16 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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16.1 Introduction

The March 2010 Jia-Shian (\( M_w \) 6.3) earthquake occurred in southwestern Taiwan and caused moderate damage (Figure 2.33a). No surface rupture was observed, reflecting a deep source that is relatively rare in west Taiwan. We develop finite-source models using a combination of seismic waveform data (strong motion and broadband stations), GPS, and InSAR to understand the rupture process and slip distribution of this event. The main shock is mainly a reverse event with a small left-lateral component. The rupture’s centroid source depth is 19 km based on a series of moment tensor solution tests with improved 1D Greens functions. The primary slip asperity of the preferred model is about 20 km in diameter and ranges in depth from 22 to 13 km. The peak slip is 42.51 cm, and the total scalar seismic moment is \( 3.25 \times 10^{18} \) N m. Both the main shock and aftershocks are located at the transition zone where the depth of the regional basal decollement deepens from central to south Taiwan. In addition, the P and T axes of this event are rotated about 40 degrees counterclockwise from the direction of the current plate collision. Hence, the deviation of the compressional stress exhibited by this event may be a regional perturbation of a pre-existing geologic structure.

16.2 Inversion and Result

We use a linear least squares inversion code based on Kaverina et al. (2002), 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 distribution of slip in space and time. A single time window is used with a fixed dislocation rise time (0.5 s) propagating away from the source with constant rupture velocity (4.2 km/s). 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 et al. (2002). The Green’s functions for southern Taiwan are taken from Chi and Dreger (2004). For the geodetic inversion, the geodetic Greens 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 both from the inversion of each data set separately and jointly.

Seven strong motion and three broadband seismic stations are used for the seismic inversion, and 108 GPS stations and 3 ALOS PALSAR interferograms are used for the geodetic inversion. The joint inversion shows coseismic slip covering a 15 \( \times \) 20 km area northwest of the hypocenter (Figure 2.33c) with an average slip of 15 cm and a peak slip of 42.5 cm.

16.3 Discussion and Conclusion

The orientation of the P and T axes of the main shock and aftershocks is different from the direction of the current plate collision (Figure 2.33d,e). However, the crustal scale (0-30 km) strain rate based on the SW Taiwan regional seismicity and focal mechanism inversions (Mouthereau et al., 2009) shows ENE-WSW compression near the Jia-Shian epicenter. This ENE-WSW compression has the same orientations as the P axes of the main shock and most of the aftershocks, which agree with the ambient strain distribution at the source depth. To conclude, the Jia-Shian event occurred along the boundary between the Western Foothills and the Central Range. The current surface strain rate is not consistent with the stress orientations in the upper crust of the Jia-Shian event. Combining all of the observations suggests that this event may be due to the reactivation of a pre-existing geological structure that is not necessarily participating in the current plate collision. Details of the kinematics or the geometry of the structure will be needed to confirm this.

16.4 Acknowledgements

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16.5 References


Figure 2.33: (a) Selected strong motion stations (triangles) and broadband stations (hexagons). The green and yellow stations belong to the west and east Taiwan velocity models, respectively. The Jia-Shian main shock and aftershocks are color coded by depth. (b) The comparison of synthetic (red) and seismic data (black) from the joint inversion. (c) Joint inversion result (variance reduction of seismic data: 74.8%; GPS: 64.9%; InSAR: 77.0%). Black arrows represent the slip direction and amplitude for each subfault. The colored circles are aftershocks since the main shock in hours. (d) P and T axes of the main shock (red and white triangles) and aftershocks (grey and dark blue circles). (e) The surface strain rate (black and white bars) and crustal scale (0-30 km) strain rate (dark blue arrows). The beach ball diagram shows the most recent earthquake in this region with a focal mechanism similar to the Jia-Shian event, which may imply an extension of this structure to the southeast. NVT indicates the region of triggered non-volcanic tremors in the Central Range.