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Coseismic and postseismic Coulomb stress changes on intra-continental dip-slip faults and the role of viscoelastic relaxation in the lower crust: insights from 3D finite-element models

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Investigating the stress interaction of faults plays a crucial role for assessing seismic hazard of a region. The calculation of Coulomb stress changes allows quantifying stress changes on so-called receiver faults in the surrounding of a source fault that was ruptured during an earthquake. Positive Coulomb stress changes bring receiver faults closer to failure, while a negative value indicates a delay of the next earthquake. Besides the coseismic ('static') stress changes, postseismic ('transient') stress changes induced by postseismic viscoelastic relaxation occur. Here we use 3D finite-element models with arrays of normal or thrust faults to study the coseismic stress changes and the stress changes arising from postseismic relaxation in the lower crust. The lithosphere is divided into an elastic upper crust, a viscoelastic lower crust and a viscoelastic lithospheric mantle. Gravity is included in the models. Driven by extension or shortening of the model, slip on the fault planes develops in a self-consistent way. We modelled an earthquake on a 40-km-long source fault with a coseismic slip of 2 m and calculated the displacement fields and Coulomb stress changes during the coseismic and postseismic phases. The results for the coseismic phase (Bagge and Hampel, Tectonophysics in press) show that synthetic receiver faults in the hanging wall and footwall of the source fault exhibit a symmetric distribution of the coseismic Coulomb stress changes on each fault, with large areas of negative stress changes but also some smaller areas of positive values. In contrast, faults positioned in along-strike prolongation of the source fault and outside of its hanging wall and footwall undergo mostly positive stress changes. Postseismic stress changes caused by viscous flow modify the static stress changes in a way that the net Coulomb stress changes on the receiver faults change significantly through space and time. Our models allow deciphering the combined effect of stress changes caused by the ongoing extension or shortening (leading to an interseismic stress increase) and by the postseismic relaxation (leading to stress increase or decrease). Depending on the viscosity and the dip and position of the receiver fault, stress changes induced by postseismic relaxation can outweigh the interseismic stress increase such that negative Coulomb stress changes can persist for decades. On other faults, the interseismic stress increase is further increased by postseismic relaxation. The viscosity of the layers has a crucial influence on the postseismic Coulomb stress changes. A lower viscosity leads to higher displacements and the process of postseismic relaxation is faster, so that a higher stress increase (and decrease) in the first years after the earthquake is possible.