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Static Coulomb Failure Function and Aftershocks of 1995 Kobe Earthquake

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Earthquakes may trigger further earthquakes. When stress perturbation by a large earthquake is applied to a fault, this fault is brought either closer to or further away from an earthquake. Static Coulomb failure function(CFF) has been used to describe stress state of a fault plane, and an increase of CFF value implies that this fault is brought closer to failure, according to the Coulomb failure criterion. Since mid-1990s, this CFF hypothesis has been widely used to explain elements of seismicity, example of which include spatial and temporal distribution of aftershocks and successive occurrence of large earthquakes in regions such as southern California and Turkey. However, seismicity itself is a complex phenomenon and it is not straightforward to quantitatively define background seismicity. Therefore it is not unclear how we are able to differentiate truly triggered events from the background seismicity, or to verify whether the static CFF hypothesis works successfully. In this study, we propose an approach to statistically verify whether the CFF hypothesis explains aftershock activities. In previous application of this hypothesis to aftershocks, it is common to assume specific fault parameters for number of events and then to compare spatial pattern of CFF values and the aftershock distribution, which means that these aftershocks are treated as point processes. Since CFF values is a measure of stress on a specific fault and thus depend on the orientation and the slip direction of target faults, it is an oversimplification to ignore variation of aftershock mechanisms(fault planes), as we are aware that aftershock mechanisms has a wide variety. Our approach is to utilize fault planes of aftershocks. We evaluate how successful static CFF hypothesis would be for aftershocks of 1995 Kobe(Hyogo-ken-nanbu) earthquake and test the statistical significance. Using aftershock mechanisms of Katao et al. [1997] we evaluate CFF on the fault planes of the aftershocks, and test whether static CFF by the main shock trigger these aftershocks. The geodetic source model of Hashimoto et al. [1996] explains more than 2/3 of aftershocks, which means static CFF hypothesis appears to work for these events(i.e., they are triggered). We derive similar results from the source model of Sekiguchi et al. [2004], which is constructed from the strong motion data. On the other hand, when we test static CFF for the events randomly from a statistically modeled regional seismicity, we find that static CFF successfully explains more than 2/3 of the background seismicity. This implies that 2/3, apparently a high number, is not statistically high enough to conclude that the static CFF effectively controls the aftershock activity, or our statistical tests do not confirm that these aftershocks are selectively excited events by the main shock. One proposed application of CFF hypothesis is to evaluate probabilistic occurrence of the future earthquake on a specific fault. This could be useful to mitigate earthquake related hazards in tectonically active circum-Pacific countries. Our results imply that it is premature to use CFF hypothesis for prediction of aftershocks, and further study is needed before CFF is incorporated in hazard mitigation program.