Systematic controls on propagation of tsunami waves in the near-field of megathrust earthquakes

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We report on an investigation which explores the controls on tsunami generation and propagation in the near-field of great megathrust earthquakes using a series of numerical simulations of subduction and tsunamigenesis on the Sumatran forearc. Recent geodetic and paleo- and historical seismological studies have indicated unambiguously that the Sunda megathrust here is advanced in its seismic cycle. The great earthquakes of 2004 and 2005 have also been shown to have significantly increased the stress on the fault segment under the island of Siberut which has been locked since the great 1797 earthquake. This superposition of risk indicates a strong likelihood of another earthquake with M$>$8 in the near future. We calculate the seafloor displacements and tsunami wave heights for about 100 complex earthquake ruptures whose synthesis was informed by reference to geodetic, and stress accumulation studies. Our work has allowed us to explore the likely consequences of tsunamis generated by these events but in this presentation we will concentrate on presenting unexpected order in the process of tsunamigenesis. Remarkably, results show that, for any near-field location: 1) the timing of tsunami inundation is independent of slip-distribution on the earthquake or even of its magnitude and 2) the maximum wave height is directly proportional to the vertical coseismic displacement experienced at that location. We will present compelling arguments to show that both observations are explained by the dominance of long wavelength crustal flexure in near-field tsunamigenesis and that, therefore, they may be general for all coastal sites in the near-field of great megathrust earthquakes. The results show, for the first time, that a single estimate of vertical coseismic displacement, which could be made within a few tens of seconds following the earthquake origin, could provide a reliable short-term forecast of the maximum height of tsunami waves which would arrive a few tens of minutes later. This knowledge will be important for developing tsunami preparedness strategies and we will argue that such forecasts could be made for all populated coastal areas near megathrust faults. The populations are most vulnerable to tsunami inundation and are least served by ocean-wide tsunami warning systems.