Overview of Coulomb-based Models in the Retrospective Canterbury Experiment

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

Coulomb map used as “filter”:
- 93% of the aftershocks in areas of $\Delta CFS > 0$
- 7% in areas where $\Delta CFS < 0$

Steacy, S., Gerstenberger, M., Williams, C., Rhoades, D., and A. Christophersen, 2013,
ETAS-Coulomb (S. Hainzl)

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

\[ \lambda(t, r) = \mu + \sum_{i: t_i < t} \frac{K}{(t - t_i + c)^p} e^{\alpha(M_i - M_0)} f_i(r) \]
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ETAS-Coulomb (S. Hainzl)

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

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

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**CRS (C. Cattania, S. Hainzl)**

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

\[
R = \frac{r}{\gamma \dot{\tau}}
\]

\[
d\gamma = \frac{1}{A \sigma} [dt - \gamma \ dCFS]
\]

- $R$: instantaneous rate
- $r$: background rate
- $\gamma$: rate evolution parameter
- $\dot{\tau}$: secular stressing rate
- $A$: constitutive parameter
- $\sigma$: normal stress
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- Stress heterogeneity included by a Monte Carlo method. It accounts for:
  1. existence of multiple receiver faults
  2. finite size of calculation cells
  3. stress changes by smaller earthquakes

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- Background seismicity uniform/non-uniform
Thank you!