Effect of Hikurangi subduction interface geometry on simulated ground-motion intensities

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1. Introduction

The Hikurangi subduction zone lies under the eastern side of the North Island and has a large down dip curvature (Williams et al. 2013). The six current Hikurangi fault rupture scenarios provided by the National Seismic Hazard Model (NSHM) all provide for a planar fault geometry that is adopted in predictions using both empirical ground-motion models (GMMs) and also prior simulations performed by the authors. In this poster, the effect of more realistically representing the curved geometry in the source description, and its influence on simulated ground motions is examined.

2. Application

The interface geometry surface is adapted from from Williams et al. (2013).
A transect of the surface was taken down the center of the fault plane, using a nearest neighbour approach, giving the surface shown in green in Fig 1a-c. The radius of curvature was determined by the harmonic mean of the curvature of each triplet of adjacent points.
This curvature was then applied to the standard NSHM fault plane (shown in blue in Fig 1a-c) by taking the point normal to the central subfault at a distance from the fault equal to the radius of curvature.
All the subfault points were then projected normal to the plane, and up or down dip, towards the center, maintaining the distance between them, such that all points are equidistant from the center of curvature. Subsequently the subfault points were translated a uniform distance normal to the original plane again, to minimise the difference between the surface transect and the curved fault transect. The dip of the fault was then altered to match that of the surface. Thus resulting in the fault geometry shown in orange in Fig 1a-c.

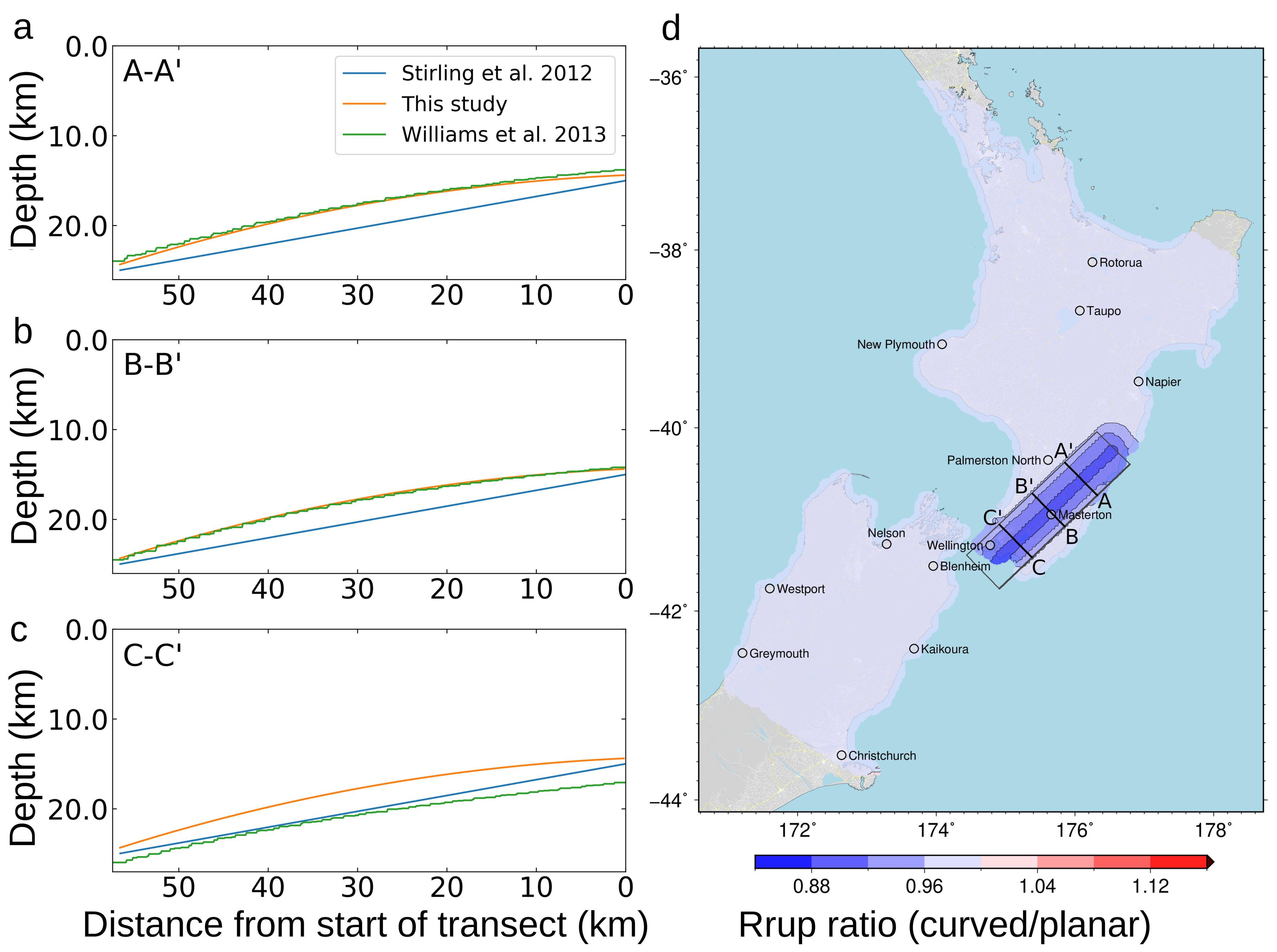

Fig 1. Transects of the Hikurangi surface and HikWgtnmin fault models (a) North, (b) central and (c) South. (d) The effect of modifying the fault geometry on station distance in terms of the ratio of the new distance to the old distance.

3. Comparison of fault and surface geometry

For this initial investigation the fault model used is HikWgtnmin as described in the NSHM (Stirling et al. 2012), representing a Mw8.22 subduction interface rupture in the Wellington/Wairarapa region.
The surface is taken from a bicubic-spline interpolation generated from multiple datasets, published by Williams et al. (2013). The transformations applied to the fault had a very small difference with the exact surface when comparing the Northern (Fig 1a) and central (Fig 1b) transects. The Southern (Fig 1c) transect showed the greatest deviation from the surface used as a result of its variation along strike and the mathematical formulation adopted.
Due to the added curvature most stations experience a decrease in distance to the fault as show in Fig 1d.

4. Simulation details

The workflow used in Cybershake NZ (Motha et al. 2020) was adapted for use with the modified fault models. Calculations were performed using EMOD3D (using Graves and Pitarka 2015 method) on a 200m grid using a transition frequency of 0.5Hz.
For this simulation 10 realisations of HikWgtnmin were generated and then calculations run both with and without the surface modification. The results presented are taken from the mean of each cohort of source model geometry.

5. Impact on simulation intensity

As shown in Fig 2 the majority of the stations see an increase in intensity of pseudo-spectral accelerations (pSA) due to the decreased distance to the fault geometry, as compared with planar results. At shorter periods there is increased variance resulting in some stations experiencing a decrease in intensity.

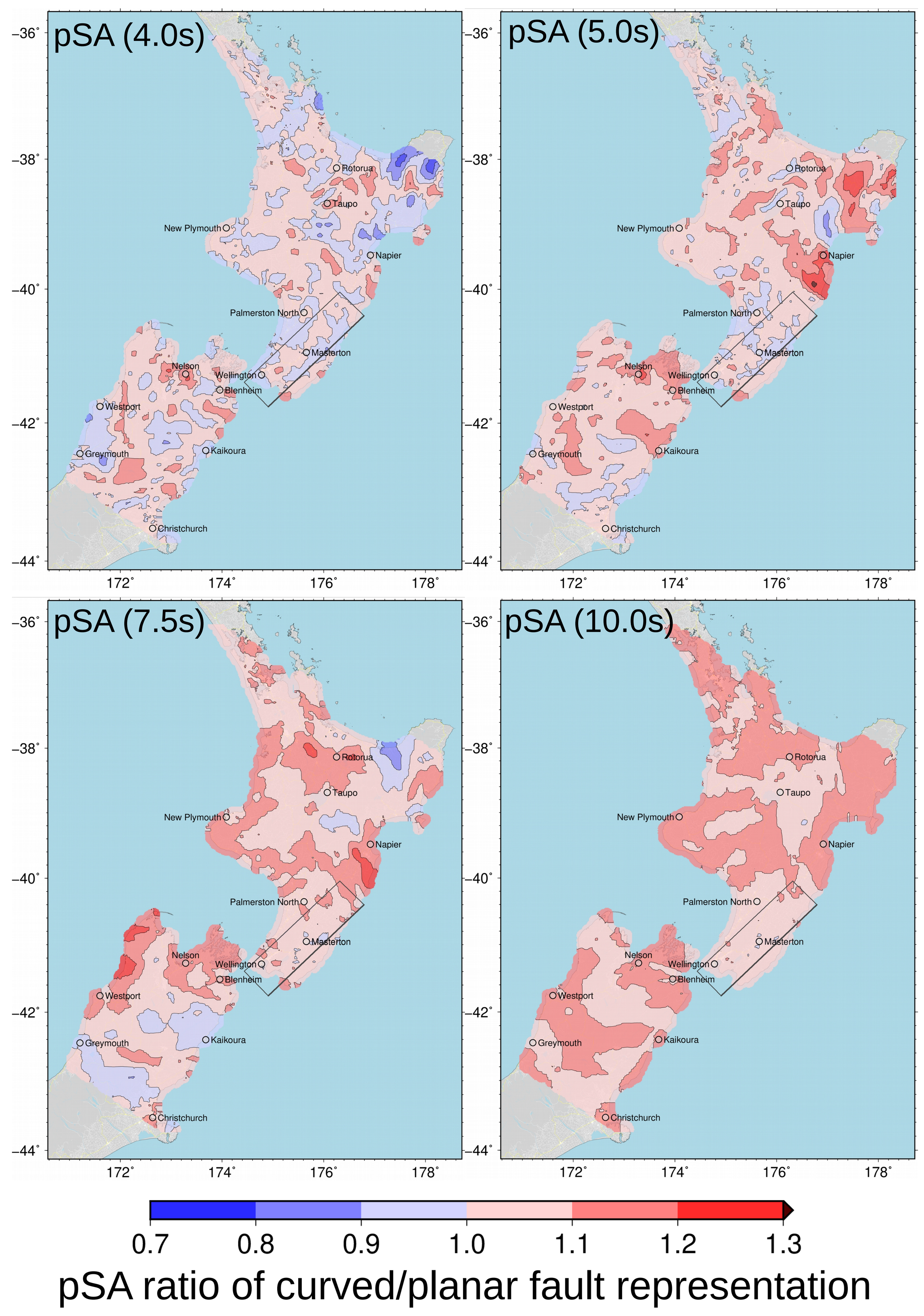

Fig 2. Spatial ratio plots of low frequency psuedo spectral acceleration in the simulation domain. Red regions represent an increase in intensity with the modified geometry, while blue represent a decrease.

6. Comparison of simulations with empirical models

Fig 3 illustrates the same intensity measures as Fig 2 as a function of distance against empirically expected values. At long periods and large distances the empirically expected values are very close to the simulation results. However as the distance and vibrational period decrease the correlation of empirical to simulated values decreases.

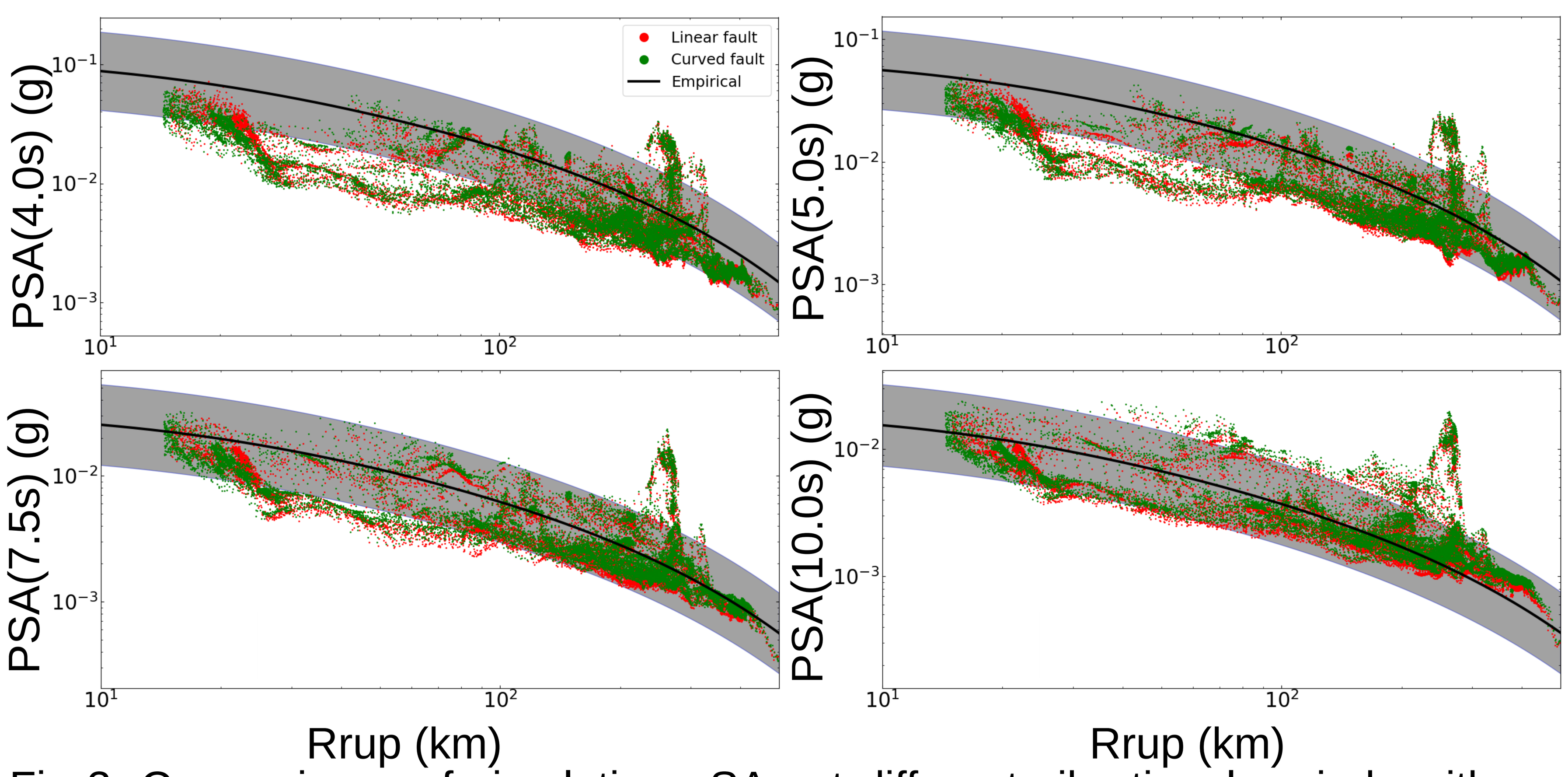

Fig 3. Comparisons of simulation pSAs at different vibrational periods with an average of empirical models. The empirical median results displayed were generated by taking the median of the values obtained from the models from Zhao et al. (2006), Abrahamson et al. (2016) and Parker et al. (2020). The uncertainty was taken from the maximum of the three models.

7. Future work

This work represents a first iteration of adapting the standard NSHM fault planes to a curved fault surface.
In future we plan to investigate the following advancements:
1. Using a curvature along strike
2. Moving the subfault points to use the exact surface of the interface
3. Adapting the HF portion of the Cybershake workflow to handle curved fault geometries.

Additionally, as geometry will be applied to large magnitude faults in particular, work on large magnitude validation will ensure the accuracy of the simulation results. Work by Dupuis et al. (2020) to improve subduction event source modelling will also have an impact on this work.