Missing links in earthquake clustering models

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Many clustering models imply two kinds of earthquakes: those triggered by previous earthquakes, and spontaneous ones independent of previous events. The pair-wise links from earlier to later earthquakes are analyzed to estimate the clustering parameters. However, earthquake catalogs are limited in time, space, and magnitude, so that potential triggers for a cataloged earthquake may not be known. As a result some important links are unrecognized and some triggered events could appear spontaneous. Here we present a method for identifying such earthquakes and reducing the bias from missing links. Our strategy is to ignore some known links from earlier earthquakes to test their importance. If known links can be safely ignored, then links from earlier, more distant, and smaller events can also be ignored. We treat earthquakes probably affected by missing links as potential causes of later events, but we exclude them in evaluating modeled effects. As the vehicle to evaluate how such data limitations affect clustering models, we use an Epidemic-type Aftershock Sequence (ETAS) model. Of its eight parameters, that most affected is the proportion of spontaneous earthquakes. For southern California, results depend strongly on the lower magnitude threshold for the catalog: small earthquakes near the completeness threshold collectively trigger many other quakes. Earthquakes before the catalog start date also seem to have a large, unknown triggering effect. However, quakes outside the spatial limits of the catalog appear much less important.