Site amplification methods for GMSV

Mini-Workshop 1: GMSV-Related Needs for Structural Response

Jeff Bayless

Agenda

- Why site amplification is needed for simulations
- Advantages of Fourier-based over Response Spectrum-based models
- Models available on the SCEC BBP
- What we can do in SCEC 6

Why site amplification is needed for simulations

Current state of simulations

- Most simulations, including CyberShake and the SCEC BBP, stop at a reference Vs30 condition representing rock or engineering bedrock.
  - CyberShake v15.4 used a floor Vs30 of 500 m/s, where Vs30 is obtained from the CVM mesh
  - SCEC BBP 1D Green's Functions often use Vs30 values of 760, 863, or 500 m/s
- Many end users need to perform structural analyses with site-specific ground motions at the ground surface.
  - Vs30 will be specific to their site (could be higher or lower than the simulation reference condition)
- This means that many pre-computed simulations stop one component short: **source** + **path** + **site**
  - Site amplification models can provide the final piece

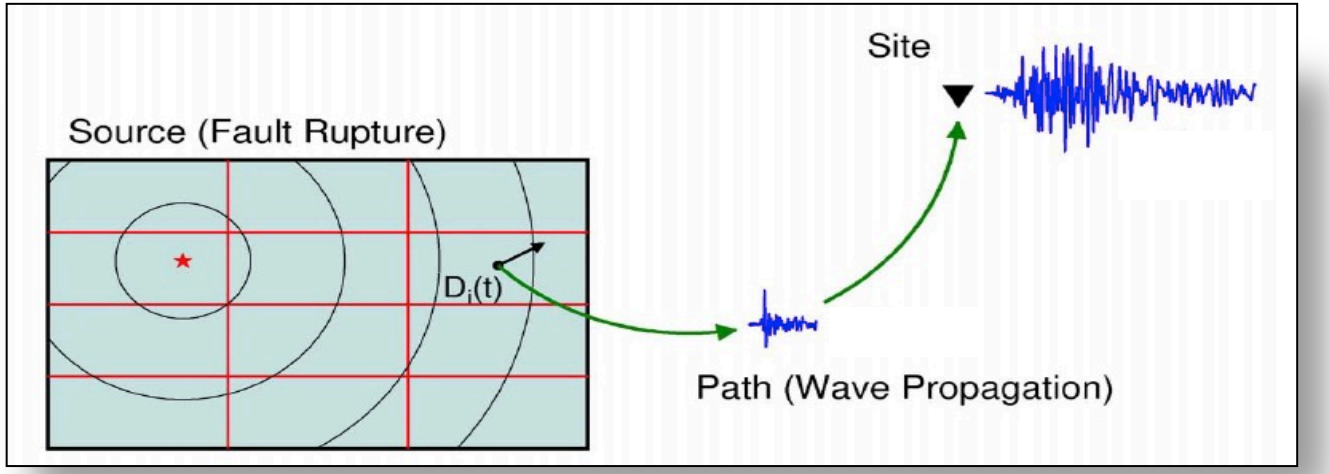
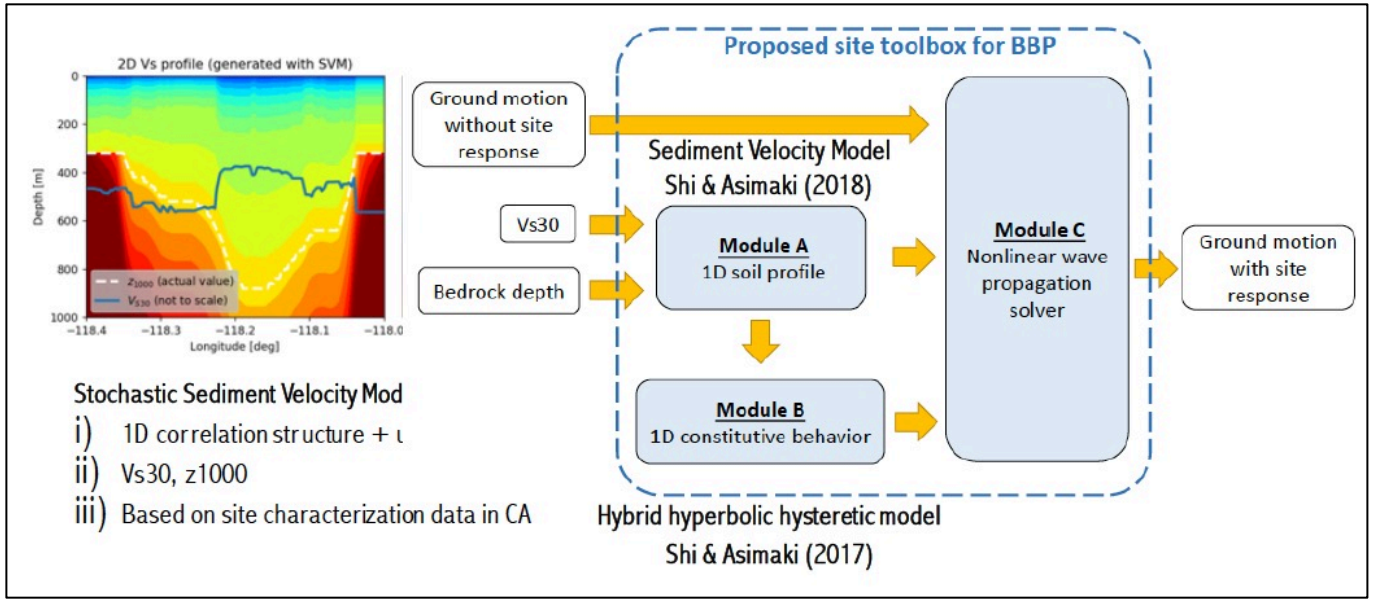


image from Graves (2014)

SCEC TAG: Nonlinear Effects in the Shallow Crust

- The NESC TAG is led by Domniki Asimaki and Ricardo Taborda with the goal to develop, verify and validate a robust family of computational tools that will advance the capabilities of SCEC ground motion simulation frameworks to capture anelastic effects in the shallow crust.
- Research efforts include:
  - Constitutive modeling of rock and soil properties
  - Development and validation of semi-empirical non-linear site factors.
  - Heterogeneity characterization and scattering attenuation modeling
- Validation of these simulations is ongoing
  (requires comparing with data – e.g. empirical models)



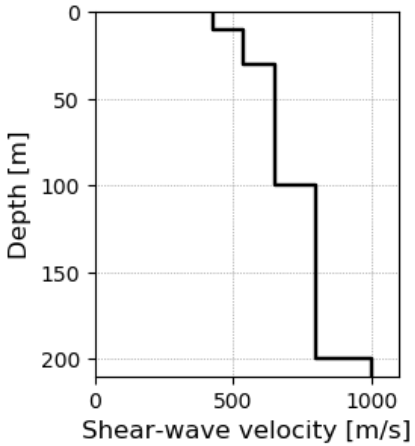
A site-response module toolbox on the BBP, Asimaki (2019)

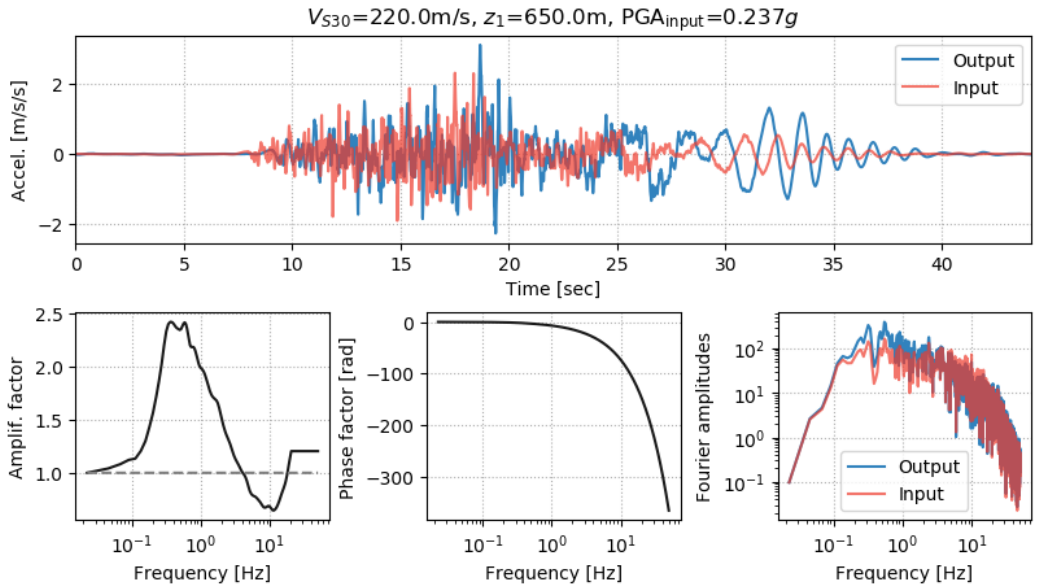
FAS vs PSA based site amplification

What is site response

- Refers to the changes in ground motion intensity, duration, frequency content and phase at the near surface: soils and weathered rock in the upper hundreds of meters of the crust.
- Models for site response can be empirical or numerical and take many different forms:
  - Fourier spectra vs Response spectra based
  - Linear, nonlinear
  - Numerical methods: solve wave equations in 1, 2 or 3D to determine transfer functions (requires a profile of soil properties)
  - Spectral methods: period or frequency dependent amplification factors (e.g. those in ergodic GMPEs)

PySeismoSoil; Shi (2019)





Spectral methods: FAS vs PSA

- When a dynamic analysis is performed, users need a simulated **time history** with the appropriate site amplification, not just a **response spectrum** adjustment.
- Therefore, **Fourier-based** models are advantageous over response spectrum-based models

Fourier-based methods

- Allow for adjustments to the Fourier amplitude and phase of the simulated time history
- When inverse transformed back to the time domain, the **time history** has the appropriate site amplification.

Response Spectrum-based methods

- Only allow for adjustments to the response spectrum of the simulated time history
- There is no way to appropriately adjust the **time history** for site amplification.

Models available on the BBP

Implemented Models

- “Model 1” as implemented by Rob Graves long ago:
  - Adjusts the Fourier amplitudes of the time series simulated for rock conditions using either the Campbell and Bozorgnia (2013) or Boore et al. (2013) linear Vs30-scaling models.
  - Both models were created for response spectra corrections even though they are being applied to Fourier amplitudes. No changes are made to Fourier phases.
- PySeismoSoil v1 (Asimaki and Shi, 2018, 2019)
  - Fourier amplitude and phase factors dependent on Vs30, Z1.0, PGA, and frequency.
  - Uses lookup-tables
  - Linear and nonlinear components

Models to be Implemented

- PySeismoSoil v2 (Asimaki and Shi, 2018, 2019)
  - Nonlinear wave propagation method, uses a provided or estimated Vs profile
  - SCEC have the codes but not yet validated/implemented
- Bayless and Stewart (in progress)
  - Empirical, regionalized model for Southern CA
  - Fourier amplitude adjustment factors dependent on region/basin, Vs30, Z1.0, PGA, and frequency.
  - Linear and nonlinear

What we can do in SCEC 6

Goals for SCEC 6

- Continue to coordinate with the NESC TAG
- Empirical models
  - Continue to refine regionalization and basin classifications (e.g. Stewart et al, 2019)
  - Partially non-ergodic models can be used to improve modeling in the LA Basin
  - Test the models and evaluate/validate them as more data are collected
  - Look to integrate information from HVSR
  - Publish and implement
- Physics-based models (NESC TAG)
  - Incorporate PySeismoSoil v2 into the BBP
  - Continue to perform validations of the components of these models (which, due to shortage of data are based on assumptions and/or simplifications)

Thank you.