Overview of Coulomb-based Models in the Retrospective Canterbury Experiment

C. Cattania, S. Hainzl, A. Jimenez, S. Steacy

I. Hybrid models

combine statistical models with a Coulomb-based **spatial kernel**

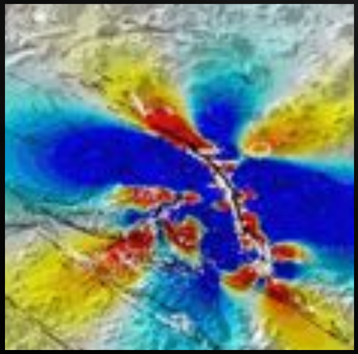
- STEP-Coulomb (S. Steacy, A. Jimenez): based on the STEP model
- ETAS-Coulomb (S. Hainzl): based on the ETAS model

II. Physical models

both space and time dependence based on physical principles

- CRS (C. Cattania, S. Hainzl): based on Rate-and-State constitutive law

Coulomb stress



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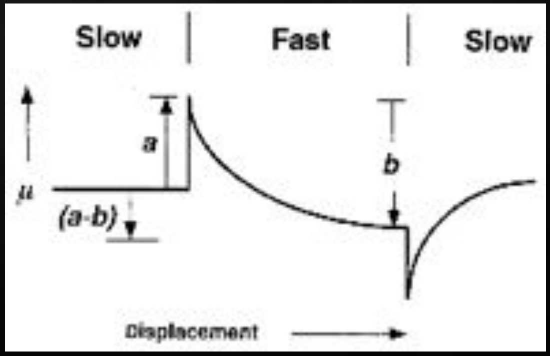
Rate-and-state frictional response



STEP-Coulomb (S. Steacy, A. Jimenez)

Based on STEP model (Gerstenberger et al, 2005; combines 3 models of increasing complexity)

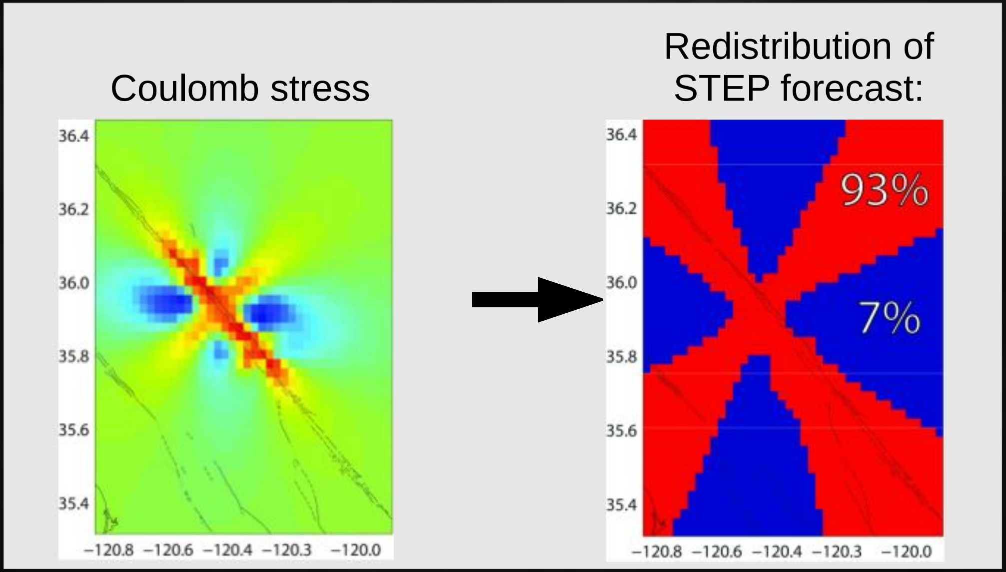
$$\lambda(t, M) = \frac{10^{a' + b(M_m - M)}}{(t+c)^p}$$

(i) generic parameters derived from part M>5.0 sequences
(ii) sequences specific, using at least 100 aftershocks
(iii) space dependent, calculated for individual grid points

STEP-Coulomb (S. Steacy, A. Jimenez)

Coulomb map used as “filter”:

- 93% of the aftershocks in areas of ΔCFS>0
- 7% in areas where ΔCFS<0



Steacy, S., Gerstenberger, M., Williams, C., Rhoades, D., and A. Christophersen, 2013,
A new hybrid Coulomb/statistical model for forecasting aftershock rates, Geophys. J. Int.

ETAS-Coulomb (S. Hainzl)

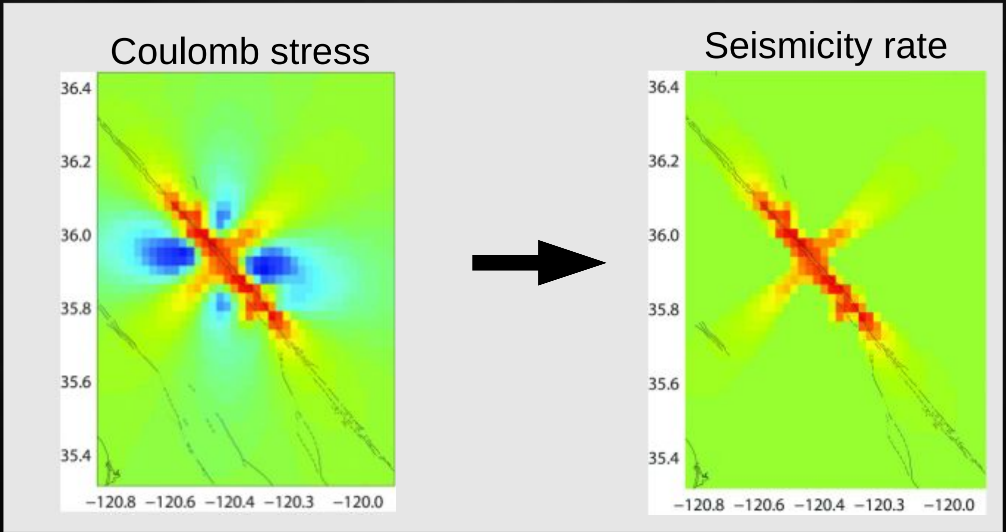
- Based on ETAS model, uses Coulomb stress map as spatial kernel:

$$\lambda(t,r)=\mu+\sum_{i:t_i<t}\frac{K}{(t-t_t+c)^p}e^{\alpha(M_i-M_0)}f_i(r)$$

ETAS-Coulomb (S. Hainzl)

- Based on ETAS model, uses Coulomb stress map as spatial kernel:

$$f_i(r) \propto \begin{cases} \Delta CFS(r) & \Delta CFS(r) \geq 0 \\ 0 & \Delta CFS(r) < 0 \end{cases}$$



Bach, C., Hainzl, S. (2012): *Improving empirical aftershock modeling based on additional source information.* Journal of Geophys. Res., 117, B04312.

CRS (C. Cattania, S. Hainzl)

- Based on constitutive law for seismicity evolution (Dieterich, 1994):

$$R = \frac{r}{\gamma \dot{\tau}}$$

$$d\gamma = \frac{1}{A\sigma}\left[dt - \gamma\, dCFS\right]$$

R= instantaneous rate
r = background rate
γ= rate evolution parameter
$\dot{\tau}$= secular stressing rate
A= constitutive parameter
σ= normal stress

CRS (C. Cattania, S. Hainzl)

- Based on constitutive law for seismicity evolution (Dieterich, 1994);

- Stress heterogeneity included by a Monte Carlo method. It accounts for:
  - (i) existence of multiple receiver faults
  - (ii) finite size of calculation cells
  - (iii) stress changes by smaller earthquakes

Cattania, C., Hainzl, S., Wang, L., Roth, F. and Enescu, B., *Propagation of Coulomb stress uncertainties in physics-based aftershock models*, in review (JGR)

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- Background seismicity uniform/non-uniform

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Thank you!

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