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Improving earthquake doublet rate predictions in ETAS by using modified spatial trigger distributions

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Earthquake sequences add significant hazard beyond the solely declustered perspective of common probabilistic seismic hazard analysis (PSHA). A particularly strong driver for both social and economic losses are so-called earthquake doublets (more generally multiplets), i.e. sequences of two (or more) comparatively large events in spatial and temporal proximity. Not differentiating between foreshocks and aftershocks, we hypothesize three main drivers of doublet occurrence: (1) the number of direct aftershocks triggered by an earthquake; (2) the underlying, independent background seismicity in the same time-space window; and (3) the magnitude size distribution of triggered events (in contrast to independent events). We tested synthetic catalogs simulated by a common, isotropic epidemic type aftershock sequence (ETAS) model for both Japan and Southern California. Our findings show that the standard ETAS approach dramatically underestimates doublet frequencies compared to observations in historical catalogs. Among others, the results partially smooth out pronounced peaks of temporal and spatial event clustering. Focusing on the impact on direct aftershock productivity, we propose two modifications of the ETAS spatial kernel in order to improve doublet rate predictions: (a) a restriction of the spatial function to a maximum distance of 2.5 estimated rupture lengths; (b) an anisotropic function with contour lines constructed by a box with two semicircular ends around the estimated rupture line. The restriction of the spatial extent shifts triggering potential from weaker to stronger events and in consequence improves doublet rate predictions for larger events. However, this improvement goes at the cost of a weaker overall model fit according to AIC. The anisotropic models improve the overall model fit, but have minor impact on doublet occurrence rate predictions.