Improvement of spatial clustering in a spatiotemporal Coulomb rate-and-state model

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Cattania et al. [2015, JGR; 2018, SRL] and Mancini [2019, JGR] applied a Coulomb rate-and-state model based on Dieterich [1994, JGR] to the modeling of the spatiotemporal seismicity. In this type of spatiotemporal modeling, the spatial clustering is represented through the spatial variation of Coulomb failure stress changes (ΔCFS) caused by each earthquake; in the aforementioned studies, (2D) spatial distribution of ΔCFS caused by an earthquake of which epicenter is located at (x_0, y_0) and moment magnitude is M_0 is formulated as $M_0/[6*\mathrm{pi}*\{(x - x_0)^2+(y - y_0)^2\}]^{1.5}$, which is derived in Chen et al. [2013, JGR].

The formula above is rewritten as $A\exp(\alpha M)/\{(x - x_0)^2 + s(y - y_0)^2 + r(x - x_0)(y - y_0) + d\}^q$ with A = 6.67e-2, α = 3.45, q = 1.5, d = 0, s = 1, and r = 0, where M denotes the (moment) magnitude of an earthquake. This study examines whether or not the spatialtemporal model is significantly improved if we allow these parameters to be adjusted (estimated).

Here, three earthquake sequences were analyzed. Two are aftershock sequences after the 1995 Kobe and 2004 Mid-Niigata (Chuuetsu) earthquakes, which have been examined in Iwata [2016, Pageoph], and one is the 2000 Izu islands earthquake swarm. The three sequences were retrieved from the earthquake catalog complied by the Japan Meteorological Agency. To consider the completeness of the recorded events in the analyzed sequences, the magnitude thresholds are 2.8, 3.0, and 3.0 for the Kobe, Chuuetsu, and Izu sequences, respectively. The size of the rectangular areas for the three sequences are 60 x 50 km, 40 x 40 km, and 60 x 100 km, respectively. Consequently, the number of analyzed events are 228 for Kobe, 358 for Chuuetsu, and 4897 for Izu sequences.

The significance of the improvement is evaluated with the Akaike Information Criterion (AIC), in the framework of (statistical) model comparison. For all the three sequences, the AIC value of the "adjusted" case is approximately several hundred or several thousand smaller (better) than that of the "non-adjusted" case, suggesting that the spatiotemporal model is significantly improved.

Keywords: spatiotemporal modeling of seismicity, rate-and-state friction, Coulomb stress, model comparison

