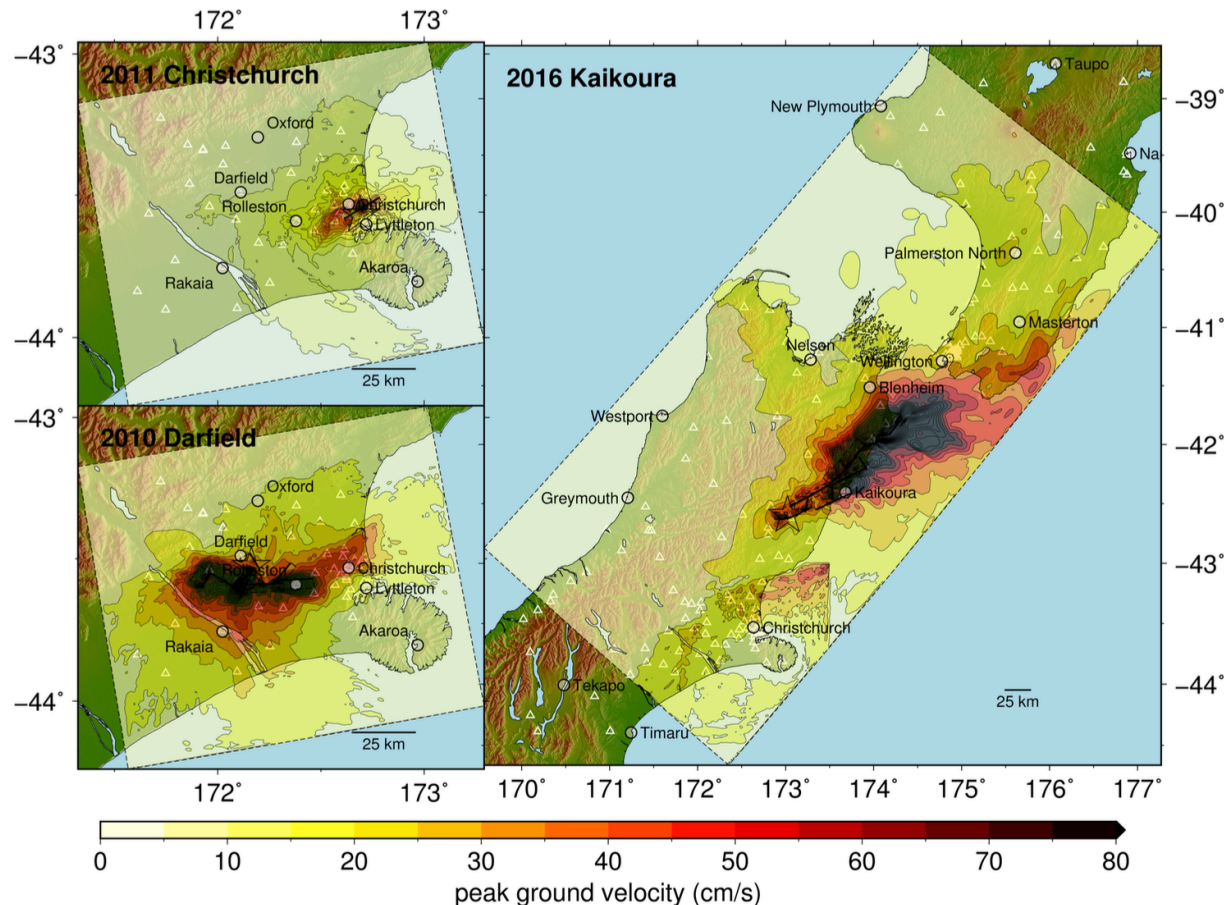


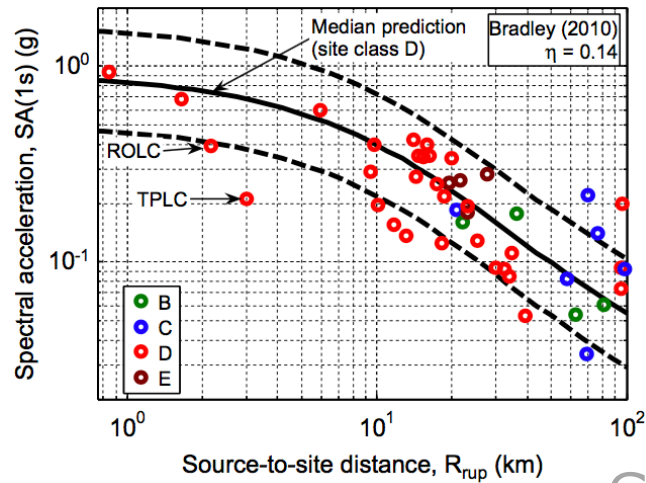
Simulation-based ground motion prediction of historical and future New Zealand earthquakes and consequent geohazard impacts



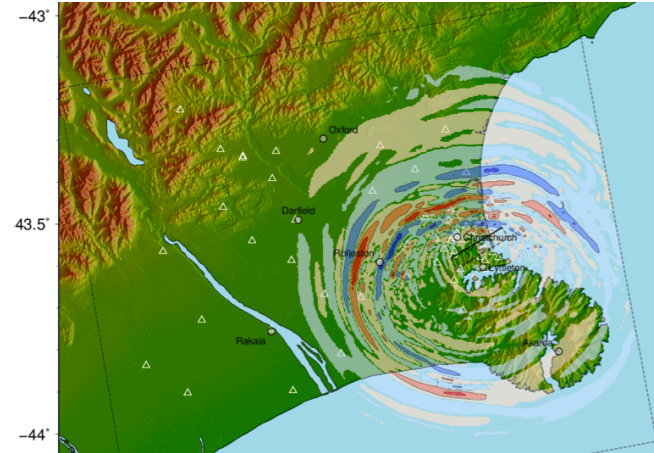
Brendon Bradley, University of Canterbury, New Zealand

Context

Empirical



Physics-based

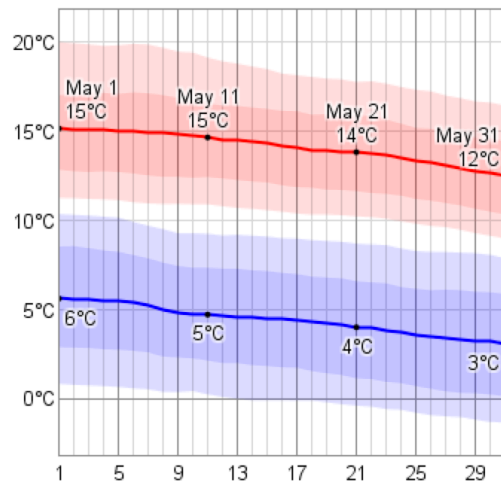


VS

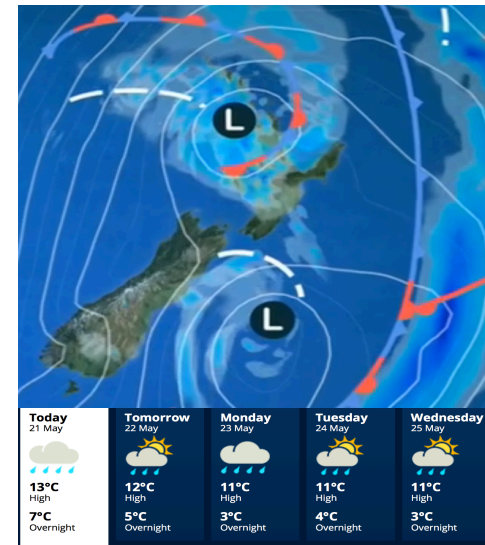
Ground motion

Weather

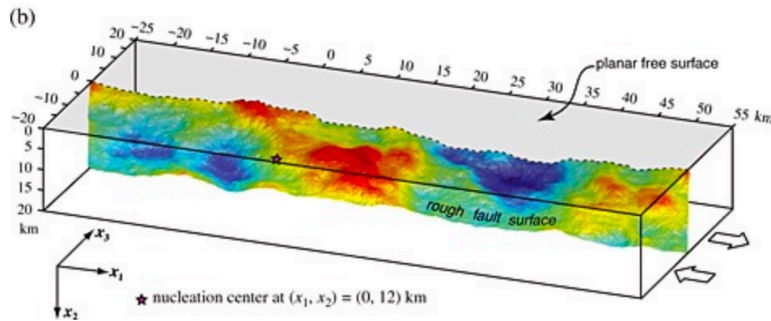
Daily High and Low Temperature in May



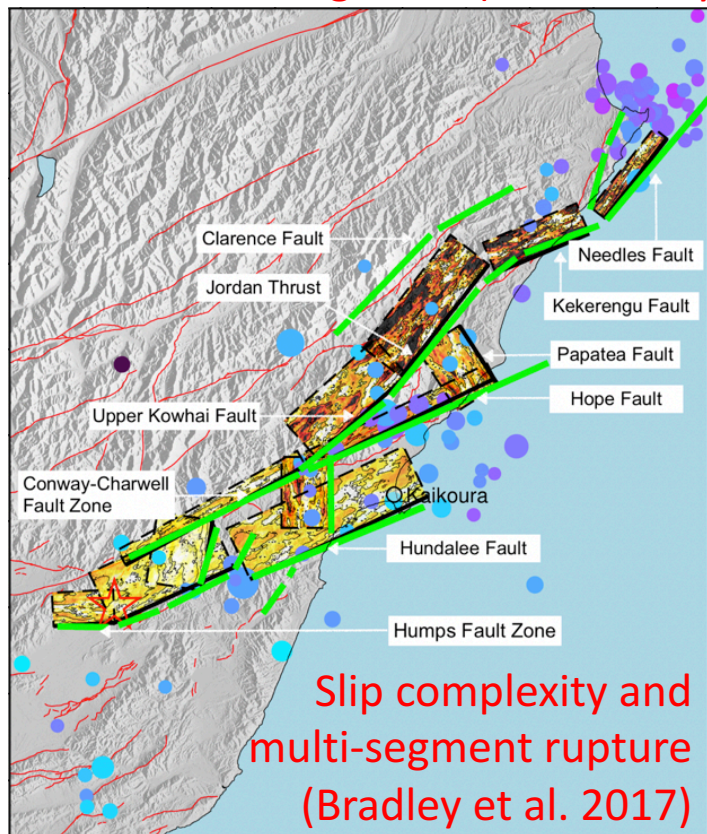
VS



Ingredient 1. Seismic source



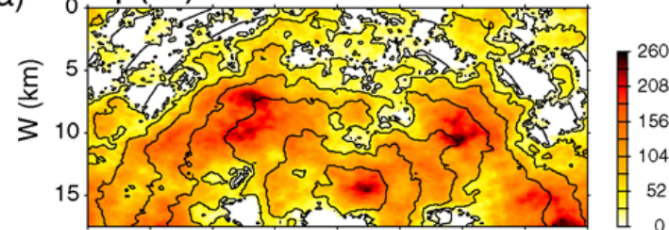
Fault roughness (Shi and Day)



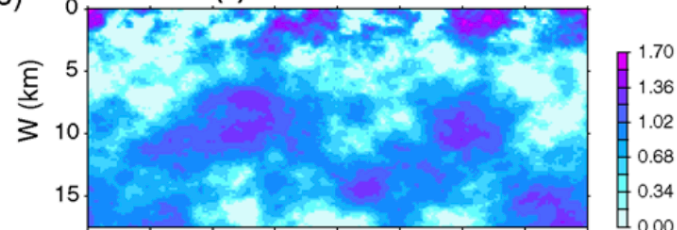
Slip complexity and multi-segment rupture (Bradley et al. 2017)

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

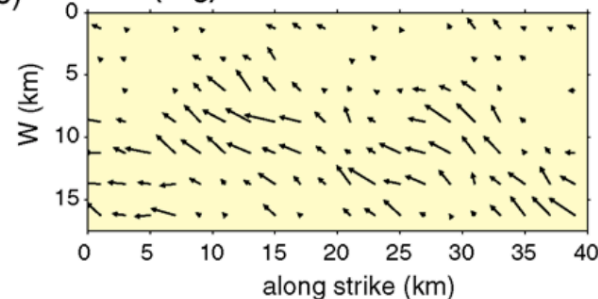
(a) Slip (cm) 0 / 69 / 255



(b) Rise Time (s) 0.0 / 0.9 / 1.7



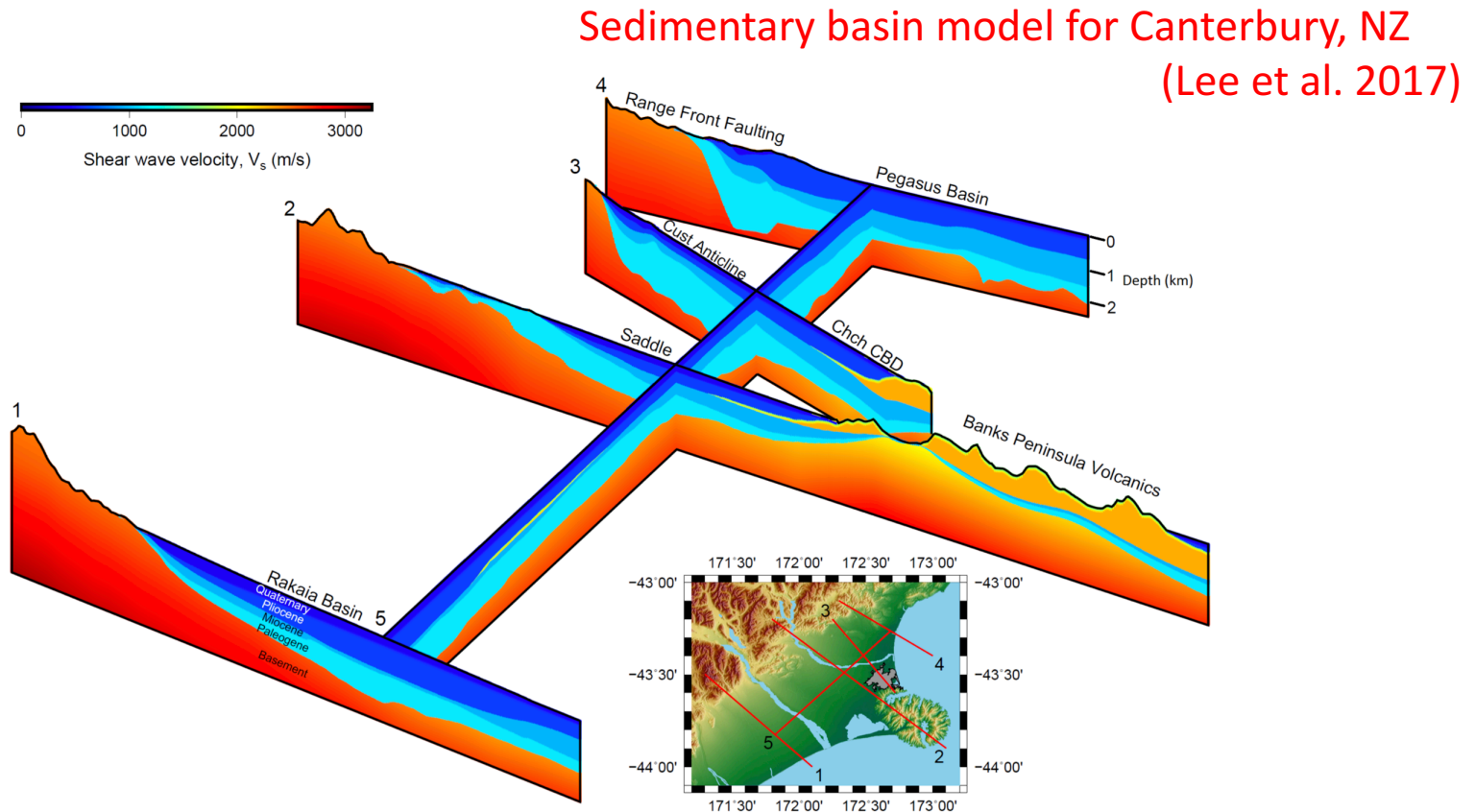
(c) Rake (deg) 93 / 145 / 205



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

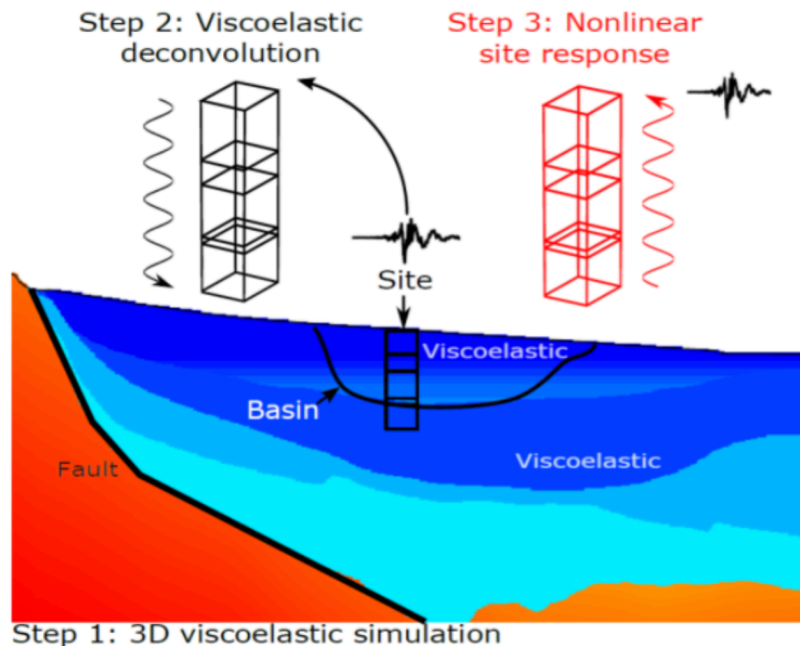
Ingredient 2. 3D crustal model

- Sedimentary basins critical for adequate simulation prediction

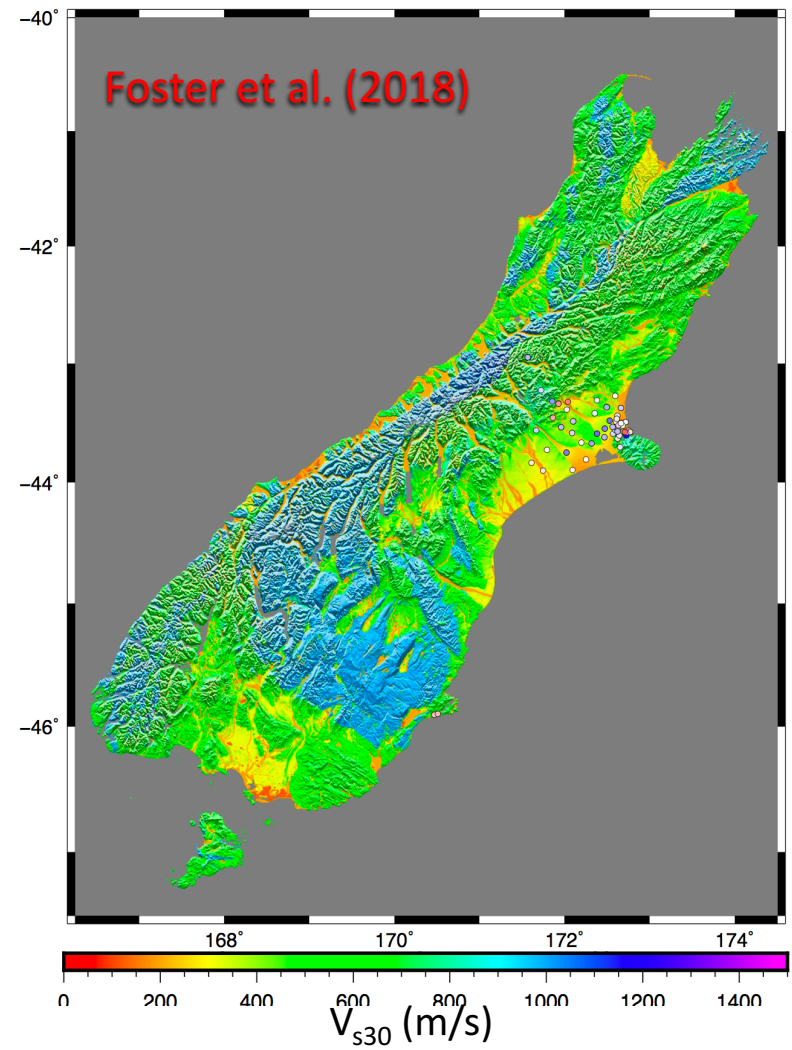


Ingredient 3. Surficial site effects

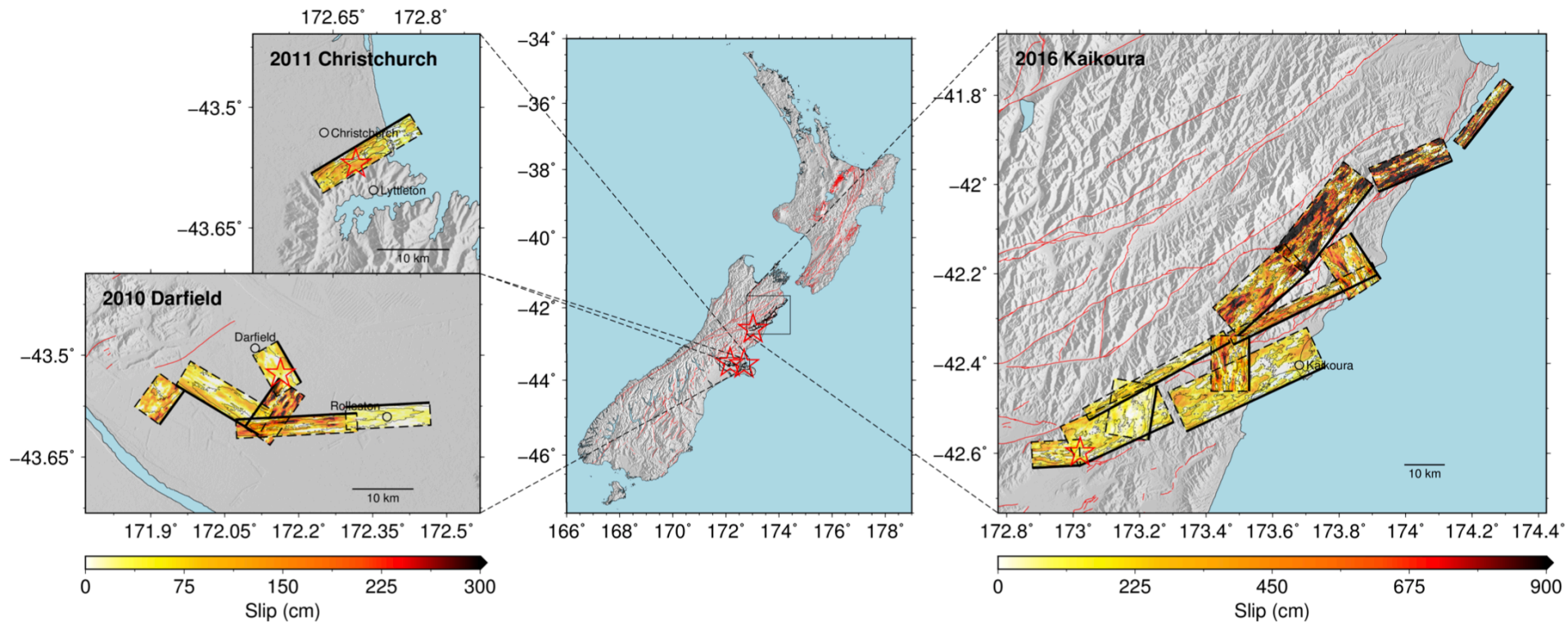
- Difficulty in modelling
 - regional effects (10-100km scale)
 - site-specific effects (1-10m scale)
- Modelling site response via:
 - Vs30-based empirical factors
 - Explicit site response via wave propagation analysis



de la Torre et al. (2017)



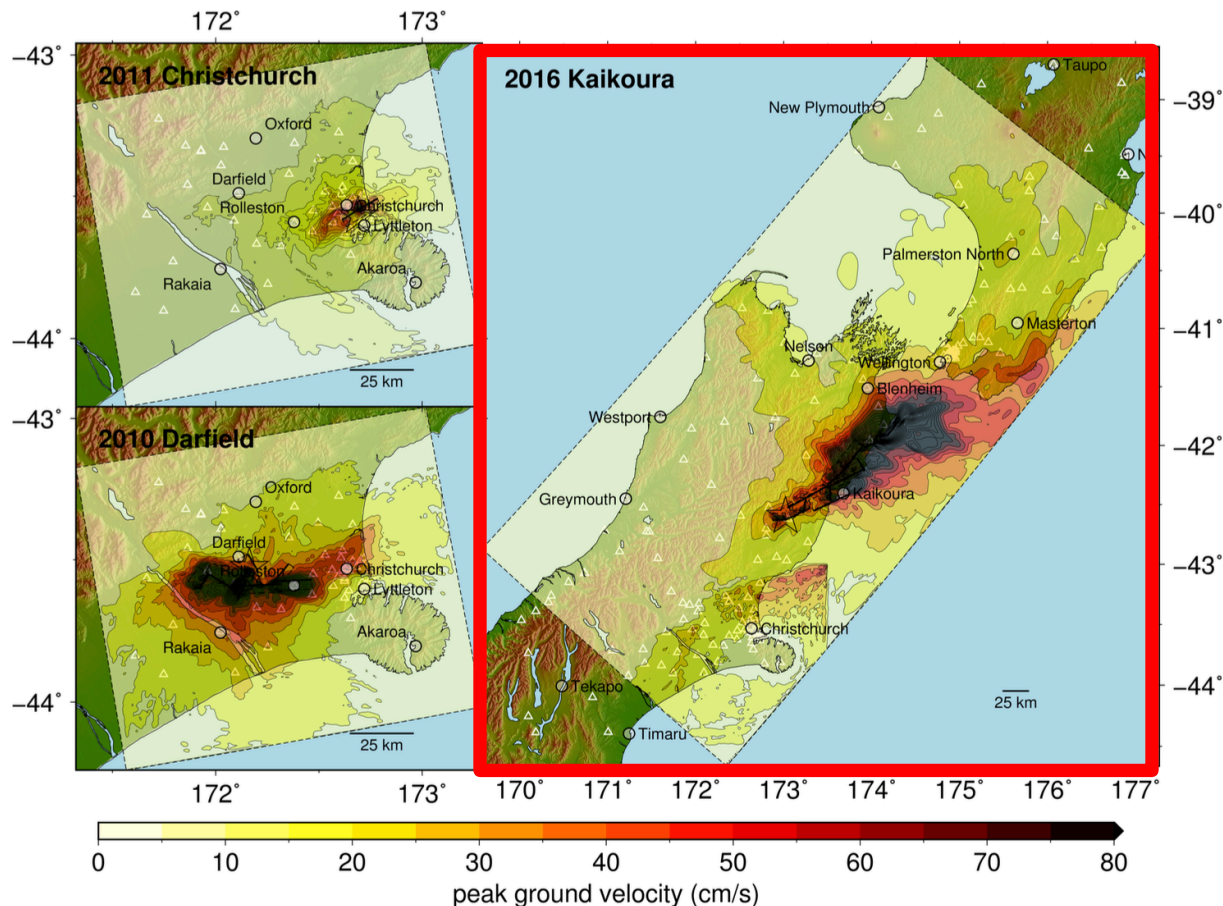
2010-2011 Canterbury and 2016 Kaikōura earthquakes



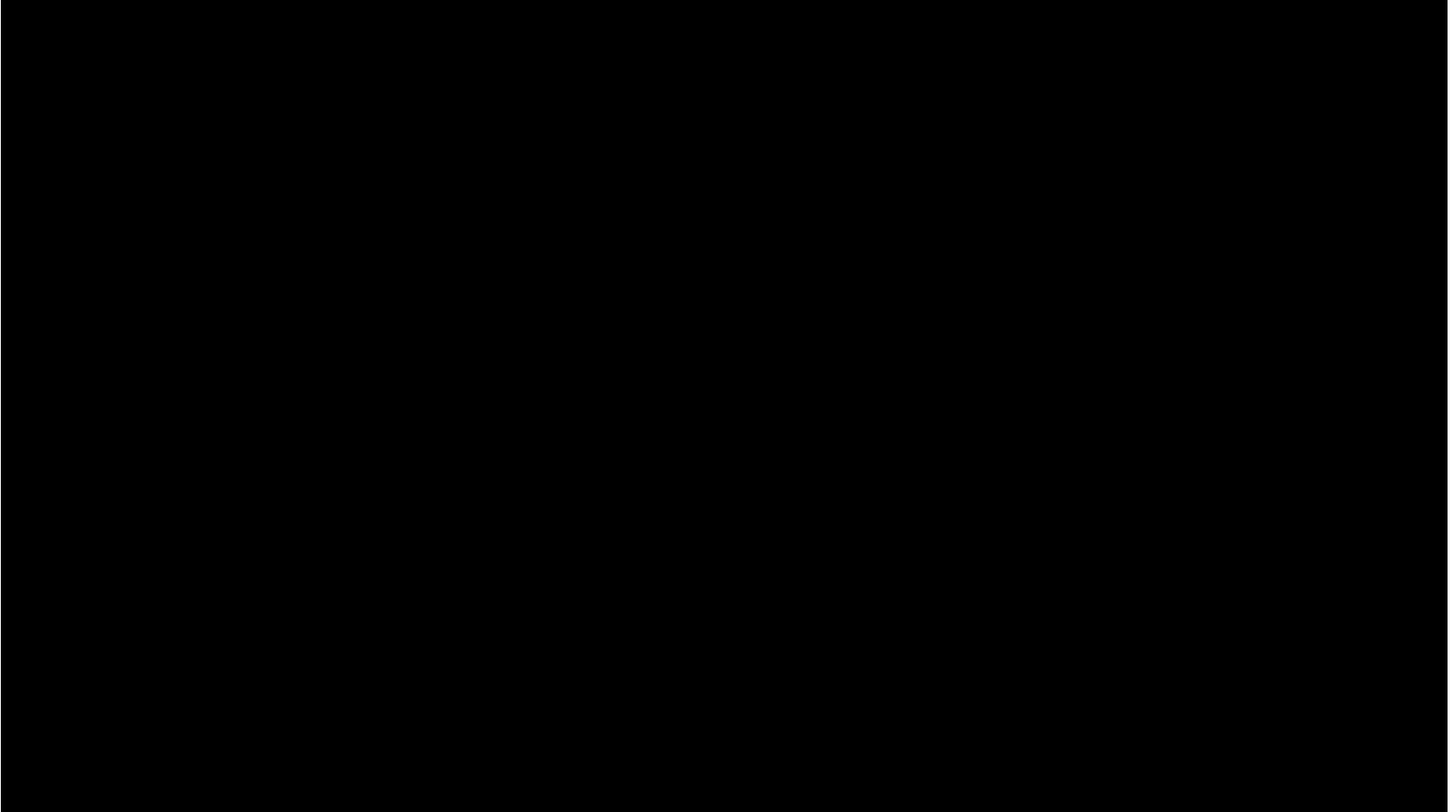
Bradley (2018)

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

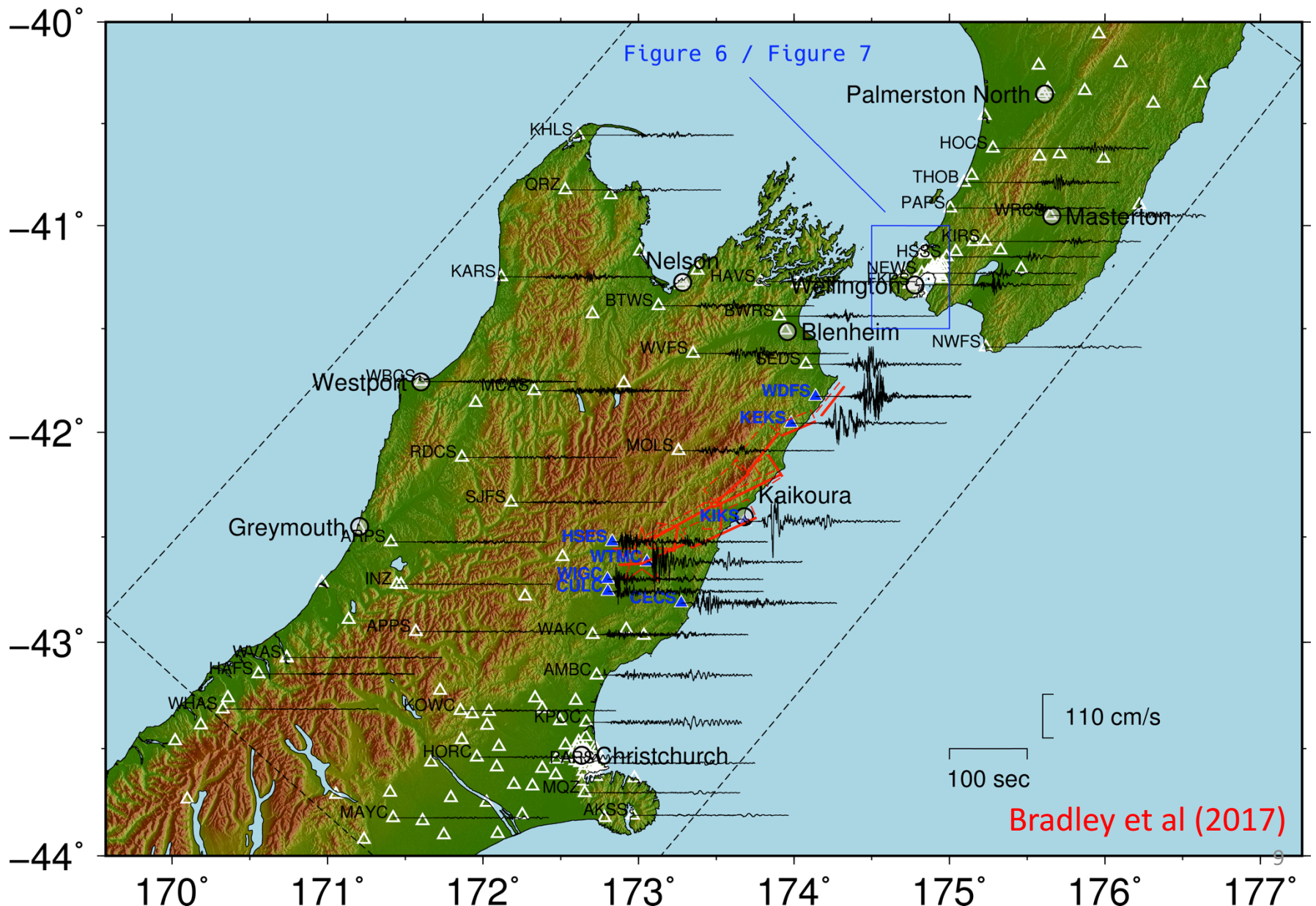


Ground motion simulation

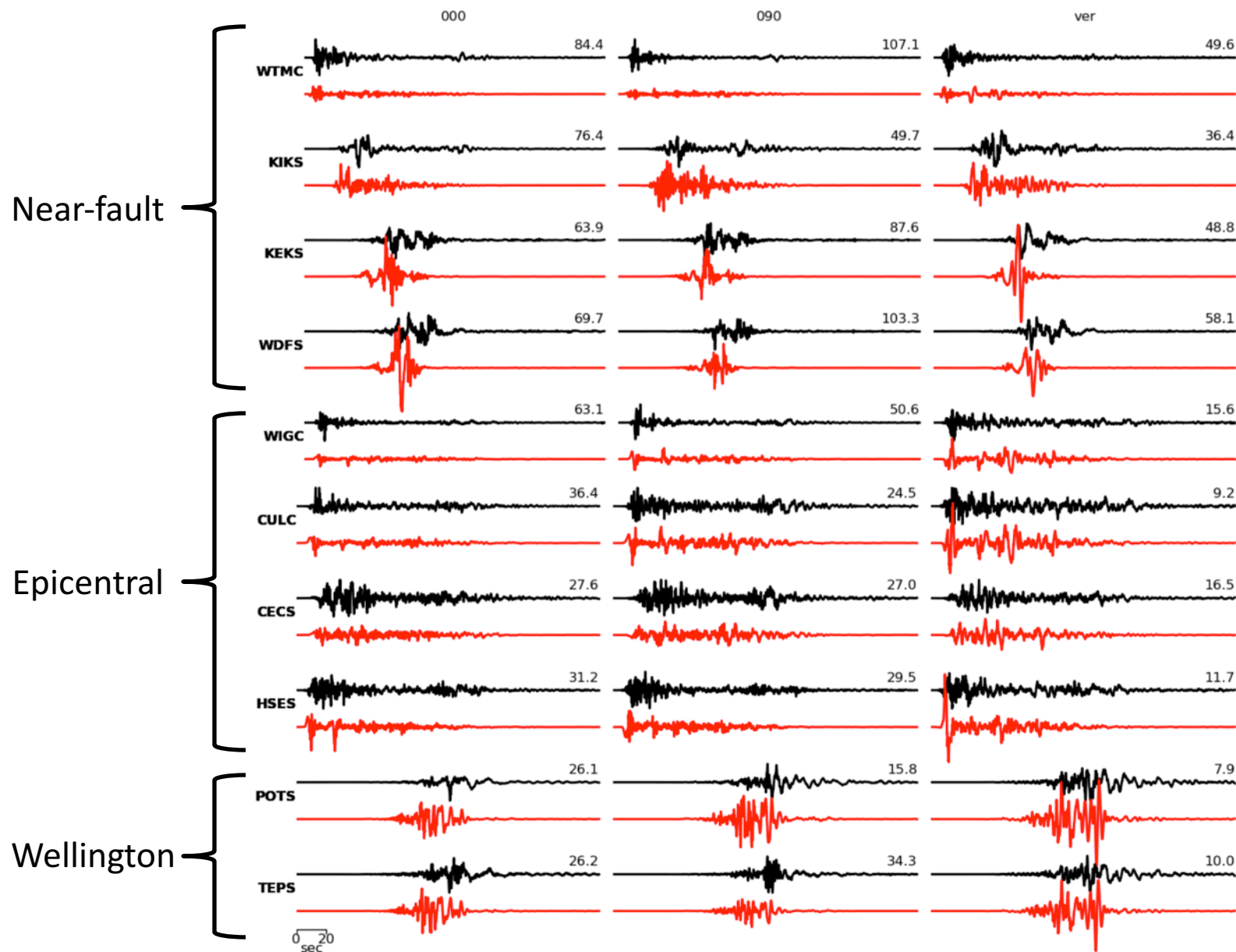


[Video: <https://www.youtube.com/watch?v=j9c-Fwhaigc>]

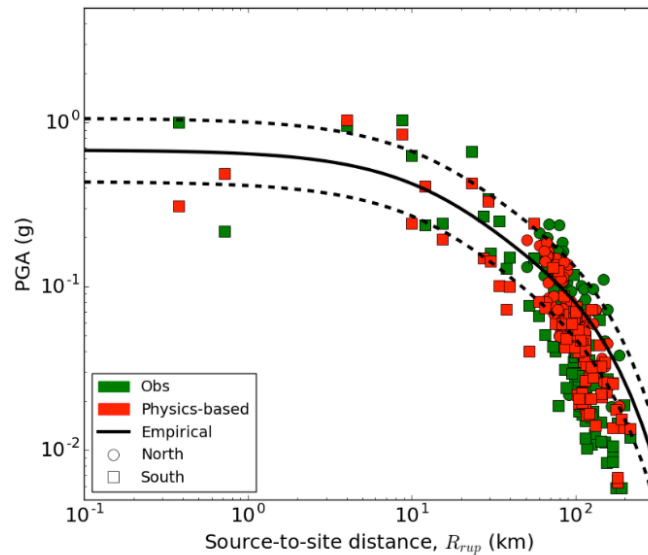
Observed ground motions



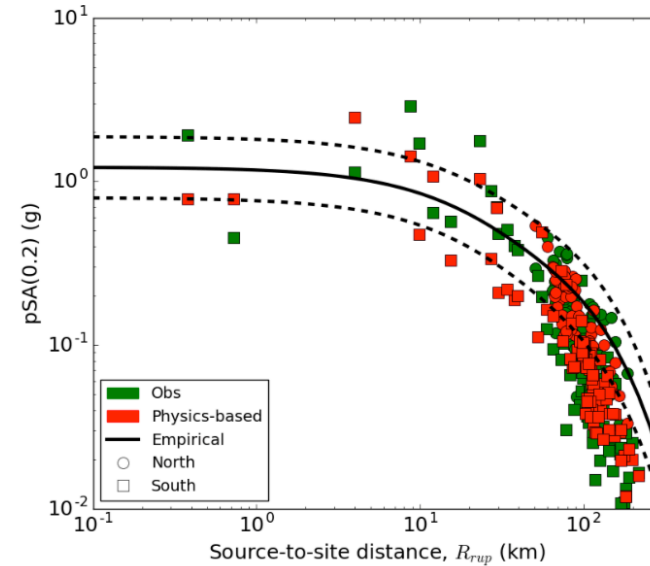
Observed and simulated motions



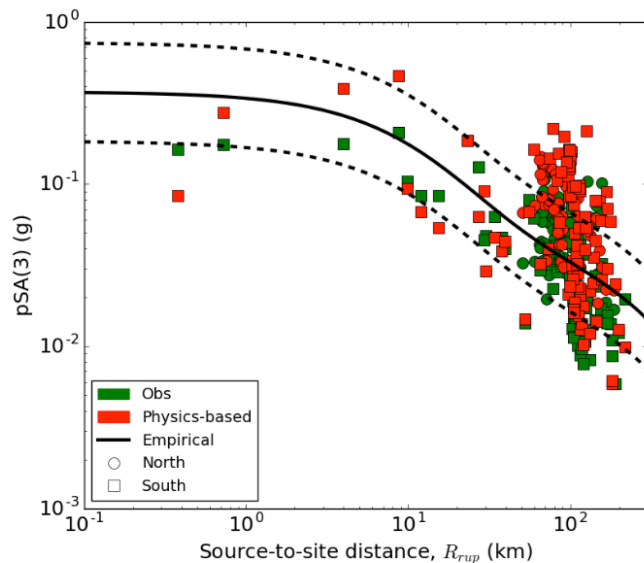
Observed and simulated response spectra



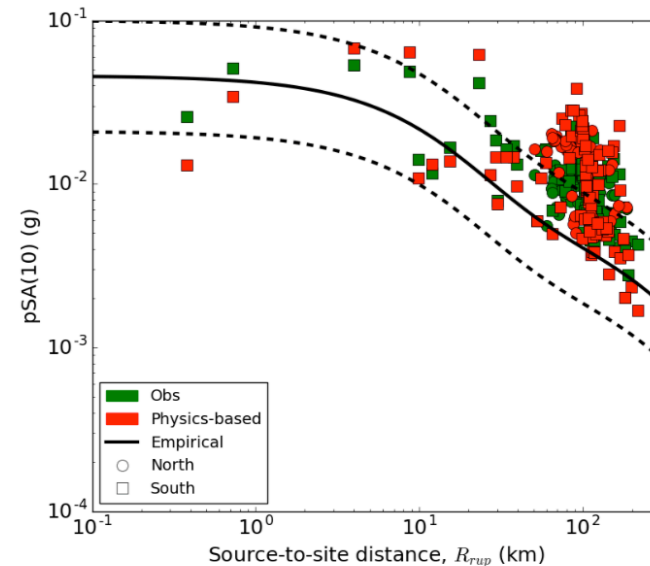
(a) PGA



(b) SA(0.2s)

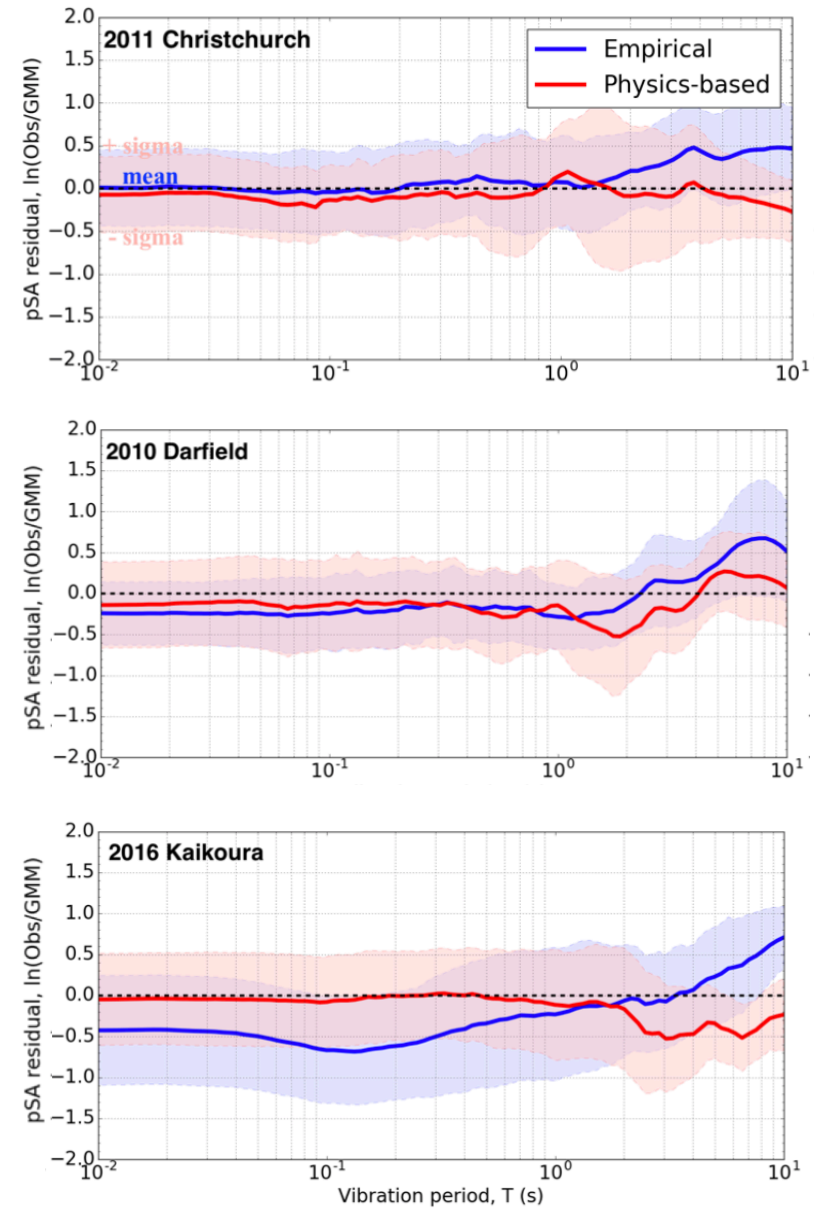
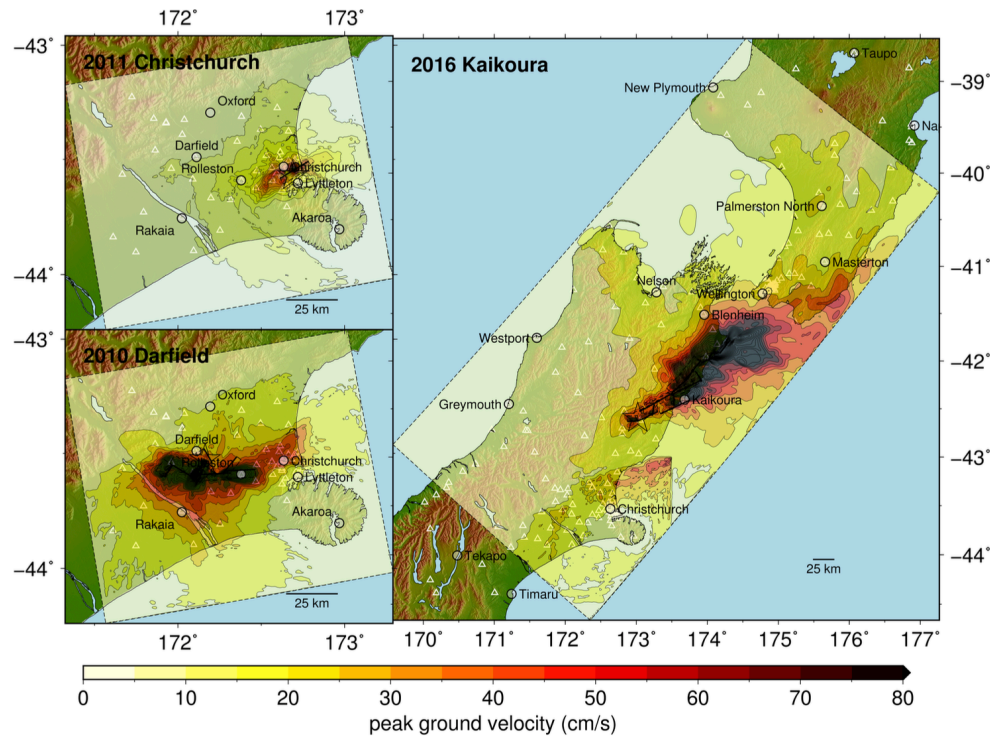


(c) SA(3.0s)



(d) SA(10.0s)

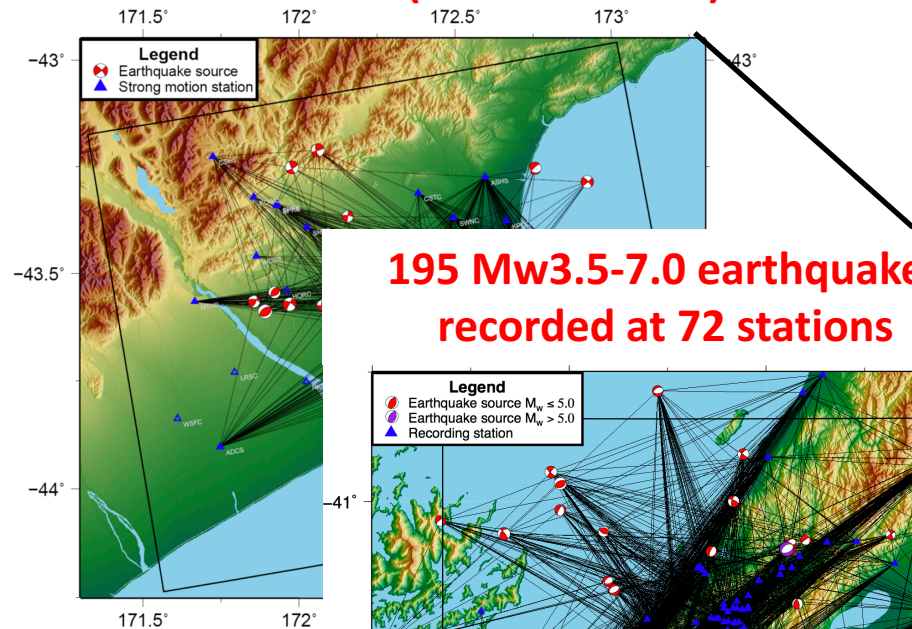
Simulation residuals



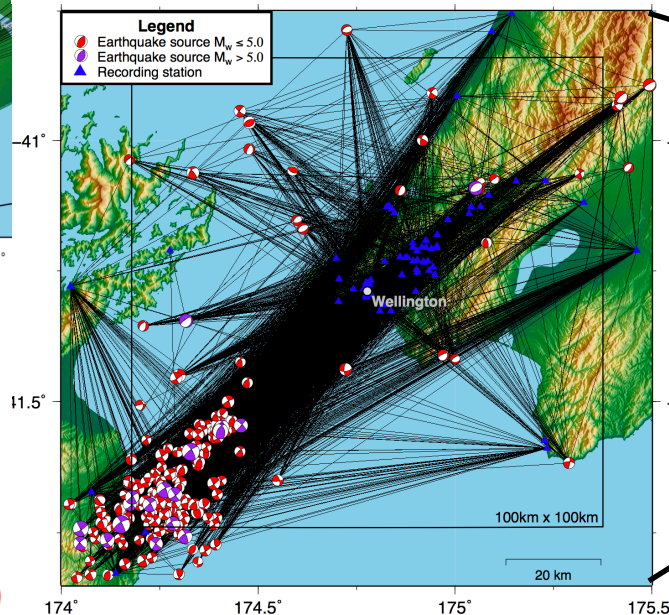
Validation

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

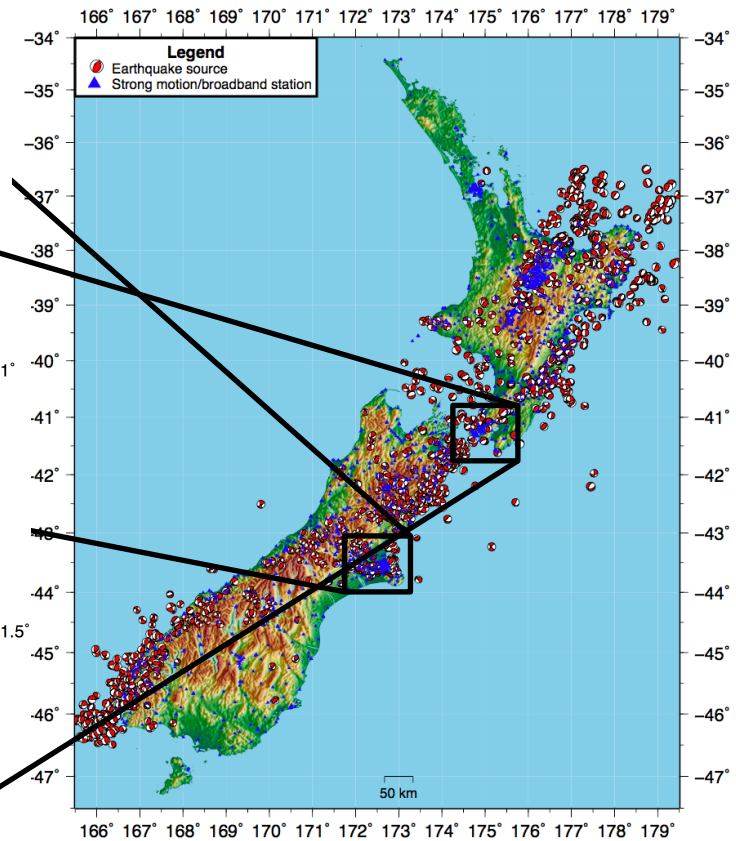
**144 Mw3.5-5.0 earthquakes recorded
at 46 stations (Lee et al. 2017)**



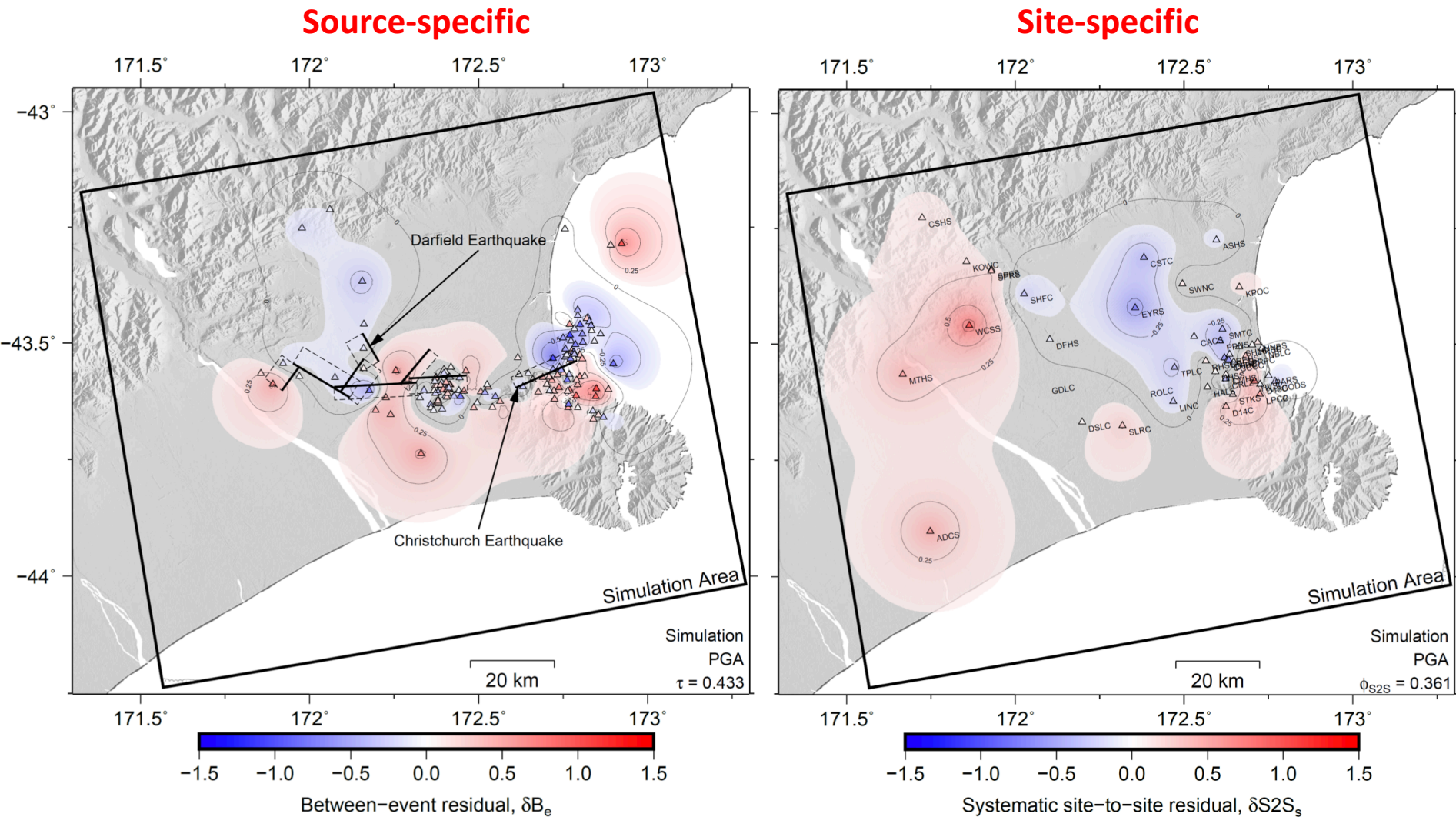
**195 Mw3.5-7.0 earthquakes
recorded at 72 stations**



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

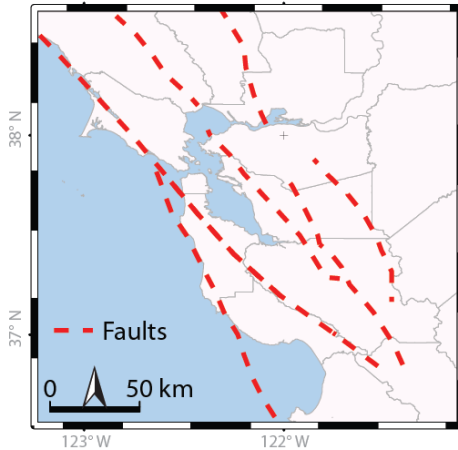


Systematic effects from validation

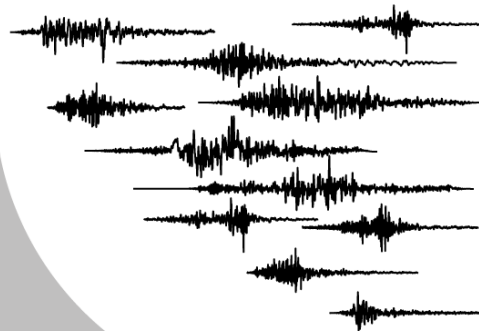


Uses of simulations

Seismic Sources

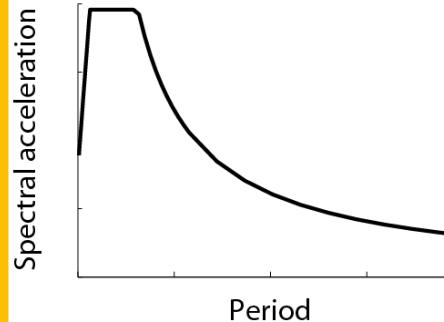


Ground Motions

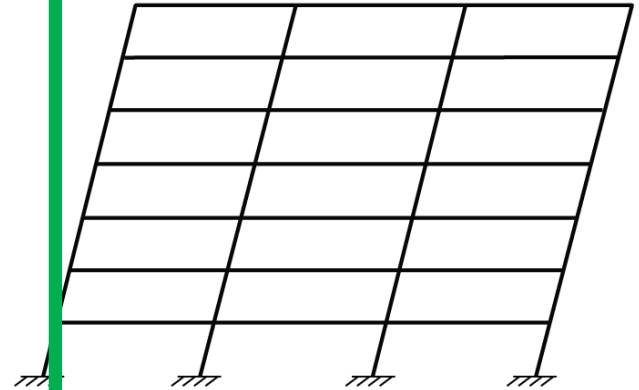


Hazard Analysis

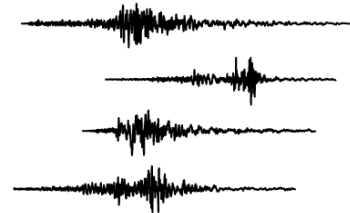
Target Response Spectrum



Structural Performance



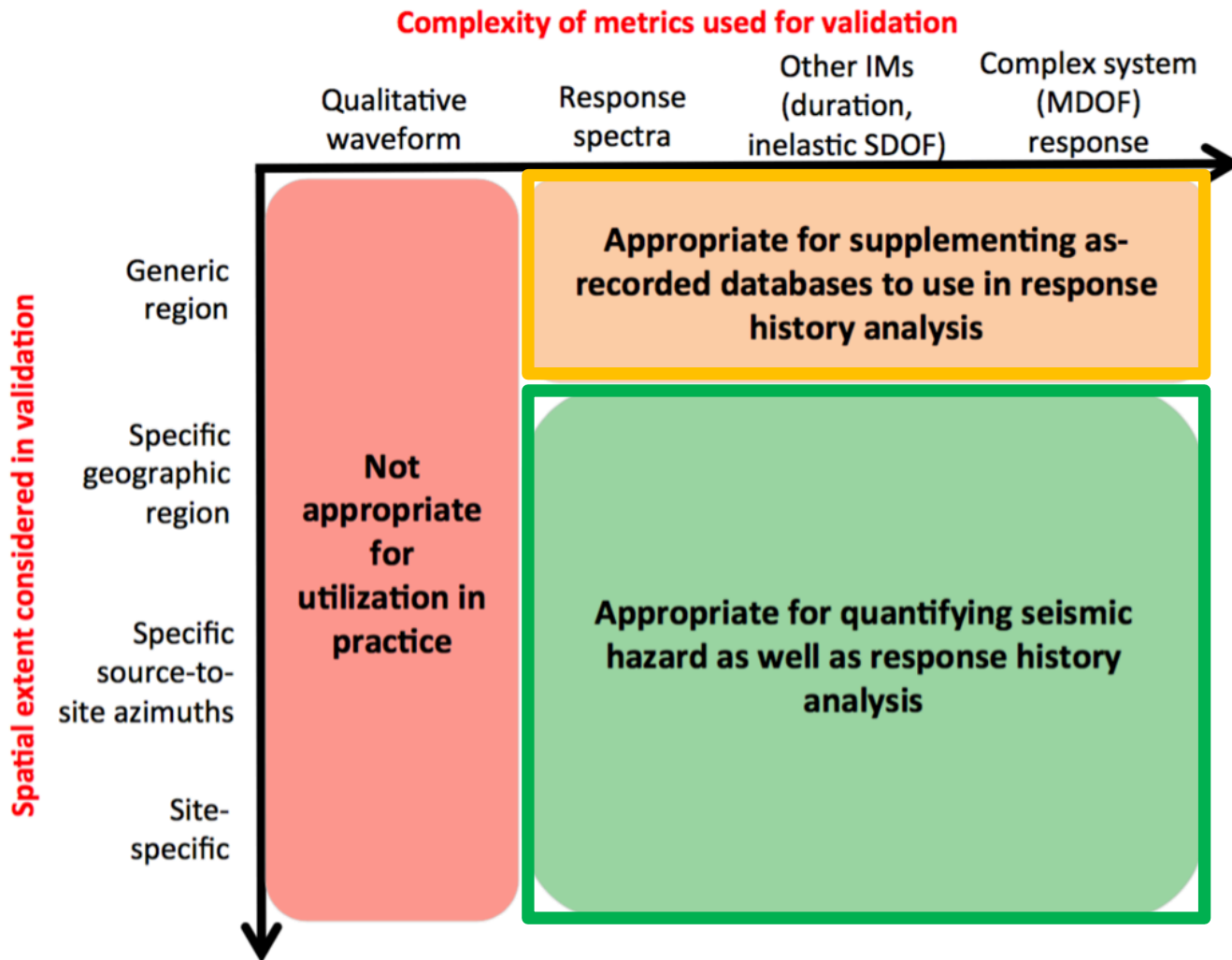
Ground Motions



Response History Analysis

(Bradley et al. 2017)

Validation and utilization guidance

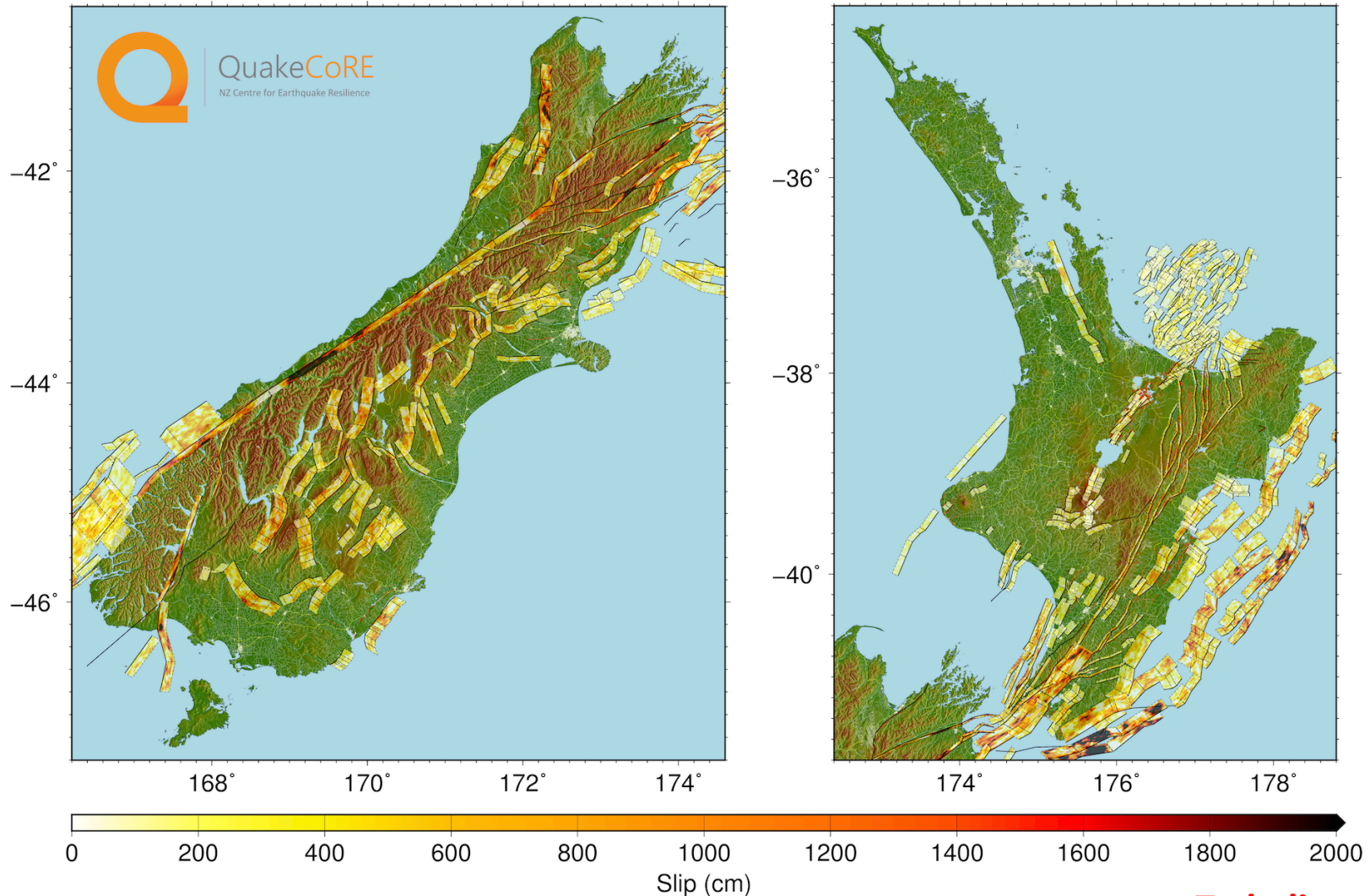


‘Validation matrix’ for simulation utilization (Bradley et al. 2017)

Seismic hazard using simulated ground motions

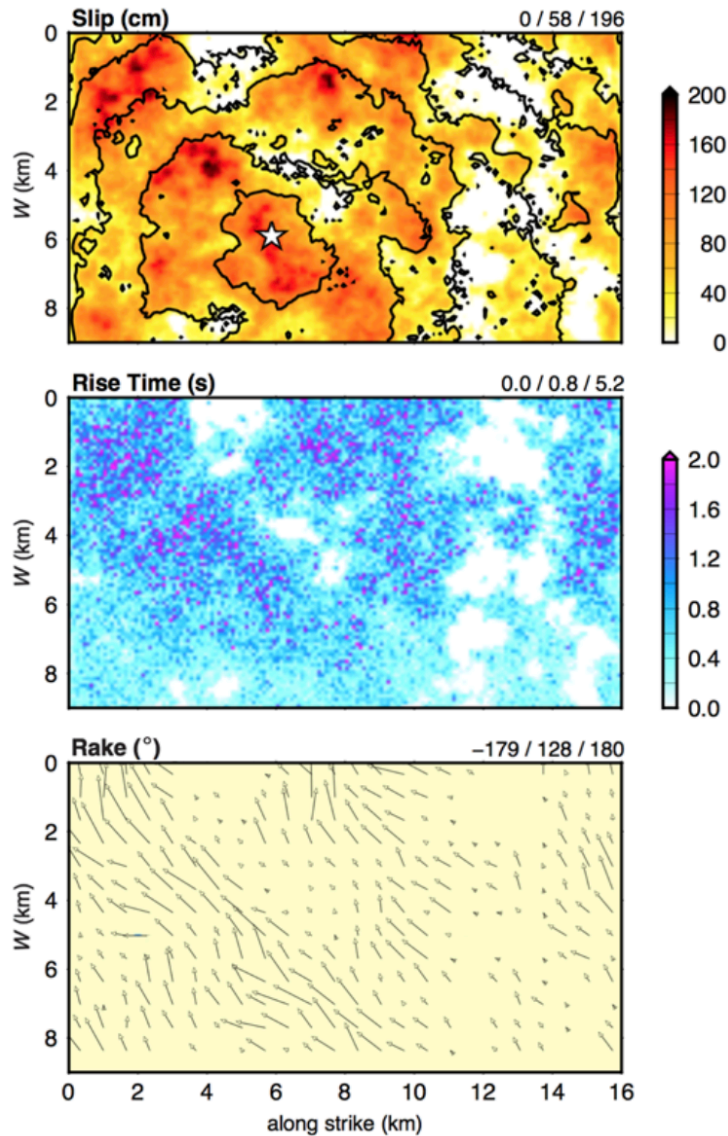
There are ~500 major mapped faults in NZ

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

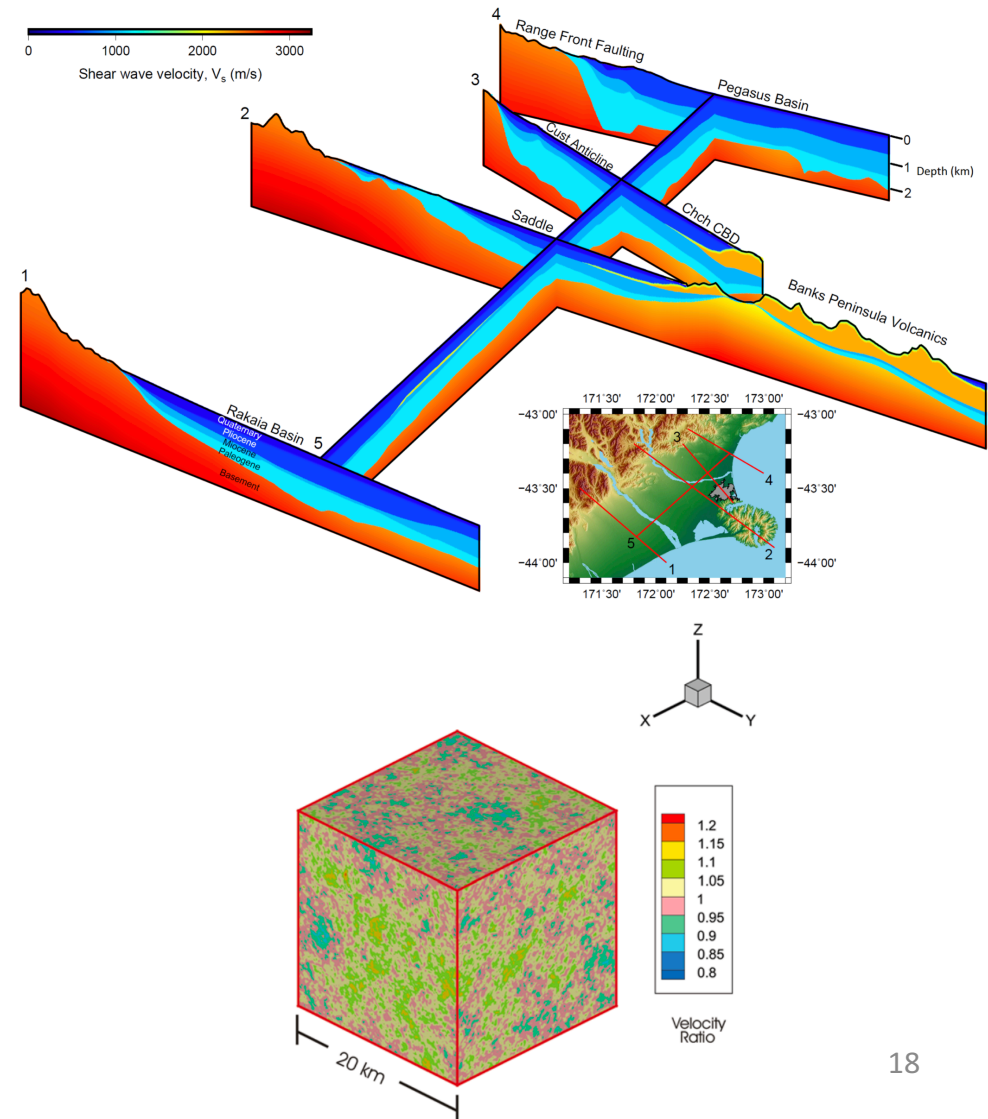


Uncertainties in source and crustal models

Source representation

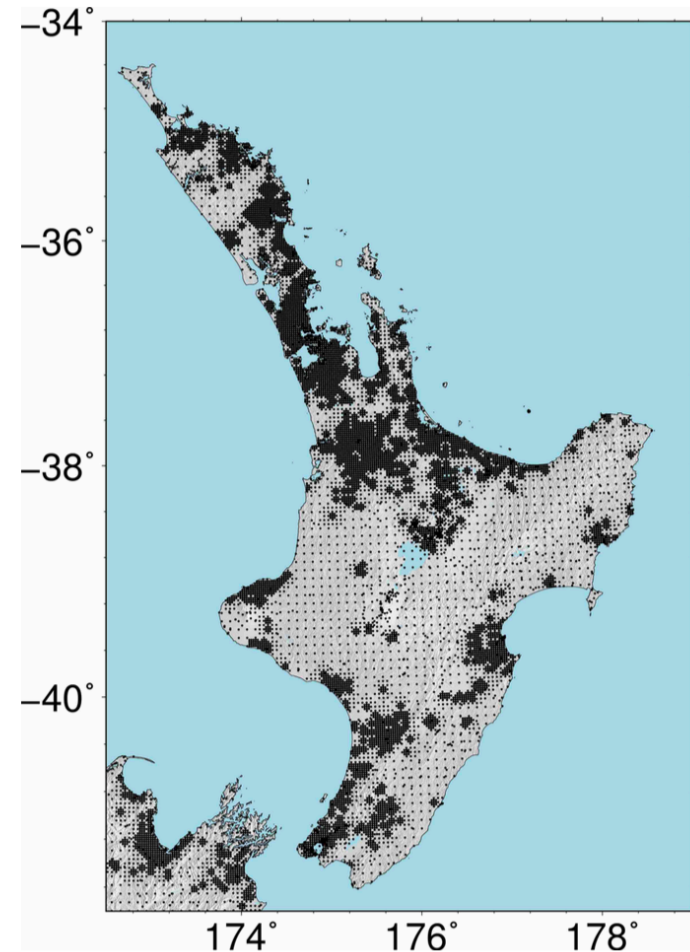
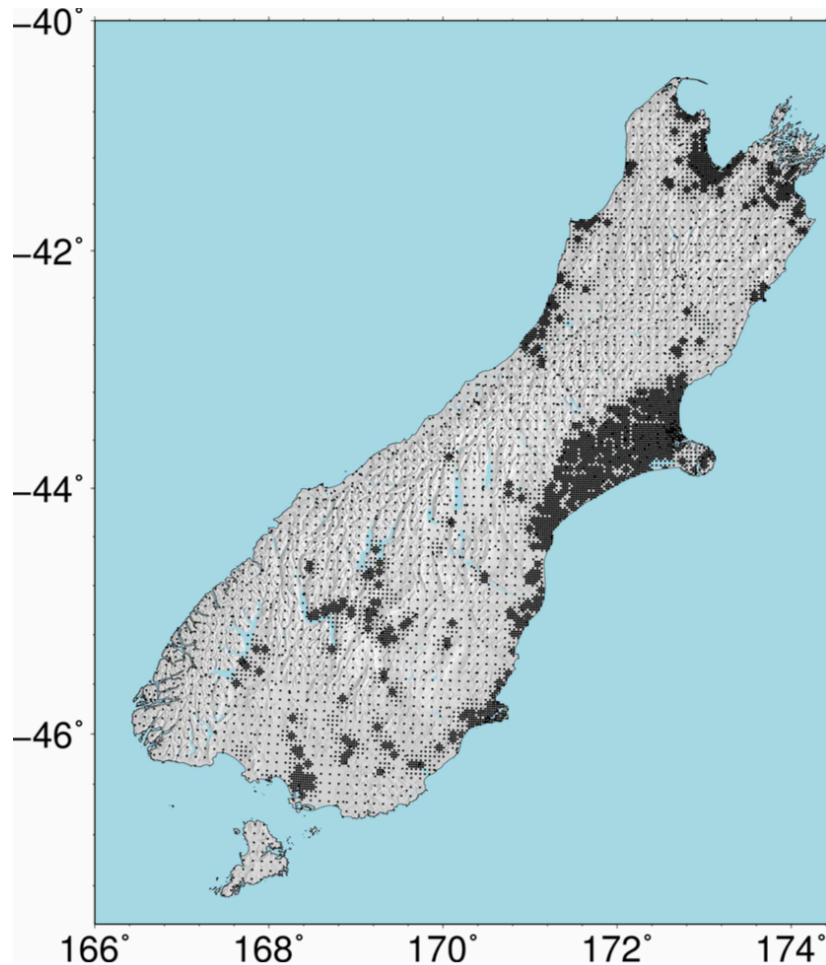


Crust representation

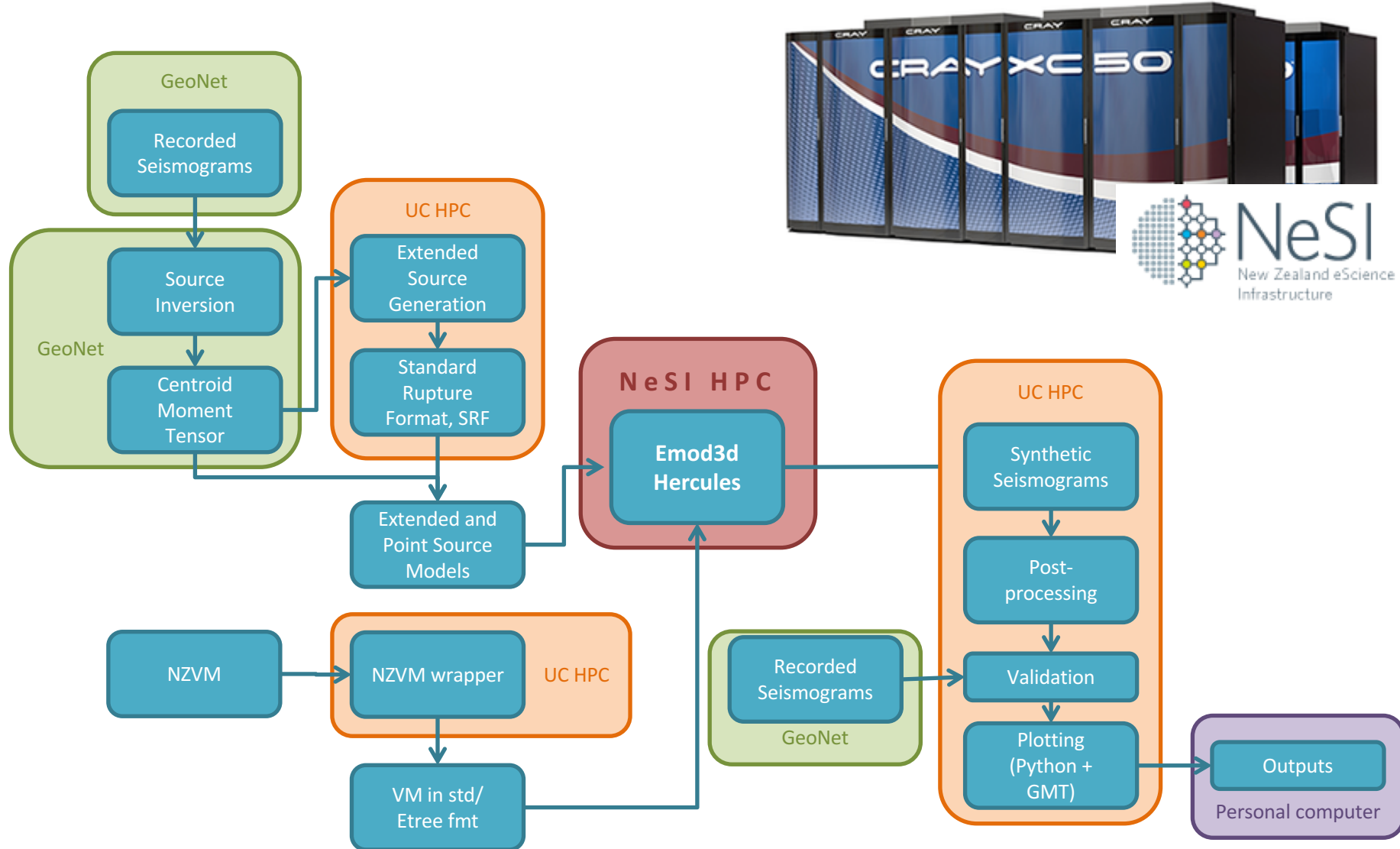


Seismic hazard using simulated ground motions

Simulations stored on a grid of $\sim 20,000$ spatial locations

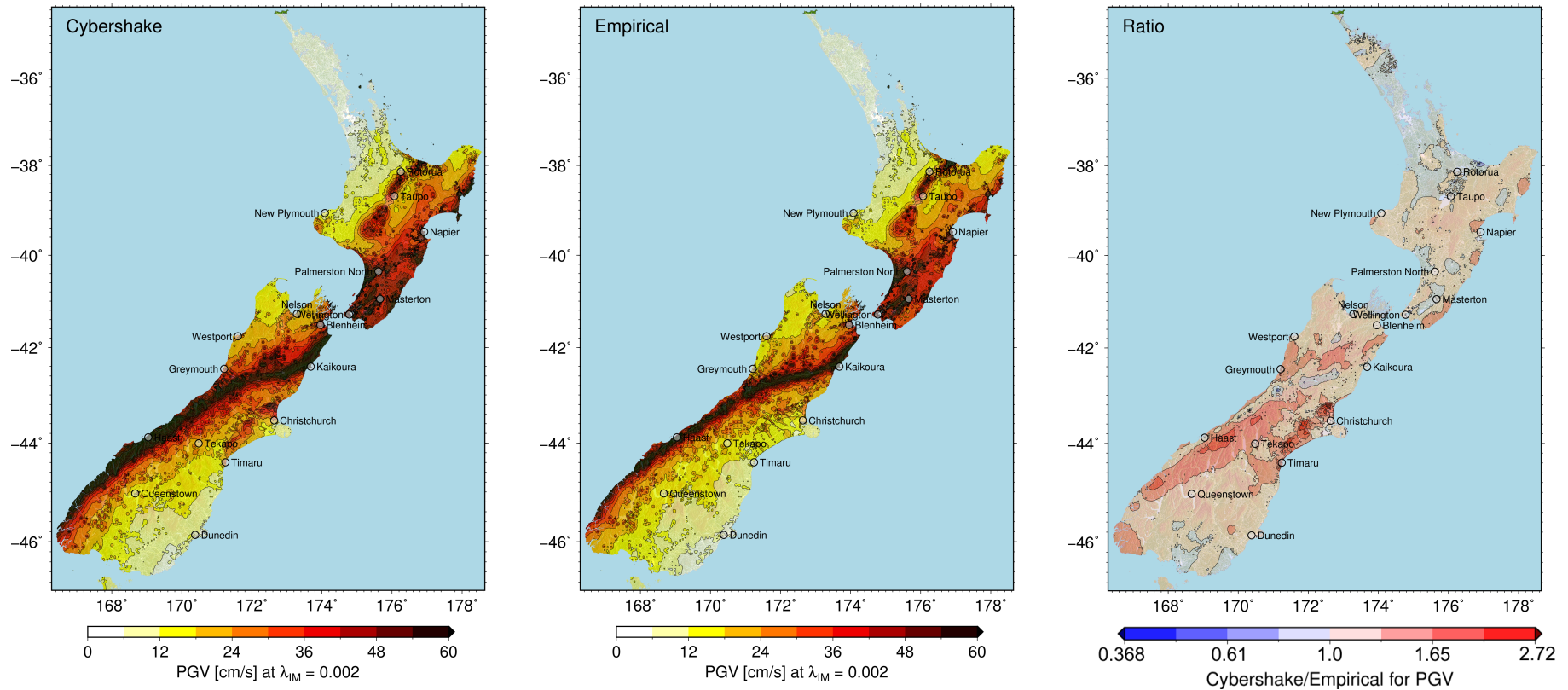


Software workflow and Integration



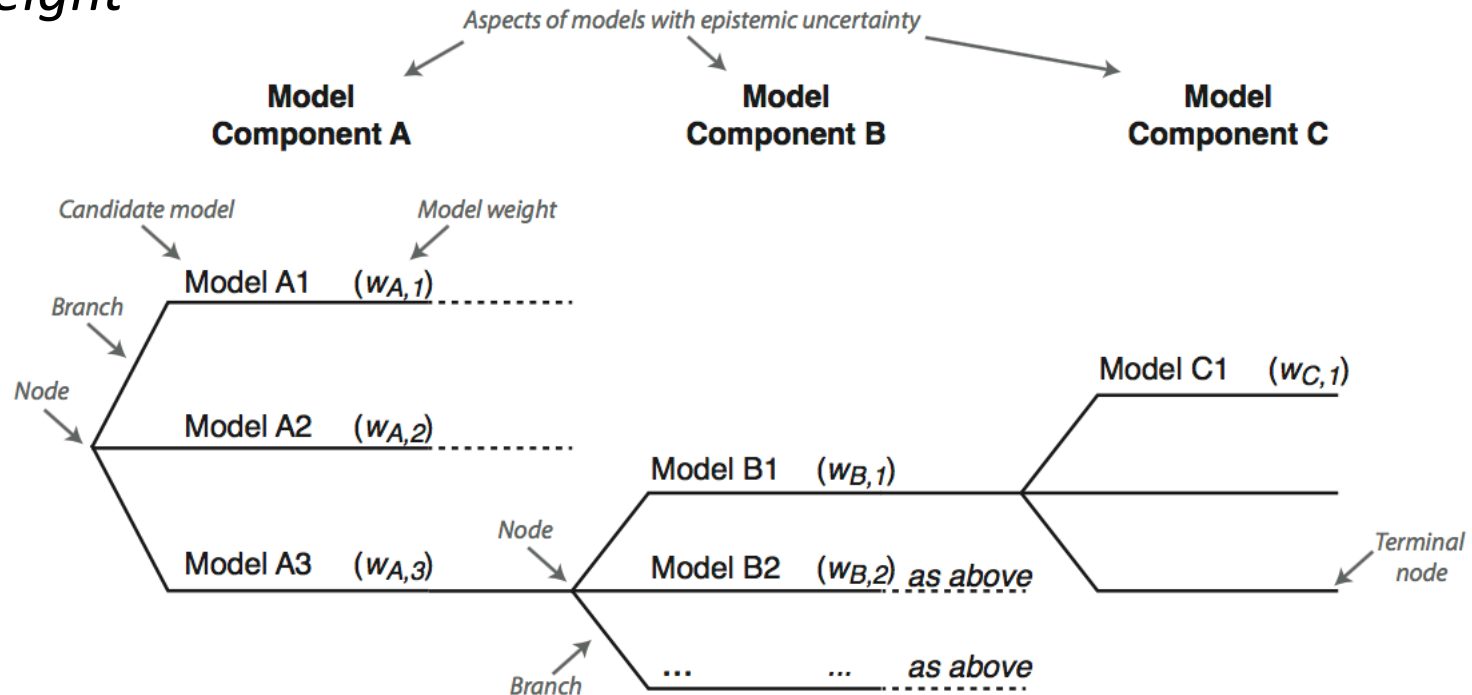
Hazard maps

Example: PGV , 2% in 50 years

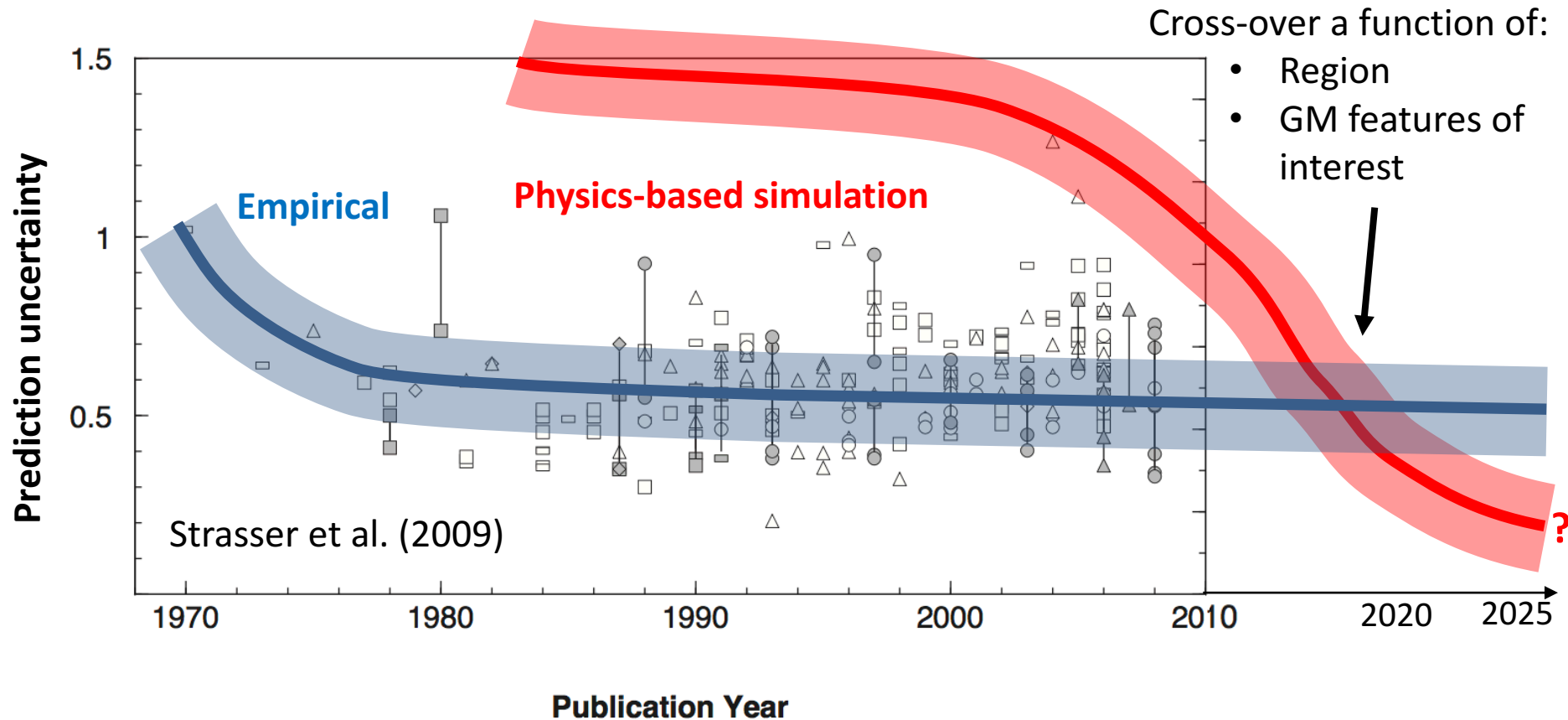


Logic trees for model uncertainty

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



Predictive capability over time



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]

The screenshot shows the SeisFinder web application interface. At the top, there is a navigation bar with the SeisFinder logo on the left and the QuakeCoRE logo on the right. The QuakeCoRE logo includes the text "QuakeCoRE" and "NZ Centre for Earthquake Resilience". Below the navigation bar, there is a horizontal menu with links: Home, Search, Help, News, Upcoming Features, About, and Signup. The "Search" link is highlighted with a mouse cursor. Below the menu, the text "Welcome to SeisFinder" is displayed. The main content area is divided into two columns. The left column contains a paragraph describing SeisFinder as a web application for extracting high-fidelity outputs from computationally-intensive earthquake resilience calculations. It mentions that the application currently focuses on providing information from ground motion simulations in a range of formats, but intends to provide outputs that cover the full hazard-to-impact pipeline of earthquake loss and resilience calculations. Below this paragraph is a link "Click here" to search for ground motions. The right column contains a "News" section with two items: "03-07-2017 Intensity Measures for Events" and "03-07-2017 New Sample Codes", followed by a "More..." link. Below the news section is an "Upcoming features" section with two items: "New selection criteria" and "Historical Events To Be Simulated", followed by a "More..." link. At the bottom of the page, there is a footer with the text "Give us your feedback" and the email address "research@quakecore.nz".

SeisFinder

QuakeCoRE
NZ Centre for Earthquake Resilience

Home Search Help News Upcoming Features About Signup

Welcome to SeisFinder

SeisFinder is a web application to enable the extraction of high-fidelity outputs from computationally-intensive earthquake resilience calculations. Currently, SeisFinder has a focus on providing information from ground motion simulations in a range of formats, but we intend to provide outputs that cover the full hazard-to-impact pipeline of earthquake loss and resilience calculations.

[Click here](#) to search for ground motions

News

- 03-07-2017 [Intensity Measures for Events](#)
- 03-07-2017 [New Sample Codes](#)

[More...](#)

Upcoming features

- [New selection criteria](#)
- [Historical Events To Be Simulated](#)

[More...](#)

Give us your feedback research@quakecore.nz

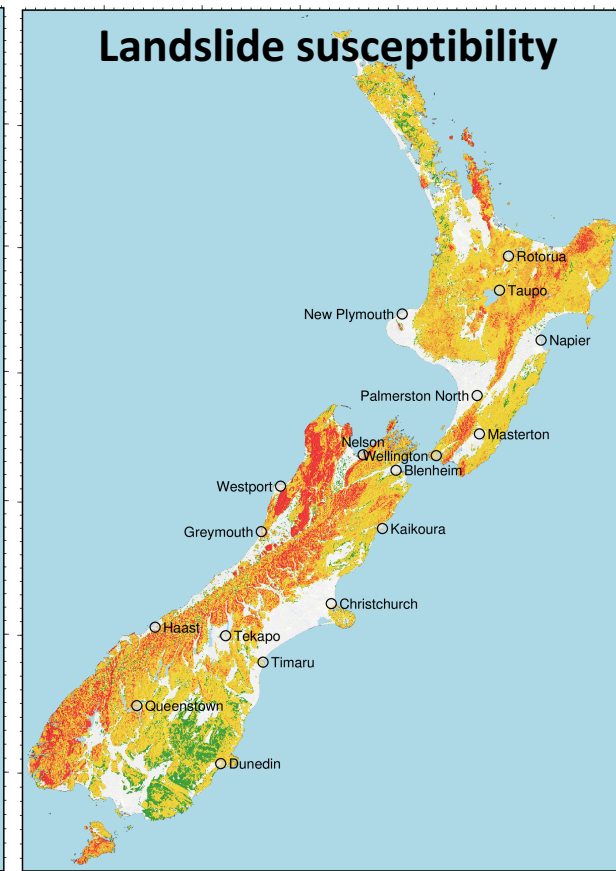
From ground motion to geohazards



200 400 600 800 1000 1200 1400
NZ-specific vs30 map – 18p4



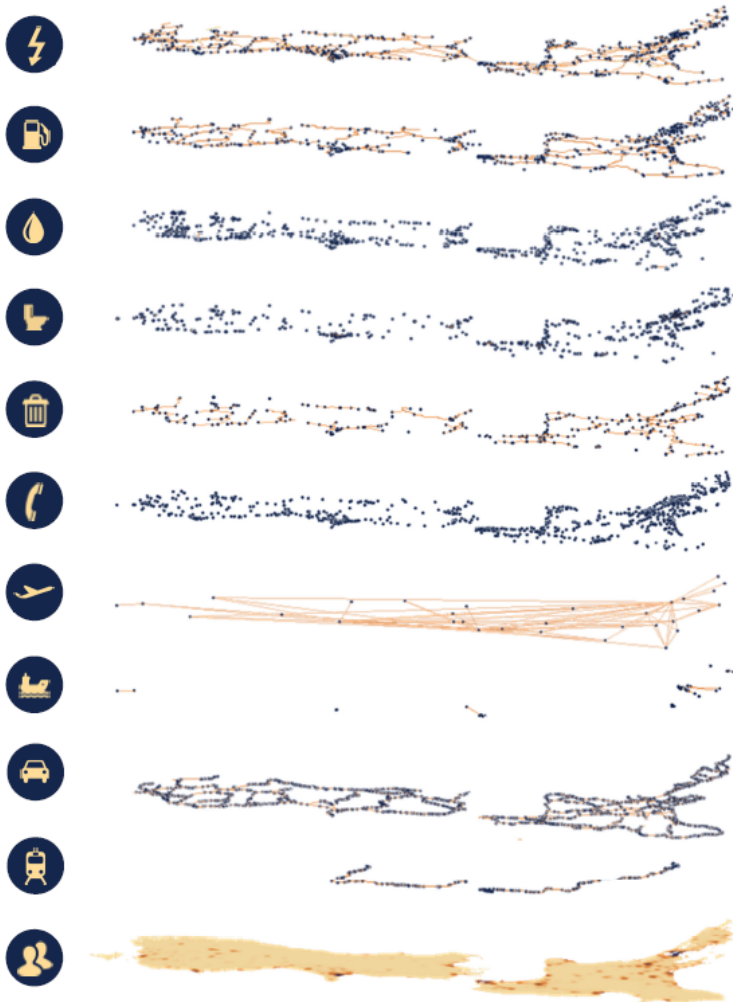
None Low Mod High V High
Liquefaction Susceptibility



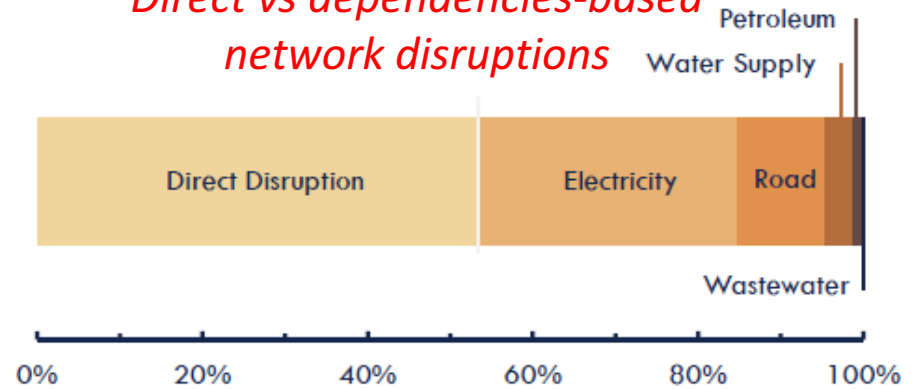
None Low Mod High V High
Landslide Susceptibility

Applied to distributed infrastructure

Hierarchical network of network models

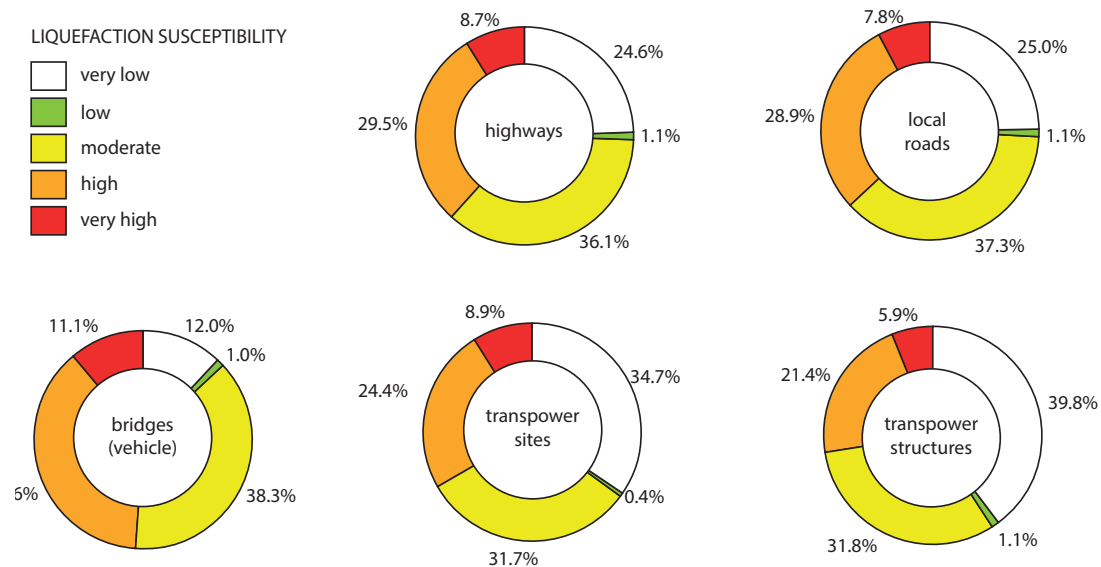


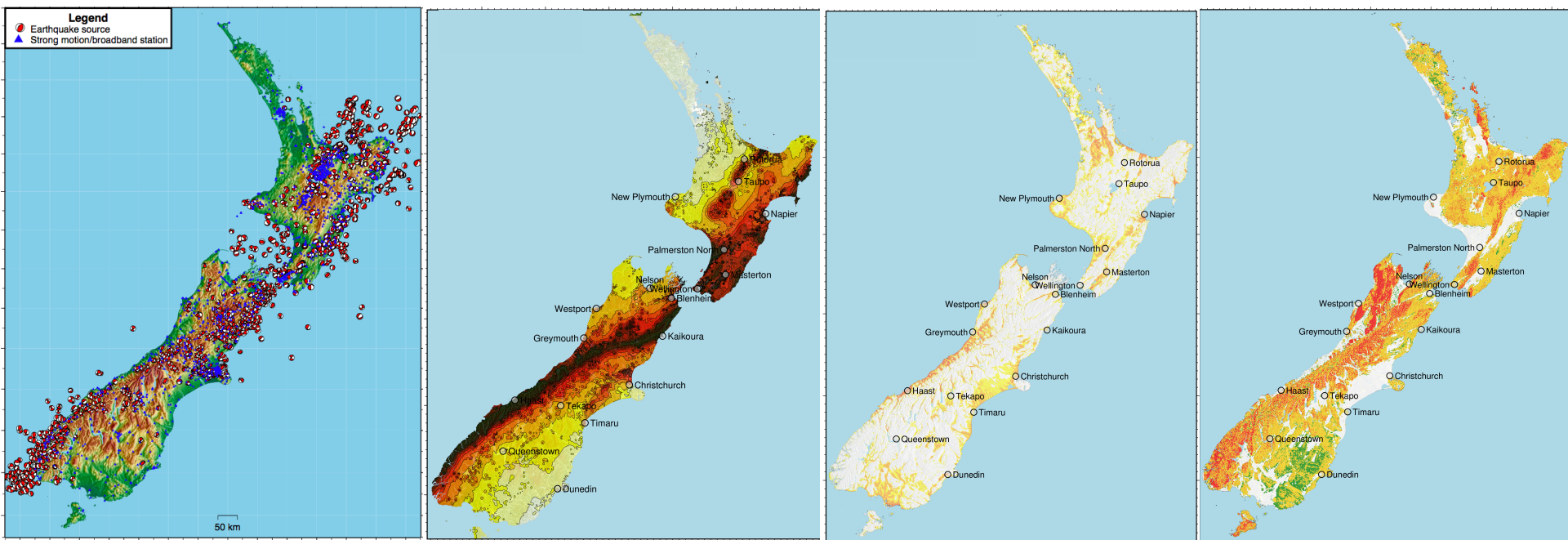
Direct vs dependencies-based network disruptions



Geohazard overlay: Liquefaction exposure of electric and transport networks

LIQUEFACTION SUSCEPTIBILITY



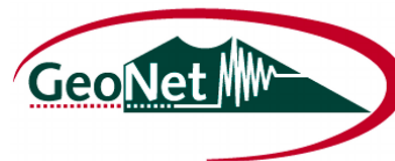


Thank you for your attention

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

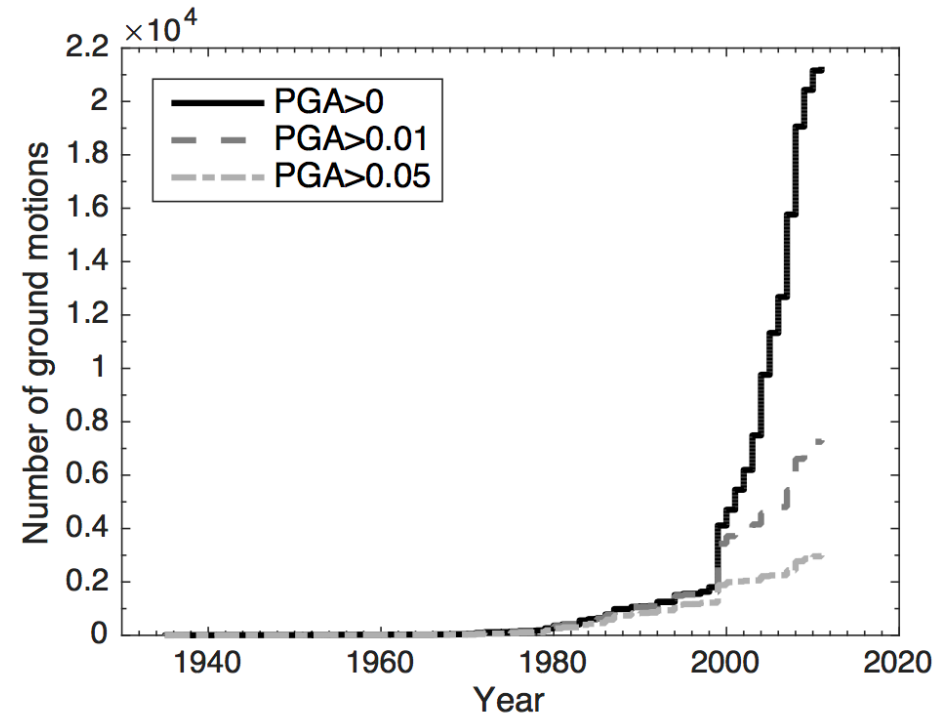
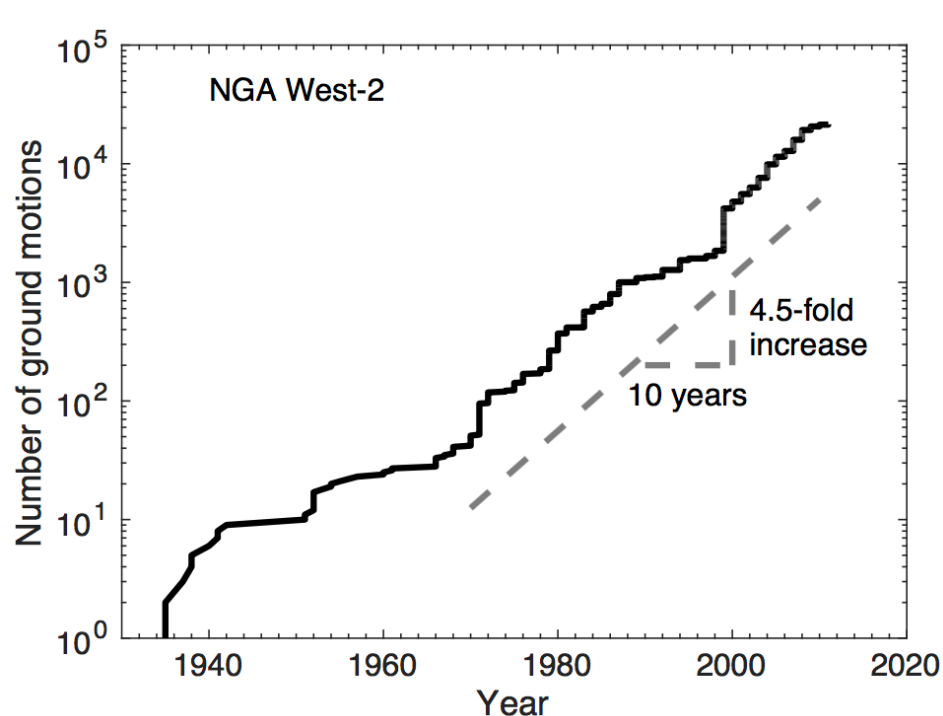


an NSF + USGS center



Leveraging exponential technologies

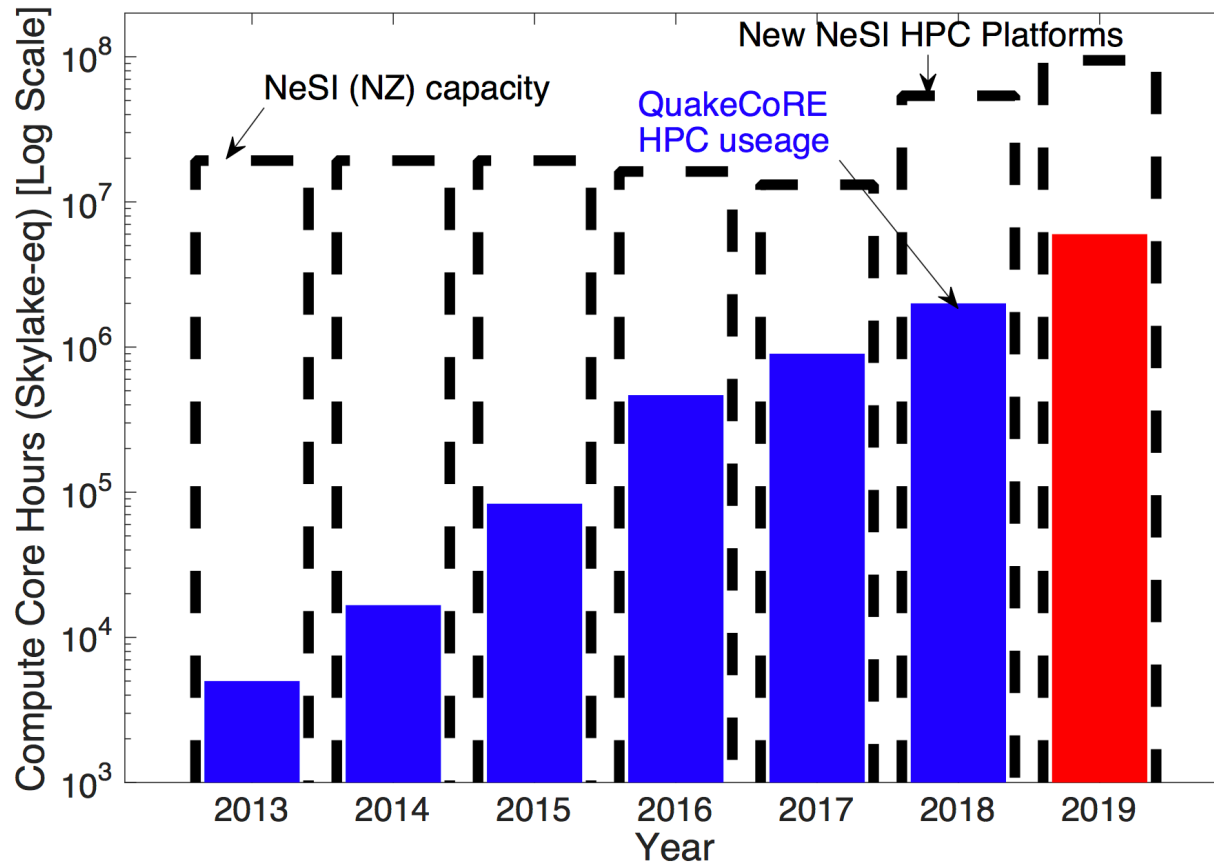
- Measurements: doubling every 4.4 years



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)

