Geophysical Research Abstracts
Vol. 18, EGU2016-10753, 2016
EGU General Assembly 2016
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Rapid ductile afterslip from coseismic heating

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Earthquakes are typically followed by months of afterslip, the total of which is generally an order of magnitude smaller than the seismic slip. The classic model for afterslip envisions seismic slip transferring stress to adjacent regions, driving accelerated stable sliding that expands the rupture area. However, a small fraction of earthquakes exhibit unusually large and rapid afterslip in the hours immediately following rupture. Here we present a new model that bridges the transition from seismic to postseismic deformation and may explain these observations of rapid afterslip. Seismic slip produces a significant temperature rise that slowly diffuses into the surrounding material following the cessation of seismic slip. Any process with strong temperature dependence is more sensitive to this heat transient than to the ambient temperatures present during the interseismic period. Coupling the temperature evolution of a fault to a ductile flow law we model postseismic deformation during the heat transient. Our idea of coseismic heating enhancing ductile flow is supported by field observations of micro-shear zones adjacent to psuedotachylyte veins. Enhanced ductility is largely confined to the zone that deformed seismically, making our model equivalent to rapid afterslip. Combining analytic and numerical methods we solve for the total afterslip in terms of the slip rate and fault strength during seismic slip and the ductile flow parameters. Our results are sensitive to the assumed rheology and deforming zone thickness, and while total afterslip is generally small some plausible parameter ranges predict afterslip comparable to or greater than the seismic slip developing over timescales shorter than an hour. We demonstrate that rapid afterslip can drive significant frictional heating, leading to a thermal runaway instability that produces a near total postseismic stress drop. To conclude we investigate the tsunami magnitude that could be produced by rapid ductile afterslip.