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Quantifying Fault Slip Rate Variations and Earthquake Clustering

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An outstanding challenge to our understanding of fault behaviour remains the appropriate characterisation and mechanistic understanding of episodic fault activity and temporal variations in slip rate. This gap in understanding inhibits our ability to reconcile geodetic and geologic strain rates and hence predict future earthquakes. Existing models for earthquake recurrence and seismic hazard are based on the key principle that a mean recurrence interval, T_{mean}can be defined. For areas of active crustal deformation where there are several active faults, and/or the regional strain rate is relatively low, historical earthquake catalogues are unable to provide adequate constraints on T_{mean} because the earthquake cycle of some faults is longer than the catalogue itself. Paleoseismological trench studies have extended the window of observation back for a few thousand years and suggest that large temporal variability in recurrence interval occurs on individual faults. Current practice in seismic hazard analysis is to characterise variability in recurrence interval by defining the Coefficient of Variation (CV) for a sequence of earthquakes where CV = σ/ T_{mean}, and σ is the standard deviation of the inter-event times. Several studies acknowledge that CV values for earthquake recurrence intervals are poorly constrained yet small differences in CV can lead to order of magnitude difference in conditional probability calculations. We use a numerical fault growth model, which includes earthquake rupture, healing and elastic interaction, to investigate the controls on CV, both spatially across the fault array and through time as the fault pattern evolves. We find that CV varies inversely with fault slip rate, which itself varies as a function of fault zone complexity, i.e., when the strain is partitioned on more than one structure CV increases. However, we also find that CV is not the most informative parameter to measure in our model output. Firstly, it only takes into account earthquake recurrence interval and not the temporal sequence and magnitudes of the fault offsets. Secondly, robust estimates of CV require a complete inventory of a large number of events ($>$10), which is unlikely to be available for real faults, thus rendering the comparison with natural data sets difficult. From the analysis of our model output, we conclude that slip rate variability SRV = (standard deviation of slip rate over a fixed time window)$\div$(long term average slip rate), provides a more robust and sensitive measure of spatial and temporal variations in fault behaviour. In particular, SRV is relatively insensitive to the completeness of the record for smaller magnitude offsets while being highly sensitive to the time order and magnitude of larger magnitude offsets. We investigate how SRV varies as a function of fault geometry, i.e., spacing, orientation and structural complexity, and compare our model results with field data on fault activity from the central Apennines of Italy.