Waveguide or not? Revised ground motion simulations for greater Los Angeles from the M7.8 ShakeOut earthquake scenario

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1. Background and Goals

- The ShakeOut simulations of a M7.8 earthquake on the southern San Andreas fault (2008) studies predicted unexpectedly large ground motions throughout Southern California due to waveguide effects from interconnected sedimentary basins in 3D velocity model.
- Here, we re-examine the ground motion predictions from the ShakeOut scenario using the most recent updates on the velocity models and the realistic surface topography from the Digital Elevation Model.

2. Computational Details

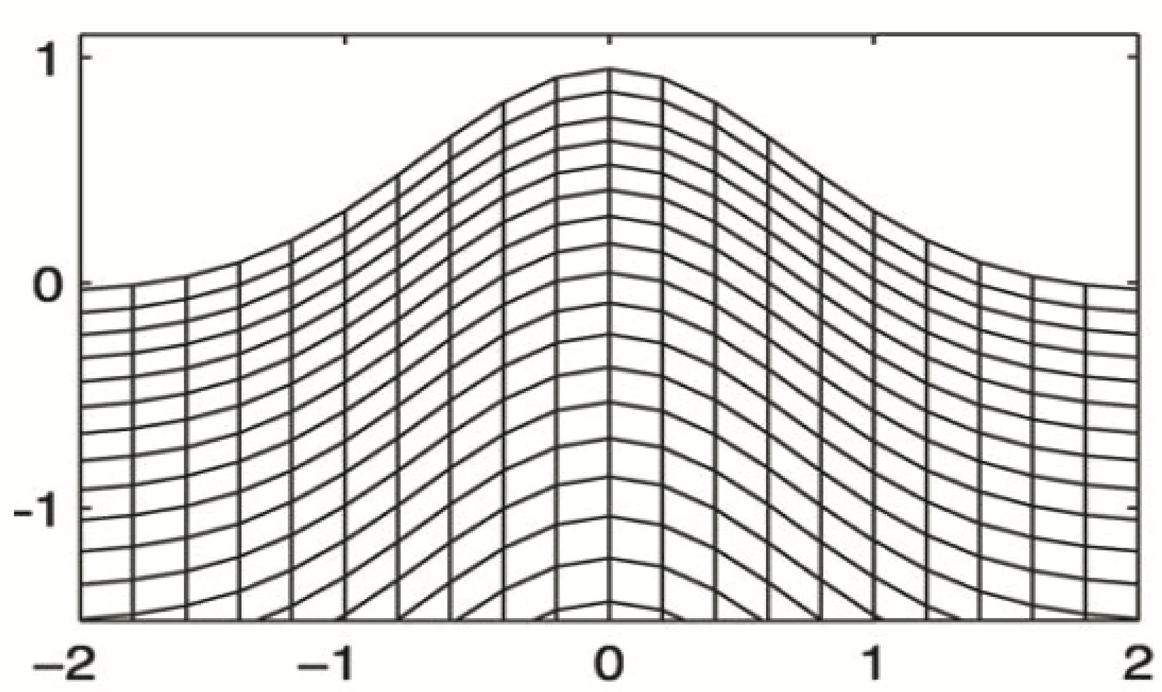
4-th order accurate staggered-grid finite-difference wave propagation simulation code **AWP-ODC**

AWP-ODC:

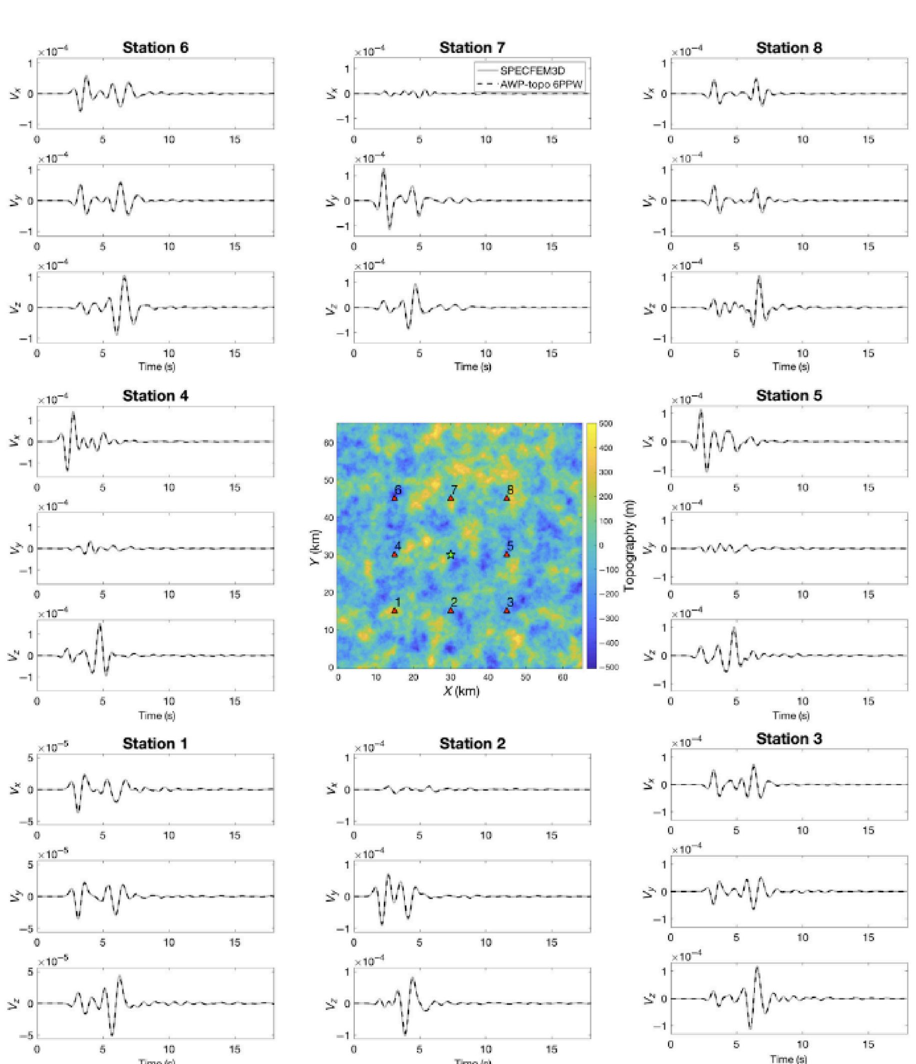
- GPU-enabled and highly scalable (Cui et al., 2013), with curvilinear grid and discontinuous mesh features
- Developed and tested on Summit at Oak Ridge Leadership Computing Facility (OLCF), with Nvidia V100 GPUs
- Verified ported HIP version, full production runs on AMD GPU machines (Frontier at OLCF)

Curvilinear grid:

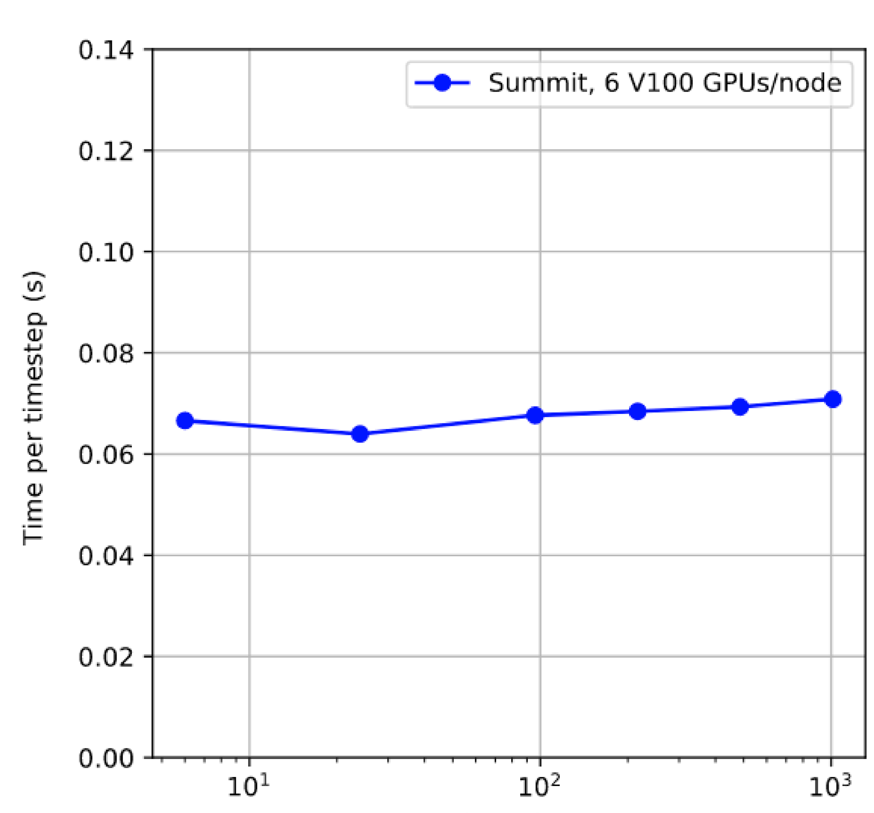
Incorporating irregular free surface topography using curvilinear grid (O'Reilly et al., 2022)



AWP has been updated to handle surface topography via a curvilinear grid by applying a 1D coordinate transform in the vertical direction (O'Reilly et al., 2022). The method has been validated against other numerical methods capable of accurately modeling irregular topography.



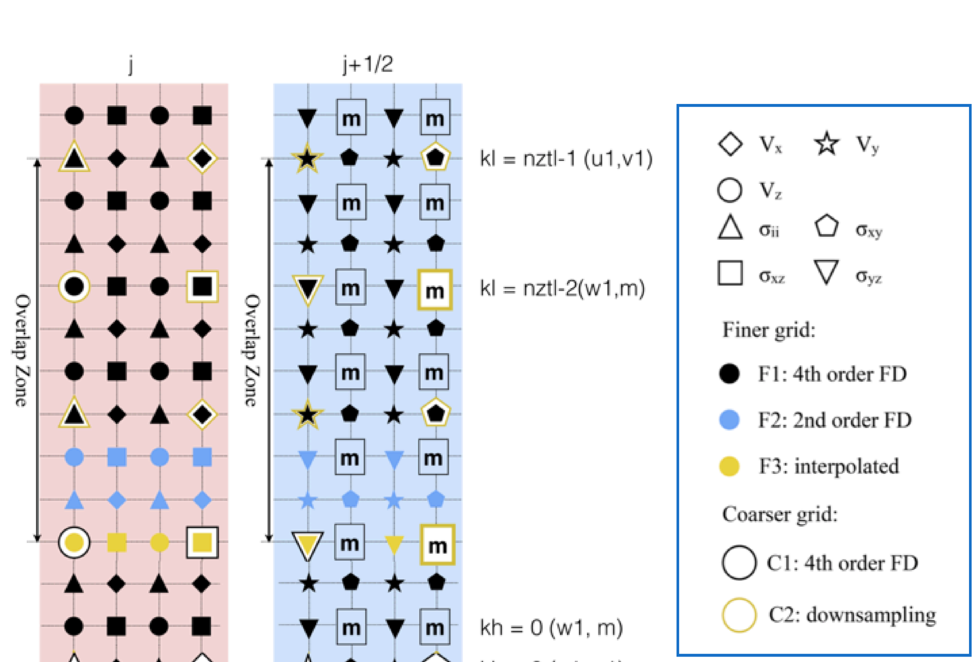
Comparison of synthetic velocity waveforms computed using SPECFEM3D (solid traces) and the AWP curvilinear method (dashed traces) with six grid points per minimum S wavelength at receivers shown by the triangles on the map at the center. The shading of the map depicts the topography for the simulation; the star depicts the epicenter.



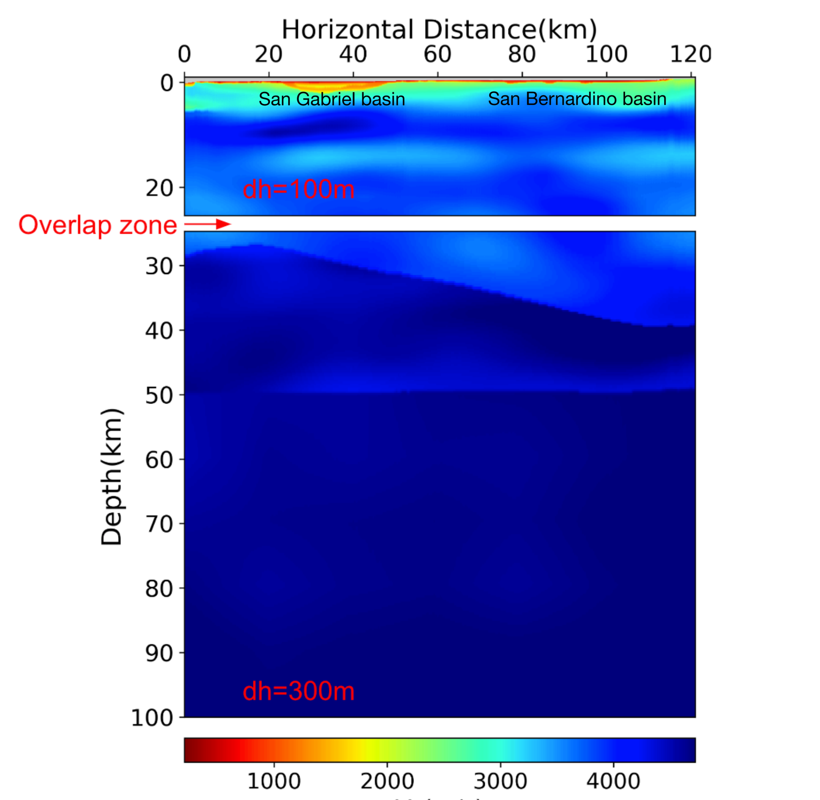
Weak scaling test of AWP conducted on Oak Ridge Leadership Computing Facility (OLCF) Summit. AWP achieves 94% weak scaling efficiency.

Discontinuous mesh (DM):

Grid spacing increased by x3 between blocks (Nie et al., 2017)

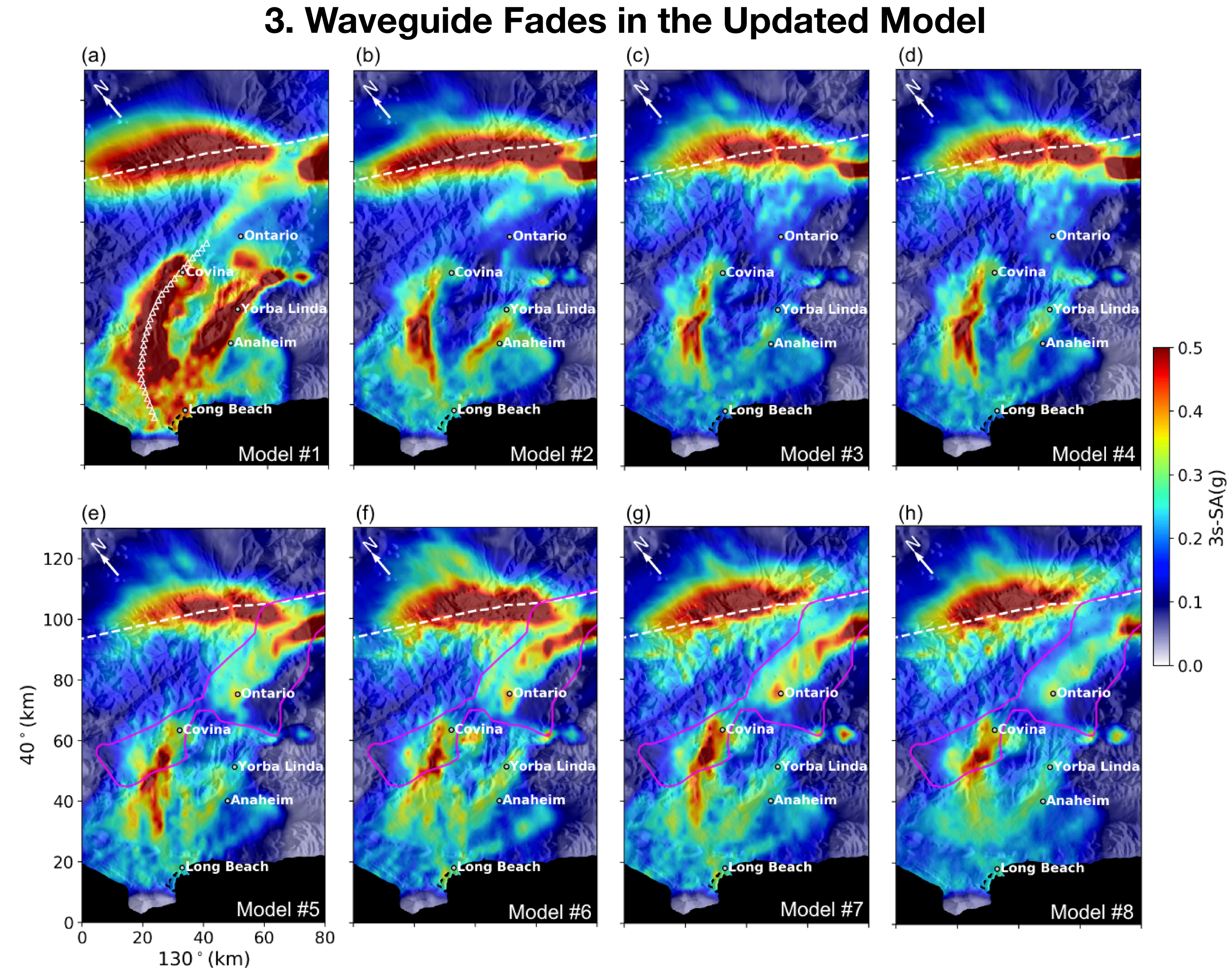


Placement of velocity and stress grids within the DM overlap zone on the XZ plane (modified from Nie et al., 2017). Icons with letter "m" denote the location of where material properties are stored.

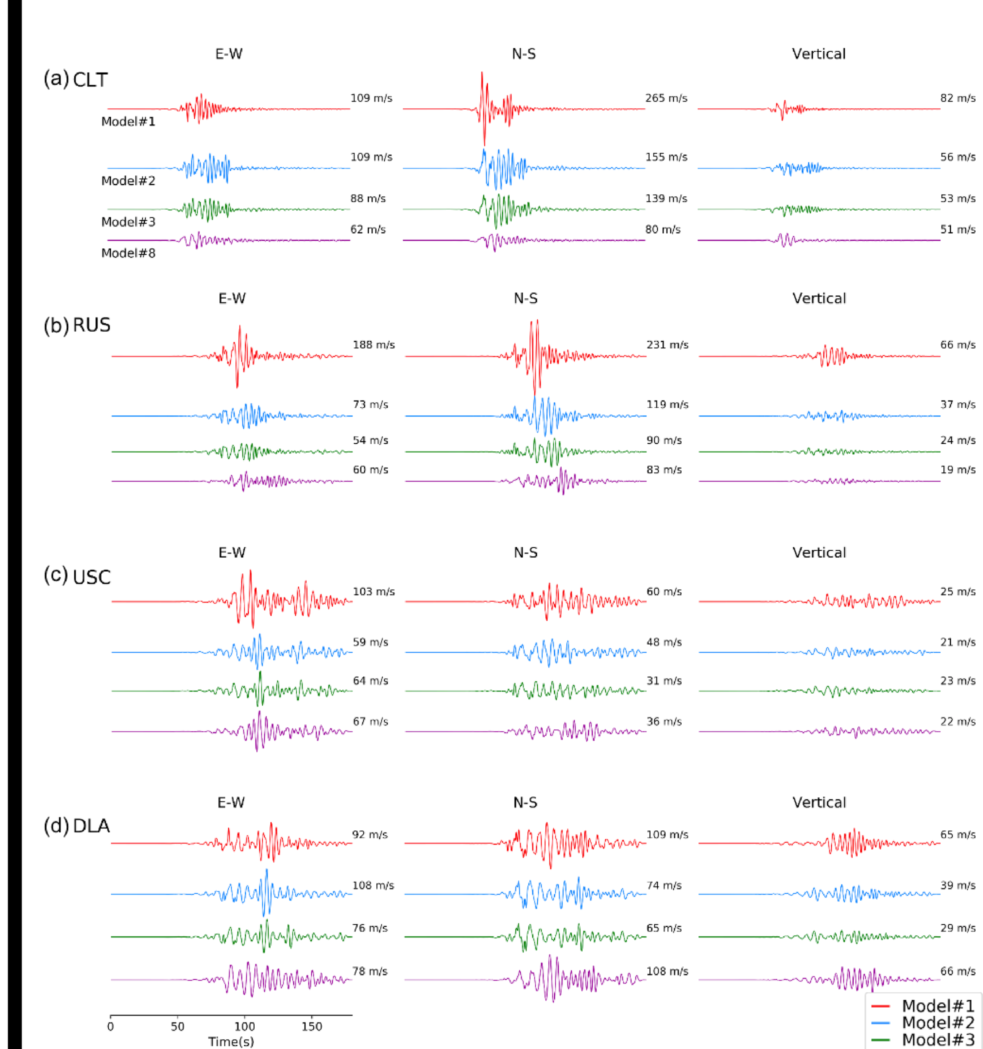


Decomposition of model using the discontinuous-mesh feature of AWP-ODC Nie et al. (2017). The top (100 m grid spacing) and the bottom mesh (300 m grid spacing) blocks are connected with an overlap zone starting at approximately 24 km depth, reducing the use of memory by 75%.

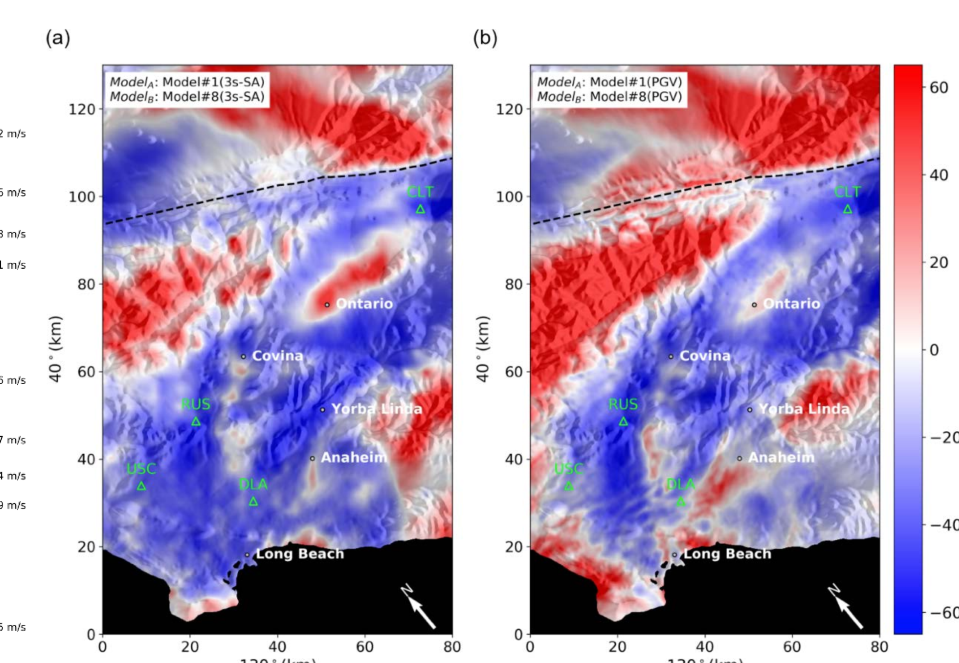
3. Waveguide Fades in the Updated Model



Evolution of the predicted ground motions in the greater Los Angeles area with the numerical earth model is updated incrementally. From (a) to (h), one can observe the significant reduction of ground motions along the waveguide channel across the interconnected basins (triangles in (a)). Dashed line depicts the surface projection of the SSAF that ruptured in the ShakeOut scenario.



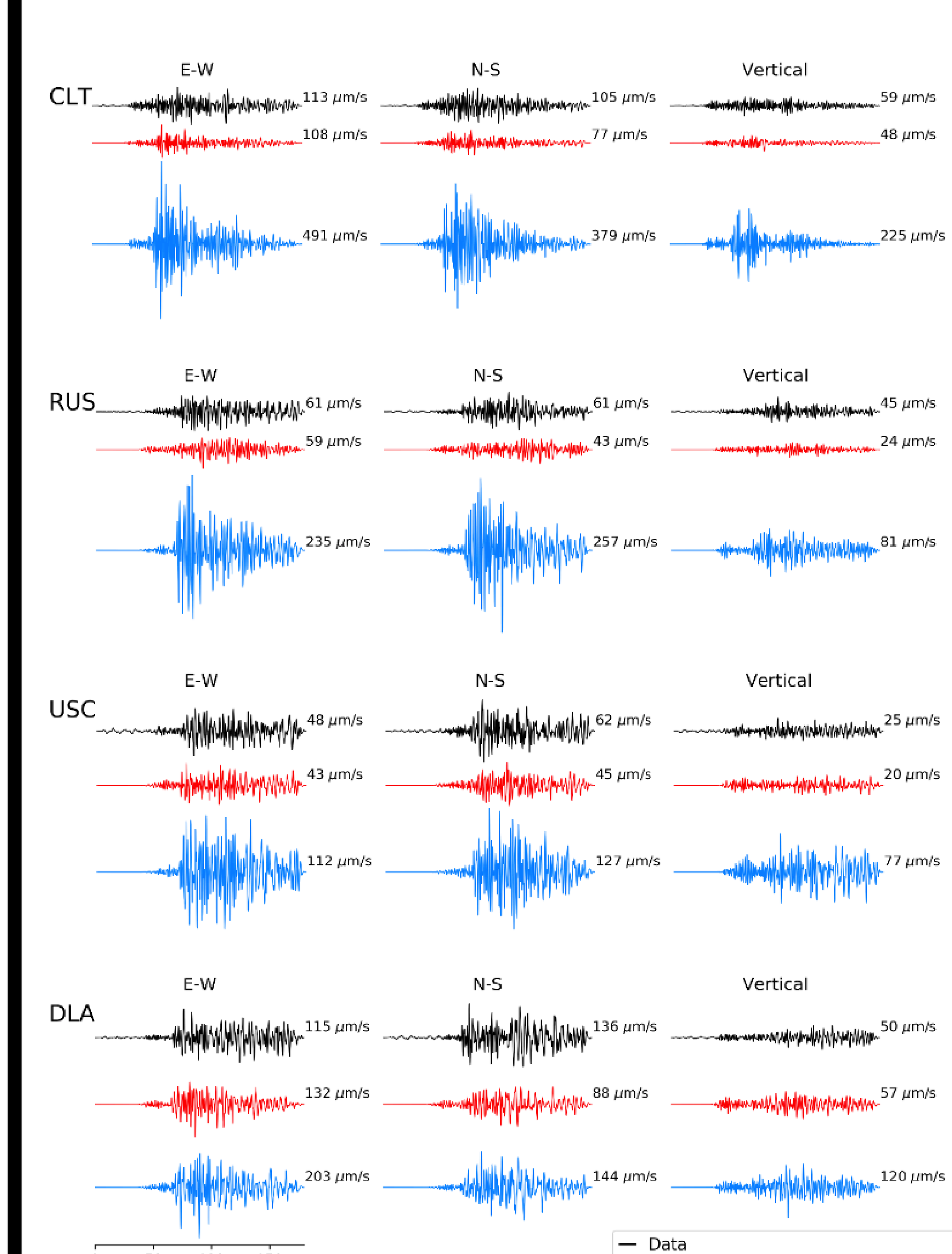
Comparison of synthetic waveforms for the ShakeOut scenario at select stations - (a) CLT (San Bernardino), (b) RUS (Whittier Narrows), (c) USC (Downtown Los Angeles), and (d) DLA (Cerritos) . The peak velocity are listed to the right of each trace.



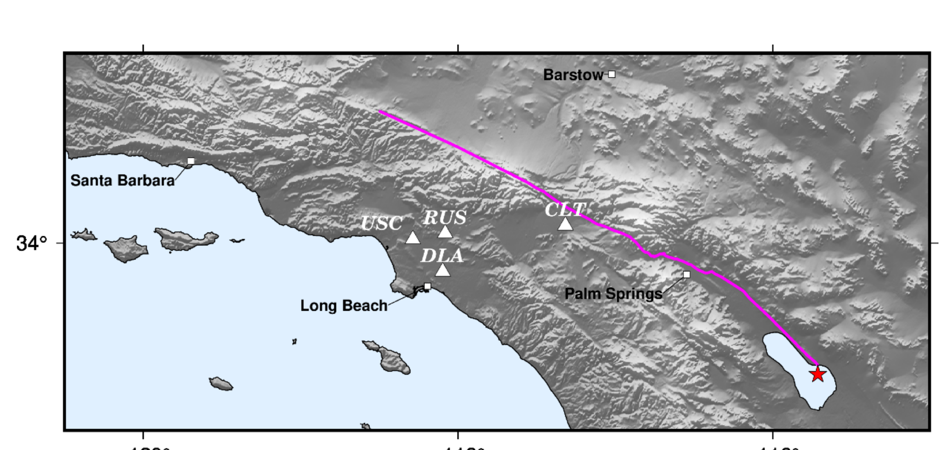
Percent difference of the (a) 3s-SA and the (b) peak ground velocity (PGV) between the final (Model #8) and the starting (Model #1) models.

Scan the QR code for more details of this study

4. Model validation



Comparison of (black) observed and synthetic waveforms for the 2016 M_W4.3 event as a validation of the final model. Synthetics in blue and red are derived using the starting model (Models #1) and the final model (Model #8), respectively. The peak velocities are listed to the right of each trace.



Location map of the Mw 4.3 event in Bombay Beach, CA (red star) for validating the final model (Model #8) and the four stations where waveform comparisons are shown in Figure 11. Magenta trace depicts the surface projection of the portion of the fault that ruptures in the M7.8 ShakeOut scenario.

5. Conclusions

- The exceptional scalability and performance of the AWP-ODC due to the most recent advancements allows for examination of plenty earth models including the irregular surface topography at low computational cost.
- Combining all model features, the predicted ground motions along both waveguide branches are reduced by 50-70% relative to the starting model
- The validation of the final model confirms the robustness of the final model up to 1 Hz.

References

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3. Nie, S., Y. Wang, K. B. Olsen, and S. M. Day, 2017, Fourth-Order Staggered-Grid Finite-Difference Seismic Wavefield Estimation Using a Discontinuous Mesh Interface (WEDMI)Fourth-Order Staggered-Grid Finite-Difference Seismic WEDMI, Bull. Seismol. Soc. Am., 107, no. 5, 2183–2193, doi: 10.1785/0120170077.

4. O'Reilly, O., T. Yeh, K. B. Olsen, Z. Hu, A. Breuer, D. Roten, and C. A. Goulet, 2021, A High-Order Finite-Difference Method on Staggered Curvilinear Grids for Seismic Wave Propagation Applications with Topography, Bull. Seismol. Soc. Am., 112, no. 1, 3–22, doi: 10.1785/0120210096.