

The Sumatra Earthquake and Indian Ocean Tsunami

of March 28, 2005

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The Earthquake

At 16:09:36 UTC on March 28, 2005 a strong earthquake struck at southwest of Banda Aceh in northern Sumatra. The epicenter was located at (1.64°N, 96.98°E), which is about 200km in the southeast direction of the epicenter of the December 26, 2004 mega earthquake (3.30°N, 95.78°E). Both earthquakes occurred near the junction of the Indian, Australian and Burma plates. It is known that the Indian plate has been subducting below the Burma microplate (at roughly 60 mm/year) along a fault line stretching from Indonesia in the south to the Andaman Islands in the north. The December 26, 2004 earthquake and aftershocks ruptured approximately 1,200 km of this fault line, along the northern Sunda Trench. It has been estimated that the March 28, 2005 earthquake only ruptured about 400 km fault line filling in the gap between 1861 earthquake and 2004 mega earthquake.

The initial estimate of the earthquake magnitude was $M_w = 8.6$, based on the Harvard University's Centroid Moment Tensor (CMT) solution. The seismic moment released on the fault plane (strike = 329° and dip = 7°) was estimated as 1.1×10^{29} dyne-cm, which is about one order of magnitude smaller than that of the December 26, 2004 earthquake. In Figure 1, the vertical and horizontal seafloor displacements resulting from the earthquake have been reported by Ji, C. (2005). The maximum positive seafloor displacement is slightly greater than 3m and the maximum negative seafloor displacement is roughly 1m. We remark here that the December 26, 2004 earthquake generated about 7m positive seafloor displacement and 3.5m negative seafloor displacement.

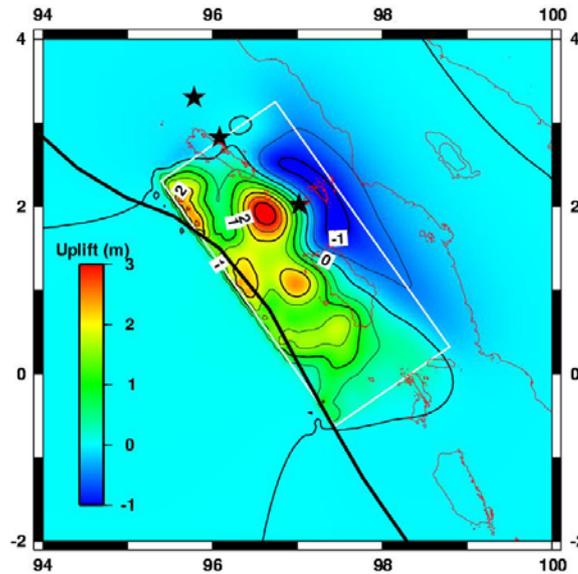


Figure 1 Uplift distribution (Ji, 2005)

The Tsunami

In view of the fact that the seismic moment for the March 28, 2005 earthquake is an order of magnitude smaller than that of the December 26, 2004 earthquake, the March 28, 2005 earthquake should not trigger giant tsunami waves. One should, however, anticipate small tsunami waves be generated for the vertical seafloor displacements are not negligible. Indeed, a relatively small tsunami was triggered. Near the epicenter several islands (Banyak Island, Simeuleu island and Nias Islands) all reported 3 – 4 m waves reaching the coastal area. Within hours, tsunami waves reached the distant shores of Sri Lanka, India, and the Maldives to the west and Cocos islands to the south. Several tide gage data show that the tsunami wave heights have reduced to 30 ~ 40cm in the Maldives.

Numerical Simulations of Tsunami Propagation

The fault plane mechanism for the December 26, 2004 earthquake is complex and the rupture process is still an open question. Since all the numerical models simulating tsunami propagation rely on the information obtained from the fault plane mechanism, it becomes a vicious cycle when one desires to use the measured data (tide gage data, satellite data and field measurements) to validate the models. On the other hand, the fault plane mechanism for the March 28, 2005 earthquake seems to be simple. Therefore, we hope that we can use the

measured data for this tsunami to validate a numerical model so that the same model can be used to help in understanding the fault mechanism for the December 26, 2004 tsunami.

The numerical model – COMCOT (Cornell Multi-grid Coupled Tsunami Model) – is used to simulate tsunami propagation. COMCOT adopts a modified Leap-Frog finite difference scheme to solve (both linear and nonlinear) shallow water equations (Liu et al. 1994). For the results to be presented herein, only the linear shallow water equations in spherical coordinates are employed. It is assumed that the initial free surface elevation of the tsunami mimics the vertical seafloor displacement, which is given in Figure 1. The coastline is located at water depth equal to or less than 5m and did not take into account the nearshore bathymetry and inland topography, which might change the direction of wave propagation and the overland flow pattern.

The simulated domain covers almost the entire Indian Ocean, ranging from 30° E to 110° E in longitude and 20° S to 25° N in latitude with a grid size of 2 minutes (ETOPO2). The dimension of grids is 2,401 by 1,351. The simulations were done on a desktop (1.5GB RAM and Athlon XP 2600+ CPU).

Numerical Results and Discussions

University of Hawaii Sea Level Center (supported by NOAA) maintains a network of sea level stations in the Indian Ocean, which report real-time sea level data on GLOSS sites (<http://uhslc.soest.hawaii.edu/>). The numerical results were compared with the available gage data at Colombo (Sri Lanka), Gan (Maldives) and Male (Maldives), as shown in Figure 2, 3 and 4, respectively. The tidal fluctuations have been removed from these filtered data. The numerical results show the correct phase of leading waves. The predicted leading wave heights at Colombo and Gan agree very well with the measured data. However, the model over-predicts the wave heights at Male. Considering the low grid resolution (2 min) and the complexity at Maldives, the numerical results match fairly well with the gage records.

Concluding Remarks

Although very coarse grid size was adopted for the numerical simulations, the tsunami simulation model (COMCOT), based on the USGS/CALTECH fault plane mechanism, match fairly well with the tide gage data for March 28, 2005 tsunami. This validation provides evidence that both the fault plane mechanism for this earthquake and the numerical model are adequate. It is hopeful that the same numerical simulation model can be used to further our understanding of the December 26, 2004 mega earthquake and the associated tsunami waves.

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