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Detection and implication of significant temporal b-value variation during earthquake sequences

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Earthquakes tend to cluster in space and time and periods of increased seismic activity are also periods of increased seismic hazard. Forecasting models currently used in statistical seismology and in Operational Earthquake Forecasting (e.g. ETAS) consider the spatial and temporal changes in the activity rates whilst the spatio-temporal changes in the earthquake size distribution, the b-value, are not included.

Laboratory experiments on rock samples show an increasing relative proportion of larger events as the system approaches failure, and a sudden reversal of this trend after the main event. The increasing fraction of larger events during the stress increase period can be mathematically represented by a systematic b-value decrease, while the b-value increases immediately following the stress release.

We investigate whether these lab-scale observations also apply to natural earthquake sequences and can help to improve our understanding of the physical processes generating damaging earthquakes. A number of large events nucleated in low b-value regions and spatial b-value variations have been extensively documented in the past. Detecting temporal b-value evolution with confidence is more difficult, one reason being the very different scales that have been suggested for a precursory drop in b-value, from a few days to decadal scale gradients. We demonstrate with the results of detailed case studies of the 2009 M6.3 L'Aquila and 2011 M9 Tohoku earthquakes that significant and meaningful temporal b-value variability can be detected throughout the sequences, which e.g. suggests that foreshock probabilities are not generic but subject to significant spatio-temporal variability. Such potential conclusions require and motivate the systematic study of many sequences to investigate whether general patterns exist that might eventually be useful for time-dependent or even real-time seismic hazard assessment.