Rupture model of a Hikurangi megathrust earthquake

Introduction

We develop a multi-segment Mw 6.6 rupture model of a Hikurangi megathrust event, including unilateral rupture with propagation towards the northeast, in accordance with Schellart and Rawlinson (2012). We use the Graves and Pitarka hybrid Inrural method (Pitarka et al., 2018; GP-IM) for developing the source model. The maximum slip over the rupture planes is approximately 14 m, and the average slip is approximately 3.5 m. Both of these values are broadly consistent with the scaling relations developed by Tajima et al., (2013) and Skarlatoudis et al. (2016). In future work, we will develop additional rupture models and will perform simulations to assess the importance of slip randomness, asperity number and location, and hypocenter location on the synthetic ground motions.

(1) Rupture Geometry

We use the geometric model from GNS Science (Stirling et al., 2012) as the basis for the Hikurangi rupture geometry. The full Hikurangi scenario is composed of three segments: northern (Raukumara), central (Hawke’s Bay), and southern (Waikarearea) as identified in Wallace et al., (2009).

The GNS northern and central segments have identical dip angle and down-dip extent. The GNS southern segment has a steeper dip angle and extends to greater depth. The parameter values for each section are listed in Table 1.

(2) Seismic Velocity Model and Magnitude Model

We developed a generic 1D seismic velocity and density model for the Hawke’s Bay region (Figure 3) in a previous QuakeCore project. This model was created by averaging profiles from the Eberhart-Phillips et al. (2010) model sampled within 100km of the Hawke’s Bay earthquake fault plane, and modified in the upper 1.5 km to have a smooth transition to Vs30=863 m/s. This is the 1D model we adopt for generating the Hikurangi source.

We use the Skarlatoudis et al. (2016) self-similar magnitude scaling relation for subduction earthquakes to determine the scenario magnitude, using the rupture area from GNS. The Skarlatoudis relationship is given as

\[ M = 3.72 + \log_{10}(\text{Rupture Area}) \]

Using the combined rupture geometry from Table 1, the total rupture area is 75,816 square km, which yields Mw 6.6.

(3) GP-IM Rupture Model Code


Up to now, the model input parameters have been only calibrated for crustal earthquakes. Rob Graves and Arben Pitarka have not used the model extensively with subduction events and recommend that the model should be validated with recordings. Based on our communication with them, we have made the following modifications to the model:

- Used the Skarlatoudis et al. (2016) scaling for the corner wavenumbers.
- Modified magnitude dependence for deltaT perturbations to rise time.
- Modifications for multi-segment rupture with continuous slip velocity.

We define the scenario SMGA areas based on advice from Hiroe Miyake (pers. comm.) and on the Murata et al., (2008) and Skarlatoudis et al., (2016) relationships. The model has four asperities (as shown in Figure 4) three with area 1,805 km² (each approximately M7.0) and one with area 5,984 km² (approximately M7.5). They are placed in the deeper portion of the rupture plane, consistent with the assumptions used in Wirth et al., (2017).

(4) Rupture Model Summary

The Hikurangi megathrust scenario rupture model we developed is shown in Figure 4. This figure shows the slip on the fault plane in shades of red, with rupture initiation contours (black lines) at 10 s intervals. The break between the northern and southern segments is indicated by the dashed blue line.

The maximum slip over the rupture planes is approximately 14 m, and the average slip is approximately 3.5 m. Both of these values are broadly consistent with the interface subduction earthquake scaling models by Tajima et al., (2013) and Skarlatoudis et al. (2016), both shown at right.

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