Data Integration and Visualization Tools for Bringing Paleoseismic Data and Simulator (& UCERF3) Results Together

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Uniform California Earthquake Rupture Forecast (UCERF3) by the Working Group on California Earthquake Probabilities (Field et al., 2014)
UCERF3 “Grand Inversion”

- Solves for event rates of fault-based ruptures
- Data constraints include:
  - Paleoseismic data
  - Slip rates
  - Regional Magnitude Frequency Distributions
  - Fault Section Magnitude Frequency Distributions

Paleoseismic data included:

- 31 Event Rate Constraints
- 23 Mean Slip Constraints

The problem: can't perfectly fit paleo & slip rate data simultaneously

- Final UCERF3 model constraint weights represent a compromise between the two datasets

Table 5. The grand inversion system of equations used in solving for the long-term rate of fault-based ruptures, where $f_j$ represents the frequency or rate of the $j$th rupture.

<table>
<thead>
<tr>
<th>Equation Set</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>$\sum D_{ij} f_j = v_i$ Slip Rate Balancing: $v_i$ is the subsection slip rate (from a deformation model) and $D_{ij}$ is the slip on the $i$th subsection in the $j$th event, averaged over multiple occurrences of the rupture and as measured at mid-seismic depth.</td>
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<tr>
<td>(2)</td>
<td>$\sum G_{ij} p^\text{av} f_j = f_i^\text{av}$ Paleoseismic Event Rate Matching: $f_i^\text{av}$ is a paleoseismically inferred event rate estimate, $G_{ij}$ specifies whether the $i$th rupture utilizes the $j$th subsection (0 or 1), and $p^\text{av}$ is the probability that the $i$th rupture would be seen in a paleoseismic trench.</td>
</tr>
<tr>
<td>(3)</td>
<td>$R^2 = R^2_0 + \frac{R^2_m}{2}$ Fault Section Smoothness Constraint: This enables forcing the nucleation rate, $R_0$, in the $m$th magnitude bin to vary smoothly along a fault section, where the $s$-1 and $s$+1 subsections are adjacent to the $s$th subsection.</td>
</tr>
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<td>(4)</td>
<td>$\lambda f_i = 0$ Improbability Constraint: This allows us to force relatively improbable events to have a lower rate (for example, based on multi-fault rupture likelihoods). A higher value of adds more misfit for a given rupture rate, forcing the inversion to minimize that rupture rate further.</td>
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<td>(5)</td>
<td>$f_i = f_i^{\text{av prior}}$ A Priori Constraint: This constrains the rates of particular ruptures to target values, either on an individual basis (for example, male Parkfield occur every ~25 years) or for a complete rupture set (for example, as close as possible to those in UCERF2).</td>
</tr>
<tr>
<td>(6)</td>
<td>$\sum \alpha_i = f_i R^2_m$ Regional MFD Constraint: This enables forcing a geographic region, $g$, to have a specified magnitude-frequency distribution (MFD), such as Gutenberg-Richter: $R^2_m$ represents the nucleation rate for the $m$th magnitude bin in the $g$th region. Matrix $\alpha_i$ contains the product of whether the $i$th rupture falls in the $m$th magnitude bin (0 or 1) multiplied by the fraction of that rupture that nucleates in the $g$th region.</td>
</tr>
<tr>
<td>(7)</td>
<td>$\sum \epsilon_i = f_i R^2_m$ Fault Section MFD Constraint: This enables forcing subsections to have specific nucleation MFDs. $R^2_m$ is the nucleation rate for the $m$th magnitude bin on the $s$th subsection. Matrix $\epsilon_i$ contains the product of whether the $i$th rupture falls in the $m$th magnitude bin (0 or 1) multiplied by the fraction of that rupture that nucleates in the $s$th subsection.</td>
</tr>
</tbody>
</table>
Paleoseismic Data and Slip Rates Battle It Out in UCERF3

High Paleoseismic Constraint Weight

[Graph showing slip rates for San Andreas with a poor fit]

[Graph showing paleo rates/constraints for San Andreas with a good fit]

High Slip Rate Constraint Weight

[Graph showing slip rates for San Andreas with a good fit]

[Graph showing paleo rates/constraints for San Andreas with a poor fit]
UCERF3 Final Model Fits

Slip Rate
Data
Model

Event Rate
----- Model
O Data
Mean Slip
----- Model
O Data

Slip Rates for San Andreas

Paleo Rates/Constraints for San Andreas
RSQSim to the Rescue?

- RSQSim fits slip rates exactly (backslip model)
- Paleoseismic fits are similar to UCERF3 on the SAF
- Magnitude Frequency Distributions don't match expected (yet)
Rebuilt from the ground up in 2016
- Replaces outdated Java3D library
- Runs on Windows, Mac OS X, Linux

Download: scedvdo.usc.edu

2016 SCEC UseIT Internship
Focused on RSQSim
- New exploration and movie making tools available
- Stop by during poster sessions for a demo
SCEC-VDO: RSQSIm Slip Rates
SCEC-VDO: RSQSim Participation Rates
Southern California Earthquake Center

SCEC-VDO: RSQSim MFDs

Results can be viewed at 3 scales

- Fault Section: UCERF3 fault section, e.g. SAF Mojave S
- Fault Subsection: Smallest UCERF3 unit where length \( \approx \frac{1}{2} \) DDW
- Patch: a single triangle with \( \approx 1 \text{km}^2 \) area
SCEC-VDO: RSQSim MFDs

Double Click
SCEC-VDO: RSQSim MFDs

Subsection

Parent

Parent 231 MFD

Sect 1851: SanAndreas(MojaveS), Subsection13 MFD

Patch

Elem 183341 MFD

Southern California Earthquake Center
SCEC-VDO: RSQSim Recurrence Intervals

At Wrightwood with UCERF3 Mean=106 yr, near Pallett Creek with UCERF3 Mean=149 yr

Patch

M≥6
Mean: 108

M≥7
Mean: 127

Subsection

M≥6
Mean: 96

M≥7
Mean: 127

Parent

M≥6
Mean: 68

M≥7
Mean: 113
SCEC-VDO: Render Movies

- Allows for visual inspection of patterns
- Previous events fade out over time
  - 50 year fade works well
- Can visualize thousands of years or specific sequences
Thank you!