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Comparison of deterministic and stochastic earthquake simulators for fault interactions in the Lower Rhine Embayment, Germany

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Time-dependent probabilistic seismic hazard assessment requires a stochastic description of earthquake occurrences. While short-term seismicity models are well-constrained by observations, the recurrences of characteristic on-fault earthquakes are only derived from theoretical considerations, uncertain paleo sequences or proxy data. Despite the involved uncertainties and complexity, simple statistical models for a quasi-period recurrence of on-fault events are implemented in seismic hazard assessments. To test the applicability of statistical models such as Brownian relaxation oscillator or the stress release model, we perform a systematic comparison with deterministic simulations based on rate- and state-dependent friction, high-resolution representations of fault systems, and quasi-dynamic rupture propagation. For the specific fault-network of the Lower Rhine Embayment, Germany, we run both stochastic and deterministic model simulations based on the same fault geometries and stress interactions. Our results indicate that the stochastic simulators are able to reproduce the first-order characteristics of the major earthquakes on isolated faults as well as for coupled faults with moderate stress coupling. However, we find that all tested statistical models fail to reproduce the characteristics of strongly coupled faults, because the potential for coseismic multi-segment rupturing is underestimated in the statistical models. Therefore the application of purely statistical recurrence models for coupled fault networks might be questionable.