Foreshocks are not predictive of future earthquake size

Morgan Page (pagem@caltech.edu), Karen Felzer, and Andrew Michael

The standard model for the origin of foreshocks is that they are earthquakes that trigger aftershocks larger than themselves. This can be formally expressed in terms of a cascade model. In this model, aftershock magnitudes follow the Gutenberg-Richter magnitude-frequency distribution, regardless of the size of the triggering earthquake, and aftershock timing and productivity follow Omori-Utsu scaling. An alternative hypothesis is that foreshocks are triggered incidentally by a nucleation process, such as pre-slip, that scales with mainshock size. If this were the case, foreshocks would potentially have predictive power of the mainshock magnitude.

A number of predictions can be made from the cascade model, including the fraction of earthquakes that are foreshocks to larger events, the distribution of differences between foreshock and mainshock magnitudes, and the distribution of time lags between foreshocks and mainshocks. The last should follow the inverse Omori law, which will cause the appearance of an accelerating seismicity rate if multiple foreshock sequences are stacked. All of these predictions are consistent with observations (*Helmstetter and Sornette,* 2003; *Felzer et al.* 2004).

If foreshocks were to scale with mainshock size, this would be strong evidence against the cascade model. For example, *Bouchon et al.* (2013) claimed that the expected acceleration in stacked foreshock sequences before interplate earthquakes is higher prior to M≥6.5 mainshocks than smaller mainshocks. Our re-analysis fails to support the statistical significance of their results. We are able to reproduce the amount of acceleration seen in the data using an epidemic-type aftershock sequence (ETAS) model.

To conclude, seismicity data to date is consistent with the hypothesis that the nucleation process is the same for earthquakes of all sizes.