Motivation and questions

**Goal:** To improve seismicity models for operational earthquake forecasting by considering the spatio-temporal complexity of the Coulomb stress field.

**Questions:**
(1) What are the most important sources of Coulomb stress uncertainty?
(2) How does small scale spatial heterogeneity affect aftershock sequences?
(3) What is the role of time dependent stresses in the postseismic phase (afterslip and stresses from previous aftershocks)?

Effect of stress heterogeneity and epistemic uncertainties

We consider these sources of uncertainties in Coulomb stress calculations:

1. Existence of several receiver fault orientations, estimated by resolving stresses on past focal planes.
2. Finite cell size: we consider the variability of stress due to the stress gradients within each cell, approximated by calculating the difference in stress between neighbour cells.
3. Slip model uncertainties: we consider the effect of small scale, unresolved slip by adding stochastic short wave-length slip to the original slip model. Additionally, we compare the forecast obtained from slip models published by different authors found on the Scimod database (4 models for Parkfield, 20 for Tohoku).

Effect of aleatoric uncertainties on model performance

To mimic the spatial stress heterogeneity due to aleatoric uncertainties (variable receiver fault and grid size error) we average the forecasts from perturbed stress fields. This method yields a better spatio-temporal fit, and a large increase in log likelihood.

Combining models with epistemic variability (alternative slip models)

Forecasts based on different slip models can be combined in an ensemble model. We find the ensemble model to outperform the individual models for both sequences.

Conclusions

1. Modeling stress heterogeneity significantly improves model performance.
2. Ensemble models based on a set of published slip models outperform single models.
3. Including secondary triggering also improves model performance.
4. The effect of afterslip is minor and its role in aftershock triggering hard to evaluate for most aftershocks due to the uncertainties in the slip distribution.