Research report

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Research Theme: Improved modeling of tsunami waveforms and its application
Host Researcher: Shingo WATADA

For tsunamis generated by large earthquakes, deep-ocean propagation has long been thought to be accurately modelled by the linear shallow water wave equations. These equations describe the two-dimensional flow of a fluid over a rigid substrate, when the wavelength is much greater than the water depth. However, two recent large earthquakes, the 2010 Maule and 2011 Tohoku-oki events, generated tsunamis that where-well recorded by many deep-ocean sensors throughout the Pacific ocean, and the observed signals showed significant discrepancies with respect to numerical simulations using the standard shallow-water theory. It was subsequently shown by *Tsai et al.* (2013) and *Watada* (2013) that these discrepancies are mainly the result of the elastic loading of the sea floor by the tsunami, which leads to discrepancies of up to 2% in travel time as well as a negative-polarity arrival that precedes the main (positive polarity) tsunami wave.

The main goal of the collaboration was to compare methods developed by *Allgeyer and Cummins* (2014) and *Watada et al.* (2014). The first method models the tsunami propagation including the effect of the deformation of the sea floor caused by the change in the loading of the water mass generated by the tsunami, as well as the effect of the density profile in the sea water column. The second method uses post-simulation correction of the phase velocity of the tsunami waveform. Both methods have their advantages and drawbacks; the first method is computational intensive but should be able to correctly simulate every wave in the wave train, whereas the second is fast but because the phase speed correction function is based on a symmetric stratified earth, it should be more difficult to have an accurate correction for late-arriving waves that result from reflection and refraction. In a first step, we derived the phase velocity of my numerical code to compare it with the correction curve computed by Watada-san. The result is shown in Figure 1. There is a good agreement of both methods for long periods. However, for shorter periods the phase velocity of my numerical code follows the trend expected for long wave velocity because it does not take into account of the short wave (Boussinesq-like) dispersion, as Watada-san's curve does.

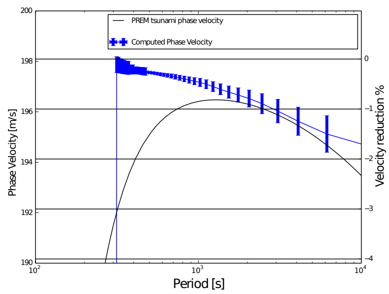

Figure 1: Comparison of the phase velocity curves of both methods.

We compared tsunami numerical simulations of a real event with the observations in Figure 2. The figure shows three time series of the Maule 2010 tsunami event as it crosses the Pacific Ocean. There is now no doubt that the classical tsunami simulations (in red) cannot reproduce the observations (in black), both published methods (in green and blue) obtain quite similar results for the first two to three hours after the first wave.

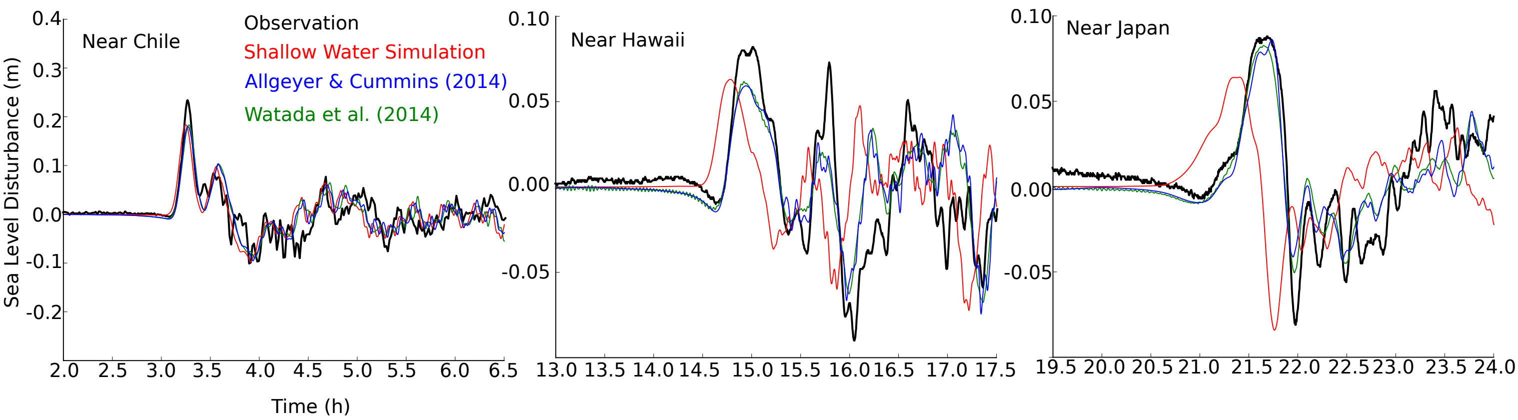

Figure 2: Comparison between the observation, classical Shallow water simulation, the code deveolped by Allgeyer and Cummins (2014), and Watada et al (2014) for three different observations across the Pacific Ocean for the 2010 Maule tsunami

References

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