SCEC

The long-run computational challenges for using 3D simulations in seismic hazard analysis

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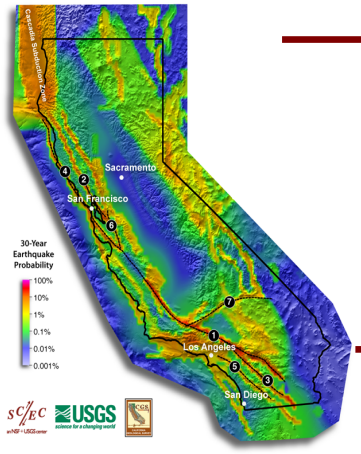
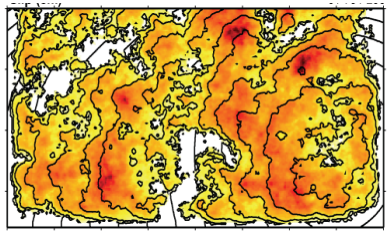
CyberShake Overview



Uniform California Earthquake Rupture Forecast

Graves-Pitarka kinematic rupture generator



UCVM

Mesh generation
1 job per site
MPI, 1500-4000 cores

AWP-ODC

SGT computation
2 jobs per site
MPI, 200-800 GPUs

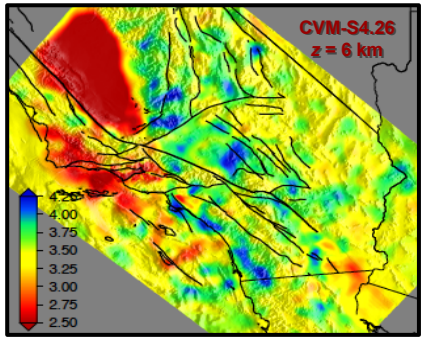
Seismogram Synthesis

Post-processing
500,000 jobs per site
MPI master/worker, 3712 cores

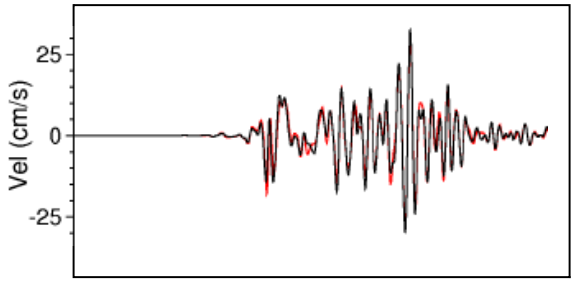
12 TB
data transfer

Data Product Generation

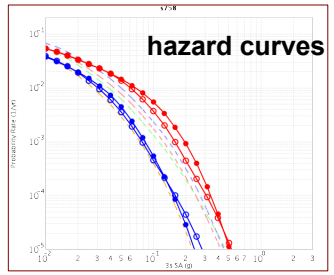
Populate DB, construct images
6 jobs per site



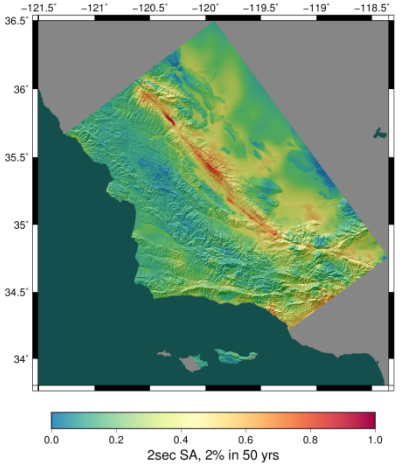
Community Velocity Model



500,000 Seismograms
75M intensity measures

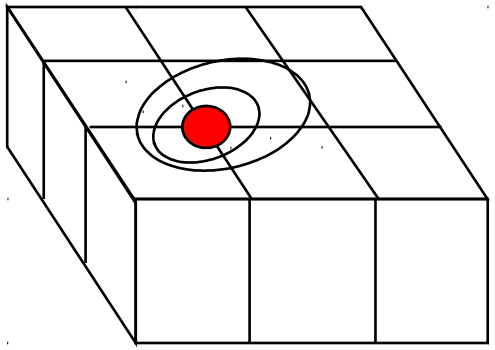


CyberShake Hazard Map

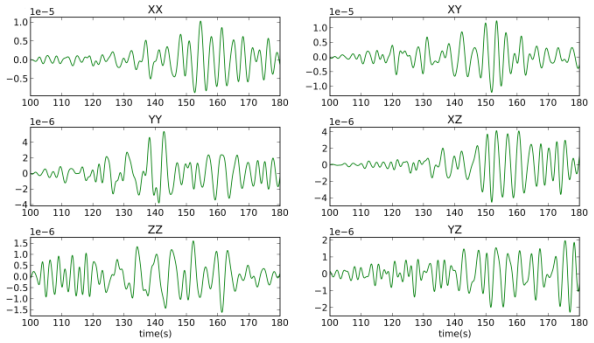


Reciprocity in CyberShake

- CyberShake uses reciprocity to reduce computational cost
- Impulse is placed at site of interest
- 2 Strain Green Tensor simulations are performed
- In post-processing, SGT time-series is convolved with slip time history at each point on fault surface to produce seismogram
- Non-linearity breaks reciprocity



Impulse



SGTs

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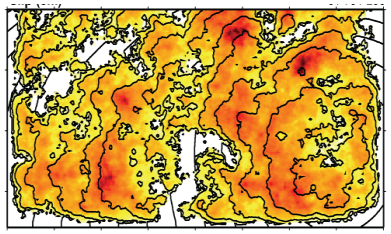
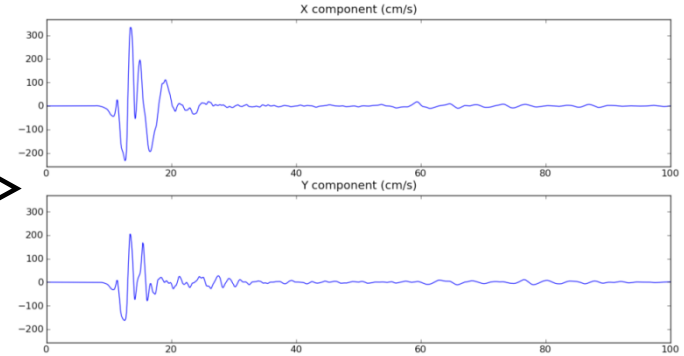


Slip time history



Seismogram

Non-Linear CyberShake: Approximation

- Pseudo-nonlinearity: continue with current workflow, adding additional non-linear approximations
- New kinematic rupture descriptions could approximate non-linear source effects
- Additional post-processing in reciprocity step could approximate non-linear crustal effects
- Could calibrate against suites of full non-linear simulations to generate pseudo-nonlinear models

Non-linear CyberShake: Hybrid

- Modify CyberShake to include forward simulations
- Converting CyberShake to forward-only is expensive
  - Most recent Study 17.3 used 21.6 million core-hours
  - Running forward-only would have used ~1.1 billion
- Less than 10% of sources account for more than 90% of the hazard
  - Even less than 10% at the rupture level
- Combine forward-simulation of a small subset of events with reciprocity for the majority
  - 3% forward (15,000 events) + 97% reciprocity = 51 million core-hours

Event Classification

- Challenge becomes how to determine which events should be forward-simulated
- For previously-run sites, can use previous disaggregation results

Source#	% Contribution	TotExceedRate	SourceName
000112	28.44	1.1660034E-4	San Jacinto;SBV+SJV+A+C
000110	08.01	3.284774E-5	San Jacinto;SBV+SJV
000111	07.77	3.1859796E-5	San Jacinto;SBV+SJV+A
000094	07.09	2.9080562E-5	S. San Andreas;SM+NSB+SSB+BG+CO
000109	06.39	2.6198057E-5	San Jacinto;SBV
000079	04.62	1.894212E-5	S. San Andreas;NSB+SSB+BG+CO
000097	02.97	1.21608555E-5	S. San Andreas;SSB+BG+CO
000093	02.77	1.1355708E-5	S. San Andreas;SM+NSB+SSB+BG
000130	02.38	9.758109E-6	San Jacinto (SB to C)
000115	02.10	8.5908005E-6	San Jacinto;SBV+SJV+A+CC+B+SM
000086	02.05	8.392931E-6	S. San Andreas;PK+CH+CC+BB+NM+SM+NSB
000114	01.79	7.3234287E-6	San Jacinto;SBV+SJV+A+CC+B

...

Event Classification

- For new sites / velocity models, can predict intensity measure and therefore predict disaggregation results
- What GMPEs do
- Can tolerate a moderate amount of error, especially by being inclusive
- Use machine learning to classify events into forward-simulation or reciprocity
  - Very preliminary work suggests this is promising
- Could mesh well with UCERF 3 ERF option
  - Classify into (GMPE, reciprocity, forward)

Conclusions

- Want to continue to integrate new developments into CyberShake
- Nonlinearity will be important especially at higher frequencies
- Pseudo-nonlinearity or hybrid approaches may provide path forward
- Questions?