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The role of fault pre-stress and geometry in earthquake triggering and seismic hazard

Zoe Mildon (1,2), Joanna Faure Walker (2), Gerald Roberts (3), and Shinji Toda (4)

(1) Centre for Research in Earth Sciences, University of Plymouth, Plymouth, UK (zoe.mildon@plymouth.ac.uk), (2) Institute for Risk and Disaster Reduction, University College London, London, UK, (3) Department of Earth and planetary Sciences, Birkbeck, University of London, London, UK, (4) International Research Institute of Disaster Science, Tohoku University, Sendai, Japan

Large and damaging earthquake sequences that happen over decades or centuries can be difficult to explain in terms of static Coulomb stress triggering, because it is common for earthquakes to skip nearest-neighbour faults where coseismic Coulomb stress transfer (CST) increases are the largest. CST models are typically produced by modelling single earthquakes with the static stress resolved onto simple planar faults. Based on this modelling, it is often assumed that the nearest neighbour fault to the earthquake will be the next to rupture. However in a study of a long sequence (667 years), the next fault to rupture is never the nearest along-strike neighbour. Therefore this typical approach to modelling CST has limited potential to improve seismic hazard assessment, and especially time-dependent hazard models.

We present a step change in the approach to modelling CST and a solution to some of these problems, by providing a method for the inclusion of strike-variable faults and Coulomb pre-stress. We demonstrate our modelling through the example of 667 years of historical seismicity and interseismic loading in the central Apennines, Italy. We model the CST associated with 34 historical earthquakes and the interseismic loading from underlying discrete ductile shear zones onto the strike-variable brittle (seismogenic) portions of normal faults. Using this, we calculate the "Coulomb pre-stress" prior to each earthquake in the historical catalogue. We show that the magnitude of the pre-stress is $\sim\pm$50bars, an order of magnitude greater than coseismic CST ($\sim\pm$2bars), therefore it is rare that the coseismic CST will overwhelm the pre-stress. For the historical record in central Italy, historical earthquakes tend to nucleate on regions of positive Coulomb pre-stress (from coseismic and interseismic loading) and propagate across both positively and negatively stressed regions. This method also provides an explanation of the unusual sequence of earthquakes that happened in central Italy I 2016. These findings highlight the issues of the traditional approach to modelling CST and demonstrate that strike-variable faults and Coulomb pre-stress are ignored yet vital factors for earthquake triggering.