CyberShake Study 21.12
Readiness Review

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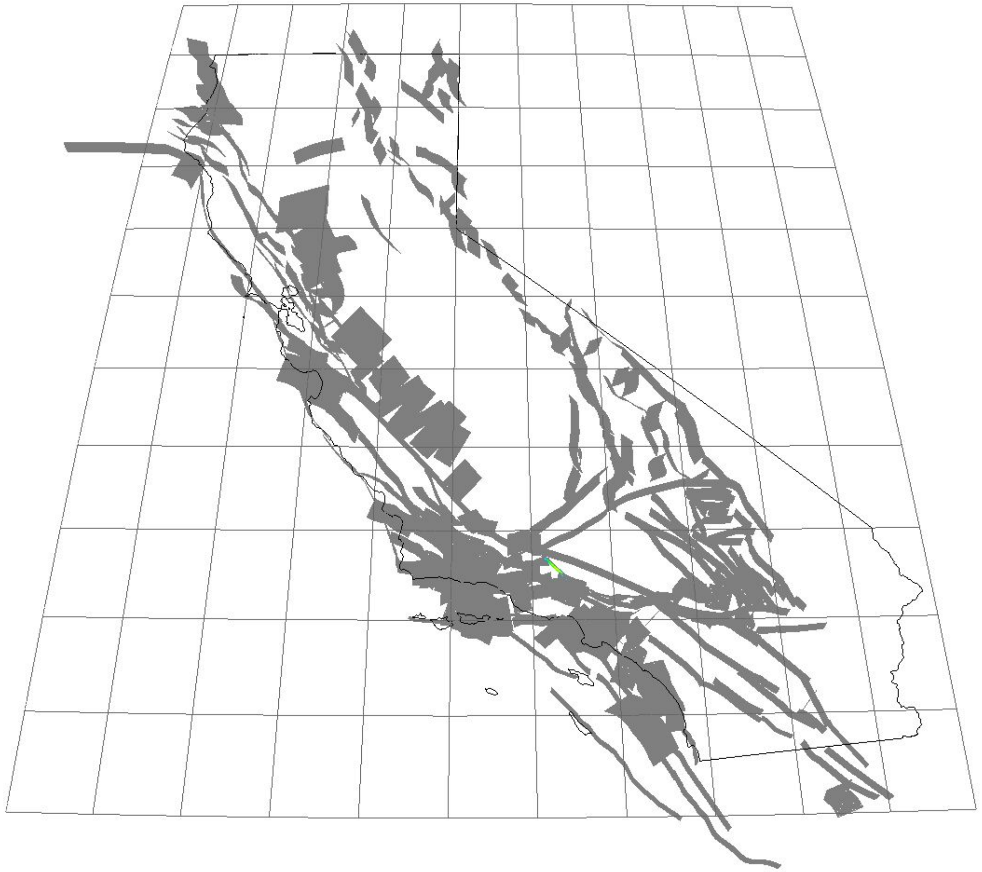
December 6, 2021

Scientific Goals

- Calculate a regional Southern California CyberShake model using an alternative, RSQSim-derived ERF
- Compare results from an RSQSim ERF to results using a UCERF2 ERF (Study 15.4)
- Quantify effects of source model non-ergodicity
- Compare spatial distribution of ground motions (including directivity) to empirical and kinematic models

Rate-State Earthquake Simulator: RSQSim

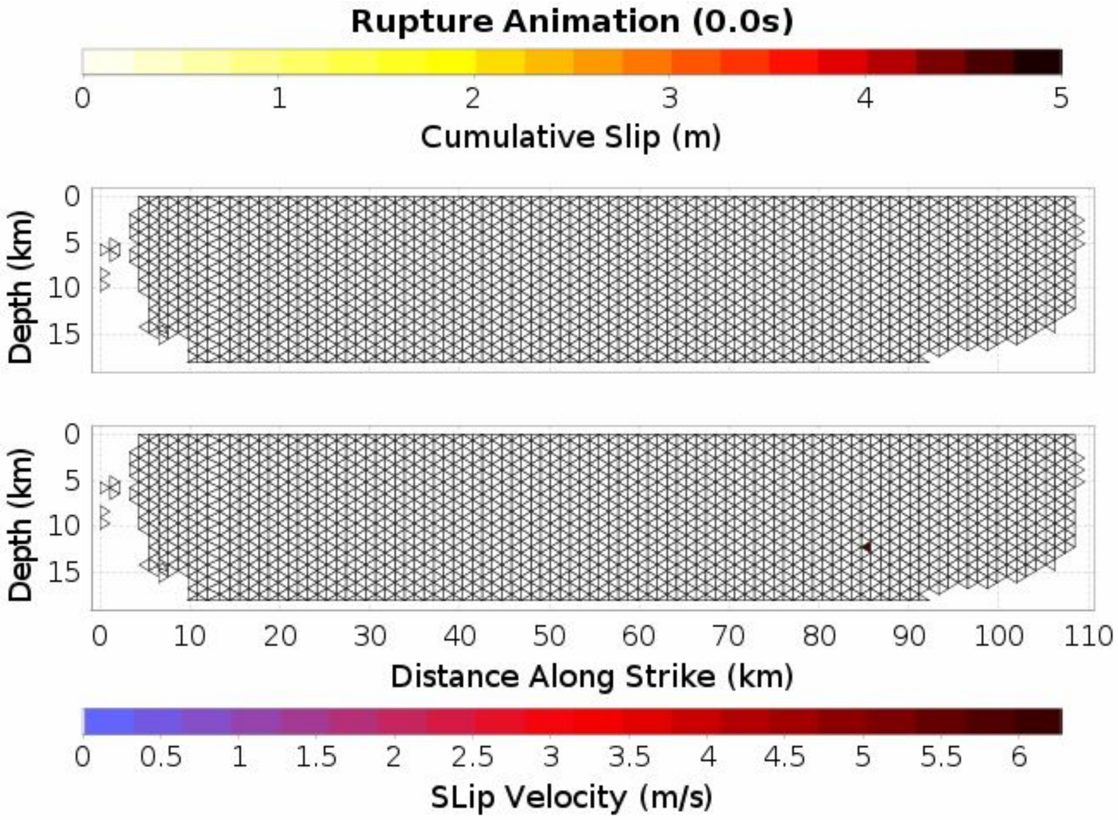
- **R**ate **S**tate earth**Q**uake **Sim**ulator
  - Richards-Dinger & Dieterich, 2012
- Physics-based multi-cycle simulator
  - Tectonic loading of faults by backslip approximation
  - Rupture nucleation by rate- and state-dependent friction
  - Dynamic overshoot
  - Stress transfer in homogeneous elastic halfspace
- No prescribed ruptures
- Synthetic catalogs of thousands to millions of years of earthquake sequences



Animation of 3,000 years of RSQSim ruptures in CA
(100 years per second)

RSQSim Rupture Slip-Time Histories

- RSQSim provides full slip-time functions for all ruptures
  - Example (right): M7.45 on SAF Mojave
- Can be used directly as input to deterministic ground motion simulations
- Unlike kinematic rupture generators, no prescribed rupture properties
  - Stress drop, hypocenter, roughness, etc, dependent on global frictional parameters and state of stress at nucleation



2021 Paper: Physics-Based Nonergodic PSHA

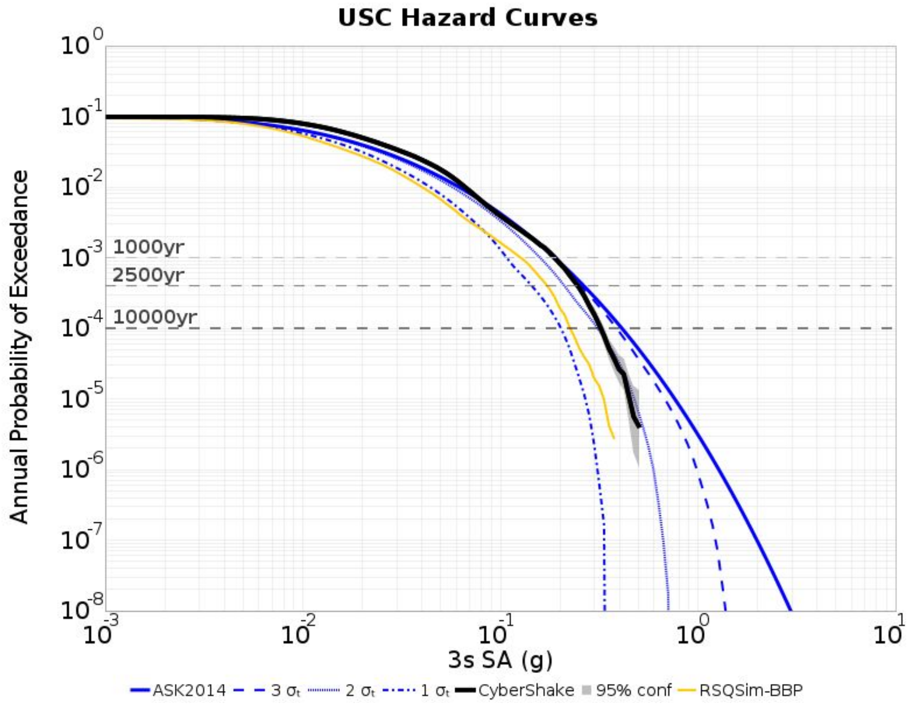
- Published in BSSA, January 2021
- Used RSQSim catalog & slip-time histories directly as input to CyberShake for ground-motion calculations
  - Long period: 0.5 Hz, T≥3s
- Focus on variability
  - Model contains comparable amount of within-event variability as empirical studies
  - Between-event variability is a little low
- RSQSim improvements for better rupture propagation velocities

RESEARCH ARTICLE | JANUARY 05, 2021

Toward Physics-Based Nonergodic PSHA: A Prototype Fully Deterministic Seismic Hazard Model for Southern California

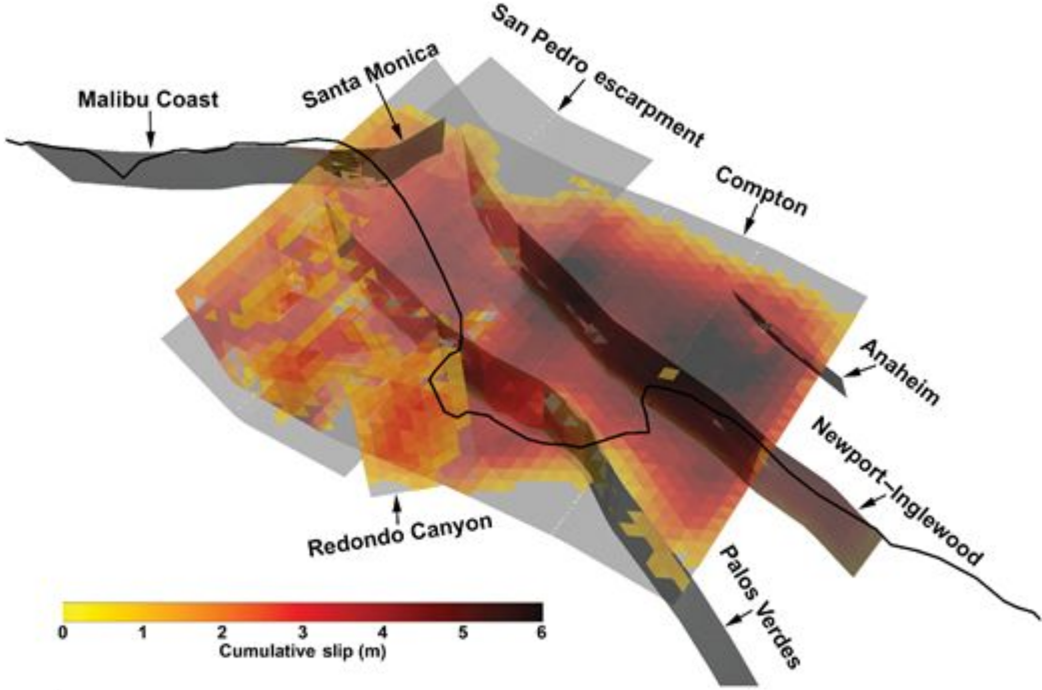
Kevin R. Milner; Bruce E. Shaw; Christine A. Goulet; Keith B. Richards-Dinger; Scott Callaghan; Thomas H. Jordan; James H. Dieterich; Edward H. Field

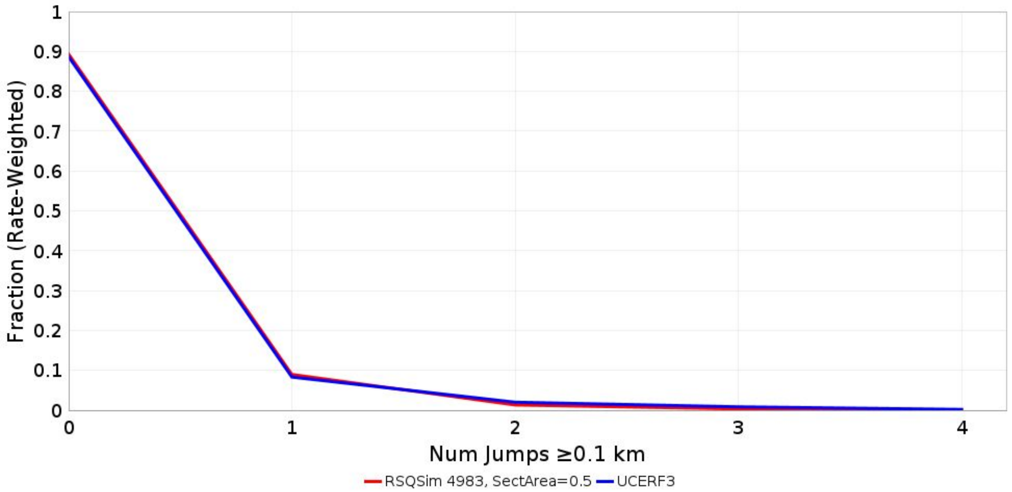
Bulletin of the Seismological Society of America (2021) 111 (2): 898–915.
https://doi.org/10.1785/0120200216 Article history



Multifault Ruptures

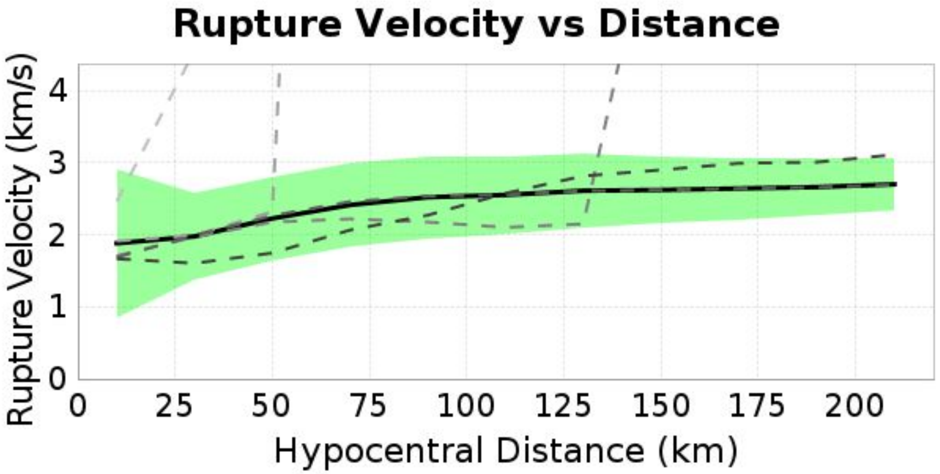
- Unlike prior CyberShake studies, model contains many multi-fault ruptures
  - Similar rate of multi-fault ruptures as exist in UCERF3
  - 10% of ruptures (~22k) have a jump of 0.1 km or greater
- Might be useful to constrain empirical GMMs & directivity models for complex ruptures

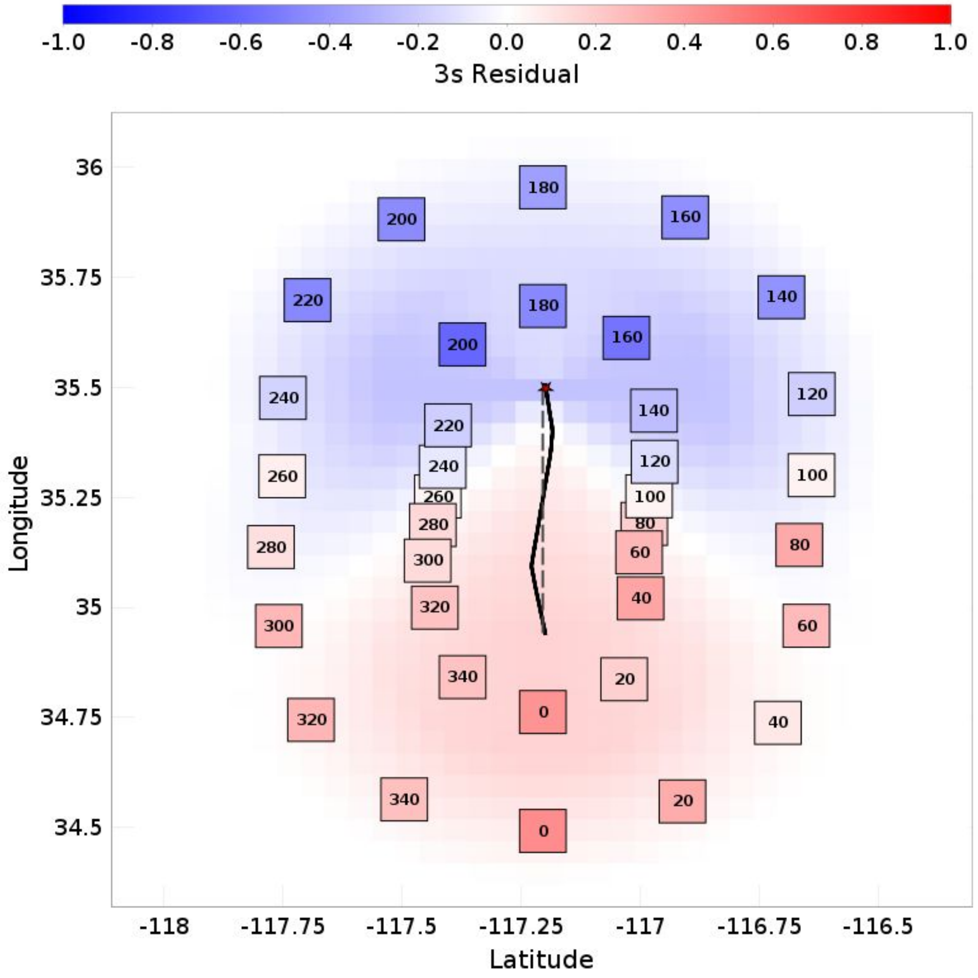




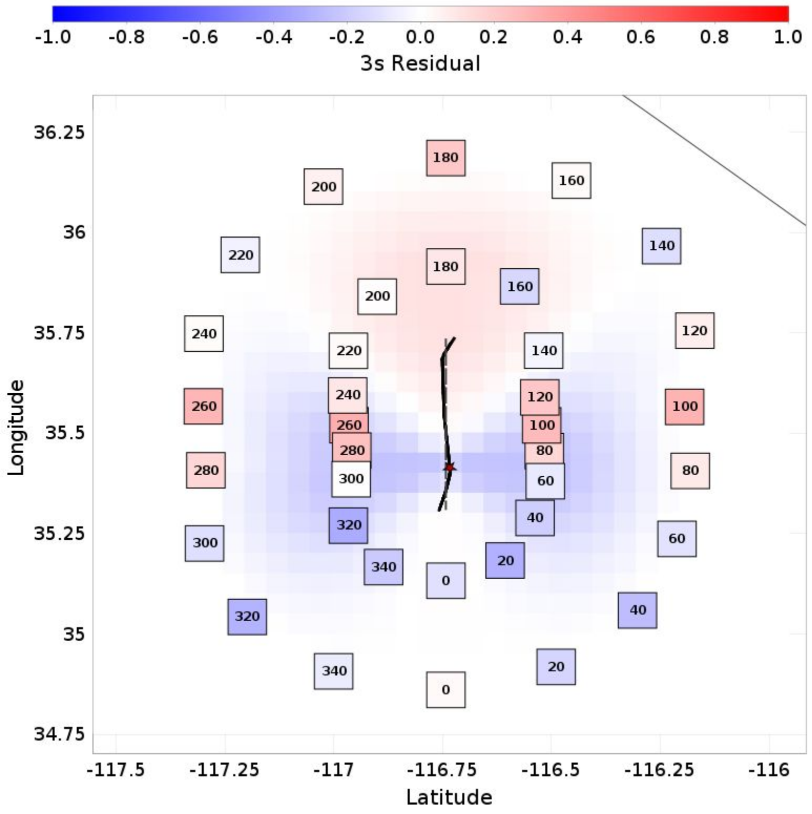
Directivity Comparisons

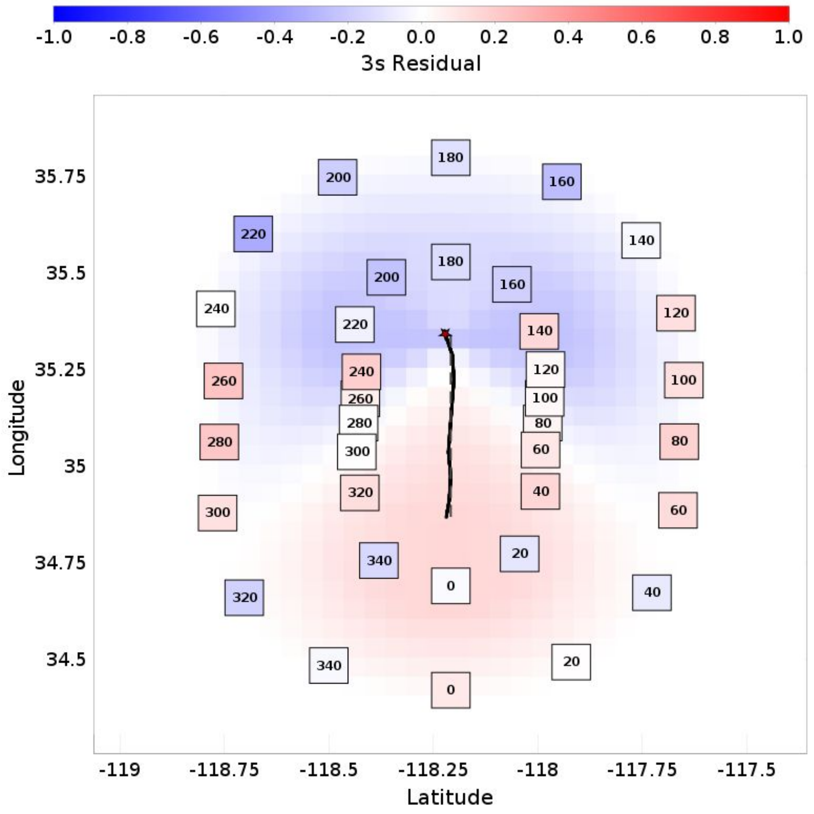
- Compared RSQSim-CyberShake ground motions to Bayless-Somerville (2013) directivity model
- Final model has good agreement
  - Early models had slow rupture propagation velocities, and low directivity

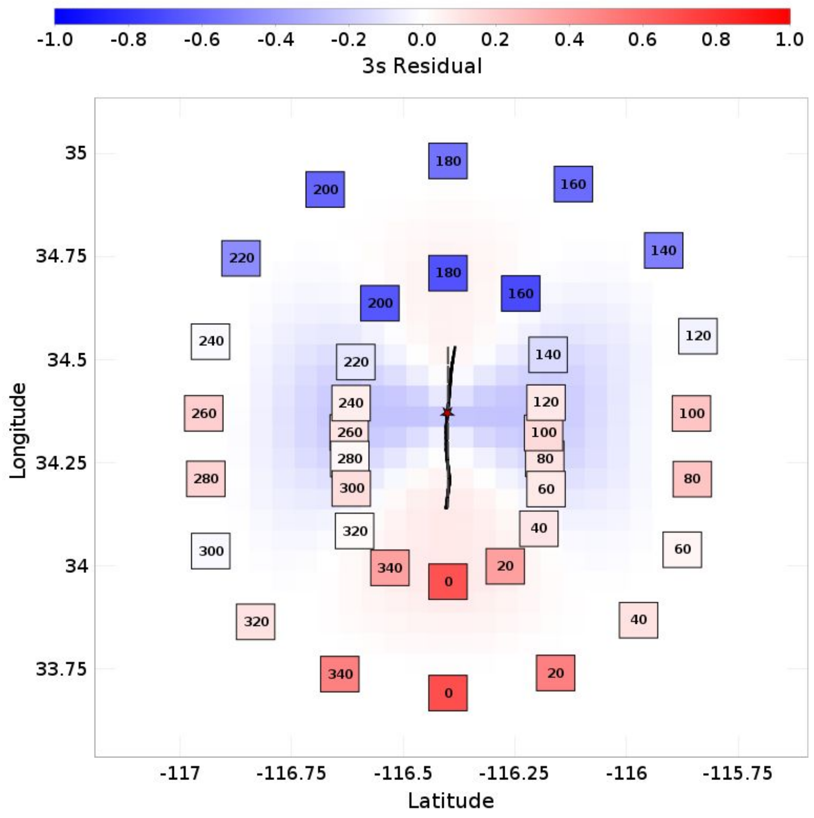




More Directivity Examples



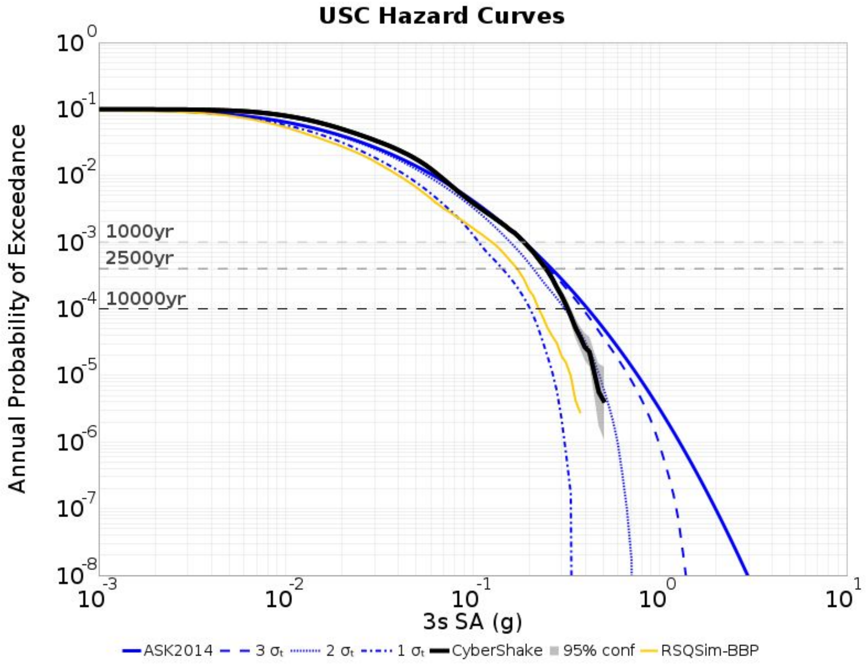




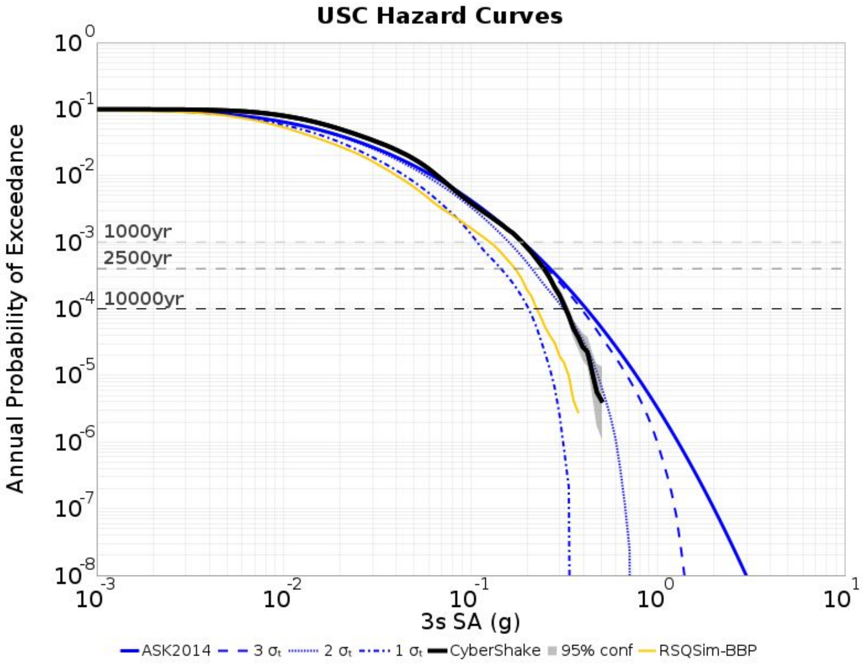
Verification Tests

Can we reproduce the 2021 paper (ERF 58) calculations? **YES**

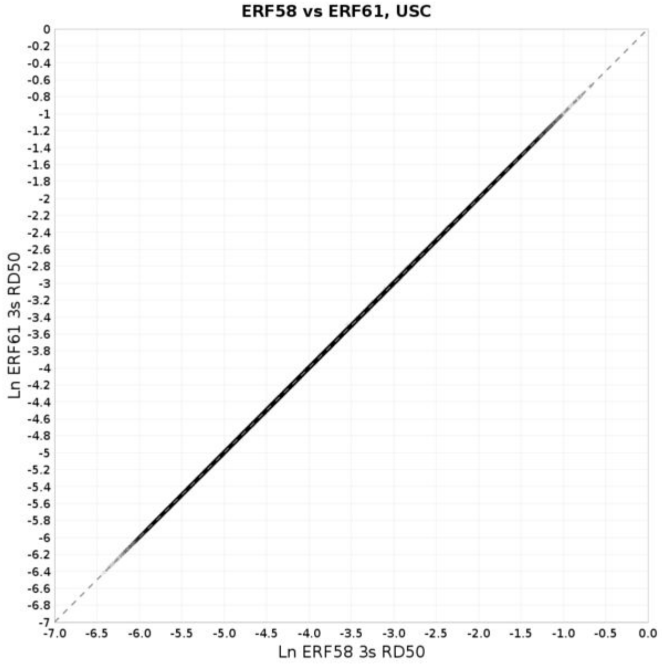
ERF 58



ERF 61



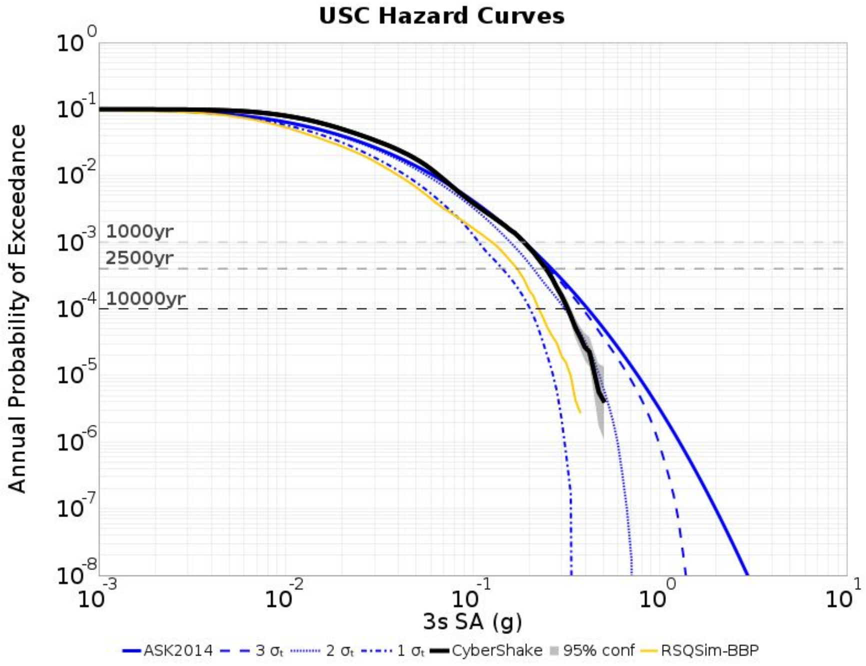
Amplitude Scatter Plot



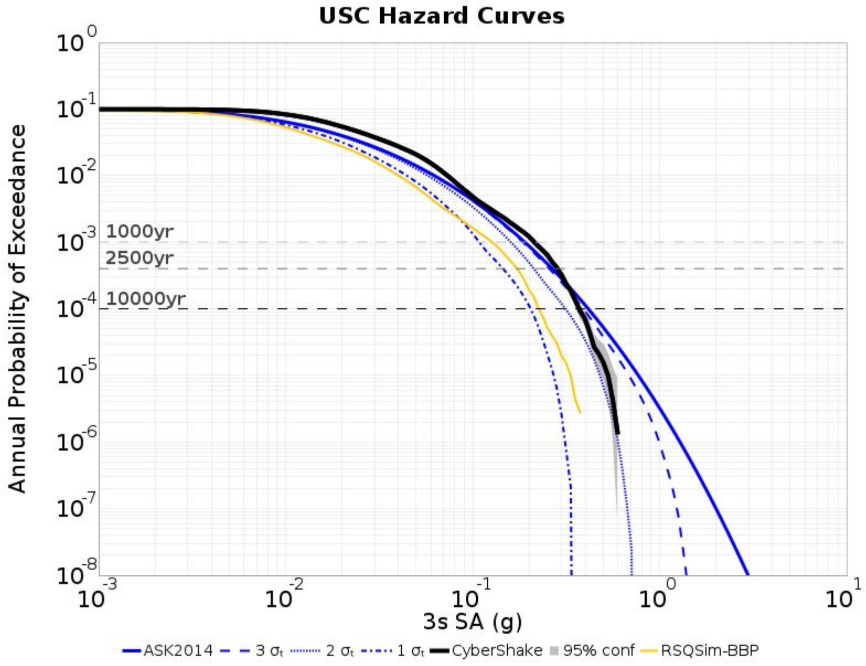
Verification Tests

Are 0.5 Hz and 1 Hz runs identical? **NO**

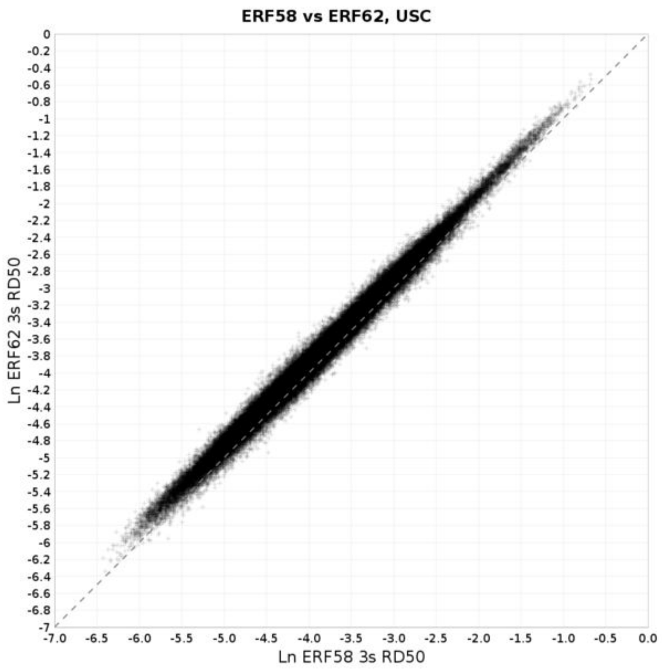
ERF 58 (0.5 Hz)



ERF 62 (1 Hz)

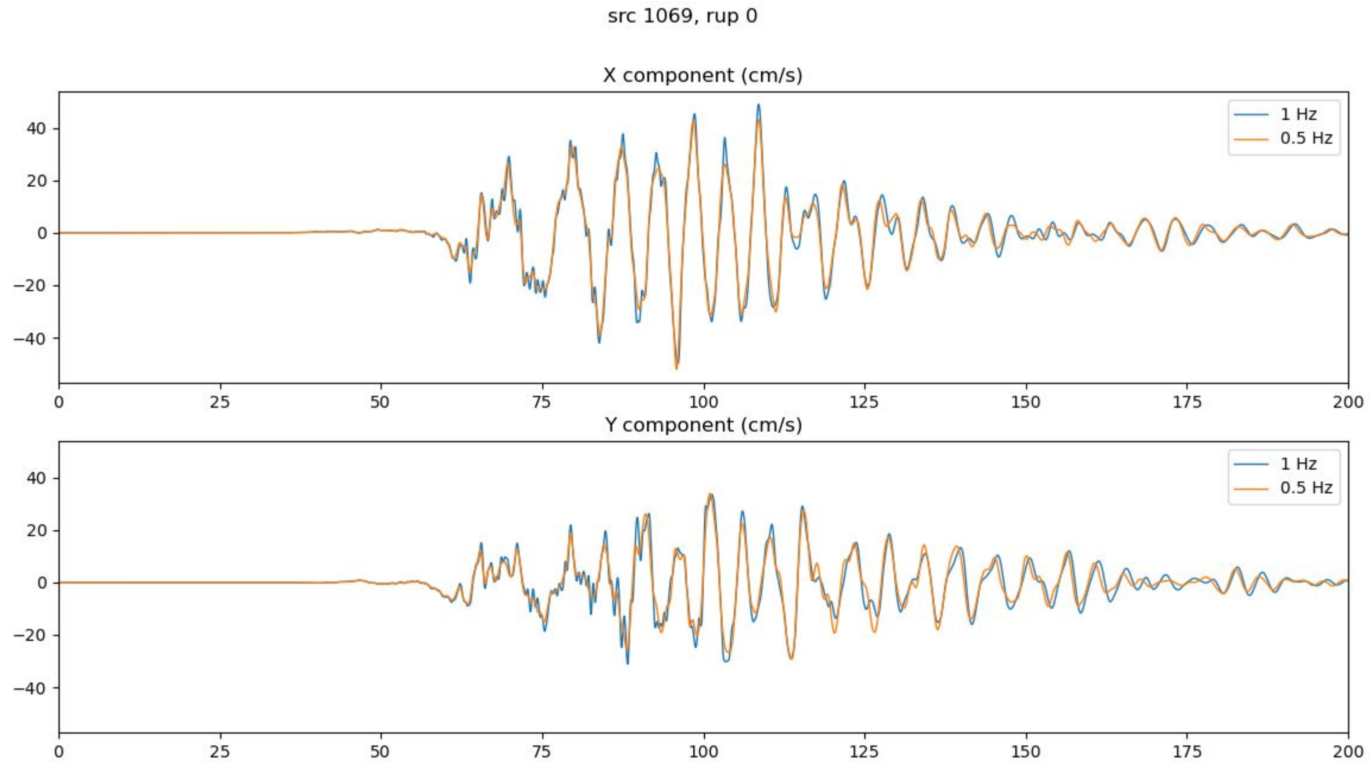


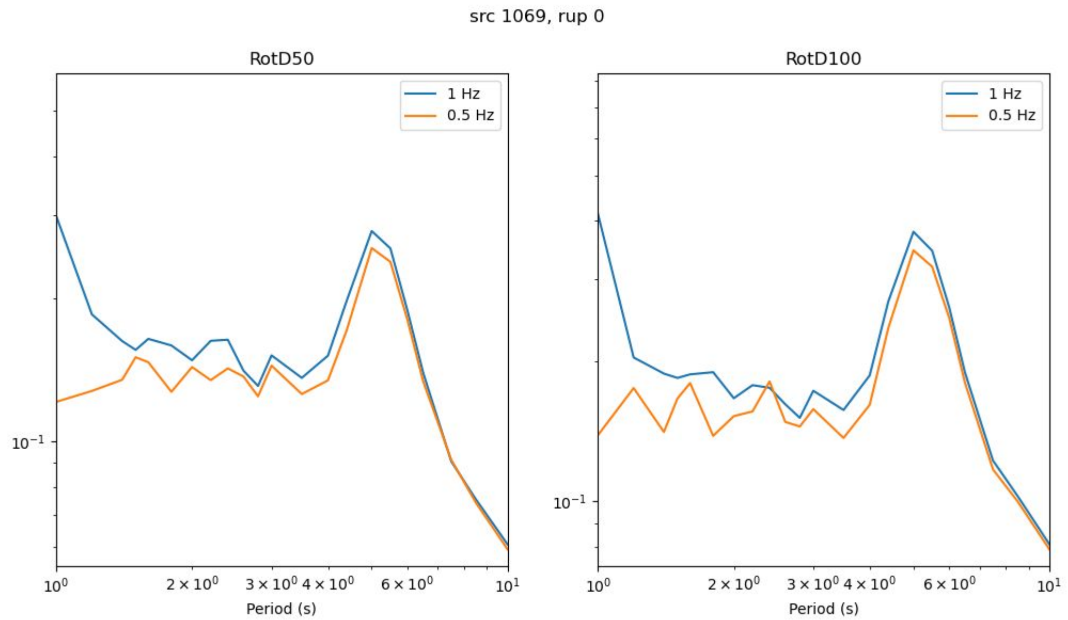
Amplitude Scatter Plot



Verification Tests

Are 0.5 Hz and 1 Hz runs identical? **NO**



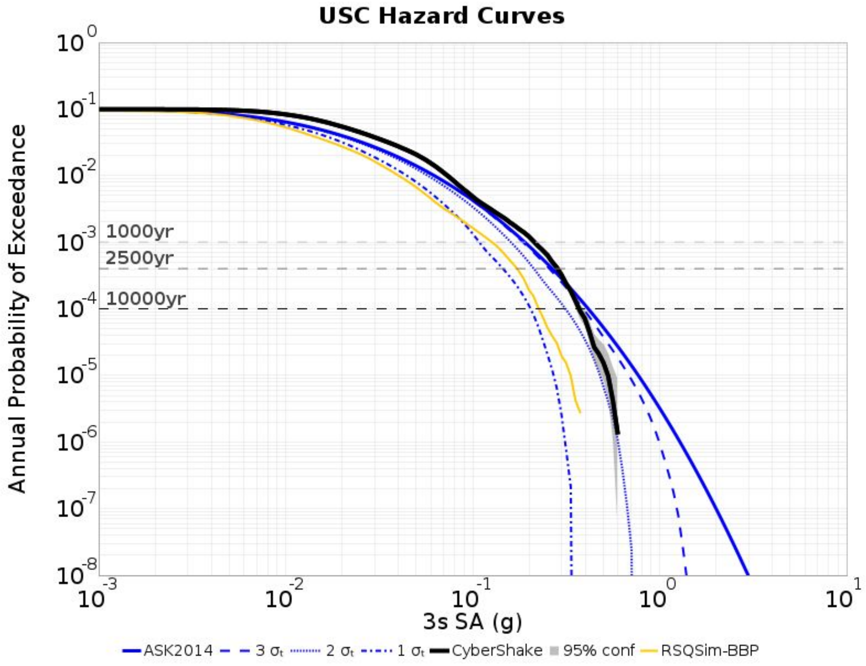


Verification Tests

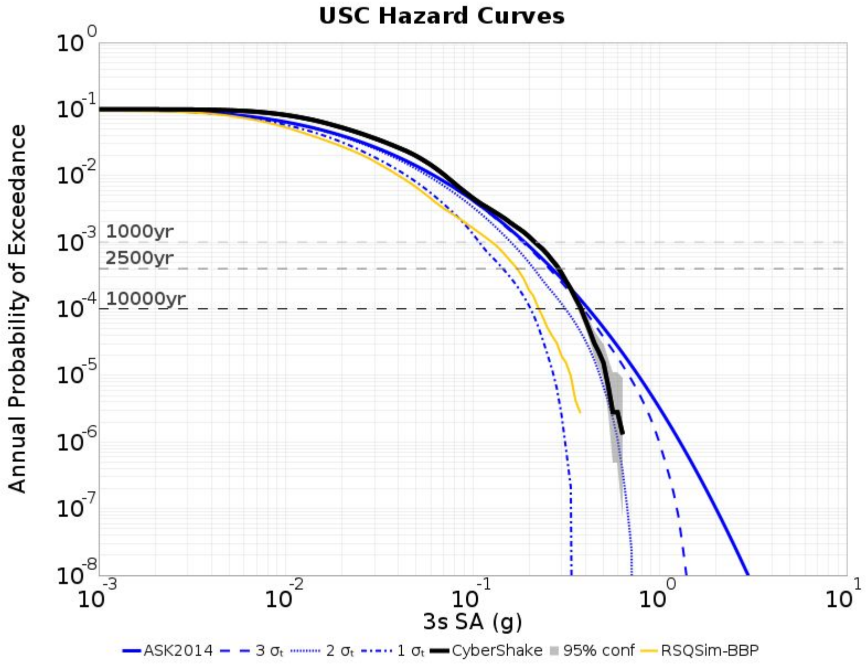
How do new simulation parameters affect results? **A little***

* This run accidentally did not have the new H/4 upper mesh velocity point setting enabled, rerun is in progress

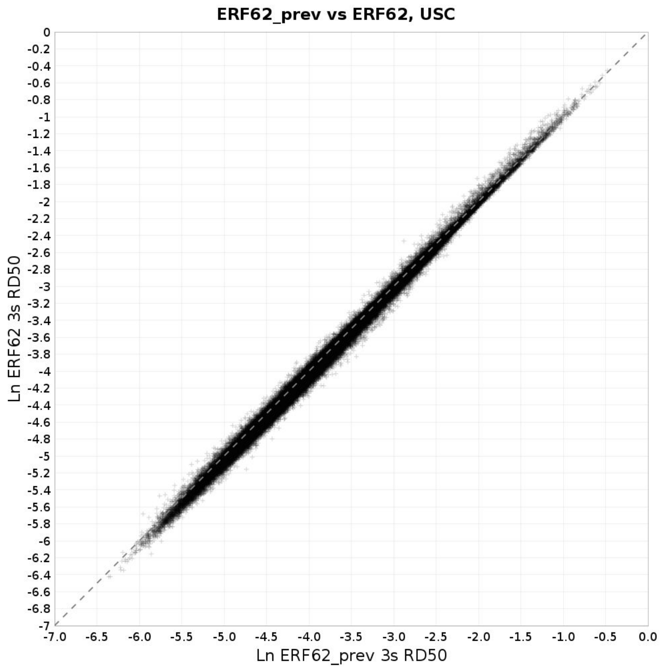
ERF 62 (1 Hz, orig params)



ERF 62 (1 Hz, production params)

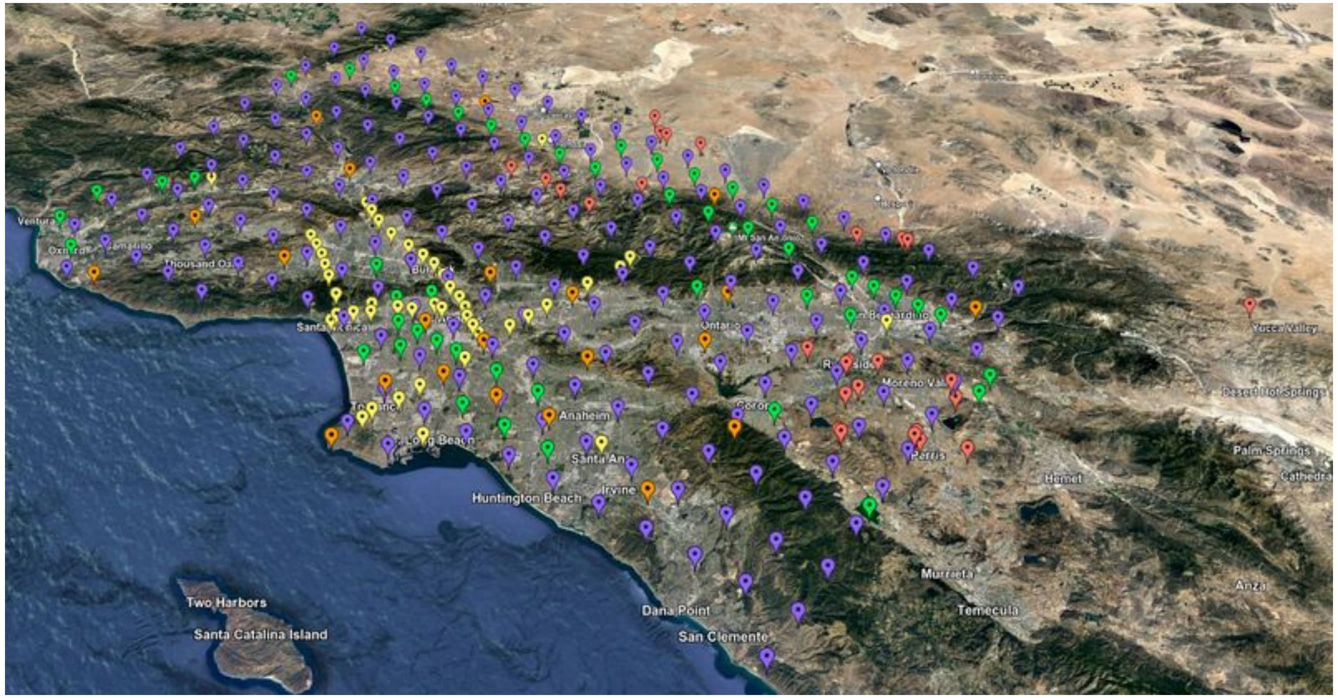


Amplitude Scatter Plot



335 Proposed Study Sites

- Set from Study 15.4
  - Diablo Canyon removed
- Site calculation order:
  - 10 sites used in 2021 paper
    - All have surface Vs=500 m/s
  - PAS
    - Hard rock test site
  - 20 km grid
  - 10 km grid
  - Additional POI’s & extra 5 km grid sites used in 15.4



Data Products: File-Based (at CARC)

- Seismograms:
  - 2-component seismograms, 8000 timesteps (400 sec) each
- PSA, X and Y spectral acceleration at 44 periods:
  - 10, 9.5, 9, 8.5, 8, 7.5, 7, 6.5, 6, 5.5, 5, 4.8, 4.6, 4.4, 4.2, 4, 3.8, 3.6, 3.4, 3.2, 3, 2.8, 2.6, 2.4, 2.2, 2, 1.66667, 1.42857, 1.25, 1.11111, 1, .66667, .5, .4, .33333, .285714, .25, .22222, .2, .16667, .142857, .125, .11111, .1 sec
- RotD50, the RotD50 azimuth, and RotD100 at 22 periods:
  - 1.0, 1.2, 1.4, 1.5, 1.6, 1.8, 2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.5, 4.0, 4.4, 5.0, 5.5, 6.0, 6.5, 7.5, 8.5, 10.0 sec
- PGV (t=1e-5)
- Durations:
  - for X and Y components, energy integral, Arias intensity, cumulative absolute velocity (CAV), and for both velocity and acceleration, 5-75%, 5-95%, and 20-80%

Data Products: SQL Database

- To be inserted into the SQL database (moment.usc.edu):
  - PSA: none
  - RotD: RotD50 and RotD100 at 10, 7.5, 5, 4, 3, and 2 sec.
  - PGV
  - Durations: acceleration 5-75% and 5-95% for X and Y components
  - RotD50 hazard curves

Other Products

- RotD50 hazard maps at 2, 3, 5, 7.5, and 10 s
- Empirical GMM comparisons (z-score histograms)
- In development:
  - Ground motion azimuthal and directivity comparisons
  - Decompose variability components:
    - Estimate within- and between-event sigma
  - Collaborate with Xiaofeng Meng on mixed effects regression analysis

Velocity Model: CVM-S4.26.M01

- We will use CVM-S4.26.M01
- Populate the velocity parameters for the surface point by querying the velocity model at a depth of (grid spacing)/4
  - For this study, the grid spacing is 100m, so we will query UCVM at a depth of 25m and use that value to populate the surface grid point
  - The rationale is that the media parameters at the surface grid point are supposed to represent the material properties for [0, 50m], and this is better represented by using the value at 25m than the value at 0m
  - This should improve empirical GMM comparisons for rock sites

Study 21.12 Parameters

- 1.0 Hz deterministic
  - 100 m grid spacing
  - 50 km depth
  - SGT dt = 0.005 sec
  - SGT nt = 40000 timesteps (200 sec)
  - Seismogram nt = 8000 timesteps (400 sec)
  - Minimum Vs=500 m/s
- Source filtered at 2.0 Hz
- RSQSim Catalog 4983 ERF
  - 220,927 M≥6.5 ruptures
  - SRF dt=0.05 s

2021 Platform Updates

- SGT parameters
  - Changed sponge zone width from 50 to 80 grid points
  - Changed padding from 30 km to 50 km
  - FP was modified from 0.5 to 1.0
  - mu and lambda are no longer adjusted.
  - The impulse is inserted by modifying velocities.
- SGT code modifications
  - Kernel updated
  - The original media parameter values of mu and lambda are used when calculating strain.
- Other updates
  - Qs in SGT header generation code changed to Qs=0.05Vs
  - Fixed off-by-one error in z-coordinate conversion

Computational Plan

- Prioritize SGT calculations on Summit before allocation ends
  - Only initially run post-processing for 10 sites from 2021 paper, plus PAS
- Post process on Summit until INCITE allocation expires on 1/31/22
  - We anticipate finishing before the end of January

Storage Requirements

- Summit
  - 240 TB temp data
  - **66 TB SGTs**
  - 1.5 TB output files
  - The default quota on Summit is 50 TB
    - TODO: Request a quota increase to 400 TB so we don't need to rely on cleanup
  - If we need to keep the SGTs for awhile before performing post-processing, the quota on HPSS is 100 TB, so we could store them there
- CARC/SCEC
  - 1.2 TB output files on /project
  - ~200 GB workflow logs (1.7 TB free on /home/shock)
  - ~38 GB database insertions (drive on moment.usc.edu has 919 GB free)

Estimated Duration

- Limiting factors:
  - Queue times on Summit are currently long
    - Unsure if this will improve once the holidays begin and in January
  - Database insertion performance
    - In Study 18.8, caused workflows to back up
- Estimated completion time is 3 weeks
  - For Study 18.8, we were able to average 4.3% of Titan
  - Averaging 4.3% of Summit would enable completion in ~10 days, but queue times may be long

Risks

- Not finishing SGTs on Summit before allocation expires
  - Possible backups: Perlmutter? INCITE discretionary allocation?
- Trouble storing SGTs between SGT and post processing workflows
  - Request quota increase on Summit
  - Ensure HPSS would be available after January
  - Other potential options:
    - Ranch tape storage at TACC
    - Work with CARC for more /project storage

Pending Science To-Dos

- Rerun 1 Hz USC test with ERF 62

SCEC
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