# Estimation of slip-weakening parameter from waveform inversion and application to strong motion prediction

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Three earthquakes under quite different tectonic settings are analyzed in this study. The 1999 Chi-Chi, Taiwan earthquake occurred on a shallow low-dipping reverse fault near the collision boundary between the Eurasian plate and the Philippine Sea plate. The 2000 western Tottori earthquake was an inland strike-slip faulting earthquake, while the 2003 Miyagi-oki earthquake occurred on a high-dipping reverse fault in the slab of the Pacific plane subductiong to the overriding continental plate. To obtain information of fault geometry from waveform inversion, data recorded at seismic stations as many as possible are used. Strong motion data recorded at 20 stations are included for the Miyagi-oki earthquake, 47 strong motion stations and 60 GPS stations for the Chi-Chi earthquake, and 18 strong motion stations for the Tottori earthquake.

Although these three earthquakes occurred under quite different tectonic settings, waveform analysis shows that they all were associated with complexity of fault geometries. Not only the shallow earthquakes but also the deep in-slab earthquake like the Miyagi-oki earthquake show complex fault geometries.

By applying mapping method to non-orthogonal grid meshes, we develop a finite different method (FDM) program applicable to a reverse and bending fault. Using this method, we can simulate a dynamic rupture and can exactly follow the bending fault model used in waveform inversion. To take into account effects from expansion functions, filter, smoothing and discrete sampling applied in our waveform inversion, we carry out some numerical tests to estimate the minimum determinable value of the slip-weakening distance (Dc) for these earthquakes. Consider heterogeneous distribution stress drop, by changing the input Dc, we found the lower limit Dc for non asperity area is about 2m, while it is 4m for the asperity with a stress drop of 25MPa for the Chi-Chi earthquake. Our simulation also suggests that because of surface breakout, in the portion above the asperity the apparent Dc becomes large.

Stress history on the fault plane is calculated by using the developed FDM. Slip-weakening distance is then estimated for these three earthquakes. Values of estimated Dc greatly differ from earthquake to earthquake. In the case of the Chi-Chi earthquake, the estimated ranges mainly from 2 to 5 m, while it ranges from 0.5 to 1.5 m for the Tottori earthquake, and from 0.8 to 2.3 m for the Miyagi-oki earthquake. Our results show that: the larger the earthquake is, the larger Dc; the larger the final slip is, the larger Dc.

To inspect effects of Dc on strong motion, here we consider two dynamic models with the same fracture energy but different Dc for the Chi-Chi earthquake, small Dc for model A and large Dc for model B. Comparison of dynamic rupture propagation shows that dynamic rupture front is basically similar to each other except for the part close to the free surface.

The effective frequency is hence up to 4 Hz. Synthetic seismogram is calculated up to 5 Hz and lowpass filtered under frequency 1 Hz. Synthetic seismograms calculated from Model A contain richer high-frequency contents than those of model B. Comparing the calculated with the observed seismograms, one can find that for the southern stations the synthetic seismograms from model A explain better than those from model B. On the contrary, model B explains the observed seismograms at northern stations better than model A. Since all the stations are closed to surface trace, they reflect the heterogeneous distribution of local Dc. It suggests that large values of Dc for the northern part and comparably small values of Dc for the southern part are reasonable estimates. The above analysis implies that Dc is a key parameter for strong motion prediction.