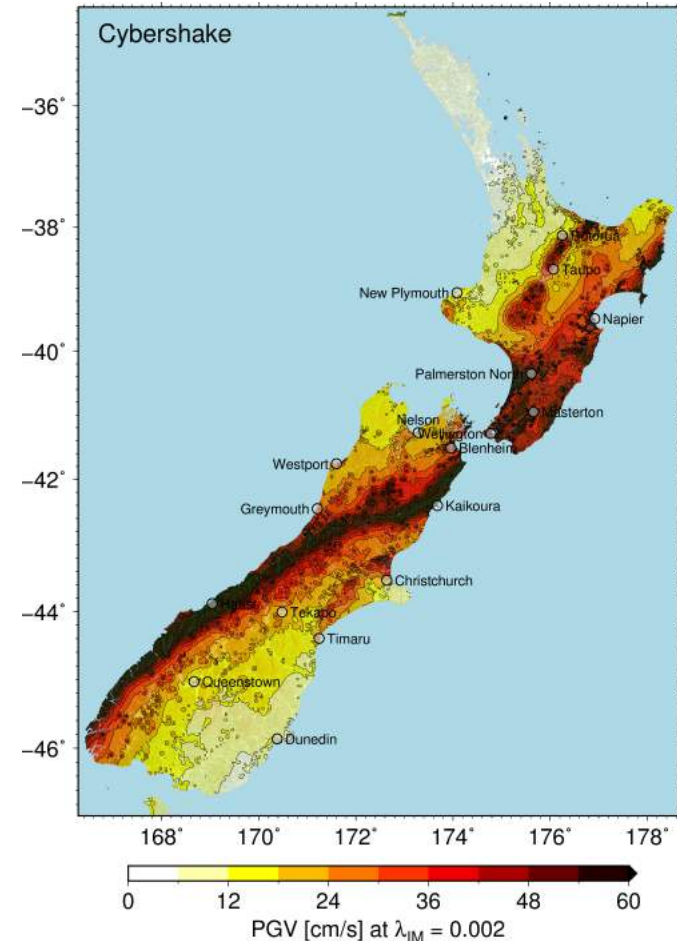
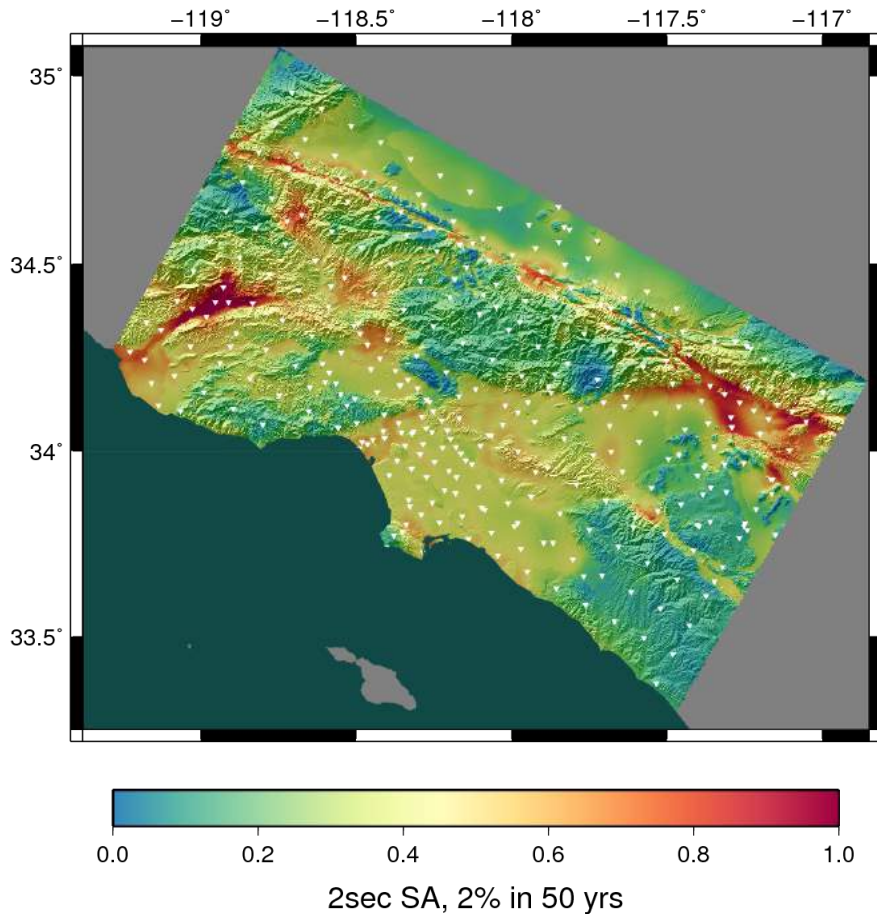


# Summary of 2019 SCEC Posters and reflection on QuakeCoRE GMSV



Brendon Bradley, Sept 2019

# Aim

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- Provide a synopsis of the 29 posters (and CVM workshop) at the 2019 SCEC Annual meeting related to ground motion prediction/simulation
- Reflect on the priorities and progress of QuakeCoRE's efforts in FP1
- Note:
  - Program at: <https://www.scec.org/meetings>
  - PDF of posters usually available ~1 month after meeting

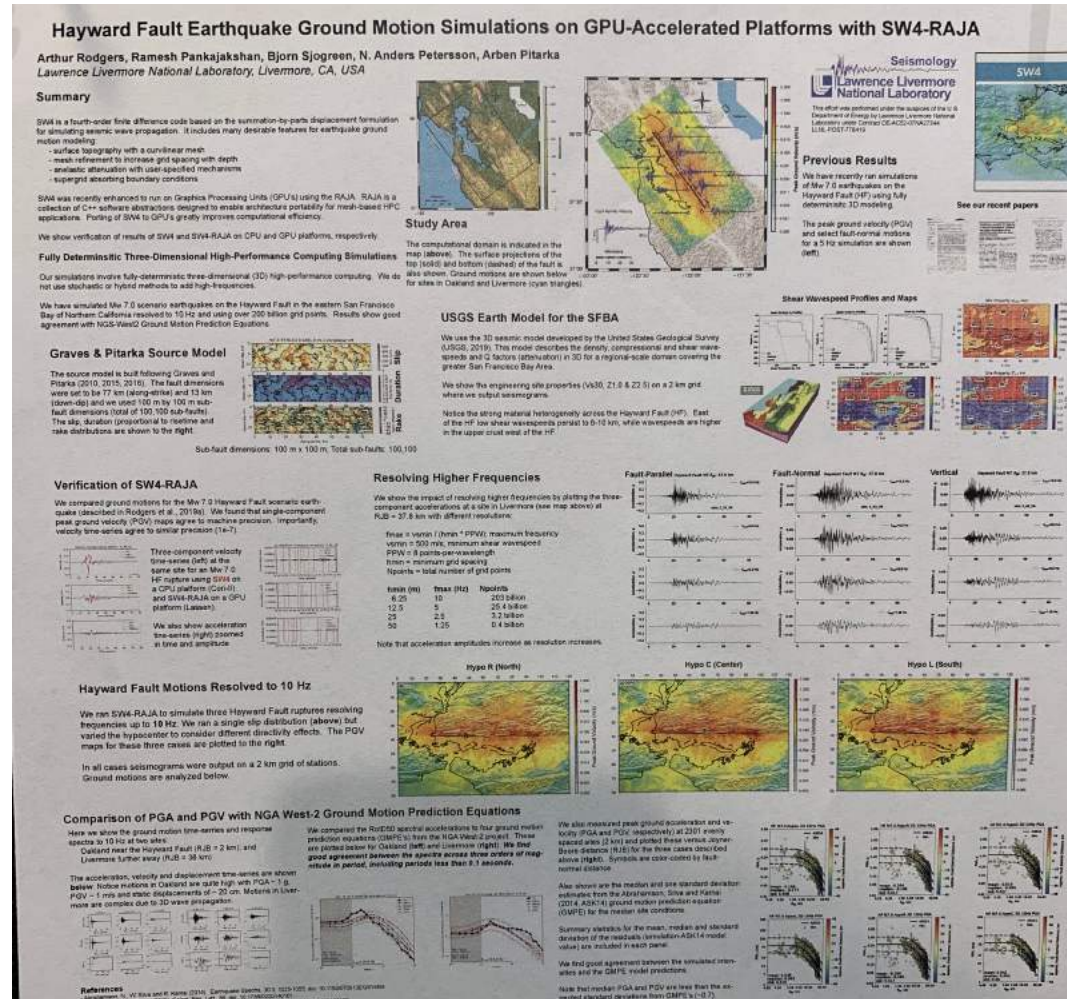
# Poster Summary

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- 5 of the 29 Presented by QC researchers!  
(Sarah, Anna, Robin, Andrei, Brendon)
- Of the remaining 24:
  - 2 adding new ‘enhancements’ to codes:
  - 4 Gm Simulation applications
  - 2 Gm Sim validation
  - 4 on shallow (geotechnical) site response
  - 2 Flagship SCEC projects (BBP and Cybershake)
  - 3 Machine learning approaches using simulated ground motions or hybrid empirical/simulated
  - Remainder misc. topics

# Gm sim applications

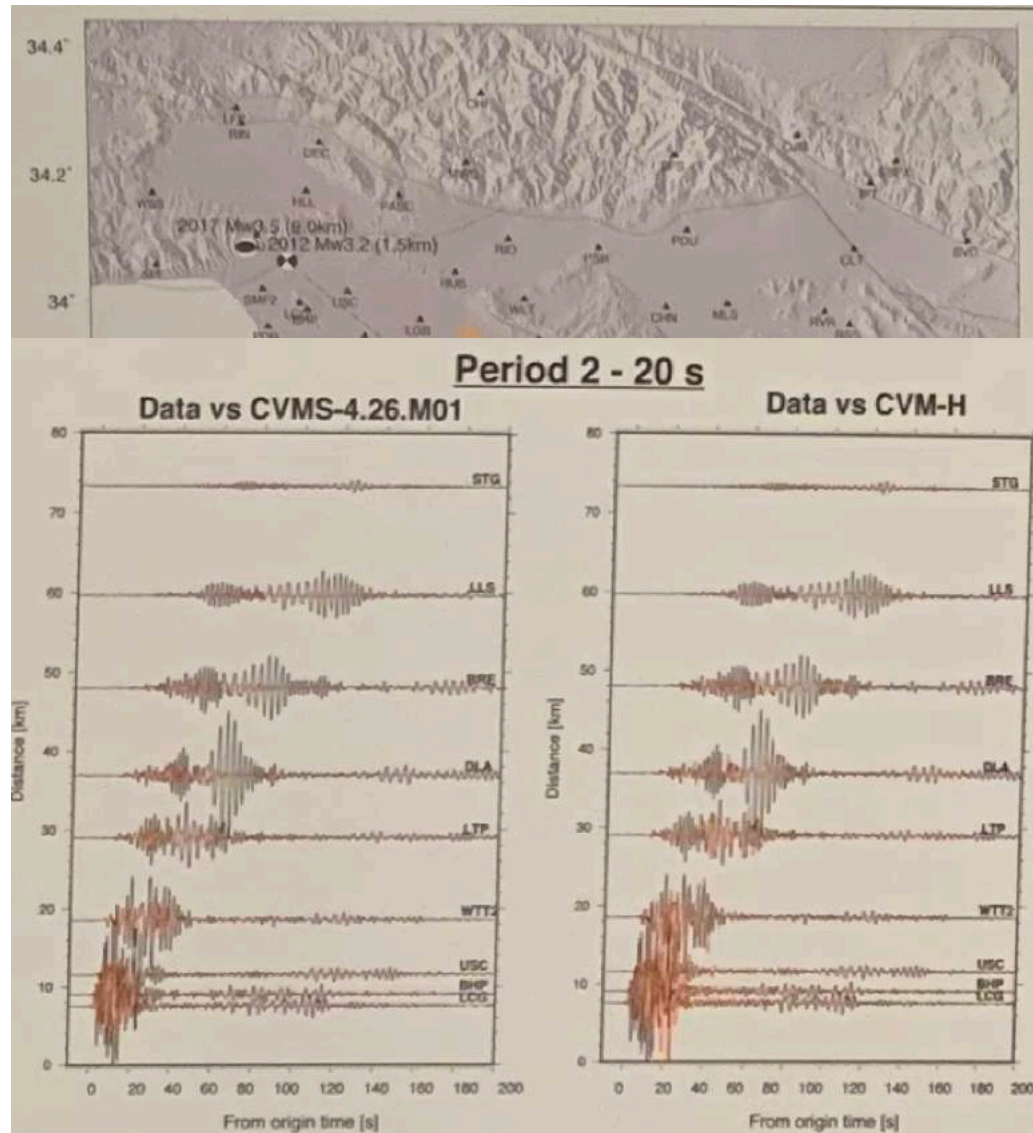
- Rodgers et al. Hayward Fault sim on SW4 up to 10Hz via 3D calculation (no 'HF' method) [200B grid points]
- Results broadly consistent with NGA-W2 methods (minimum  $V_s=500\text{m/s}$ , no nonlinear soil response)
- This LLNL project is focused on pushing calculations to Exa-scale – Art openly mentions that they don't realistically believe that they can resolve the fault or crustal structure at the length scale of 10Hz (yet)





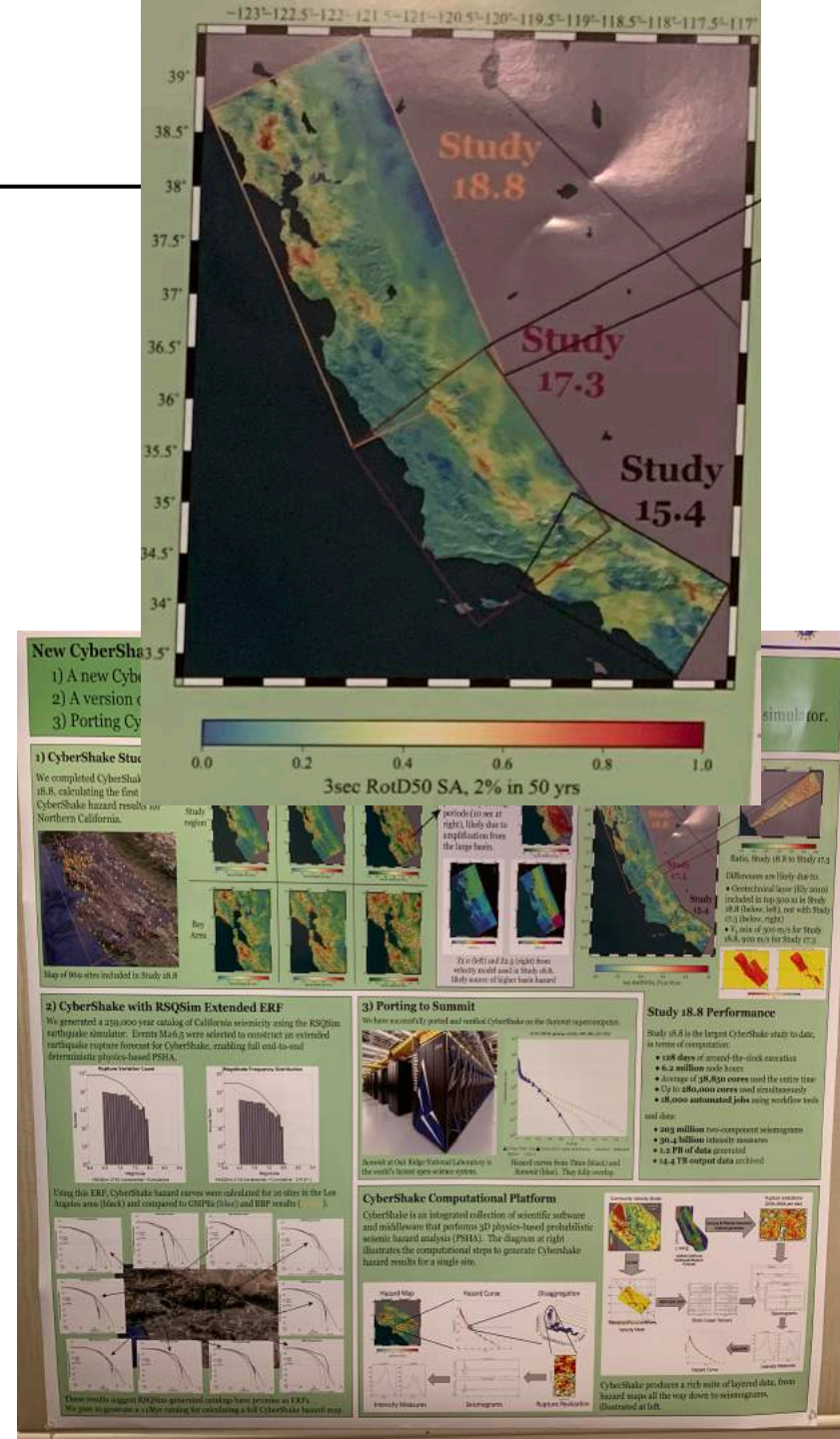
# Gm sim validation (2 of 2)

- Lai et al. Sim vs. Obs for two events in LA Basin
- Mw3 events in Westwood and Beverly Hills
- Considered CVM-S and CVM-H velocity models (base)
- CVM-S: Does not lead to basin wave reverberation ('basin-edge' is too smooth)
- CVM-H: Amplitudes of direct arrivals too large, but basin-edge waves too small also.
- Highlight the issues with these models at freq. greater than they were developed for



# SCEC Cybershake

- Callaghan et al.
- CS v18.8 in Northern California, essentially run the GP10 hybrid method at  $f_{max}=1\text{Hz}$ .
- ~400k ruptures, ~800 sites
- Largest to date (~250M core-hours; n.b. QC has access to ~2 Million core-hours/year)
- See May 2018 GMSV call for technical comparison of QC vs. SCEC Cybershake efforts



# Shallow geotechnical response

- Shi and Asimaki site response method for BB simulations based on  $V_{s30}$  /  $Z_{1.0}$  (vs. GMM-based  $V_{s30}$  amplification)
- They present the theoretical benefits. Time domain, so can include site response effects on duration etc also.
- Has not been used in validation studies to date
- Obvious thing to consider for NZ-based GM sim work

**A site response toolbox for the SCEC Broadband Platform: implementation and verification**  
 Jian Shi and Domniki Asimaki  
 California Institute of Technology, Pasadena, CA

**1. Overview**

**(1) Motivation**  
 Site modules in the BBP are based on NGA-West2 GMPE terms, which are based on response spectral ratios and equivalent linear analyses of strong ground motions. Within SCEC, we have developed prototypes of generic  $V_{s30}$ -profile generators, synthetic complex Fourier amplification factors, and wave propagation-based site modules as separate libraries MATLAB, Python and Fortran. We here schematically illustrate the toolbox we are developing to link the above individual packages/libraries into a site module toolbox for implementation on the SCEC BBP.

**(2) PySeismoSoil: an open-source library**

- Written in Python
- Cross-platform support
- Parallelizable
- Built-in visualization functionalities

**(3) Main functionality**

- Randomized 1D Vs profiles from  $V_{s30}$ ,  $Z_{1.0}$
- Synthetic nonlinear site factors
- Site-specific (wave-propagation based) nonlinear site response calculation

**2.1. Demo: site effect adjustments**

**2.1. Prepare inputs: input ground motions**

sample\_accel.txt  
 PGA = 2.84 m/s<sup>2</sup>

sample\_vel.txt  
 PGA = 0.284 m/s

sample\_disp.txt  
 PGA = 0.0284 m

**2.2. Apply adjustments**

The users only needs to know  $V_{s30}$  and  $z_1$  of a site in order to apply the adjustments.  
 (In case  $z_1$  is not known, it will be automatically calculated from  $V_{s30}$  using an empirical formula.)

$V_{s30} = 220.0$  m/s,  $z_1 = 650.0$  m,  $PGA_{input} = 0.284$  g

Both the amplitude and the phase of the input motion is adjusted. The phase adjustments controls the time lag between input/output.

**3. Demo: 1D and 2D Vs profile generation**

PySeismoSoil can generate randomized 1D/2D Vs profiles using the Sediment Velocity Model (SVM) proposed by Shi & Asimaki (2018).

Below is a brief demonstration.

$V_{s30} = 320.0$  m/s,  $z_1 = 320.0$  m

$V_{s30} = 320.0$  m/s,  $z_1 = 53.3$  m

$V_{s30} = 320.0$  m/s,  $z_1 = 53.3$  m

It can also be used to generate 2D Vs profiles (i.e., cross section):

Depth [m] vs. Shear-wave velocity [m/s] vs. Latitude [deg]

**3. Comparison of state of the art**

$V_{s30} = 190$  m/s,  $z_1 = 500$  ft (152.4 m)

$V_{s30} = 760$  m/s,  $z_1 = 50$  ft (15.2 m)

Amplification vs. Frequency [Hz]

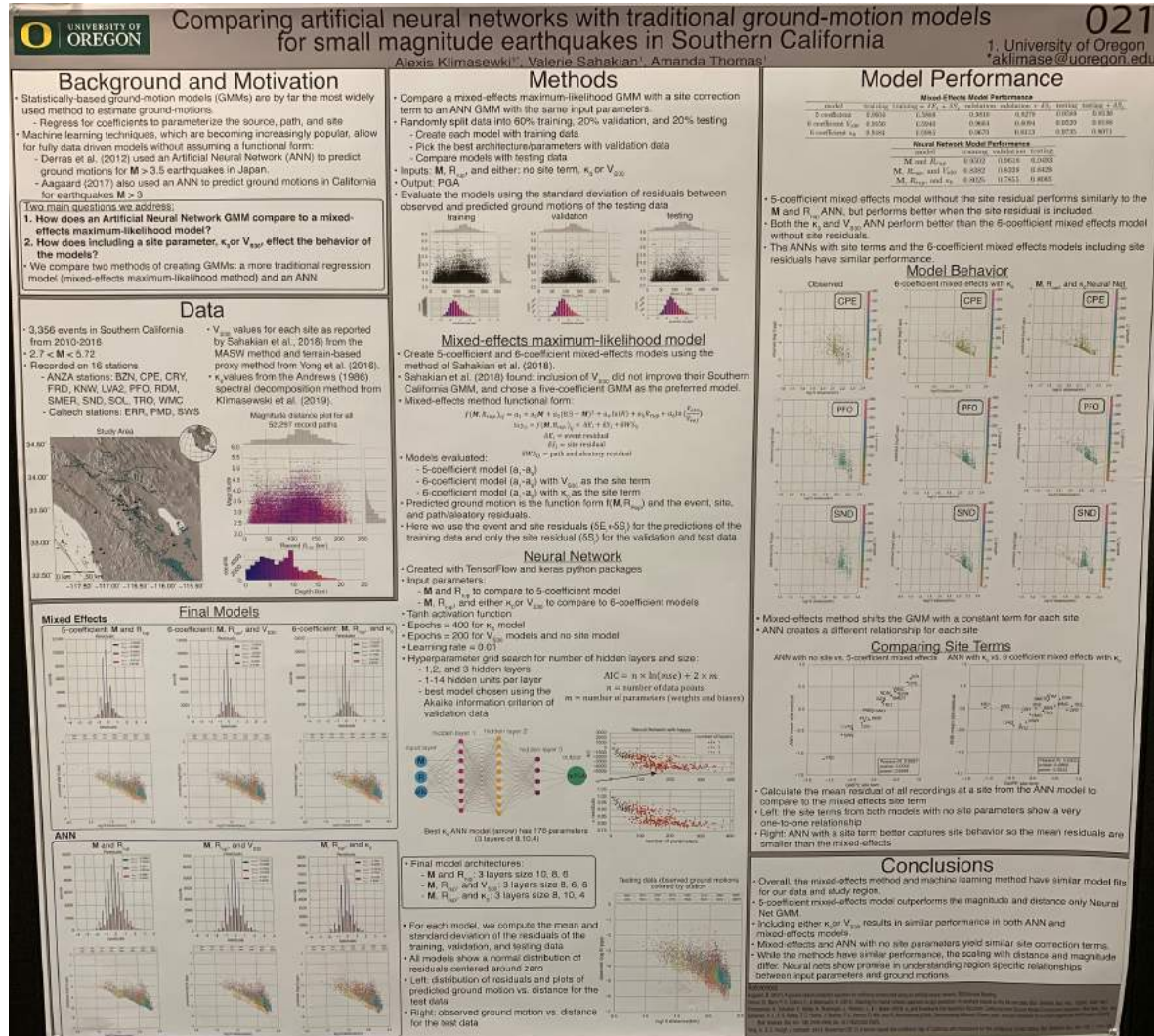
Comparison of KAS14 (raw), KAS14 ( $V_{s30}$  adjusted), SAG19 (res. spect.), SAG19 (Fourier), HH18 (raw), and HH18 ( $V_{s30}$  adjusted).

Kamei et al. (2014) | This study | Hashash et al. (2016)



# Machine Learning applications

- Klimasewki et al. compared traditional GMM (parametric) with Neural Net for fitting to empirical data
- Find similar standard deviation in residuals
- i.e. NNet does not lead to lower residuals
- Also, Nnet will not extrapolate beyond the data as well (as compared to traditional model were functional form can be 'set' based on theoretical guidance)
- Conclusion: ML directly with empirical data not fruitful (until several orders of magnitude more data)

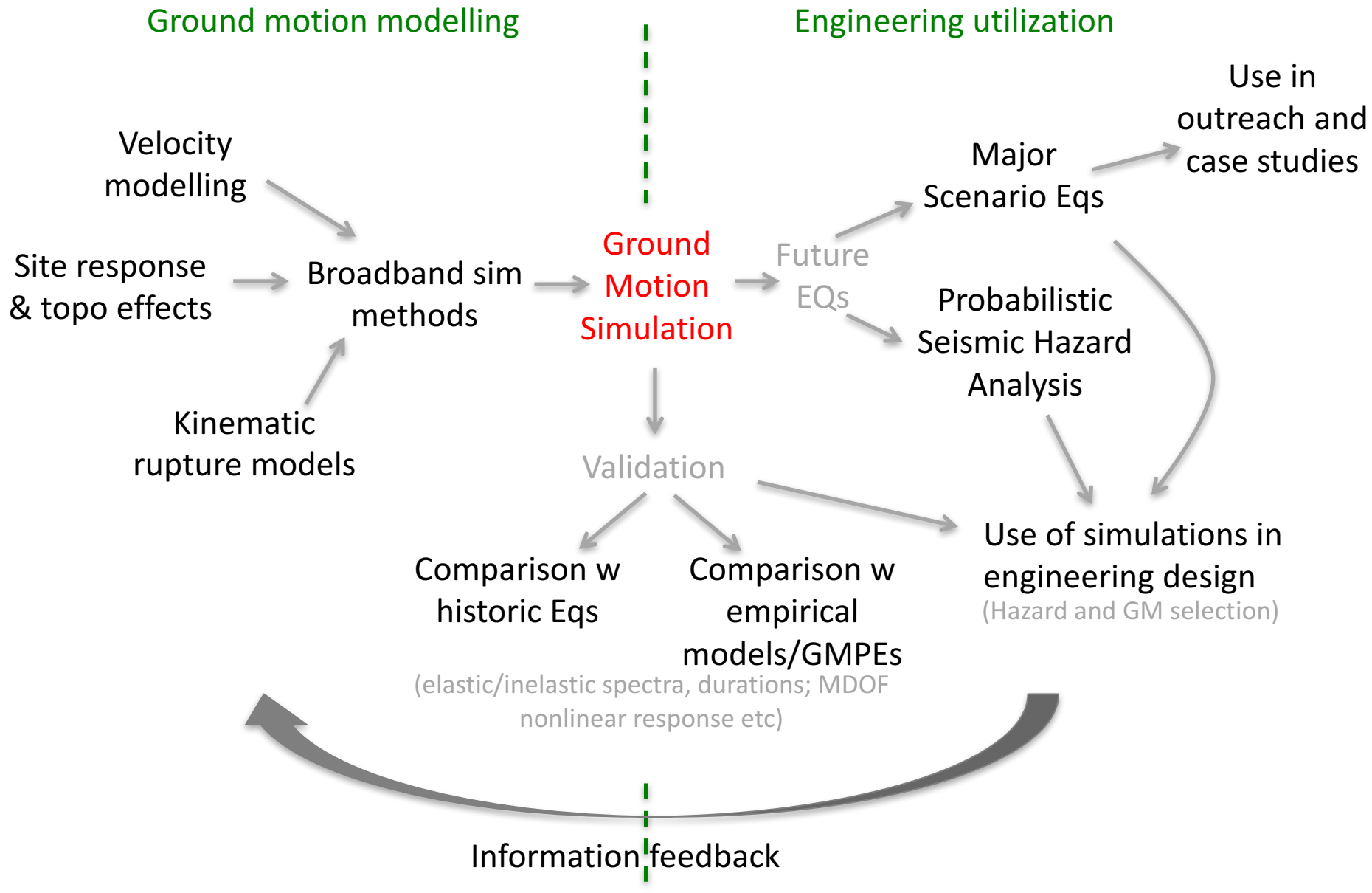




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# Reflections on QuakeCoRE GMSV activities

# Spectrum of research



# Take-away sentiments (my own biased views)

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- Access to computing
  - More than 50x greater capacity in US – no point trying to undertake bleeding-edge sims at high f.
  - Advances in theory will generalise to global application, so we can reap benefits from intl. colleagues.
- Validation ('formal', not simply GMM comp.)
  - QC's thinking is significantly more advanced wrt validation (considering ~600 events in NZ so far, vs. a handful of events in California). Many comments of 'yeah, we should be doing this'
  - This is a strategic advantage to continue to focus on, and also the principal hurdle for demonstration of practical utility to enable widespread adoption
  - Validation also suggests that for  $f > 1\text{Hz}$ , 3D-based calculations can still not yet reliably outperform 1D-based simplified approaches
- Shallow site response
  - SCEC emphasis on this increasing. Several 'simplified' approaches (Shi and Asimaki) useful to consider for NZ applications.
- Machine Learning
  - Main benefit to be gained based on training using simulation data and then using as a surrogate model for a multitude of applications