FAULT VALVING AND PERMEABILITY EVOLUTION IN SLOW AND FAST FAULT SLIP DYNAMICS

Danyang JIANG [1], ***Antonio P. RINALDI*** [1], ***Luca DAL ZILIO*** [2,3]

[1] Swiss Seismological Service, Swiss Federal Institute of Technology, ETHZ, Zurich, Switzerland
[2] Earth Observatory of Singapore, Nanyang Technological University, Singapore, Singapore
[3] Asian School of the Environment, Nanyang Technological University, Singapore, Singapore

contact: danyang.jiang@sed.ethz.ch

Conventional earthquake models often overlook dynamic fluid pressure and poroelastic effects, despite faults potentially acting as either barriers or conduits to fluid flow. To address this, we develop the Hydro-Mechanical Earthquake Cycles (H-MECs) model, integrating solid-fluid interactions, poroelastic stresses, and fluid flow on- and off-fault. Our model employs a 2-D antiplane strike-slip fault framework in a poro-visco-elasto-plastic compressible medium governed by rate- and state-dependent friction and incorporates a permeability evolution law reflecting changes due to fault slip and healing. The model simulates fluid ascent in the seismogenic zone, sourced from metamorphic reactions, and tests various nucleation sizes to study the interplay between fault friction and solid-fluid interactions coupled by poroelasticity. When the nucleation size is relatively large and the healing time is prolonged, we observe an increased dominance of solid-fluid interactions and poroelastic effects within the fault system. This leads to an increase in fault permeability that facilitates the migration of over-pressurized ascending fluids and initiates slow-slip events within the seismogenic zone. Conversely, smaller nucleation sizes enhance the interplay between fault friction and solid-fluid interactions, triggering the upward migration of seismic swarms. These smaller earthquakes are closely followed by pore pressure diffusion of ascending fluids due to fault valving effects, highlighting the critical role of transient fluid effects in slow-slip events and the propagation of seismic swarms. This research advances our understanding of the coupling between strain localization, poromechanics and friction throughout the earthquake cycle.