Validation of Ground Motion Modelling of the Largest M5.7+ Aftershocks of the Canterbury 2010-2011 Earthquake Sequence

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Modelling Approach (Holden and Kaiser, 2016)

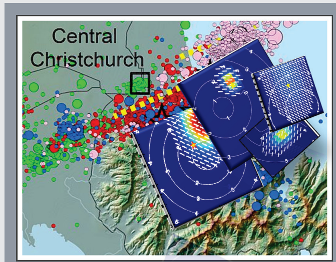

Figure 1: Surface projection of slip distributions for the February, June and the 2 December 2011 earthquakes (see Holden and Beavan (2012))

1- Identifying fault strong motion generation areas

2- Broadband rock motion modelled via purely stochastic approach
[0.1-10 Hz] modelled using a Finite Fault stochastic code (EXSIM - Motazedian and Atkinson, 2005)

3- Stress drop, regional Q and site responses (Fig. 2 and 3):
(Oth and Kaiser, 2014; Kaiser et al., 2013)

- **Advantages:** simple, comprehensive and effective
  - Capturing realistic features of source and site effect
  - Excellent for rock and shallow sites
  - Key engineering parameters: PGA, durations and response spectra
- **Limitations:**
  - Non-linear shaking
  - Absence of realistic phases

Validation schemes

- **Time and frequency metrics (Fig. 2,3):**
  - Key scalars: PGA, PGV
  - Overal signal duration envelop
  - Key phase arrivals
  - Dominant frequencies
  - Response spectra for various damping
- **Engineering specific metrics (Rezaeian et al., 2015) (Fig. 4,5,6):**
  - capture entire time evolution of intensity and frequency content
  - 1: mean-square intensity of acceleration in time
  - 2: cumul. number of zero level crossings: evolution of main freq. of motion
  - 3: cumul. number of peaks: evolution of the freq. bandwidth with time

Case study: ground motion modelling of the Mw 5.9 Dec. 2011 earthquake

Time and frequency metrics

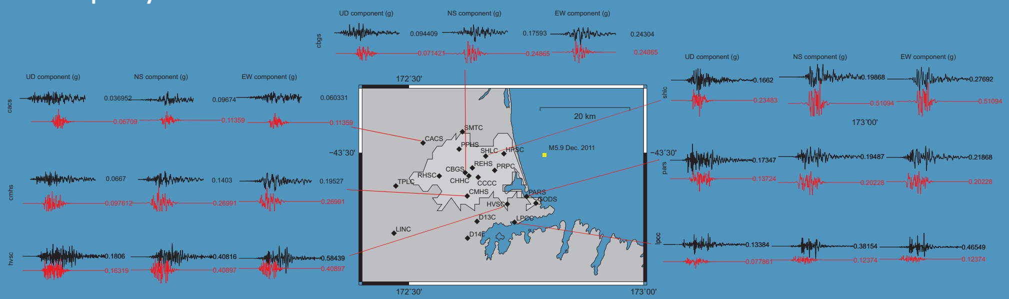

Figure 2: acceleration time histories (15 seconds) for vertical and horizontal components of GM at selected sites following the Mw5.9 December 23rd earthquake (RED Synthetic - BLACk Observed) - See Holden and Kaiser (2016) for more details.

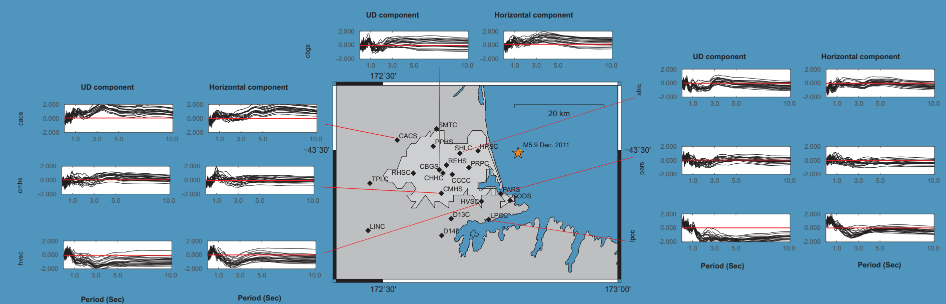

Figure 3:[ln(OBS)-ln(SYNTH)] spectral acceleration (5% damping) for vertical (left) and horizontal (right) components of GM in Christchurch following the Mw5.9 December 23rd earthquake (20 iterations).

- For most sites, very good fit of acc. envelop and PGA (Fig.2)
- Duration above 6%g matched within 1 sec for all sites but HVSC and LPCC

- Short period spectral accelerations are appropriately captured at all sites (Fig. 3)
- Long period spectral accelerations are appropriately captured at all sites but LPCC and CASC (Fig. 3)
- LPCC and HVSC likely experienced secondary local eq.

Engineering-specific metrics (Rezaeian et al., 2015)

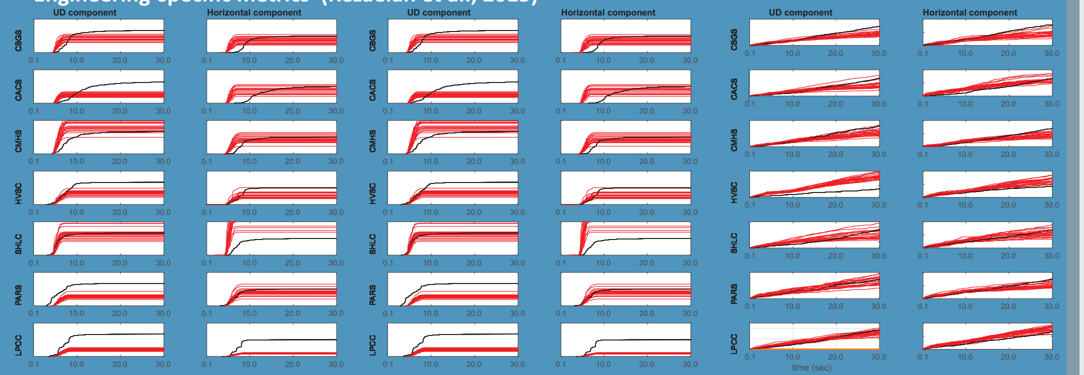

Figure 4: **Evolution of intensity** against time for recorded (black) and simulated (red - 20 iterations) ground motions (i.e. mean-square intensity of the acceleration time series)

Figure 5: Evolution of cumulative numbers of zero-level up-crossings for recorded (black) and simulated (red - 20 iterations) ground motions - The slope at any given time represents **the instantaneous predominant frequency of the waveform**.

Figure 6: Evolution of cumulative number of negative maxima and positive minima for recorded (black) and simulated (red - 20 iterations) ground motions, which quantifies the **evolution of the frequency bandwidth** of the motion.

- New metrics highlight some deficiencies in synthetic ground motions (Fig. 4,5,6)
- As expected total energy not completely captured by modelling (Fig. 4) due to lack of secondary phases and simplicity of source model (see CACS)
- Energy derived from site-specific synthetics tends to increase too fast (see SHLC) possibly due to limitation of time-stationary freq. dependent site response factors
- Fig. 5 and 6 shows that the high frequency part of the signals is captured satisfyingly in the modelling for the core part of the signal (matching slopes for first 10 seconds)
- However the fit clearly departs from 15 seconds due to lack of secondary phase arrivals and simple model of the earthquake rupture.
- How much would deterministic modelling contribute to complex phase modelling in frequency and time ?
- What would be the impact of a more complex source model ?

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