Learning from Earthquakes

The Great Sumatra Earthquake and Indian Ocean Tsunami of December 26, 2004

__Editor's Note:__ In the three previous issues, we presented the first four reports of the many teams that observed the effects of the earthquake and tsunami in countries around the Indian Ocean. Below is a report on disaster impacts in Sri Lanka. Publication of this report is supported by funds from the National Science Foundation through EERI's Learning from Earthquakes Program under grant # CMS-0131895.

Report #5

Tsunami Survey in Sri Lanka

Within three days of the December 26, 2004 earthquake and tsunami, a survey team of eight scientists from the United States and one from New Zealand was formed and dispatched to Sri Lanka. The team surveyed the south and southwestern coasts of Sri Lanka between January 10 and January 14, 2005, collecting data at more than 30 sites.

To cover as much territory as possible, the team divided into two. The International Tsunami Survey Team was made up of Philip L.-F. Liu, Cornell University; Patrick Lynett, Texas A&M University; Harindra Fernando, Arizona State University; Bruce E. Jaffe, the U.S. Geological Survey; Hermann Fritz, the Georgia Institute of Technology; Bretwood Higman, University of Washington; Robert Morton, the U.S. Geological Survey; James Goff, GeoEnvironmental Consultants, New Zealand; and Costas Synolakis, the University of Southern California.

***Figure 1.** Surveyed locations along the south and southwestern coast of Sri Lanka.*

Introduction

The Mw 9.0 earthquake struck at 06:28 a.m. local time in Sri Lanka, and the first tsunami wave arrived at Galle and Matara, on the island's southern tip, at 9:10 a.m. Two more waves followed.

Tsunami Survey

The team measured maximum tsunami heights, maximum runup heights, inundation distances, and areas of inundation in the villages indicated on Figure 1. Team members also collected soil samples from tsunami deposits, did a limited aerial inspection along the southwestern coast, and recorded eyewitness accounts. The elevations of water marks on buildings (see Figure 2), scars on trees (see Figure 3), and rafted debris were measured as indicators of the maximum tsunami height, defined relative to sea level. Maximum runup height is the elevation at the inundation distance, as depicted in Figure 4. Inundation distance is the distance from the shoreline to the inland limit of tsunami flooding.

Every mark used for the measurement was photographed, and its location was identified using a GPS.

Wave Heights and Runups

Figure 5 shows the measured tsunami heights and runup heights, adjusted for the tide levels at the time the tsunami hit. The measured values are also compared with predictions from an established tsu-

Figure 2. *Water marks on buildings were measured for tsunami elevations.*

Figure 3. *Scars on trees were measured for tsunami elevations.*

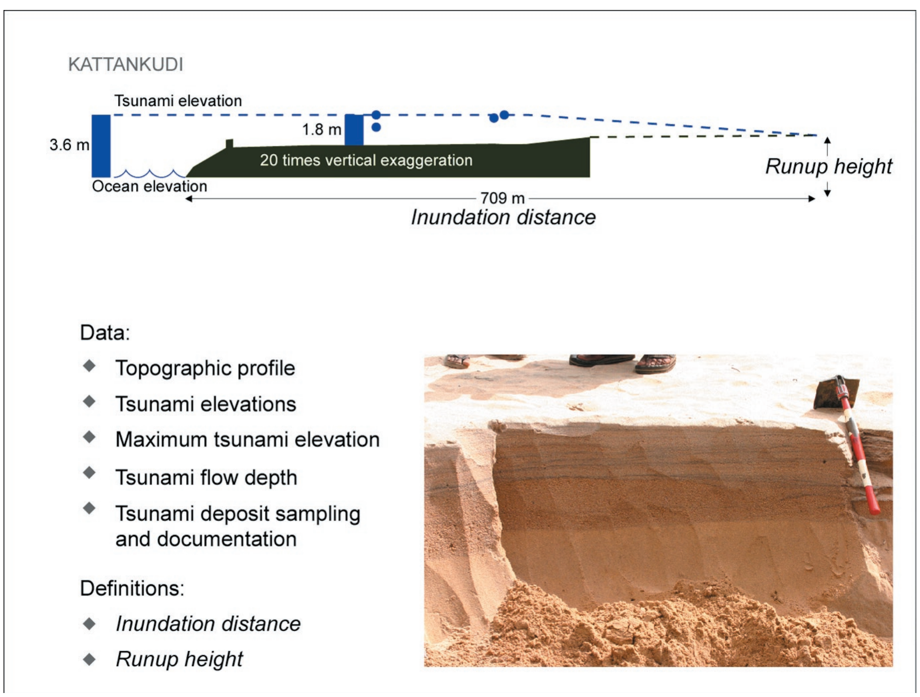

Figure 4. *Tsunami elevation, runup height, and inundation distance.*

nami computer model (Liu et al. 1995). These predictions were obtained by solving linear shallow-water equations on a two-minute by two-minute spherical coordinate grid. This model inserts the coastline at 5m water depth, and thus does not take into account the near-shore bathymetry and inland topography, which might change the direction of wave propagation and the overland flow pattern. The fault mechanism in the tsunami source region was provided by Titov (2004).

As can be seen in Figure 5, the model predicted reasonably well the hardest hit regions on the east coast, where the measured tsunami heights ranged from 3-6 m. However, much higher maximum runup heights, e.g., 12.5 m at Yala, were

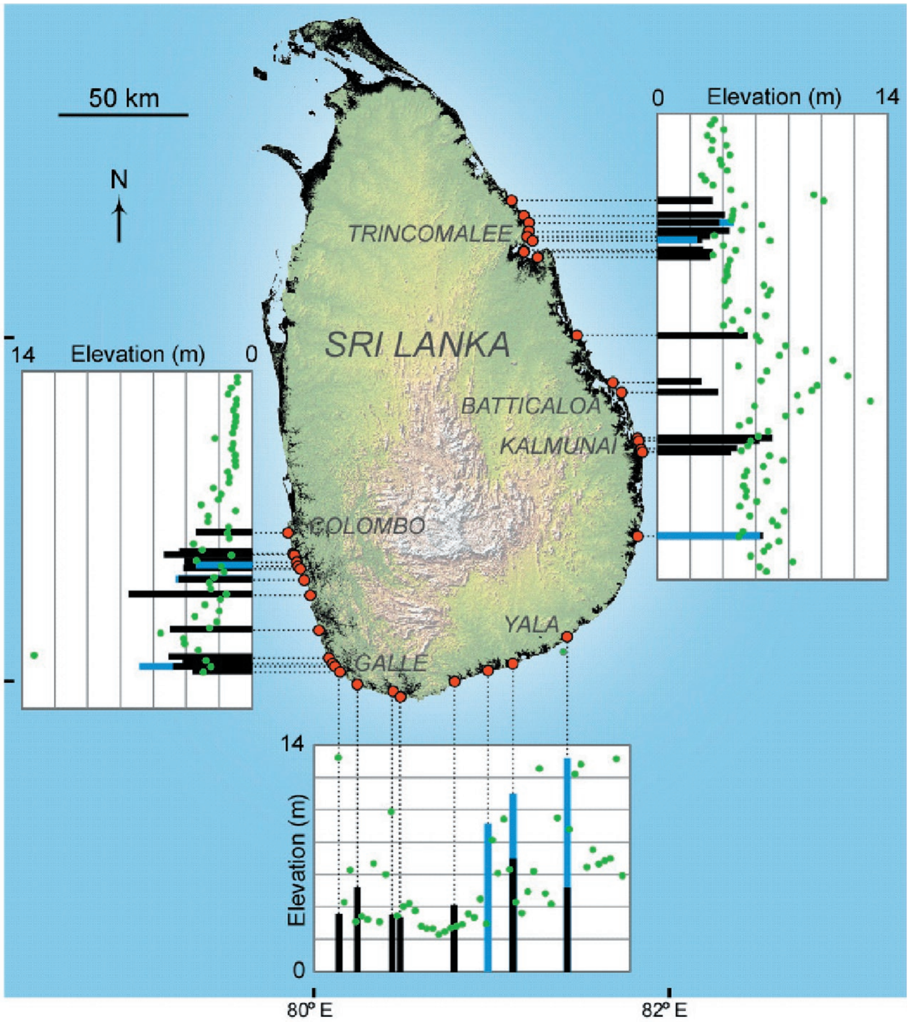

Figure 5. Measured tsunami runup heights (blue), measured tsunami heights (black), and numerical results for maximum tsunami heights (green). Coastal areas shaded black are less than 10m in elevation (map modified from NASA/GSFC/METI/ERSDAC/JAROS, and ASTER).

measured along the south coast. This was mainly a result of local steep topography.

Eyewitnesses described one to three waves, depending on their locations. From the southern tip of Matara to about Galle, the first wave arrived around 9:10 a.m. local time, with a wave height of less than a meter. It was followed by a second large wave at about 9:20 a.m. (see Figure 6), with wave height of up to 10 m. On the southwest coast north of Galle, up to Kaluthara, a third wave several meters high arrived near noon, possibly reflected from the coast of India or from the Maldives. Tide gauge records in Colombo showed water levels oscillating with crest-to-trough distances of 1m for five hours after the first tsunami wave hit. On the south coast, the first wave was small, rising like a tide of about a meter, while the second wave was large and fast. On both the south and southwest coasts, eyewitnesses reported a major recession of hundreds of meters between the first and second waves.

Tsunami Sand Deposits

The tsunami in Sri Lanka carried sand from the beach and ocean floor and deposited it in buildings, on top of boulders, and on the ground. Tsunami sand deposits were found at all sites that the two Sri Lanka teams visited. Although tsunamis are capable of eroding the land, erosion in Sri Lanka was often concentrated in a relatively narrow zone near the coast. For example, at Mankerni, there was evidence that a grassy area eroded about 1 m in the vertical in a zone about 20 to 30 m wide near the coast. Tsunami sand deposits at Mankerni started about 50 m inland, and decreased in thickness from about 10 cm to about 2 cm at about 150 m inland. In other locations where the tsunami was larger, both the width

Figure 6. A clock stopped at 9:20 was found near Galle.

Figure 7*. A damaged building near Kalmunai.*

Figure 8. *The post office at Kalmunai was not structurally damaged.*

of the erosion zone and the tsunami deposit were larger.

Damage to Structures

Most of buildings on the east coast of Sri Lanka are made of bricks. Damage to these buildings was most apparent in regions where part of the building was left standing (see Figure 7). However, in most cases, the only indication of a preexisting building was a remnant of a foundation. In some areas, there was a zone near the coast where all structures were completely destroyed; however, the damage to structures varied over short stretches of coast. In one part of Kalmunai, the zone of destruction extended about 0.5 km inland, but less than 2 km from there, most of the structures were standing and relatively undamaged at distances greater than 100 m from the shoreline.

This variability may have resulted from differences in both the tsunami heights and the quality of con struction (see Figure 8). Large scour was noted in most areas (see Figure 9), which appeared to result from both the incoming and returning flow, undermining the foundations of many structures.

Acknowledgments

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Figure 9. *Typical scour damage at the foundation of a building.*