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Multi-regional foreshock statistics and the role of small magnitude events in foreshock occurrence

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In the previous years, there has been growing skepticism regarding the potential of using foreshock occurrence as a mean to predict large earthquakes, since foreshocks generally do not show systematic patterns and/or are often indistinguishable from the normal behavior of seismicity. At the same time, existing studies are limited by the amount of available data: by the number of mainshocks in regional catalogues and by the number of foreshocks (high magnitude of completeness Mc) in global catalogues. In this sense detailed statistics are desirable.
We therefore reinvestigate foreshock statistics by systematically examining a large set of foreshock sequences using the Epidemic-Type Aftershock Sequence (ETAS) model - which assumes a uniform triggering mechanism of earthquake generation - as a null hypothesis and compare ETAS predictions against observed foreshock data in various regions. Our statistical parameter of interest is the number of foreshocks, which we define as the quantity of earthquakes preceding a mainshock. The analysis for varying cut-off magnitudes (range from 2.0 to 4.0 with 0.5 bins) and mainshock magnitudes (range from 4.5+ to 6+ with 0.5 bins) allows us to detect possible changes in foreshock statistics compared to the null hypothesis. We apply our testing procedure to a large number of regional catalogues (Southern California, Northern California, Italy and many others) and compare against equivalent synthetic catalogs from ETAS, using region-specific parameterizations. We obtain probability distributions for our parameter of interest by combining foreshock counts of various mainshocks and different regions.
The comparison of preliminary foreshock statistics suggests a significant difference between the probability distributions for observed and ETAS-generated foreshock seismicity in case of high mainshock magnitudes and low cut-off magnitudes. This result is reinforced when results from multiple regions are combined. The rejection of the null-hypothesis shows that either the parameters or the whole model do not appropriately reflect the underlying earthquake generation mechanism. A model of stress accumulation for foreshock generation provides an elegant explanation of this result. Furthermore, our study substantiates the importance of small magnitude events as potential precursors of large events. To our knowledge, this is the first study to combine a large number of earthquake catalogues (i.e. multi-regional approach) in order to improve foreshock statistics at a global level.