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Contrasting strike-slip motions on thrust and normal faults: Implications for space-geodetic monitoring of surface deformation

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Recent GPS records of surface deformation caused by earthquakes on intra-continental dip-slip faults revealed in unprecedented detail a significant strike-slip component near the fault tips, which is markedly different for thrust and normal faults. In the hanging wall of the thrust fault ruptured during the 2003 Chengkung (Taiwan) earthquake, a divergent displacement pattern was recorded (Hsu et al., 2009). In contrast, a convergent slip pattern was observed in the hanging wall of the normal fault that produced the 2009 L'Aquila (Italy) earthquake (Cheloni et al., 2010; Serpelloni et al., 2012). Remarkably, such convergent slip patterns are also evident in field records of cumulative fault slip (e.g., Jackson et al., 1982; Roberts & Koukouvelas 1996), which underlines the coseismic origin of the cumulative slip pattern. Here we use three-dimensional numerical modeling to demonstrate that the observed fault-parallel motions are a characteristic feature of the coseismic slip pattern on normal and thrust faults (Hampel et al., in press). Modeled slip vectors converge toward the center of normal faults whereas they diverge for thrust faults, which causes contrasting fault-parallel displacements at the model surface. Our model also predicts divergent movements in normal fault footwalls, which were recorded for the first time during the L'Aquila earthquake. During the postseismic phase, viscous flow in the lower crust induces fault-parallel surface displacements, which have the same direction as the coseismic displacements but are distributed over a larger area that extends far beyond the fault tips. Hence, detecting this signal requires GPS stations in the prolongation of the fault's strike. Postseismic velocities vary over several orders of magnitude depending on the lower-crustal viscosity and may reach tens of millimeters per year for low viscosities. Our study establishes the link between coseismic and cumulative slip patterns on normal and thrust faults and emphasizes that understanding fault-parallel slip components and associated surface displacements is essential for inferring regional deformation patterns from space-geodetic and fault-slip data.

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