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Bridging Long- and Short-term Behavior Shows Fault Strength as a Strain-average

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The strength of faults is subject of an important debate throughout various Earth Scientific disciplines. Different scientific communities have different perspectives with respect to appropriate values for friction coefficients μ. Geodynamicists with a long-term perspective require very low effective strengths (μ<0.05), while at the same time realizing mountains need to be sustained as well. Geologists and seismologists typically start from Byerlee friction coefficients of 0.6<μ<0.85, whereas rock mechanics experiments at high seismic slip rates show short-term low dynamic friction values of 0.03<μ<0.3. Here I show that both long- and short-term approaches can be made more compatible through considering that a regional or global frictional strength should be approached as a strain-averaged quantity. Doing this accounts for large variations of strain in both time and space. What matters for large-scale models is that most deformation occurs over a very small space and time during which friction is exceptionally low, thus making the representative long-term strength low. This is supported by seismo-thermo-mechanical models that self-consistently simulate the dynamics of both long-term subduction and short-term seismogenesis. The latter sustain mountain building, while representative earthquake-like events occur on faults with pore fluid pressure-effective static friction coefficients between 0.125 and 0.005 (or 0.75<Pf/Ps<0.99). These low friction values suggest faults are weak and suggest the dominant role of fluid pressures in weakening faults in subduction zones. This is confirmed in analytical considerations based on mechanical energy dissipation, which provide an equation to calculate the long-term fault strength as a strain-average quantity. Constraining the four parameters in this equation by observations confirms that fluid weakening is more important for long-term weakening than dynamic frictional weakening and low static friction coefficients. From the short-term perspective of modeling earthquake rupture dynamics it is now also becoming evident that fluid overpressured faults are preferable. They namely facilitate the incorporation of laboratory-observed dynamic weakening (70-90%) by limiting the stress drop to reasonable values. In summary, this cross-scale perspective supports long-term effective friction values in the range of about 0.03 to 0.2.