Ground Motion Simulation Validation using Advanced Intensity Measures: NZ Small-Magnitude events

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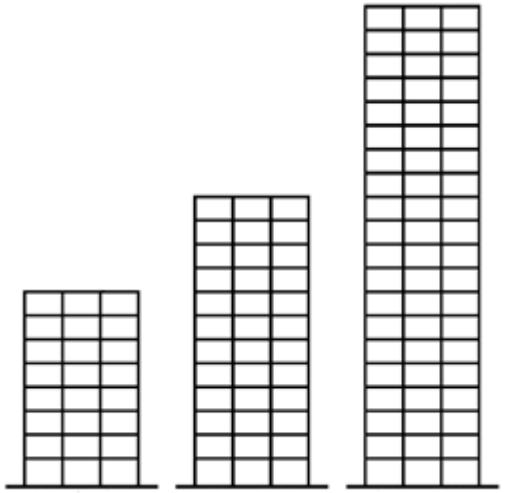
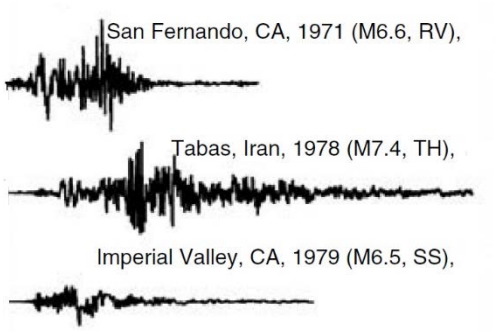
Motivation

Application in response history analysis:





Limitations:

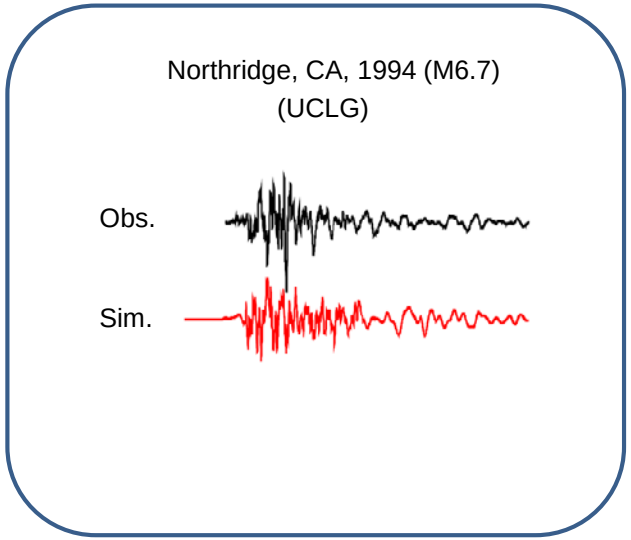
- ✓ Scarcity of ground motion representing the specific-site hazard
- ✓ Incompatibility of selected ground motions in terms of causal parameters

Potential solution:

- ✓ Using simulated ground motions
- ✓ Validation is necessary before use

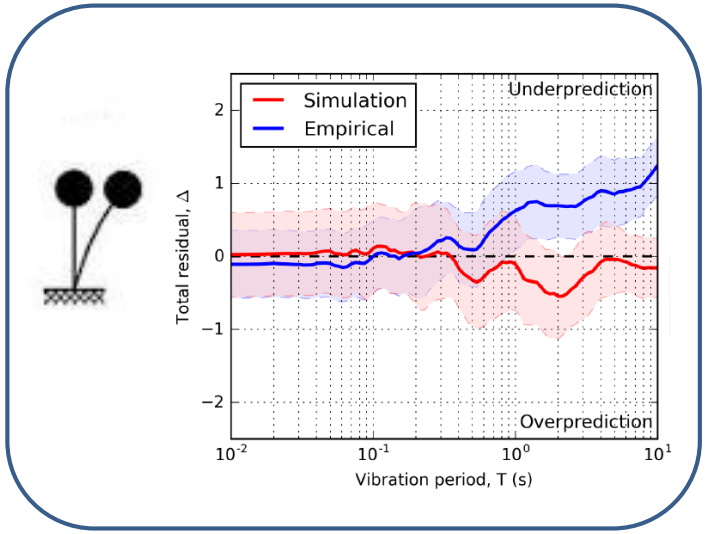
Validation levels

Qualitative
(waveform comparison)



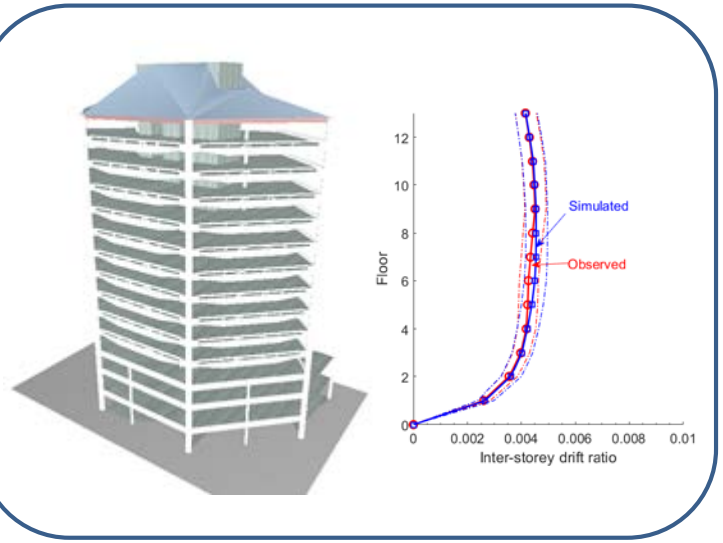
- Informative but not sufficient
- Not appropriate to use in practice

Response spectra
(Simplified Intensity Measures)



- Generalizable and easy to calculate
- Limited and imprecise

Building response
(Advanced Intensity Measures (IMs))



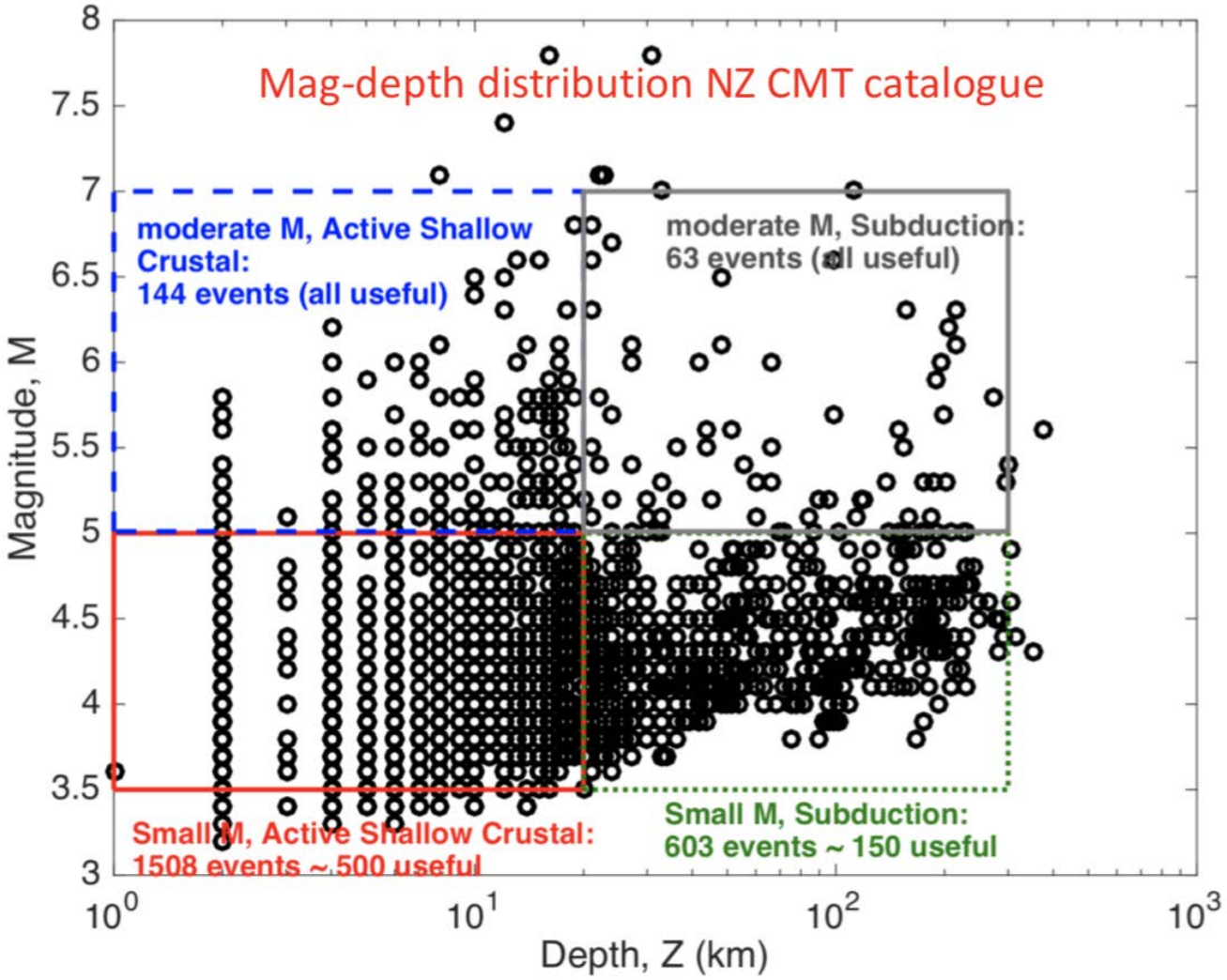
- Complex and comprehensive
- Model-specific

Objectives

Research Objectives :

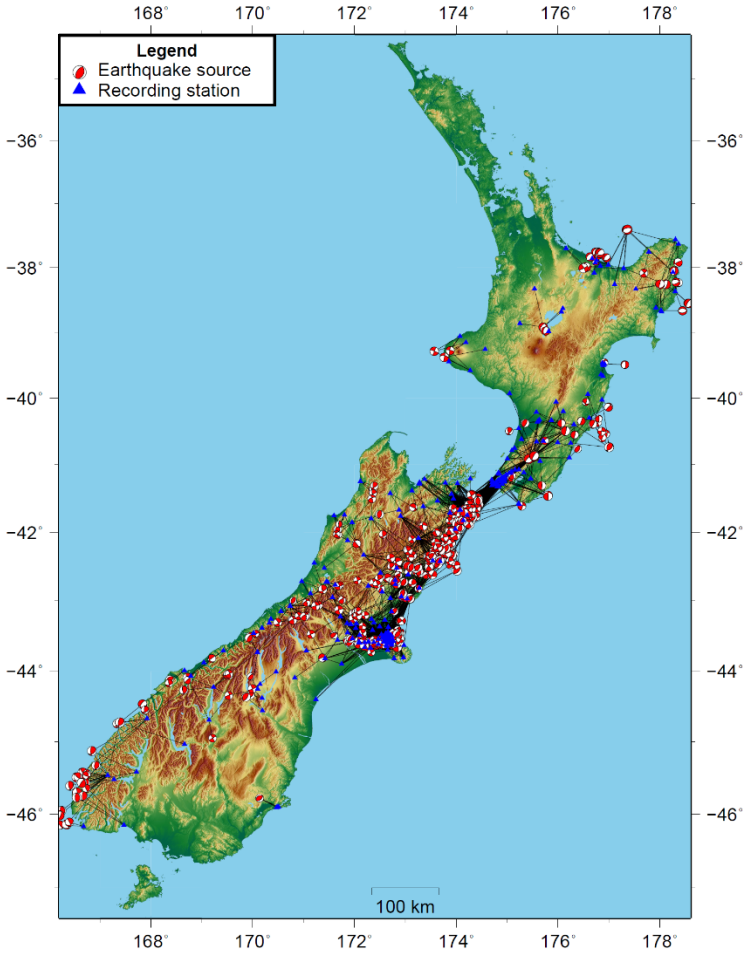
- Develop an analysis framework to infer the probable causative sources related to the discrepancies between observed and simulated ground motions via advanced IMs
- Provide feedback for improving ground motion simulation methodologies
- Investigating the application of simulated ground motions in practice

Selection of Ground motion data set

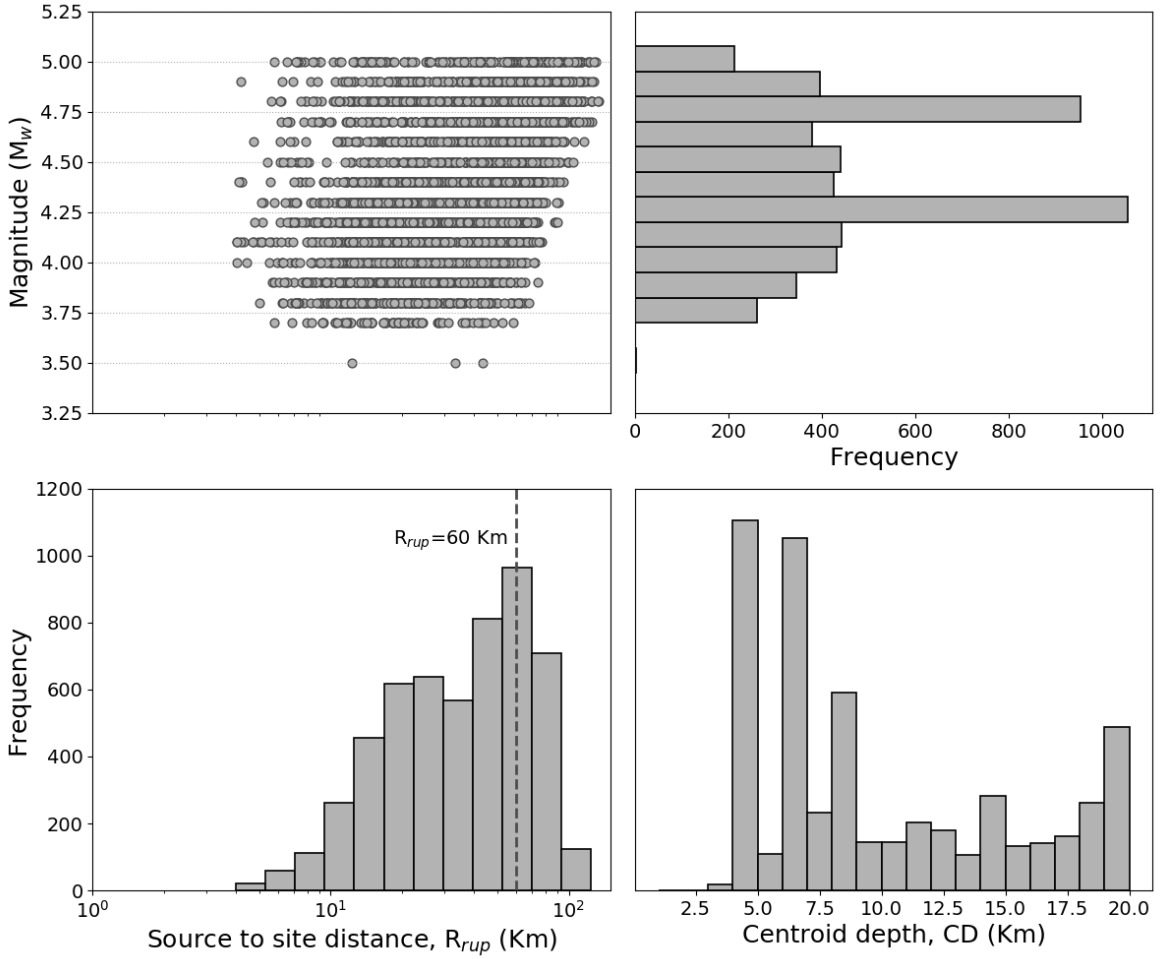


New Zealand small-magnitude events

Ground Motions:



- 489 small-magnitude events $(3.5 < M_W < 5.0)$



- 5350 ground motions

Structural properties

Case study:

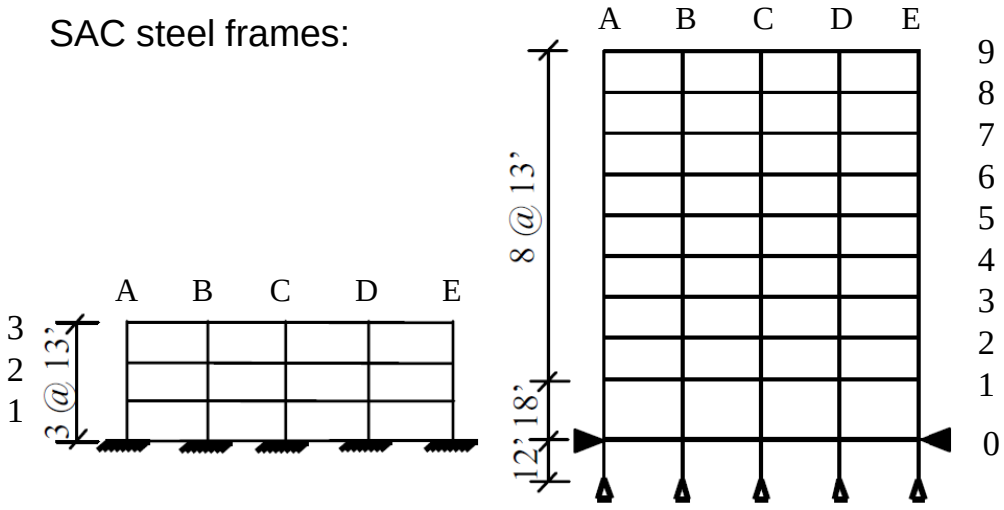
- Three SMRF archetypes
  - ✓ 3-storey, T_n= 0.98 sec.
  - ✓ 9-storey, T_n= 2.95 sec.
  - ✓ 5-storey, T_n= 1.64 sec.

- Nonlinear Model:
  - ✓ Elastic Elements Lumped Plastic Hinges
  - ✓ Modified Ibarra-Medina-Krawinkler hysteretic model

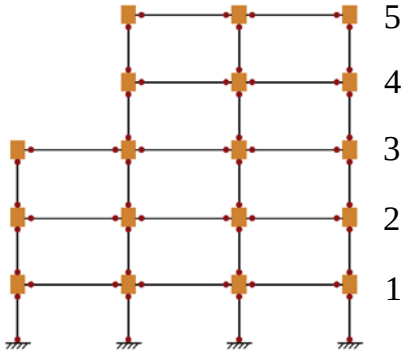
  Note:
  - ✓ Linear behaviour subjected to small-magnitude events

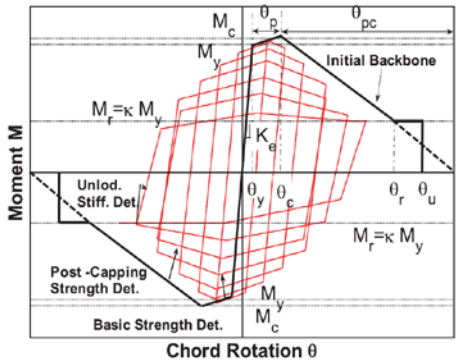
- Responses :
  - ✓ Inter-story drift ratio (IDR)
  - ✓ Peak floor acceleration (PFA)

SAC steel frames:



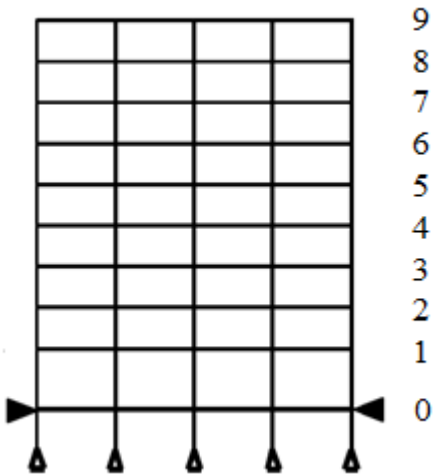
a) 3-storey b) 9-storey

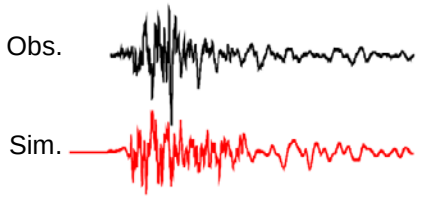




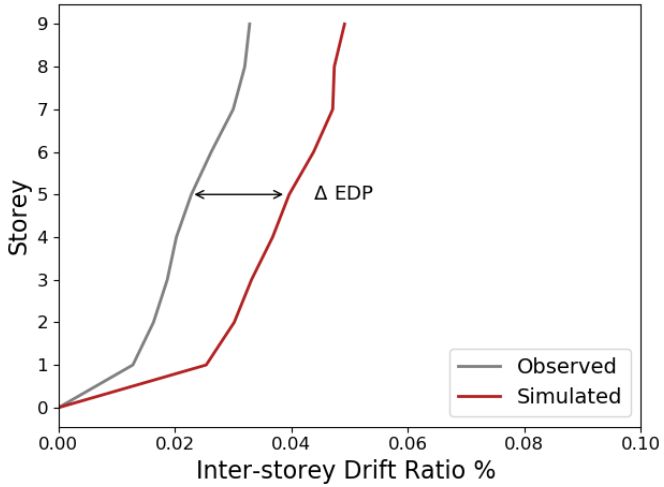
c) 5-storey d) hysteretic model

Analysis Framework

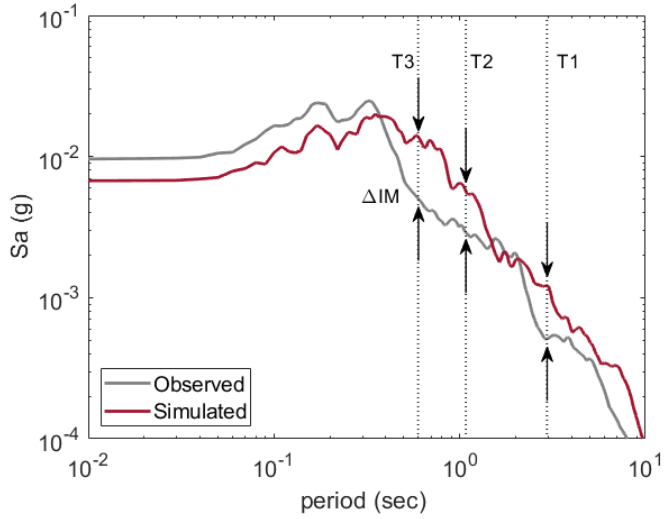




Building response



Response spectra



$$\Delta EDP \sim f(\Delta IM_1, \ldots, \Delta IM_n \ldots)$$

Analysis Framework

ΔEDP relationship with ΔIM:

$$\Delta_{EDP} \sim f\left(\Delta_{IM_1}, \dots, \Delta_{IM_n}, \dots\right)$$

$$\Delta_{EDP} = a_0 + a_1\Delta_{IM_1} + \dots + a_n\Delta_{IM_n} + \xi$$

IM = Simplified IMs
(e.g. PGA, pSa(T)…)

EDP = Advanced IMs
(e.g. Drift at n^{th} story…)

Main findings:

- To find which IMs contribute in the EDP of interest
- To find how much bias **can be explained** by the considered IMs
- To find how much bias **cannot be explained** by the considered IMs
- To find other candidates which can be the future IMs

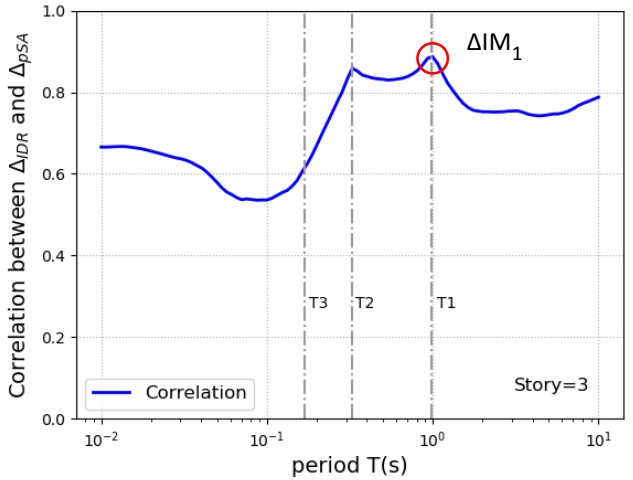
Variable Selection

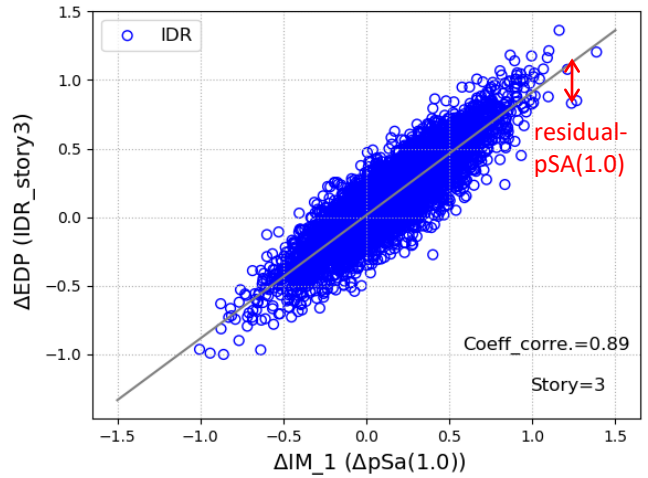
Variable selection methods:
(forward stepwise selection approach)

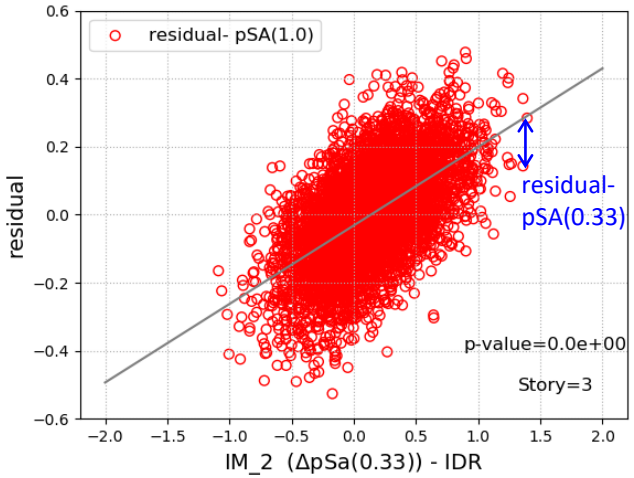
- Correlation analysis (p-value)
- K-fold cross-validation
- AIC/BIC

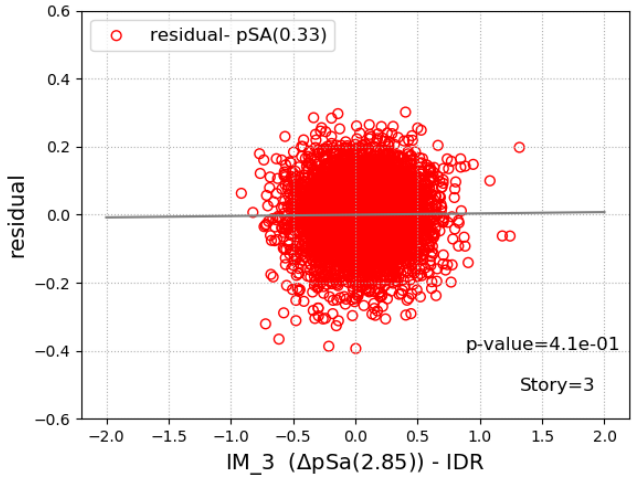
$$\Delta IDR_{story3} = a_0 + a_1 \Delta pSa(1.0\ s) + a_2 \Delta pSa(0.33\ s) + \xi$$

Correlation analysis (p-value)



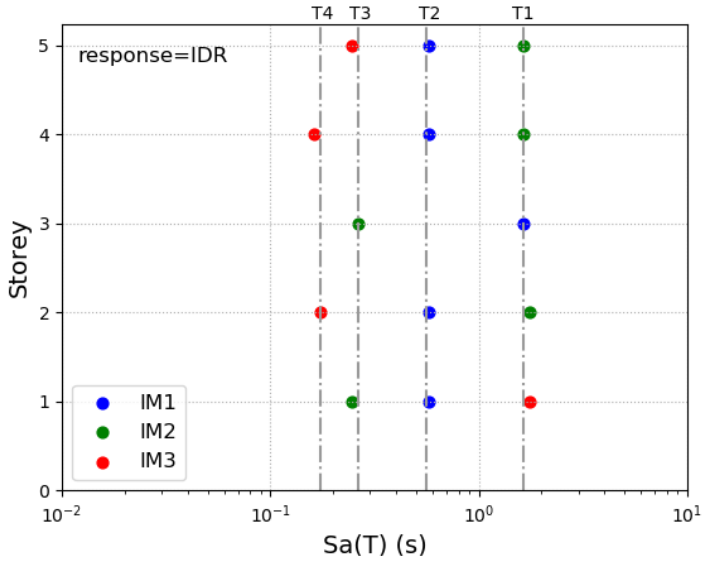


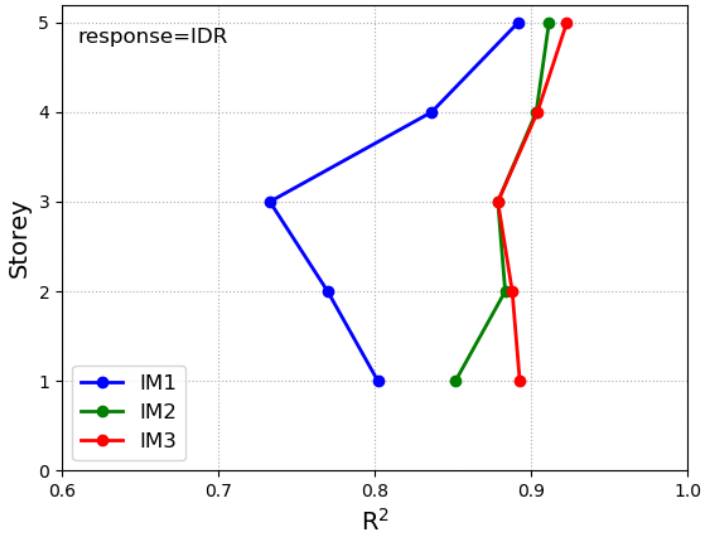




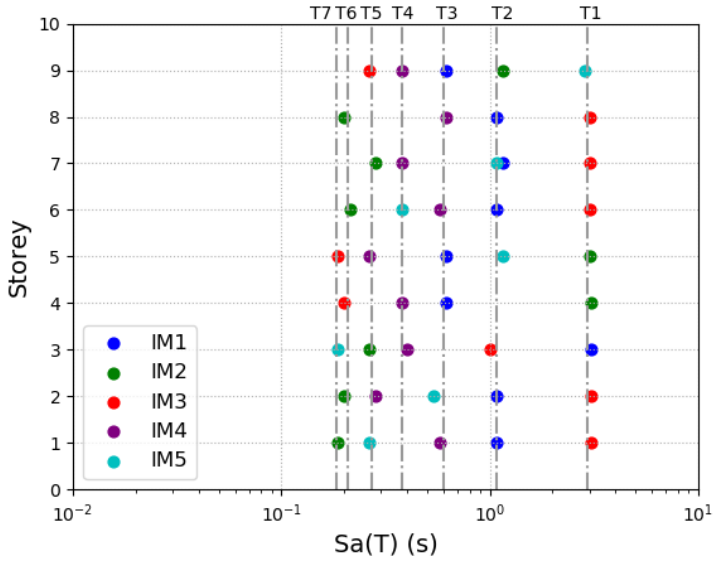
Analysis results

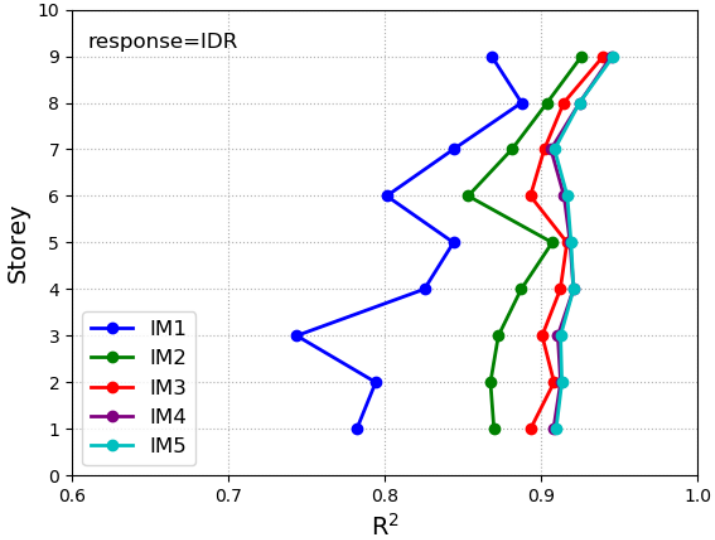
5-Storey model - IDR:





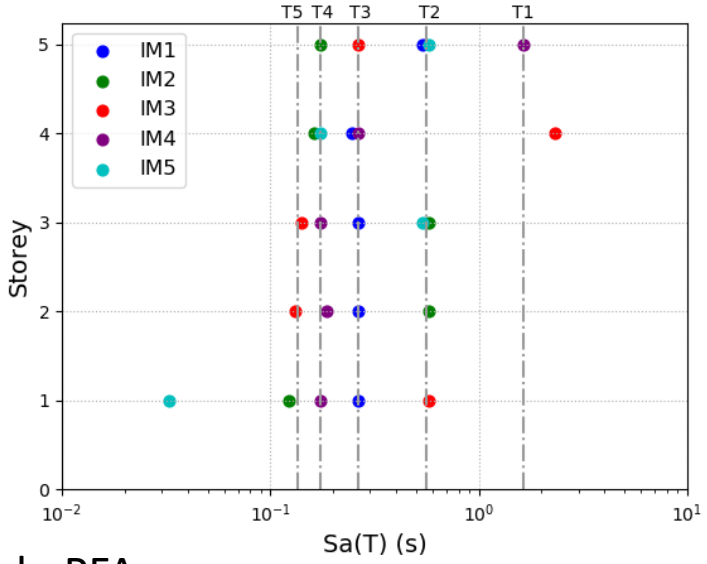
9-Storey model - IDR :

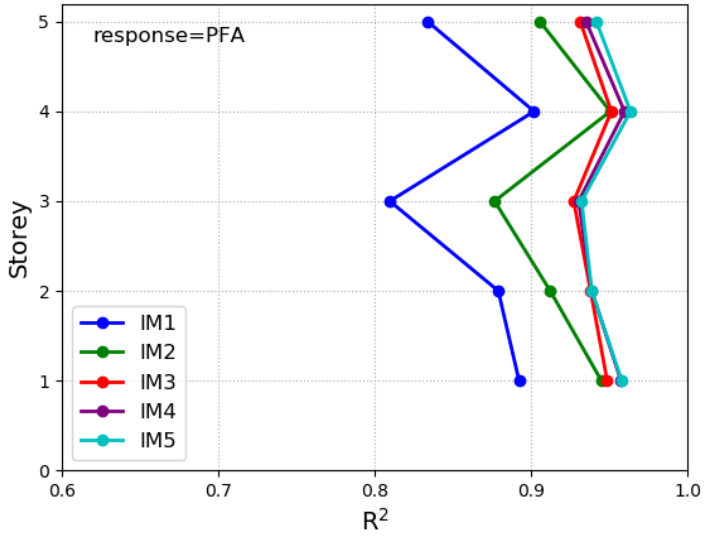




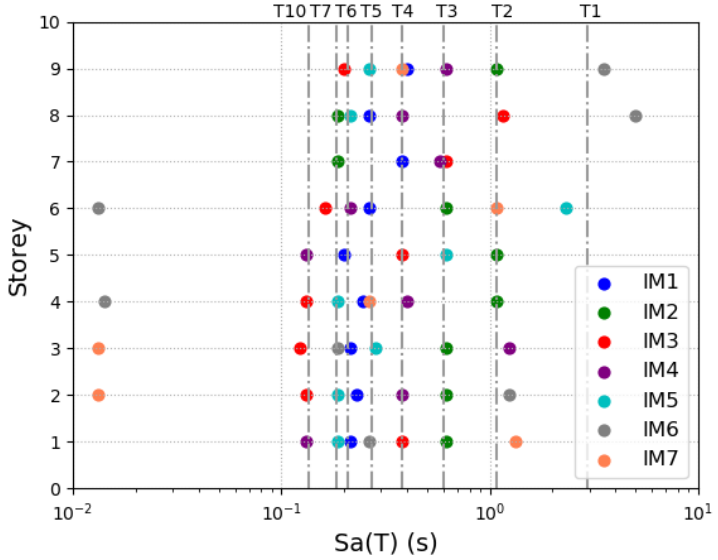
Analysis results

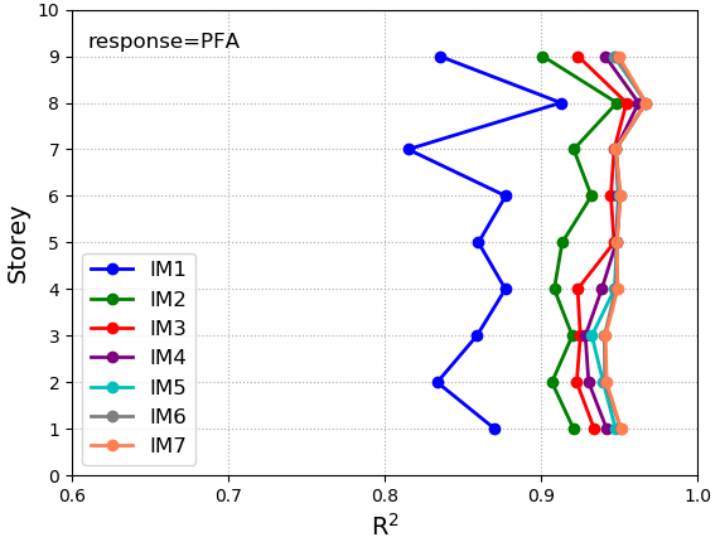
5-Storey model - PFA:





9-Storey model - PFA :





Summary

Conclusions :

- Developing an analysis framework to infer the probable causative sources related to biases between observed and simulated ground motion via response of complex models
- Providing a benchmark for analysis framework in linear level
  (This will be extended to consider non-linear responses)
- The majority of the biases can be explained by the difference of the spectral acceleration at the **main modes of vibration** contributed to the selected response
- More than **90%** of the differences can be explained via selected variables
- Simulated ground motions which can capture the response spectra at the main modes of vibration can capture the response of structure well in the linear level

Future plans

Future Works :

- Validation of NZ moderate-to-large magnitude events ($5 < M_W < 7$)
  (to capture the nonlinear behavior and collapse cases)

- Considering different structural models
  (3D model to consider the effect of torsion…)

- Comparing different GMs simulation methods

- Seismic performance assessment using simulated ground motions

Thank You!

Questions…?