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The relationship between afterslip and aftershocks: a study based on Coulomb-Rate-and-State models

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The original Coulomb stress hypothesis, as well as most physics based models of aftershock sequences, assume that aftershocks are triggered by the instantaneous coseismic stress: in other words, the stress field is treated as stationary following the mainshock. However, several lines of evidence indicate that postseismic processes may affect aftershock triggering. The cumulative seismic moment of afterslip can be a significant fraction of the coseismic moment, generating comparable stress changes; moreover, afterslip has a similar time dependence as aftershocks, suggesting that the two processes may be linked. Aftershocks themselves contribute to the redistribution of stresses, and they can trigger their own aftershocks: spatial clustering, and the success of statistical models which include secondary triggering (ETAS) suggest that, even though aftershocks typically generate stresses orders of magnitude smaller than the mainshock, they are significant on a local scale.

Our goal is to study the effect of postseismically induced stresses in the spatial and temporal distribution of aftershocks. We focus on the two processes described above (afterslip and secondary triggering), and do not consider other phenomena such as poroelastic response and viscoelastic relaxation. We study a period of 250 days following the mainshock, for two case studies: the Parkfield, Mw=6.0 and the Tohoku, Mw=9.0 earthquakes. We model the seismic response to stress changes using the Dieterich constitutive law, derived from a population of faults governed by Rate-and-State dependent friction; we also consider uncertainties in the input stress field using a Monte Carlo technique.

We find that modeling secondary triggering systematically improves model performance; afterslip has a less significant overall impact on the model, but in both cases studies we observe clusters of seismicity which, due to their location relative to the coseismic and postseismic slip, are better explained when afterslip is included. Our results indicate that consideration of time dependent stress fields has the potential to improve physics based aftershock models.