Impact of OScat surface wind data on T574L64 assimilation and forecasting system – a study involving tropical cyclone *Thane*

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Ocean surface wind vector data from Scatterometer (OScat) on-board India's Oceansat-2 satellite are available to global meteorological and oceanographic community on near real-time basis from the National Remote Sensing Centre (NRSC), Hyderabad. The quality of these wind vectors has improved recently and now is almost equivalent to that of any other present-day scatterometer sensors. The OScat winds are available in real-time and hence analysis procedures are developed for assimilating these winds into T574L64 Global Data Assimilation and Forecasting (GDAF) system at NCMRWF, Noida. In this study an attempt is made to quantify the impact of the OScat data through an observational system experiment using the procedure developed. The impact has been examined for the 17 December 2011–1 January 2012 involving the case of tropical cyclone *Thane*. This case study clearly demonstrates that the inclusion of OScat data is beneficial to the GDAF system, especially in simulating active cyclonic systems in both analysis and forecast.

Keywords: Cyclone *Thane*, Oceansat-2, OScat surface, scatterometer sensors, wind vectors.

THE National Centre for Medium Range Weather Forecasting (NCMRWF) is actively involved in developing a global data assimilation and forecasting (GDAF) system for India. Presently, its regular forecasts are based on the T574L64 GDAF system which has a horizontal resolution of about 22 km and 64 levels in vertical (a detailed description of this system can be found in Prasad *et al.*[1]). NCMRWF is continuously making efforts to improve the quality of the analyses and forecasts of this system by incorporating more observations.

The Indian Space Research Organisation (ISRO) launched Oceansat-2 in 2009. Its main payloads are the Ocean Colour Monitor-2 (OCM-2) and scatterometer (OScat). The main objectives of Oceansat-2 are to study surface winds and ocean surface strata, observe chlorophyll concentrations, monitor phytoplankton blooms and study atmospheric aerosols and suspended sediments in ocean water. This communication deals with the use of scatterometer data in weather prediction.

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The OScat data are available in real time from the National Remote Sensing Centre (NRSC), Hyderabad, and information regarding formats in which the data are available can be found in Padia[2]. The quality of the data is regularly being monitored by NCMRWF. Improvement in the quality of data was noticed after implementation of version 1.3 processing software and was deemed to be operationally usable[3].

The present communication deals with the development and implementation of data decoding and its assimilation process for OScat data. An observational system experiment (OSE) involving OScat data is carried out to study its impact on analysis and forecast in T574L64 system.

The scatterometer is a satellite radar instrument which observes surface backscatter radiance and thereby provides a measure of vector wind near the sea surface. These winds are one of the crucial observations over the data-sparse ocean region for accurate analysis of flow patterns, centre of circulations, etc. At present, NCMRWF receives scatterometer data from two global missions: (a) ASCAT – Advanced Scatterometer on-board MetOp from EUMETSAT. (b) OScat – Scatterometer on-board Oceansat-2 from ISRO.

The Oceansat-2 satellite revolves at an height of 720 km high in near-polar Sun-Synchronous Orbit with 98° inclination around the Earth. The scatterometer is a Ku-band (13.515 GHz) pencil-beam sensor. It uses a 1 m dish antenna rotating at 20 rpm with two spot beams of about 25 km × 55 km size on the ground, a horizontal polarization beam HH and vertical polarization beam VV at incidence angle of 43° and 49° respectively, that sweep the surface in a circular pattern. This results into a swath of 1800 km and covers 90% ocean surface in 24 h and represents substantial improvement compared to the side-looking scatterometers such as ASCAT, NSCAT and ERS.

The OScat data are available on an orbit-by-orbit basis as level 1B, level 2A and level 2B products in HDF-5 format. NCMRWF uses level 2B product, which is organized into a 50 km grid wind vector cell (WVC), thus

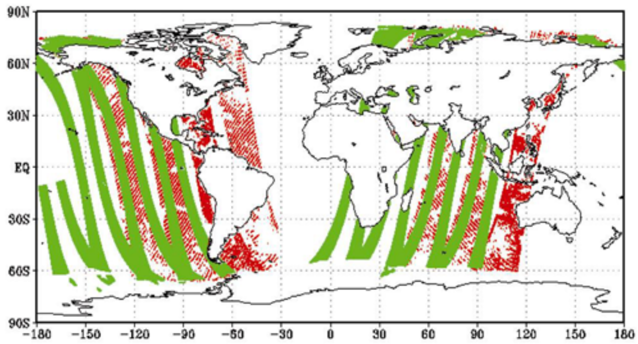

Figure 1. Distribution of ASCAT (green) and OScat (red) winds for 06z assimilation cycle for a typical day.

Table 1. Types of observation assimilated in the T574L64 GDAF system

Observation category	Observations
Surface	Land surface, mobile, ship, buoy (SYNOP)
Upper air	Temp and pilot (land and marine), dropesonde, wind profiler
Aircraft	AIREP, AMDAR, TAMDAR, ACARS, KAMDAR
Atmospheric motion vectors	Meteosat, GOES, MTSAT, MODIS
Scatterometer winds	ASCAT
NESDIS/POES ATOVS radiances	AMSU-A, AMSU-B/MHS, HIRS3/HIRS4 level 1B data
Satellite-derived ozone data	NESDIS/POES, AURA orbital Ozone
Precipitation rates	TRMM precipitation rates
Bending angle	GPSRO observations from COSMIC series
AQUA and METOP radiance	IASI and AIRS brightness temperature

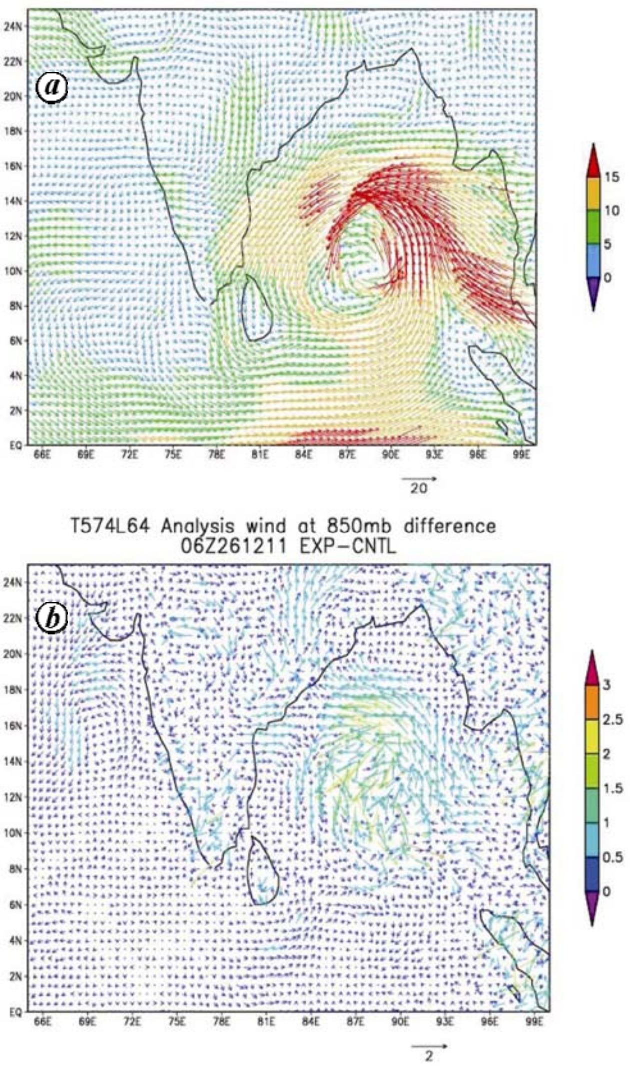

Figure 2. Tropical cyclone in the 26 December 2011 06z analysis cycle. (***a***) Control and (***b***) Difference between experimental and control.

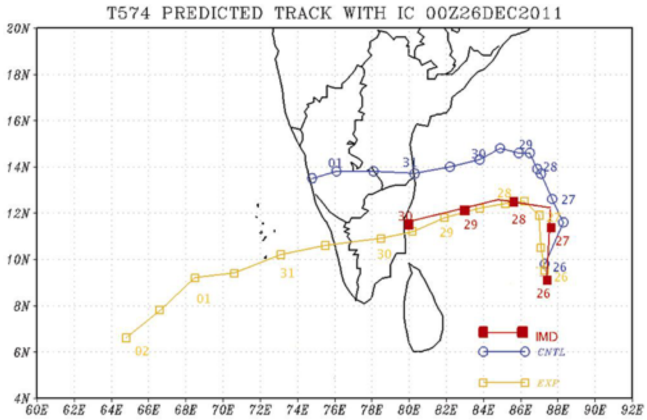

Figure 3. Predicted cyclone track for both EXP and CNTL runs starting from 00 UTC on 26 December 2011 along with IMD's best track.

resulting in 36 cells in a swath. Both the ASCAT and OScat observational datasets are complementary to each other (Figure 1).

NCMRWF's T574L64 GDAF system handles data only in NCEP BUFR format. Hence details of OScat data have to be added in the BUFR tables following defined conventions according to NCEP's BUFR manual. The complete data processing chain has been developed to process, archive in regular BUFR tank file format (BUFR files are organized in date-wise subdirectories) and then extract and process them for use in data assimilation.

The scatterometer is capable of measuring wind speeds in the range 0–50 m/s, but wind speeds over 25 m/s are generally less reliable[4]. At low wind speeds, wind direction and speed may vary considerably with the water vapour content (WVC). Further, over calm areas (< 2 m/s wind speed) little or negligible backscatter occurs. It is also well known that the quality of scatterometer retrievals are affected by moderate and heavy rainfalls. Thus, in this study non-rainy WVC, with wind measurements between 2.5 and 25 m/s are only considered for use in the assimilation.

In the T574L64 GDAF system, data assimilation is based on the gridpoint statistical interpolation (GSI) scheme developed by Wu *et al.*[5]. It is a 3D variational system and runs at six hourly intermittent method. Thus analysis cycles are run four times a day at 00, 06, 12 and 18 UTC. All types of datasets received through GTS in the 6 h time window around the analysis cycle time along with satellite datasets that are directly received from their

Table 2. Error with respect to IMD's best track and cyclone central location in model analysis in 06 UTC for both EXP and CNTL runs

Date/cycle	IMD observed cyclone location	Model analysis in CNTL run	Model analysis in EXP run	Error computed with respect to IMD in CNTL run (km)	Error computed with respect to IMD in EXP run (km)
27 December 2011 06 UTC	87°E, 12°N	87.2°E, 12.3°N	87°E, 12.2°N	39.6	22
28 December 2011 06 UTC	85°E, 12.5°N	84.8°E, 12.1°N	84.8°E, 12.1°N	49.5	49.5
29 December 2011 06 UTC	82°E, 12°N	82°E, 11.7°N	82°E, 11.7°N	33	33
30 December 2011 06 UTC	79°E, 11.8°N	79.2°E, 11.7°N	79.2°E, 11.7°N	22	22
Mean error				36	30

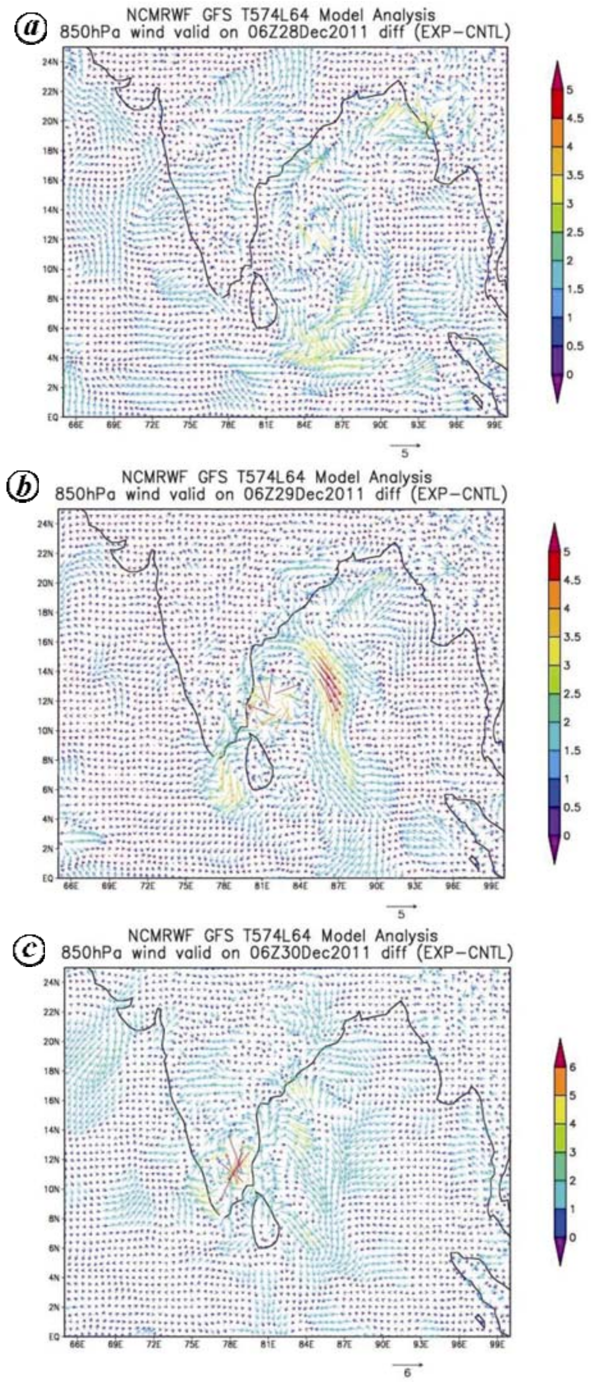

Figure 4. Difference between 06 UTC analysis from EXP and CNTL runs over North Indian Ocean. ***a***, 28 December 2011; ***b***, 29 December 2011; ***c***, 30 December 2011.

respective suppliers are considered for the analysis. Details of the analysis system implemented at NCMRWF can be found in Dutta and Prasad[6]. The datasets presently assimilated are given in Table 1 and include scatterometer wind from ASCAT. These runs are considered as control (CNTL) and experimental (EXP) runs are repeated by including ocean surface wind vector data from OScat for the period 17 December 2011 to 1 January 2012. Starting from 20 December 2011 (00 UTC) onwards forecast experiments up to 120 h are carried out with different initial conditions of 00 UTC till 1 January 2012. The analyses and forecasts thus generated by using OScat wind vectors are compared with those of the control run. The impact of OSE is examined in terms of anomaly correlation coefficients, RMSE and skill scores. This period is chosen as it includes the tropical cyclone *Thane*. The circulation features of the cyclone both in analysis and forecast are also studied.

The tropical cyclone *Thane* was the strongest cyclone over the North Indian Ocean in 2011. It developed as a tropical disturbance to the west of Indonesia around 25 December 2011 and gradually intensified into a tropical cyclone over the next couple of days while moving towards over northwest. It was declared as tropical cyclone on 27 December 2011 and made landfall in the early hours of 30 December 2011 on north Tamil Nadu coast between Cuddalore and Puducherry.

The scatterometers provide information about wind vector distribution over sea surface at 10 m height. Thus it is expected to improve the circulation features in the analysis and thereby improve the quality of forecasts in terms of position and intensity of the system. Figure 2 depicts the model analysis valid at 06 UTC on 26 December 2011 in the control run and the difference between the control and experimental runs over the North Indian Ocean. It clearly shows the change in the location of the centre of the system and the distribution of winds around the system. The centre of the system in the CNTL (without OScat) run is at 9.8°N, 87.3°E, whereas in EXP (with OScat) run it is at 9.5°N, 87.3°E. According to India Meteorological Department (IMD) observations, the centre of the cyclone on 26 December 2011 at 06 UTC was at 9.5°N, 87.5°E. So, the error in model analysis of cyclone centre, with respect to IMD's observed location, in CNTL and EXP runs is 40 and 22 km respectively. Hence, OScat data have improved cyclone location in

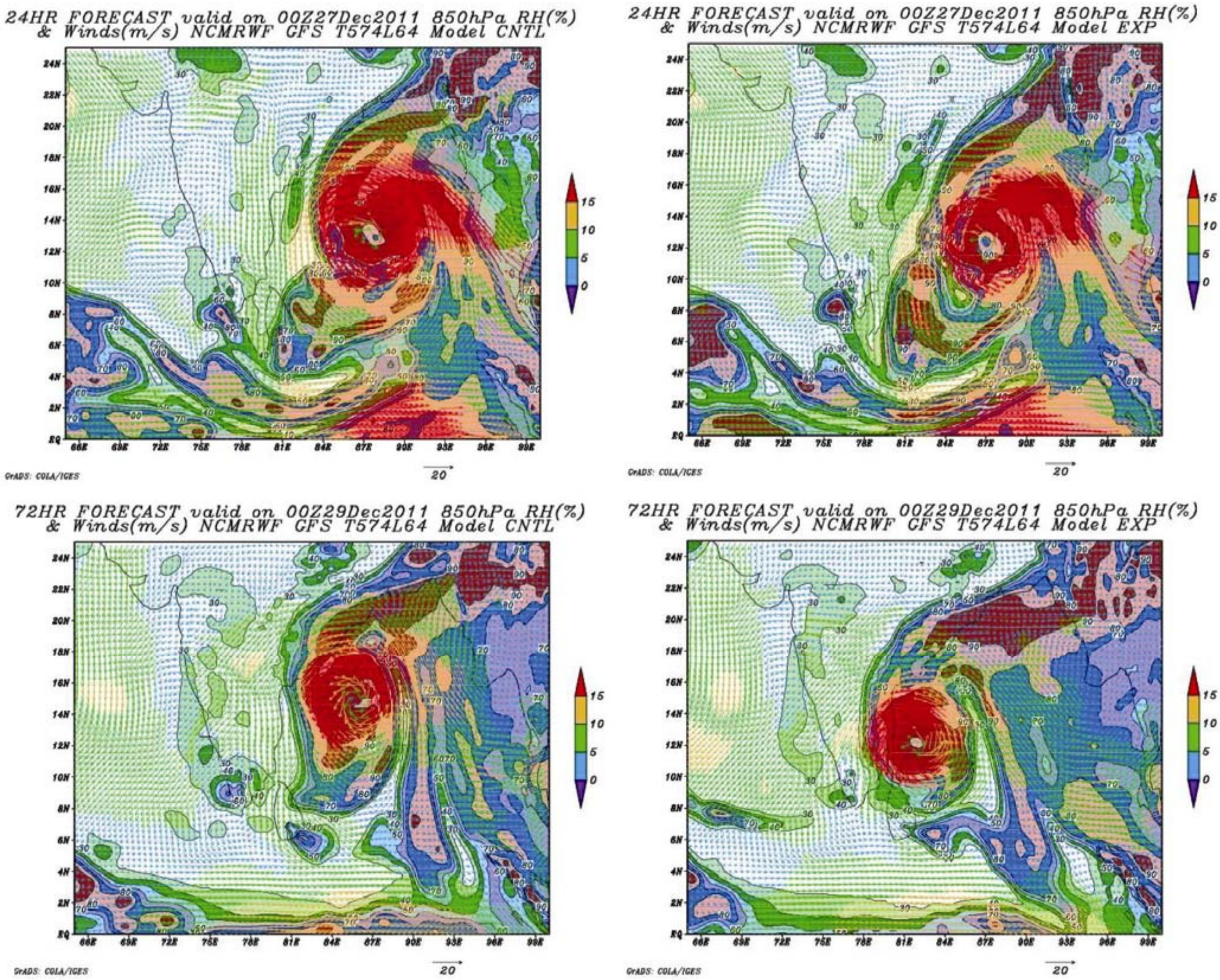

Figure 5. The 24 and 72 h forecast humidity and wind fields around cyclone *Thane* for CNTL and EXP runs.

model simulations for 26 December 2011. Figure 2 also depicts about 2–3 m/s increase in wind speed. The predicted forecast tracks based on the 26 December 2011 initial conditions for EXP and CNTL runs, along with the observed track are shown in Figure 3. It clearly indicates that there is a better agreement between observed track and EXP track (which is able to simulate change in the direction of movement).

In the NCMRWF GDAF system, the cyclone bogus procedure is activated automatically once any system attains cyclonic strength, based on *JTWC Tropical Cyclone Bulletin*; in this case it was activated on 27 December 2011 from 00 UTC onwards. Table 2 shows a comparison of cyclone centers in the EXP and CNTL runs with that of IMD's best track positions (observed position) from 27 December till the system became weak on 30 December 2011. It clearly shows that the centre of cyclone in case of the EXP run is closer to observed position on 27 December 2011 and remained the same as that of the CNTL run for remaining days. This result is expected, as the same bogus procedure is applied in both runs. Noticeable differences in the wind field can be observed around the cyclone (Figure 4) due to the use of OScat wind in EXP. These differences in the wind field seem to be able to modify even the humidity structure around the system in the forecast runs (Figure 5). The eye of the cyclone is well resolved in the EXP run consistently even up to 72 h forecast compared to CNTL runs.

Further, to study the impact of OScat scatterometer wind vector data on GDAF system forecast objective score, namely anomaly correlation for the respective analysis, is computed for the whole period 17 December 2011–1 January 2012 based on CBS standard of the World Metrological Organization. In the present work, a detailed study has been conducted over five regions – (1) northern hemisphere, (2) southern hemisphere, (3) the tropics (30°S to 30°N), (4) RSMC region (10°S–40°N, 40°–100°E) and the entire globe. Figure 6 shows the mean

Table 3. Anomaly correlation of 24, 72, 120 and 144 h forecasts of meridional component of wind (*v*) at 850 hPa in CNTL and EXP runs

	Northern hemisphere		Southern hemisphere		Tropics		RSMC		Global	
Fore cast (h)	EXP	CNTL	EXP	CNTL	EXP	CNTL	EXP	CNTL	EXP	CNTL
24	0.95	0.94	0.93	0.93	0.88	0.88	0.91	0.91	0.94	0.93
72	0.83	0.82	0.81	0.8	0.7	0.71	0.77	0.79	0.81	0.8
120	0.61	0.6	0.61	0.62	0.6	0.61	0.68	0.7	0.61	0.61
144	0.45	0.47	0.51	0.55	0.53	0.55	0.61	0.62	0.49	0.52

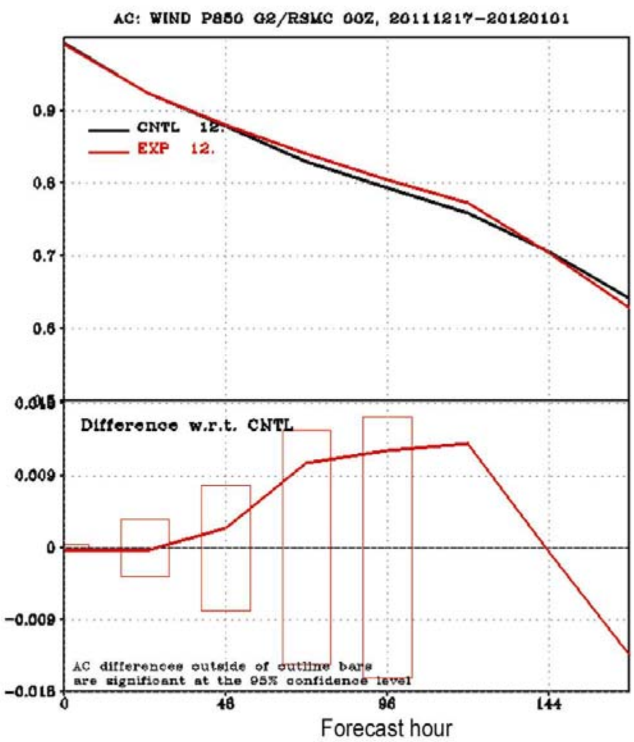

Figure 6. Mean anomaly correlation for the period 17 December 2011–1 January 2012 for 850 hPa wind.

850 hPa wind anomaly correlation for the entire forecast length over the RMSC region for the whole period. It can be seen that there is clear improvement in the forecast skill in case of EXP run, especially between 48 h and 120 h at 90% confidence level. Subsequently a slight deterioration is seen, which is not statistically significant. Table 3 depicts the anomaly correlation of 24, 72, 120 and 144 h forecasts, for meridional component of wind (*v*) at 850 hPa in CNTL and EXP runs over the five regions. It presents a mixed result and most of the improvements are noticeable as forecast length increases in RMSC and tropical region in the case of EXP runs.

This study has clearly brought out the following: (1) Oceansat-2 scatterometer-derived surface wind has a positive impact on T574L64 model analysis and forecast for the period of this study, which includes the tropical cyclone *Thane*. (2) Verification statistics shows a clear increase in anomaly correlation in model forecasts in the case of EXP run compared to that of CNTL run, particularly over RSMC and the tropics. (3) Model analysis in EXP run shows improvement in location of the centre of the cyclone. There is a reduction in the mean position error of the cyclone with respect to IMD's best track in the EXP run. (4) The predicted track of cyclone *Thane* is in better agreement with IMD's observed track in EXP runs.

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