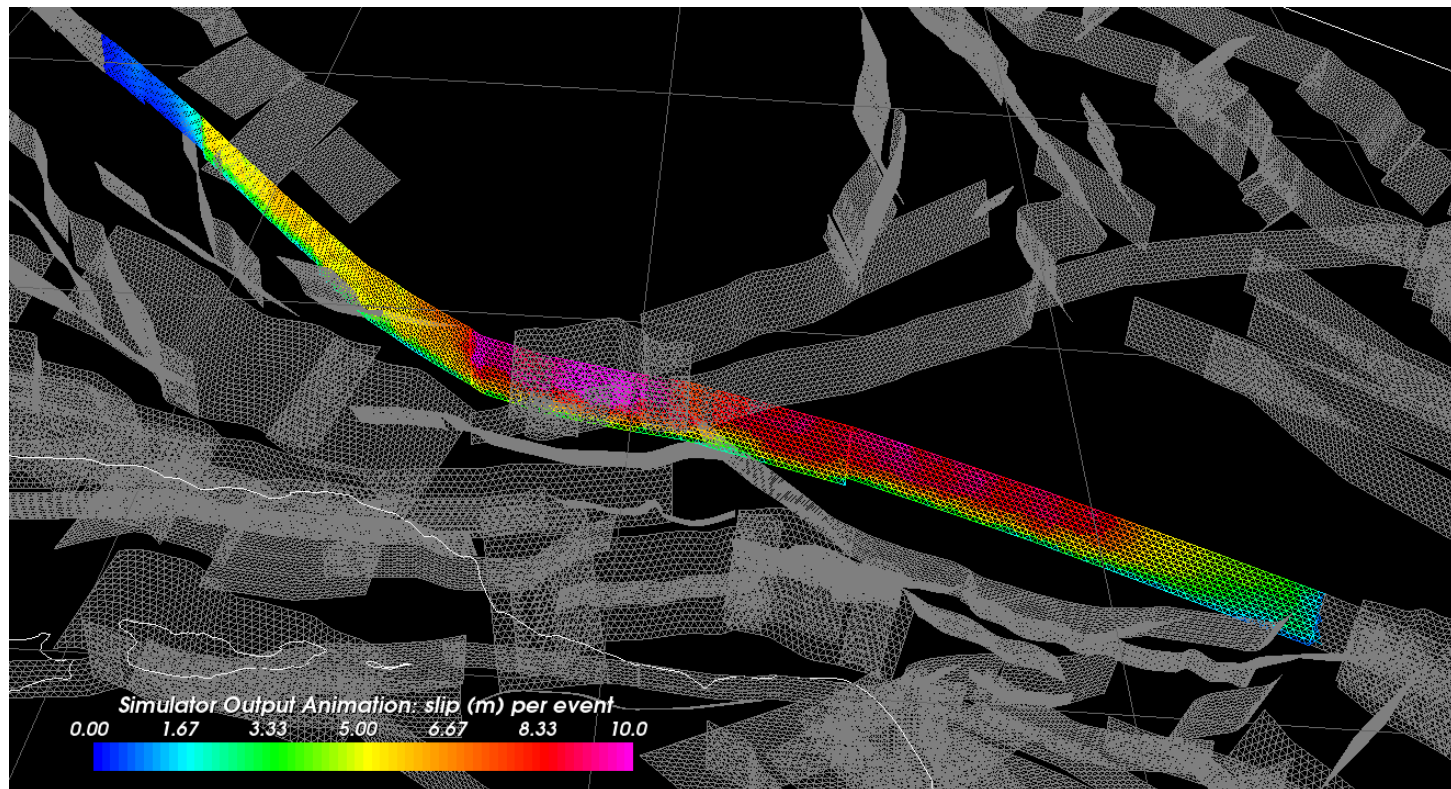


# Data Integration and Visualization Tools for Bringing Paleoseismic Data and Simulator (& UCERF3) Results Together

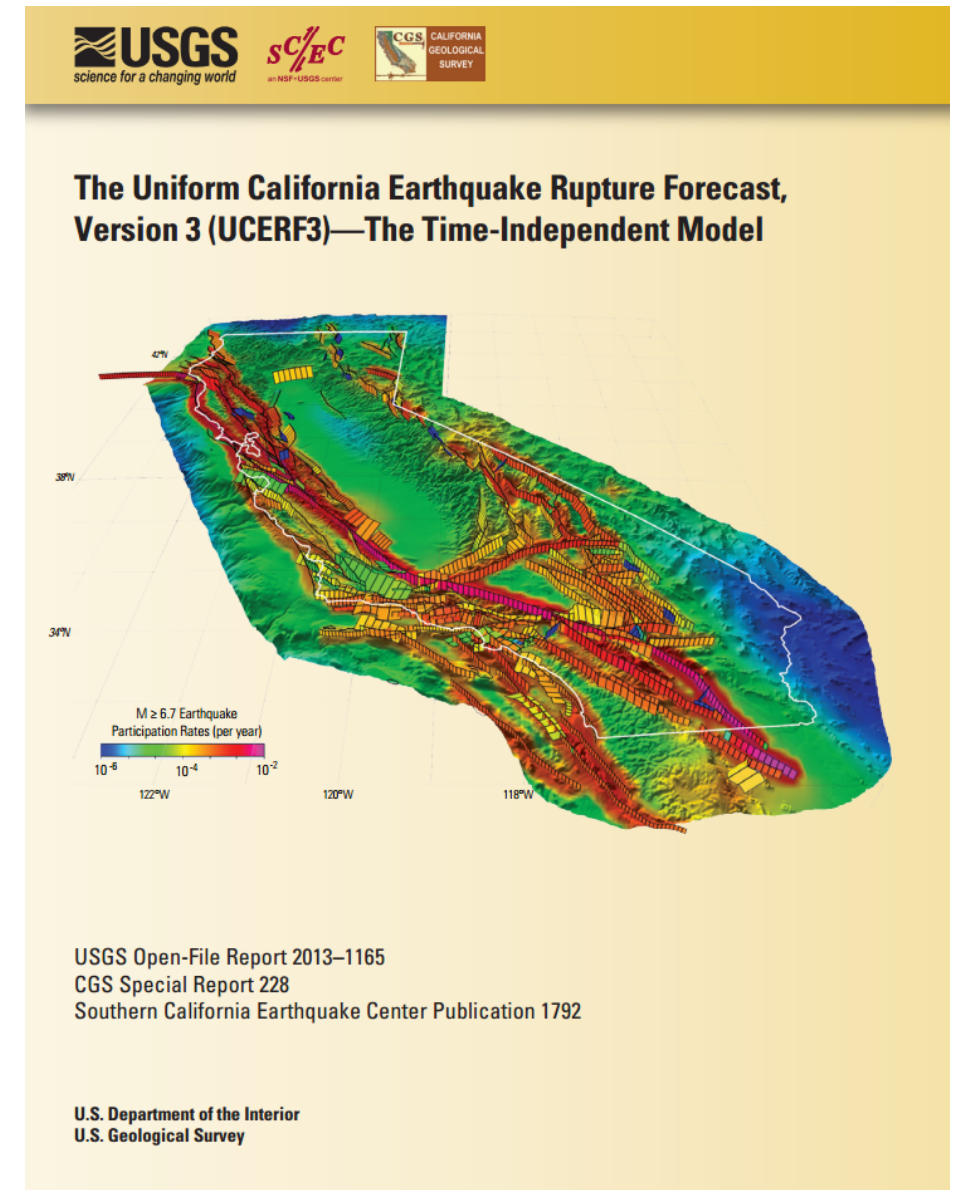
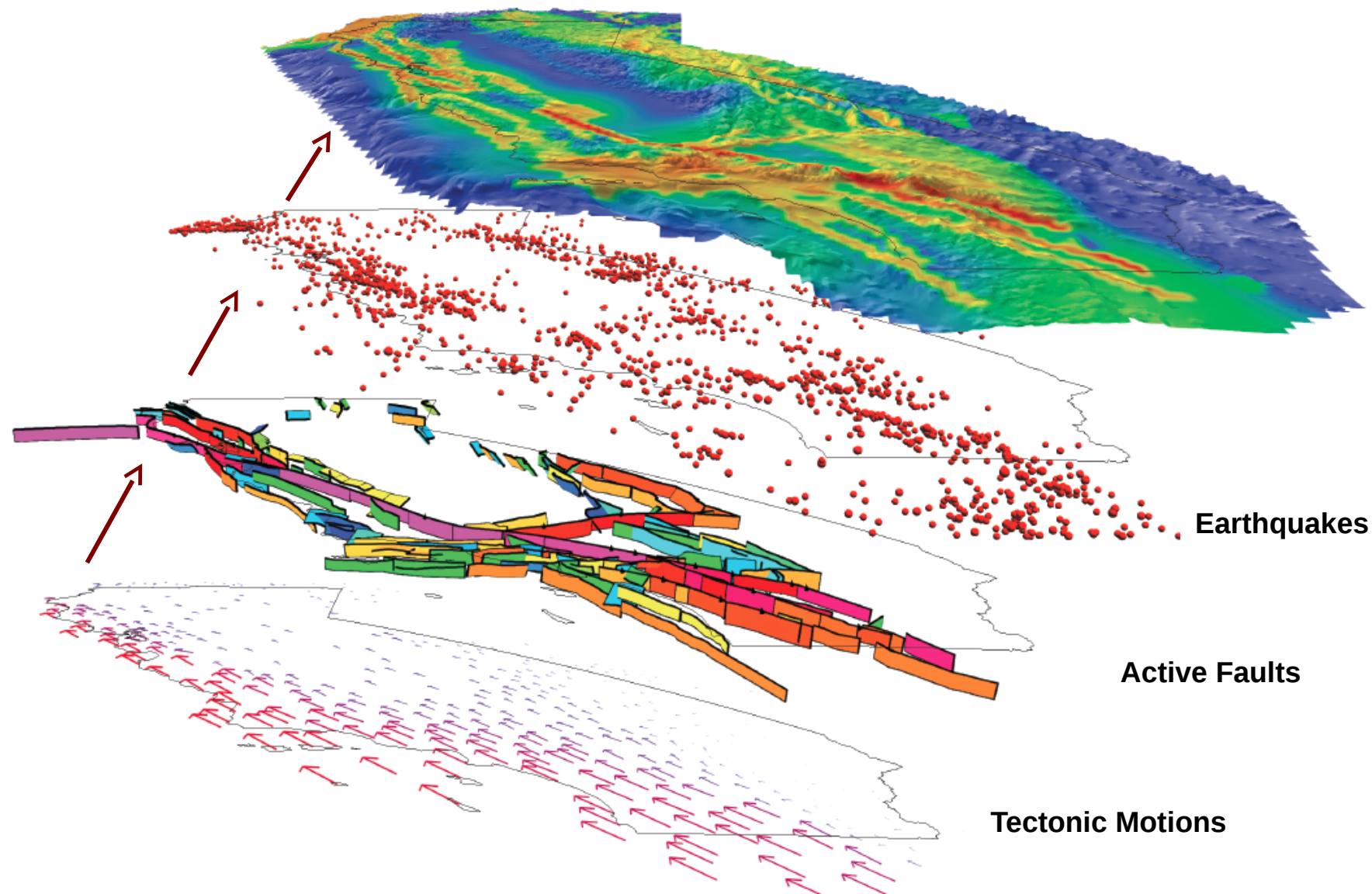


**Kevin R. Milner**  
University of Southern California

SoSAFE Workshop, 2016 SCEC Annual Meeting  
September 10, 2016

# UCERF3

## *Uniform California Earthquake Rupture Forecast (UCERF3) by the Working Group on California Earthquake Probabilities (Field et al., 2014)*





# Paleoseismic Data and Slip Rates Battle It Out in UCERF3

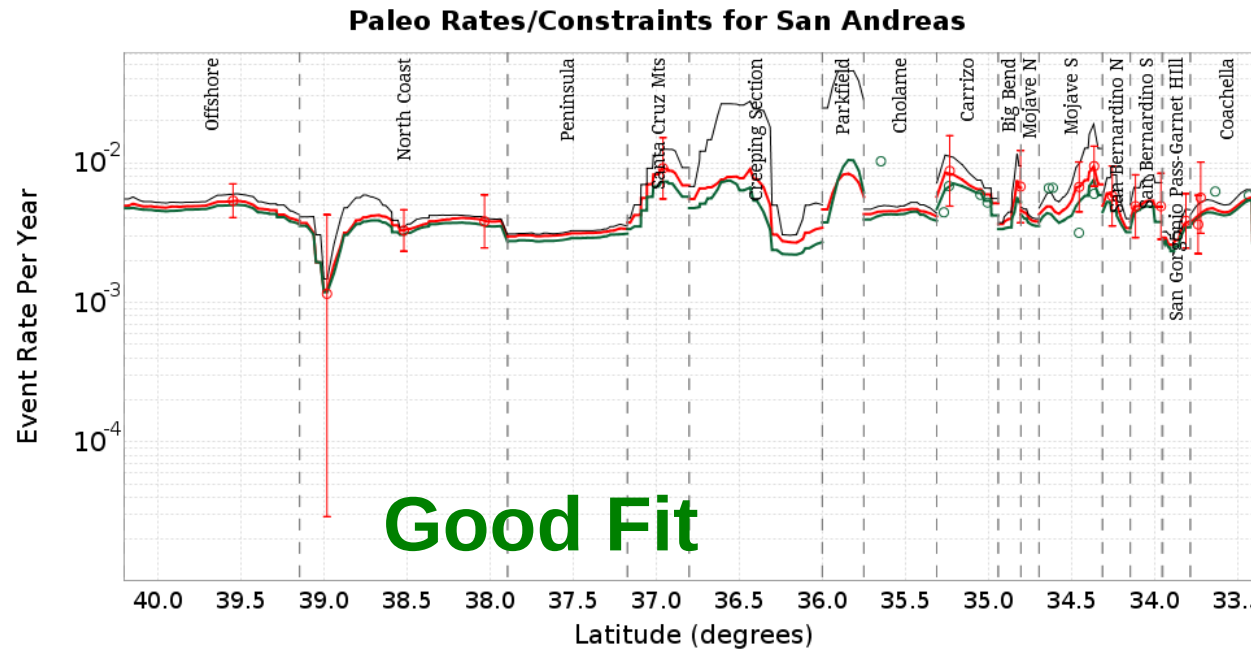
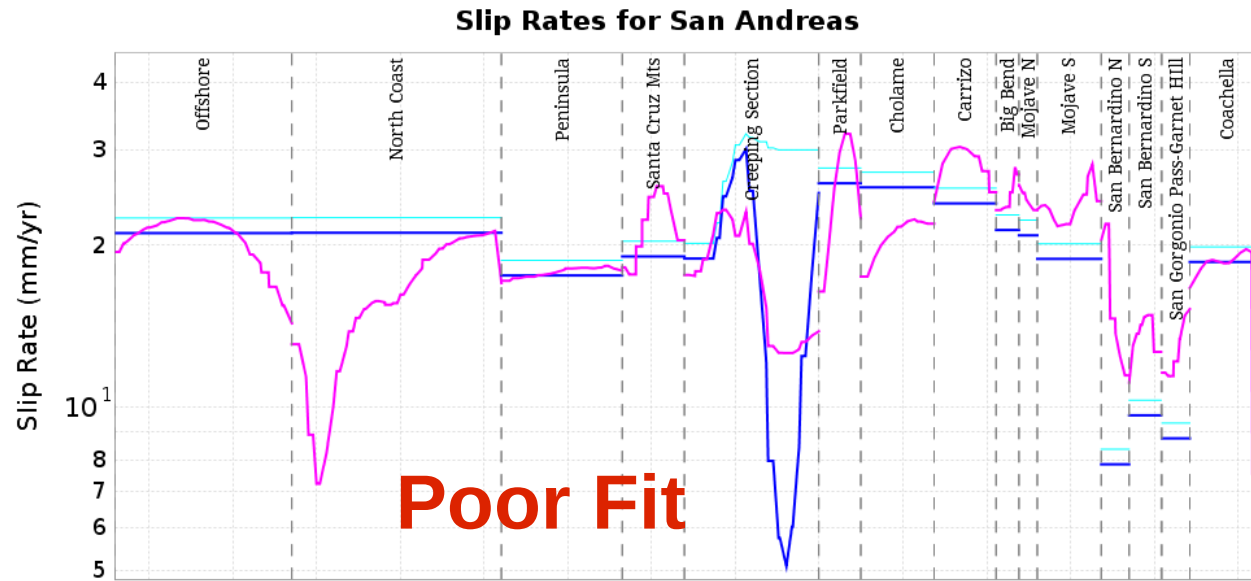
- **UCERF3 “Grand Inversion”**
  - Solves for event rates of fault-based ruptures
  - Data constraints include:
    - Paleoseismic data
    - Slip rates
    - Regional Magnitude Frequency Distributions
    - Fault Section Magnitude Frequency Distributions
- **Paleoseismic data included:**
  - 31 Event 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  $f_r$  represents the frequency or rate of the  $r^{\text{th}}$  rupture. [Important implementation details, such as equation-set weighting, are given in appendix N (this report)]

Equation set	Description
$\sum_{r=1}^R D_{sr} f_r = v_s$	(1) <b>Slip Rate Balancing:</b> $v_s$ is the subsection slip rate (from a deformation model) and $D_{sr}$ is the slip on the $s^{\text{th}}$ subsection in the $r^{\text{th}}$ event, averaged over multiple occurrences of the rupture and as measured at mid-seismogenic depth.
$\sum_{r=1}^R G_{sr} P_r^{\text{paleo}} f_r = f_s^{\text{paleo}}$	(2) <b>Paleoseismic Event Rate Matching:</b> $f_s^{\text{paleo}}$ is a paleoseismically inferred event rate estimate, $G_{sr}$ specifies whether the $r^{\text{th}}$ rupture utilizes the $s^{\text{th}}$ subsection (0 or 1), and $P_r^{\text{paleo}}$ is the probability that the $r^{\text{th}}$ rupture would be seen in a paleoseismic trench.
$R_s^m = \frac{R_{s-1}^m + R_{s+1}^m}{2}$	(3) <b>Fault Section Smoothness Constraint:</b> This enables forcing the nucleation rate, $R$ , in the $m^{\text{th}}$ magnitude bin to vary smoothly along a fault section, where the $s-1$ and $s+1$ subsections are adjacent to the $s^{\text{th}}$ subsection.
$\lambda_r f_r = 0$	(4) <b>Improbability Constraint:</b> 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.
$f_r = f_r^{\text{a-priori}}$	(5) <b>A Priori Constraint:</b> This constrains the rates of particular ruptures to target values, either on an individual basis (for example, make Parkfield occur every ~25 years) or for a complete rupture set (for example, as close as possible to those in UCERF2).
$\sum_{r=1}^R M_{gr}^m f_r = R_g^m$	(6) <b>Regional MFD Constraint:</b> This enables forcing a geographic region, $g$ , to have a specified magnitude-frequency distribution (MFD), such as Gutenberg-Richter. $R_g^m$ represents the nucleation rate for the $m^{\text{th}}$ magnitude bin in the $g^{\text{th}}$ region. Matrix $M_{gr}^m$ contains the product of whether the $r^{\text{th}}$ rupture falls in the $m^{\text{th}}$ magnitude bin (0 or 1) multiplied by the fraction of that rupture that nucleates in the $g^{\text{th}}$ region.
$\sum_{r=1}^R M_{sr}^m f_r = R_s^m$	(7) <b>Fault Section MFD Constraint:</b> This enables forcing subsections to have specific nucleation MFDs. $R_s^m$ is the nucleation rate for the $m^{\text{th}}$ magnitude bin on the $s^{\text{th}}$ subsection. Matrix $M_{sr}^m$ contains the product of whether the $r^{\text{th}}$ rupture falls in the $m^{\text{th}}$ magnitude bin (0 or 1) multiplied by the fraction of that rupture that nucleates on the $s^{\text{th}}$ subsection.

# Paleoseismic Data and Slip Rates Battle It Out in UCERF3

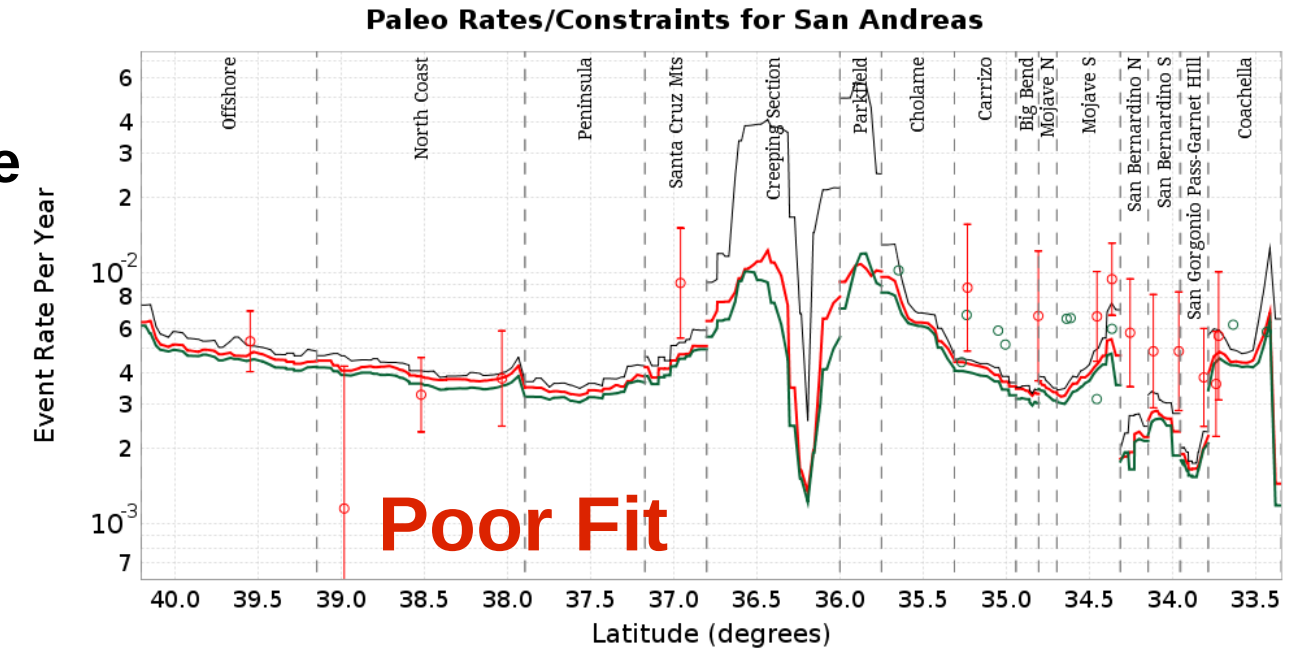
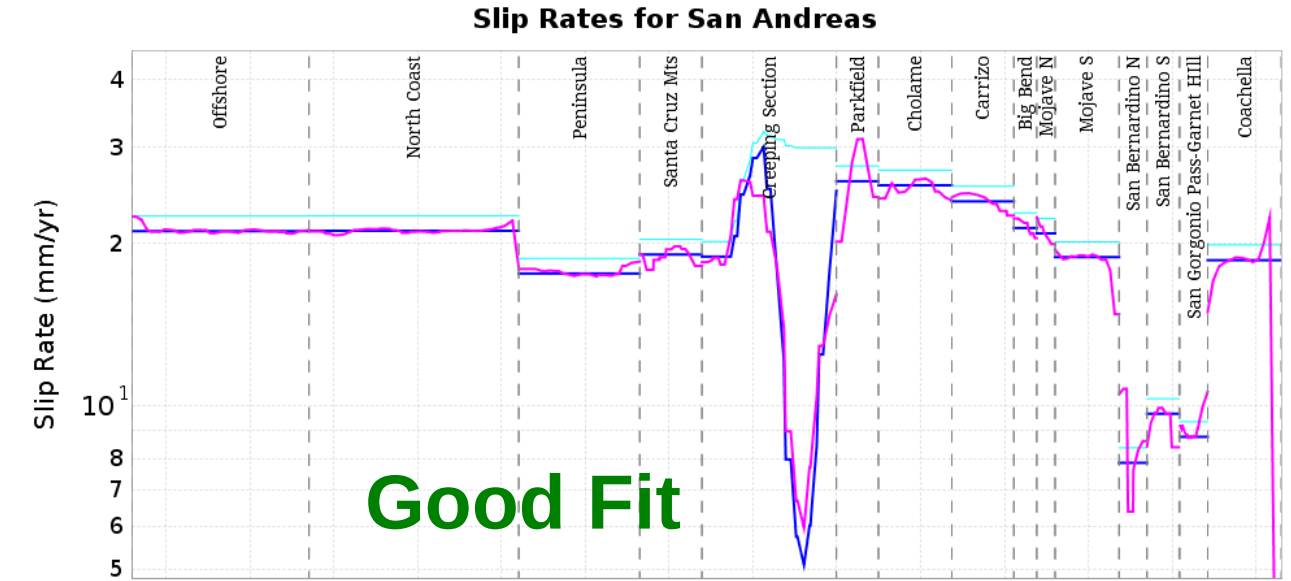
## High Paleoseismic Constraint Weight



Slip Rate  
Data  
Model

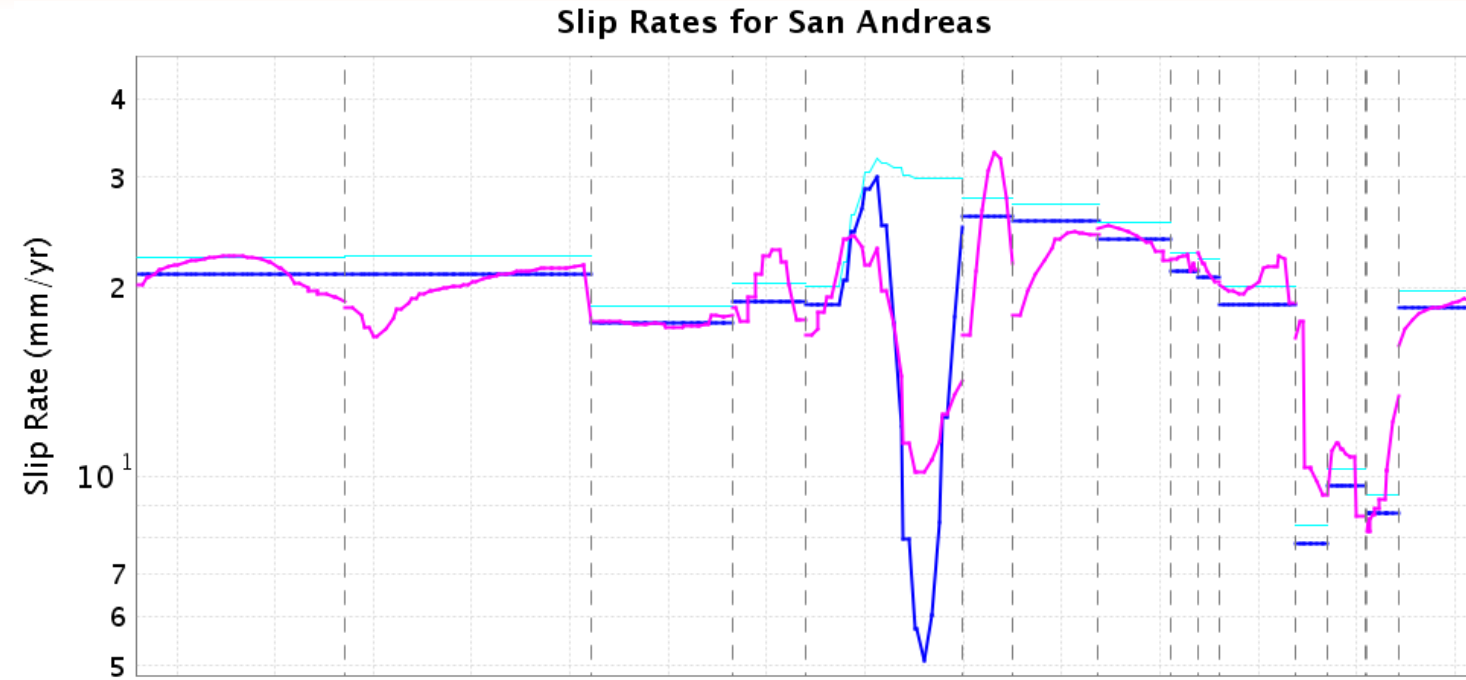
Event Rate  
---- Model  
O Data  
Mean Slip  
---- Model  
O Data

## High Slip Rate Constraint Weight

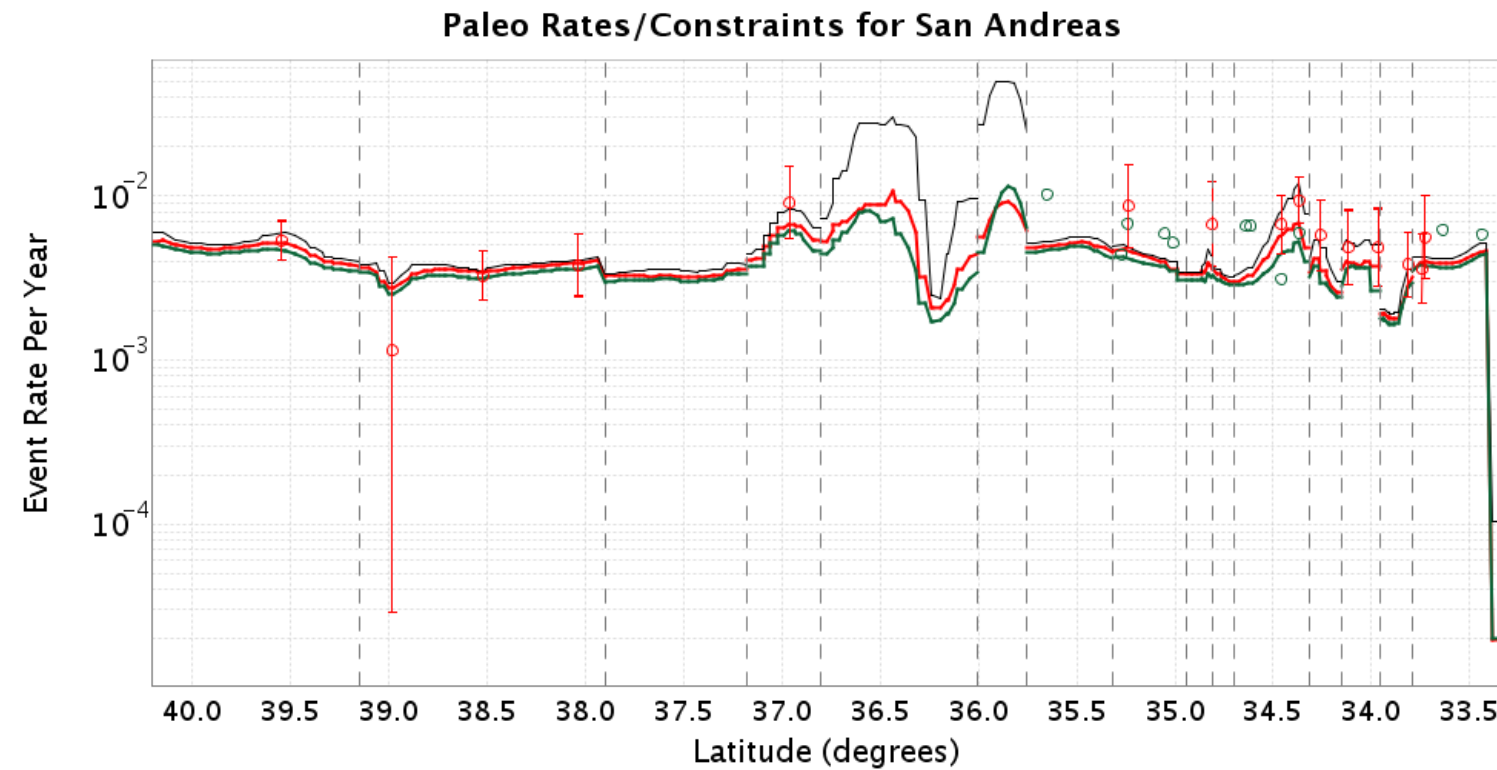


# UCERF3 Final Model Fits

Slip Rate  
Data  
Model

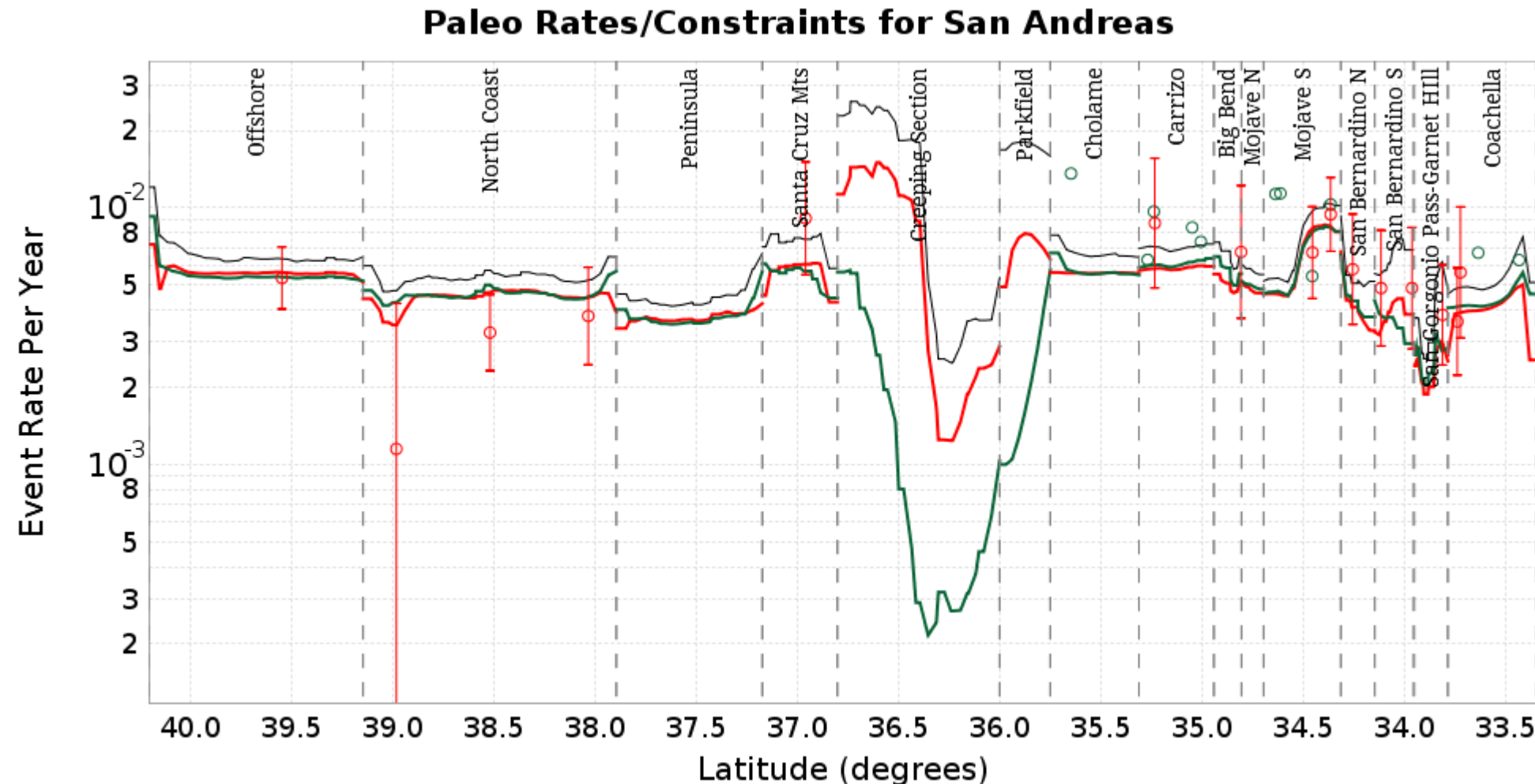


Event Rate  
---- Model  
O Data  
Mean Slip  
---- Model  
O Data



# RSQSim to the Rescue?

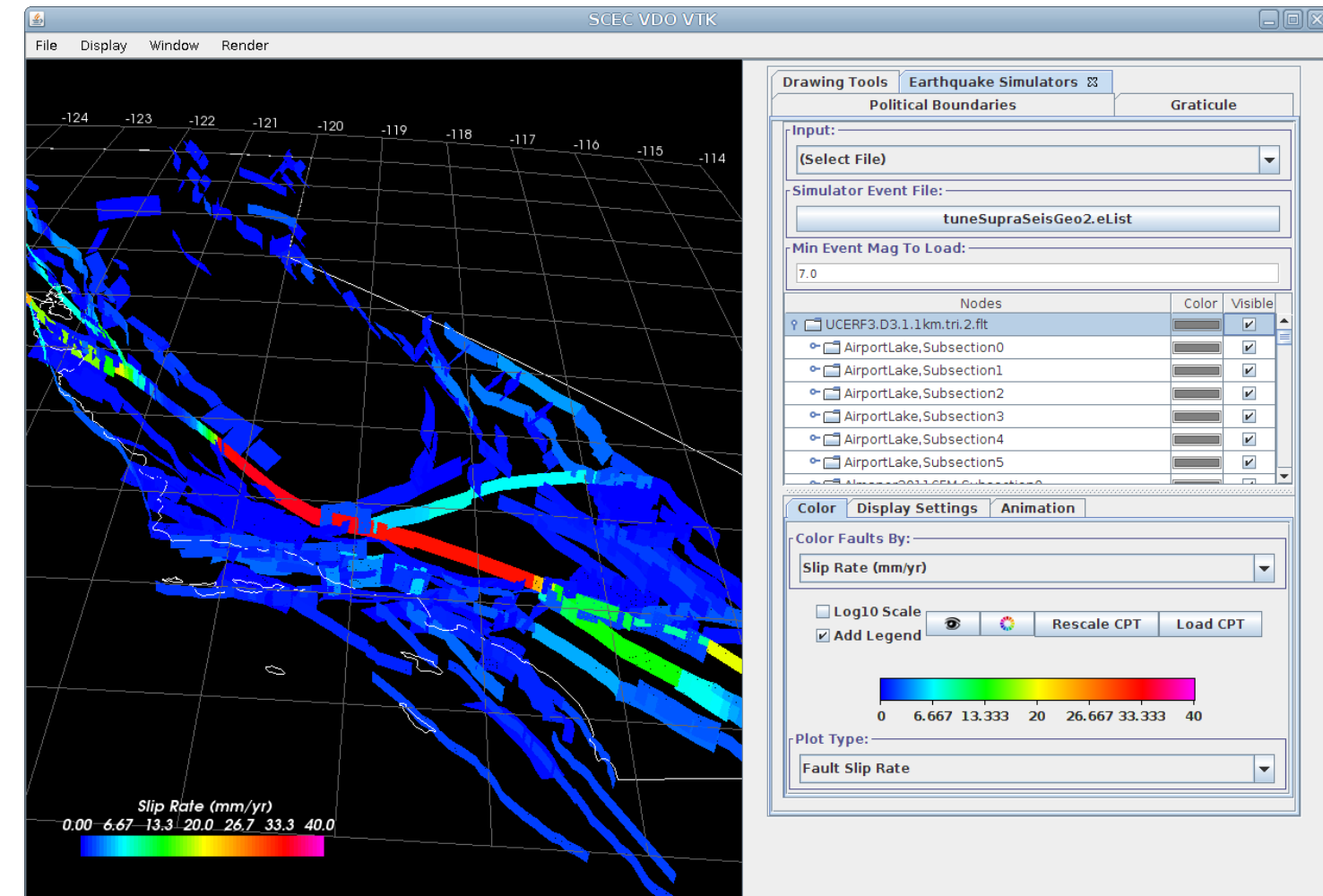
- RSQSim fits slip rates exactly (backslip model)
- Paleoseismic fits are similar to UCERF3 on the SAF
- Magnitude Frequency Distributions don't match expected (yet)



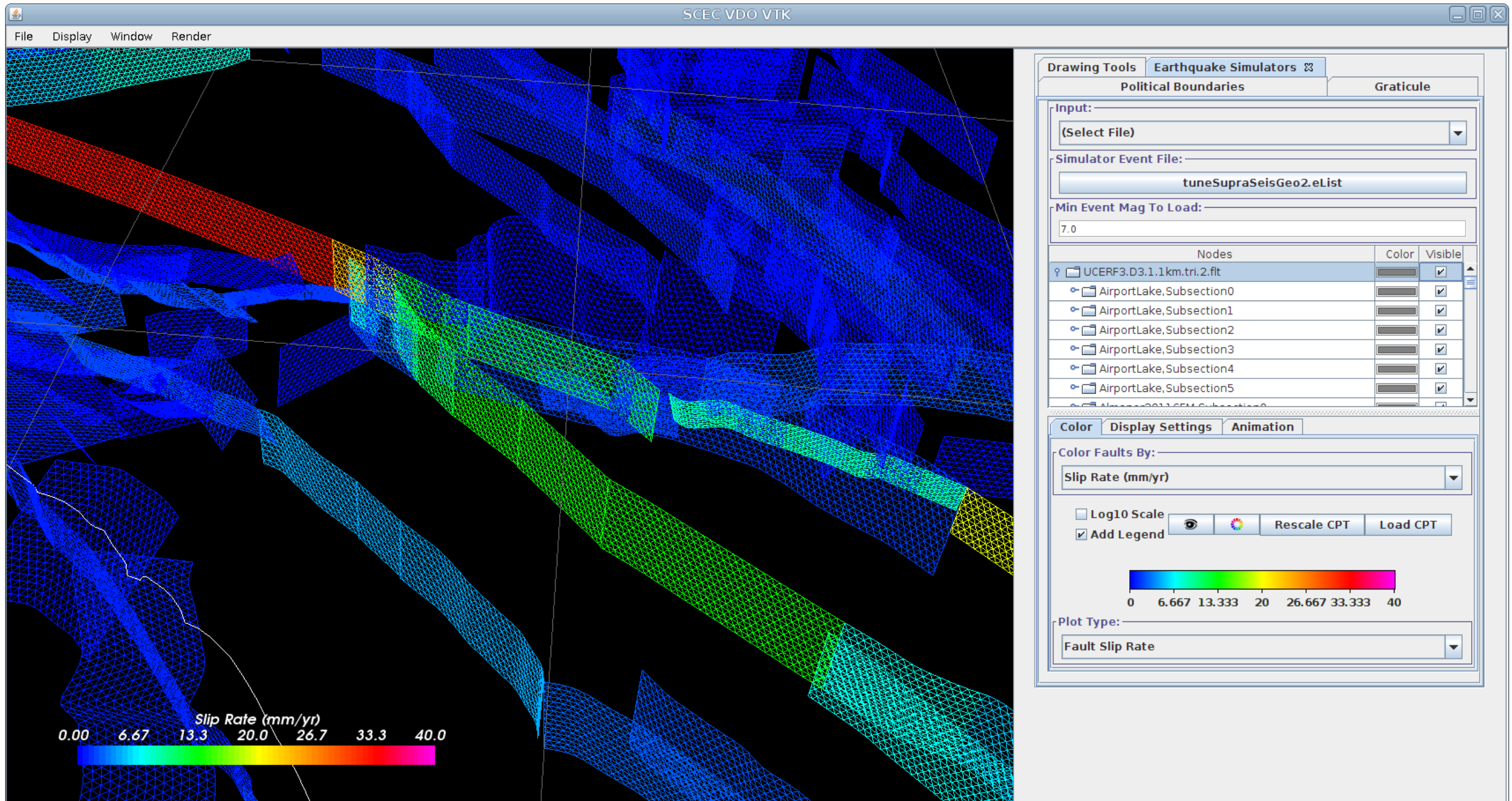


# SCEC-VDO

- **Rebuilt from the ground up in 2016**
  - Replaces outdated Java3D library
  - Runs on Windows, Mac OS X, Linux
- **Download: [scedvdo.usc.edu](http://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

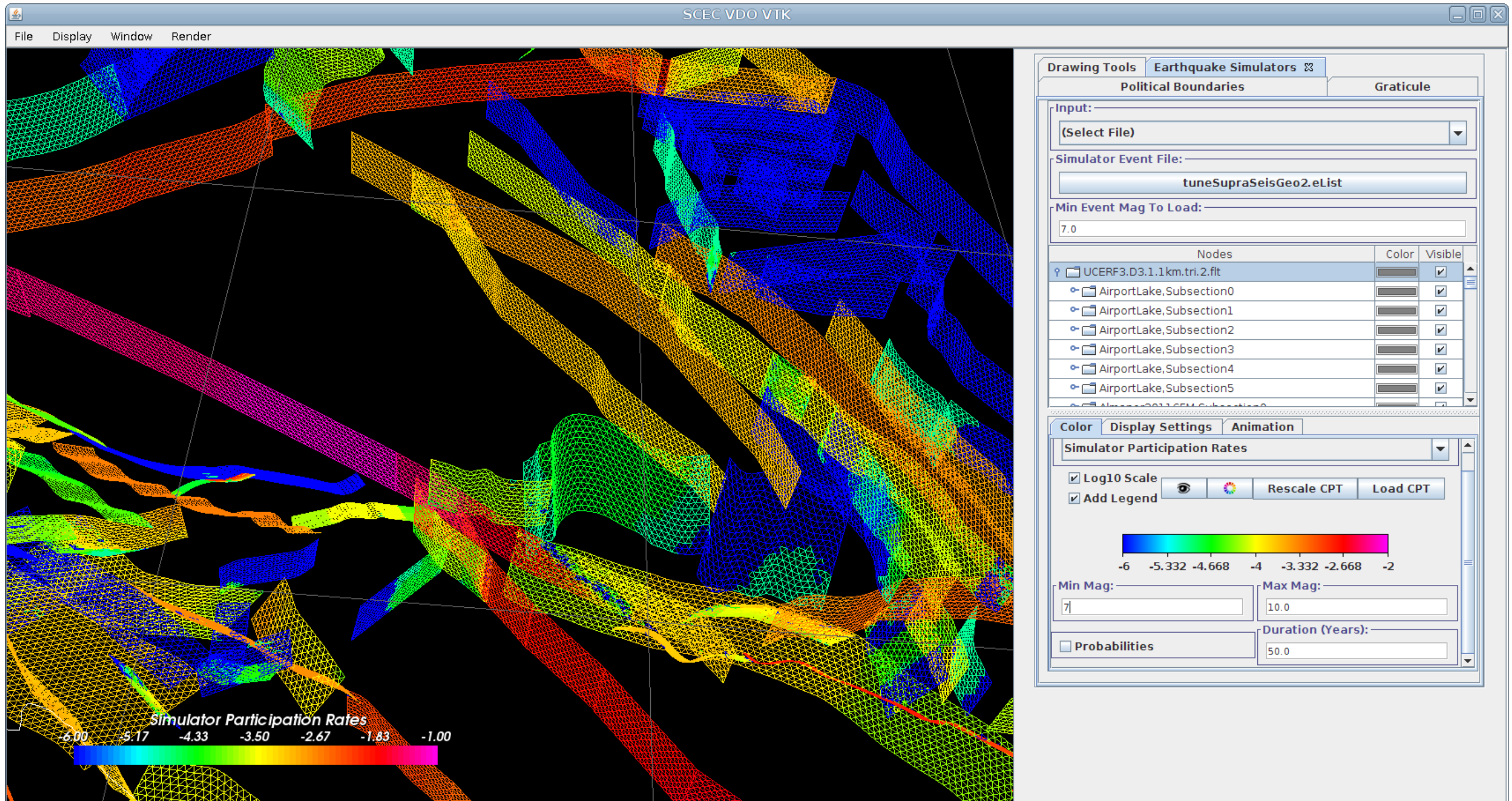


# SCEC-VDO: RSQSim Slip Rates





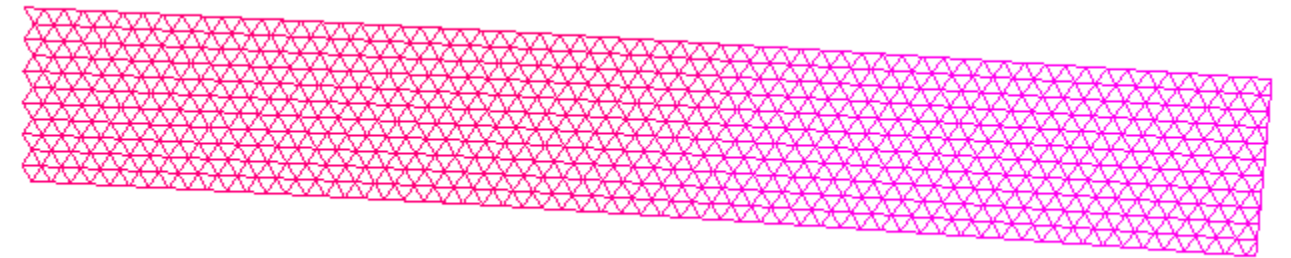
# SCEC-VDO: RSQSim Participation Rates



# 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  $\sim$   $\frac{1}{2}$  DDW**

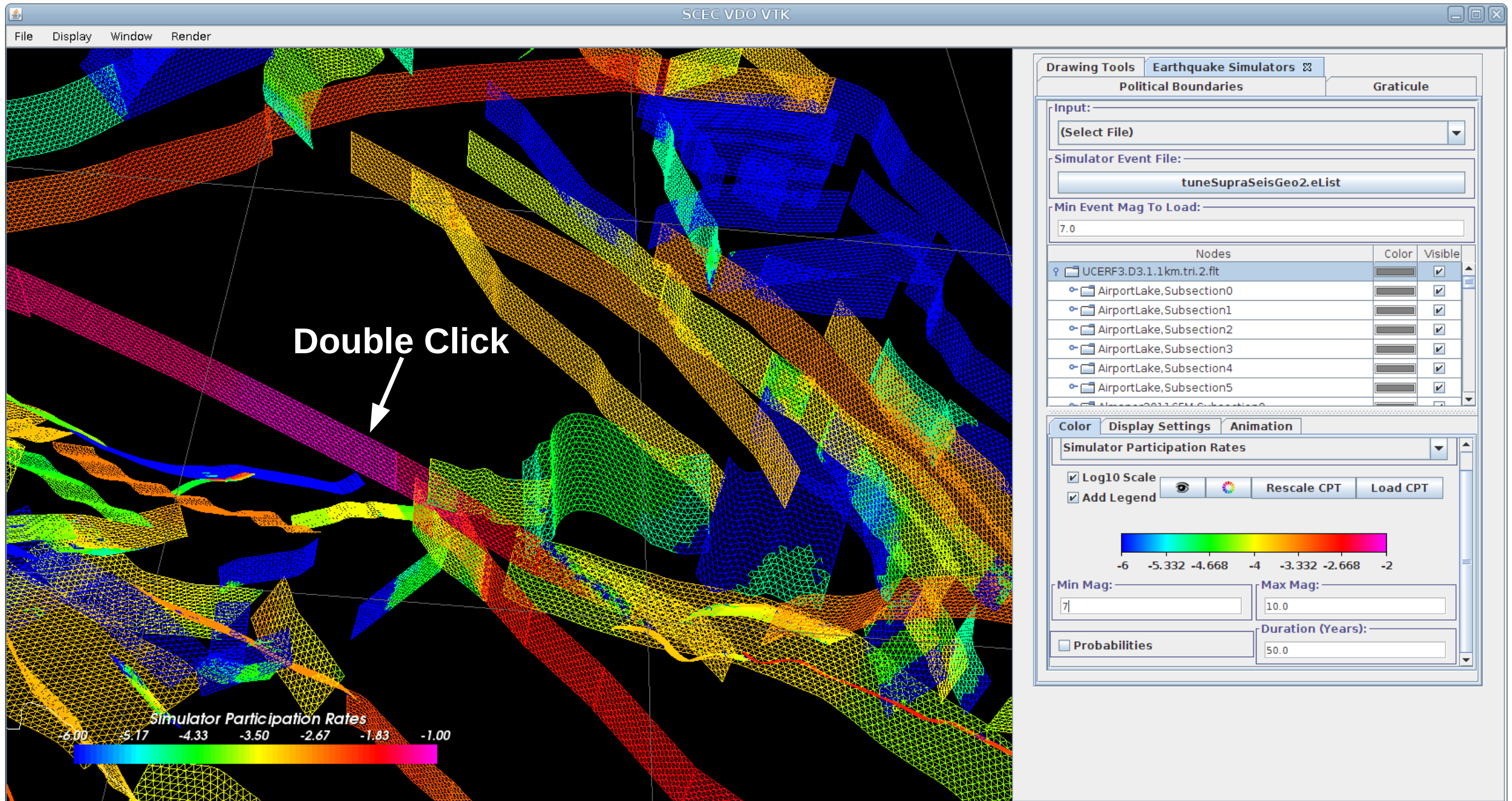


- **Patch: a single triangle with  $\sim 1\text{km}^2$  area**



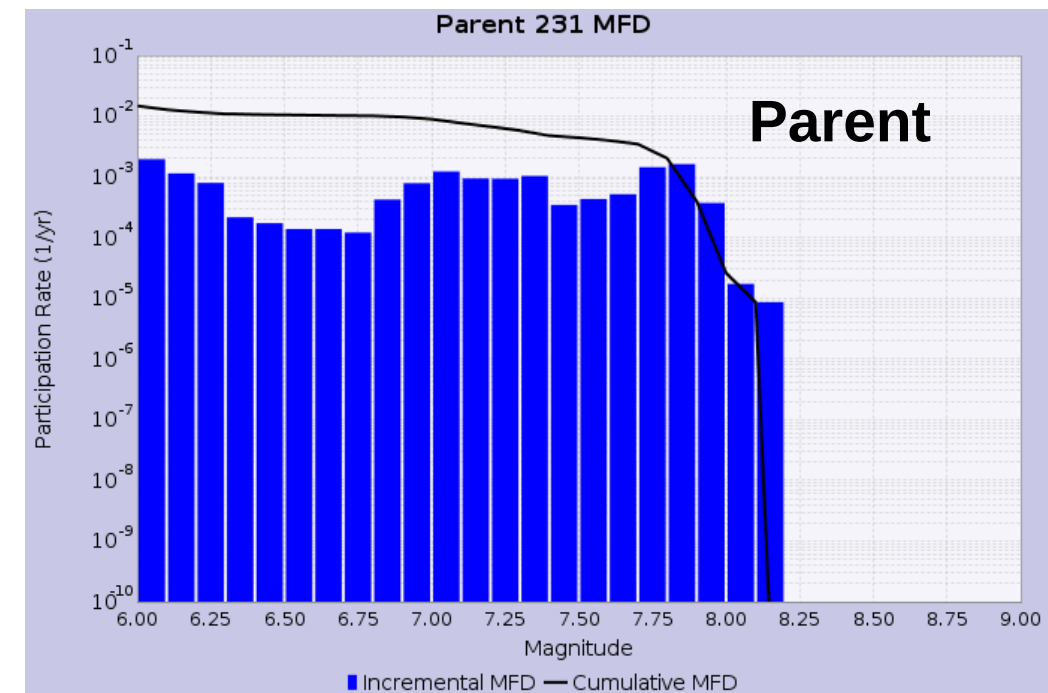
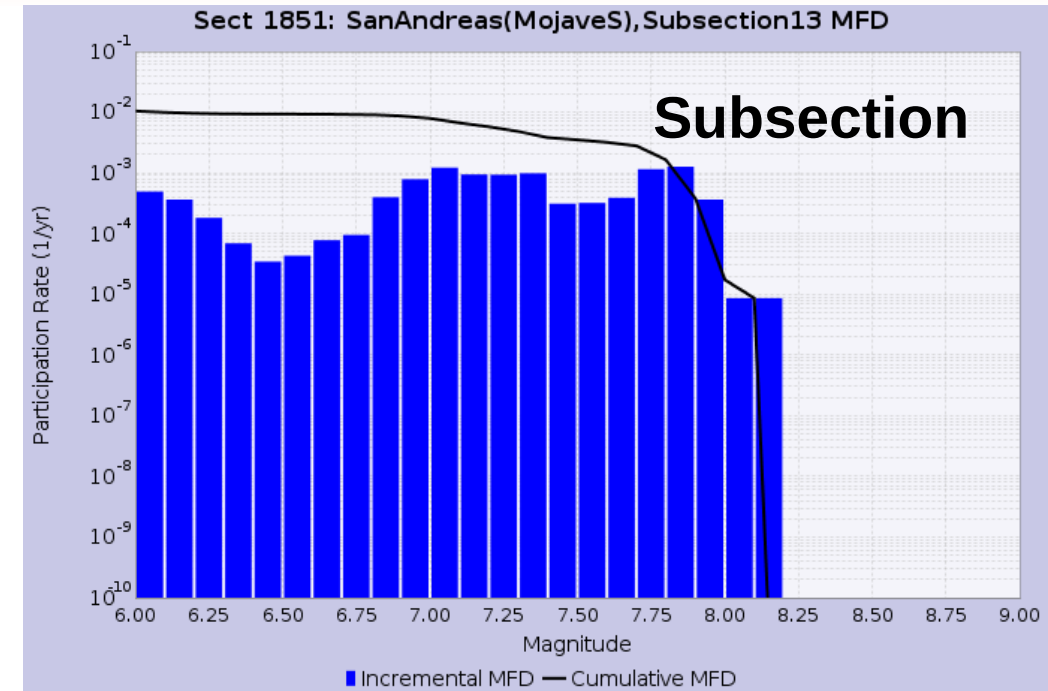
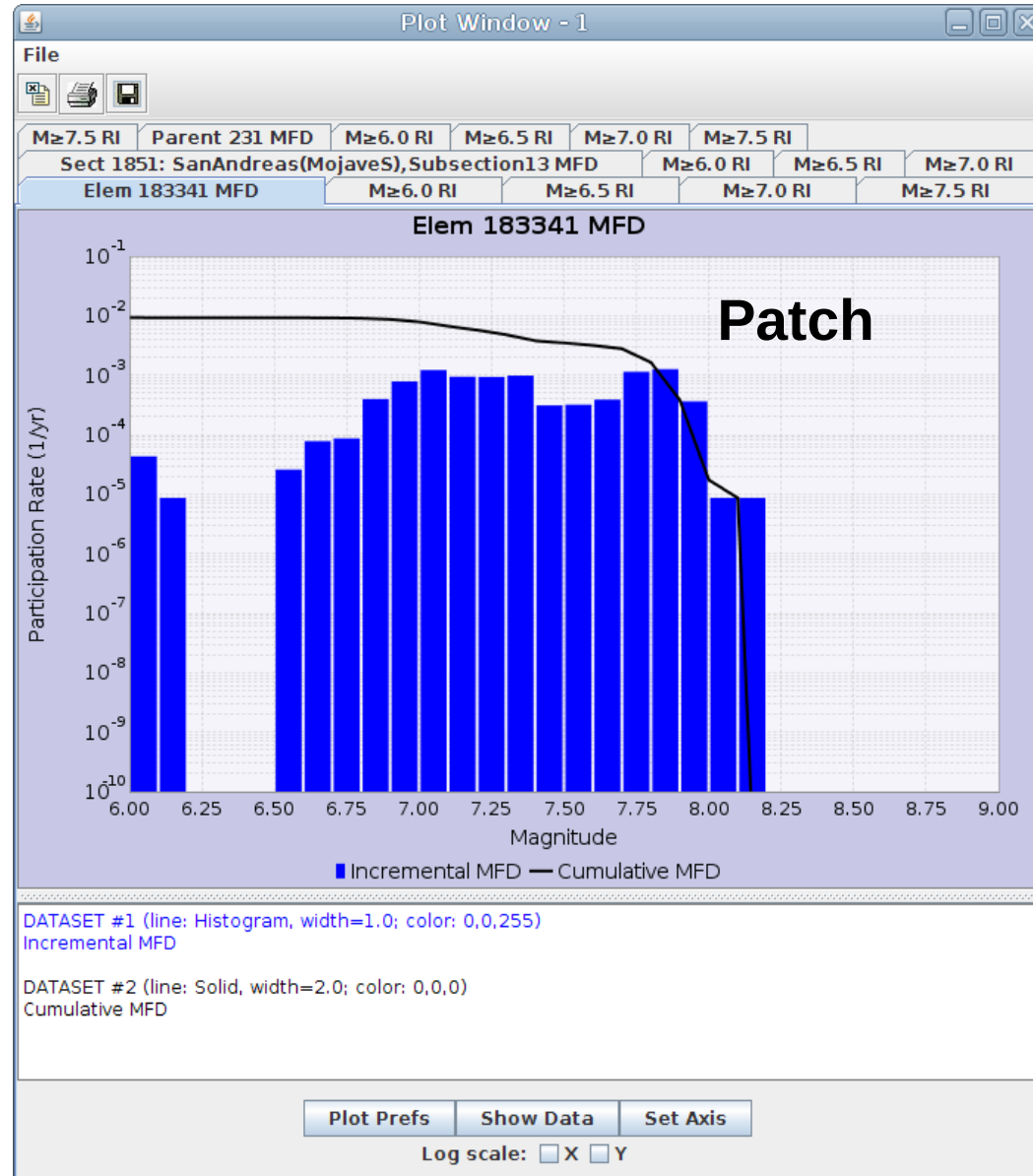


# SCEC-VDO: RSQSim MFDs





# SCEC-VDO: RSQSim MFDs



# SCEC-VDO: RSQSim Recurrence Intervals

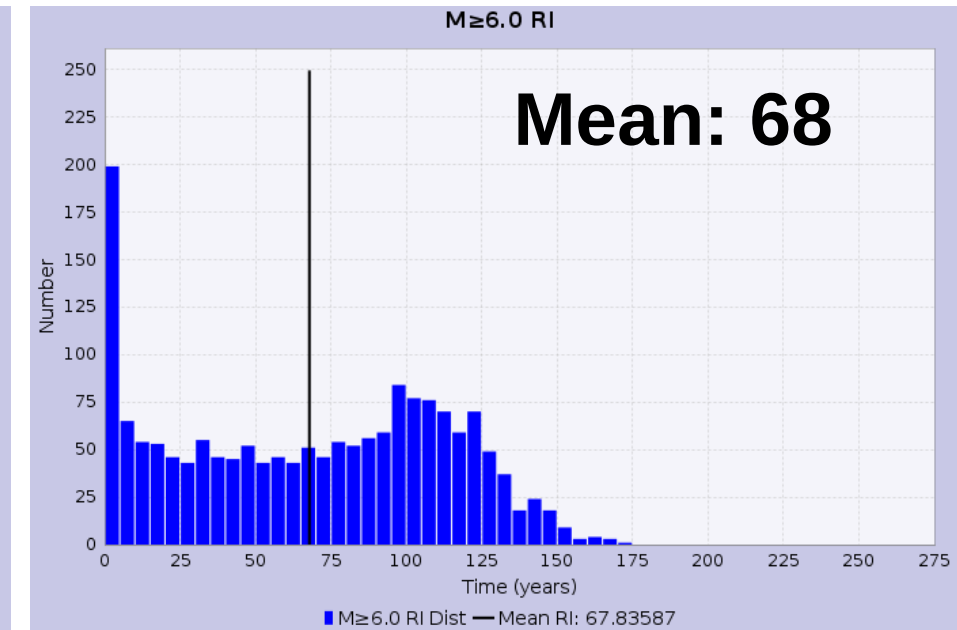
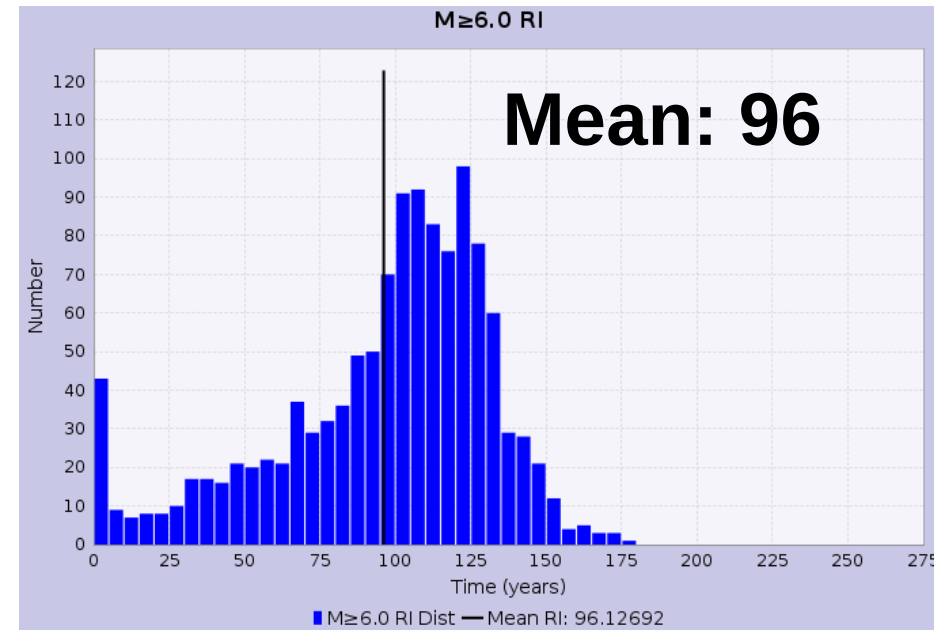
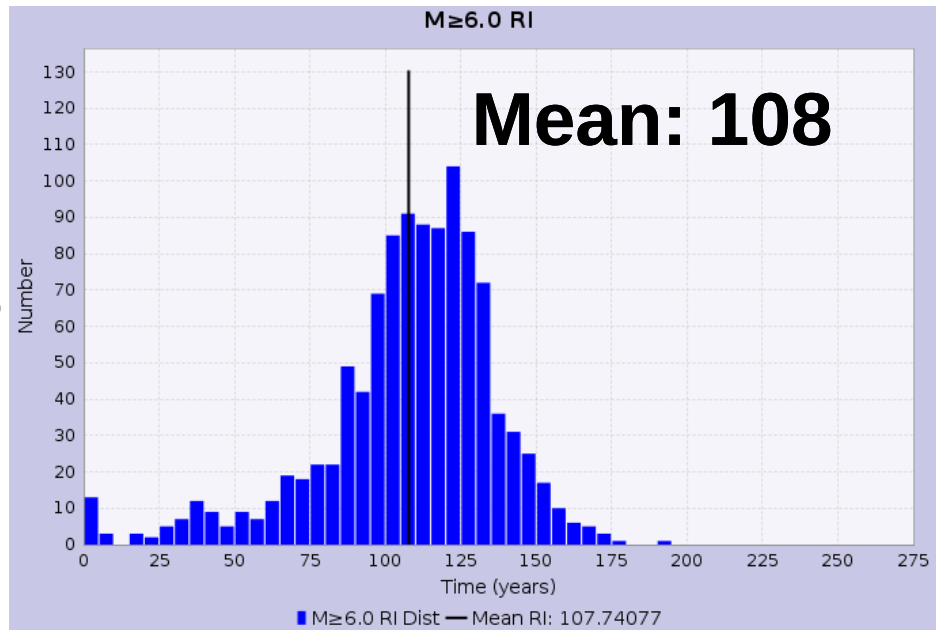
At Wrightwood with UCERF3 Mean=106 yr, near Pallett Creek with UCERF3 Mean=149 yr

Patch

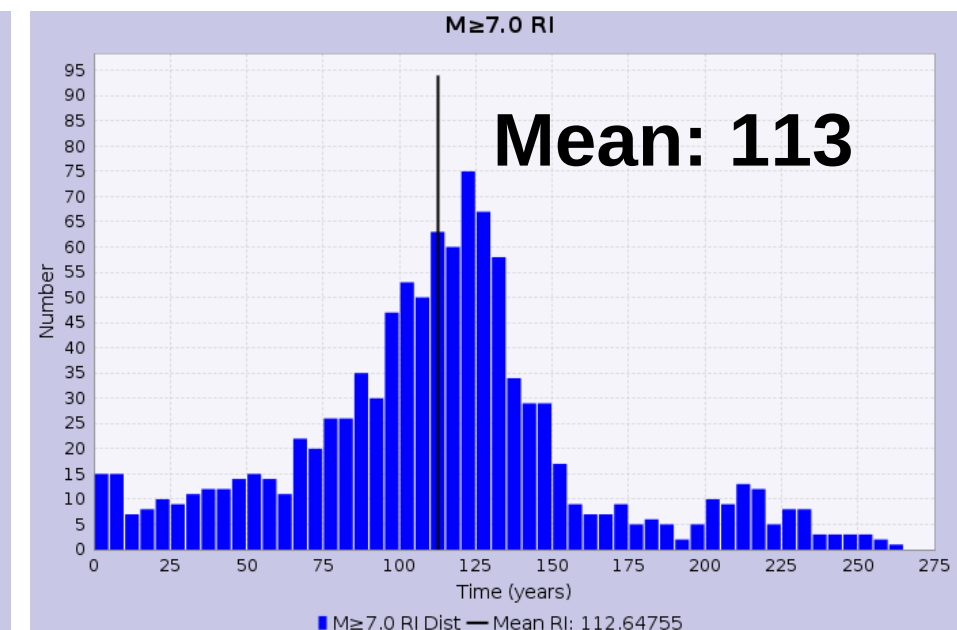
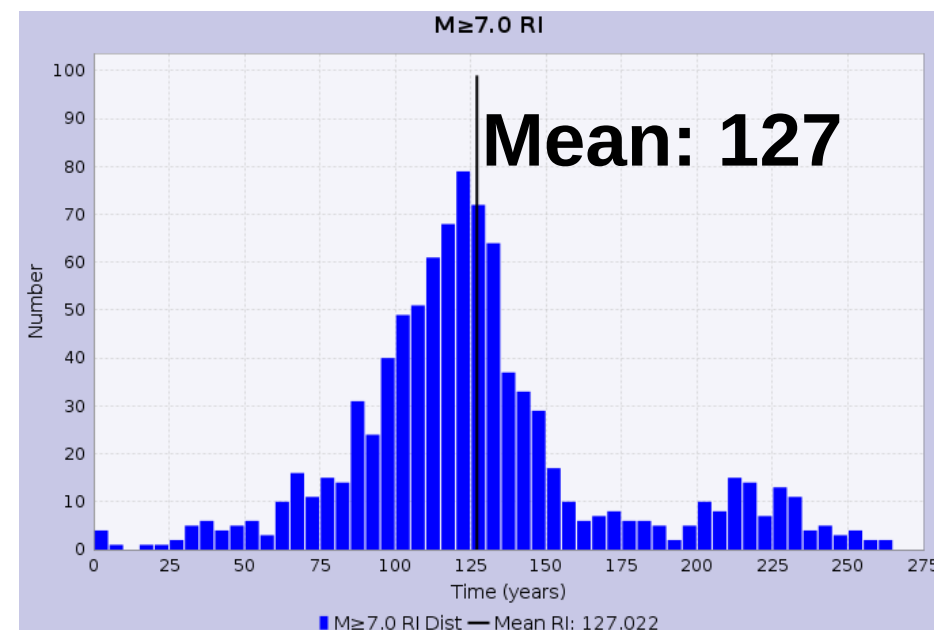
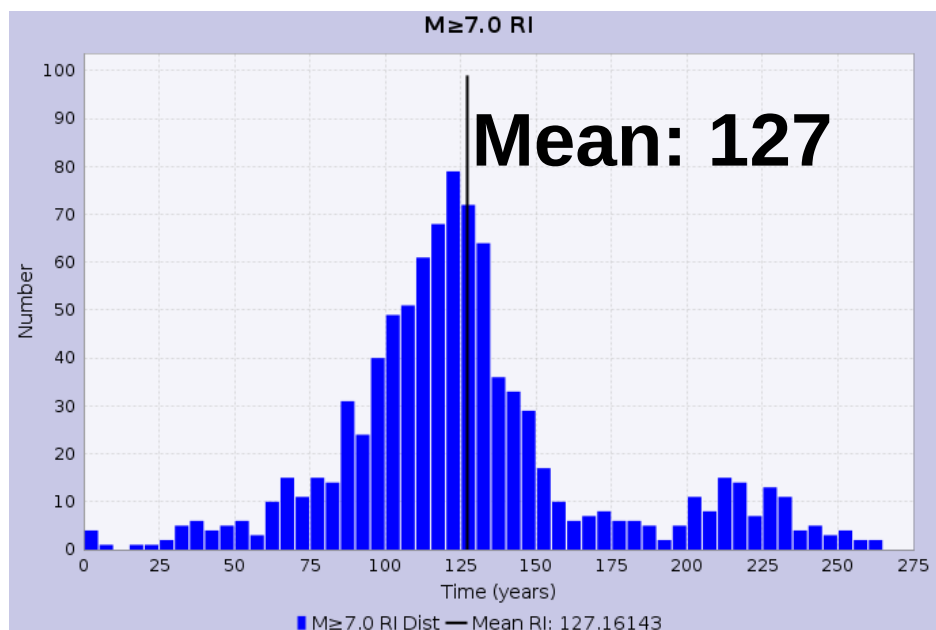
Subsection

Parent

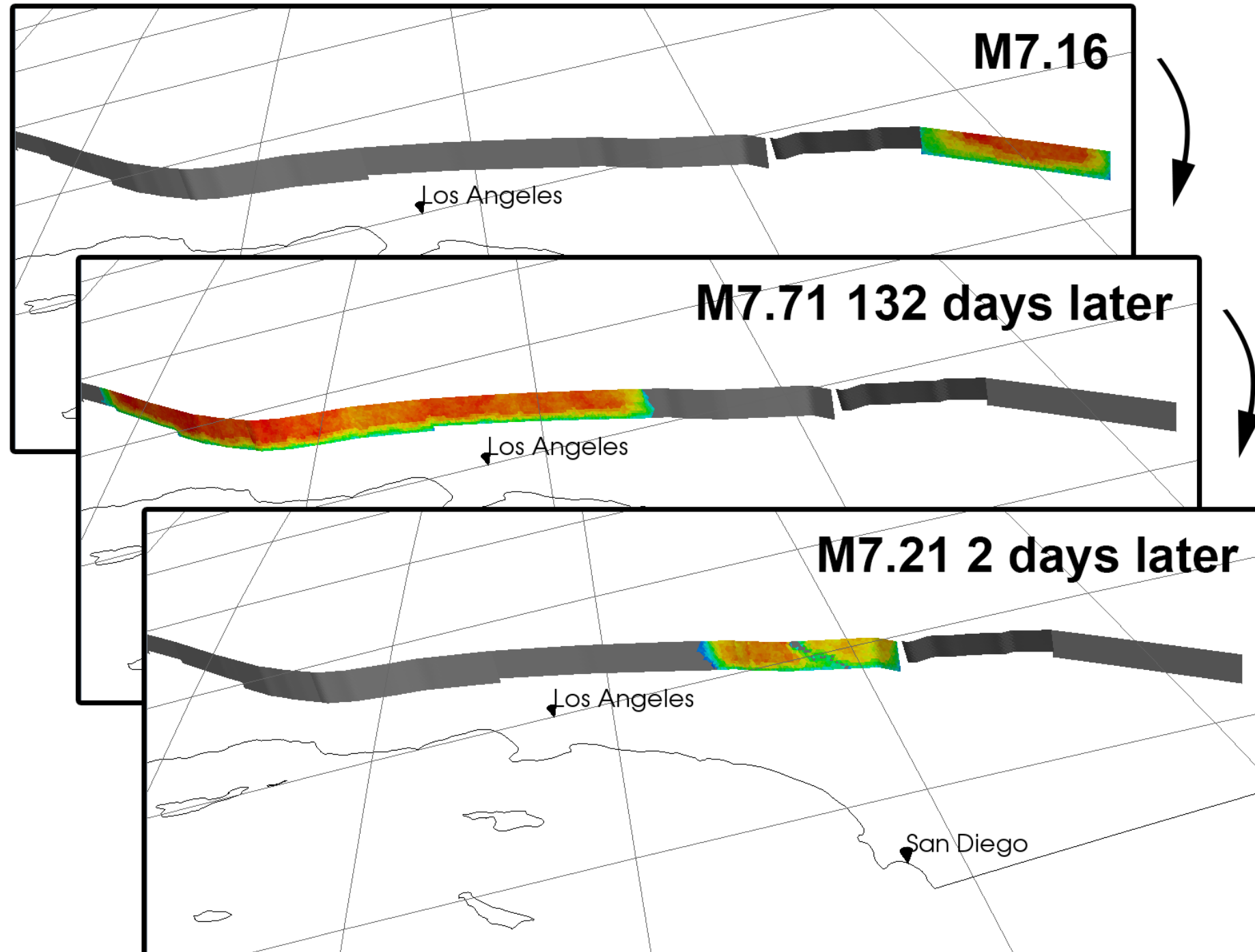
$M \geq 6$



$M \geq 7$



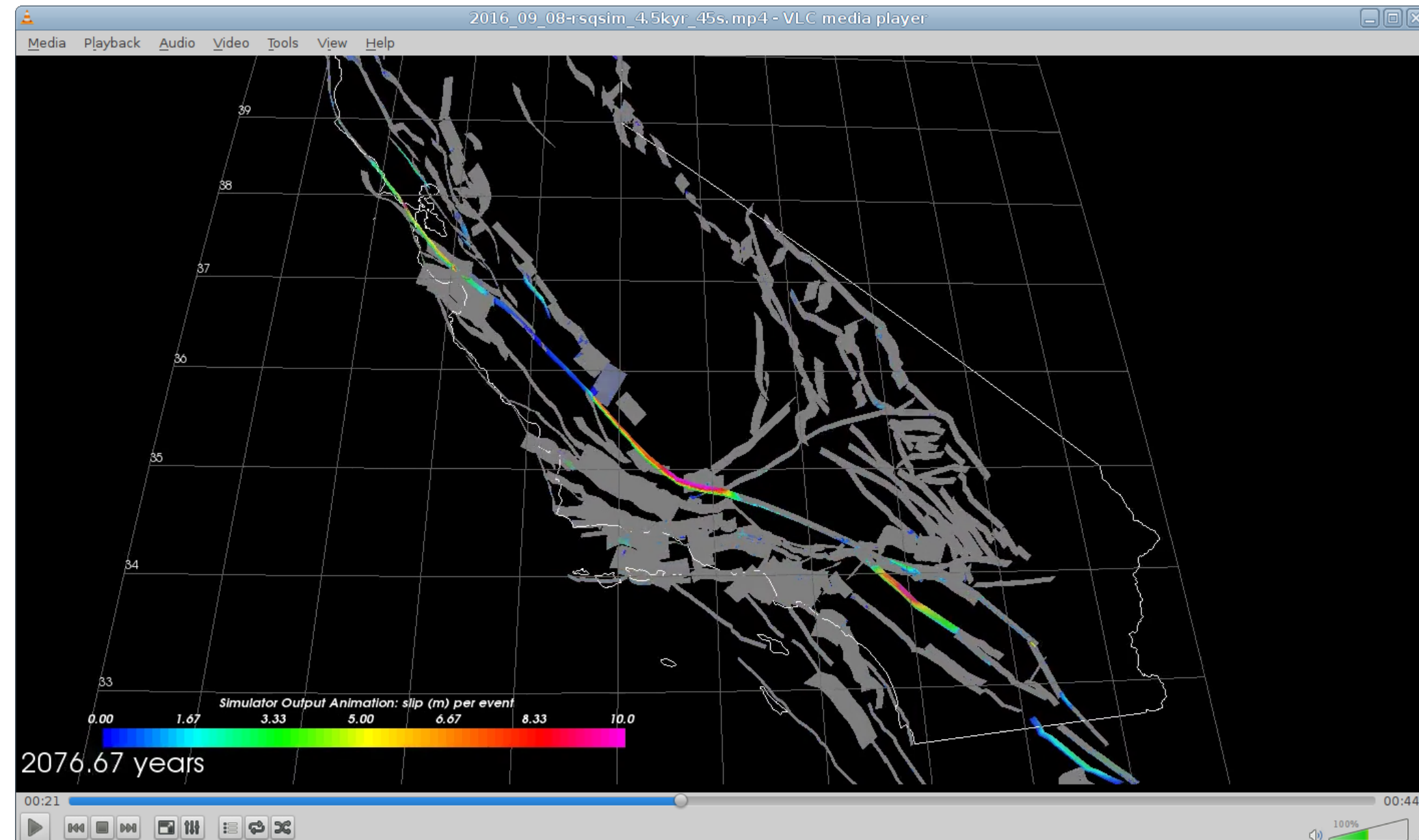
# SCEC-VDO: View Sequences





# 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!***