Quasi-static earthquake cycle simulation based on large-scale viscoelastic finite element analyses

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Earthquake cycle simulation is extensively studied in the field of solid earth science as a tool to explain earthquake generation processes. It is also expected to play an important role in disaster mitigation, such as generation of possible earthquake scenarios as inputs for earthquake damage estimation. An approach combining a boundary element approach based on Green’s function in an elastic half space and the rate- and state-dependent friction law is widely used for this simulation (e.g. Hori 2009; Barbot et al. 2012). On the other hand, in crustal deformation computation, complex physics such as the mantle rheology and the effect of gravity are not negligible in some cases. To consider extensibility for such effects, it is desirable to develop an earthquake cycle simulation combining crustal deformation computation based on numerical simulation such as finite element (FE) method with the rate- and state-dependent friction law. This approach used to be practically difficult because of the associated computational cost, but the recent development of a fast and scalable FE solver (Ichimura et al. 2016) assuming use of supercomputers is expected to make it feasible. Therefore in this study, we seek to apply the crustal deformation computation using the viscoelastic FE analysis method developed by Ichimura et al. (2016) to earthquake cycle simulation based on the rate- and state-dependent friction law.

We use the equation of motion, the rate- and state-dependent friction law, and a slowness law as the governing equations of the earthquake cycle simulation. However, instead of computing stress changes along the fault plane by superimposing slip response function as in the previous studies, we compute them using the time history calculation of viscoelastic deformation using the FE method. For now, the time integration scheme and other components of the simulation method all follow the approach in Hyodo and Hori (2014).

We are now performing verification of the developed simulation code using a normative three dimensional problem, where a circular-shaped velocity-weakening area is set in a square-shaped fault plane. In the presentation, we will discuss the comparison of our results with those obtained using the previous methods. If possible, we would also like to discuss the change of earthquake generation process due to the introduction of viscoelasticity in the cycle simulation, as an example of the effect by mantle rheology.

Keywords: Earthquake cycle simulation, Finite element method, the rate- and state-dependent friction law, large-scale numerical simulation

