PATH EFFECTS ON SURFACE-WAVE AMPLIFICATION IN SEDIMENTARY BASINS (S23C-0546)

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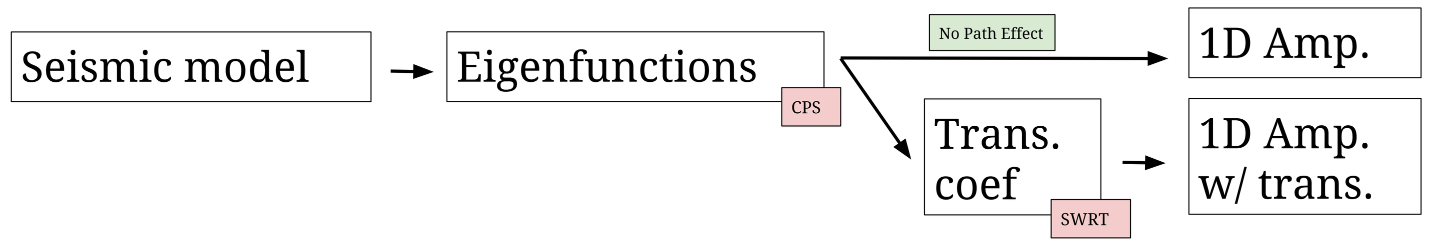
MOTIVATIONS

- Surface waves propagating in sedimentary basins strongly affect earthquake ground motions and cause strong damage *(Kawase, 1996)*
- *Bowden & Tsai (2017)* proposed a 1-D semi-analytical method to predict surface-wave basin amplification between two sites
- 1-D approximation of the near-surface geologic structure does not account for path effects (reflections, conversions)

⇒ The current study aims to provide quantitative estimates of the importance of these various path effects on surface-wave amplification and also extend the current 1-D theory to more complex multi-dimensional basin structures.

1 - SEMI-ANALYTIC MODELS



Pure 1D theory

- Conservation of energy flux
  ⇒ relative amplitude between two sites:

$$\frac{A_n}{A_n^R} = \frac{u_n(0)}{u_n^R(0)}\left(\frac{UI_0}{U^R I_0^R}\right)^{-1/2},$$

where A_n wave amplitude at the surface,
$u_n(0)$ surface-wave eigenfunction amp. at the surface,
U group velocity, $I_0 = \int_0^\infty \rho(z)(u_1(z)^2 + u_2(z)^2)dz$

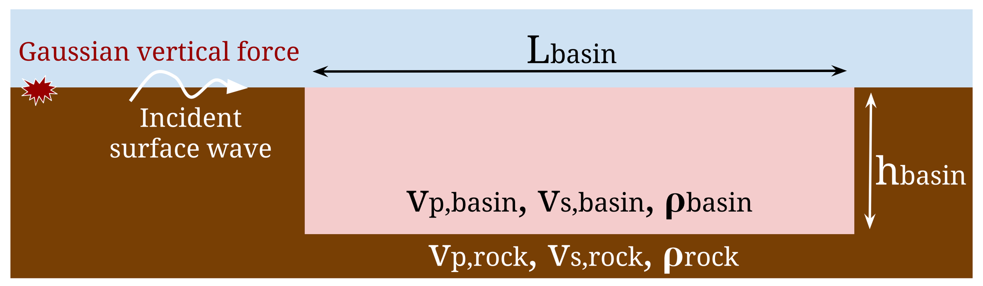
- Neglect path effects (reflections and mode conversions)

1D Theory w/ transmission coef. (SWRT)

- *Levshin (1989)* At a vertical boundary
  ⇒ wavefield = incident, reflected and transmitted waves
- Approximation of reflection/transmission coef. by Green's function method of *Its and Yanovskaya (1985)*
- Numerical code for transmission coef. by *Datta (2018)* named Surface Wave Reflec. Trans. (SWRT)
- Neglect body-wave diffraction at the basin edge

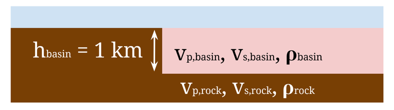
Eigenfunctions: computed using Computer Program in Seismology *(Herrmann, R. B., 2013)*.
Reference solutions: high-order numerical axisymmetric solutions from SPECFEM package *(Komatitsch & Vilotte 1998)*.

2 - SIMULATION SETUP

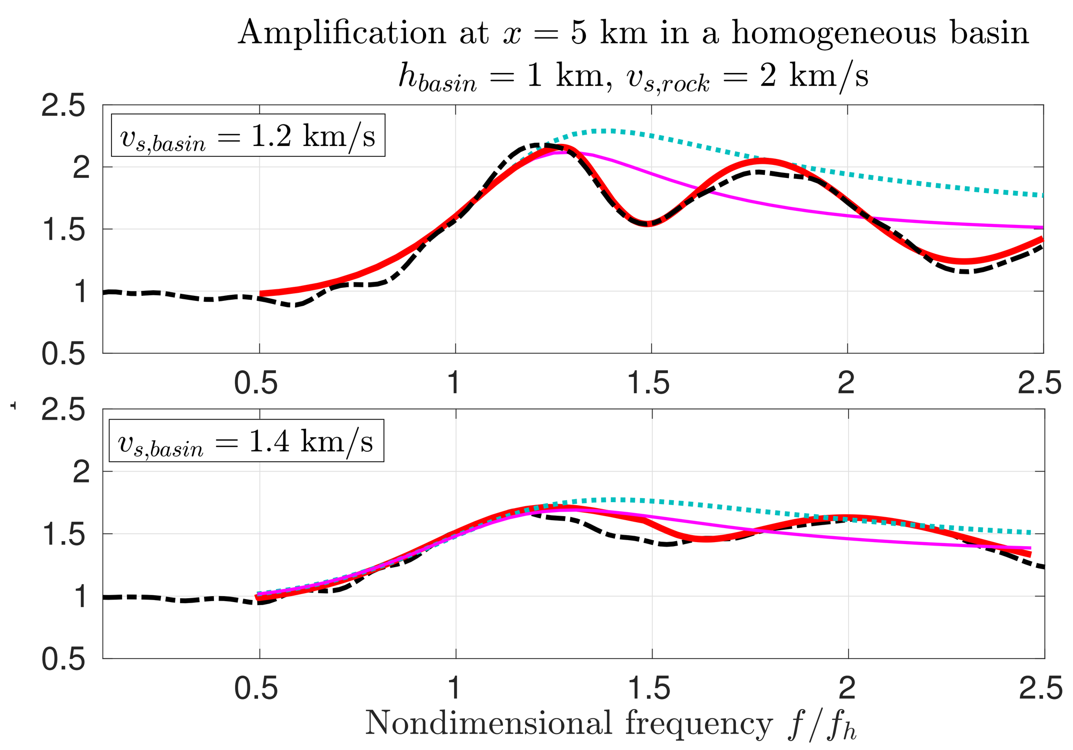


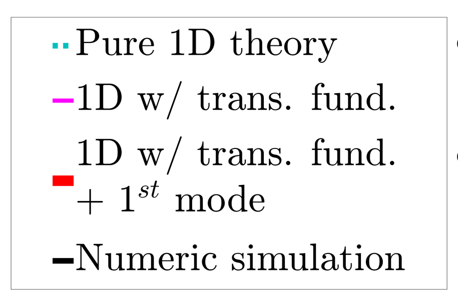
- Axisym. basin with length L_{basin}, depth h_{basin} and shear veloc. $v_{s,basin}$
- Relationships between v_p, v_s and ρ are extracted from *(Brocher, 2005)*
- We use a nondimensional freq. $f_h \approx \frac{f}{v_{s,basin}/3h_{basin}}$ *(Colombero, 2018)*

3 - TRANSMISSION AND CONVERSION IN SEMI-INFINITE BASINS ($L_{basin} \rightarrow \infty$)

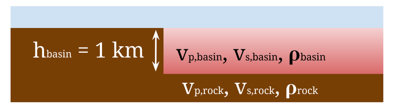


Homogeneous semi-inf. basin w/ various shear velocities

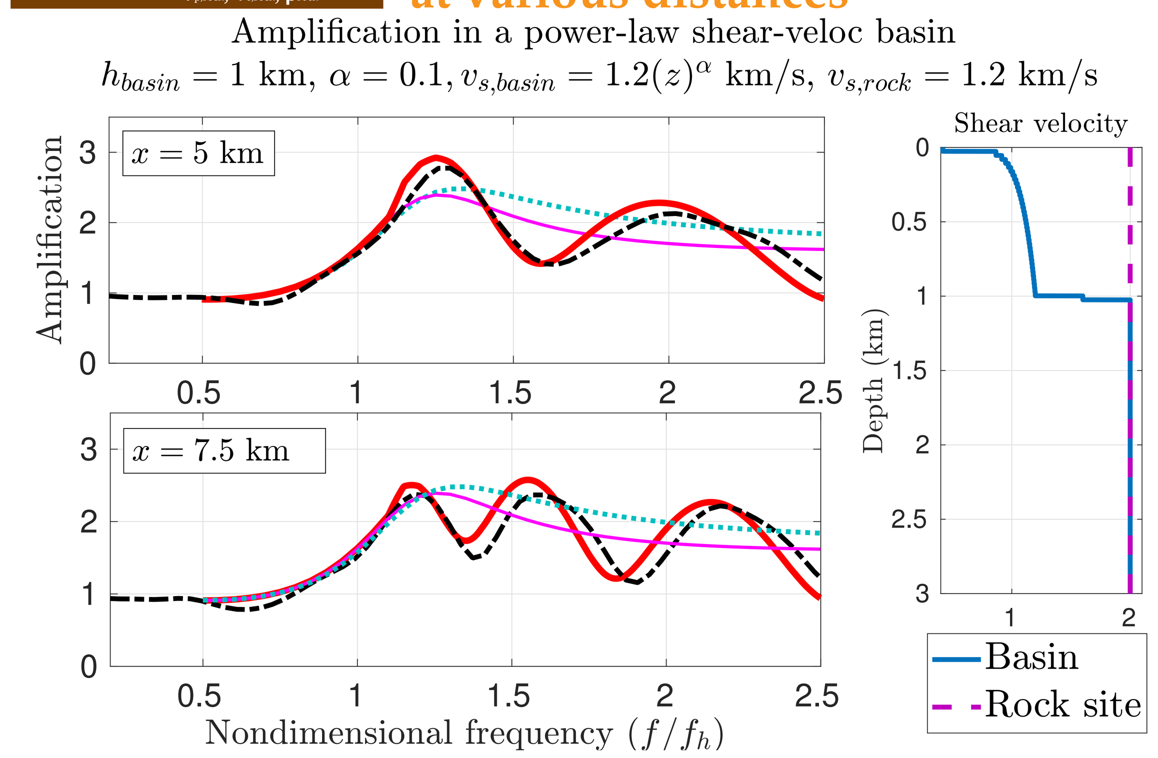




- Fund.-mode transmission coefficient captures well the average amplification spectrum
- Higher modes introduce strong oscillations in the spectrum that can be reproduced by considering fund.-to-higher modes conversions



Heterogeneous semi-inf. basin at various distances



- Amplification spectra for vertically heterogeneous basin velocity structures can be well approximated by transmission coefficients
- Main amplification peak amplitude can be increased by higher modes

4 - 1D FUND.-MODE AMPLIFICATION

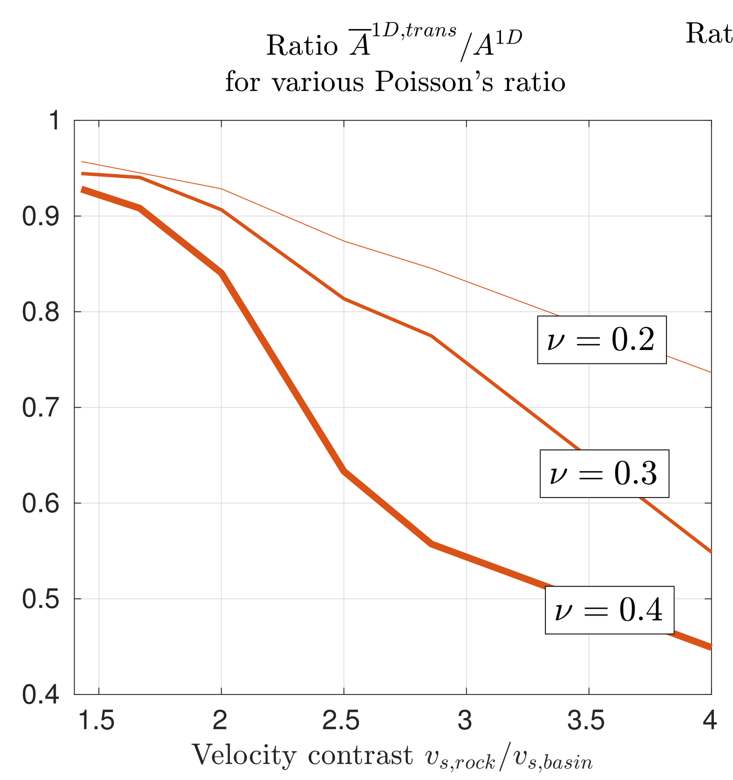


Figure: Ratio of max. amplification from the 1D theory A^{1D} and the mean transmission coefficients over the 10 first km from basin edge $\overline{A}^{1D,trans}$ against velocity contrasts for various Poisson's ratio

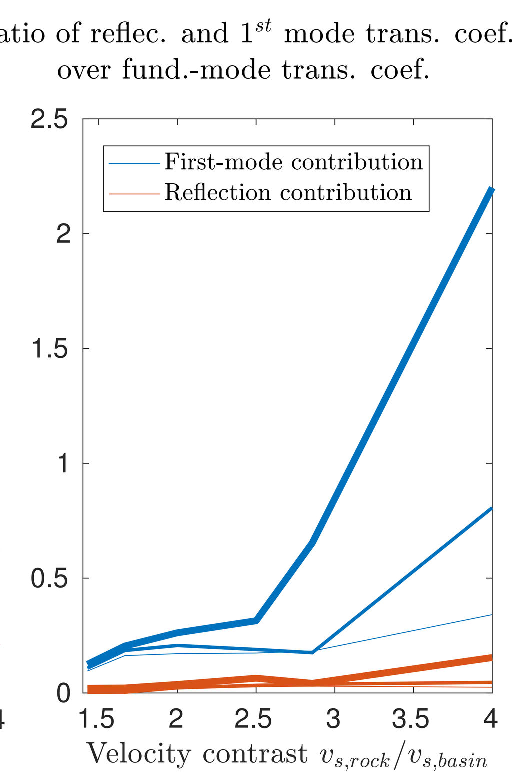


Figure: Ratio of reflection and 1^{st} mode trans. coef. over $A^{1D,trans}$

- Discrepancies between pure 1D theory and trans. coef. come from mode conversions and reflection at the basin boundary
- Using a nondimensional freq. f_h we can assess the accuracy of the 1D theory to predict the surface-wave amplification

5 - LATERAL RESONANCE

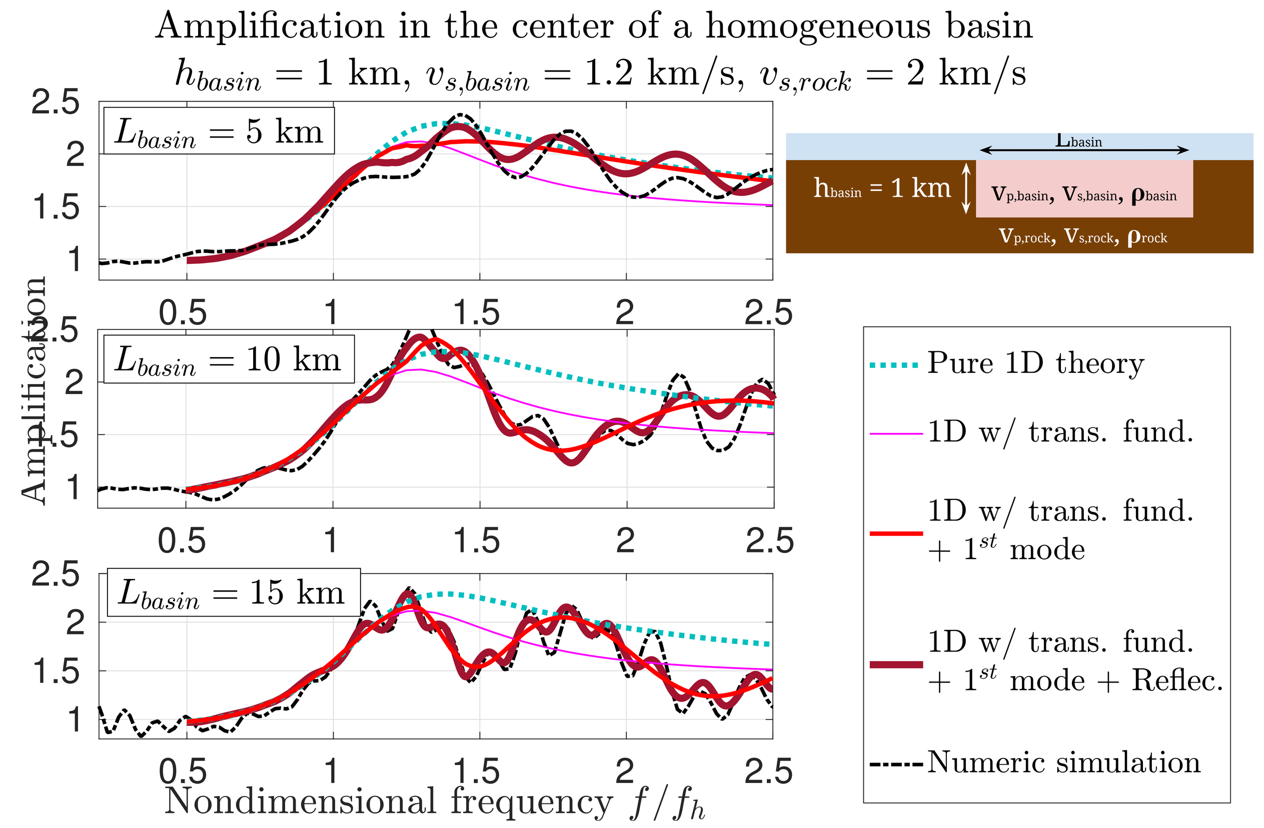
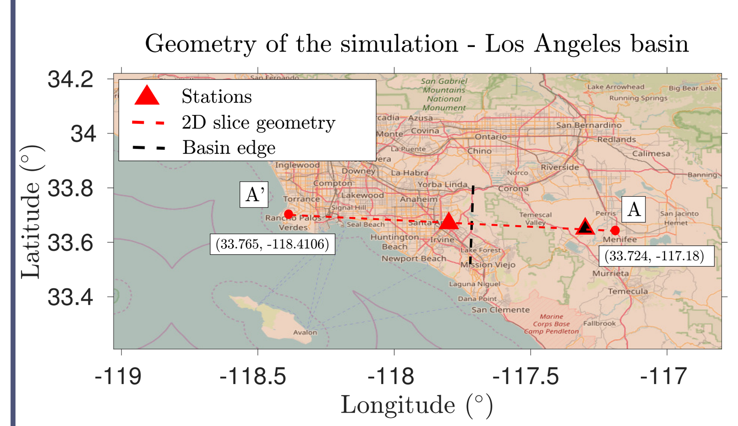


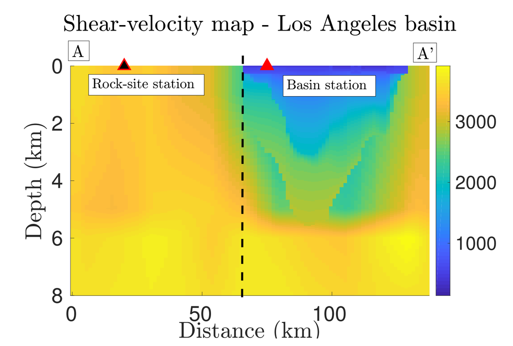
Figure: Top to bottom, Spectral amplification against nondimensional frequency f_h for basin length $L_{basin} = 5, 10, 15$ km and basin depth $h_{basin} = 1$ km.

- Lateral boundaries introduce extra oscillations in the amplification spectrum due to back and forth reflections within the basin
- Close to the basin edges and/or as the surface-wave wavelength range tends to the basin length, the maximum amplitude can be significantly altered

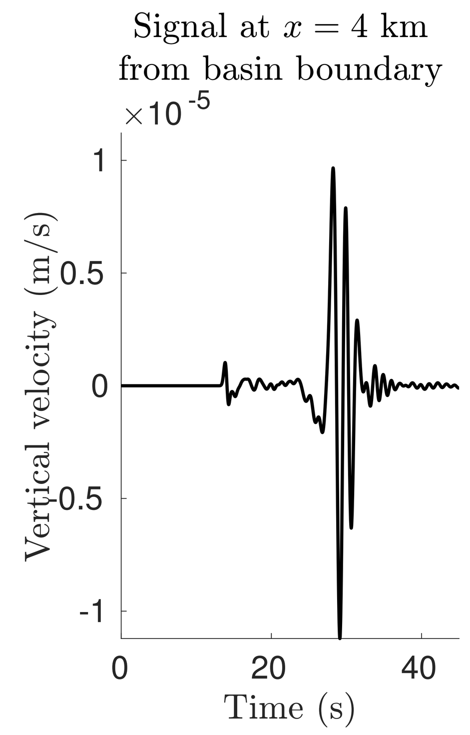
6 - LOS ANGELES BASIN AMPLIFICATION

- 2D velocity profile in the LA basin extracted from SCEC Community Velocity Model (CVM-S4.26, *Lee (2014)*) w/ sharp velocity jump
- Basin edge location is chosen at the largest horizontal shear-velocity jump ($d \approx 66$ km)
- Transmission coefficients are computed from the 1D profiles beneath the stations





- Simple 1D seismic models provide a good estimate of the amplification main frequency peaks
- The fundamental-mode low-frequency amplification is well captured by the pure 1D theory
- The conversion between fundamental to 1^{st} overtone has a significant impact on amplification and we can capture the higher-mode amplification frequency range and amplitude



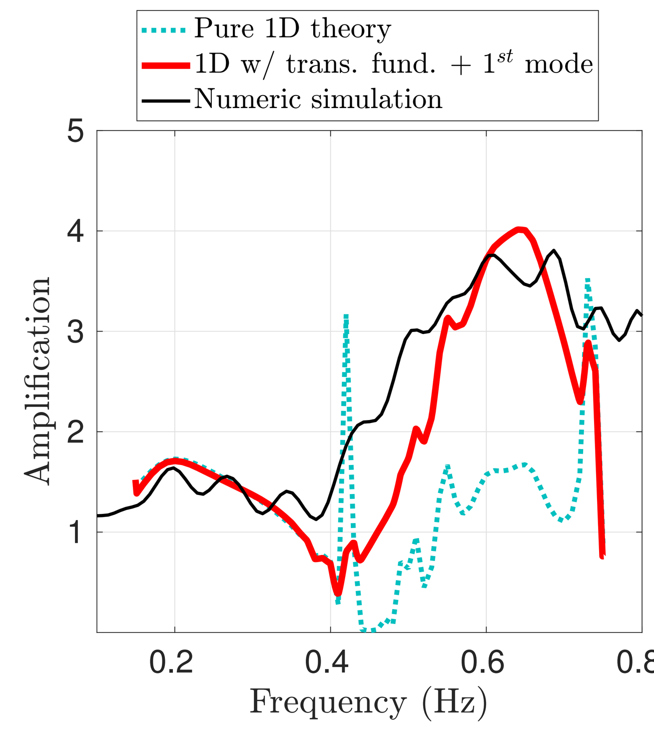


Figure: Left, Vertical velocity against time at the basin station. Right, amplification spectrum against frequency at the basin station

CONCLUSIONS AND FUTURE WORK

Conclusions

- 1D Theory
  ⇒ **good estimate of the amplification** (over-predict. < 30% of max. amp.) **for low velocity contrast** $\frac{v_{s,rock}}{v_{basin}} < 2.5$
- Approximate trans./reflec. coefficients:
  ⇒ can very well reproduce amplitude and variations of the amp. in axisym. basins
  ⇒ **good estimate of amplification in laterally heterogeneous axisym. sedimentary basins** w/ sharp vertical boundaries

Future work will include

- More complex axisym. basin geometries
- Love-wave amplification and Rayleigh-to-Love conversions
- Full 3D basins structures and subsequent path effects