NOTES

A NOTE ON THE 26 DECEMBER 2004 TSUNAMI IN THE INDIAN OCEAN

The Indian Ocean, in the vicinity of Sumatra, was jolted by a 9 M earthquake in the morning of 26 December 2004, with the following parameters:

Date	26th December 2004
Origin Time	06 Hours 29 Minutes (IST)
Magnitude	9
Epicentre	Latitude: 3.7 degree North
	Longitude: 95.0 degree East
Region	Off the west coast of Sumatra Island (Indonesia)

The earthquake was followed by a number of aftershocks, which are still continuing; more than 150 exceeding M 5 having already occurred. Notably among them was an earthquake of magnitude 7.3 which occurred off the coast of Great Nicobar with the following parameters:

Date	26th December 2004
Origin Time	09 Hours 52 Minutes of IST
Magnitude	7.3
Epicentre	Latitude: 7.3 degree North
	Longitude: 92.7 degree East
Region	Off the coast of Great Nicobar

There was widespread damage, and loss of property and human lives as a tsunami generated by the Sumatra earthquake hit the Andaman & Nicobar group of islands, and later hit the east coast of India. The tide-gauge located at the Chennai Port gives the time of the Tsunami reaching there around 9:00 A.M. The devastation has been unprecedented. At the time of writing this note on 12 January 2005, it is estimated that more than 1,60,000 people have been killed This includes almost 10,000 people from the Indian coasts. The biggest toll has been in Indonesia – the figure hovering around 1,00,000 as on date.

Tsunamis are generated when an earthquake causes a vertical movement at the base of the ocean, thereby disturbing the entire column of water. The waves travel with a velocity of 800 to 900 km/hr in the open ocean. However, the velocity is significantly reduced when these enter the coastal areas. In the open oceans, the amplitude of tsunami is not very significant. However, as the entire column of water is moving and as the tsunami enters the shallow waters, the energy is transferred into large amplitudes. Table 1 gives a list of large tsunamis in the past.

It must be noted that the 26 December 2004 earthquake

Table 1. List of large tsunamis in the historical past

November 1, 1775	the great Lisbon earthquake generates a wave up to 20-feet high that strikes coastal Portugal, Spain and Morocco.
August 27, 1883	the eruption of the volcano Krakatau generates a massive wave that sweeps over the shores of nearby Java and Sumatra, killing 36,000 people.
June 15, 1896	the Sanriku tsunami strikes Japan without warning. A wave estimated at more than 70 feet high hits a crowd gathered to celebrate a religious festival, killing more than 26,000 people.
December 17, 1896	tsunami washes away part of the embankment and main boulevard of Santa Barbara, California.
January 31, 1906	a devastating offshore quake submerges part of Tumaco, Colombia, and washes away every house on the coast between Rioverde, Ecuador, and Micay, Colombia. Death toll estimated at 500 to 1,500.
April 1, 1946	Alaskan quake generates a tsunami that destroys North Cape Lighthouse, killing five. Hours later the wave arrives at Hilo, Hawaii, killing 159 people and cauing millions of dollars in damage.
May 22, 1960	a wave reported as up to 35-feet high kills 1,000 in Chile and causes damage in Hawaii, where 61 die, and in the Philippines, Okinawa and Japan as it sweeps across the Pacific.
March 28, 1964	Good Friday earthquake in Alaska sends out a wave swamping much of the Alaskan coast and destroying three villages. The wave kills 107 people in Alaska, four in Oregon and 11 in California as it sweeps down the West Coast.
August 16, 1976	tsunami kills more than 5,000 people in the Moro Gulf region of the Philippines.
July 17, 1998	an offshore quake triggers a wave that strikes the north coast of Papua-New Guinea, killing some 2,000 people and leaving thousands more homeless.

of magnitude 9 is the 5th largest earthquake ever recorded in the history of earthquakes, and is the largest earthquake after the M 9.3 earthquake of Alaska in 1964. It may also be noted that never before an earthquake of this size occurred in this part of the world. Originally, the Andaman earthquake of M 7.3 soon after the Sumatra earthquake was thought to be an independent earthquake. However, now it is clear that it was an aftershock of the Sumatra earthquake. As a matter of fact, this M 9 earthquake has broken a sector of the plate boundary extending some 1000 km, with vertical displacements of up to 20 m.

If one looks at the distribution of earthquakes globally, more than 75% of earthquake energy is released in the circum-Pacific belt, about 20% in the Alpine-Himalayan belt, and remaining 5% through the mid-oceanic ridges and other Stable Continental Region earthquakes. Due to the frequent occurrence of tsunami on the coasts of the Pacific rim countries, a consortium came into existence in 1964 for warning the populations of the Pacific coast countries, in advance about the arrival of tsunami waves at specific locations. Known as the Tsunami Warning System in the Pacific (TWPS), it is supported by 28 Pacific rim countries. It is possible to estimate the size of the waves and the time of arrival at a given location, depending upon the computed displacement at the ocean floor due to an earthquake, its distance to a specific point, and the bathymetry which contributes significantly to the height of the waves.

However, as far as the Indian coastline is concerned, the areas which could possibly generate tsunamigenic earthquakes are the extension of Java-Sumatra earthquake belt into Andaman & Nicobar, and some areas in the Arabian Sea (possibly extension of the faults responsible for the 1819 and 2001 earthquakes into the Arabian Sea). Tsunami is not a common phenomenon in the Indian coasts. Murty, T.S. et al. ("Tsunamis on the coastlines of India", Science of Tsunami Hazards, v.17(3), 1999, p.167) have listed six tsunamis (Table 2) dating back to 326 B.C. Out of these, definite evidence exists for the August 27, 1883 tsunami as a consequence of the Krakatoa volcanic eruption.

An often asked question after the tragedy of the 26th December tsunami is that why it was not observed by the data buoys deployed in the Bay of Bengal. It is important to note that the ocean surface is not quiet at any given time, and in open oceans, waves of several meters are a common happening. However, these waves have no signature when you go to depths of 200 m or so. At the bottom of the ocean, it is very quiet. However, when a tsunami is generated, the whole column of water gets affected and as this disturbance moves, a transducer set at the ocean bottom can detect a tsunami which could not be done by ocean surface data buoys.

Table 2. Tsunamis on the coastlines of India

Date	Remarks
326 B.C.	Alexander the Great
Between 1st April and 9th May 1008	Tsunami on the Iranian coast from a local earthquake
August 27th 1883	Krakatoa 1.5 m tsunami at Madras, 0.6 m at Nagapattinam, 0.2 m at Arden
1884	Earthquake in the western part of the Bay of Bengal. Tsunamis at Port Blair, Dublet (mouth of Hooghly River)
26th June 1941	8.1 quake in the Andaman Sea at 12.9°N, 92.5°E. Tsunamis on the east coast of India with amplitudes from 0.75 to 1.25 m
27th November 1945	8.25 quake 70 km south of Karachi at 24.5°N, 63.0°E. Tsunami amplitude at Kutch was 11.0 to 11.5 m.

What would be important for India is to try to locate tsunamigenic earthquakes in near real time, deploy ocean bottom sensors of the kind deployed in the Pacific region to detect generation of tsunamis, calculate the travel time from possible sources to Indian coasts based on bathymetry and other relevant information, prepare inundation maps and the affect on coastal areas, and develop a proper mechanism of communication as early as possible to the stakeholders.

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