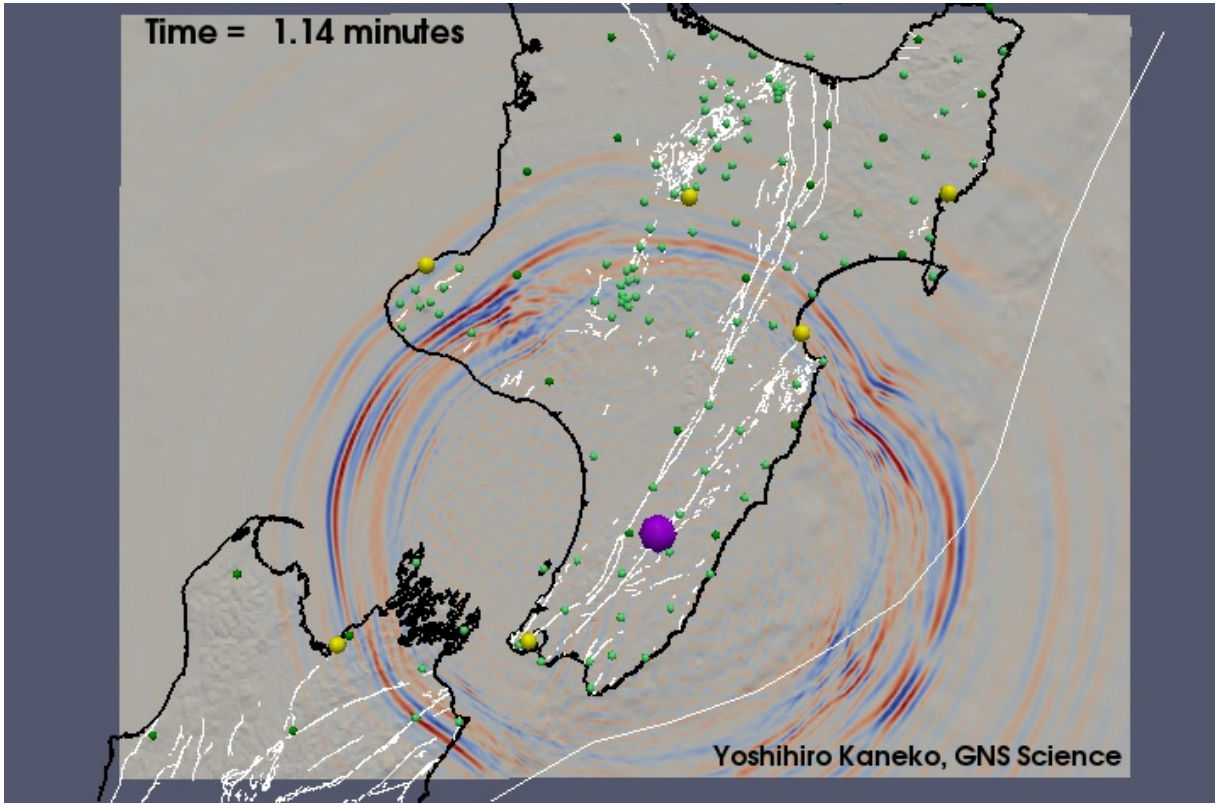
Seismic wavefield simulations of earthquakes in North Island of New Zealand



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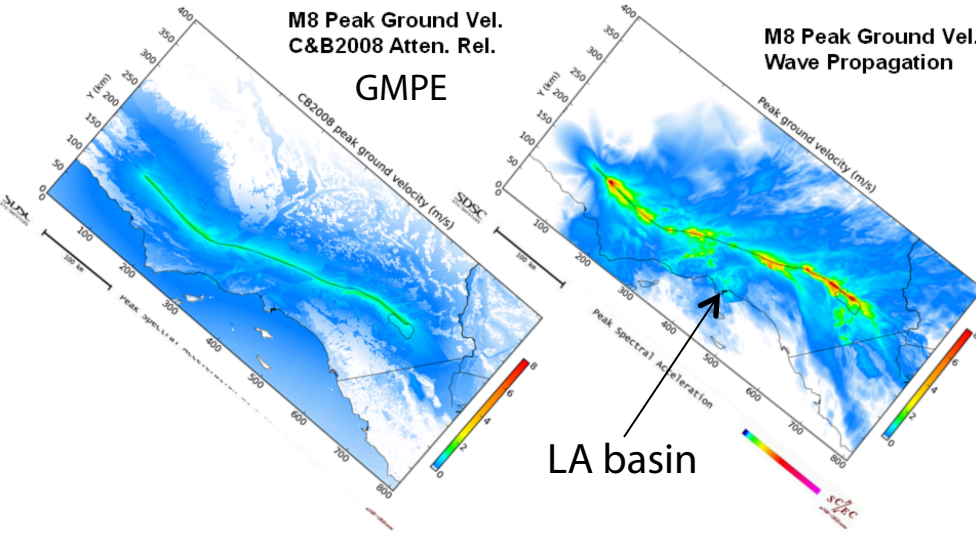
Collaborators:

Carl Tape, U. of Alaska – Fairbanks

John Ristau, GNS Science

Motivation



(Graves et al., 2010)

- Deterministic simulations of seismic wave propagation is a promising approach for probabilistic seismic hazard analysis (PSHA)
- Scenario earthquake modeling provides insights into source parameters controlling strong ground motion (e.g., in preparation for a potential M9 Hikurangi earthquake)
- Ground motion = source + path (+ site)
- An accurate and high-resolution velocity model is essential

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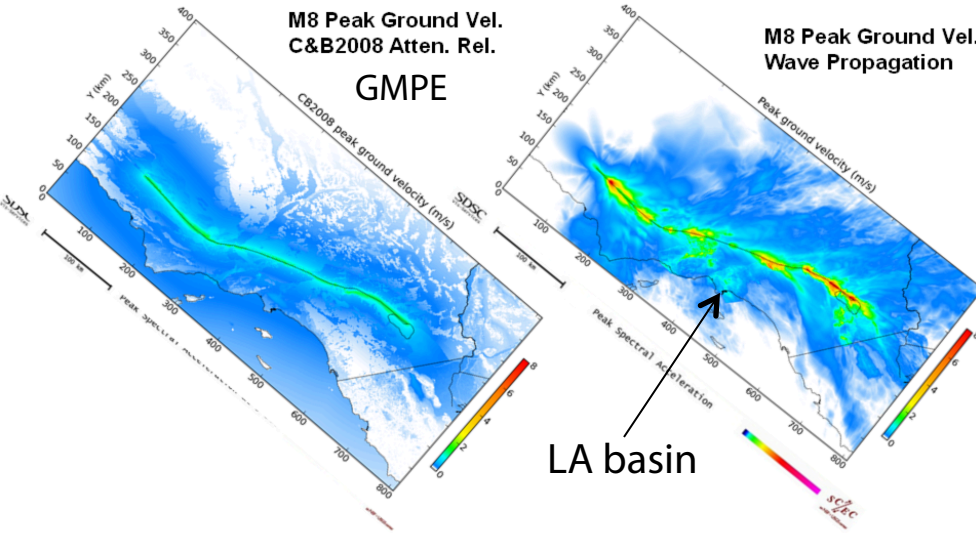

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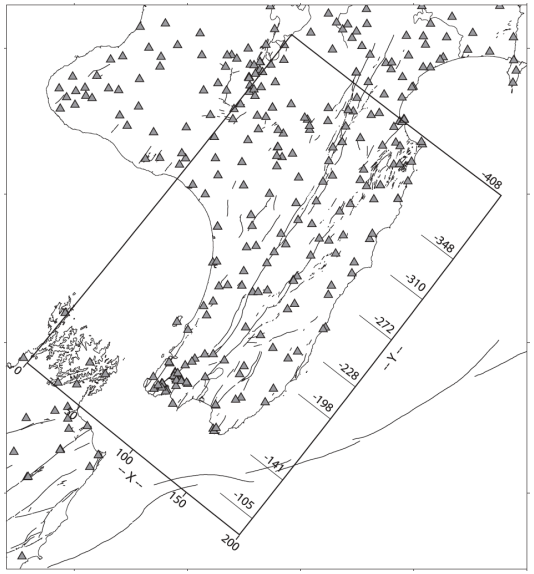
Objective

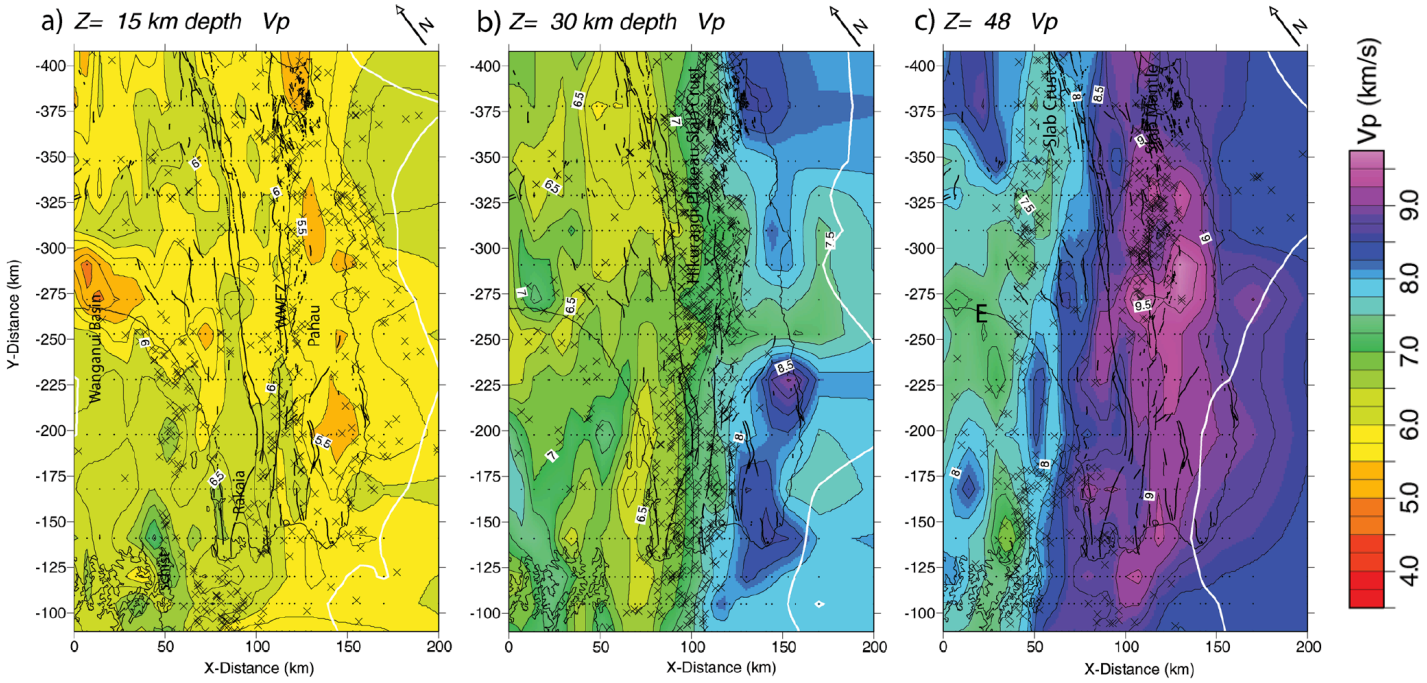
Validate the 3D velocity model of North Island; perform full wavefield simulations of earthquakes (4.0<M<5.5) using SPECFEM3D and quantify travel-time misfits between data and synthetics

3D velocity model of North Island

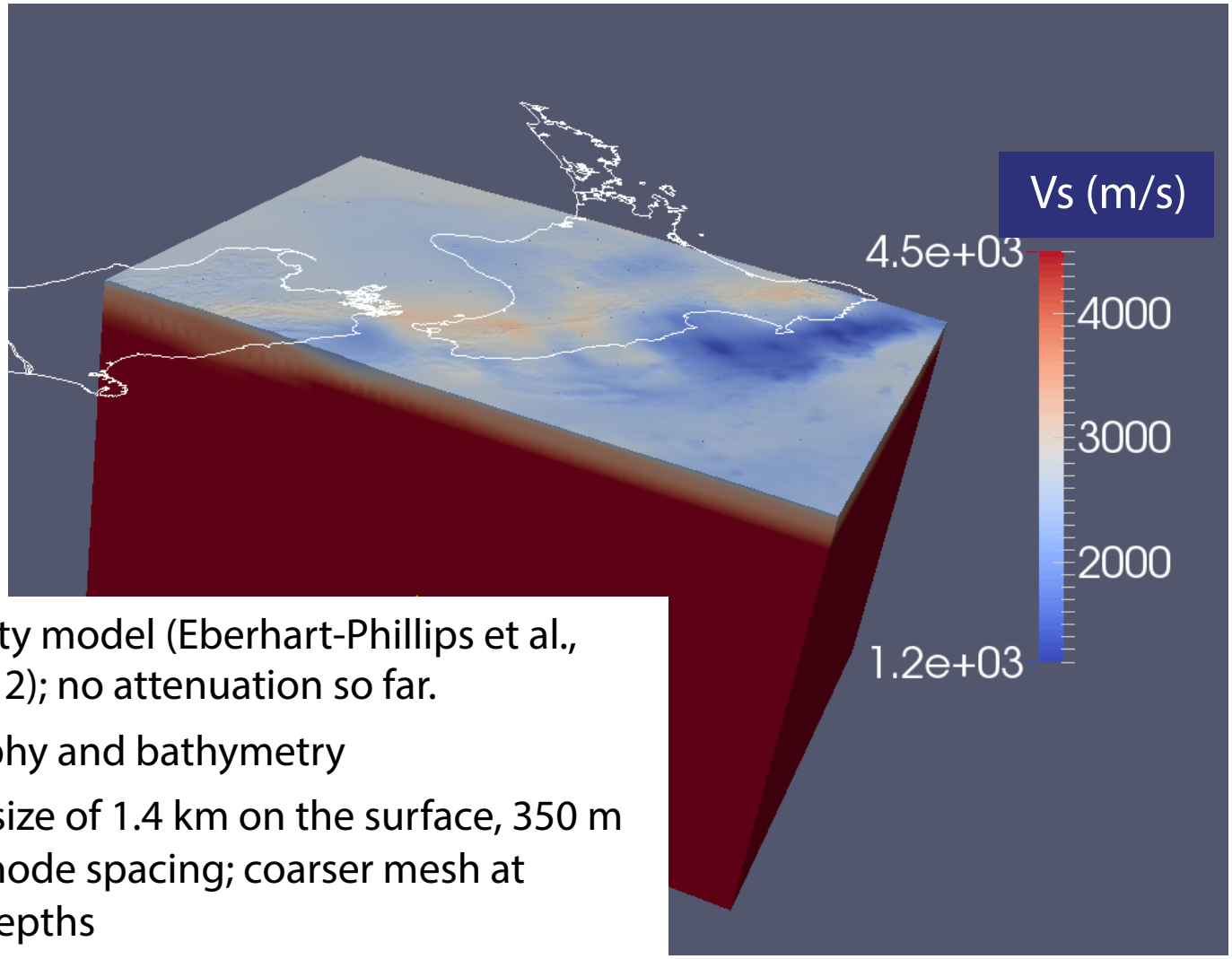


- Body-wave tomography, inverting for Vp and Vp/Vs
- Ray theory (**infinite frequency approximation** - all the sensitivity of the wave is confined to the ray)
- High-velocity subducted slab
- Low-velocity zone above the slab
- Sedimentary basin (e.g., Wanganui)
- Some small-scale patchy anomalies are artifacts

(Eberhart-Phillips et al., 2010; 2012)



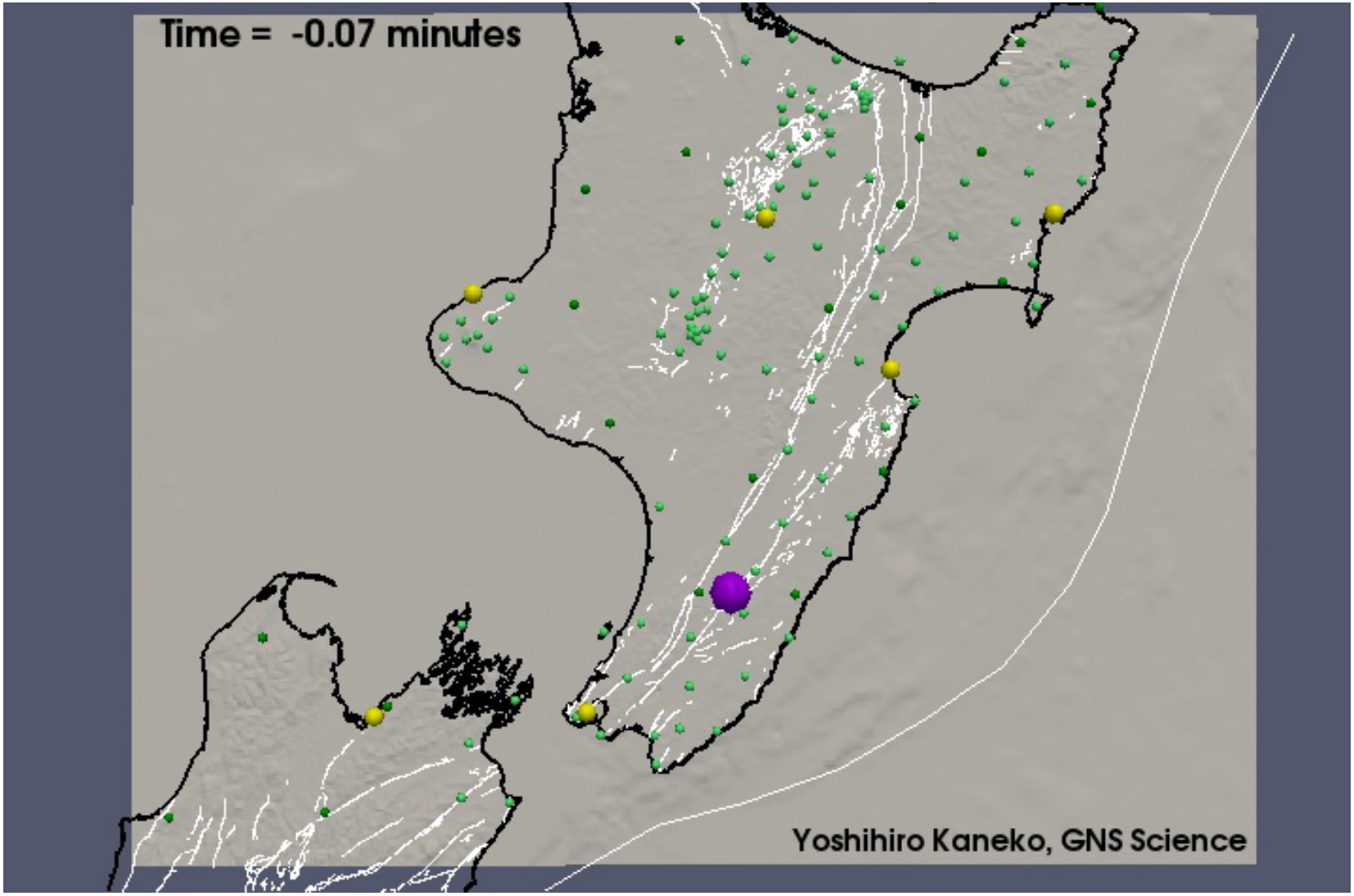
Finite element mesh



- 3D velocity model (Eberhart-Phillips et al., 2010; 2012); no attenuation so far.
- Topography and bathymetry
- Element size of 1.4 km on the surface, 350 m average node spacing; coarser mesh at greater depths
- Total of ~70 million node points; one simulation takes ~1 h using 144 cores on NeSI
- Simulated waves are accurate down to 2.5 s

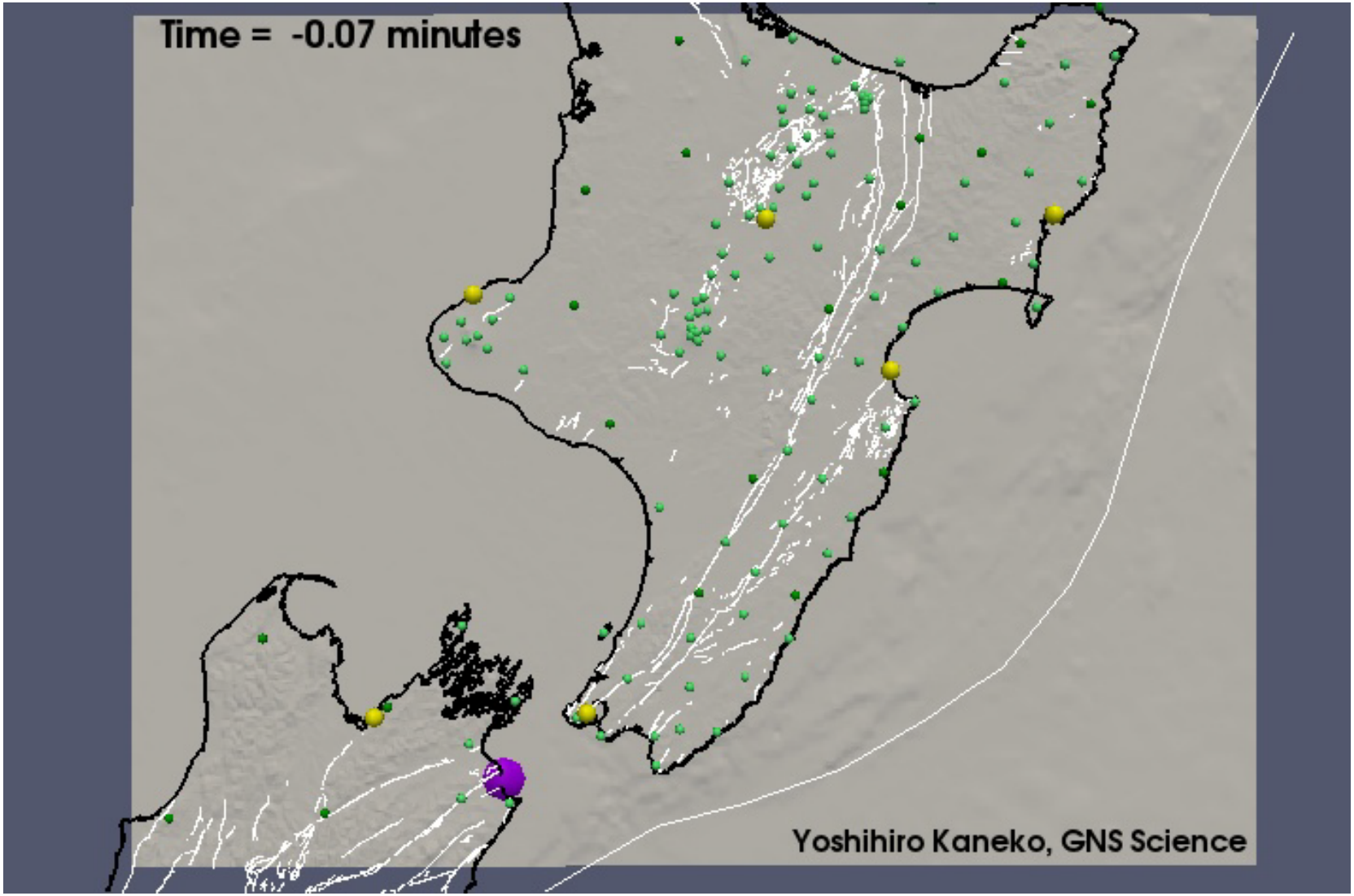
Full wavefield simulation movie

2014 M6.2 Eketahuna EQ (normal faulting event at depth of 25 km)



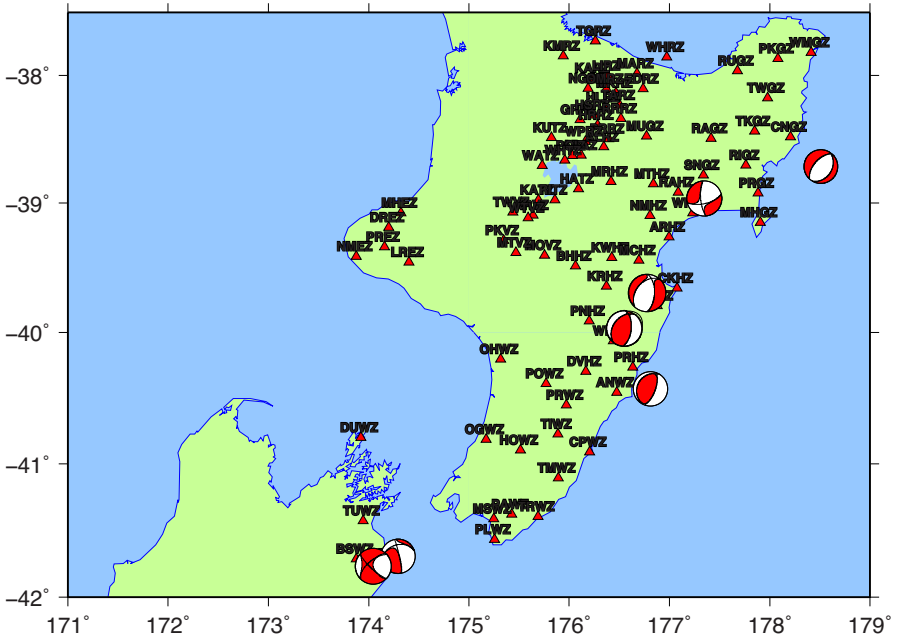
Full wavefield simulation movie

2013 M6.5 Cook Strait EQ (strike-slip event at depth of 12 km)

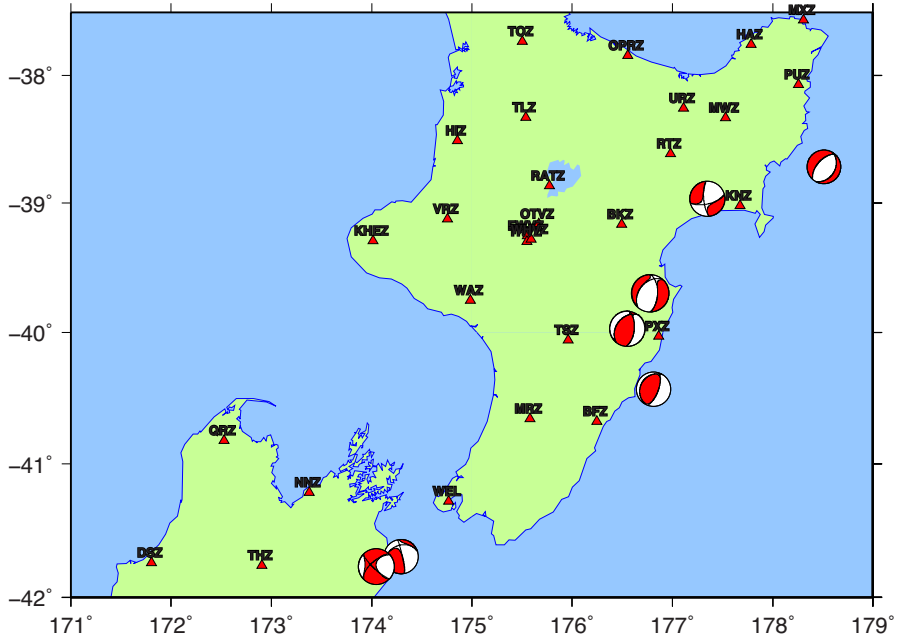


GeoNet stations

92 short-period stations



28 broadband stations

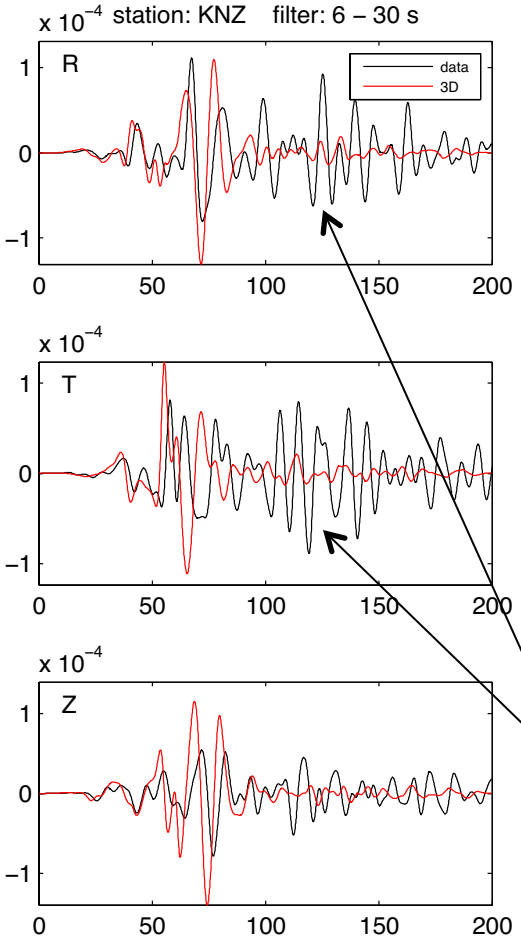


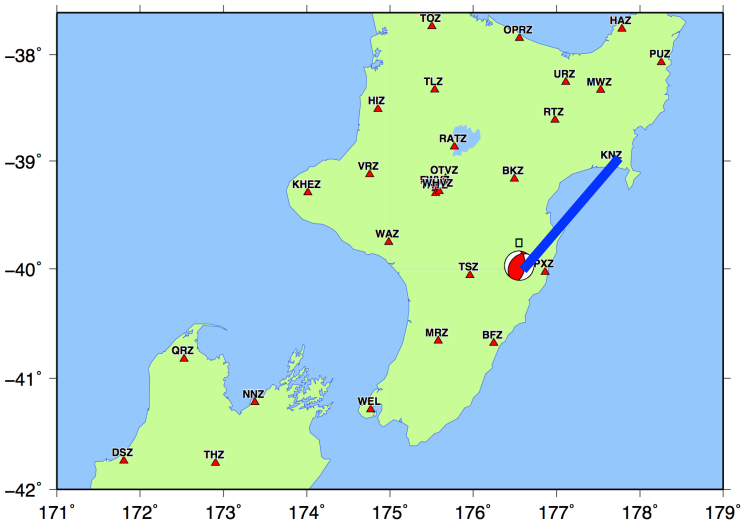
7 M~5 events recorded at broadband and short-period stations

Waveforms recorded at short-period stations are noisier for longer periods (T>4 s)

Use broadband stations only in this study

Comparisons between data and synthetics using a M5.1 event





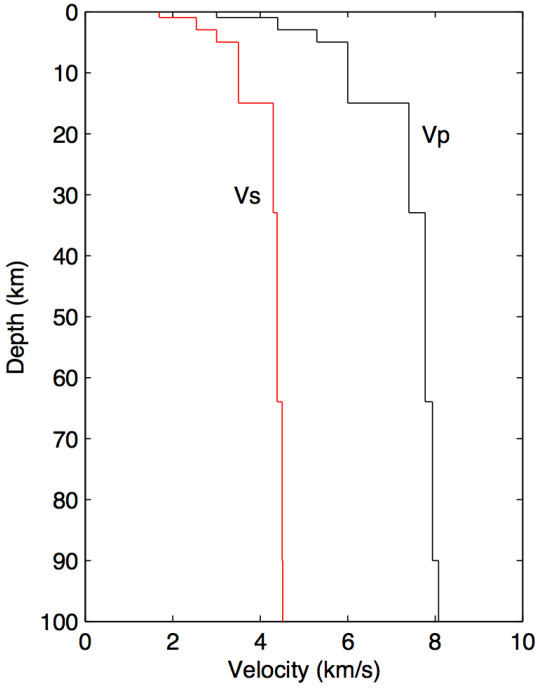
3-component displ. seismograms;
Data – black; Synthetics – red;
Filter: 6 – 30 s

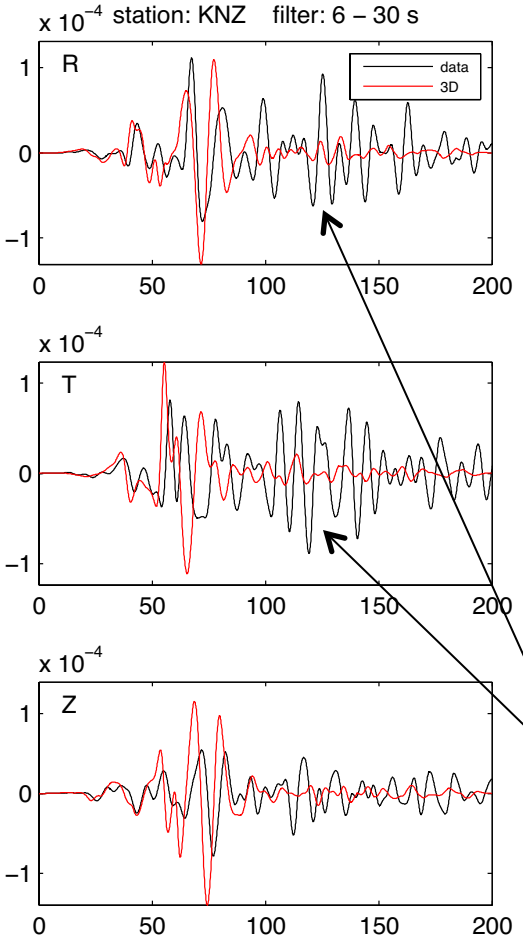
Complexity in data is not captured by the 3D model

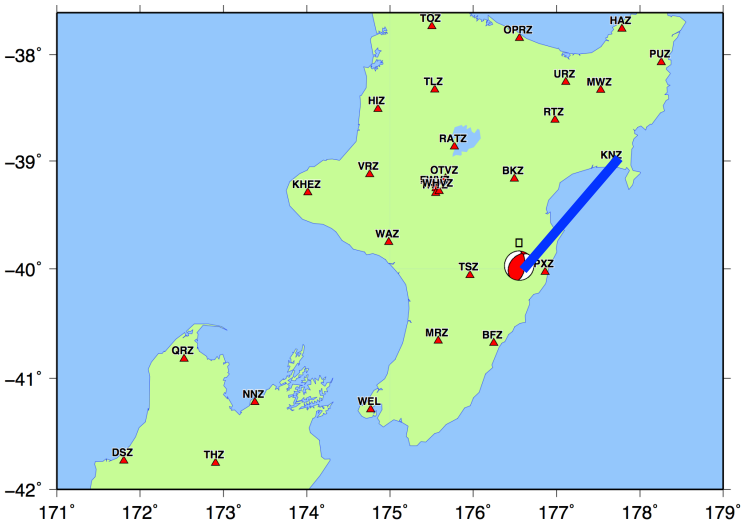
1D synthetics do not fit data well

Comparisons between data and synthetics using a M5.1 event

1D model of North Island (Ristau, 2008)







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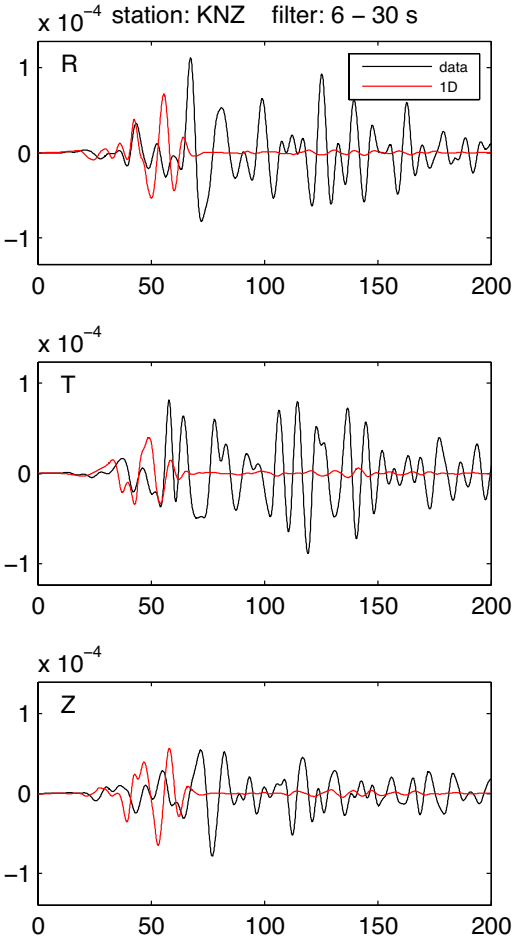

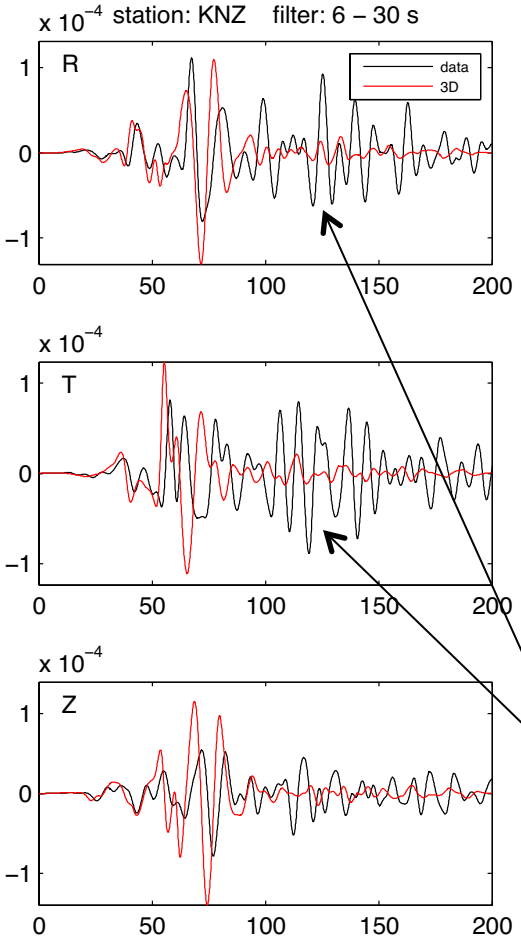

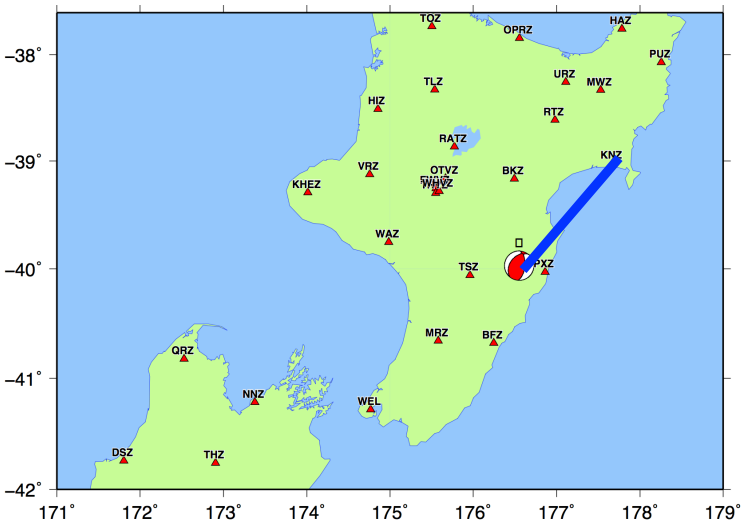

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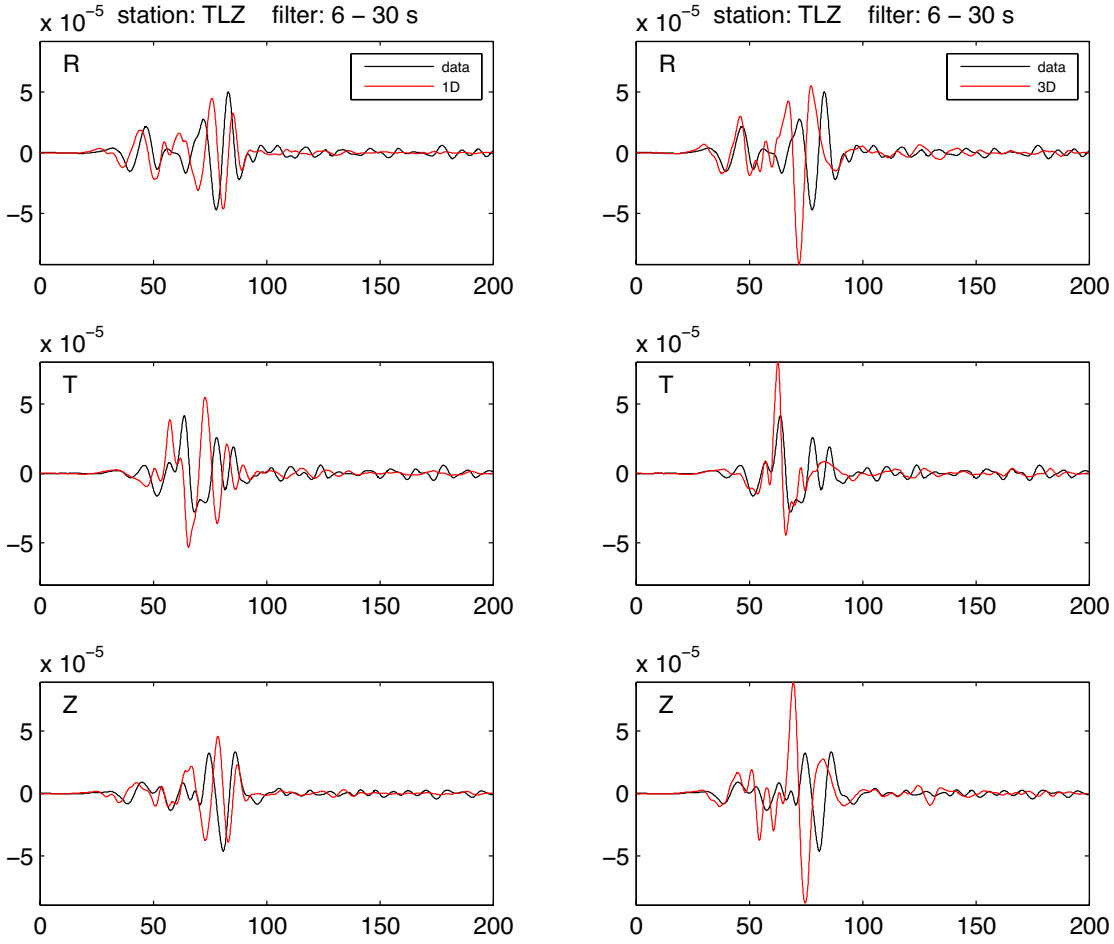

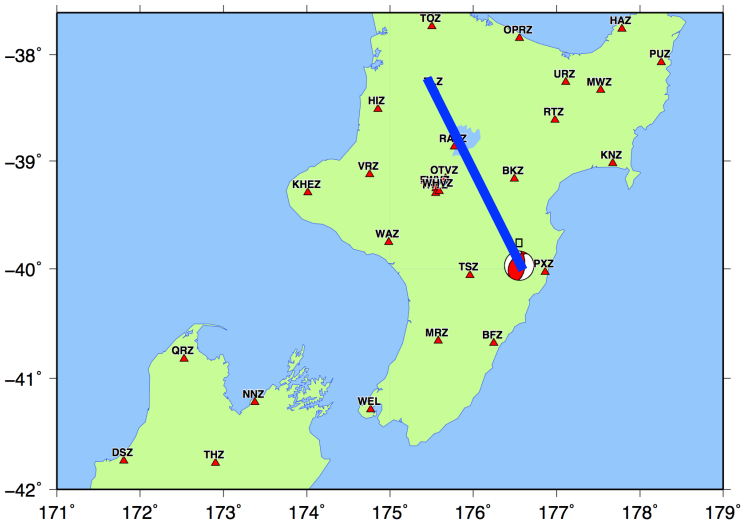

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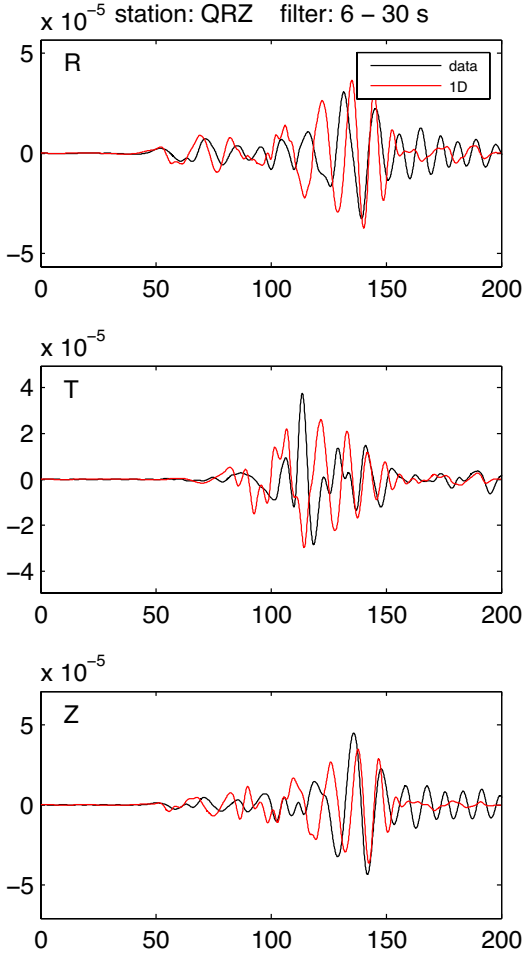

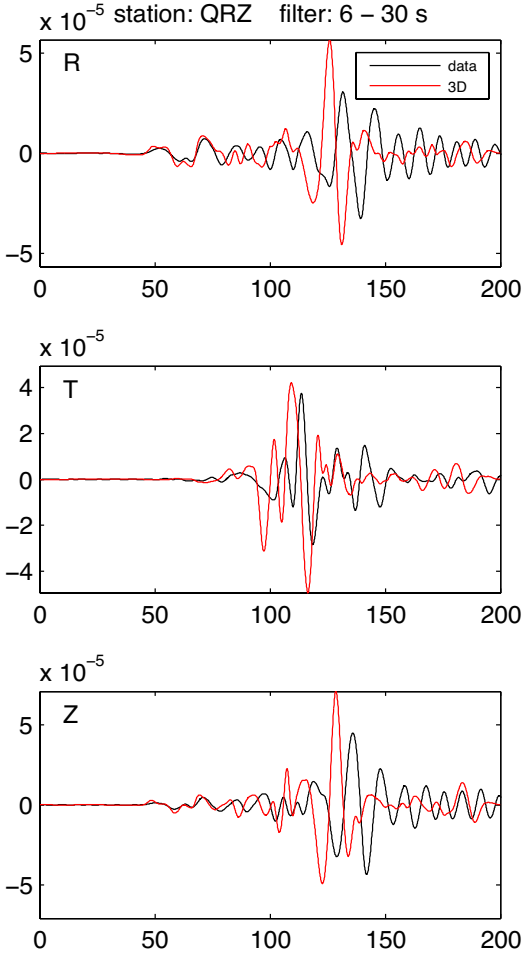

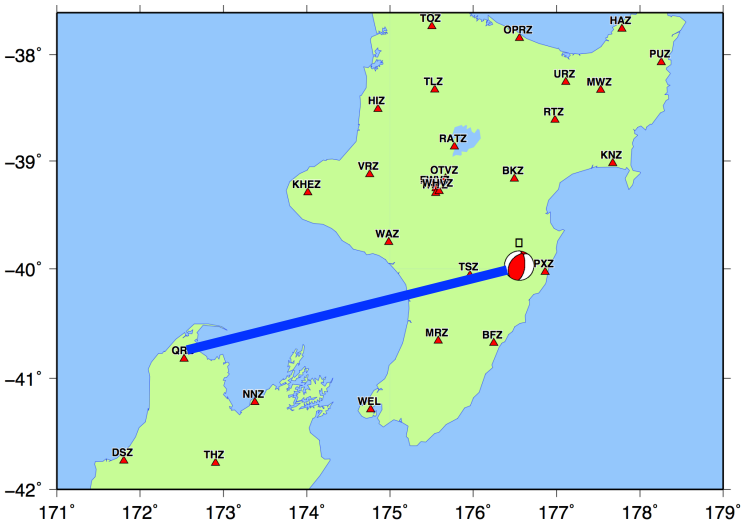

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The 3D model appears to be faster than the real structure

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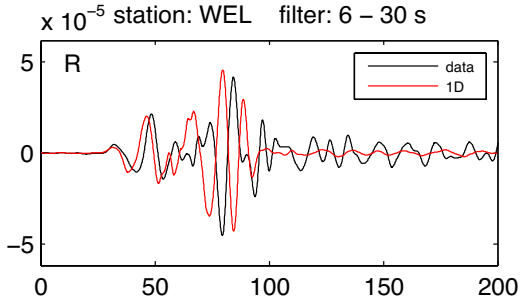

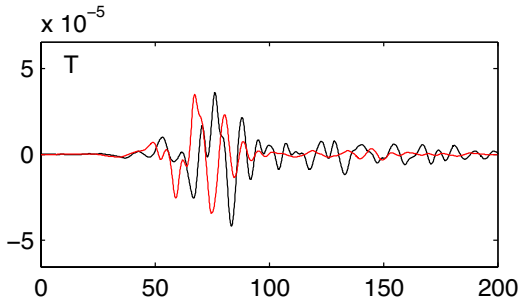

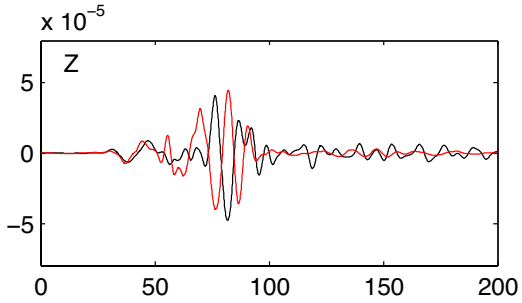

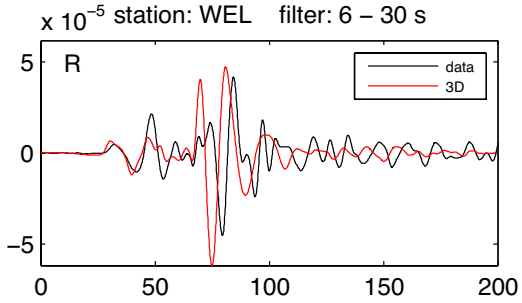

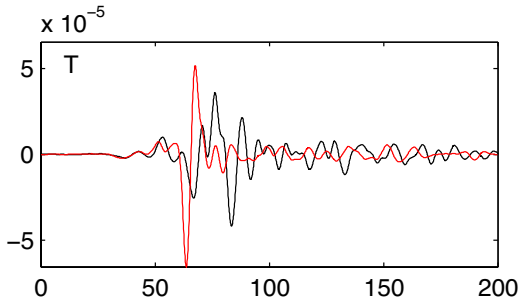

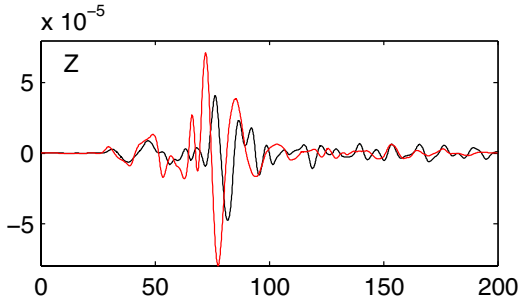

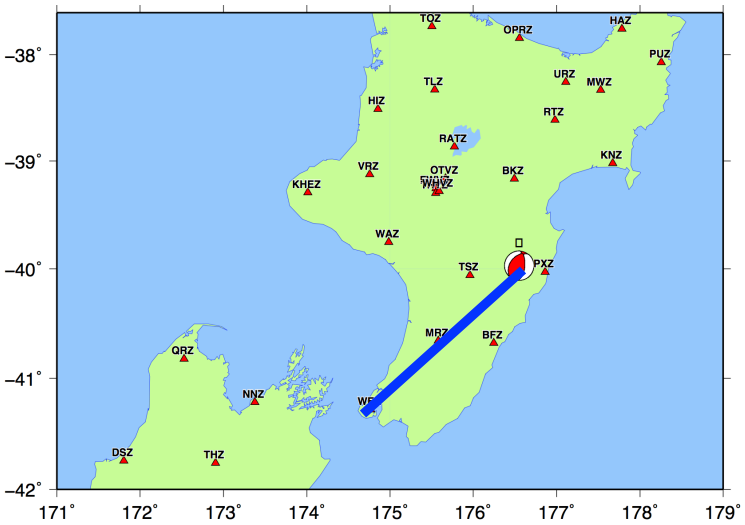

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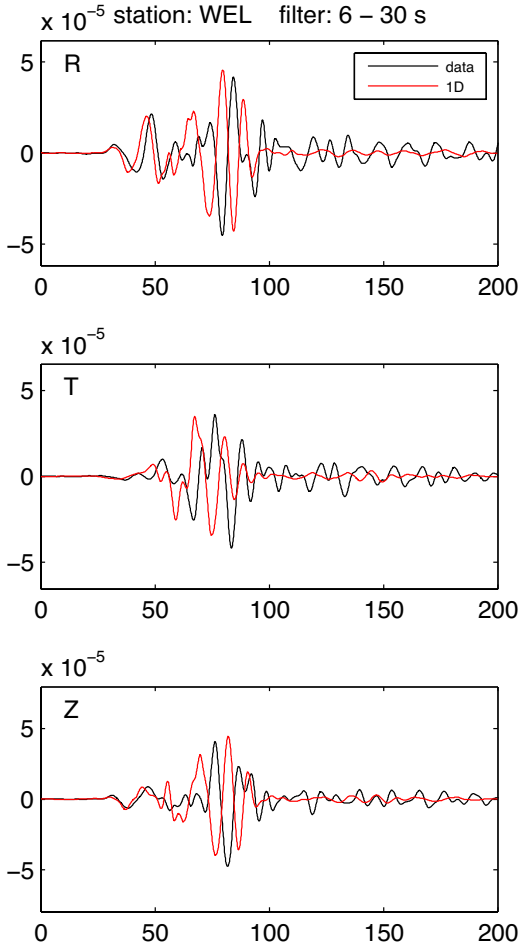

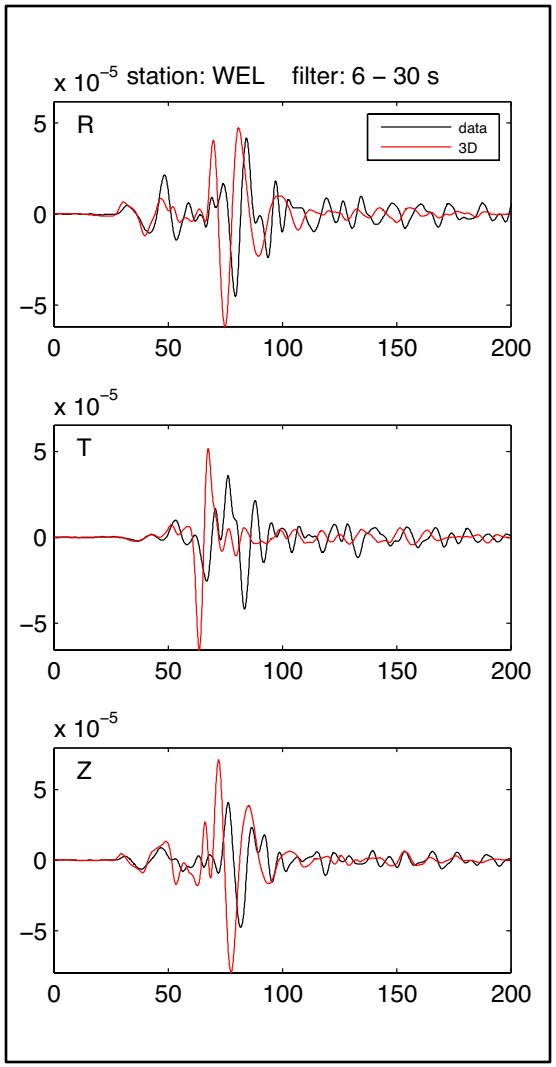

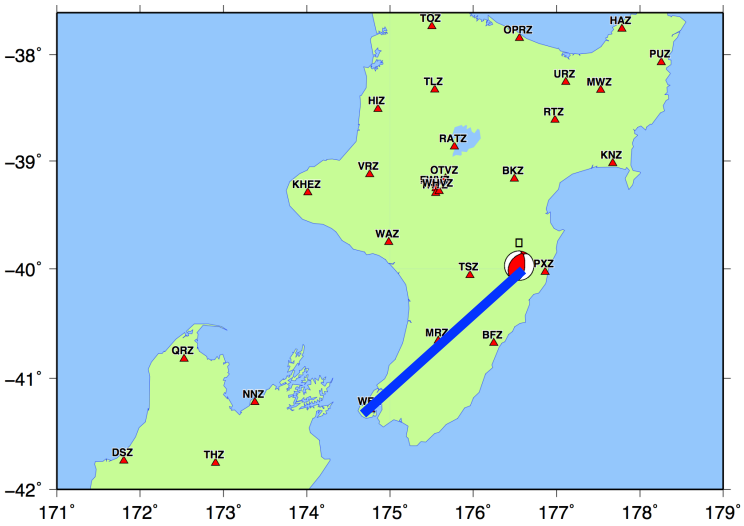

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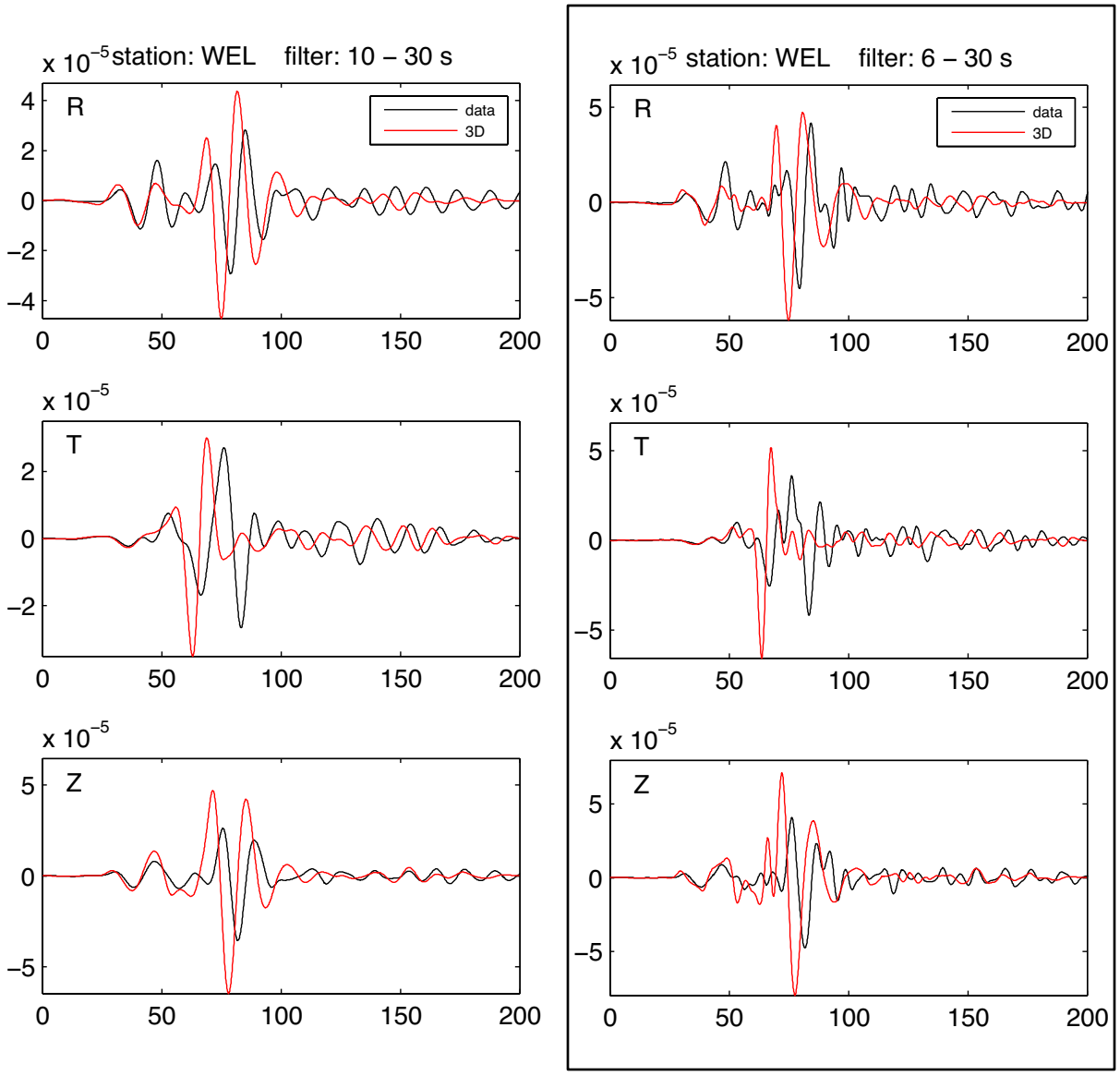
Higher frequency waves are more difficult to be modeled



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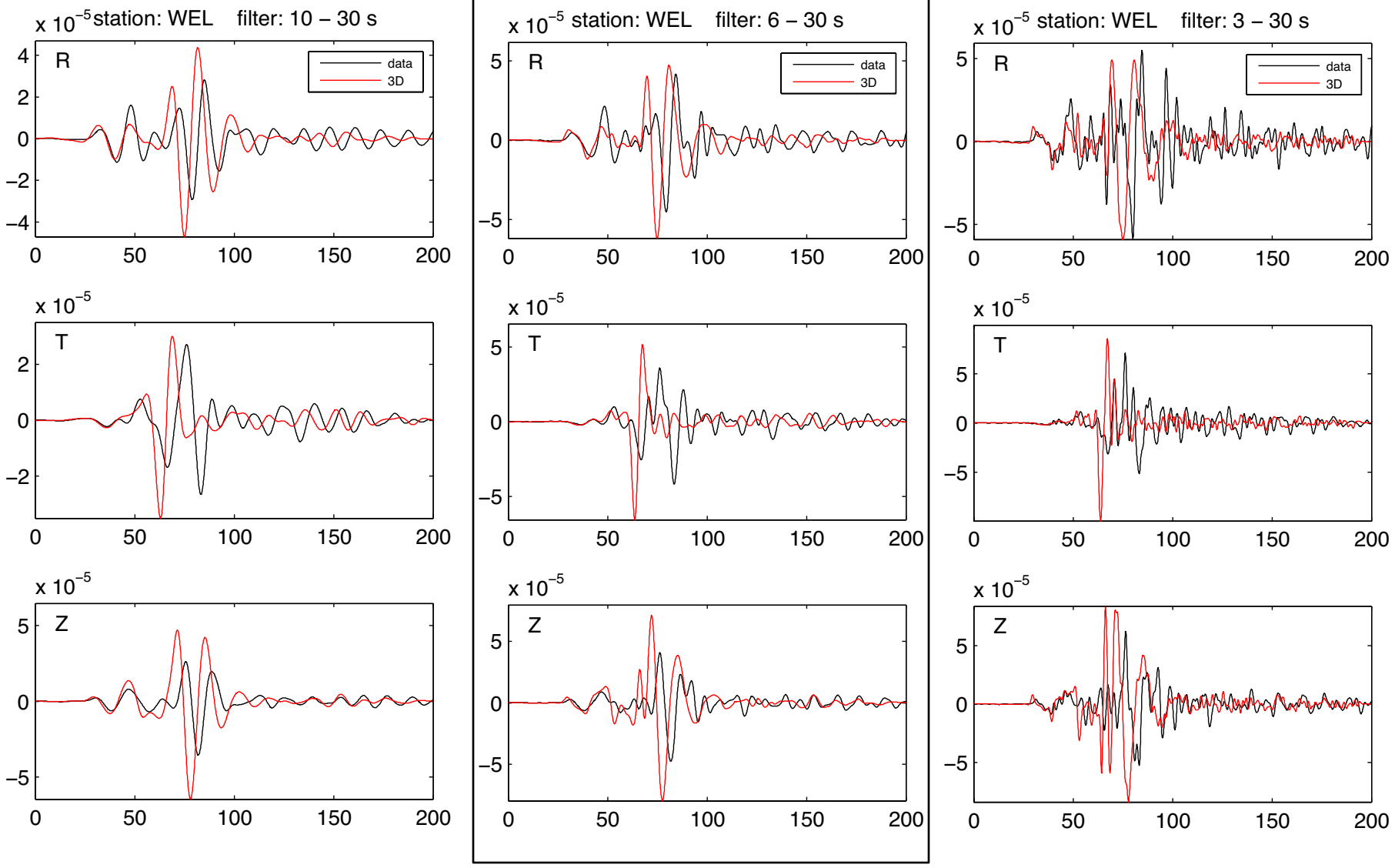
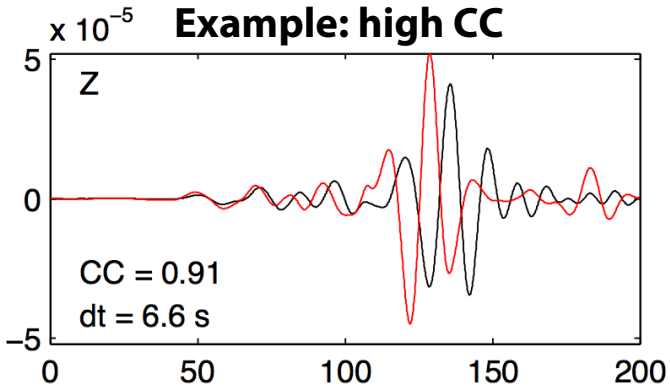
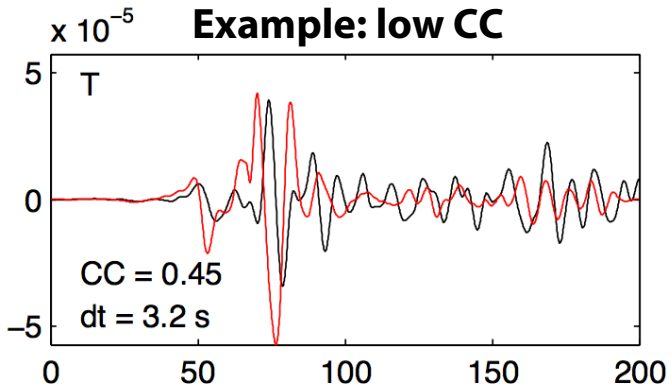


Quantitative validation

Measure travel-time phase delay and cross-correlation coefficient (CC)





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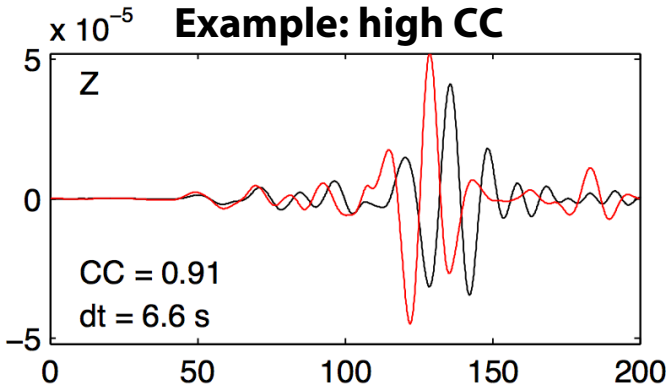

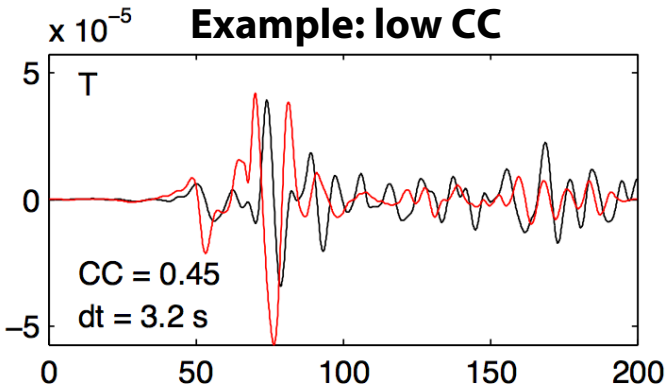

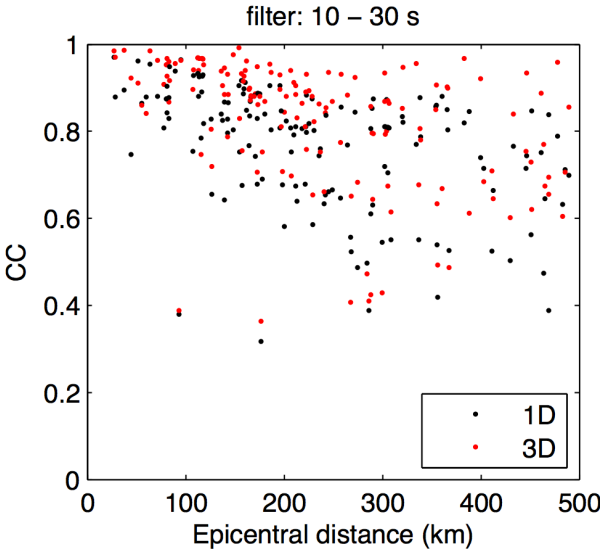

CC are larger for the 3D model

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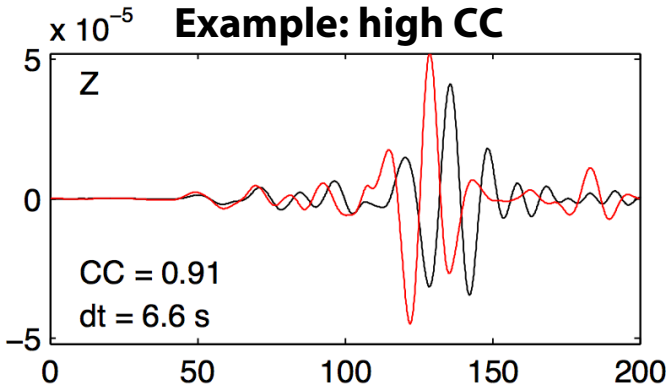
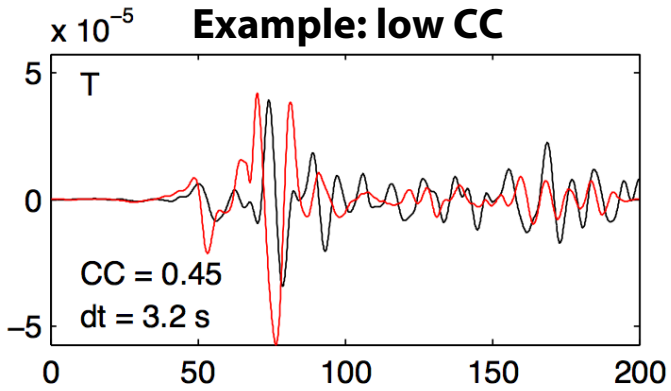
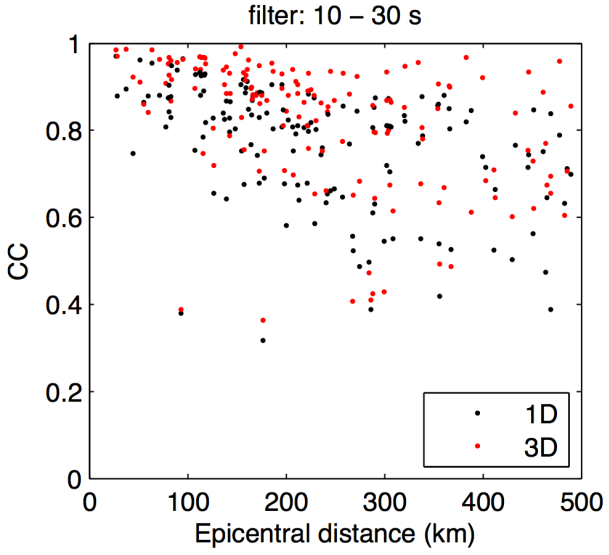
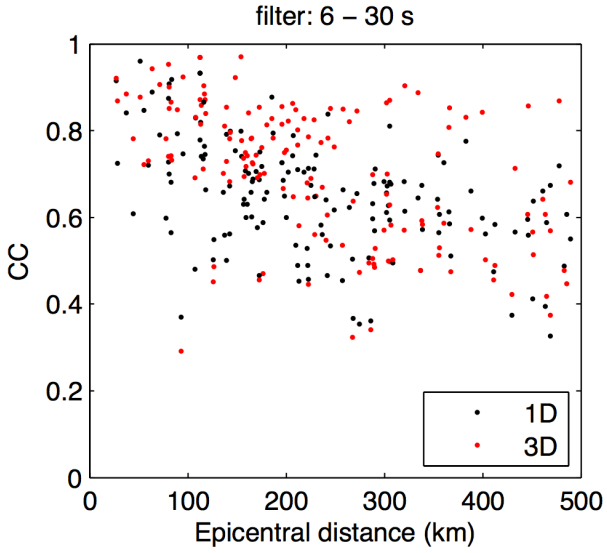
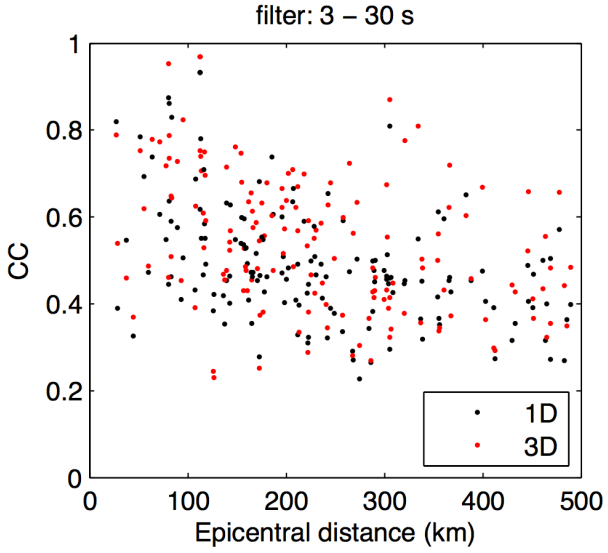








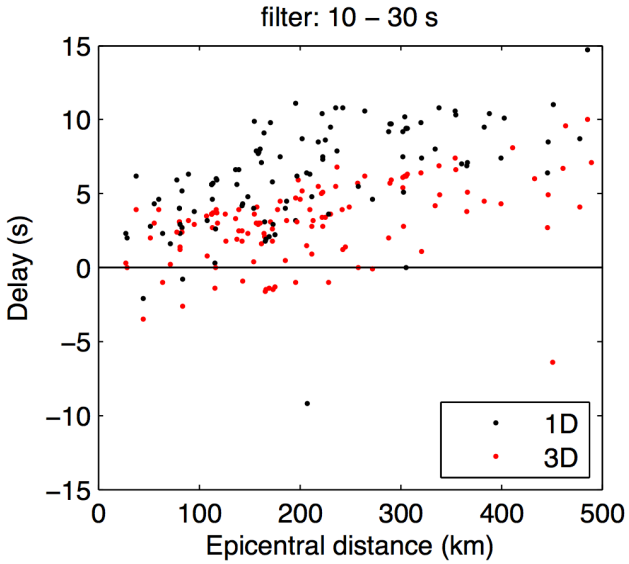


CC are larger for the 3D model

CC are smaller for high-frequency waves

Quantitative validation

Plotting only CC > 0.7 (i.e., synthetics and data are similar)



A positive (linear) trend between phase delay and epicentral distance is observed

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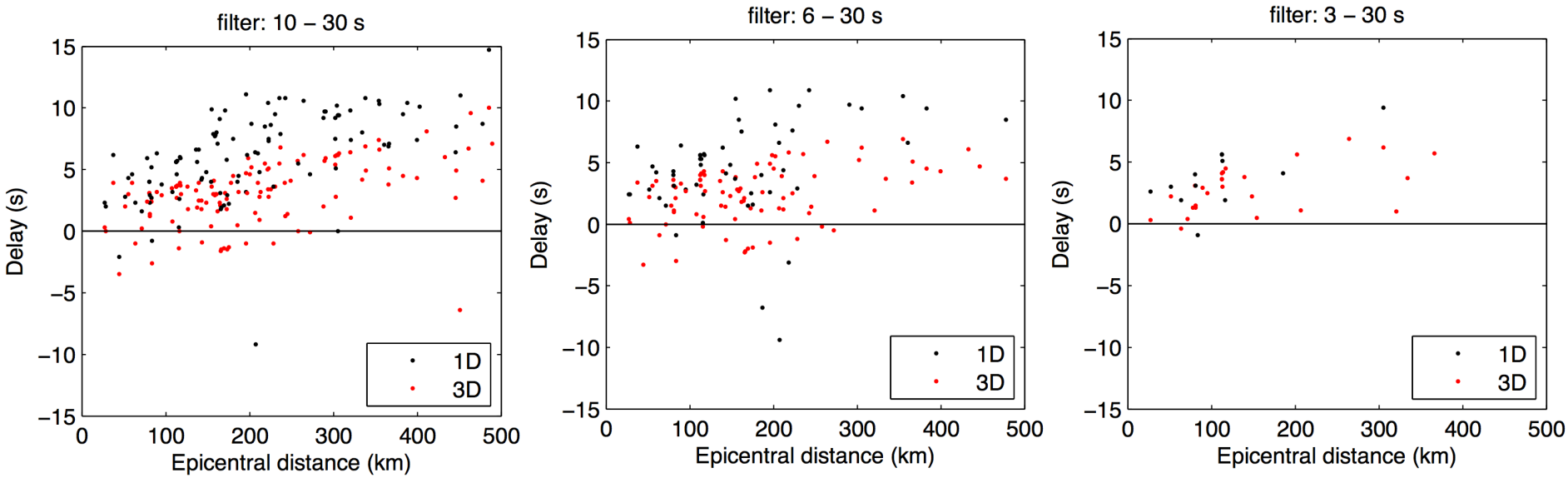

A positive (linear) trend between phase delay and epicentral distance is observed

Positive trend is systematically observed for all three period bands

These results suggest that the actual velocity structure is slower (>15%) than the 3D model

Conclusions

- We have simulated seismic wave propagation within the latest 3D velocity model of North Island and assessed the accuracy of the model
- Compared to the 1D model, the 3D model fits observed waveforms better
- Yet, the 3D model appears to be systematically faster than the real structure

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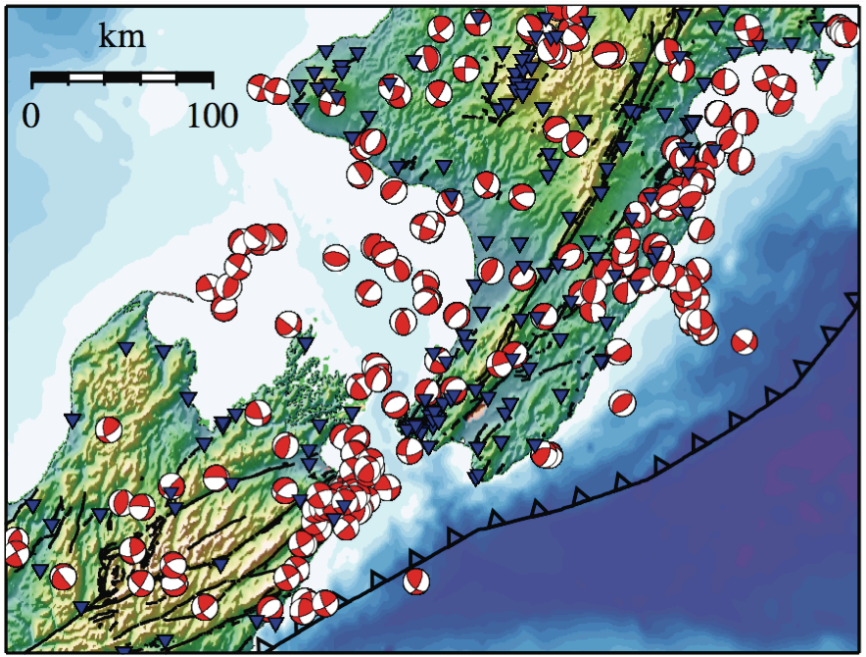

Future work

- Include a latest 3D attenuation (Q) model and compare waveform amplitudes
- Improve the 3D velocity model by performing full-waveform inversion (Tape et al., 2009; 2010)