The Numerical Simulation on Tsunamis and the E/M_0 calculation of the 2006 Ping-Tung Earthquake

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Abstract

The tsunami propagation and coastal runups generated by the 2006 Ping-Tung earthquake is studied numerically. The numerical model – COMCOT, which adopts a modified Leap-Frog finite difference scheme solving nonlinear Shallow Water Equations (NSWE), is employed. Several possible fault plane mechanisms are examined. The results are compared with the field tidal gauge data at many locations. The result shows that the tsunami amplitude is about 35 cm and about 20-min period with the first depression at SyunGuaggZuei (蟳廣嘴).

We also calculate the Energy-Moment ratio of the 2006 Ping-Tung earthquake to investigate the component of "tsunami earthquake". Results show a lack of deficiency in E/M_0 and the earthquake is not a tsunami earthquake.

Introduction

A M_w 6.9 earthquake occurred in the southwestern Taiwan on 26 December 2006, at 12:26 UTC and was followed by another M_w 6.8 earthquake at 12:34 UTC, according to the Havard CMT Catalog. Given the locations and sizes, both events are tsunamigenic earthquakes and thus provide us precious opportunities to enhance capabilities of tsunami simulations for earthquakes around Taiwan.

In this study, tsunami propagation is simulated by a validated tsunami simulation model -- COMCOT, which adopts a modified Leap-Frog finite difference scheme to solve nonlinear Shallow Water Equations (Liu et al., 1994; Liu et al., 1995; Liu et al., 1998). Uniform 1-minute grid is implemented for all the simulations. The simulated domain ranges from 119.5E to 122E in longitude and 21N to 24N in latitude. Radiation open boundary condition is utilized, in which the domain boundary is adjacent to the ocean.

The static vertical displacement of the ocean floor is modeled using elastic dislocation theory (Okada, 1985). Assuming a rigidity of 3.3×10^{11}dyn cm^{-2}, the fault length, width and slip are inferred from the seismic moment through scaling laws (Geller, 1976). Together with centroid depth and fault geometry described by strike, dip, and rake, we are able to calculate the seafloor displacements caused by the earthquake. We then follow the conventional approach to perform hydrodynamic simulation using the static deformation field as initial condition. The approach is validated by the general rule that seismic rupture is much faster than water wave propagation.

With the occurrence of two major earthquakes at different times, the simulation result considering both earthquake events is shown in figure 1. Figure 2 shows the numerical gauge data at different gauge locations. Figure 3 shows the comparison between the tidal gauge data provided by Central Weather Bureau (CWB) with the numerical data. The result shows that the tsunami amplitude is about 35 cm and 20-minute period with the first depression at SyunGuaggZuei (蟳廣嘴).

The minor tsunamis observed at the tidal gauge stations entitle the Ping-Tung event as a tsunamigenic earthquake. However, we would like to ask if it a tsunami earthquake? Tsunami earthquakes are generally defined as those which generate much larger tsunamis than expected from their size measured over the seismic frequency band (Kanamori, 1972). Tsunami earthquakes can be discriminated from normal earthquakes by their deficiency in the energy-moment ratio (E/M_0). We use generalized P wave (P, pP, sP) recorded at teleseismic broadband stations to calculate energy of the earthquake (Newman and Okal, 1998) and show the results on a energy-moment plot (Figure 4). Figure 4 shows that the 2006 Ping-Tung earthquake is not a tsunami earthquake, neither are other tsunamigenic earthquakes around Taiwan (the Mar. 31, 2002 Hualien earthquake, the Dec. 10, 2003 ChengKung earthquake). .

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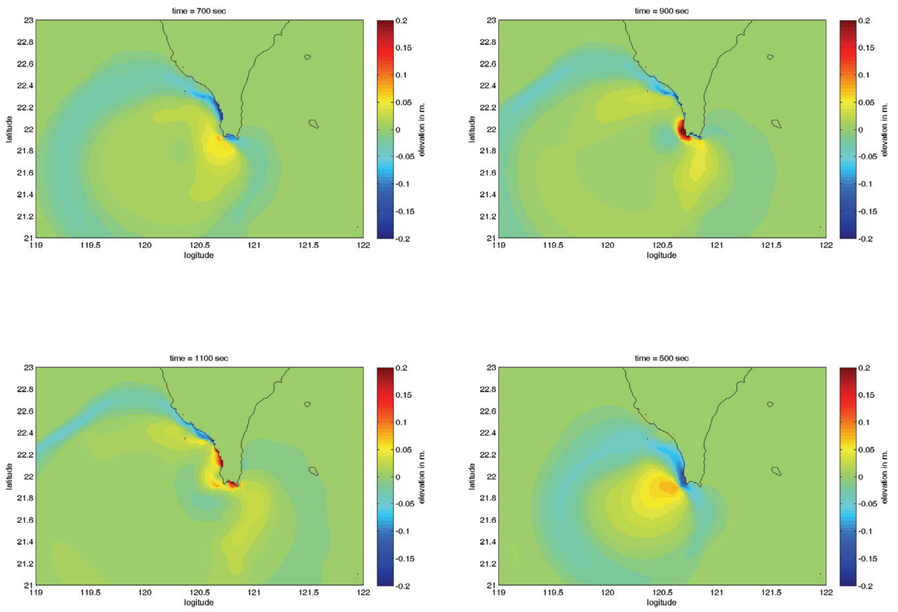

Figure 1. The snapshots of 2006 Ping-Tung tsunami at time = 500, 700, and 900 sec.

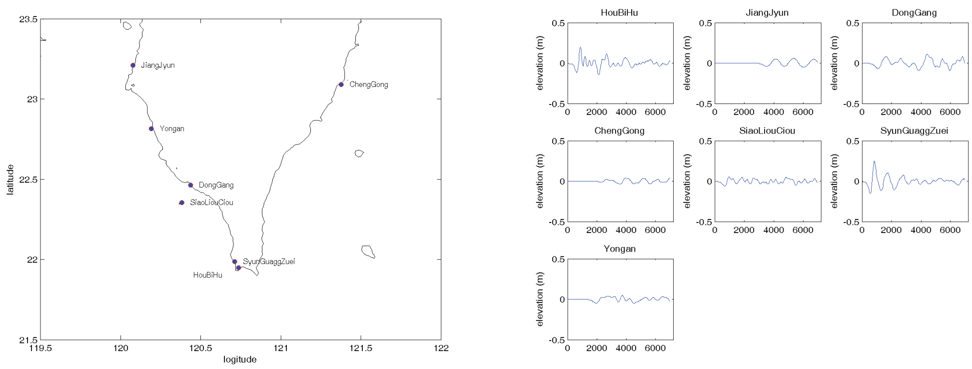

Figure 2. The time-history free-surface elevation at seven different gauge sites.

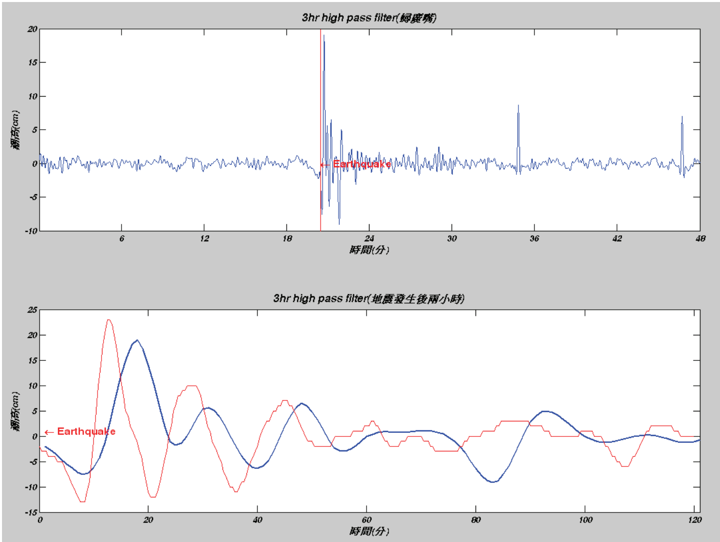

Figure 3. The comparison of time-history elevation between the filed measurement provided by CWB (blue line) and the numerical simulation (red line) at SyunGuaggZuei.

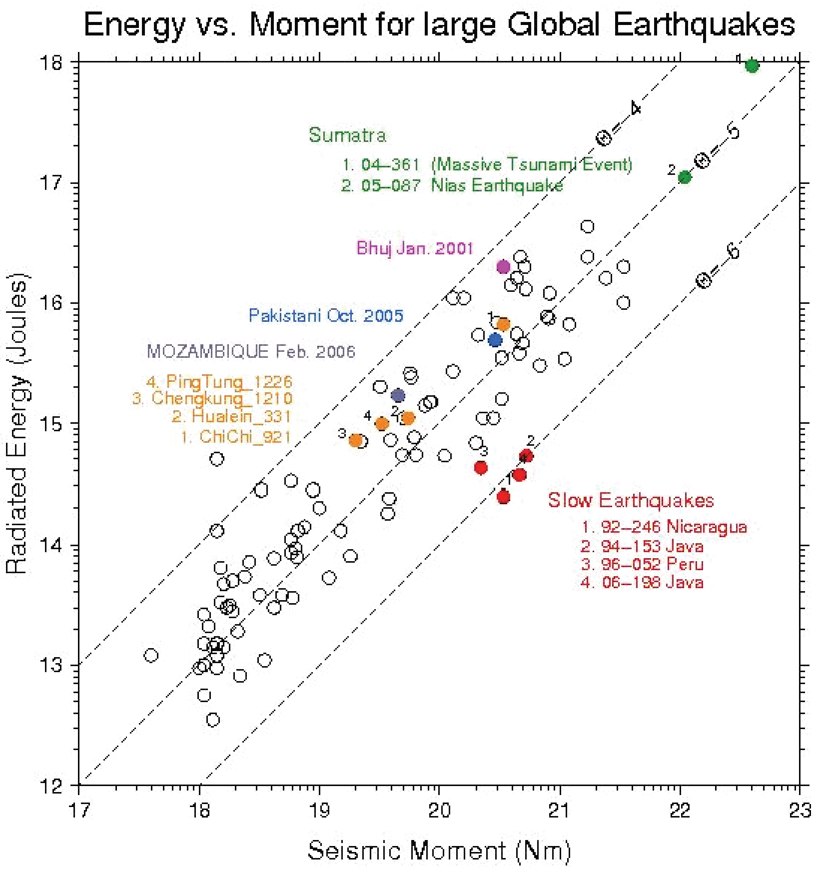

Figure 4. The energy-moment plot for large global earthquakes.