Ground motion simulations for Hauraki Rift earthquakes

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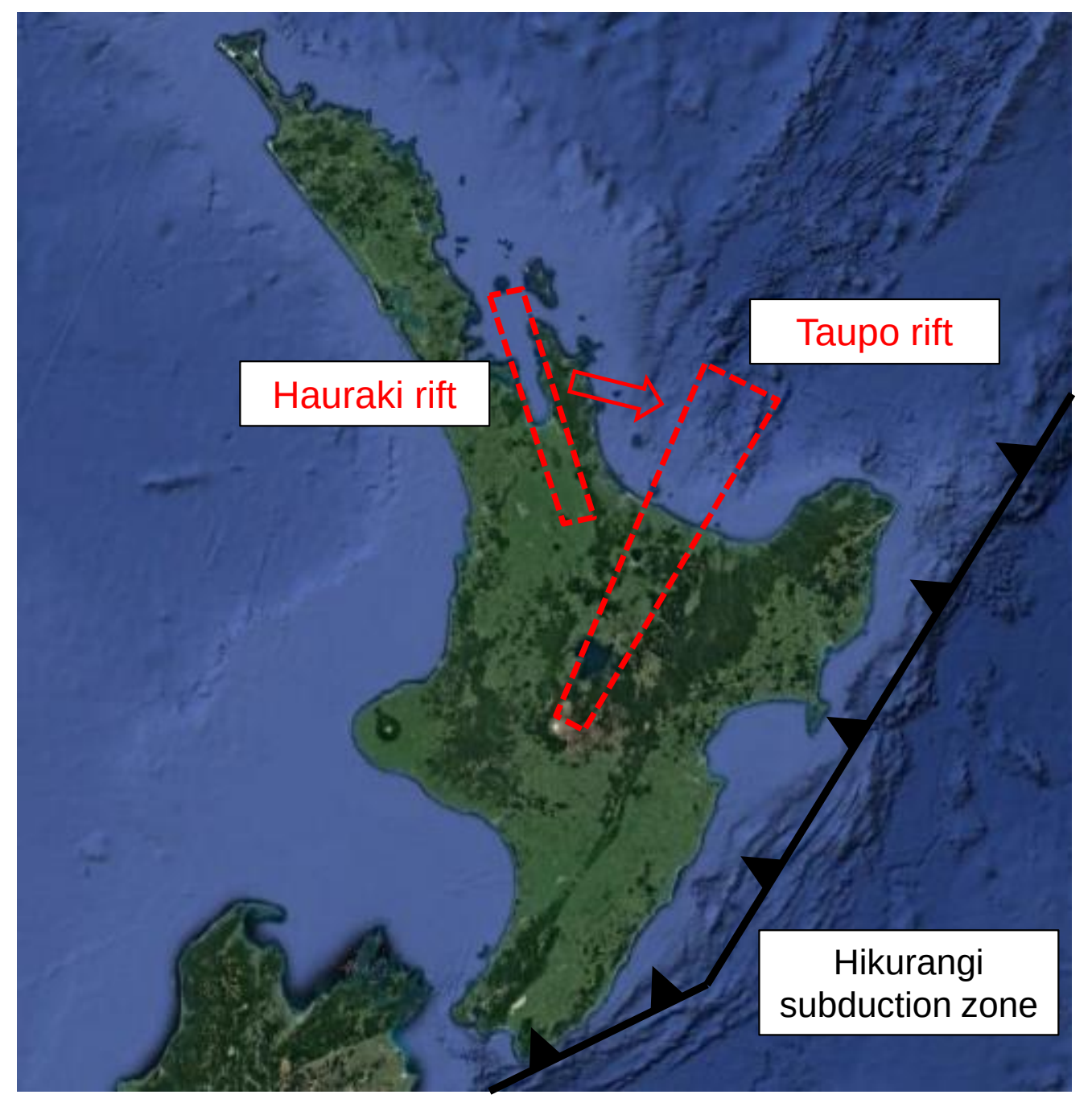
Hauraki rift and potential hazard

The Hauraki Rift is a half-graben which extends from the Taupo Rift NNW towards the Hauraki Gulf. It separates the Hunua and Hapuakohe Ranges from the Coromandel and Kaimai Ranges. The rift includes the Hauraki depression, the Firth of Thames, and a part of the Hauraki Gulf. Rifting started ca. 5 Ma, but then shifted to Taupo rift ca. 2-3 Ma. As for the Taupo rift, it is a back-arc continental rift caused by the ongoing subduction of the oceanic Pacific plate under the continental Australian plate in the Hikurangi zone in the East.

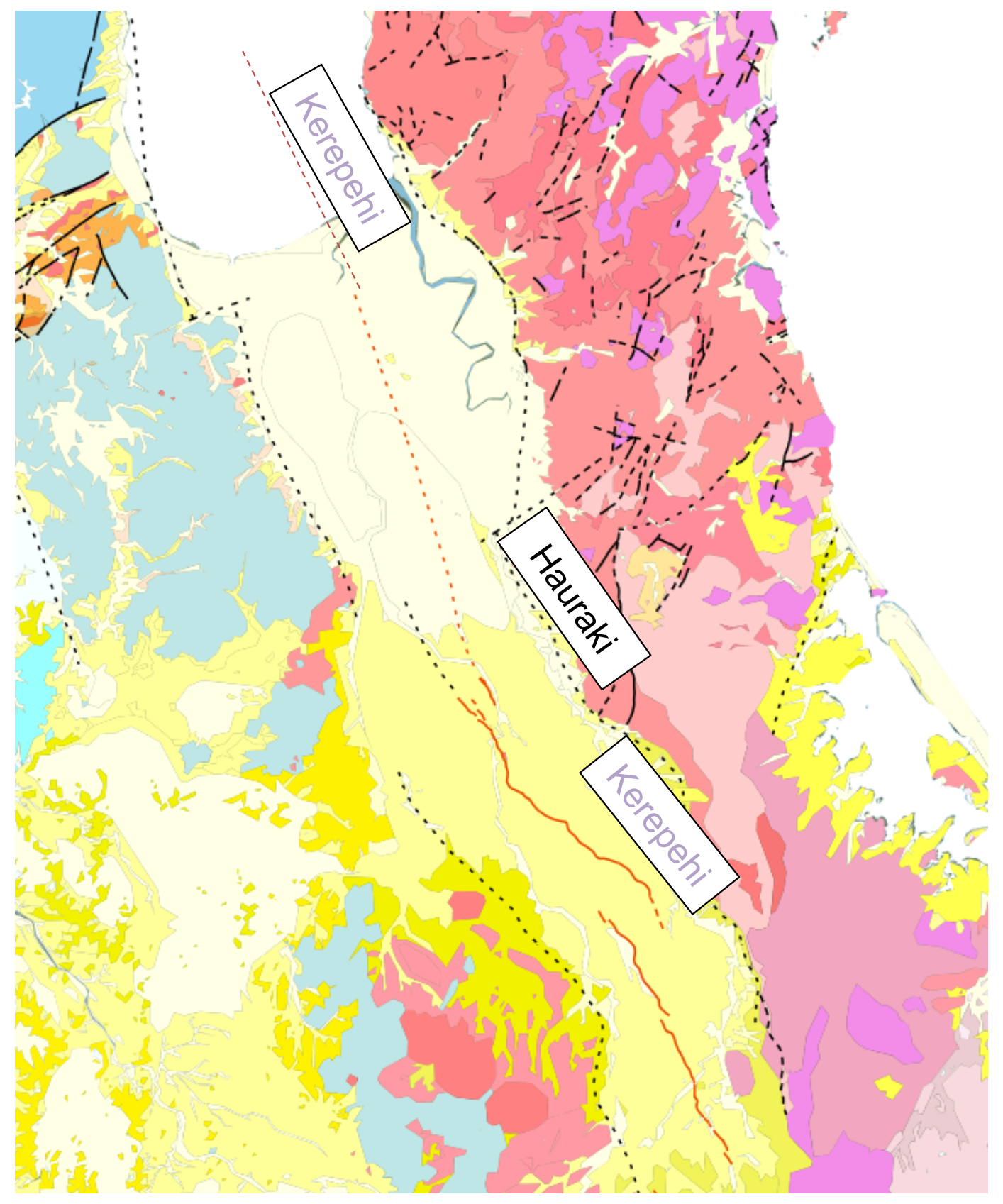
Many clues indicate a continuous rifting process, albeit of much smaller scale than in Taupo:

- Shallow seismic activity (< 12 km)
- Three hot springs with chemistry indicating high temperatures (250-300°C) at depths less than five kilometers. This suggests the presence of an upper mantle swell under the region.
- Recorded subsidence in the rift basin at 1.5 mm/year.

Hauraki rift map



Kerepehi and Hauraki faults map

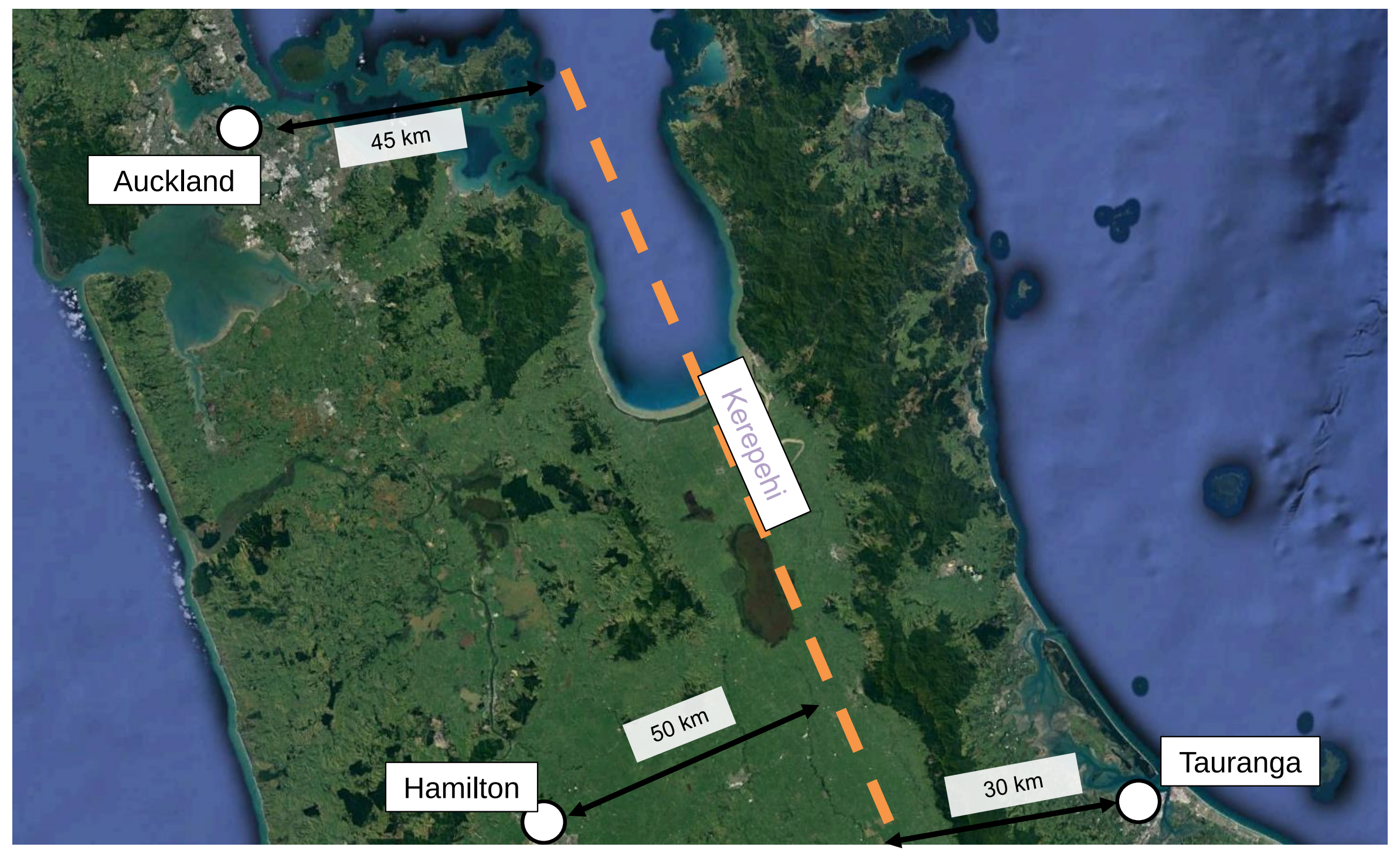


The Hauraki depression, the on-shore part of the Hauraki rift, contains two NNW-trending main faults, both normal: the non-active Hauraki Fault, responsible for the formation of the Kaimai Ranges, and the Kerepehi fault, still active.

The most significant Earthquake recorded within the rift had a magnitude of 5.4 (1979). It has been estimated that the Kerepehi fault could generate earthquakes with a magnitude up to 7.4 if all of its segments were to rupture concurrently (Persaud et al., 2016). This would be similar to what happened in the Edgecumbe earthquake (1987), with a magnitude of 6.5, also occurring on a normal fault within a rift. As the fault includes an offshore segment, a tsunami could potentially be generated in the Hauraki Gulf (Chick et al., 2001).

40% of New Zealand's population lives within 50 km of the Kerepehi fault, including the population centres of Auckland, Hamilton, and Tauranga. As seen during the Edgecumbe earthquake, normal fault rupture can cause significant damage. This motivates our assessment of the risks for the different human settlements through the study of ground motion simulations.

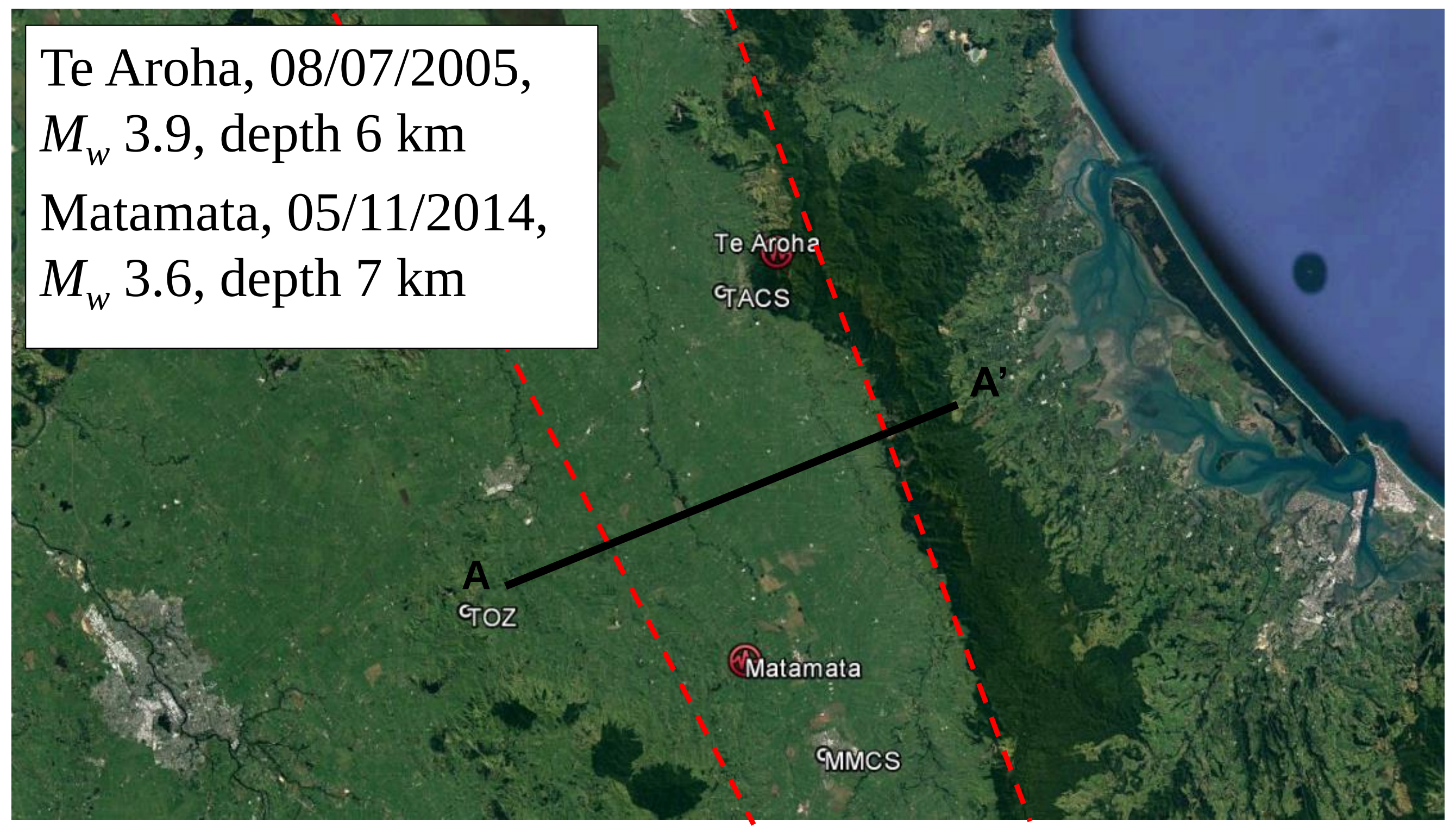
Kerepehi fault hazard map



Velocity model construction

In order to calibrate a ground motion simulation model, we use two recorded events with strong motion acceleration data available from GeoNet stations.

Selected historical earthquakes

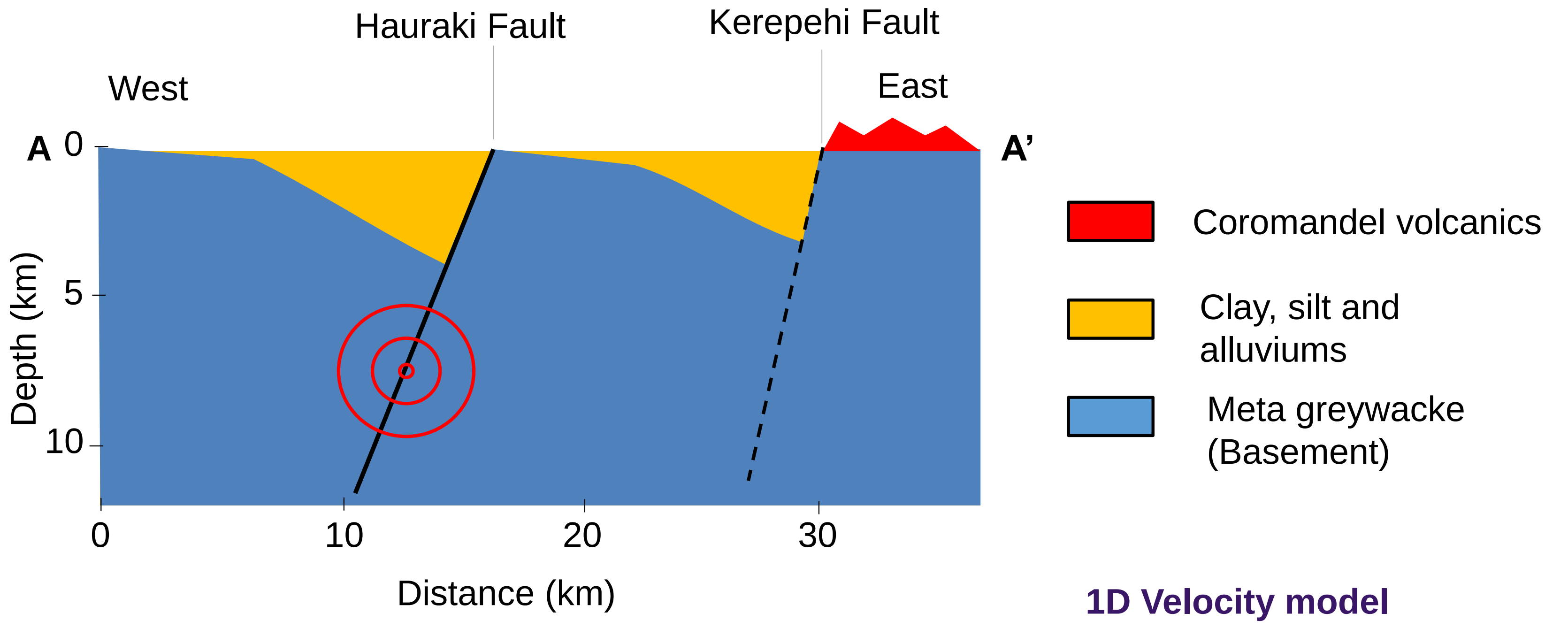


To construct a velocity model, we look at the rift geology. As the earthquakes occurred at relatively shallow depths, two geological formations are considered:

- Unconsolidated sediments, clay, silts at depths less than five kilometers, expected to have low density and velocities.
- Dense metagraywacke with higher density and velocities.

The disposition of those formations is mainly dictated by the past action of the two normal fault discussed earlier.

Hauraki rift cross-section



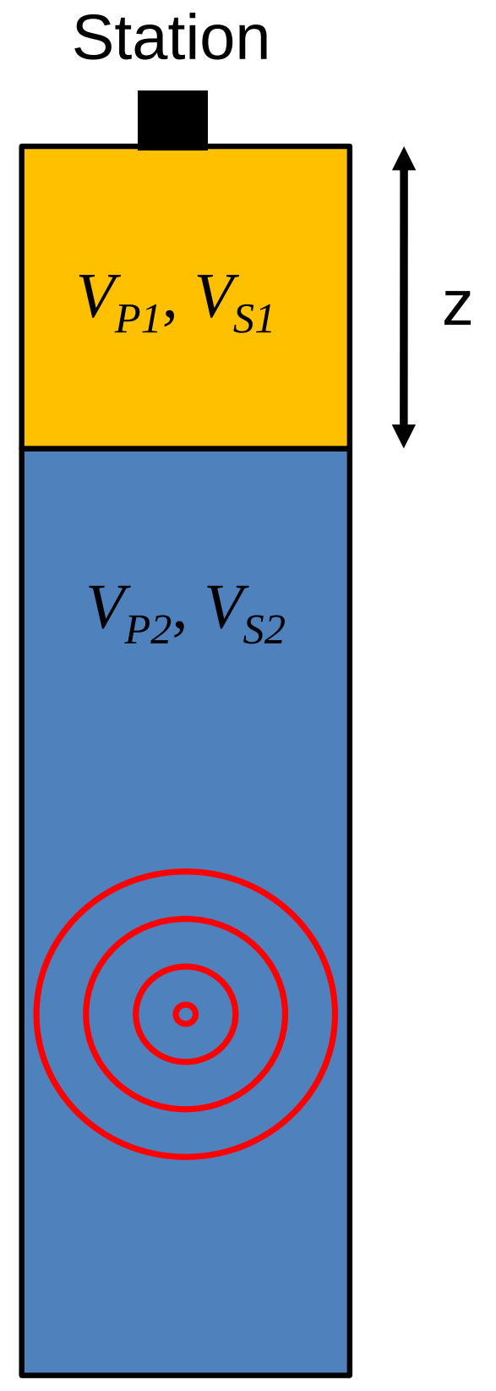
Adapted from Hochstein and Nixon (1979)

As there is no existing velocity model for this region, we propose to start with a simple one dimension velocity model with the two formations discussed.

We use a fixed V_p/V_S ratio. To calibrate our model, we consider three parameters: z, the depth of the sediment formation, V_{P1} and V_{P2}, the P-wave velocity of the sediments and metagraywacke basement respectively. We use the density values found in the literature.

As a rupture model, given the small size of the events studied, we use a simple point source model. The dip and azimuth of the fault is given by measures of the Kerepehi faults found in Hochstein and Nixon (1979), while we consider the rupture to be purely normal, thus with a rake of 90 °.

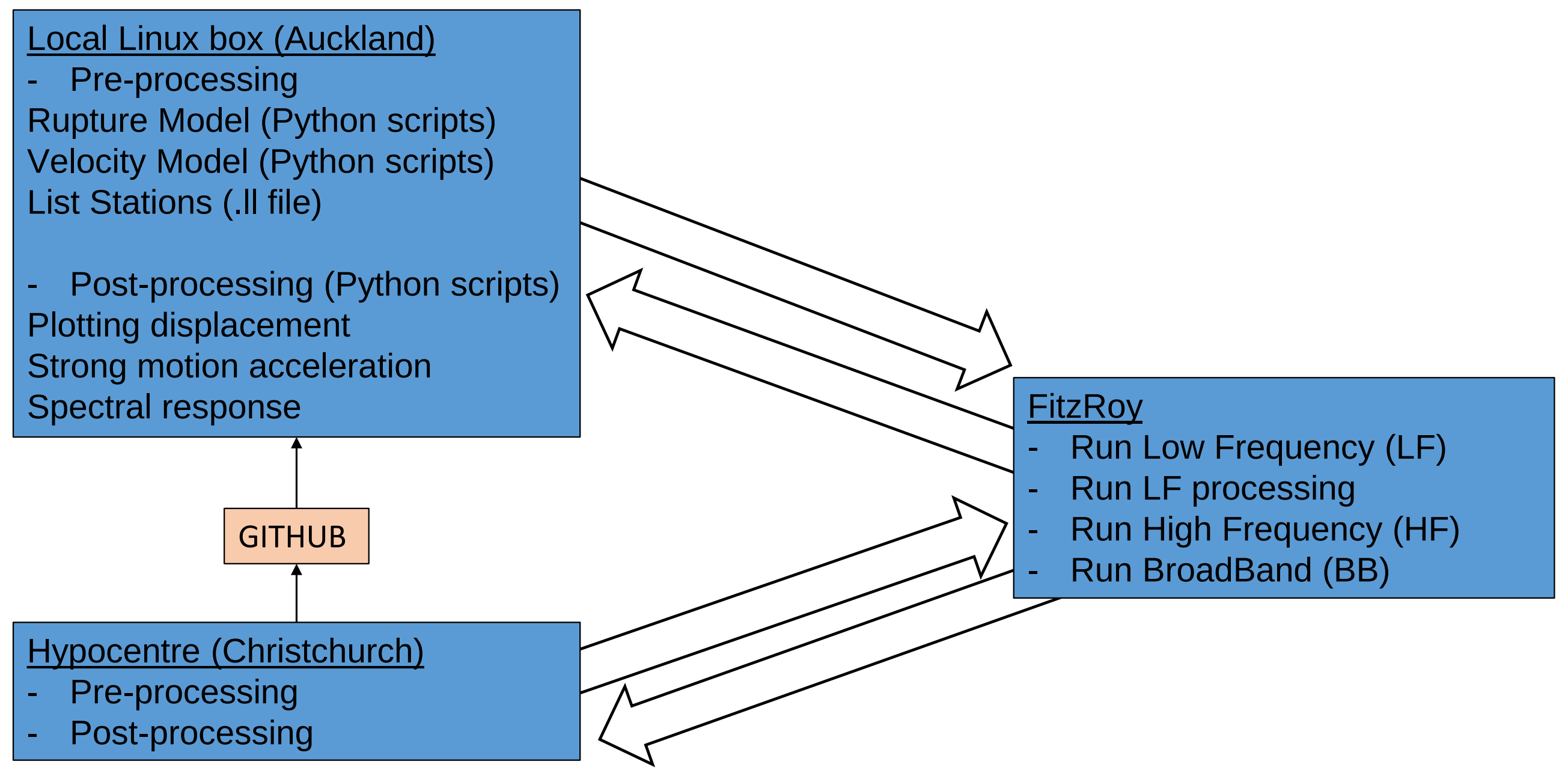
1D Velocity model



QuakeCoRE calibration

Broadband ground motion simulations are performed using the Graves and Pitarka (2010) method implemented in other QuakeCoRE studies. Because of their computational expense, we run the simulations on FitzRoy, a High Performance Computing platform of NeSI. Usually, pre-processing, post-processing, and communication with Fitzroy are done using a local computer at the University of Canterbury, Hypocentre. Because we are based at the University of Auckland, we had to replicate the Hypocentre operations on a local machine. Thus, we improve the portability of the QuakeCoRE platform for future projects.

QuakeCore simulation workflow



Local Linux box (Auckland)
- Pre-processing
Rupture Model (Python scripts)
Velocity Model (Python scripts)
List Stations (.ll file)

- Post-processing (Python scripts)
Plotting displacement
Strong motion acceleration
Spectral response

GITHUB

Hypocentre (Christchurch)
- Pre-processing
- Post-processing

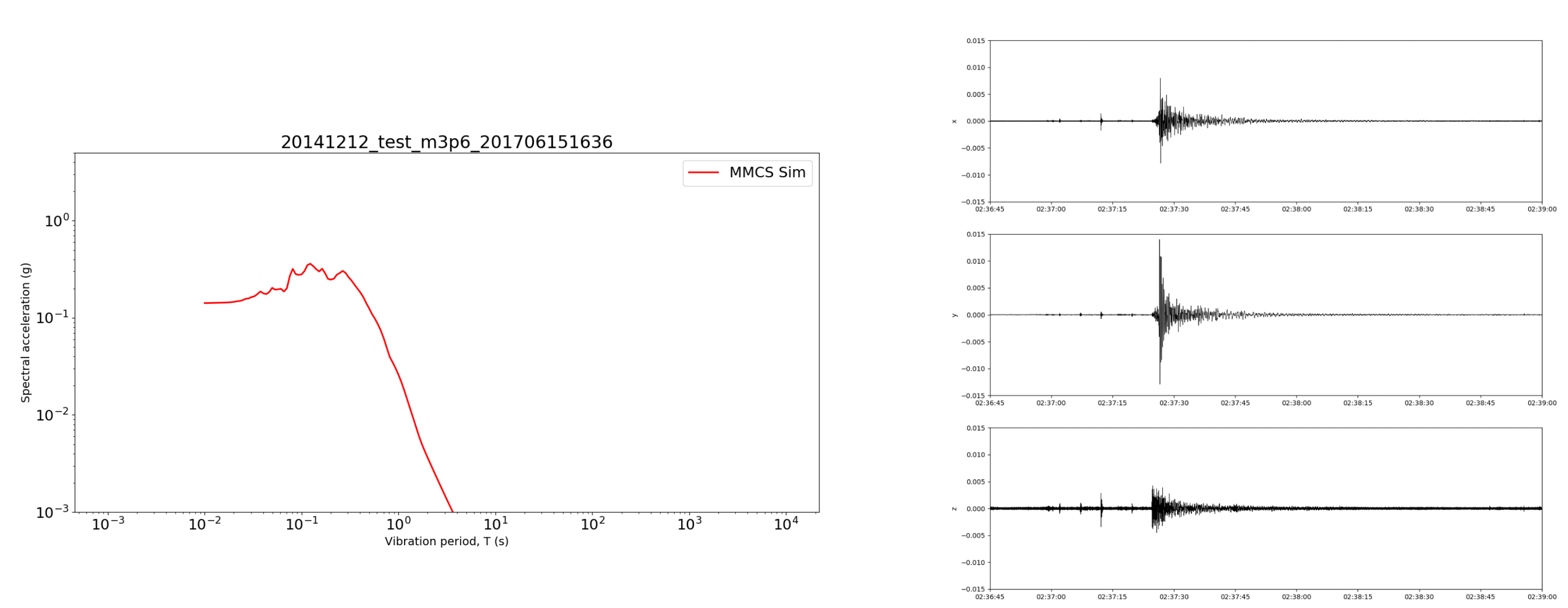
FitzRoy
- Run Low Frequency (LF)
- Run LF processing
- Run High Frequency (HF)
- Run BroadBand (BB)

This project highlights some of the challenges when working with QuakeCoRE, such as rupture models for events with a magnitude lower than 4.0, and the use of non processed strong motion acceleration as comparison data.

Ultimately, we aim to implement an automatic calibration algorithm for simple velocity models, and thus allow quick construction of ground motion simulations in other regions of New Zealand.

Once the workflow implemented, we will investigate uncertainty quantification using for example Markov Chain Monte Carlo algorithms. The aim is to improve the accuracy of predictions from the ground motion simulation models.

Comparison of site response for MMCS station, model and data



a) QuakeCoRE output

b) RAW data

Chick, L. M., W. P. De Lange, and T. R. Healy. "Potential tsunami hazard associated with the Kerepehi Fault, Firth of Thames, New Zealand." *Natural hazards* 24.3 (2001): 309-318.

Graves, R. W., & Pitarka, A. (2010). Broadband ground-motion simulation using a hybrid approach. Bulletin of the Seismological Society of America, 100(5A), 2095-2123.

Hochstein, M. P., & Nixon, I. M. (1979). Geophysical study of the Hauraki Depression, North Island, New Zealand. *New Zealand journal of geology and geophysics*, *22*(1), 1-19.

Persaud, M., Villamor, P., Berryman, K. R., Ries, W., Cousins, J., Litchfield, N., & Alloway, B. V. (2016). The Kerepehi Fault, Hauraki Rift, North Island, New Zealand: active fault characterisation and hazard. *New Zealand Journal of Geology and Geophysics*, *59*(1), 117-135.