Ground-motion modeling in Cascadia for the U.S. National Seismic Hazard Model:
Current modeling approaches and open questions

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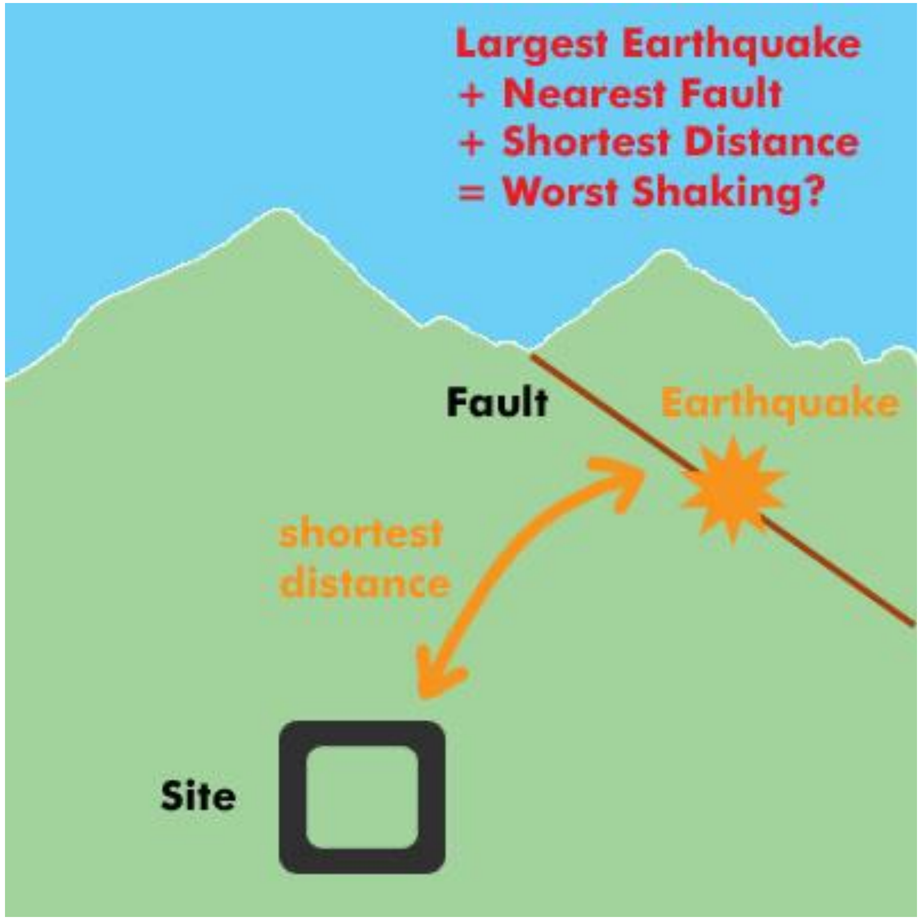
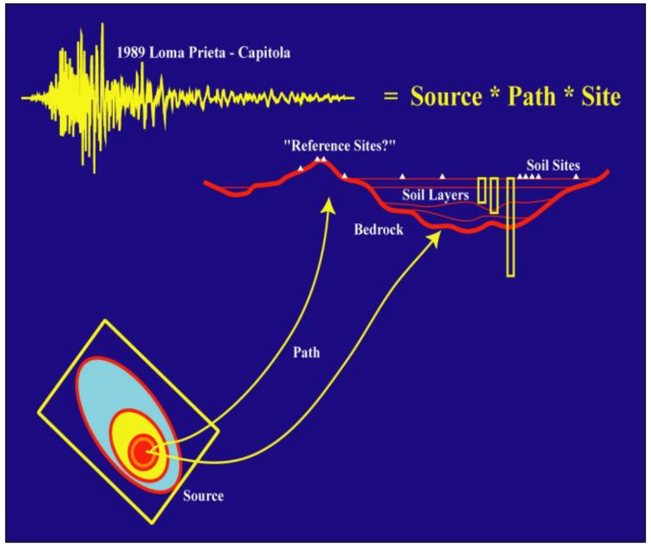
Ground Motions in Probabilistic Seismic Hazard Analysis (PSHA)



- PSHA consists of suites of predicted ground motions
- In WUS and Cascadia, ground-motion models (GMMs) specify ground motion (median and standard deviation)
- Selecting and combining GMMs has direct input on hazard

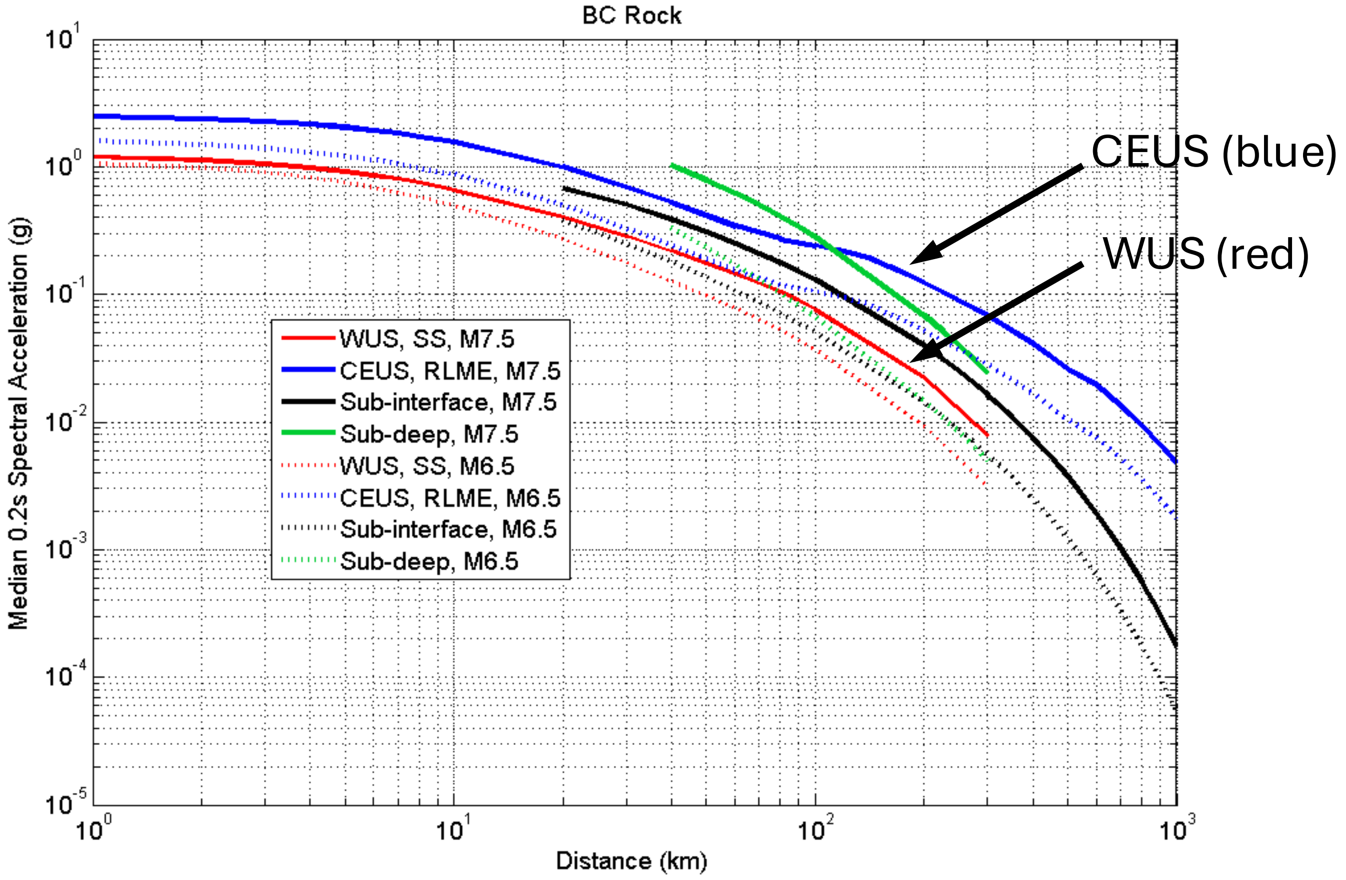
Selecting, modifying, combining ground-motion models (GMMs) for seismic hazard



$$\mu_{\ln Y} = c_0 + F_P + F_M + F_D + F_S$$

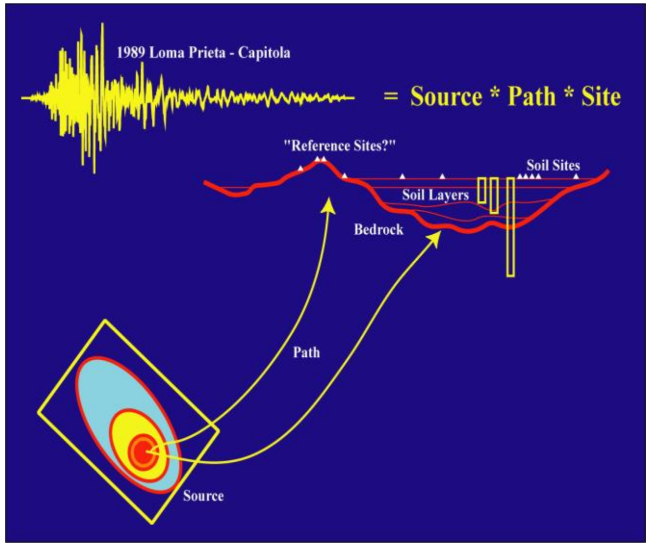
(path) (magnitude) (depth) (site)

$$\mu_{lnY} = f(M, R, V_{S30}, Z_1, Z_{2.5}, X)$$



(figure courtesy S. Rezaeian)

Selecting, modifying, combining ground-motion models (GMMs) for seismic hazard



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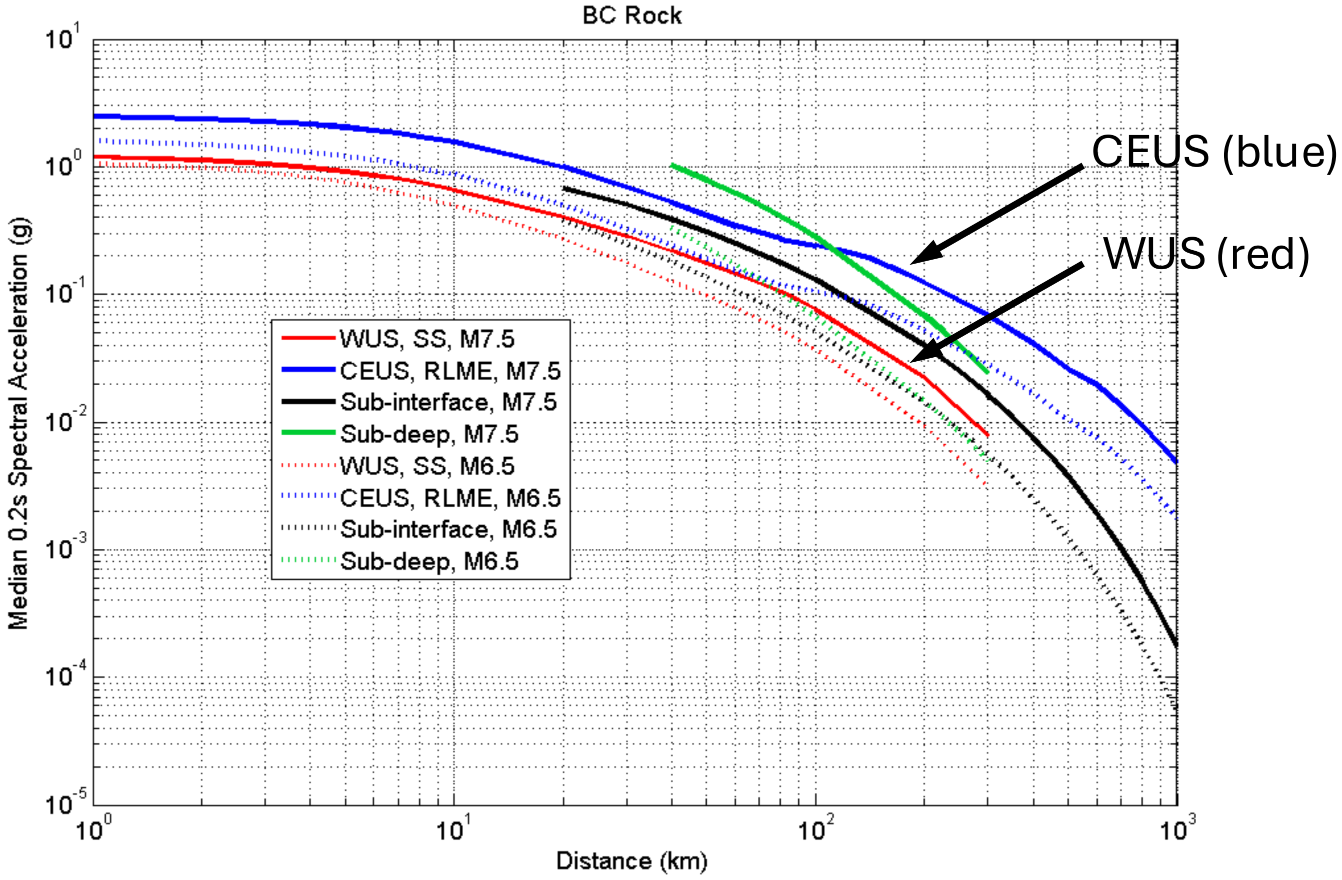
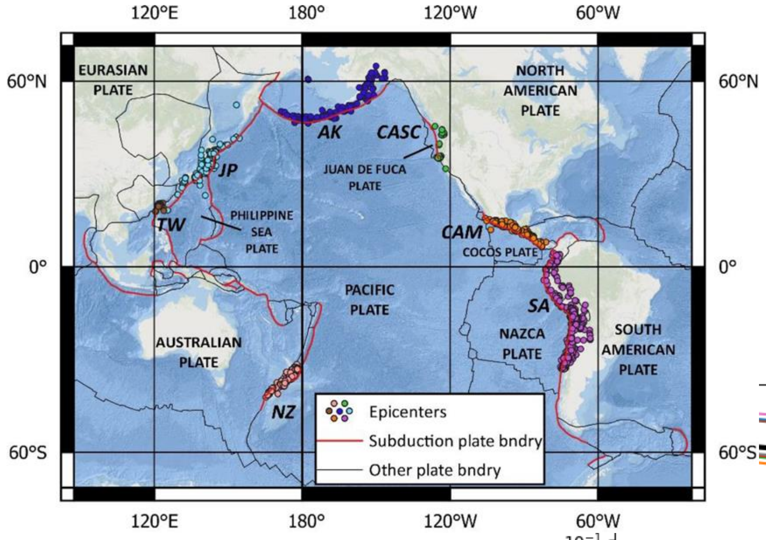
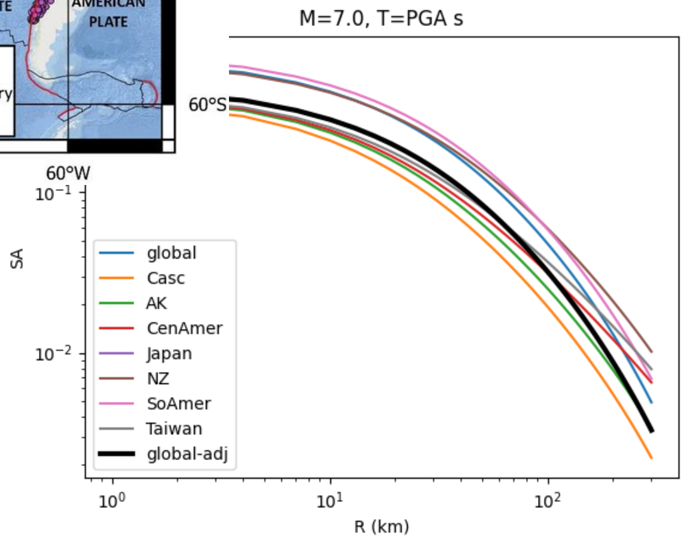
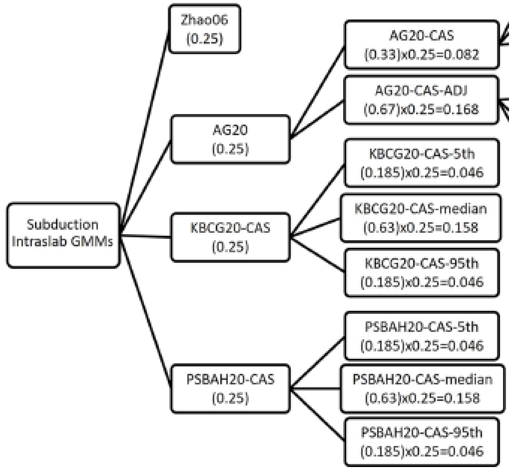


(figure courtesy S. Rezaeian)

Ground-motion models (GMMs) for Cascadia

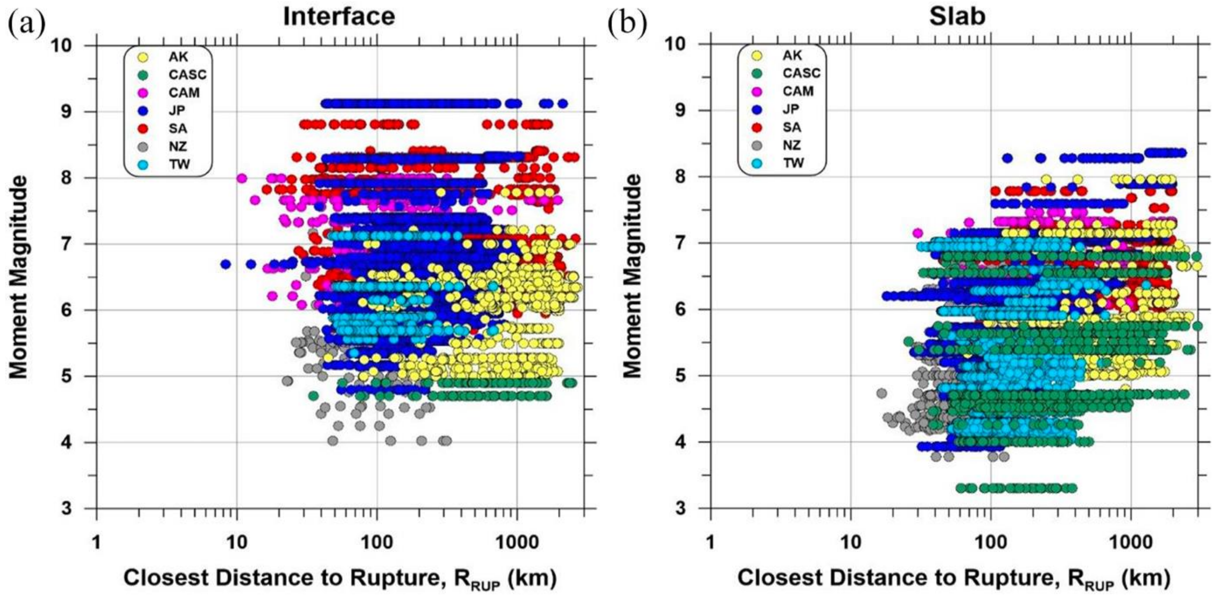




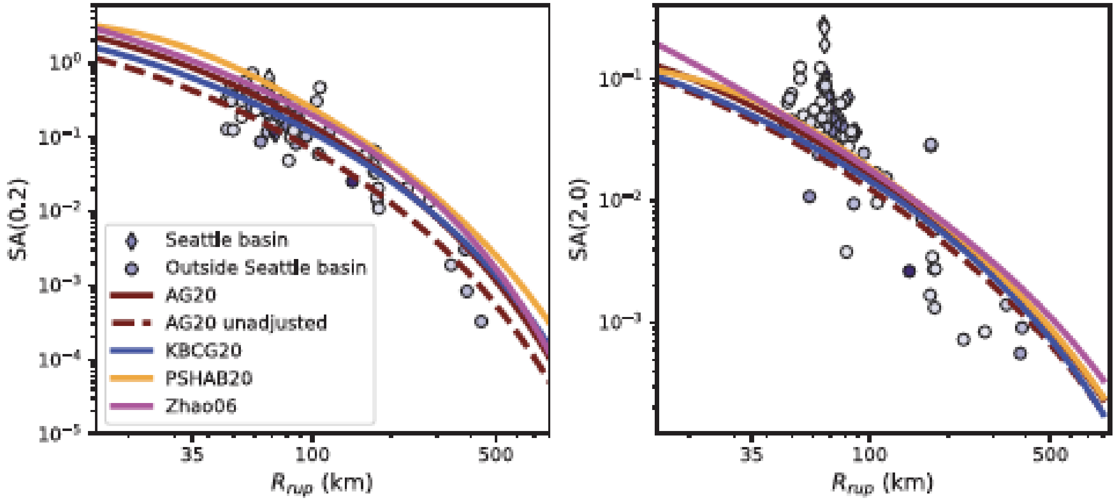


- Ground-motion modeling for subduction earthquake benefits from NGA-Subduction project
- NGA-Sub GMMs take advantage of largest-available ground-motion dataset, development of functional forms
- Cascadia-regionalized site response (VS30), basin effects, anelastic attenuation
- Alternative models are included through logic trees

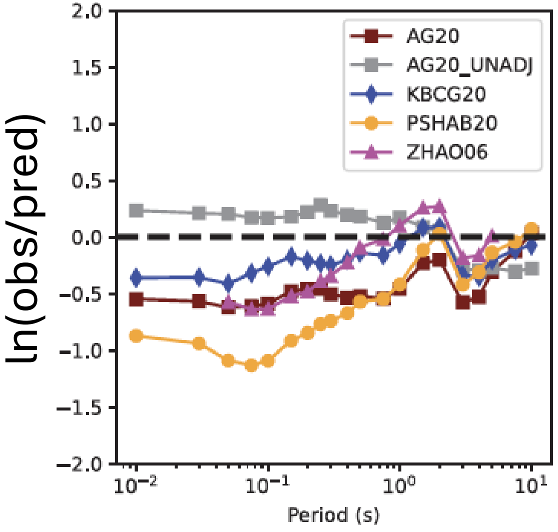
Impact of limited data in Cascadia for Cascadia GMMs



(Bozorgnia et al., 2022)

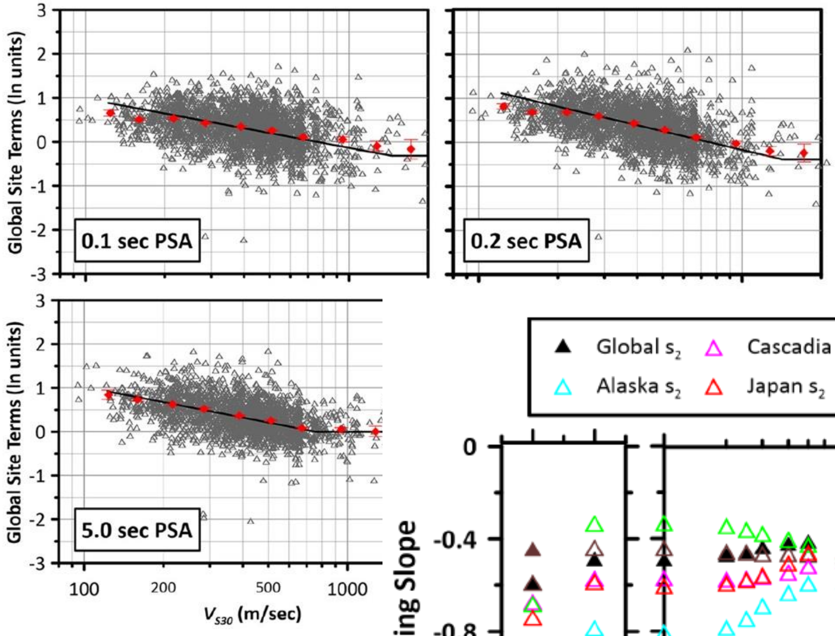


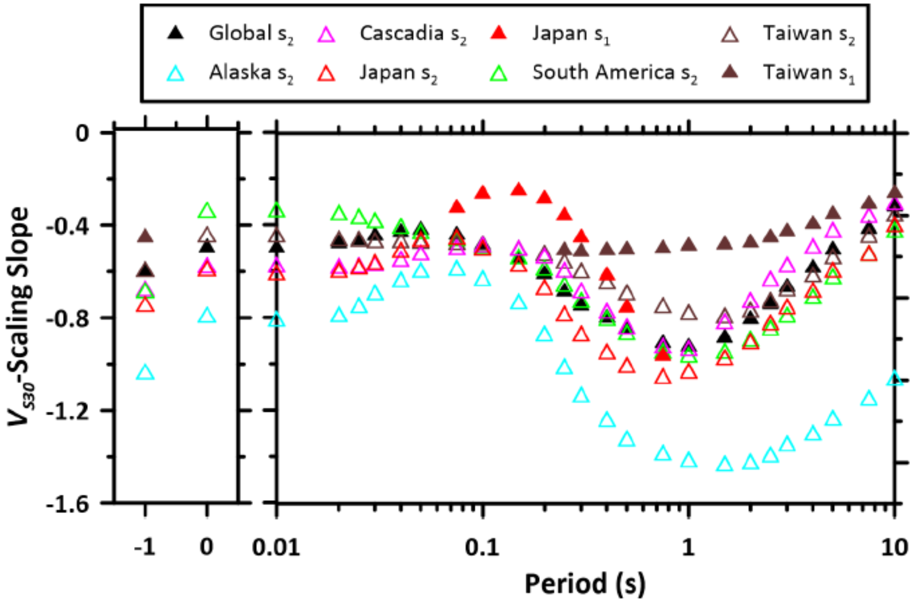
(Smith et al., 2024)



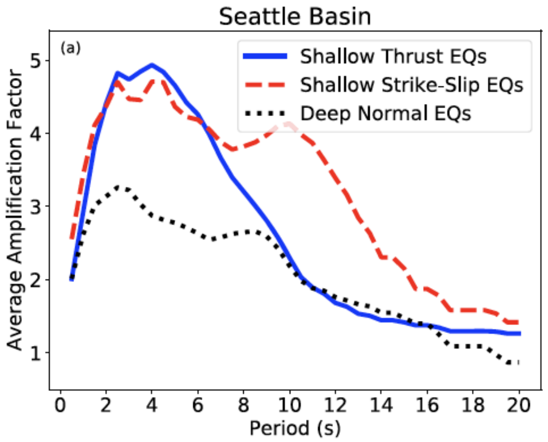
Regional site response

USGS
science for a changing world





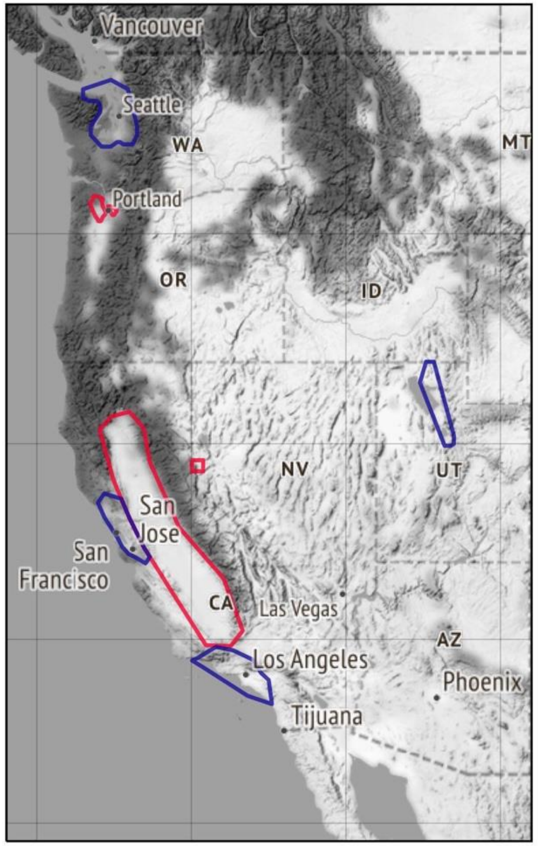
Parker et al. (2022)

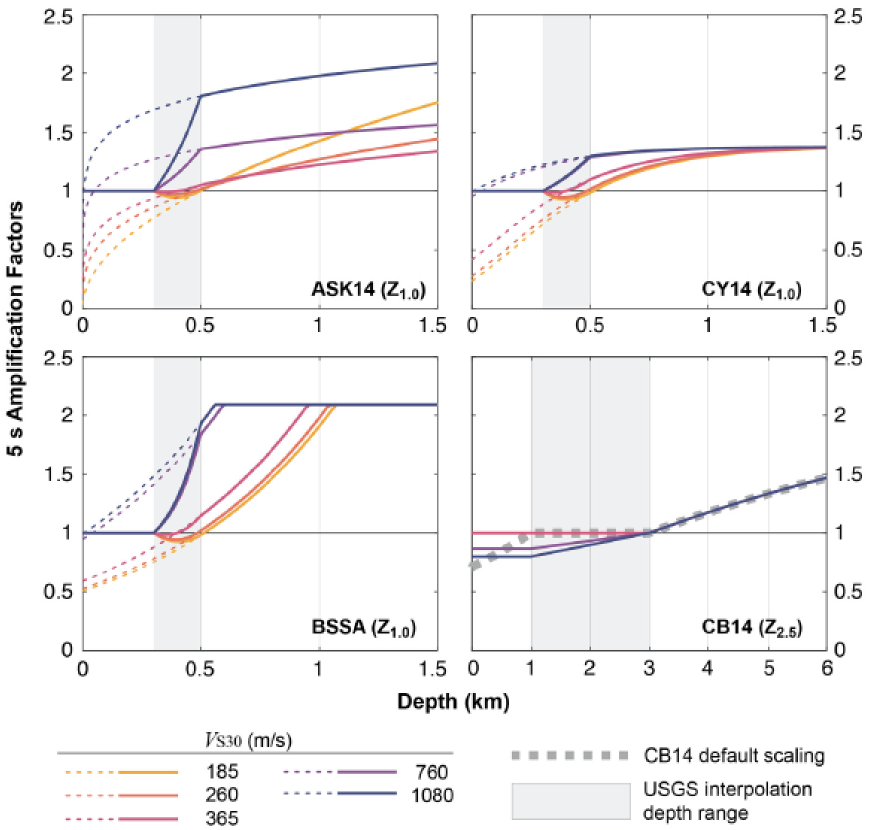


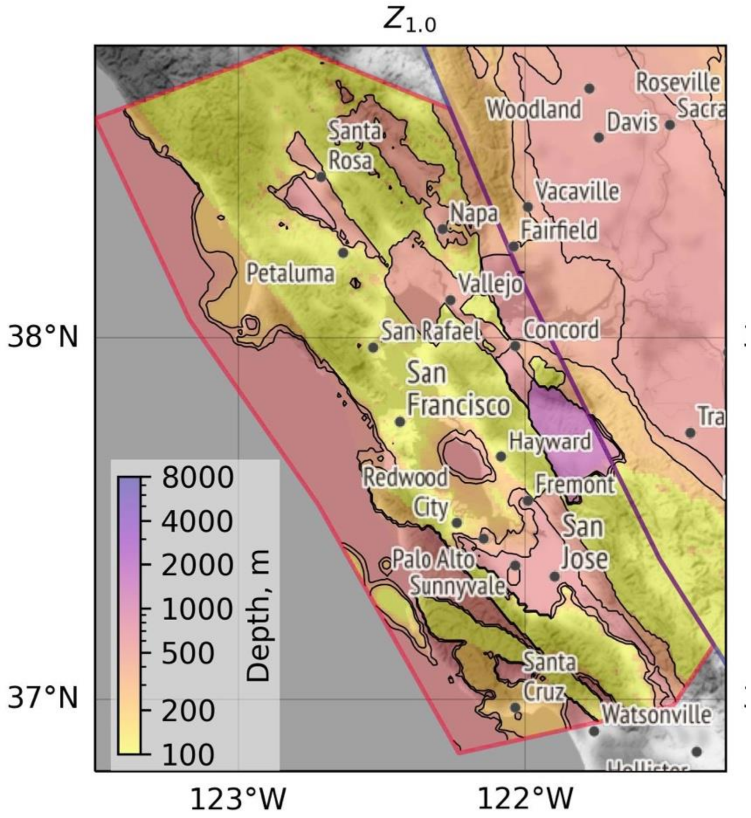
Wirth et al. (2019)

- How (and why) does site response in Cascadia differ from other regions?
- What controls regional site amplification? What is spatial extent of these effects?
- Does site response vary with source depth/type, azimuth, other factors?

Basin implementation, 2023 and 2018

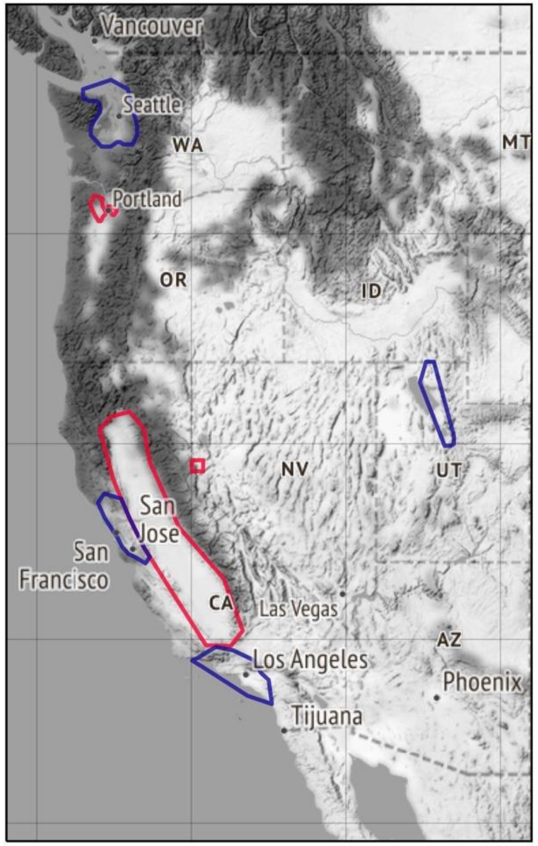


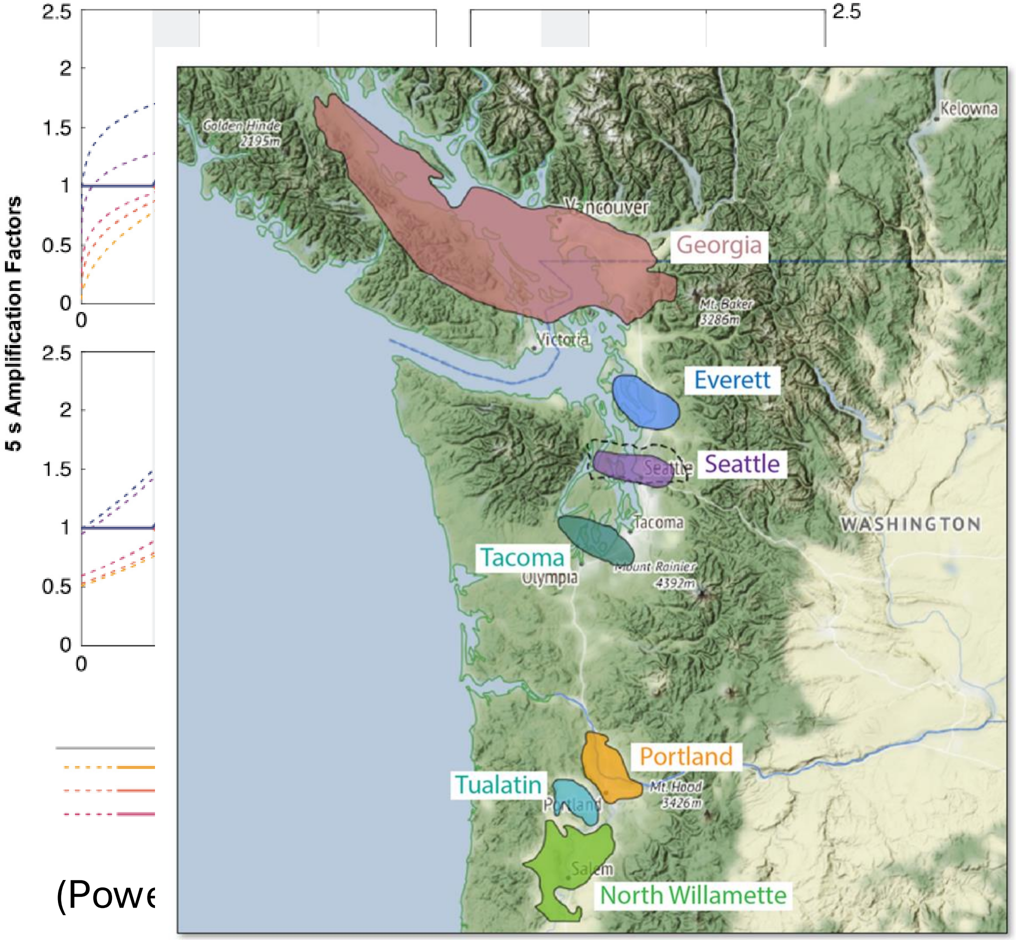


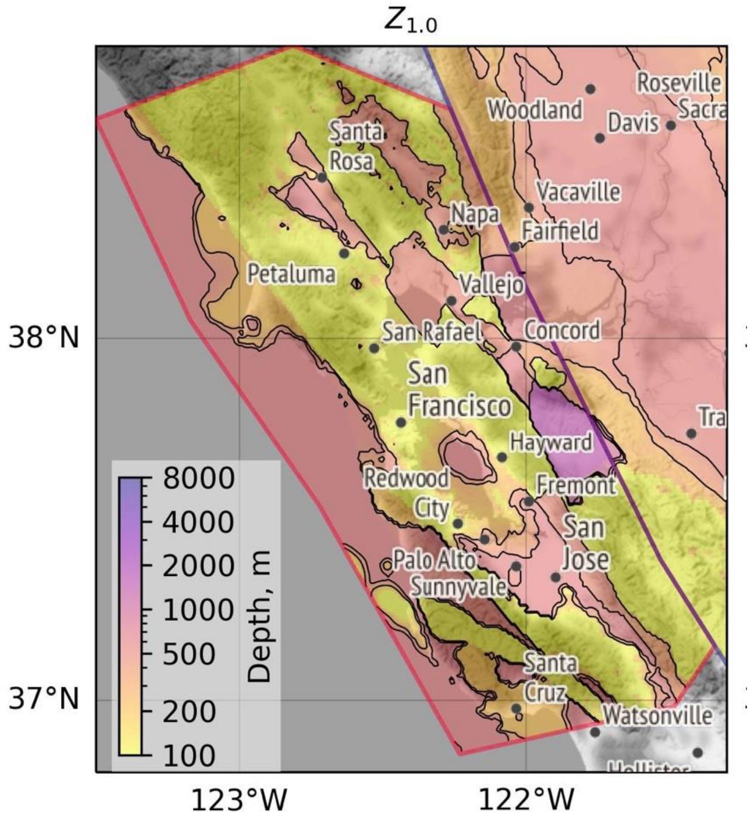


(Powers et al., 2020)

Basin implementation, 2023 and 2018

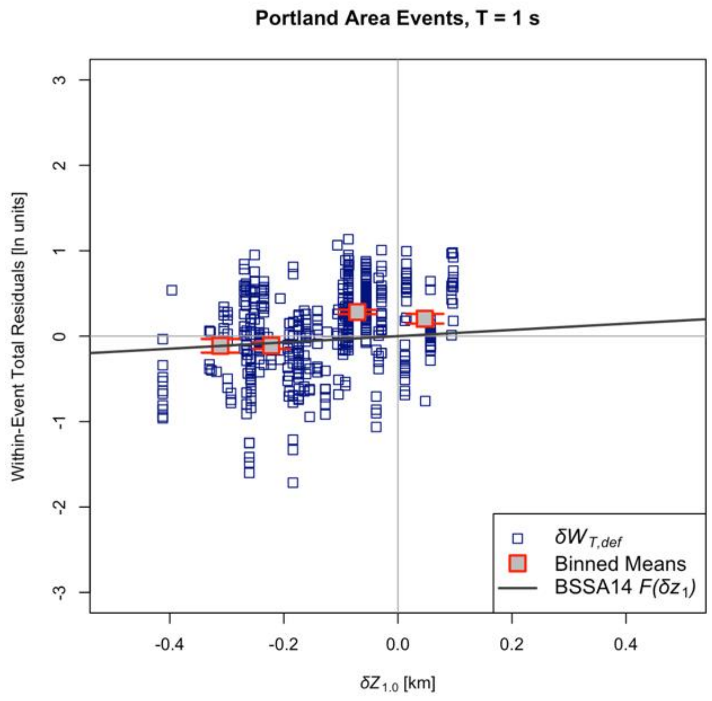


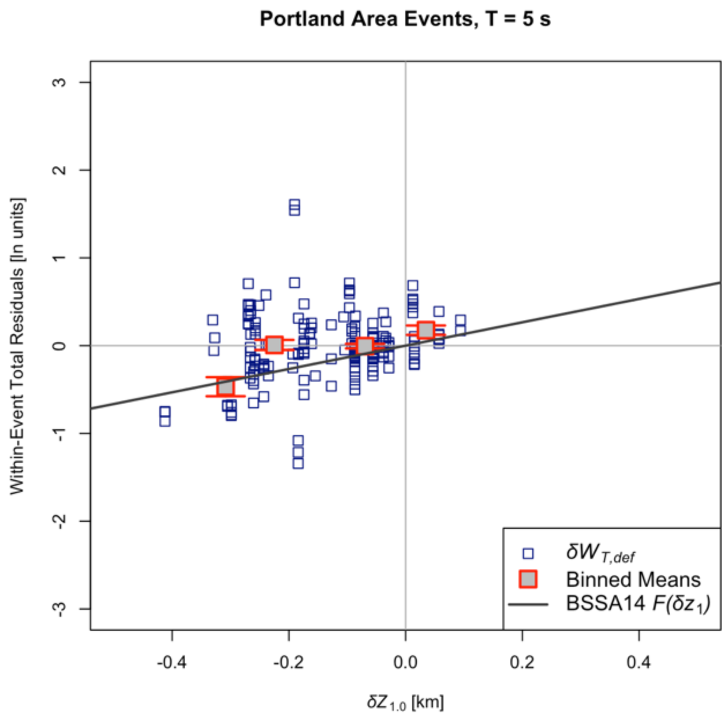


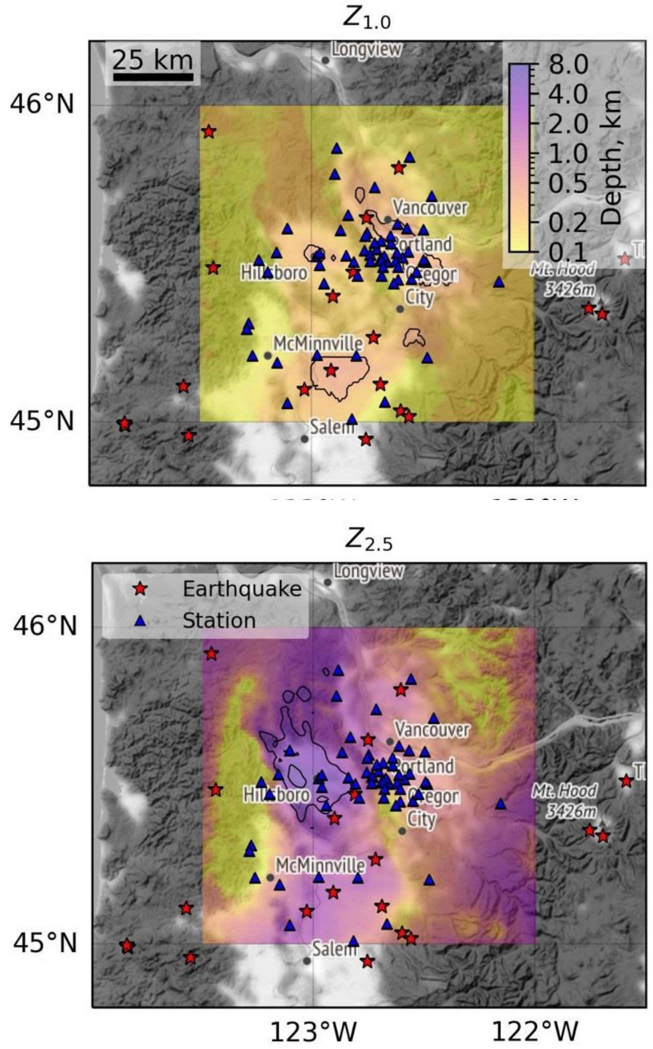


Portland/Tualatin Basin

- Basin model from National Crustal Model–surfaces controlled by Columbia River Basalts (Z1) and top of early Eocene basement (Z2.5)
- Include Portland/Tualatin basins

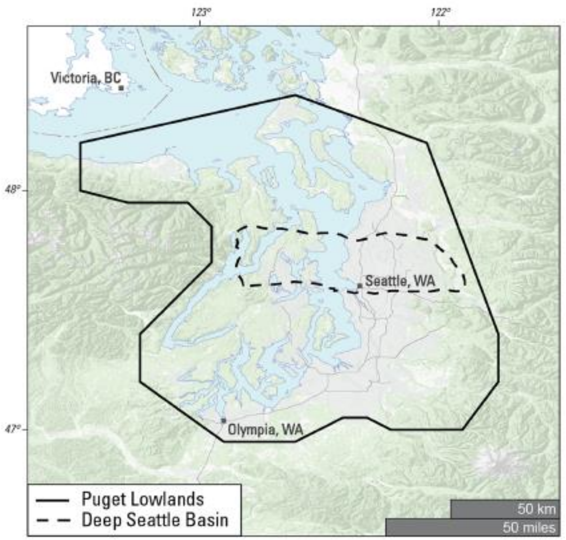


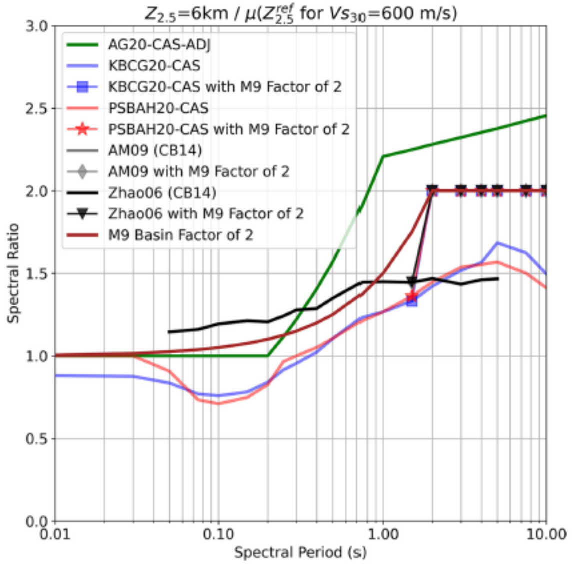




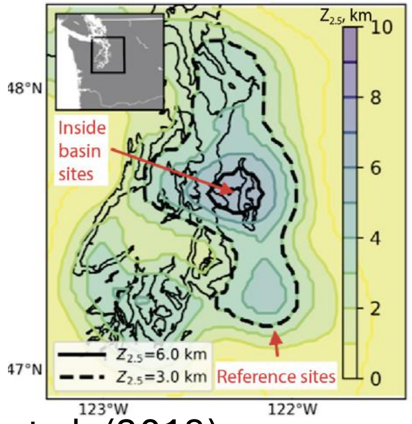
(Ahdi et al. 2024)

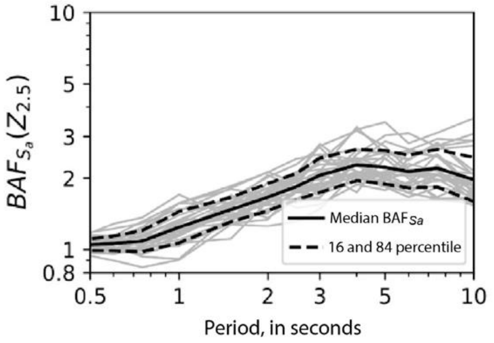
Basin effects from ground-motion simulations





Rezaeian et al. (2024): 2023 NSHM

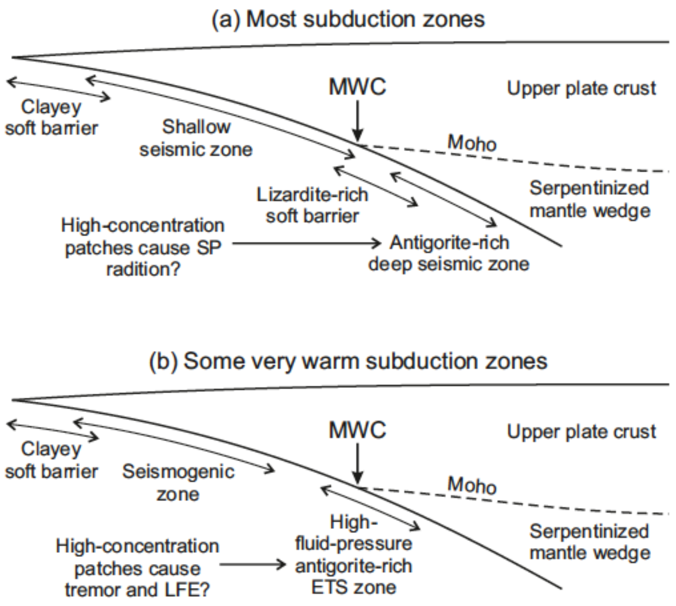




Wirth et al. (2018)

- Basin amplifications from 3D ground-motion simulations in Seattle basin (2023 NSHM)
- Factors from M9 simulations (Frankel, Wirth, and others)
- Implemented basin factors uniformly within deepest parts of Seattle basin—no depth dependence from simulation-based ground motions
- Further work on understanding and modeling basin amplification, as well as additional simulations to constrain effects, would be valuable.

Some outstanding questions/directions...



Wang (2025)

- **Slab ground-motion amplitudes**: Will future subduction intraslab earthquakes exhibit lower (than global) ground motions, similar to most recorded data?
- **Interface ground-motion amplitudes**: How will ground shaking from future Cascadia megathrust earthquakes compare with earthquakes globally?
  - What is the effect of warm, young subduction zone on ground motions? on presence and participation of deep high-stress-drop events (SMGAs)?
- **Simulations**: How can we increasingly incorporate simulations into Cascadia ground-motion modeling? Direct use of simulations is one long-term vision. Near-future will probably employ simulations to modify GMMs or replace GMM components.
  - Effect of subduction-zone geometry, basin amplification
- **Finite-source effects**: Parallel work to incorporate directivity for crustal fault sources. What are predominant effects of megathrust rupture directivity? Are there preferred loci of rupture in Cascadia?