Earthquake scaling relations, and testing/evaluation of the New Zealand national seismic hazard model 2022

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ABSTRACT

We summarise two projects that contributed to the development of the New Zealand National Seismic Hazard Model 2022 (NZ NSHM 2022). We first summarise the development of new magnitude-source area scaling relations for crustal and subduction interface earthquakes. The relations are of the form Mw = logA + C, and are based on quantitative evaluation of a suite of recently published scaling relations (post 2010). Second, we summarise efforts to test and evaluate NZ NSHM 2022. The evaluation phase involved comparisons of numerous model components against data, and the testing phase involved quantitative comparisons of predicted ground motion exceedance rates to the rates observed at accelerograph station sites around New Zealand. The testing results show that the observed exceedance rates can be drawn from NZ NSHM 2022 with probabilities greater than 0.05, indicating overall compatibility.

1 INTRODUCTION

Update of the New Zealand national seismic hazard model 2022 (NZ NSHM 2022) has been the most comprehensive national-scale update to occur since the efforts of Stirling et al. (1998; 2002). The more recent Stirling et al. (2012) model received a substantial data-based update, but only a modest methodological update. The 2022 update incorporated significant scientific advances, and substantial treatment of epistemic uncertainty (Gerstenberger et al., 2022). The New Zealand Loading Standard NZ1170.5 (Standards New Zealand, 2004) was based on the Stirling et al. (2002) model, so "the code" is expected to receive a substantial update from NZ NSHM 2022 in due course.

This paper provides a precis of two areas of update for NZ NSHM 2022 that were carried out by the authors of this paper. These are: the development of new magnitude-area scaling relations for crustal and subduction interface sources; and the testing and evaluation of the 2022 model. Documentation of these two pieces of work is provided in Stirling et al. (2023a and b).

2 MAGNITUDE-AREA SCALING RELATIONS

Development of new scaling relations of the form Mw = logA + C was a requirement for source modelling in NZ NSHM 2022, and the first step involved the selection and evaluation of recently-published (post 2009) scaling relations for crustal and subduction interface sources. In all, 16 relations were selected. Evaluation of the relations followed the methods of Stirling et al. (2013), but also required the development of a historical earthquake database "flatfile". The "flatfile" was used to perform a residual analysis to quantify the differences between predicted and observed magnitudes. The residuals then became the basis for scoring the scaling relations, and eliminating the most poorly-performing relations. The final step involved fitting of Mw = logA + C relations over the range of crustal relations, and again over the range of subduction interface relations. A single set of crustal relations was produced after the normal, reverse and strike-slip relations were found to be virtually identical. Graphs of the resulting crustal and subduction interface Mw = logA + C relations are listed below, and graphically depicted in Figure 1.

Crustal relations:

Mw=logA+3.9

Mw=logA+4.1

Mw=logA+4.3

Subduction interface relations:

Mw=logA+3.6

Mw=logA+3.9

Mw=logA+4.1

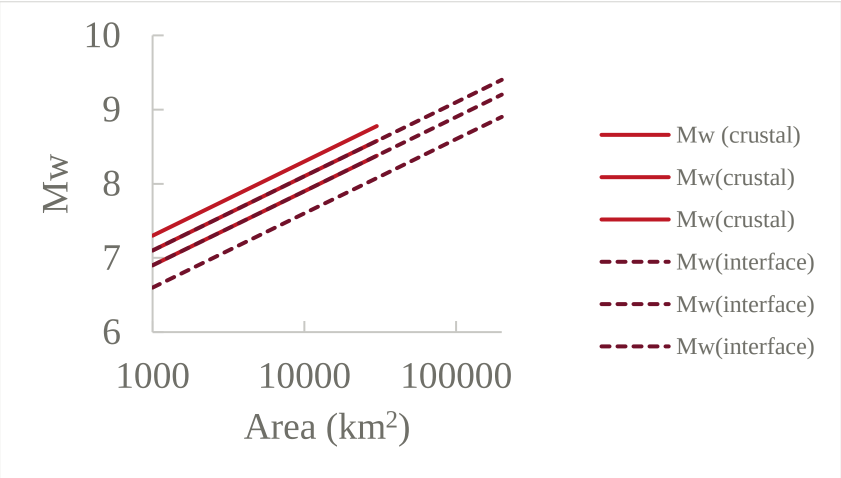

Figure 1: Mw=logA+C scaling relations for crustal and subduction interface sources.

3 TESTING AND EVALUATION

Testing and evaluation of NZ NSHM 2022 involved two main phases: (1) evaluation of elements of the source recurrence model (SRM) and ground motion characterisation model (GMCM) against the relevant data to optimise model compatibility with the available constraints; and (2) comparison of the observed exceedance rates of 0.1g and 0.2g peak ground acceleration (PGA) levels at New Zealand strong motion sites to the predicted exceedance rates of those PGA levels at the same sites. Phase 1 was achieved by comparing parameters like predicted to observed earthquake rates, and predicted ground motions to relevant observations in the strong-motion database. The evaluations formally considered in this study were limited to the comparisons of models to data, and did not include the numerous evaluations and adjustments made on the basis of expert opinion and consensus. Phase 2 was achieved by way of statistical analysis, and was analogous to the methods developed by Marzocchi and Jordan (2018). Earlier New Zealand-based efforts used accelerograph data to test the NZ NSHM 2002, and showed that the observed exceedance rates to be somewhat greater than the rates produced by the model (Stirling and Gerstenberger, 2010). The discrepancy was attributed to the extra exceedances produced by aftershocks, given that aftershocks were not considered in the development of the NZ NSHM 2002.

Four example comparisons of Phase 2 comparisons for 0.1g PGA exceedances at the 94 strong motion sites are shown in Figure 2. These sites were chosen to show the contrasting results across the country, and the plots show the comparisons in terms of the predicted and observed number of exceedances in the time periods of recording at each station site. The binomial probability density functions for the NZ NSHM 2022 are shown as red and black lines, and the observed number of exceedances are shown as green vertical lines. P-values are shown for all of the stations in Figure 3, in which the p-value is the probability that the observed number of exceedances could be drawn from the predicted number of exceedances. The plot shows that 73 of the 94 stations provide no evidence for poor performance of the NZ NSHM 2022 (poor performance is defined as a p-value < 0.05, following standard statistical practice). For 0.2g exceedance, 87 of the 94 stations provide no evidence for poor performance. Many of the sites showing evidence for poor performance were found to be in Christchurch and in the vicinity of the Kaikoura and Cook Strait earthquakes. This demonstrates the impact of short-term earthquake clusters, which are not explicitly modelled in the NZ NSHM 2022.

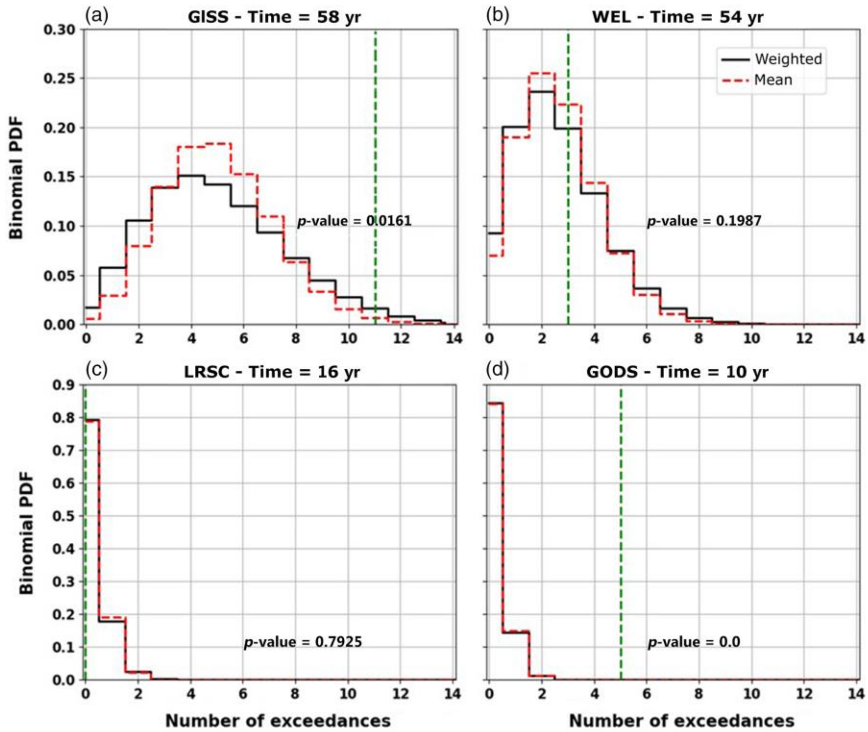

Figure 2: Examples of the comparisons of predicted (histograms) to observed (dashed vertical line) numbers of exceedances of 0.1g for accelerograph stations: (a) GISS in Gisborne; (b) WEL in Wellington; (c) LRSC in Ashburton; and (d) GODS in Christchurch. The binomial distributions are also shown (dashed non-vertical lines), and the p-value (the probability that the observed record could be drawn from the combined distribution) is listed.

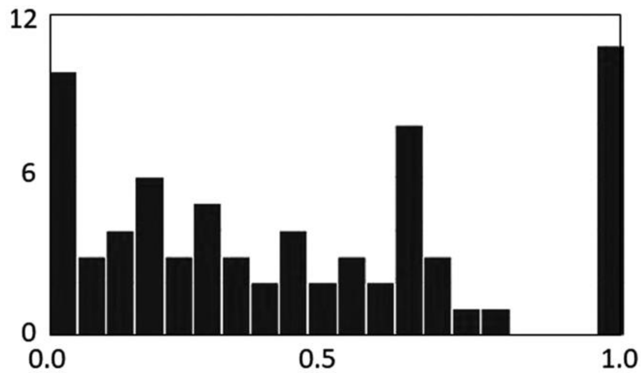

Figure 3: Histogram of p-values (x-axis) for 0.1g exceedance.

4 CONCLUSIONS

We have summarised two projects that contributed to the development of NZ NSHM 2022: (1) New magnitude-source area scaling relations of the form Mw = logA + C have been developed for crustal and subduction interface earthquakes; and (2) NZ NSHM 2022 has been evaluated by comparison of numerous model components against data, and tested by comparing predicted ground motion exceedance rates to the observed rates at New Zealand accelerograph stations. The testing results indicate overall compatibility between model and observation.

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