J162-004 **Room: 302** **Time: May 16 9:38-9:52**

Finite Fault Process of the 1999 Chi-Chi, Taiwan Earthquake Sequence

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The 1999 Chi-Chi, Taiwan earthquake has inflicted huge damage to Taiwan, but at the same time, the earthquake sequence generated one of the best strong motion datasets in the 20th century. We inverted the strong motion waveforms for the finite source parameters of the 1999 Chi-Chi, Taiwan earthquake and its 6 large aftershocks. For each event, we derived a preferred model by doing grid-search on different focal mechanisms, hypocenters, rupture velocities, dislocation rise times, as well as different combinations of stations in more than 1000 inversions. By testing a wide range of parameters we were able to derive more reliable slip models. One of our slip models coincides with the fault imaged by a published seismic profile. We documented how the fits between the waveforms and the corresponding synthetics deteriorated as the hypocenter and focal mechanism deviate from those of the preferred model. Through the grid search we found that we generally recovered 80% of the preferred model's synthetic waveform fit if the hypocenter is within 5 km of the optimal hypocenter and the focal mechanism is within 20 degrees of optimal strike, dip, and rake. Particularly, using accurate dip angle for the thrust events and strike direction for the strike-slip events can dramatically improve the waveform fits in the inversions. Unlike the dislocation rise time, the rupture velocity used in the inversion had a strong influence on the waveform fits. These results will help to determine how accurate these parameters must be if we wish to derive slip models in near real-time for generating shakemaps. In terms of plate kinematics, P-axes of the derived models have azimuths consistent with current plate motion. Also, GPS displacement derived from the 6 slip models can explain 80% of the post-seismic deformation observed in the aftershock regions, indicating that studies of post-seismic deformation must take into account the cumulative effects of large, shallow aftershocks. We used the derived slip models to interpret the seismogenic structures near the Chi-Chi earthquake region and found some surprising results: (1) The mainshock slip is constrained in a triangular region where the topography is low. (2) For the thrust aftershocks, they were all initiated near the east-dipping decollement where large strains released during the mainshock. However, they can rupture not only updip on the decollement, but also updip on a backthrust, or downdip on a basement fault. As a result, the seismogenic structures derived from this study differ dramatically from previous studies. (3) The decollement is not a total stress barrier. A strike-slip aftershock has initiated in the basement, then ruptured across the decollement before releasing most of the seismic energy above the decollement. All of these results have implications for rupture process studies and can help interpreting the seismogenic structures of Taiwan mountain belt.