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Improving the New Zealand seismic hazard model

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ABSTRACT: In recent years Institute of Geological and Nuclear Sciences (GNS) has applied the methods of probabilistic seismic hazard analysis to develop a new seismic hazard model for New Zealand. GNS is now undertaking collaborative work with organisations from the USA and Italy to improve the New Zealand model by incorporating new input data, and by developing methods to validate the model. The initial part of this work includes: (1) critically reviewing the input parameters responsible for anomalously high seismic hazard in the present probabilistic seismic hazard maps for New Zealand; (2) introducing new active fault parameters and earthquake scaling relations to the model that come from recently-completed major seismic hazard assessments; (3) introducing variable site geology into the model; (4) comparing the methodology of probabilistic seismic hazard analysis embodied in the New Zealand and USA models against geodetic data and historical MM Intensity data, and; (5) engaging in a project to cross-validate a number of probabilistic seismic hazard source codes. Experiences gained from this work may eventually be applied to seismic hazard models outside of New Zealand and the USA.

1 INTRODUCTION

In recent years the GNS has published a new national seismic hazard model (NSHM) for New Zealand that incorporates the methods of probabilistic seismic hazard assessment (Stirling et al. 1998; 2002). The most significant advance of the new model over the predecessor model of Smith and Berryman (1986) has been the incorporation of active faults as discrete seismic sources into the model. The changes in the spatial distribution and absolute levels of hazard across the country from the old to the new model have been profound. The new model is currently being used as input to a revised Building Code for New Zealand (see McVerry, this volume).

Efforts at GNS are now focused on improving the existing NSHM. The improvements being carried out at present fall under three general topic areas, which are: (1) the introduction of new data and relationships (e.g. scaling laws) into the model; (2) the introduction of site geology into the model, and; (3) the development and utilisation of methods for testing and cross-validating the model. In this paper we will outline the efforts being undertaken to fulfil (1) to (3) above. While we also anticipate being able to further enhance the NSHM by incorporating conditional probabilities into the model, we will not discuss these efforts in any detail here. We expect to eventually be able to utlilise the actively-growing body of “conditional probability” data and models, such as; foreshock and aftershock occurrence, elapsed time since the last earthquake on a fault, and earthquake forecast models to supplement our current time-independent estimates of long-term average hazard with estimates of time-varying hazard on a variety of time-scales.

2 NEW DATA & RELATIONSHIPS

As soon as the current NSHM was published, considerable attention was focused on addressing areas of anomalously high hazard on the maps. These are areas of high hazard inconsistent with our understanding of seismotectonics in New Zealand. In many of these cases, critical examination and adjustment of the parameters responsible for the anomalies has resulted in modifications to the resulting hazard estimates. An example of these modifications is given in Figure 1. The “hot spot” anomalously high seismic hazard that used to appear in Otago (Fig. 1, left map) has now been removed (Fig. 1b, right map) as a result of detailed field examination of the causative faults (the Blue Mountain and Spylaw Faults; Stirling et al. 2002). Likewise, detailed field investigations for various commercial projects have resulted in considerable modification to fault parameters in the Taupo Volcanic Zone and Waitaki region. These studies have also produced new scaling relationships that relate the size of the earthquake to the dimensions of the fault source (length, width and expected single-event coseismic displacement), and these will all be incorporated into the model. Lastly, the seismicity catalogue for New Zealand now has four more years of earthquake data than the version used in the current model, so these new data will also be introduced into the model.

Figure 1. The process of addressing areas of anomalously high seismic hazard in maps produced from the National Seismic Hazard Model. Here a combination of fieldwork and use of new scaling relationships resulted in new seismicity parameters and reduced hazard estimates.

3 SITE CONDITIONS

A start has been made on incorporating site geology into the NSHM. The existing maps assume a uniform site (ground) class across the entire country, and so ignore the spatial differences in site response that might be expected to result from spatial differences in site geology. The resulting seismic hazard maps show small differences to the uniform maps for the short period accelerations (e.g. peak ground acceleration) but marked differences at longer periods (e.g. 1 second spectral acceleration). While these maps do not incorporate basin response or sediment thickness information and have no more utility at a site-specific scale than the uniform maps, they do provide a more realistic portrayal of national and regional hazard than the uniform maps do. As such they will be more useful as a planning and broad-scale zoning tool at the national and regional scale (e.g. for Regional Councils) than the uniform maps.

4 TESTING & VALIDATING THE CURRENT MODEL

Considerable effort is currently going into testing the NSHM. Tests are grouped under the following categories:

- Tests of predicted earthquake recurrence parameters (magnitude, frequency, seismic moment rate). These involve comparing the earthquake recurrence parameters derived from the NSHM against independent estimates of these parameters. The comparisons include the following: (1) comparing the earthquake magnitude-frequency distribution predicted from the earthquake source model of the NSHM to a historical earthquake or plate motion-balanced Gutenberg-Richter magnitude-frequency distribution; (2) comparing NSHM-derived seismic moment release rates to those derived from geodetic data (geodetic data are not currently used in the NSHM; Fig. 2); and (3) comparing the NSHM-derived frequency of ground rupturing earthquakes to the historical frequency of those events. Although some technical issues still have to be resolved, the results generally show reasonable agreement in the case of (1) and (2), except that in (1) the model overpredicts the number of earthquakes in the magnitude range M7.0-7.3 when compared with either historical data or a plate-motion-balanced Gutenberg-Richter magnitude-frequency distribution. Within this magnitude range there is a deficit of distributed-source earthquakes and a more-than compensating surplus of earthquakes on fault sources in the NSHM. In the case of (3) the frequency of ground-rupturing earthquakes in the NSHM significantly overpredicts the historical record, the discrepancy due to easily-identifiable assumptions made in the NSHM (the reader can see the magnitudeof some of the changes made to the NSHM recurrence intervals for faults by comparing Table A1 of Stirling et al.2002 to Table 4 of Van Dissen et al *this volume*). Much of this work is described in Rhoades et al. (2002).

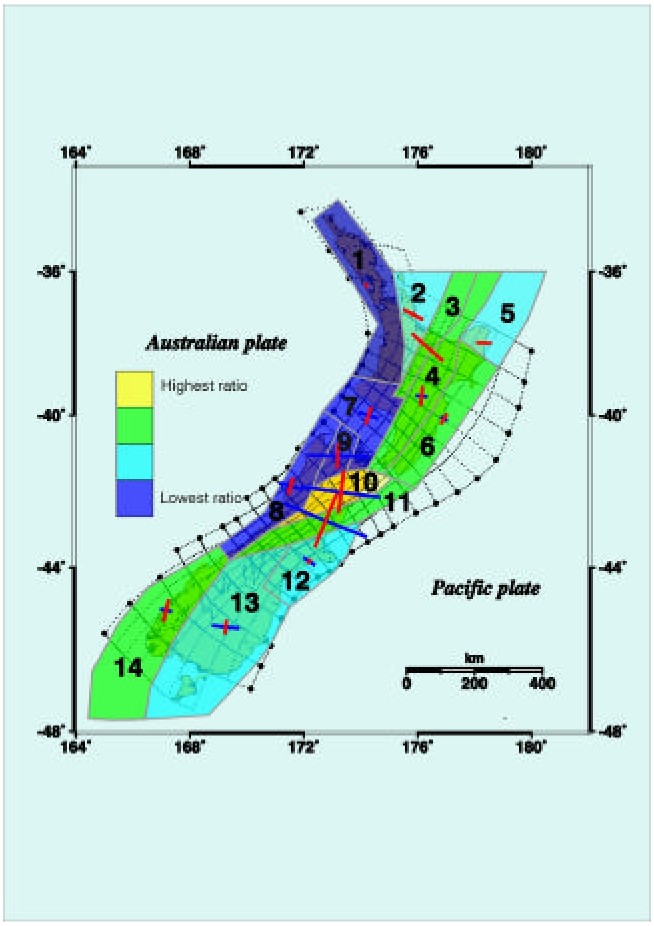

Figure 2. Ratio of the seismic moment rates derived from the National Seismic Hazard Model to moment rates derived from the geodetic data. A ratio of 1 is at the boundary of yellow (top box) and green (next box down), and principal axes of the strain rate tensor are shown as the red (lighter) and blue (darker) orthogonal lines (contraction=blue and extension=red).

- Tests of predicted ground motions. These involve comparing the ground motions and the associated annual frequencies predicted from the NSHM against independent estimates of these parameters. The tests have thus far compared the frequency of exceedance of various levels of MM Intensity against the historical incidence of these MM Intensity levels. The tests have been extended to the USA as part of a collaborative programme between GNS and the US Geological Survey (USGS), and similar tests will hopefully be undertaken in Italy as part of a wider international study. The historical MM Intensity data have not been used directly in the NSHM and the USGS model, hence the ability to use these data for testing. Carrying out the same test on both New Zealand and USA models has the advantage of more thoroughly testing the modern methods of PSHA in general than a test restricted to New Zealand. Tests have in the majority of cases been preliminary, and will need to be completed with a greater degree of statistical rigor in the future. Preliminary results show the NZ model to be producing results that are compatible with to somewhat higher than the historical record (Dowrick & Cousins *in press*), but the USGS model significantly underpredicts the historical record. We are also intending to commence a programme that will use the distribution of prehistoric "precarious" landforms (e.g. balanced rocks) as a test of the longer term estimates of ground motions from the NSHM. Preliminary studies of precarious rocks have been undertaken in the USA in the last decade (e.g. Brune, 1996; Anderson & Brune, 1999; Stirling et al. *in press*) and tend to show the opposite trend to the historically-based test for the USA.
- Cross-validation of computer code. We are currently taking part in a study funded by the Pacific Earthquake Engineering Research group (PEER) that uses a standardised set of earthquake sources to cross-validate the basic arithmetic and computational functions of the NSHM computer code against other widely-used USA codes. The exercise is seen as essential by many end-users in New Zealand and the USA as it verifies whether or not the computer codes are giving arithmetically and computationally consistent and correct results. Preliminary results show that the NSHM computer code is producing similar results to all of the other widely-used USA codes.

5 SUMMARY & CONCLUSIONS

We are currently directing considerable efforts into improving and validating the NSHM. This is being achieved by improving the input parameters and scaling relations used for computing the hazard, incorporating site geology into the model, submitting the predicted earthquake parameters and resulting ground motions to tests provided by independent estimates of these parameters and ground motions, and by cross-validating the arithmetic and computational functions of the NSHM computer code against other widely-used USA codes. The results of the validation efforts are thus far encouraging except that there is a significant discrepancy between the high predicted frequency of occurrence of ground rupturing earthquakes in New Zealand and the lower historical incidence of these events.

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