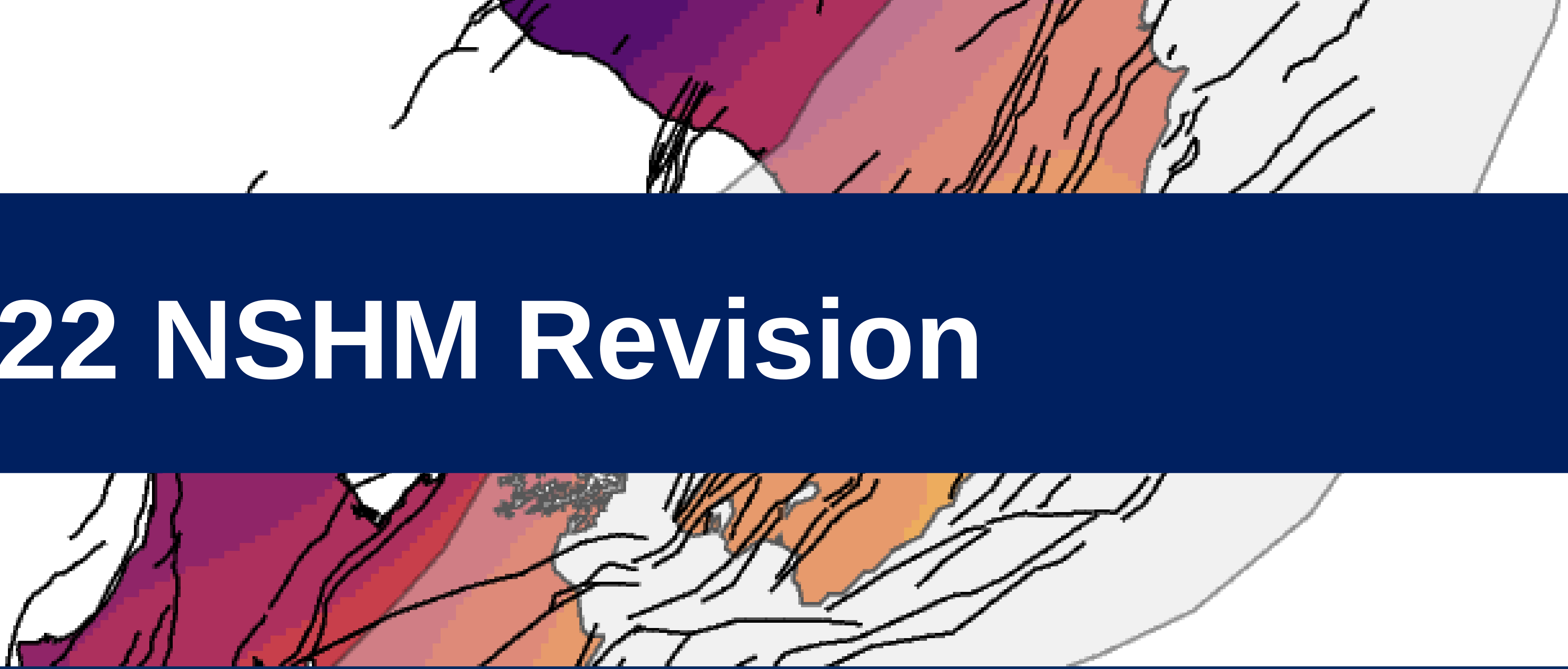


The 2022 NSHM Revision

Matthew Gerstenberger
GNS Science

Te Tauira Matapae Pūmate Rū i Aotearoa

NSHM The New Zealand National Seismic Hazard Model

A GNS Science Led Research Programme

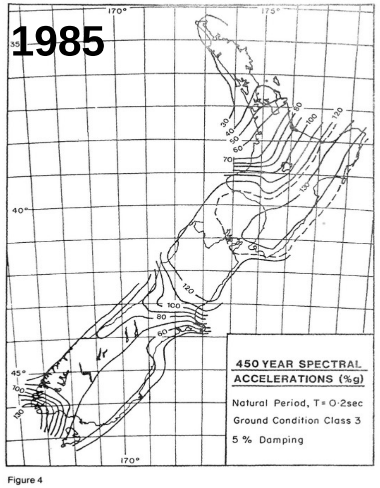
E mahi ana me
In collaboration with

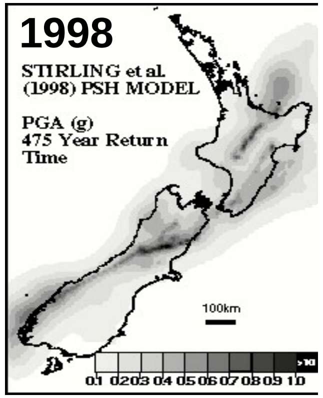
University of Canterbury · University of Otago · The University of Auckland · Victoria University of Wellington Te Herenga Waka · USGS · Indiana University · WSP · Australian Government Geoscience Australia · SCEC Southern California Earthquake Center (An NSF+USGS Center) · Missouri S&T · GEM Global Earthquake Model · GFZ Potsdam · UCLA · NIWA Taihoro Nukurangi · Lamont-Doherty Earth Observatory Columbia University | Earth Institute

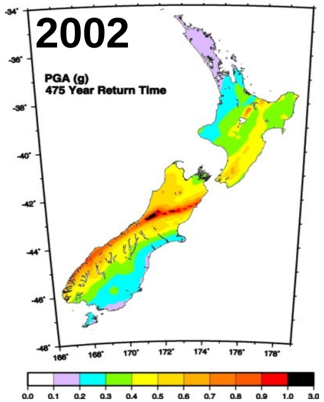
Ngā hoa tuku pūtea
Funding partners

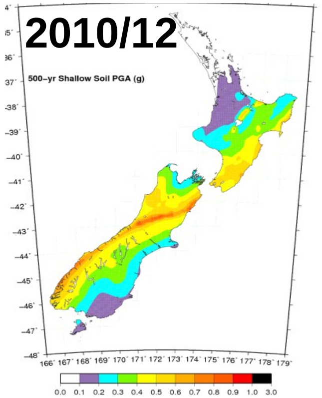
Ministry of Business, Innovation & Employment Hīkina Whakatutuki · Toka Tū Ake EQC

A revision was long overdue









1998: last significant revision

2002: minor update to part of the model
- Significant component only using methods/data up to 1996

2010: data update to part of the model
- Significant component only using methods/data up to 1996

USA, Japan, Taiwan, Canada and Australia on regular ~5 year (significant) revision cycles

The science development and review process

We aim to represent a broad range of scientific views

- with something as complex as earthquakes it is not realistic or prudent to develop a single consensus model – users need to understand the uncertainty (most want to)
- Expert selection (who is an expert?) and structured elicitation process

NSHM includes scientific understanding from around the world

- Includes a broad range of scientific views
- More than 50 scientists from around New Zealand and around the world
- University of Canterbury, University of Otago, University of Auckland, NIWA and others
- United States, Canada, Italy, Germany, Australia, England

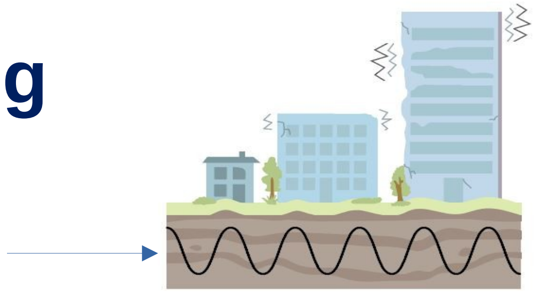
NSHM Participatory peer review:

- Technical advice on the development of the NSHM has been provided by a 17-member panel of international scientists, engineers, insurance using a participatory review process.
- Scientifically detailed involvement from panel – weekly input
- Panel included key NSHM end-users
- Time consuming and challenging, but very beneficial

Assurance review:

- International review of processes: science, decision making and peer review, with positive outcomes

The NSHM produces probabilistic forecasts of shaking



What time is the forecast for?

The NSHM provides a probabilistic forecast of earthquake shaking. The probabilities are determined from the scientifically credible range of shaking we might experience over the next **100 years**. Often these probabilities are mapped using the average forecast.

PROBABILISTIC MODEL

Past earthquake events
+
statistical and physical science

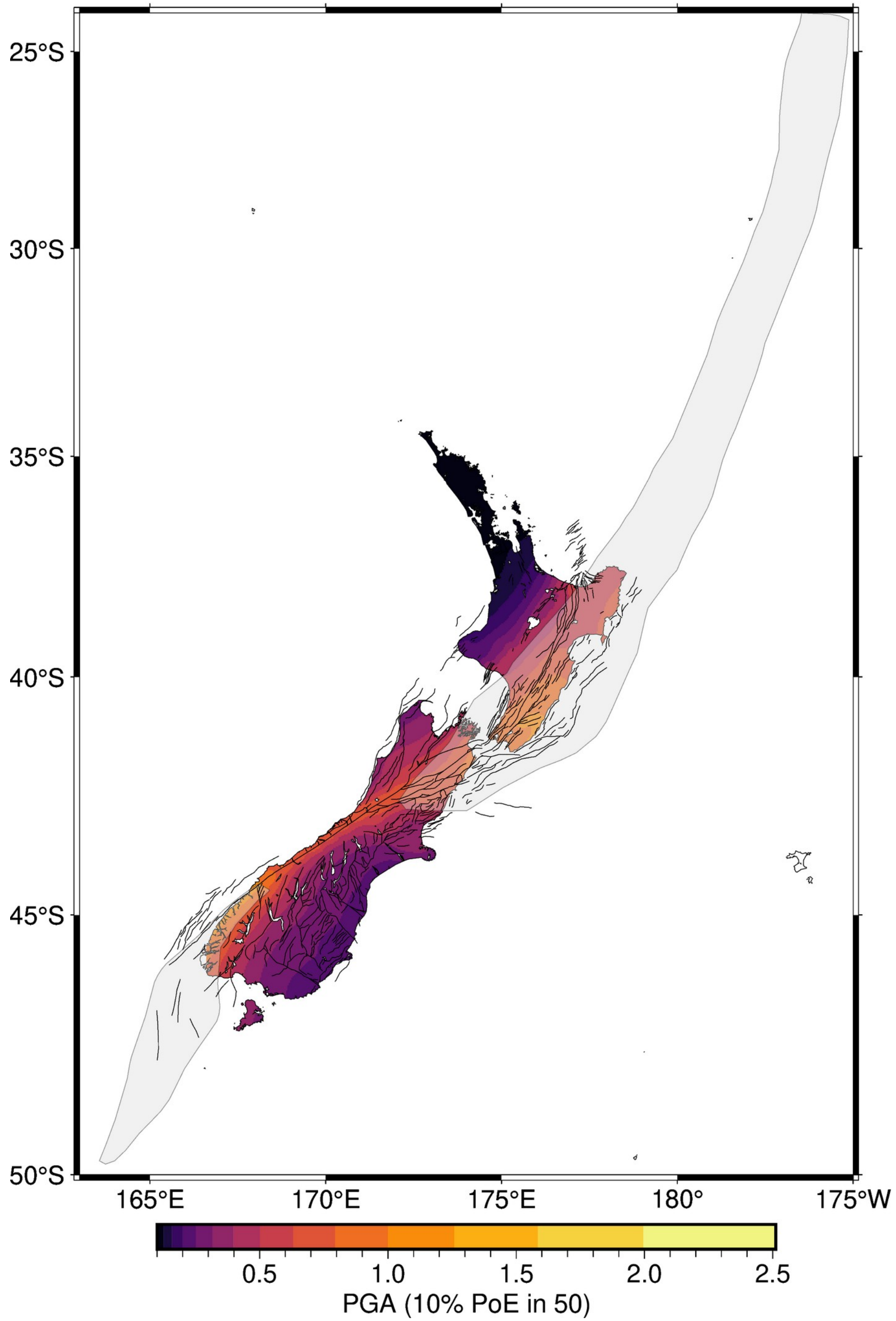
Range of future possible shaking

The forecast is a distribution of shaking, not a single number

The confidence in the forecast is shown by looking at the range of possible futures and how likely they are. Each one of these can be expressed as a different map or different outputs for engineers

Uncertainty for informing risk based decisions

How do we make the NSHM?



Two Components of the NSHM

1 **Earthquake Ruptures**

2 Ground Shaking

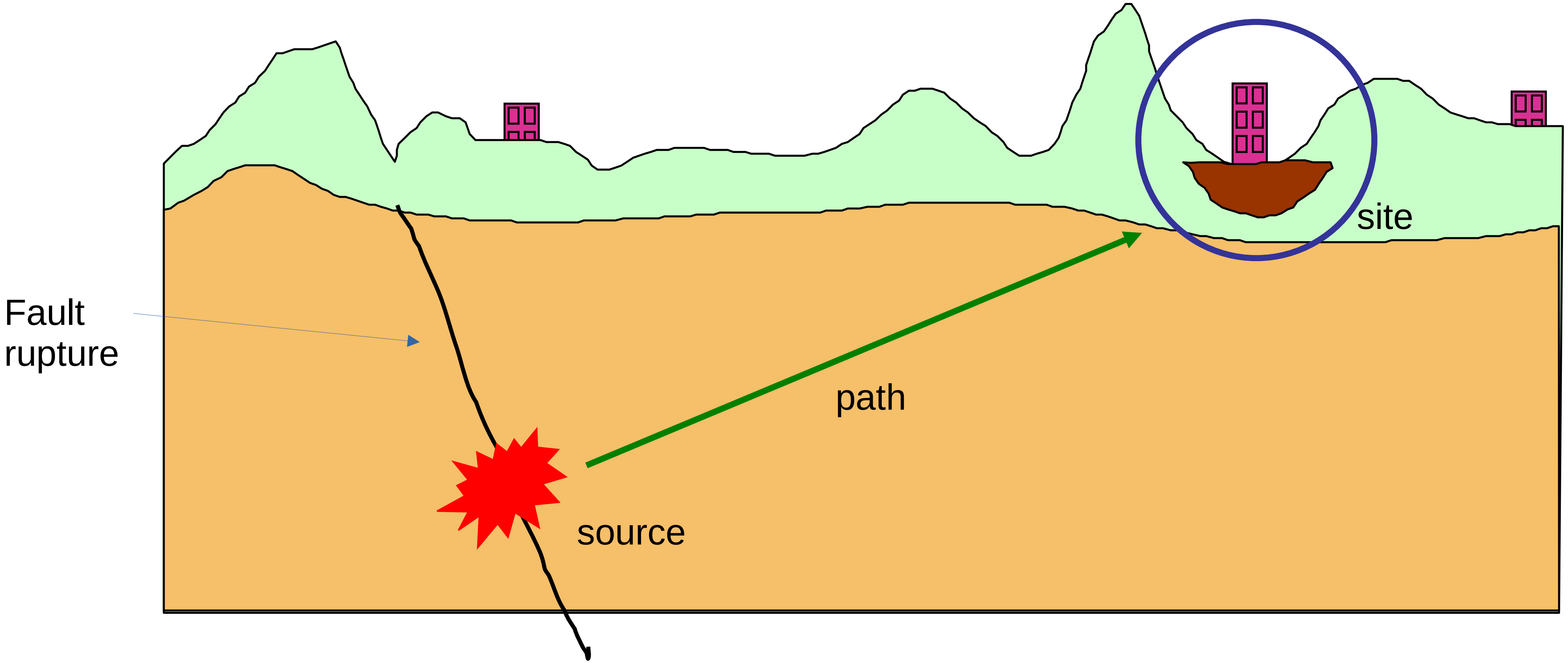
1. Earthquake Ruptures: where, what frequency and what magnitudes

- Hundreds of thousands of modelled ruptures based on around 1,000 known faults and how they can rupture
- Many hundreds of thousands of random ruptures considered for faults that are unknown

2022 NSHM faults including Hikurangi-Kermadec and Puysegur Subduction Interfaces

Main Model Components

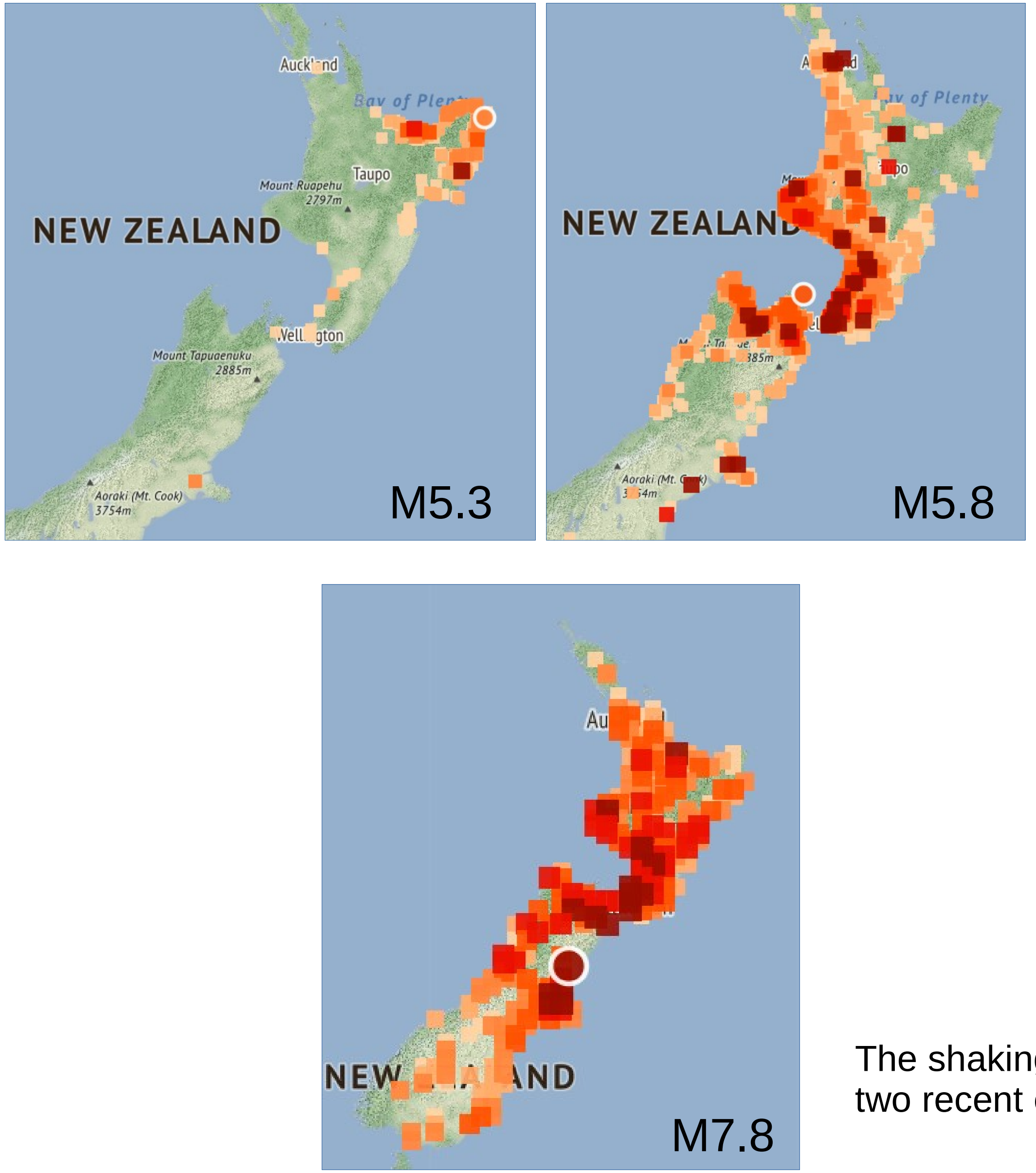
Ground shaking = source effects + path effects + site effects



Two Components of the NSHM

1 Earthquake Ruptures

2 **Ground Shaking**



2. Ground shaking: what is the range of possible shaking when all ruptures are considered

- Use of many models, some internationally developed, some specifically optimised to New Zealand earthquakes
- Each model can give a different forecast for the same rupture
- Final shaking estimate includes all possible ruptures, and the range of shaking possible for each one of those

The shaking people felt in the Kaikoura M7.8 and two recent earthquakes

What contributed the most to hazard changes?

A focus on uncertainty	• Many scientifically credible futures considered • Communication of confidence in results
Use of many data sets	• Allowing for best possible forecasts
Complex multi-fault ruptures	• More realistic forecast • Important for risk considerations
Hikurangi Subduction zone, ruptures and shaking	• Big changes in ground shaking modelling
Use of many ground motion models	• Critical changes for higher hazard areas
How many earthquakes will there be?	• Fundamental changes to how this been done, critical for hazard changes
Specific modelling for lower hazard regions (Auckland and Dunedin)	• Acknowledge lack of data • Influences hazard

From individual faults to complex ruptures

Some modelling key concepts:

- Ruptures can be complex and not just straight linear movement of one fault – as seen in large earthquakes in the last 200 years in NZ

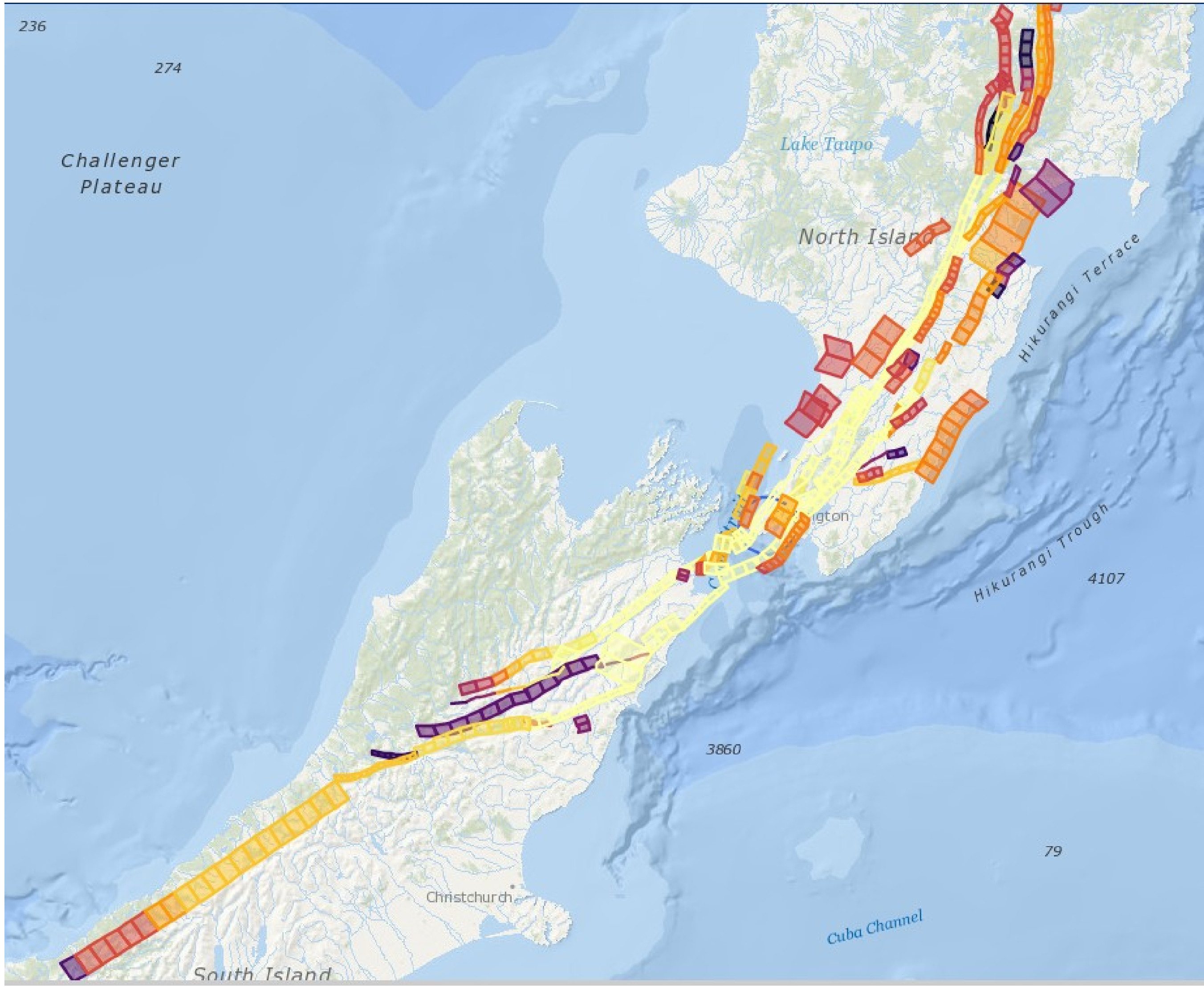
- There is uncertainty in magnitude and length

- We have many datasets: each one gives us a slightly different window into the future, and into what complex ruptures may occur

No longer only one fault rupture with one magnitude and one rupture length

Fault connectivity

- Many different forecast earthquake ruptures are shown on this map
- Each passes within 20km of Wellington
- In the past only a one or two ruptures were considered for Wellington (and other urban faults) now there are hundreds.

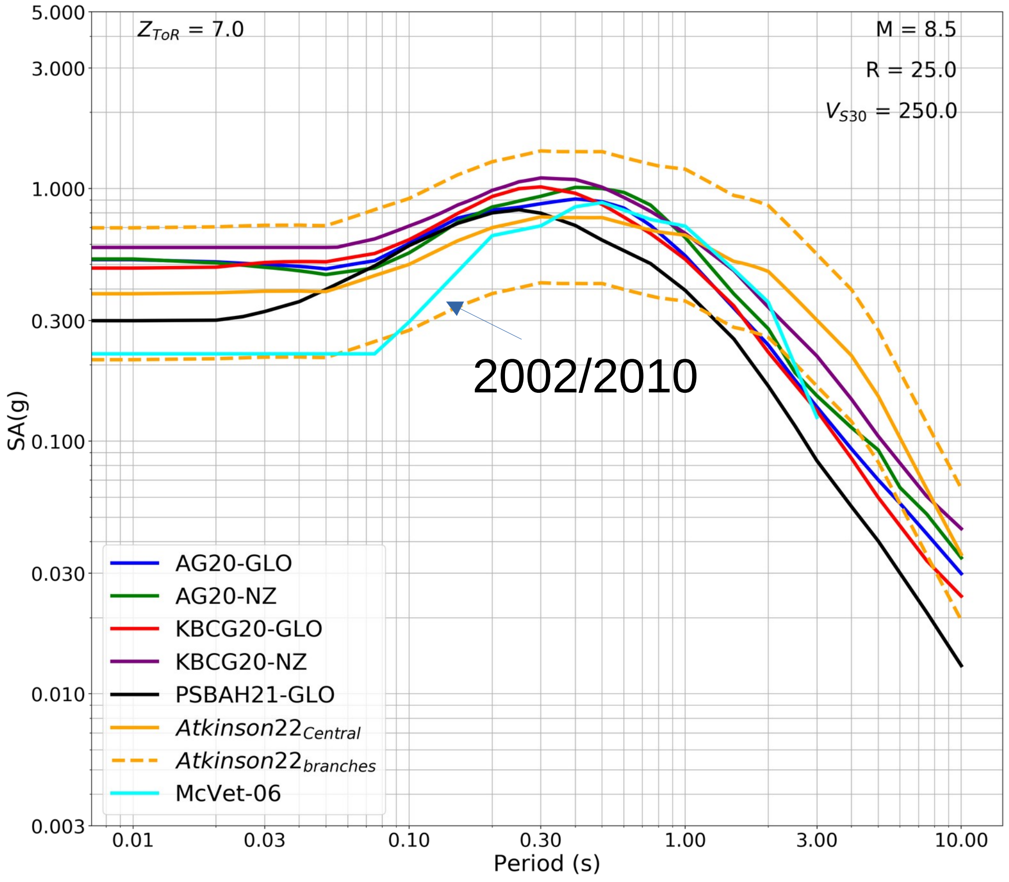


Large differences from 1998/2002/2010 models to 2022 model

Ground Motion Models

- ~25 years additional data and advancements in understanding/modelling
- Single forecast from past models generally at the bottom of the range from new models
- Significant increases!

M8.5 at 25km



Short buildings

Tall buildings

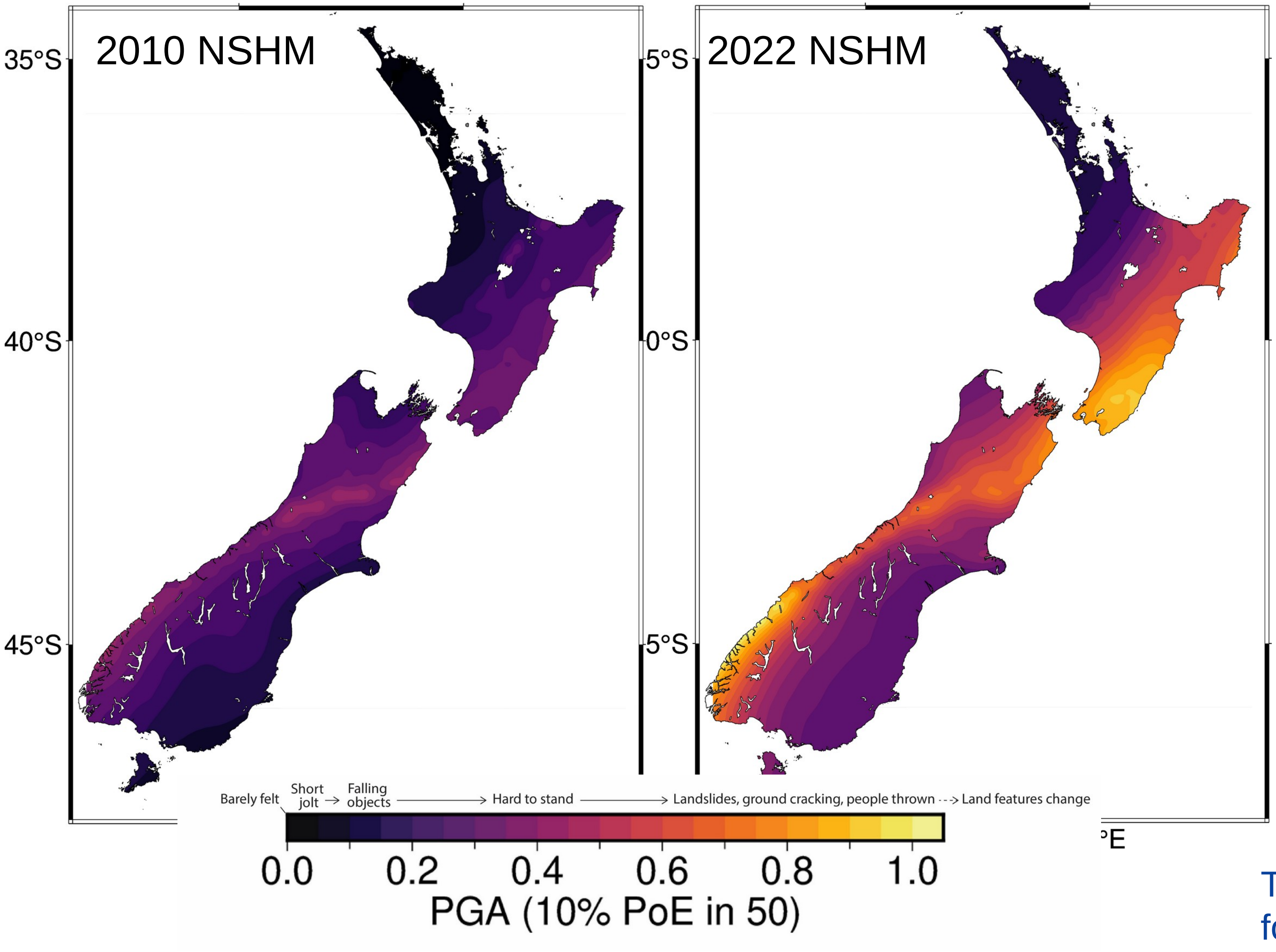
Sample Example Hazard Results (full results available online)

Comparison of 2010 and 2022 PGA *Hazard* Maps

PGA: 10% Probability of Exceedance in 50 years

One of many possible comparisons – does not illustrate range of results.

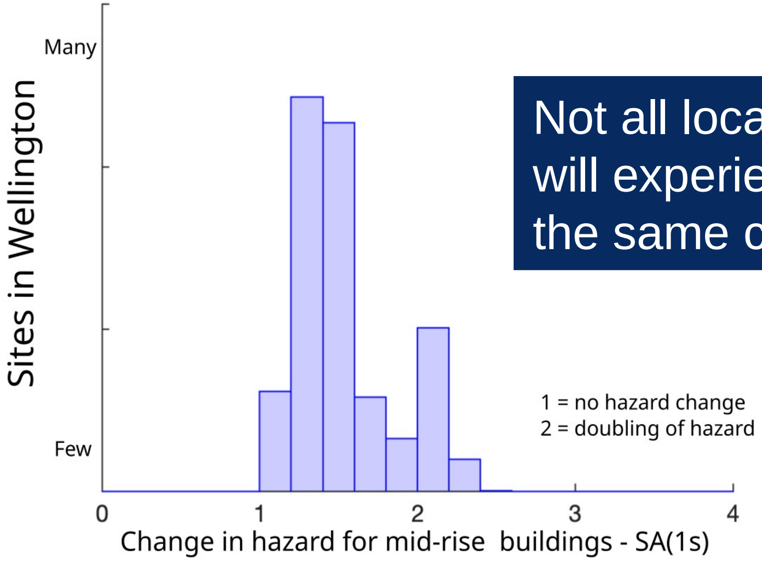
Across all hazard parameters a range from no increase to more than double is seen. When considering site condition/Vs30 differences, the average increase is about 50% or more



Example shaking for Vs30=250m/s

Location	2010 PGA(g)	2022 PGA(g)
Auckland	0.05	0.13
Wellington	0.32	0.82
Christchurch	0.17	0.42
Dunedin	0.1	0.26

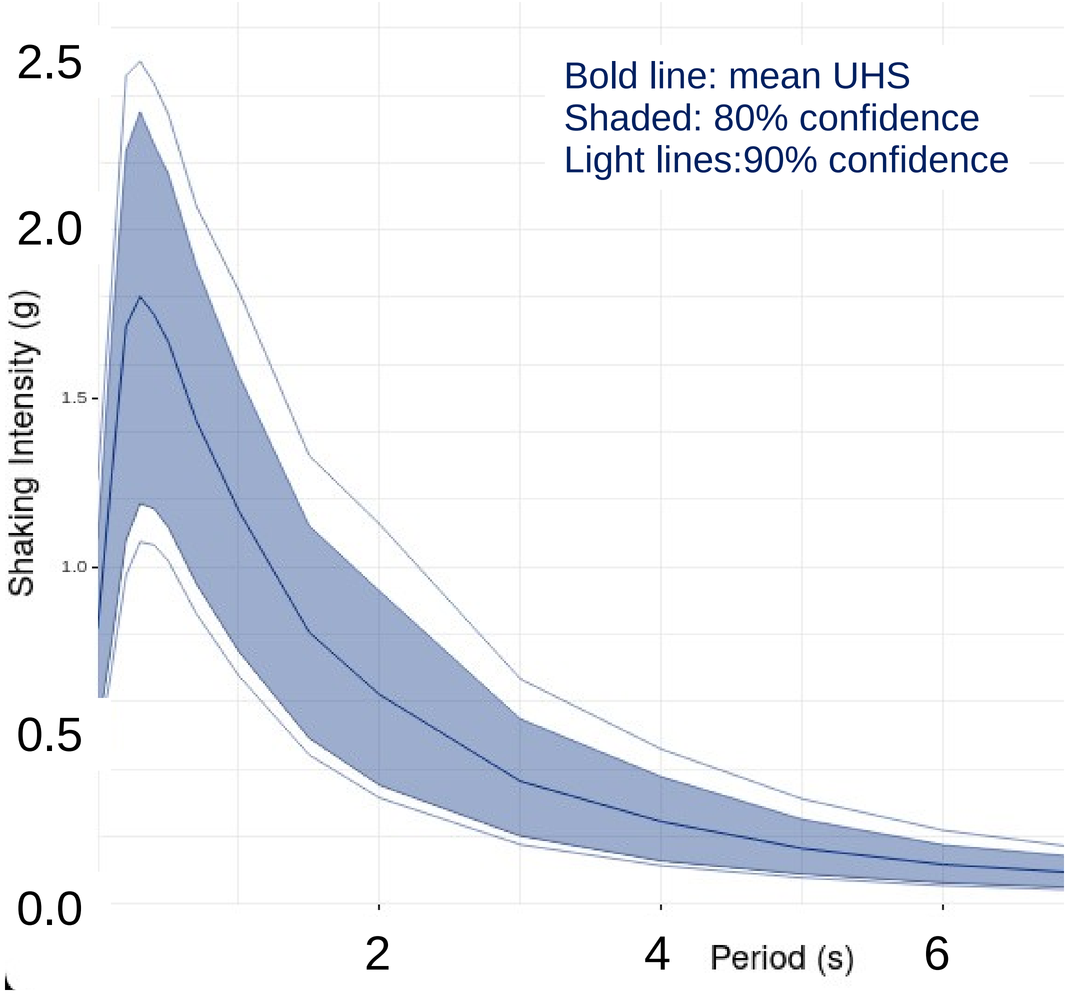
Increasing hazard does not necessarily translate to an equivalent increase in impact, as impact does not always increase proportionally to the hazard.



Not all locations will experience the same change

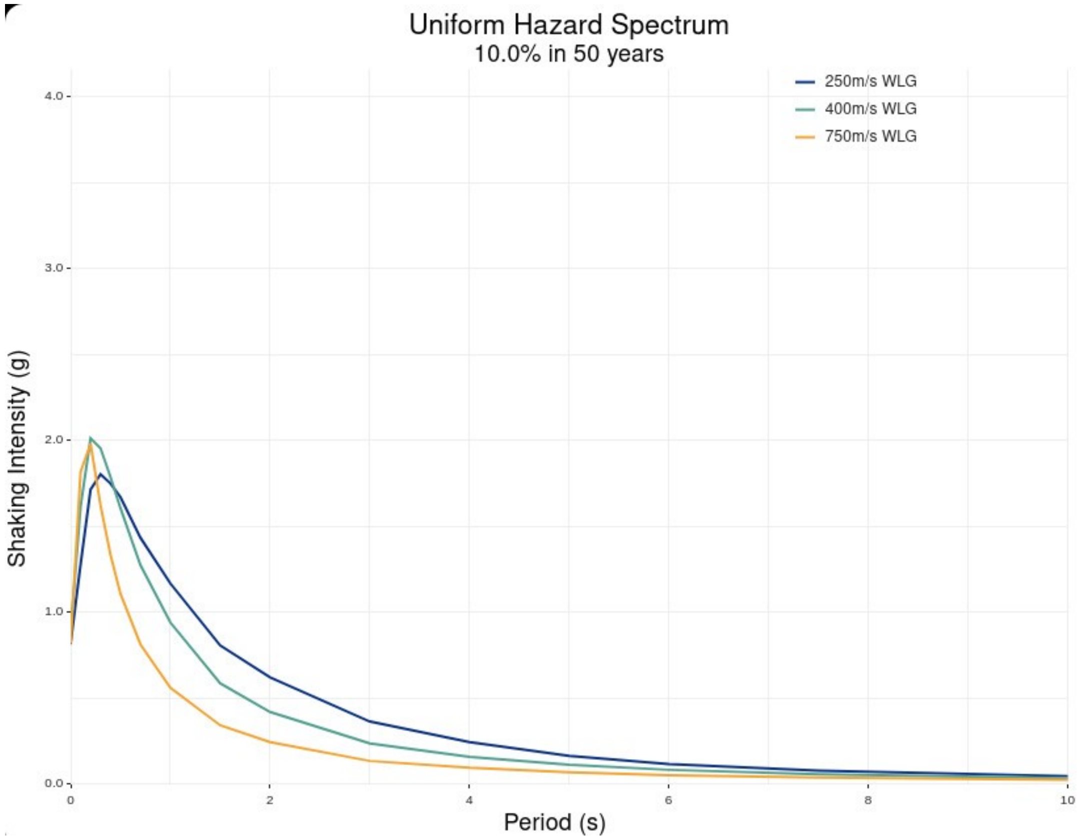
The variability in hazard forecast for mid-rise buildings for an extensive range of sites across Wellington

UHS and uncertainty



10% PoE in 50 years, Vs30 = 250 m/s

Uncertainty in hazard



Wellington

Variability across Vs30

Setting the lower-bound values

- Lower-bound spectrum = Auckland CBD's 90th percentile uniform hazard