Non-ergodic Ground Motion Models for Bay Area

Seismic Velocity Model Workshop

Grigorios Lavrentiadis[1] [1] Norman A. Abrahamson[2] [1]

[1]Department of Civil and Environmental Engineering,
University of California, Berkeley

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[1]glavrent@berkeley.edu
[2]abrahamson@berkeley.edu

Ergodic vs. Non-ergodic gmpes [1/1]

Ergodic Paradigm:

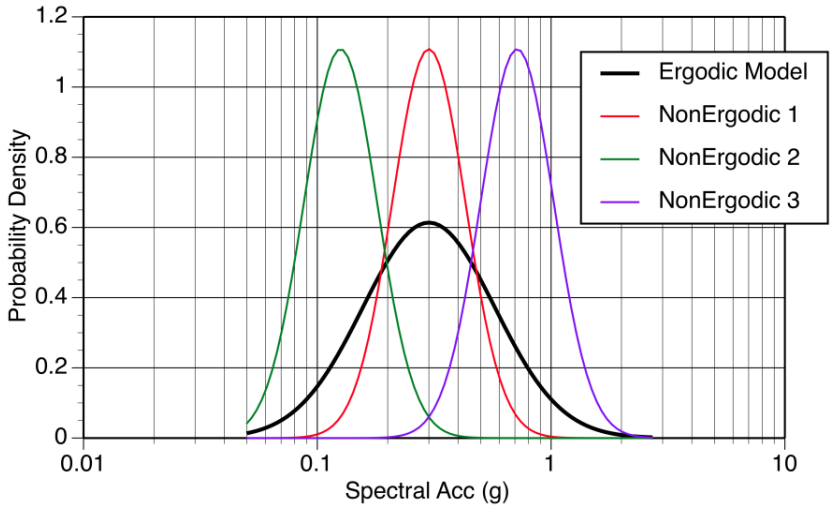
- Global data from similar tectonic environments can be combined to develop a GMPE
- The same model can be used anywhere in the world

Non-ergodic Paradigm:

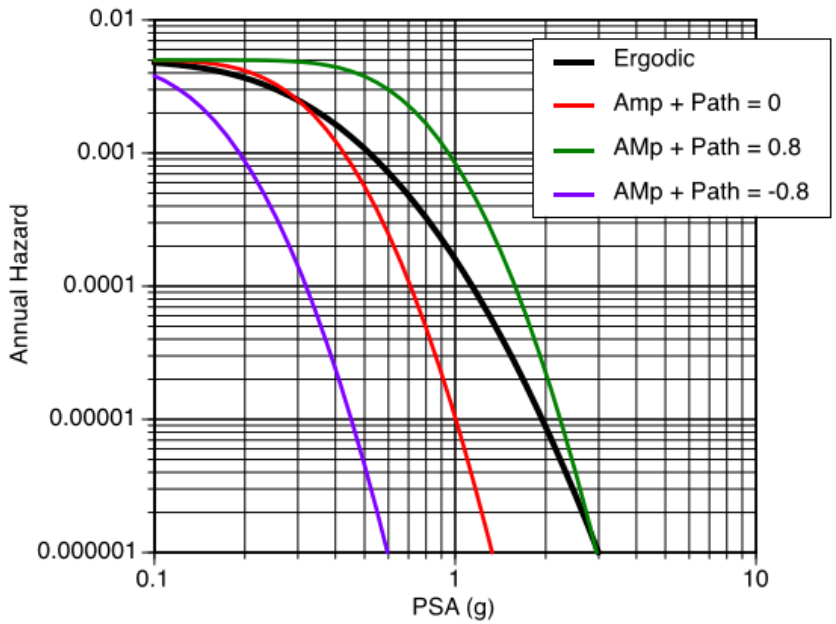
- Repeatable effects systematically change the GM at a site compare to the global average model
- Site specific aleatory variability is smaller than that of the global GMPE

Ergodic vs. Non-ergodic gmpes [2/2]

Non-ergodic hazard curves are steeper but the systematic shifts needs to be estimated



(a) Aleatory variability comparison



(b) Hazard curves comparison

Figure: Ergodic vs. Non-ergodic GMPEs

Evolution of non-ergodic GMPEs

Ergodic GMPE:

$$ln(Sa) = GMPE(M, R, Vs_{30}, F_N, ...) + \delta W_{es} + \delta B_e$$

Partially non-ergodic GMPE:

$$ln(Sa) = GMPE(M, R, Vs_{30}, F_N, ...) + \delta_{S2S} + \delta WS_{es} + \delta B_e$$

Fully non-ergodic GMPE:

$$ln(Sa) = GMPE(M, R, Vs_{30}, F_N, ...) + \delta_{L2L} + \delta_{P2P} + \delta_{S2S} + \delta W^o_{es} + \delta B^o_e$$

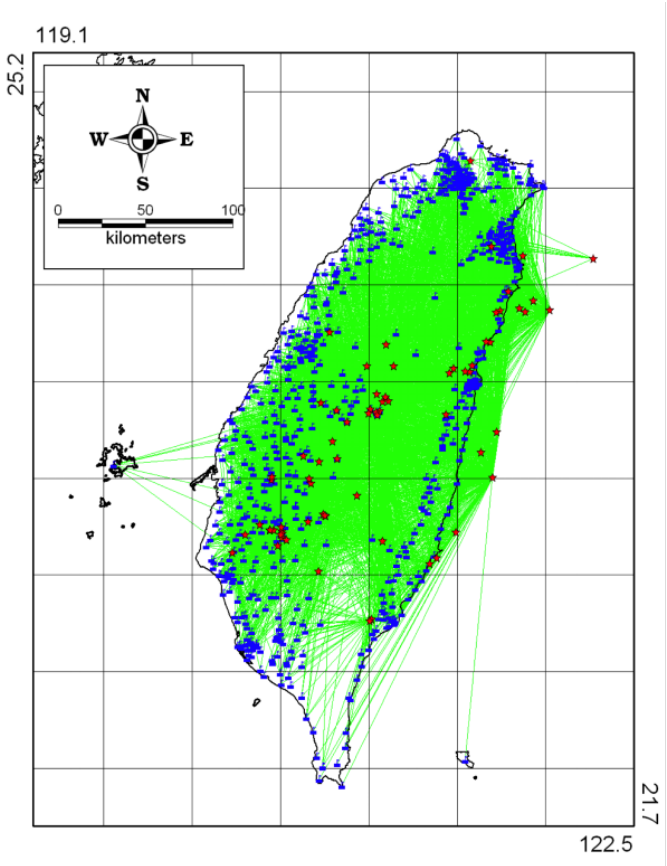


Figure: Repeated path terms [LCA+11]

Varying-coefficient GMPE [1/3]

In VCM the coefficients are allowed to vary by geographical location [LKSA16]

Functional form:

$$
\begin{aligned}
ln(Sa) = {} & \beta_{-1}(\boldsymbol{t_{eq}}) + \beta_0(\boldsymbol{t_s}) + \beta_1 M + \beta_2 M^2 \\
& + (\beta_3(\boldsymbol{t_{eq}}) + \beta_4 M) ln(\sqrt{R_{JB}^2 + h^2}) \\
& + \beta_5(\boldsymbol{t_{eq}}) R_{JB} + \beta_6(\boldsymbol{t_s}) ln(V_{S30}) \\
& + \beta_7 F_R + \beta_8 F_{NM} + [\delta W_{e,s} + \delta B_s]
\end{aligned}
$$

Varying-coefficient GMPE [1/3]

(a) Spatial Variation of β_0 (Site term)

(b) Spatial Variation of β_3 (Geometrical Spreading)

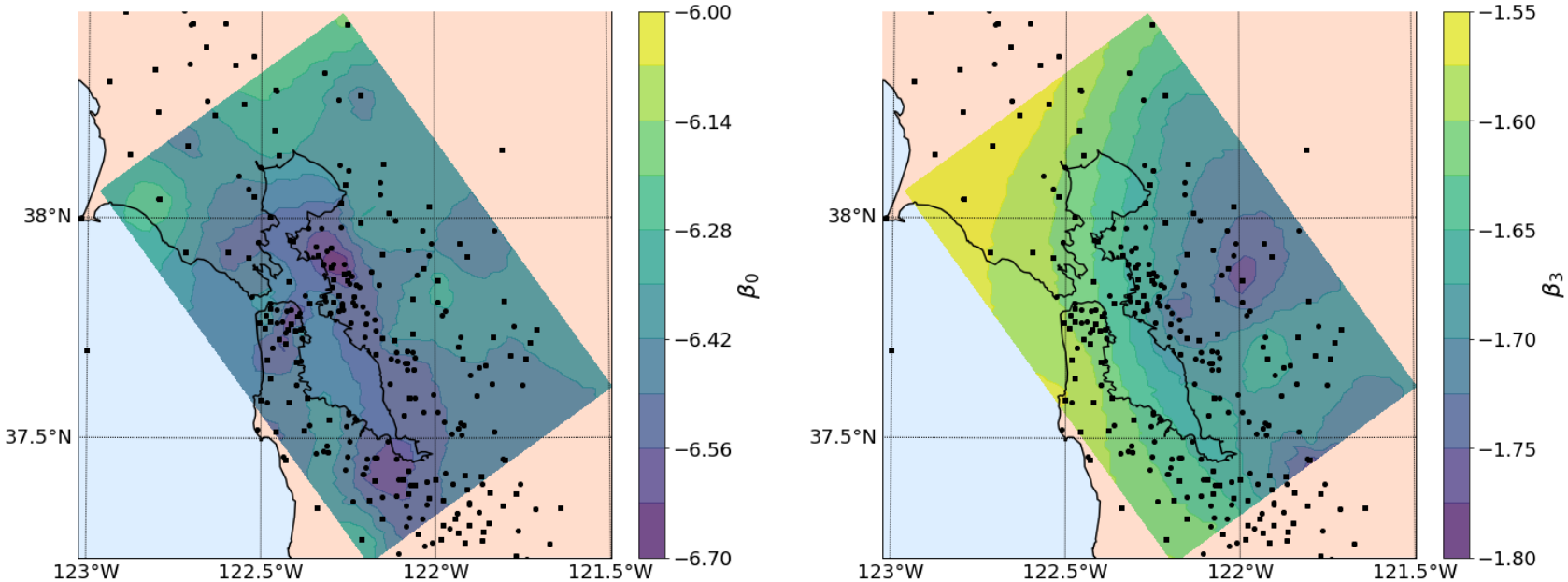


Figure: Spatial Variation of [LKSA16] GMPE coefficients for T = 1*sec*

Varying-coefficient GMPE [3/3]

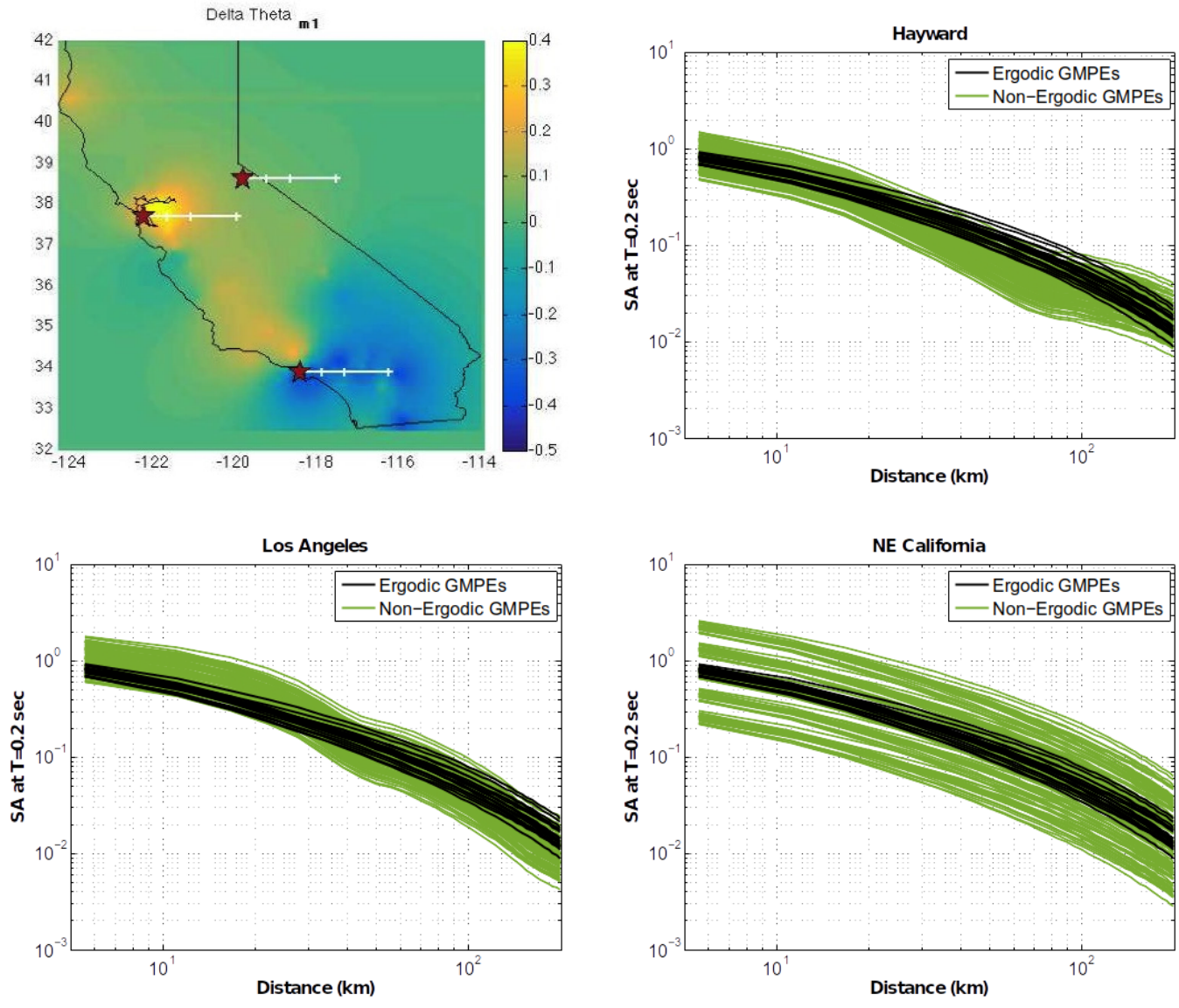


Figure: Spatial variation of distance scaling, courtesy of K. Wooddell

Test of Nonergodic GMPE: 2014 Napa Earthquake

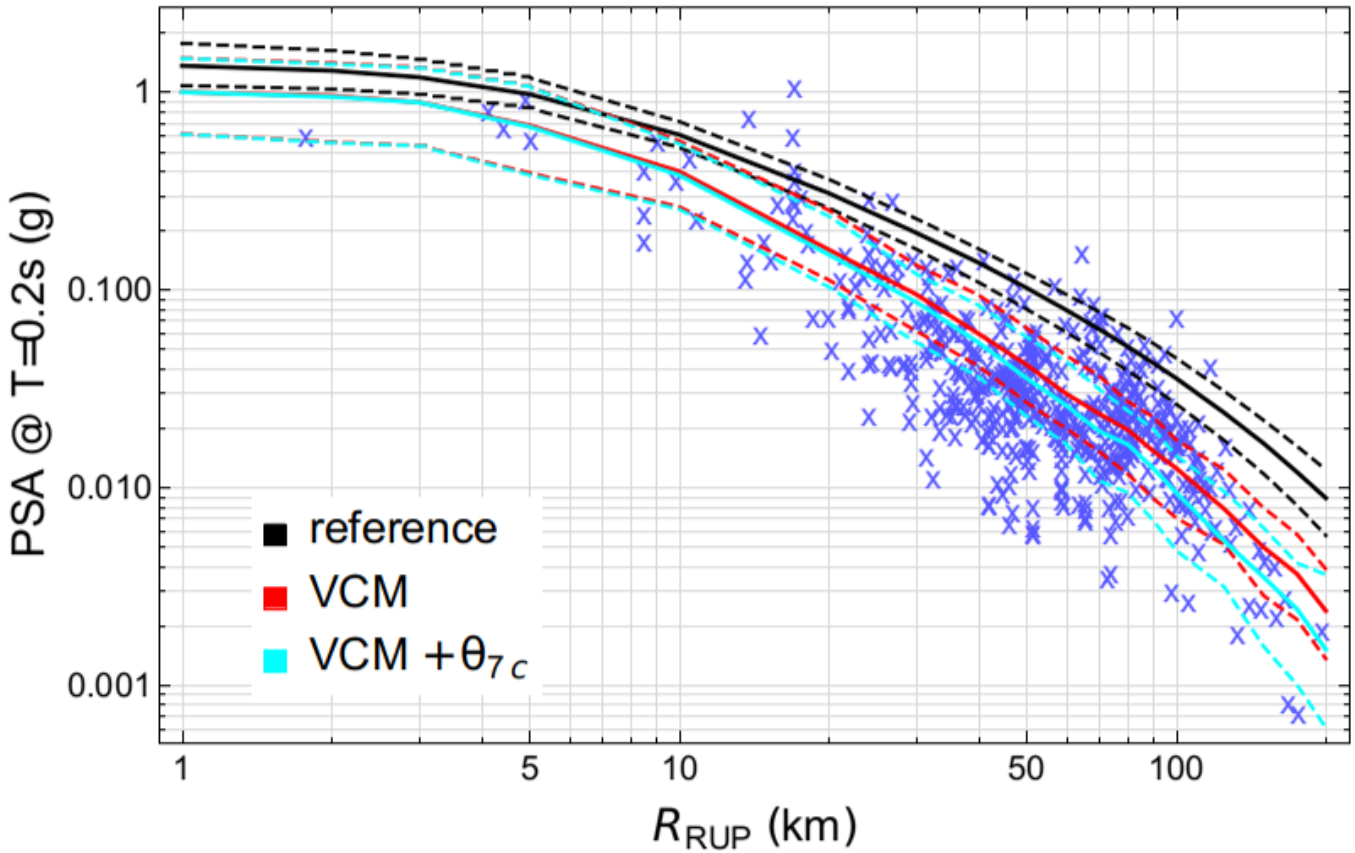


Figure: 2014 South Napa Earthquake, comparison with ergodic and non-ergodic gmpes, courtesy of Abrahamson

Non-ergodic Gmpes and $3D$ simulations

Coupling of Non-ergodic GMPEs and $3D$ Numerical simulations:

- Validation of $3D$ simulations with non-ergodic GMPEs
- Augment databases for non-ergodic GMPEs with $3D$ simulations

Example of $3D$ simulations

Scenario: **M** 7 eq. at Hayward Fault [RPP$^+$18]:

(a) $Sa(T = 1sec)$ (b) $Sa(T = 4sec)$

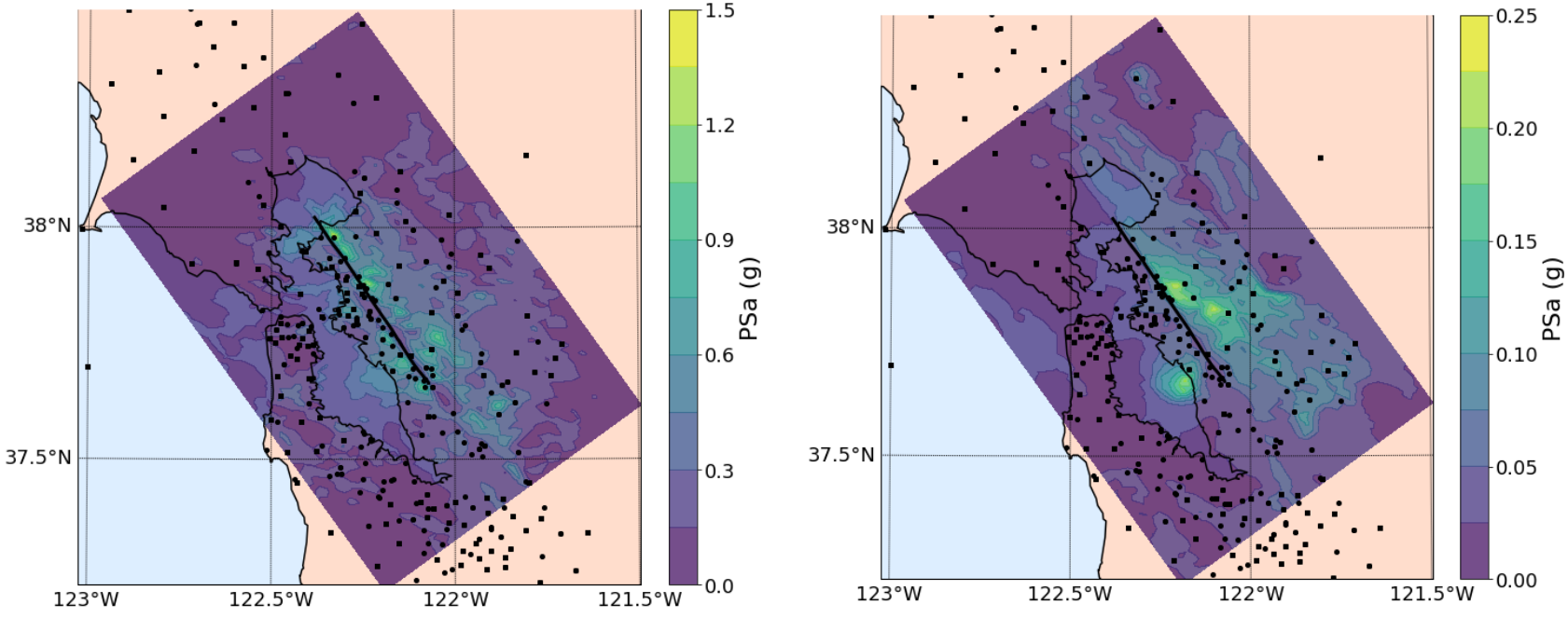


Figure: Spatial Variability of spectral acc. after [RPP$^+$18]

The minimum Vs in the simulations is 500 m/sec

Site response adjustment for shallow layers

The $3D$ simulation data were adjusted for the low-velocity layers using $1D$ site response [Kot18]

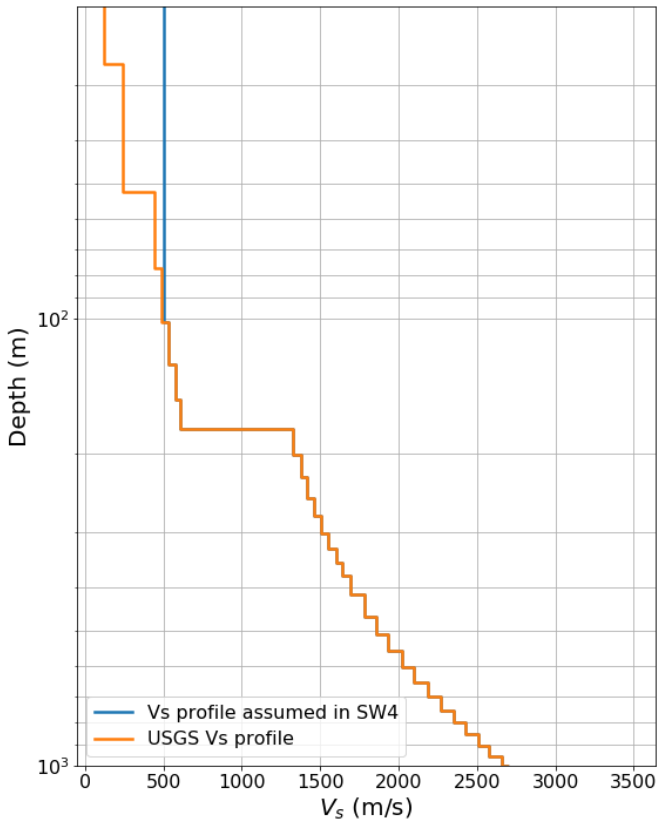


Figure: Example of a velocity profile in Berkeley

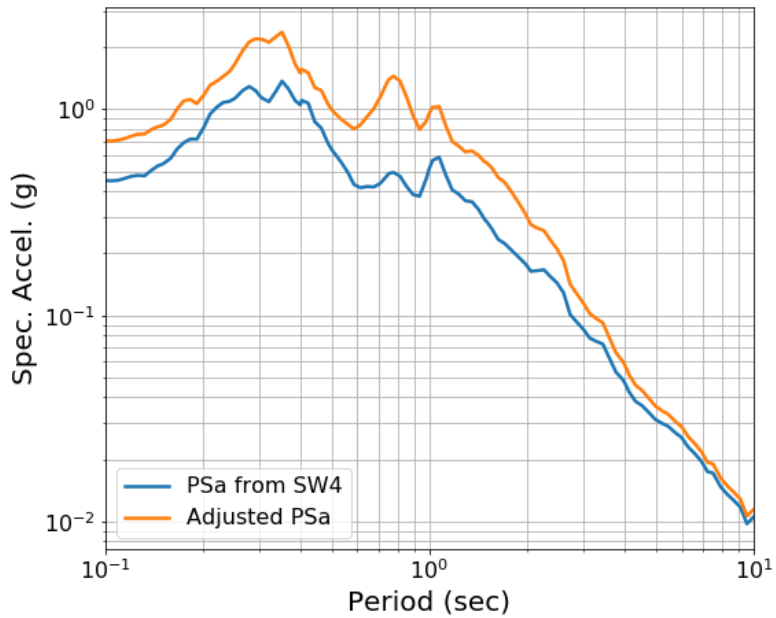


Figure: Response spectrum adjustment

$$Sa_{adj.}(T) = \frac{Sa'_{adj.}(T)}{Sa'_{3Dsim}(T)} Sa_{3Dsim}(T)$$

Comparison $3D$ simulation vs. Non-ergodic GMPE [1/2]

(a) Adjusted SW4

(b) Non-ergodic GMPE

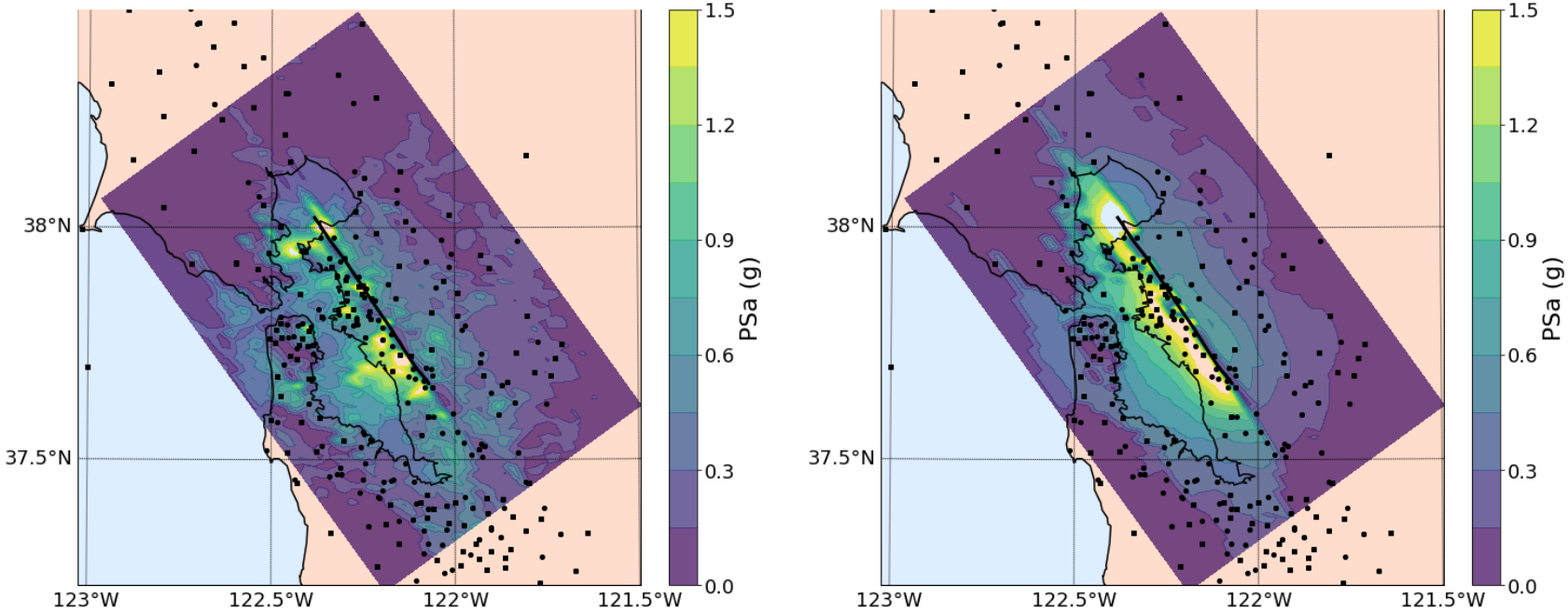


Figure: Spatial comparison of spectral accelerations at $T = 1.0sec$

Comparison $3D$ simulation vs. Non-ergodic GMPE [2/2]

(a) Adjusted SW4

(b) Non-ergodic GMPE

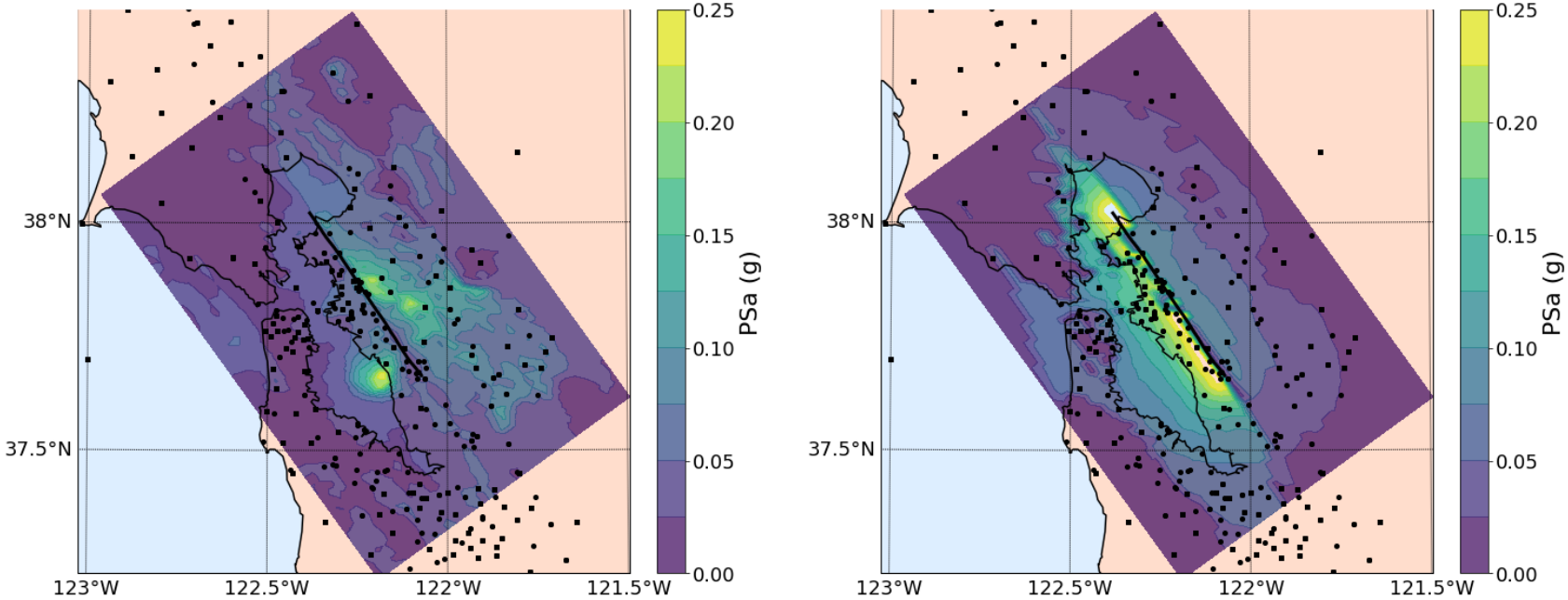


Figure: Spatial comparison of spectral accelerations at $T = 4.0sec$

Next Steps

- Currently there is large difference between $3D$ simulations and empirical non-ergodic gmpes.
- We need to understand what is correct, to do that we can evaluate the $3D$ simulations and non-ergodic gmpes against well recorded events.
- After sufficient validation of $3D$ simulations use them to augment the data-base of the non-ergodic gmpes

Bibliography I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Arthur J. Rodgers, Arben Pitarka, N. Anders Petersson, Björn Sjögreen, and David B. McCallen, *Broadband (0–4 Hz) Ground Motions for a Magnitude 7.0 Hayward Fault Earthquake With Three-Dimensional Structure and Topography*, Geophys. Res. Lett. **45** (2018), no. 2, 739–747.

Thank You!

Questions?