

Simulation Based Earthquake Forecasting with RSQSim

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Main Objectives

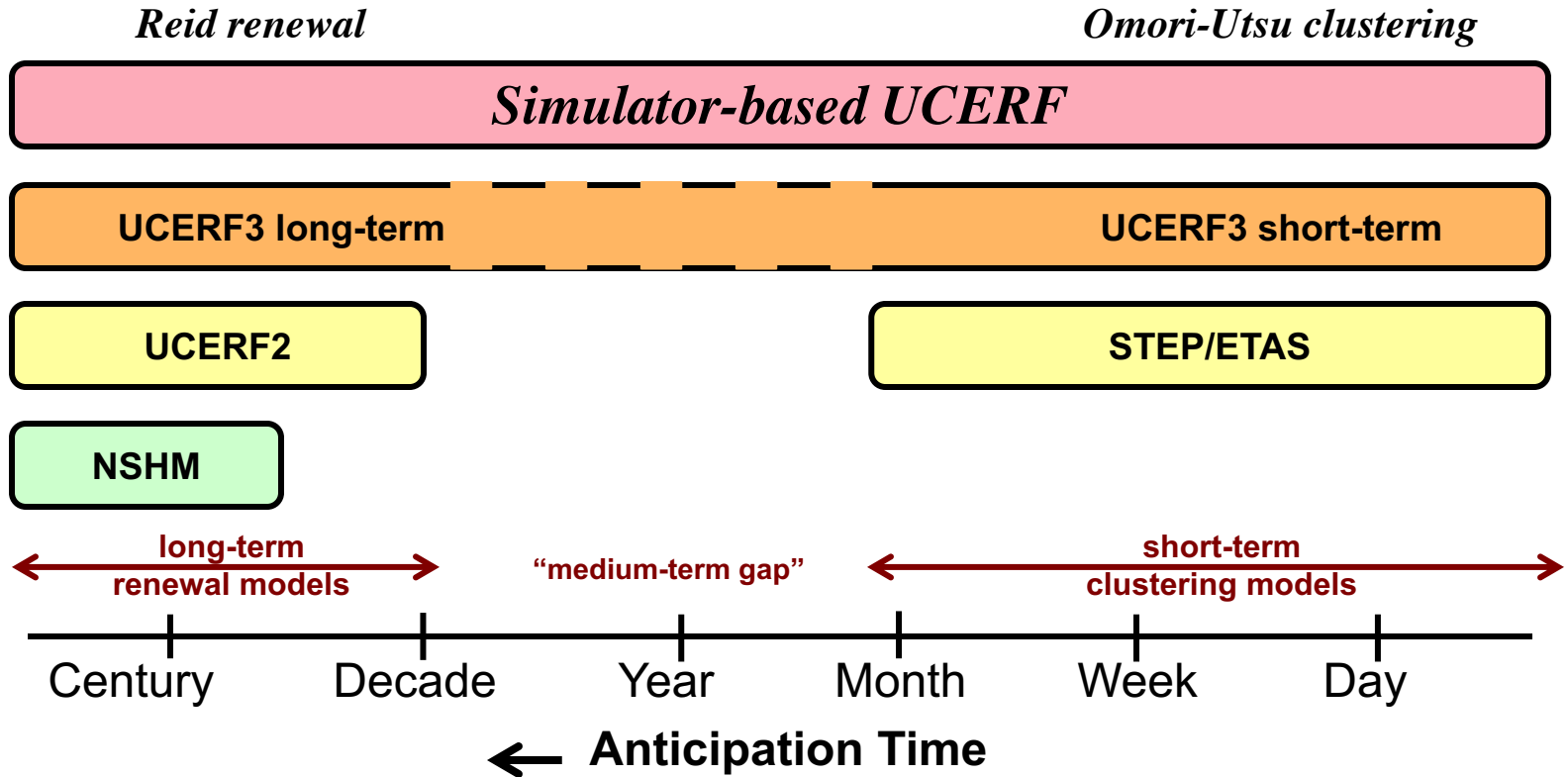
- Develop a physics-based forecasting model for earthquake rupture in California
 - Produce a suite of catalogs (~50) to investigate the epistemic uncertainty in the physical parameters used in the simulations.
 - One million years of simulated time
 - Several million M4-M8 events
 - Varied simulation parameters and fault models
 - Compare with other models (UCERF3) to see what we can learn from the differences.

RSQSim: Rate-State earthQuake Simulator

(Dieterich & Richards-Dinger, 2010; Richards-Dinger & Dieterich, 2012)

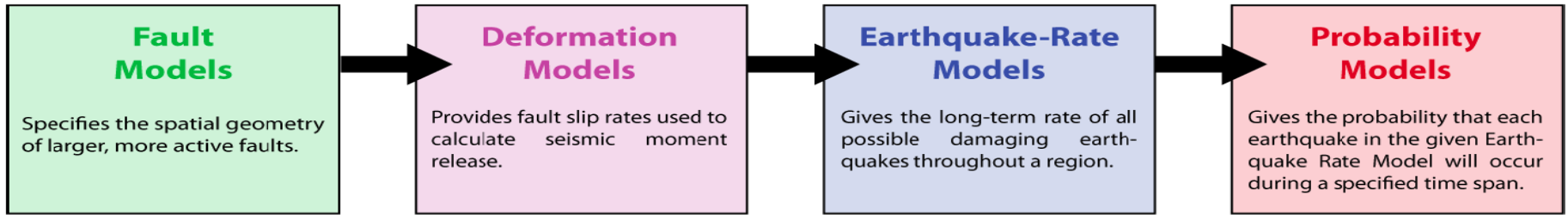
- **Multi-cycle earthquake simulations (full cycle model)**
 - Interseismic period -> nucleation and rupture propagation
- **Long catalogs**
 - Tens of thousands to millions of years with millions of events
- **Complicated model geometry**
 - 3D fault geometry; rectangular or triangular boundary elements
- **Different types of fault slip**
 - Earthquakes, slow slip events, continuous creep, and afterslip
- **Physics based**
 - Rate- and State-dependent friction
- **Foreshocks, aftershocks, and earthquake sequences**
- **Efficient algorithm**
 - Event driven time steps
 - Quasi-dynamic rupture propagation

California Earthquake Forecasting Models



Use of simulations for long-term assessment of earthquake probabilities

Components of the Uniform California Earthquake Rupture Forecast



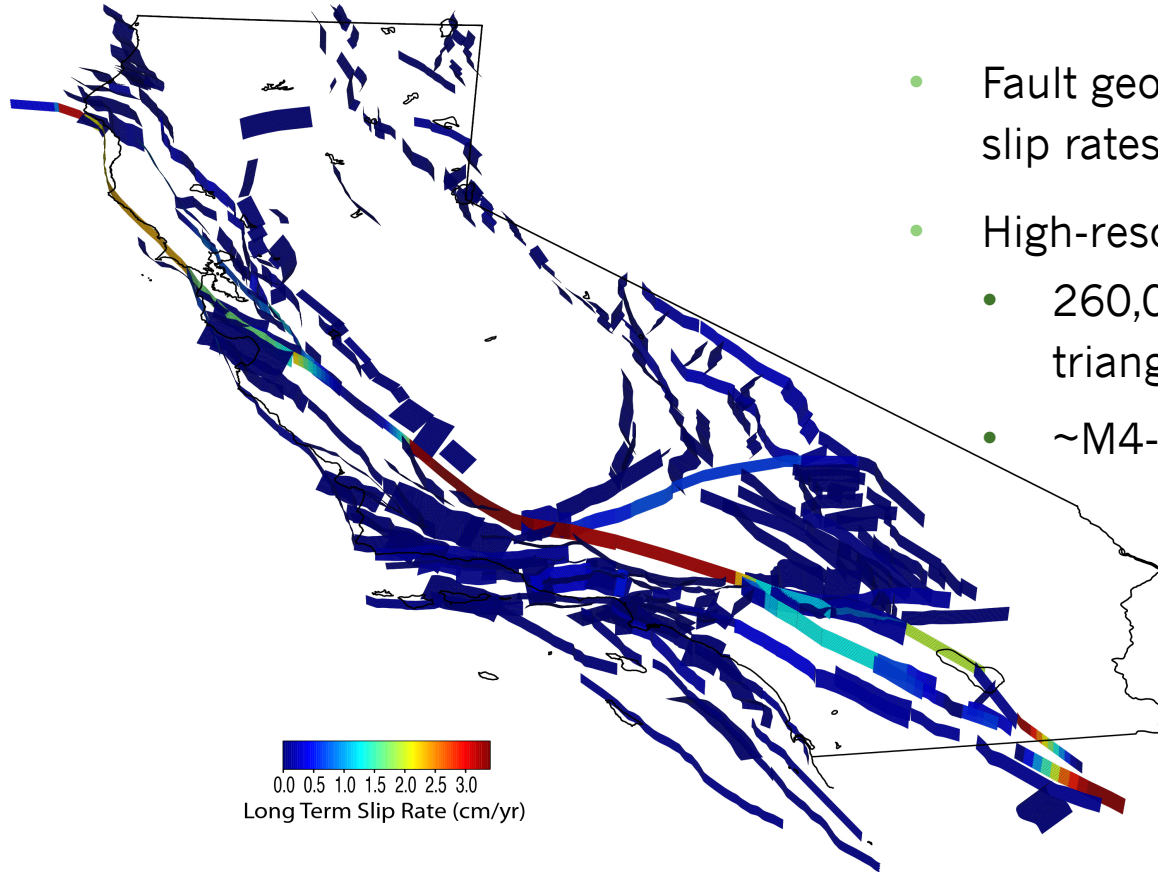
Inputs to simulations

Use tuned earthquake simulations to generate earthquake rate models

RSQSim Calibration

- Develop a model that generates an earthquake catalog that matches observed California seismicity as closely as possible.
- The UCERF3 data set is used for calibration, and cross-validation of the model, as well as specification of fault geometry.
 - Fault Model
 - Long-Term Slip Rates
 - Recurrence Intervals

Calibration: Faults & Long-term Slip Rates

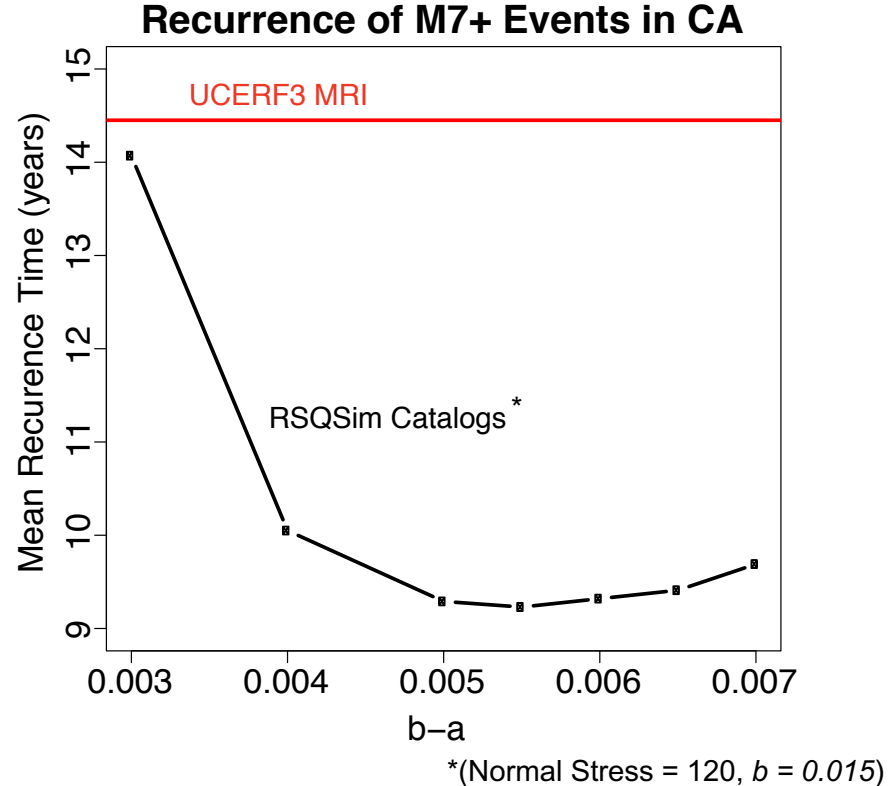
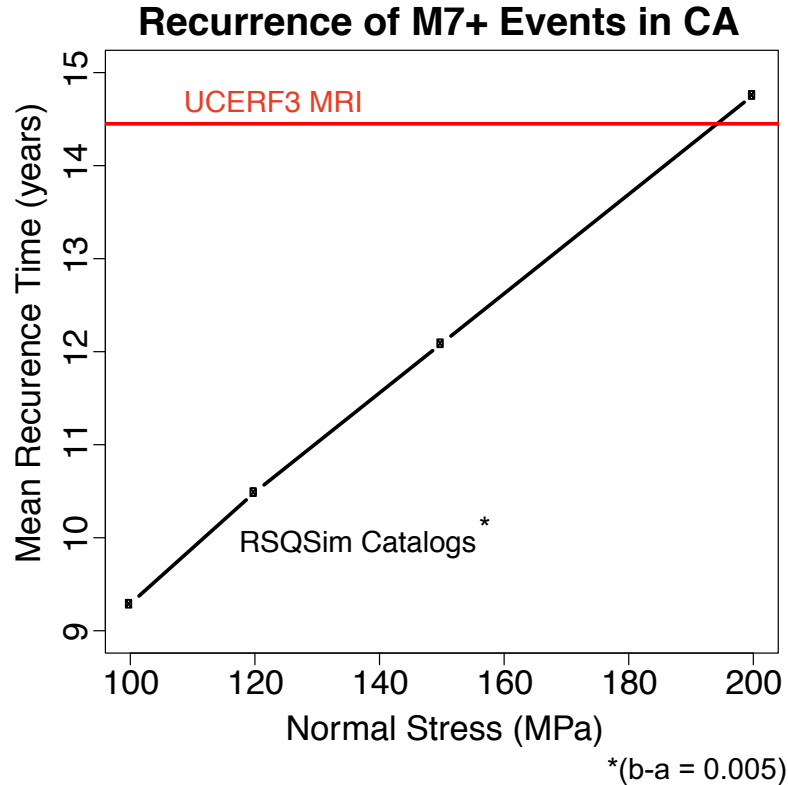


- Fault geometry and geologic slip rates from UCERF3
- High-resolution Model
 - 260,000+, 1 km², triangular patches
 - ~M4-M8 events

Simulation Parameters

- **Rate- and State-friction Parameters**
 - a , b , and D_c (rate and state coefficients, and the critical slip distance)
- **Other Model Parameters**
 - τ and σ (shear and normal stresses)
 - Earthquake slip rate
- **Adding heterogeneity of parameters**
 - Vary a , b , and σ with depth
 - Adding deep creeping segments

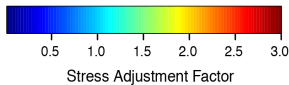
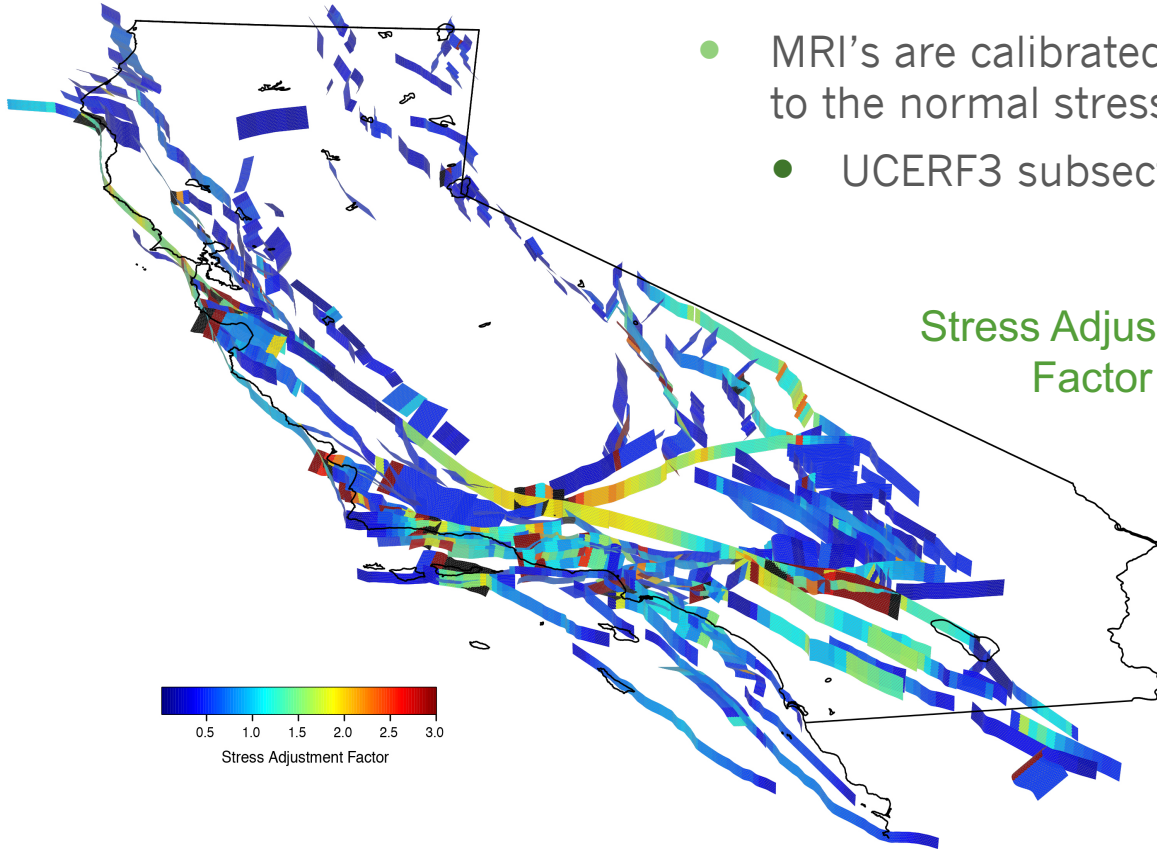
Parameter Sensitivity Tests



Calibration: Mean Recurrence Intervals

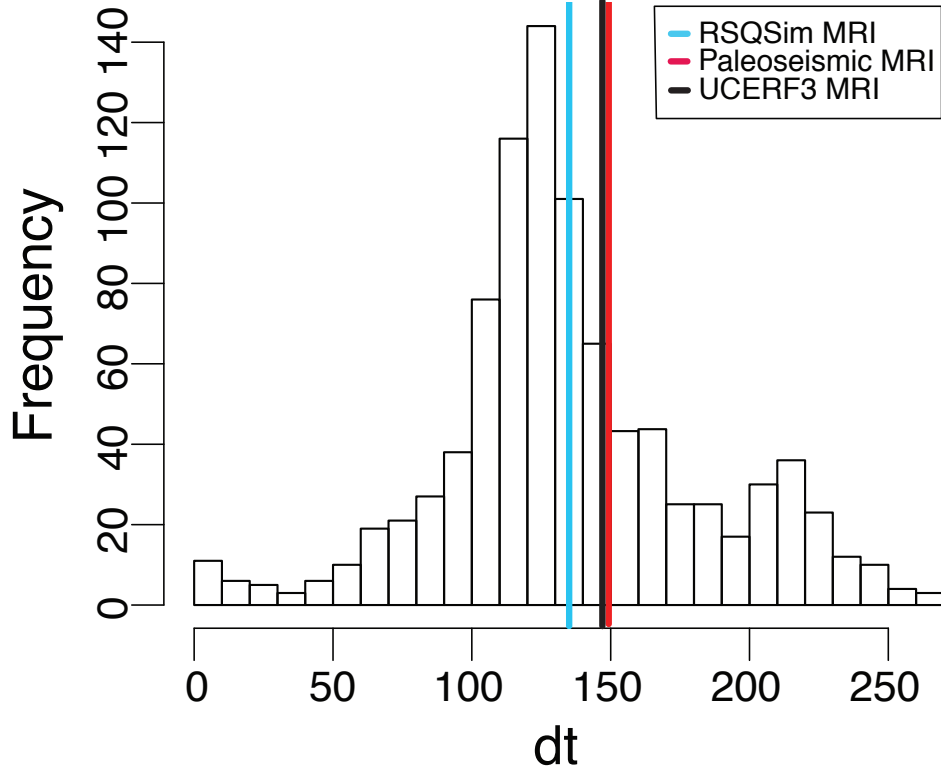
- MRI's are calibrated by making adjustments to the normal stress.
- UCERF3 subsection MRI's

$$\text{Stress Adjustment Factor} = \frac{\text{UCERF3 MRI}}{\text{RSQSim MRI}}$$



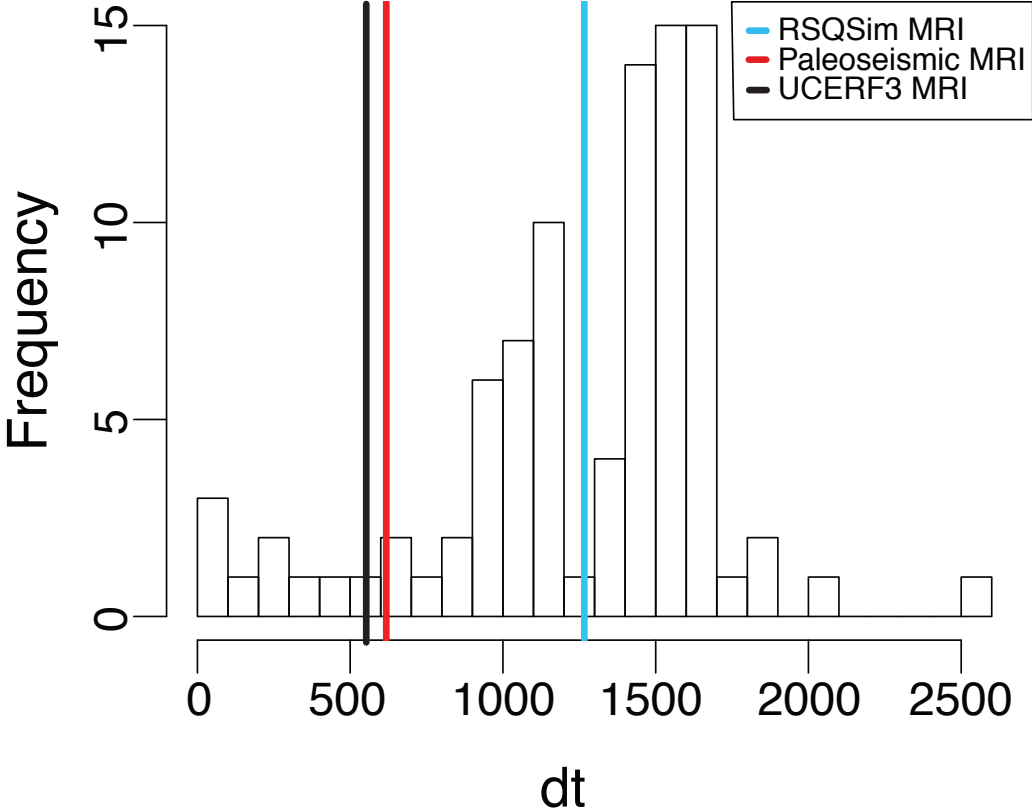
Result From Two MRI Calibration Rounds

SSAF Pallett Creek



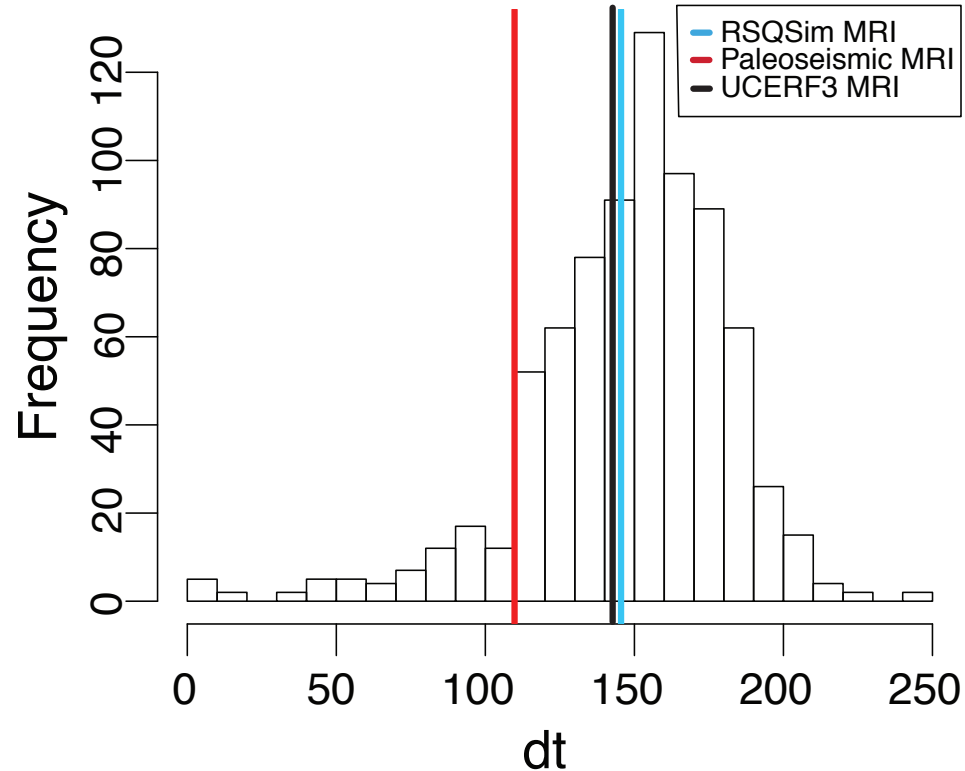
Result From Two MRI Calibration Rounds

Calaveras-North



Result From Two MRI Calibration Rounds

NSAF Santa Cruz

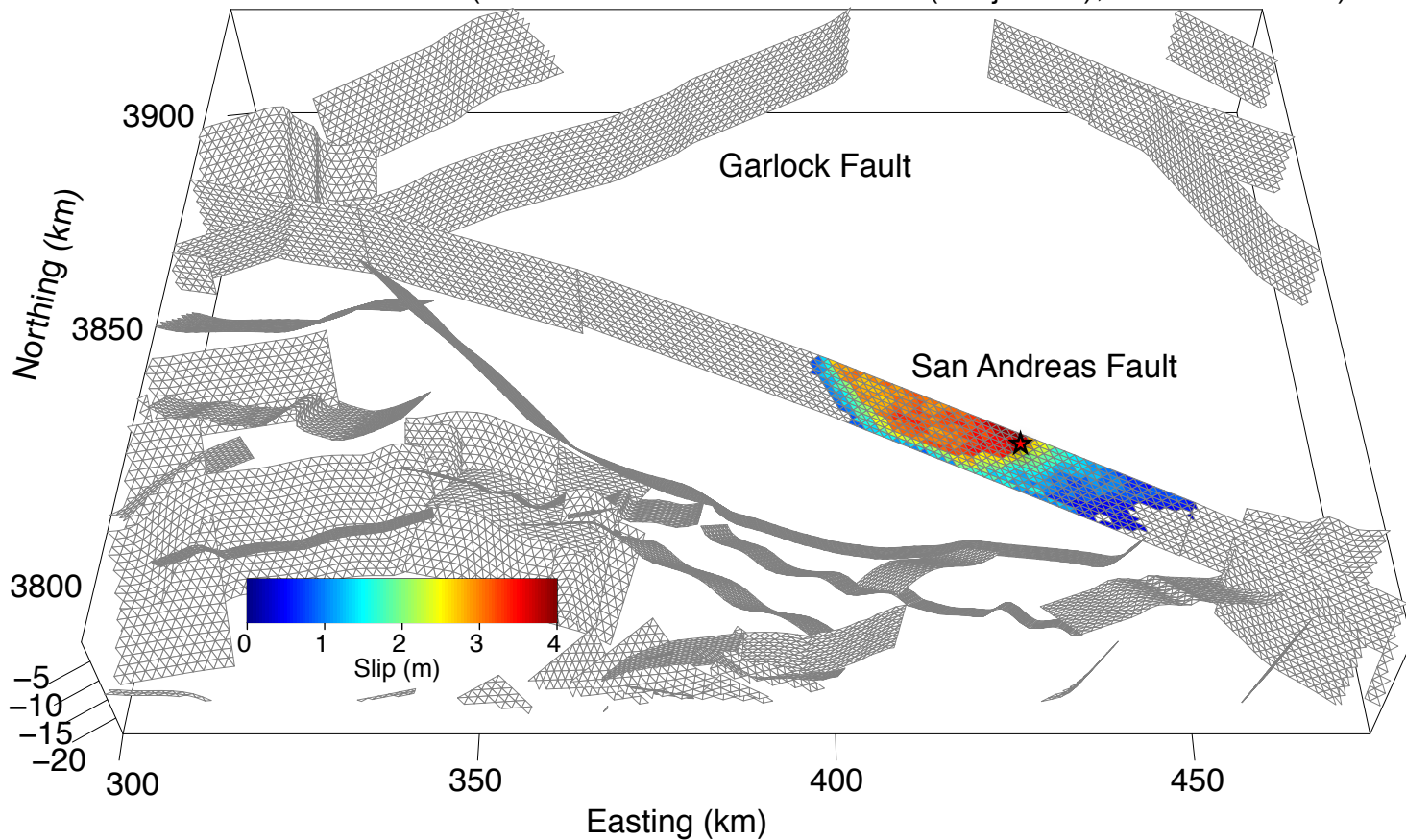


Mojave M7 Scenario

- Magnitude 7 on the San Andreas Fault in the Mojave is followed by another Magnitude 7 within a week.

Mojave M7 Scenario

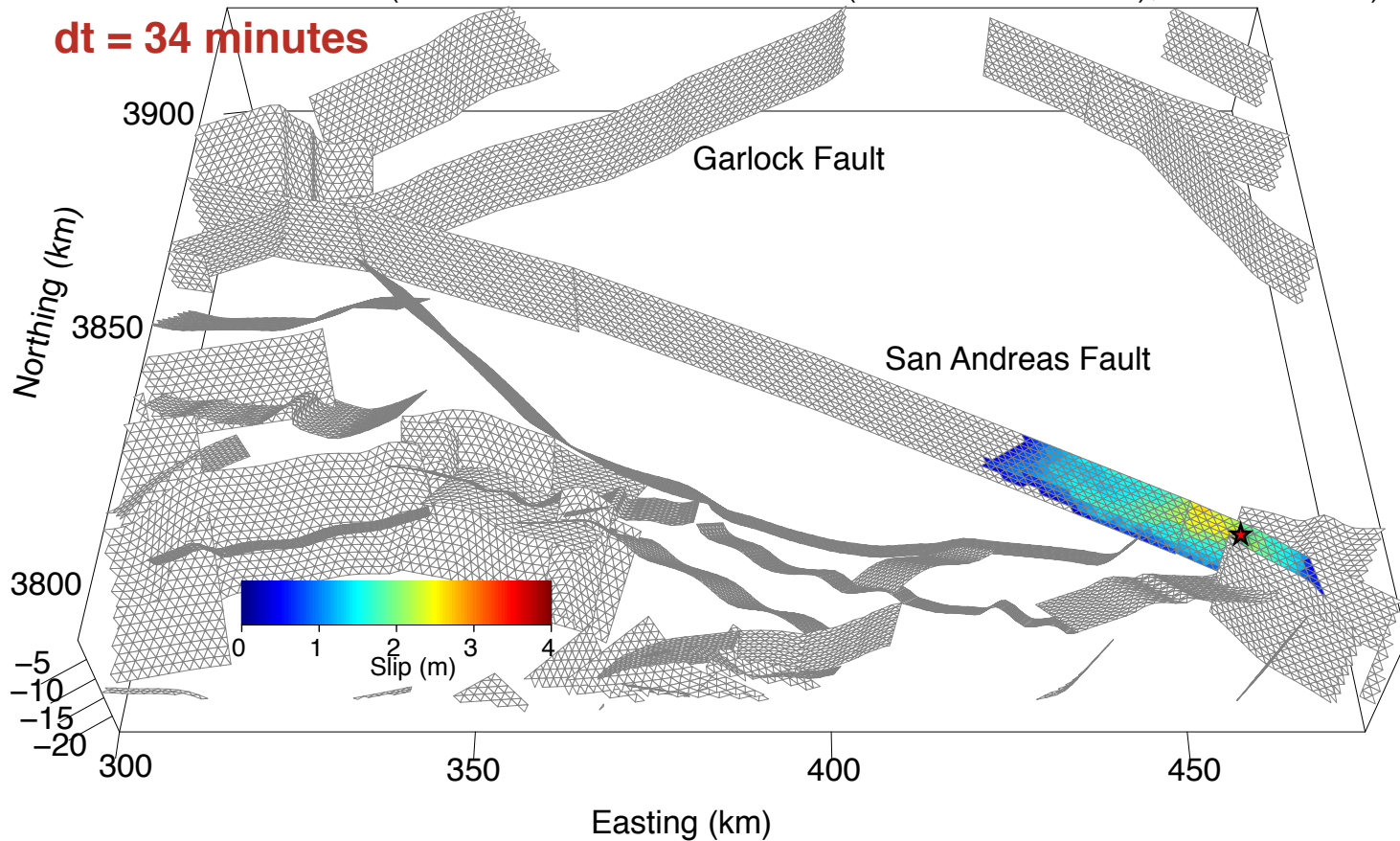
Event # 1: $M = 7.1$ (Nucleated on SanAndreas(MojaveS),Subsection11)



Mojave M7 Scenario

Event # 2: M = 7 (Nucleated on SanAndreas(SanBernardinoN),Subsection1)

dt = 34 minutes



Mojave M7 Scenario

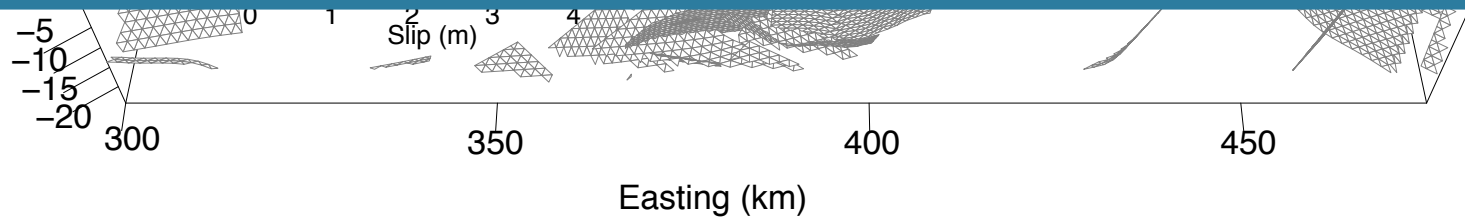
Event # 2: M = 7 (Nucleated on SanAndreas(SanBernardinoN),Subsection1)

dt = 34 minutes

Probability of a **magnitude 7 or greater** earthquake anywhere in California, **within 1 week** following a **magnitude 7** on the San Andreas in the Mojave:

UCERF3 = 4.5%

RSQSim = 5.6%



Conclusions

- Using RSQSim to develop a physics-based forecasting model for earthquakes in California.
- Initial calibration and validation tests are promising (but we still have some work to do on the model).
- Initial results illustrate how rupture simulators might assist forecasters in understanding the hazards due to multi-event sequences and complex faulting.

Thank you!