

Source Rupture Process and Seismic Wave Propagation of the 1999 Chi-Chi Earthquake

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A comprehensive source process inversion, including three-dimensional fault geometry and three-dimensional Green's functions, was used to explore the high-resolution spatiotemporal slip distribution of the 1999 Chi-Chi, Taiwan, Earthquake. The 3-D fault geometry was adopted from the aftershock distributions and high-resolution reflection experiment studies. It shows that the dip angle of the fault becomes shallower from south to north and near flat at the deeper portion of the fault. The 3-D Green's functions were calculated from a 3-D finite-difference code using a 3-D velocity structure derived from tomographic studies for a grid size of 500 m and a time interval of 0.05 sec. The 3-D Green's functions show significant azimuthal variation of the waveform. The waveforms in the north tend to have more complicated wiggles than in the south. The waveforms to the east show higher frequency content than that to the west due to the effect of lateral heterogeneity in velocity. These variations suggest the necessity of the 3D Green's function calculations in Taiwan. Considering the 3-D fault geometry and 3D Green's functions, we invert the spatial/temporal slip distribution of the 1999 Chi-Chi earthquake using the dense strong motion waveforms considering multiple time windows. Our results show that the largest asperity located near the bending of the fault is well constrained, as observed by other slip distribution studies. However, the slips at the deeper portion of the fault are more refined by the 3D fault geometry. Comparisons between the simulation results and observed waveforms from a dense strong motion network demonstrate that the variation of the 3D velocity structure and the complex fault slip history significantly affect the damage during the Chi-Chi earthquake. Our study emphasizes the necessity of 3D fault geometry and 3D Green's function to correctly account for the large damaged earthquake's complicated source process and wave propagation effect.

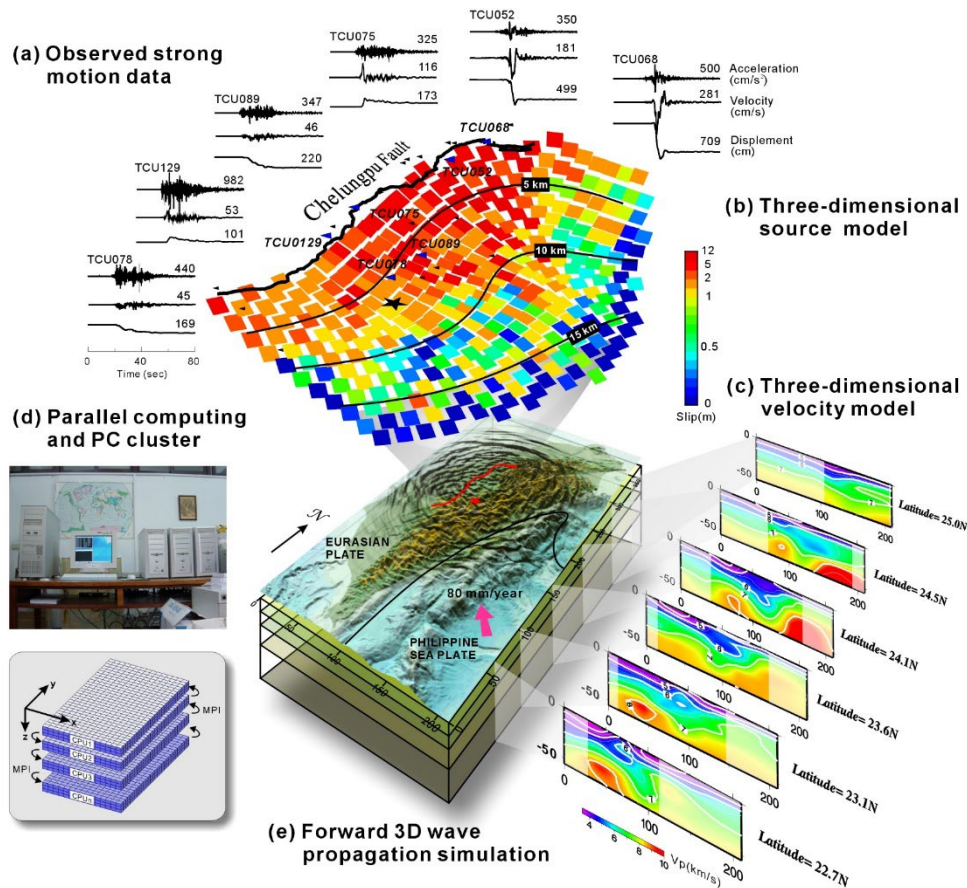


Figure 1. Three-dimensional ground motion simulation framework of the 1999 Chi-Chi, Taiwan, earthquake. (a) The near field strong motion records. Labels at the end of the waveforms indicate the maximum acceleration (cm/s^2), velocity (cm/s), and displacement (cm), respectively. (b) The 3D rupture process model from the source inversion study by Lee et al. (2006). (c) The 3D velocity model used in the study was derived from a travel-time tomography inversion (Rau and Wu, 1995). (d) A parallel computing technique is applied using a PC cluster in this simulation. The model is decomposed with respect to depth, and the message-passing interface (MPI) is used to communicate the information between computing nodes. (e) The forward ground motion simulation derives from a realistic source process and 3D crustal structure. By combining most of the recently available near-field ground motion records and earthquake source information, this comprehensive study successfully reproduced major properties of strong ground shaking during the 1999 Chi-Chi earthquake (Lee et al., 2007).

REFERENCES

- Lee, S.-J., Ma, K.-F., & Chen, H.-W. (2006). Three-dimensional dense strong motion waveform inversion for the rupture process of the 1999 Chi-Chi, Taiwan, earthquake. *Journal of Geophysical Research: Solid Earth*, *111*(B11), B11308. <https://doi.org/10.1029/2005jb004097>
- Lee, S.-J., Chen, H.-W., & Ma, K.-F. (2007). Strong ground motion simulation of the 1999 Chi-Chi, Taiwan earthquake from a realistic three-dimensional source and crustal structure. *Journal of Geophysical Research: Solid Earth*, *112*(B6), B06307. <https://doi.org/10.1029/2006jb004615>
- Rau, R.-J., & Wu, F. T. (1995). Tomographic imaging of lithospheric structures under Taiwan. *Earth and Planetary Science Letters*, *133*(3–4), 517–532. [https://doi.org/10.1016/0012-821x\(95\)00076-o](https://doi.org/10.1016/0012-821x(95)00076-o)