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The discontinuous Galerkin method for sequences of earthquakes and aseismic slip

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Earthquakes and aseismic slip are typically modelled as a displacement discontinuity on a prescribed infinitesimally thin fault surface embedded in linear elastic or viscoelastic media. The fault slip behaviour can be described by laboratory-derived rate and state friction laws, which are suitable to model frictional sliding throughout the complete seismic cycle, i.e. interseismic, coseismic, and post-seismic phase. The governing time scales vary from years in the interseismic phase to seconds in the coseismic phase and the respective spatial scales vary from hundreds of kilometres of tectonic structures to metres (or less) on-fault. Therefore, simulating the entire seismic cycle is computational challenging and as such mandates utilization of high performance computing (HPC).

We present the open-source code tandem which is designed to model quasi-dynamic sequences of earthquakes and aseismic slip (SEAS). In tandem we explore the usefulness of the symmetric interior penalty Galerkin (SIPG) method using unstructured simplicial meshes for the computation of the elastostatic response to a displacement discontinuity. The potential of the SIPG method for SEAS models lies in (i) its geometric flexibility, (ii) its high-order approximation spaces, (iii) and its natural ability to deal with discontinuities.

Using a number of 2D and 3D SCEC community benchmarks (Erickson et al., 2020) we verify the tandem SIPG implementation. Based on the same reference models, we demonstrate benefits of using highly refined unstructured meshes and a high-order geometric representation of the fault. We also explore whether using a high-order discretisation in space is advantageous. Lastly, we outline how tandem may leverage modern supercomputing resources.