution number 21509 of 15th Oct 2013 which are shown in Figures 12 and 13.

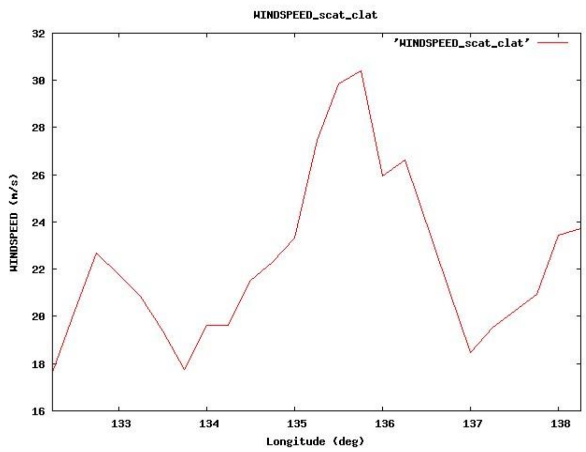

Figure 12. Zonal profile of wind speed along 31.5 degree. latitude for revolution no. 21509 on 15th Oct 2013 of OSCAT.

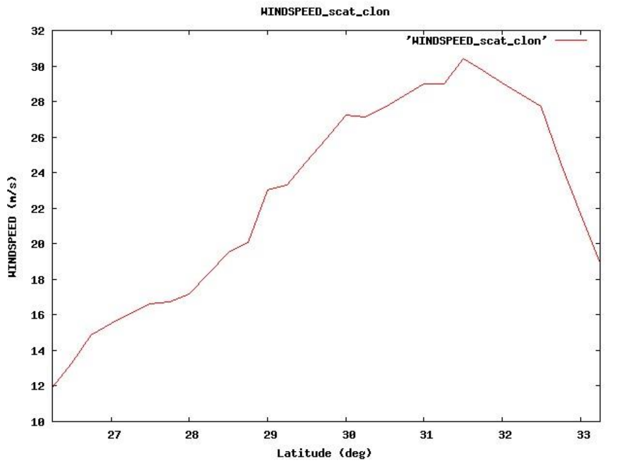

Figure 13. Meridional profile of wind speed along 135.75 deg longitude for revolution no. 21509 on 15th Oct 2013.

Unlike in the case of AltiKa, clear peaks of high winds with a drop at the centre are not observed in OSCAT on both the days though they are somewhat clear on 14th Oct 2013. This could be because the eye of the cyclone could not be detected in the OSCAT observations (Figure. 8 and 11) because its spatial resolution 25 km is poor compared to that of AltiKa (7 km).

5. CONCLUSION

In spite of spatial and temporal limitations of an altimeter compared to a scatterometer, AltiKa derived winds could easily distinguish the eye of the cyclone and the eye wall or radius of maximum winds (RMW), which is an important feature of tropical cyclones. Such a clear distinction is not possible from OSCAT observations, which could be because of its poor spatial resolution of 25 km as compared to 7 km of AltiKa. Though eye wall can be observed in OSCAT winds on 14 October, it is not clear on the next day because of the increase in intensity of the cyclone due to which the RMW decreases. Thus, we can conclude that AltiKa can supplement the OSCAT observations, particularly, in studying the RMW and the centre of the cyclone. AltiKa and OSCAT wind magnitudes compare well though they do not compare with the actual cyclonic winds because of the limitations of the model functions deriving wind speeds from both these sensors.

6. ACKNOWLEDGEMENTS

The authors acknowledge the support and encouragement provided at NRSC. We have downloaded the SARAL AltiKa SIGDR products from AVISO CNES data center (http://aviso-data-center.cnes.fr/ssalto/login.do) and OSCAT Level-2B data products from OS2 web portal of NRSC website. (www.nrsc.gov.in).

7. REFERENCES

Abdhalla, Saleh., 2014. Calibration of SARAL AltiKa windspeed. IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, VOL. 11, NO. 6.

Ali, M.M., Suchandra, A., Bhowmick, Rashmi Sharma, Aditya Chaudhury, 2014. A Neural Network Model Funtion for SARAL-Altika Winds. IEEE, GRSL (Submitted).

Blanchard, Brian.W., and Hsu, S.A., 2006 "On the Radial Variation of the Tangential Wind Speed Outside the Radius of Maximum Wind During Hurricane Wilma (2005)". Louisiana State University.

Hsu, S.A., and Babin, Adele., 2005. "Estimating the Radius of Maximum Winds via Satellite during Hurricane Lili (2002) Over the Gulf of Mexico".

Joshi, P.C., Pal, P.K., Kishtawal, C.M., and Neeru Jaiswal, 2009. “Recent Advances in Satellite Observations for Tropical Cyclone Studies: Indian Perspective”, SECOND INDIA DISASTER MONITORING CONGRESS, New Delhi, 4-6 November, 2009.

Nagamani, P.V., Ali, M.M., Goni, G.J, Dinezio, P.N., Pezzullo, J.C., UdayaBhaskar, T.V.S., Gopalakrishna, V.V., Nisha, K., 2012. “Validation of satellite-derived tropical cyclone heat potential with in situ observations in the North Indian Ocean”, Remote Sensing Letters, vol.3(7); 2012; 615-620.

SARAL/AltiKa Products Handbook, 2013. SALP-MU-M-OP-15984-CN, Issue 2, Revision 4, December 9,2013.

Tournadre, J., Lambin, J., and Steunou, N., 2009. “Cloud and rain effects onAltiKa/SARAL Ka band radar altimeter. Part I: Modeling and mean annual data availability,” IEEE Trans. Geosci. Remote Sens., vol. 47, no. 6, pp. 1806–1817.

.