ENERGY BUDGET OF EARTHQUAKES: CONNECTING REMOTE OBSERVATIONS WITH LOCAL PHYSICAL BEHAVIOR

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Many seismological studies seek to shed light on earthquake rupture physics using averaged event quantities, such as the average slip and static stress drop, as well as energetic estimates such as the radiated energy, (averaged) breakdown energy, and radiation efficiency. These inferences rely on the use of idealized rupture models, whereas the actual spatial distribution of slip and local stress change may vary substantially throughout the ruptured area. The relationship between observationally-inferred average rupture characteristics, such as breakdown energy and radiation efficiency, and their actual values is therefore not directly evident. We explore this relationship using fully dynamic simulations of sequences of seismic and aseismic slip incorporating standard rate-and-state friction as well as enhanced dynamic weakening due to thermal pressurization (TP) and flash heating.

We find that standard energy considerations inspired by dynamic fracture mechanics generally hold for simulations that produce crack-like shear ruptures, within a relatively modest error of a factor of 2. Moreover, models incorporating TP are able to reproduce the observationally inferred trends of increasing breakdown energy with event size, magnitude-invariant stress drops, and radiation efficiency around 0.5. In contrast, the standard energy budget does not apply to simulations that result in self-healing pulse-like ruptures, which are characterized by a substantial stress undershoot, and thus greater discrepancies between the average dynamic and static stress changes. If large earthquake ruptures propagate as such self-healing pulses, as have been suggested by a number of studies, then inferences about their energy budget need to be reconsidered.