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A modified Coulomb failure seismicity model to study earthquake occurrence and frequency-magnitude distributions

Torsten Dahm
GFZ German Research Centre for Geosciences, S2.1 Physics of Earthquakes and Volcanoes, Potsdam, Germany
(torsten.dahm@gfz-potsdam.de)

The linear Coulomb failure (LCM) and the rate-and-state model (RSM) are two widely-used physics-based seismicity models both assuming Coulomb stress changes acting on pre-existing populations of faults. While both predict background earthquake rates and time-dependent stress effects, only the RSM can additionally explain the time-dependent triggering of aftershocks.

We develop a modified effective media Coulomb model which accounts for the possibility of earthquake nucleation and retarded triggering of rupture. The new model has only two independent parameters and explains all statistical features of seismicity equally well as the RMS, but is simpler in its concept and provides insights in the possible nature of time-dependent frequency-magnitude distributions. Some of the statistical predictions are different compared to the RSM or LCM. For instance, the model domain is not limited to positive earthquake background or stressing rates; it can also simulate seismicity under zero stressing assumptions. The increase of background seismicity with tectonic stressing is nonlinear, different to the other models, and may even saturate if the tectonic stress loading is very strong. The Omori aftershock decay is predicted in the new model with an exponent of p=1 also for time periods much larger than the aftershock decay time, however, the productivity factor K is time dependent with a very slow exponential attenuation. The attenuation may explain the apparent variation of p in observed aftershock sequences. Interesting is also that the new model predicts a co-seismic peak of triggered aftershocks, which depends on the magnitude of the stress step and does not influence the attenuation of aftershocks following the stress step. It could be a physical explanation for the c-value in Omori's law, the origin of which is still under discussion.

We compare the new model to RSM and LCM and discuss the possible implications for earthquake clustering and frequency magnitude distributions.