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

QuakeCoRE
NZ Centre for Earthquake Resilience
Te Hiranga Rū

Modelling Local Site Effects in Physics-Based Earthquake Ground Motion Simulations: Thesis Plan

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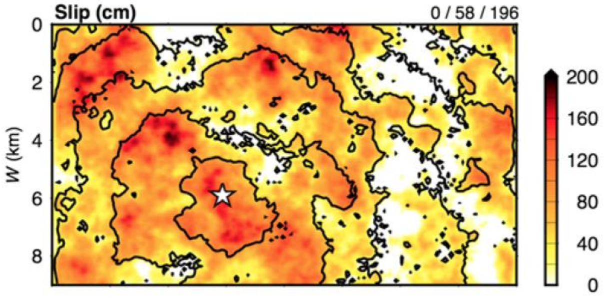
DT1 Call | 31/03/2022

Motivation

Ingredients of physics-based ground motion simulations:



source

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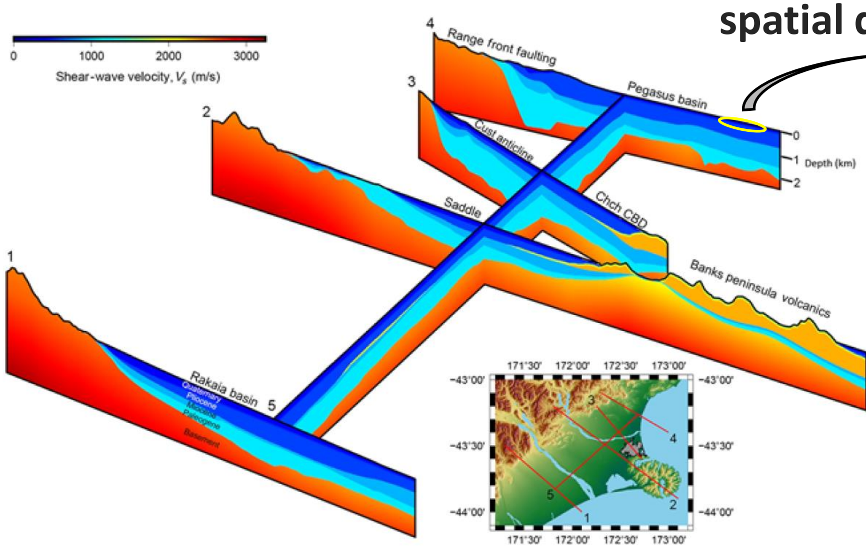


path

spatial domain = kilometers

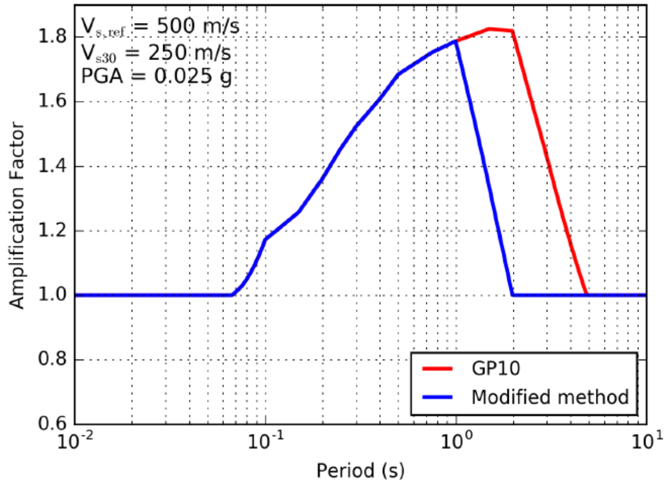
grid spacing ~ 100 m

minimum Vs ~ 500 m/s

+

spatial domain = meters

Empirical amplification factor



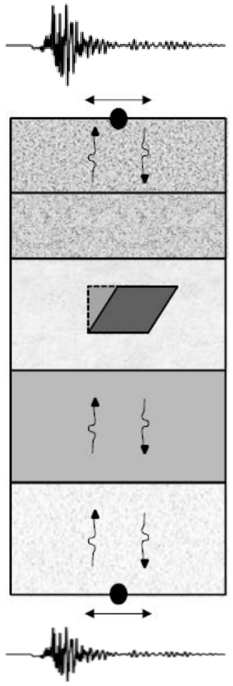
local site effects

↓

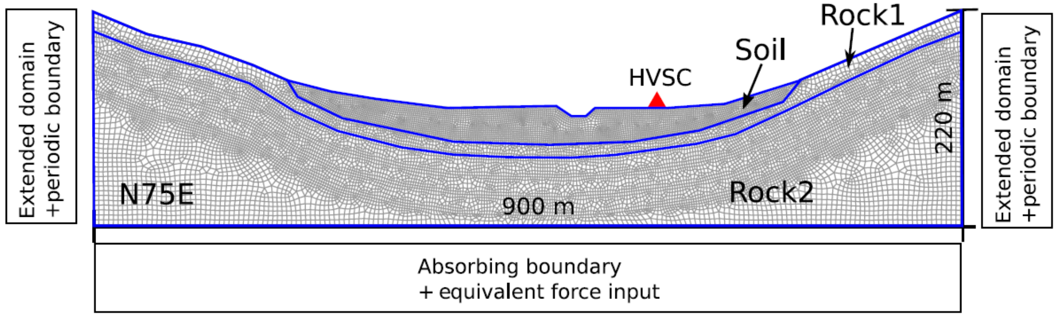
Can we improve predictions using more advanced approaches?

Motivation

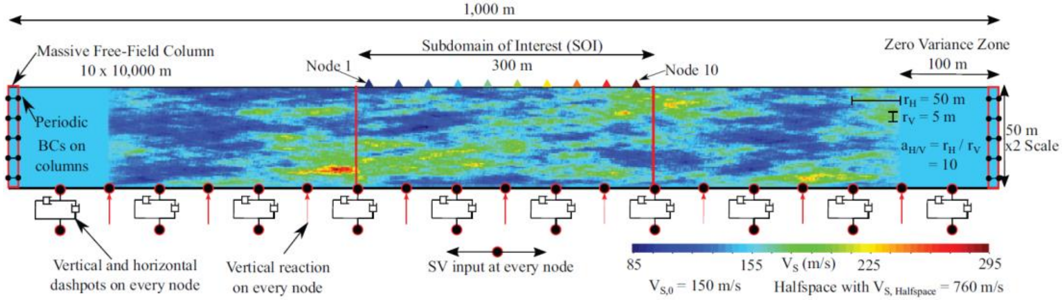
Model 1



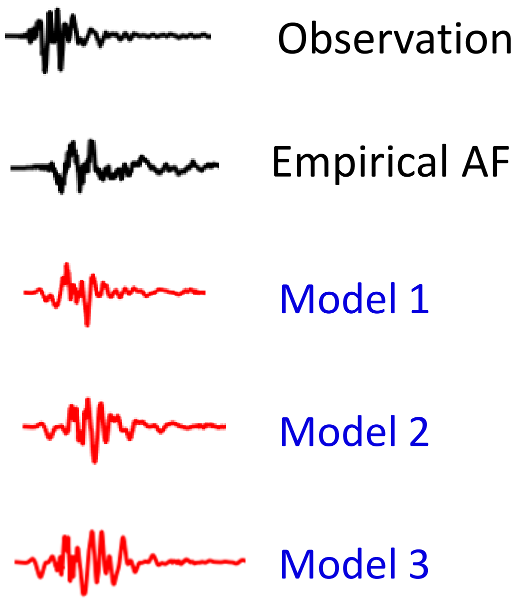
Model 2



Model 3



Can we improve predictions?



- Lack of validation studies on large datasets of events and quality SMS site information
- New Zealand is a good laboratory: multiple earthquakes and SMS sites

Past Validation Studies in NZ

Lee et al. (2020; 2022)

Approach: Empirical amplification factors

- Big portion of total variability inferred to result from systematic site effects
- Underestimation of the significant duration for softer sites
- Several sites showed systematic biases in SA prediction: site-specific complexities that are not captured using Vs30-based amplification factors

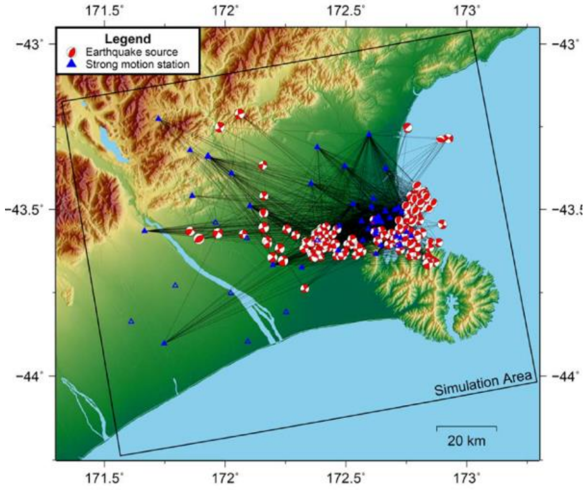
de la Torre et al. (2020)

Approach: 1D Site-response analysis

- Site-specific improvements: very soft sites or sites with large impedance contrasts near the ground surface
- Other ‘general’ sites did not exhibit consistent improvement using site-specific response analysis modelling

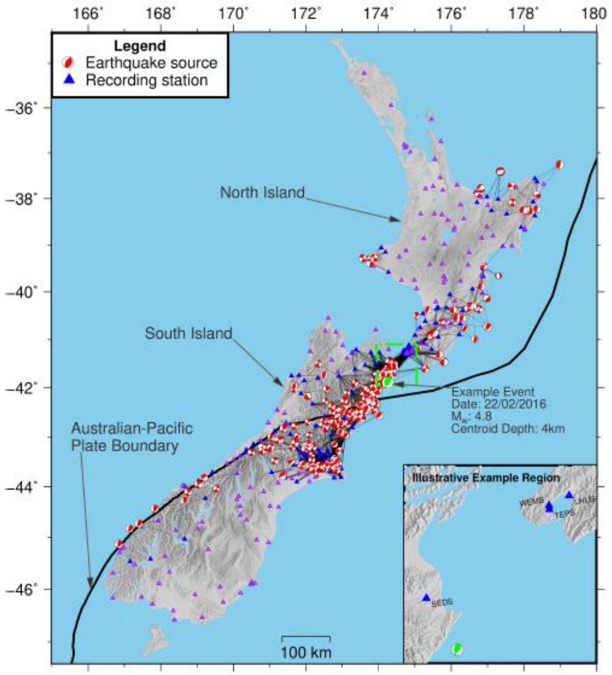
Lee et al. (2020)

148 Small Magnitude Events | 43 Sites



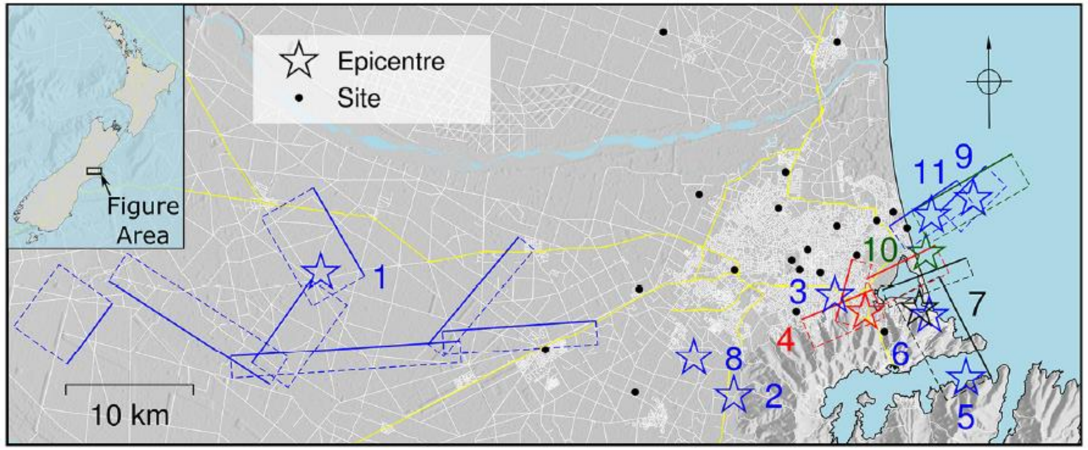
Lee et al. (2022, under review)

479 Small Magnitude Events | 212 Sites



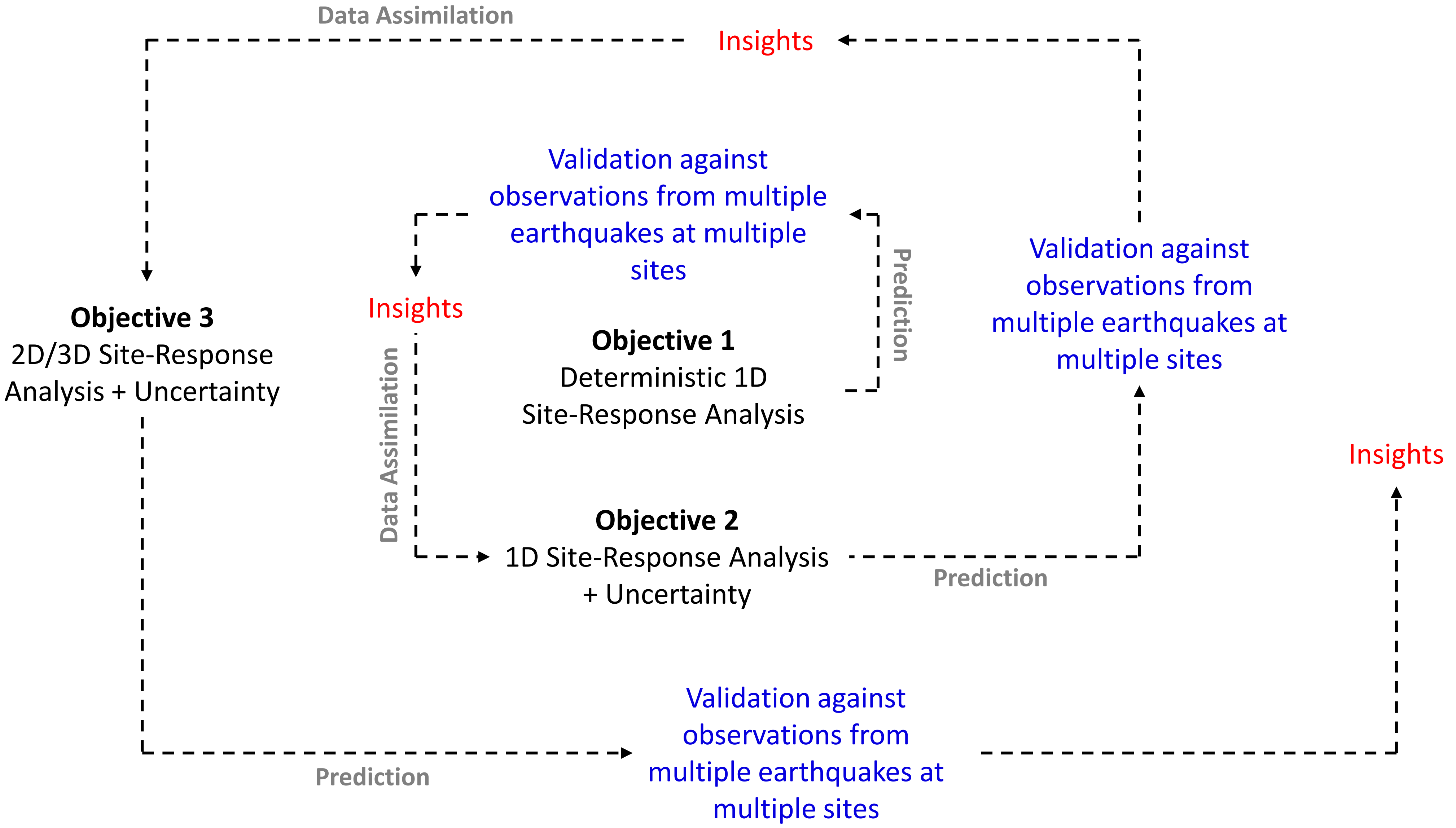
de la Torre et al. (2020)

11 Significant Events | 20 Sites



Thesis Plan

‘Inference Spiral’ of System Science (Jordan, 2015)



Objective 1

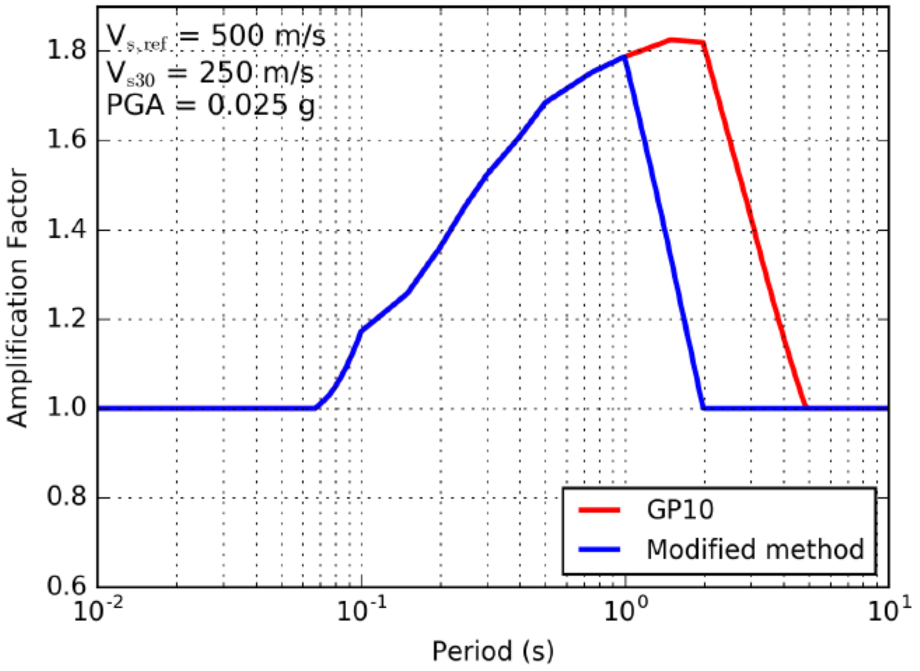
Validation of 1D Site-Response Analysis on a Nationwide Scale

Validation study	Number of earthquakes	Range of magnitudes	Number of stations	Number of ground motions	Intensity measures
de la Torre et al. (2020)	11	$4.7 \leq M_w \leq 7.1$	20	200	SA
Proposed study	> 400	$3.5 \leq M_w \leq 7.8$	> 50	> 2000	SA, PGV, CAV, AI, D_{s575}, D_{s595}

Under what conditions does 1D site-response analysis perform significantly better than the simplified empirical approach?

- Quality and quantity of site characterization data
- Complexity of the site
- Ground motion intensity, etc.

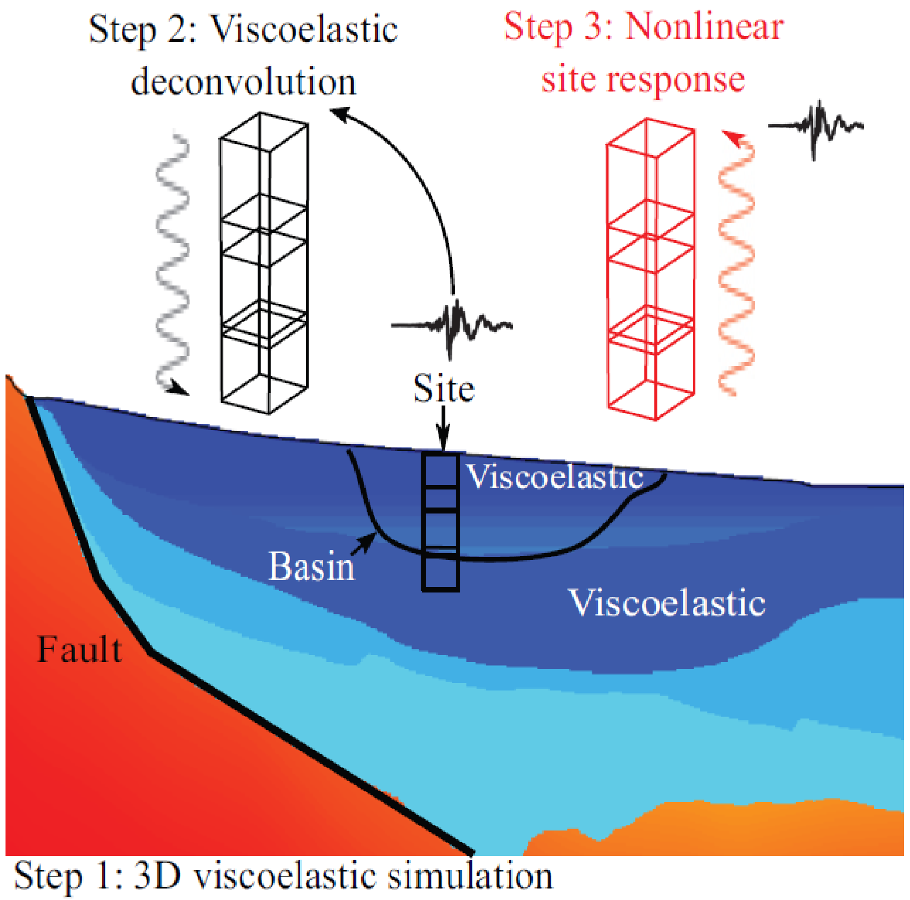
Objective 1: Methodology



Lee et al. (2022, under review)

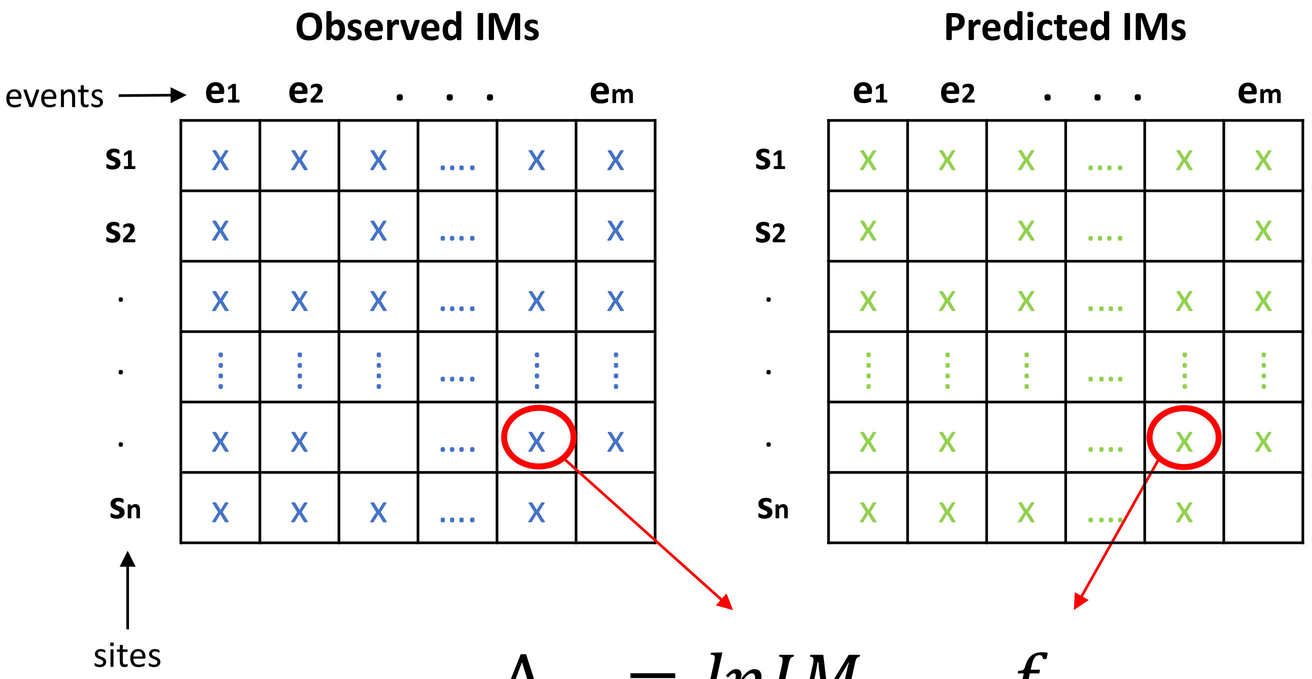
vs

Uncoupled approach



de la Torre et al. (2020)

Objective 1: Methodology



$$\Delta_{es} = lnIM_{es} - f_{es}$$

Prediction residual

$$\Delta_{es} = a + \delta B_e + \delta S2S_s + \delta W^0_{es}$$ → Inferences

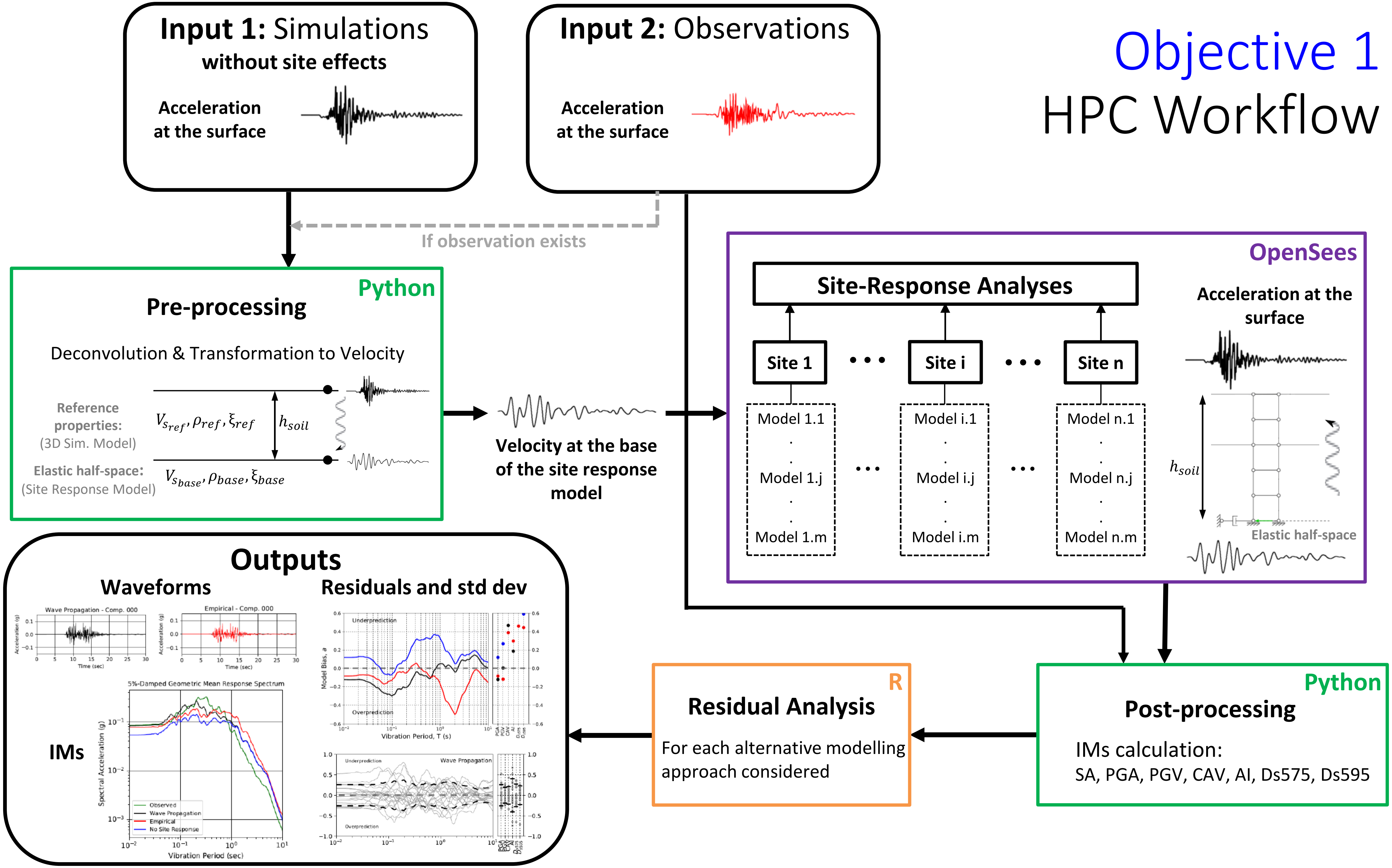
Model bias

Between-event residual

Site-to-site residual

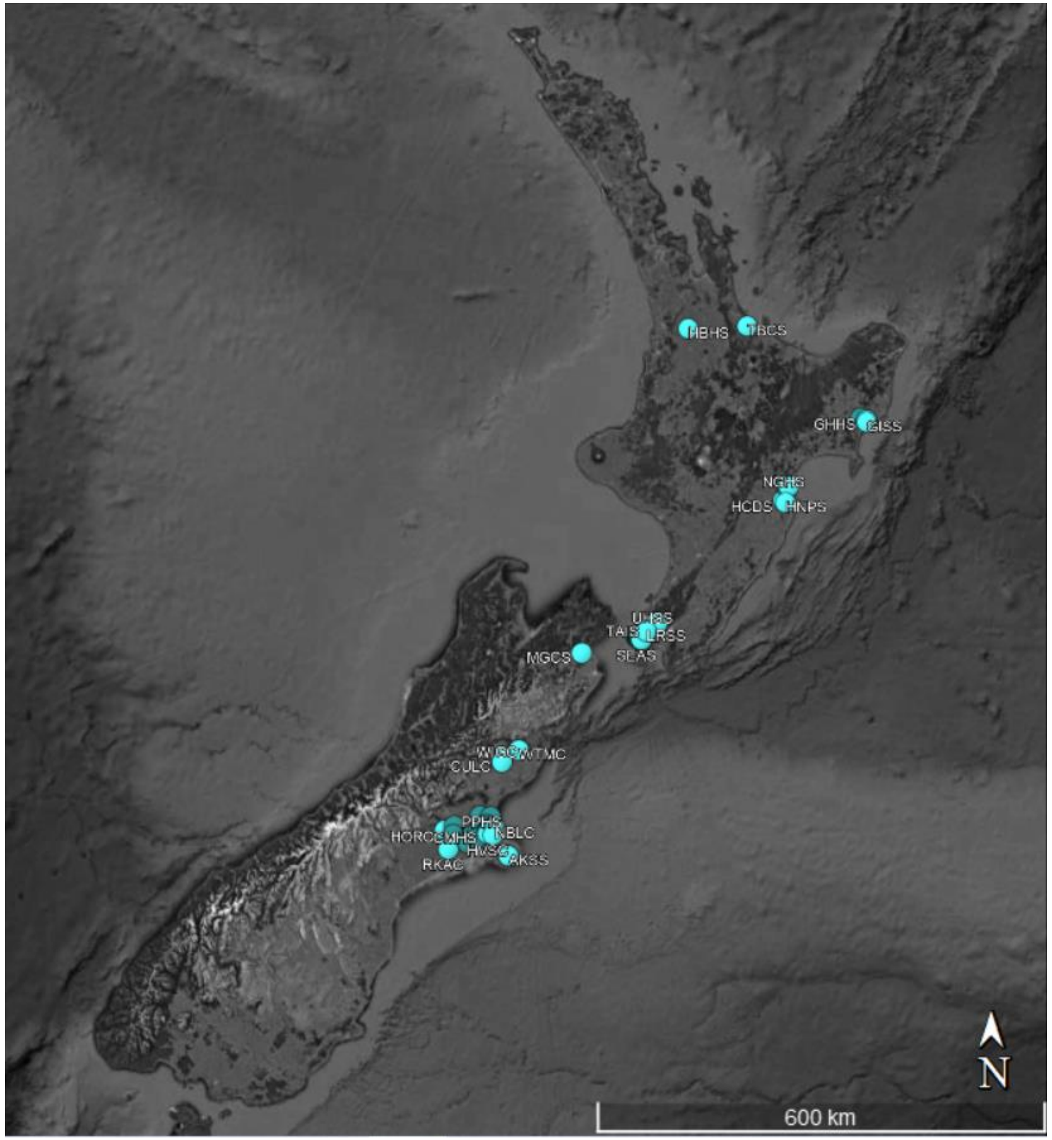
Remaining residual

Objective 1
HPC Workflow

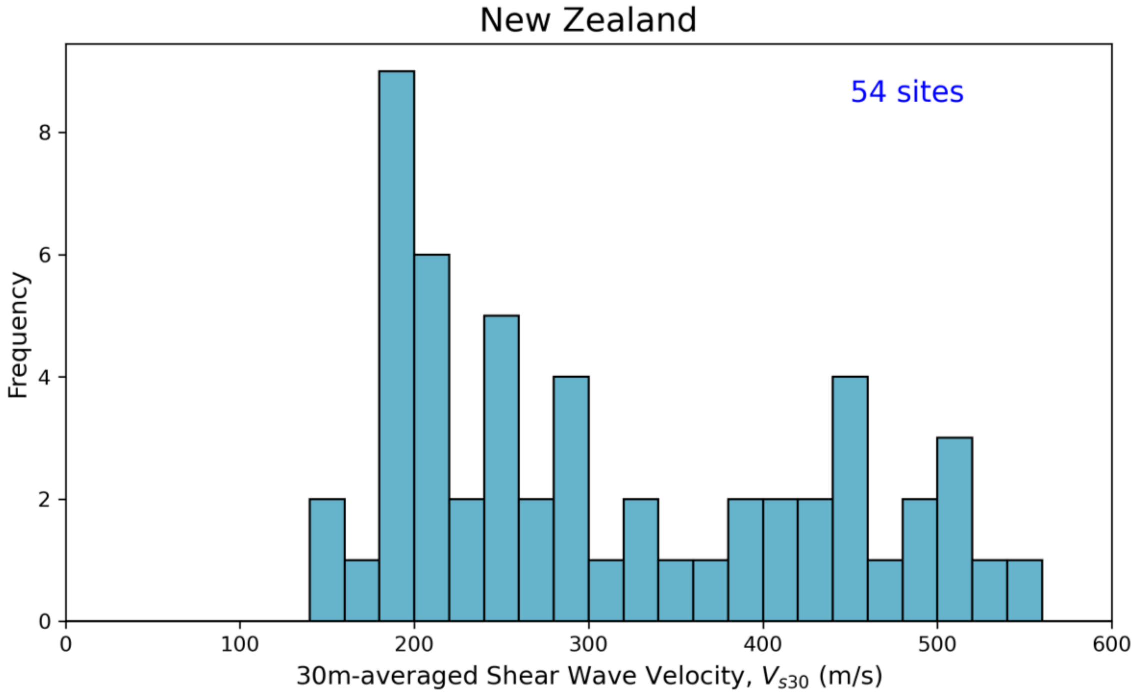


Objective 1: Sites

Wotherspoon et al. (2015); Deschenes et al. (2018); Cox & Vantassel (2018); Stolte et al. (2021), etc.



Currently, **54 SMS sites** with high-quality Vs profiles

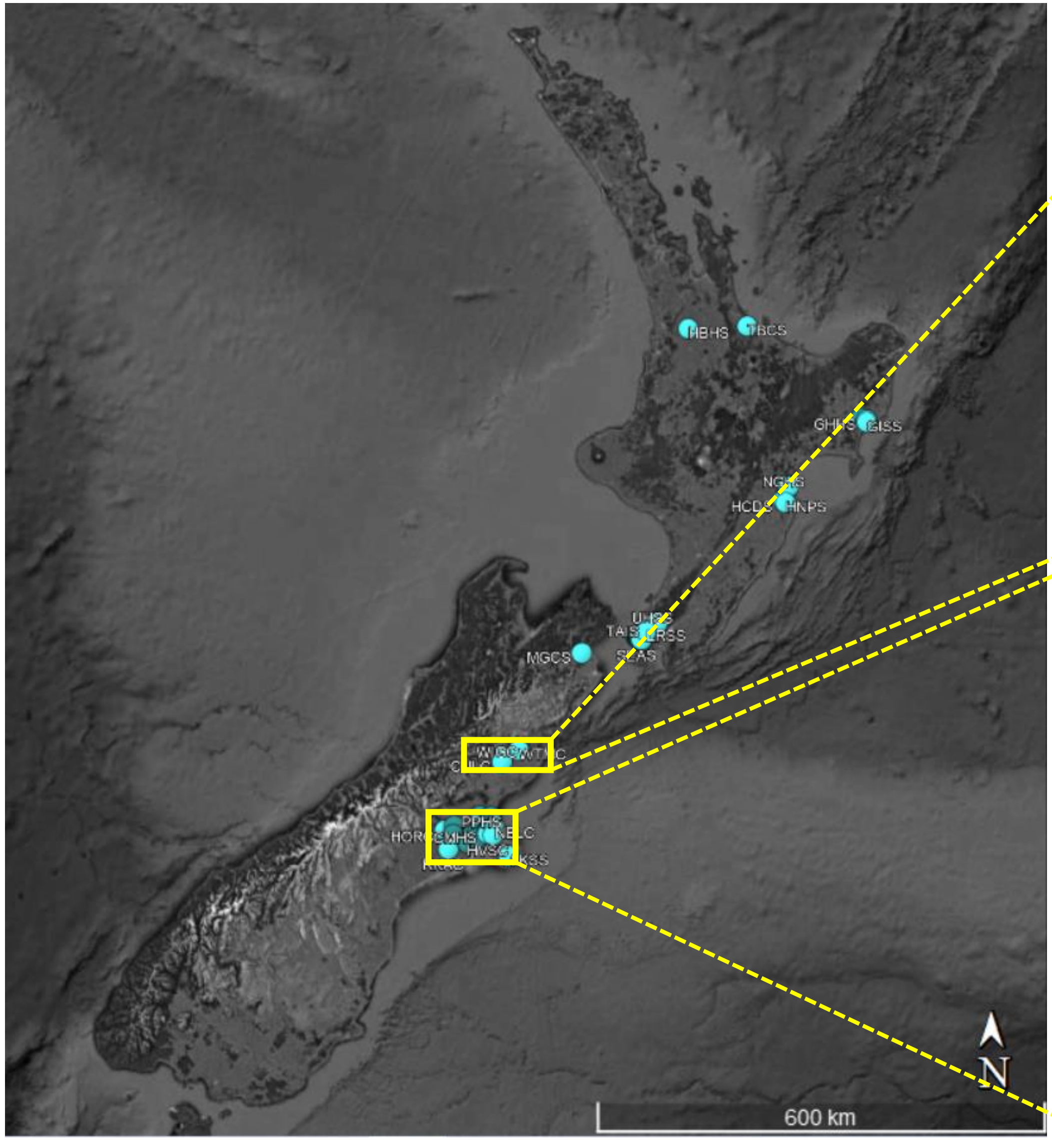


~ 60% with CPTu (but some very shallow)

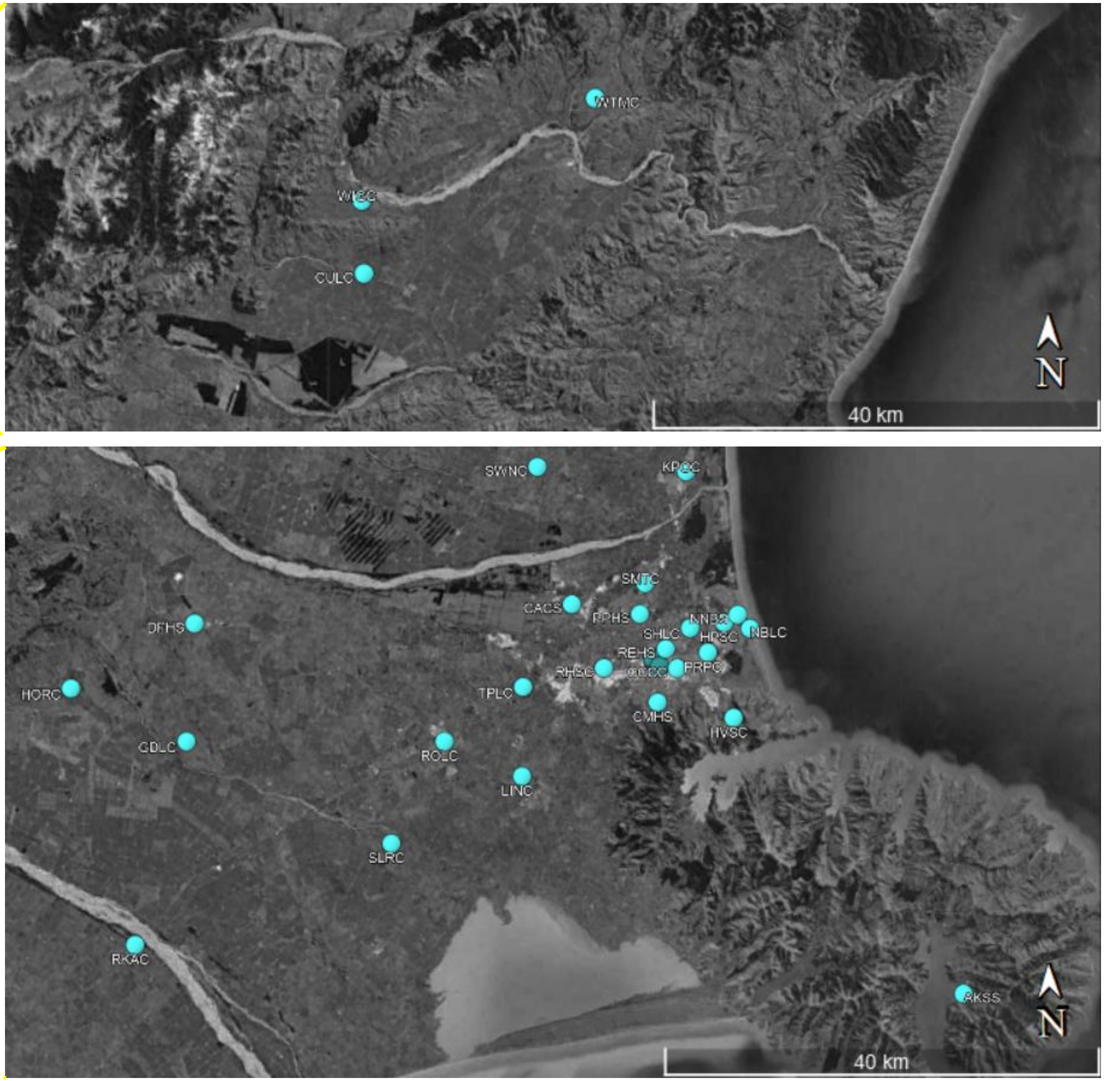
~ 80% with HVSR from microtremors measurements

100% with HVSR from ground motion records

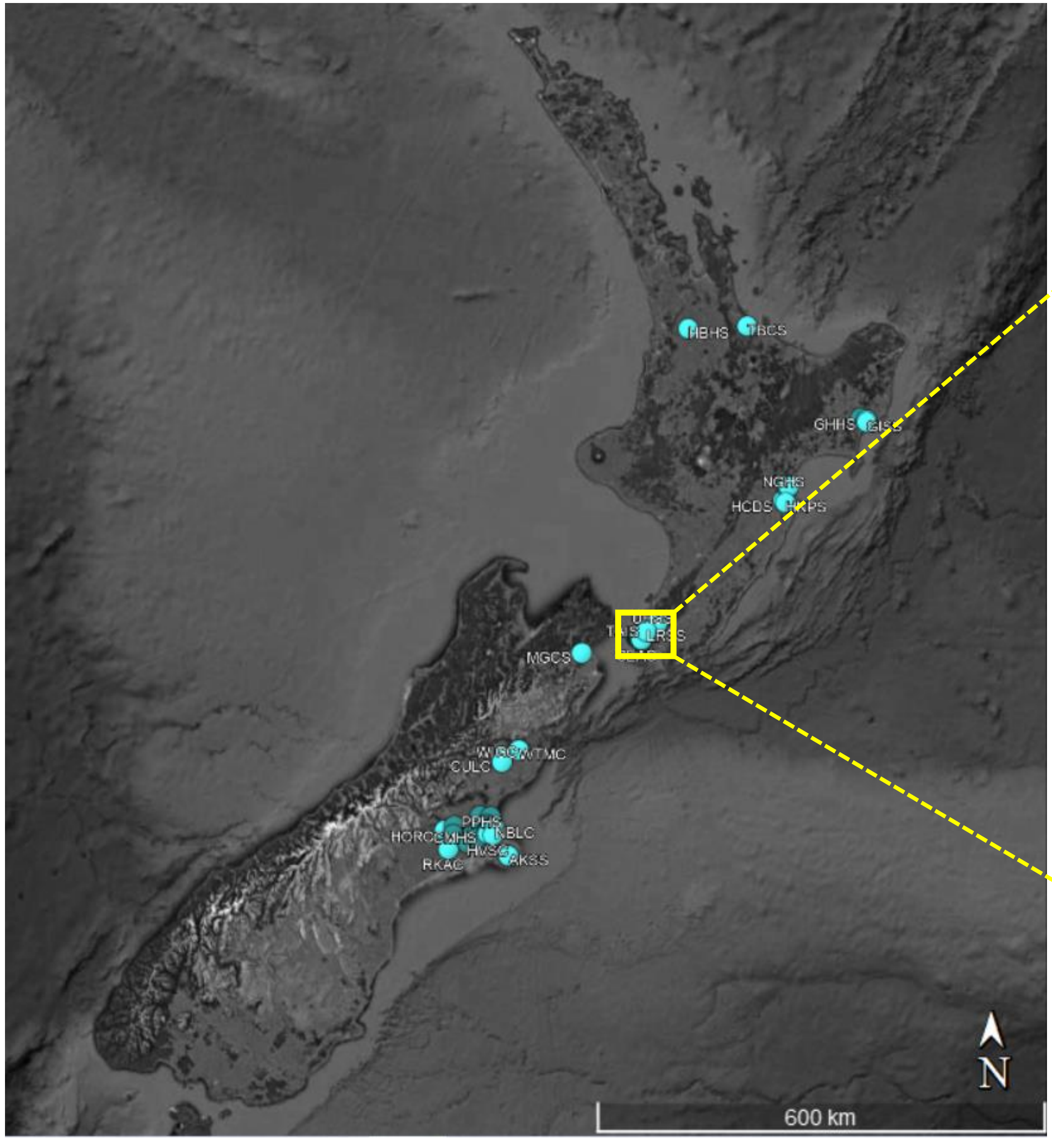
Objective 1: Sites



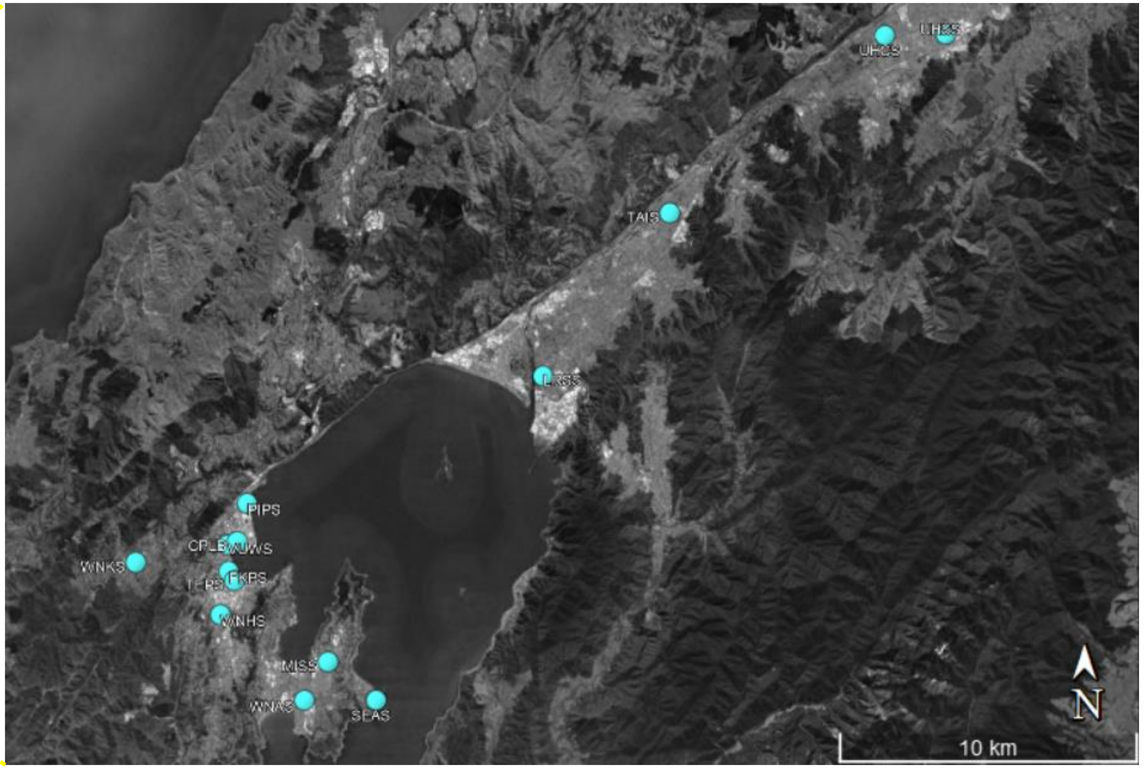
Canterbury Region: 29 Sites



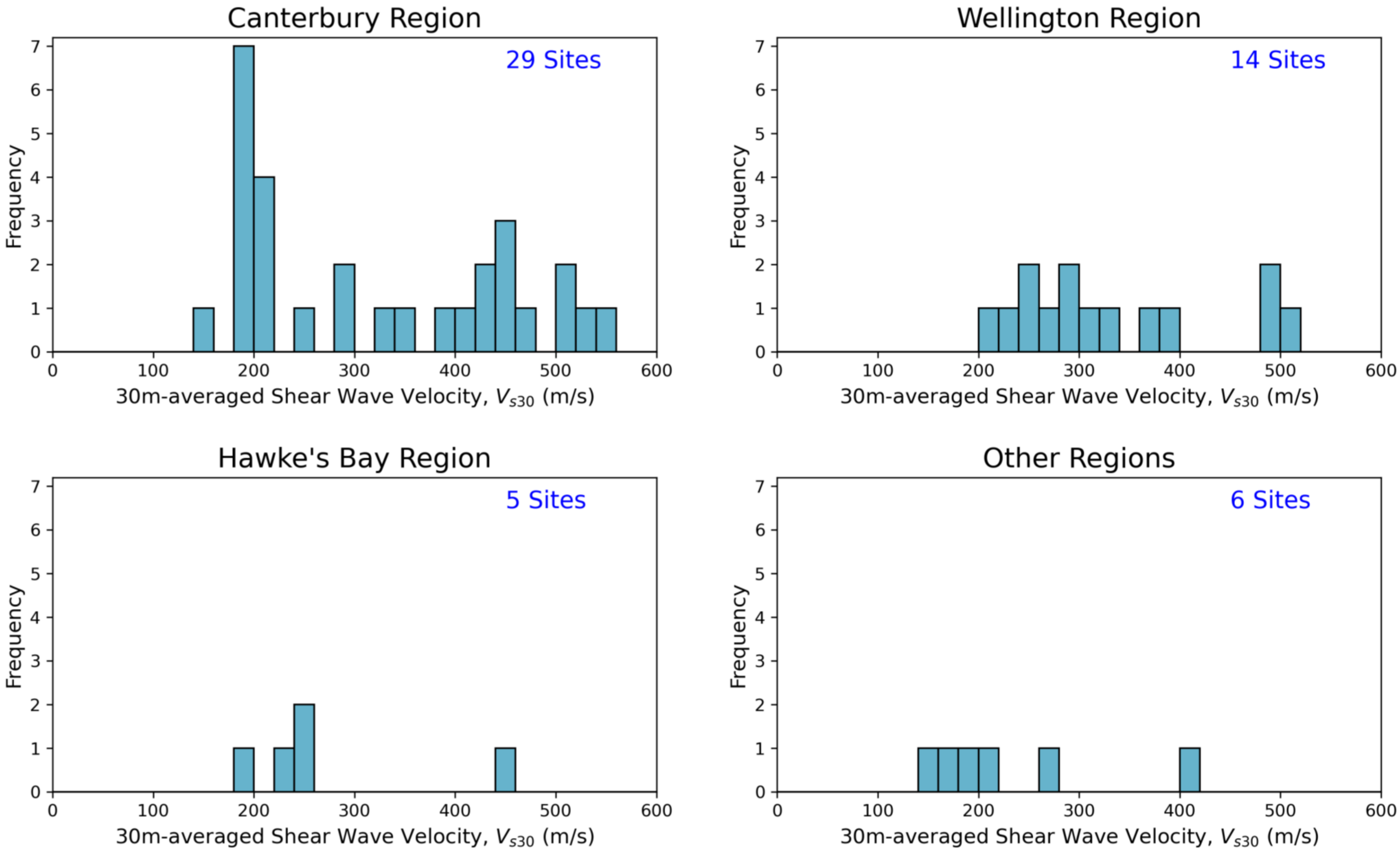
Objective 1: Sites



Wellington Region: 14 Sites



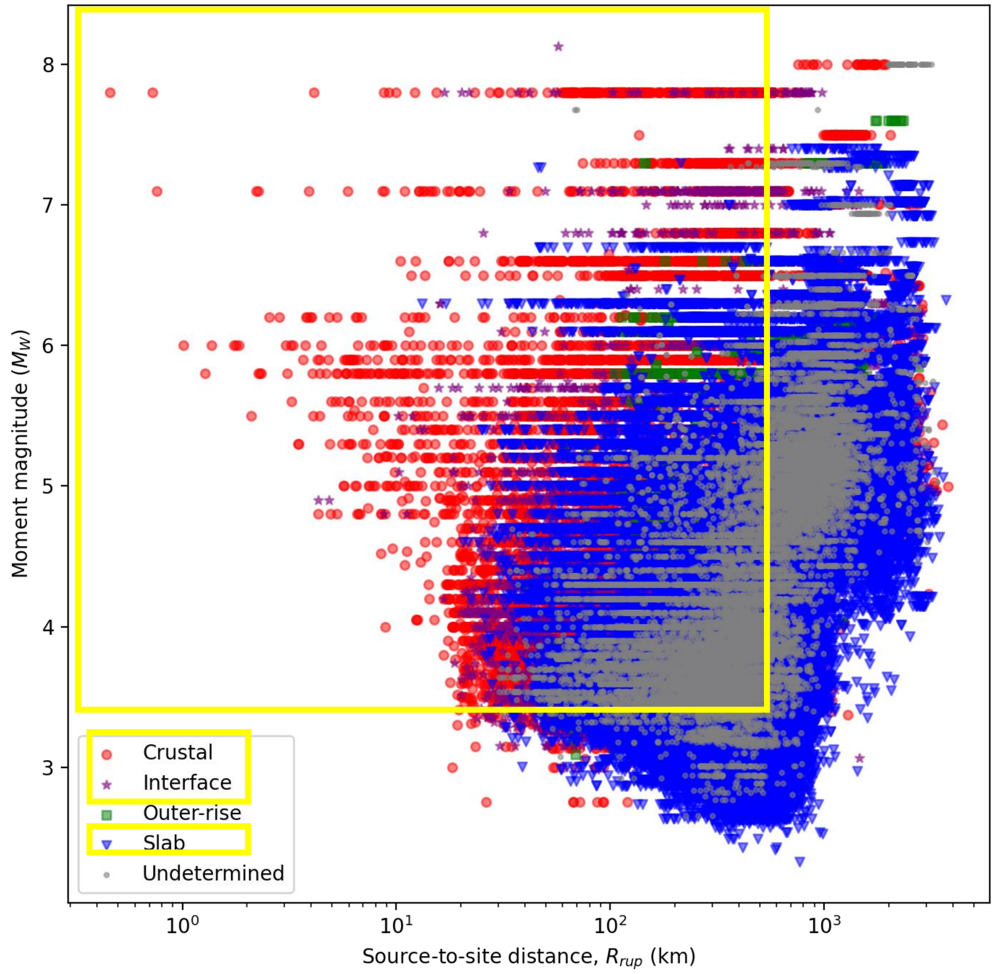
Objective 1: Sites



Objective 1: Ground Motions

2021 New Zealand Ground Motion Database

Hutchinson et al. (2022, under review)



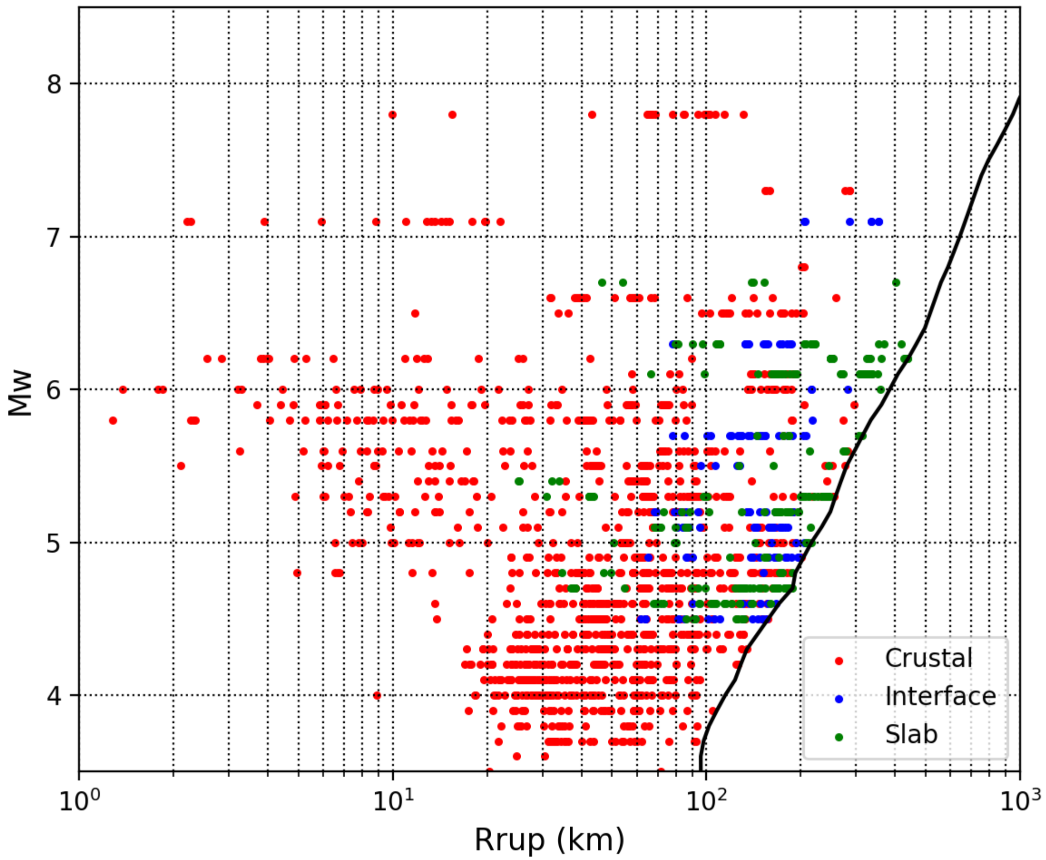
Significantly expanded the number of ground motions from the previous 2017 NZ Database:

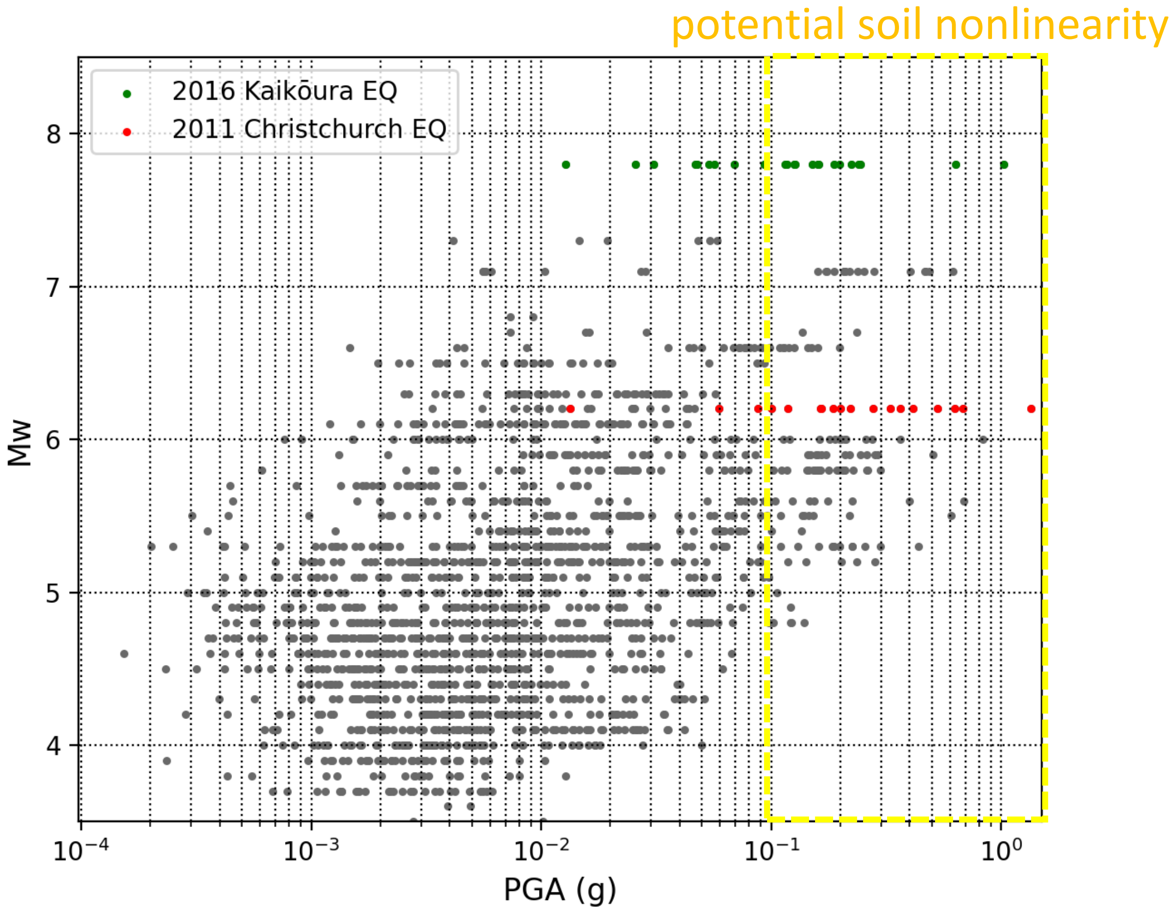
Events with records x 45

Ground motions x 50

Objective 1: Ground Motions

Usable ground motion records at the sites considered

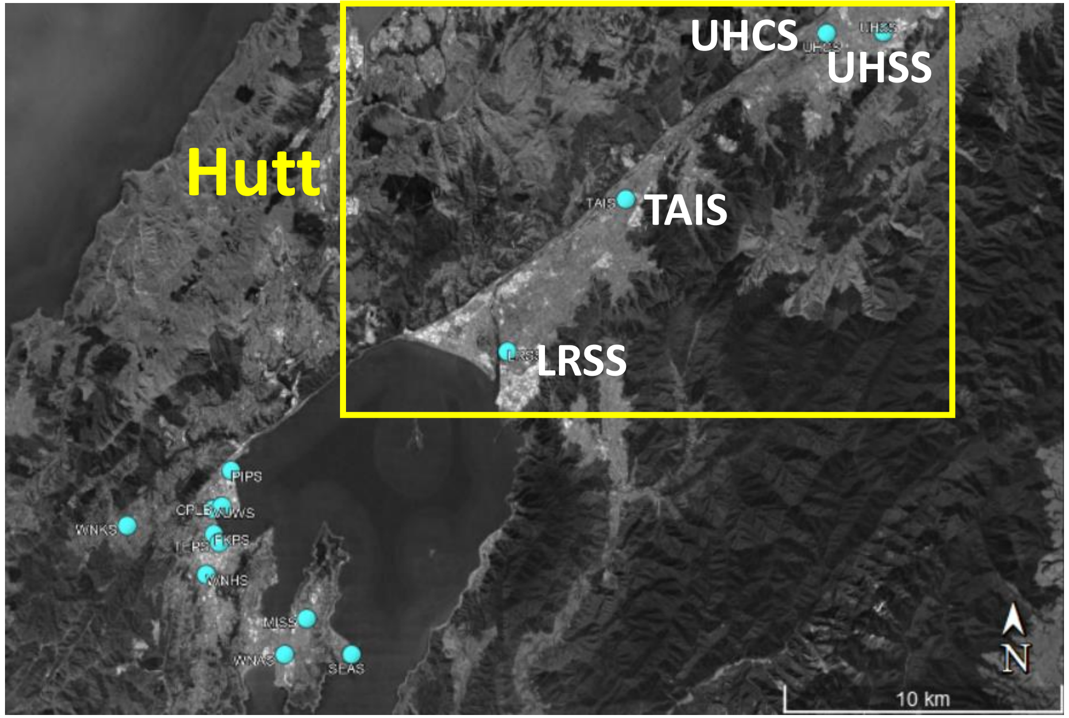




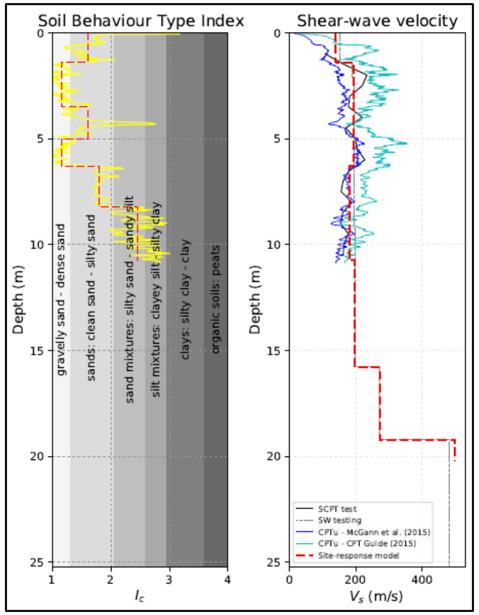
Simulations:
- Crustal EQs: Lee et al. (2021; 2022, in review; ongoing work)
- Interface and slab EQs: Mike Dupuis's ongoing work

Preliminary Results

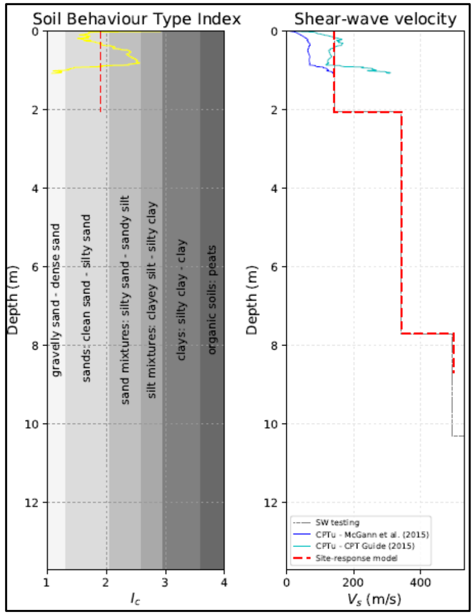
Wellington Region



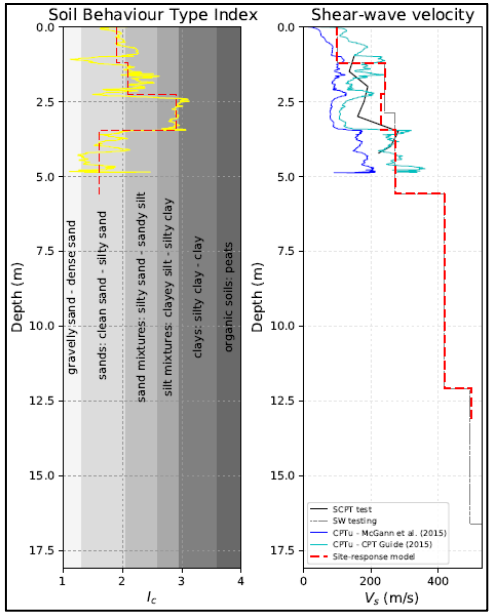
LRSS | Vs30 = 256 m/s



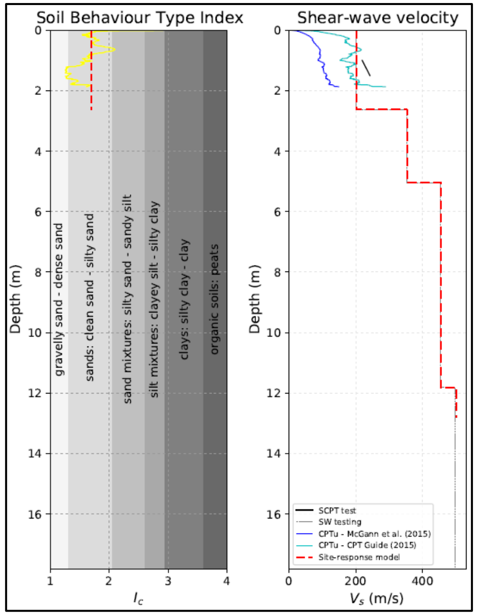
TAIS | Vs30 = 510 m/s



UHCS | Vs30 = 390 m/s



UHSS | Vs30 = 481 m/s



Preliminary Results

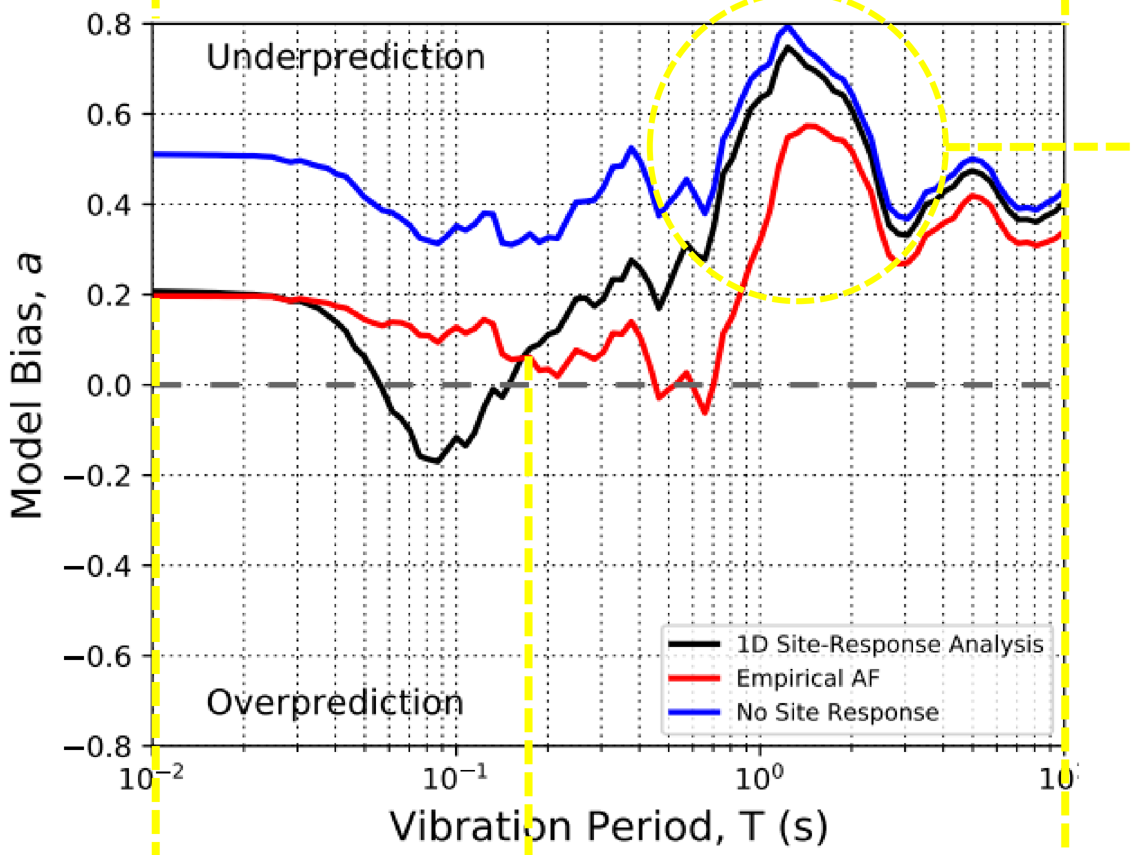
Moderate magnitude EQs (5.0 < Mw ≤ 7.0)
Lee et al. (2021; ongoing work)

Site	N° ground motions
LRSS	9
TAIS	11
UHCS	14
UHSS	10
	44

Next steps:

- More sites and events!
- Systematic trends at different sites
- Better capturing site amplification at longer periods while using 1D site-response analysis

Overall, better performance when site effects are considered



Basin effects

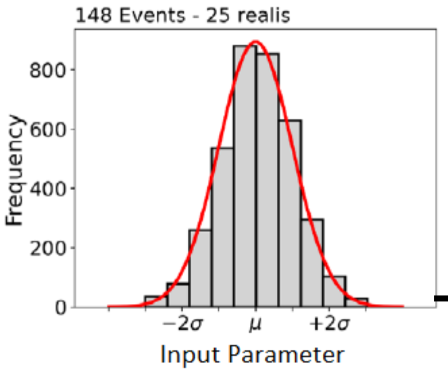
Similar to better performance using 1D site-response analysis

Better performance using empirical AF

Objective 2

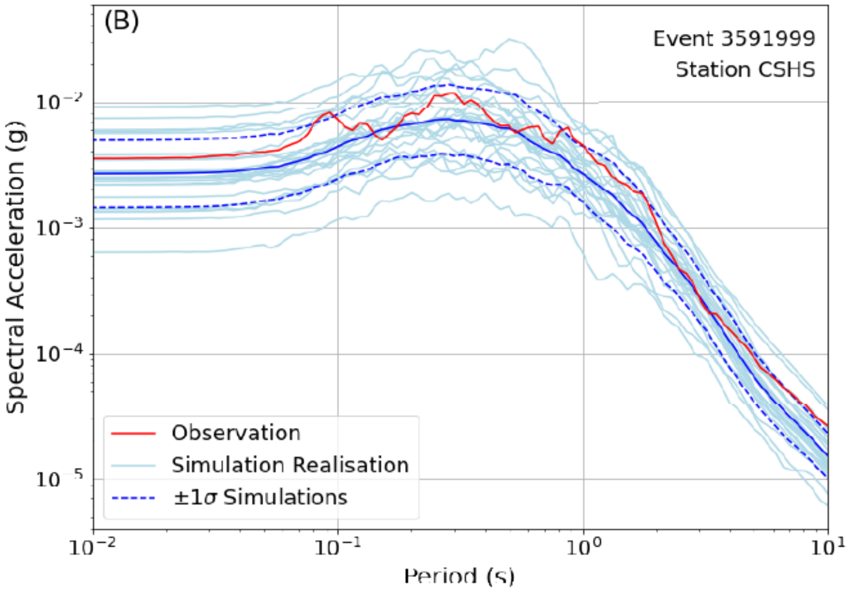
Validation of 1D Site-Response Analysis including Uncertainty ⟶ PSHA

Sarah Neill’s ongoing work:

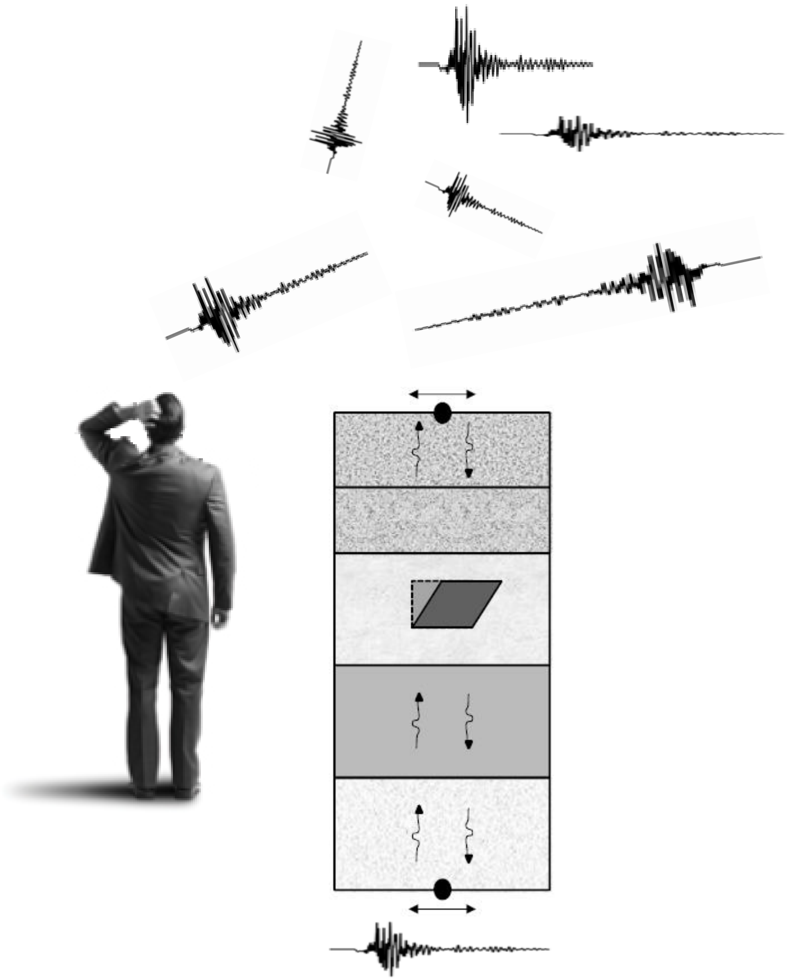


Uncertainty in input parameters:

- Source
- Path
- Site (empirical approach)

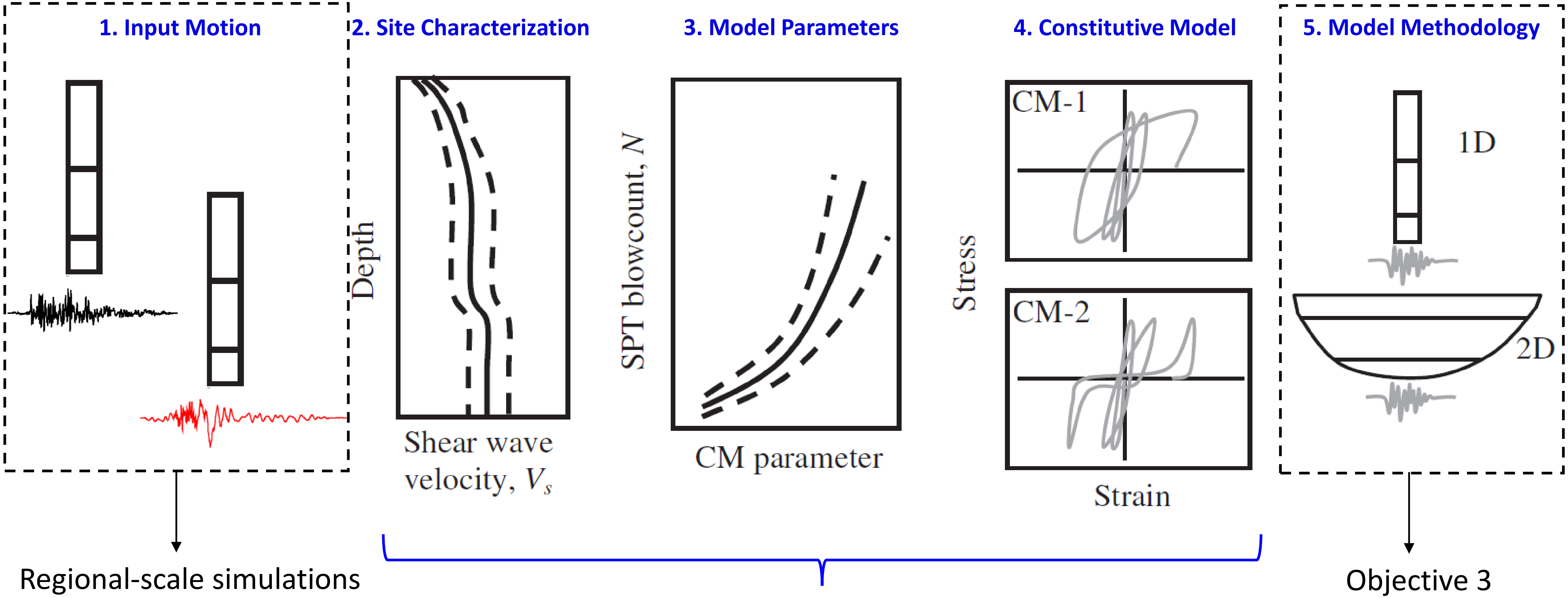


Neill et al. (2021)



Objective 2

Types of uncertainties in site-response analysis (based on Bradley, 2011):



Regional-scale simulations (Sarah Neill's ongoing work)

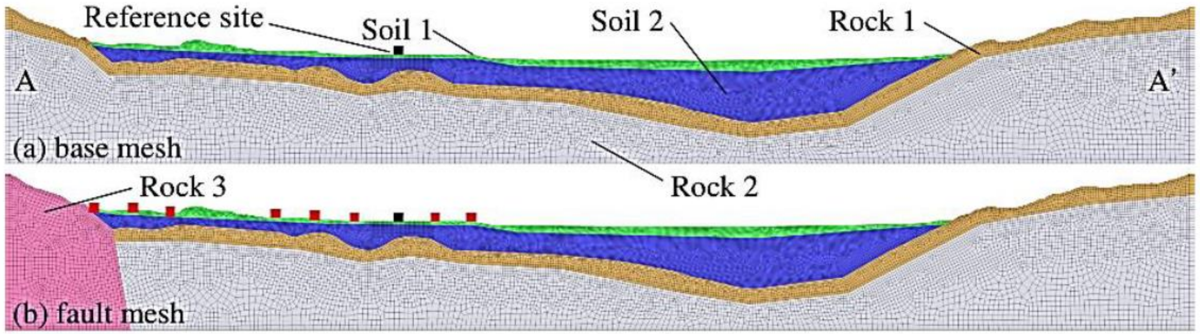
Focus of Objective 2

Objective 3

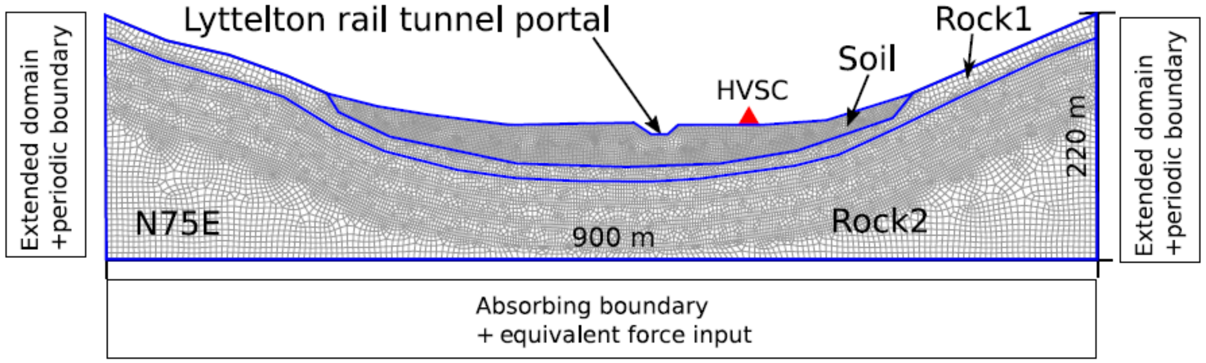
Objective 3

Validation of 2D/3D Site-Response Analysis including Uncertainty

Thorndon Basin, Wellington — McGann et al. (2021)



Heathcote Valley, Christchurch — Jeong & Bradley (2017)



Objective 1 + Objective 2

Systematic identification of locations where 1D site-response analysis doesn't work well

Objective 3

Systematic validation of 2D/3D models, including uncertainty

↑ Model complexity ⇨ ↑ Parametric uncertainty

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