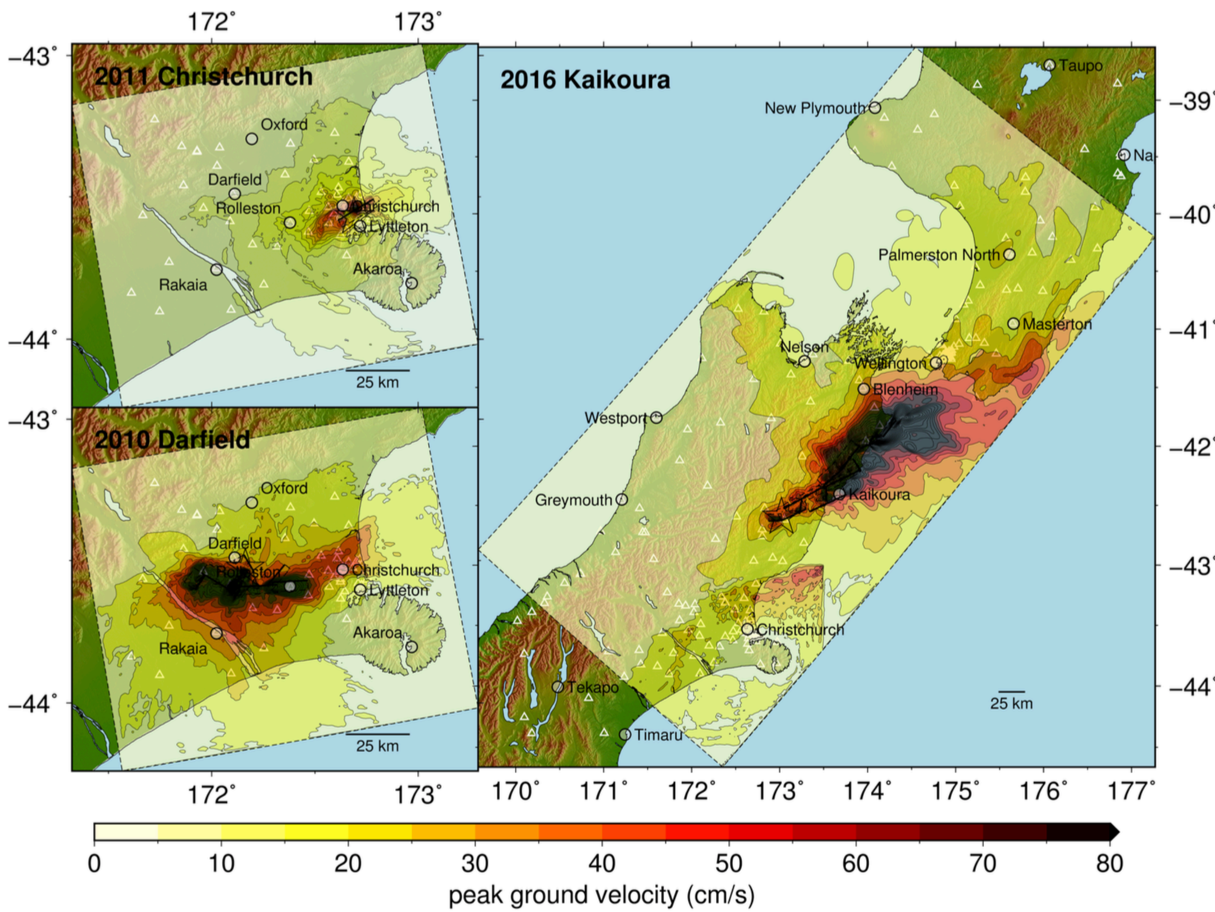
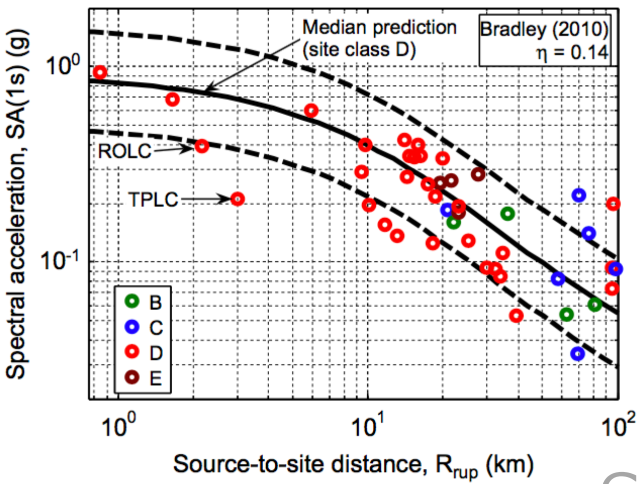
Simulation-based ground motion prediction of historical and future New Zealand earthquakes and consequent geohazard impacts



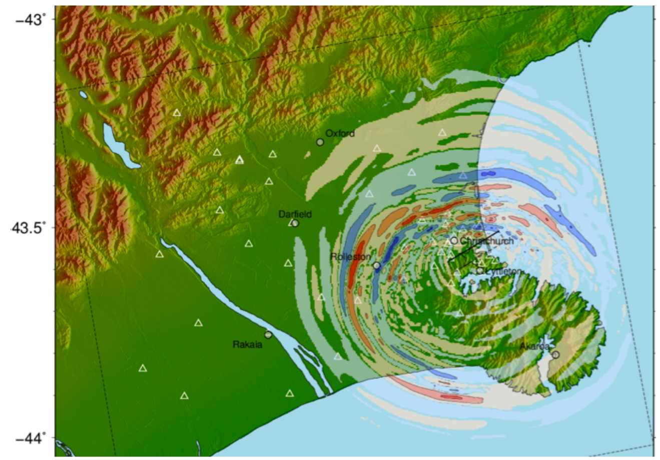
Brendon Bradley, University of Canterbury, New Zealand

Context

Empirical



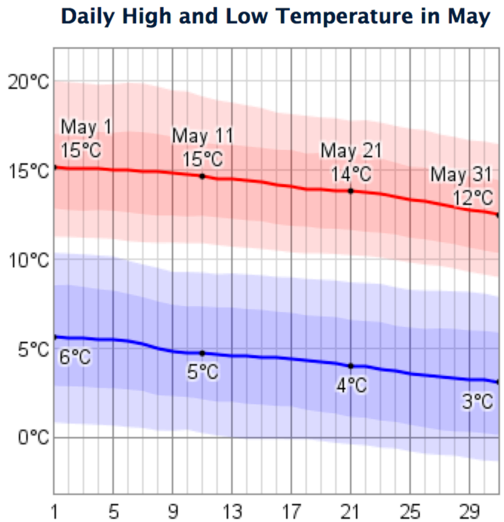
Physics-based



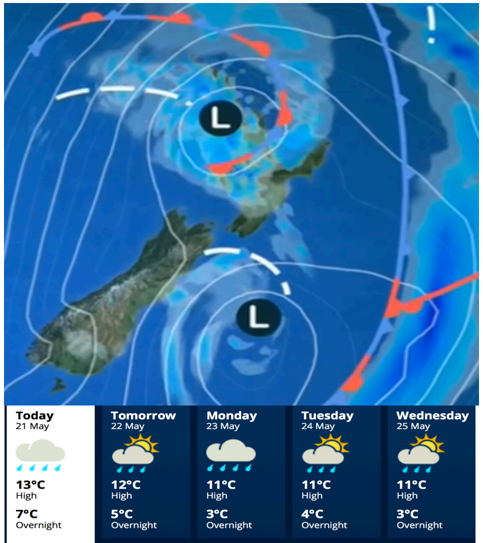
VS

Ground motion

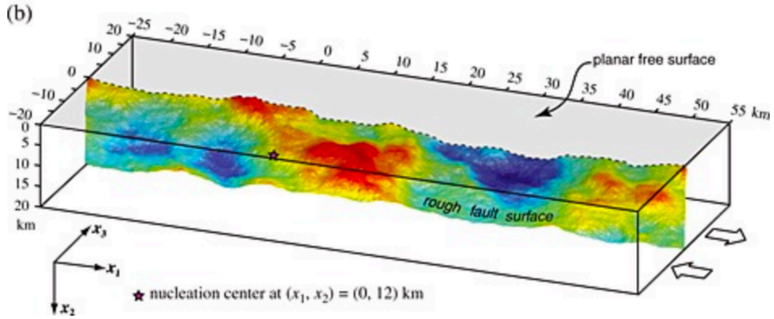
Weather



VS

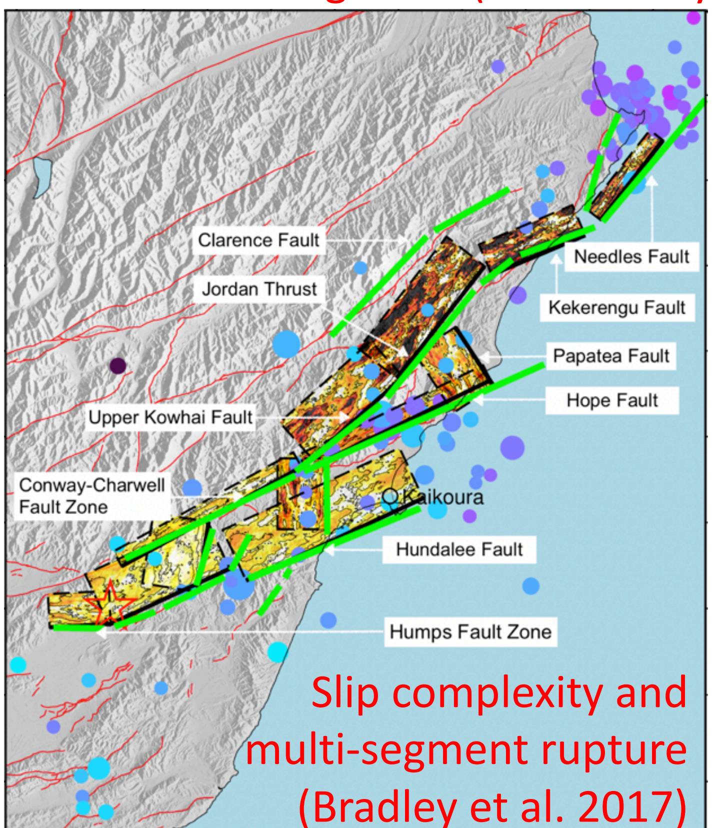


Ingredient 1. Seismic source

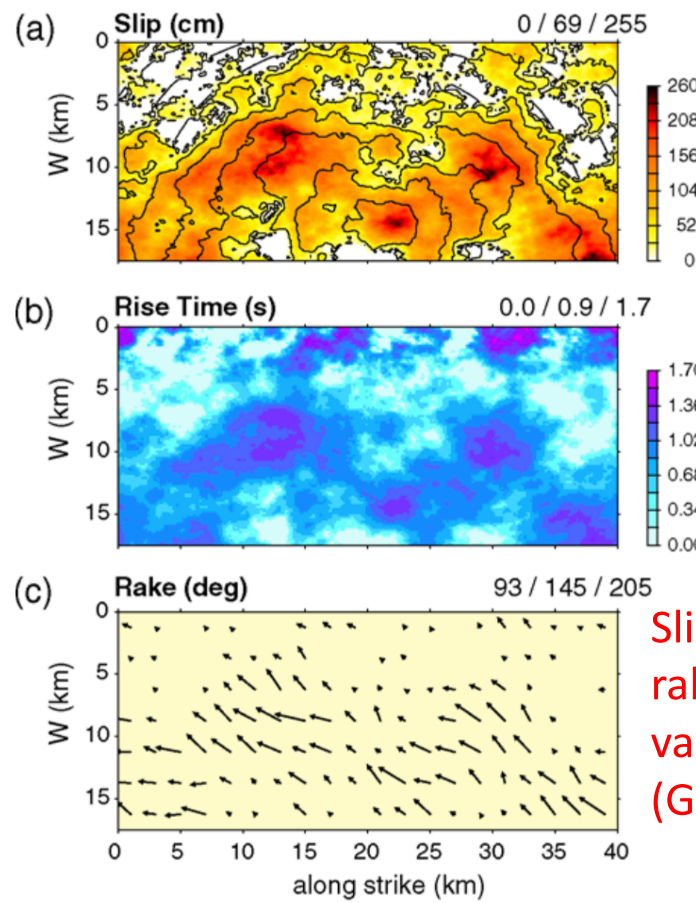


Fault roughness (Shi and Day)

- Fractal complexity in source modelling
- Uncertainty analysis to account for different source representations



Slip complexity and multi-segment rupture (Bradley et al. 2017)

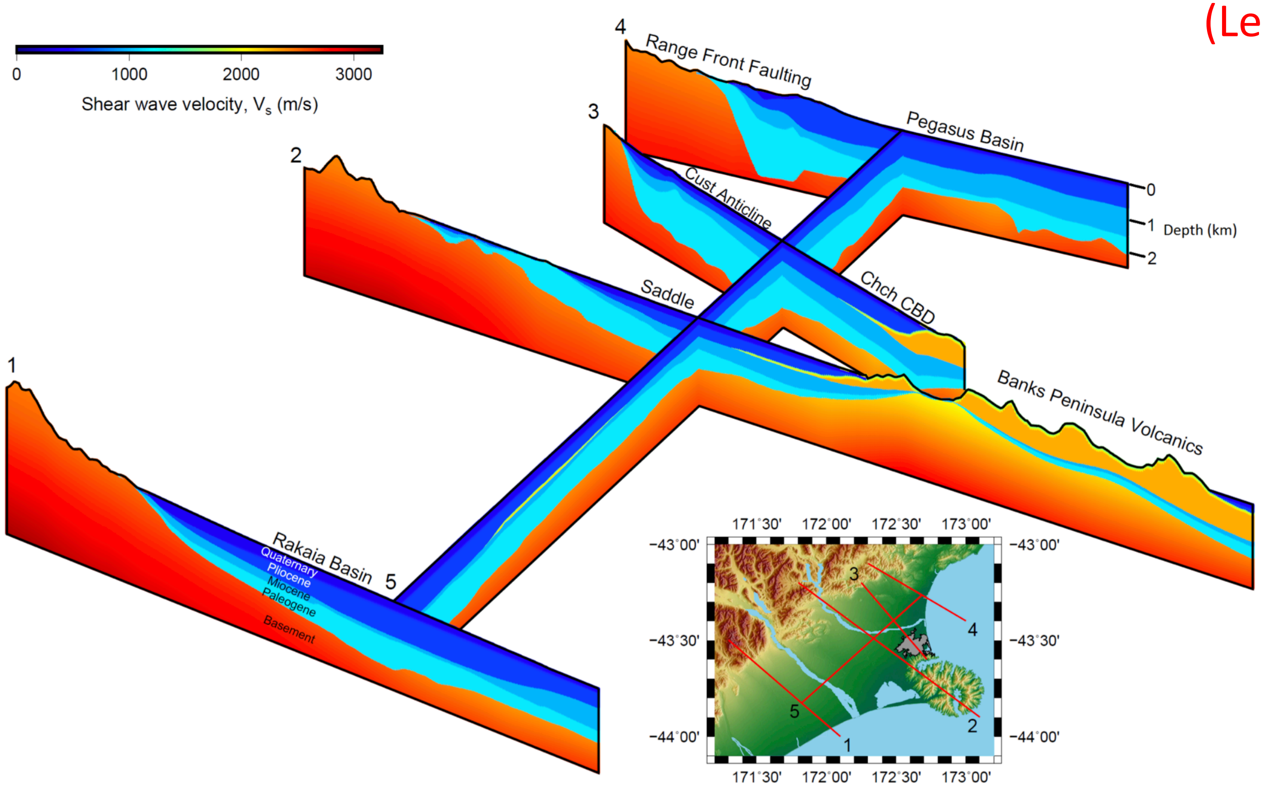


Slip, rise time, rake, rup velocity variability (Graves+Pitarka)

Ingredient 2. 3D crustal model

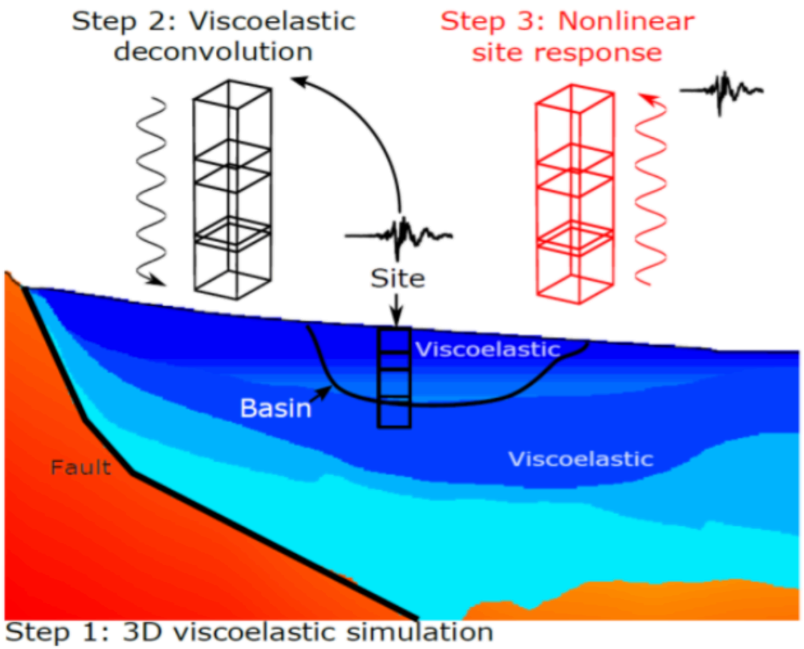
- Sedimentary basins critical for adequate simulation prediction

Sedimentary basin model for Canterbury, NZ (Lee et al. 2017)

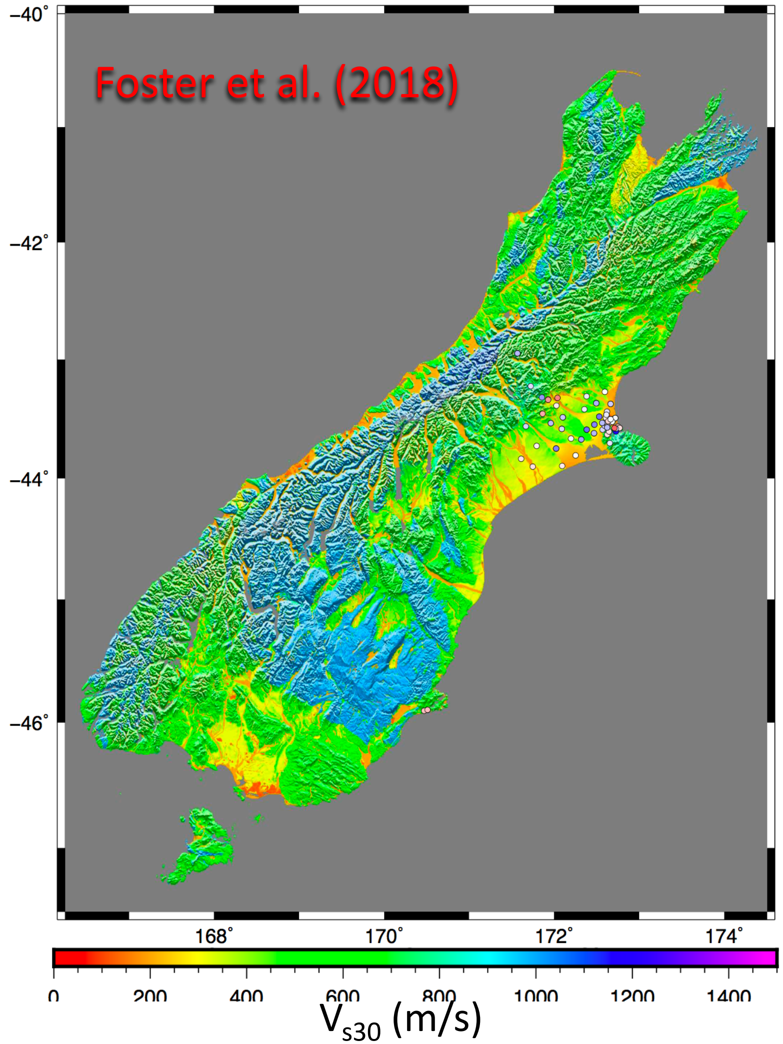


Ingredient 3. Surficial site effects

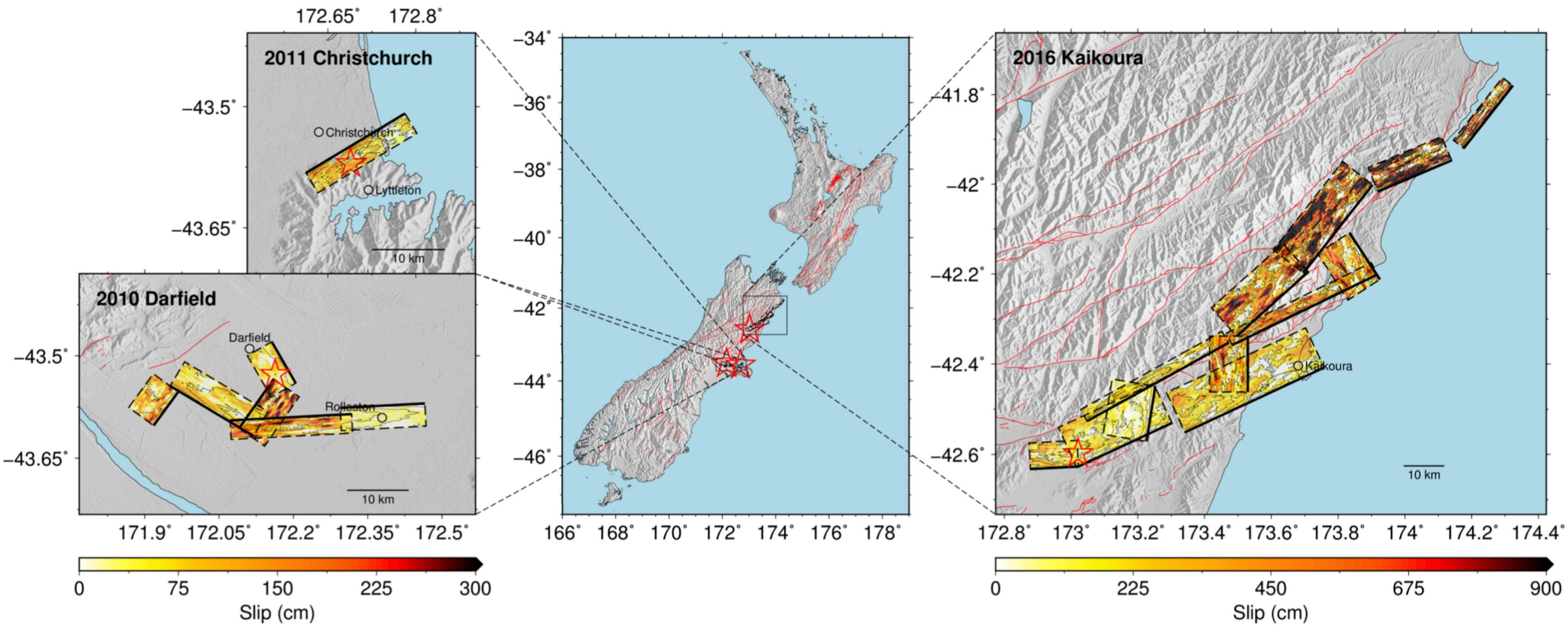
- Difficulty in modelling
  - regional effects (10-100km scale)
  - site-specific effects (1-10m scale)
- Modelling site response via:
  - Vs30-based empirical factors
  - Explicit site response via wave propagation analysis



de la Torre et al. (2017)



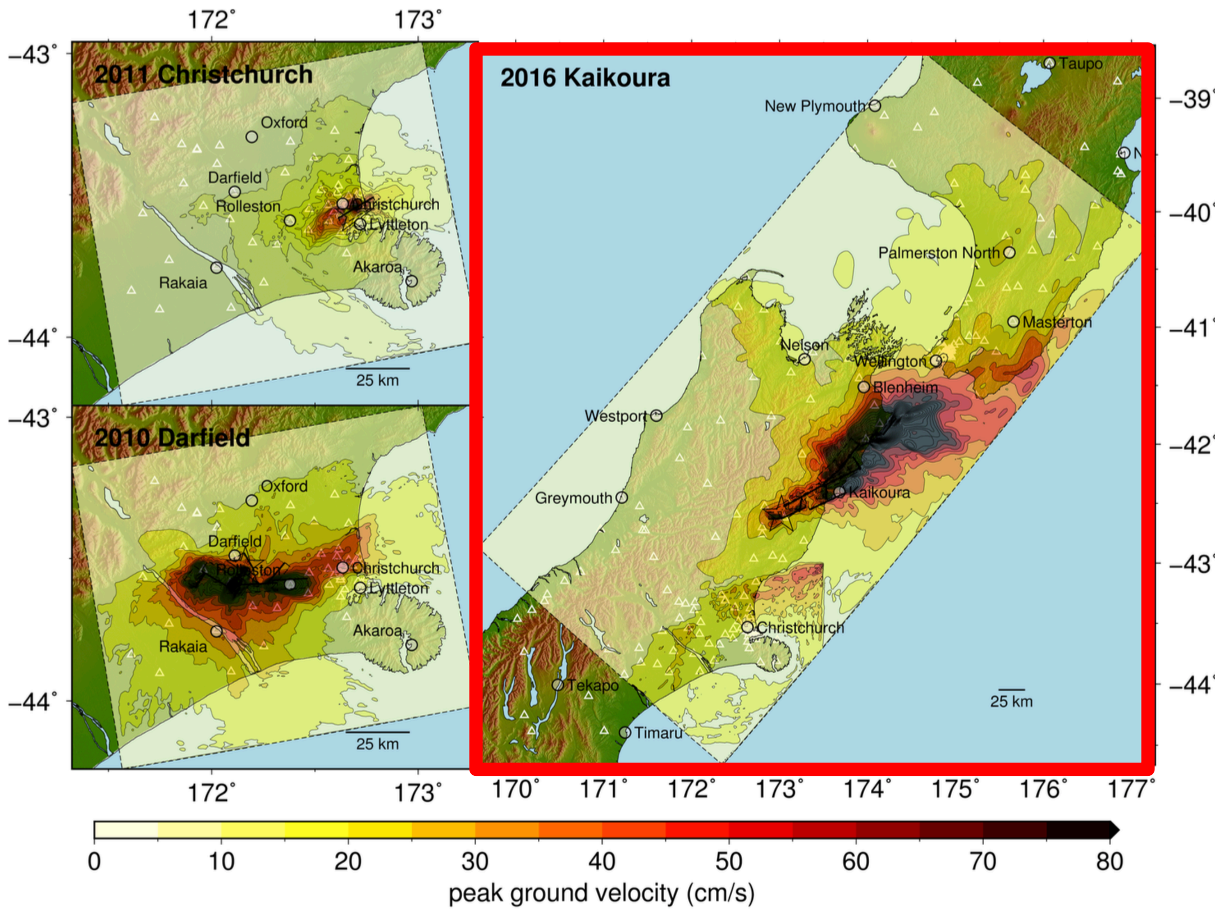
2010-2011 Canterbury and 2016 Kaikōura earthquakes



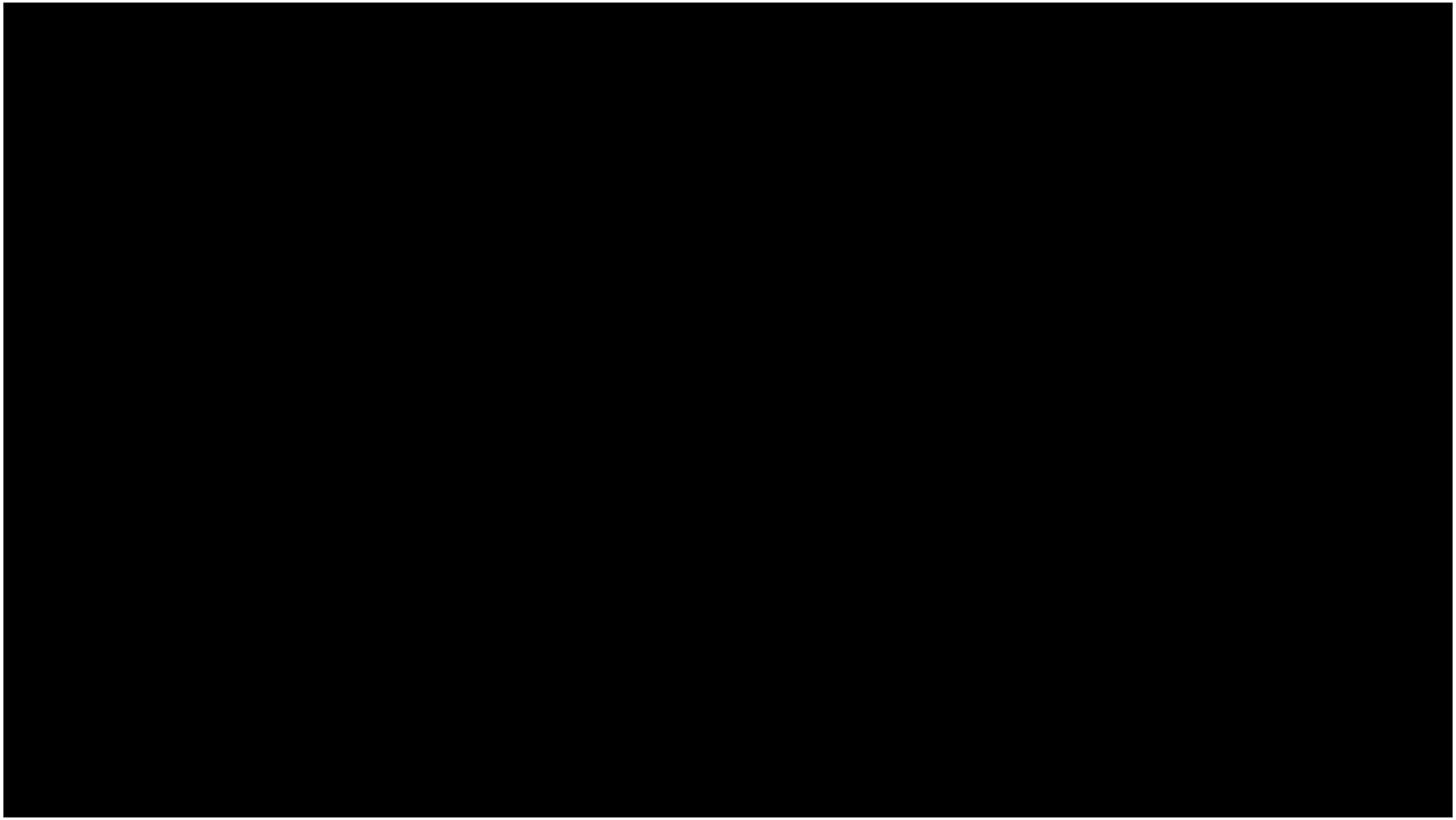
Bradley (2018)

2010-2011 Canterbury and 2016 Kaikōura earthquakes

- All simulations utilize the same methodology and input parameters, with only rupture models and simulation domain varying between events



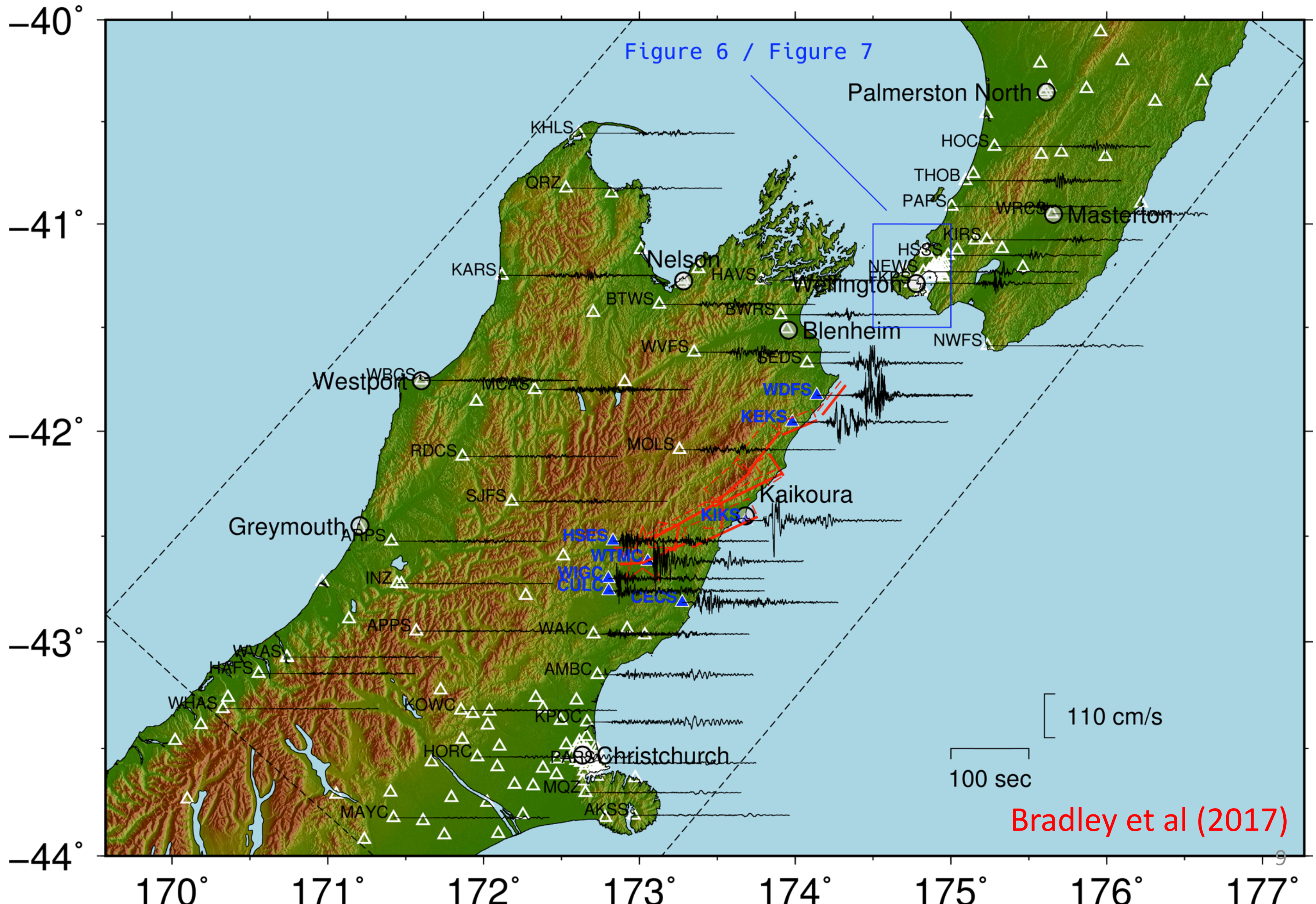
Ground motion simulation



[Video: https://www.youtube.com/watch?v=j9c-Fwhaigc]

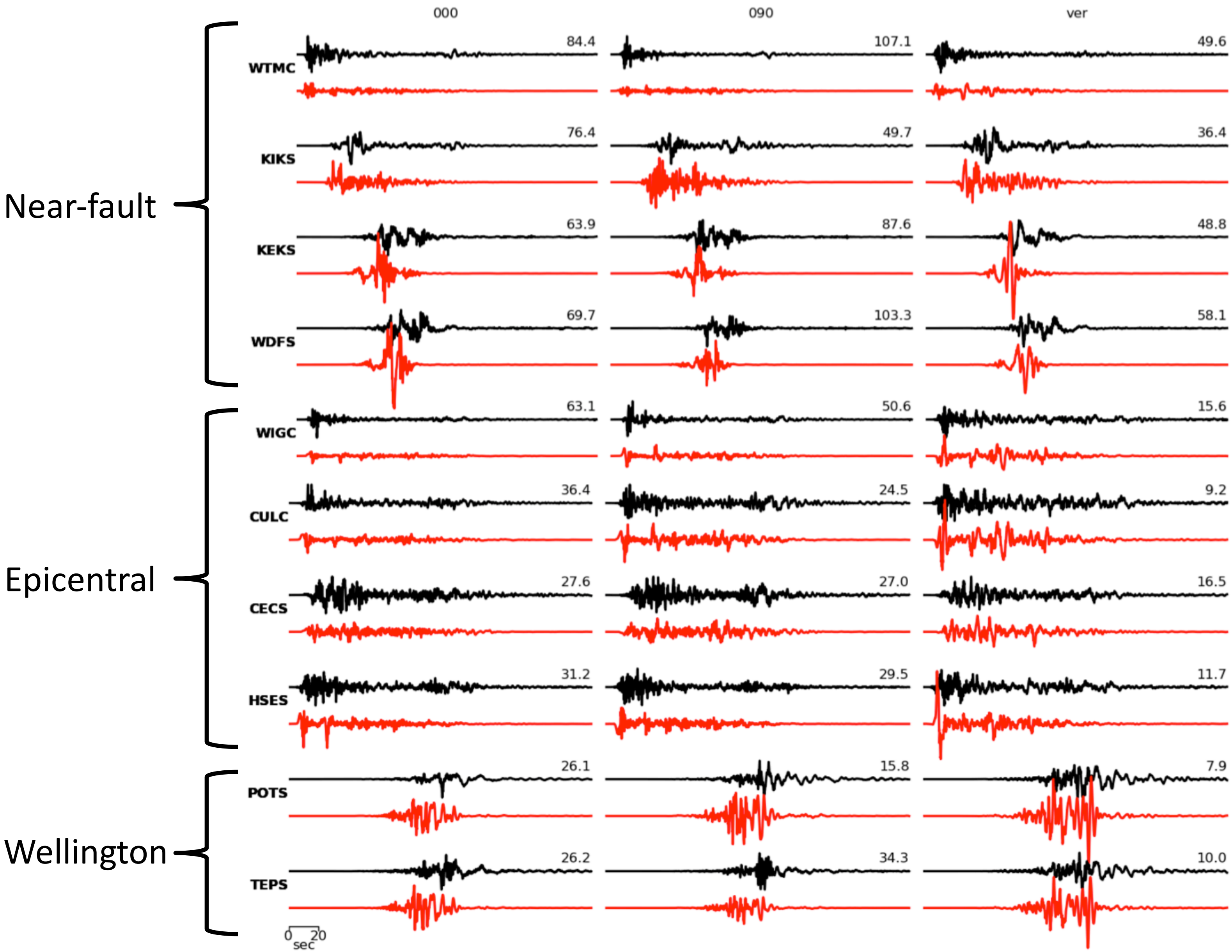
Bradley et al (2017)

Observed ground motions



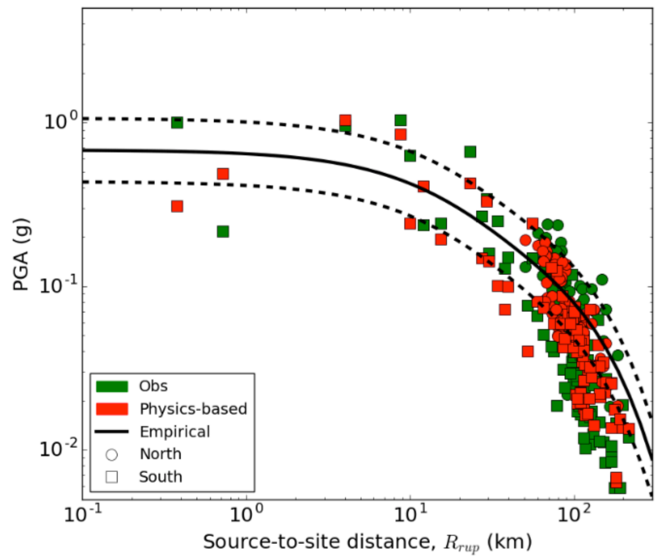
Bradley et al (2017)

Observed and simulated motions

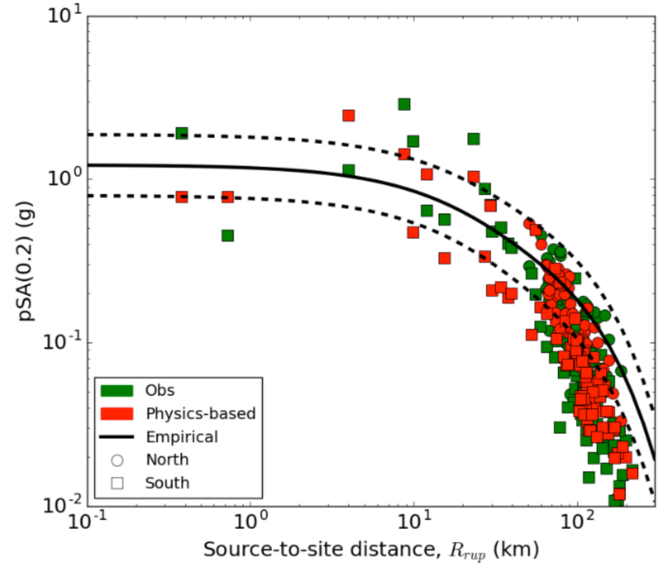


Bradley et al (2017)

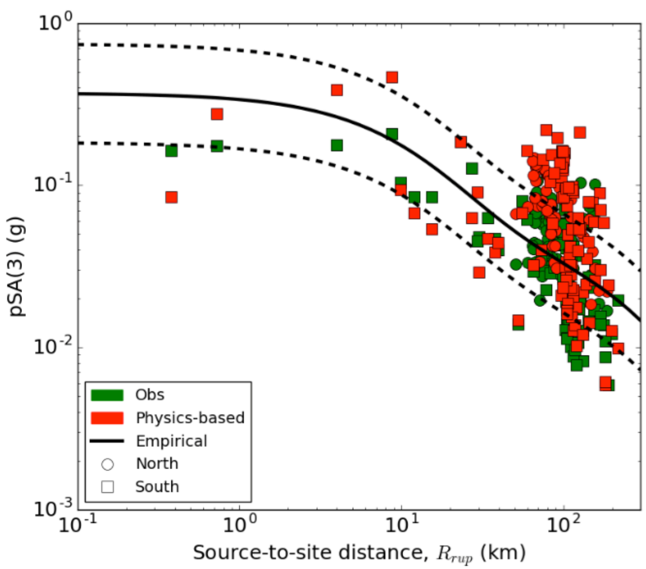
Observed and simulated response spectra



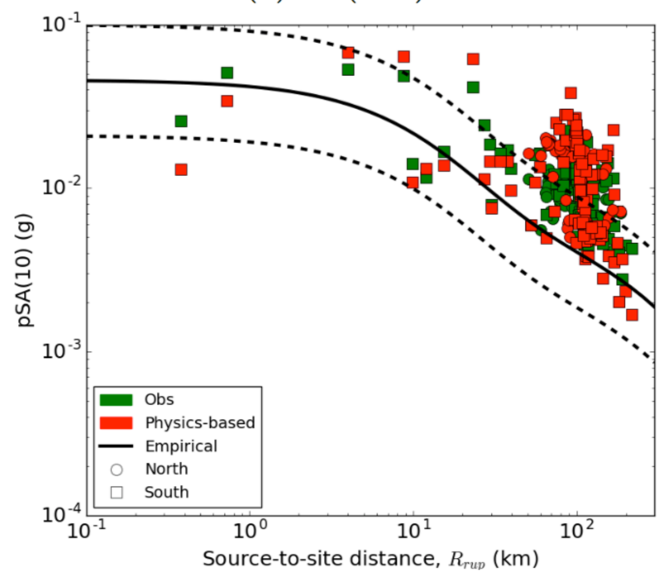
(a) PGA



(b) $SA(0.2s)$



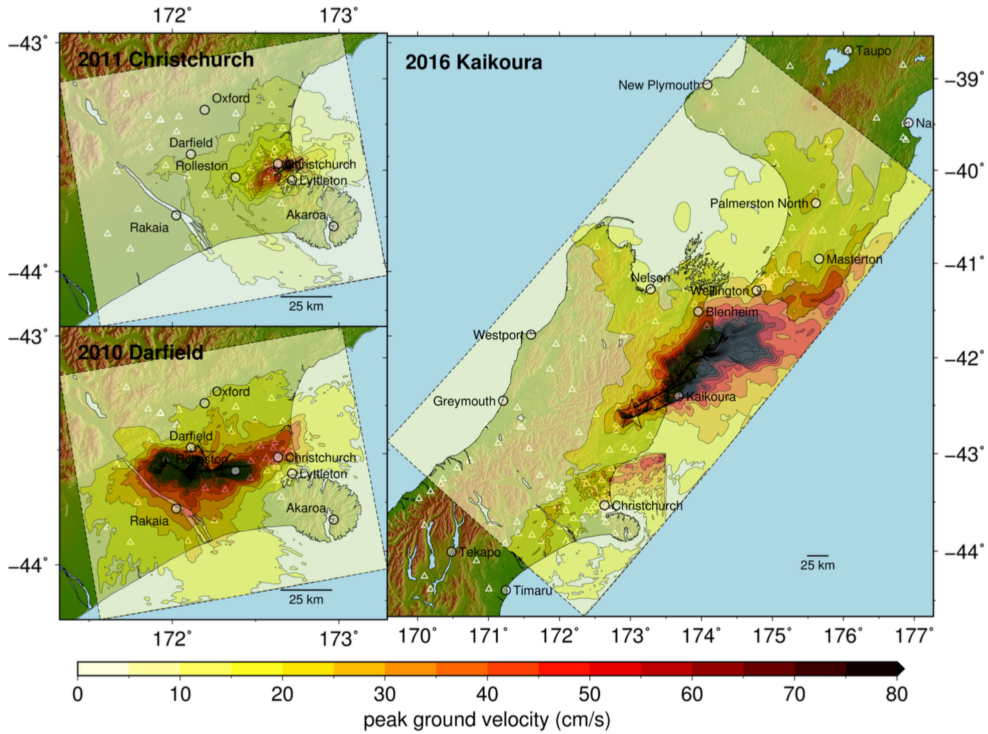
(c) $SA(3.0s)$

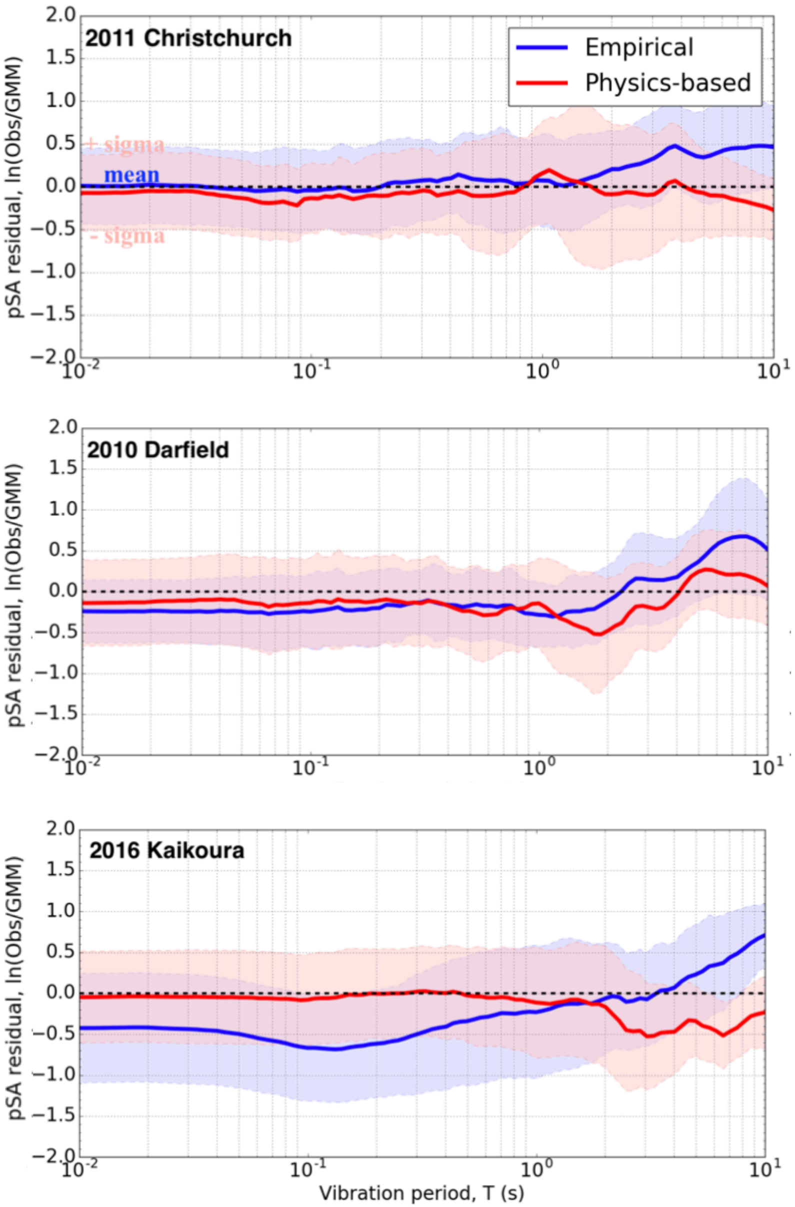


(d) $SA(10.0s)$

Bradley et al (2017)

Simulation residuals



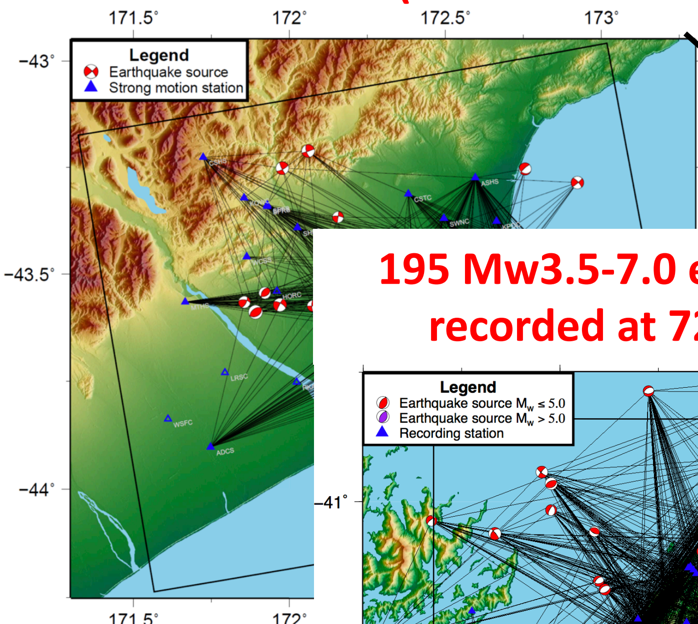


Bradley (2018)

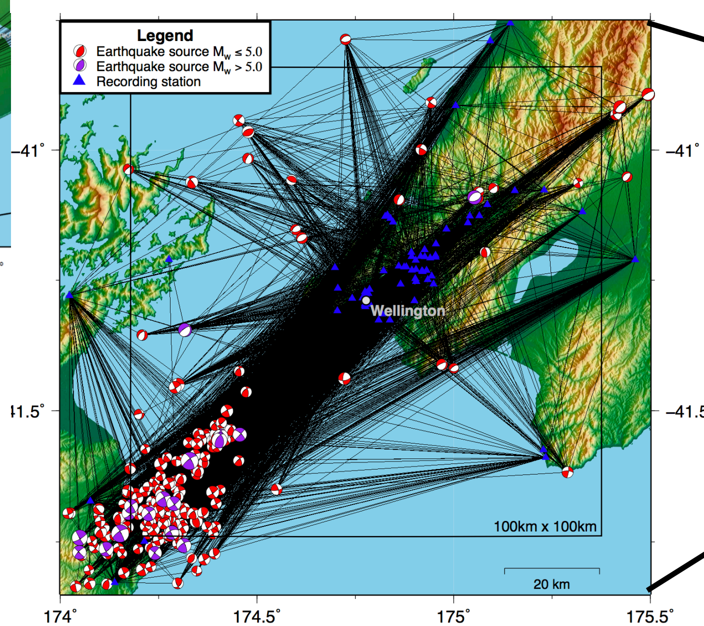
Validation

- Validation is critical for demonstrating the (potential) superior performance of simulations over conventional empirical models

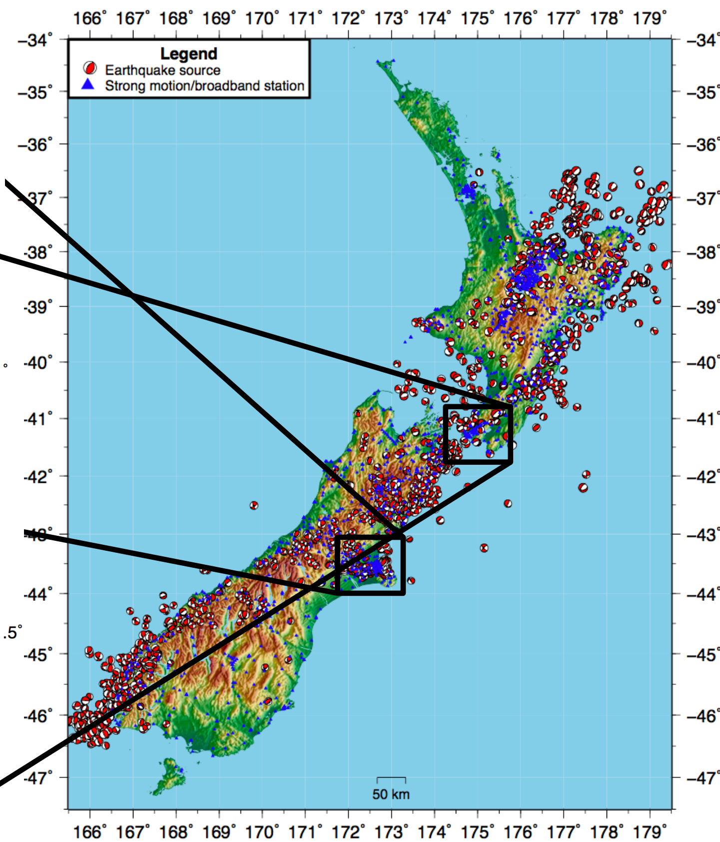
144 Mw3.5-5.0 earthquakes recorded at 46 stations (Lee et al. 2017)



195 Mw3.5-7.0 earthquakes recorded at 72 stations

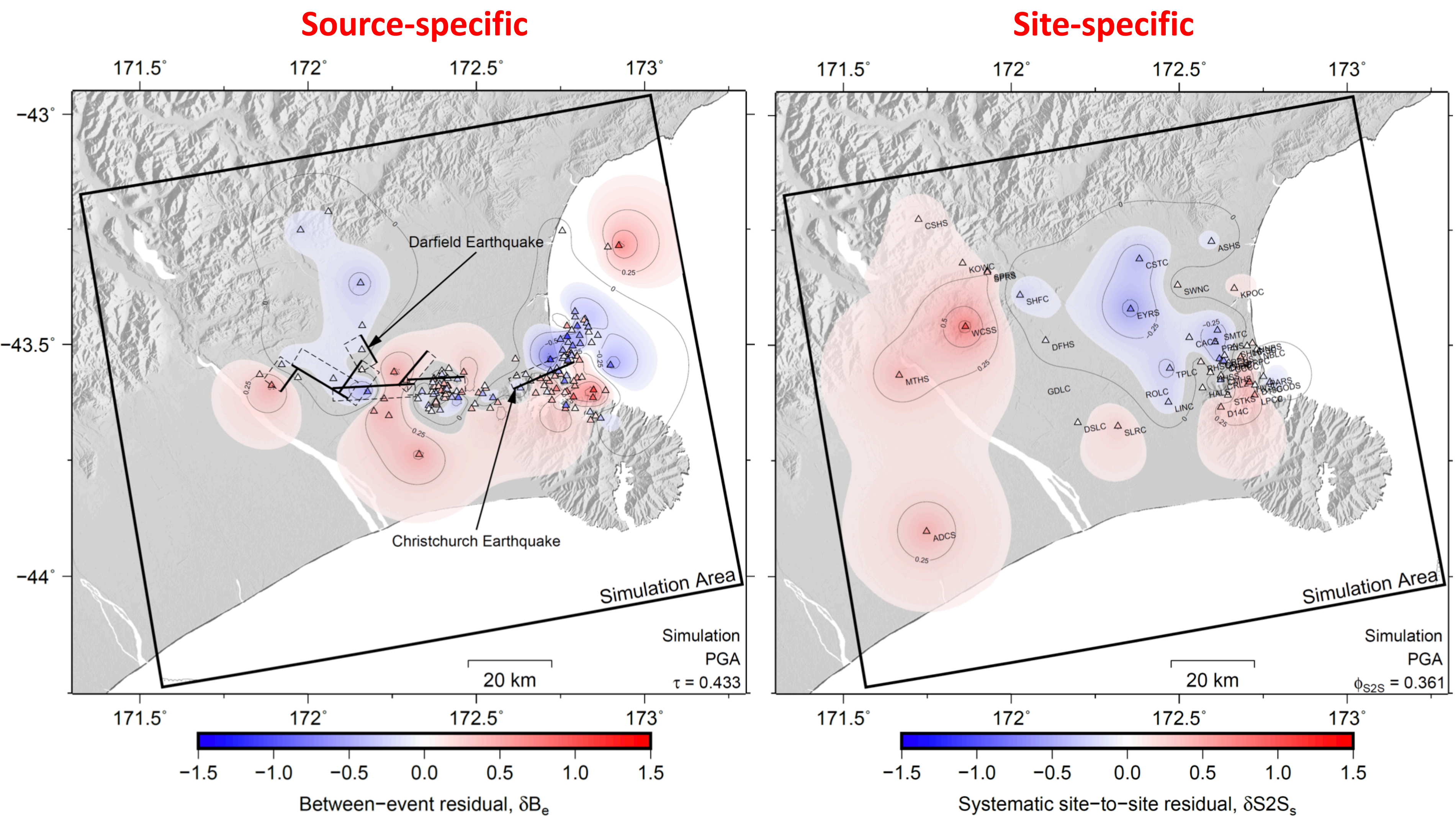


On-going validation using ~2000 Mw3.5+ earthquakes recorded since 2003



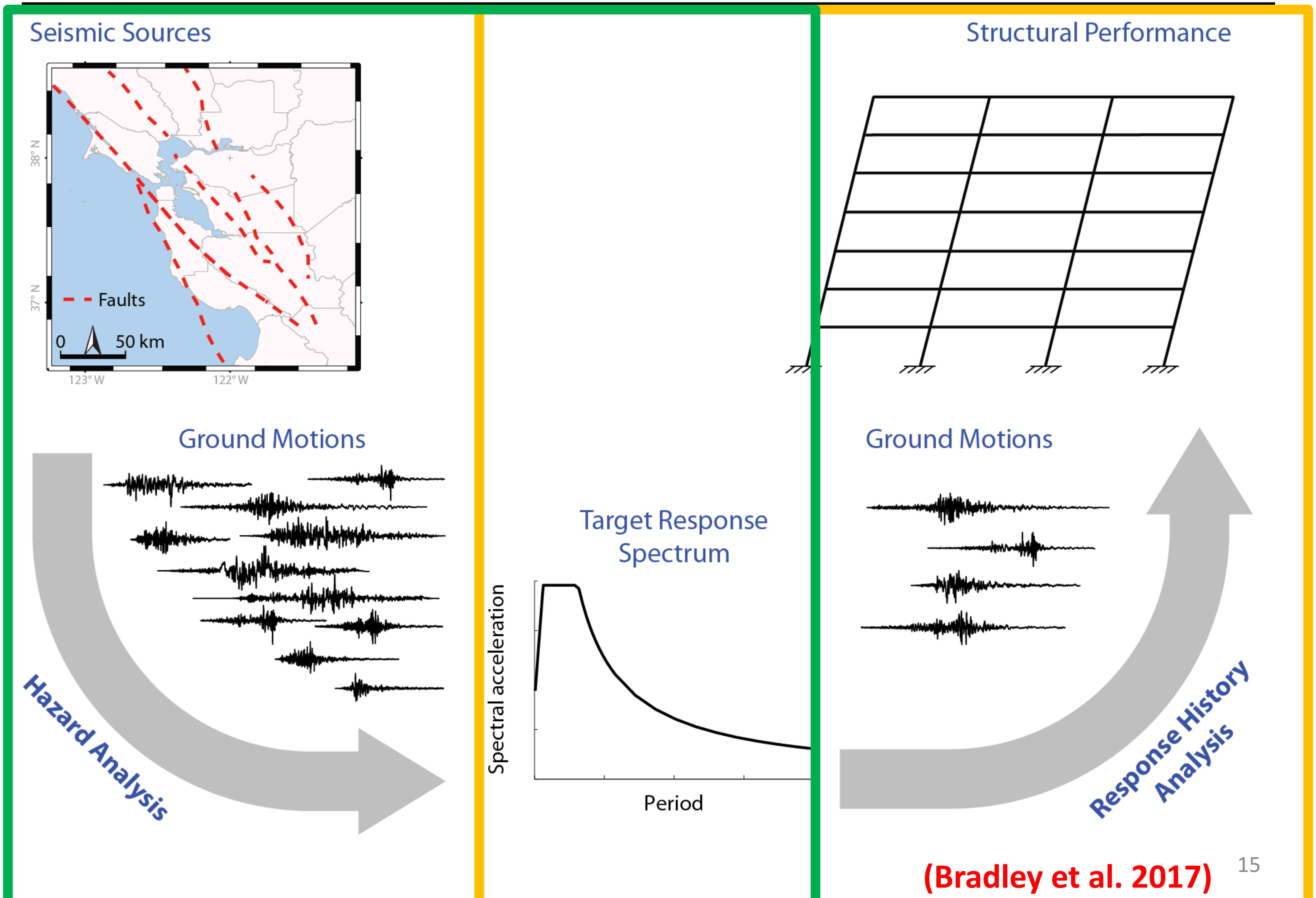
Lee et al. (2018)

Systematic effects from validation



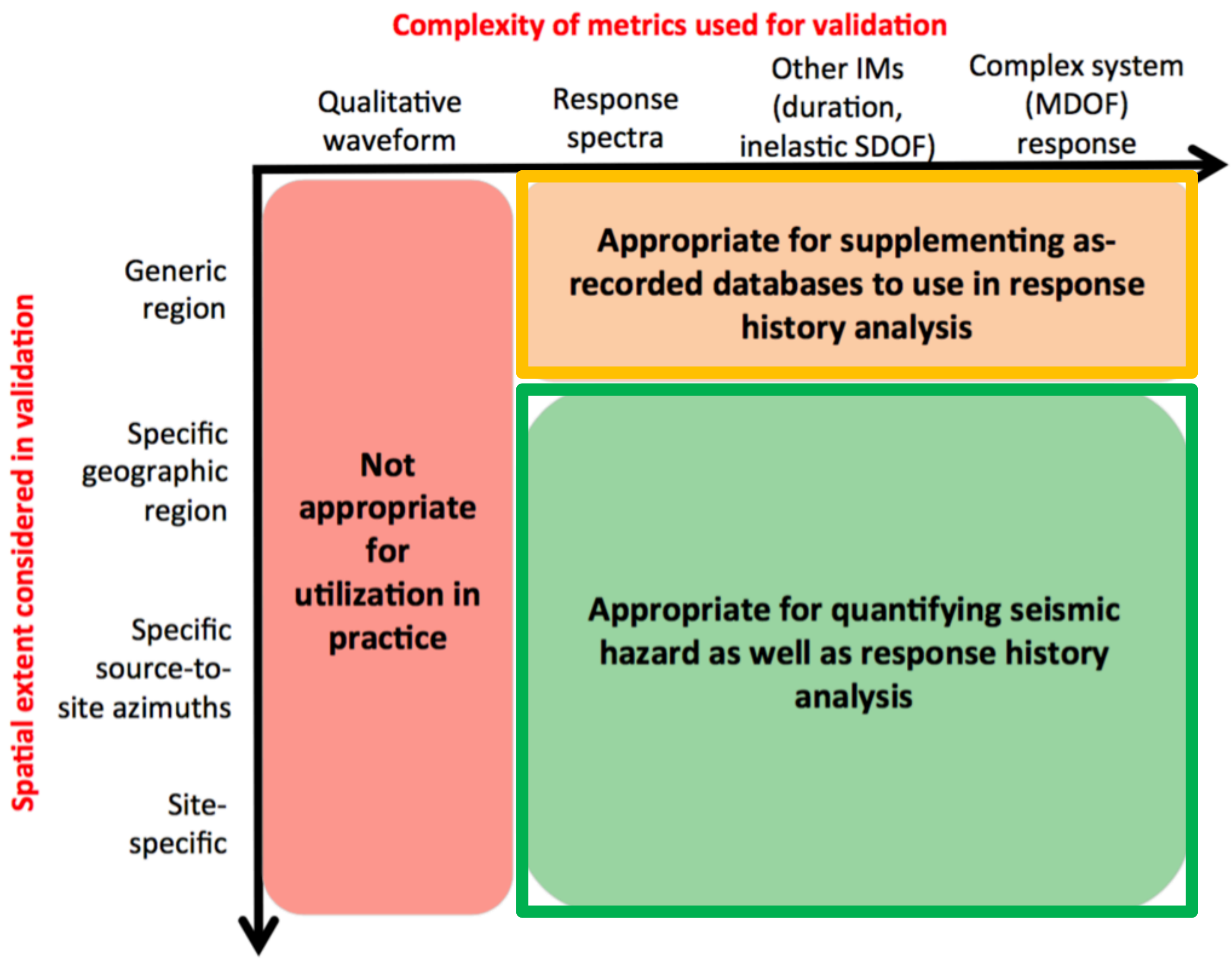
Lee et al. (2018)

Uses of simulations



(Bradley et al. 2017)

Validation and utilization guidance

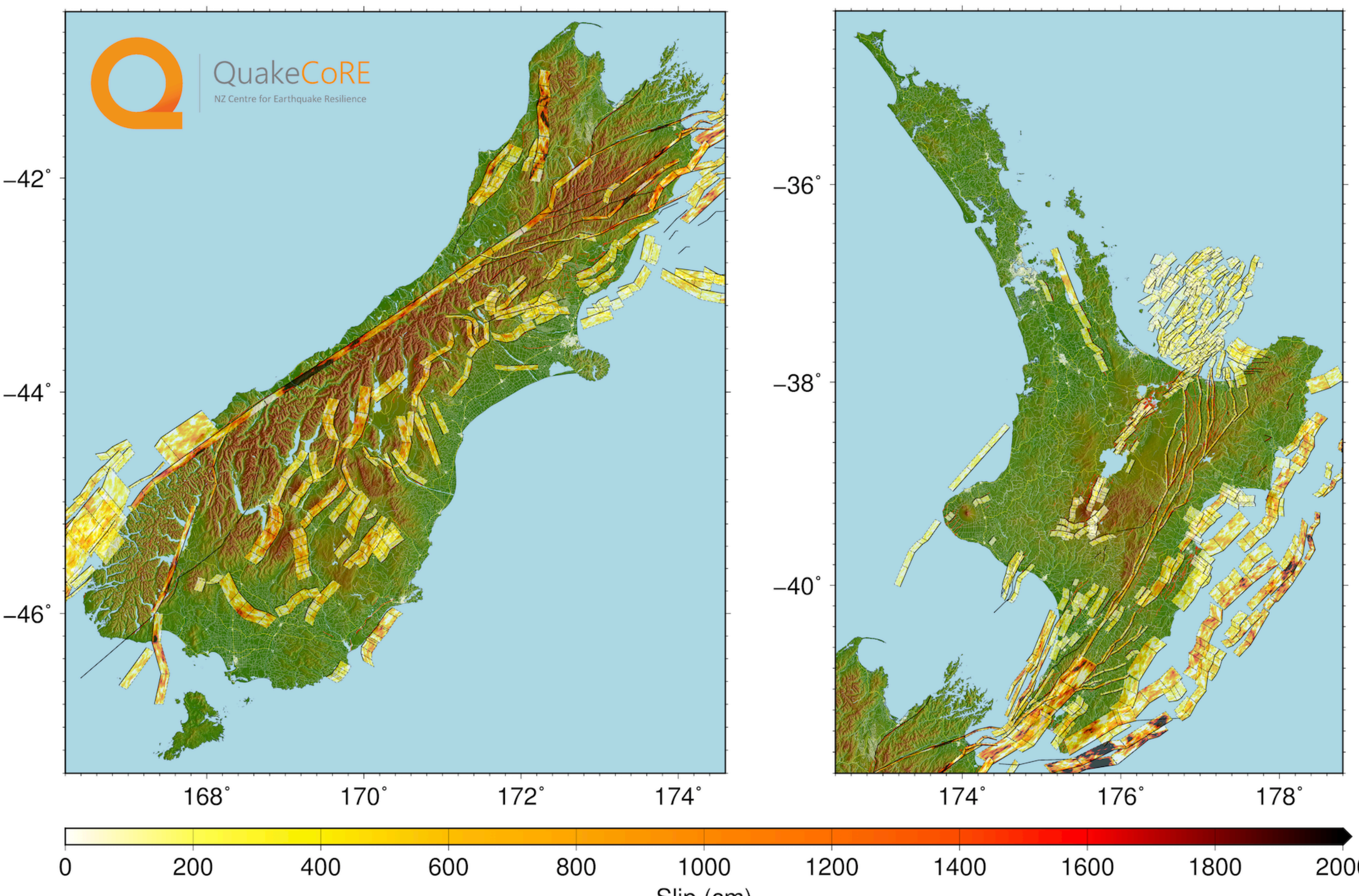


'Validation matrix' for simulation utilization (Bradley et al. 2017)

Seismic hazard using simulated ground motions

There are ~500 major mapped faults in NZ

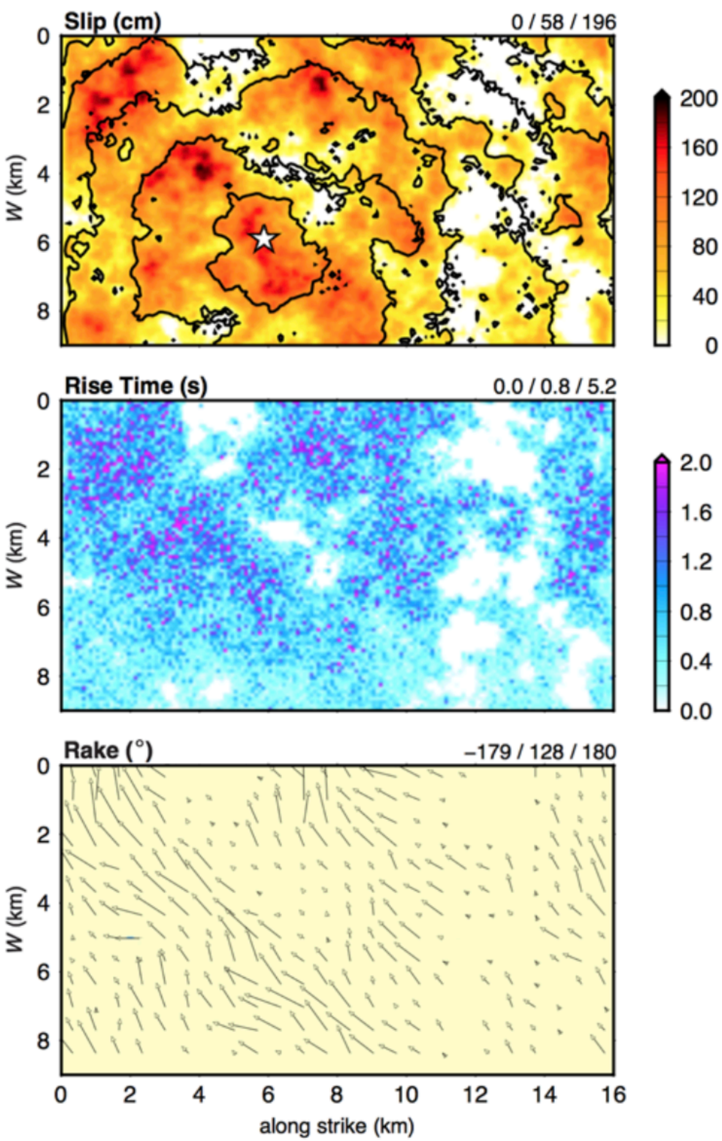
Simulated ruptures considering uncertainties (~3,200 ruptures modelled in v18.5)



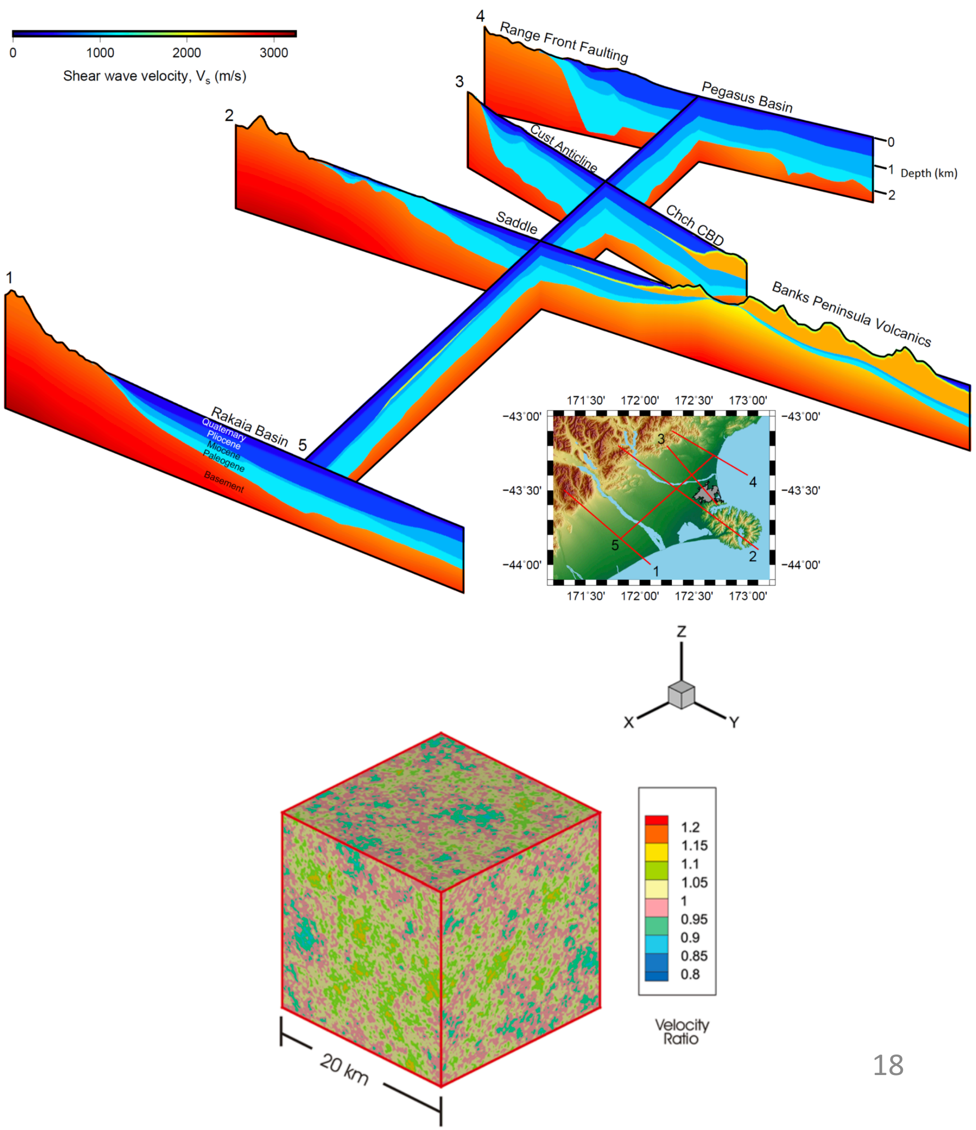
Tarbali et al. 2018

Uncertainties in source and crustal models

Source representation

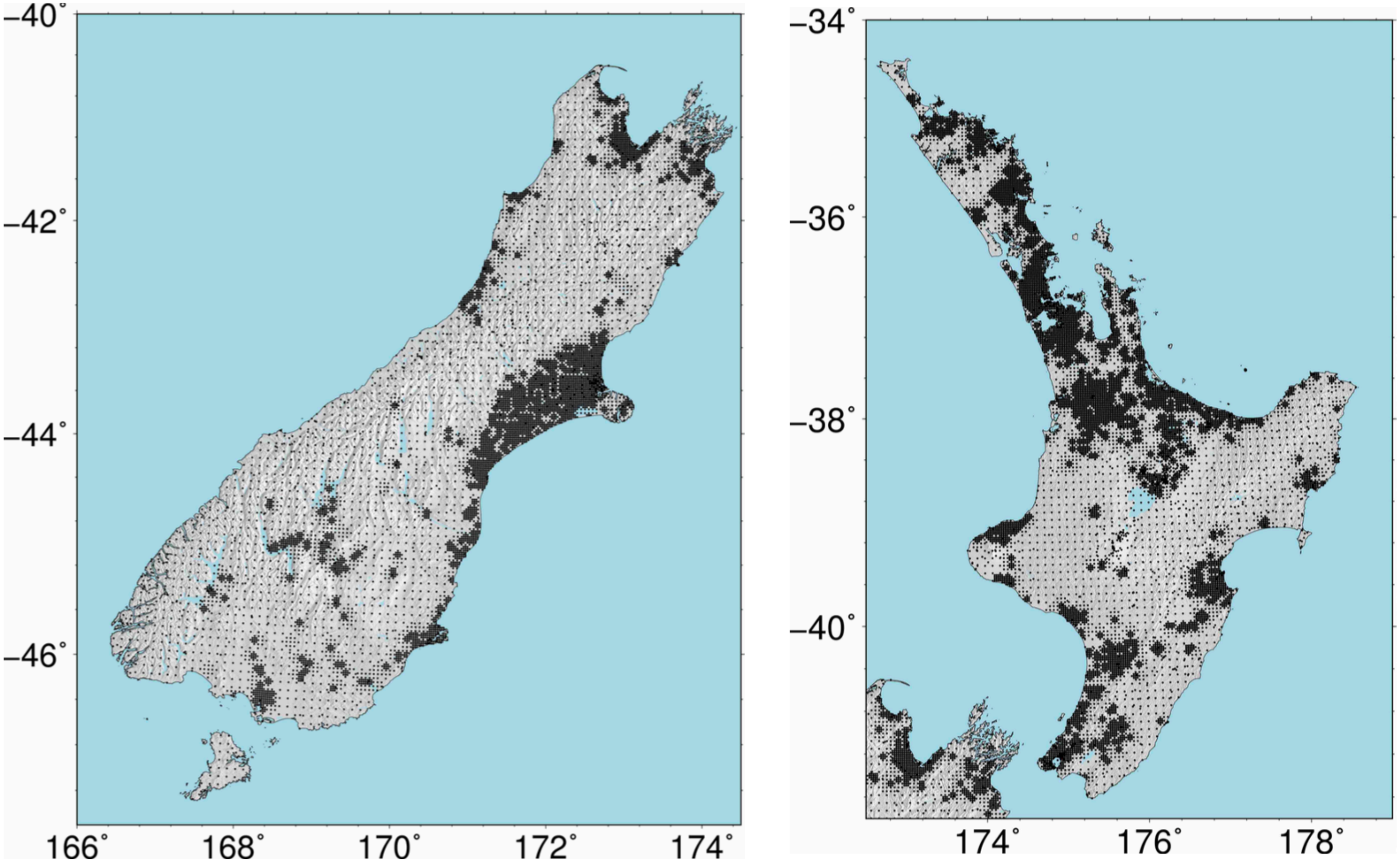


Crust representation



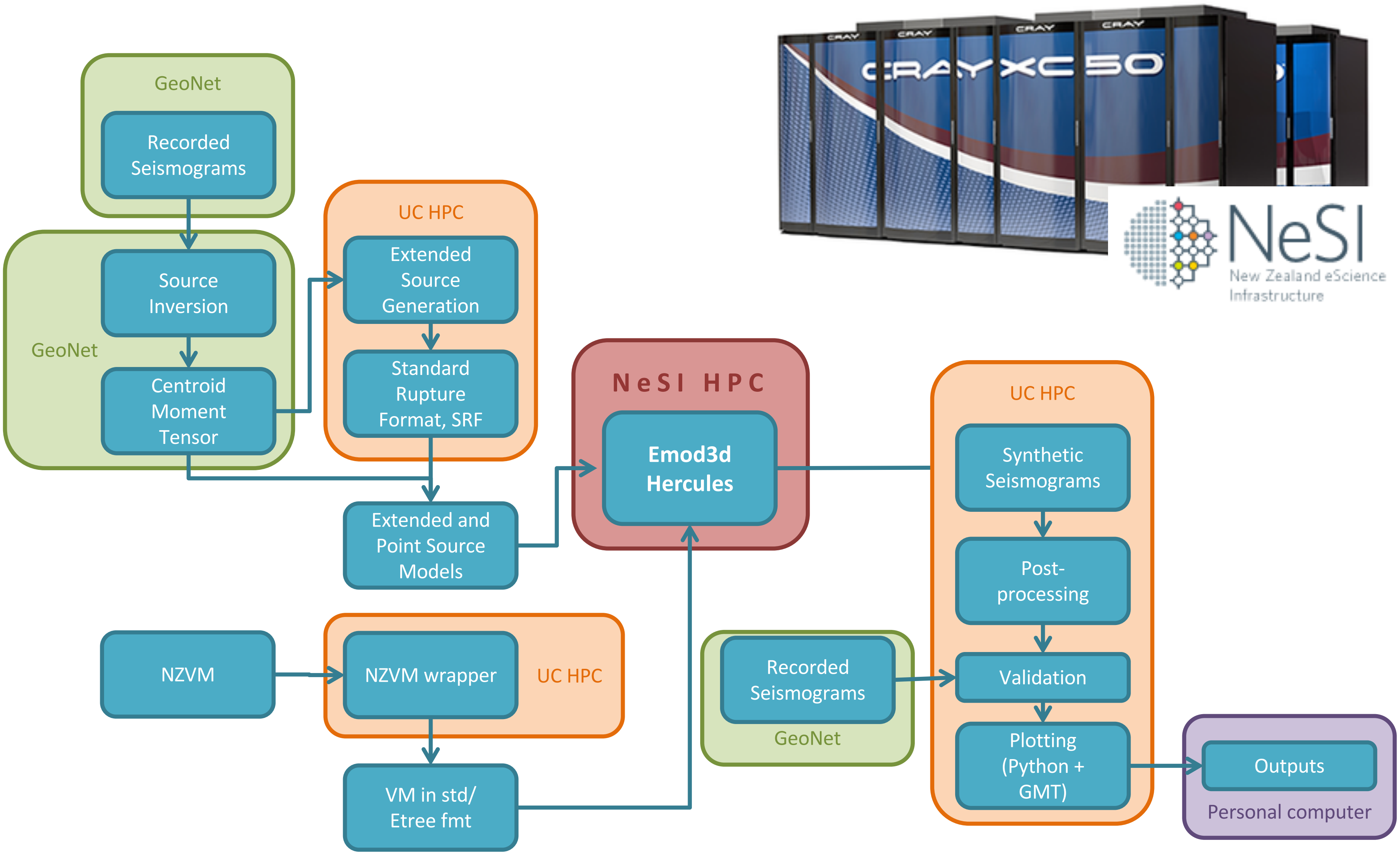
Seismic hazard using simulated ground motions

Simulations stored on a grid of ~20,000 spatial locations



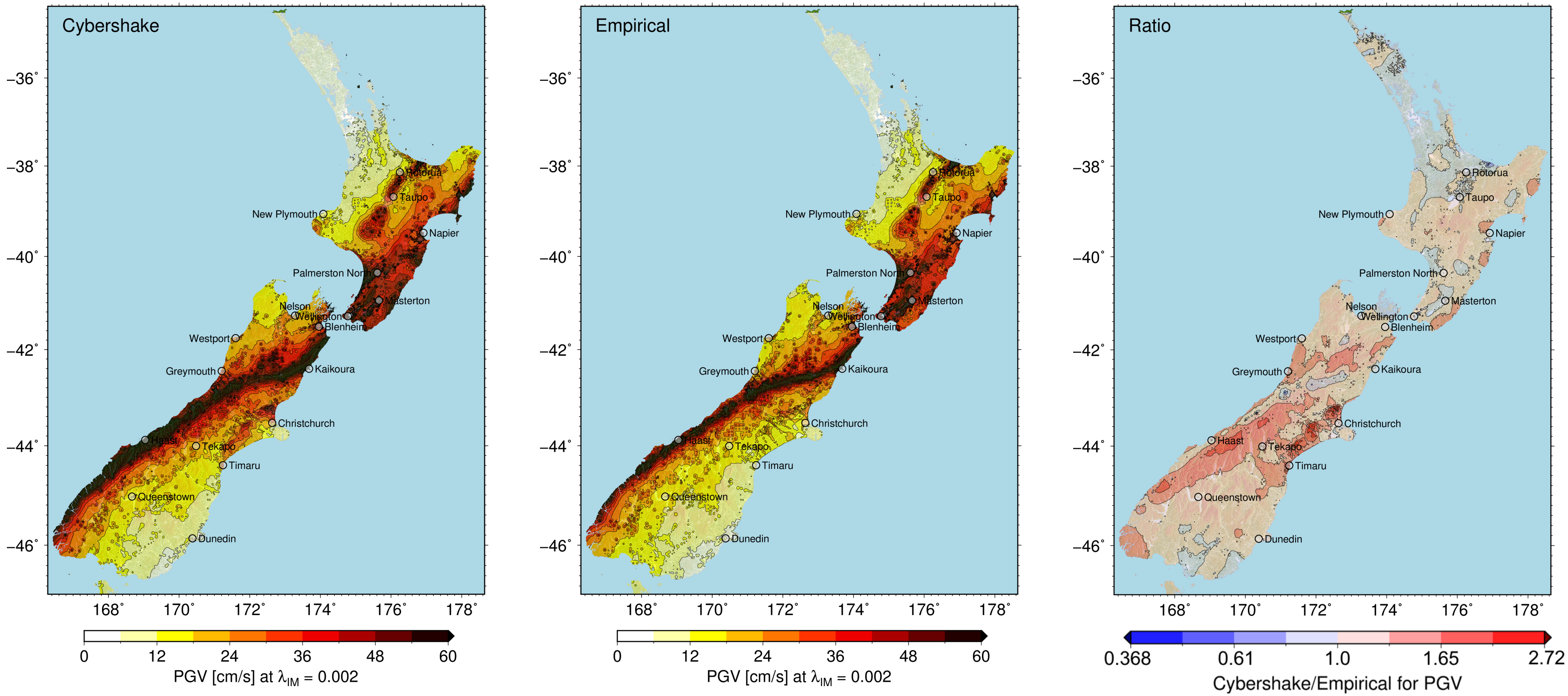
Tarbali et al. 2018

Software workflow and Integration



Hazard maps

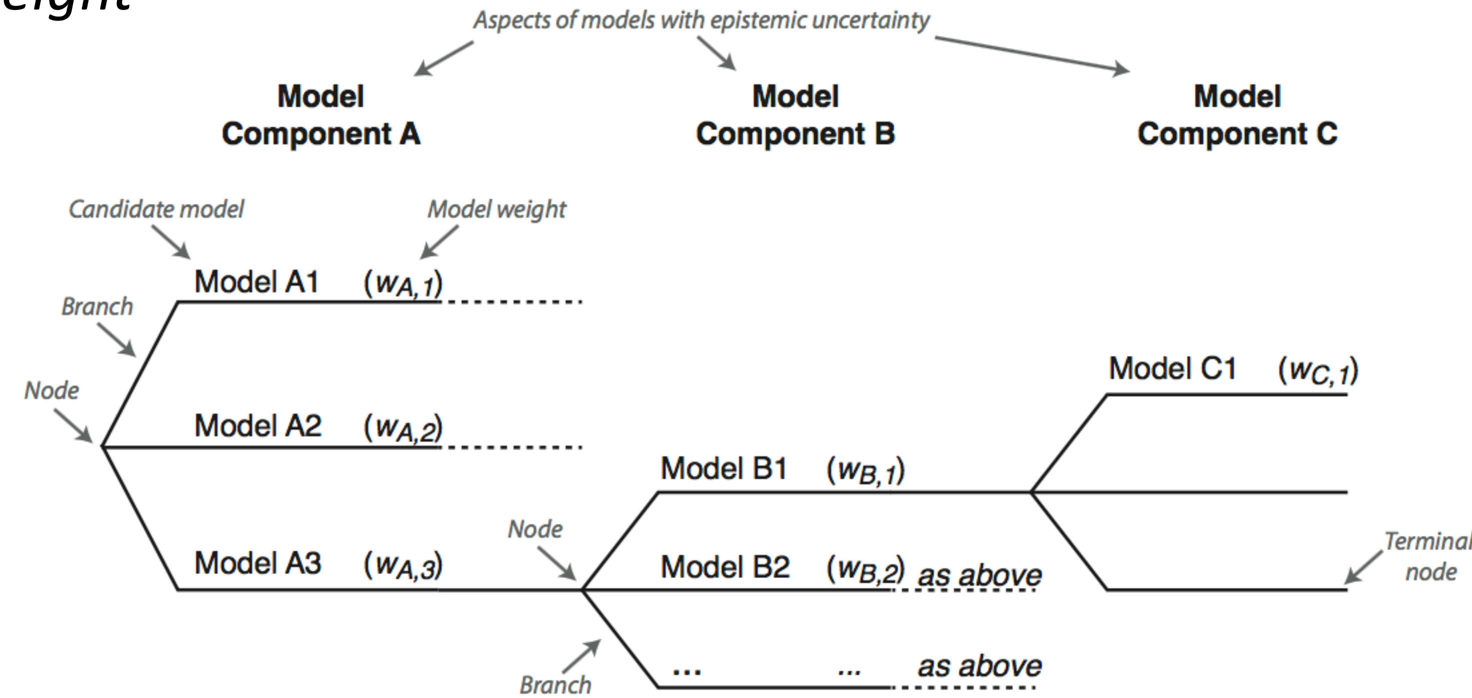
Example: PGV , 2% in 50 years



Tarbali et al. 2018

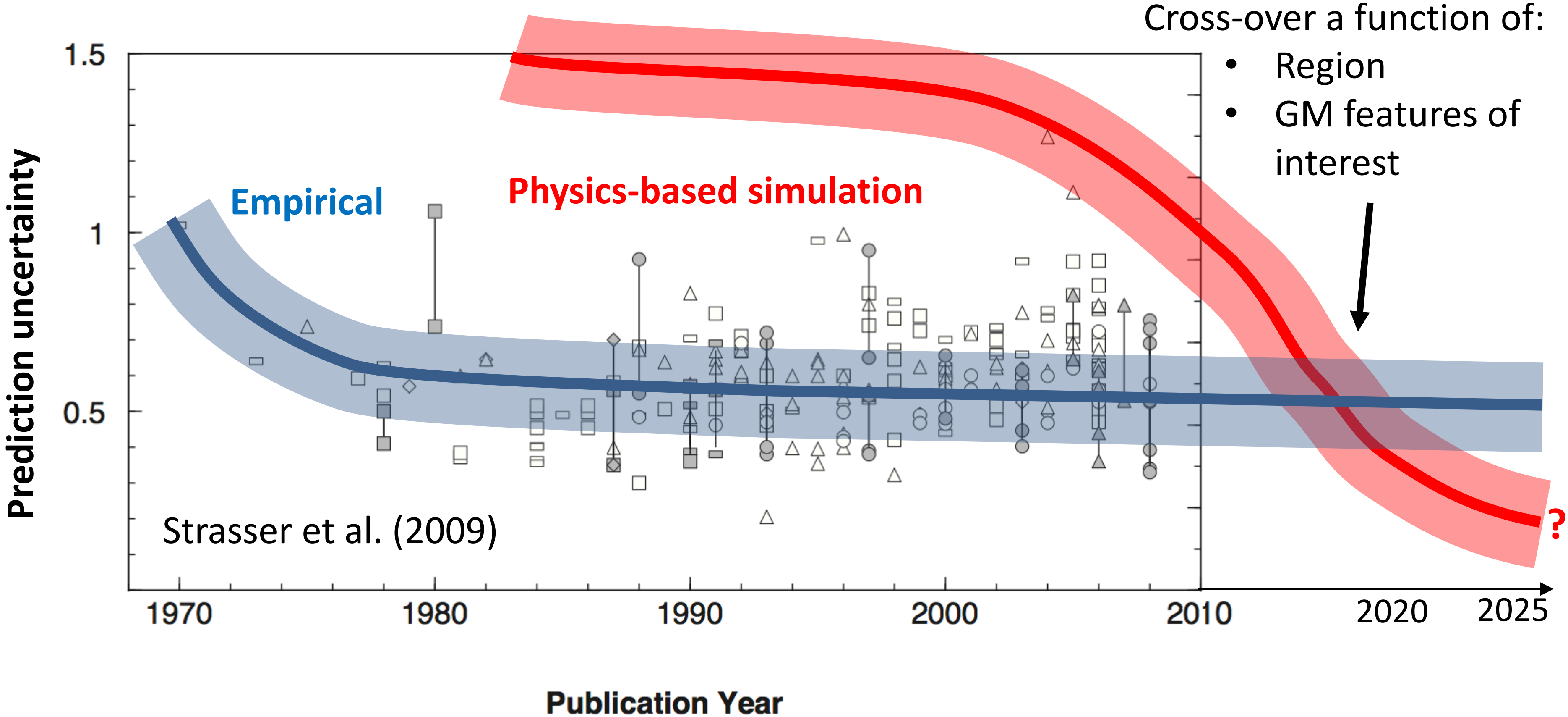
Logic trees for model uncertainty

- Simulation-based ground motion prediction incorporated in logic tree along with empirically-based predictions
- *Predictive capability* of modelling alternatives drives *model weight*



Baker, Bradley, Stafford (2018, Cambridge Press)

Predictive capability over time

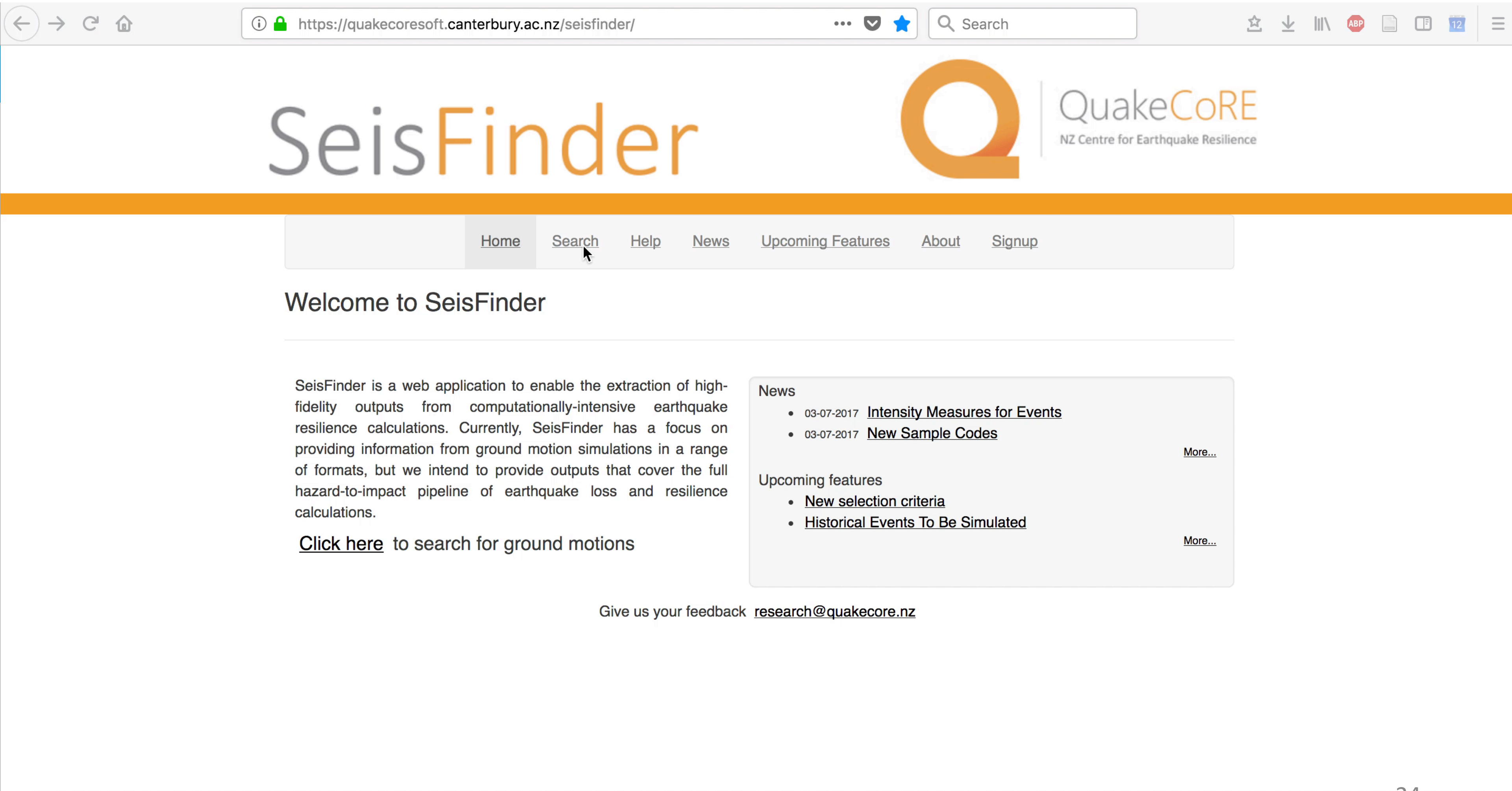


Cross-over a function of:

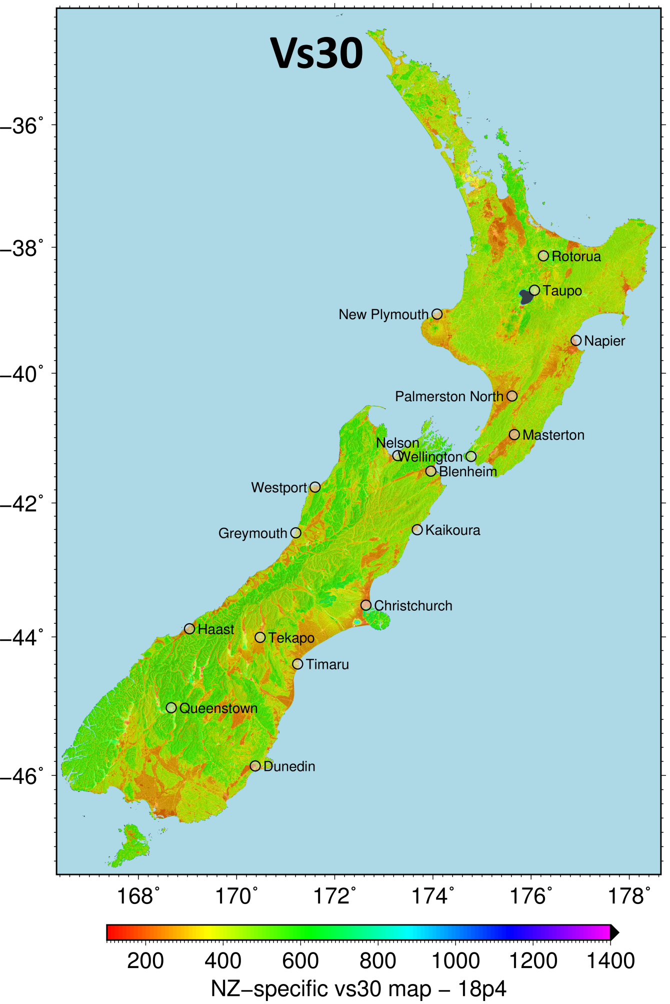
- Region
- GM features of interest

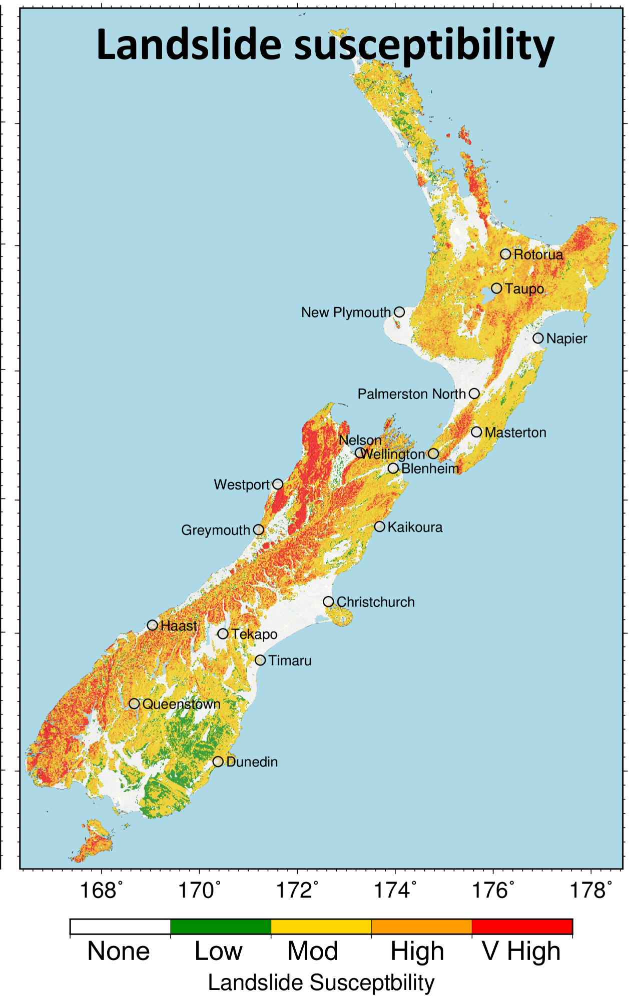
On-demand simulation ‘data-as-a-service’

- How engineers/other users will obtain desired results, e.g.: SeisFinder 2017 demonstration prototype [video: https://www.youtube.com/watch?v=Aaiy_a3lbdY]



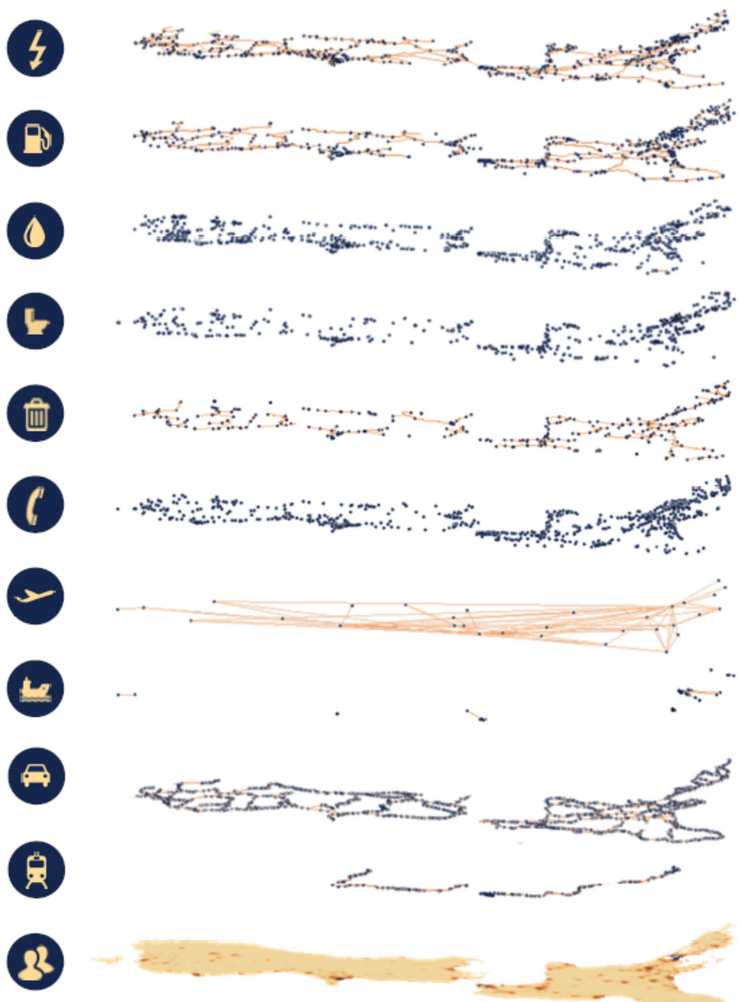
From ground motion to geohazards



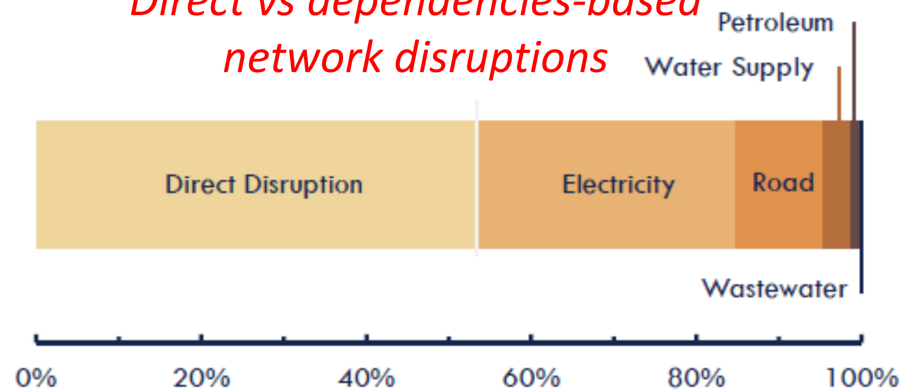


Applied to distributed infrastructure

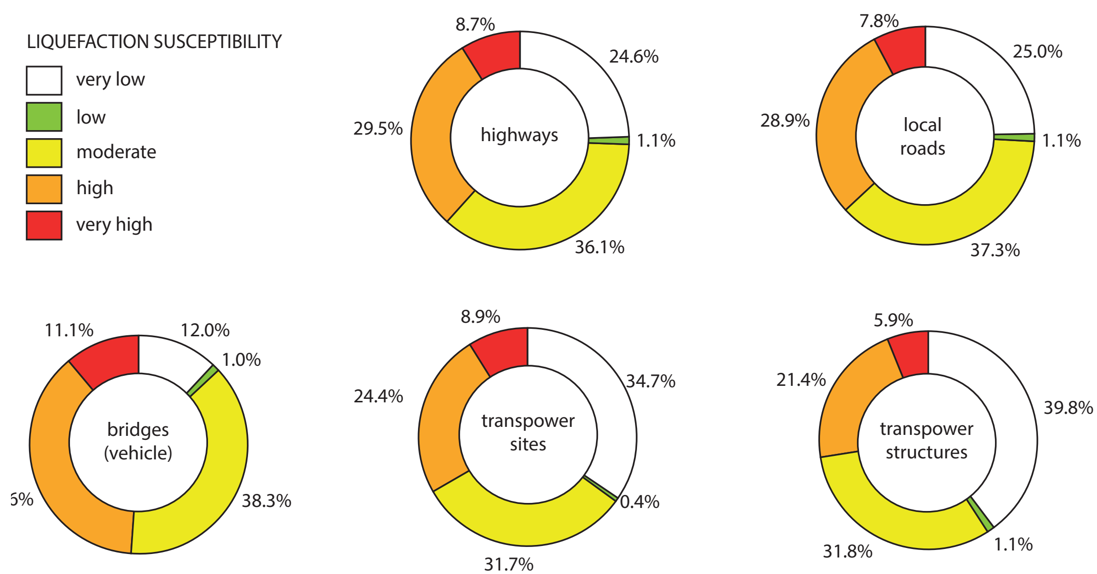
Hierarchical network of network models



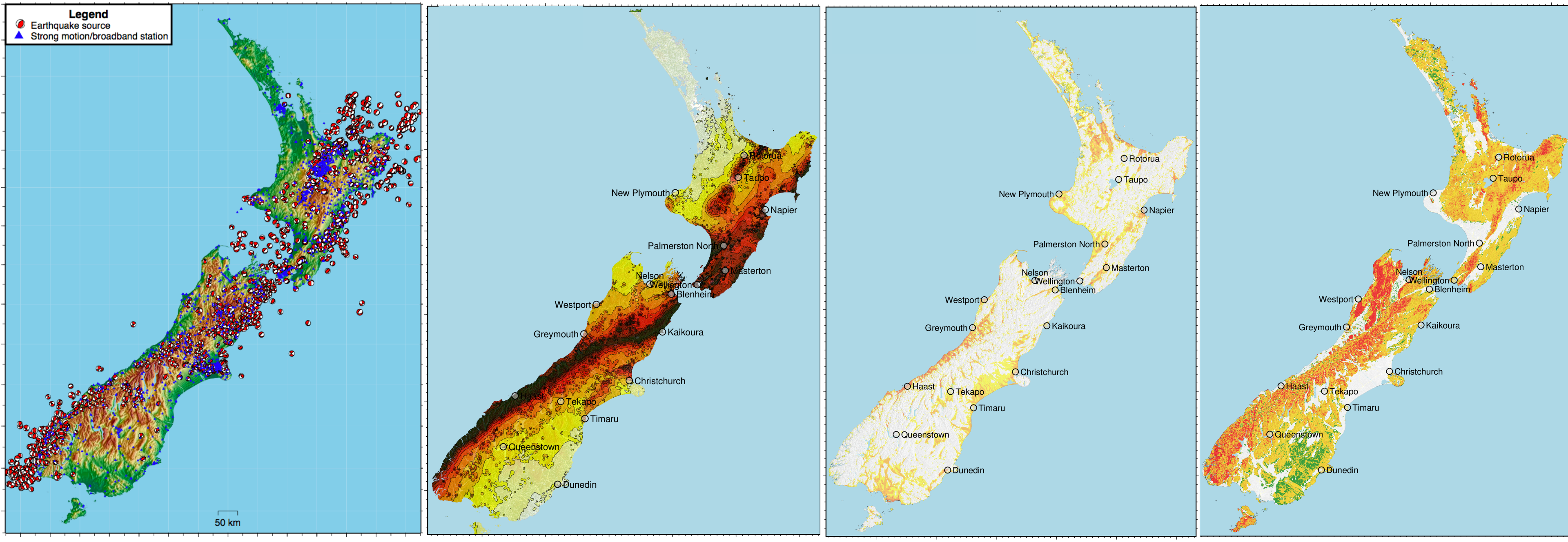
Direct vs dependencies-based network disruptions



Geohazard overlay: Liquefaction exposure of electric and transport networks



Zorn; Wotherspoon et al. 2017



Thank you for your attention

https://sites.google.com/site/brendonabradley/

UC UNIVERSITY OF CANTERBURY Te Whare Wānanga o Waitaha CHRISTCHURCH NEW ZEALAND

NeSI New Zealand eScience Infrastructure

EQC

QuakeCoRE NZ Centre for Earthquake Resilience

NSF

the ROYAL SOCIETY of NEW ZEALAND TE APĀRANGI

MARSDEN FUND TE PŪTEA RANGAHAU A MARSDEN

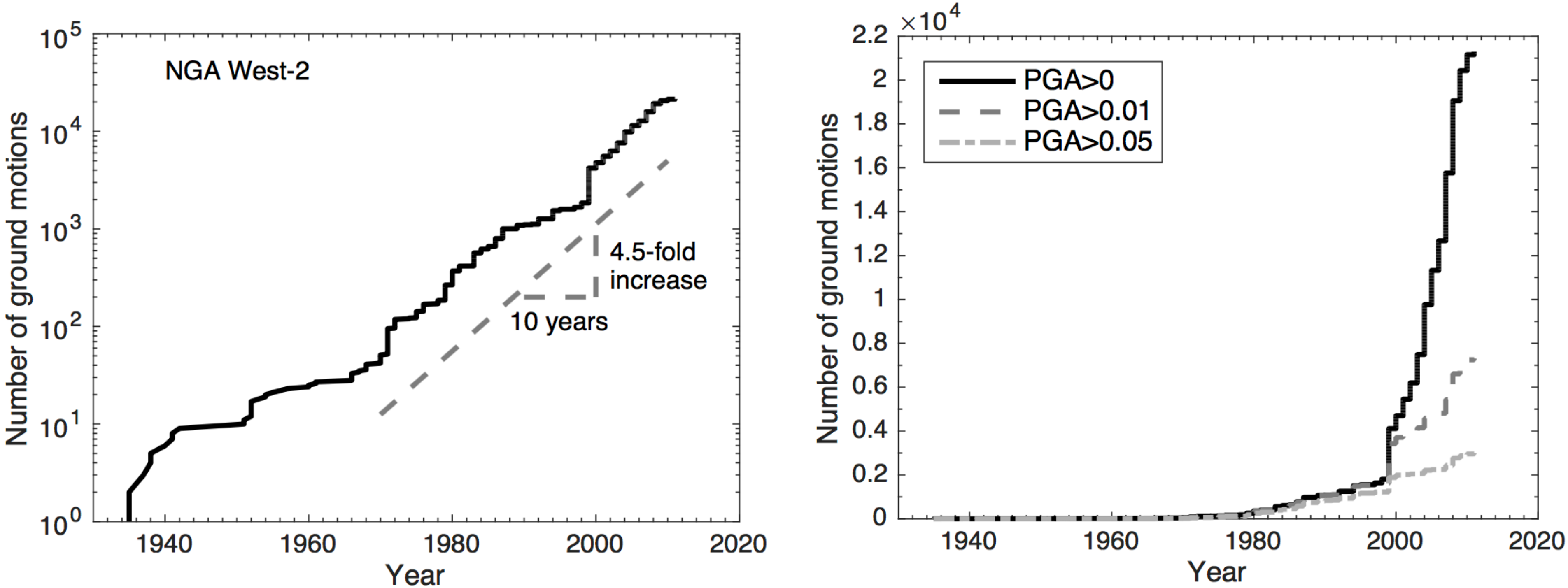
SCEC an NSF+USGS center

GeoNet

USGS science for a changing world

Leveraging exponential technologies

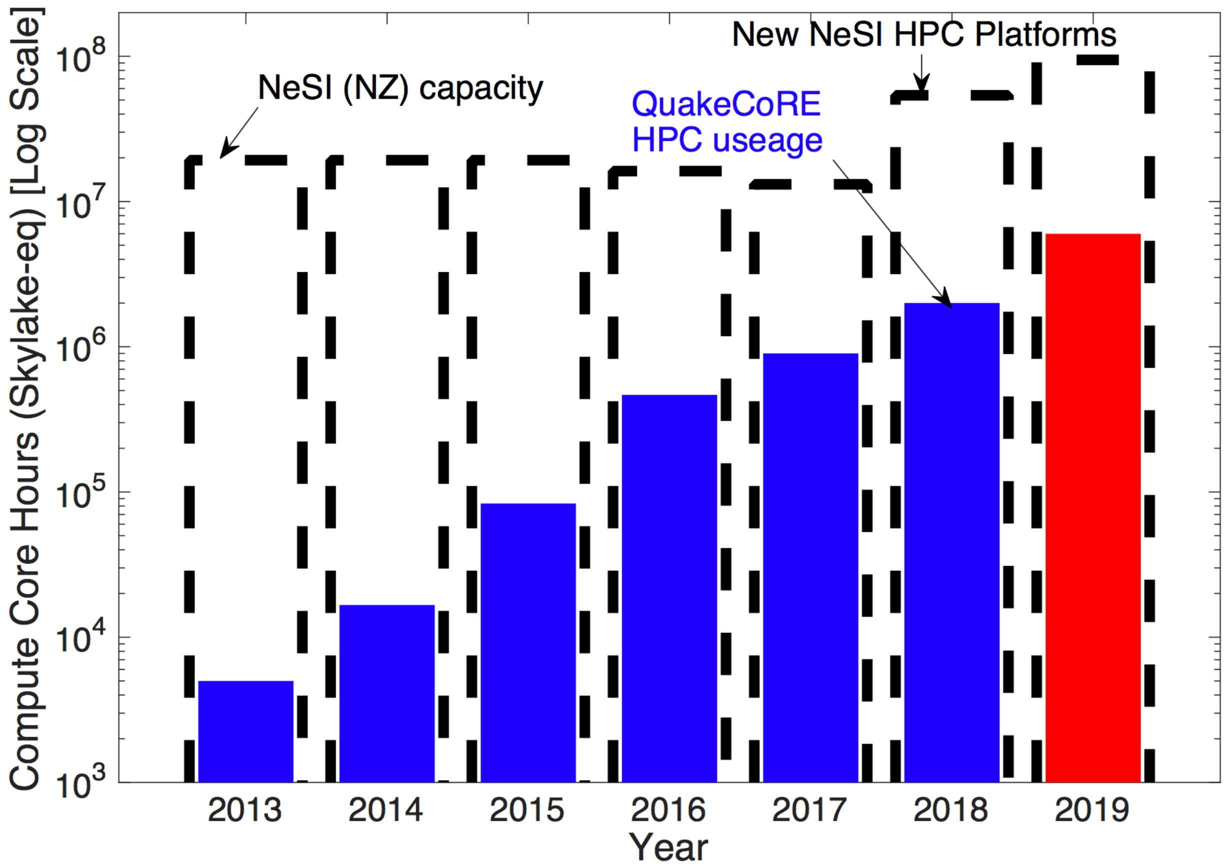
- Measurements: doubling every 4.4 years



Baker, Bradley, Stafford (2018, Cambridge Press)

Leverages exponential technologies

- Computing hardware: Doubling every <2 years + increases in utilisation efficiency



(NeSI/QuakeCoRE, 2018)

Leverages exponential technologies

- Software: Machine Learning (Neural Nets)