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Origin of the reversed initial amplitude of distant tsunami

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Distant tsunami waveforms recorded at deep open sea from the 2010 Chile earthquake and the 2011 Tohoku-Oki earthquake show a reversed prolonged small initial tsunami phase arrival, which is easily identified by the reversed polarity of the large amplitude tsunami arrival following the small-amplitude initial phase arrival. The small reversed polarity before the main peak is visible in the original tidal pressure data and not introduced during the de-tide process. Thanks to the low noise DART data from large earthquakes, the arrival of the small initial phases at distant buoys are identified as early as 1 hour before the arrival of large amplitude tsunami with a reversed polarity. The small initial amplitude is as large as 10 % of the amplitude of the main phase at largest distances. Such an initial phase is not observed at buoys near the earthquakes.

The synthetic tsunami for 1D PREM earth model including the effect of the elastic crust, mantle, and core of the earth, and the effect of the compressibility of the ocean water, and the effect of the gravity potential change caused by the motion of the mass of the water and the solid earth during the tsunami propagation, has been computed. Compared with the tsunami synthetics waveforms computed based on a conventional non-dispersive long-wavelength water waves, the tsunami for 1D earth shows a delayed arrival of the main amplitude peak of the tsunami, in addition to a prolonged small initial amplitude phase with reversed polarity before the main peak.

Two features, delayed arrival of the main amplitude peak and the small amplitude initial phase with a reversed polarity, are successfully re-produced by the tsunami computation for 1D PREM earth model.

The small initial tsunami with a reversed polarity observed at distant locations is caused by the dispersion of the long-wavelength tsunami, and should not be misinterpreted as an evidence of a precursory crustal movement prior to the large earthquakes.

Figure Left: shows synthetic tsunami waveforms of dispersed tsunami and non-dispersive tsunami. Right: observed tsunami waveform at DART buoys after the 2011 Tohoku-Oki earthquake.

Keywords: tsunami propagation, initial amplitude anomalies, Tohoku-oki earthquake, Chile earthquake, GPS wave gauge, ocean bottom pressure gauge