Kinematic Source Inversion using Strong Motion Data Considering Three-Dimensional Fault Geometry

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Motivation
Near-source strong ground motions during large earthquakes are governed by spatiotemporal slip progression on the fault plane. Many previous studies succeeded to obtain precise slip distributions of large earthquakes from strong motion and other seismic and geodetic data set.

The geometry of source fault is also known to be important to quantitatively explain near-source strong ground motions (e.g., Iwata et al., 2000; Gutiérrez et al., 2009). However, most of source inversion studies except special cases assumed one or plural planar fault planes in their kinematic inverse analysis.

In recent studies on the detailed aftershock relocations for large earthquakes, it is known that the geometry of the source fault is complex rather than simple planar shape (e.g., Kato et al., 2005).

In order to include effects of fault geometry on near-source ground motions, we are trying to develop a method to invert slip distribution with its fault geometry. The proposed method is applied to the 2008 Iwate-Miyagi Nairiku earthquake, which is a Mw 8.9 inland crustal earthquake occurring in northeast Japan.

Method

1st step
Conventional Linear Waveform Inversion

Spatiotemporal slip history on a single planar fault model is solved using the multiple window linear waveform inversion method.

2nd step
Nonlinear Waveform Inversion

Strike and dip angles at control points are simultaneously solved with the slip amounts at each time-window at each subfault by the iterative inversion using the Lavenberg-Marquardt method.

The initial model of the 2nd step is the solution of the 1st step. The geometry of the source fault is represented by strike and dip angles at some control points. Then, strike and dip angles for individual subfault are set by bilinear interpolation.

Velocity Structure Model

It is quite important for obtaining a reliable source model from observed data to use appropriate Green’s functions. So we use a set of station-dependent velocity structure models to calculate Green’s functions for each station. The one-dimensional layered velocity structure is modeled for each strong motion station by waveform modeling of aftershock records following the procedure by Asano and Iwata (2009).

Firstly, the reference velocity structure model, which is used for all stations, is assumed. Then, thicknesses of sedimentary layers are estimated for each station by simulating waveforms for a moderate aftershock event using GA. For deeper part (crust and mantle), horizontal layered structure is assumed based on the refraction survey by Iwasaki et al. (2001).

Inversion Results

Single planar fault model
The strike and dip angles of the fault plane are fixed at 209° and 51°, respectively (from P- and first moment tensor solution by NIED).

Seismic Moment: 2.89 x 10^19 Nm (Mw 6.9)
Maximum Slip: 6.4 m
Average Slip: 1.4 m
The rupture propagation velocity of the first time window: 2.4 km/s (~0.7 Time (s))

Variable strike and dip model
Here, we are showing the source model obtained after 30 iterations.

Seismic Moment: 2.89 x 10^19 Nm (Mw 6.9)
Maximum Slip: 6.4 m
Average Slip: 1.4 m
The rupture propagation velocity of the first time window: 2.4 km/s (~0.7 Time (s))

Conclusions
We propose a method to estimate the spatiotemporal slip history with unknown fault geometry from strong motion data, and applied to the data set of the 2008 Iwate-Miyagi Nairiku earthquake.

The obtained fault geometry appears to be consistent with the detailed aftershock distribution and the surface rupture observations. We may improve the constraint for the fault geometry by including geodetic data (e.g. static GPS data).

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References
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