15 Joint Inversion of Seismic and Geodetic Data for the Source of the 4th March 2010 $M_w$ 6.3 Jia-Shian, SW Taiwan, Earthquake

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15.1 Introduction

The 4th of March 2010 Jia-Shian ($M_w$ 6.3) earthquake occurred in southwestern Taiwan and caused moderate damage. Compared with other $M_w$ 6+ events in the world (e.g. 2004 $M_w$ 6.1 Parkfield earthquake), this event has a smaller coseismic slip and no fault related surface rupture, reflecting an unusually deep source in west Taiwan. The reported focal depth is 23 km, below the fold and thrust belt of Taiwan. In this study, we inverted geodetic (GPS and InSAR) and seismic waveform (strong motion and broadband) data for finite-source models. We compare inversions from each individual data set to better understand their respective contributions and to determine the appropriate weights and smoothing parameters for a joint inversion. A joint inversion of the geodetic and seismic data reveals a preferred model that shows a primary slip patch that is approximately 20 km in diameter with a peak slip of 28 cm and total scalar seismic moment of $3.65 \times 10^{25}$ dyne cm ($M_w$ 6.34).

15.2 Inversion and Preliminary Result

We use a linear least squares inversion code based on the method of Hartzell and Heaton (1983) in which the finite source is discretized with a finite distribution of point sources in both space and time. A damped, linear least squares inversion with a positivity constraint (allowing only for thrust dip-slip component) is used to determine the spatiotemporally distributed slip. A single time window is used with a fixed dislocation rise time (0.5 s) propagating away from the hypocenter with a constant rupture velocity (2.6 km/s). A spatial smoothing with linear equations minimizing differences in slip between subfaults is applied to stabilize the seismic and geodetic inversion. Different weighting and smoothing parameters are applied to the simultaneous inversion using the method proposed by Kaverina and Dreger (2002). The Green’s functions for southern Taiwan are taken from Chi and Dreger (2004). For the geodetic inversion, the geodetic Green’s functions are computed by assuming the same layered elastic structure as for the seismic inversion. A $50 \times 50$ km NW dipping fault geometry with 625 subfaults was considered for the inversions. The coseismic slip distribution is estimated from the inversion of each data set separately and jointly.

Eight strong motion and three broadband seismic stations are used for the seismic inversion, and 108 GPS stations and three ALOS PALSAR interferograms are used for the geodetic inversion. Both geodetic and seismic inversions reveal a consistent pattern for the main rupture asperity near the hypocenter (Figure 2.31b). The joint inversion shows a coseismic slip covering a $15 \times 20$ km area northwest of the hypocenter with an average slip of 15 cm and a peak slip of 28 cm.

15.3 Discussion and Future Work

Both seismic and geodetic inversions obtain good fits to the data, but the predicted moment magnitudes from the two inversions are slightly different ($M_w$ 6.3 for seismic; $M_w$ 6.34 for geodetic). The difference of the two predicted moments is equivalent to a $M_w$ 5.7 earthquake. We note that the geodetic inversion shows more slip near the largest ($M_w$ 5.0) aftershock (Figure 2.31b), which suggests that the difference may in part be due to deformation from the early aftershocks spanned by the geodetic data. Consideration of both seismic and geodetic inversions can provide information about the main shock and the early aftershocks.

Further work will focus on additional improvements of the seismic inversion and the aftershocks analysis. For example, the seismic inversion does not fit the directivity in station CHY089 well (Figure 2.31a), which might be due to an over-simplified fault geometry or improper Green’s functions. With these improvements, we will aim to better understand the kinematic process of this event and its tectonic framework in west Taiwan.

15.4 Acknowledgements

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15.5 References


Figure 2.31: (a) Right: The study area and the comparison of the GPS data (black arrows) and model prediction (white arrows) using the finite source inversion. The circles are the aftershocks for the first 24 hours. The triangles show the locations of the seismic station. The white dashed rectangle shows the fault geometry. Left: The comparison of the strong motion seismic data (black) and the predicted models (gray) using the finite source inversion. Note that the larger amplitude of station CHY089 is due to the directivity of this event. (b) The comparison of the coseismic fault slip based on seismic (left) and geodetic (right) inversions. The arrows indicate the slip orientation of each subfault. The circles show the distribution of the aftershocks.