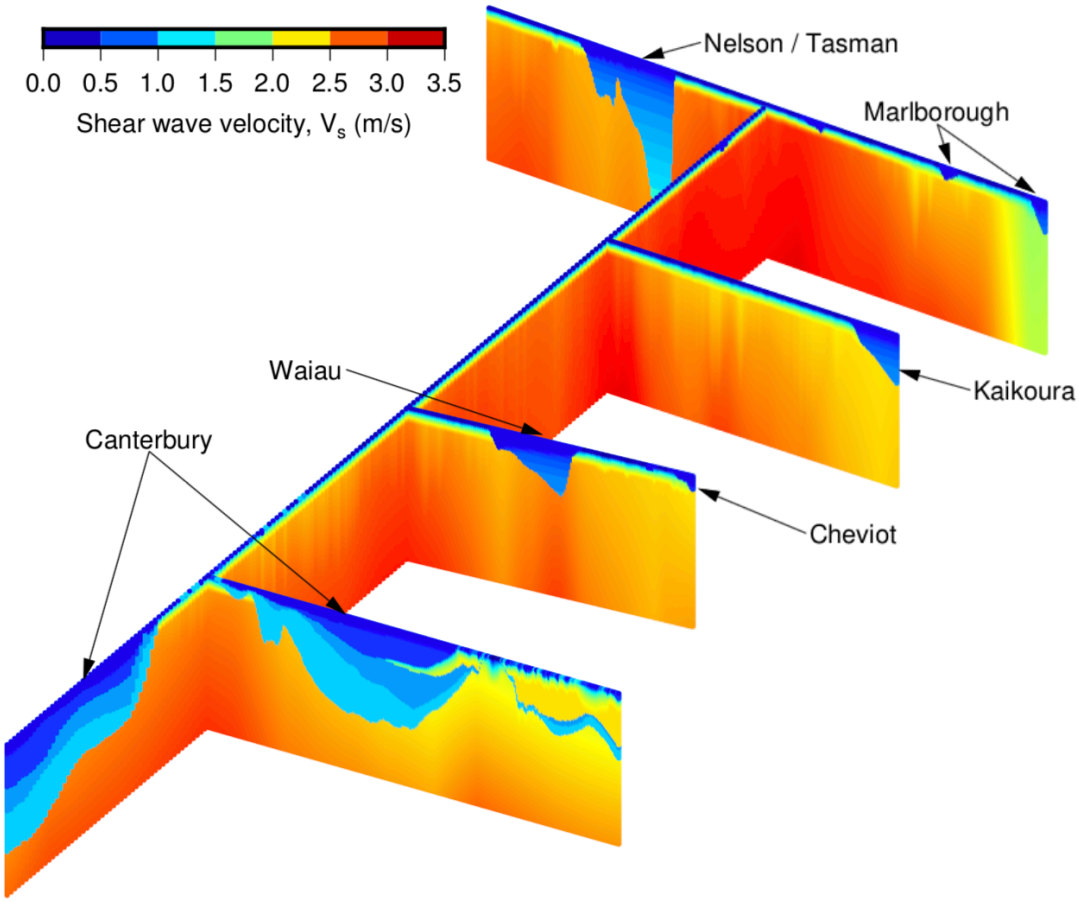
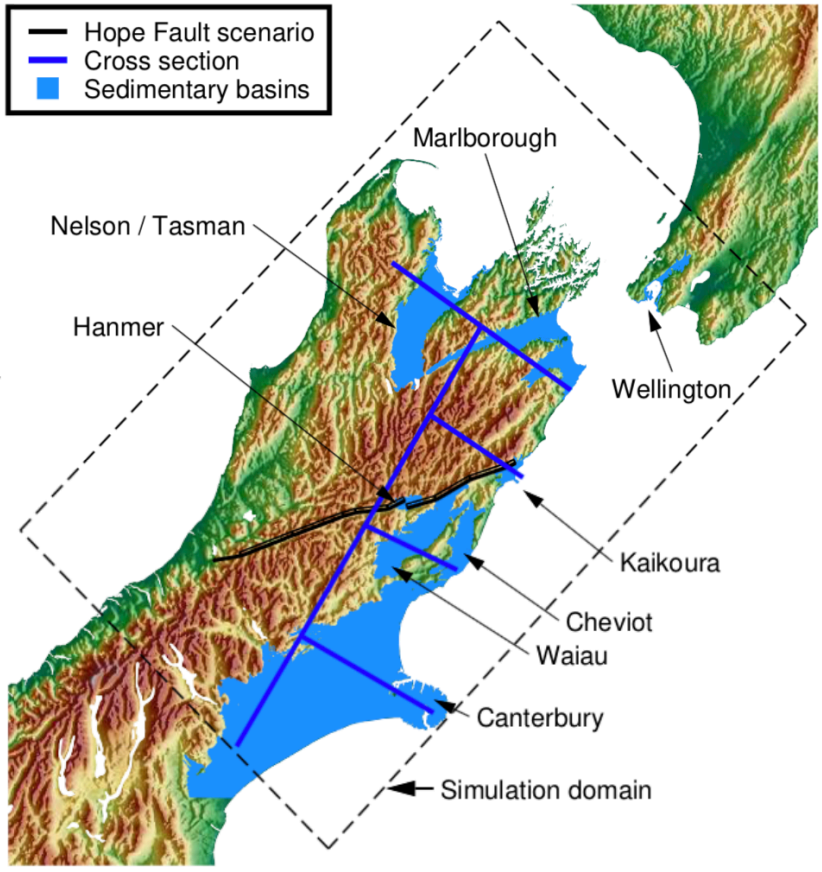
The New Zealand Community Velocity Model (NZVM): Development, iteration and applications



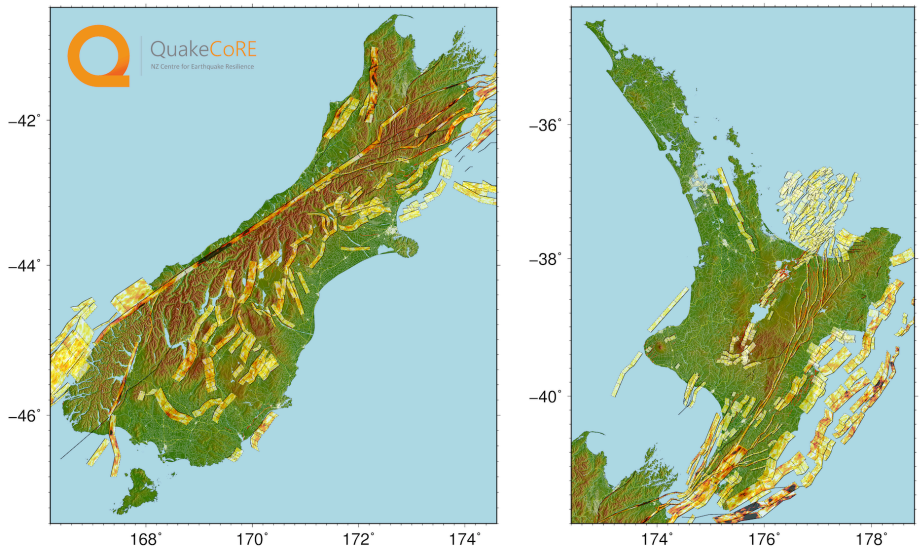


Brendon Bradley, University of Canterbury, New Zealand

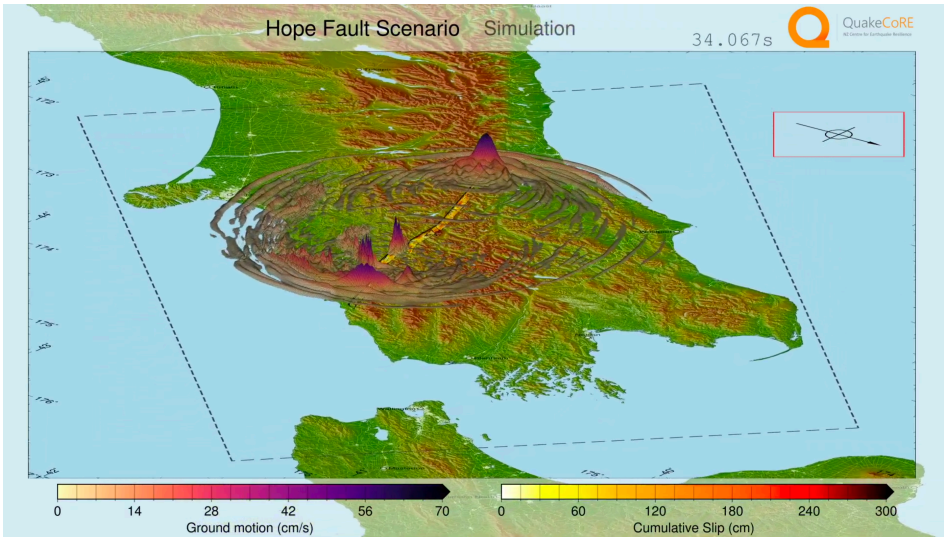
Overview

1. Primary motivation for NZVM
2. NZVM details
3. Validation: Ground motion simulation
4. On-going work on FWT

Primary motivation: GM Simulation

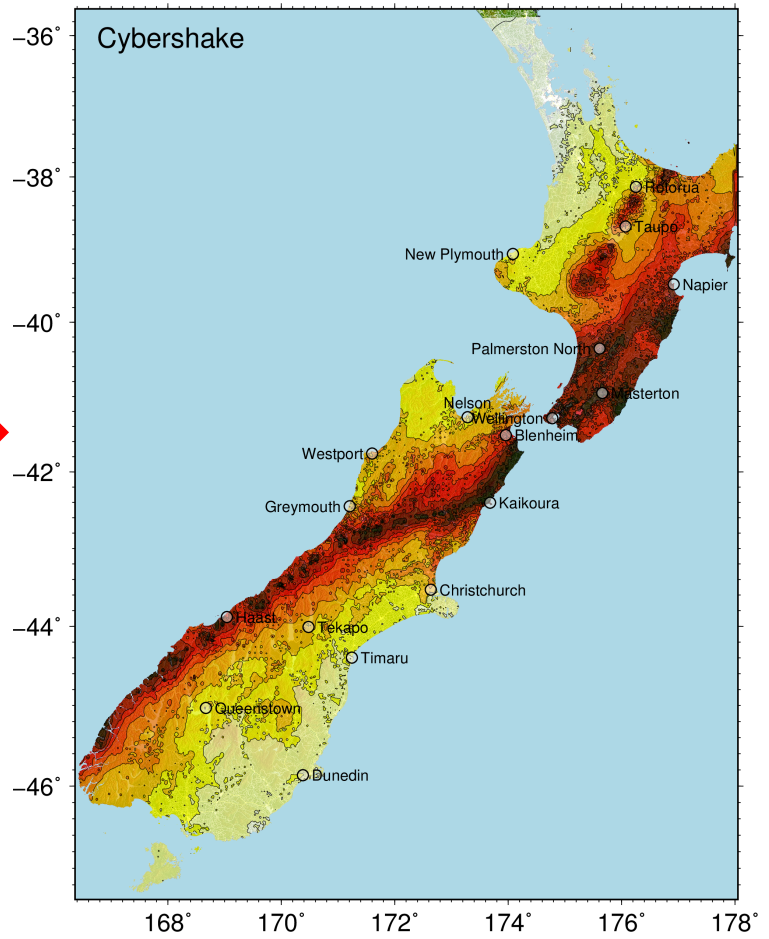


Earthquake Rupture Forecast



Ground motion prediction

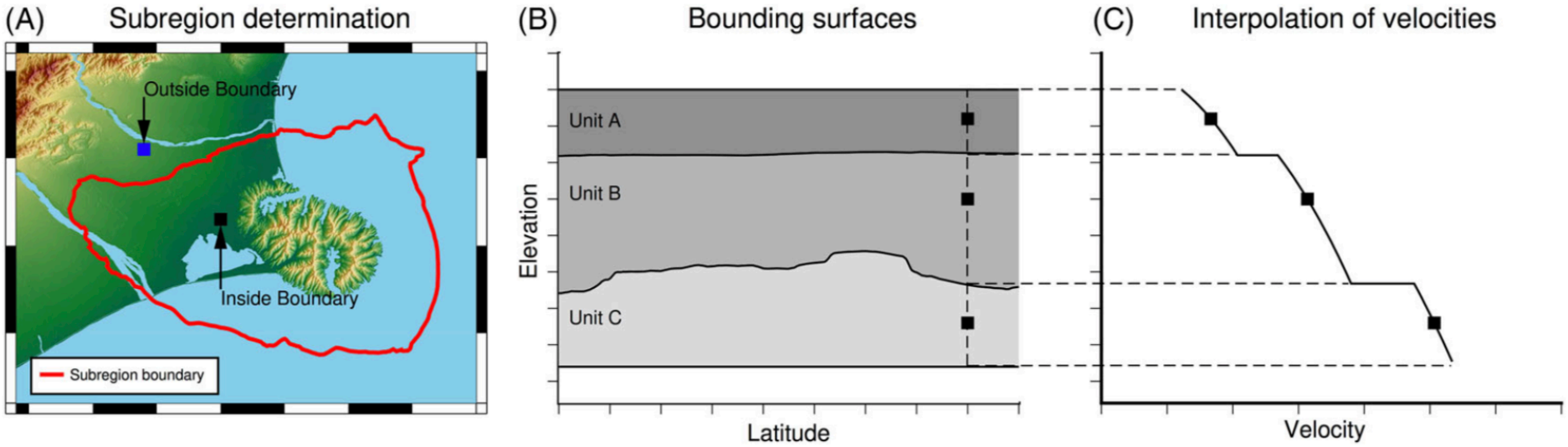
Probabilistic hazard outputs



Bradley et al. (2019)
SCEC Poster #019

NZVM Framework

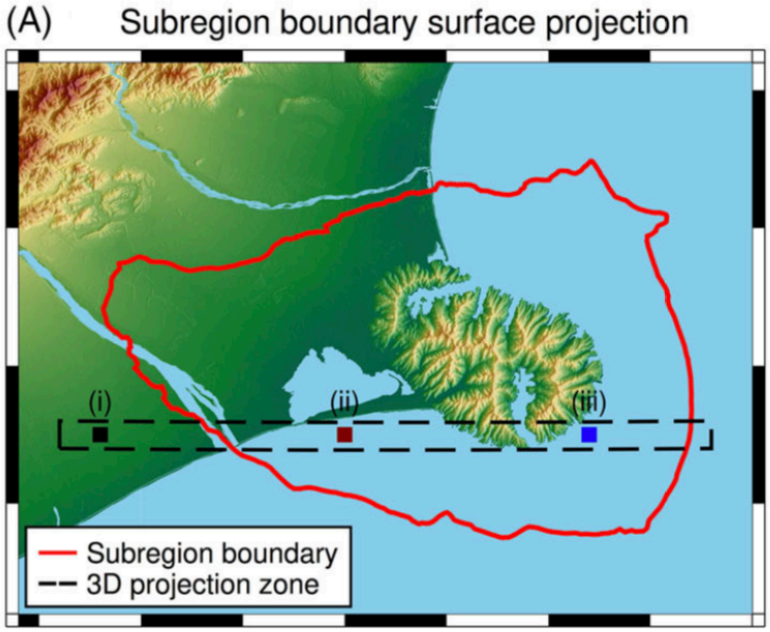
- ‘Surface’ based approach, allowing flexible prescription of velocity parametrization within volumes

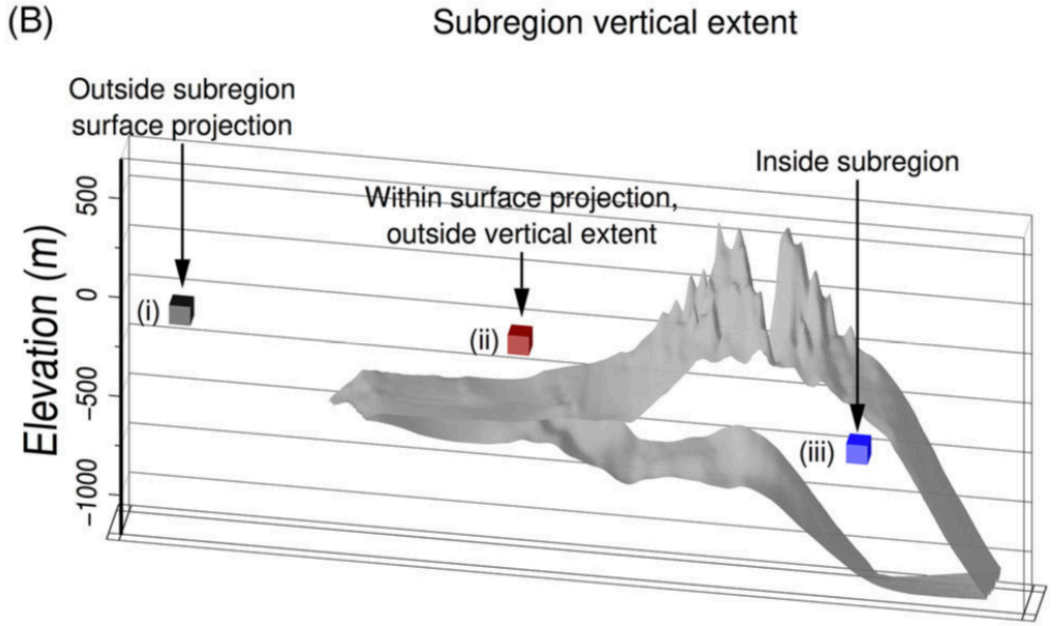


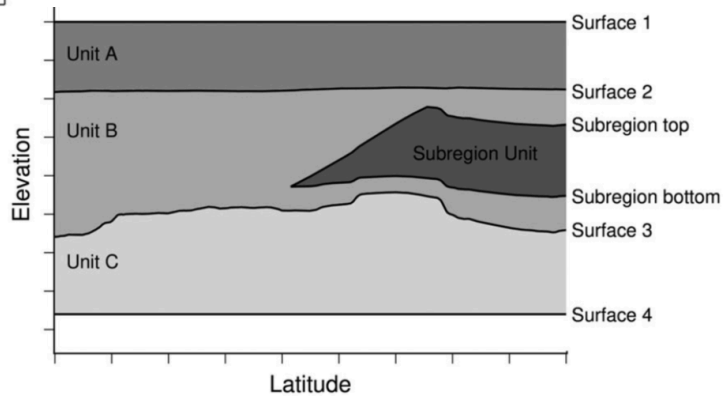
Thomson et al. (2019) *NZJGG*

Sub-region definition

- Sub-region notion to limit the geographical extent required for specifying surfaces



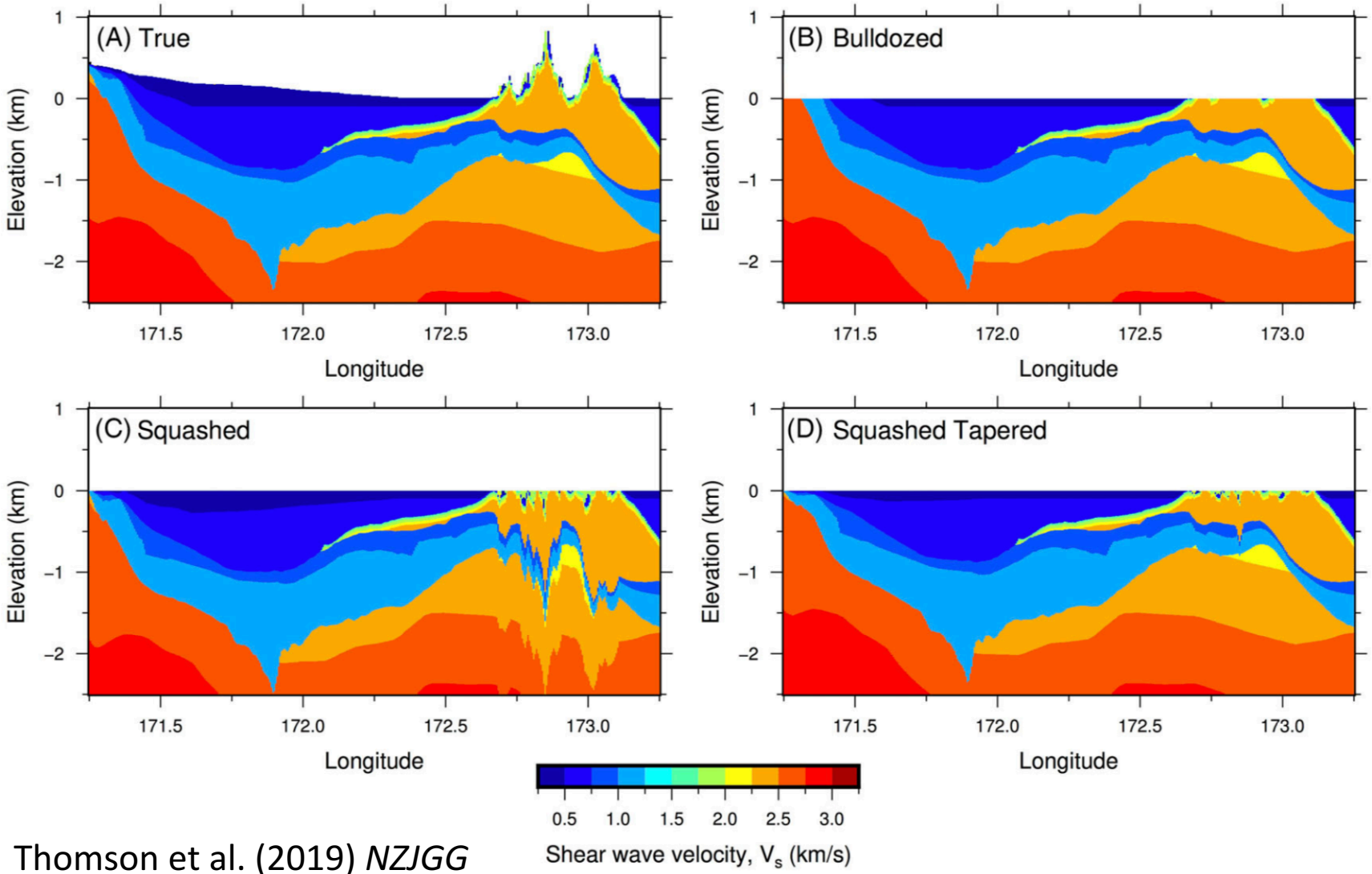




Thomson et al. (2019) *NZJGG*

Topographic representation

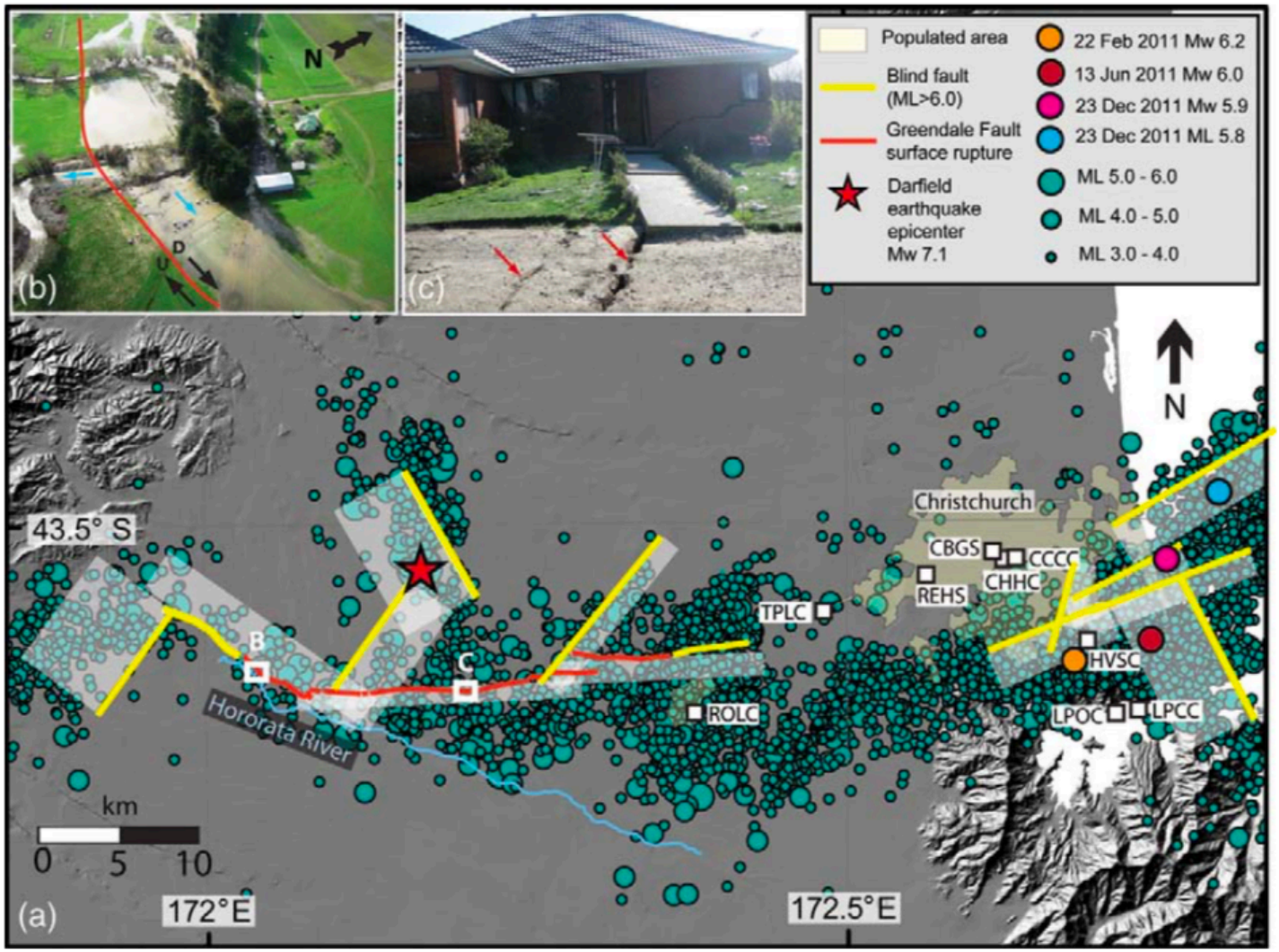
- Four options for topography



Thomson et al. (2019) *NZJGG*

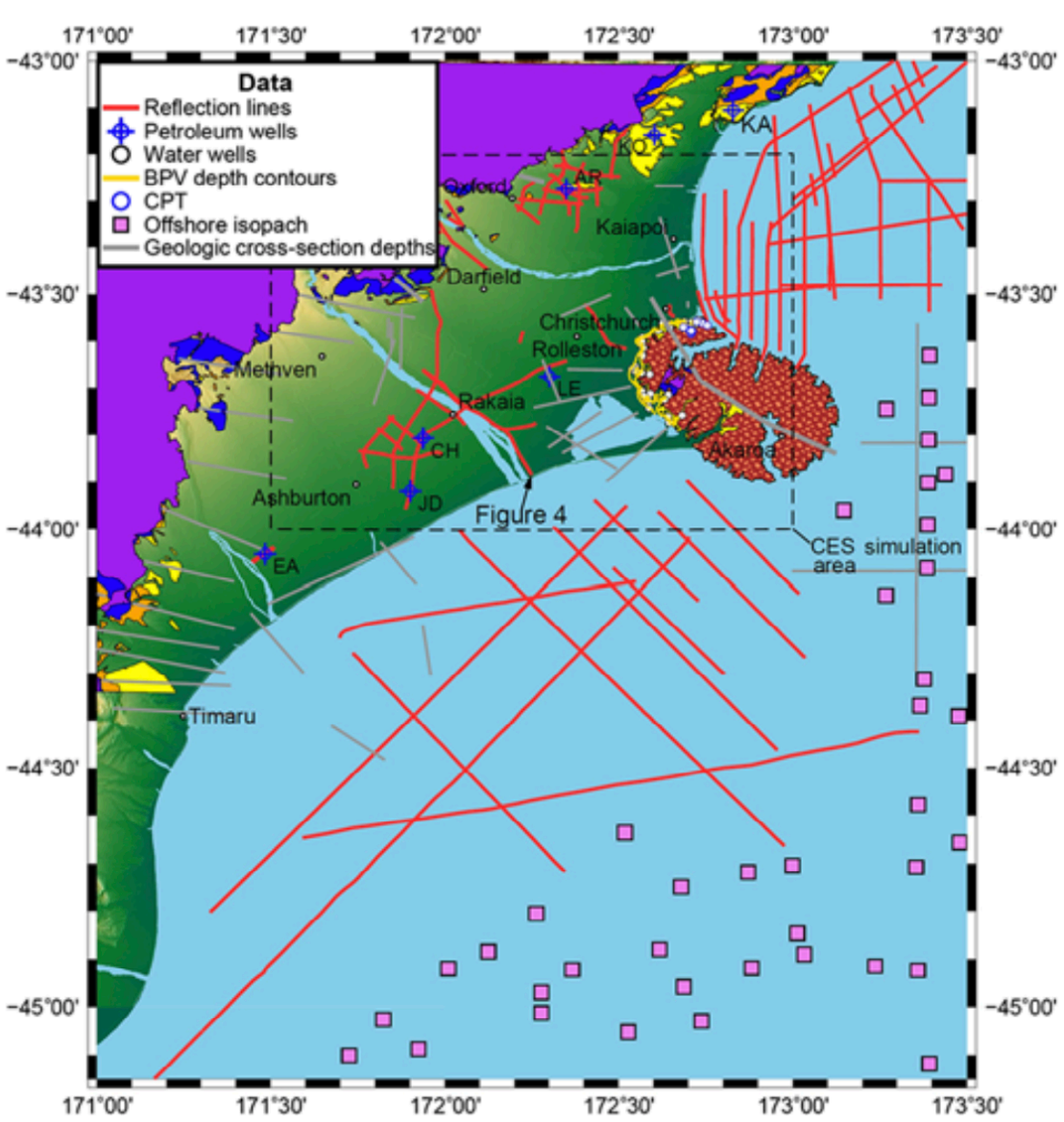
NZVM 1.X – Canterbury NZ

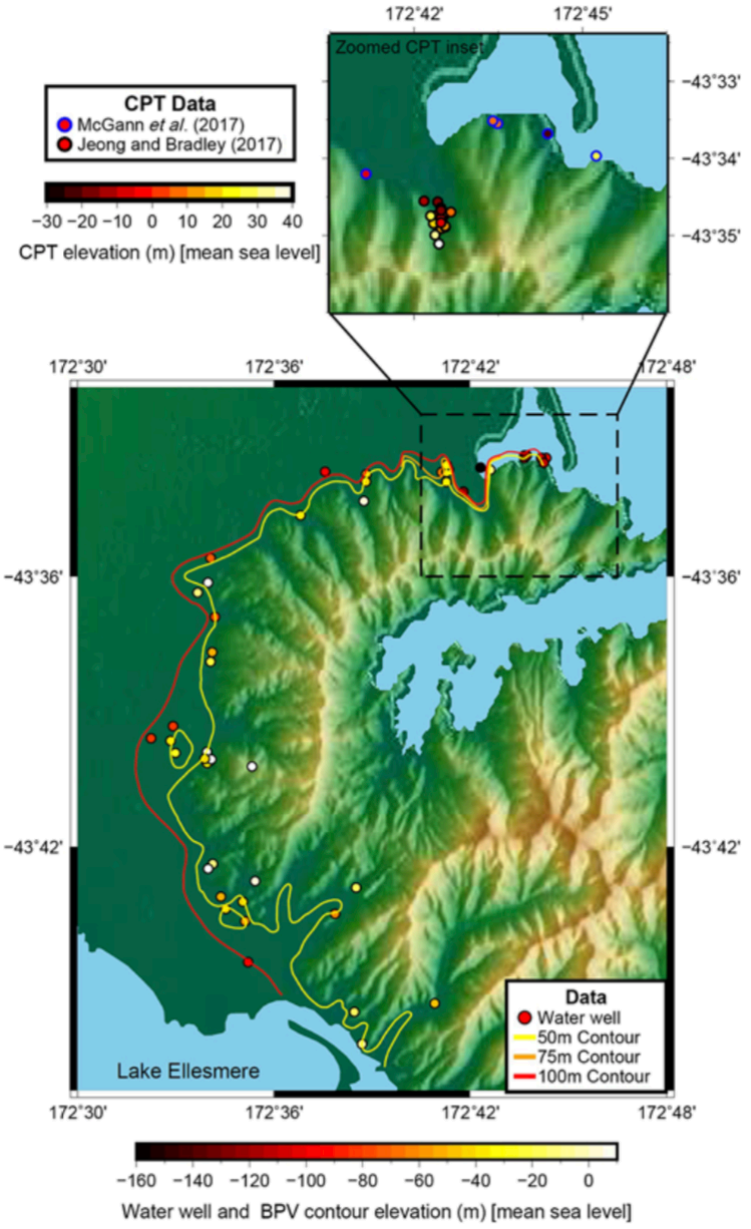
Motivation: Perform ground motion simulations for events in the 2010-2011 Canterbury earthquake sequence



Bradley et al. (2014) *Eq. Spectra.*

Datasets considered in VM development

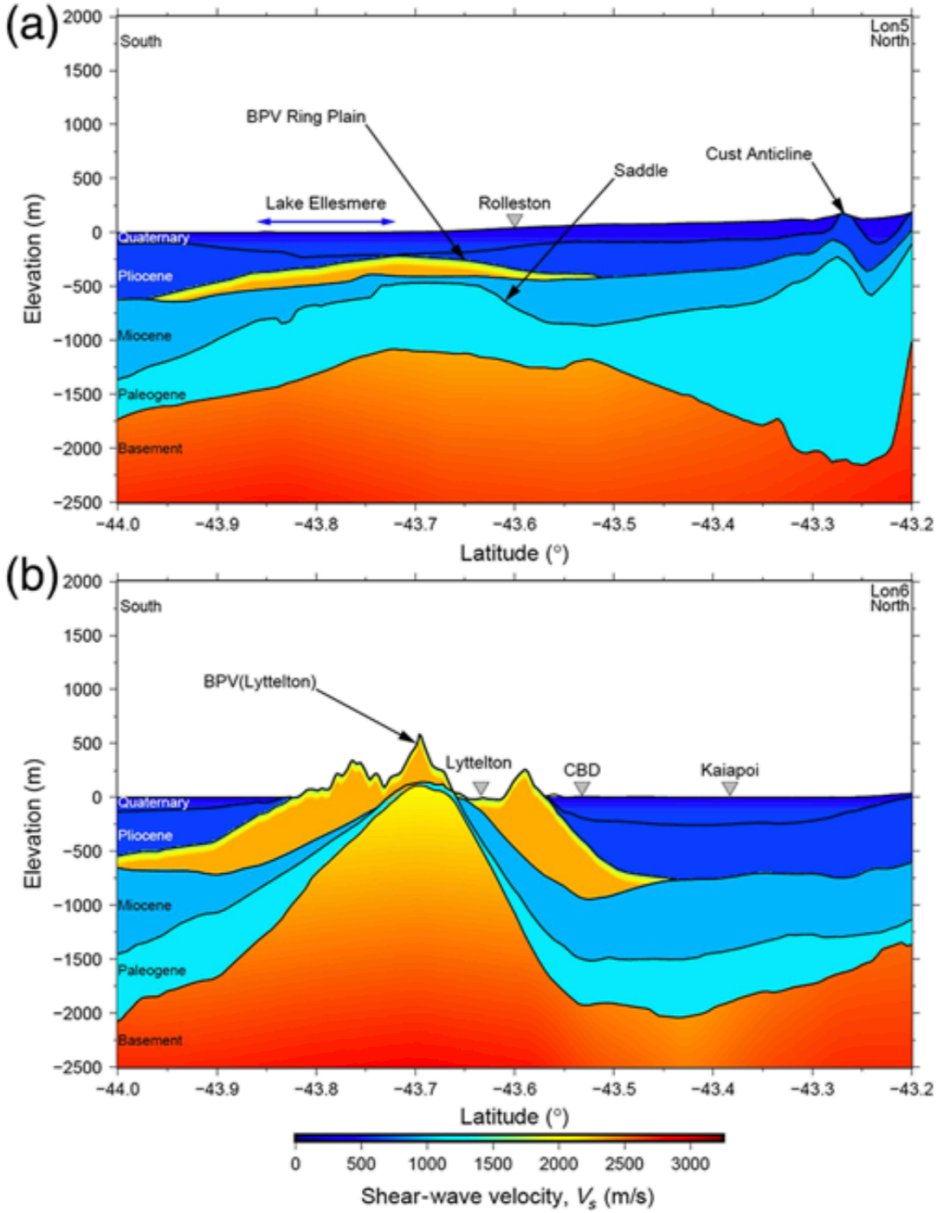




Lee et al. (2017) *BSSA*

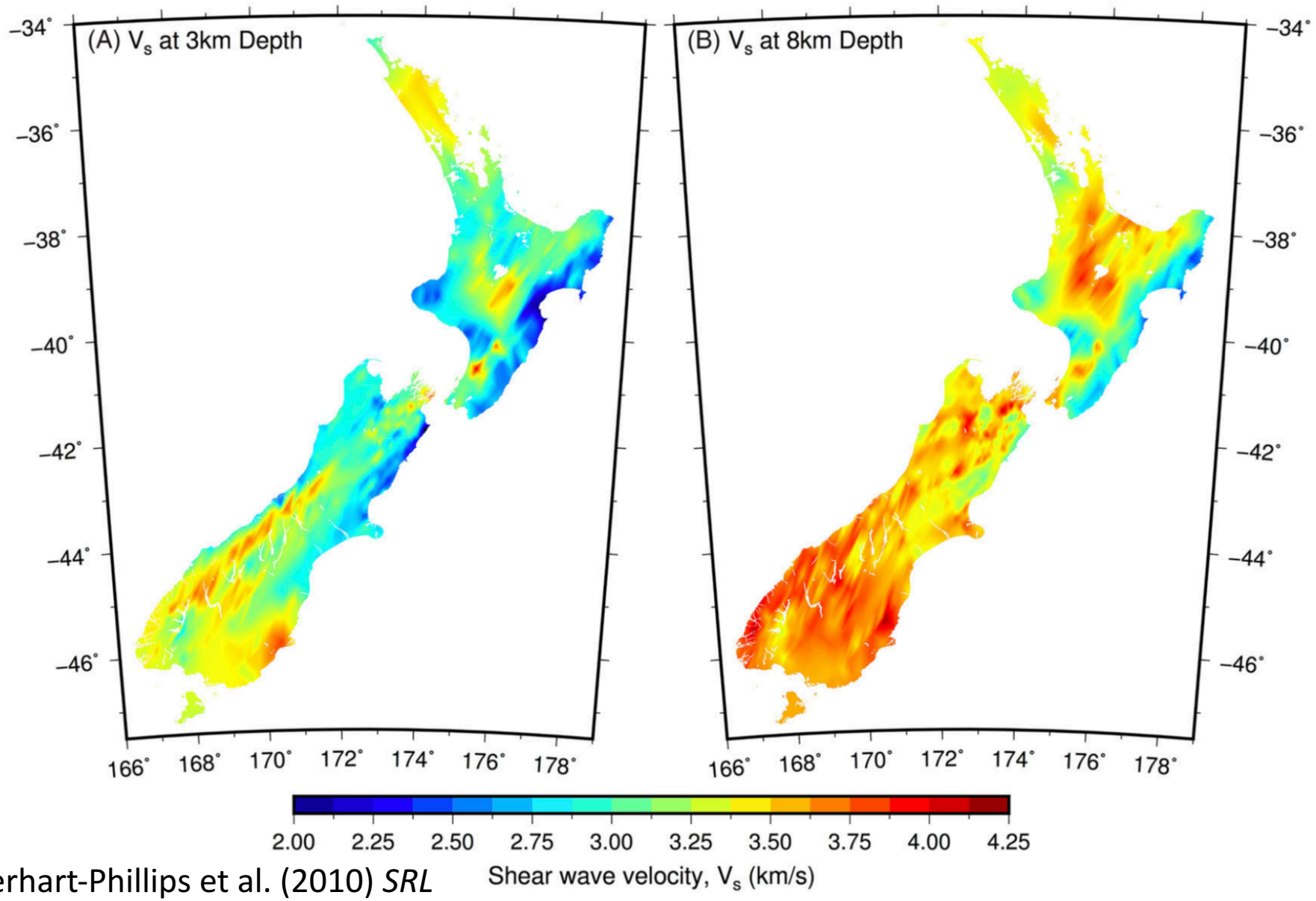
Surfaces based on lithographic properties

Unit* and reflections	Equivalent formation and inferred age (Ma)
	Ground surface
Quaternary	Interbedded gravels, silts and sandstones
Pliocene	Kowai Formation (about 4–1.2 Ma)
ⓐ	a. Banks Peninsula volcanics (~11–6 Ma)
ⓑ Miocene	b. Tokama Siltstone (5.0 Ma) and interbedded sandstones and mudstones
Paleogene	Amuri Limestone (30 Ma) and interbedded sandstones and mudstones
Late Cretaceous	Conway and Broken River formations (65 Ma), sandstones, mudstones and coal
ⓒ	c. Mt. Somers volcanics (89 Ma)
Basement	Torlesse Composite Terrane (>120 Ma), graywackes and schists



Except for the basement and Quaternary models, velocities constant within a given layer (insufficient data to constrain depth-dependent velocity at the time)

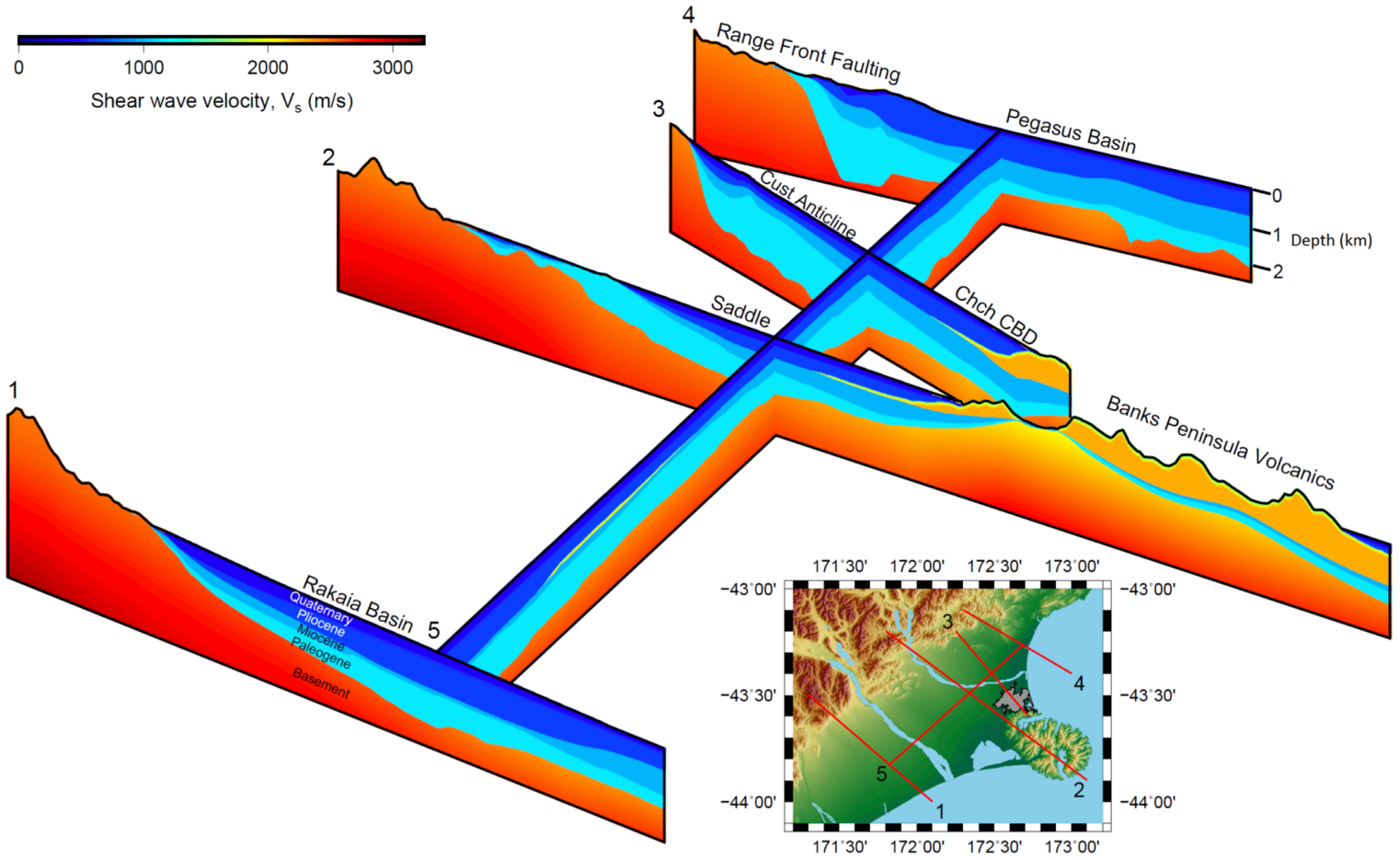
NZ-wide 3D crustal model ('basement' below basins)



Eberhart-Phillips et al. (2010) *SRL*

NZVM 1.67 – Canterbury NZ

- Fence diagram along five transects



Lee et al. (2017) *BSSA*

NZVM 2.X - Extension to NZ-wide model

- Desire to consider all sedimentary basins in NZ
- Variable data quality - Introduced 'Type' classification
- Currently 10 basins implemented

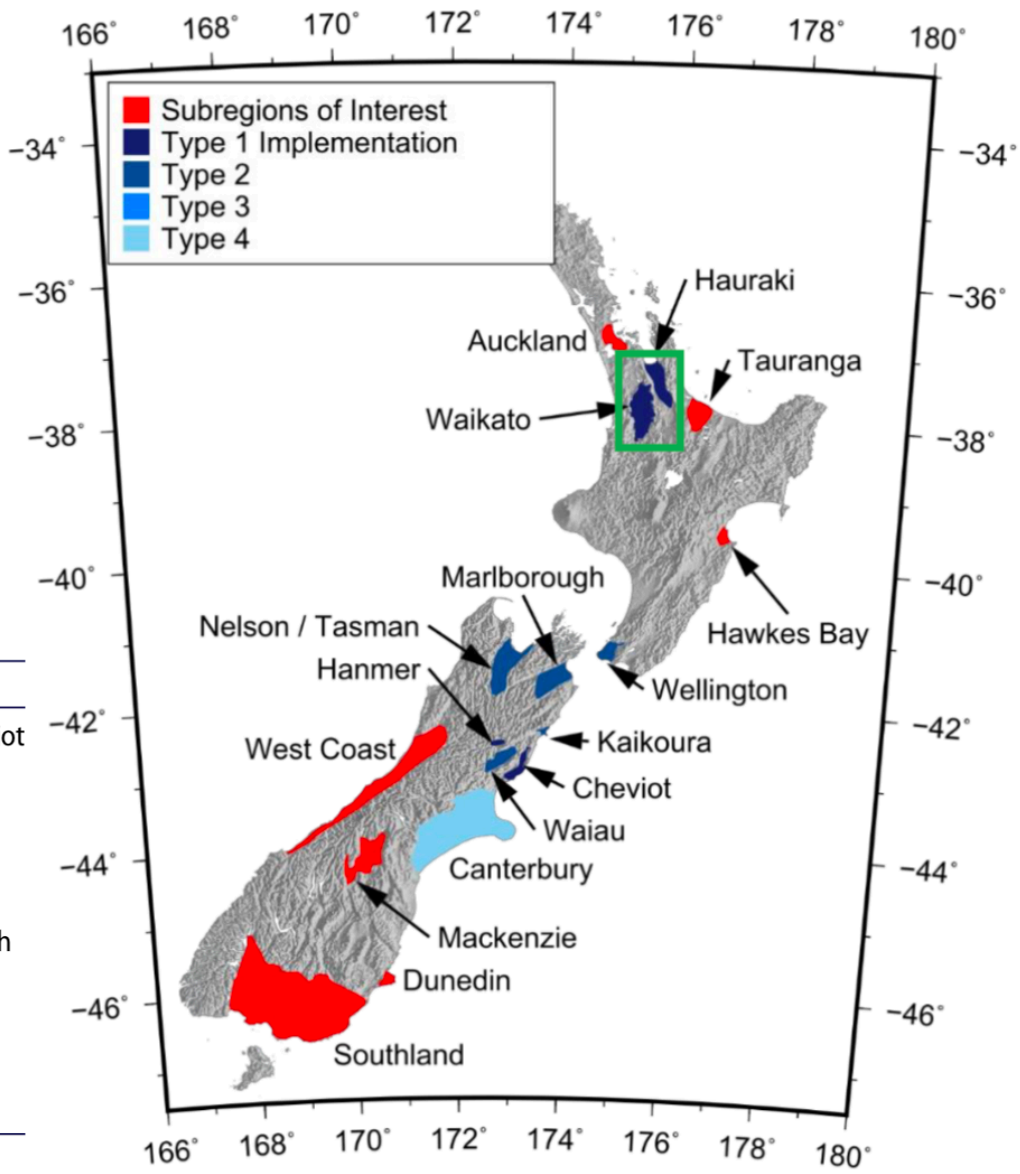
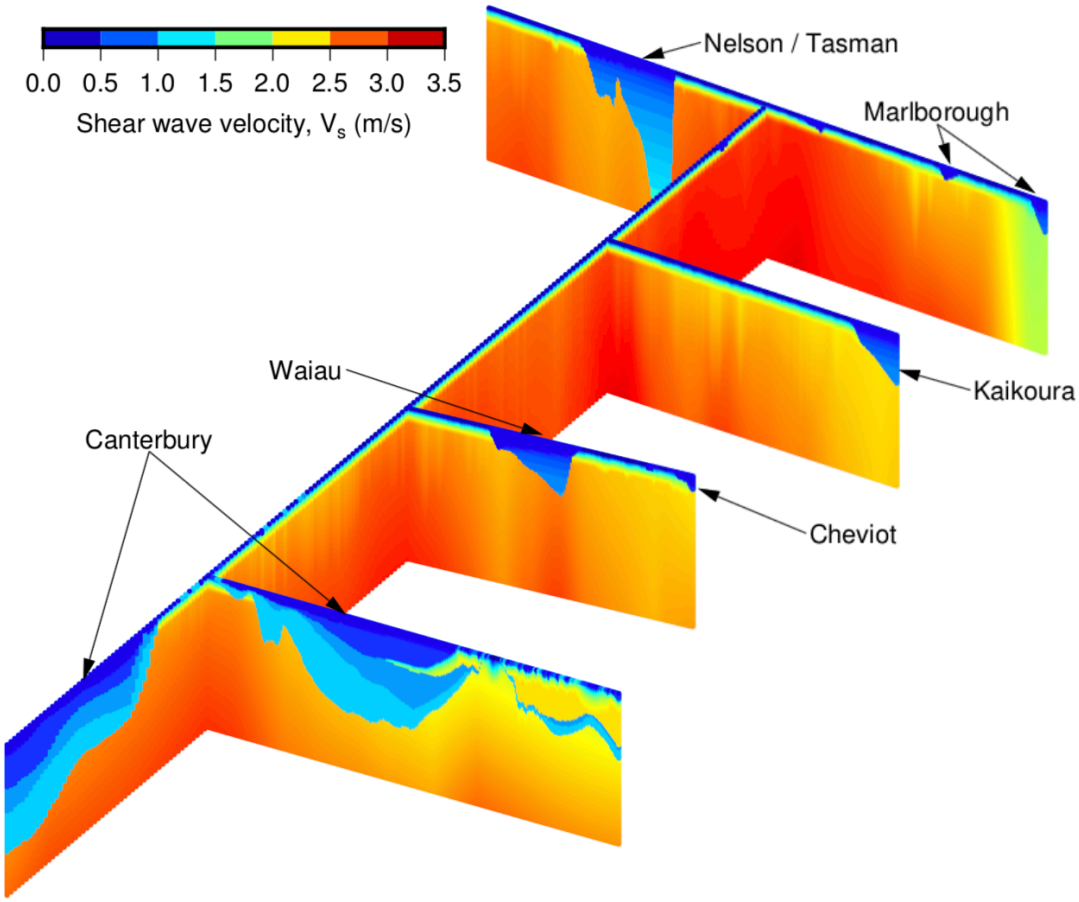


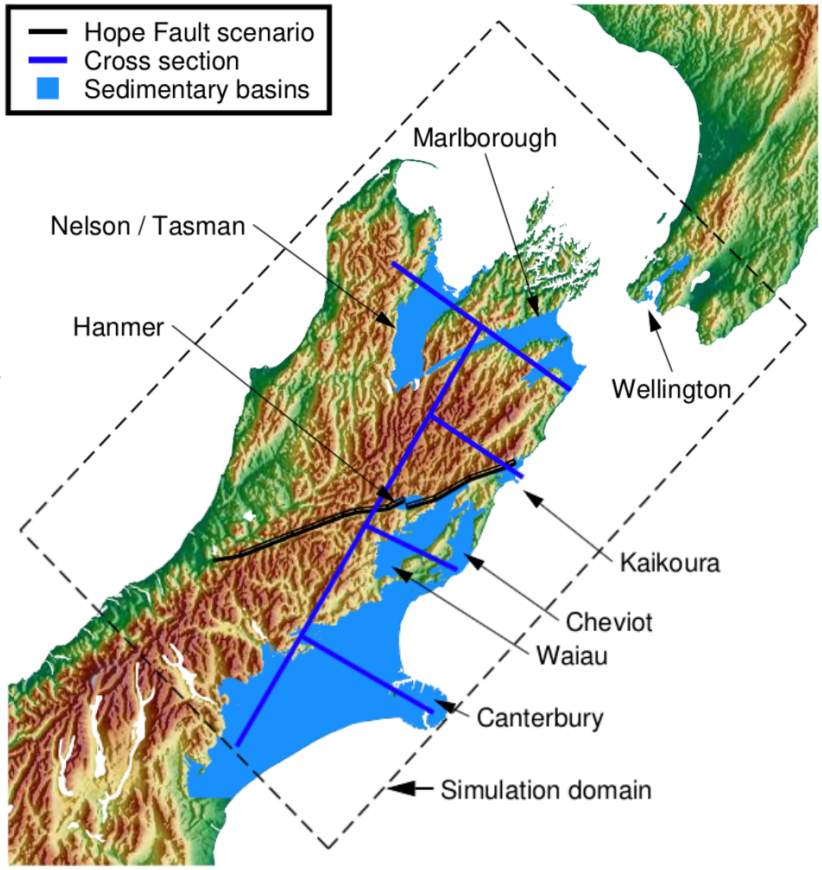
Table 1. Characteristics of NZVM2.0 subregion types.

Type	Features	Subregions
1	No direct measurements. Basin geometry based on topographic slope at outcrops, geologic cross sections. Generic 1D basin velocity model.	Hanmer Cheviot
2	As for 1, but incorporating direct measurements used to infer basin surface depth (e.g. ambient measurements, HVSR).	Waiau Kaikōura Marlborough
3	As for 2, but incorporating velocity profile information allowing departure from generic model.	Wellington Nelson-Tasman
4	Arbitrarily complex model, multiple geologic surfaces and specific velocity modelling.	Canterbury

Thomson et al. (2019) *NZJGG*

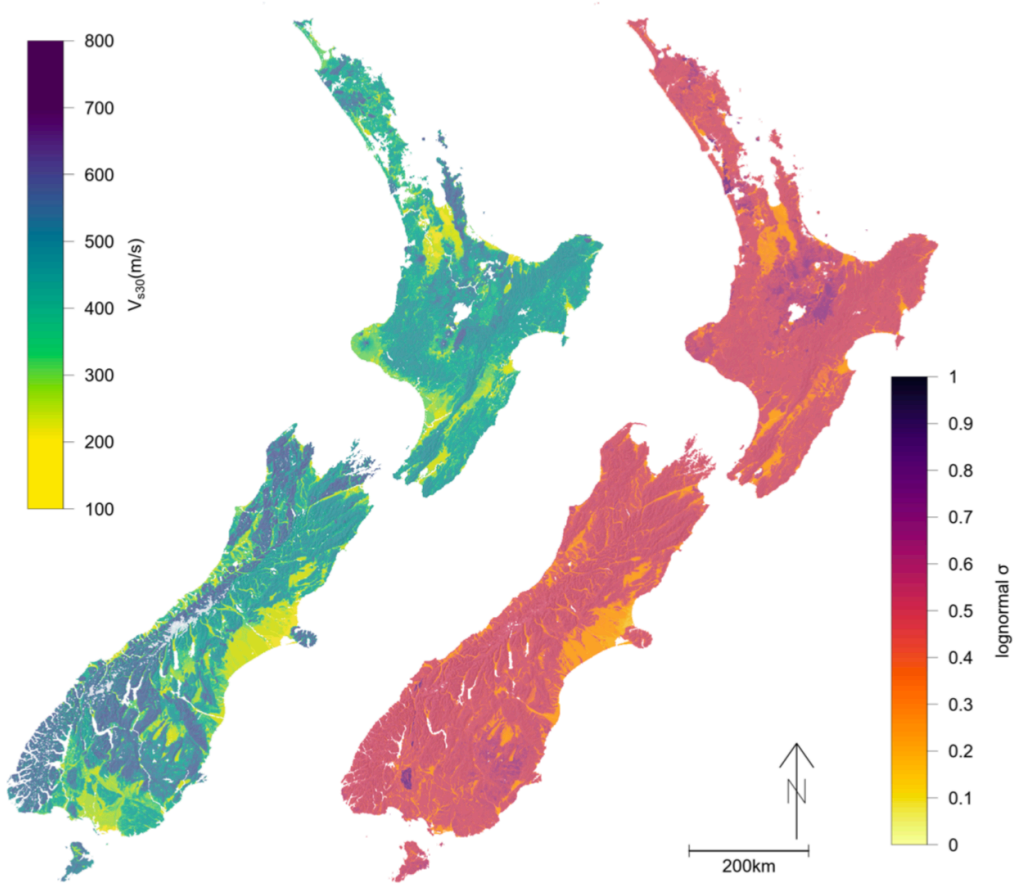
Example


0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
Shear wave velocity, V_s (m/s)
Nelson / Tasman
Marlborough
Waiau
Kaikoura
Canterbury
Cheviot


Hope Fault scenario
Cross section
Sedimentary basins
Marlborough
Nelson / Tasman
Hanmer
Wellington
Kaikoura
Cheviot
Waiau
Canterbury
Simulation domain

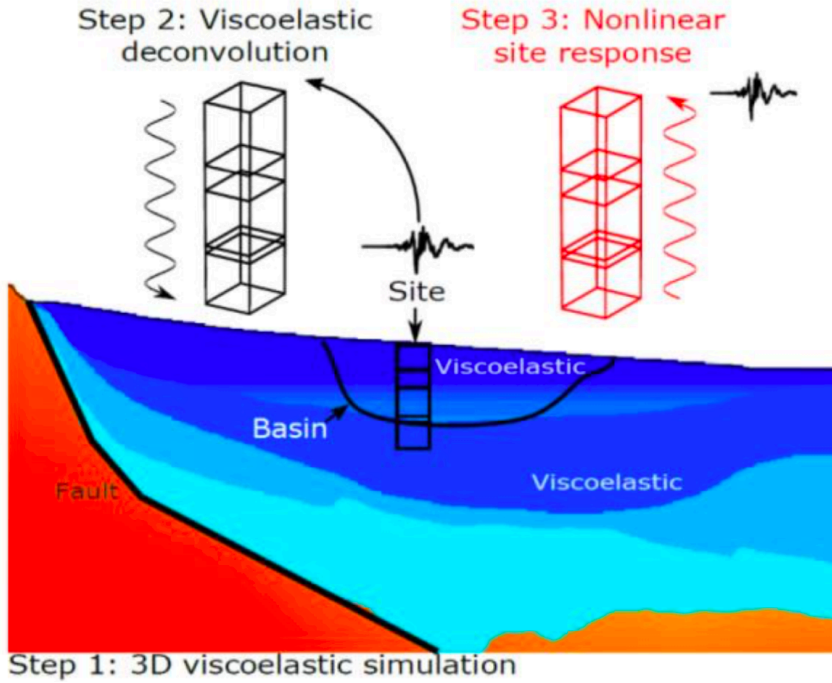
Shallow VM representation

Approach 1: Shallow site-effect modelling via Vs30 for regional modelling ('Vs30-taper')



Foster et al. (2019) *Eq. Spectra*

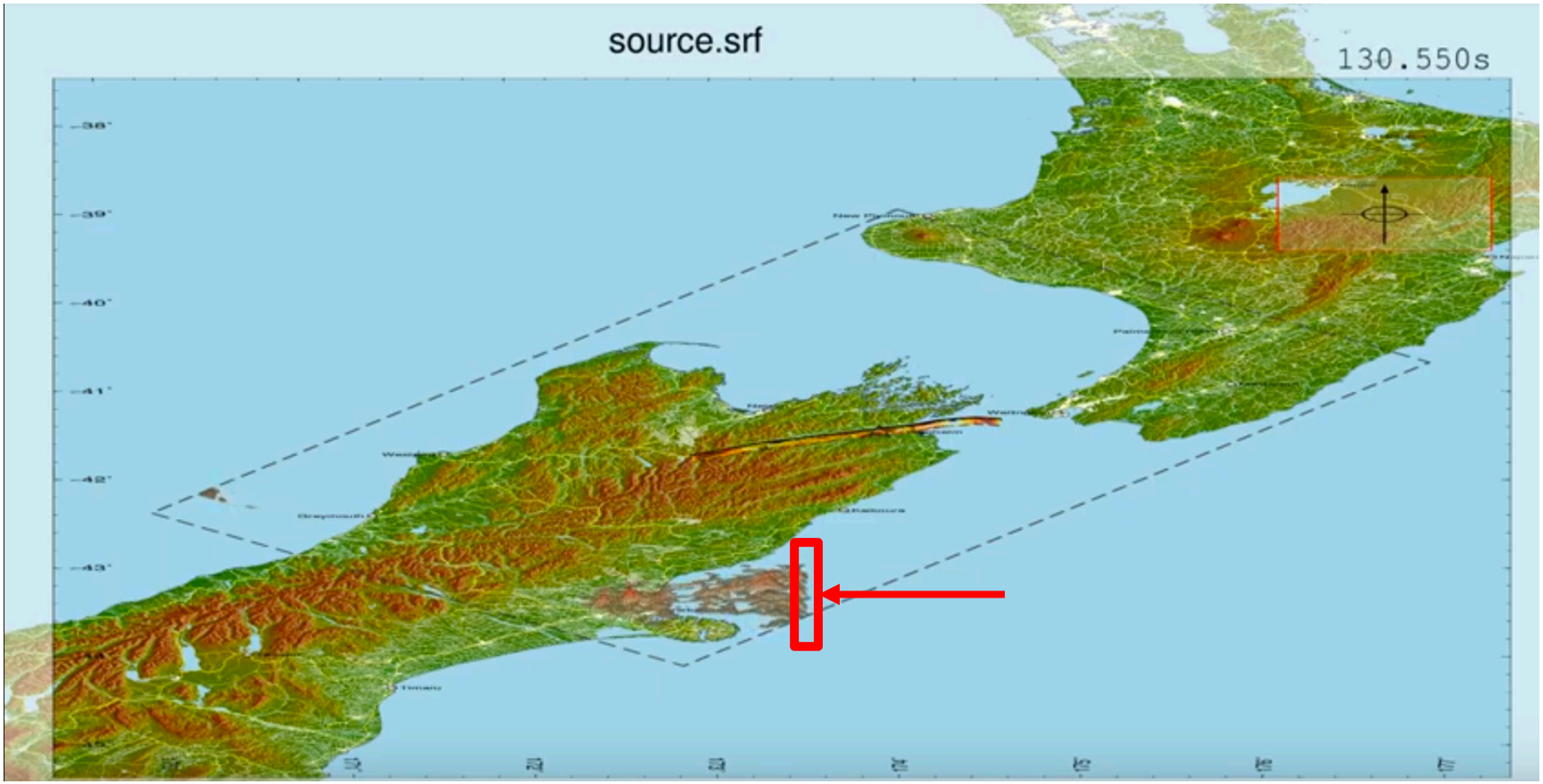
Approach 2: Site-specific geotechnical response for location-specific modelling



de la Torre et al. (2019) *Soil Dy. Eq. Eng.*

‘Boundary’ effects

- (1) splicing of different regional crustal models; (2) sedimentary basin boundaries with non-zero depth – mainly offshore edges

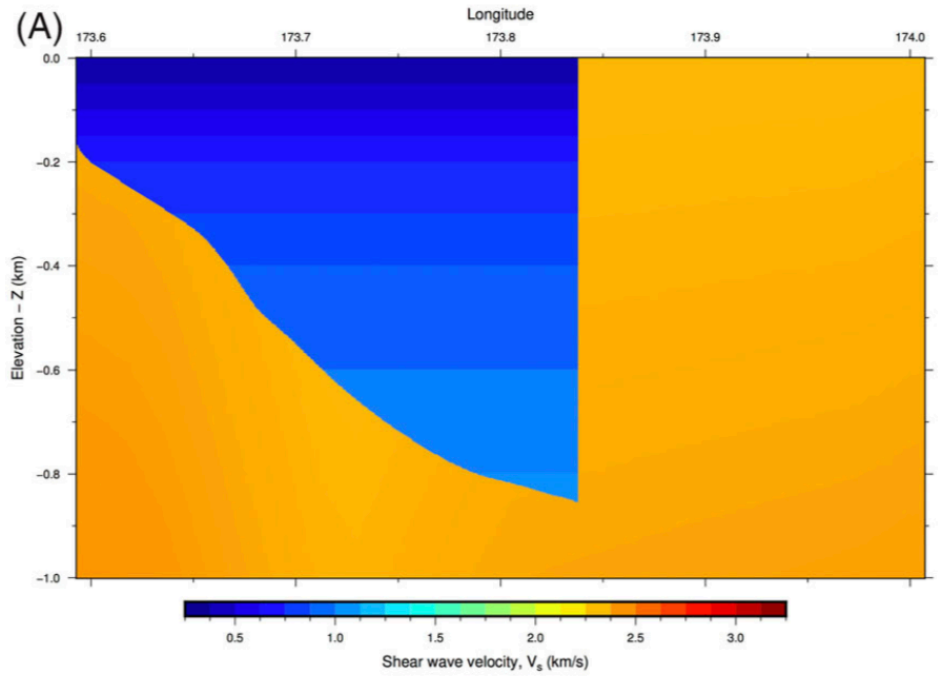


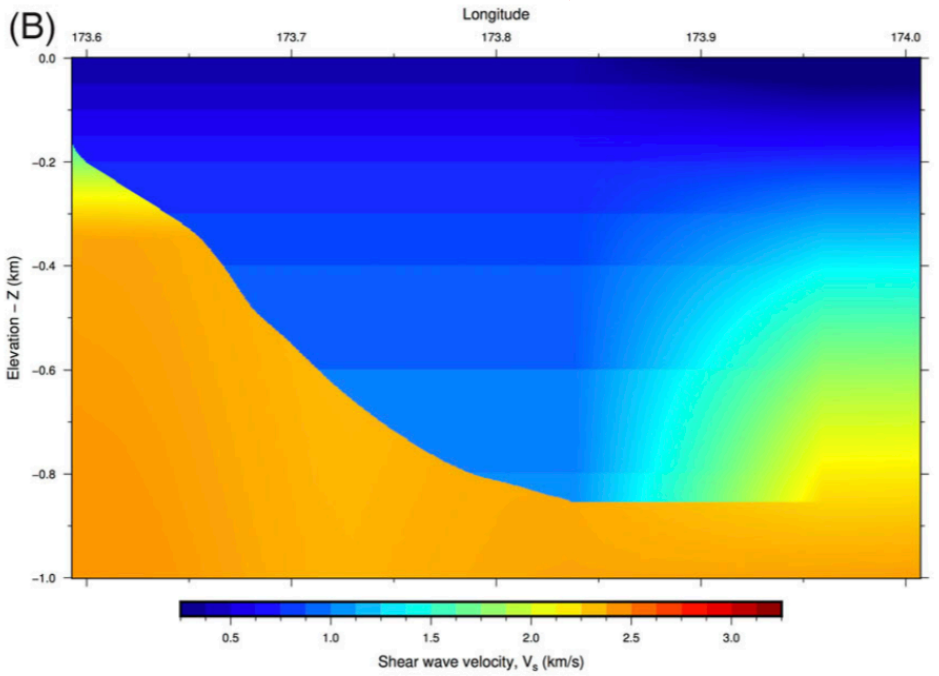
Offshore discontinuities

Basin model extent

Basin model extent

Lateral smoothing over 10km

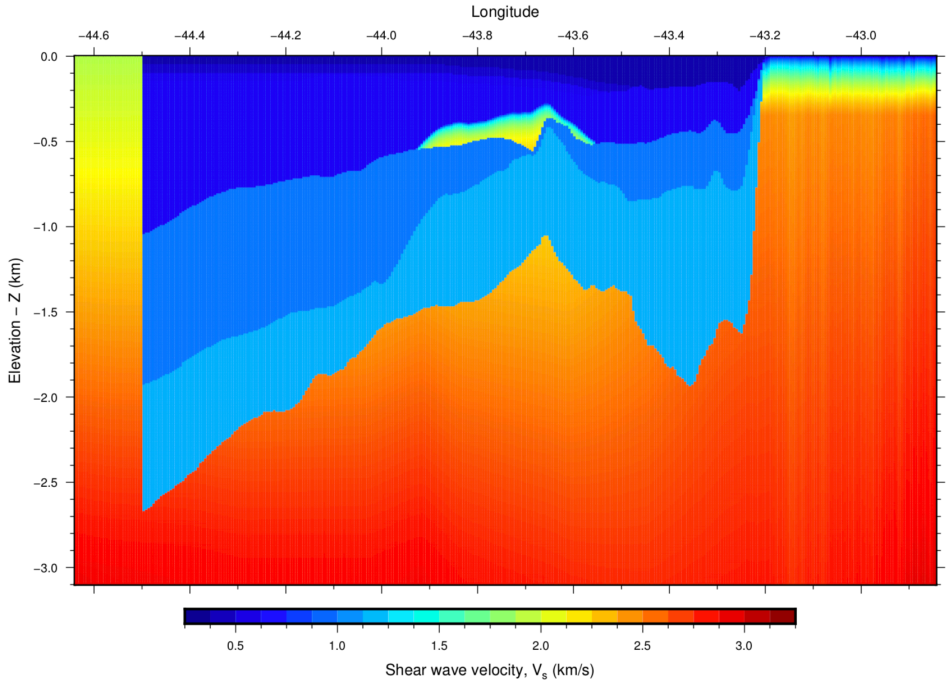




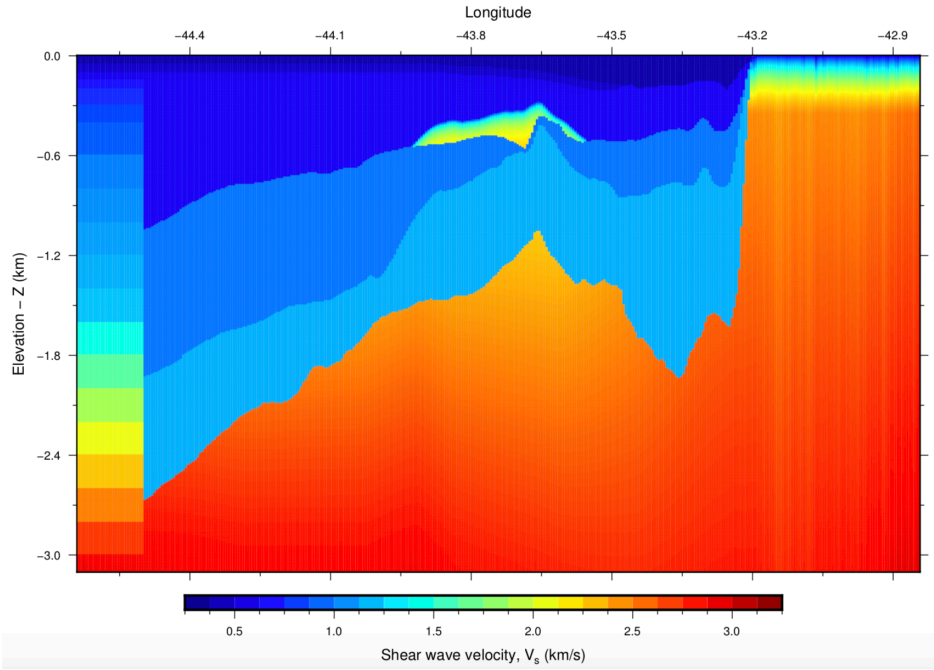
Offshore generic basin

- Generic offshore basin: (i) depth as a function of distance from coast; (ii) generic 1D Vp/s profile

No modification



Generic offshore basin



NZVM Open-source

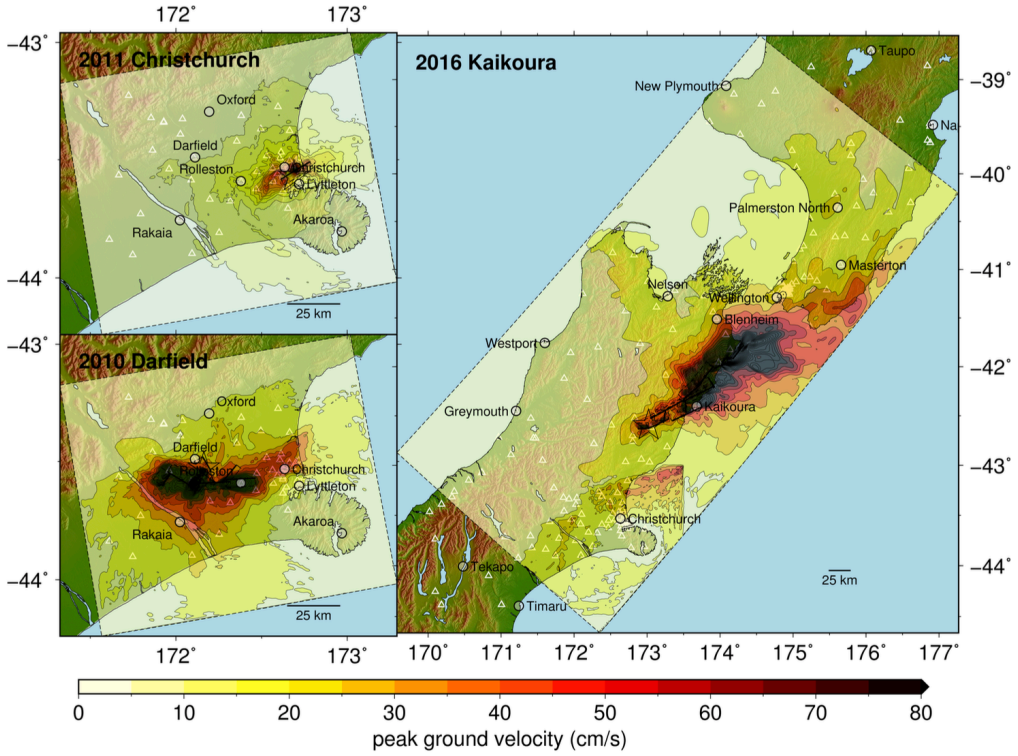
github :
https://github.com/ucgmsim/Velocity-Model

NZVM validation

- Two forms:
  - Incrementally-collected data is compared with latest NZVM version to examine discrepancies (and potentially leads to updates)
  - NZVM using in ground motion simulation that is directly validated against observations (such validation also includes predictive capability of the GM simulation method – so small magnitude events best for 'isolating' VM-based errors)

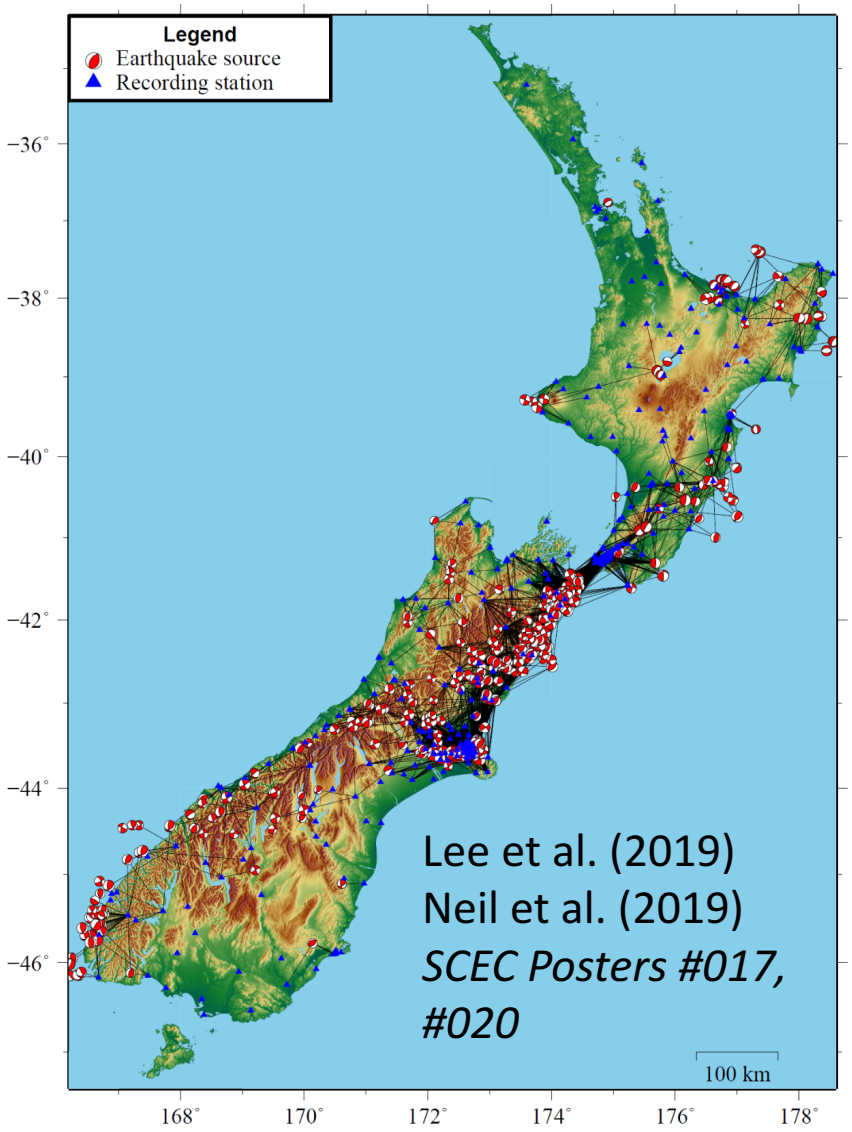
Predictive capability via validation

Rare, impactful events

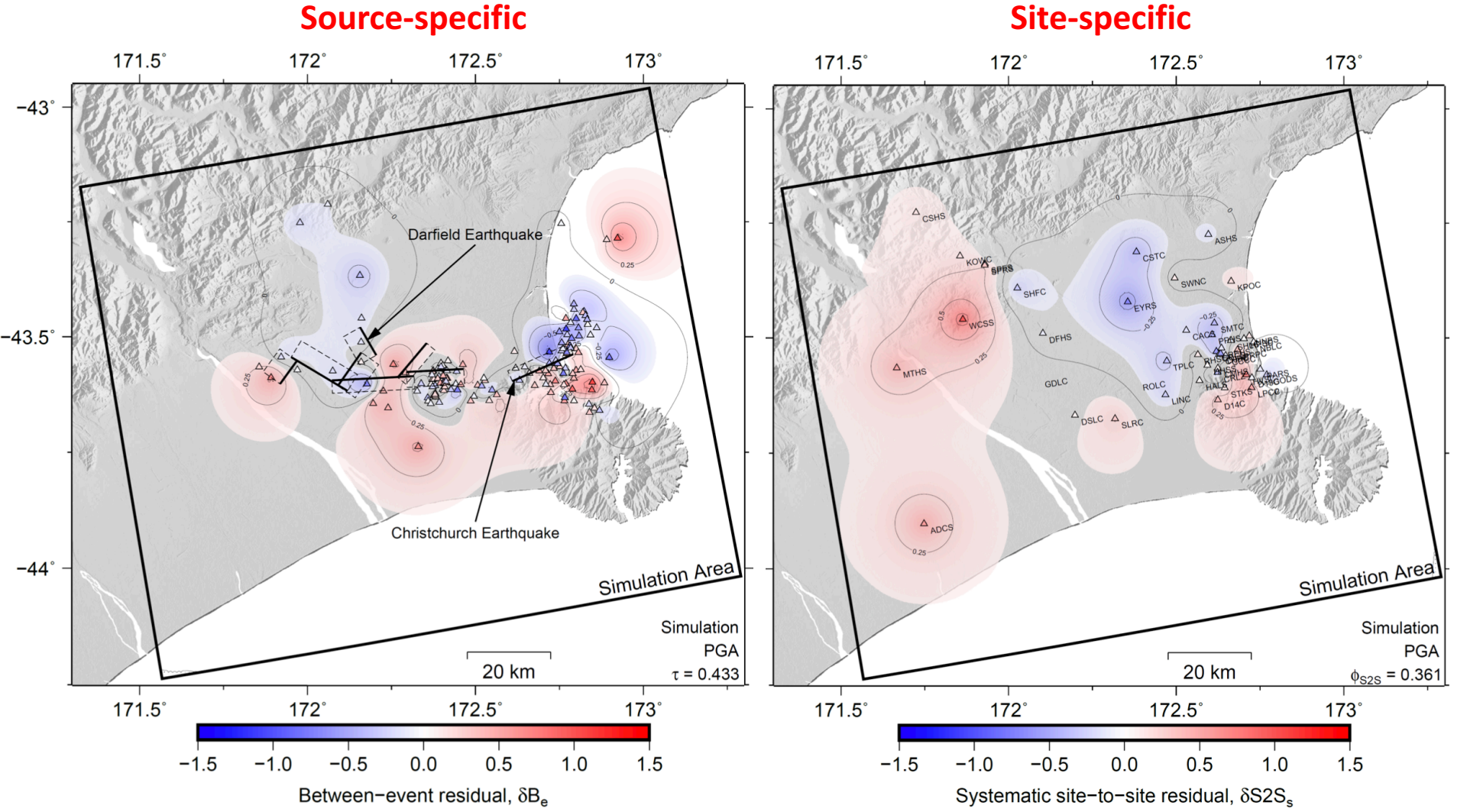


Validation performed for over 600 events in New Zealand

Numerous small events

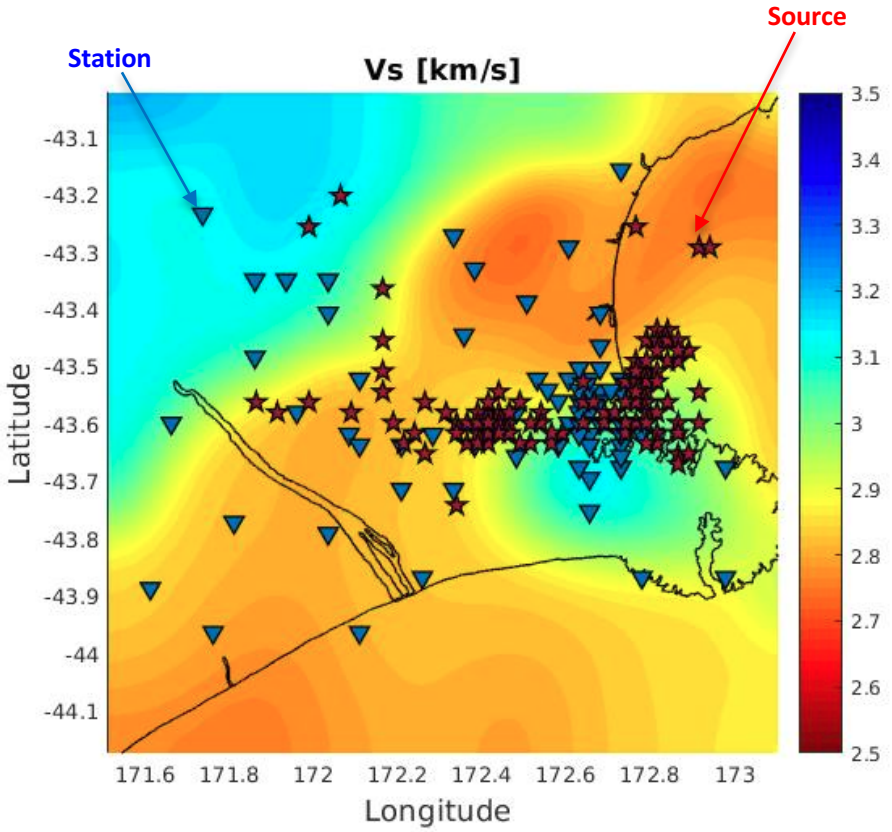


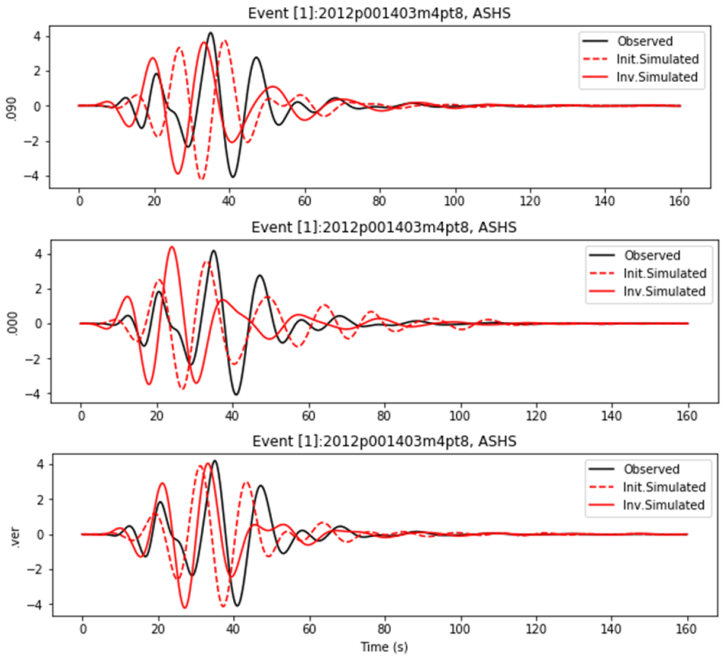
Systematic effects from validation: Example - Canterbury region



Lee et al. (2018)

Full Waveform Tomography for velocity model in Canterbury region

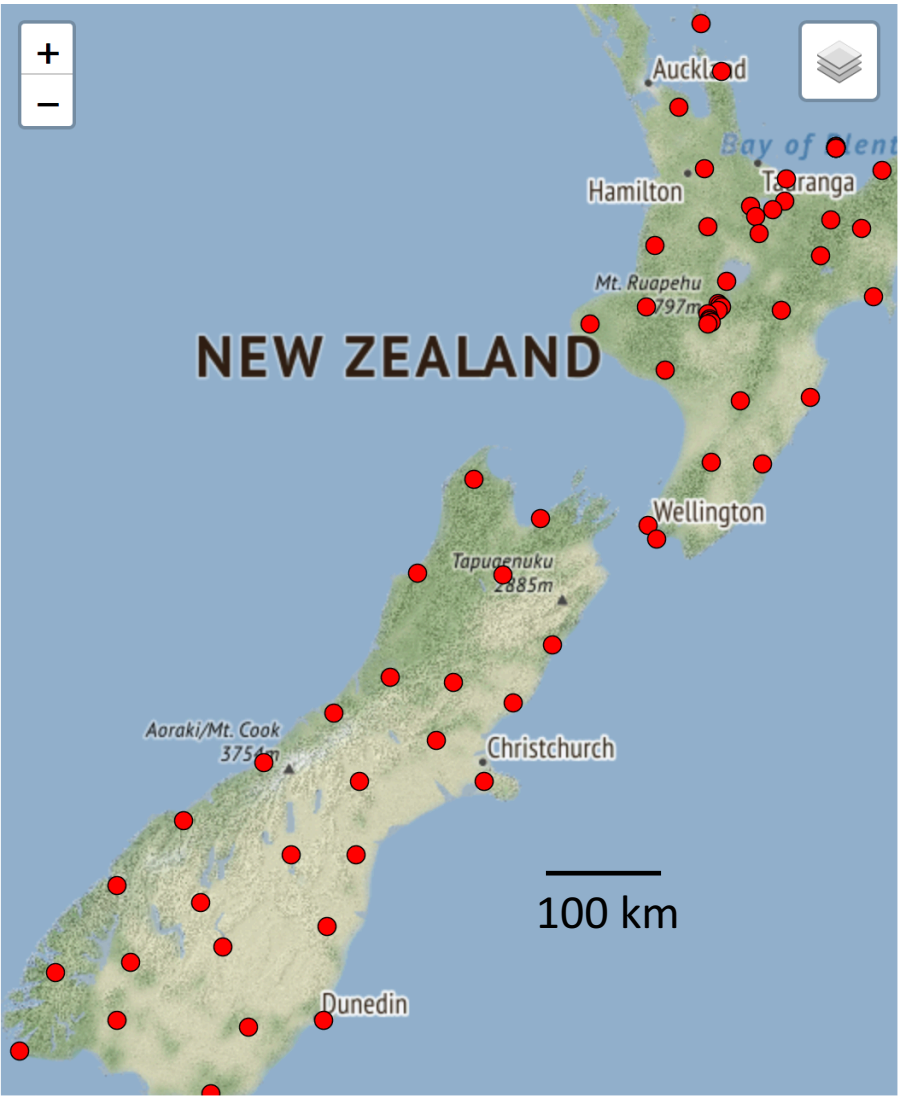




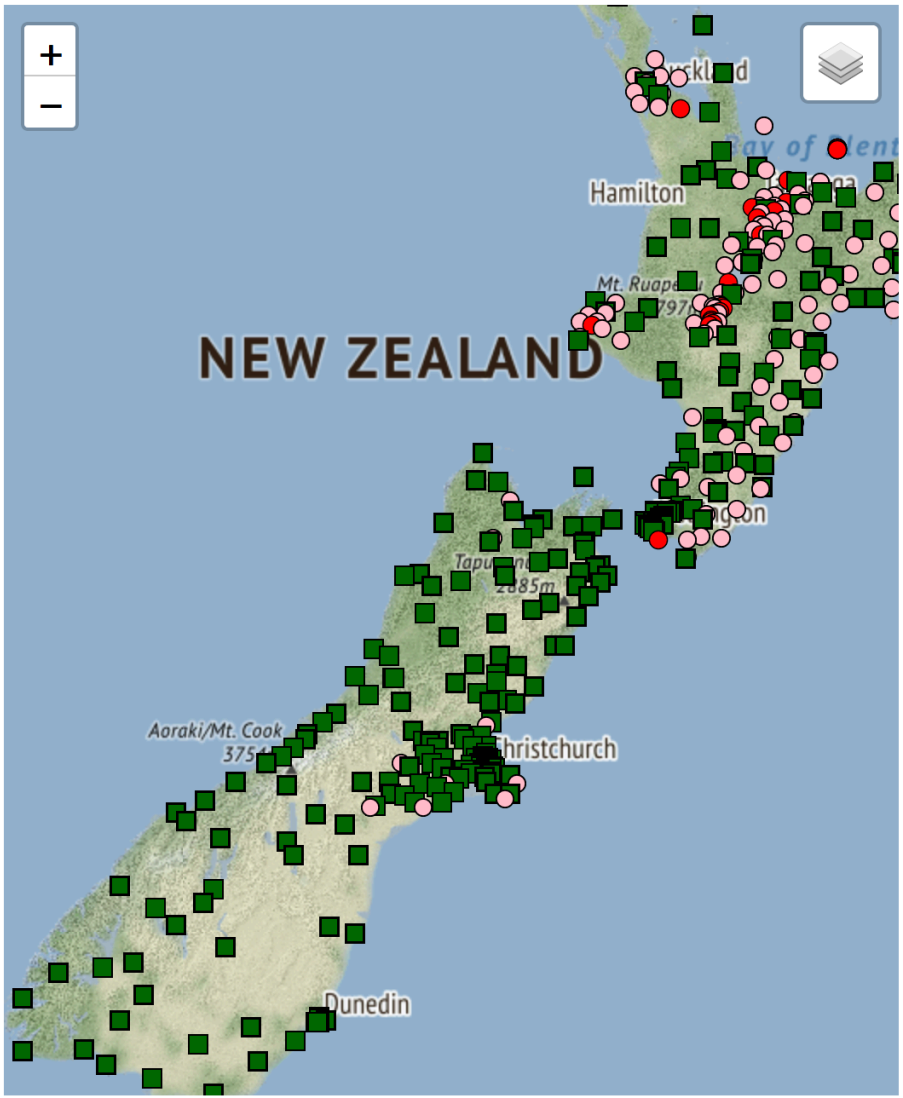
Nguyen et al. (2019)
SCEC Poster #310

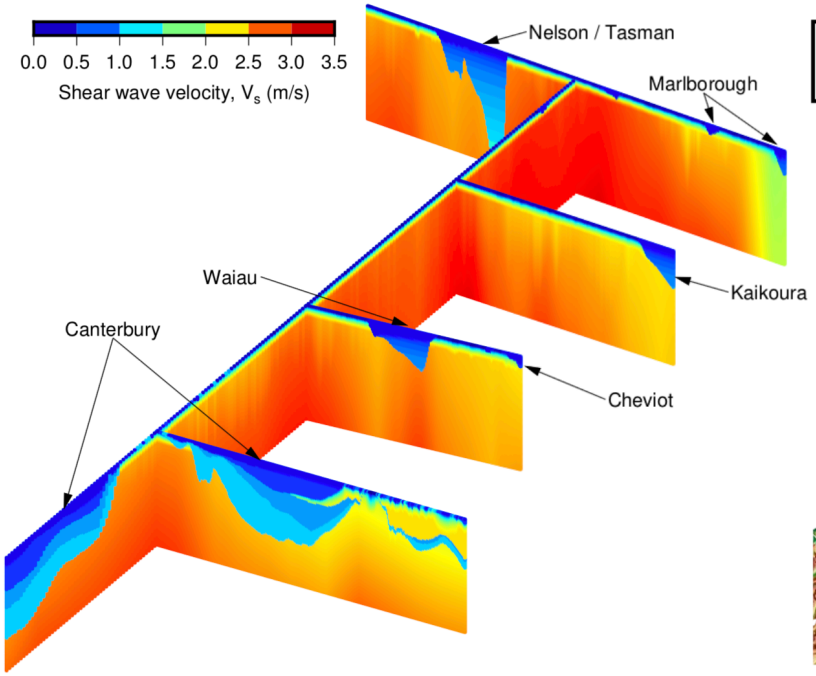
Full waveform tomography with non-ideal data

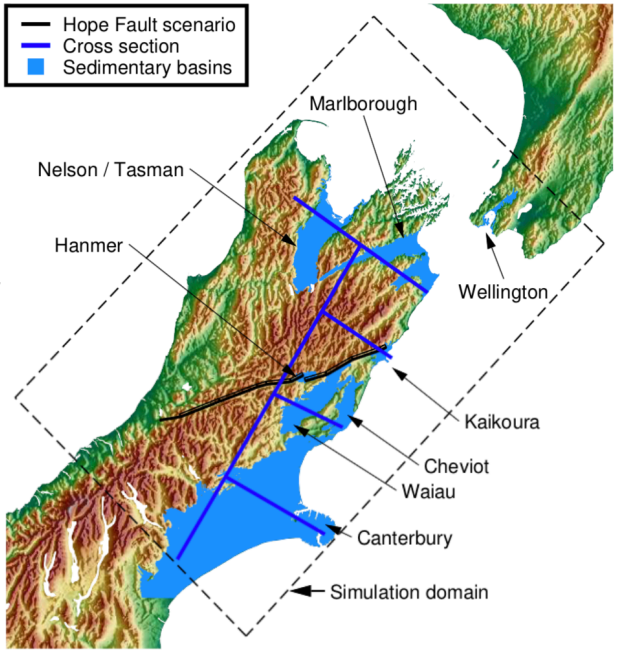
Broadband seismometers only



Additionally short period and strong motion instruments







Thank you for your attention

Slide deck: https://sites.google.com/site/brendonabradley/presentations

References:

1. Thomson et al. (2019). “Methodology and computational implementation of a New Zealand Velocity Model (NZVM2.0) for broadband ground motion simulation” *NZJGG*. doi: 10.1080/00288306.2019.1636830
2. Lee et al. (2017). “Development of a 3D Velocity Model of the Canterbury, New Zealand, Region for Broadband Ground-Motion Simulation” *BSSA*. doi: 10.1785/0120160326
3. Foster et al. (2019). “A *Vs*30 Map for New Zealand based on Geologic and Terrain Proxy Variables and Field Measurements” *Eq. Spectra*. doi: TODO
4. De la Torre et al. (2019). “Modeling Nonlinear Site Effects in Physics-Based Ground Motion Simulations of the 2010-2011 Canterbury Earthquake Sequence” *Eq. Spectra*. (in review)
5. Eberhart-Phillips et al. (2010). “Establish*ing a Versatile 3-d seismic Velocity Model for new Zealand” SRL. doi:* 10.1785/gssrl.81.6.992
6. Andrei Ref.

Basin Types

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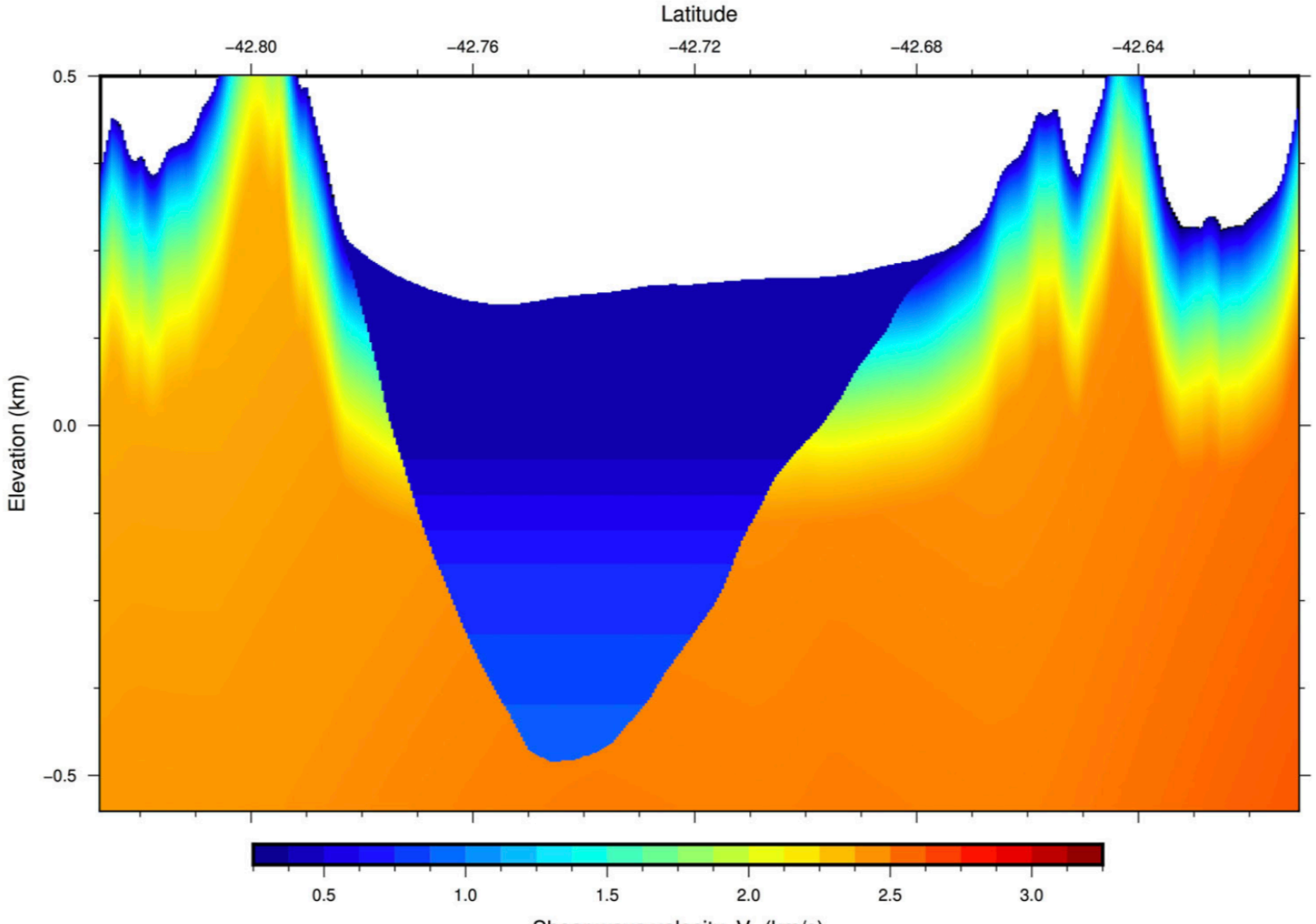
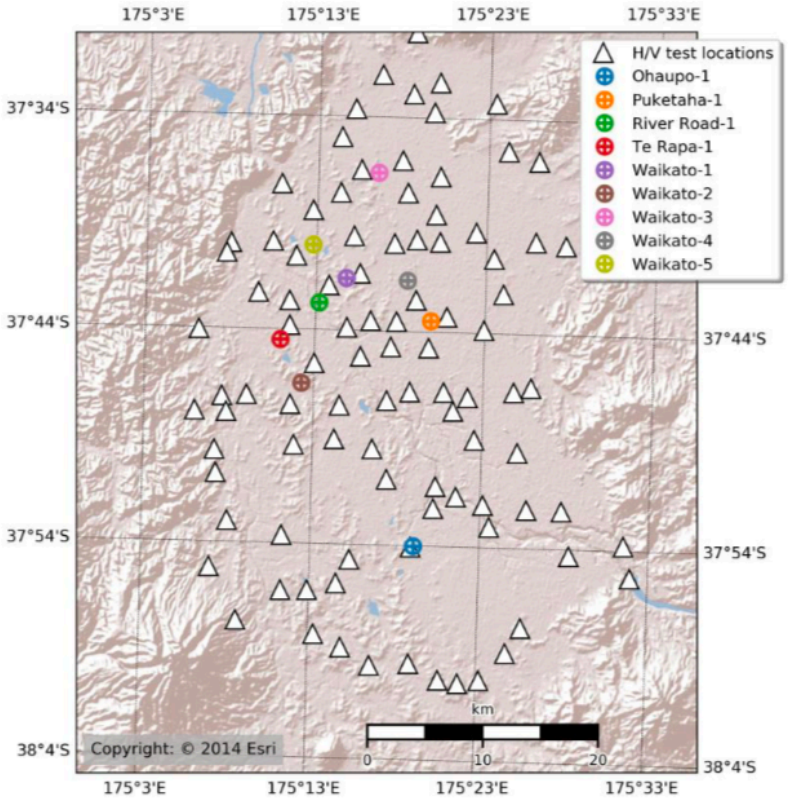
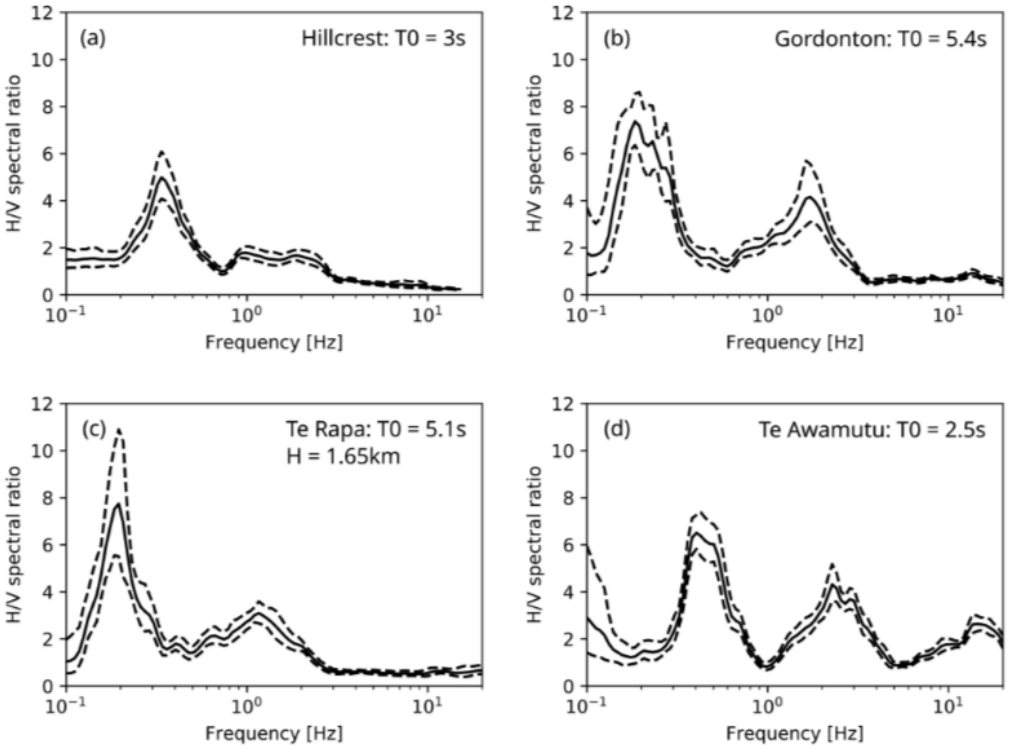
Example Type 1 basin

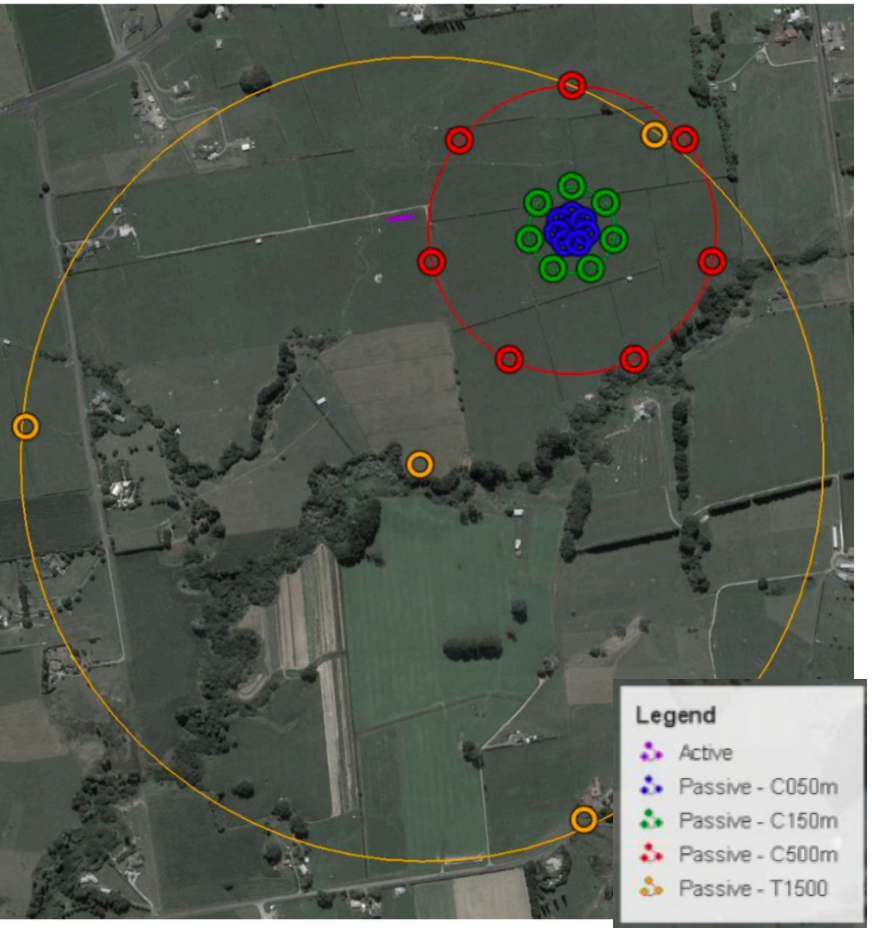


Example Type 2 - Basin depth from site period

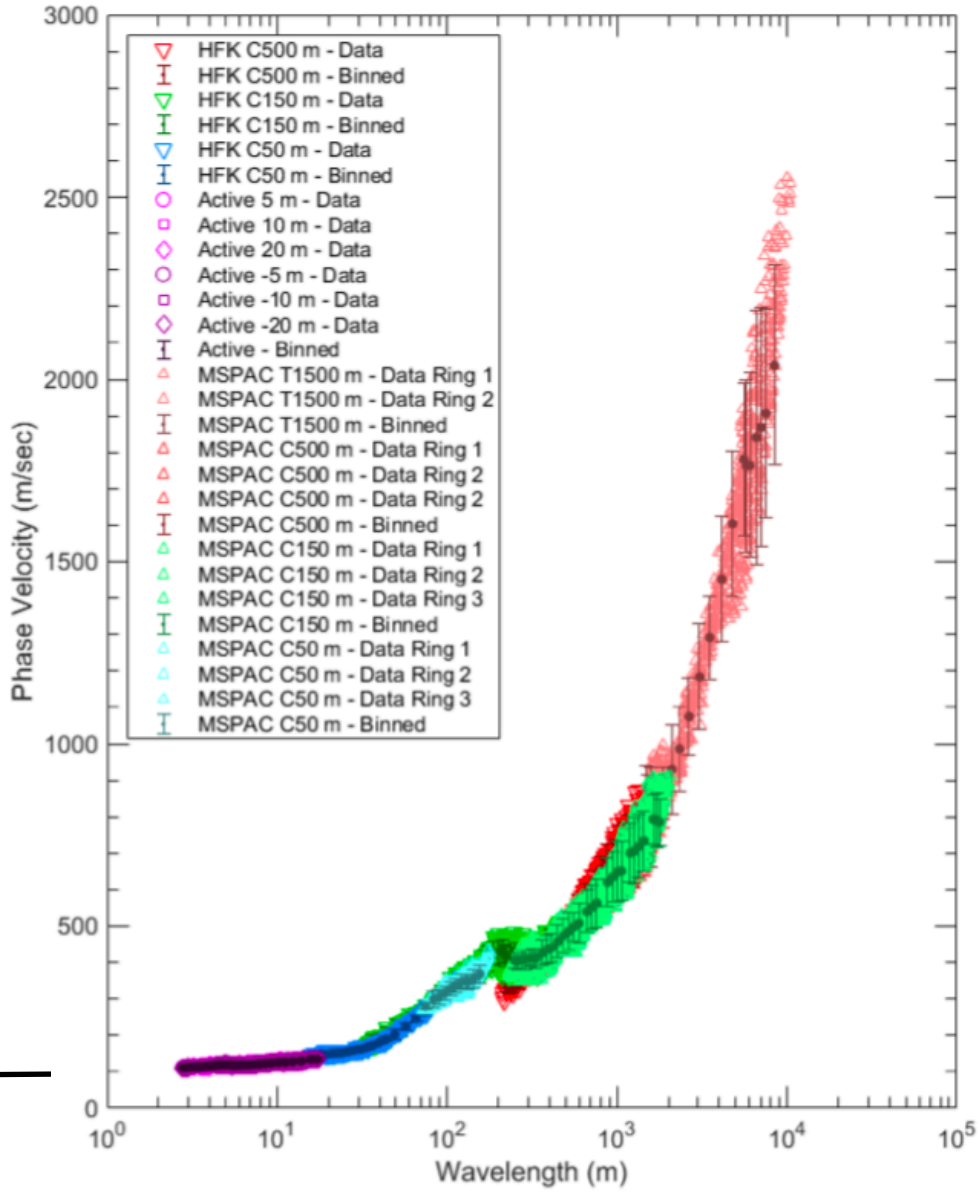




Example Type 3 basin – velocity profile



Site-specific 1D velocity profile from geophysical data



Example Type 2 - Basin depth from site period

- Depths to the basement from the petroleum log data (Edbrooke *et al.*, 2009)
- A power-law relationship between H and f_0