Increasing the spatial resolution in physics-based site term estimates: results from southern San Andreas ruptures

Poster #236

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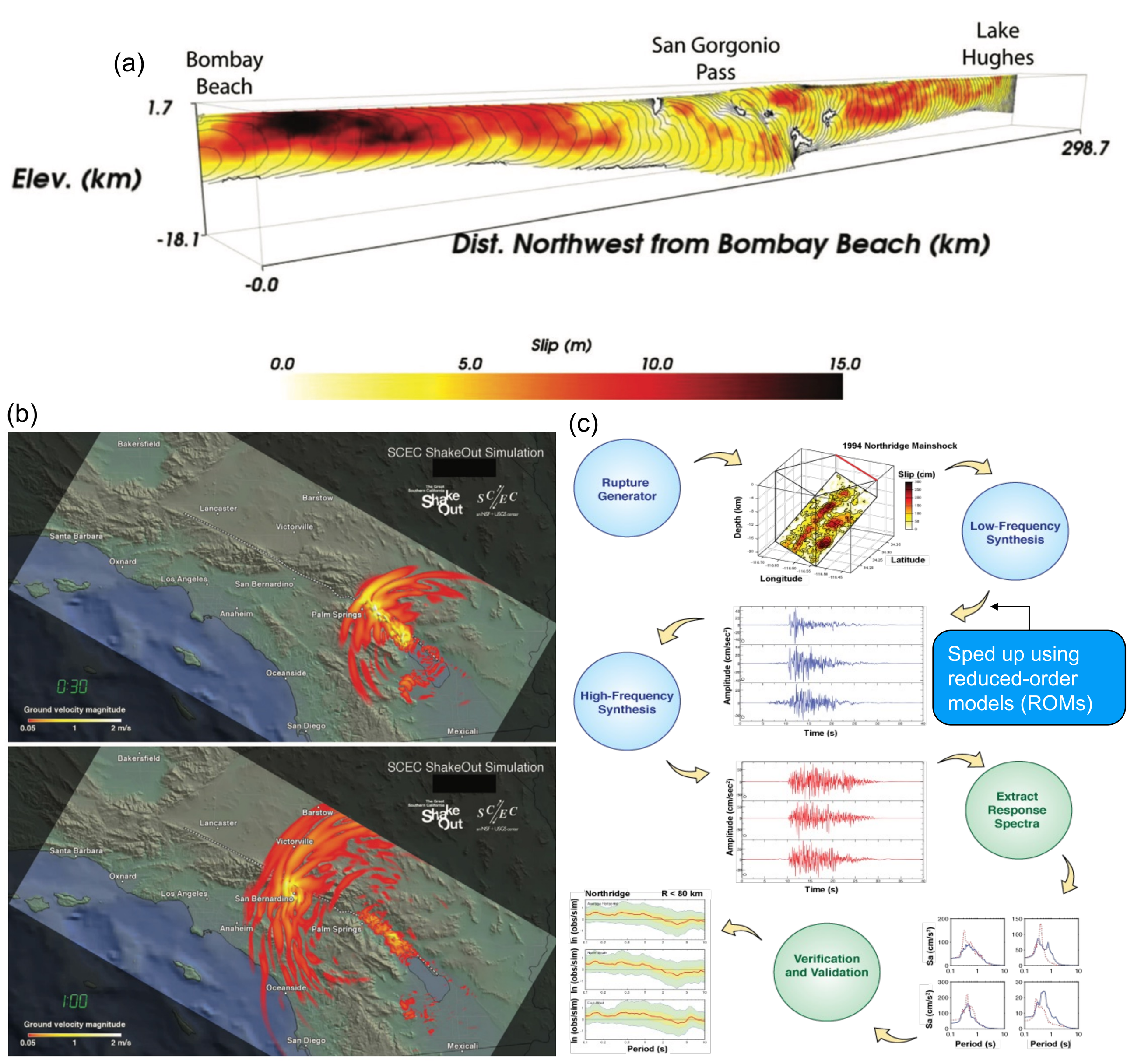
Key points

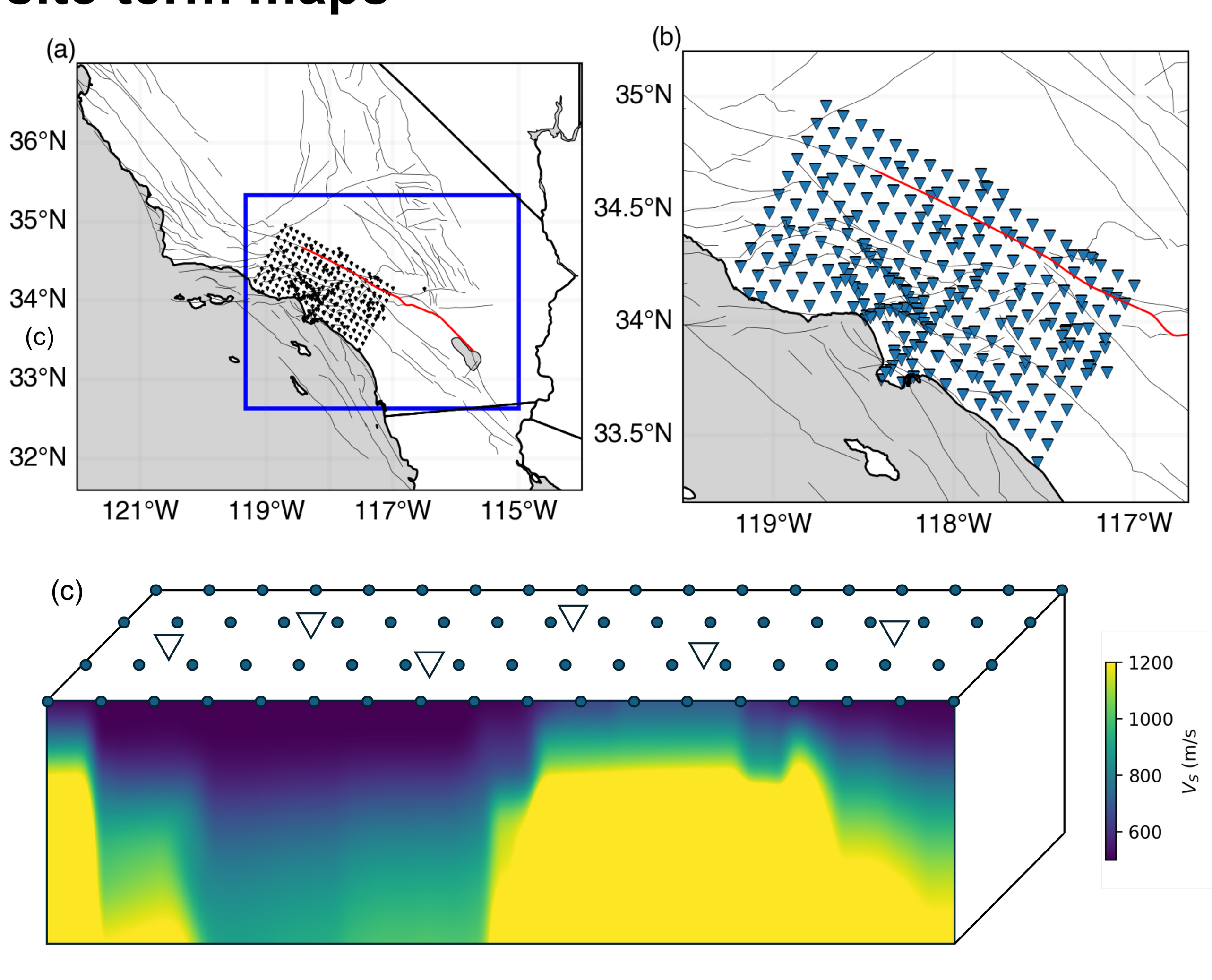
- Computational costs quickly escalate when performing a physics-based probabilistic seismic hazard analysis for many faults and sites and can become prohibitively expensive.
- We compare the interpolation of CyberShake 22.12 site terms against high resolution site terms computed for earthquakes on the Southern San Andreas fault.
- We identify local discrepancies for our set of earthquake sources with peak ground velocities differing by up to a factor of approximately three, suggesting that atypically high or low ground motions would be missed with the interpolation.

The 2008 SCEC ShakeOut scenario: source model and simulated wavefields



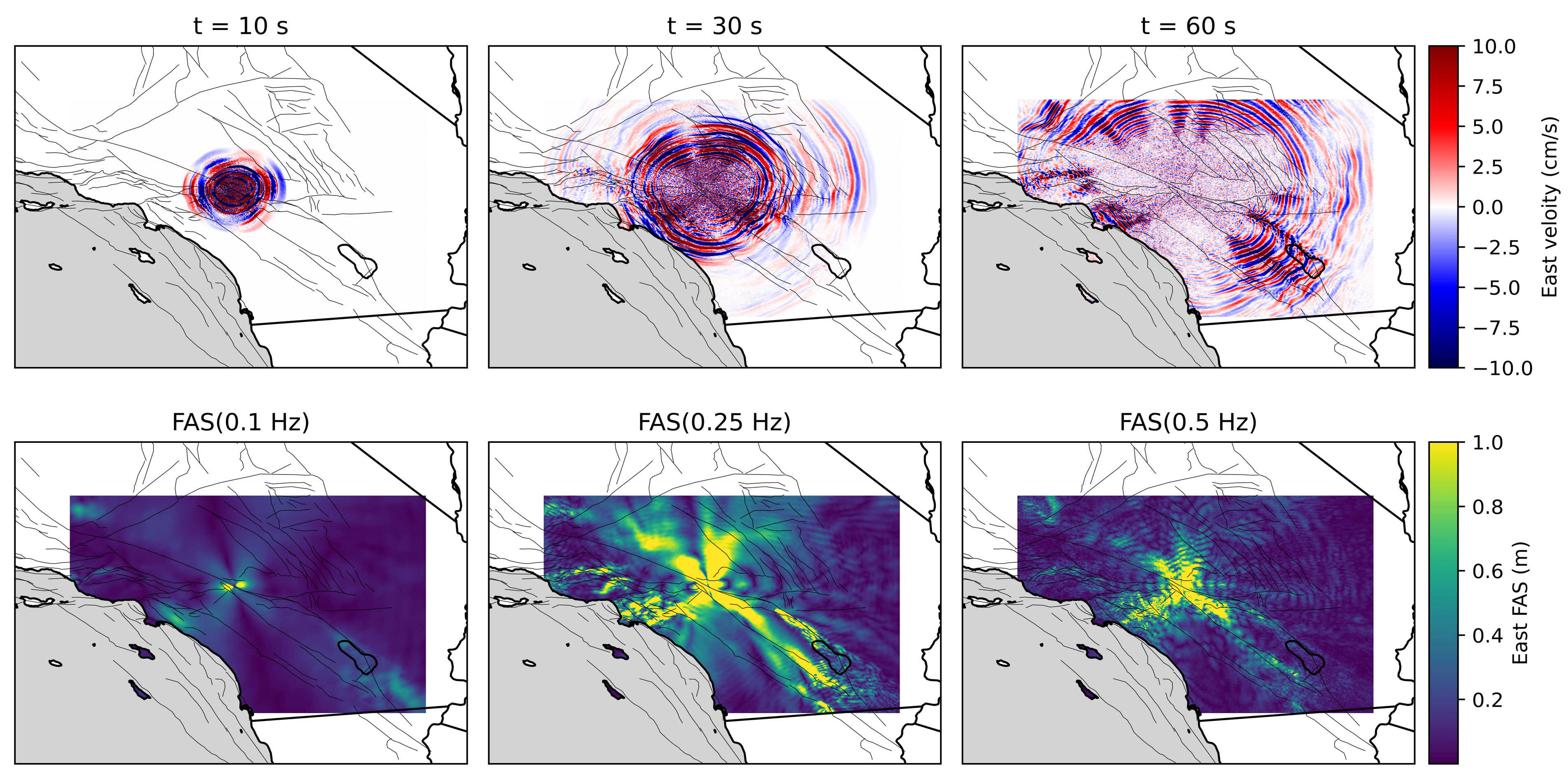
The 2008 SCEC Shakeout scenario[1,2] shown in is based on a possible M7.8 earthquake on the Southern San Andreas Fault, with the rupture model shown in (a). A simulation of this hypothetical earthquake using a detailed velocity model, shown in (b) provides insight into the high-resolution wavefield and ground motion to inform effects on buildings and structures. Physics-based probabilistic seismic hazard analysis (PSHA) such as the CyberShake project[3] (c) complements these results by considering many sources, though it is computationally expensive. Our approach here speeds up the low-frequency synthesis using a reduced-order modeling technique for rapid seismograms[4,5].

Creation of high-resolution, physics-based site term maps



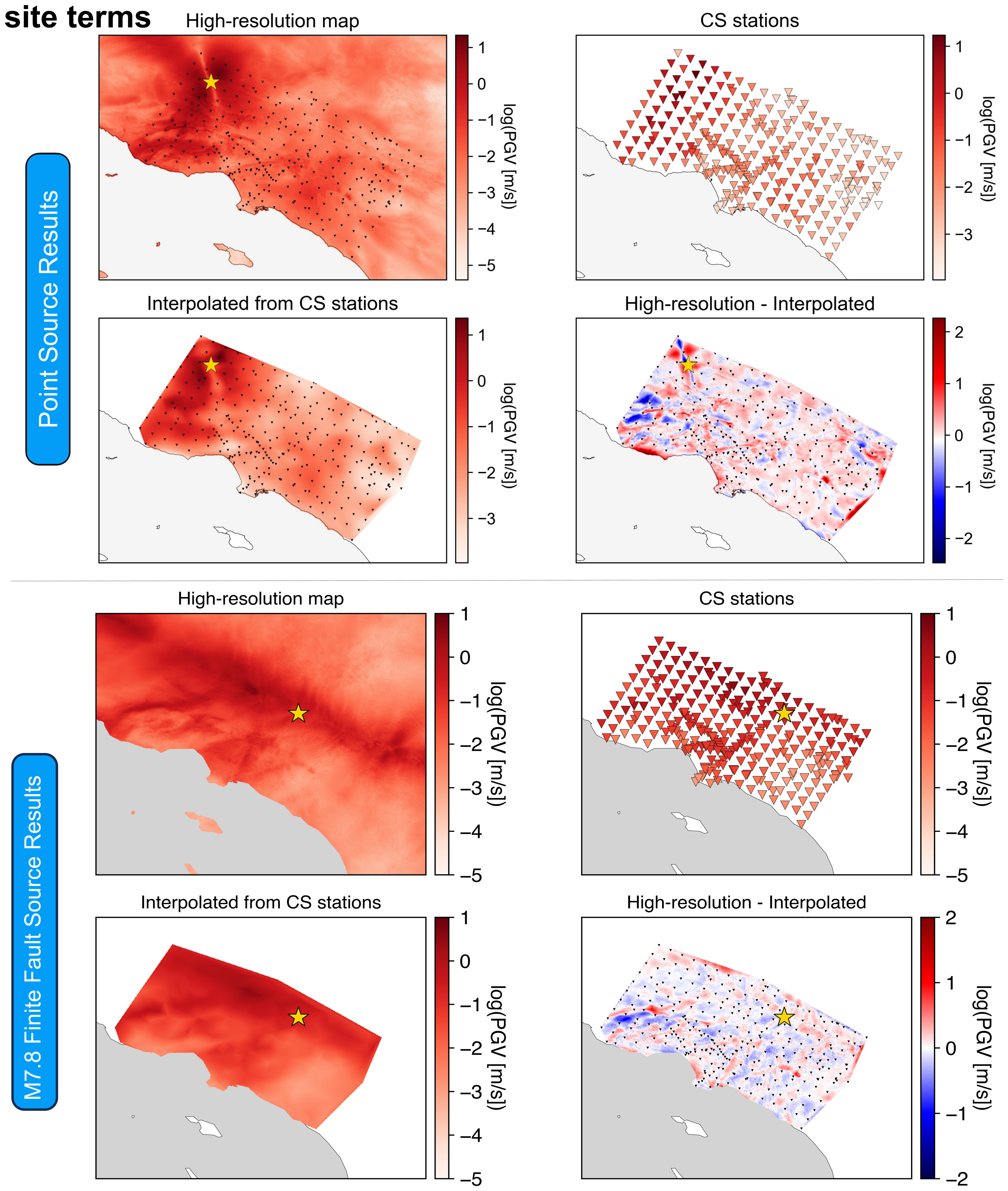
(a) shows the CyberShake 22.12 site locations in triangles, our high-resolution simulation area in a blue rectangle, and the nonplanar San Andreas fault section in red. The other faults from UCERF3 are shown as black lines. (c) shows a conceptual image of the high-resolution receiver approach, where the triangles are the chosen sites of interest and the circles mark the high-resolution grid. The velocity model shown is a slice through the Los Angeles basin using CVM-S4.M26.01.

High-resolution wavefield simulations and Fourier amplitude spectra ground motion maps



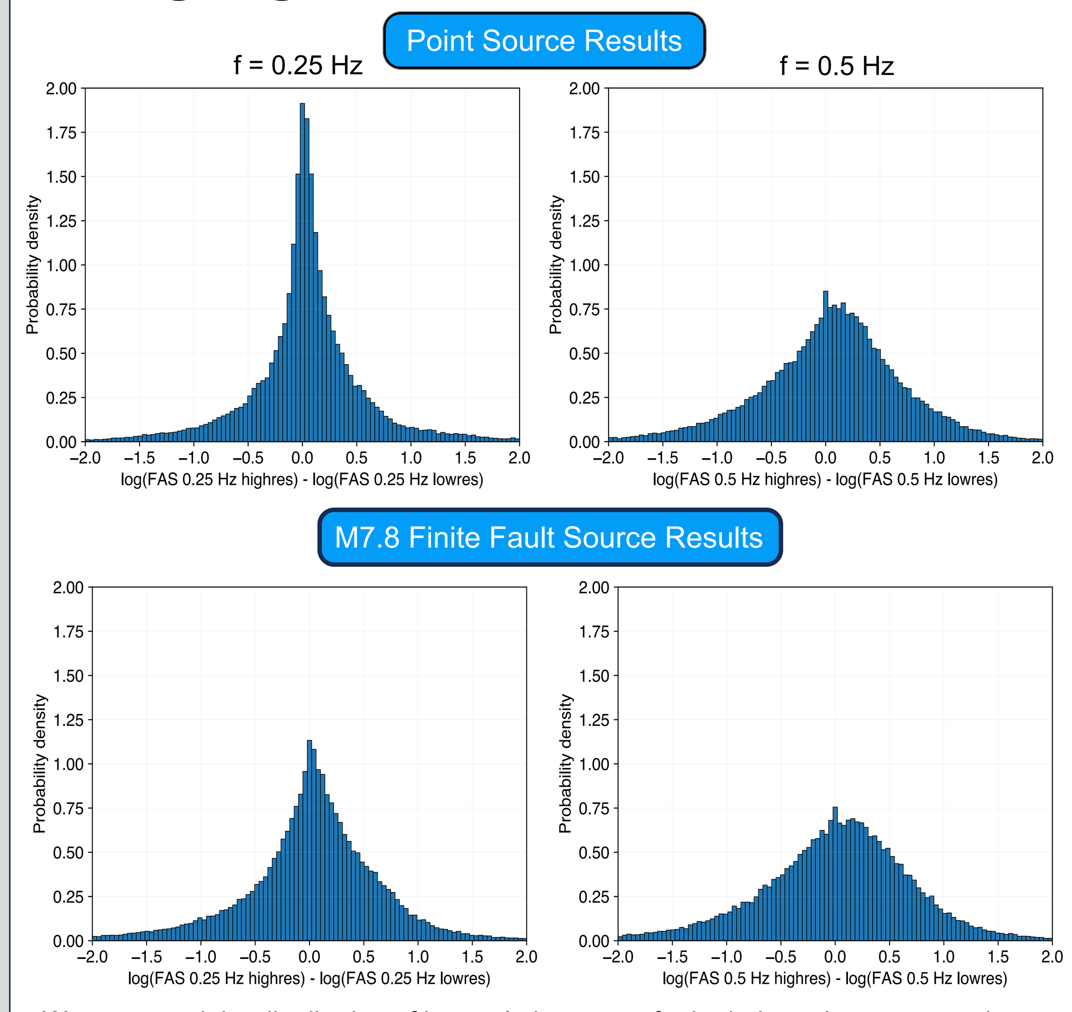
For each point source, we simulated 3 minutes of 3D seismic wave propagation using SeisSol[6] and 6th order accuracy. Using the simulated seismograms, we compute the Fourier amplitude spectra (FAS) to examine frequency-dependent site terms[7]. The Fourier spectra show complex patterns that require sufficiently high spatial resolution to resolve. We then use the point source data to simulate finite fault ruptures using a reduced-order modeling approach.[4,5] Our finite fault models are generated using the Graves and Pitarka rupture generator and the SCEC Broadband Platform.[8]

Comparison between high-resolution and CyberShake interpolated site terms

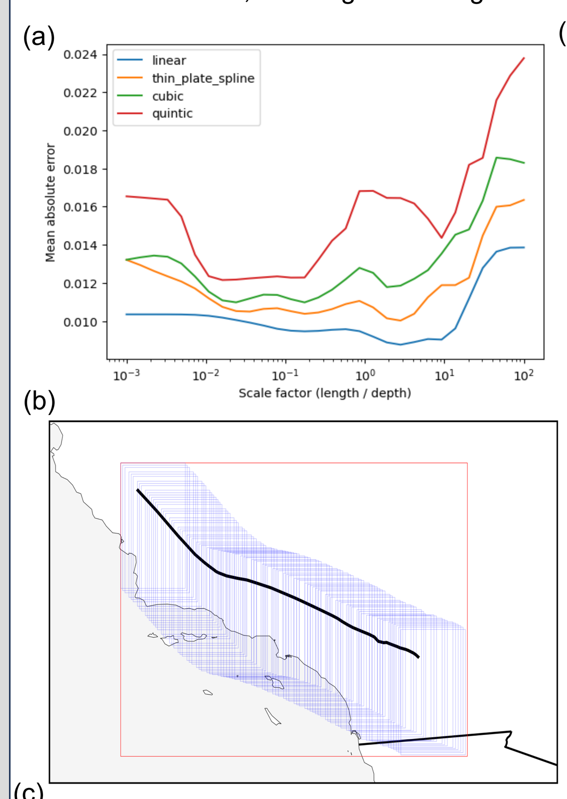


(a) PGVs computed from the high-resolution (250 m spacing) simulated seismogram data located in Southern California. The point source location is indicated by a gold star. (b) PGVs measured at the CyberShake study 22.12 stations. (c) Interpolation of the PGVs measured at the CyberShake stations. (d) Difference between the high-resolution and interpolated PGV maps. The bottom four panels indicate the same results but for a M7.8 finite fault rupture source model.

Quantifying the improvement by using high-resolution site terms

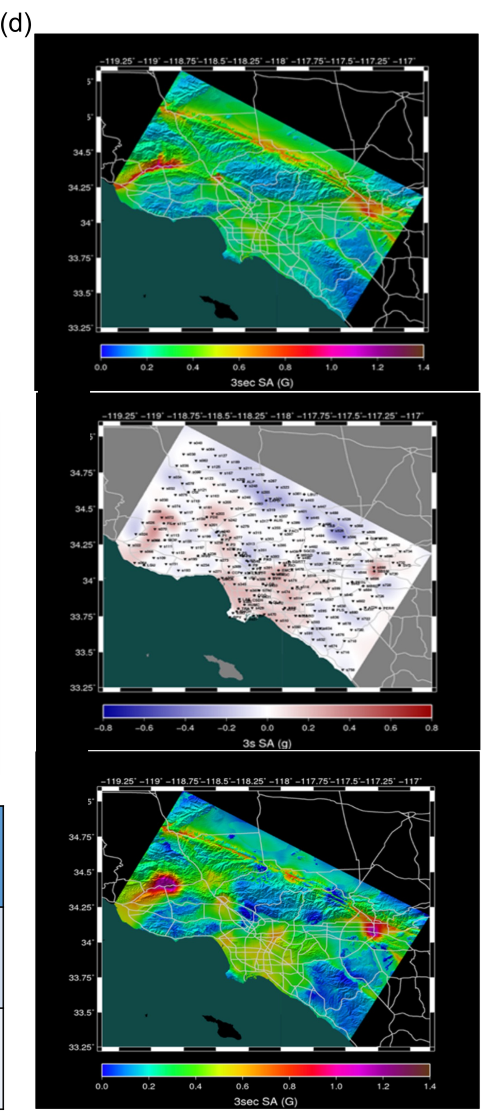


We computed the distribution of interpolation errors for both the point source and finite fault source, showing increasing standard deviations for higher frequencies.



(c)

	FOM (CPUh)	ROM (CPUh)	Speed-up
Point source	1157	0.0017	6.8×10^6
Finite fault	1157	1.70	680



Similar to the CyberShake hazard maps (d), we plan to construct maps using our high-resolution site terms. We will use the ROM with potential accuracy improvements using parameter scaling of the hypocenter depths against the length parameter (a), or by using a centering approach to improve near-fault accuracy (b). A substantial ROM speedup (c) enables us to consider many more scenarios on the SSAF compared to ShakeOut.

Conclusions

- We identify local discrepancies for our set of earthquake sources with peak ground velocities differing by up to a factor of approximately three.
- We identify areas where unexpectedly high or low ground motions could be missed when using the interpolated dataset to create a hazard map. These findings highlight areas where interpolation methods may underestimate or overestimate earthquake hazard.
- We will make the ROMs accessible through the Quakeworx gateway.

References

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