EGU2020-11079
https://doi.org/10.5194/egusphere-egu2020-11079
EGU General Assembly 2020

What controls b-value variations: insights from a physics based numerical model

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The magnitudes of earthquakes are known to follow a power-law distribution, where the frequency of earthquake occurrence decreases with the magnitude. This decay is usually characterized by the power exponent, the so-called b-value. Typical observations report b-values in the range 0.5-2. The origin of b-value variations is however still debated. Seismological observations of natural seismicity indicate a dependence of the b-value with depth, and with faulting style, which could be interpreted as a signature of a stress dependence. Within creeping regions of major tectonic faults, the b-value of microseismicity increases with creep rate. Stress dependent b-value of acoustic emissions is also commonly reported during rock failure experiments in the laboratory. Natural and laboratory observations all support a decrease of b-value with increasing differential stress. I report here on the origin of b-value variations obtained in a fault model consisting in a planar 2D rate-and-state frictional fault embedded between 3D elastic slabs. This model assumes heterogeneous frictional properties in the form of overlapping asperities with size-dependent critical slip distance distributed on a creeping segment. This allows to get complex sequences of earthquakes characterized by realistic b-values. The role of frictional heterogeneity, normal stress, shear stress, and creep rate on the b-value variations is systematically explored. It is shown that the size distribution of asperities is not the only feature controlling the b-value, which indicates an important contribution from partial ruptures, and cascading events. In this model cascades of events (and thus b-value) is strongly influenced by frictional heterogeneity and normal stress through fracture energy distribution. If the decrease of b-value with differential stress is reproduced in these simulations, it is also shown that part of the b-value fluctuations could be attributed to changes of nucleation length and stress drop with normal stress. A slight increase of b-value with slip rate exists but remains an order of magnitude smaller than the observations.