2021 SCEC Project Report

Updating CVM-S 4.26 in Salton Trough Using Explosion Waveforms

SCEC Award No. **21059**

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Proposal Categories:
A: Data Gathering and Products

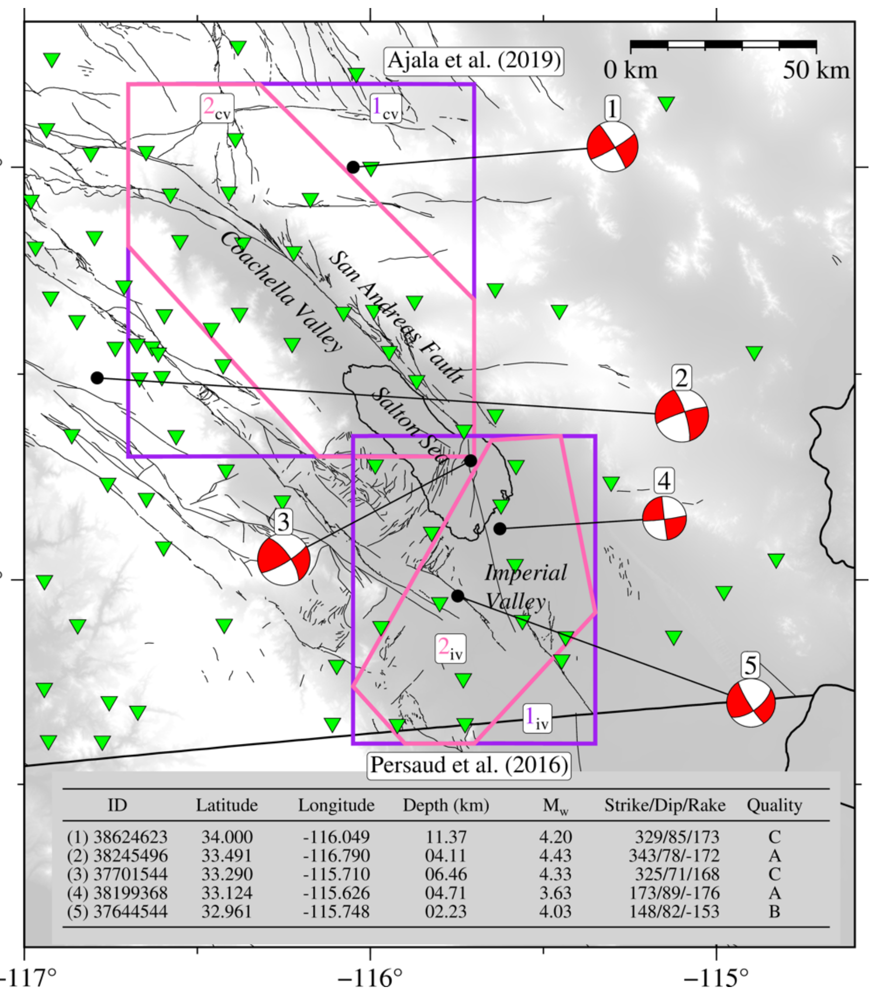
Disciplinary Group:
Seismology, Computational Science

SCEC Science Priorities:
P4.a, P3.a, and P2.b

Interdisciplinary Working Groups:
Ground Motions (GM)
San Andreas Fault System (SAFS)
SCEC Community Models (CXM)

ABSTRACT

The current proposal seeks to finalize our work in the SCEC5 research cycle by utilizing the Salton Seismic Imaging Project (SSIP) active source waveforms in full waveform inversion to update the current best Earth model in Salton Trough. The project will benefit from tools developed in our previous SCEC-funded projects and fully automated full-waveform inversion software available in the seismology community. Ajala & Persaud (2021) showed that embedding 3D travel time basin models for the Imperial Valley (Persaud et al., 2016) and Coachella Valley (Ajala et al., 2019) developed using SSIP active source data improves the waveform prediction ability of SCEC community models at low frequency. Here, we extend previous results by exploring other hybrid models generated using 13 sets of embedding parameters – and summarize their effect on waveform predictions up to a minimum period of 2 s. To evaluate our models, we check ground-motion predictions from the hybrid models against the pure regional models. We compare all model predictions to 3-component ground displacement records from five moderate magnitude earthquakes filtered in 2-30 s, 3-30 s, and 6-30 s bands with signal-to-noise ratio ≥ 3.



ID	Latitude	Longitude	Depth (km)	M_w	Strike/Dip/Rake	Quality
(1) 38624623	34.000	-116.049	11.37	4.20	329/85/173	C
(2) 38245496	33.491	-116.790	04.11	4.43	343/78/-172	A
(3) 37701544	33.290	-115.710	06.46	4.33	325/71/168	C
(4) 38199368	33.124	-115.626	04.71	3.63	173/89/-176	A
(5) 37644544	32.961	-115.748	02.23	4.03	148/82/-153	B

***Figure 1**. Map of Salton Trough wavefield simulation area in the vicinity of the southern San Andreas fault. Black circles identify the validation events with their focal mechanisms (Yang et al., 2012). The map legend provides additional information on the earthquakes. The green*

triangles are the seismic stations used. The purple polygons (1iv and 2cv) are areas with active source tomographic models for Imperial Valley (Persaud et al., 2016)and Coachella Valley (Ajala et al., 2019). The pink polygons (2iv and 2cv) indicate well-resolved volumes of the models. cv = Coachella Valley. iv = Imperial Valley.

METHODOLOGY

Under a previous award, "Assimilating SSIP data into a Full 3D Tomography (F3DT) model of the Salton Trough" (Award: 20023; Year: 2020), we showed that the community models can be improved by embedding high-resolution local models. With these new models, we can improve seismic hazard assessment in Southern California in a timely manner. Our algorithm and basin-scale models have been made available to the SCEC UCVM developers for use by the research community. The algorithm and all models including the hybrid models are also available in two publications (Ajala & Persaud, 2021; Ajala & Persaud, 2022) with key highlights summarized below. In addition, our detailed explorations of two standard SCEC Community Models and the influence of topography, geotechnical layer, and attenuation on wavefield predictions are available in Ajala, Persaud & Juarez (2022). Insights from these initial efforts have motivated our future research to further improve the hybrid models using SSIP data.

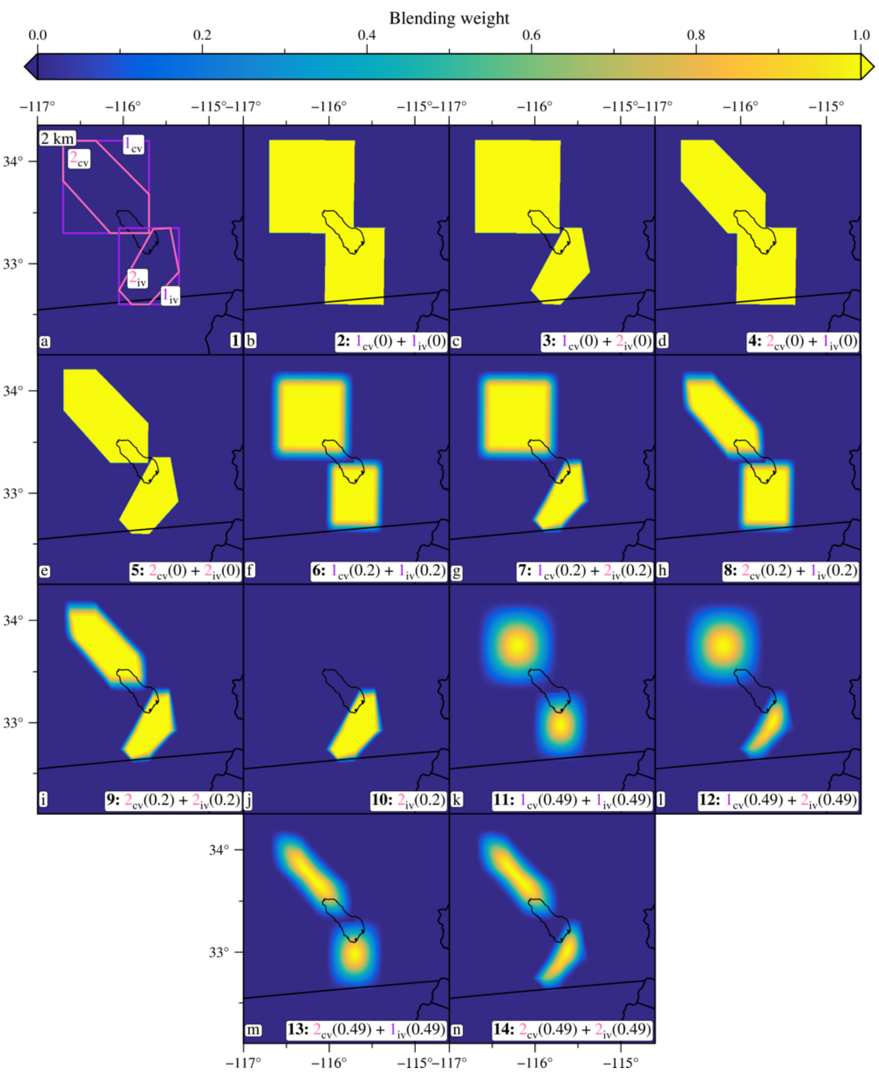


Figure 2. *Blending maps used to produce the hybrid models in Fig. 3. We use two different volumes for the local models to merge them with the CVMs; 1 refers to the entire model domain (purple polygon), while 2 refers to the irregular volumes with good ray coverage (pink polygons). The blending maps are used to make 13 cvmh hybrid and 13 cvms hybrid models (Fig. 3). We consider three levels of tapering: no tapering (taper ratio = 0), moderate tapering (taper ratio = 0.2), and strong tapering (taper ratio = 0.49). The bottom right label indicates the model number, polygon numbers and taper ratios. Details are provided in Ajala & Persaud (2022).*

Here, we consider four models, the latest versions of the SCEC Community Velocity Model (CVM) – (cvms; Lee et al., 2014) and – Harvard (cvmh; Tape et al., 2010) and two basin-scale models (purple and pink polygons in Figs. 1 and 2), which are travel-time tomographic models created using a combination of borehole-explosion data and local earthquakes in Imperial Valley (Persaud et al., 2016) and Coachella Valley (Ajala et al., 2019). Hybrid models are constructed using a recently modified UCVM software (Ajala & Persaud, 2021; Small et al., 2017) that merges models in arbitrarily shaped volumes while ensuring smooth boundaries (Figs. 2 and 3). S wave velocity and density for the basin models are empirically determined (Brocher, 2005). Geotechnical layering in the top 350 m (Ely et al., 2010) and high-resolution (~30 m) topography are included. Simulations are performed in anelastic media using the Olsen attenuation equation (Olsen et al., 2003) to generate the Q model. Synthetic seismograms are computed using the spectral-element method (Komatitsch & Vilotte, 1998). With an S wave velocity cutoff of 600 m/s our results are globally valid to 2 s period. We compute the percentage misfit (normalized squared error) change of the hybrid model relative to the pure model.

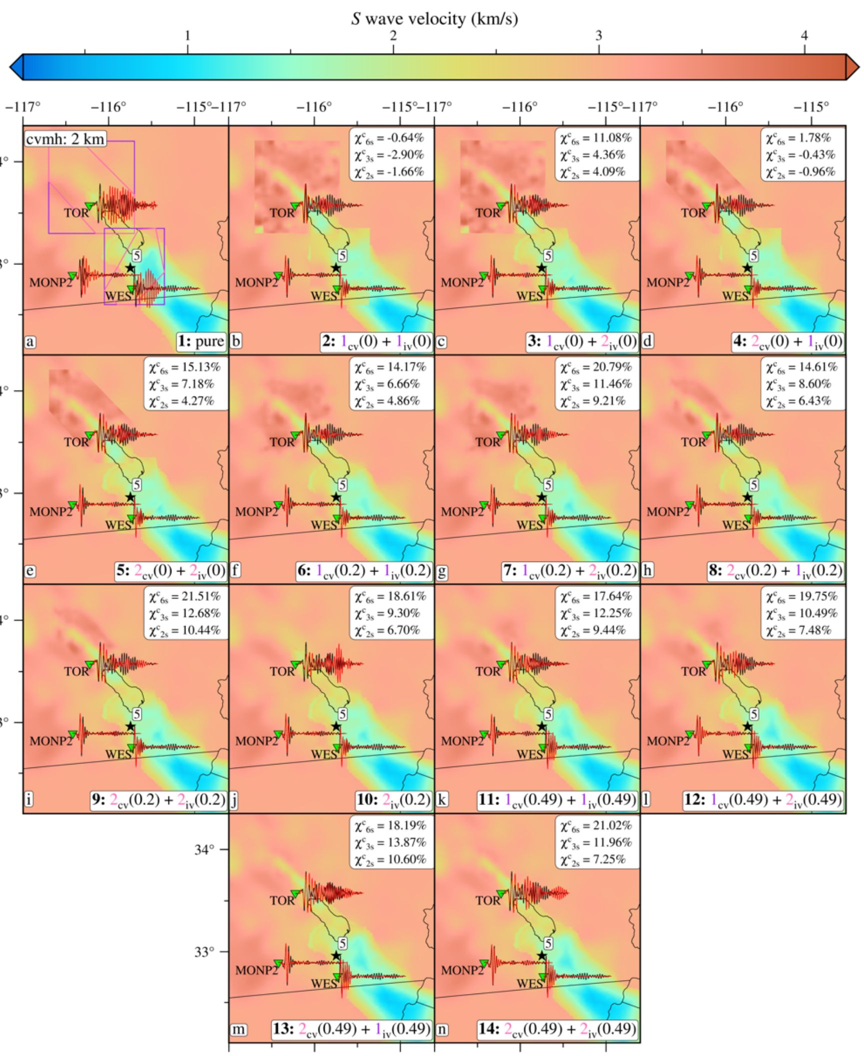


Figure 3. *S wave velocity maps at 2 km depth from the hybrid cvmh models with data (black) and synthetic (red) 6-30 s seismograms at some stations for events 5 and 3 (black stars). N-S components are shown for the hybrid and pure cvmh. The top-right label shows the percentage misfit change relative to the original SCEC CVM model for the three frequency bands (2-30 s, 3-30 s, and 6-30 s). Blending maps used to generate the models are shown in Fig. 2.*

RESULTS

At 6-30 s, hybrid cvmh model 2 (Fig. 3b - cvmh) is the only hybrid model that underperforms relative to the pure cvmh model, with model 9 (Fig. 3i - cvmh) being the best hybrid model. At 3-30 s and 2-30 s, hybrid cvmh models 2 and 4 (Fig. 3b, d - cvmh) underperform, with model 13 (Fig. 3m - cvmh) producing the best ground motions. Waveforms for event 5 in Coachella Valley (TOR), Imperial Valley (WES), and the Peninsular Ranges (MONP2) show that all models except pure cvmh produce decent waveforms. For the hybrid cvms models (for figures, see Ajala & Persaud, 2022) and all the period intervals, only model 10 (Fig. 2j), which embeds just the Imperial Valley basin model, outperforms the pure cvms model. Hybridization does not offer the largest model improvements at higher frequencies. Although the trends in the different period bands are similar, the pure and hybrid models have a poorer performance at shorter periods (Fig. 4). The same pattern holds for the cvms and its hybrid models. Our hybridization technique allows us to directly test the accuracy of the shallow basin structure in the community models relative to the embedded basin models. The results for the cvmh and cvms hybrid models are markedly different even though the pure cvms model outperforms the pure cvmh models in the three period intervals. Thus, the same hybridization approach may not produce better hybrid models regardless of the regional model used and sub-domains of hybrid models must be evaluated to ensure compatibility. The presence of merging artifacts does not necessarily imply that a hybrid model will underperform relative to the pure model.

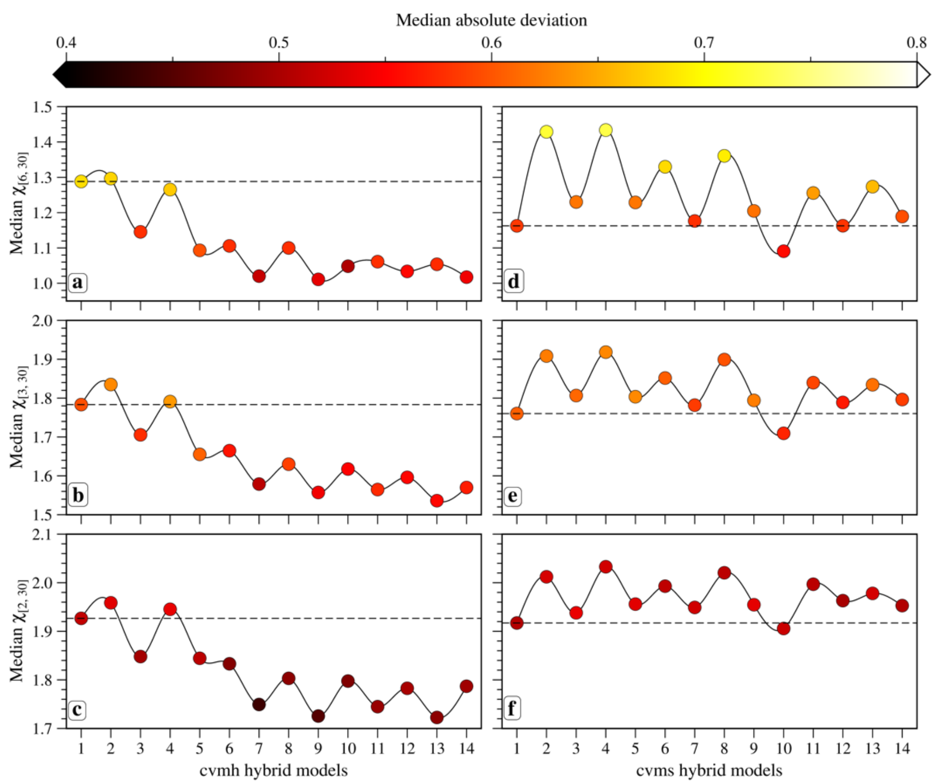


Figure 4. *Summary of the simulation results for cvmh (a-c) and cvms (d-f) hybrids showing the median misfit for each model and frequency band color-coded by the median absolute deviation. The horizontal dashed line is the median misfit value of the pure cvmh and cvms models before hybridization. Hybrid models below the dashed line produced better matching waveforms than the original models. The model numbers correspond to those shown in Fig. 3.*

INTELLECTUAL MERIT

Our algorithm and basin-scale models used to improve the SCEC CVMs have been made available to the UCVM developers for use by the research community. The algorithm and all models including the hybrid models are also available in two publications (Ajala & Persaud, 2021; Ajala & Persaud, 2022). In addition, our detailed explorations of two standard SCEC Community Models and the influence of topography, geotechnical layer, and attenuation on wavefield predictions are available in Ajala, Persaud & Juarez (2022). Insights from these initial efforts have motivated our future research to further improve the hybrid models using SSIP data.

BROADER IMPACTS

This project involved one PhD student and an early-career faculty. The results from this research have been used in several presentations and lectures given by the PI. The algorithm and methodology provide a low-cost way to improve earthquake ground motion estimates and produce integrated Statewide Community Models for geological, geodynamic and earthquake studies. Our algorithm and the Salton Trough study will benefit other high seismic hazard regions particularly those located above sedimentary basins.

PEER-REVIEWED PUBLICATIONS RESULTING FROM THIS AWARD

Ajala R. & P. Persaud (2022), Ground Motion Evaluation of Hybrid Seismic Velocity Models, *The Seismic Record.* 2(3), 186–196, https://doi.org/10.1785/0320220022

Ajala R., P. Persaud & A. Juarez (2022), Earth Model Space Exploration in Southern California: Influence of Topography, Geotechnical Layer, and Attenuation on Wavefield Accuracy, *Frontiers in Earth Science*, vol 10, https://doi.org/10.3389/feart.2022.964806

Ajala, R., & Persaud, P. (2021). Effect of merging multiscale models on seismic wavefield predictions near the southern San Andreas fault. *Journal of Geophysical Research: Solid Earth*, 126, e2021JB021915. https://doi.org/10.1029/2021JB021915

PRESENTATIONS RELATED TO THIS PROJECT

Persaud, P., Ajala, R., Nardoni, C. & Juarez, A. (2023, 09). Scaling-up Community Earth Models: A Hybrid Approach. Oral Presentation at 2023 SCEC Annual Meeting. SCEC Contribution 12865

Persaud, P., & Ajala, R. (2022, 09). Ground-Motion Predictions for Salton Trough Using Cross-Pollinated Earth Models. Poster Presentation at 2022 SCEC Annual Meeting. SCEC Contribution 11955

Ajala, R., Persaud, P. & Juarez, A. (2021, 08). Beyond 1 Hz: Double-difference active source adjoint tomography of Salton Trough. Poster Presentation at 2021 SCEC Annual Meeting. SCEC Contribution 11547

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