Explicit validation of uncertainties in GM simulation

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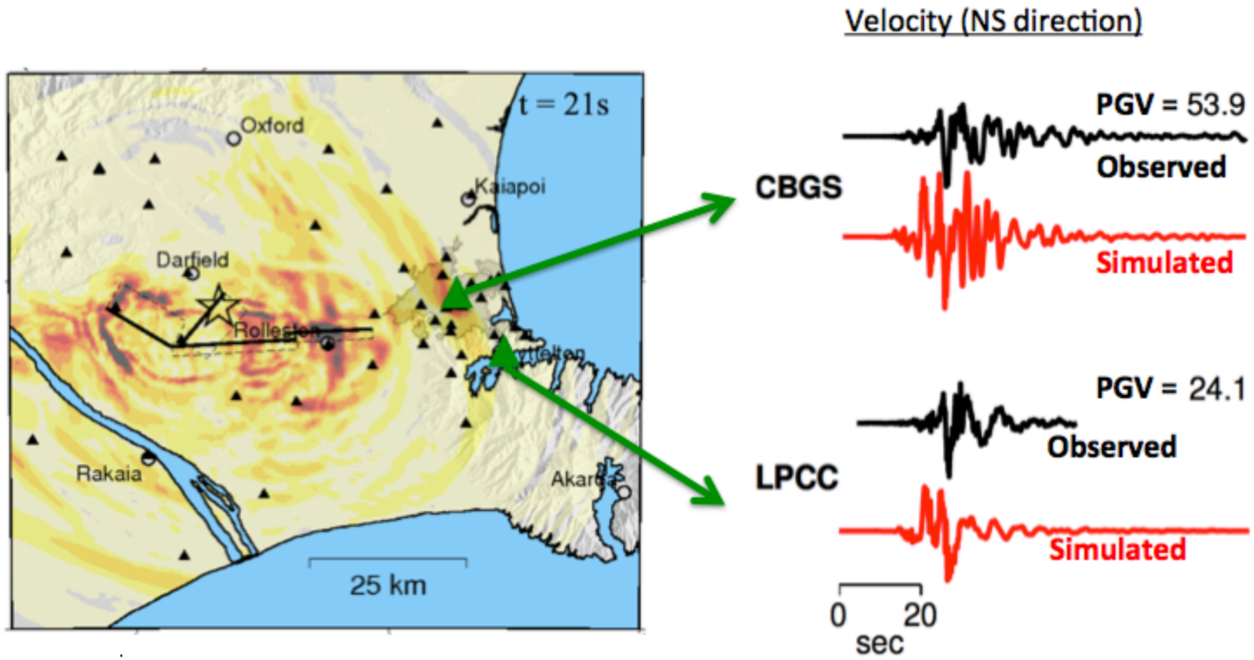
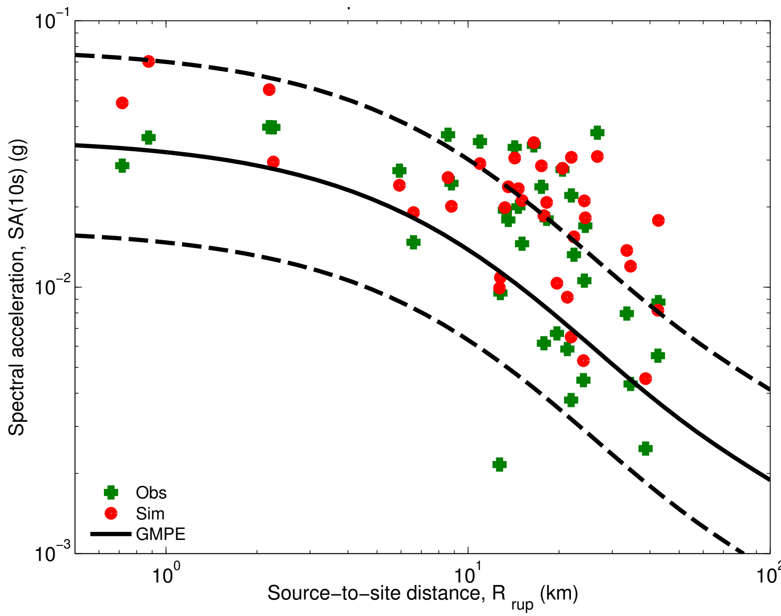
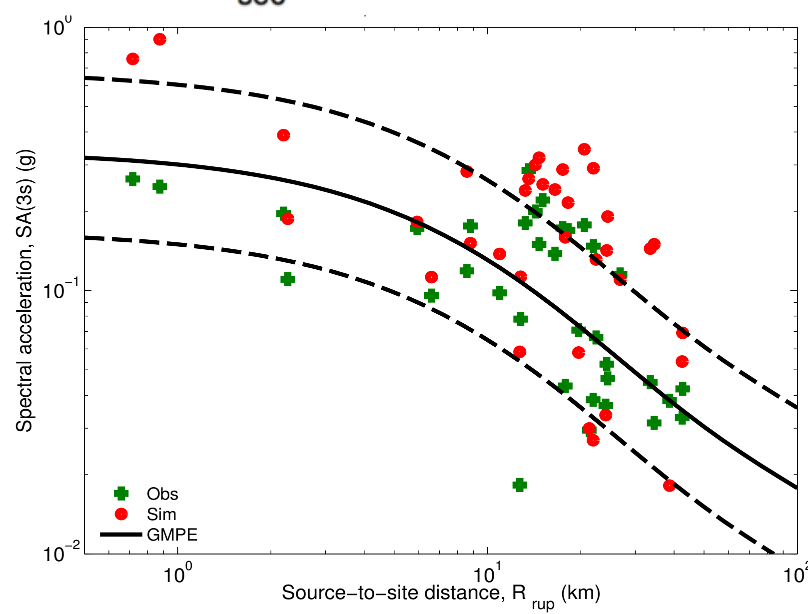
Motivation

- Use of GM simulations in seismic hazard analysis (PSHA) requires validation of their predictive capabilities
- A critical component in hazard analysis is representation of the complete distribution of ground shaking (i.e. mean, stdev etc)
- Conventional GM simulation validation approaches focus only on the mean prediction

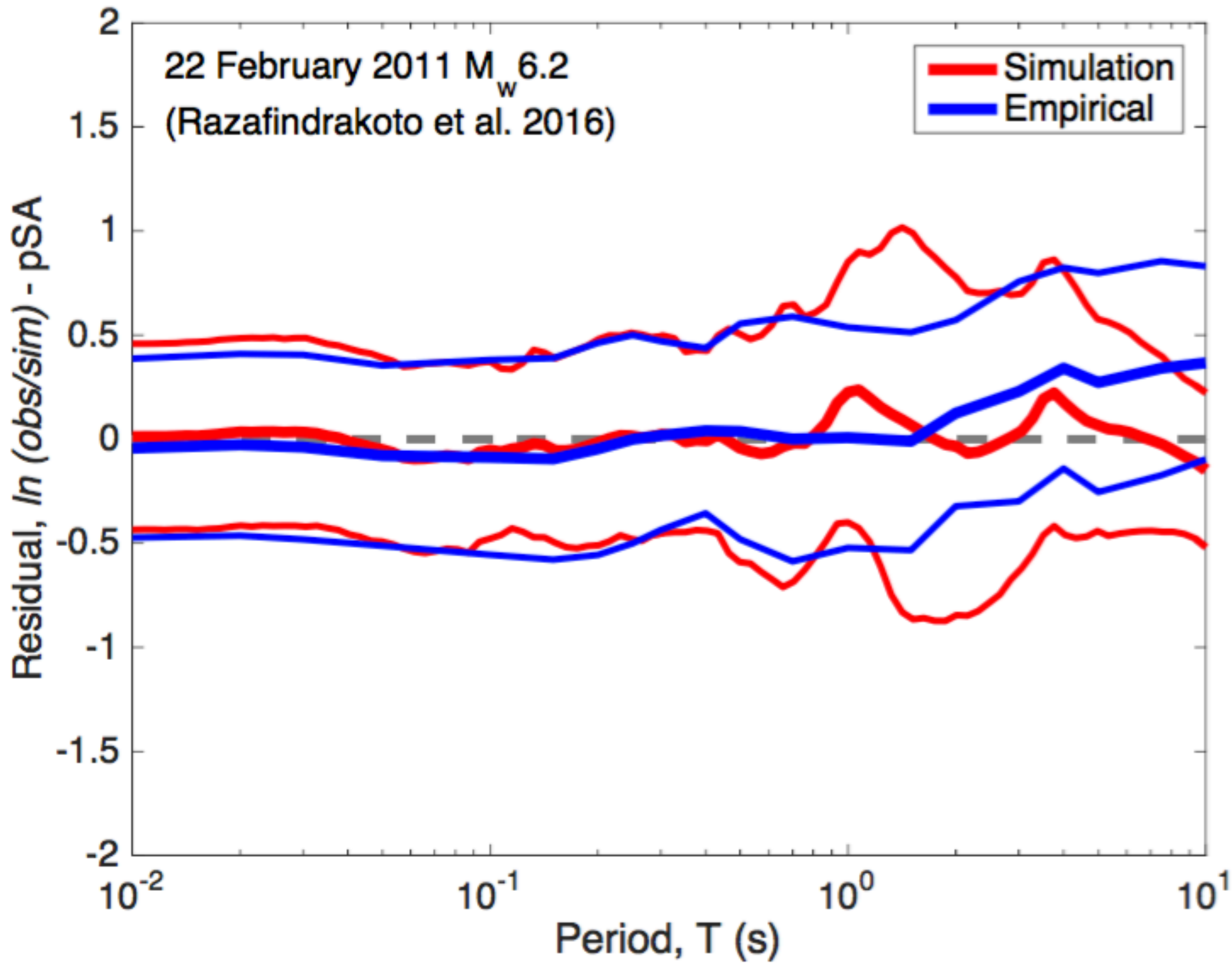
Conventional validation







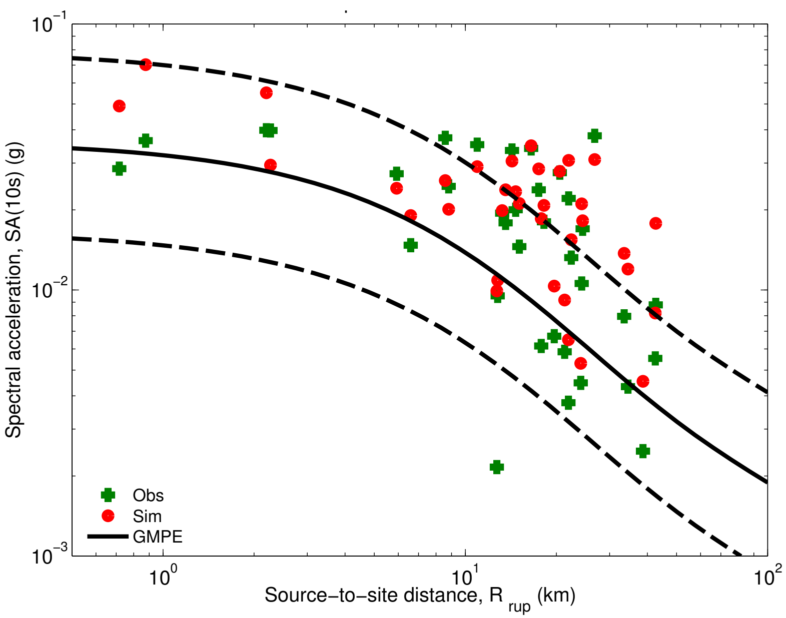
Conventional validation



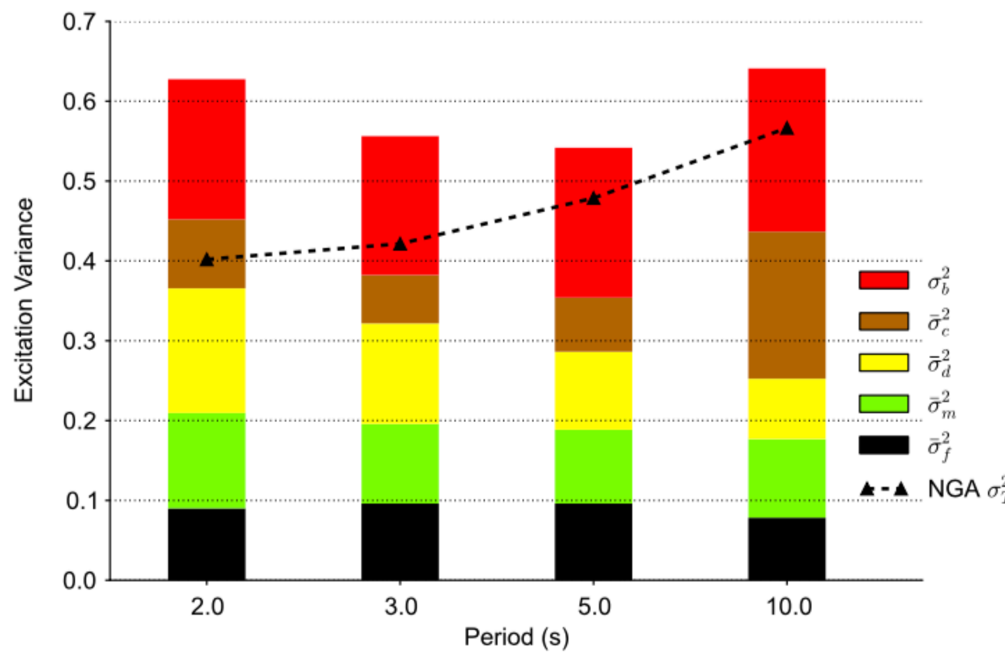
- Simulations have smaller bias than empirical model at long periods
- Standard deviation of residuals similar for sim & empirical

How much uncertainty should their be in simulations??

The same as empirical models?

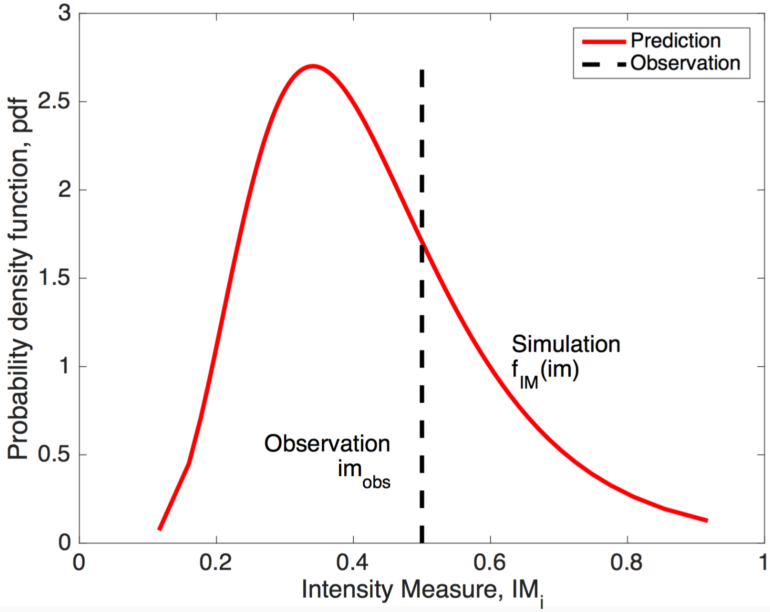


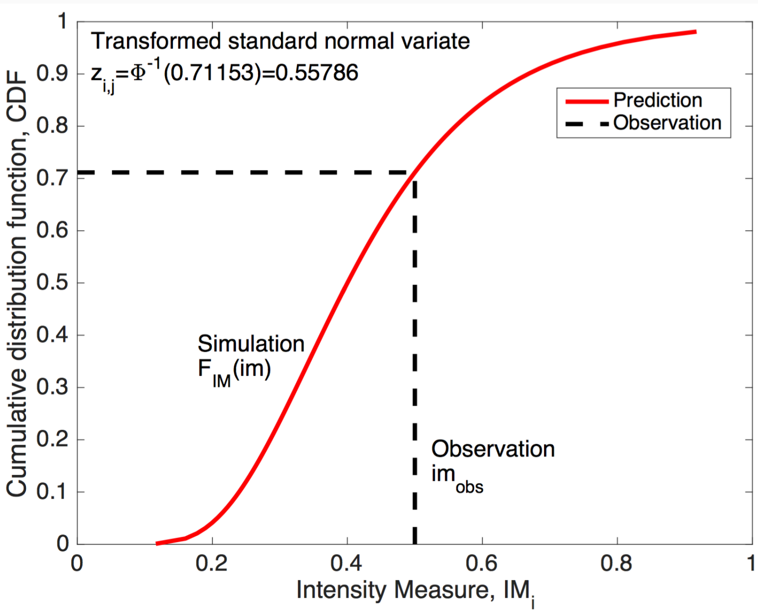
Less, because more physics is captured?



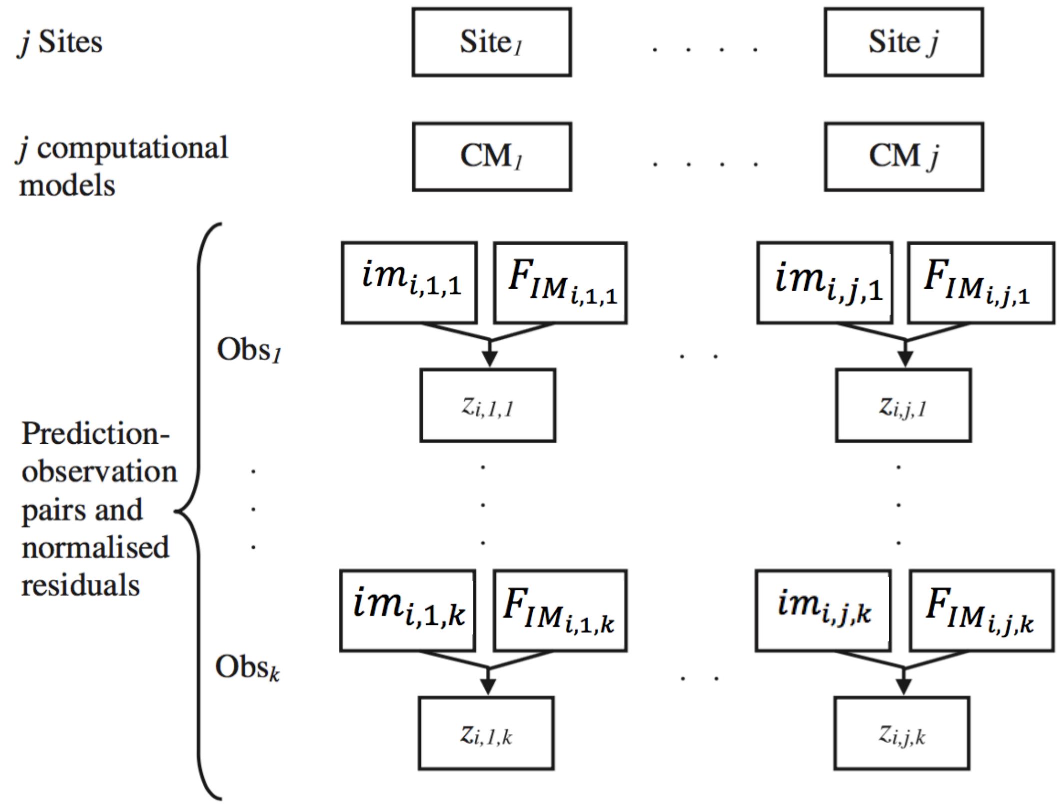
Observations vs. simulation distribution

At a single site, for a single observation





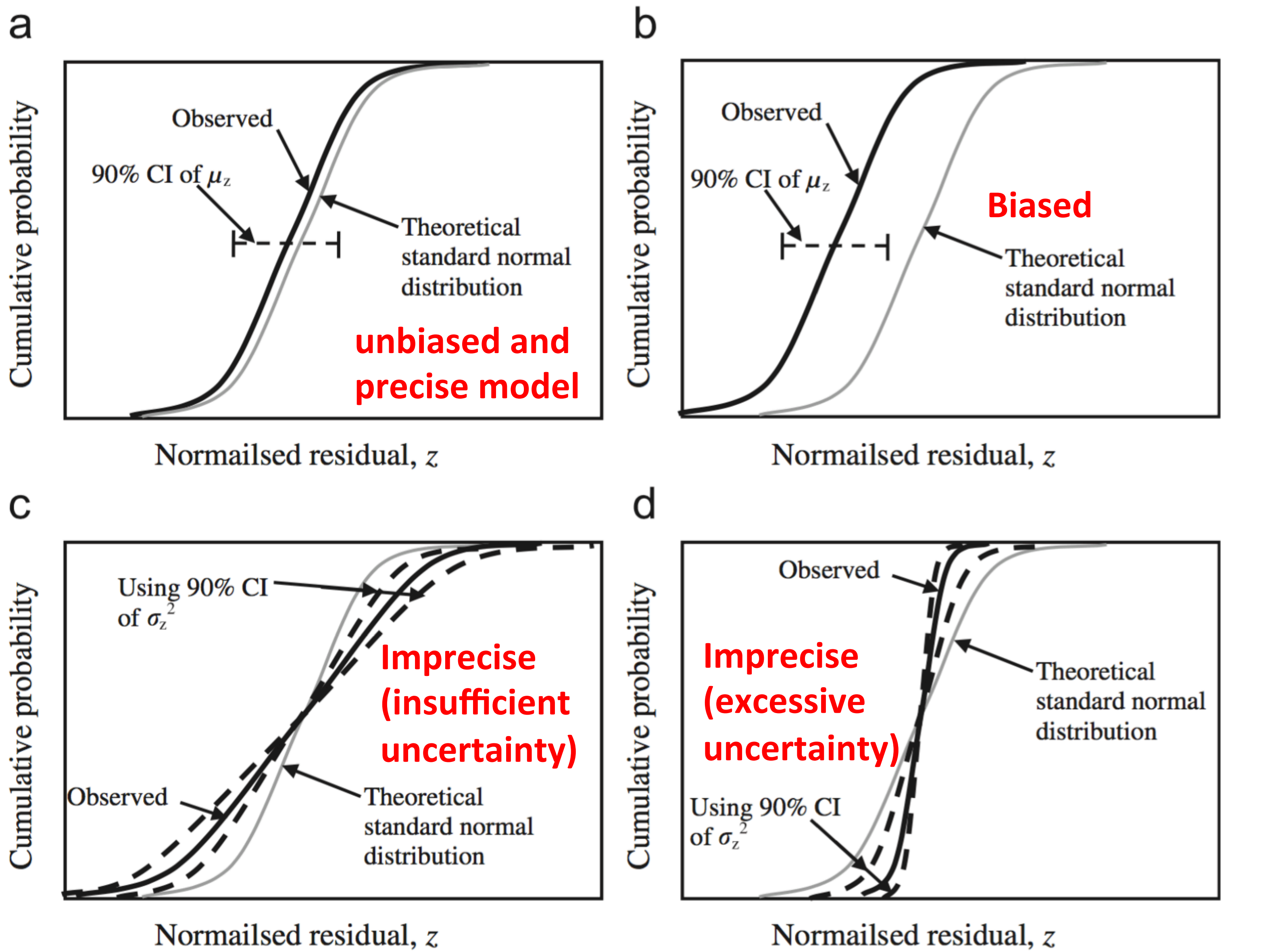
Over multiple sites and observations



If the model is consistent with observations, the standardised residuals, z_{ijk}, have a standard normal distribution

$$Z \sim N(0,1)$$

'Types' of Z residual distributions



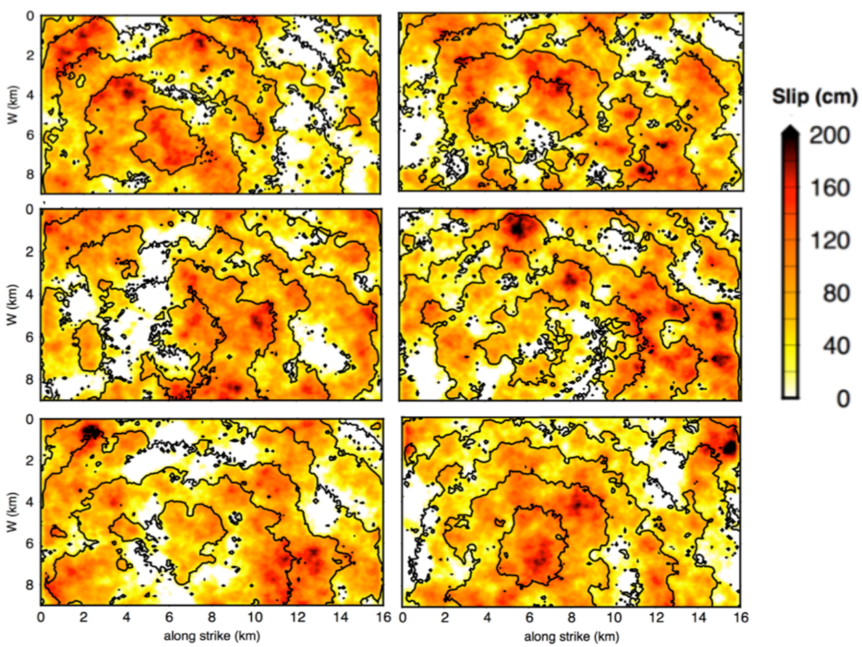
Example results: 22 Feb 2011 EQ

Uncertainties resulting from 10 different stochastic rupture realizations

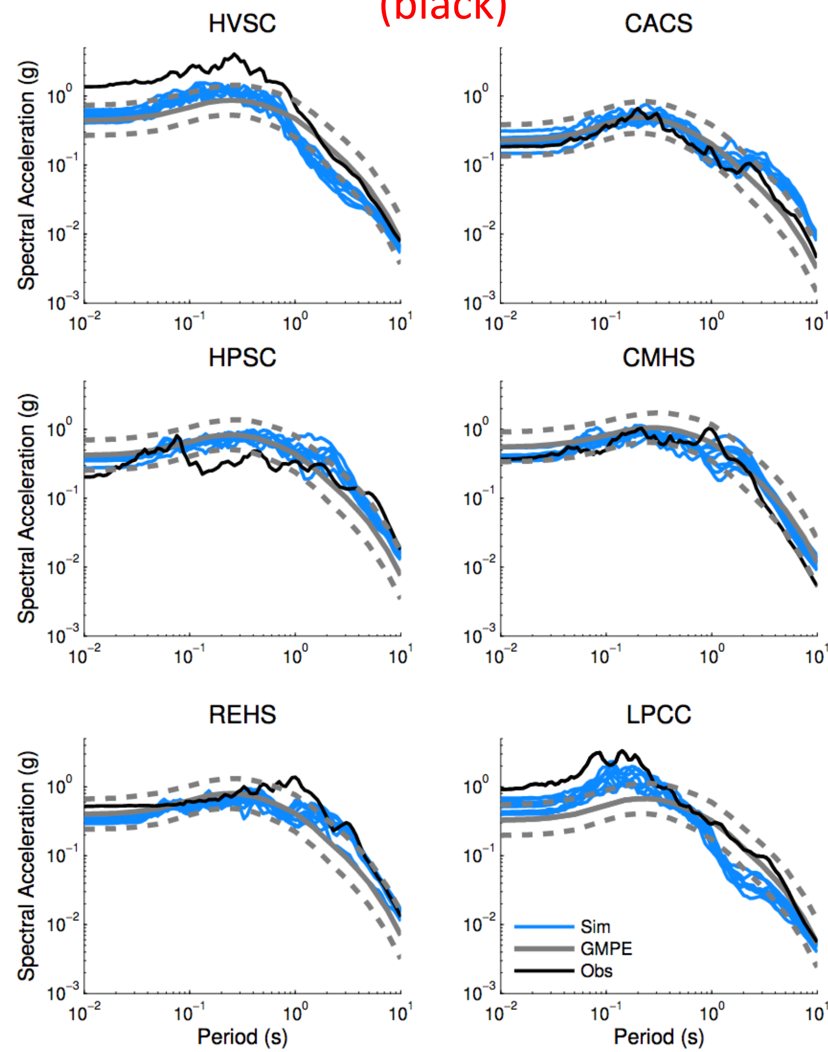
Hypocentre fixed, based on first-arrival solution

Fixed fault geometry (from geodetic info)

Example slip distributions from 10 rupture realizations

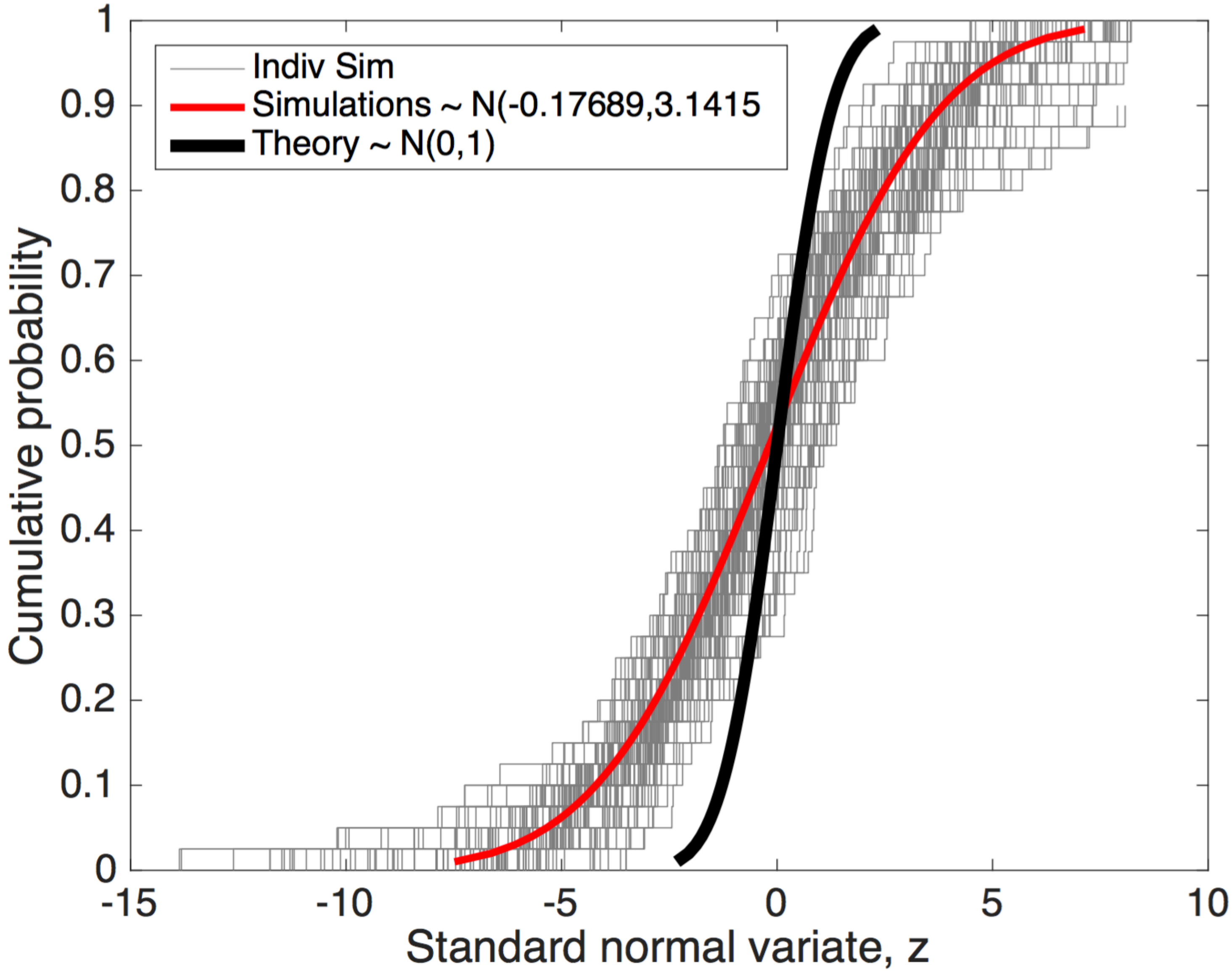


Simulations (blue) vs. observations (black)

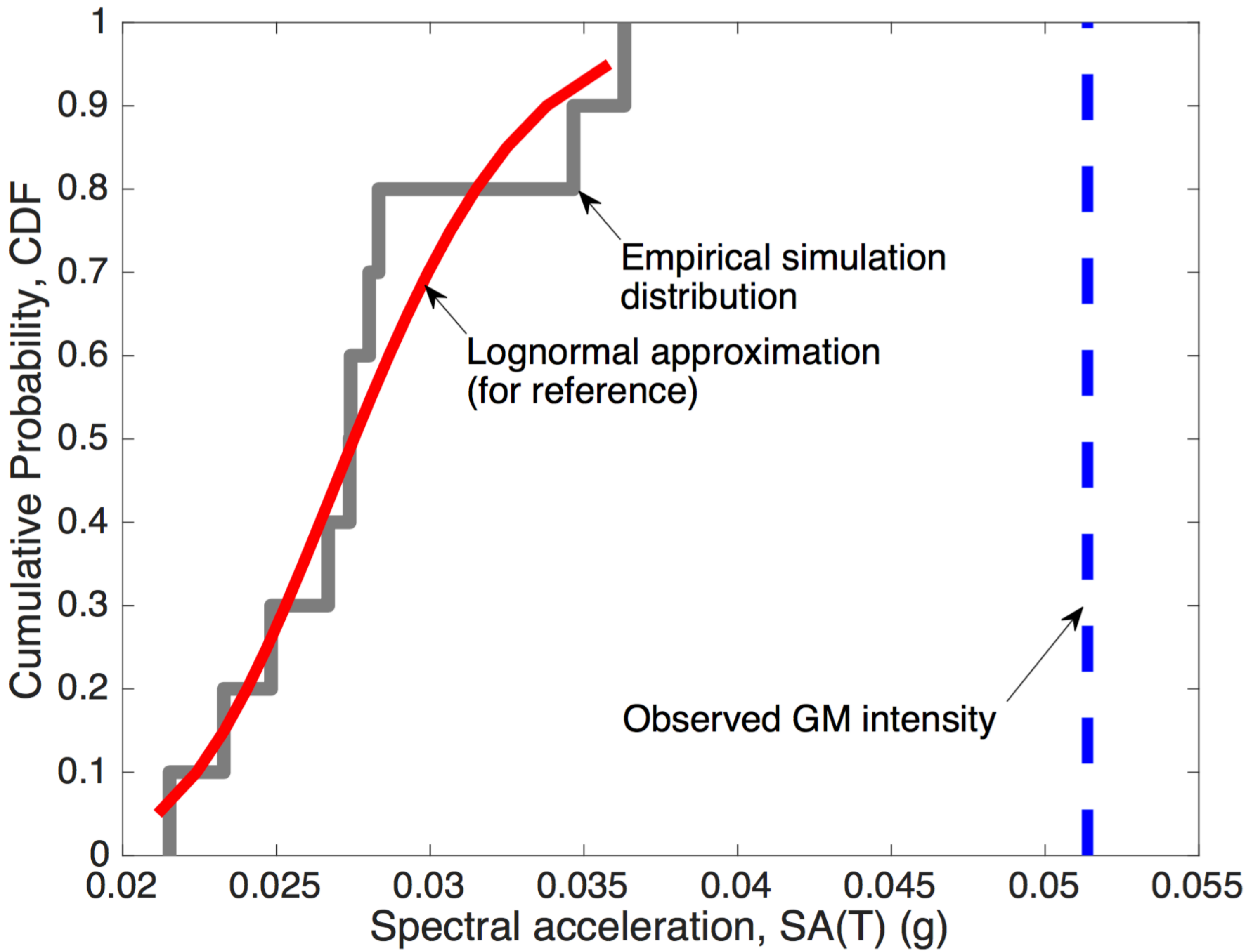


Simulation normalised residuals

4,000 prediction-observation pairs from 40 stations and 100 vibration periods [T=0.01-10s]

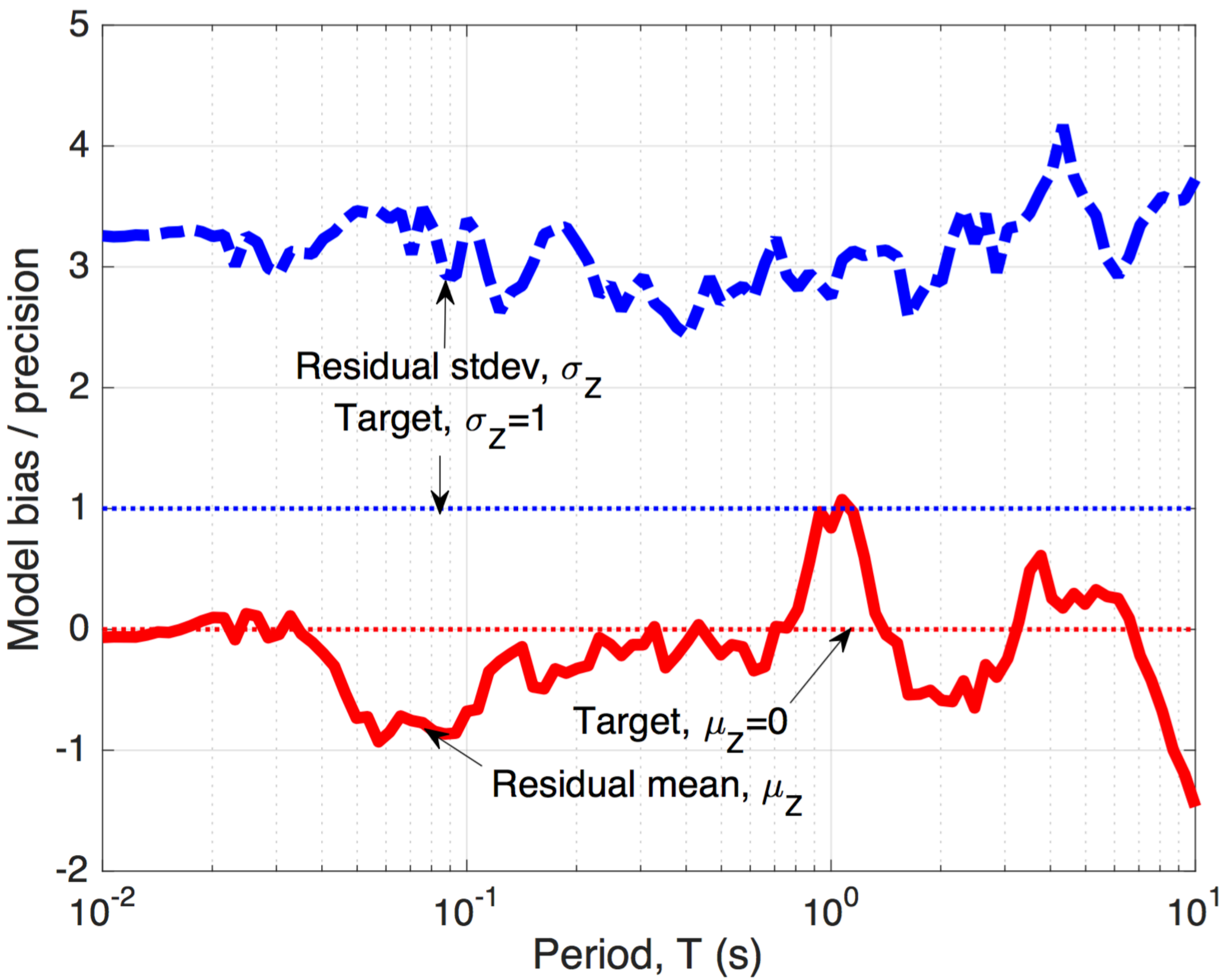


What is happening?



Simulation normalised residuals

Bias and precision as a function of vibration period



Discussion

- This framework provides a means to explicitly validate the predicted GM distribution from simulations (as needed for use in PSHA)
- Results indicate that rupture realization uncertainty alone is insufficient (adopted here, and in current CyberShake), and more comprehensive uncertainty consideration is required

Table 1: Source, path, and site uncertainties in ground motion simulation separated into measurable quantities, constitutive modelling (including parameter determination) and overarching modelling methodology assumptions

Term	Measurable quantities	Constitutive model (incl. parameters)	Model methodology
Source	Rup geometry, Magnitude, Hypo location, Rup velocity (avg), Rake (avg)	Slip-time function, Rise time-corner frequency correlation, Rise time-rup velocity correlation, Fault roughness	Kinematic vs. Dynamic
Path	3D velocity model (V_p, V_s, ρ),	Attenuation, $Q_{p/s} \sim f(Vs)$	Anelastic vs. Inelastic
Site	Shallow velocity structure, Soil shear strength	Drucker-Prager, Stress-Density models (+ parameters)	1D-3D site response, Total/effective-stress

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