UNIVERSITY of WASHINGTON

Effects of Cascadia Subduction Zone M9 Earthquakes on Bridges

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Acknowledgments

> Other Contributors:

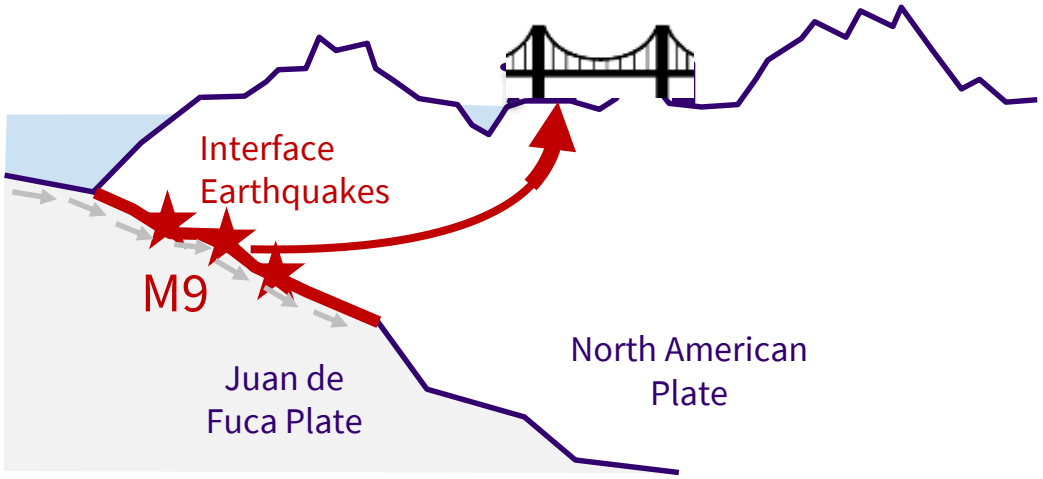
- Alison Duvall (PI, NSF M9 Project), UW
- **Arthur Frankel, USGS**
- **Alex Grant, USGS**
- **Erin Wirth, USGS**
- Steve Kramer, UW
- Andrew Makdisi, UW
- Brett Maurer, UW
- and others

> Funding Agencies:

- National Science Foundation (Award #: EAR-1331412)
- United States Geological Survey
- Earthquake Engineering Research Institute
- Washington State Dept. of Transportation

Motivation

- Cascadia Subduction Zone
- 10% Chance of ~M9 Occurring in 50 Years
- Impacts of Tsunamis and Ground Motions on:
  - Landslides
  - Liquefaction
  - Buildings
  - **Bridges**



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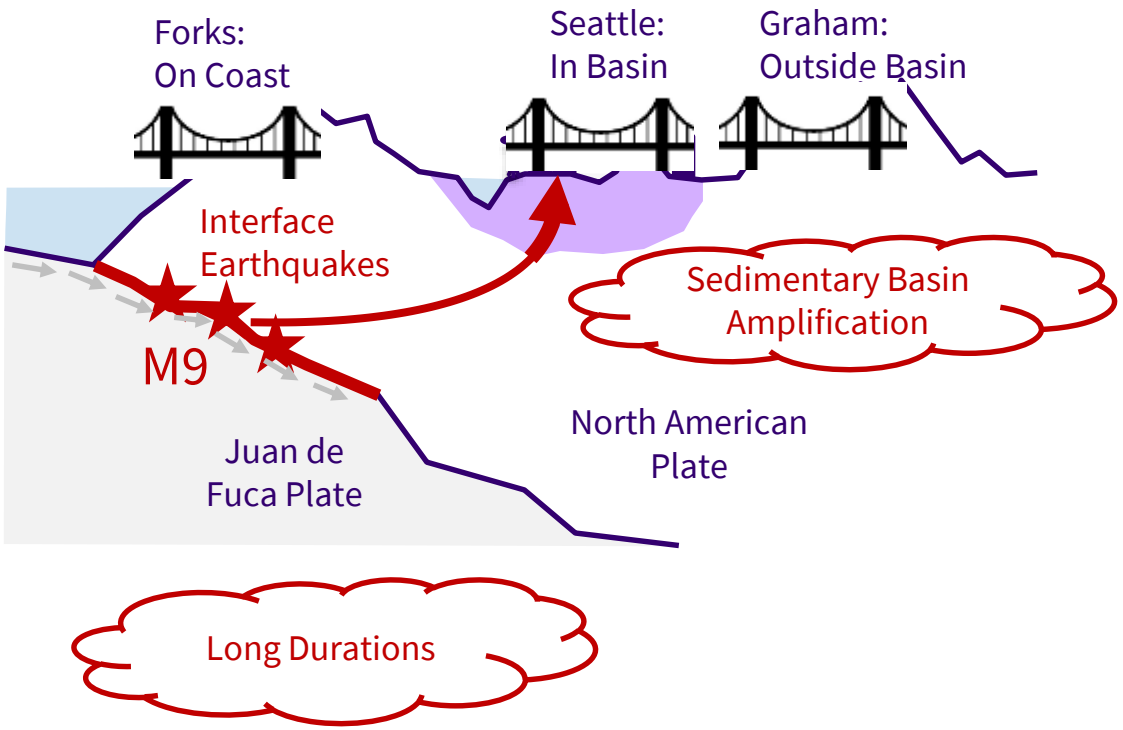
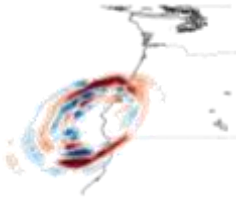


Outline

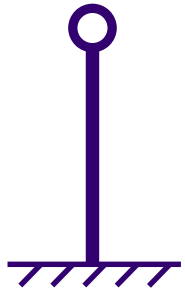
M9 Simulations



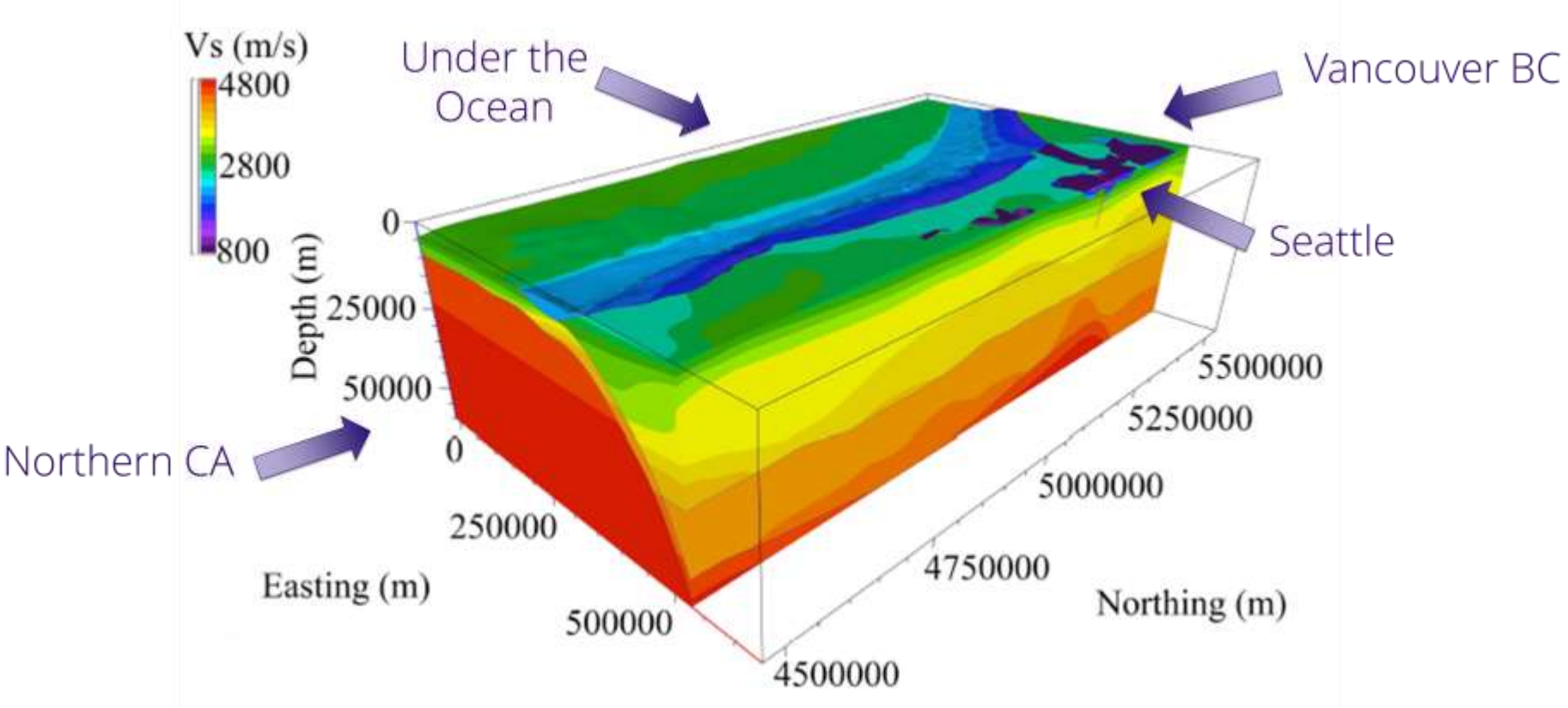
Properties of Ground Motions

Effects of 1D Site Amplification

Performance of Idealized Bridges

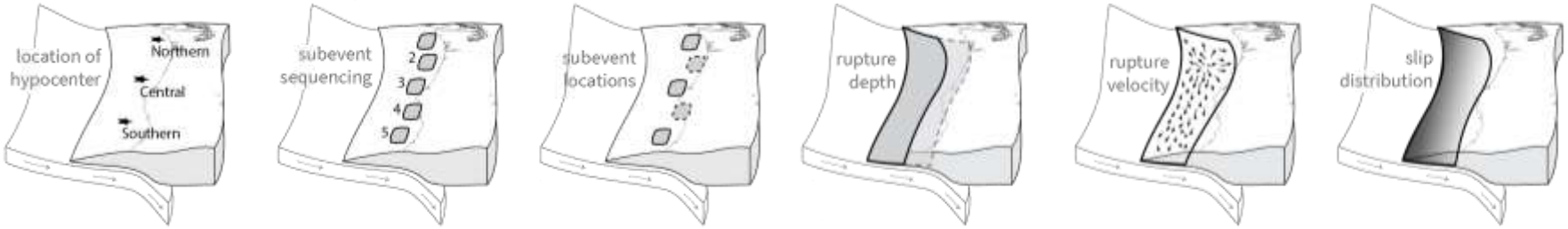


PNW Seismic Wave Velocity Model (Stephenson, USGS)



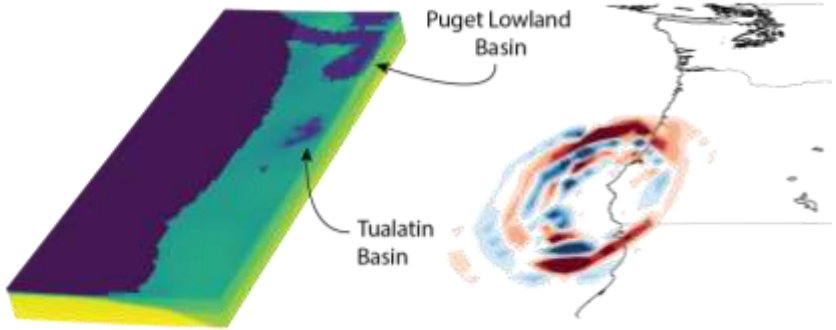
Reference: Frankel, A., Wirth, E., Marafi, N, Vidale, J., Stephenson., W. “Broadband Synthetic Seismograms for Magnitude 9 Earthquakes on the Cascadia Megathrust Based on 3D Simulations and Stochastic Synthetics”, BSSA, 2018

M9 CSZ Simulations (Art Frankel and Erin Wirth, USGS)

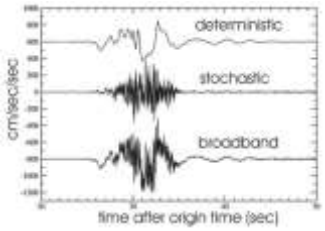


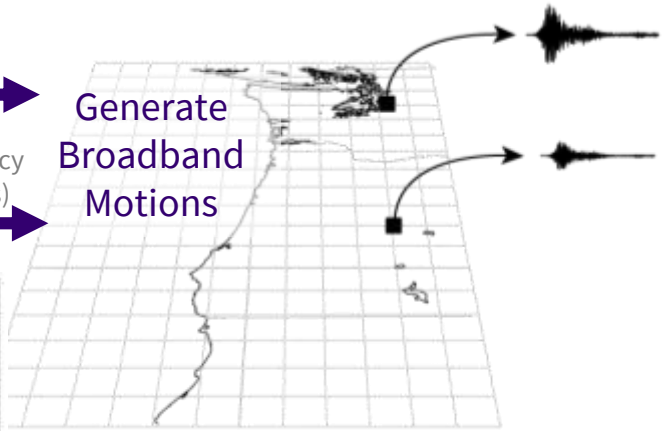
Selecting Rupture Parameters

Seismic Wave Velocity Model → **Finite-Difference Simulations** → Low Frequency Motions (>1s) → Generate Broadband Motions



Stochastically Generated Motions → High Frequency Motions (<1s) → Generate Broadband Motions





USGS science for a changing world

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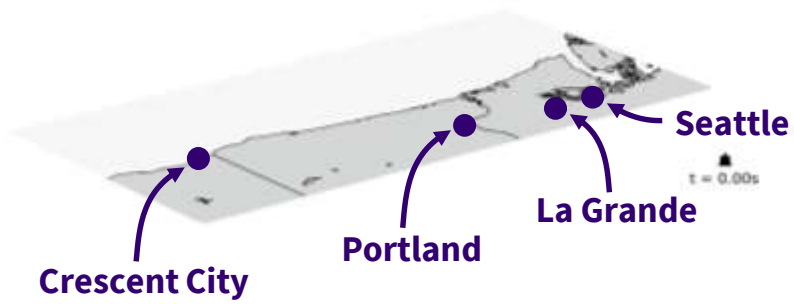
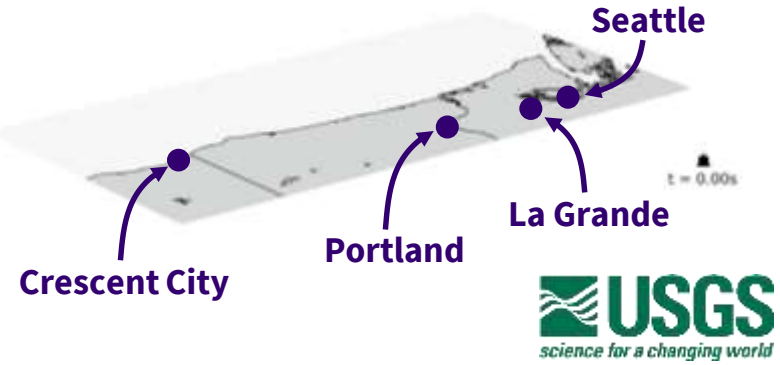
Two Example Realizations

Realization #1: Rupturing **towards** Seattle



Realization #2: Rupturing **away** from Seattle



USGS
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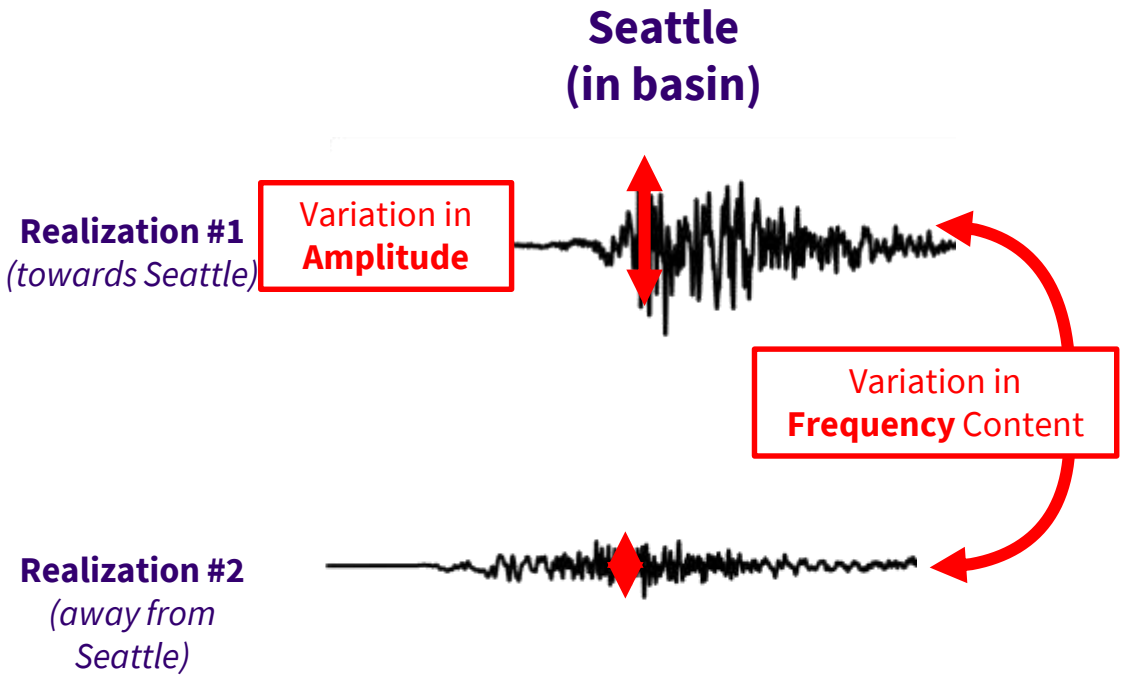
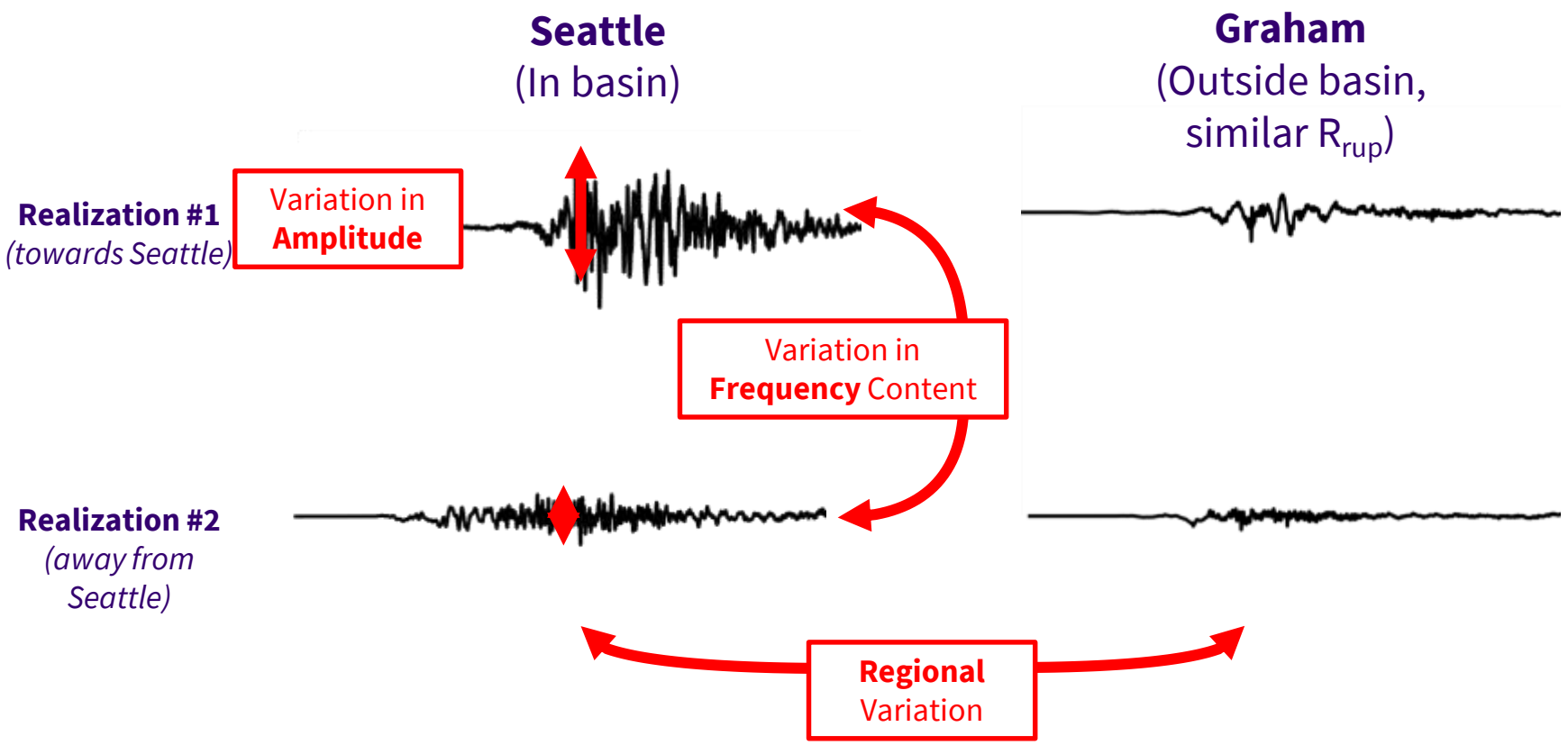
Time Histories



Time Histories



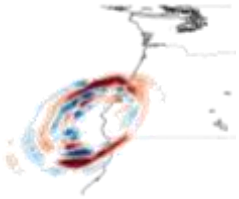
Outline

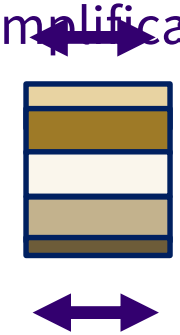
M9 Simulations

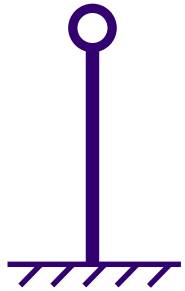
Properties of Ground Motions

Effects of 1D Site Amplification

Performance of Idealized Bridges

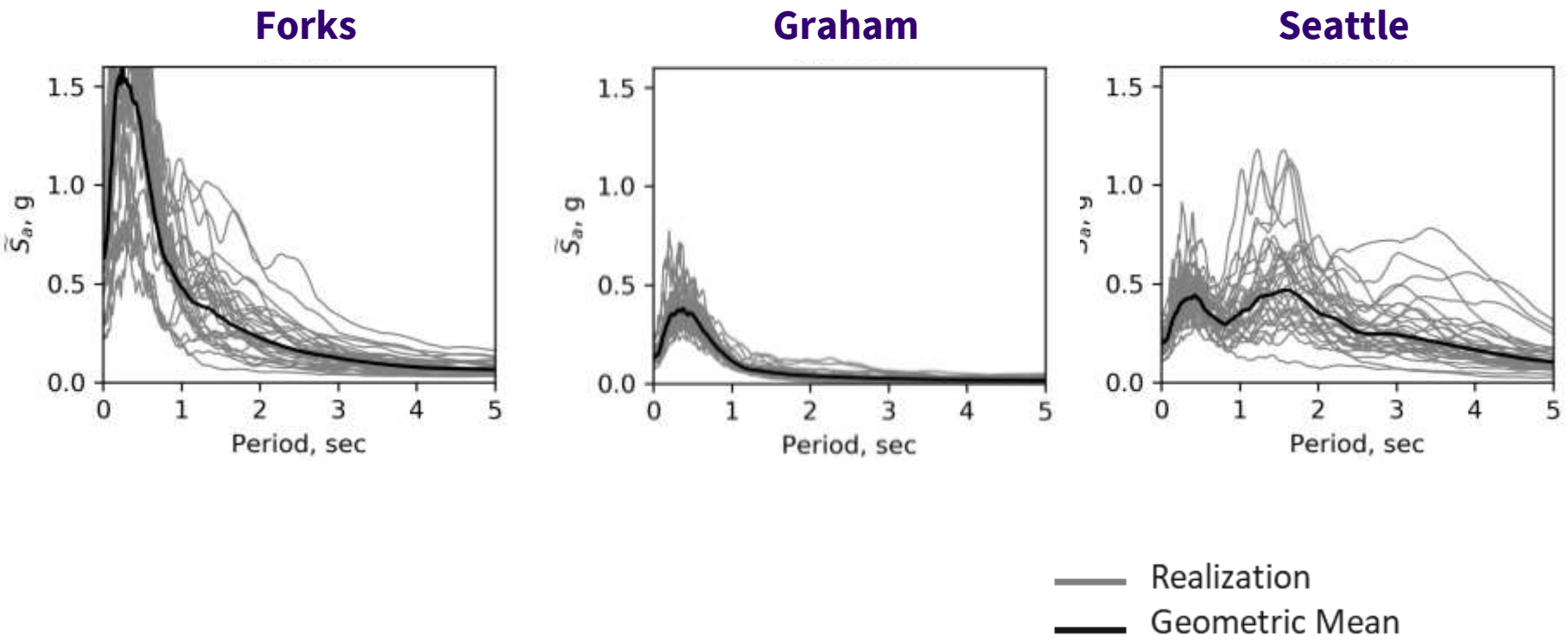






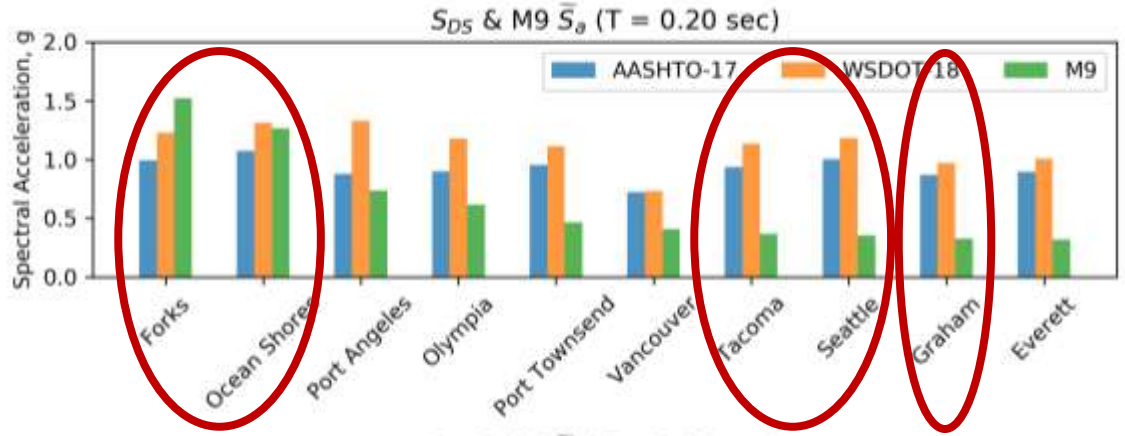
- Acceleration Response Spectra
- Spectral Shape
- Duration

Acceleration Response Spectra

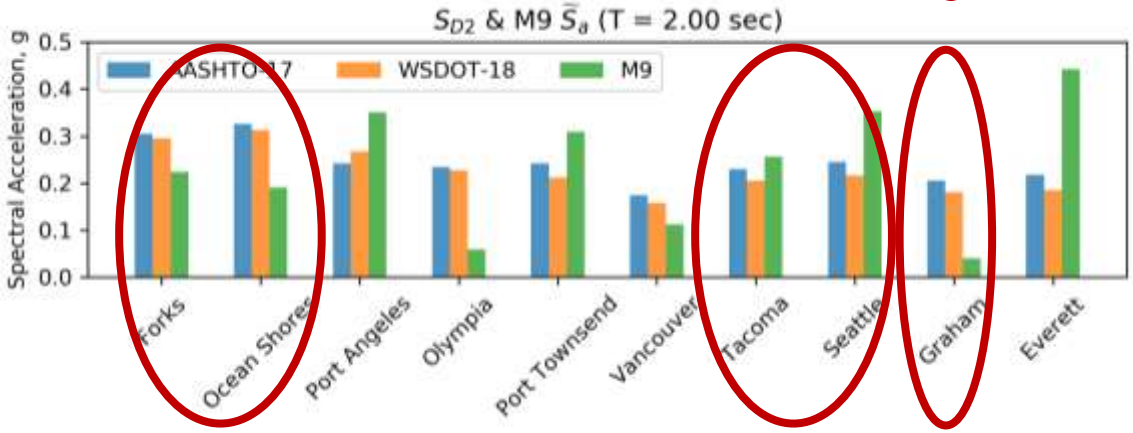


Acceleration Response Spectra

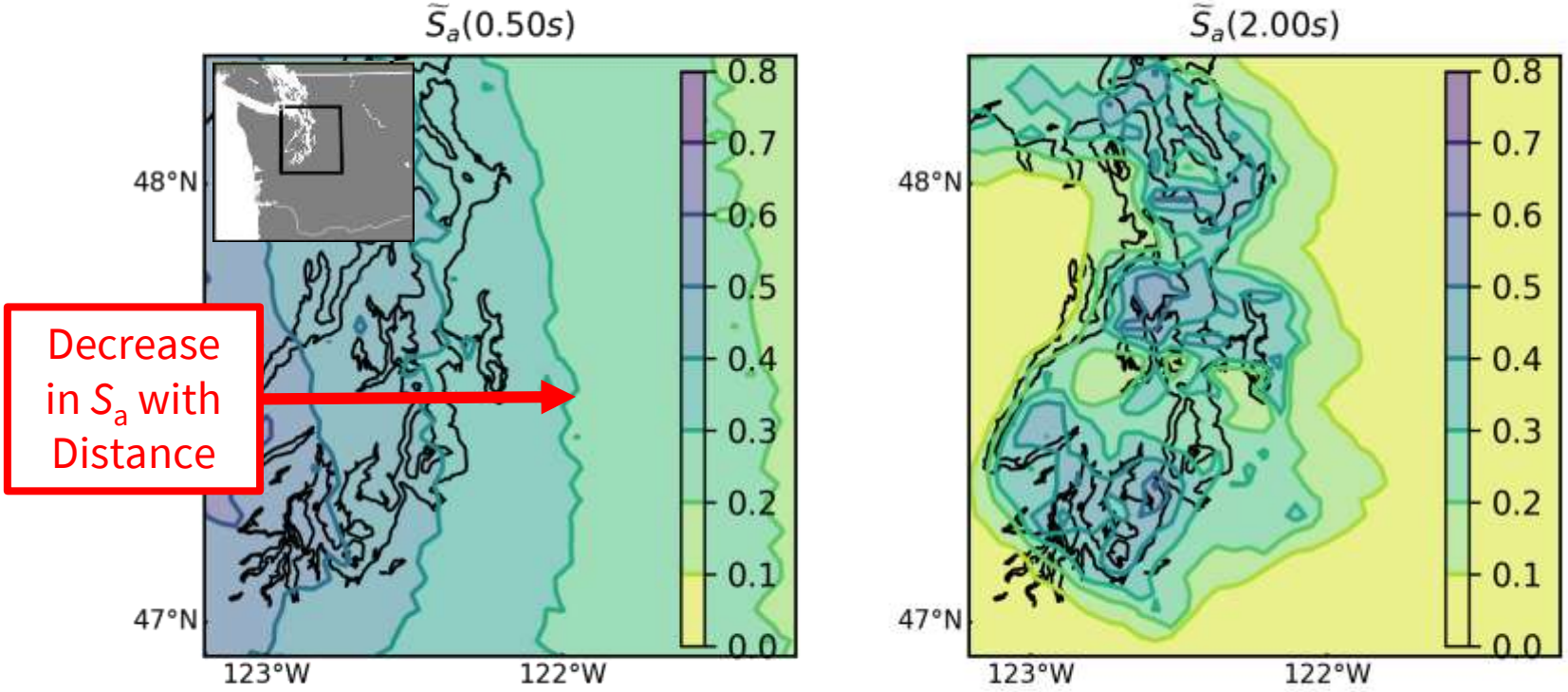
T = 0.2s



T = 2.0s

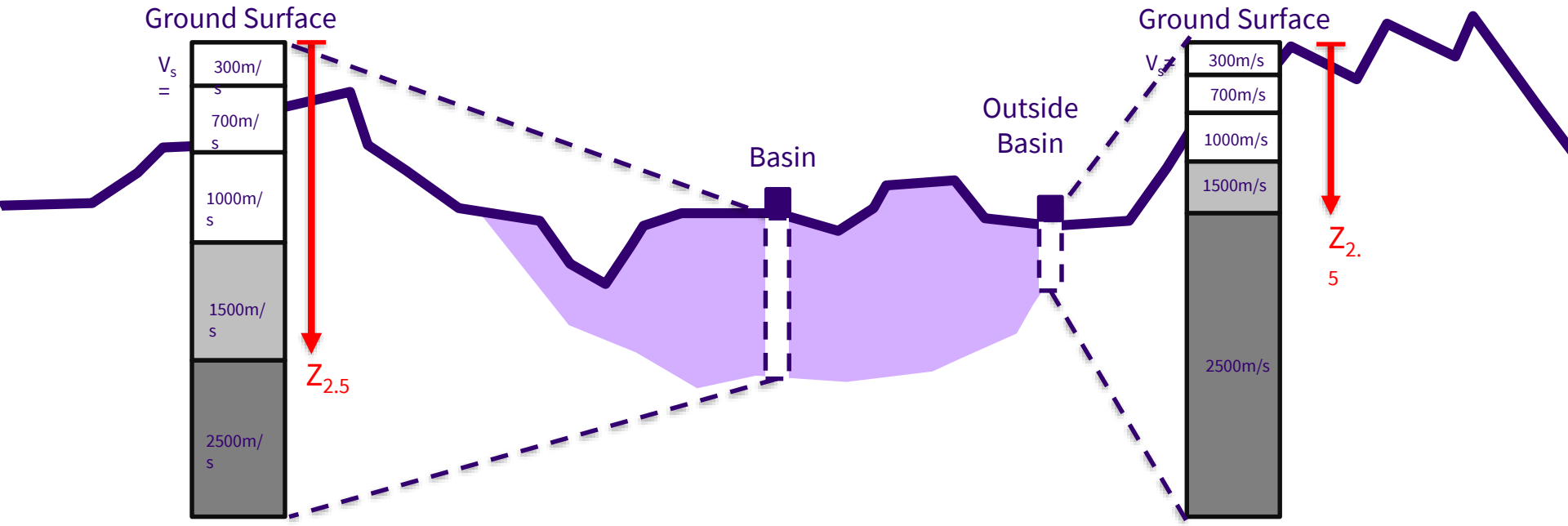


Regional Variation of S_a

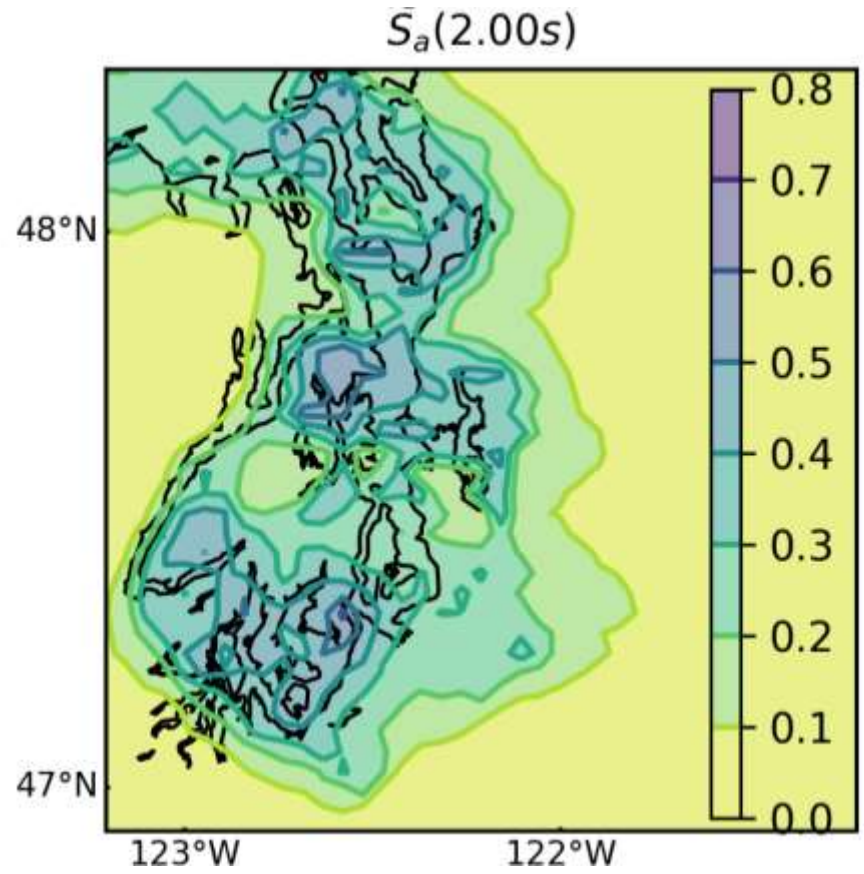


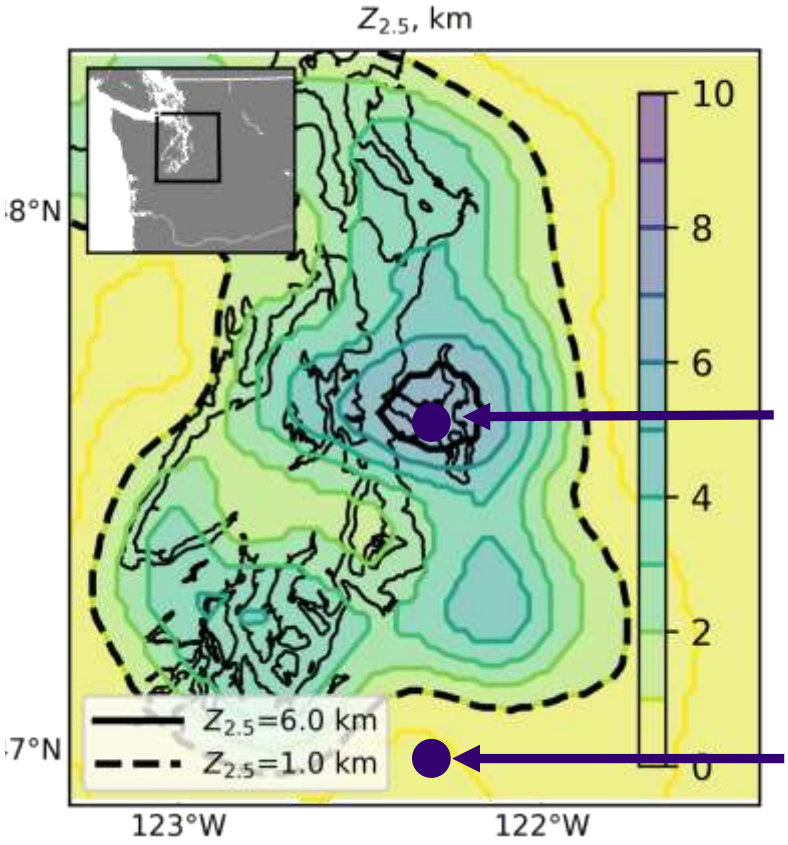
$Z_{2.5}$: A measure of Basin Depth

> Depth to sediment layer with V_s = 2500 m/s



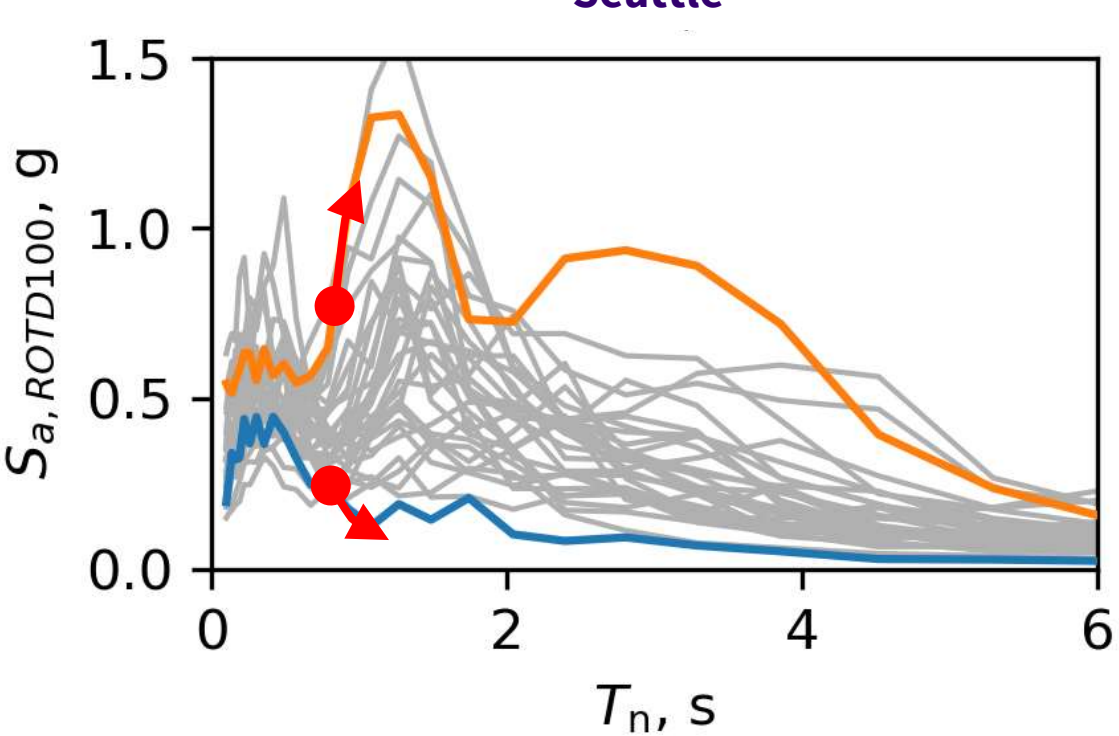
Deep Sedimentary Basin



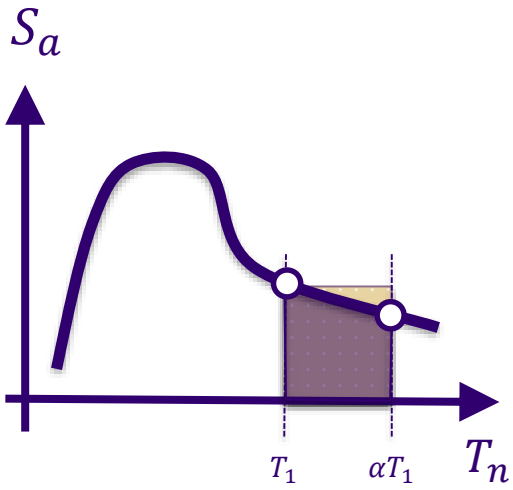


Spectral Shape

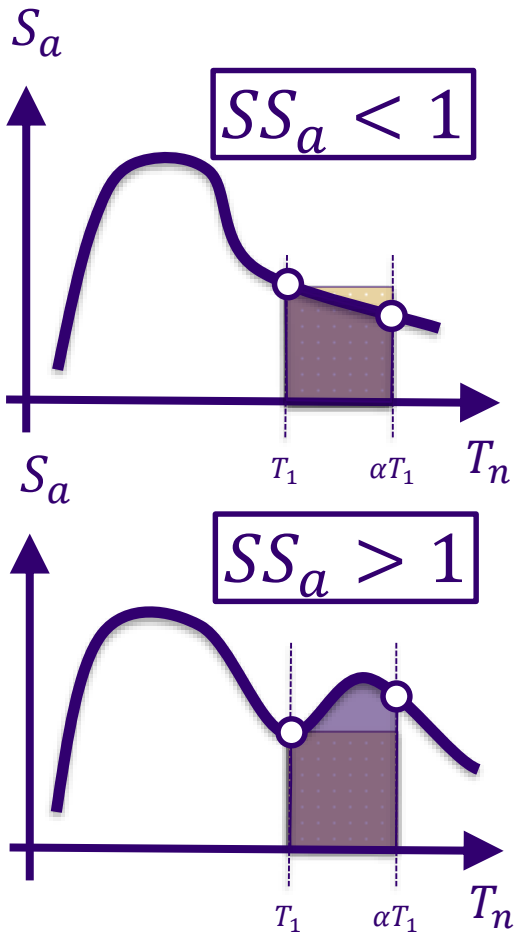
- Bridge period elongates under strong shaking
- Frequency content at periods longer than the elastic period matters



Spectral Shape

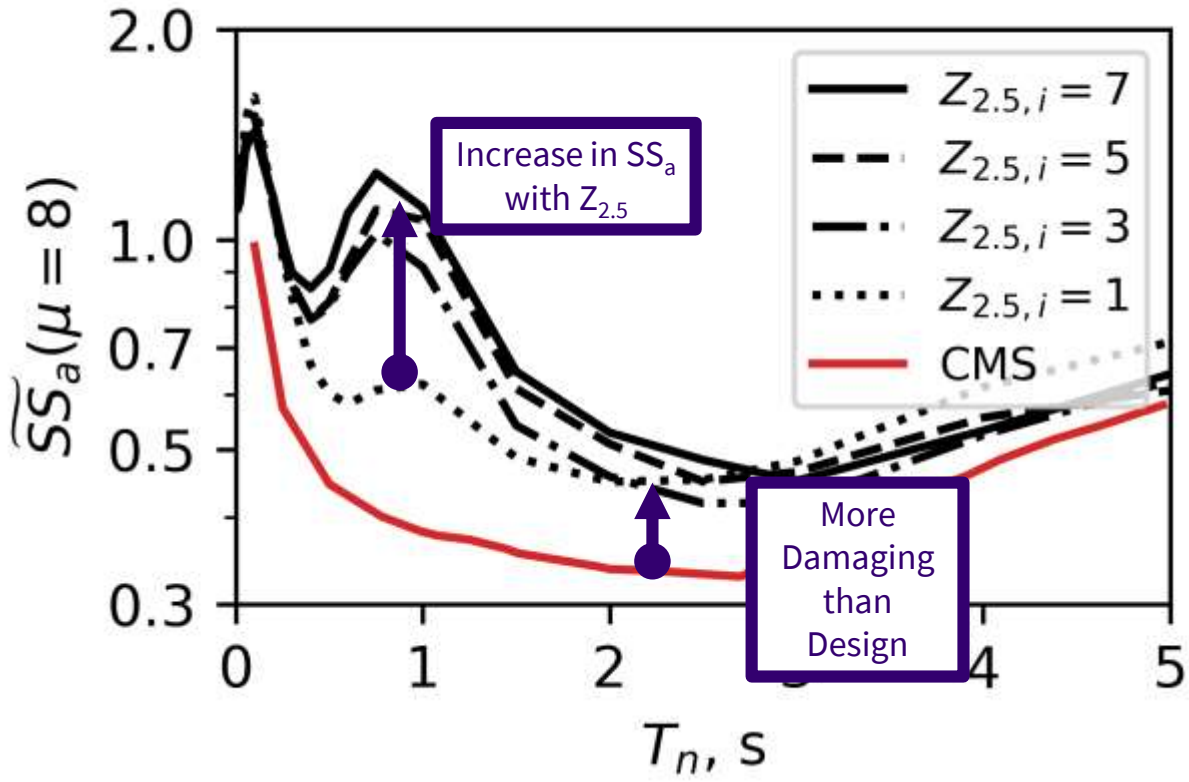


$$SS_a(T_1, \alpha) = \frac{\int_{T_1}^{\alpha T_1} S_a(T_n) dT_n}{T_1(\alpha - 1)\, S_a\,(T_1)}$$



Reference: Marafi, Berman, and Eberhard (2016) Ductility-dependent intensity measure that accounts for ground-motion spectral shape and duration , Earthquake Engineering Structural Dynamics

Spectral Shape



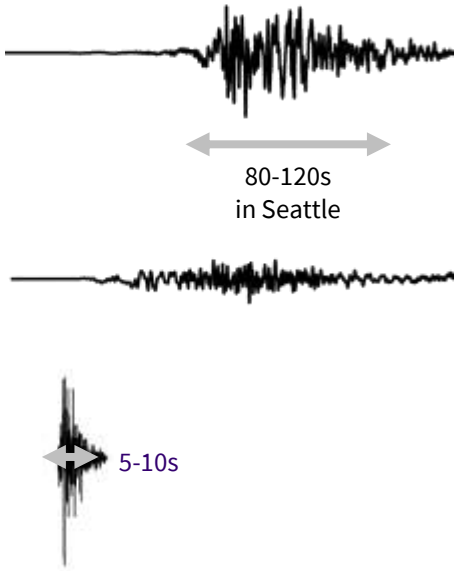
Ground-Motion Duration

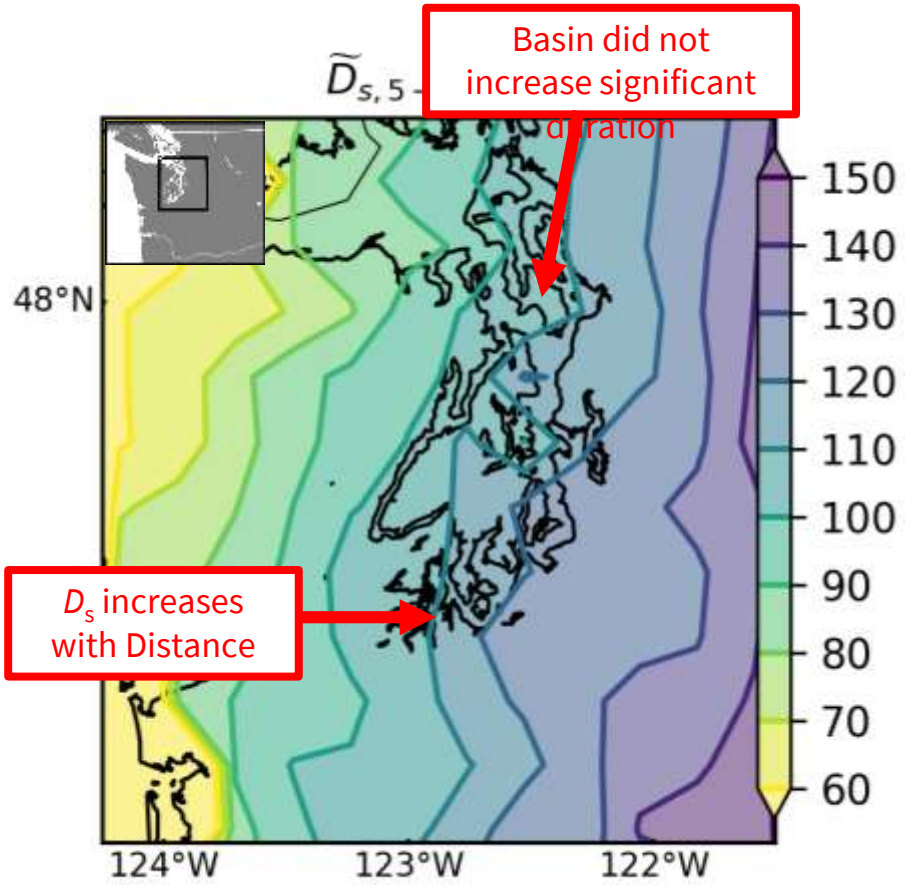
Scenario #1 *(towards Seattle)*

Scenario #2 *(away from Seattle)*

Crustal Earthquakes (Northridge)

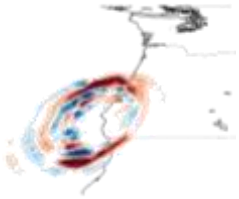
Seattle





Outline

USGS M9 Simulations



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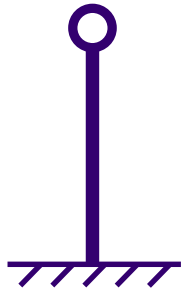
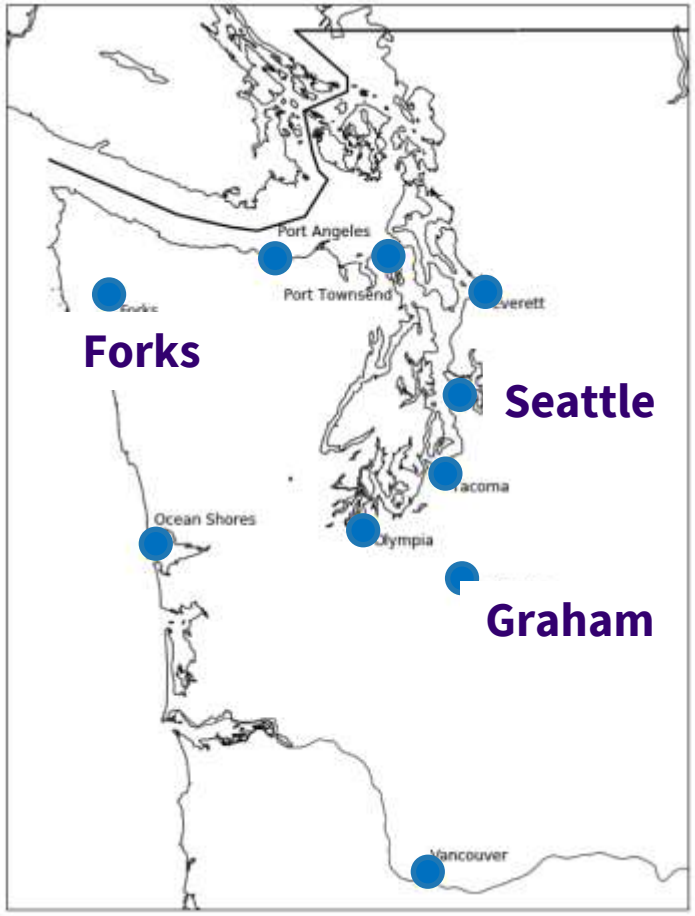


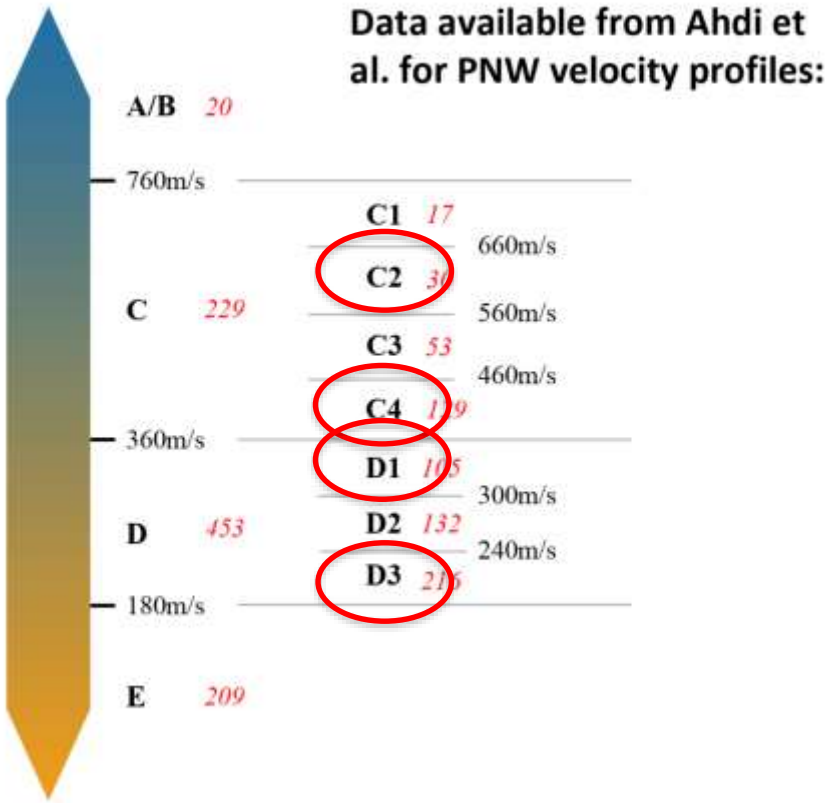
1D Site Amplification

- 30 Simulations
- E-W and N-S Directions
- 10 Locations



1D Site Amplification

- 30 Simulations
- E-W and N-S Directions
- 10 Locations
- Site Classes (C2, C4, D1, D3)
- 30 profiles per site class (Ahdi et al.)



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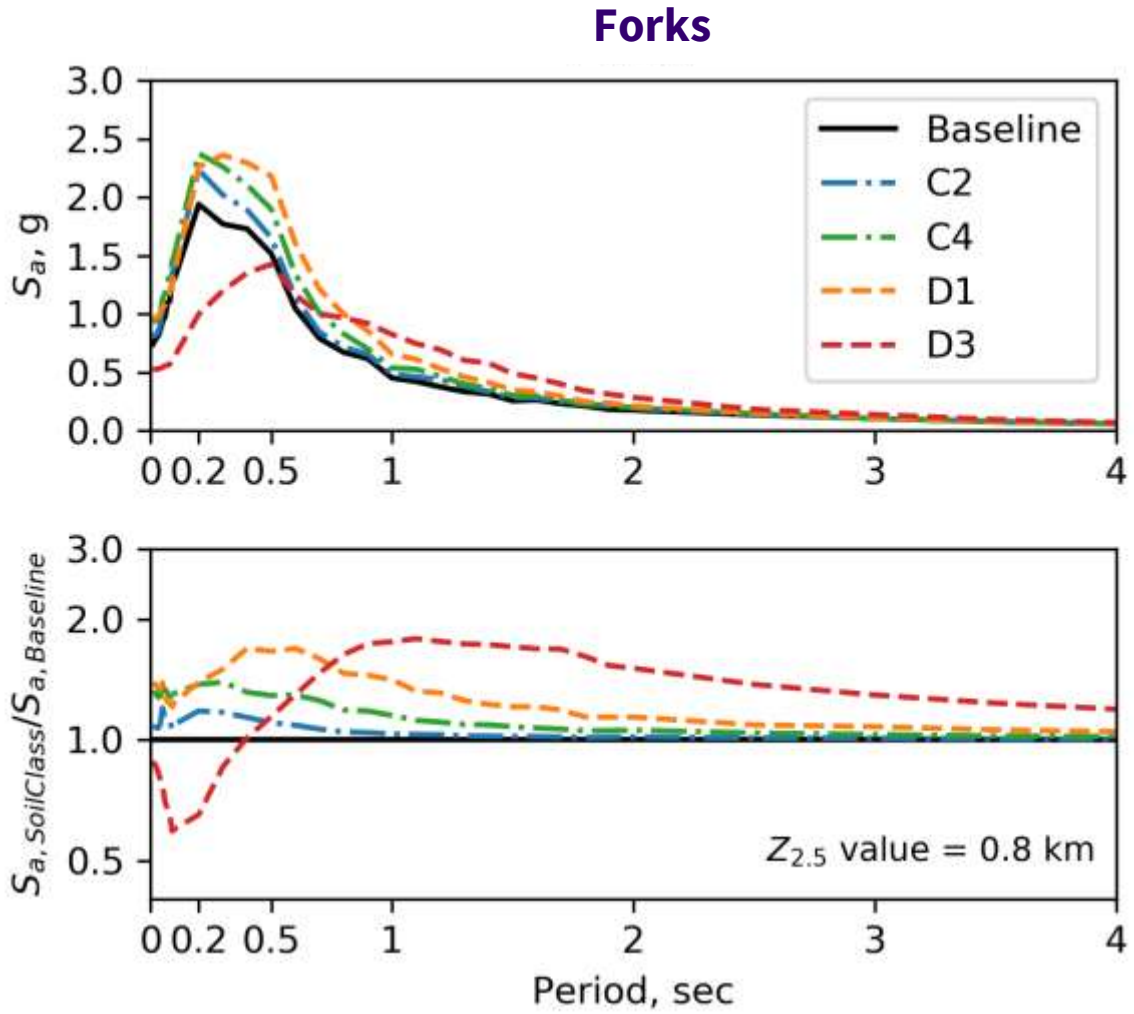

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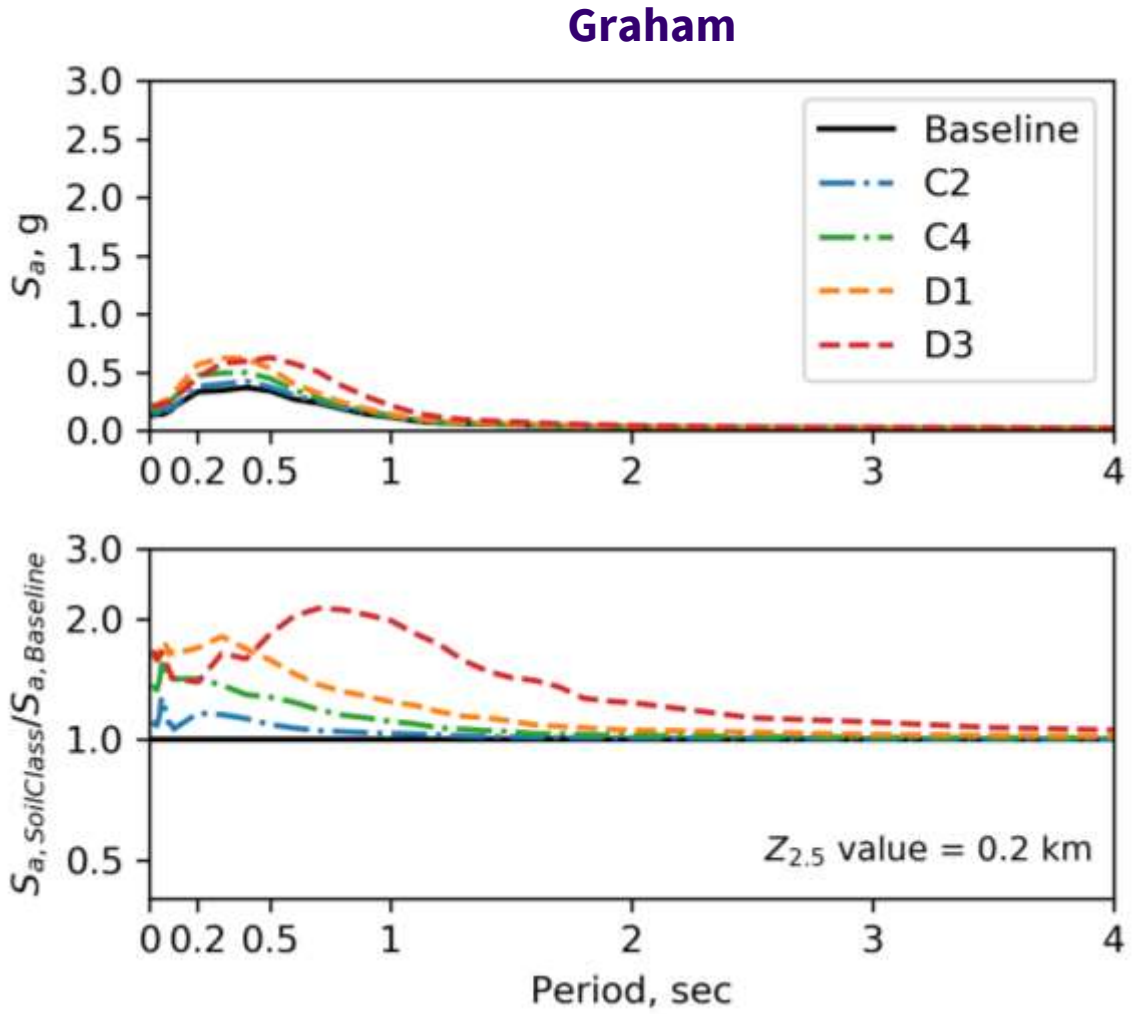

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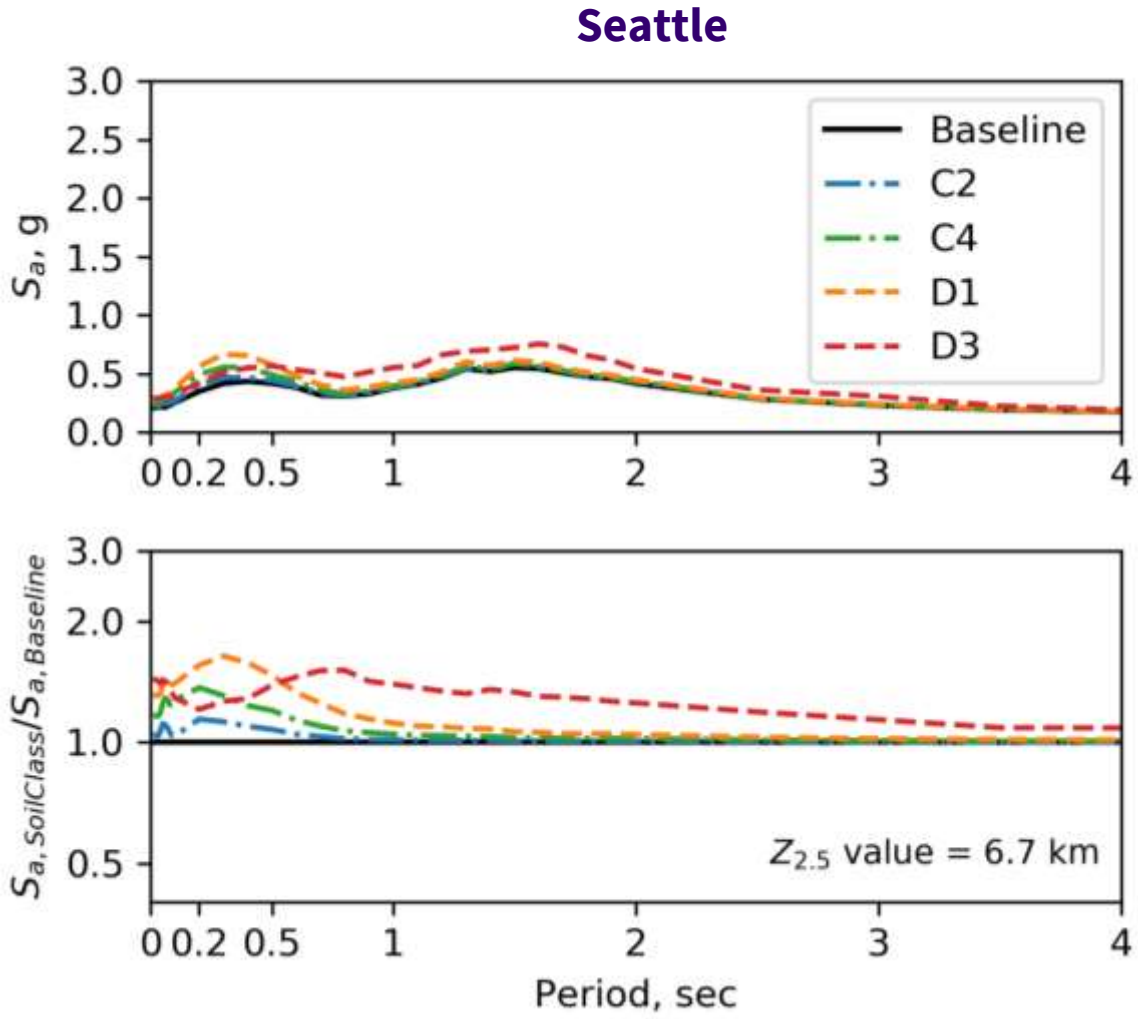
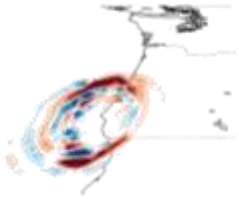


Organization

M9 Simulations



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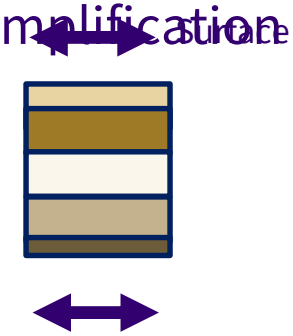
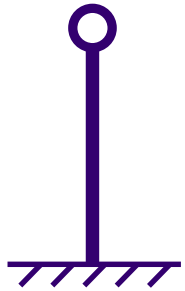
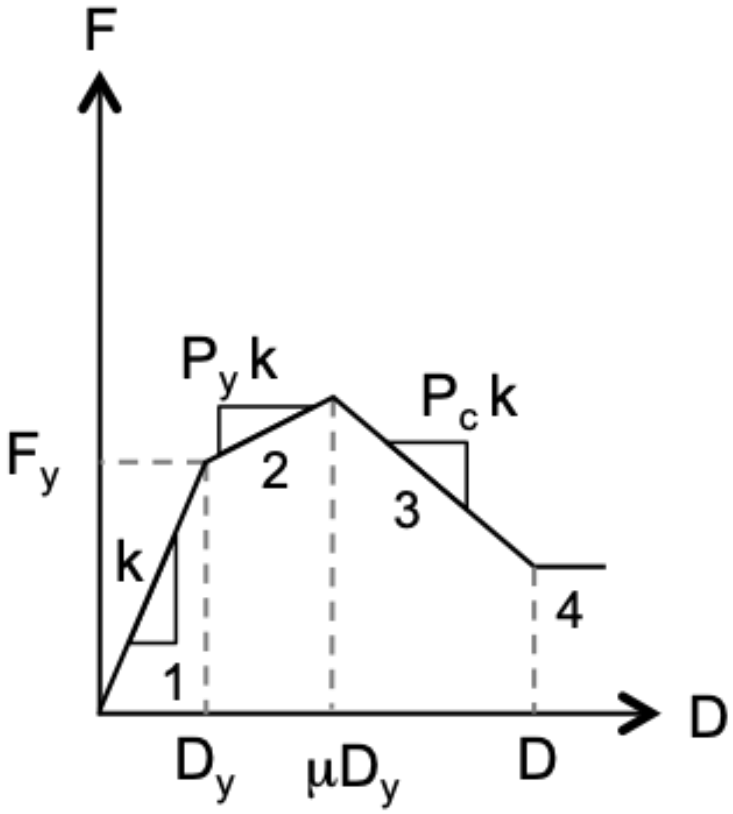


Performance of Idealized Bridges



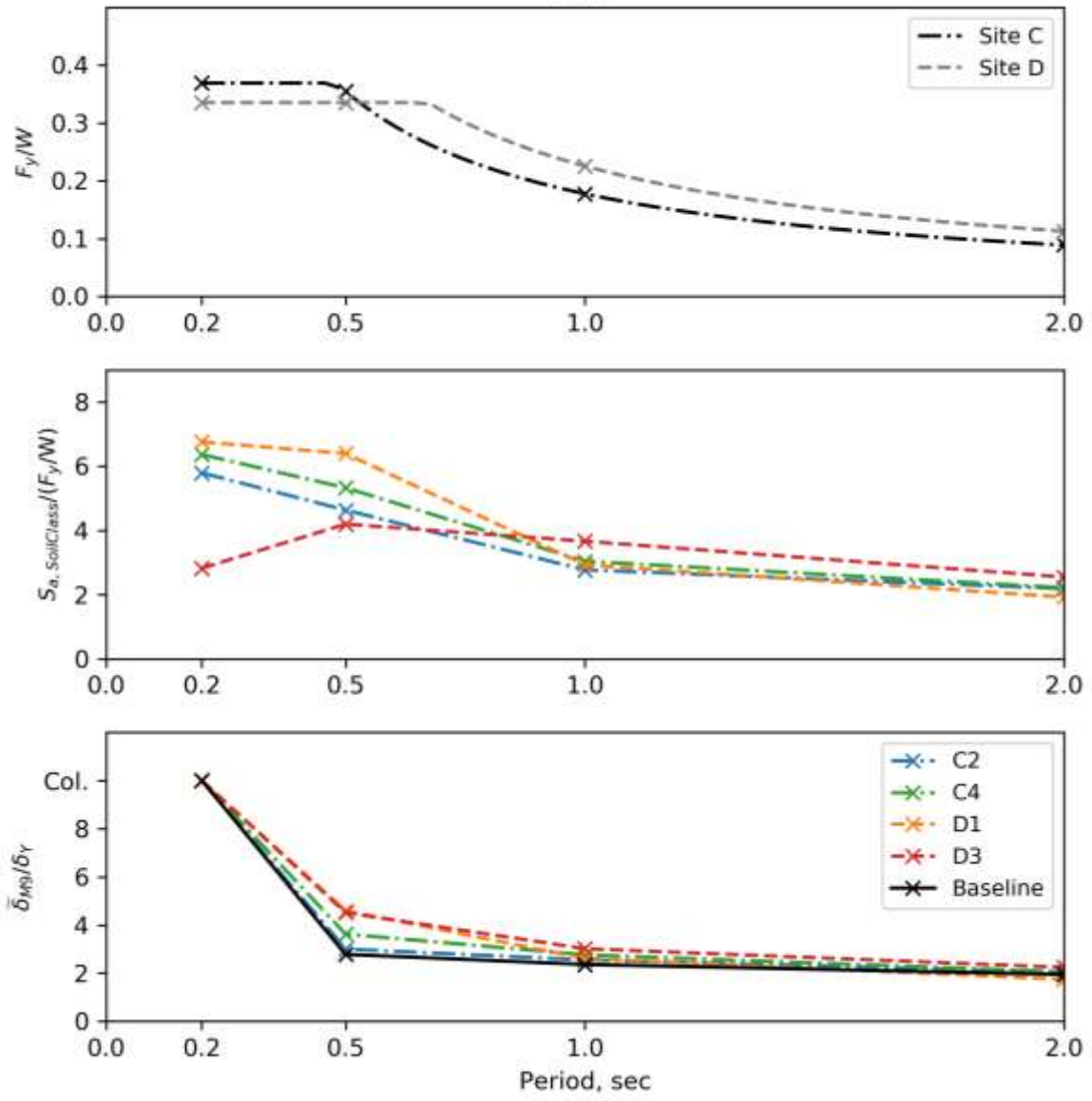
SDOF Parametric Study

- SDOF Properties
  - WSDOT 17
  - Overstrength factor = 1.5
  - Displacement ductility = 5
- 4 periods
  - 0.2s, 0.5s, 1.0s, 2.0s
- 4 SDOF systems
  - Elastic
  - Elastic Perfectly-Plastic
  - Ibarra-Medina-Krawinkler (IMK) without cyclic deterioration
  - IMK with cyclic deterioration



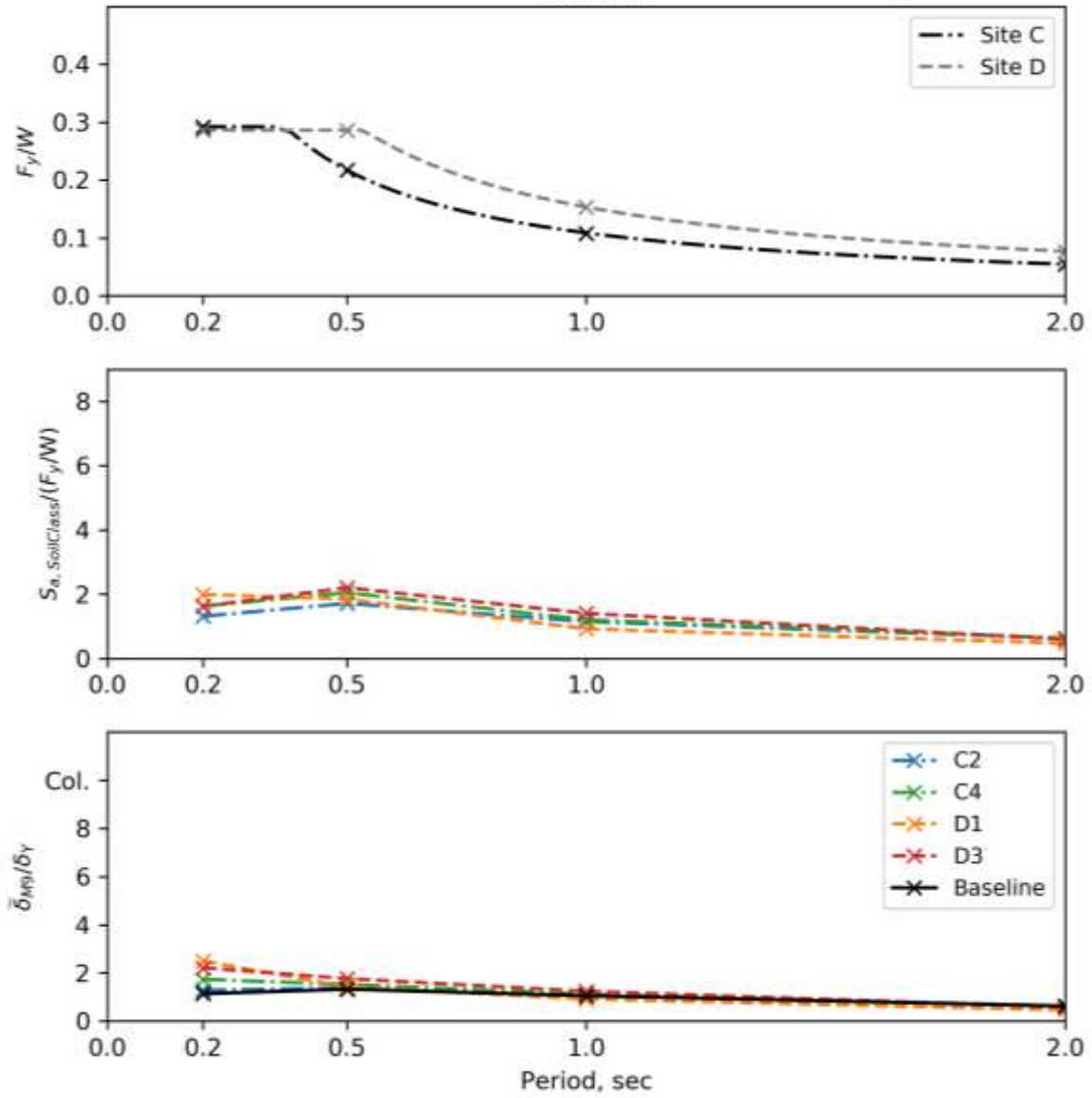
SDOF Parametric Study

Forks



SDOF Parametric Study

Graham



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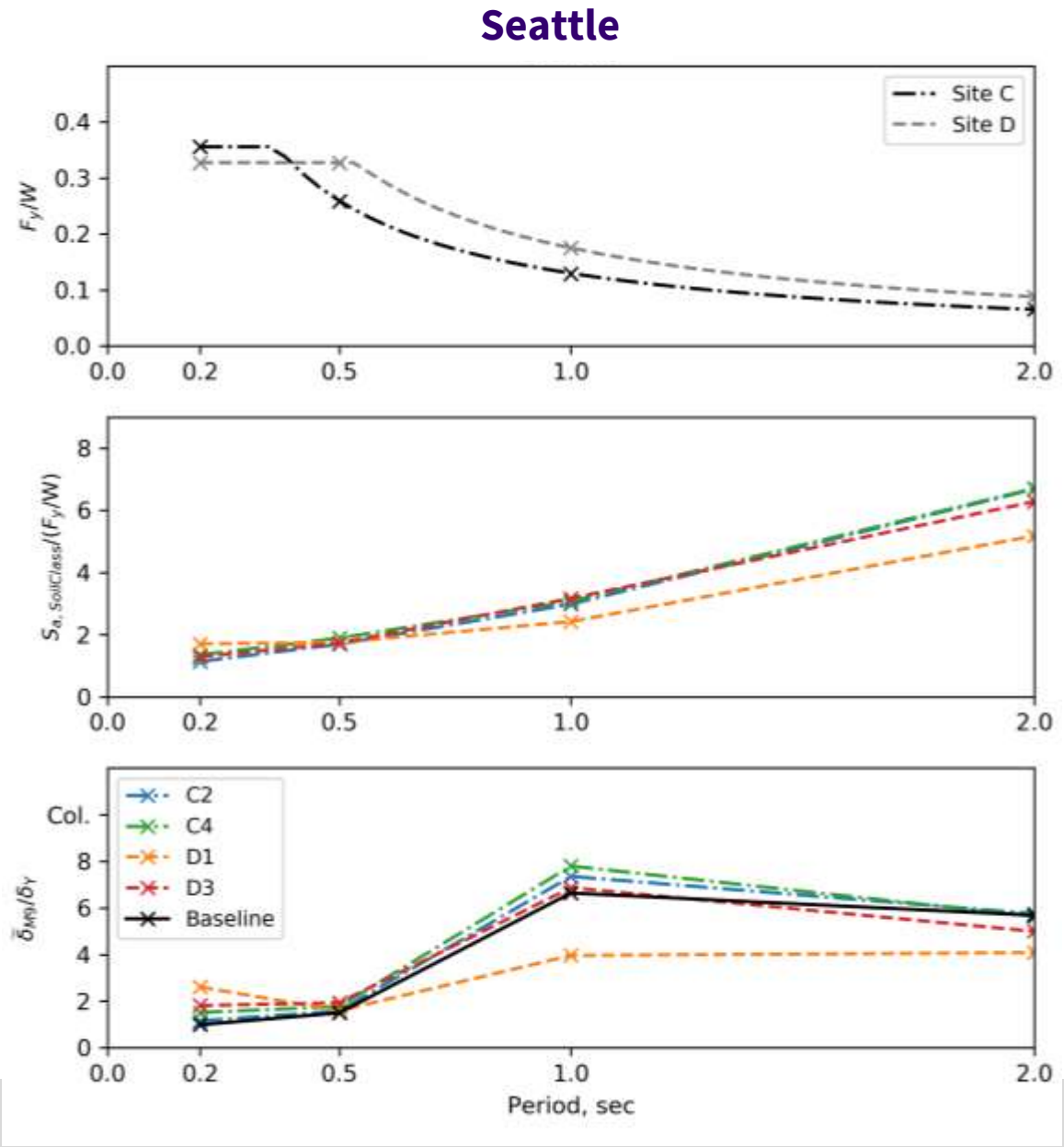

Conclusions

	Coast	Outside Basin	In Basin
Spectral Accelerations	High (as expected)	Low	Amplified (1s to 4s)
Spectral Shapes	Normal	Normal	More Damaging (0.5s to 3s)
Duration	Long	Long	Long
Expected Damage	High (Very Short Tn) Moderate (Mod. Or Long Tn)	Low	High (Long Tn) Low (Short Tn)

Thank You