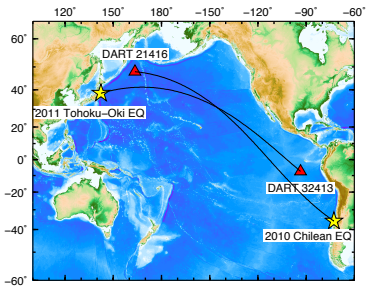
Discovery of delay and initial phase reversal of distant tsunamis

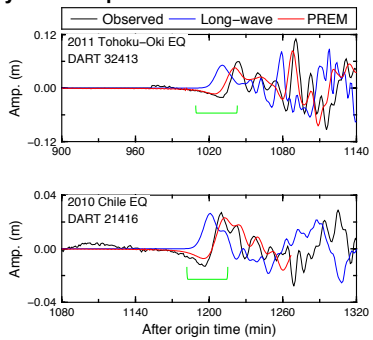
Shingo Watada (ERI, University of Tokyo)

✔Discovery

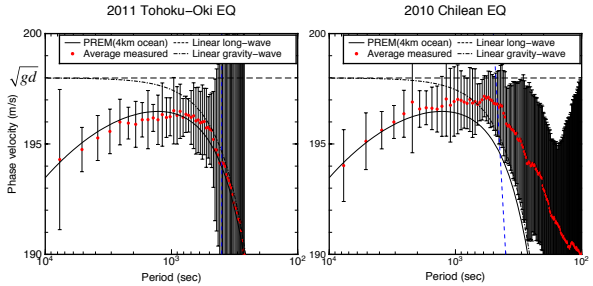
Traveltime delay



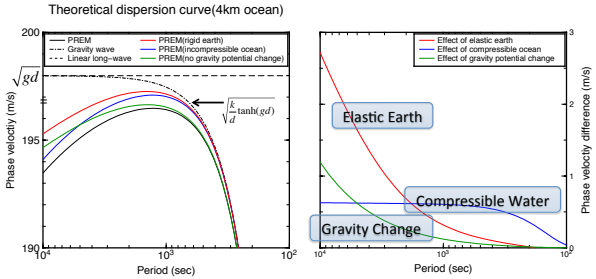
Initial phase reversal



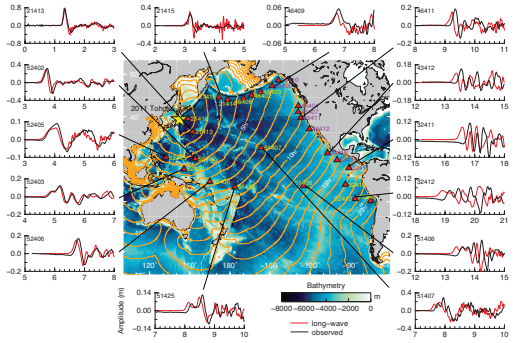
Tsunami phase velocity measurements



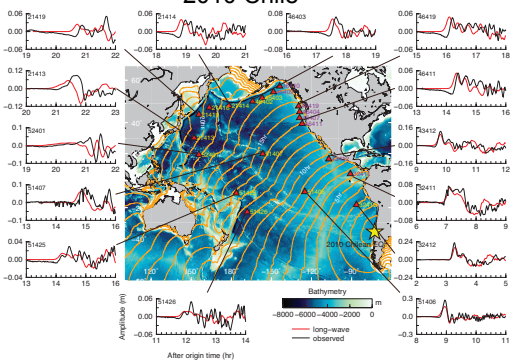
Theoretical tsunami phase velocities



2011 Tohoku-Oki

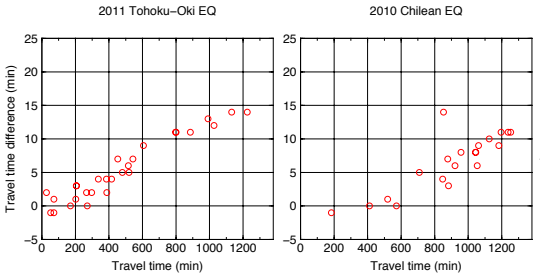


2010 Chile



Abstract

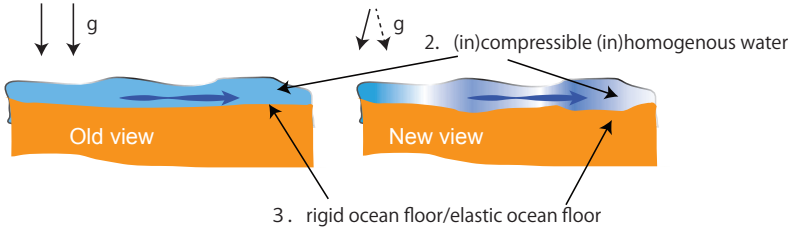
Systematic tsunami traveltime delays of up to 15 min relative to the numerically simulated long waves from the 2010 Chilean and 2011 Tohoku-Oki earthquakes were widely observed at deep ocean tsunamimeters. Enigmatic small negative phases appearing before the main peak were commonly found only at the trans-oceanic locations. The frequency dependence of the measured tsunami phase velocities shows reverse dispersions at long periods, i.e., the tsunami speed becomes slower at periods beyond 1000 s. This is consistent with the phase velocities of a tsunami mode coupled with a self-gravitating elastic Earth, suggesting that the effects of compression and dilatation of seawater, elastic tsunami loadings on a solid Earth, and the geopotential variations associated with the motion of mass during tsunami propagation are responsible for the traveltime delays and the initial negative phases. Simple 1-D tsunami propagation tests confirm that the reverse dispersion creates a small negative phase that precedes the main peak at large distances. A new method to simulate tsunami waveforms on real ocean bathymetry that takes into account seawater compressibility, the elasticity of the Earth, and geopotential perturbations has been developed by applying a phase correction to the simulated long waves. The simulated waveforms, in which phase corrections are applied for the dispersion effects, accurately reproduce the observed waveforms, including a small initial negative phase that appears at distant locations. The traveltime difference between the observed and simulated waveforms has been decreased to less than 5 min and the waveform difference between them remarkably diminishes.



$$\frac{\Delta c(tsunami)}{c(tsunami)} \approx \textbf{-1.2\%}$$

✔Mechanism

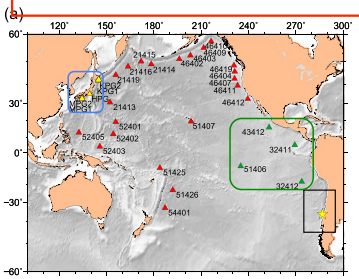
1. constant gravity/time-variable gravity change associated with mass motion



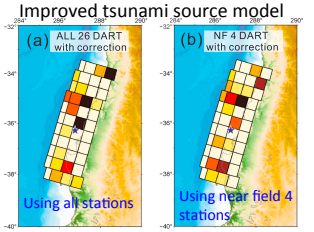
✔Application

Improved Tsunami prediction and source models

- Tsunami waveform inversion based on the new tsunami propagation theory produce slip distribution similar to seismic/geodetic inversions.
- Tsunami source can be accurately estimated from far-field tsunami waveform data only.
- Inversion of near-field tsunami data can be used for real-time tsunami forecast at far field.



Improved tsunami source model



Improved waveform prediction