Guidance on the utilisation of ground motion simulations in engineering practice

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1. Background and Objective

This poster presents ongoing work to develop guidance on the utilization of ground motion simulations for engineering practice. The two central ideas in the guidance are, firstly, the indended use of the simulations: For hazard analysis and/or providing ground motion records for use in seismic response analysis of engineered structures. Secondly, a heriarichal validation matrix to systematically develop predictive confidence in the simulated motions in generic regions through to site-specific applications.

There are two principal manners in which simulated ground motions can be utilized:

- **In determination of the seismic hazard:** Most rigorously, the seismic hazard would be directly obtained from ground motion simulation-based PSHA (e.g. CyberShake). Alternatively, simulations can inform the functional form in empirical ground motion models.
- **Ground motions for seismic response analysis:** Simulated ground motions can supplement existing empirical (as-recorded) ground motion databases (e.g. for large M_w-small R_{rup} cases which are poorly represented). Target amplitudes can be defined from traditional or simulation-based PSHA, or a code-based response spectrum.

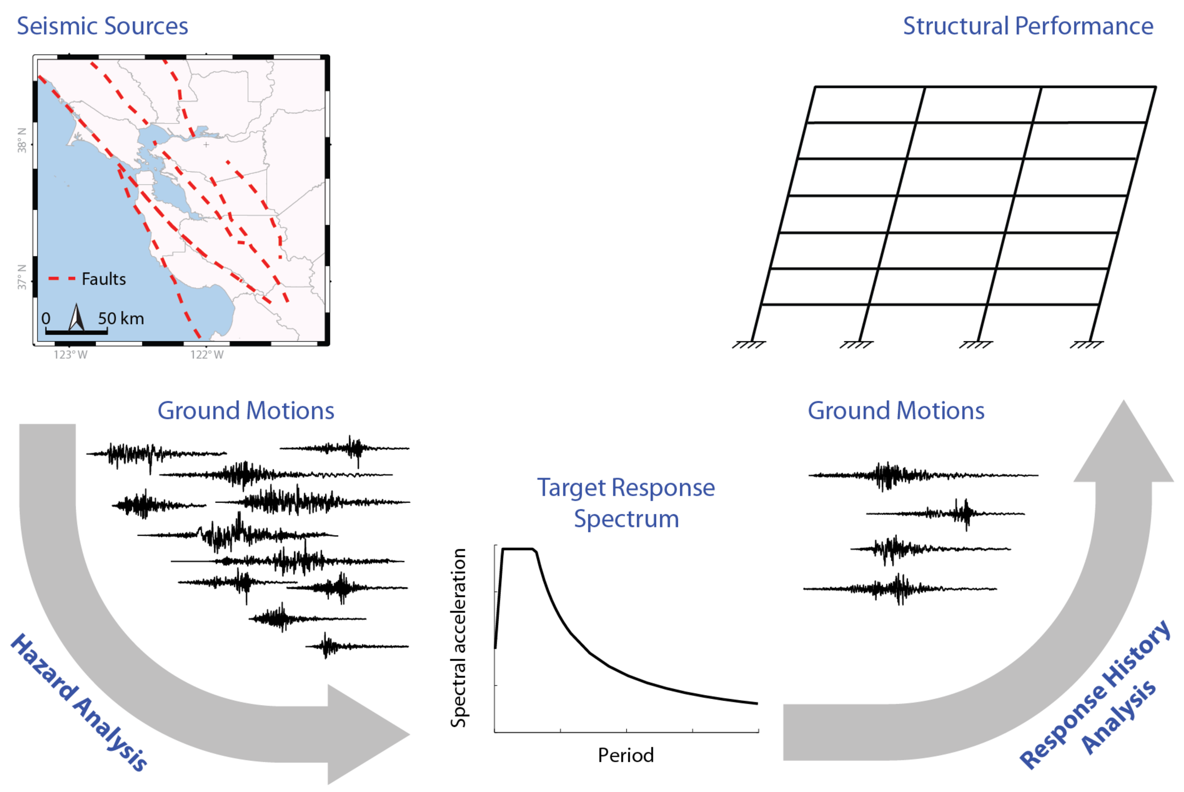


Figure 1: GM simulation utilization for seismic hazard definition and/or ground motion records for use in response history analysis (Burks and Baker)

2. Verification, validation and utilisation documentation

Verification, validation, and utilization documentation are critical components to ensure predictive confidence in computational science simulations and their reproduceability (Oberkampf et al. 2002).

- **Verification** is the assessment of the accuracy of the solution of the computational model, and is focused on good software programming practices and the appropiateness of numerical algorithms
- **Validation** is the assessment of the accuracy of a computational model at representing reality, as measured based on 'experimental' observations.
- **Utilisation documentation** provides the specifics of the simulations undertaken (software versions, source and velocity model specifics, spatial and temporal discretization, HPC resources utilized) as well as the specific utilization of the simulations for engineering practice

Because verification and utilization documentation are relatively generic for all computational science problems, then it is validation that deserves the great discipline-specific conceptual development.

In this context, two underpinning concepts are the regional-to-site-specific applicability of simulations and the specific engineered system that the simulations will be used for.

Figure 2 illustrates the validation matrix which describes these two underpinning concepts. Moving down the rows of the matrix transitions from a generic validation of a simulation method through to a region- and site-specific validation. Moving right across the columns is associated with more comprehensive validation metrics, and will depend on the specific engineering system for which the simulations will be used.

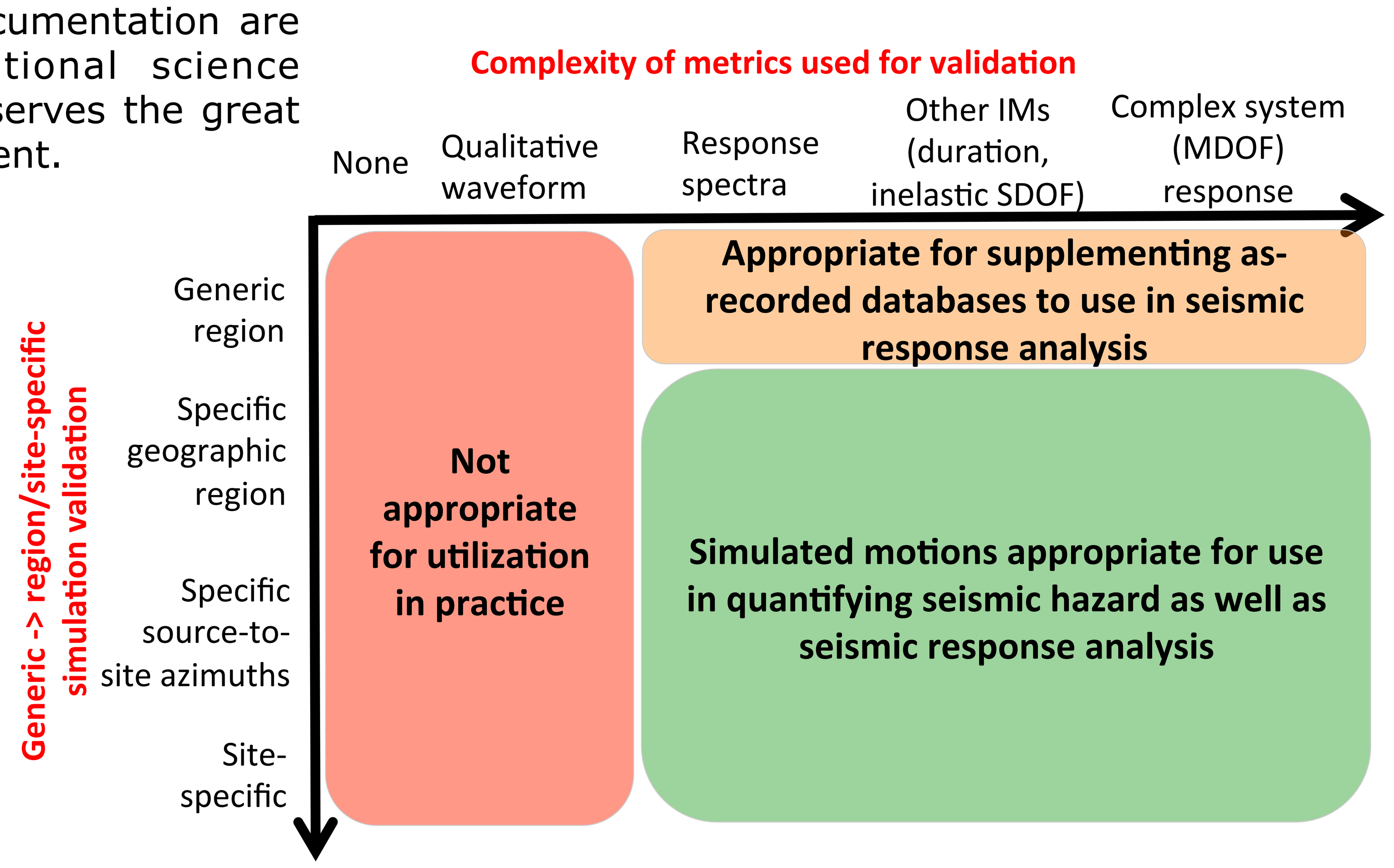
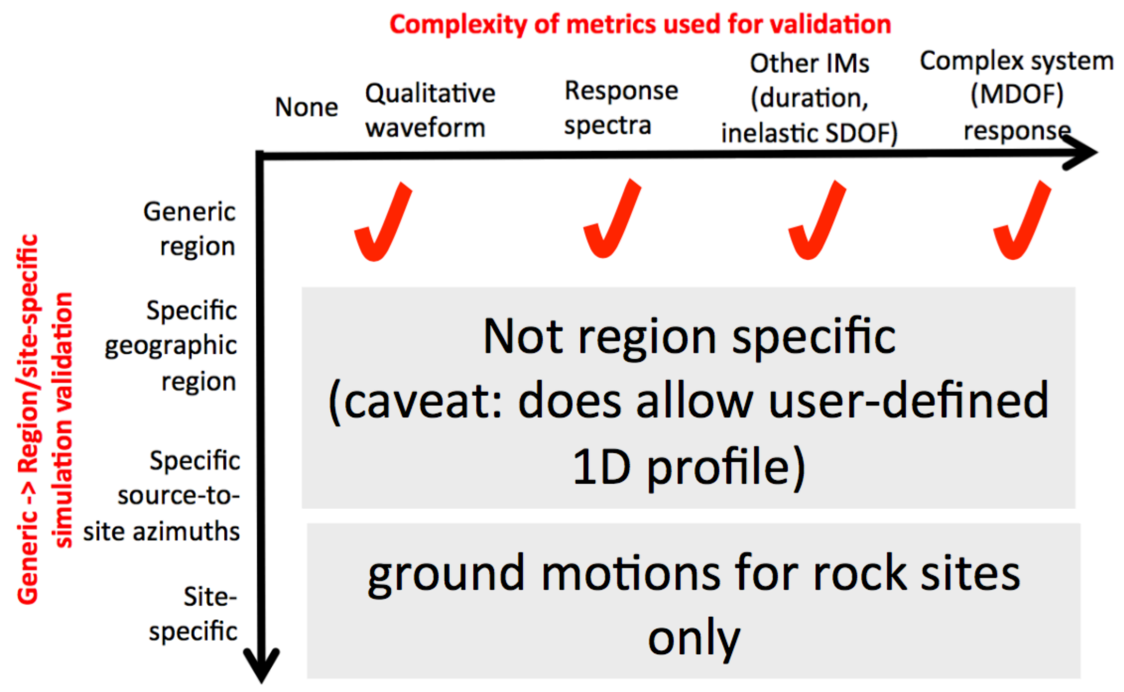


Figure 2: Validation matrix for GM simulations and illustration of appropriateness for utilization in the context of Figure 1

3. Example applications using validation matrix

Two examples are examined below to illustrate the use of the validation matrix to assess the predictive capability of ground motion simulations for a specific application in engineering practice. No prescriptive pass/fail criteria are given here, however, from a engineering utilization perspective a pass can be considered as outperforming conventional empirical ground motion models.

3.1 Example 1: SCEC Broadband Platform (BBP)



The SCEC BBP is an open-source software distribution for simulating broadband ground motions. Five different simulation methods are available, and those methods have been validated as follows:

- Qualitative waveform and quantitative response spectra comparison for past earthquakes and against empirical models (Dreger et al, 2015)
- Inelastic spectra and spectral correlations (Burks and Baker, 2014)
- Comparsion via nonlinear dynamic analysis of building structures (Galasso et al. 2012)

Despite the significant number of validation metrics considered for some methods, the BBP implementation is restricted to the use of (generic) 1D velocity models. In addition, the simulations are for generic rock site conditions (no site response). Thus, in the context of Figure 2, BBP-based ground motions could be considered appropiate for use in seismic response analyses when scaled to a target spectrum.

3.1 Example 2: Alpine Fault simulations in the South Island, New Zealand region

- Simulations of Alpine Fault ruptures in Canterbury (Fig 4c) have utilized the generically-validated Graves and Pitarka (2010, 2015) methodology.
- Simulations of the 2010-2011 Canterbury EQs (Fig 4a) have been used to validate the methodology and Canterbury Velocity Model v1.0 (Lee et al. 2016).
- Ongoing simulations of Mw3.0-4.5 events in the South Island (Fig 4b) are being used to validate specific source-to-site azimuths of relevance.
- Site-specific response analyses (Fig 4d; Heathcote Valley) have illustrated significantly improved simulation predictions over the use of empirical site response amplification factors.

Figure 5 illustrates the validation matrix for GM simulations of Alpine Fault EQs on the Canterbury region

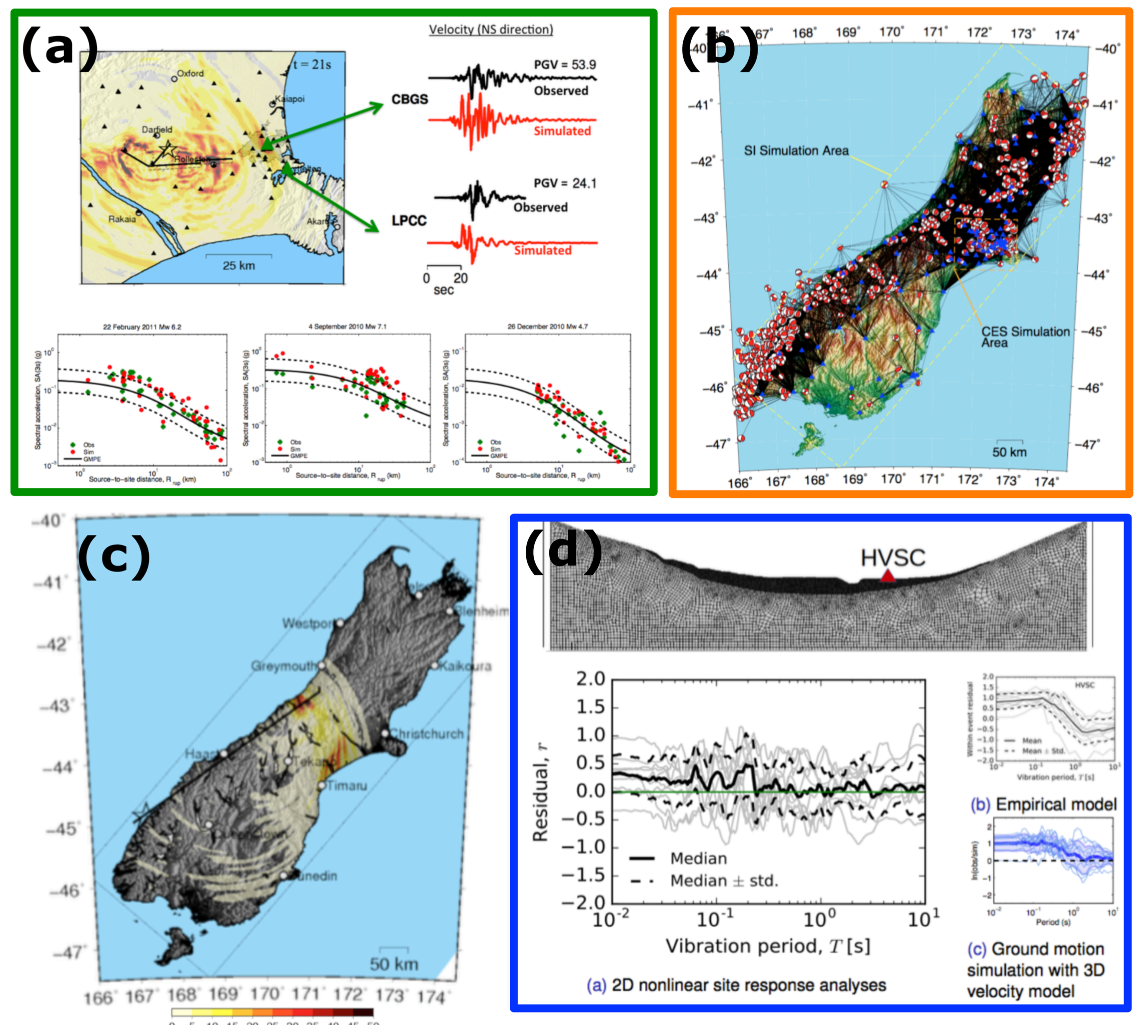


Figure 4: Illustration of validation examples (a,b,d) for Alpine Fault simulations (c)

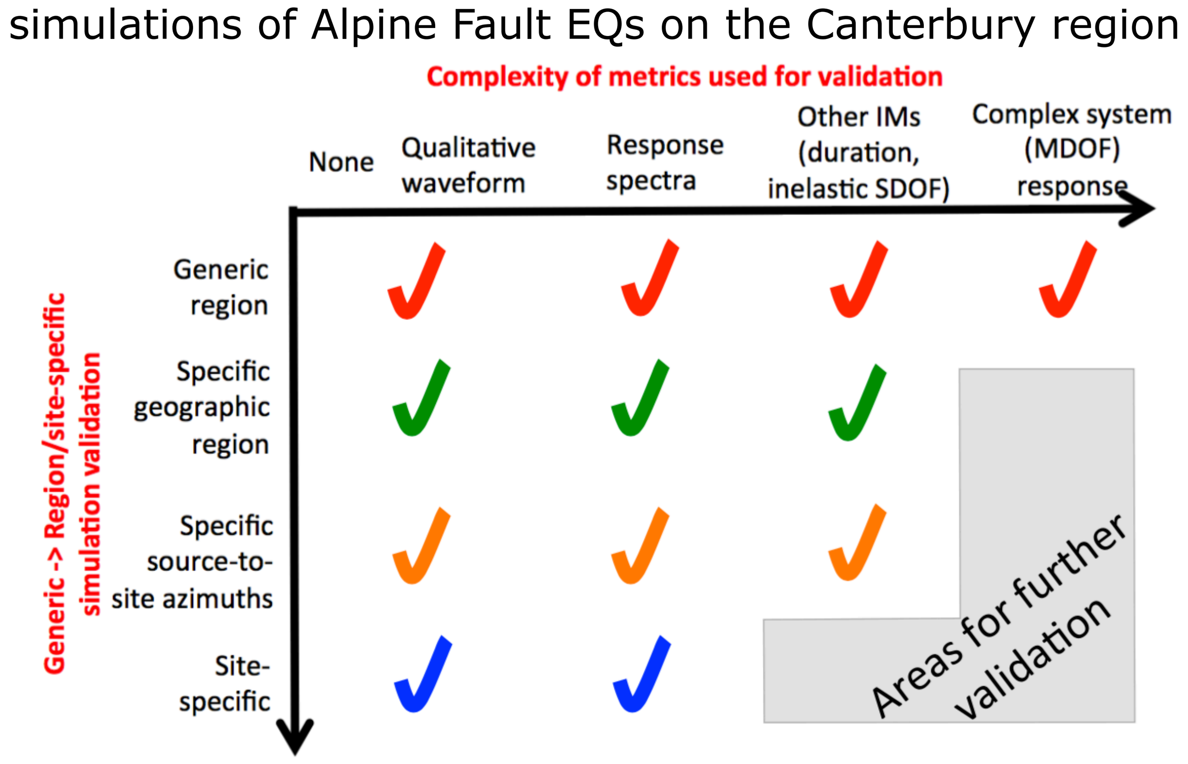


Figure 5: Validation matrix for GM simulations of Alpine Fault EQs on the Canterbury region

4. Other considerations

Specific guidance on how each component of the validation matrix applies to rupture generators, velocity models, and site response modelling

Explicit consideration of modelling uncertainties in ground motion simulation validation

Benchmarking empirical GM models – i.e. what is the 'pass' criteria for each part of the matrix