A Pump-Probe Analysis of Nonlinear Elastic Behavior on the San Andreas Fault

Andrew Delorey
Los Alamos National Lab, EES-17 Geophysics, United States of America (andrew.a.delorey@gmail.com)

Fracture networks in the subsurface influence nearly every aspect of earthquakes and natural hazards. These aspects, including stress, permeability and material failure, and are important for hazard assessment. However, our ability to monitor fracture behavior in the Earth is insufficient for any type of decision-making regarding hazard avoidance. I propose a new method for probing the evolution of fracture networks in situ to inform public safety decisions and understand natural systems.

In heterogeneous, fractured materials, like those found in the Earth, the relationship between stress and strain is highly nonlinear. This nonlinearity in the upper crust is almost entirely due to fractures. By measuring to what extent Earth materials exhibit nonlinear elastic behavior, we can learn more information about them. Directly, measuring physical properties may be more useful than just detecting that fractures are present or how they are shaped and oriented. We measure nonlinearity by measuring the apparent modulus at different strains.

In this study we use a pump-probe analysis, which involves continuously probing velocity (as a proxy for modulus) while systematically straining the material. We will use solid Earth tides as a strain pump and empirical Green's functions (EGF) as a velocity probe. We apply this analysis to the San Andreas Fault near Parkfield, California. We chose Parkfield because there is a long-term deployment of borehole seismic instruments that recorded before and after a M6 earthquake. We find evidence that nonlinear behavior is correlated with the seismic cycle and therefore it may contain information on the both the evolution and current state of stress on faults.