Physics-based Forecasting of Earthquake Sequences

Supervisors

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Project description

Recent earthquakes from around the world have shown that our cities suffer greatly not only from unexpected great earthquakes but also from their catastrophic aftershocks, despite their transient temporal nature. Examples of such earthquake sequences include the 2011 magnitude 6.3 Christchurch earthquake in New Zealand, the 2013 magnitude 6.9 Lushan earthquake in China, and the 2015 magnitude 7.8 Gorkha earthquake in Nepal. To help communities prepare for pending disasters due to devastating aftershocks, real-time seismic hazard updates are required that provide the public, government and other end-users with the necessary input for informed decision-making. Empirical (statistical) models have shown considerable skill in forecasting aftershock sequences in case studies. The goals of this PhD project are to improve our understanding of the physics of earthquake sequences and to provide time-dependent earthquake forecasts that are based on physics and may thus provide improved forecasts.

The first objective of this project is to conduct retrospective evaluations of physics-based forecasting models in areas of high seismic hazard (the Himalayan Belt, Japan, China, California, Italy, Greece, New Zealand). The goal is evaluate the ability of physics-based models to forecast the spatio-temporal evolution of triggered seismicity. These models combine laboratory-derived rate-and-state friction laws with Coulomb failure theory. The predictive power of the forecast models, and therefore the importance of the physical mechanism in triggering aftershocks, will be determined by comparing them against simple empirical/statistical models that are derived from averaging over past observations of aftershock sequences. The attached figure presents examples of physics-based forecasts for the first week following the 1989 Loma Prieta magnitude 6.9 earthquake in Northern California (Segou et al., 2013). Several different model choices will be evaluated during this retrospective stage, such as additional stress sources from postseismic afterslip and aftershocks, and an accurate representation of fault geometry and its uncertainty. The most robust and informative model will be assembled across all retrospective case studies.

This new knowledge will be channeled back into the development of real-time earthquake forecast models that will be submitted to the Collaboratory for the Study of Earthquake Predictability (CSEP, www.cseptesting.org), where the models will be evaluated in an automated, blind and prospective manner and compared against other existing models. Prospective evaluation will make sure that the improved model can demonstrate its predictive skill against new data.

In addition, real-time earthquake likelihood estimates can be coupled with ground motion models to generate short-term probabilistic seismic hazard assessments. Together with exposure and vulnerability data and models, these hazard estimates form one important component in risk estimates that can provide a rational decision-making basis for reducing seismic risks. The student will have the opportunity to connect with government agencies, potential end-users and other stake-holders for tailor dynamic seismic hazard and risk estimates to their needs.

References:

Segou, M., T. Parsons, and W. Ellsworth (2013), Comparative evaluation of physics-based and statistical forecasts in Northern California, J. Geophys. Res. Solid Earth, 118, 6219–6240, doi:10.1002/2013JB010313.

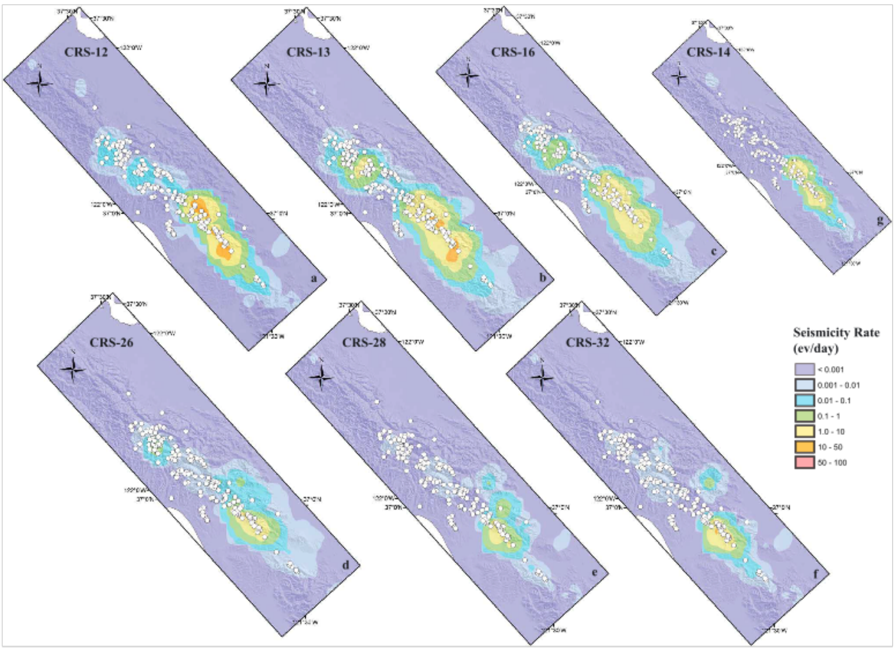

Figure 1: Maps of daily seismicity rates forecast by physics-based models (Segou et al., 2013) for the first 10 days after the magnitude 6.9 1989 Loma Prieta mainshock in Northern California for models based on (a) optimally oriented strike slip fault planes with a low-stressing rate San Andreas Fault (SAF) and a gridded reference seismicity model, (b) same as (a) but considering a smoothed gridded reference seismicity model, (c) same as (b) but considering a medium-stressing rate SAF , (d) receiver planes derived from predominant geology with a low-stressing rate SAF and a smoothed-gridded reference seismicity model, (e) receiver planes derived from predominant geology with a high-stressing rate SAF and a gridded reference seismicity model, (f) shear stress changes on receiver planes derived from predominant geology with a medium-stressing rate SAF and a smoothed-gridded reference seismicity model, and (g) same as (c) considering a declustered background seismicity model.