Geometrical evolution of wavy fault and earthquake cycle: effect of kink-generated normal stress heterogeneity

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We consider interactions between dynamic ruptures and geometrical evolution of a non-planar wavy fault with numbers of kinks, during repeated earthquake events by using numerical simulations. We had found that kinks could generate intensive shear stress concentration around them, which resulted in the generation of secondary new faults from kinked parts of a preexisting fault. Here I extend the model from the previous version (Ando and Scholz, 2007, JPGU) and the effect of the normal stress, neglected in the previous model, is included through the Coulomb friction, where the frictional strength is proportional to the normal stress. We find two features make the model behaviors different from those shown in the previous model. First, because the shear stress symmetrically distributes about a planar fault, the previous model basically did not show asymmetric features regarding the direction of kinking. However, the normal stress is antisymmetric about the fault, and some characteristic behaviors are found related to the difference of kinks toward right or left. For the case of a right lateral mode II crack, a rupture more easily propagates beyond kinks toward right than those toward left, because, in this case, the rupture extends into tensional stress fields due to kinking like as the situation of a right step over for a right lateral fault. Contrary, ruptures even can be arrested after left kinking in some cases. Second, it is found that a passage of a rupture beyond kinks leaves the heterogeneity of resultant normal stress distribution on the fault around kinks as well as the surrounding off-fault areas, leading the intensive strengthening by compression or weakening by tension occurring there. Due to these localized weakened parts on the fault near kinks, for the next rupture event after a loading period, a rupture can be initiated on this preexisting fault. This behavior did not occur in the previous model since the shear stress tended to become homogeneous after the rupture due to assumed slip weakening law with a constant residual strength level, although the off-fault shear stress field became inhomogeneous due to kinks, hence the nucleation occurred only off the fault with generation of a new fault. The strength heterogeneity also complicates rupture propagation processes. The pattern of geometrical fault evolution due to an earthquake cycle appears to become more diverse with the effect of the normal stress.