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COMPARISON OF THE SEASTATE DURING THANE AND NILAM CYCLONES ALONG SOUTH EAST COAST OF INDIA – USING WAM

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ABSTRACT: Knowledge on the ensemble wave characteristics such as significant wave height (H_s) during the propagation of a cyclone is important in the planning of mitigation measures along the coastal zone. This is in addition to the design of structures in the nearshore and along the coast for its sustainability. Hence, the wave climate which persist along the south-east coast of India during two different cyclones Thane and Nilam that made landfall in the successive years 2011 and 2012 are simulated using WAM. The model simulation has been validated with field observations. The detailed results are discussed in this paper.

Keywords: Extreme wave characteristics, wind wave modeling, tropical cyclone.

INTRODUCTION

The East coast of Indian Peninsula, precisely the coastal stretch extending from 10ºN and 13ºN experiences frequent cyclonic landfall on an annual basis, in particular during the months of Nov-Dec. Four major harbours and four minor harbours apart from several fish landing centres are located along this stretch of the coast. The coast is also exposed to one of the world's largest alongshore drift to an extent of about 1million m^3 per annum directed towards North. This in fact had resulted in several challenging perennial problems like siltation of harbour channels and river mouths, erosion along the coast, steepening of beach fronts, etc. The mitigation measures need a clear understanding on the wave heights during the occurrence of a cyclone. It has significant important in the design criteria of almost all types of ocean structures especially in the coastal zone.

The prediction methods of these extreme events are thus vital. Young (1987) developed a relation based on an equivalent fetch for estimating the wave parameters within hurricanes. Young (2002) further investigated four different cyclonic data sets to arrive at a set of standard relations to define a hurricane wave field which is being widely used in the design of offshore structures. The transformation of water masses and circulation from deep-waters into the continental shelf have been extensively studied by Huthnance (1995) that provide an insight on its influence on the cyclonic track in the continental shelf. Sanil Kumar et al. (2003) investigated wind and wave characteristics due to eleven cyclones that have occurred in the vicinity off Nagapattinam coast along south-east coast of India and formulated site-specific empirical relations to estimate significant wave height (H_s) and peak period (T_p) for the maximum wind speed (U_{max}). Phadke et al. (2003) compared parametric models of cyclone winds and applied them to drive WAM for simulating conditions of hurricane. It was stated that the modified Rankine vortex method has shown a good agreement with Iniki hurricane of 1992 that had occurred near Hawaii Island. Brown (2010) studied the combined effect of wave and storm surge under storm using WAM and SWAN to simulate the shallow water conditions inside a bay which has significant effect from tide, surge and wave interaction. An one-dimensional surge model has been incorporated into the wave model. Zijlema et al. (2012) investigated the effect of bottom friction and wind drag on wave models, which is essential to get the bottom dissipation particularly in the near shore region.

CYCLONES CONSIDERED FOR THE STUDY

In the present work, the extreme wave climate that occurred during the recent cyclones off the South East coast of India, i.e., within latitudes from 10ºN to 13ºN has been studied in detail. The recent cyclones Thane (that made landfall during 25th – 30th Dec., 2011) and Nilam (that made landfall during 28th Oct. – 1st Nov., 2012) are considered for the present study. Out of this, the cyclone Nilam has made a land fall at about 60km south of Chennai and Thane had its intervention on to the coast near to Pudhucherry, which is about 150km south of Chennai coast. However the sea state at Chennai was observed to be higher for Thane than for that of Nilam. Hence, it is interesting to understand the sea states due to Thane and Nilam. These are simulated

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using wind wave model (WAM) after validating the WAM results with field measurements.

Cyclone 'Thane'

The cyclone Thane can be considered as the strongest tropical cyclone in the past five years. The cyclone, that was centred at 9.5°N, 87.5°E, started gaining momentum from 26th December 2011 and it had obtained further momentum by moving towards north-westwards. During its strongest state, it had centred at 12°N, 80.6°E at 1800 hours on 29 Dec 2011 with a maximum sustainable wind speed of 150 km/hr prior to crossing the coast at Puducherry (11.8°N, 79.9°E) at 0730 hours on 30th Dec. 2011.

Cyclone 'Nilam'

The Nilam cyclone started as a depression from the forenoon of 28th Oct. 2012 when it was centred at 9.5°N, 86.0°E. Later, it obtained momentum by moving towards western and north-western direction. It was at its strongest state when centred around 11.0°N, 81.0°E, during the forenoon of 31st October 2012, with a maximum sustainable wind speed of around 80km/hr prior to crossing the east coast of India near Mahabalipuram at around 1630 hours on the same day.

The location of cyclone eye, central pressure drop and maximum sustained wind during the Thane and Nilam cyclones were obtained from Indian Meteorological Department (IMD) and are presented in Tables 1and 2, respectively.

WAVE MODELLING – WAM

The numerical wave model (WAM) is a regional wind-wave prediction model, the details of which along with its governing spectral transport equation are given by Komen et al. (1994). The bathymetry of required resolution over the domain and the wind field at required time step are essential for better wave prediction. The directional wave spectrum can be generated over the entire domain at the grid points at each time step. Given the constraint of the numerical modelling capabilities, the wave prediction accuracy depends on the precision of wind vectors. The model domain considered is 0º-25ºN and 75ºE-95ºE covering Bay of Bengal that is shown in Fig.1. A grid resolution of 0.1°x0.1° is considered. ENCEP wind data from NOAA with a grid resolution of 0.5°x0.5° is used for simulation.

Table 1. Location, Cental pressure drop and Maximum sustained surface wind velocity during the cyclone Thane (obtained from IMD)

Date	Time (UTC)	Eye centre		Estimated central pressure (hPa)	Estimated max sustained surface wind (Knots)
		Lat ˚N	Long ˚E		
26.12.2011	0000	9.5	87.5	998	30
	0600	10.0	87.5	998	30
	1200	10.5	87.5	998	30
	1800	11.0	87.5	996	35
27.12.2011	0	11.5	87.5	994	40
	0600	12.0	87.0	994	40
	1200	12.5	86.5	992	40
	1800	12.5	86.0	990	45
28.12.2011	0000	12.5	85.5	990	45
	0600	12.5	85.0	988	45
	0900	12.5	85.0	986	55
	1200	12.5	84.5	982	65
	1500	12.5	84.0	980	65
	1800	12.5	84.0	978	65
	2100	12.5	83.5	976	65
29.12.2011	0000	12.3	83.0	974	70
	0600	12.0	82.0	972	75
	0900	12.0	81.7	972	75
	1200	12.0	81.3	972	75
	1800	12.0	80.6	972	75
30.12.2011	0000	11.8	79.9	972	75
	0300	11.8	79.5	986	55
	0600	11.8	79.0	998	30
	1200	11.8	78.2	1000	25
31.12.2011	0000	The system weakened into a well marked low pressure area over north Kerala and neighbourhood.			

Table 2. Location, Cental pressure drop and Maximum sustained surface wind velocity during the cyclone Nilam (obtained from IMD)

Date	Time (UTC)	Eye centre Lat ˚N	Long ˚E	Estimated central pressure (hPa)	Estimated max sustained surface wind (Knots)
28.10.2012	0600	9.5	86.0	1004	25
	1200	9.5	85.0	1003	25
	1800	9.5	84.5	1002	25
29.10.2012	0000	9.5	84.0	1000	30
	0300	9.5	83.5	1000	30
	0600	9.0	83.0	1000	30
	1200	9.0	82.5	1000	30
	1800	9.0	82.0	1000	30
30.10.2012	0000	9.0	82.0	999	30
	0300	9.0	81.9	998	35
	0600	9.0	81.8	996	35
	900	9.5	82.0	996	35
	1200	9.5	81.8	994	40
	1500	9.5	82.0	994	40
	1800	10.0	82.0	992	40
	2100	10.0	82.0	992	40
31.10.2012	0000	10.5	81.5	990	45
	0300	11.0	81.0	990	45
	0600	11.5	81.0	990	45
	0900	12.3	80.5	990	45
	1200	12.7	79.8	991	35
	1500	13.0	79.5	996	35
	The cyclone crossed East coast of India near Mahabalipuram on the south of Chennai(12.6º N, 80.2º E) between 1600 and 1700 hrs IST				
	1800	13.0	78.5	998	30
01.11.2012	0000	13.0	77.5	999	20
	0300	13.5	77.0	1002	20
	0600	13.5	77.0	1002	20
	1200	14.0	77.0	1002	20
	1800	14.5	77.0	1004	20
02.11.2012	0000	The system weakened into a well marked low pressure area over Rayalaseema and neighbourhood.			

With this background information, an attempt is made to validate the predictions of wave characteristics with WAM model during extreme events like cyclones and depressions along the south east coast of India.

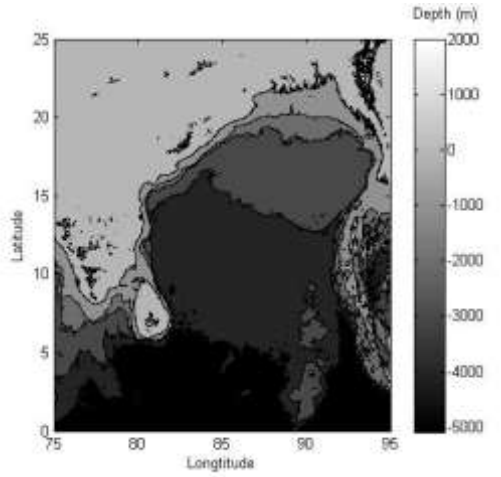

Fig.1 The domain considered for WAM simulation

RESULTS AND DISCUSSION

Wave characteristics - comparison and discussion

Typical contours of wave height obtained from WAM model over the domain during 0600 hours of 29th December 2011 for Thane and during 0600 hours on 31st October 2012 for Nilam (during which both the cyclones are at its strongest state) are projected in Figs.2a and 2b, respectively. From this, we can observe that the diameter of wind system of Thane is greater than that of Nilam. The wave characteristics, H_s, T_m and θ_m from the measurements in 20m water depth off Chennai coast during Thane cyclone are compared with the WAM simulation as presented in Fig.3a.

The wave characteristics, H_s and θ_m from the measurements in 8m water depth off Pudhucherry coast during Nilam cyclone are compared with the WAM simulation as shown in Fig.3b. It is inferred from Fig.3a that H_s, T_m and θ_m obtained from WAM are in good agreement with the field measurements even during cyclonic activities. Whereas, a clear deviation between the observed and simulated H_s and θ_m (field observed data for T_m was not available) can be seen. It is due to that the measurements were made in a comparatively shallow location and hence, the shallow water effect such as shoaling and refraction has played a major role in it. Even though, depth induced refraction was considered in the WAM simulation, the dissipation due to shallow water effects were not modelled in the numerical simulation.

Since the comparison from field measurements and WAM simulation are in reasonable agreement, the discussion of wave characteristics obtained from WAM

simulations has been made. The maximum H_s obtained from WAM simulation off Chennai coast during Thane is 5.8m at 24 hours prior to the intervention of cyclone over the coast. During Nilam, the maximum H_s was observed to be 6.1m during the invasion of Nilam on to the coast. Whereas, off Pudhucherry coast, the maximum H_s during Thane is 5.89m at 24 hours prior to land fall and during Nilam, it is found to be 4.1m at few hours prior to the landfall.

From the analysis, it is seen that H_s during the occurrence of the Thane cyclone is having more or less of the same order on either side of the land fall, but on the other hand, a difference is observed during the Nilam. In order to investigate this aspect the spatial variation of H_s derived from WAM along a plane normal and passing through the eye of the cyclone as well as closer to the shore near the landfall for both the cyclones have been obtained and projected in Fig.4a and 4b. Based on the results, it is clear that the heading direction of cyclone system has an impact on H_s at the coasts on either side of the landfall.

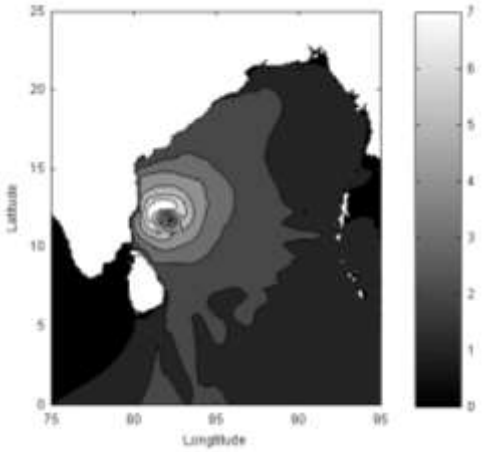

Fig. 2a Typical H_s contour (6:00 am, 29th Dec. 2011 – during Thane) obtained from WAM

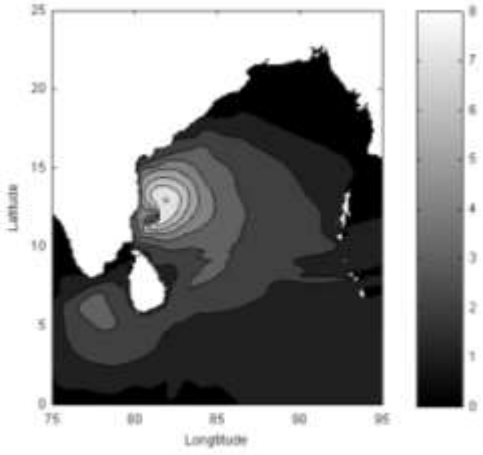

Fig. 2b Typical H_s contour (6:00 am, 31st Oct. 2012 – during Nilam) obtained from WAM

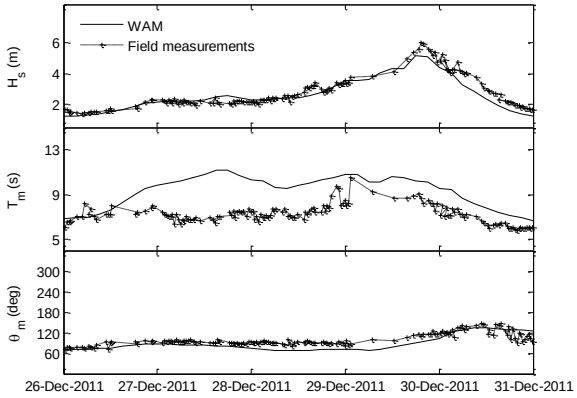

Fig. 3a Comparison of results from WAM with field measurements off Chennai coast during **Thane** cyclone in a water depth of 20m

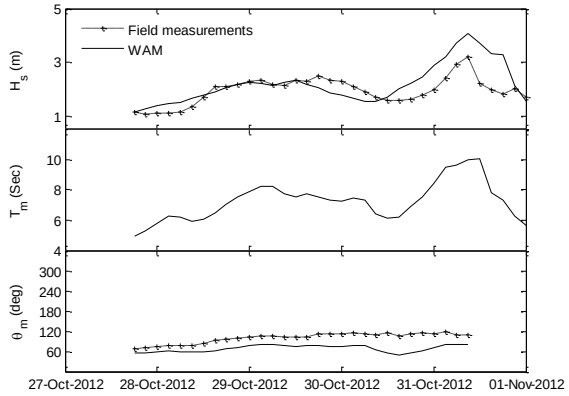

Fig. 3b Comparison of results from WAM with field measurements off Pudhucherry coast during **Nilam** cyclone in a water depth of --m

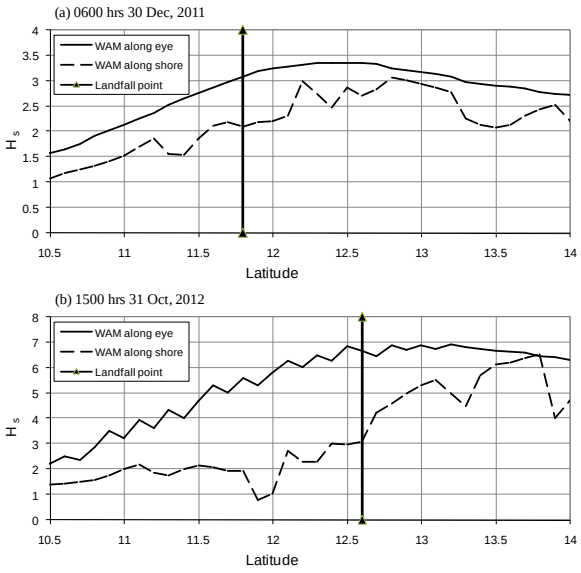

Fig. 4 spatial variation of H_s across the eye of cyclone and at the coast during the occurrence of landfall for both the cyclones (a)Thane - 0600 hrs 30/12/2011 and (b)Nilam -1500 hrs 31/10/2012

Impact along the coast of Chennai

The coastal morphological changes can be classified under two categories: long time such as annual changes due to seasonal wave climate; and, the other one, short time morphological changes due to the impact of rough sea along with a raise in sea level (storm surge) resulting from a cyclonic storm. Even though, the impact due to the storm is of few days duration, it can cause an equivalent impact of a seasonal change.

The impact of Nilam on the beach profile on the north Chennai coast is shown in Fig.5a and b. Both the profiles are taken at a distance of 20m apart and the net volume loss is about $330m^3$ due to the cyclone (the profiles are taken 24 hrs before and after the passage of Nilam). On the other hand during the Thane cyclone, the entire beach was washed away once after the event, further it causes a large damage to the head sections of the north Chennai groin field. The post cyclone surveys show some of the damages due to Thane cyclone, which are shown in Photos 1 and 2. The photos exhibit not only the damage to the rubble mound but also the lifting of concrete slab placed on the revetment.

Even though the cyclone Nilam had the land fall near the Chennai coast than that of Thane, the impact felt due to Thane is much more. It shows the important of wind speed and the intensity of the cyclone

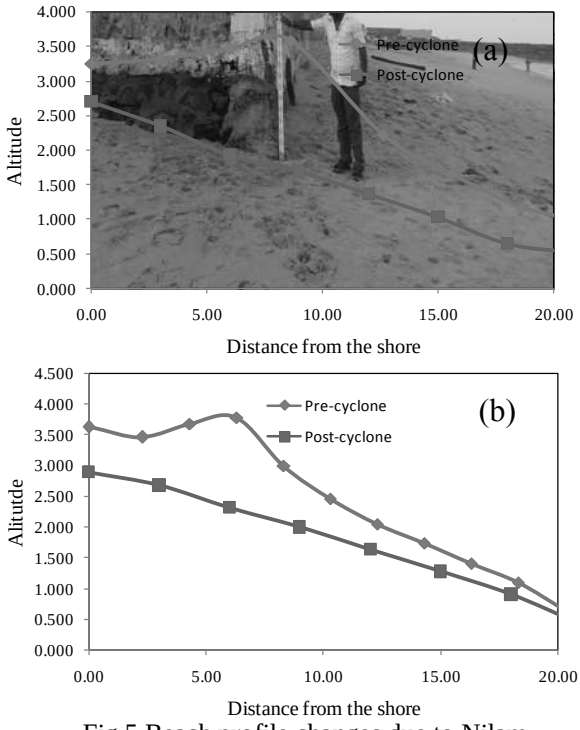

Fig.5 Beach profile changes due to Nilam

(1)

(2)

Photos. 1 and 2 damages to the revetment due to 'Thane'.

SUMMARY AND CONCLUSION

The extreme wave climate due to severe cyclones Thane and Nilam off south east coast of India precisely Chennai and Puidhucherry coasts has been studied in detail. The simulation from the wind wave model WAM is compared with the field measurements off Chennai coast during Thane cyclone and off Pudhucherry coast during Nilam cyclone. From the results and discussions, it is clearly seen that the heading direction of cyclone system and the wind intensity are the main criteria, based on which the effects are felt on the coast. It is reemphasized from the impact felt by Thane which is more than that of Nilam.

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wave characteristics at Pudhucherry at the time of Nilam cyclone.

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