Co-rupture, quasi-coseismic, and post-seismic EM fields generated by the rupture process of a finite fault embedd in a porous medium

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The electrokinetic effect related with the electric double layer between rock and fluid is one of the most possible generation mechanisms of earthquake-related electromagnetic (EM) signals. Previous numerical simulation studies of earthquake-related EM signals have indicated that the electrokinetic effect is able to generate co-rupture and coseismic EM fields as well as post-seismic electric fields. However, the amplitudes of the simulated co-rupture EM signals are under the natural EM noise levels. This means they are unobservable. Thanks to the improvement in the instrument and approach applied in the field observation of EM anomalies, reports on the co-rupture electric or magnetic signals finally appeared in recent years although such reports are very rare. Quasi-coseismic EM signals which are synchronous with seismic arrival have also been recorded in field observation. According to previous simulations on the electrokinetic effect, they are thought to be the coseismic EM fields, which are local responses to the seismic arrivals in a porous medium. In this study, we carry out numerical simulations of the electrokinetically coupled seismic and EM wavefields generated by a finite fault in a layered model consisting of porous and solid materials. Results confirm that the electrokinetic effect does can generate observable co-rupture EM signals, and the observability depends on the epicentral distance, properties of the medium where the fault is located, and local EM noise levels. It is shown quasi-coseismic EM signals can be generated even if the top layer, which is above the ground water level, is assumed to be a solid layer. The quasi-coseismic EM signals at least are partially contributed by the evanescent EM waves generated at the shallow subsurface interfaces. The evanescent EM waves are sensitive to the properties of the shallow subsurface fluid. Besides the radiation EM waves of interface response, the evanescent EM waves possibly also have some potential applications associated with the shallow subsurface fluids. Our results also show that electrokinetic effect can generate post-seismic electric and magnetic fields. They are presumably induced by the low-frequency fluid diffusion after the earthquake. The post-seismic magnetic field has not been identified in previous simulations on the electrokientic effect, because its generation requires a sufficiently strong medium heterogeneity, which the uniform porous half-spaced utilized in previous simulations cannot provide. Further studies on the evanescent EM waves and the EM fields associated with the fluid diffusion caused by the stress change may provide a better understanding and interpretation of the earthquake-related EM signals.
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