Validation of ground motion simulations via response history analysis of special moment resisting frames using an automated workflow

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1. Motivation

Validation is an essential step to assess the applicability of simulated ground motions for utilisation in engineering practice. A comprehensive analysis should include both simple intensity measures (PGA, SA, etc.), as well as the seismic response of a range of complex systems obtained by response history analyses.

The aim of this poster is to examine the seismic response of two structural systems when subjected to observed and simulated ground motions (GMs) for the 22 February 2011 (22Feb2011) Christchurch earthquake (Razafindrakoto et al. (2018)) via an automated workflow. The layout and technical details of the automated workflow are described at Motha et. al. (2019).

2. Structural Properties

Two special moment resisting frame (SMRF) buildings from the SAC Steel project were selected (Figure 1a) for analysis. Two models were designed for a site in Seattle based on US standards as part of the SAC Steel Project (FEMA 2000). The buildings were designed as office buildings located at a site with stiff soil. OpenSees software (Ver. 2.5.0) was used for nonlinear response history analysis.

- **Building A** is a three-storey steel SMRF. The fundamental period of building A is 0.98 sec.
- **Building B** is a nine-storey steel SMRF. The fundamental period of building B is 2.95 sec. The 9-storey building has a basement indexed by 0.
- **Nonlinear modelling:** Elastic elements with lumped plastic hinges at the end of beams and columns were used for the nonlinear model. The plastic hinges were modelled by using the Modified Ibarra-Medina-Krawinkler (Modified IMK) deterioration model with the bilinear hysteretic response (Figure 1b). The shear behaviour of the panel zone and the effect of P-Δ were considered in the analysis by using a trilinear backbone curve and a pinned leaning column, respectively.

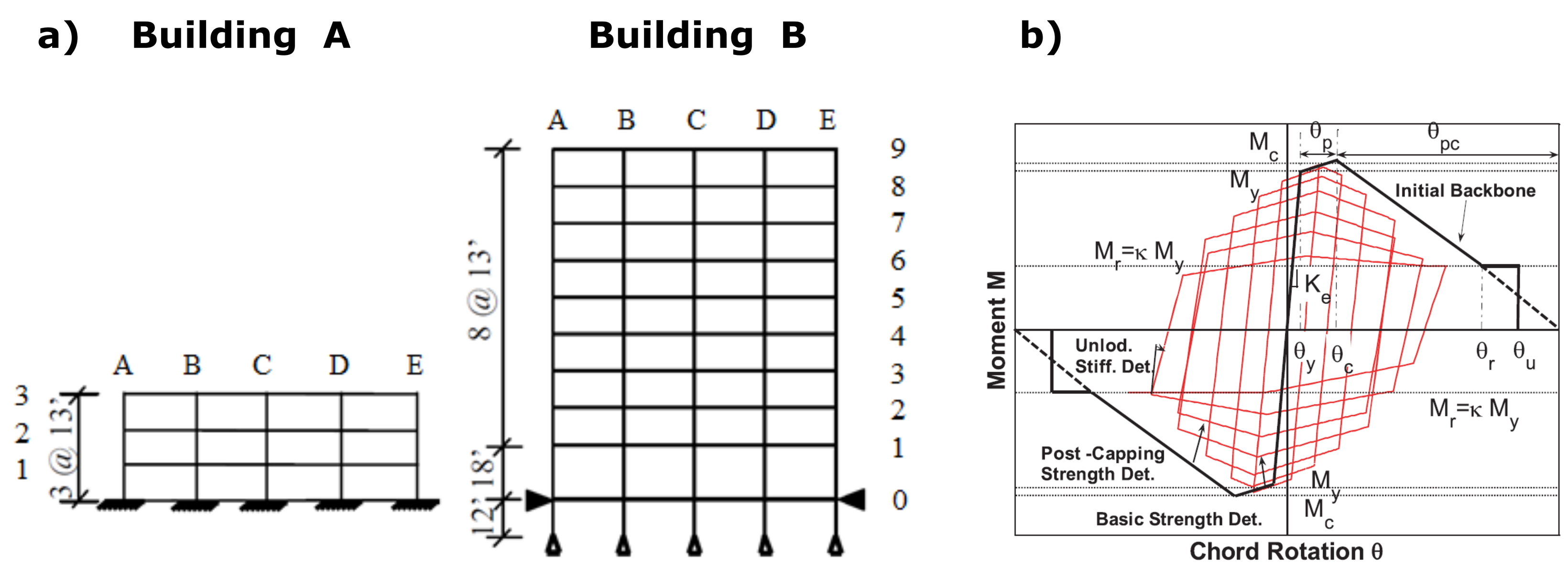

Figure 1: a) View of 3-storey and 9-storey SAC Steel models (FEMA 2000). b) Nonlinear model of plastic hinges (Lignos et. al. (2011)).

3. Simulated and observed Ground Motion (GM) Properties

The selected buildings are subjected to unscaled simulated and observed GMs from the 22Feb2011 Earthquake at 40 stations. The response spectra of simulated and observed GMs are shown in Figure 2a-b.

- Simulations are computed using the hybrid broadband method developed by Graves and Pitarka (2010, 2015).

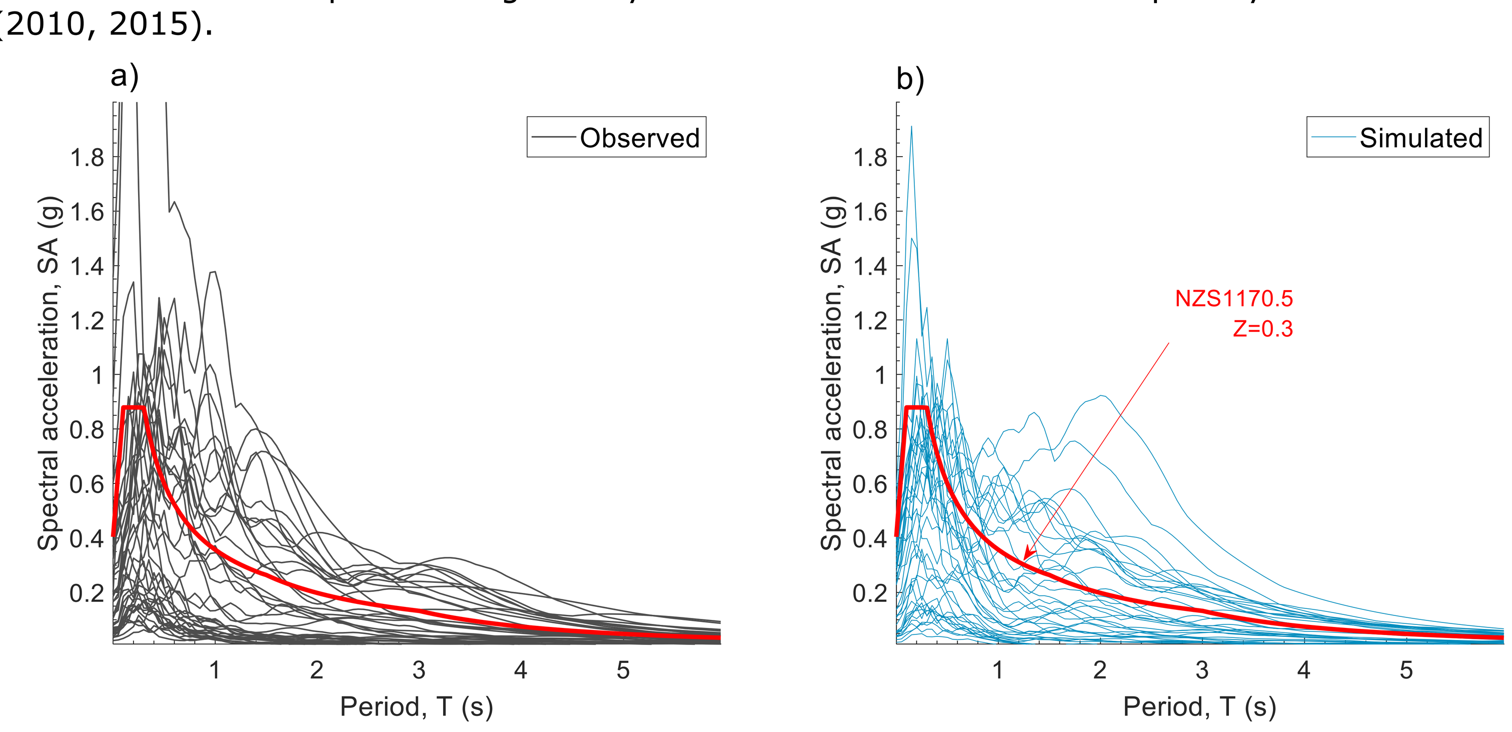

Figure 2: a-b) Comparison of response spectra of observed and simulated GMs used in response history analysis.

4. Comparison between Engineering Demand Parameters (EDPs)

The seismic responses of Building A and B subjected to unscaled simulated and observed 22Feb2011 GMs are compared. The validation of scaled 22Feb2011 GMs was studied by Loghman et. al. (2018). The seismic responses of the structures are principally quantified via the peak floor acceleration (PFA) and the inter-storey drift ratio (IDR).

4.1 Comparison between the time-series of observed and simulated responses

Figure 3a-d compare the time-series of observed and simulated responses at station CCCC for Building A and B at the top storey level.

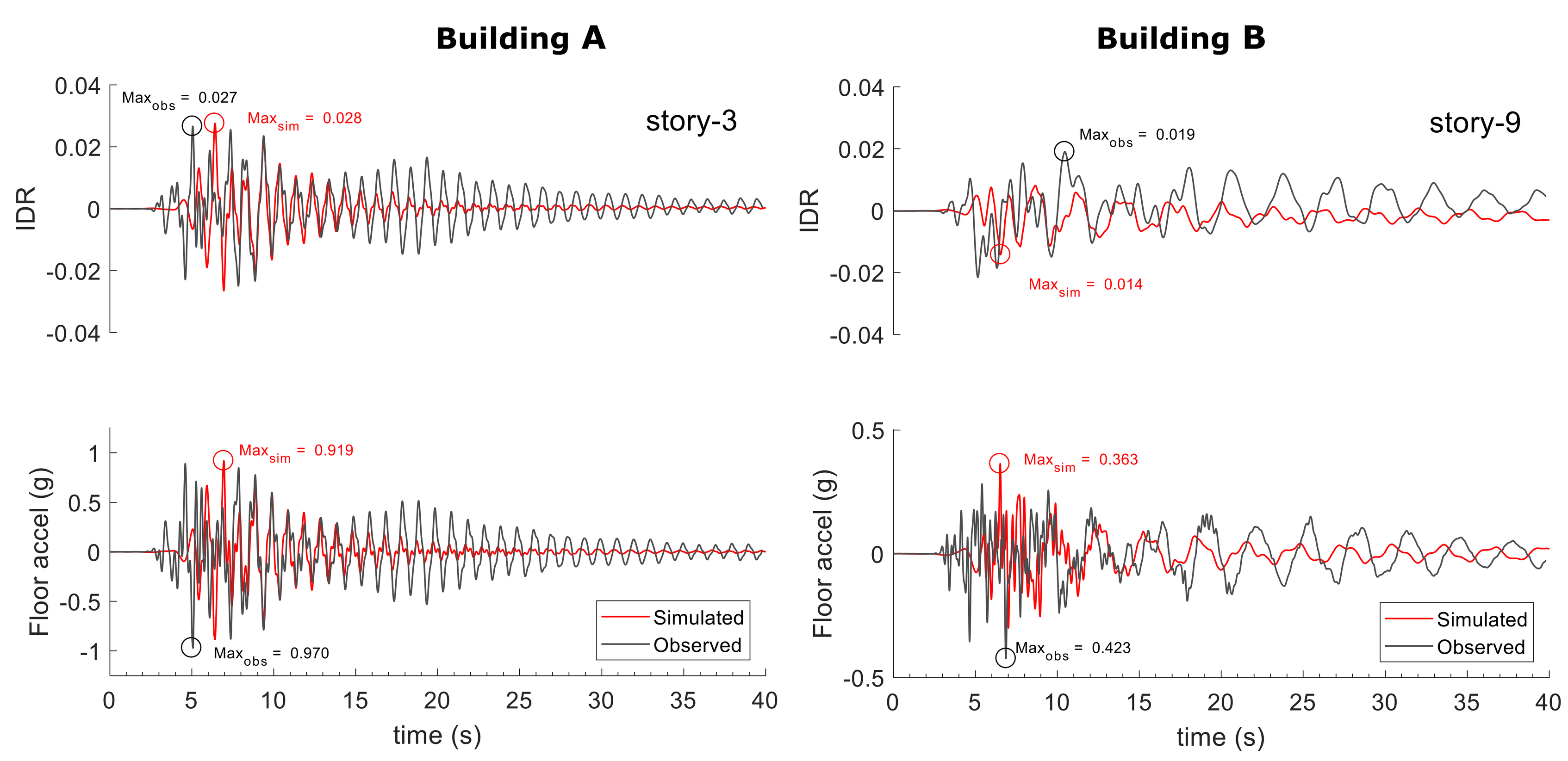

Figure 3: Comparison between the observed and simulated time-series at station CCCC a-b) Building A drift and accel. c-d) Building B drift and accel.

4.2 Comparison between the ratios of simulated to observed GM responses

Figure 4 shows the ratio of peak simulated to observed responses along the height of the buildings. In this figure, each grey line shows this ratio for a given station, and the black line shows the geometric mean of all stations. The red line shows unity, indicating the same responses from simulated and observed GMs. The 16th and 84th percentiles of the responses are also shown in this figure.

- Figure 4a-d show a good agreement between the responses of Building A and B subjected to simulated and observed GMs.

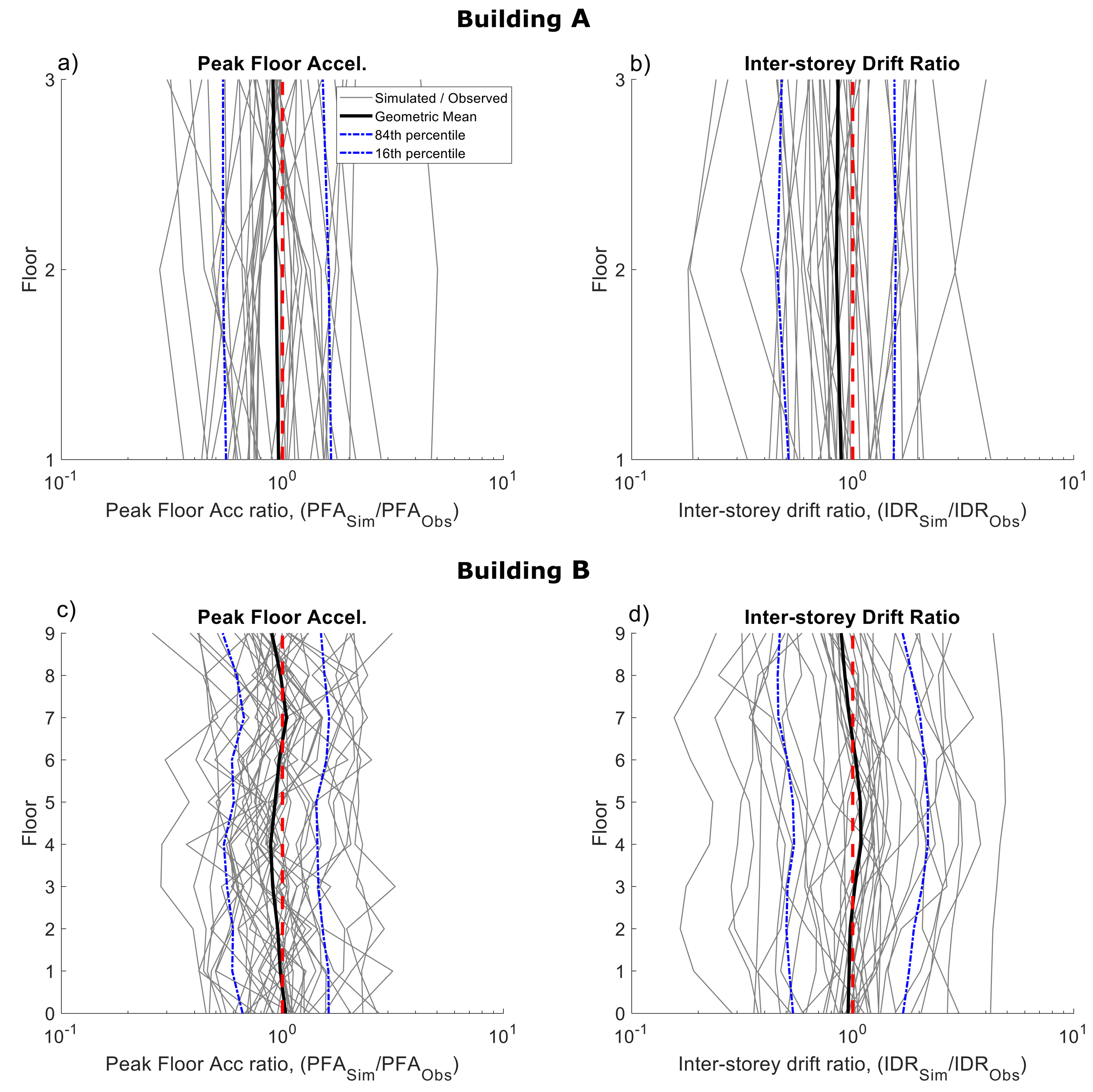

Figure 4: The ratios of simulated to observed responses. a-b) Building A accel. and drift; c-d) Building B accel. and drift.

6. EDP trends with respect to data sample size

Herein, the differences between the responses of observed and simulated GMs are assessed to determine whether these differences (Figure 4) systematically exist in the two groups of responses, or they are due to using a limited dataset (40 GMs) in the analyses. The bootstrap sampling technique and hypothesis testing are utilised to investigate whether the differences are statistically significant.

- Calculating p-values demonstrates the statistically significant difference only for the IDR at Building A second floor, while there is no statistically significant difference for other responses (PFA and IDR) for Building A and B (Figure 5a-d).

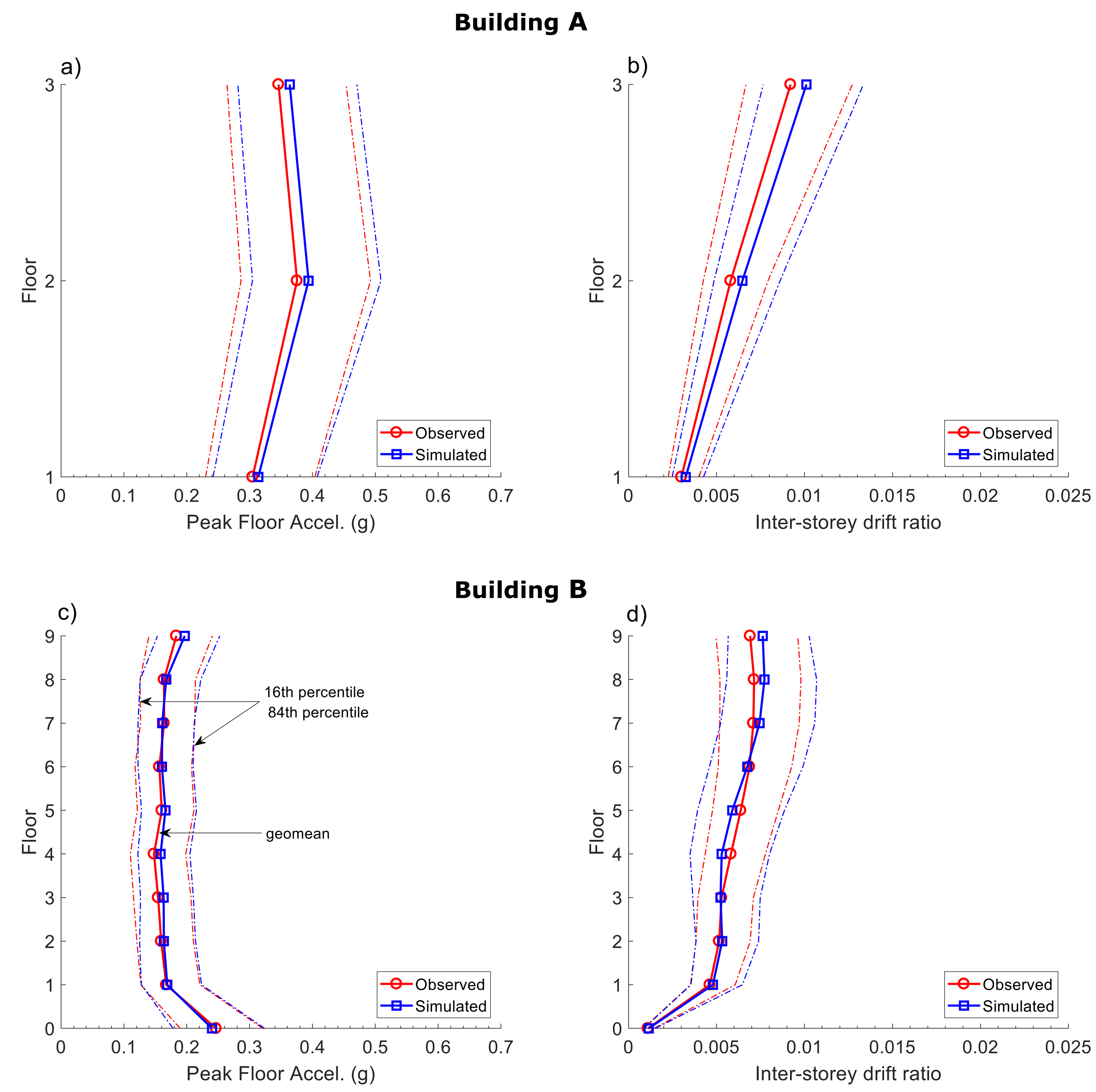

Figure 5: Geometric mean and percentiles of bootstrapped samples a-b) Building A accel. and drift; c-d) Building B accel. and drift.

7. Conclusion

Validation of simulated ground motions (GMs) is an essential step to scrutinise the applicability of simulated GMs in response history analysis. For this purpose, An automated workflow was developed to streamline the complicated validation procedure. This enables us to validate different GM sets generated by different simulation methods via response of various structural systems. Herein, validation of simulated GMs is investigated by comparing responses of two structural models subjected to unscaled observed and simulated GMs from the 22Feb2011 Christchurch earthquake. Attempts are made to investigate the similarities and differences between the response of the systems excited by both sets of records. The results indicate a general agreement between the Peak Floor Acceleration (PFA) and the Inter-storey Drift Ratio (IDR) calculated by the simulated and recorded GMs for two buildings.