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Improving models of seismic hazard assessment: Insights from a simple, seismotectonic analogue model

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Models for the assessment of seismic hazard along a fault rely on the long-term record of earthquakes and statistical models that describe their distribution in time and space. There is a lack of insight into the long-term record of earthquakes and deformation accumulation because of the limited availability of information from historical events. Many of the models, such as the Brownian passage-time model, are validated with historical catalogues and numerical simulations, but lack a comparison with experimental data.

We combine three different rheologies into a fully scaled seismotectonic analogue model of a strike-slip fault to model the complex interaction of elastic upper crust, rate-and-state frictional faults, and viscoelastic lower crust. The setup is able to generate reproducible slip events showing all components of a seismic cycle. A long period of interseismic locking alternates with phases of fast coseismic slip followed by a short period of non-linear relaxation. The surface displacement patterns during the experiment show qualitative similarity with natural observations and a quantitative match with analytical solutions for interseismic and coseismic slip. To model various slip modes on a single fault we use glass beads as an analogue for the rate-and-state-dependent friction on the fault because they display a large range of slip behaviours, including microslips that may be precursors of large slip events.

With this model, we are able to bridge the gap between the long-term deformation of plate tectonics and the short-term deformation of seismic and aseismic slip. Combining the experimental results with a numerical code, we are able to simulate the experiment on a laboratory scale. Therefore, we are able to draw connections between the individual parameters that control the behaviour of a fault system and its importance for the variability of the seismic cycle in space and time.