Lessons from the 2004 Indian Ocean Tsunami

Tohoku University Student Member Angela Santos
Tohoku University Member Shunichi Koshimura
Tohoku University Member Fumihiko Imamura

1. Introduction

The 2004 Indian Ocean Tsunami shocked the world by its extension of damage, power of destruction and casualties. It was very well documented firstly due to real time information broadcasted worldwide by the mass media; and secondly recorded in terms of instrumental measurements (tide gauge stations, seismological stations and satellite observation).

The objective of this paper is to summarize the lessons of this event in order to discuss the basic idea of a Tsunami Warning System (TWS) and to increase public awareness with historical tsunamis and hazard maps.

2. What information should be provided by TWS

2.1. Real time data

Real time data on tsunamis is essential for TWS. The Pacific Tsunami Warning Center had real time access to 2 of the 26 tide gauge stations available in the Indian Ocean. Both stations measure "a small tsunami". Therefore, the net of stations in the Indian Ocean should be increased, in order to obtain more accurate evaluation of future tsunamis.

On the other hand, the satellite Jason-1 measured the tsunami but the transmission of data was not fast enough for a possible tsunami warning.

2.2 Prediction with Numerical model: as *a posteriori* approach

Tsunami forecasting is also important information in TWS. We carried out the tsunami numerical simulation using the linear shallow water theory in a spherical coordinate system, with a staggered leap-frog scheme [Goto *et al.*, 1997] in order to discuss the possibility of TWS. For the initial sea surface displacement we used the Okada [1985] Theory and its parameters are summarized in Table 1

Table1: Fault Parameters used in the model [Koshimura *et al.*, 2005]

Parameters	South Subfault	North Subfault
Origin of the fault	94.8°E, 2.5°N	92.0°E, 6.5°N
Length (km)	500	400
Width (km)	150	150
Dislocation (m)	11	11
Strike	329°	358°
Dip	15°	15°
Slip	90°	90°
Depth (km)	10	10

We used a spatial grid size of 2 min and time step of 3 sec. The bathymetry data is 2-minute Gridded Global Relief data (ETOPO2) [National Geophysical Data Center, 2005] in order to make a comprehensive overview of the tsunami. Then, we used 1 min grid size [GEBCO, 2003] focusing on Thailand and India. Figure 1 indicates the waveforms computed with 2 and 1 min grid size, at Tuticorin, India. We can conclude that although we used the same model for the initial sea surface displacement when we used 1 min grid size, the first half cycle is in good agreement with the observation.

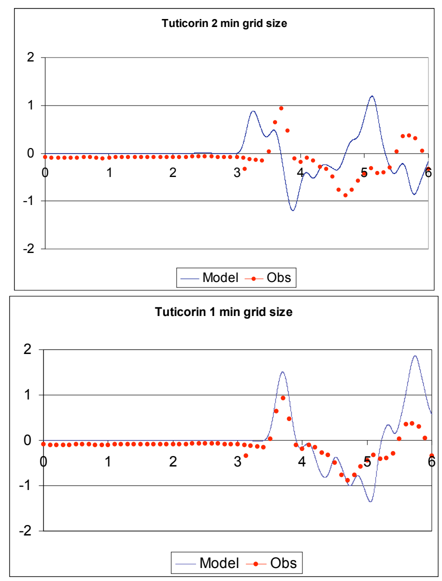

Figure 1: modeled and observed waveforms in Tuticorin; upper figure is the model results with 2 min grid size and lower figure with 1 min.

2.3 Stakeholders and coordination

There was no coordination between the several authorities (international, national, regional, local) during the 2004 event ; this coordination is very important for TWS. In some areas there was a misunderstanding between the authorities and the information did not reach the populations.

3. Knowing hazards and increasing Awareness

3.1 Historical events

Tsunamis are rare events, and even in the areas at significant risk, people forget very easily the lessons. In the case of 2004 Indian Ocean Tsunami, there were several examples of people that could be saved due to previous knowledge of these waves: the Moken in Myanmar and Thailand escaped to high land when they read the nature's signs; in Simeulue Island, Indonesia people also evacuated due to an old saying; in Maikhao beach, Thailand a young girl remembered her geography class about tsunamis and people evacuated to safe areas. Major historical events around the Sumatra Island occurred in 1797 (M~8.4), 1833 (M~9), 1861 (M~8.5), 1881 (M~7.9), 1941 (M~7.9) [Lay et al., 2005].

3.2 Tsunami hazard maps

Although there were 4 earthquakes in the past that generated tsunamis near Sumatra Island, there are no tsunami hazard maps. Nobody knew where was safe to escape. After this tsunami, the populations (especially in Banda Aceh, Indonesia) were aware of the safe zones; but this was not a systematic research, instead the populations took actions by their own.

3.3 Post Tsunami Survey for scientific feature

The International Tsunami Survey Team (ITST) conducted the measurement of tsunami heights at the hit zones in order to obtain accurate run-up heights.

Indonesia: the average run-up was ~10.2m. Western coasts of North Aceh, Sumatra due to inaccessibility from damaged coastal roads and bridges. In Banda Aceh, the Yokohama National University measured 48.8 m.

Sri Lanka: the average run-up was ~5.5m. A train was washed away in Kahawa. It is still difficult to make surveys at northern part of eastern coasts of Sri Lanka due to political conflicts.

India: The average run-up was ~6.5m. It was difficult to go to Nicobar Islands due to security reasons and logistic problems.

Thailand: the average run-up was ~7.8m.

Maldives: the average run-up was ~2m.

The role of mangroves: coastlines with mangroves were less damaged than those where mangroves were absent or had been removed. Since the tsunami energy was absorbed by the trees, the run-up and velocity decreased. On the other hand, the mangroves prevented people to be washed away. It allowed also the driftwood and other objects to be trapped, preventing property damage/loss. Green belts of other trees, coastal dunes, and intact coral reefs performed similar functions. Although Mangroves are a very effective natural tool against tsunamis, they are being lost to aquaculture, shrimp farming, coastal development, etc. Therefore, the proper management of the mangroves should be evaluated.

4. Mitigation of tsunami disaster

4.1 Law

Unlikely many other tsunamis, most of the damage and casualties were due to the tsunami. Even in Banda Aceh, Indonesia, the city closest to the epicenter, the damage was not significant.

In Sri Lanka the government tried to implement the "100/200 m law'. This law was an attempt to kept people away from the coast, by forbidden the constructions in a range of 100 m from the coastline.

In most of the places hit by the tsunami, there was total destruction. In this extreme case, probably there was no construction or measure power enough to hold on such a force.

4.2 Recovery

Immediately after the disaster, several non governmental organizations moved to the hit areas for disaster relief. Their priority, on the first few days, was to rescue the survivors and provide food and water to isolated populations. The governments of the hit countries didn't have any action. The fact that the tsunami hit 11 countries all over the Indian Ocean made the rescue/recovery process a mega operation. Although nobody was prepared for this disaster, everything was made to make the daily life of the populations go back to normal.

4.3 Mass media

The mass media had two major roles: worldwide live broadcasting of the disaster, providing quick information to a large number of people; and special reports with educational programs, interviews with experts, awareness of natural disasters, etc.

On the other hand, the public interest increased due to the involvement of victims from "western" countries. Finally, videos, photos and satellite images helped to understand more details or this evnt.

5. Conclusions

To build a TWS we should analyze the results of the numerical model focusing first on the travel time; the survey data made by the ITST should be used to make tsunami hazard maps. A network of real time data is fundamental to warn the populations to escape to designated refuge areas. By improving the law and the role of stakeholders, a future evacuation would be more organized, saving many lives.

References

GEBCO Digital Atlas, General Bathymetric chart of the Oceans, British Oceanographic Data Centre, 2003.

Goto, C., Ogawa, Y., Shuto, N., Imamura, F., Numerical Method of Tsunami Simulation With the Leap-frog Scheme, IUGG/IOC Time Project, International Oceanographic Commission Manuals and Guides 35, UNESCO. 1997.

Koshimura, S., M. Takashima, S. Suzuki, H. Hayashi, F. Imamura, and Y. Kawata, Estimation of the possible tsunami disaster potential within the Indian Ocean, Annual Journal of Coastal Engineering, JSCE, Vo. 52, pp.1416-1420, 2005.

Lay, T., Kanamori, H., Ammon, C. J., Nettles, M., Ward, S. N., Aster, R. C., Beck, S. L., Bilek, S. L., Brudzinski, M. R., Butler, R., DeShon, H. R., Ekström, G., Satake, K. and Sipkin., S., "The Great Sumatra-Andaman Earthquake of 26 December 2004", Science, vol. 308, pp 1127 -1133, 20 May 2005.

Okada, Y., Surface Deformation Due to Shear and Tensile Faults in a Half Space, Bull. Seismol. Soc. Am., 75(4), pp 1135-1154, 1985.

National Geophysical Data Center, 2-Minute Gridded Global Relief Data, 2005, http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html