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Earthquake source statistics inferred from earthquake source physics - Toward developing an extended earthquake rupture forecast model

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Earthquake rupture forecast (ERF) models and empirical ground motion prediction equations (GMPEs) are two core elements in probabilistic seismic hazard analysis (PSHA). Although there are limitations in simulation-based seismic hazard analysis, they provide several advantages over the empirical approaches, including explicit consideration of scenario-specific source effects, such as different hypocenters, slip, and rupture time distributions; and the computation of full three-component, site-specific, waveforms. This study aims to improve simulation-based ground motion prediction methods, consequently simulation-based seismic hazard analysis methods, by effectively characterizing earthquake source processes and quantifying their variability with spatial data analysis tools, commonly used in geostatistics. The earthquake source process is described by key kinematic source parameters, such as final slip, rupture velocity, and slip duration. One point statistics, i.e. marginal probability density function (PDF) for each source parameter characterizes and constrains the range of key source parameters and their likelihood within the range at each point on the fault, and two point statistics, i.e. auto- and cross-coherence, characterize the heterogeneity of each source parameter and their linear dependency (coupling). We analyzed several kinematic and dynamic rupture models to demonstrate the efficiency of these new techniques and found that many interesting features of earthquake rupture can be captured in this way. For instance, the correlation maximum between slip and rupture velocity can be shifted from zero offset, i.e. large slip may generate faster rupture velocity ahead of the current rupture front, which may be important for rupture directivity. This type of statistical analysis may provide improved understanding of earthquake source characteristics, and how they control the characteristics of near-fault strong ground motions. Consequently, it may help us constrain the possible rupture scenarios of future events and develop an extended earthquake rupture forecast model for full-waveform-simulation-based hazard analysis.