(Nonlinear) site response in SCEC: Present & future

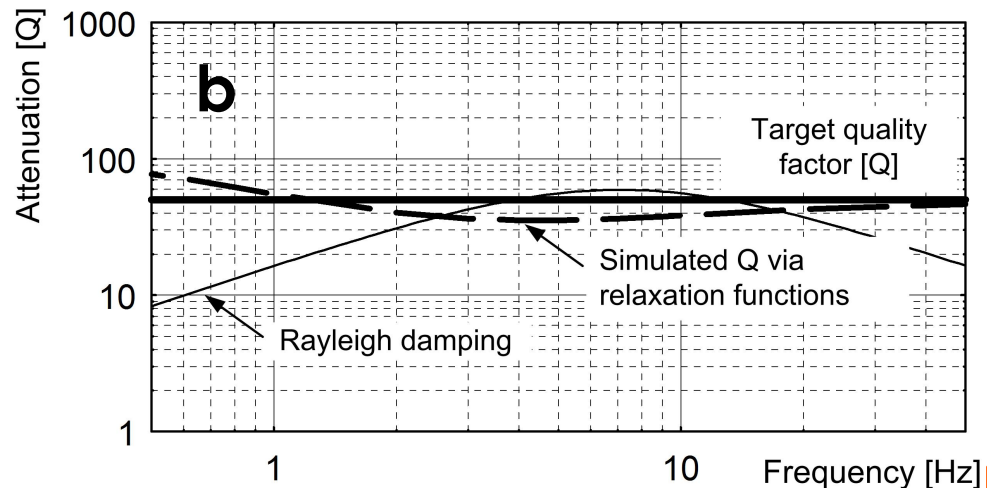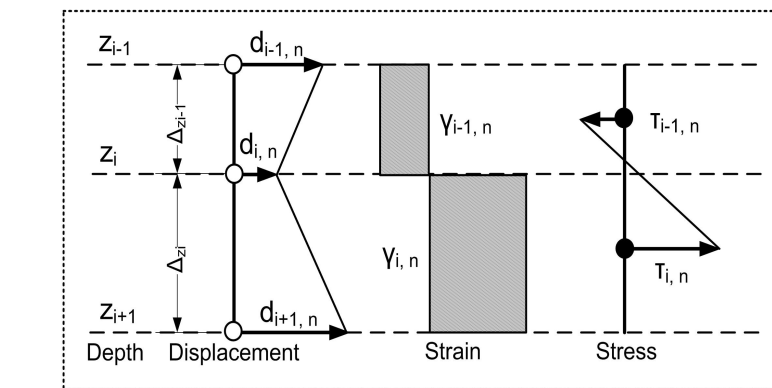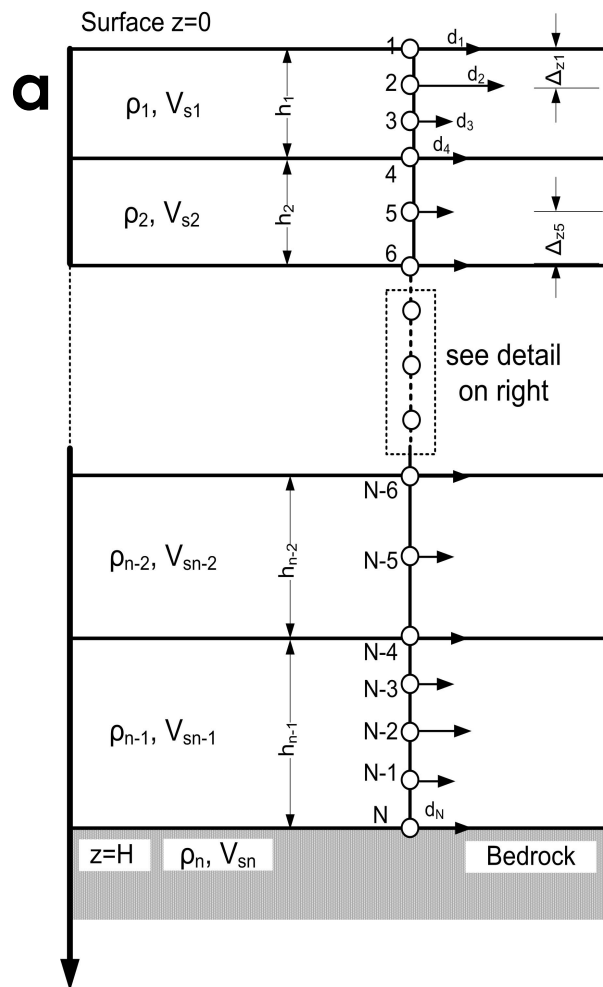**Domniki Asimaki[1]**, Jian Shi[1], Ricardo Taborda[2] and Alan Yong[3]

[1]MCE, California Institute of Technology
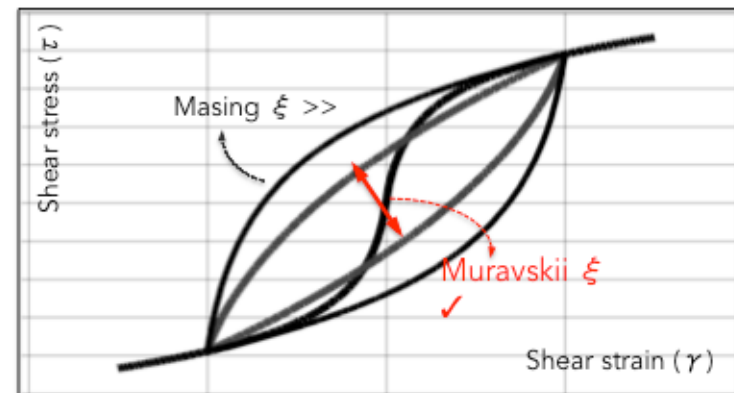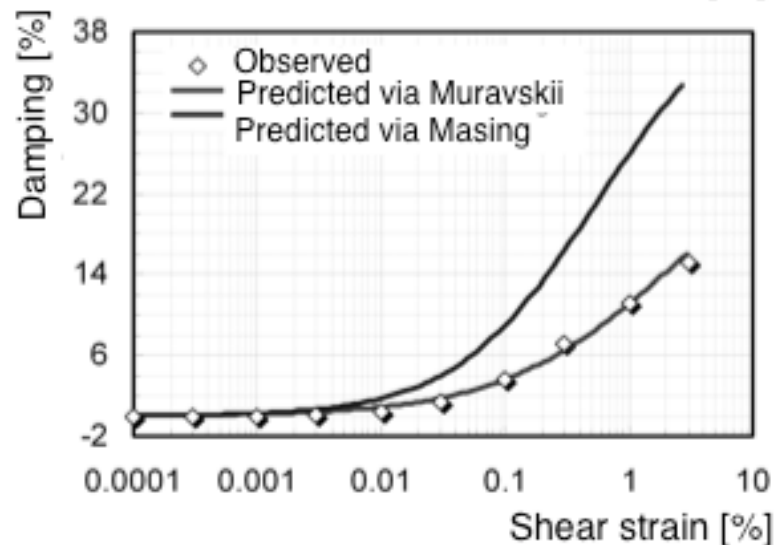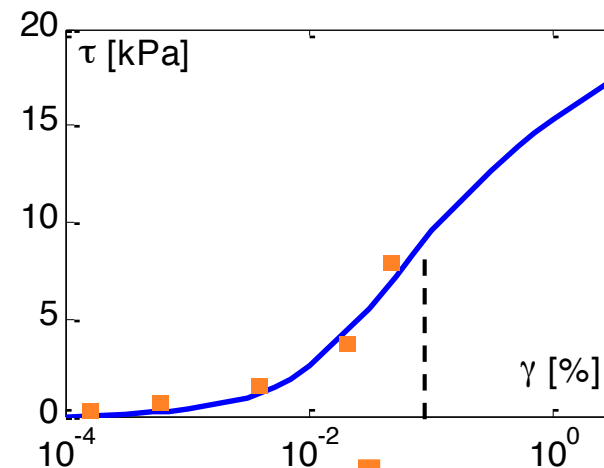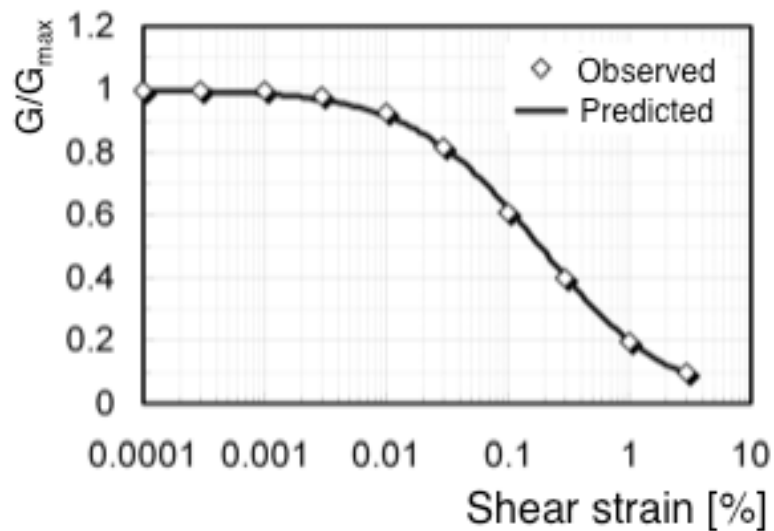[2]CERI, University of Memphis
[3]USGS, Pasadena

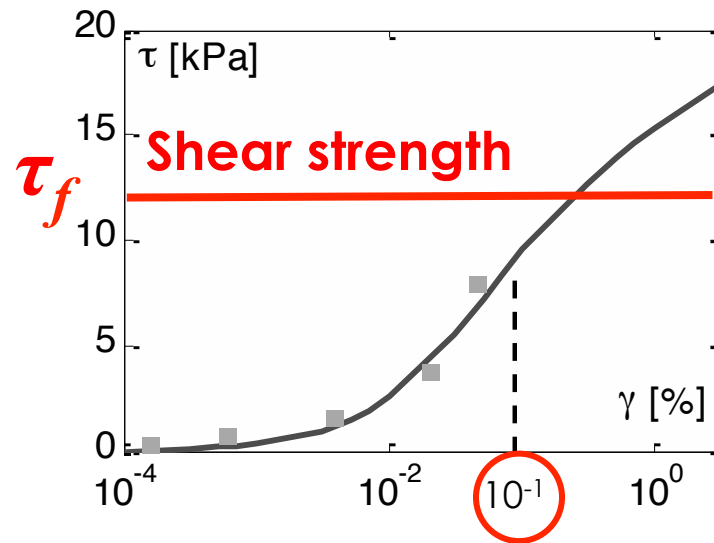# Present: 1D site-specific nonlinear response

a. **Numerical formulation:** Finite differences, PML boundary conditions
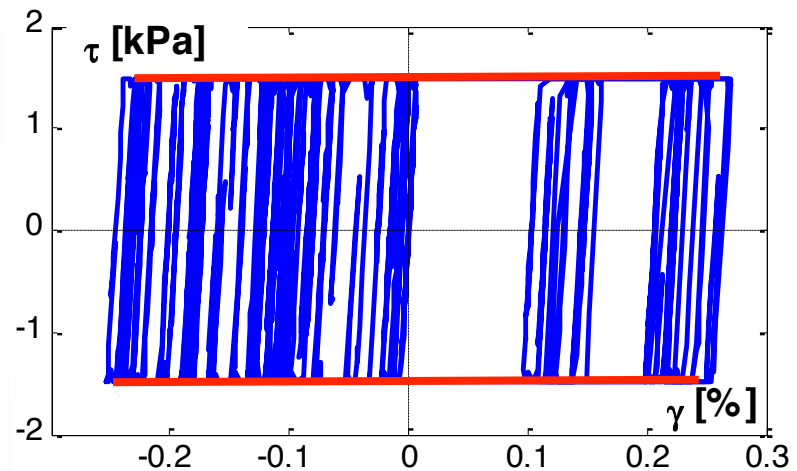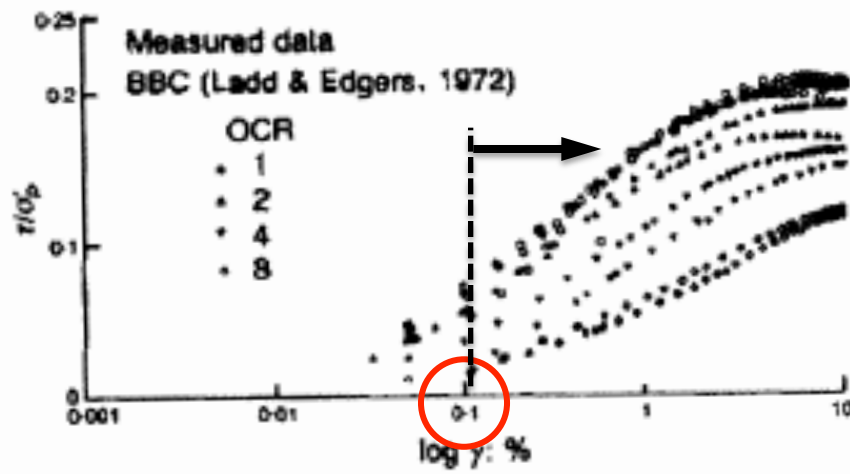b. **Small-stain damping (ξ):** SLS in parallel (Liu & Archuleta, 2006)

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Stress-strain model compatible with G/G_{max}, Q

Realistic shear strength (large strain range)

τ_f

Shear strength

τ [kPa]

γ [%]

Direct simple shear test

Measured data
BBC (Ladd & Edgers, 1972)

OCR
· 1
· 2
· 4
· 8

τ/σ'_p
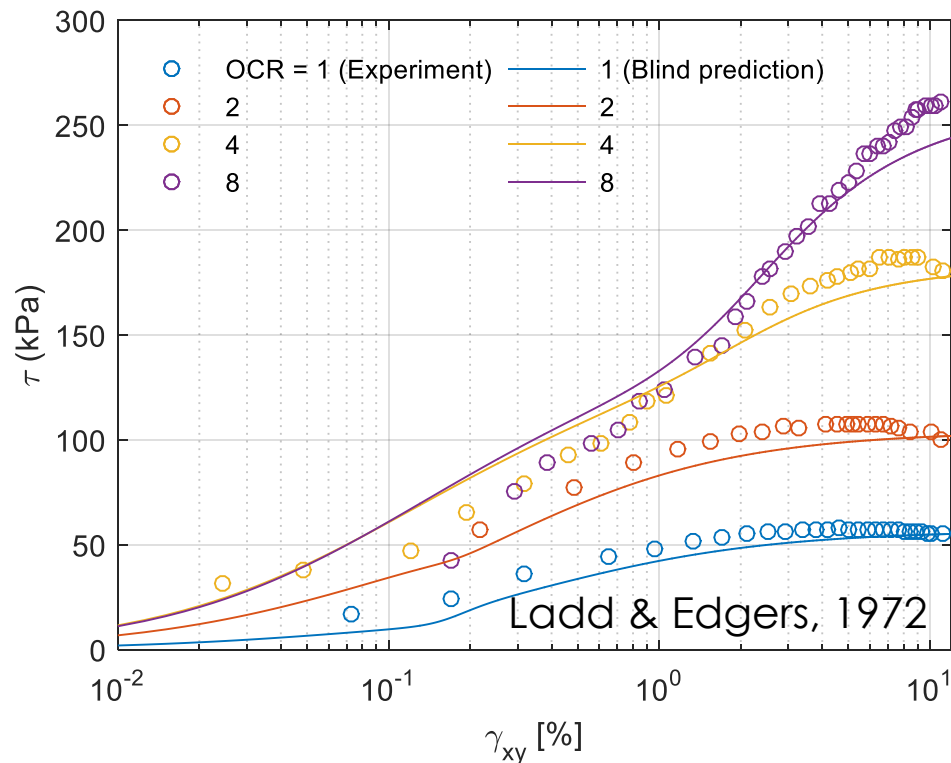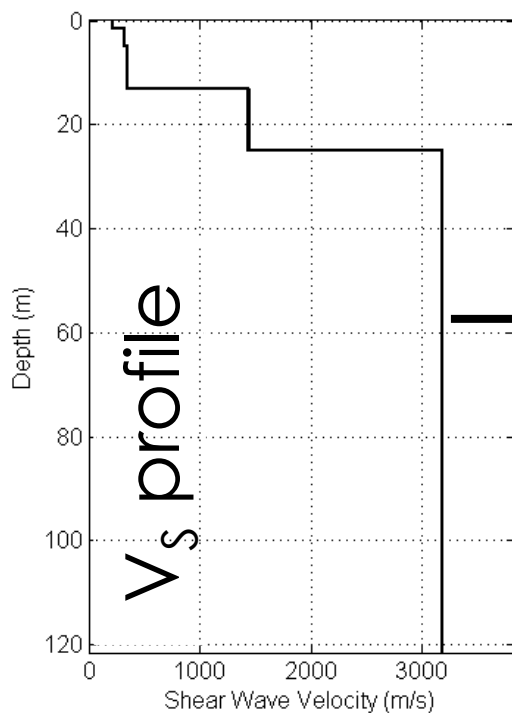
log γ: %

τ [kPa]

γ [%]

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Hybrid model from stiffness to strength

$$\tau_{HY}(\gamma) = w(\gamma) \times \tau_{MKZ}(\gamma) + [1 - w(\gamma)] \times \tau_{\mu KZ}(\gamma)$$
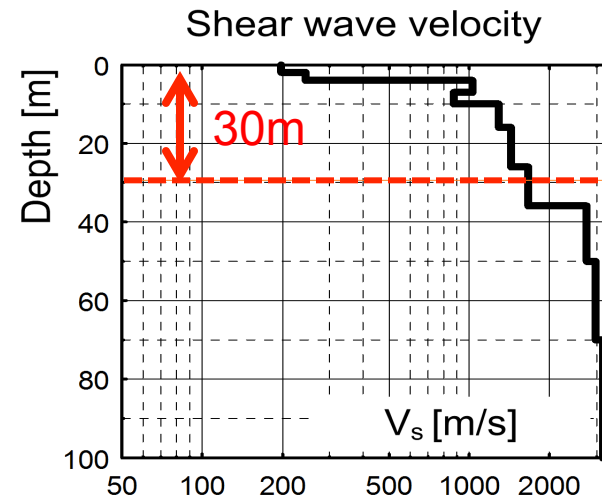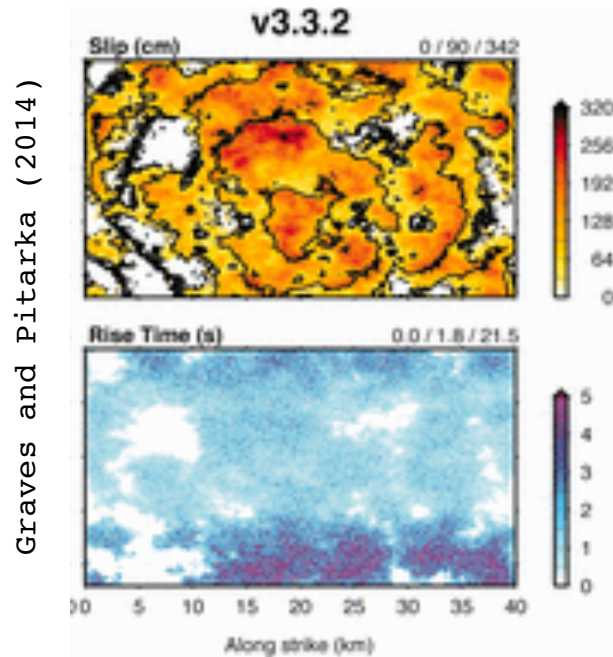
Nonlinear optimization to achieve smoothness

Darendeli (2001)

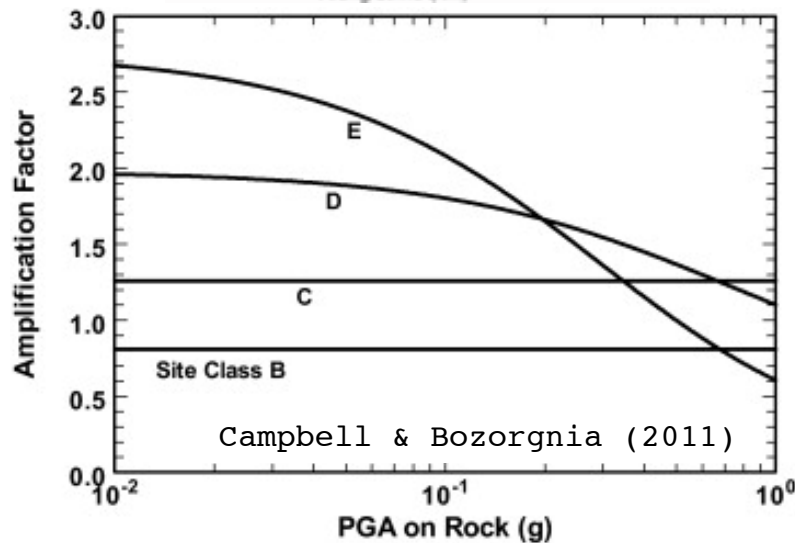Ladd (1991), Mayne et al (1996, 1998)
Vardanega & Bolton (2011)

Ladd & Edgers, 1972

+... verification, validation etc. (Shi & Asimaki, 2015)

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Present: Broadband platform site factors

Graves and Pitarka (2014)

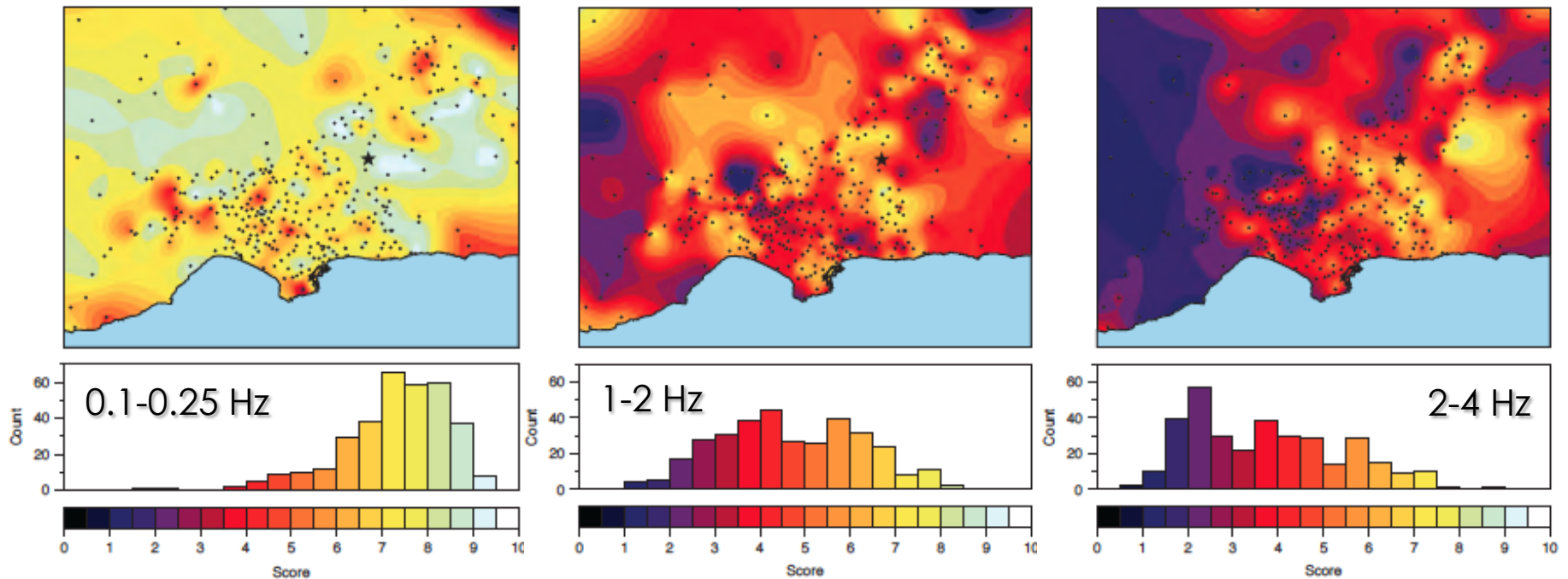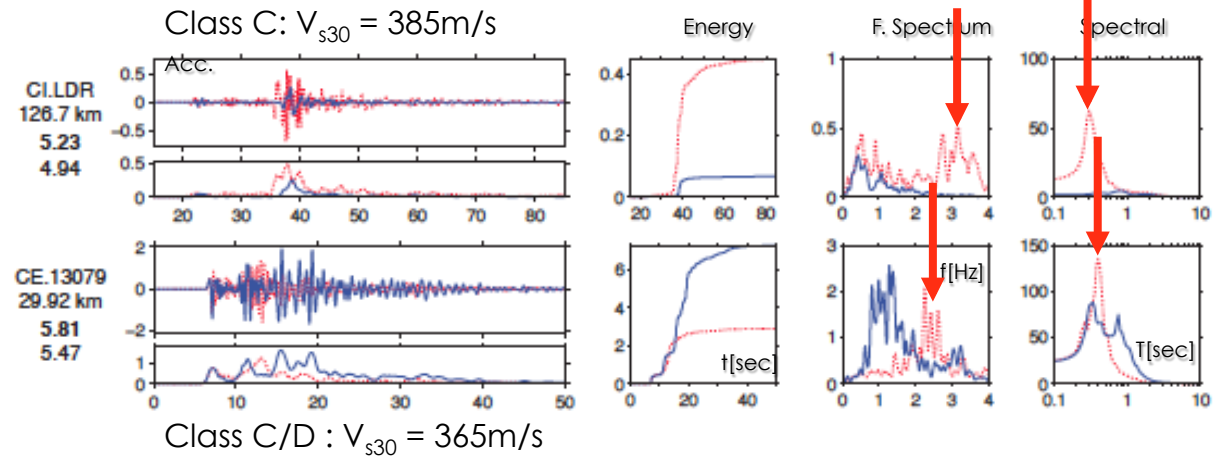Campbell & Bozorgnia (2011)
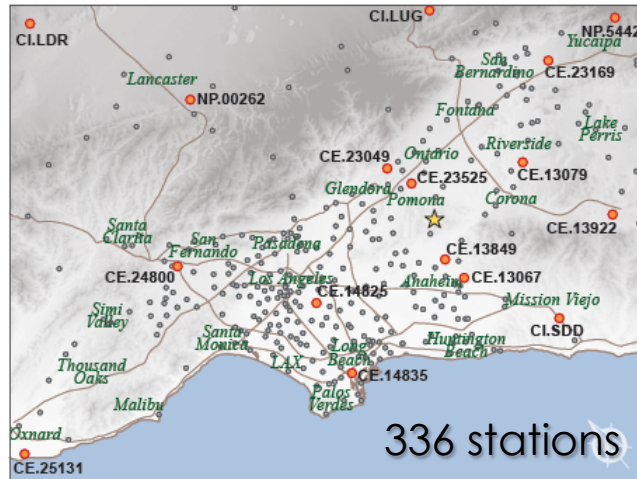

Shear wave velocity

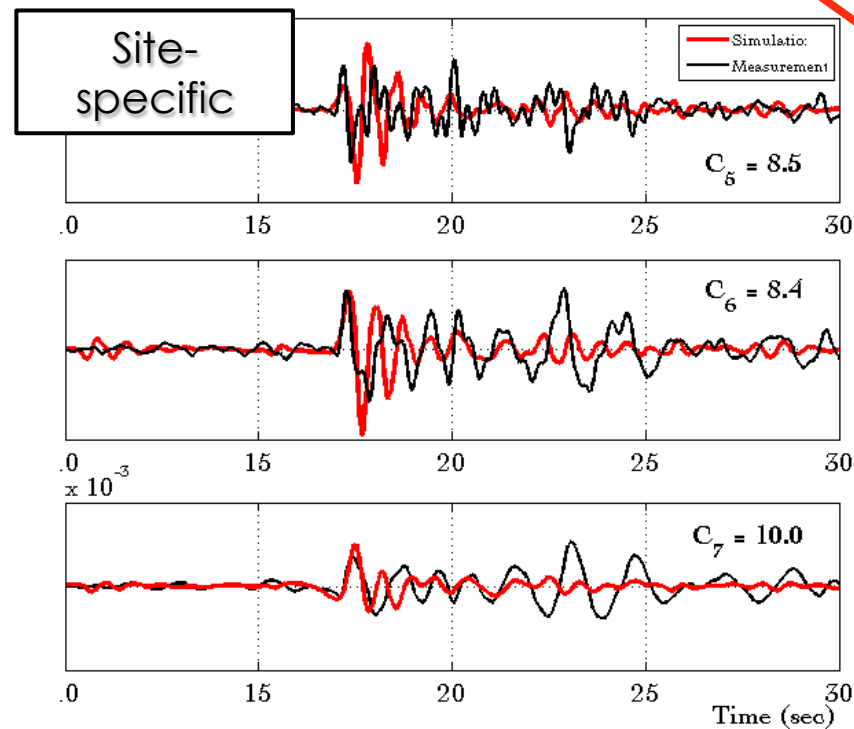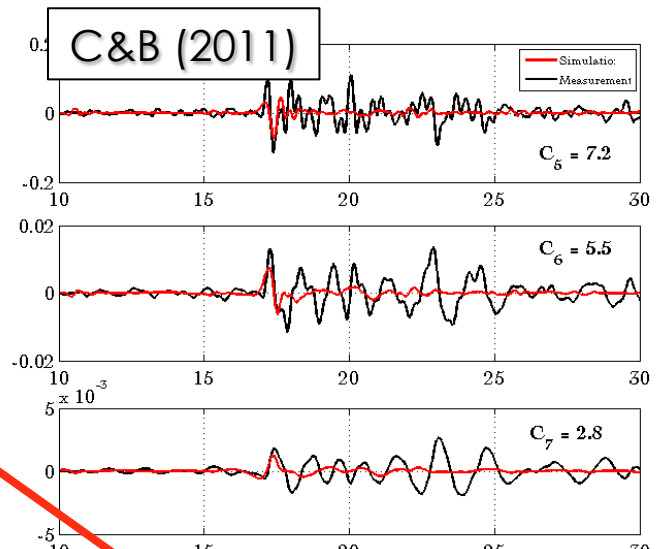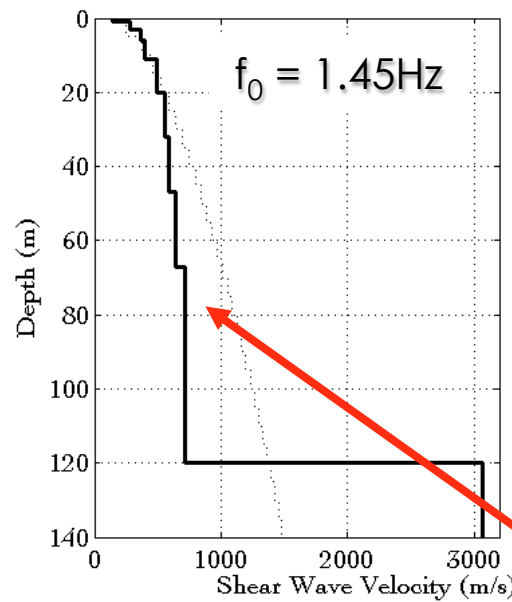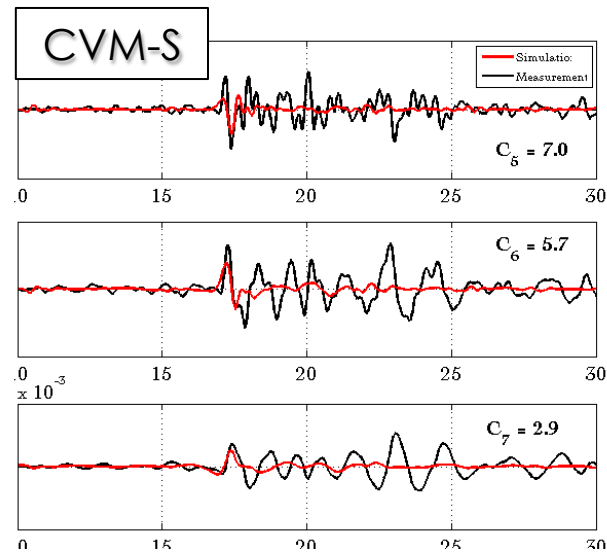$$V_{s}30 = \frac{\sum V_{si} \times t_i}{\sum t_i}$$

Response spectral amplitude ratio

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Future: BBP planned site modules

- Implement, verify and validate 1D site-specific response 'corrections' (input V_s)

- Develop Fourier-based amplification factors (amplitude and phase) based on 1D site-specific analyses with realistic nonlinear model

- Implement Fourier-based site factors (input $V_{s,30}$)

+... Outcomes of this workshop? ☺

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Present: 3D-1D hybrid physics-based models

336 stations

Class C: V_{s30} = 385m/s
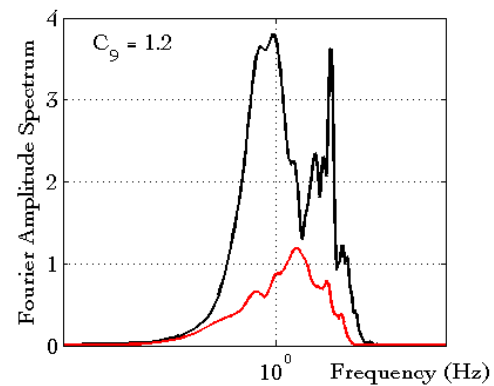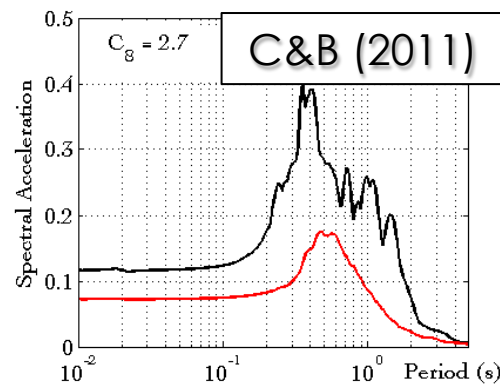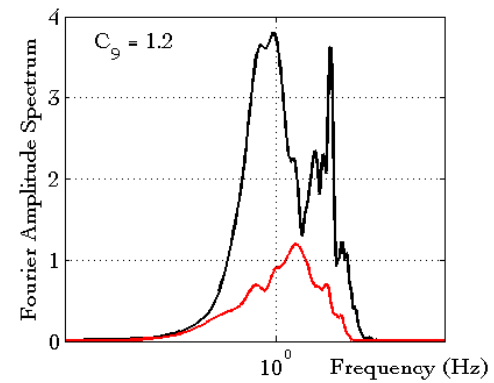
Class C/D : V_{s30} = 365m/s

Energy   F. Spectrum   Spectral

CI.LDR
126.7 km
5.23
4.94

CE.13079
29.92 km
5.81
5.47

0.1-0.25 Hz   1-2 Hz   2-4 Hz

Taborda & Bielak (2013)

CVM-S

$C_5 = 7.0$

$C_6 = 5.7$

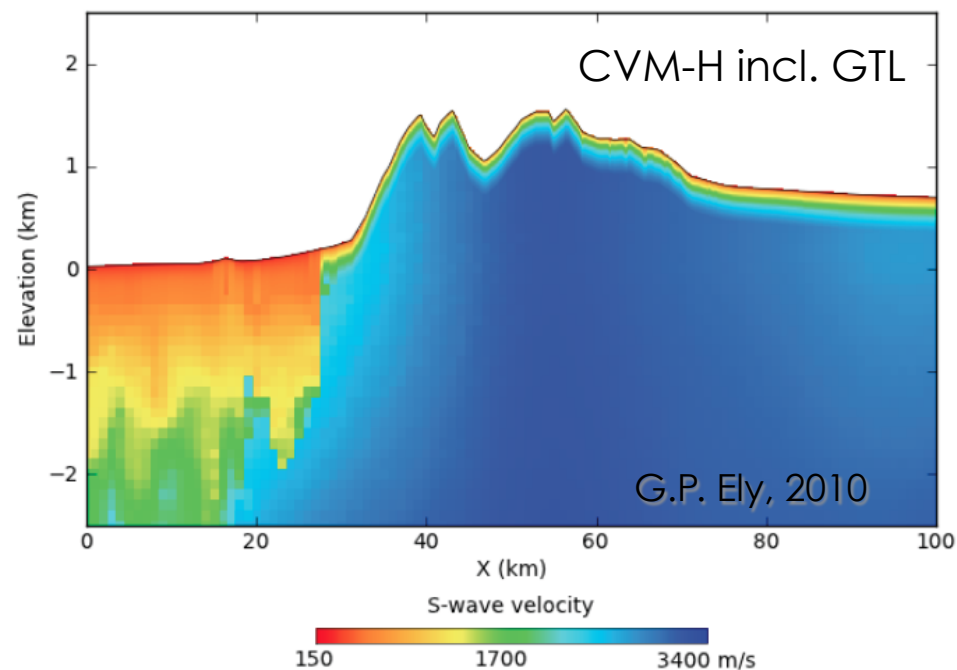$C_7 = 2.9$

$f_0 = 1.45Hz$

Depth (m)

Shear Wave Velocity (m/s)

C&B (2011)

$C_5 = 7.2$

$C_6 = 5.5$

$C_7 = 2.8$

Site-specific

$C_5 = 8.5$

$C_6 = 8.4$

$C_7 = 10.0$

Time (sec)

Yong et al (2013)
Asimaki et al (2014)

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CVM-S

$C_8 = 2.7$ $C_9 = 1.2$

C&B (2011)

$C_8 = 2.7$ $C_9 = 1.2$

Site-specific

$C_8 = 7.2$ $C_9 = 5.7$

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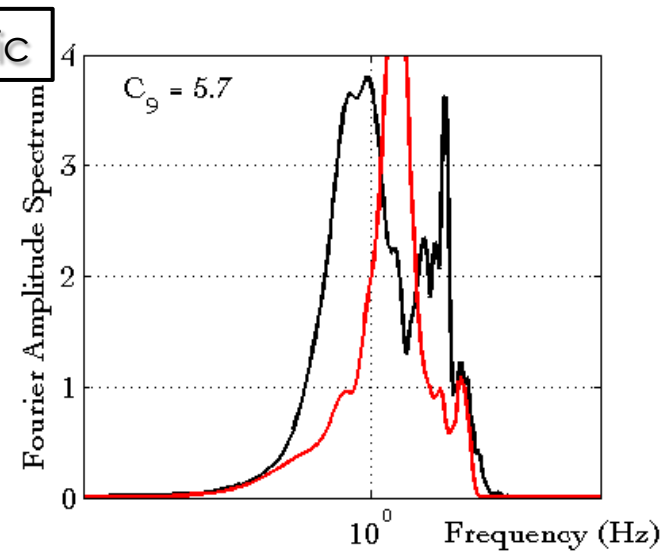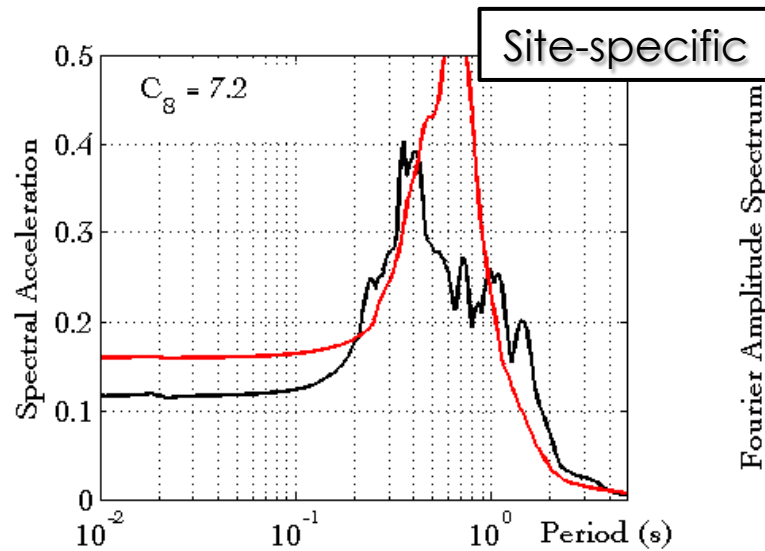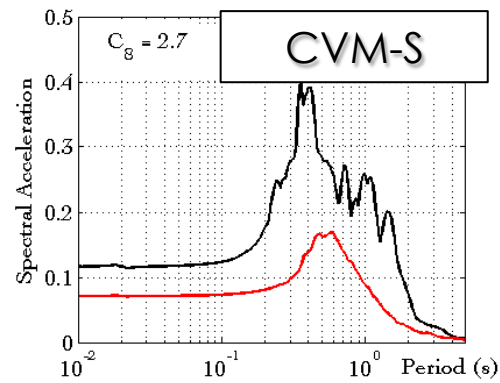
Present: CVM Geotechnical Layer

G.P. Ely, 2010

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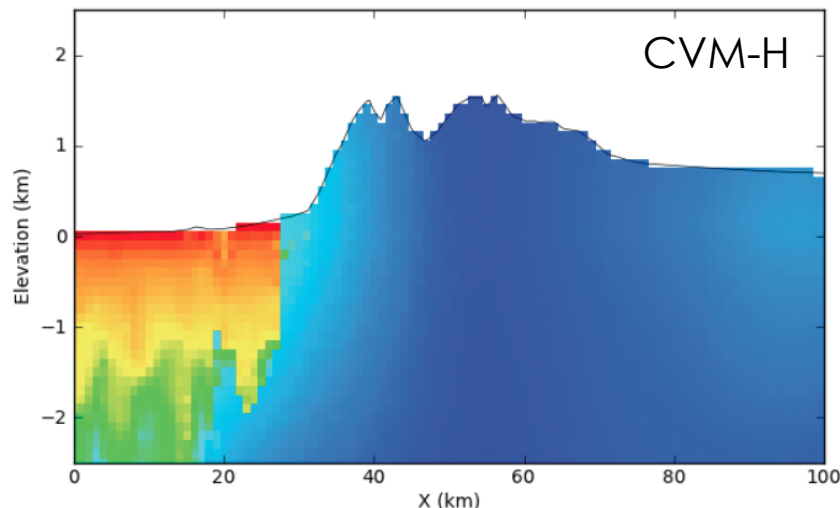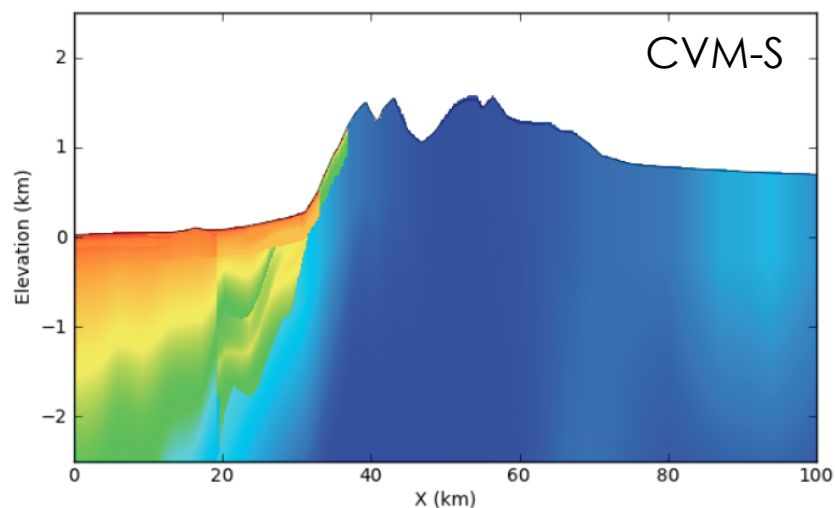
GTL vs. V_s profiles at strong motion stations
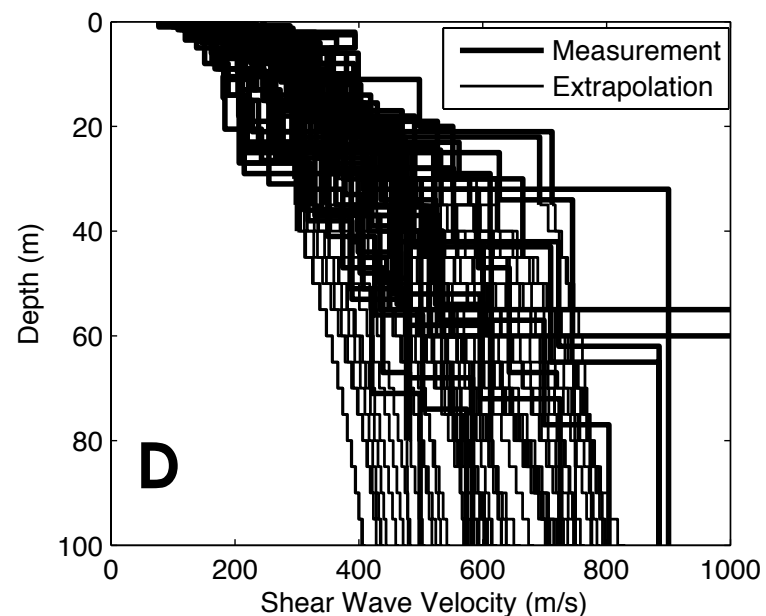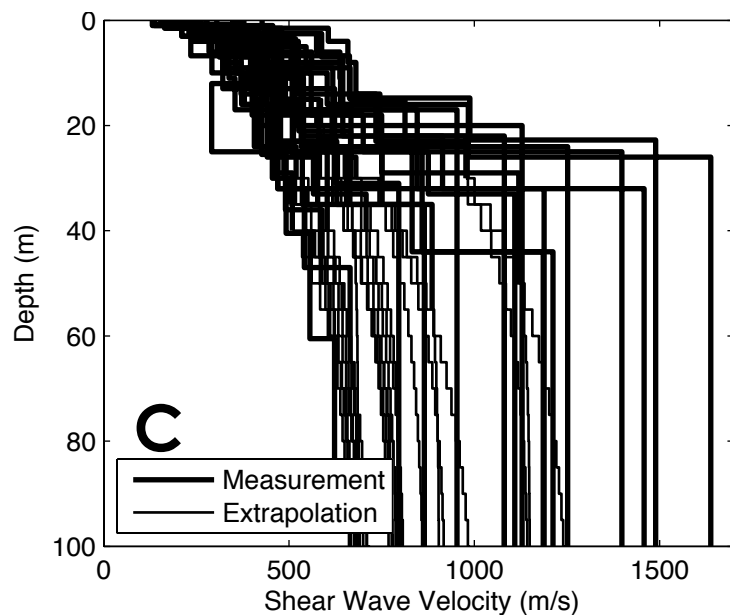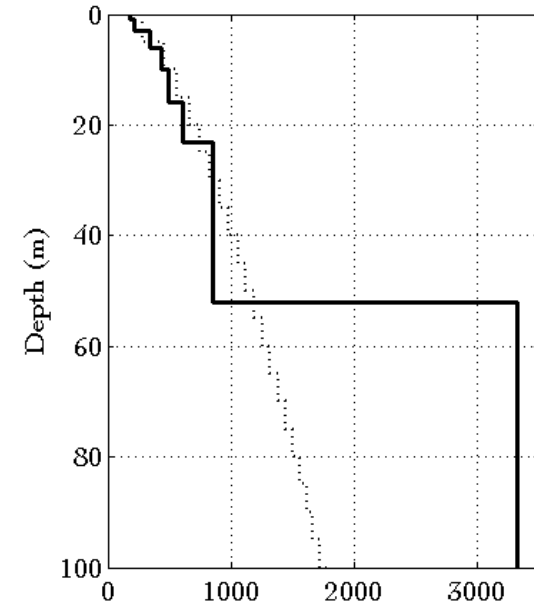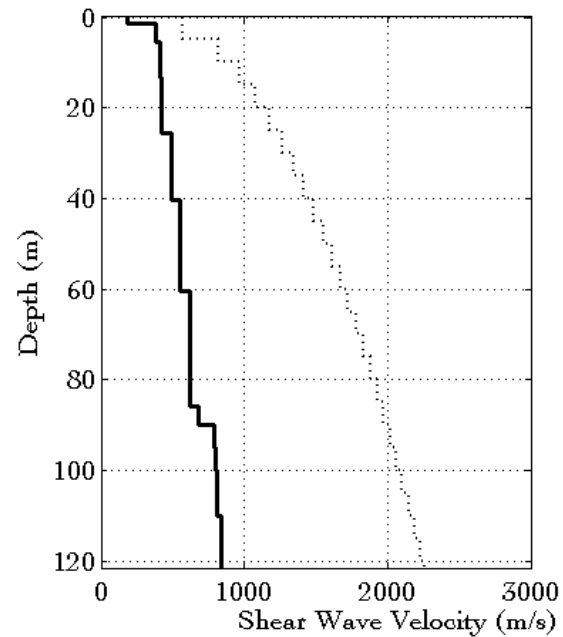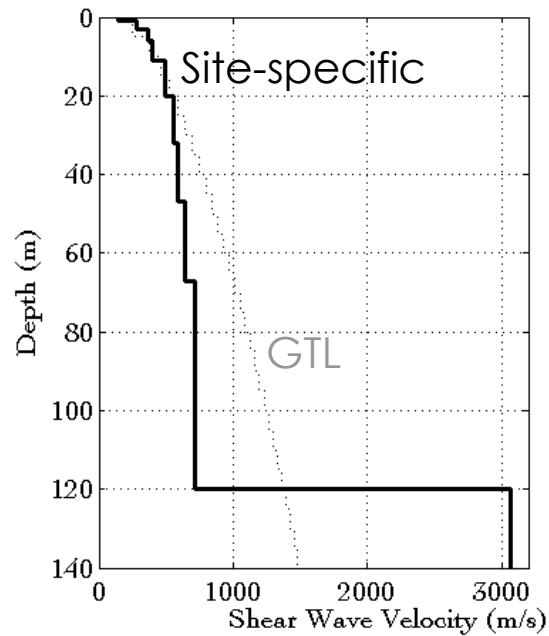
Future: 3D physics-based simulations

- Hybrid 3D-1D for larger magnitude event (Northridge)

- Improve GTL = $f(V_{s,30})$: Site-class dependent gradient

- Full 3D GM simulations with nonlinear response

+… Outcomes of this workshop? ☺

Future: Cybershake

- 3D physics-based simulations with nonlinear response to develop 'correction' factors analogous to the BBP for 1D?

+ … Outcomes of this workshop? ☺

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