Spatially-distributed ground motion intensity maps: Application for site-specific liquefaction evaluations in Christchurch

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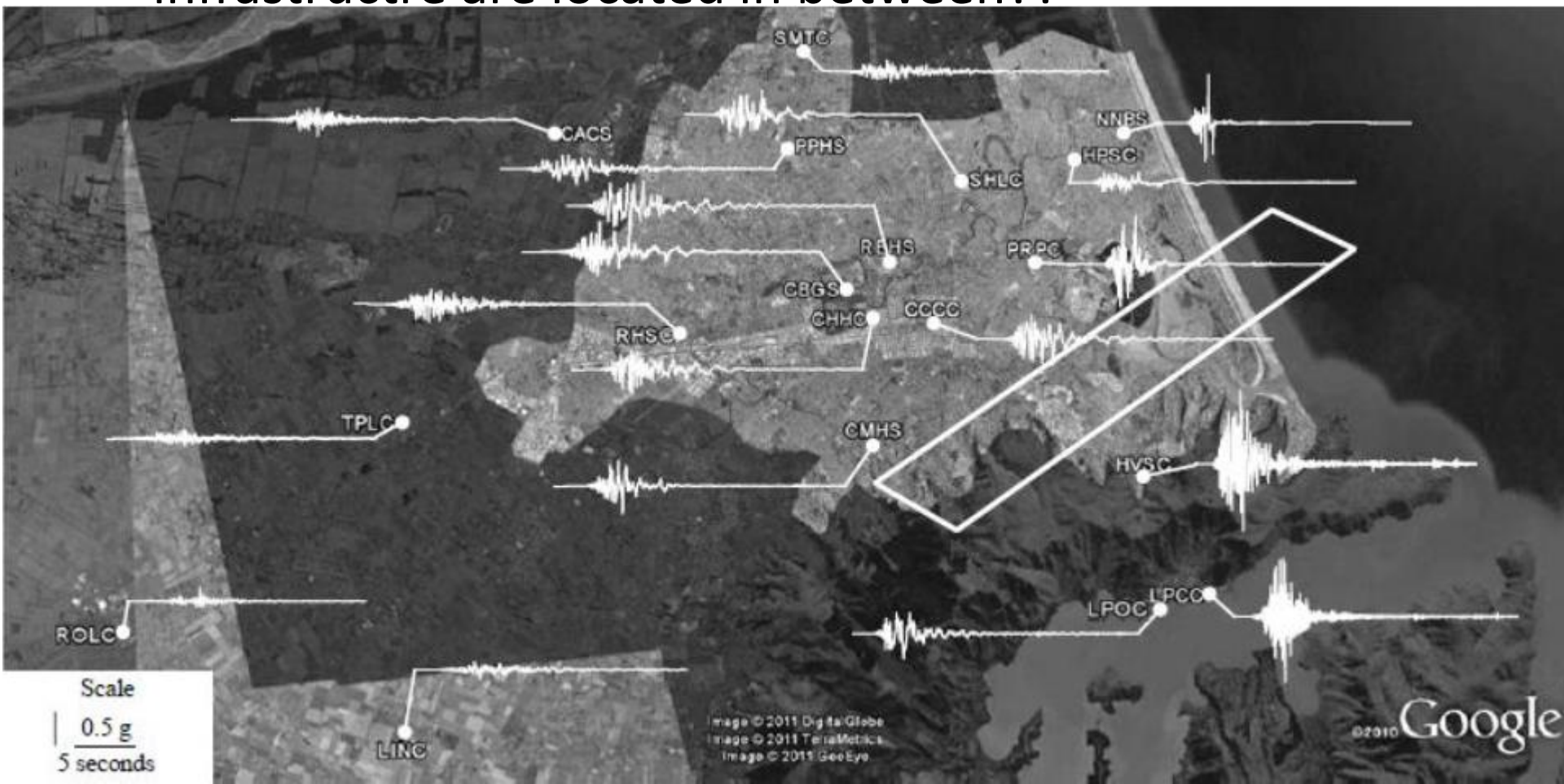
Motivation

Spatial distribution of ground motion intensity observed

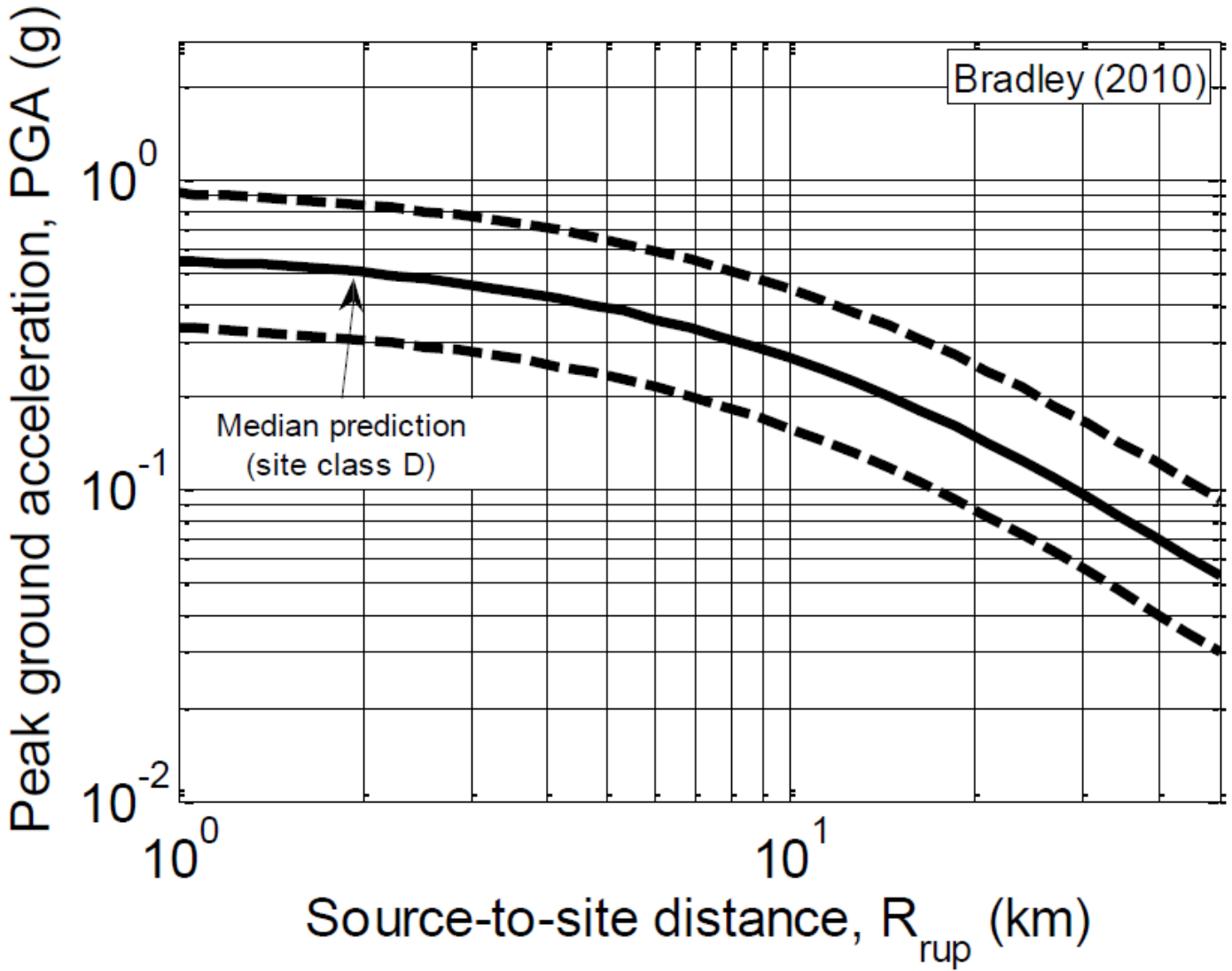
- Great wealth of information provided by strong motion records, but only at discrete locations.
- What is happening where all our structures and infrastructre are located in between??



How the conditional PGA distribution is obtained

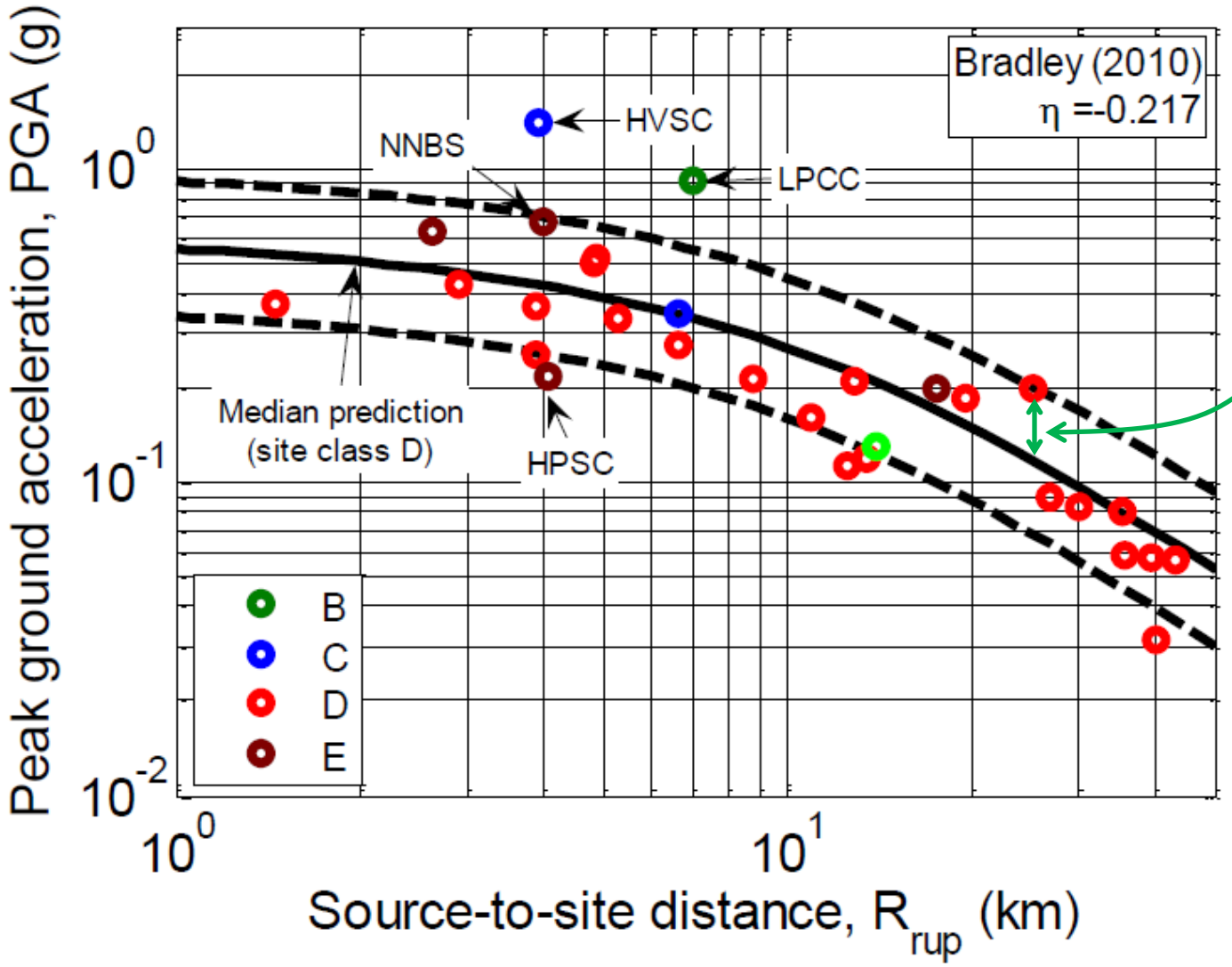
Conditional PGA distribution calculation

1. Empirical models can be used to predict the PGA at a given distance for an earthquake rupture



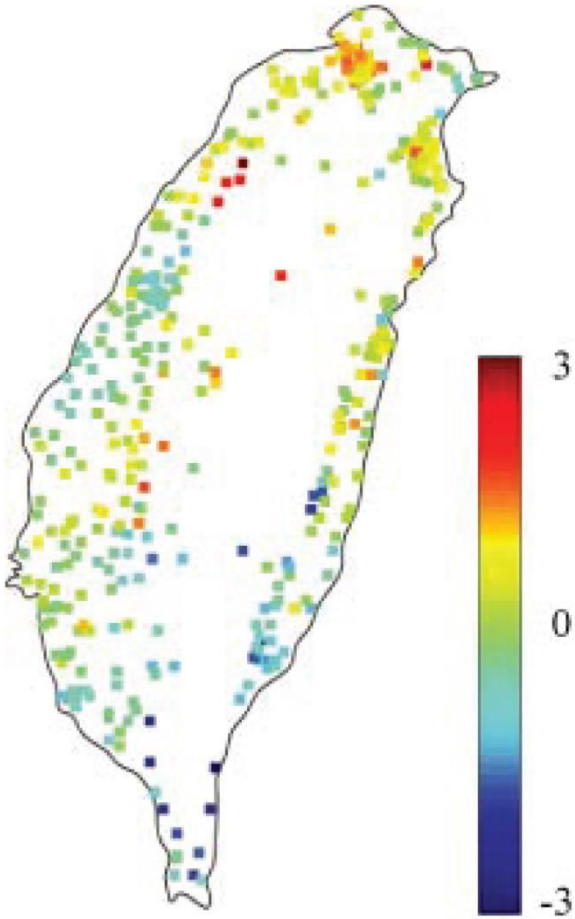
Conditional PGA distribution calculation

2. The earthquakes provide for a comparison between prediction and observation at the strong motion station locations



Correlation of ground motion

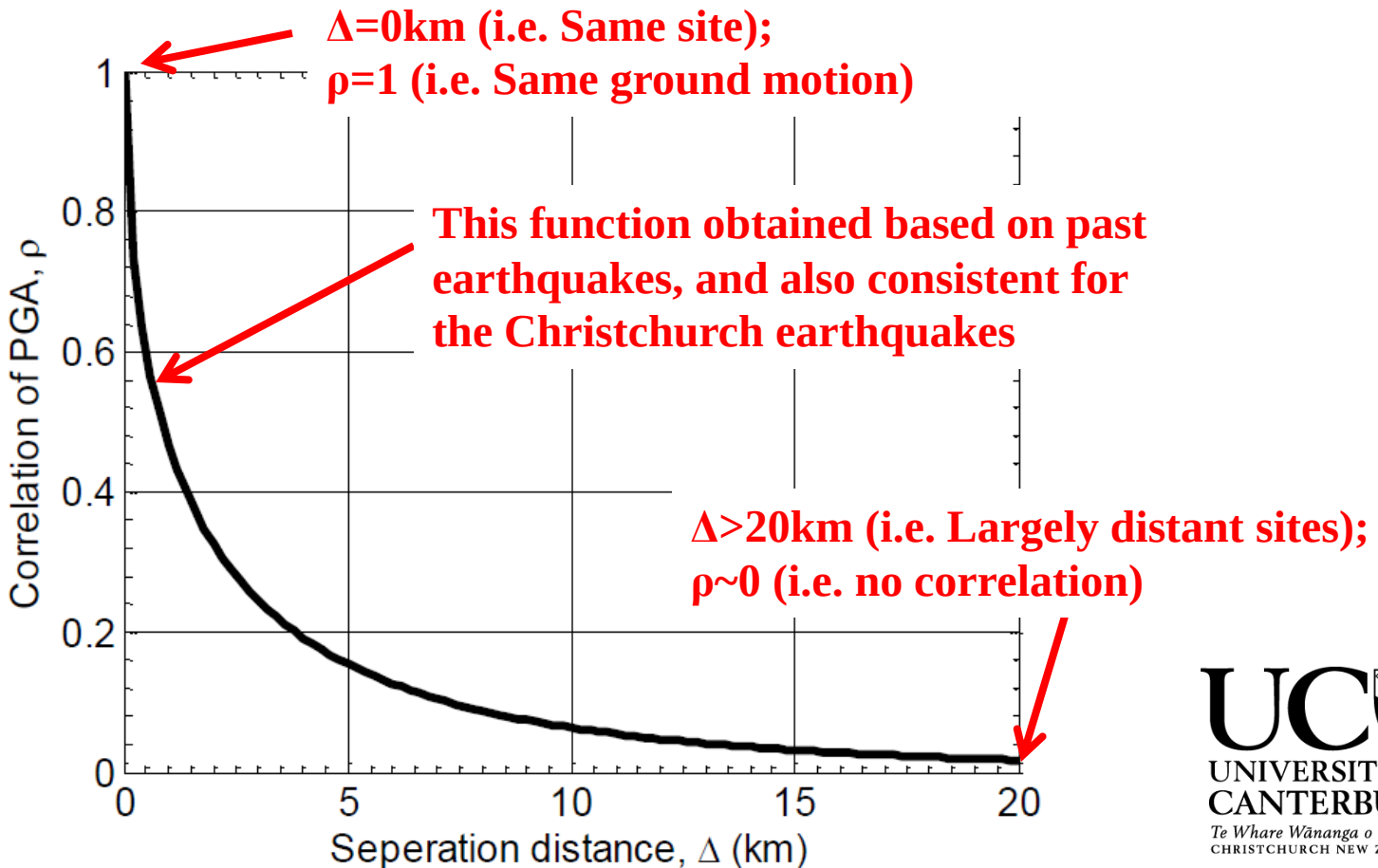
- Observations of past earthquakes show that the residuals are correlated at nearby sites, due to:
  - Common earthquake source
  - Similar wave propagation paths
  - Similar site effects



Observed residuals from the 1999 Chi-Chi earthquake (Park et al. 2007)

Correlation of ground motion

- As you might expect, the correlation between the ground motion at two sites is a function of separation distance.



Conditional PGA prediction

- So, we can combine:

  1. The predicted distribution of PGA using the empirical model (unconditional prediction)

  and

  2. The observed ground motions at strong motion stations (SMS), and the distance of the site of interest to these SMS.

  to predict the ground motion amplitudes over a spatially distributed region.

- Hence, the unconditional prediction, is **updated** based on the additional information from the recorded ground motions at the SMS
- Theory can be found in the paper

Examination of conditional PGA results

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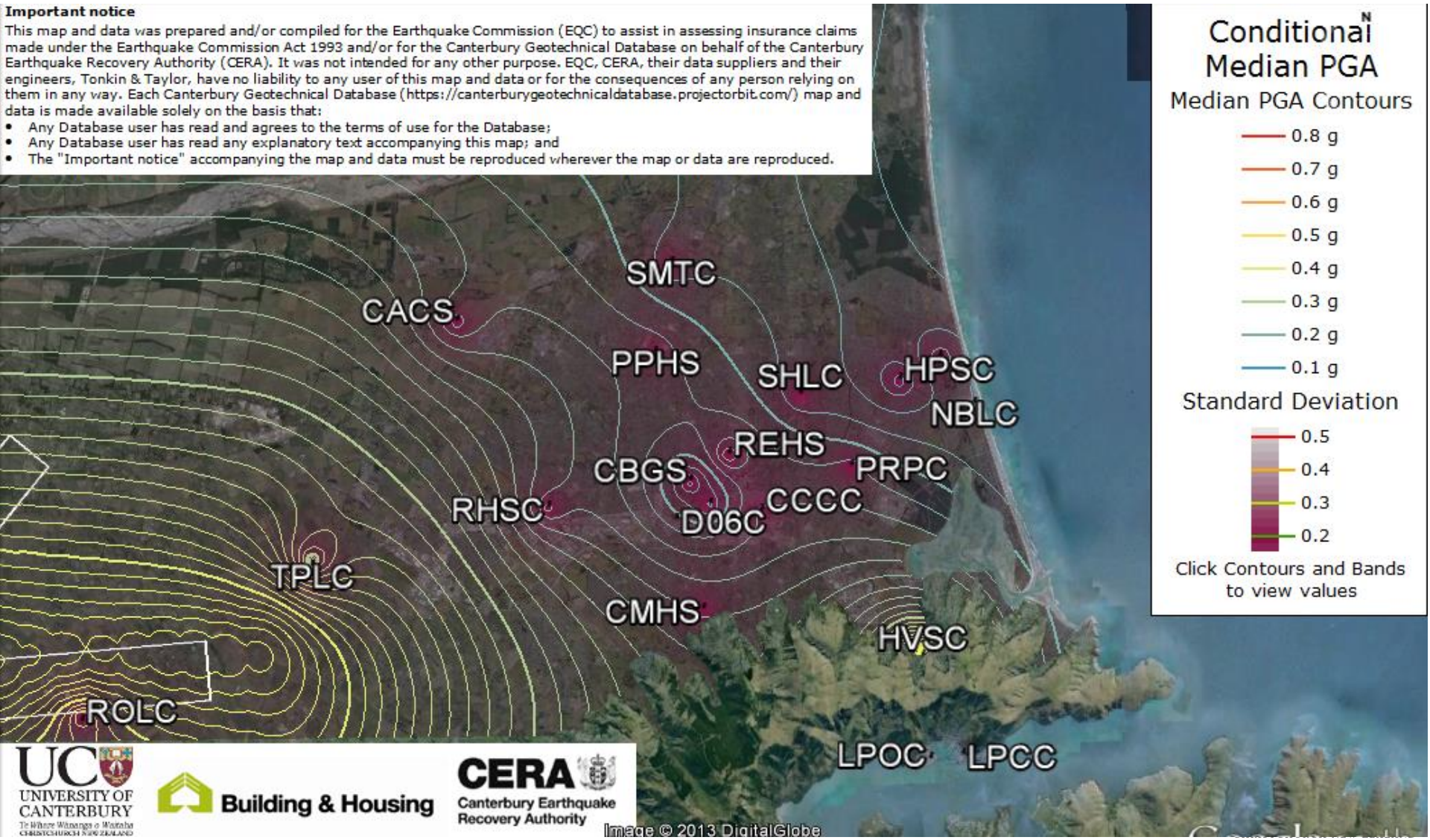
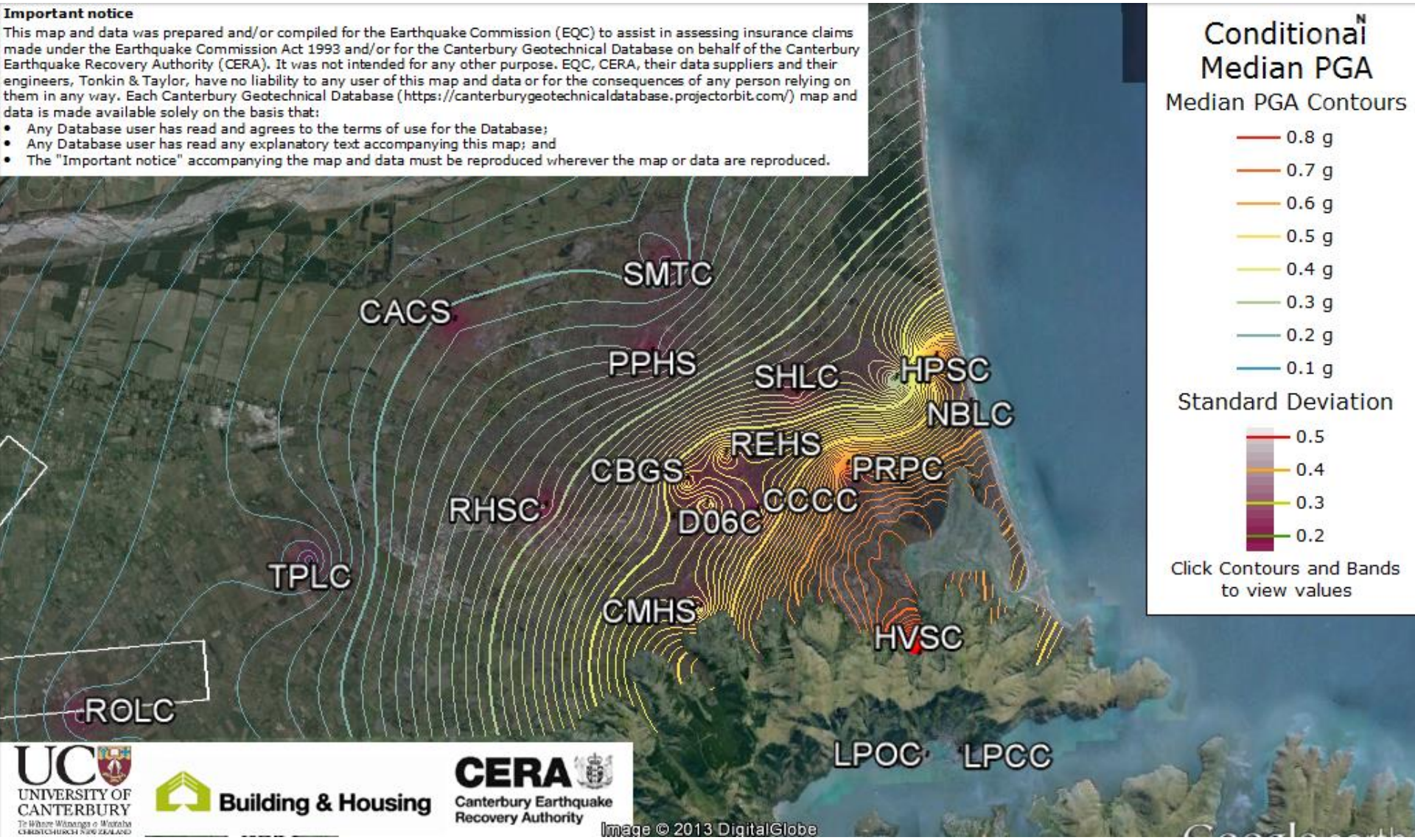
4 Sept 2010: Google earth files on Canterbury Geotechnical Database

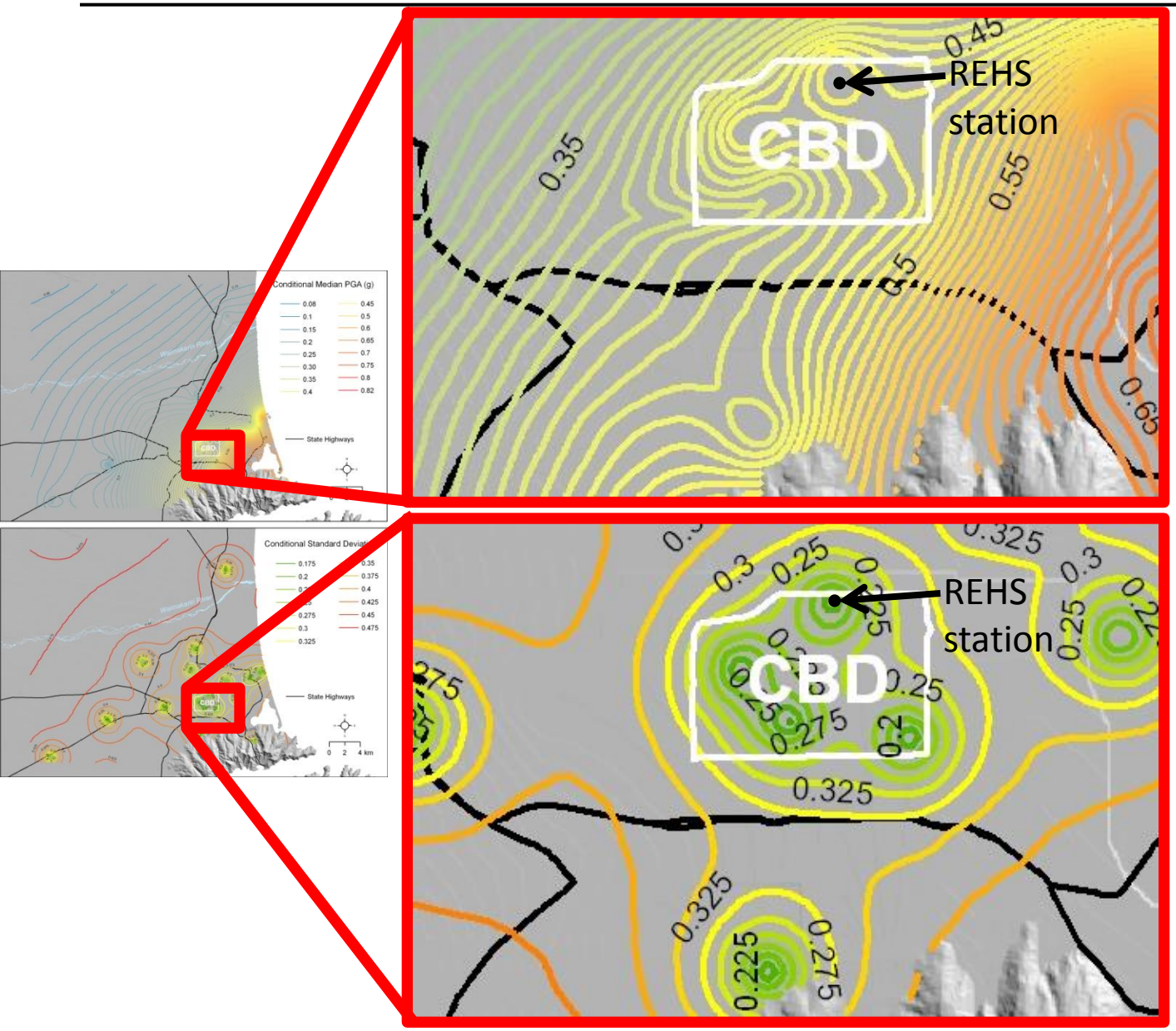


B.A. Bradley

22 Feb 2011: Google earth files on Canterbury Geotechnical Database



A closer look: CBD during 22 Feb 2011



As the location tends to the REHS site:

1. The median value approaches 0.52g (that recorded by the SMS)
2. The standard deviation approaches zero

This is because as $\Delta \rightarrow 0$
The correlation, $\rho \rightarrow 1$

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Application for liquefaction assessment

Application for liquefaction assessment

- Correct the conditional PGA for the event considered to that for M_w7.5

$$PGA_{7.5} = PGA\frac{1}{MSF}$$

$$MSF = 6.9 * exp\left(-\frac{M_w}{4}\right) - 0.058 \leq 1.8$$ Idriss and Boulanger (2008)

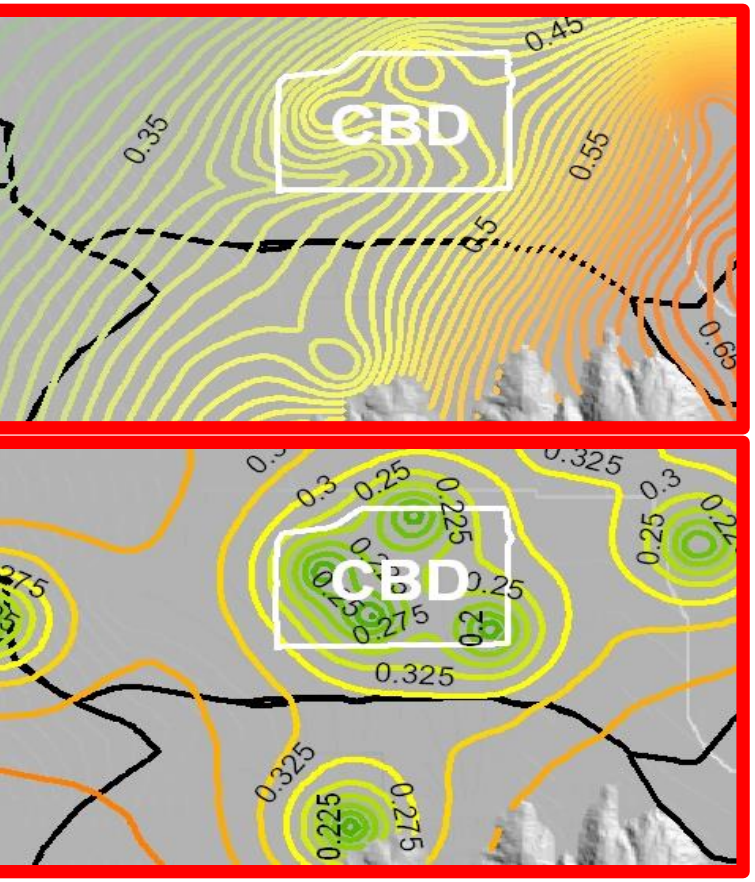
Event	Magnitude, M_w	MSF
4 September 2010	7.1	1.11
22 February 2011	6.2	1.41
13 June 2011	6.0	1.48

- Then use in the usual manner to compute CSR

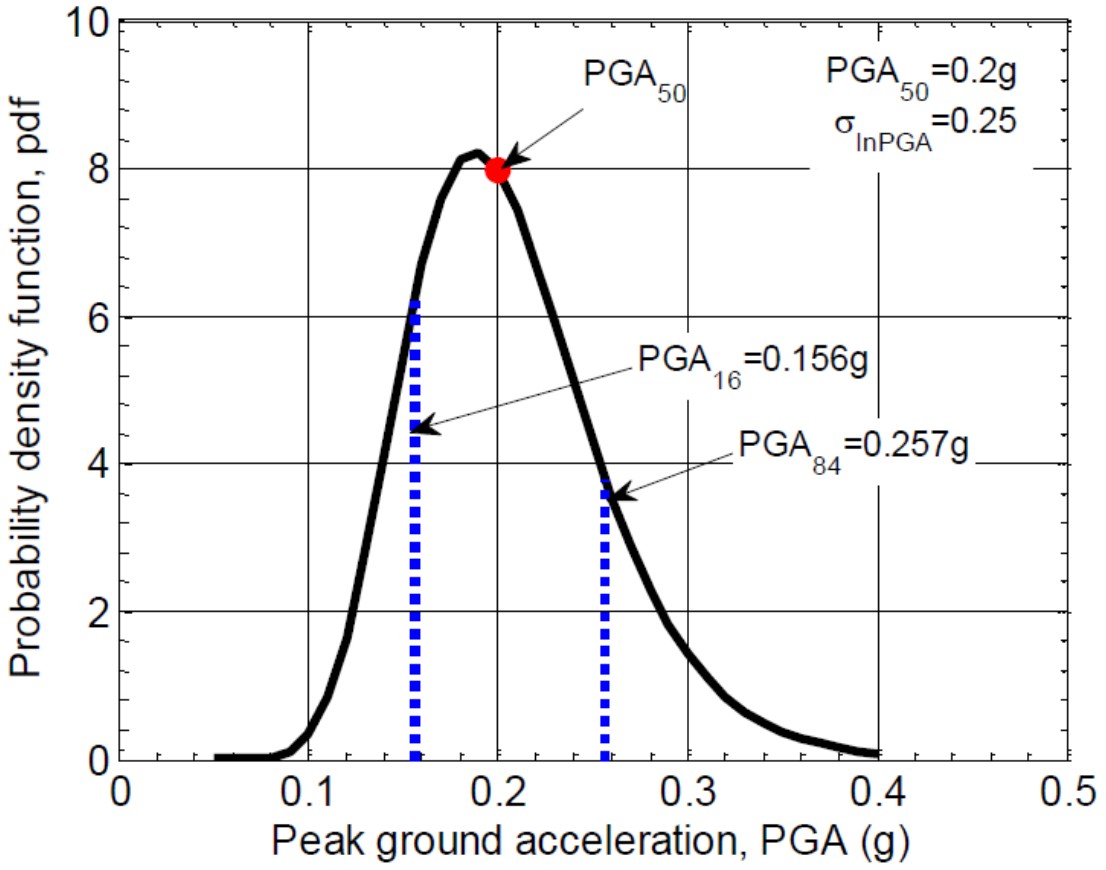
$$CSR_{7.5} = 0.65PGA_{7.5}\frac{\sigma_{vo}}{\sigma'_{vo}}r_d$$

Consideration of uncertainty

- The conditional median is just that – there is a 50% probability that the ground motion was more/less



Example: CBD prediction (Darfield earthquake)
Median = 0.2g; Std dev. = 0.25



Consideration of uncertainty

Ministry of Business, Innovation, and Employment prescription:

"....where a site has experienced at least 170% of design SLS (using the conditional median pga values ..."

170% is approximately the median + one std dev for the CBD example (σ=0.25). However, further from strong motion stations there will be a greater std dev. (so 170% will be less than median + one std dev).

Limitations for application

Other applications

- The results in this paper are:
  - conditional PGAs for use in liquefaction assessment in site class D/E soils only (i.e. 'flat land'). They can also be appropriately be used for liquefaction assessments in shallower soils (site class C).
  - Cannot be used for rock fall assessment (i.e. as not site class B and also do not account for important topographic effects).
- However, the general spatial ground motion estimation methodology has several potential uses (site-specific spectra for structural assessments, immediate triaging of buildings following an event)

Acknowledgements

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Thank you for your attention

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Overview

- Motivation
- The two ‘parts’ to how the conditional ground motion (in this case: PGA) distribution is obtained
  - Empirical ground motion predictions
  - Strong motion station recordings
- Examination of the conditional PGA results
- Applications for liquefaction assessment as adopted by MBIE
- Limitations for application