Geophysical Research Abstracts
Vol. 16, EGU2014-9827-1, 2014
EGU General Assembly 2014

W-phase estimation of first-order rupture distribution for megathrust earthquakes

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Estimating the rupture pattern for large earthquakes during the first hour after the origin time can be crucial for rapid impact assessment and tsunami warning. However, the estimation of coseismic slip distribution models generally involves complex methodologies that are difficult to implement rapidly. Further, while model parameter uncertainty can be crucial for meaningful estimation, they are often ignored. In this work we develop a finite fault inversion for megathrust earthquakes which rapidly generates good first order estimates and uncertainties of spatial slip distributions. The algorithm uses W-phase waveforms and a linear automated regularization approach to invert for rupture models of some recent megathrust earthquakes.

The W phase is a long period (100-1000 s) wave which arrives together with the P wave. Because it is fast, has small amplitude and a long-period character, the W phase is regularly used to estimate point source moment tensors by the NEIC and PTWC, among others, within an hour of earthquake occurrence. We use W-phase waveforms processed in a manner similar to that used for such point-source solutions. The inversion makes use of 3 component W-phase records retrieved from the Global Seismic Network.

The inverse problem is formulated by a multiple time window method, resulting in a linear over-parametrized problem. The over-parametrization is addressed by Tikhonov regularization and regularization parameters are chosen according to the discrepancy principle by grid search. Noise on the data is addressed by estimating the data covariance matrix from data residuals. The matrix is obtained by starting with an a priori covariance matrix and then iteratively updating the matrix based on the residual errors of consecutive inversions. Then, a covariance matrix for the parameters is computed using a Bayesian approach.

The application of this approach to recent megathrust earthquakes produces models which capture the most significant features of their slip distributions. Also, reliable solutions are generally obtained with data in a 30-minute window following the origin time, suggesting that a real-time system could obtain solutions in less than one hour following the origin time.