Te Hiranga Rū | QuakeCoRE
Aotearoa New Zealand Centre for Earthquake Resilience

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Ground motion simulation validation with explicit uncertainty incorporation for small magnitude earthquakes in the Canterbury region

QuakeCoRE Flagship 1 meeting

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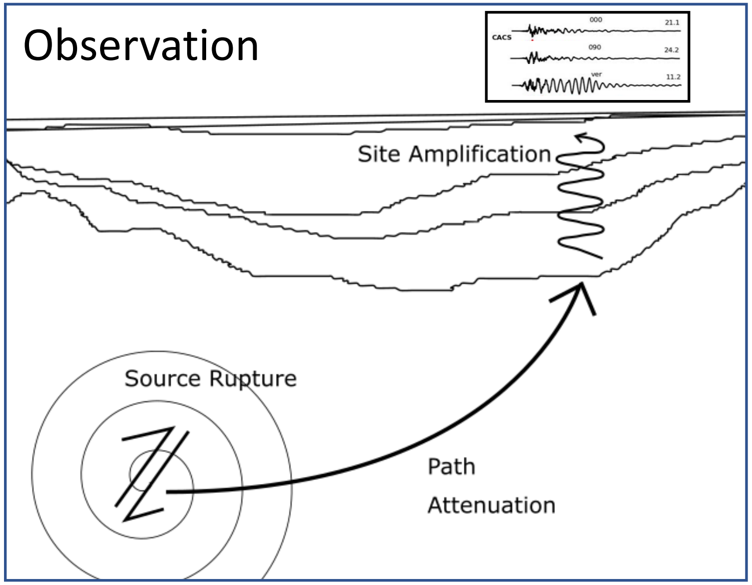
Background

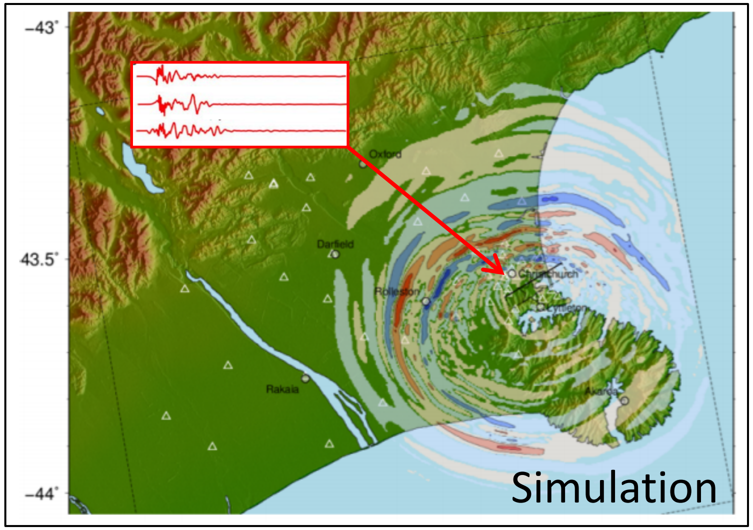
Overview:

- Explicitly incorporating uncertainty
- Validation
- Uncertainty in forward prediction

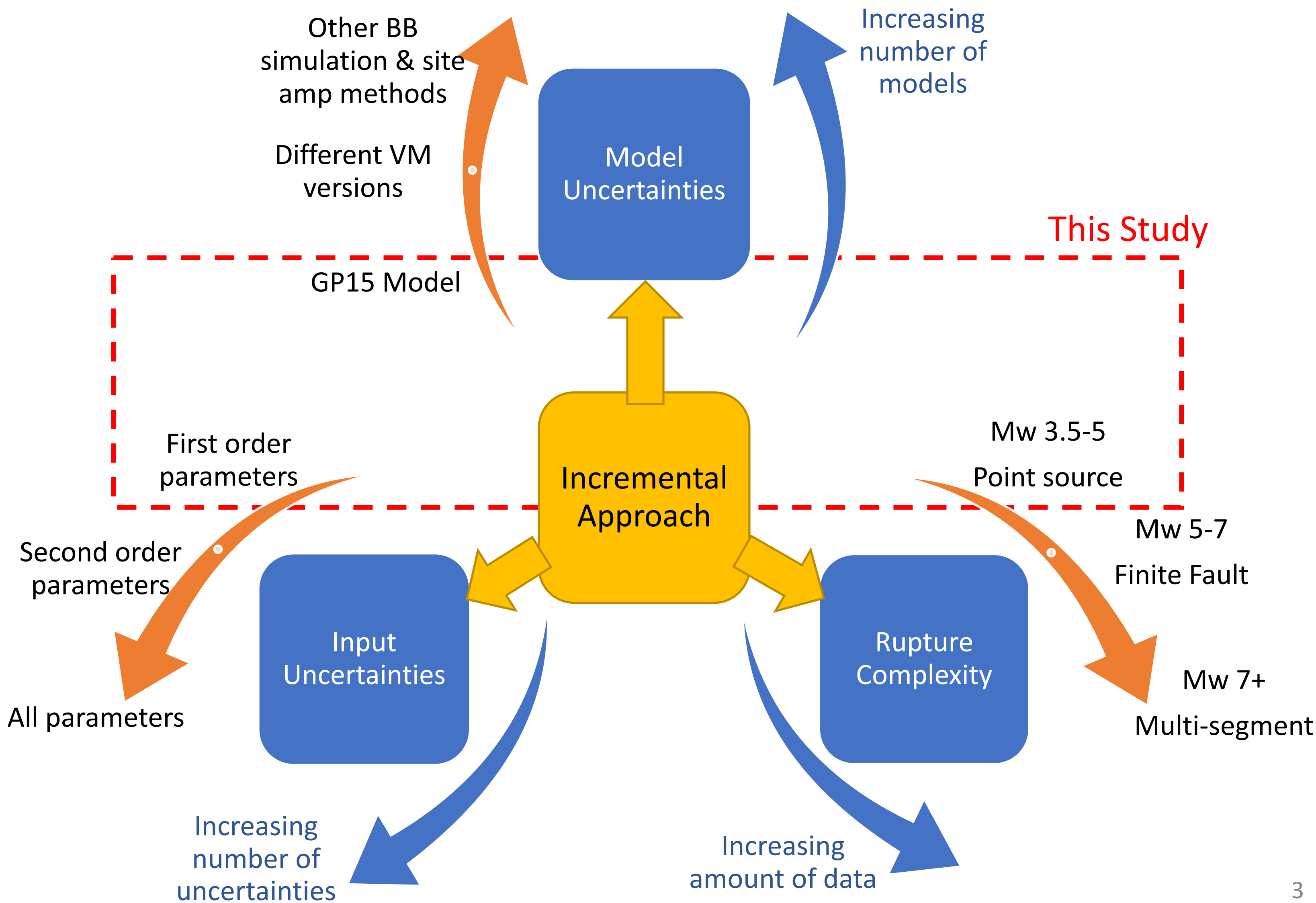


Motivation:

- Misfit – due to model limitations
- Forward prediction limitations
- Captured by incorporating uncertainty



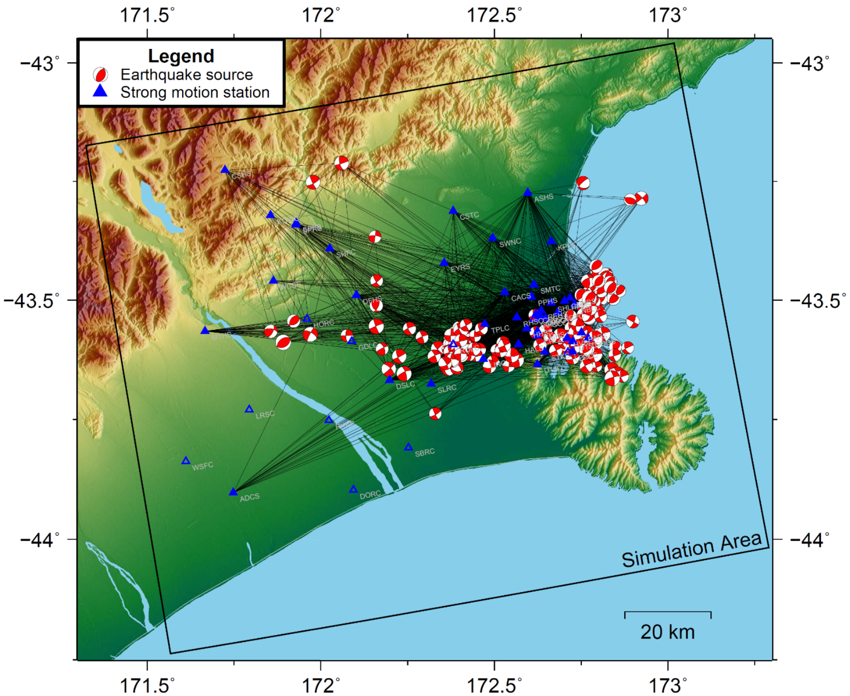
Uncertainty Validation Framework



This Study: Uncertainty Validation

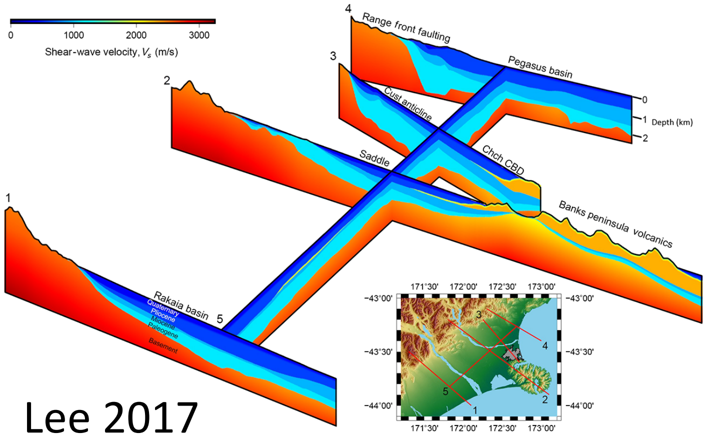
Data:

- Small magnitude events (Mw 3.5 – 5)
- Canterbury region
- 148 events
- 42 Sites



Benefits:

- Point source assumption
- Canterbury data
- Canterbury VM
- Linear
- Less uncertainties

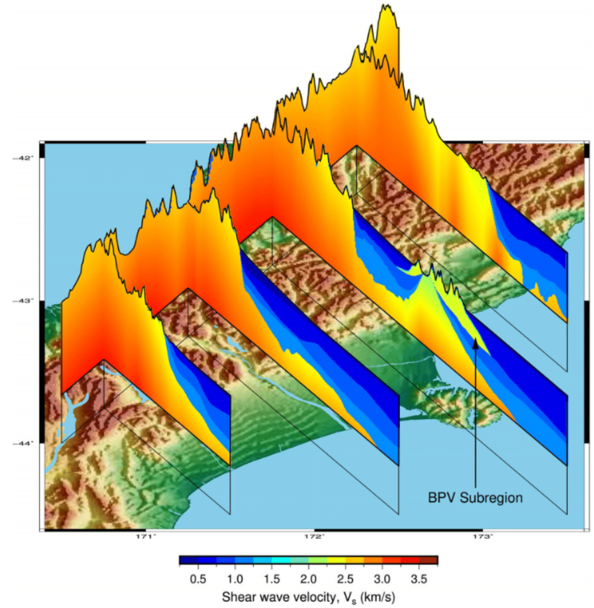


Lee 2017

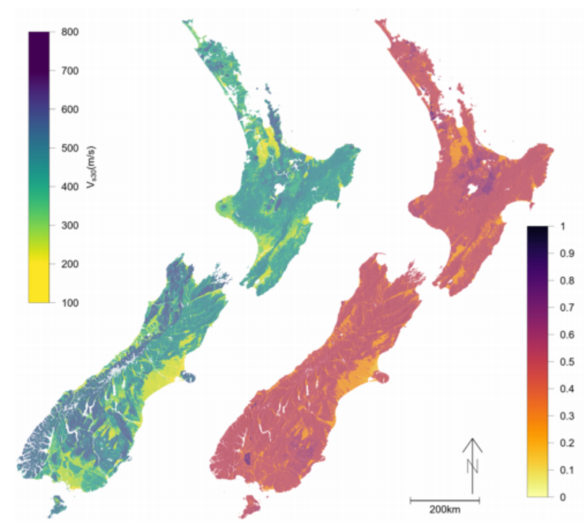
Uncertainty Validation

Method:

- Graves and Pitarka hybrid method
- LF comprehensive physics,
- HF simplified physics
- Ruptures modelled as point sources
- LF waveforms computed in 3D NZVM, FD, 400m grid
- HF waveforms computed stochastically (Boore 2003)
- Transition frequency
- HF empirical Vs30 based site amp.



Thomson (2019)

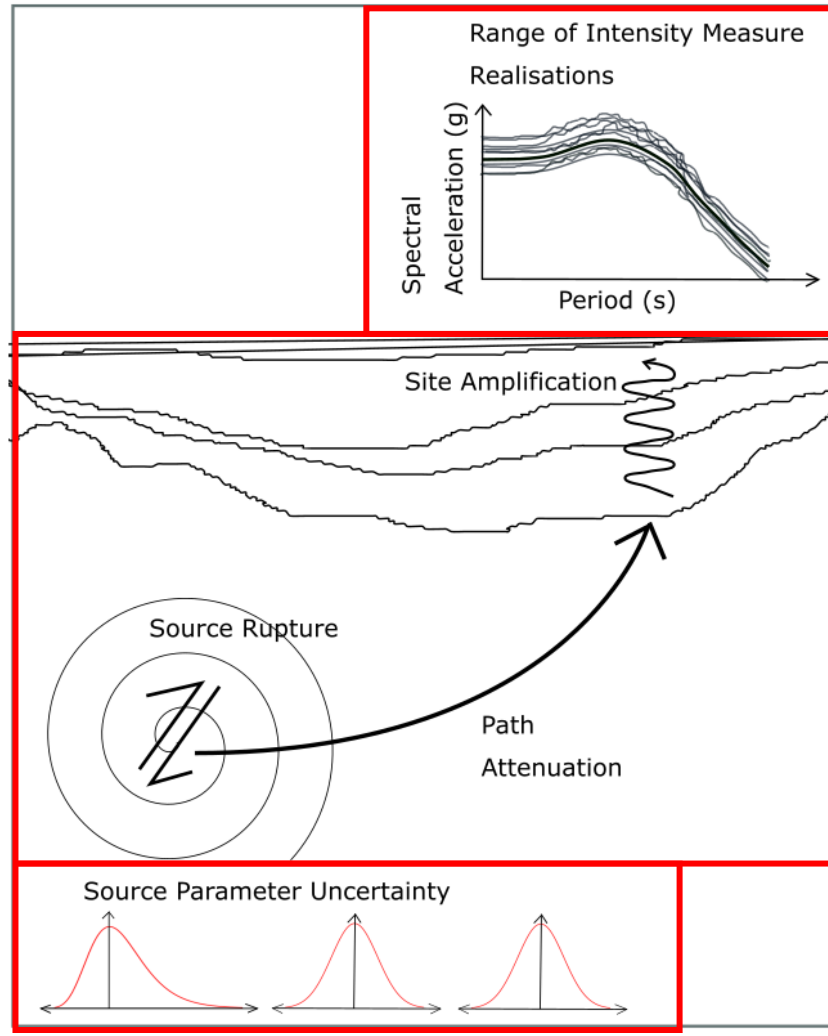


Foster (2019)

Incorporating Uncertainty

Method:

- Set prior distributions for parameter uncertainty
- Monte-Carlo sampling
- Generate 20 realisations
- Propagated through ground motion simulation
- Simulate ground motions



Post-processing:

- Intensity measures calculated
- To compare against observations

Source Randomisation Example

Source parameter uncertainty

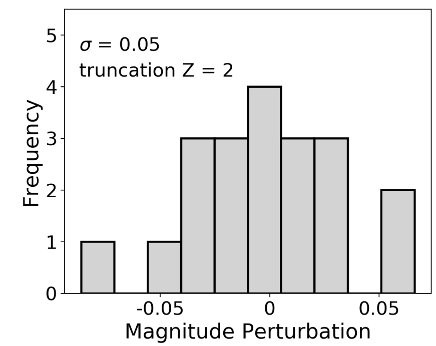
20 realisations

Accounts for:

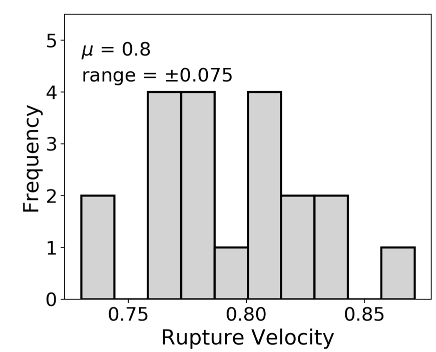
- Measurement errors
- Parameter assumptions
- Modelling limitations

Prior distributions:

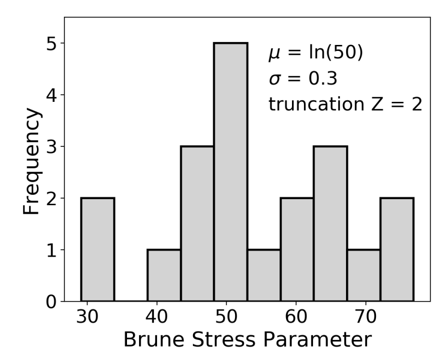
- Magnitude
- Truncated normal
- σ = 0.05, Z = 2



- Rupture velocity
- Uniform
- μ = 0.8, range = ±0.075



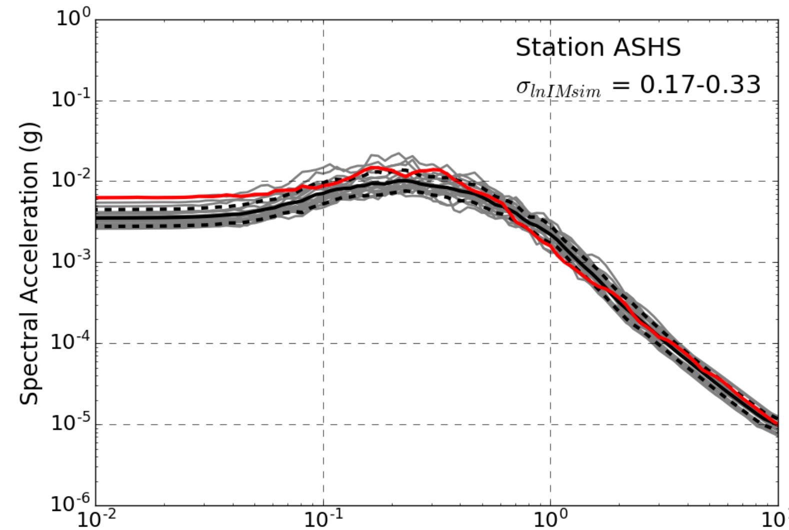
- Brune stress parameter
- Truncated lognormal
- $\mu = \ln(50)$, $\sigma_{\ln} = 0.3$, $Z = 2$



Response Spectra Example

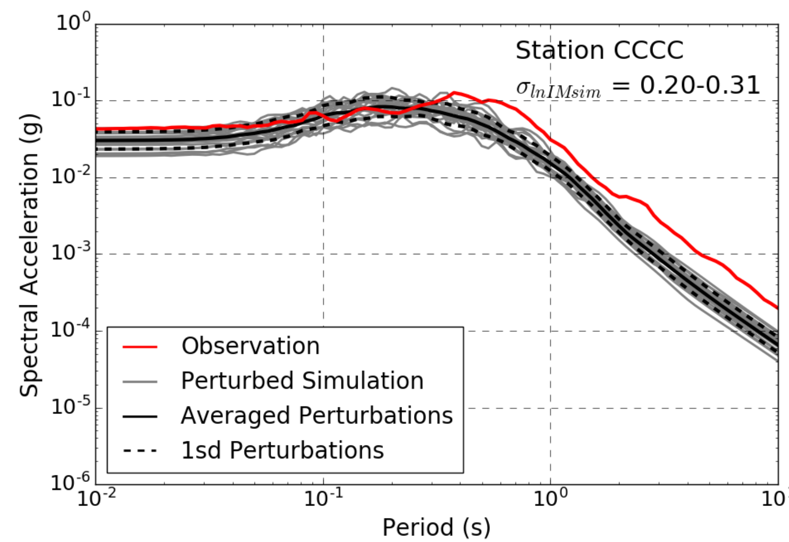
Response Spectra:

- Multiple realisations
- ~1800 event/site combinations



Example:

- Mw 4.2, Christchurch, 22/02/2011
- Ashley School and Chch Cathedral College stations



Results: Individual event & site

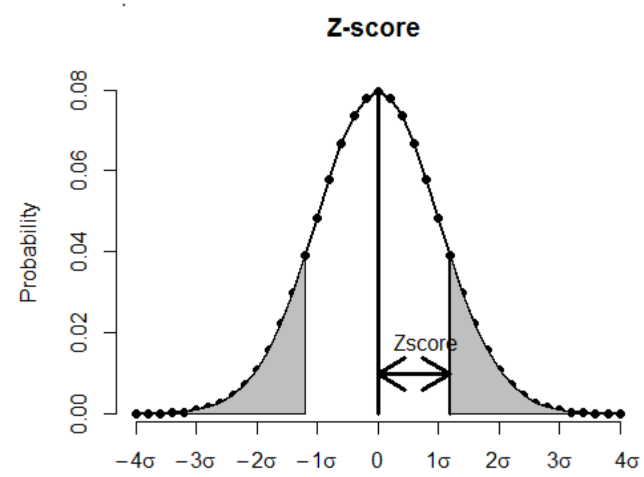
Validation with observations:

- Normalised residual for each event and site

$$Z = \frac{\ln(IM_{obs}) \; - \; \mu_{\ln(IM_{sim})}}{\sigma_{\ln(IM_{sim})}}$$

- Z = Number of standard deviations that an observation is above/below simulation mean
- Assumes a lognormal distribution

$$\ln(IM_{obs}) = \; \mu_{\ln(IM_{sim})} + Z \, \sigma_{\ln(IM_{sim})}$$



Results: All events & sites

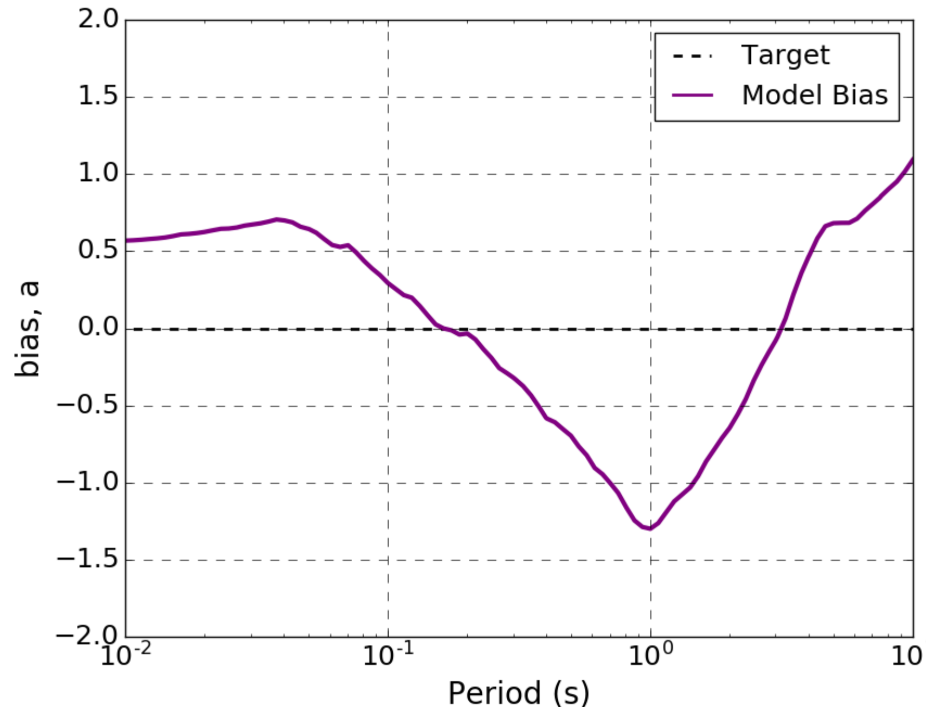
Mixed effects regression

Partitioning of Normalised Residual (Z)

$$Z = a + \delta_e + \delta_s + \delta_{es}$$

Components:

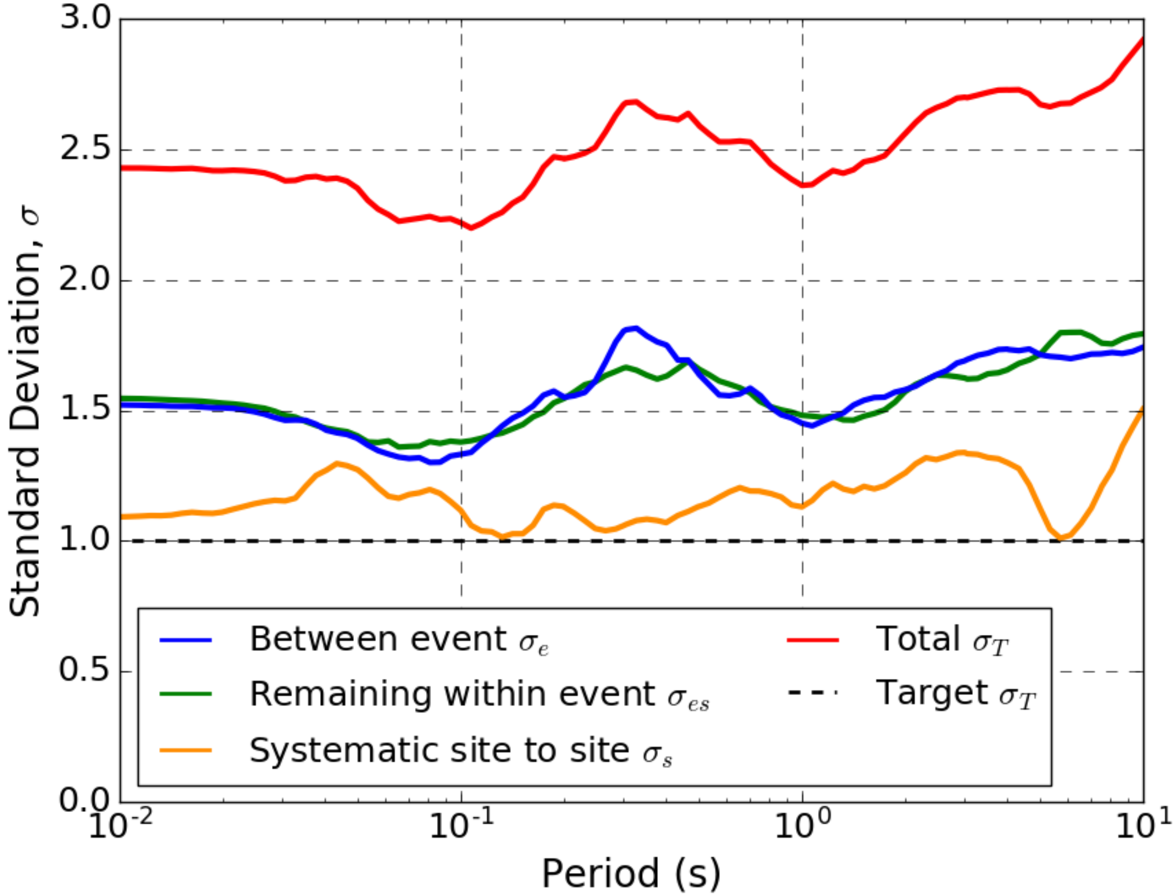
- Model bias
- Between event effects
- Systematic site-to-site effects
- Remaining within-event



Model bias
Target = zero

Results: All events & sites

- Standard deviation of partitioned components
- Total target σ = 1



Conclusions

- Insufficient uncertainty
- Refine uncertainty
- Additional uncertainties:
  - Path and site uncertainties
  - More source uncertainties
- Higher VM resolution

Next: Short term

- More refined study:
  - More realisations (50)
  - Less events (20)
  - Finer grid (400 → 200m)
- Generate non-SA IMs
- More uncertainties:
  - Source (current): Mw, Δσ, Vr
  - Source (new): lat/long, depth, dip rake (fc)
  - Path: Qs, Qp, q_k
  - Site: κ_0
  - Higher Mw uncertainty

Next: Mid term

- Source uncertainties:
  - Parameter depth dependencies
  - More parameter uncertainties (eg fc, radiation param.)
  - Perturbate 1D VM
- Path uncertainties:
  - Parameter depth dependencies
  - Perturbate 1D VM
  - Duration
- Site uncertainties:
  - Vs30
- Parameter correlations

Thank you