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Modelling dynamic fault slip and seismic wavefield for production-induced seismicity in Groningen

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Induced seismicity from a gas-producing region such as Groningen is believed to be caused by reservoir depletion due to long-term gas production. However, because of the complexity and uncertainty regarding the underground structure and composition, it is difficult to quantify the effect on induced seismicity due to gas production. Here we use finite-element modelling to investigate the seismogenic potential of a pre-existing fault reactivated due to fluid depletion, considering different model settings. By applying quasi-static poroelastic loading representing reservoir depletion, the stress and strain fields are derived from the resulting displacement field. The equilibrium of the fault is then evaluated using either rate-and-state or slip-weakening behaviour for friction. When the critical state is reached on the fault, where the shear stress is greater than the friction, the reactivation of the fault takes place. This reactivation is simulated by using a dynamic solver to observe the propagation and the arrest of the dynamic faulting, as well as the resultant wavefield due to seismic slip. By comparing the depletion value at both aseismic and seismic ruptures, and looking at the stress distribution on the fault, the pattern of rupture nucleation, and the resulting seismic wavefield, we are able to evaluate separately the effect of different model settings, including the geometry and material property of both caprock and reservoir, reservoir depletion pattern, and the friction law. Furthermore, by combining our study with the observed seismic wavefield, it is possible to obtain useful insights on the spatial variation in the source region.