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Real-time discrimination of earthquake foreshocks and aftershocks

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Immediately after a large earthquake, the main question asked by the public and decision-makers is whether it was the mainshock or a foreshock to an even stronger event yet to come. So far, scientists can only offer empirical evidence from statistical compilations of past sequences, arguing that normally the aftershock sequence will decay gradually whereas the occurrence of a forthcoming larger event has a probability of a few per cent.

We analyse the average size distribution of aftershocks of the 2016 Amatrice–Norcia (Italy) and Kumamoto (Japan) earthquake sequences and we suggest that in many cases it may be possible to discriminate whether an ongoing sequence represents a decaying aftershock sequence or foreshocks to an upcoming large event.

We propose a simple traffic light classification (FTLS, Foreshock Traffic Light System) to assess in real time the level of concern about a subsequent larger event and test it against 58 sequences, achieving a classification accuracy of 95 per cent.

We finally test, in near-real-time, the performance of the FTLS to the 2019 Ridgecrest sequence, California: a Mw6.4 followed, about 2 days later, by a Mw7.1. We find that in the hours after the first Ridgecrest event (Mw 6.4, the b-value drops by 23% on average, when compared to the background value, resulting in a ‘red’ foreshock traffic light.

Mapping in space the changes in b, we identify an area to the north of the rupture plane as the most likely location of a subsequent event. The second mainshock of magnitude 7.1 then indeed occurred in this location and after this event, the b-value increased by 26 percent over the background value, resulting in a green traffic light state.