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Observational analysis on the run-up height and inundation along the Andhra coast during December 26, 2004 Indian Ocean tsunami

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ABSTRACT

The 26 December 2004 earthquake with magnitude of 9.3 triggered one of the most destructive tsunamis in the Indian Ocean and caused widespread inundation and extensive damage in terms of life and property along the coasts of several Asian countries. In India, the Andaman and Nicobar group of Islands, the coastal states of Tamil Nadu, Andhra Pradesh and Kerala were severely affected. Post tsunami field surveys were conducted along the Andhra coast (central part of east coast of India) to assess the tsunami run-up heights and inundation. Estimation of tsunami run-up heights and inundation relative to the mean sea level were made based on the water marks on permanent structures and marks of debris on trees. Observations revealed that the Andhra coast was largely affected by the tsunami and in general the intensity of the tsunami along the Andhra coast decreased from south to north. Maximum run-up heights of 4.5 m were observed in the southern parts and minimum run-up heights of 2 m were observed in the northern parts of the Andhra coast. While, the distance of inundation varied from 60 to 900 m along the coast. The interdependency between the tsunami run-up height and inundation with the physical setup of the shoreline has been identified. Also local features such as dunes, vegetation and steepness of beaches played vital role in reducing the impact of tsunami. Dependency of tsunami parameters on Coastal Characteristic Index (CCI) was attempted for the first time for the Indian coast. Good correlation has been observed between run-up heights, inundation and CCI. The width of the continental shelf also played a crucial role in causing damage to the coast.

1. Introduction

Tsunami is a long period gravity wave generated by undersea earthquakes, landslides, volcanic eruptions or meteorite impacts. History reveals that on an average two tsunamis occurred every year throughout the world causing damage to the source region. Destructive tsunamis occurred once in 15 years, causing substantial damage to the coasts (Gusiakov, 2002). Most of the tsunamis occurred in the Pacific Ocean, while tsunamis in the Indian Ocean are very few. It is estimated that on an average eight tsunamis occurred per year in the Pacific Ocean and once in 3 years in the Indian Ocean (Loughlin and Lander, 2003) which had badly affected the coastal areas of several countries including Indonesia, Malaysia, Thailand, Myanmar, Sri Lanka and India (Titov et al., 2005). The Indian coast was severely affected for five times by tsunamis during the last 123 years (1881–2004) (Sadhuram, 2005). The earliest recorded tsunami along the Indian coast was on December 31, 1881 due to an earthquake measuring Mw = 7.9 near Car Nicobar (Murthy and Bapat, 1999).

As per the USGS reports the devastating mega thrust earthquake of 26 December 2004 occurred on Sunday at 00:58:53 GMT (7:58:53 AM local time at the epicenter) with Mw = 9.3 NEIC Epicenter Latitude 3.32°N, Longitude 95.85°E (Murty et al., 2007). Ioualalen et al. (2007) described the tsunami as the third largest earthquake ever recorded. In this tsunami, it was reported that the Andaman and Nicobar Islands and part of the Tamil Nadu coast were the worst affected in the Indian region (Yeh et al., 2005, 2006; Jayakumar et al., 2005; Chadha et al., 2005; Ramana Murthy et al., 2005). The above studies on run-up heights and inundation limits based on post tsunami surveys along the coastal stretch 10–14°N indicate maximum run-up heights of 5–7 m at Nagapattinam and minimum of 2 m at Chennai along Tamil Nadu coast; whereas for Andhra coast the observed run-up heights were 2.5 m at Krishnapatnam and 1.5 m at Visakhapatnam. The studies emphasized the role of coastal geomorphology and bathymetry in the variation of run up heights and inundation.

In the present study the effect of tsunami and the resultant inundation along the Andhra coast covering 19 landmark stations of varied topography and coastline configuration (see Fig. 1) have been taken up. As the intensity of the tsunami is observed to vary along the coast, the authors studied the variability of tsunami event based on three important coastal features viz. physical setup

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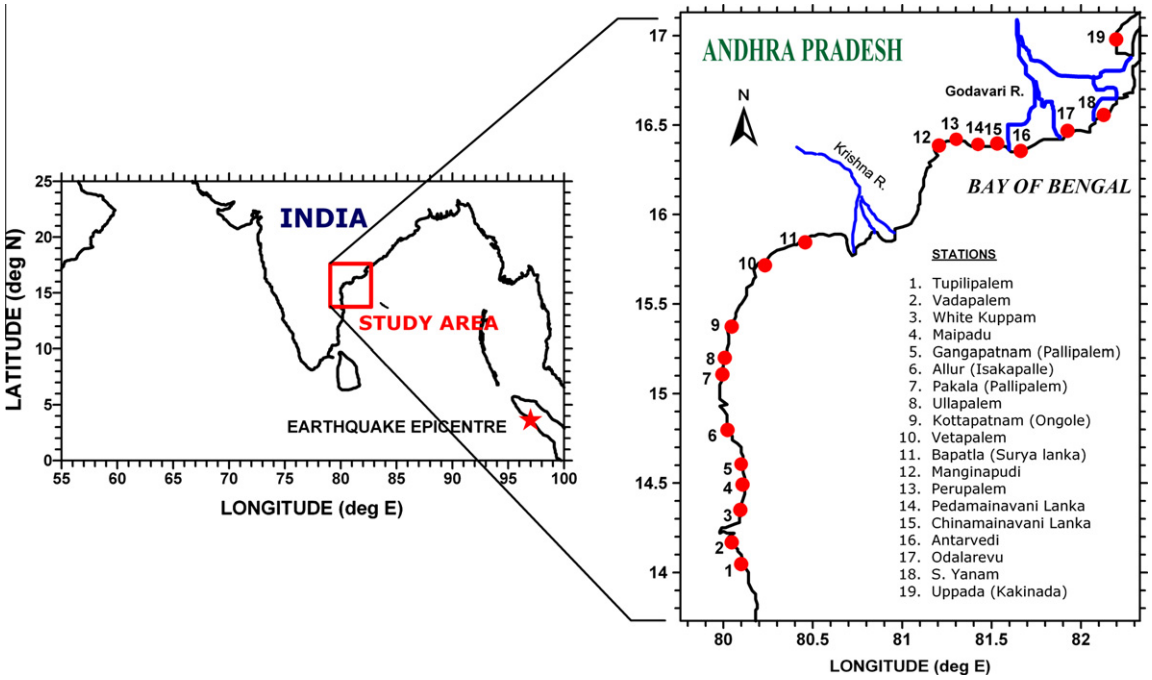

Fig. 1. Station locations along the study area.

of the coastline, shape of the offshore contour depth and Coastal Characteristic Index (CCI *here after*). Details of these features are explained in the discussion part of this paper.

2. Data and methodology

The variability of run-up heights and water levels along Indian Ocean for the December 26, 2004 tsunami were reported earlier by various workers (Ramana Murthy et al., 2005; Sadhuram, 2005; Suresh et al., 2006; Natarajan et al., 2006; Iwan, 2006; Usha et al., 2009). As part of post tsunami survey program funded by the Department of Science and Technology, Government of India, a number of surveys were conducted by the Andhra University from 26th to 31st March, 2005 along the Andhra coast from Tupilipalem to Kakinada (Uppada) (Fig. 1) covering 19 stations to identify the regions affected by the tsunami. The measurements at the selected locations along the coastline include tsunami run-up height as well as the extent of horizontal inundation. Station locations and respective run-up heights and inundations are tabulated in the Table 1. The tsunami run-up height was obtained visually, based on water marks and damage on structures or trees (Figs. 3 and 4) as well as from eye witness accounts. The inundation was measured by locating two points; one at the shoreline and the other at the end point of the affected area by using Hand-held GPS. This method was repeated 2–3 times for at least 1 km alongshore at each station and then the mean value was taken to reduce the error in the estimation. The vertical elevation of the beach at

Table 1
Station locations and respective run-up heights and inundations along with remarks.

ID	Location/Station	Latitude (°N)	Longitude (°E)	Survey date	Inund. distance (m)	Tsunami run-up (m)	Remarks
1	Tupilipalem	14.06	80.10	26-3-05	300	3.8	Thick vegetation reduced the effect
2	Vadapalem	14.18	80.04	26-3-05	200	4.5	
3	White Kuppam	14.36	80.10	27-3-05	700	4.5	Flat beach, no plantation
4	Maipadu	14.51	80.11	27-3-05	200	3.8	
5	Gangapatnam	14.63	80.10	28-3-05	900	4.5	Village is surrounded by two creaks (Max. Damage)
6	Isakapalle	14.81	80.02	28-3-05	200	3.0	Damage to boats
7	Pallipalem	15.12	79.99	29-3-05	400	3.5	Damage to houses and boats
8	Ullapalem	15.22	80.01	29-3-05	300	3.5	Flat beach with salt water ponds
9	Kottapatnam	15.39	80.04	30-3-05	−50	3.8	Elevated road obstructed inundation
10	Vetapalem	15.73	80.23	30-3-05	400	3.0	Thick vegetation
11	Suryalanka	15.86	80.45	30-3-05	150	2.3	Steep beach slope
12	Manginapudi	16.38	81.20	30-3-05	800	2.3	Flat beach slope
13	Perupalem	16.41	81.30	31-3-05	200	3.0	Stable backshore
14	Pedamainvani Lanka	16.38	81.42	31-3-05	900	3.0	Eroded shore
15	Chinamainavani Lanka	16.38	81.53	31-3-05	700	2.5	Deaths and boats lost due to flat profile
16	Antarvedi	16.35	81.66	31-3-05	150	2.5	Beach is fairly steep
17	Odalarevu	16.46	81.92	31-3-05	70	0.75	Drilling sites were damaged
18	S. Yanam	16.55	81.13	31-3-05	60	0.8	No significant change
19	Uppada	17.00	82.20	31-3-05	70	2	Less effect