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Status Report

Tsunami and the Effects on Coastal Morphology and Ecosystems: A Report

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Tsunamis are one of the most destructive natural hazards that affect the coastal areas. Tsunami waves that impact the coast with enormous energy are capable of destroying the objects on the coast and re-shaping the coastal geography, geomorphology and ecosystem. These waves can also cause extensive damage and disruption to human lives, their livelihood, infrastructure and economic activities. The 26 December 2004 Sumatra-Andaman earthquake, one of the largest recorded and deadliest tremor, created an unparalleled catastrophic tsunami wiping out thousands of human lives and throwing millions homeless. This event attracted the interest of several geoscientists in India and stimulated extensive scientific research. This article summarizes the tsunami related research work carried out in India during the past four years.

Key Words: **Tsunami; Earthquake; Sumatra & Makran Subduction Zones; Numerical Modeling; Coastal Morphology; Coastal Vulnerability; Ecosystems**

Introduction

The 9.3 magnitude earthquake off coast of Sumatra on 26 December 2004 and the subsequent tsunami in the Indian Ocean caused unprecedented loss to human life and property in the coastal regions of India and neighbouring countries. About 230,000 people perished in the countries along the Indian Ocean rim by the waves thus generated. The disaster raised awareness of tsunamis and prompted nations to support research and equipment. As a consequence, the warning systems setup in the Indian Ocean can now effectively forecast as to when and how the tsunamis will cross ocean basin and hit the coastlines thousands of kilometers away from the location of the earthquake.

In India, the research related to tsunami was unheard of prior to the occurrence of the event on 26 December 2004. Mostly, the research related to tsunami dealt with seismicity of the tsunamigenic regions, modeling and observations of tsunami waves, changes in coastal morphology, changes in ecosystems and paleo-tsunamis. A total of 77 research publications from Indian authors appeared in various journals dealing with above aspects during the past four years. The major findings of these research publications are summarized.

Seismicity of Tsunamigenic Regions

A study by Mishra *et al*. (2011) based on 3-D P-wave tomography for the entire rupture zone of the Andaman and Nicobar region using the aftershocks of the 2004 Sumatra–Andaman earthquake (Mw 9.3) demonstrated the role of crustal heterogeneity in seismogenesis that caused the strong shakings and tsunamis. Ambikapathy *et al*. (2010) studied the rupture model of the 2007 Bengkulu earthquake using GPS measurements. The measurements provided estimates of high coseismic displacements reaching 1.2 m. The modeling of this near-field data suggested that the 250 × 100 km^2 earthquake ruptured the gently dipping plate interface with a maximum slip of 7.0 m under the Pagai Island. Majority of the slip on the rupture was confined in the depth range of 13-40 km and the rupture did not extend till the trench. The earthquake, despite its large size, did not generate a major tsunami as most of the high slip occurred under the islands and shallow water, so that the volume of the water displaced by the coseismic uplift was too low to cause any major tsunami. Jaiswal *et al*. (2011) studied the aftershock sequence of the 2004 Sumatra earthquake and simulated the 2007 Bengkulu earthquake and showed that as the path of the tsunami for Indian coastlines was oblique; hence, no impacts along the Indian coastline except near the coast of epicentral region. Study of multi-sensor temporal satellite data of pre- and post earthquake period for six months around Andaman and Nicobar Islands revealed that northwestern part of the Island Belt experienced emergence of landmass while major parts of South Andaman, part of Little Andaman and islands of Nicobar Group suffered submergence. Further study for a period of six months following the main shock, established that the uplifted northwestern part of the

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Andaman-Nicobar Island Belt experienced reverse changes and the southeastern part suffered further submergence due to post-earthquake readjustment while the central part of the belt remained stable (Das and Pramanik, 2011).

Based on an assessment of the repeat periods of great earthquakes from past seismicity, convergence rates and paleoseismological results, Jaiswal *et al*. (2008) identified Central Sumatra, Java, Makran coast, Indus Delta, Kutch-Saurashtra, Bangladesh and southern Myanmar as possible source zones of earthquakes in near future which might cause tsunamis in the Indian Ocean. Kundu and Gahalaut (2010) suggested that the lack of sufficient width of subducting Indian plate slab under the Irrawaddy region (between latitudes 15° N and 18° N) makes the region aseismic and limits the potential for major and great earthquakes to be generated. Accordingly, the seismic and tsunami potential of this region may not be as high as that in the Andaman and Arakan regions. Gupta and Gahalaut (2009) concluded that the northern Bay of Bengal does not have a tectonic environment conducive for the occurrence of a megathrust tsunamigenic earthquake.

Modeling and Observations on Tsunami Waves

Prabhudesai *et al*. (2008) indicated the importance of having high-sensitivity and real-time monitoring and internet-accessible sea-level stations on India's island locations for effective tsunami warning purposes for the mainland.

Numerical modeling of tsunamis helps in generating faster and reliable forecasts of tsunamis propagating through the ocean and striking coastal communities. The modeling also assists the coastal communities in their efforts to assess the risk, and mitigate the potential of tsunami hazard. The run-up and inundation extent obtained from the modeling is very useful to plan future disaster management by preparing the vulnerability and hazard maps. Ilayaraja *et al*. (2008) simulated the 26 December, 2004 earthquake for the Andaman & Nicobar Islands region to provide a scenario of the tsunami impact on the region. The results were validated through observations from a tide gauge record at Port Blair and run-up surveys. Ioualalen *et al*. (2010) simulated the same event for the Tamil Nadu coastal zone and provided full scenario of the tsunami impact on the area using the fully nonlinear Boussinesq model.

Praveen *et al*. (2011) simulated the 2004 tsunami along the southwest coast and Lakshadweep Islands of India and found reasonable agreement between the observations and the results of numerical simulations. Numerical modeling studies for the Car Nicobar Islands region by Usha *et al*. (2009) revealed their high vulnerability to tsunami hazards. The Islands seems to be most vulnerable along the eastern and the southern side compared to the western side. Rani *et al*. (2011) simulated tsunami propagation and inundation due to two scenarios of tsunamigenic earthquakes in the Sumatra–Andaman subduction zone (26 December 2004 earthquake and a possible earthquake in the Andaman region) and their impact at Visakhapatnam, Andhra Pradesh. The run-up heights and inundation extent along the Visakhapatnam coast in the case of the Andaman earthquake was more than the case of the December 26, 2004, Sumatra earthquake. Rao *et al*. (2011) simulated the tsunami run-up and inundation distances along Krishnapatnam, Kavali, and Ongole coasts of Andhra Pradesh using TUNAMI N2 model and compared with the observed features of tsunami of the 26 December, 2004. Kurian and Praveen (2010) studied the implications of the wave propagation characteristics on tsunami run-up and inundation along the Kerala coast for two probable sources of tsunami viz. Sumatra and Makran through numerical modeling for same rupture intensity and found that the central and northern sectors of the coast are more hazard prone to the event along Makran than that along Sumatra.

The 1945 Makran earthquake is known to have generated tsunami surges that affected the coasts of Iran, Pakistan, Oman and India. However, there is a significant delay in tsunami arrivals at various coastal sites with respect to the time of the earthquake. Rajendran *et al*. (2008) modeled the earthquake parameters for tsunami wave propagation and attributed the disparity in the tsunami arrival times to submarine landslides triggered by the earthquake. These authors have also suggested the incorporation of submarine landslide mechanism triggered due to an earthquake in the regional tsunami hazard models of both the Bay of Bengal and Arabian Sea. Srivastava *et al*. (2011) showed that the tsunami from the Makran subduction zone arrived at Ratnagiri eight minutes earlier than that at Mumbai due to the wide shelf (> 250 km) at Mumbai. However, using a numerical model Neetu *et al*. (2011) showed that the persistent high waves along the Makran coast and at Karachi were the result of trapping of the tsunami-wave energy on the continental shelf off the Makran coast and that these coastally-trapped edge waves were trapped in the alongshore direction within a 300 km stretch of the continental shelf.

Kumar *et al*. (2008) prepared a Tsunami Travel Time (TTT) atlas for various coastal locations surrounding the Indian Ocean rim. Chamoli *et al*. (2010) presented wavelet analysis of earthquake events which gives a methodology for tsunami warning based on the frequency content of the seismogram which is fast and can overcome the problems of conventional tsunami warning methods in practical situations.

Jaiswal *et al*. (2009) simulated the Arabian Sea tsunami using the TUNAMI N2 model and presented the run-up elevation maps, depicting the possible areas that might inundate due to different wave heights along the parts of Gujarat coast. These results will be useful in planning the protection measures against inundation due to tsunami. Using numerical models, Arjun *et al*. (2011) showed that the run-up due to the 1945 Makran tsunami along the southwest coast of India and Lakshadweep Islands was considerably less than that of the 2004 Sumatra tsunami.

Bapat and Murty (2008) presented the field survey results at Kanyakumari, the southernmost tip of India. On a coastline of about 4.8 km in long, the tsunami amplitudes varied from about 1.5 m to about 9.5 m. The horizontal extent of inundation ranged from a few meters to about 1,000 m. The large tsunami run-up variations over such short distances were caused by the convergences and divergences of waves due to local shoreline geometry, its orientation and the near shore bathymetric gradients. Cho *et al*. (2008) documented the run-up and inundation of recent tsunamis and loss of life due to the December 26, 2004, tsunami in the Andaman and Nicobar Islands. Satheeshkumar *et al*. (2008) studied the tsunami impact along Chennai coast starting from Pulicat to Kovalam using GIS tools.

Coastal Morphology, Shoreline Changes and Coastal Maps

Tsunami hazard map is the key step in tsunami risk assessment and forms the basis for evacuation and future land use planning along coastal areas. Murthy *et al*. (2011) prepared Tsunami hazard maps for coastal Cuddalore by overlaying the numerical model outputs along with details on land use, elevation, cadastral land parcels, infrastructure, high tide line, and coastal regulation zones. Inundation mapping of the 2004 December Tsunami by Chittibabu and Baskaran (2009) along the Karaikal region highlighted vulnerable areas of tsunami inundation and provided demarcations of suitable sites for rehabilitation.

Kumar *et al*. (2010) prepared coastal vulnerability maps for the Orissa state using remote sensing data, in situ observations, numerical modeling, and GIS analysis tools. The maps showed that 22% of the Orissa coastline is in the high vulnerable category, 62% in the medium vulnerable category, and 16% in the low vulnerable category. Such coastal vulnerability maps serve as a broad indicator of threats to people living in coastal zones and can be effectively used by coastal managers and administrators for better planning to mitigate the losses due to hazards and establish priorities of areas for evacuation during disasters. Mahendra *et al*. (2011) developed a methodology for coastal multi-hazard vulnerability assessment using parameters like maximum storm surge height return periods, future sea level rise, coastal erosion and high resolution coastal topography with the aid of the remote sensing and GIS tools. Sonak *et al*. (2008) recommended the application of the ICZM (Integrated Coastal Zone Management) concept for the reconstruction efforts in the tsunami affected areas.

Changes in the beach profiles, longshore currents, breaking wave characteristics in the surf zone at selected locations along the Tamil Nadu coast were studied during January, April, October 2005 and January 2006 by Jayakumar *et al*. (2008) to understand the coastal environment. At most locations, the shoreline was observed to recede by about 20 m and built-up of backshore by about 0.5 m. Observations from the field investigations and comparisons with earlier studies along this stretch of the coastline indicated that the coastline is yet to return completely to normalcy. Using Digital Shoreline Analysis System of ArcGIS, Mujabar *et al*. (2011) studied the shoreline changes along Kanyakumari and Tuticorin. Srivastava and Sivakumar (2009) illustrated an analytical design approach that is necessary for a shoreline protection system.

Effects of Tsunami on Coastal Ecosystems

Tsunami waves can produce extensive changes in coastline topography due to considerable erosion and subsequent deposition of substantial quantity of sediments in relatively short time spans. Translation of large amounts of seawater on land by tsunami waves introduces large amounts of salt into surface and ground water, substantially impacting the coastal ecosystem like mangroves, coral reefs, forests etc. Ranjan *et al*. (2008) studied the impact of the tsunami on Pichavaram mangrove ecosystem and observed significant spatial variations in nutrient concentration in mangrove water and increase in the concentration of inorganic nitrogen and phosphorus causing the threat of eutrophification in the area. They also found significant alteration in sediment composition and characterization with respect to heavy metal concentration after 2004 tsunami. Senthilkumar *et al*. (2008) observed increase in salinity after the tsunami due to the opening of sand bar at Coleroon river mouth causing an influx of sea water into the Pichavaram mangroves region.

Pari *et al*. (2008) studied the morphological changes at the Vellar estuary in Tamil Nadu and reported that the high momentum tsunami waves swept the bottom sediment and deposited either in low-lying areas or deep regions of the estuary (mouth). The sand dunes in the foreshore regions and vegetation in the hinterland acted as successive stages of barriers to tsunami wave energy. Anandan *et al*. (2008) showed that at Kalpakkam coast, inundation ranged between 95 and 530 m and the run-up varied between 3.3 and 7.7 m. The morphological changes along the coast in the form of reappearance of old drainage have been observed. Coastal vegetation such as small shrubs and grasses were either washed away or uprooted. A fair amount of sediments, including traces of monazite sands got deposited all along the coast. Narayana (2011) discussed the geomorphic changes associated with the 2004 earthquake and subsequent tsunami in the Andaman-Nicobar region using IRS-P6 LISS III data.

Singarasubramanian *et al*. (2009) in their geomorphological and sedimentological study near the Vellar river and the M.G.R. island area of the central Tamil Nadu coast concluded that stabilized dunes with vegetation offer protection to the coast from marine disasters like cyclones, storm surges, tsunamis or extreme waves. Also the Vellar River and the Muzhukkuthurai lagoon reduced tsunami inundation and extent of destruction in the inland region. Thus, the coastal morphologies played an important role in protecting the coast and the coastal communities. The particle size analysis in the study area indicated that the sediments that got deposited inland by the waves of the tsunami ranged from fine to medium and well-sorted sands. These deposits showed typical color and textural variations from the normal tidal sediments. Near the estuary they were superimposed over the pre-existing dark carbonaceous estuarine clays. Overall, the deposits exhibited trampled structures over the planar beds which indicate that the tsunami deposition of sediments occurred under high wave velocity conditions. Hentry *et al*. (2010) recommended a costal barrier or Rubble Mount Sea Walls of 15 m in height and encouraged mangroves plantation to protect the coast from the erosion associated with tsunami. They also suggested for beach nourishment, bioshield, tree plantations and developing artificial sand dunes to help in mitigating the effects of tsunami.

Bahuguna *et al*. (2008) assessed the status of vital coastal ecosystems using pre- and post-tsunami data obtained from Advance Wide Field Sensor (AWiFS) on board Indian satellite RESOURCESAT. Among the coastal ecosystems, the coral reefs suffered the maximum with the Nicobar reefs, 69% eroded and 29% degraded. Bearing the brunt, more than 54% of the Andaman reefs eroded and 22% degraded. Mangroves on both the groups of islands were impacted due to uprooting and inundation of seawater leading to stagnation.

Jha *et al*. (2011) assessed the coral reef resources of Pongi Balu coast to quantify the change in coral reef area between the pre-tsunami and post-tsunami conditions using GIS technique. A total of 161.6 ha of existing coral reefs were monitored along the Pongi Balu coast and out of that ‘live coral’ was found over 81.4 ha and ‘dead coral’ over 60.6 ha. 19.6 ha of coral was lost and therefore was categorized as ‘no coral’ suggesting that a reduction in coral reef area from 2004 to 2009.

Raghunathan *et al*. (2010) investigated the density and diversity of corals and their associated faunal communities by underwater survey in Katchal and Teressa Islands of Andaman and Nicobar Archipelago in order to assess the post-tsunami status of corals. The study revealed that the density of scleractinian corals in Katchal Island is 1-13 colonies/10m^2, and in Teressa Island it ranged from 1 to 18 colonies/10m^2.

Porwal *et al*. (2011) studied the spatially explicit scenario of damaged, submerged and lost forest areas and corresponding area statistics, vital for understanding and mitigating the medium and long term effects of tsunami events. Prasad *et al*. (2010) presented an approach to classify forest density and to estimate canopy closure of the forest of the Andaman and Nicobar archipelago, which would serve as a significant measure to assess forest health in disaster management specially for the post-tsunami assessment and analysis. Rasingam and Parathasarathy (2009) compared patterns of tree species diversity and extent of damage by tsunami at eight sites in Little Andaman Island. Deforestation of an area of 3292.5 ha in the North Andaman Islands by the tsunami of 26 December, 2004 was revealed by the application of remote sensing and GIS Technique (Prasad *et al*. 2009). Sathyaraj *et al*. (2009) estimated the damage to agricultural land due to the tsunami in the Nagappattinam district as 9567.09 ha.

Singh (2008) studied the impact of earthquake and tsunami of December 26, 2004, on the groundwater regime at Neill Island (South Andaman). The aquifer system has been submerged, cracked and lifted at various places leading to deterioration in groundwater quality. It has been found that the shell limestone aquifer at few places have developed cracks due to the earthquake and these openings have allowed quick movement of seawater into the aquifer resulting in the deterioration of the quality of groundwater. Groundwater quality studies by Ravisankar and Poongothai (2008), in the tsunami affected areas of Sirkazhi taluk, Nagapattinam district, revealed the decline of ground water quality in the region due to inundation.

Chandrasekharan *et al*. (2008) studied the variability of soil-water quality in the coastal belt of the Nagapattinam district in Tamil Nadu. Three sets of soil samples, up to a depth of 30 cm, from the land surface were collected for the first six months of the year 2005 from 28 locations and the ground water samples were monitored from seven existing wells and hand pumps covering the study region. It was revealed that the soil salinity and pH of the majority of agricultural regions became suitable for agricultural production by June 2005.

Deeper aquifers of coastal environment are fragile and are under the threat of salt water intrusion due to over exploitation. This becomes more serious when shallow aquifer is also contaminated by shallow waters due to invasion and percolation of sea water by the giant tsunami waves. Chidambaram *et al*. (2008) made an attempt to measure the variation in the salinity of the ground water after the tsunami using geo-electrical method in the region from Parangipettai to Pumpuhar along the coastal Tamil Nadu. Significant variations were observed in apparent resistivity values, due to percolation of sea water in to shallow aquifers. The impact of tsunami on the shallow aquifer reveals that Q type of P.S. Pettai has changed to K type and H to A at certain locations. The hydro-geochemical study by Chidambaram *et al*. (2010) in the same region showed decline in the ground water quality due to the inundation by tsunami waves.

Sivakumar *et al*. (2010) demonstrated the application of groundwater modeling to understand the process of salinization of groundwater resources by tsunami. It also helped to determine the time that it would take for remediation of the aquifer system by rainfall recharge. Kume *et al*. (2009) provided important management implications for soil, groundwater, and vegetation in the tsunami affected regions of the Nagapattinam district, Tamil Nadu.

Salinity studies by Raja *et al.* (2009) in the south Andaman region revealed that irrespective of soil series and water resources, the soluble salt concentration increased markedly post-tsunami (2005) making the soil highly saline/saline sodic. However, high rainfall during the subsequent years (3774 mm in 2005 & 3072 mm in 2006) has drastically reduced the salinity levels to almost close to pre-tsunami levels. Nayak *et al*. (2010) also reported tsunami led conversion of acid soils to saline acid soils and acid sodic soils to acid saline sodic soils in South Andaman. Impact of the 2004 tsunami on the near-shore seabed of Kalpakkam was studied using the pre- and post-tsunami bathymetry data (Anandan and Sasidhar, 2008). A post-tsunami analysis of soils of mangroves of the Andamans showed higher levels of saturation in Na and Mg and marked reductions in microbial biomass (Chaudhuri *et al*. 2009).

Hydrobiological studies at Kudankulam coast by Satheesh and Godwin (2009) showed higher concentrations of nitrates, nitrites, and phosphates and phytoplankton density immediately after the tsunami. The dissolved oxygen content and the zooplankton abundance decreased considerably. Post-tsunami data indicated that the coastal ecosystem recovered from the impact within five months. Kume *et al*. (2009) confirmed that rainfall of monsoon was essential resource not only for desalinization but also for agricultural production in the Nagapattinam district.

Srinivasulu *et al*. (2009) studied the characteristics of the 2004 tsunami deposits along the northern Tamil Nadu coast. At few places, the tsunami deposits have reworked due to subsequent events that caused modification in internal stratigraphy. The tsunami deposits of the northern Tamil Nadu coast comprise at least 50% or more reworked foraminiferal specimens, indicating that the tsunami sediments may have been derived from a paleostrandline from a water depth of at least 45 m. Rashi *et al*. (2011) studied the tsunami- sediment signatures in the Manakudy estuary and found the post-tsunami sediment texture is predominantly coarser. Granulometric analysis indicated a shift of well-sorted, coarse skewed and platykurtic nature during the pre-tsunami season, to moderately sorted, fine skewed and leptokurtic behavior, after the tsunami.

Sedimentological studies by Srinivasulu *et al*. (2008) along the Southeast coast of India revealed significantly high contents of dissolved salts in sediments (Na^+, K^+, Ca^{+2}, Mg^{+2}, Cl^-) in water-soluble fraction due to seawater deposition and evaporation. Geochemical analysis of the pre and post tsunami samples collected off southeast coast of India showed that the tsunami waves had high energy to transport the sediments to deeper areas (Srinivasulu *et al*. 2010). Ilayaraja and Krishnamurthy (2010) analyzed a total of 48 surface sediment samples from various coastal geomorphological features such as beaches, estuaries/ creeks and mangrove areas in the Andaman group of islands to understand the effects of tsunami.

Hussain *et al*. (2010) signifies the importance of ostracoda species in identifying major natural events (e.g. tsunamis) in the coastal regions. The depositional feature of ostracoda species in the beach and estuarine region also infers on the nature and force of tsunami waves in a particular region.

Shukla *et al*. (2010) presented the coastal geomorphology and processes acting along the Kachchh coast. Six distinct segments were identified along the Kachchh coast and were described for their possible response to tsunami event. Mascarenhas and Jayakumar (2008) discussed the role of sand dunes in dissipating the powerful waves caused due to tsunamis and storm surges. Also recommended to consider options for adaptation against, rather than mitigation of, coastal hazards, and adopt measures for restoration of coastal sand dunes with sufficient forested shelter belts backshore as long term, sustainable management solutions for Indian coasts.

Sarangi (2011) observed high chlorophyll at selected transects in the aftermath of the tsunami event in coastal regions and offshore waters in the Bay of Bengal. Debaje *et al*. (2011) observed an unusual maximum Ozone (O_3) concentration of 28 ppbv in the morning and a minimum

(16 ppbv) in the evening on 26 December 2004 at Tranquebar (11°N, 79.9° E, 9 m) over the west coast of the Bay of Bengal. Ganesh *et al*. (2009) observed low Aerosol Optical Thickness (AOTs) at Mysore on December 26, 2004 compared to all other days in the month of December 2004. Barren Island (ca. 10 km^2) volcano, the only active volcano in the Indian subcontinent resumed eruptive activity in May 2005 after the 2004 tsunami (Chandrasekharam *et al*. 2009). The study probably indicates the link between tectonics and magmatism in Burma–Andaman–Java subduction area.

Srijothi and Neelamalar (2011) described the role played by the media in improving the life styles of affected women after the tsunami in Tamil Nadu. It was suggested that progress made in media communications should not be limited to disaster periods only but should be expanded to help improve preparedness for future events that may occur. Sustainable society development with emphasis on safety from disasters should be an extensive and substantial process that needs to be continuously supported by the mainstream media.

Paleo Tsunamis

Malik *et al*. (2011) conducted coastal stratigraphy study near Port Blair, Andaman Islands, where the 2004 Sumatra-Andaman earthquake produced ~1.0 m of subsidence. This study also provided evidence for two prior earthquakes during the past 400 years. The first of these (event I) was marked by an abrupt mud-over-peat contact best explained by subsidence similar to that in 2004. Event II was evidenced by an overlying chaotic layer composed of mud clasts in a sandy matrix that is connected with feeder dikes. Coastal sediments on the Andaman Islands were also investigated to find evidence for paleo-tsunamis and paleo-earthquakes using optically stimulated luminescence (OSL) and radiocarbon dating method (Kunz *et al*. 2010). The results showed a tsunami that occurred about 1,000 or 3,000 years before the present.

Rajendran *et al*. (2008) obtained radiocarbon dates from coastal terraces of the island belt which vary from 1.33 mm yr^{-1} in the Little Andaman to 2.80 mm yr^{-1} in South Andaman and 2.45 mm yr^{-1} in the North Andaman. The radiocarbon dates converged on ~600 yr and ~1000 yr old coastal uplifts, which were attributed to the level changes due to two major subduction earthquakes in the region.

Rajendran *et al*. (2011) presented sedimentary evidence from an archaeological site to validate the textual references to the Chola period (early medieval) tsunami event. A sandy layer showing bed forms representing high-energy conditions, possibly generated by a seaborne wave, was identified at the Kaveripattinam coast of Tamil Nadu, South India. Its sedimentary characteristics included hummocky cross-stratification, convolute lamination with heavy minerals, rip-up clasts, an erosional contact with the underlying mud bed, and a landward thinning geometry. Admixed with 1000-year-old Chola period artifacts, it also provided an OSL age of ~ 1091-66 years and a thermoluminescence age of 993-73 years for the embedded pottery sherds. The dates of these proxies converge around 1000 yr B.P., correlative of an ancient tsunami reported from elsewhere along the Indian Ocean coasts.

Conclusions

There could be some more research work that might have escaped the attention of the authors. Contribution of Indian scientists in tsunami-related studies is increasing at a rapid pace with substantive contributions and methodological innovations.

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