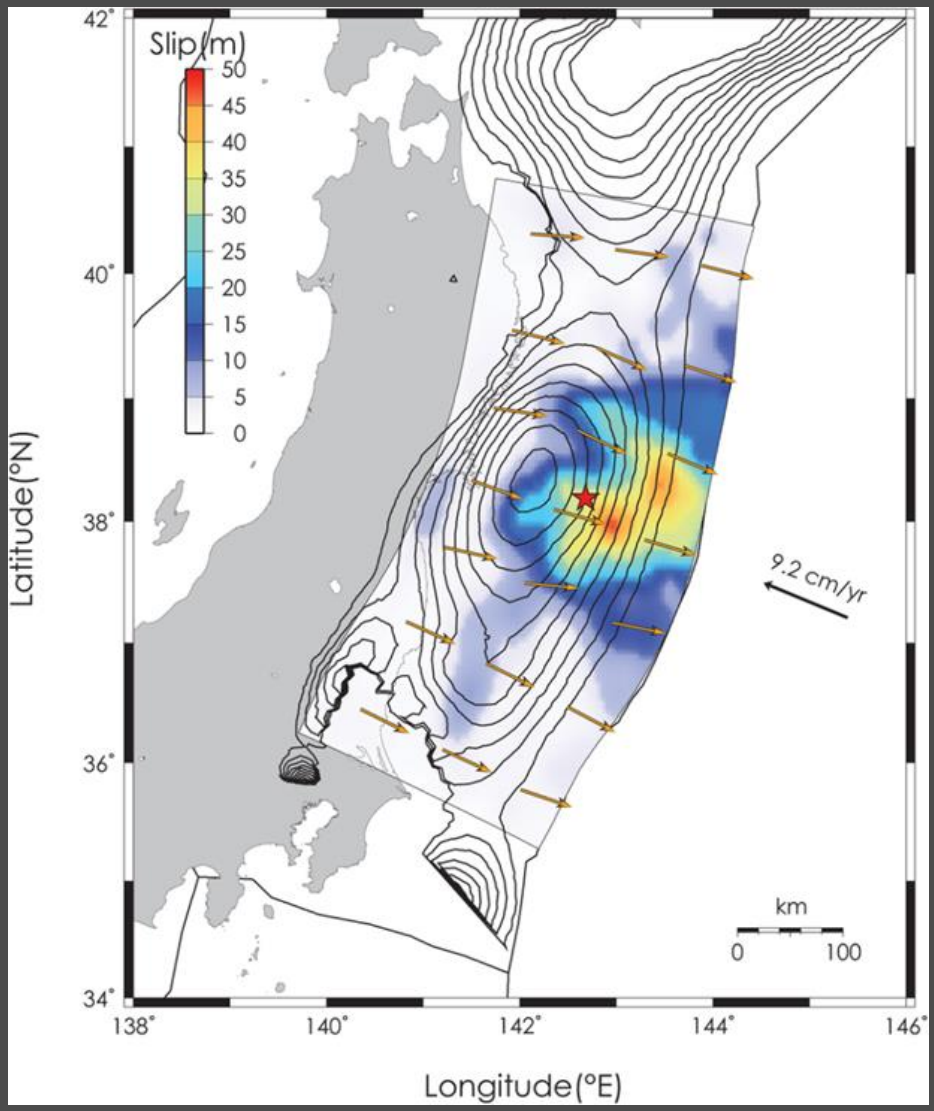
Tsunami Science

Presented by William Power
Contains the work of many people

GNS SCIENCE
TE PŪ AO

Changes in scientific understanding

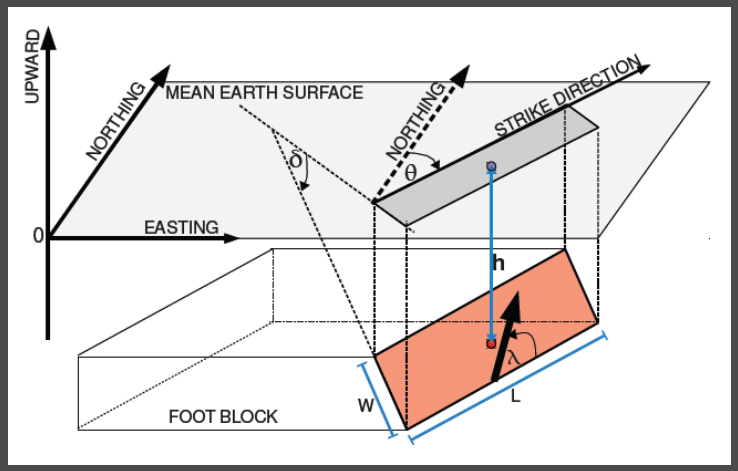
- Earthquake details can make a big difference to tsunami inundation, especially for local sources
- The intervals between the largest earthquakes may be thousands of years.
- Paleotsunami in NZ were bigger than historical tsunami.

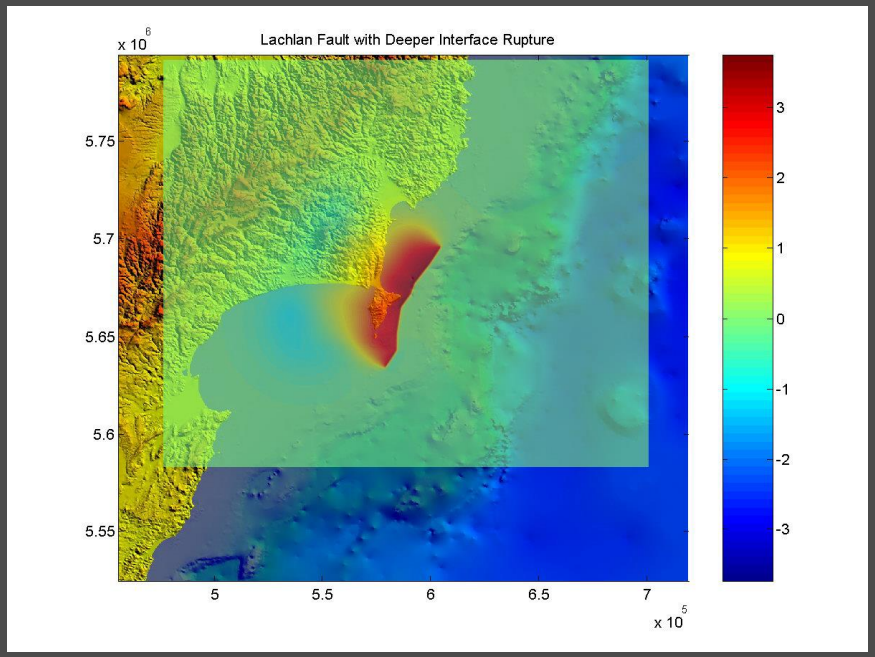


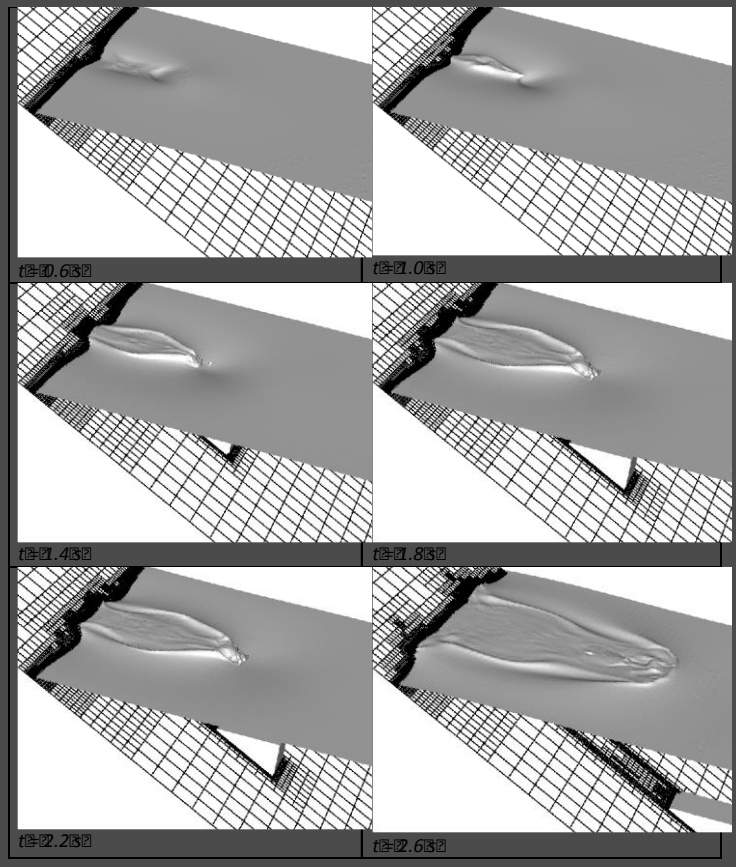
Modelling methods

- **Numerical modelling (computer simulation of physical processes)**
  - Source models
  - Propagation models
  - Inundation models
- **Empirical modelling (finding relationships between cause and effect by looking at data from past events)**

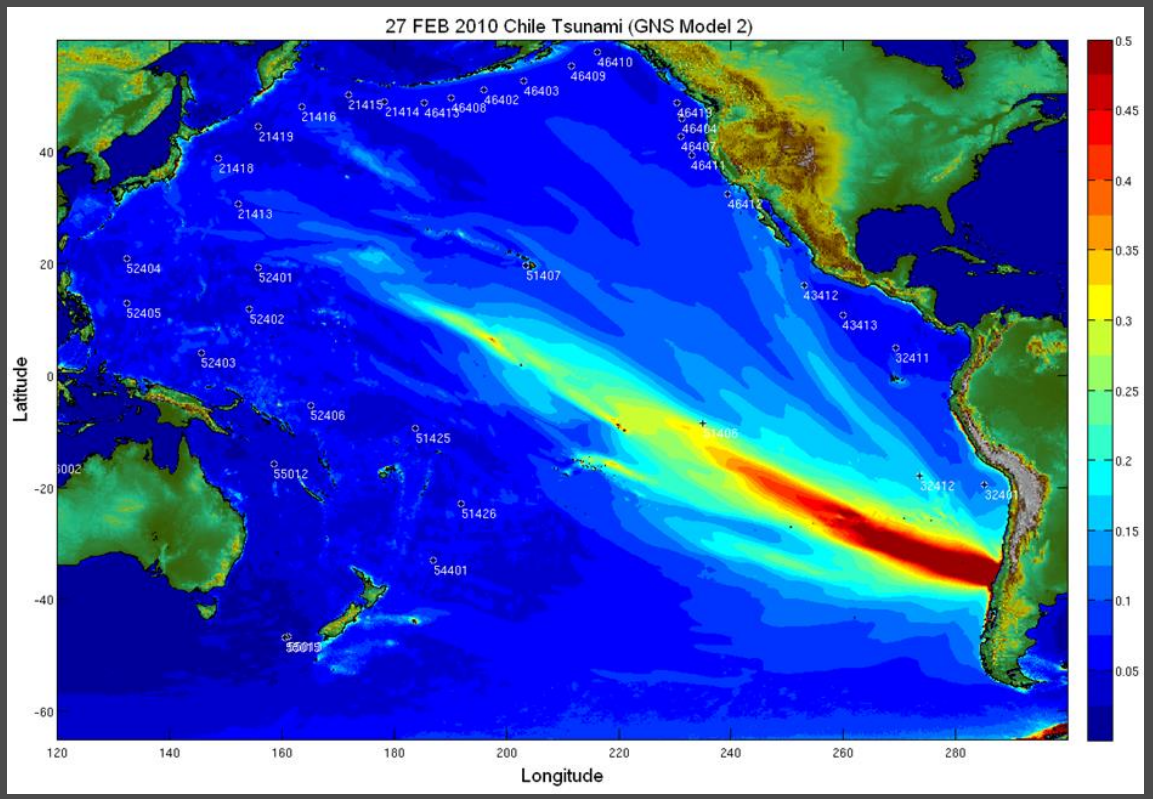
Source models

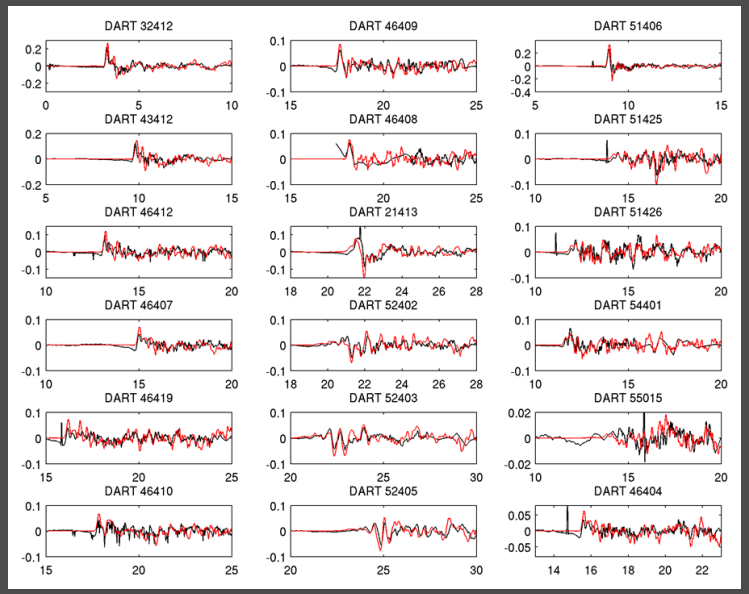




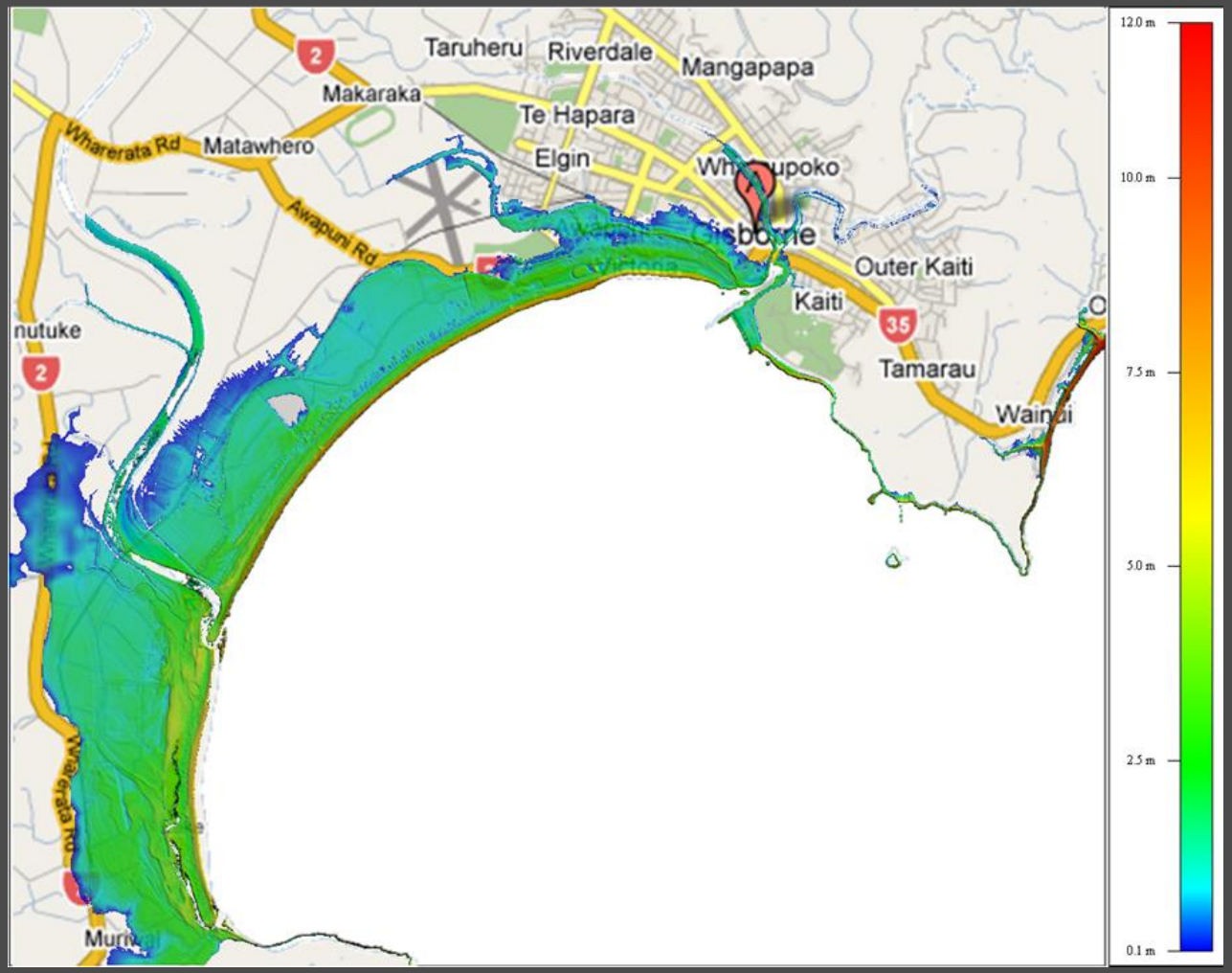


Propagation models





Inundation models



Empirical models

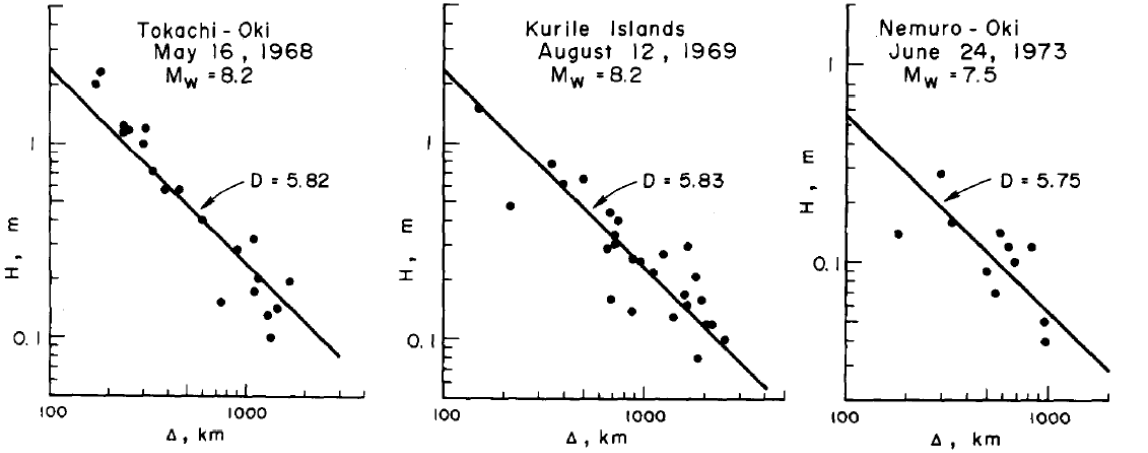
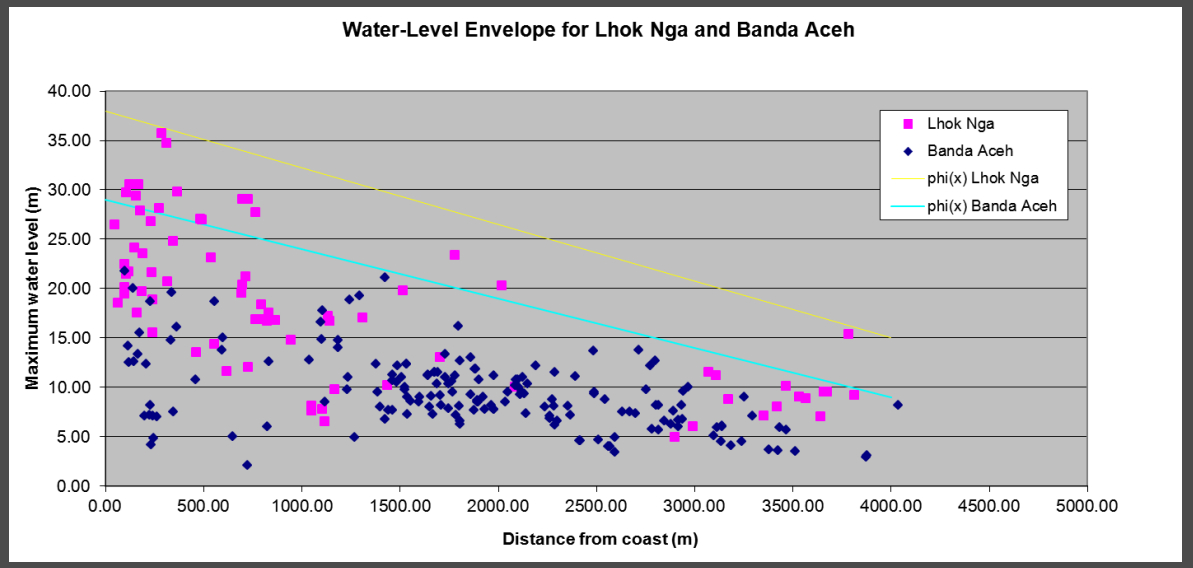


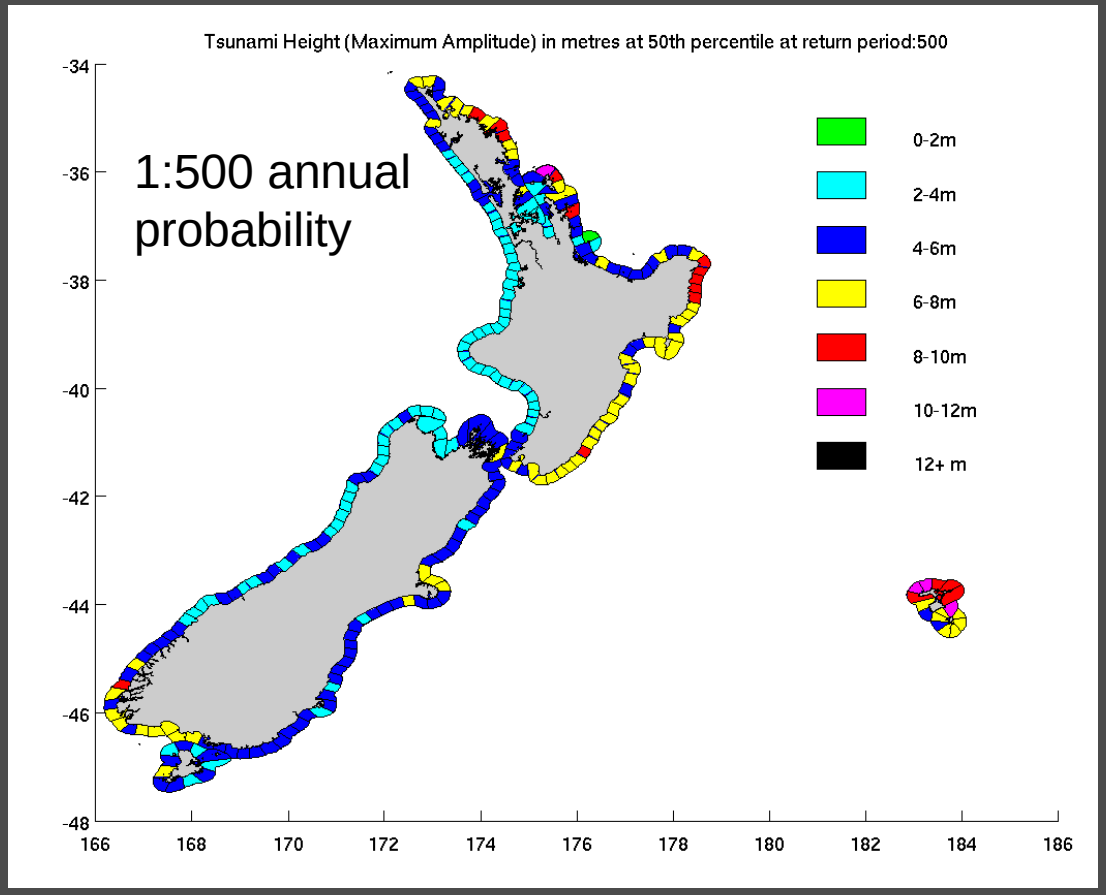
Fig. 2. Relation between log H and log Δ for three calibration events. H is the maximum amplitude in metres, and Δ is distance in kilometres. The straight line is the least-squares fit of $\log H = M_w - D - \log \Delta$ to data, where M_w is the moment magnitude of the earthquake.

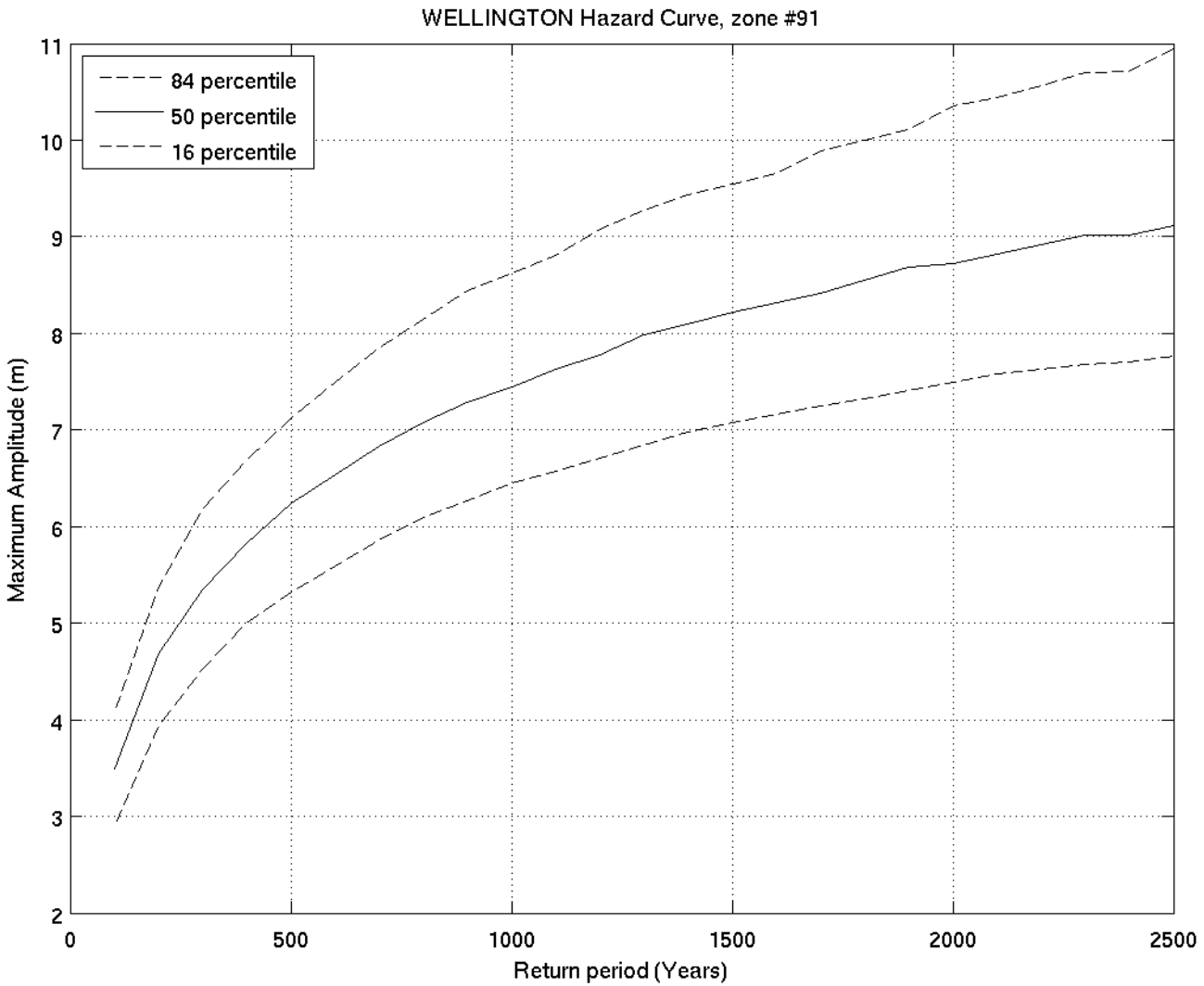
Abe, 1981, PEPI



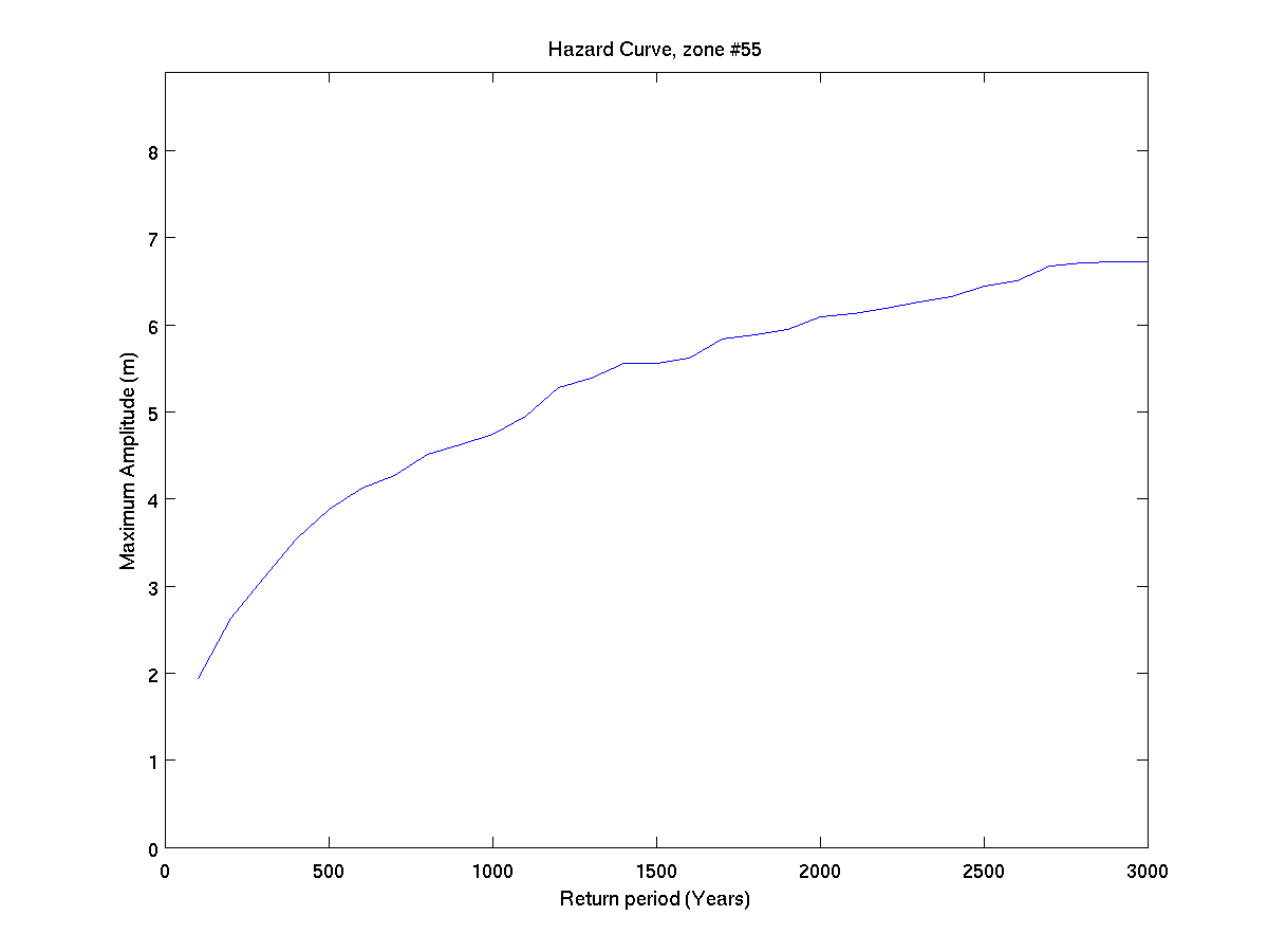
Quantifying tsunami hazard

- National probabilistic model, now covers all coasts
- Based on simulating a long sequence of earthquakes and the tsunami they cause
- Estimates maximum tsunami heights at different return periods and levels of confidence

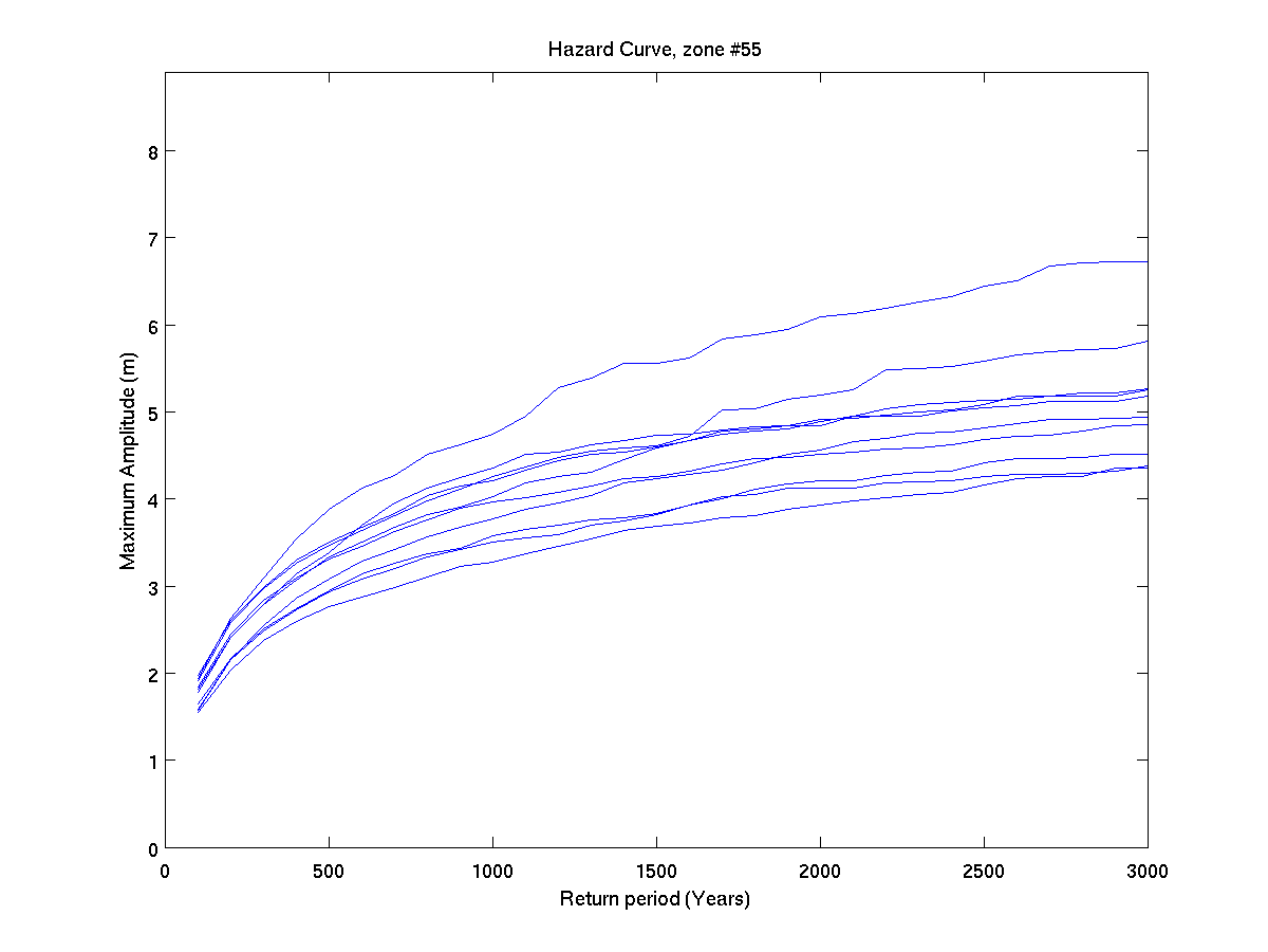



WELLINGTON Hazard Curve, zone #91
84 percentile
50 percentile
16 percentile
Maximum Amplitude (m)
Return period (Years)
11
10
9
8
7
6
5
4
3
2
0
500
1000
1500
2000
2500

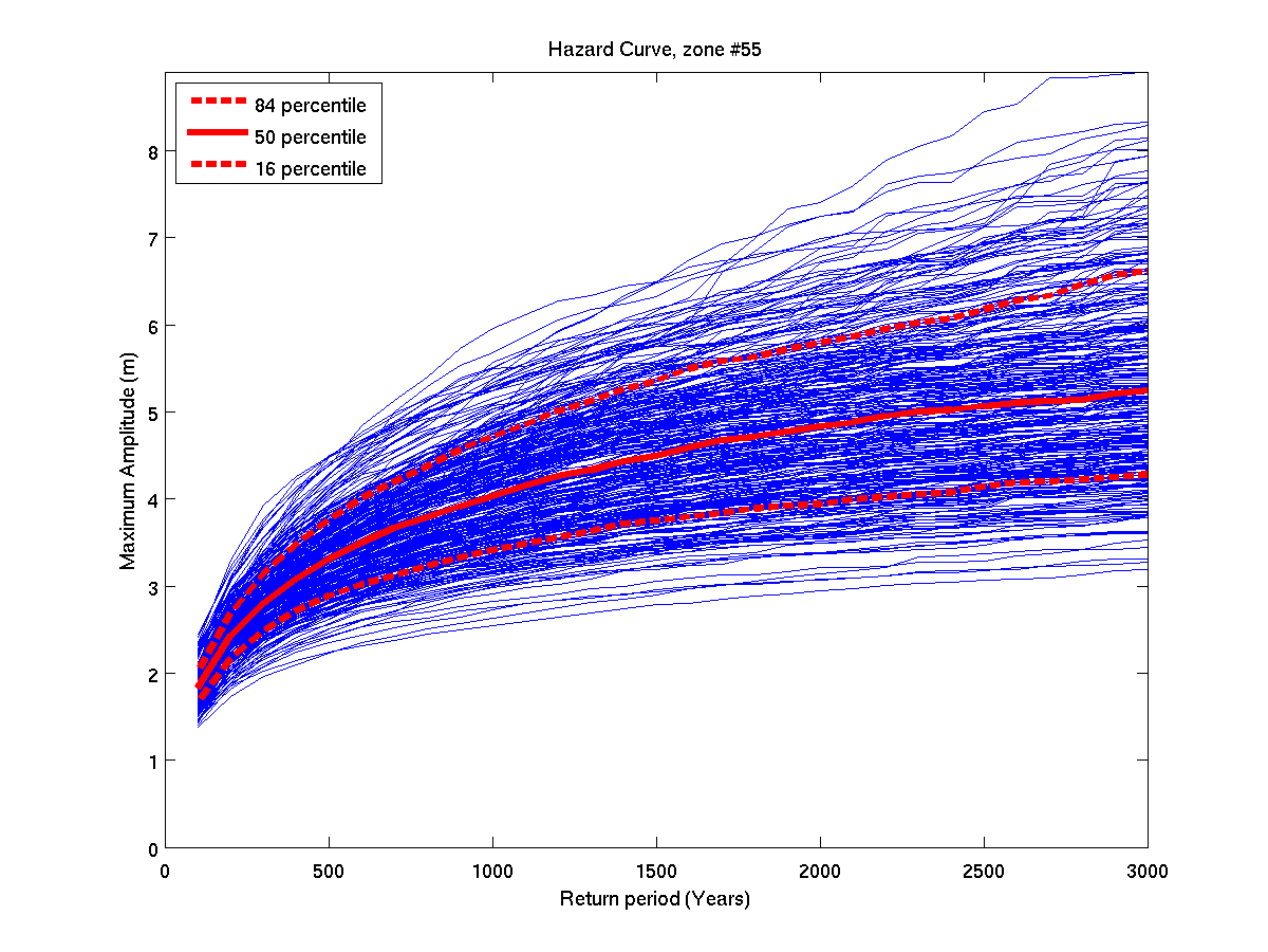
1 Hazard Curve



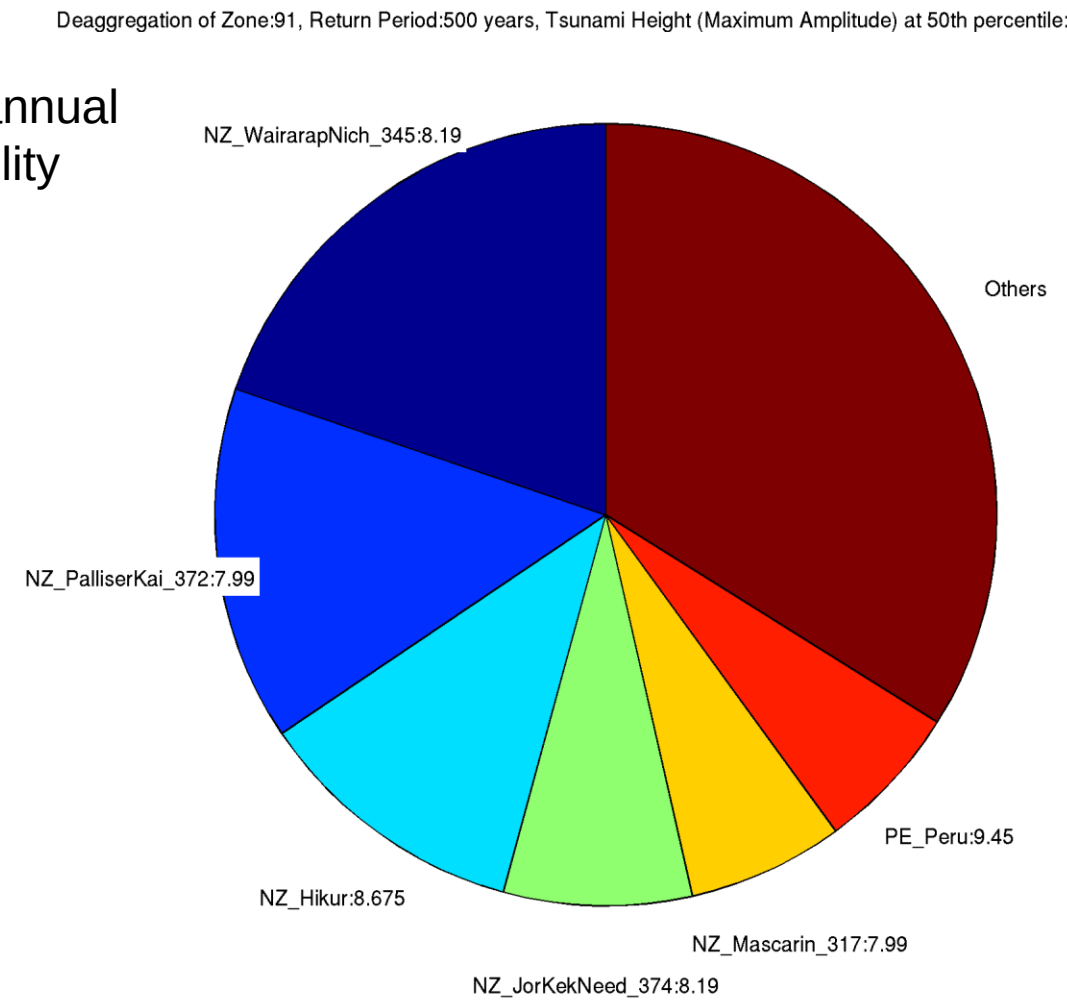
10 Hazard Curves



300 Hazard Curves



1:500 annual probability



Hazard and Risk

- **Risk formula:**

  Risk = Likelihood x Consequence

- **Hazard: ‘This place has a 1:200 probability of being inundated per year’**

- **Risk: ‘This building has a 1:1000 probability of being destroyed per year’**

- **Need to model inundation and fragility, and to know what is exposed, in order to estimate risk**

- **Risk is the preferred way to think about hazards, but more difficult and more expensive**

Applications of hazard and risk

- Evacuation zoning
- Land use planning
- Response and recovery planning
- Engineering
- Insurance

Factors that affect the quality of studies

- Methodology
- Bathymetry
- Topography
- Modelling software
- Modeller experience
- Clear goals!

Levels of modelling for evacuation zoning (original)

- Level 1 – bathtub
- Level 2 – rule based, fixed wave height at shore
- Level 3 – model based, fixed wave height at shore
- Level 4 – inundation modelling of all relevant events

Levels of modelling (proposed revision)

- Level 1 – bathtub
- Level 2 – rule based, fixed wave height at shore
- Level 3 – model scenarios for chosen return period
- Level 4 – inundation modelling of all relevant events

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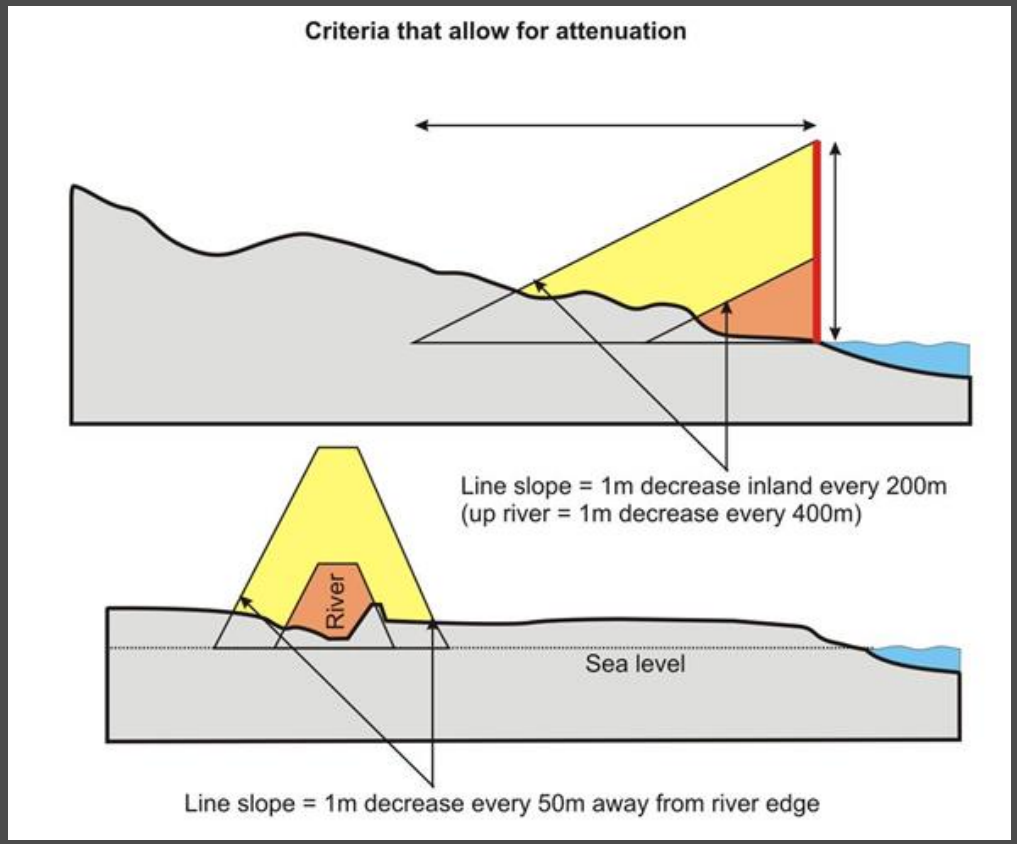
Level 2

- Based around empirical data describing how tsunami height envelope reduces with distance from the coast.
- Uses estimates of maximum run-up height within the zone

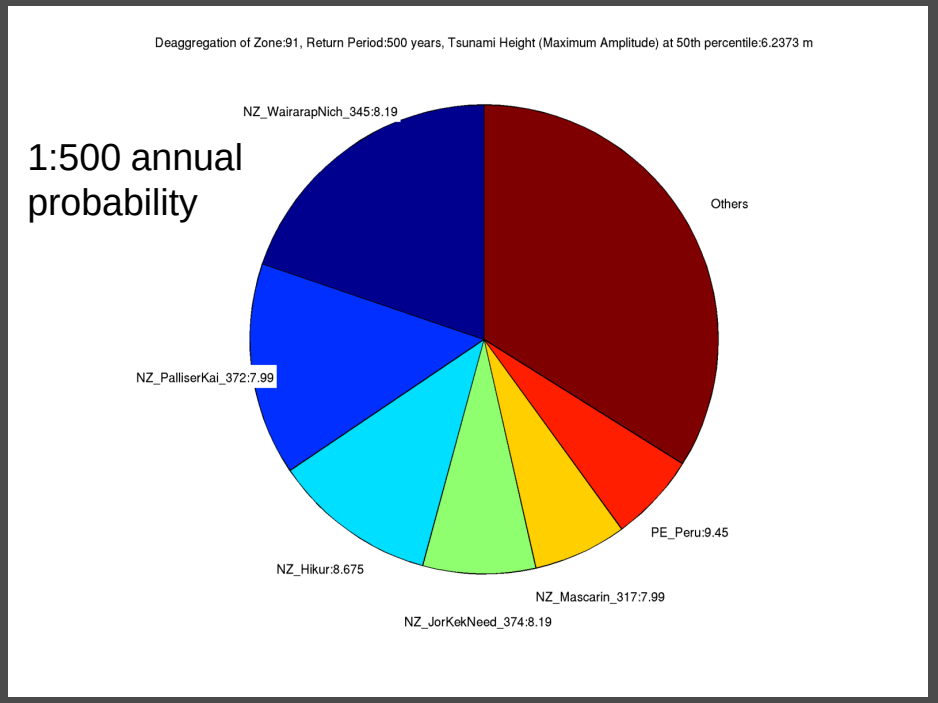


Level 2

- **Is intended as an interim method**
- **Is designed conservatively**
  - Consequently prone to over-evacuation especially of cities
  - Considered to be safer than other methods where topographic data is poor
  - Not suited for risk assessment? land use planning?
- **Has been tested using data from the Japan 2011 tsunami**

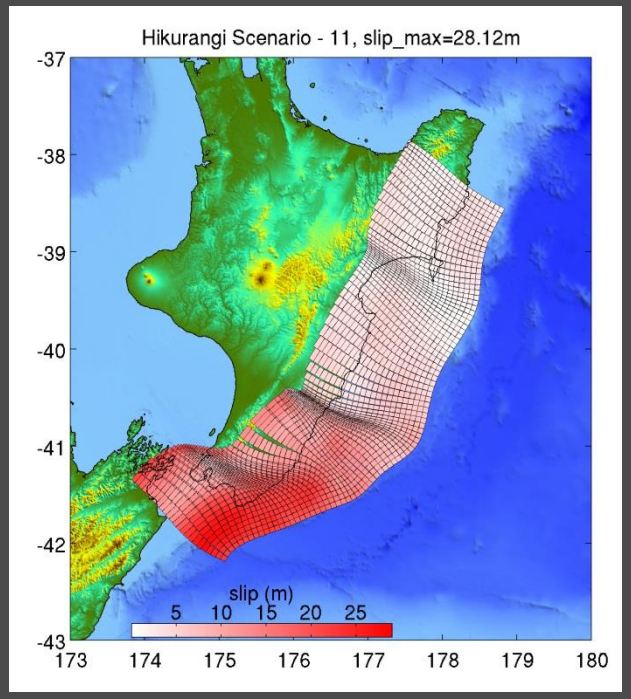
Level 3 (proposed)

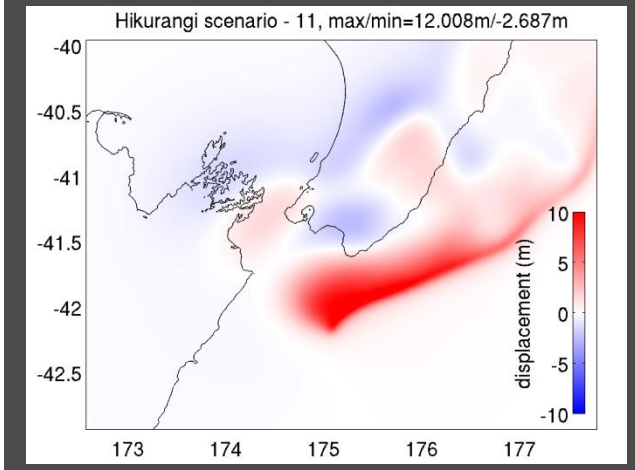
- Model inundation caused by scenarios that correspond to a specific return period
- Has been tested using data from the Japan 2011 tsunami

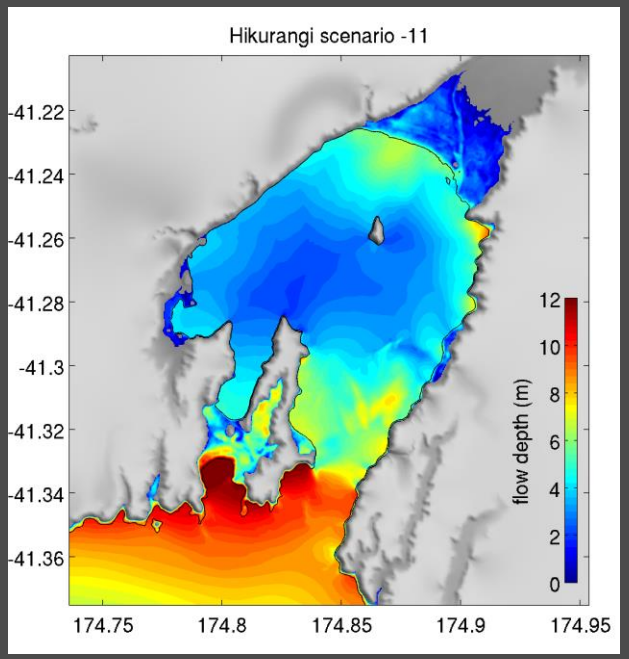


Level 4

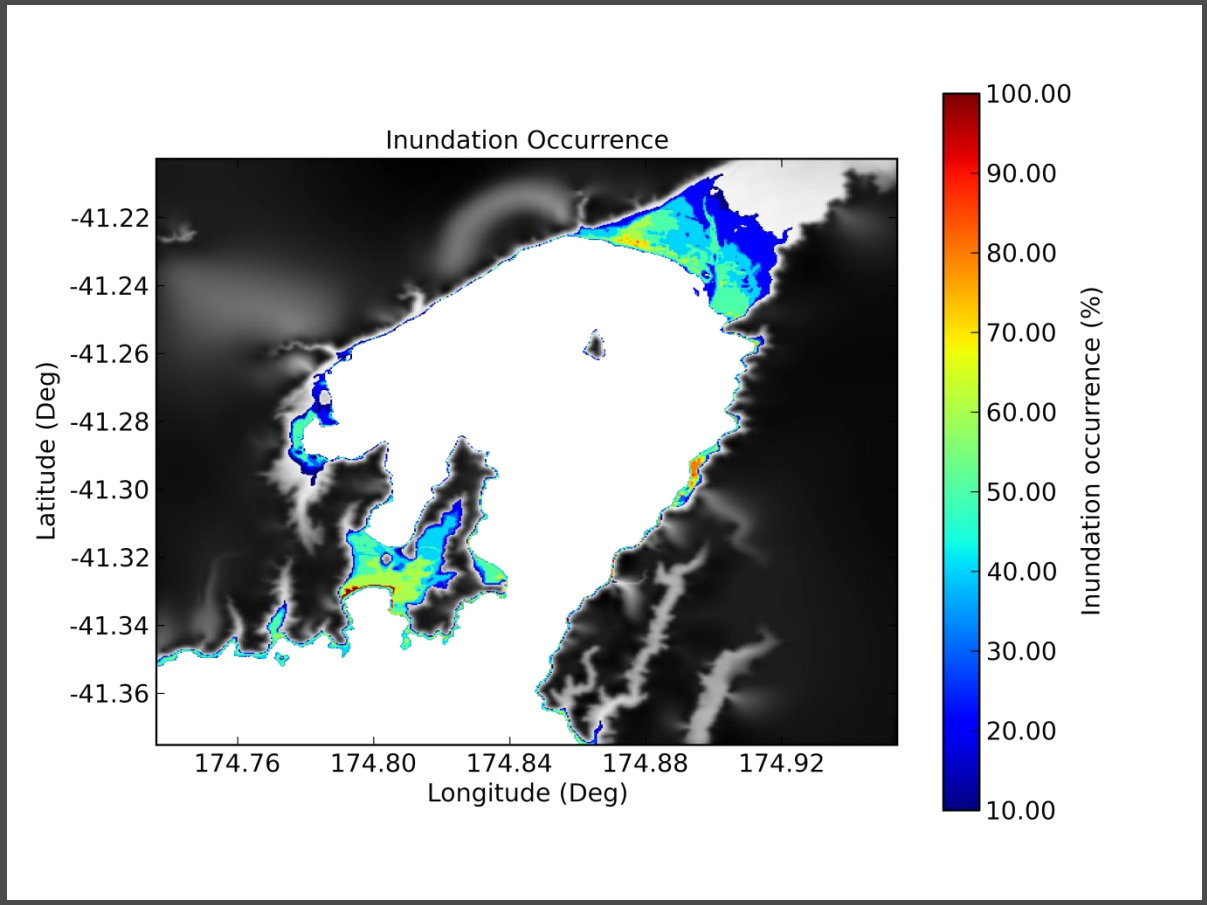
- Model all relevant events through to inundation
- Allow for variation in earthquake properties
- Has not been done yet!







Repeat many times


Inundation Occurrence
-41.22
-41.24
-41.26
-41.28
-41.30
-41.32
-41.34
-41.36
Latitude (Deg)
174.76
174.80
174.84
174.88
174.92
Longitude (Deg)
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
Inundation occurrence (%)

National consistency

- The benefits of consistency
- Return periods and confidence levels
- Evacuation zones
- Land uses
- Critical facilities

Using existing data

- Historical data
- Paleotsunami data
- GNS Hazard report data
- Using evacuation zones for planning???
- Existing modelling – where does it fit?

Challenges and Opportunities

- **National Consistency**
  - In how results are presented to the public
  - In how evacuation zones are calculated
  - In hazard and risk studies
  - In planning criteria

- **Evacuation modelling**
  - Reducing the risks involved in evacuations

- **Improvements in forecasting**
  - More detailed forecasts for key locations

Spare / optional slides follow

Wave period

- The model was run for 5 wave periods: 5, 10, 15, 20 and 25 min
- The area inundated increases with increasing wave period
- The distribution of water heights along the coast changes significantly when the wave period changes
- The highest water height at the coast is generated by the 10 min period wave and is located at the part of the coast backed by sand dunes
- The water heights at the coast start decreasing with further increase of wave period