Assessing the suitability of the CRESCENT CVM0 for seismic hazard assessment in the Cascadia region

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Abstract

The Cascadia Subduction Zone (CSZ) poses a significant hazard to the Pacific Northwest, with the potential for earthquakes as large as magnitude 9 megathrust events. However, because of the relative quiescence of the Cascadia subduction zone during the era of modern seismic networks, constraining future ground motions with empirical ground motion models (GMMs) has been challenging. Recent research has shown promise in using physics-based ground motion simulations as a supplement in regions with limited data to constrain GMMs. However, these simulations require detailed and accurate seismic velocity models, with an understanding of how velocity model uncertainty propagates into hazard estimates.

In this study, we assess the suitability of the CRESCENT CVM0 (CRESCENT Generation 0 Cascadia Community Velocity Model) for this purpose. The model has been constrained using joint inversion of teleseismic receiver functions and ambient noise data, and is unique as it also provides uncertainty estimates, which are critical for seismic hazard assessment. With a carefully selected database of 100 earthquakes including interface, intraslab and crustal events, we generate synthetic seismograms up to 1Hz using the 3D wavefield simulation package SPECFEM3D. We then compare metrics computed for both real data and synthetic seismograms for each of the earthquakes, including peak ground acceleration (PGA), peak ground velocity (PGV), duration, and Fourier spectral amplitudes. We assign a score to each synthetic seismogram based on how it compares to its corresponding data record. Ultimately, we will make an assessment on the suitability of the use of the CRESCENT CVM0 in providing reliable synthetic seismograms for seismic hazard assessment in the Cascadia region.

Motivation

- Existing ground motion models in Cascadia are based on the limited earthquake data available in the region, providing a compelling argument for the use of physics based wavefield simulations instead for hazard assessment.
- The accuracy of physics based simulations, relies on the ability of a structural model of the Earth in providing reliable synthetic seismograms, necessitating its validation first, using existing earthquake data.

Data Selection

We search the USGS earthquake catalog with the following event selection criteria to shortlist the events for this study:

- Longitude range: -129E to −117E
- Latitude range: 40N to 49N
- Magnitude range: 3 to 6
- Time range: 2000-01-01 to 2026-01-16
- One event per grid cell (~50km x ~50km x 10km)
- Events with an available moment tensor solution

Validation Dataset

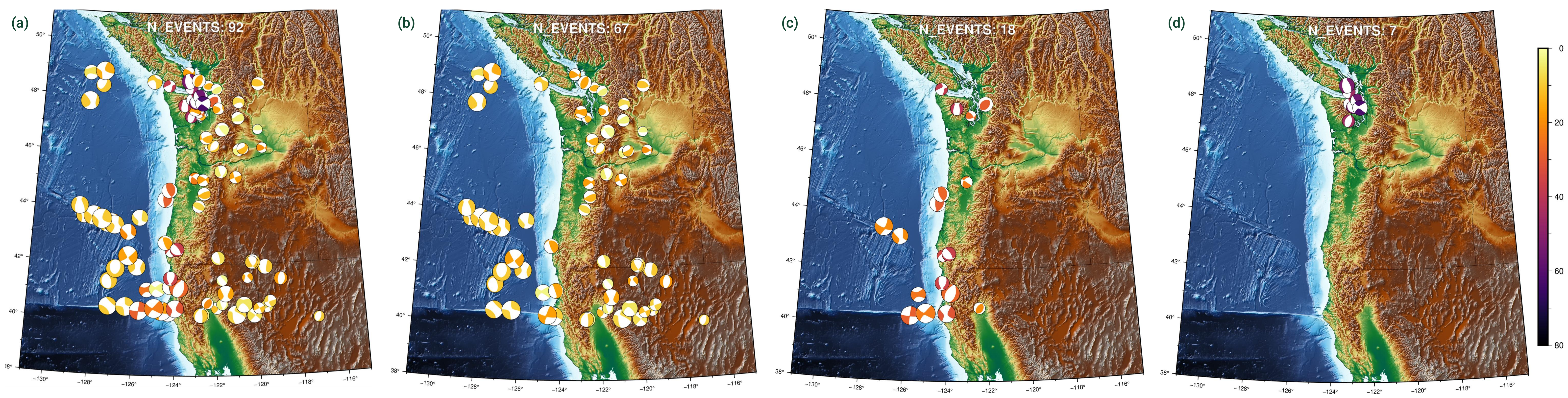

Figure 1: (a) Map of the Cascadia region showing the 92 earthquakes shortlisted for the validation of the CRESCENT CVM0 [3]. The beachballs depict the focal mechanisms as well as the locations of the earthquakes. They are sized by magnitude and colored by depth. The earthquakes include a mix of crustal, slab interface and in-slab events. The shortlisting criteria for these events is provided in the "event selection" section. **(b)** Same as (a) but for events with depths shallower than 20 km. There are 67 such events, and most of them are crustal events. Most of the offshore events lie along the boundaries of the Juan de Fuca and Gorda plates. **(c)** Same as (a) but for events with depths between 20 km and 40 km. There are 18 such events. Some of them are slab interface events, while some are crustal. Most of these events also lie along the boundaries of the Juan de Fuca and Gorda plates. **(d)** Same as (a) but for events deeper than 40 km. There are 7 such events. All of these are in-slab events and are limited to the Seattle region. The deepest event found with the given search criteria is 62.2 km deep with a magnitude of 4.7. More deep events can be found for potential inclusion in the validation dataset by expanding the search to pre-2000 events, smaller magnitude events, and events without an available moment tensor solution in the USGS earthquake catalog.

Wavefield Simulations

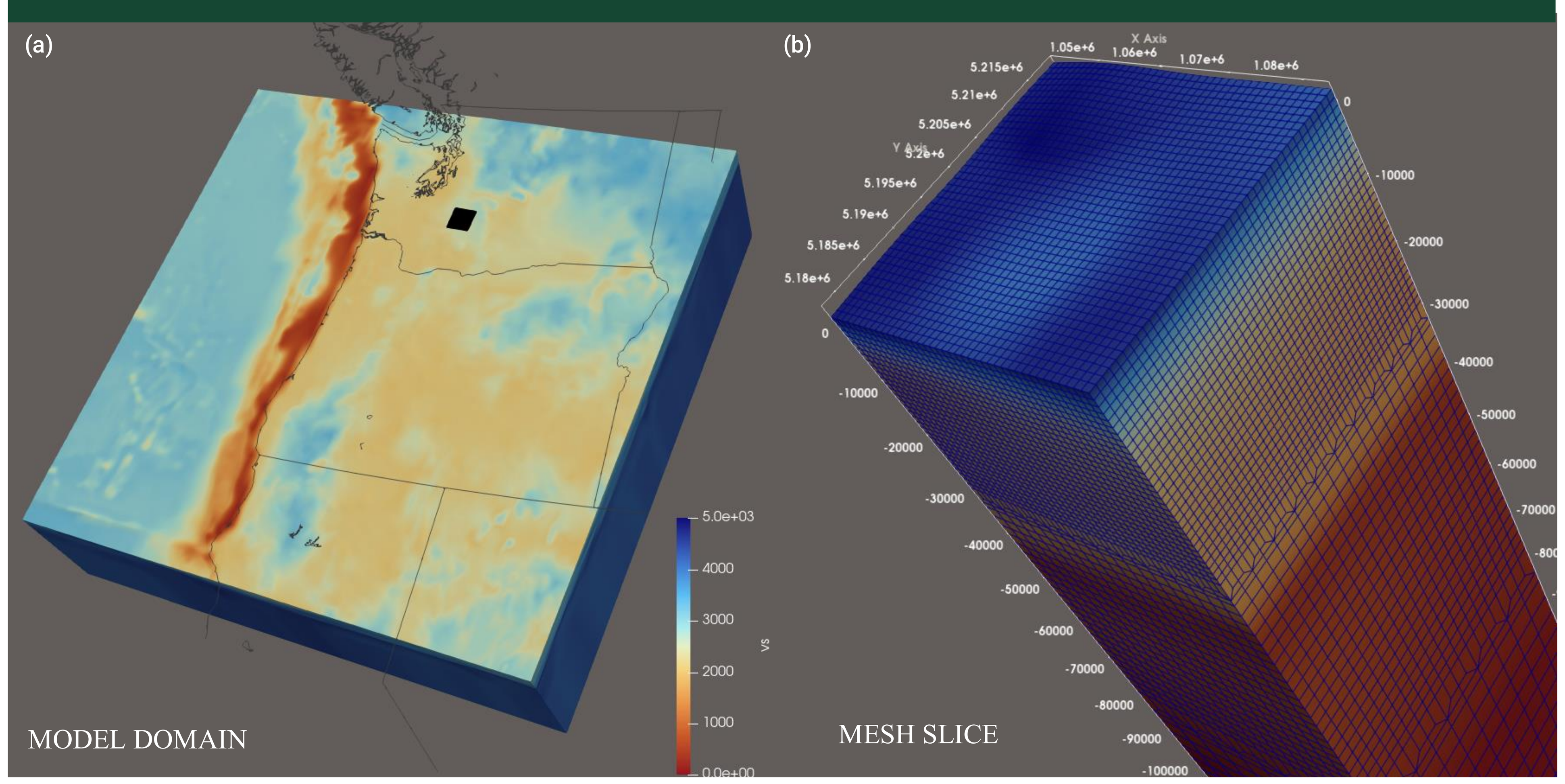

Figure 2: (a) Model domain and finite-element mesh for the Cascadia region, with topography, for wavefield simulations using SPECFEM3D Cartesian [1,2]. Colors depict the shear wave velocity (units in m/s) model adapted from the CRESCENT CVM0 [3]. The domain is 1000 km x 1000 km in area and 250 km deep. Coastlines and political boundaries are shown using black lines. **(b)** Sub-mesh showing one of the 576 slices of the entire domain, indicated by the black square in (a). The location of the sub-mesh corresponds to the location of Mt. Rainier, chosen for its high elevation to demonstrate how the mesh conforms to the topography. The mesh has two doubling layers roughly corresponding to ~31km and ~80km depths.

Future Work

- Expand the event search to include deep events from the pre-2000 era as well as those with magnitudes < 3 as a measure for the paucity of recorded deep events in the Cascadia region, and explore their usability.
- Fetch moment tensor solutions for deep events without existing moment tensor solutions. The deep events in the present dataset are extremely limited in spatial extent.
- Generate a flat file to archive the finalized dataset, including various seismogram metrics observed at stations having recordings with a good SNR for each event.
- Optimize wavefield simulations for computational cost by exploring choices for domain size, element size, resolvable frequencies, and available processor architectures.
- Run 3D wavefield simulations, for each event from the finalized validation dataset, after adapting the CRESCENT CVM0 [3], using SPECFEM3D Cartesian [1,2].
- Run suites of simulations with velocity model perturbations based on provided uncertainty estimates, to study resultant ground motion distributions for the same events.
- Compare metrics computed from both real data and synthetic seismograms at each station for each event and assign a score to each comparison.
- Assess region-wise, the suitability of the use of the CRESCENT CVM0 [3] in providing reliable synthetic seismograms for seismic hazard assessment in Cascadia.

References

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