CyberShake Study 22.12 Science Readiness Review

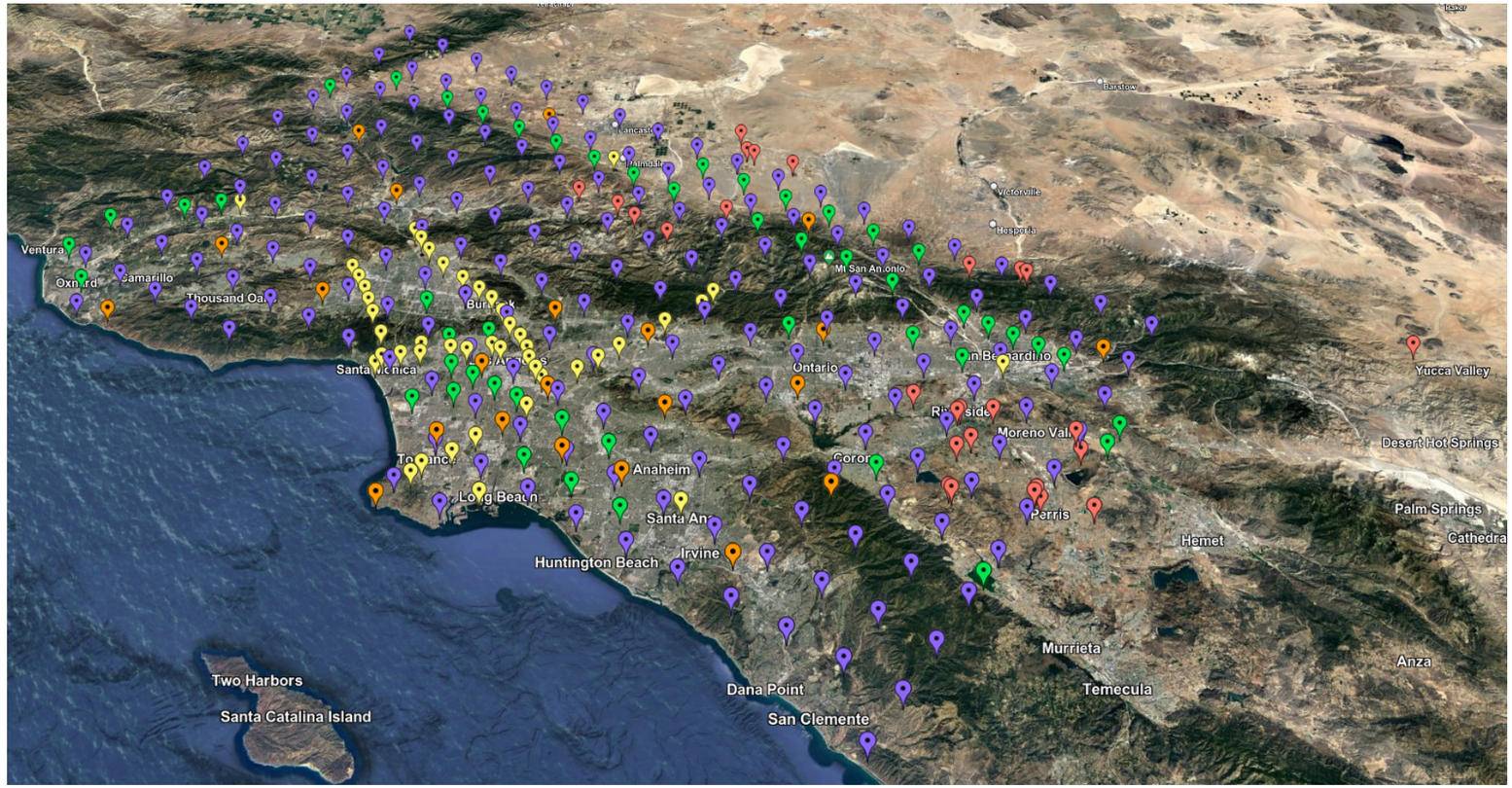
Scott Callaghan

Study 22.12 Scientific Goals

- Perform an updated Broadband CyberShake calculation in Southern California.
  - First since Study 15.12
  - BBP v22.4 codes used for high-frequency calculation
- Calculate CyberShake results with a modified velocity model.
  - Merged taper model, using CVM-S4.26.M01 with the Ely-Jordan taper to 700m
- Use an updated version of the Graves & Pitarka rupture generator
  - V5.5.2, same as is used in the BBP v22.4
  - Includes sampling of variability in rupture velocity
  - Denser hypocentral spacing (4.5 km to 4 km) → 31% more variations/site

Proposed Study sites

- Same 335 sites as were used in Study 21.12
- Site calculation order:
  - Standard 10 (USC, PAS, LADT, LBP, WNGC, SABD, SBSM, FFI, CCP, SMCA)
  - 20 km grid
  - 10 km grid
  - Additional POIs, PBRs, broadband stations
  - 5 km grid sites



Study 22.12 Data Products

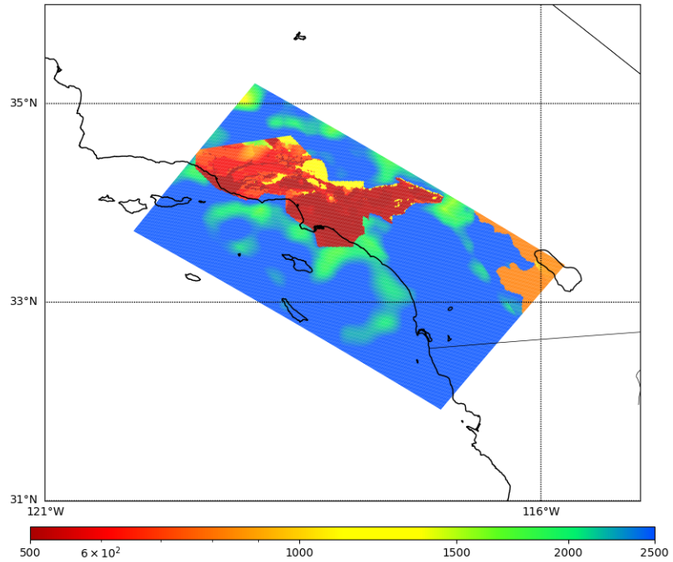
- Two-component seismograms (626k/site x 335 sites x 2 = 420 million)
- Intensity measures
  - Deterministic
    - RotD50 and 100 at 25 periods (1-20 sec) + PGV (https://strike.scec.org/scecpedia/CyberShake_Study_22.12#Deterministic)
    - 2, 3, 4, 5, 7.5, and 10 sec for RotD50 and RotD100 stored in DB
  - Broadband
    - RotD50 and 100 at 66 periods (0.01-20 sec) + PGA, PGV (https://strike.scec.org/scecpedia/CyberShake_Study_22.12#Broadband)
    - 19 periods, PGA, PGV stored in DB
- Duration metrics (same for both deterministic and broadband)
  - Energy integral, Arias intensity, cumulative absolute velocity, significant durations (5-75%, 5-95%, 20-80%) for velocity and acceleration and X and Y
  - Acceleration 5-75% and 5-95% for X and Y stored in DB
- Hazard curves for 335 sites (0.1, 0.2, 0.5, 1, 2, 3, 4, 5, 7.5, 10 sec)
- RotD50 hazard maps at 0.1, 0.2, 0.5, 1, 2, 3, 5, and 10 sec

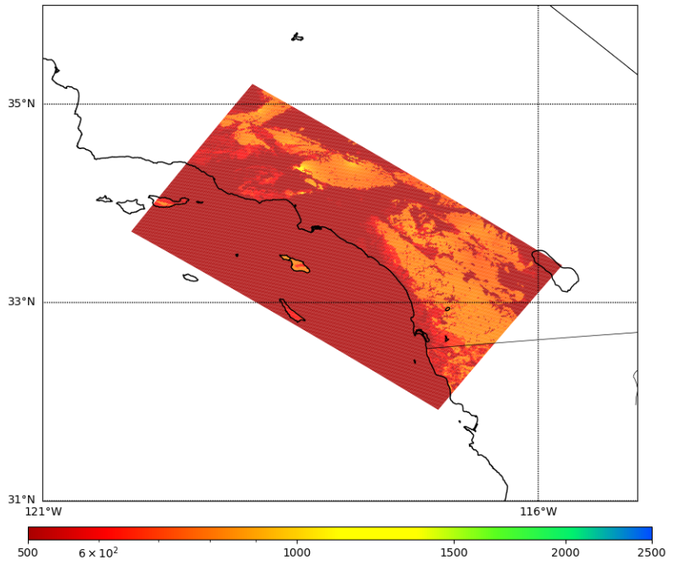
Velocity Model

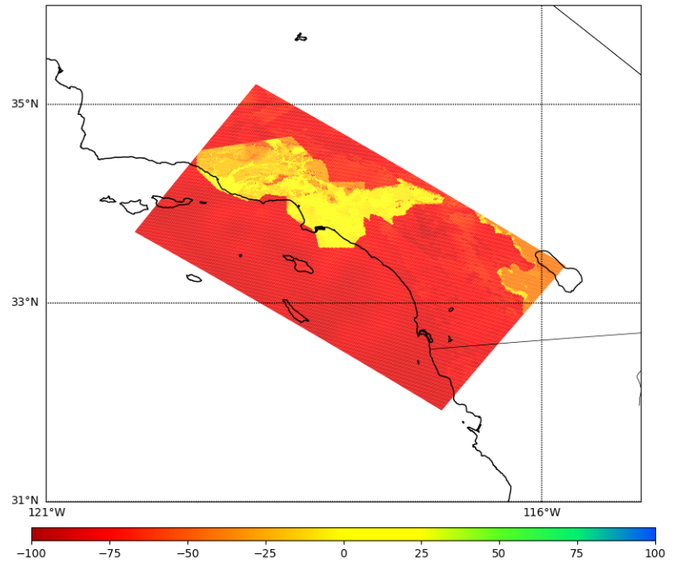
- Modification to velocity model generation to reduce high near-surface values outside of basins
- For mesh points in the top 700m:
  - Query CVM-S4.26.M01 model
  - Calculate the velocity values using the Ely-Jordan taper, with a depth of 700m
  - Select the approach which produces the smaller Vs value
- For deeper points, just use CVM-S4.26.M01
- Vp/Vs ratio is now preserved
  - If Vs floor (500 m/s) is applied, Vp is scaled to preserve ratio
- Surface point is populated by querying at depth 25m

CVM-S4.26.M01 | Merged taper | Percent difference

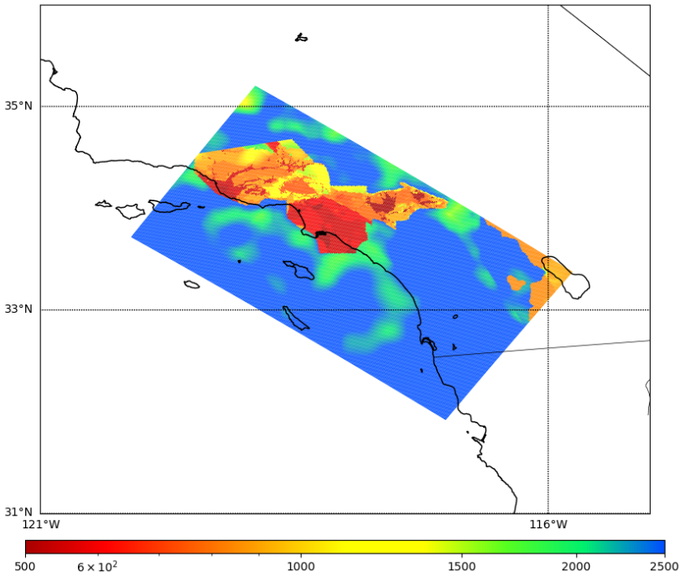
Surface (25m)

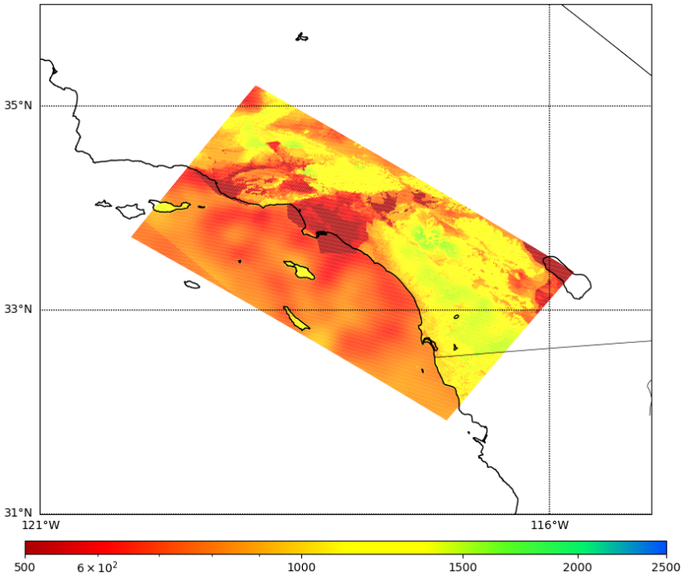


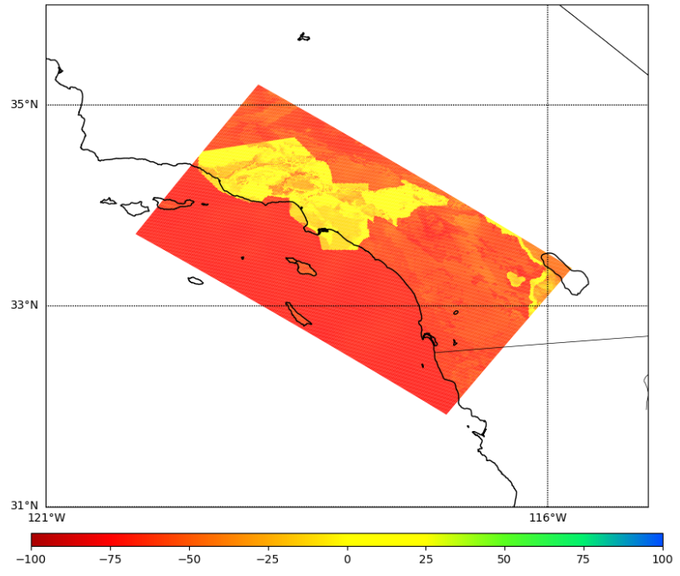




100m



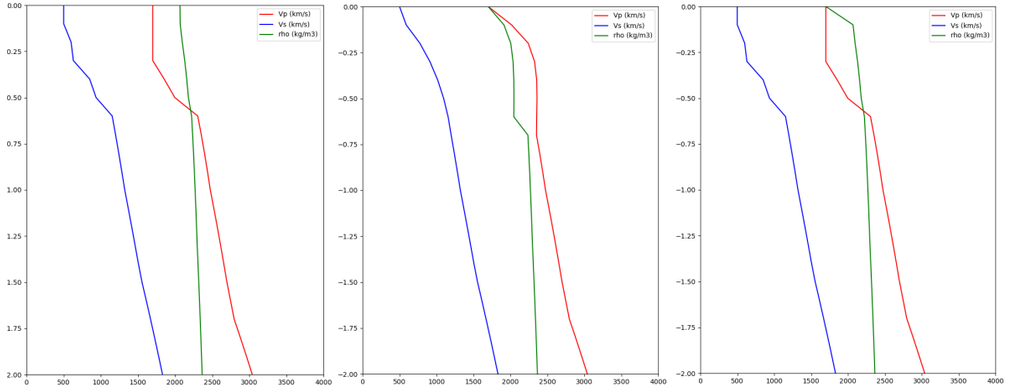




Additional cross-sections available at https://strike.scec.org/scecpedia/CyberShake_Study_22.12#Cross-sections

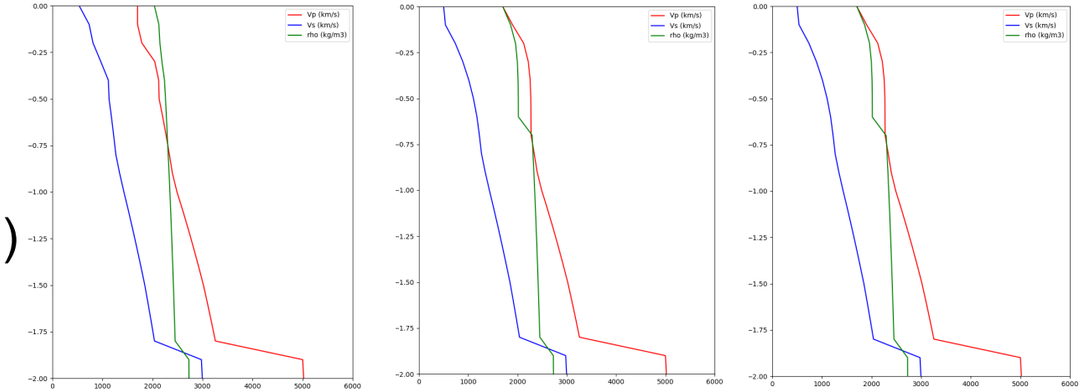
CVM-S4.26.M01 | Taper | Merged Taper

USC (in basin)

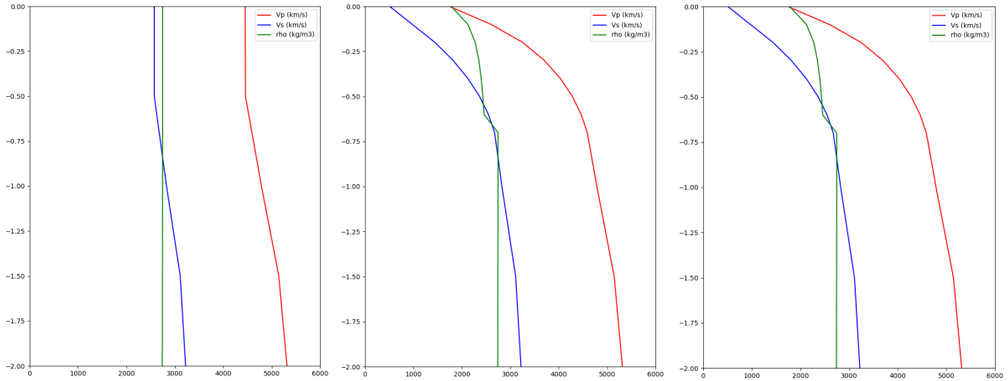


CVM-S4.26.M01 | Taper | Merged Taper

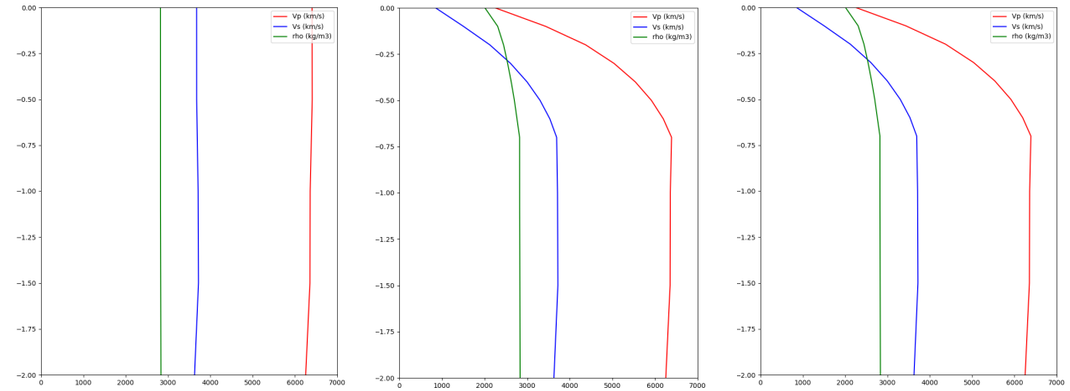
SBSM (in basin)



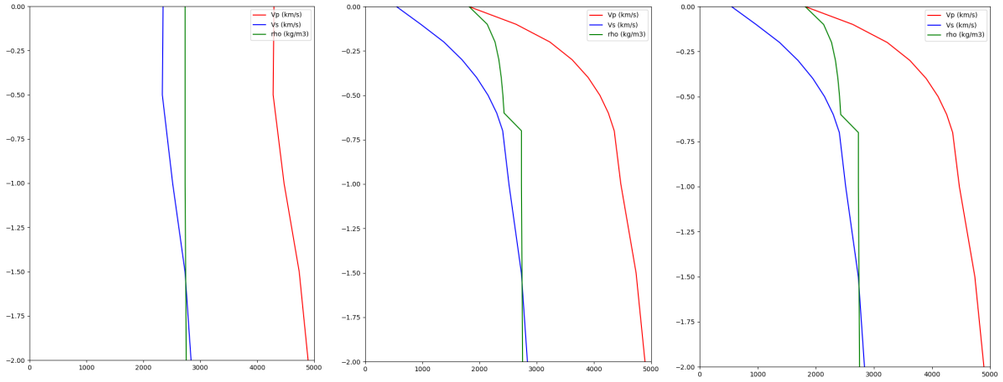
LAPD (out of basin)



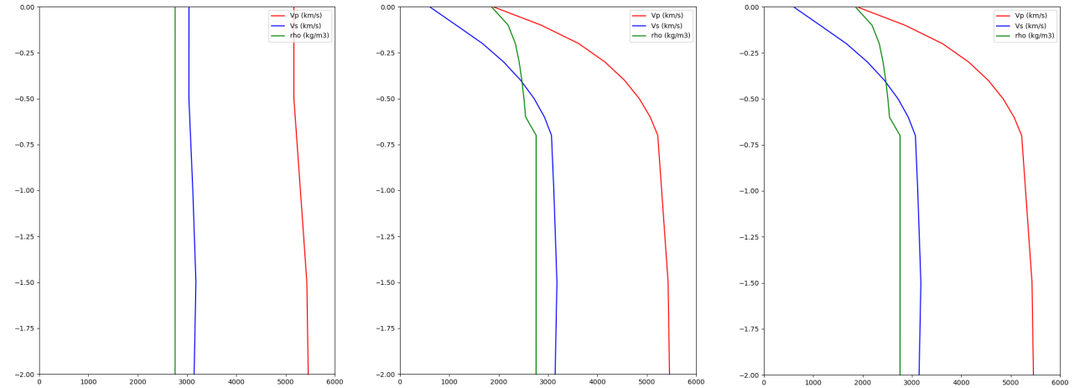
PERR (out of basin)



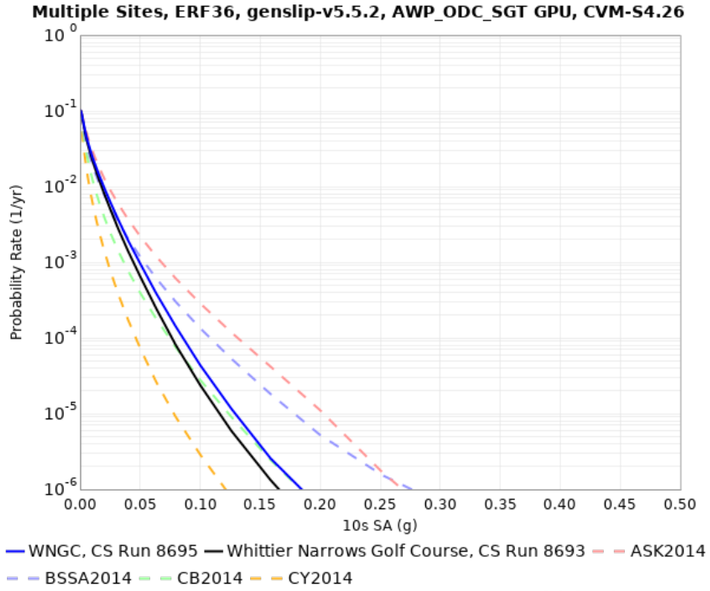
MRVY (out of basin)

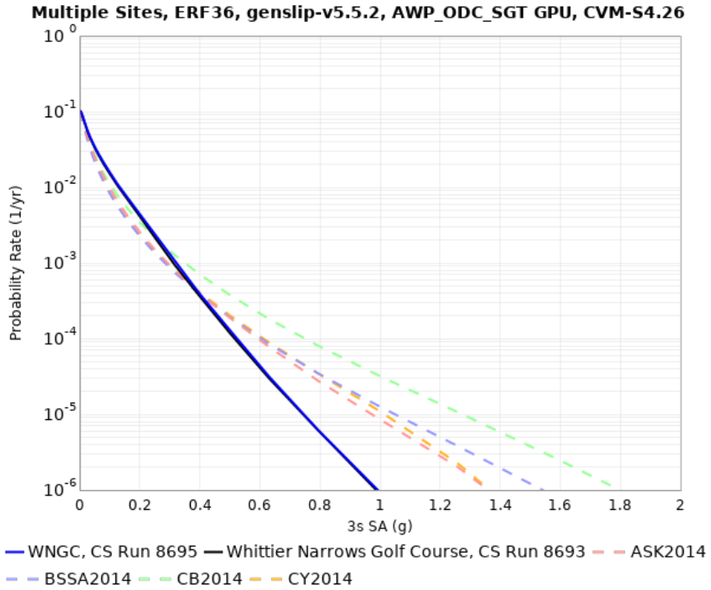


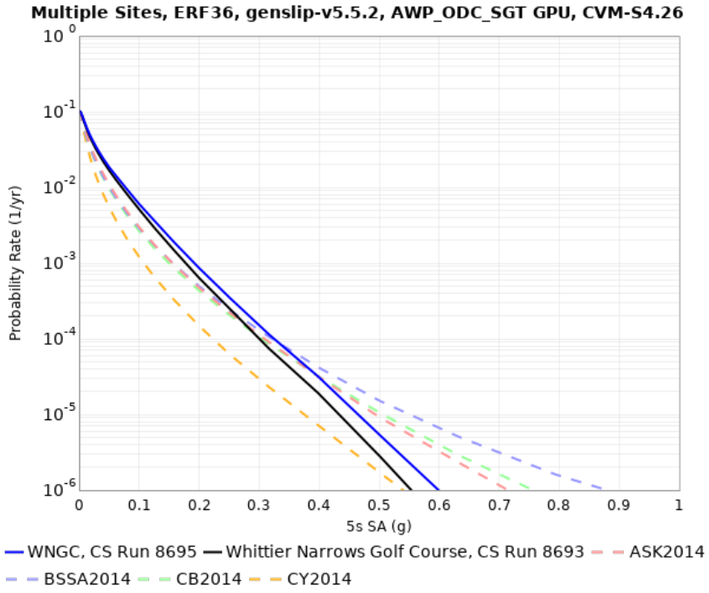
s035 (out of basin)

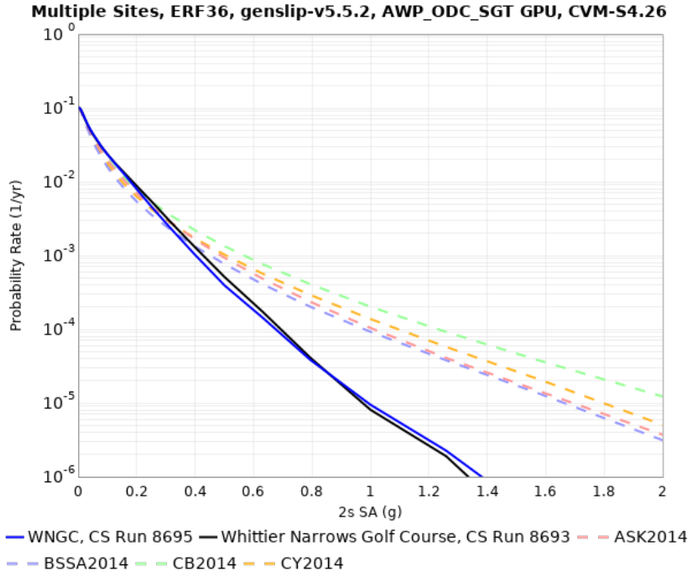


Impact on Hazard



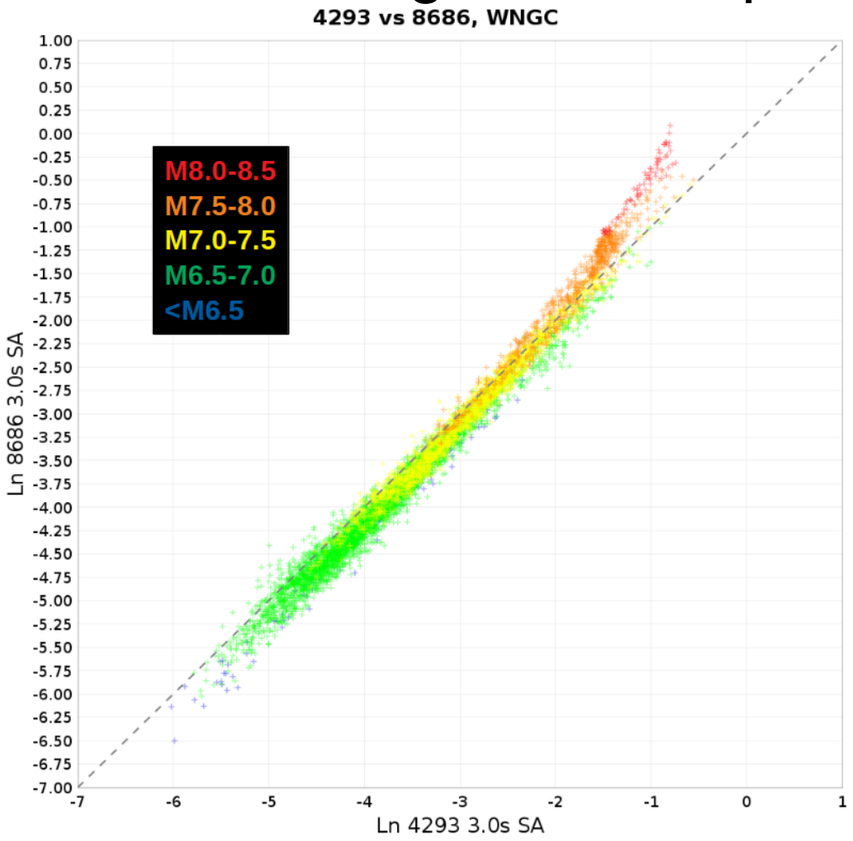




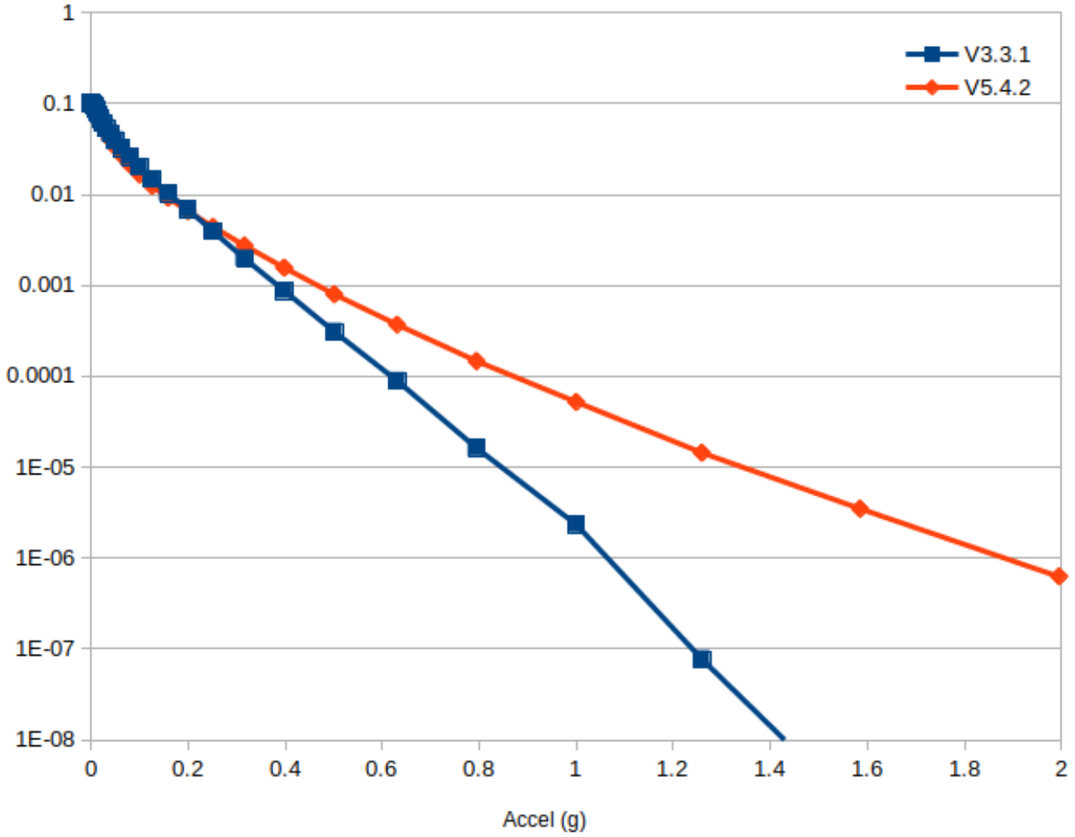


Rupture Generator

- Originally looked at GP v5.4.2
  - Produced larger-than-expected ground motions at 2-3 sec for M8+ sSAF events



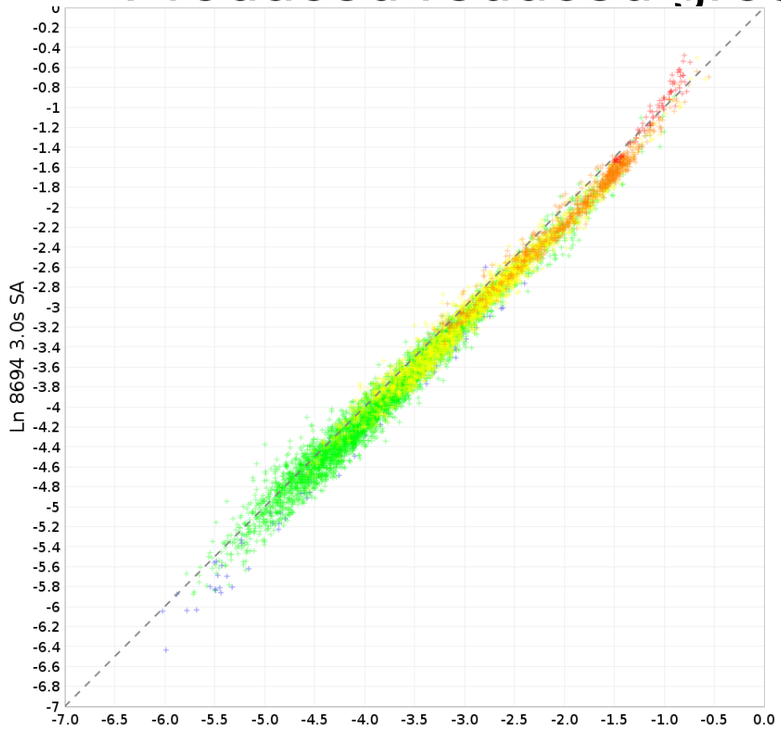
WNGC, 3 sec, v3.3.1 vs v5.4.2



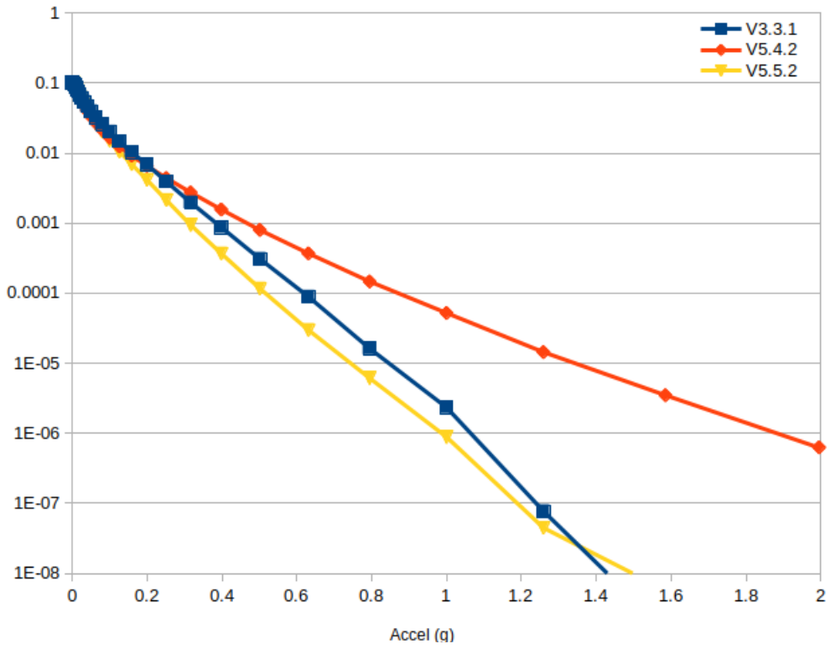
WNGC, 3 sec, v3.3.1(blue) vs v5.4.2 (red)

Rupture Generator

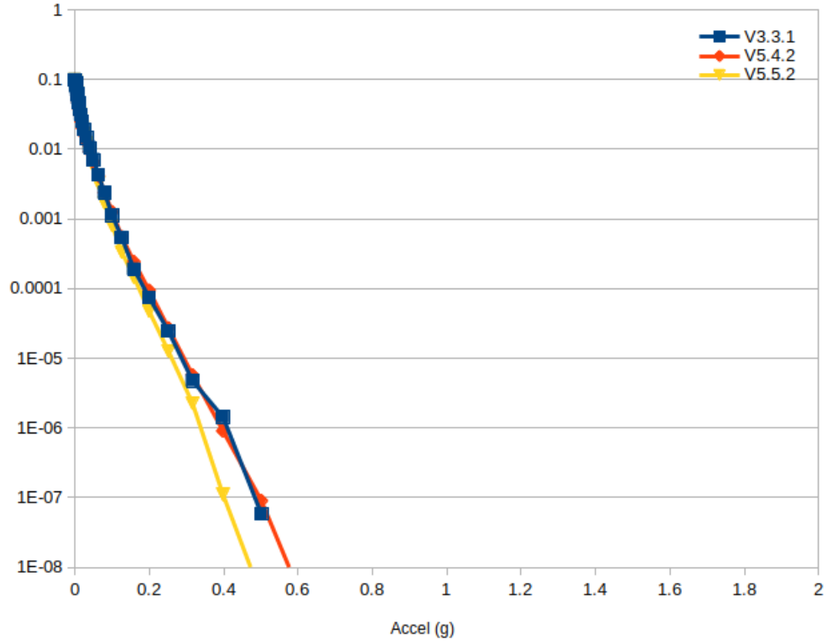
- Updated to GP v5.5.2
  - Correlates risetime and slip more strongly
  - Modified risetime value of 2.3 (slower risetimes)
  - Produced reduced ground motions in keeping with expectations



WNGC, 3 sec, v3.3.1 vs v5.5.2



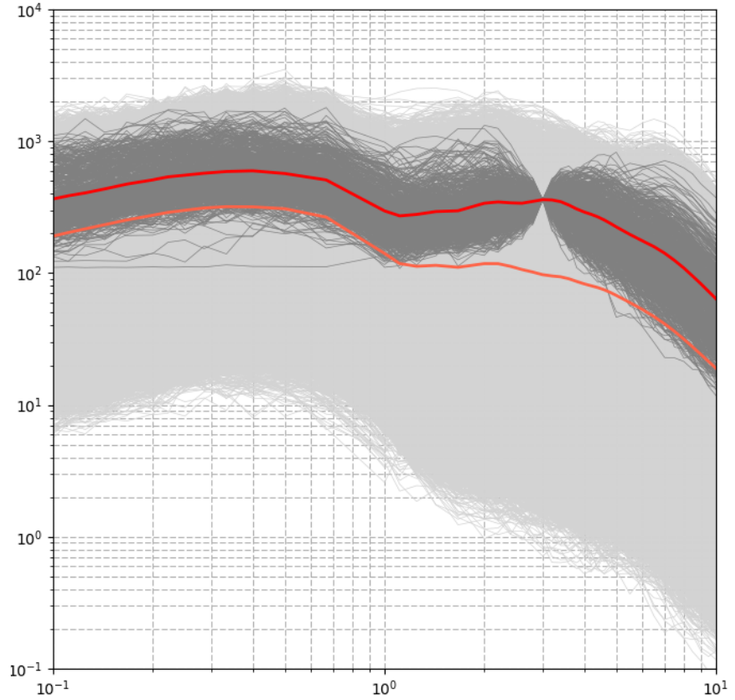
WNGC, v3.3.1 (blue), v5.4.2 (red), v5.5.2 (yellow)



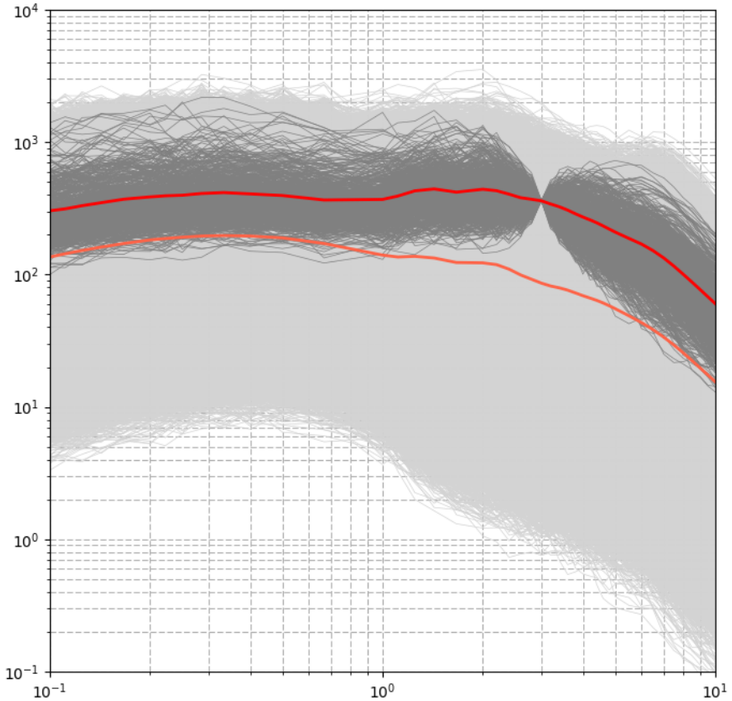
PAS, v3.3.1 (blue), v5.4.2 (red), v5.5.2 (yellow)

Spectral Discontinuity

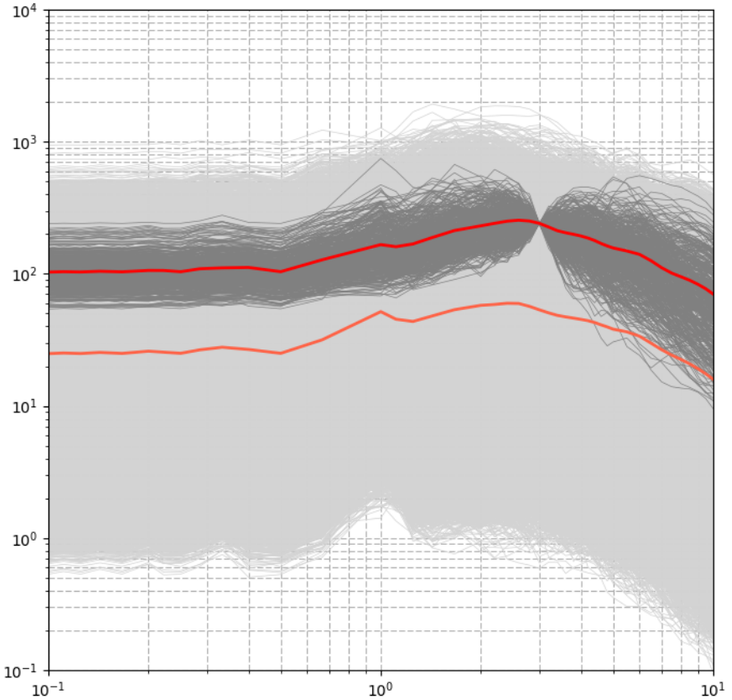
- Study 15.12 spectral discontinuities around 1 Hz seem resolved
  - Rupture variations at 3 sec geo mean within 1% of target (dark gray)
  - All rupture variations (light gray)
  - Improvements due to combo of rupture generator and HF code



WNGC from Study 15.12



WNGC, Study 22.12 config



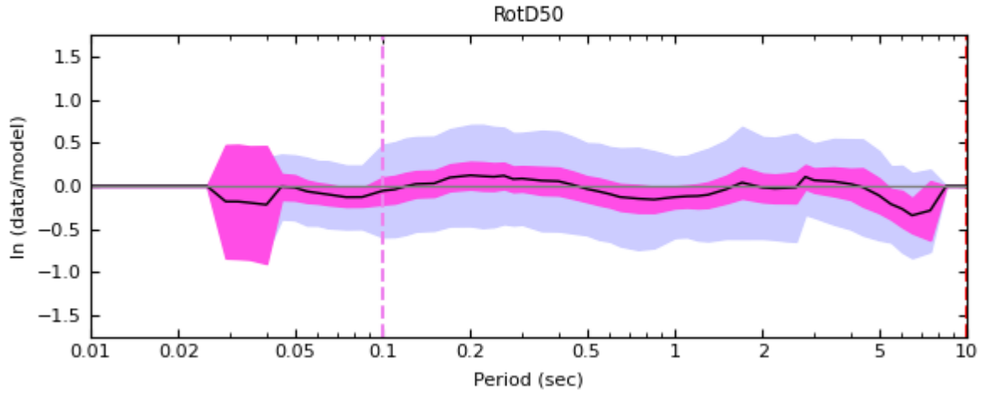
USC, Study 22.12 config

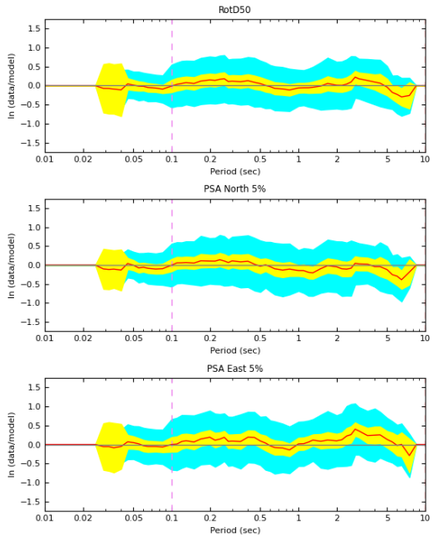
Rupture Velocity

- Previous CyberShake studies used constant rvfrac=0.8
- BBP has moved to sampling rvfrac from distribution
  - Uniformly distributed from [0.675, 0.875]
- To ensure reproducibility, we specify rvfrac
  - Calculate it using BBP codes
  - Store in database, for each variation
  - Pass into rupture generator when variations are created
- Use similar process for random seed

Validation

- Extensive validation against BBP and historic events has been performed throughout the study development
  - Northridge, Chino Hills, Whittier, Landers
  - Steps in validation documented at https://strike.scec.org/scecpedia/Broadband_CyberShake_Validation
- Northridge (previous HF code)





Best CS realization

- Northridge and Landers (single-segment) rerunning with study config

Study 22.12 Parameters

- 1.0 Hz deterministic
  - 100 m grid spacing
  - 50 km depth
  - SGT dt = 0.005 sec, nt = 40000 timesteps (200 sec) for most, 60000 timesteps/300 sec if any hypocenter-site distances are greater than 450 km
  - Source filtered at 2 Hz
  - Seismogram dt=0.05, nt = 8000 timesteps (400 sec)
- 50 Hz stochastic
  - Seismogram dt=0.01, nt=40000 timesteps (400 sec)
  - High-frequency code hb_high v6.1.1
  - Merging performed over range (~0.9-1.1 Hz)
  - Site adjustments applied based on Vs30
- UCERF 2 ERF
- Graves and Pitarka (2022) rupture generator

Computational Plan

- Perform 20-site stress test
- Calculate SGTs for remaining 315 sites
- Calculate low-frequency post-processing for remaining 315 sites – this will use our remaining Summit allocation
  - Best to calculate this entirely on Summit, so SGTs don't have to be transferred.
- If we can, run broadband calculations on Summit
- If OLCF cuts us off, run broadband calculations on Frontera

Storage Requirements

- Summit (learned from Study 21.12 that no quotas are enforced on scratch)
  - 507 TB SGTs
  - 553 TB temporary data
  - 73 TB output data
- CARC
  - 73 TB output files to project storage
  - 66 TB free; will migrate additional pre-Study 15.4 data to OLCF HPSS
- Database on moment.usc.edu
  - 654 GB needed; moment has 379 GB on disk + 846 GB in database free
- Shock-carc workflow submission host
  - 737 GB workflow logs (1.5 TB free)

Estimated Duration

- At Study 21.12 throughput rates:
  - 116 days to use up Summit allocation
  - 252 days to finish study
- Anticipate higher throughput on Summit due to job bundling
- At Study 21.12 percentage of system usage, 88 days to complete broadband calculations on Frontera
- Overall estimated duration of 90 days on Summit + 88 days on Frontera with 30 days overlap = 150 days.

Risks

- Storage on Summit
  - ~460 TB for SGTs for 315 sites
  - May need to temporarily store them elsewhere (OLCF HPSS, CARC scratch, TACC Ranch)
- Storage on CARC
  - Plan to migrate more data to OLCF HPSS (can move ~1.5 TB/day)
  - After study completes, investigate data compression for seismograms
- Limited compute time on Summit
  - Move calculations to Frontera
  - Additional resources include CARC, Expanse, Perlmutter, Delta
- Reduced support during holidays

Action Items

- Finish and share Northridge and Landers validation results with Study 22.12 configuration