

The Kaikoura earthquake and implications for Wellington

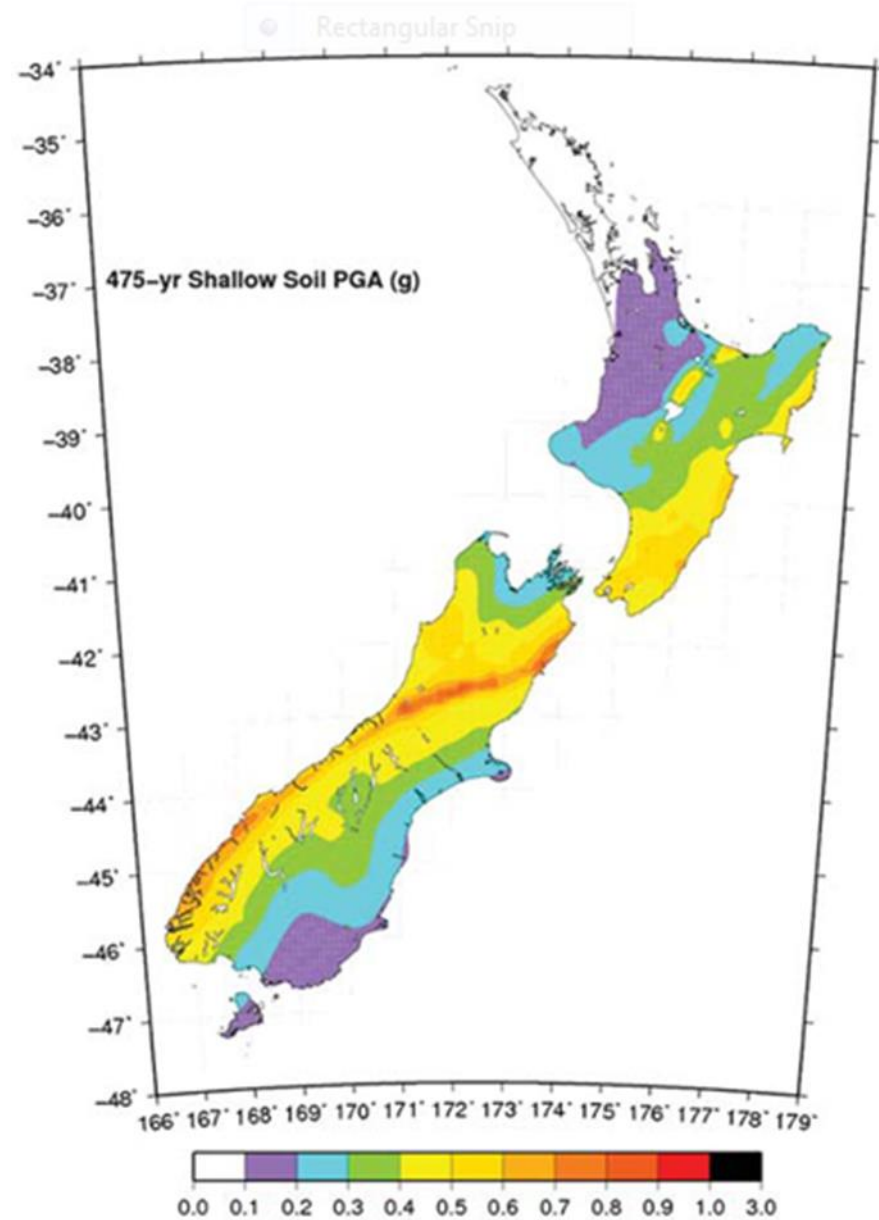
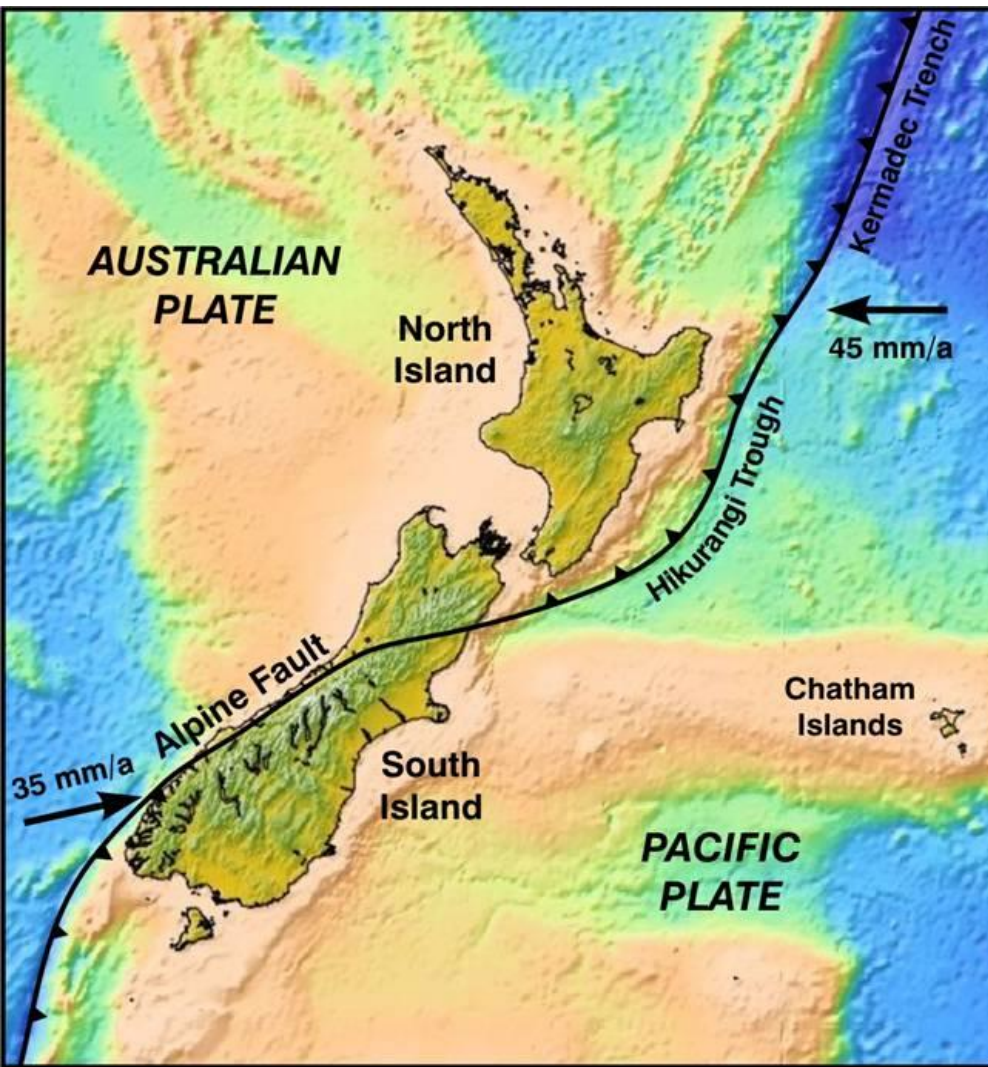


Kekerengu fault rupture, Kaikōura earthquake, 14th Nov 2016

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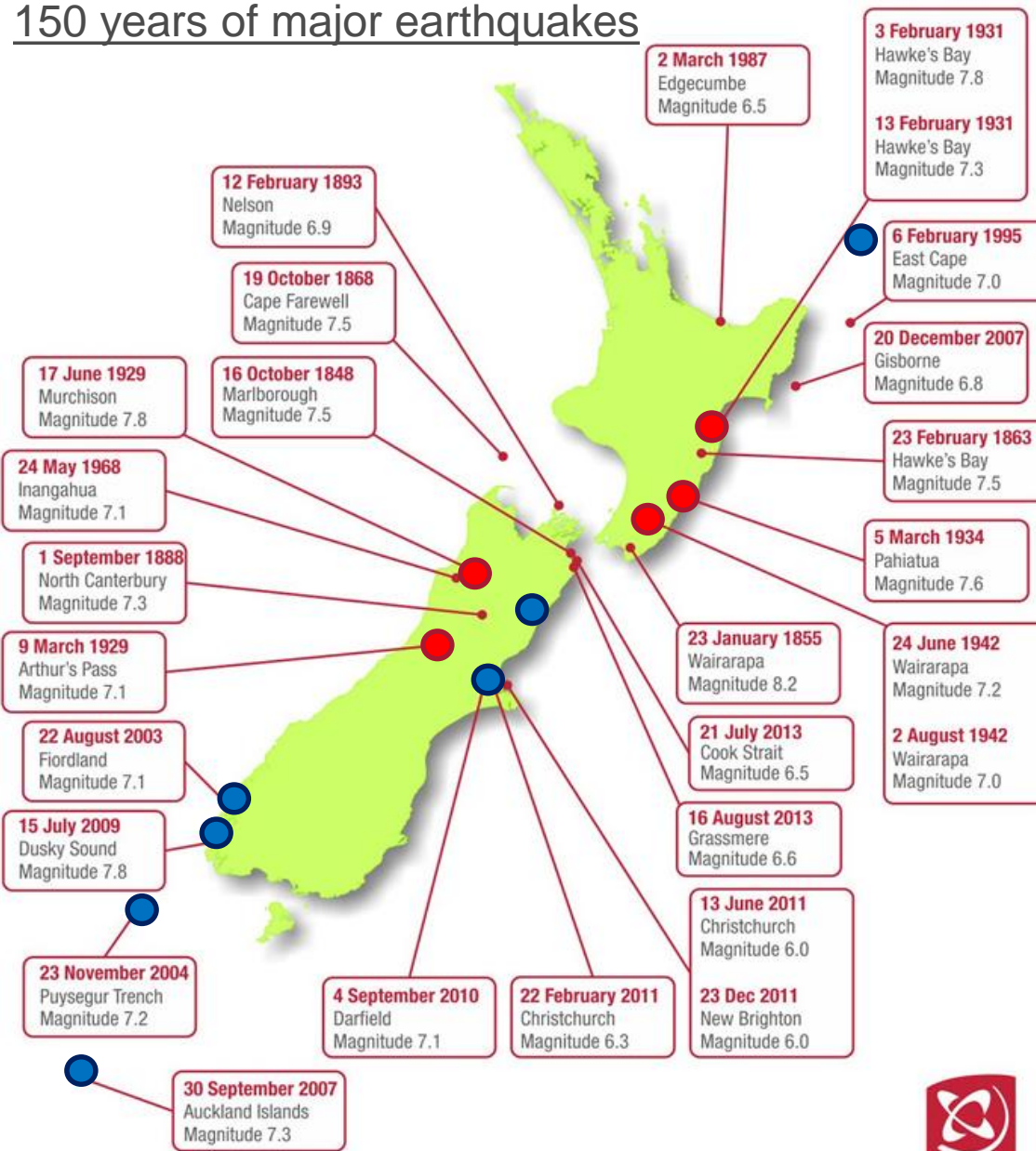
Context



Stirling et al, 2012

Context: A burst of earthquake activity since 2003

150 years of major earthquakes

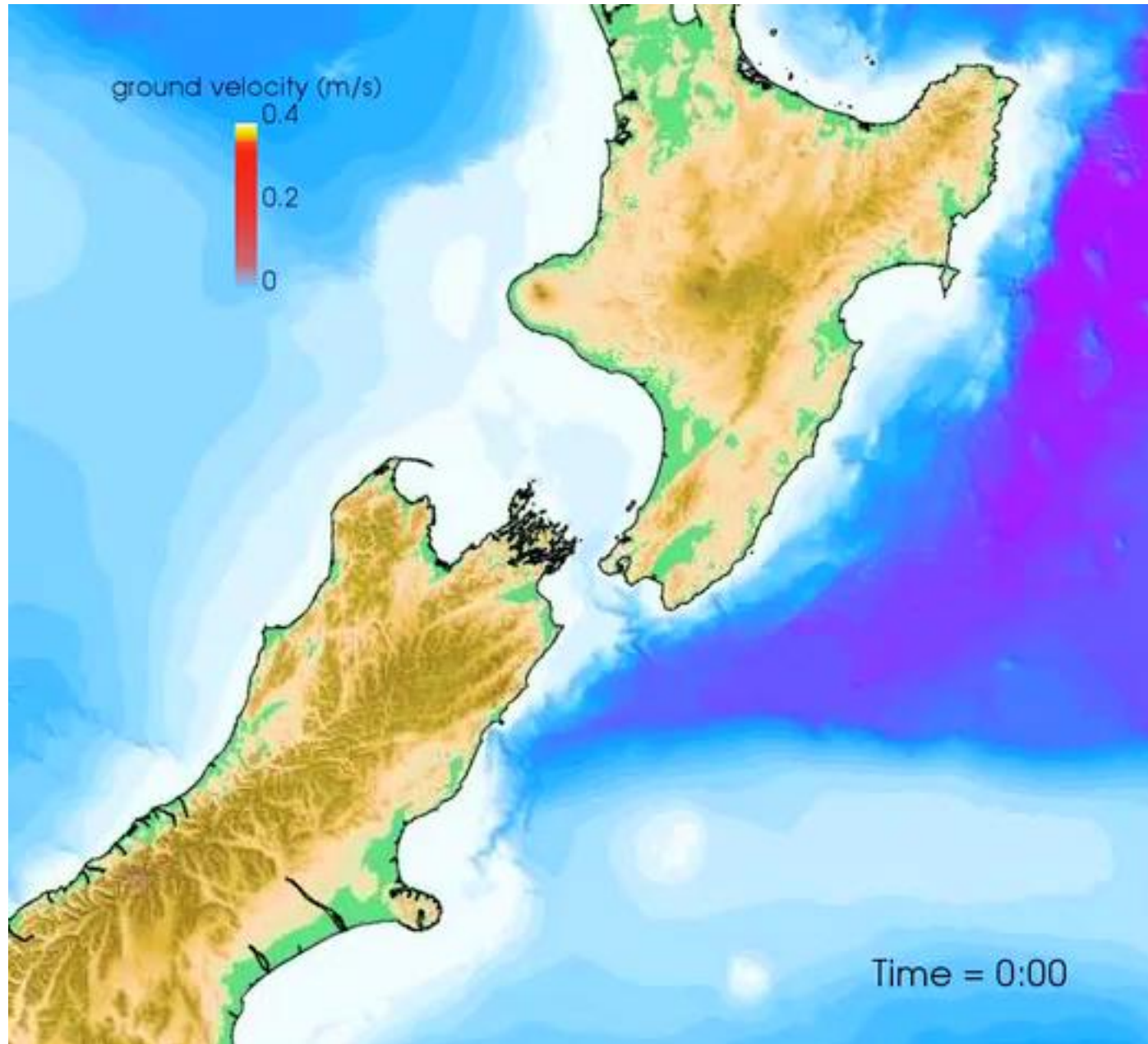


- ### 1929-1942
- 9 March 1929
Arthurs Pass
Magnitude 7.1
 - 17 June 1929
Murchison
Magnitude 7.8
 - 3 February 1931
Hawkes Bay
Magnitude 7.8
 - 13 February 1931
Hawkes Bay
Magnitude 7.3
 - 5 March 1934
Pahiataua
Magnitude 7.6
 - 5 March 1934
Pahiataua
Magnitude 7.6
 - 24 June 1942
Wairarapa
Magnitude 7.2
 - 2 August 1942
Wairarapa
Magnitude 7.0
 - 24 June 1942
Wairarapa
Magnitude 7.2
 - 2 August 1942
Wairarapa
Magnitude 7.0

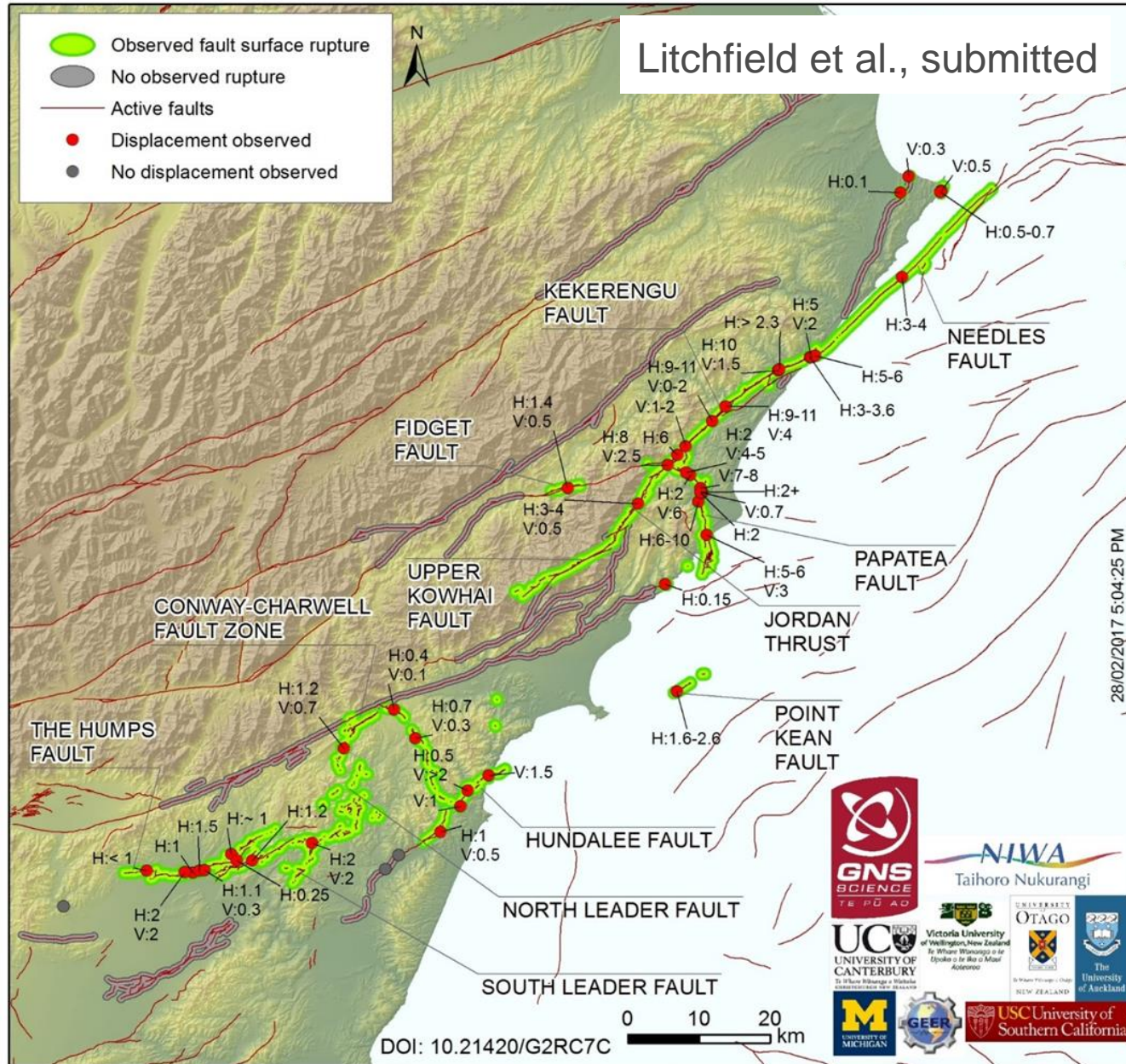
- ### 2003-?
- 22 August 2003
Fiordland
Magnitude 7.1
 - 23 November 2004
Puysegur Trench
Magnitude 7.1
 - 30 Sept 2007
Auckland Islands
Magnitude 7.3
 - 15 July 2009
Dusky Sound
Magnitude 7.8
 - 4 September 2010
Darfield
Magnitude 7.1
 - 2 September 2016
East Cape
Magnitude 7.1
 - 14 November 2016
Kaikoura
Magnitude 7.8



Kaikōura Earthquake



Kaikōura Earthquake

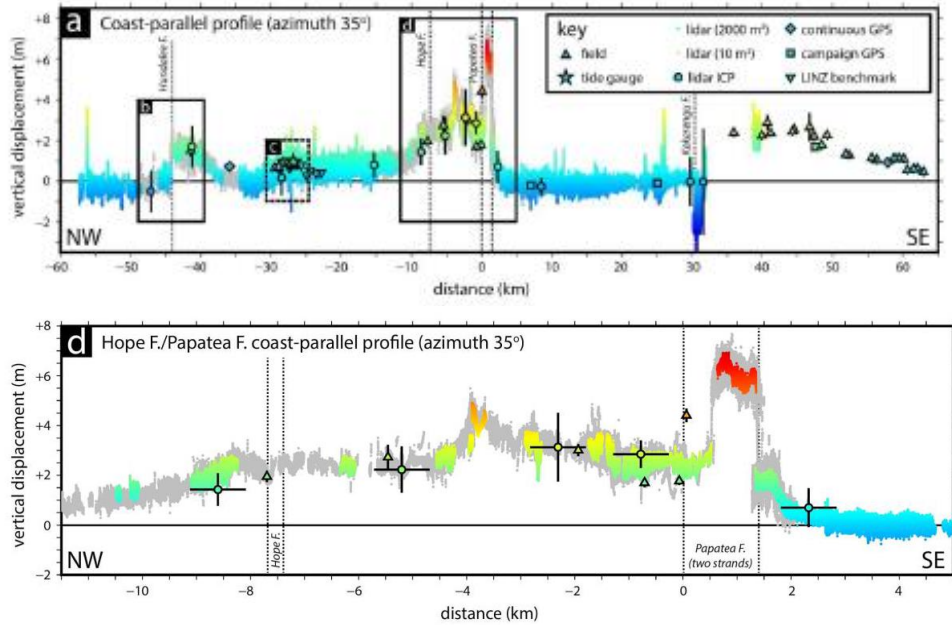


Litchfield et al., submitted

Surface Fault Ruptures

Coastal Uplift

Clark et al, 2017 (*EPSL*)



(a) Field, lidar, and geodetic measurements of coseismic vertical deformation projected to a straight line roughly parallel to Kaikōura District coastline. (d) Detailed coastline-parallel uplift measurements from across the Hope and Papatea faults.

Geodetic Fault Model

Hamling et al, 2017 (*Science*)

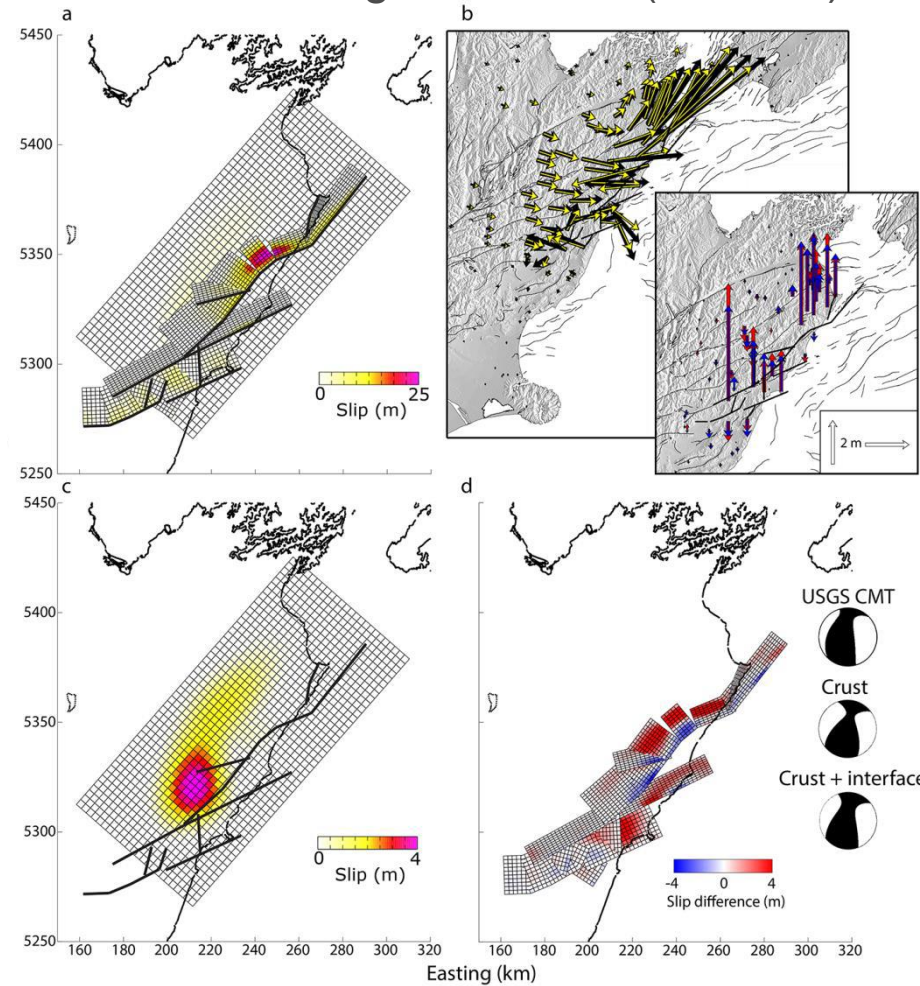
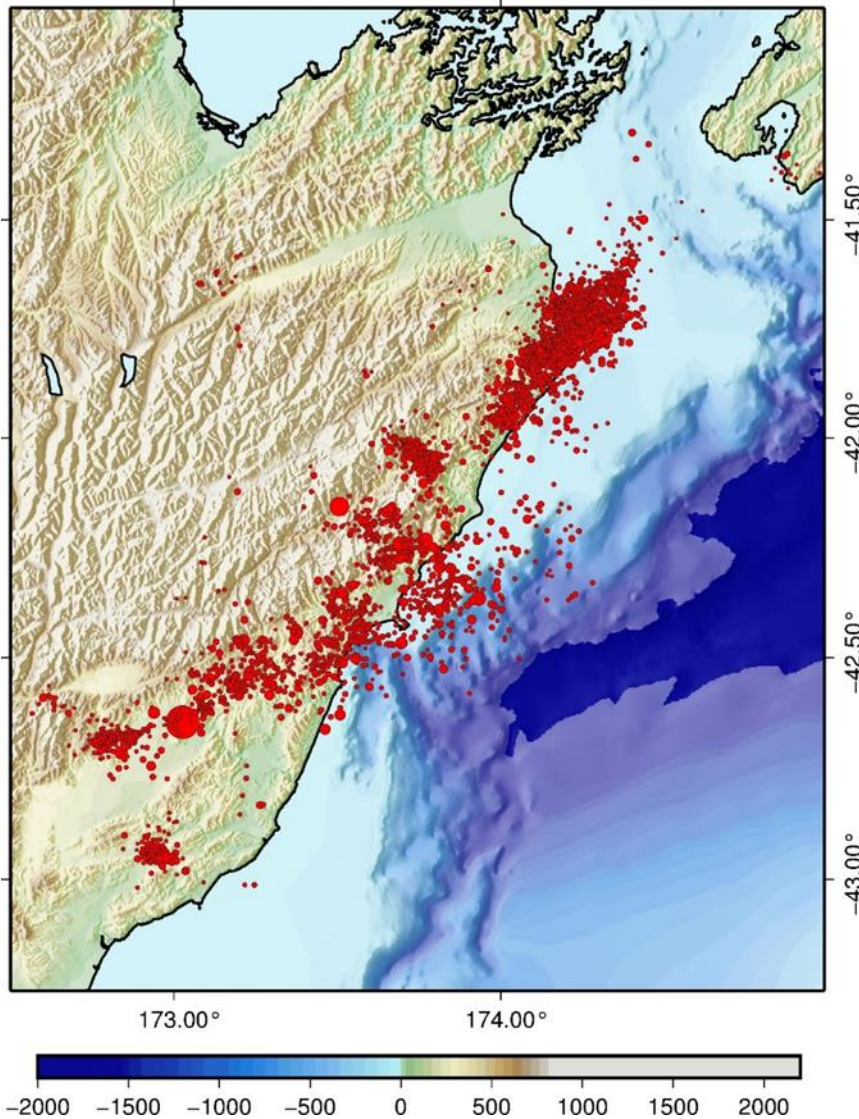


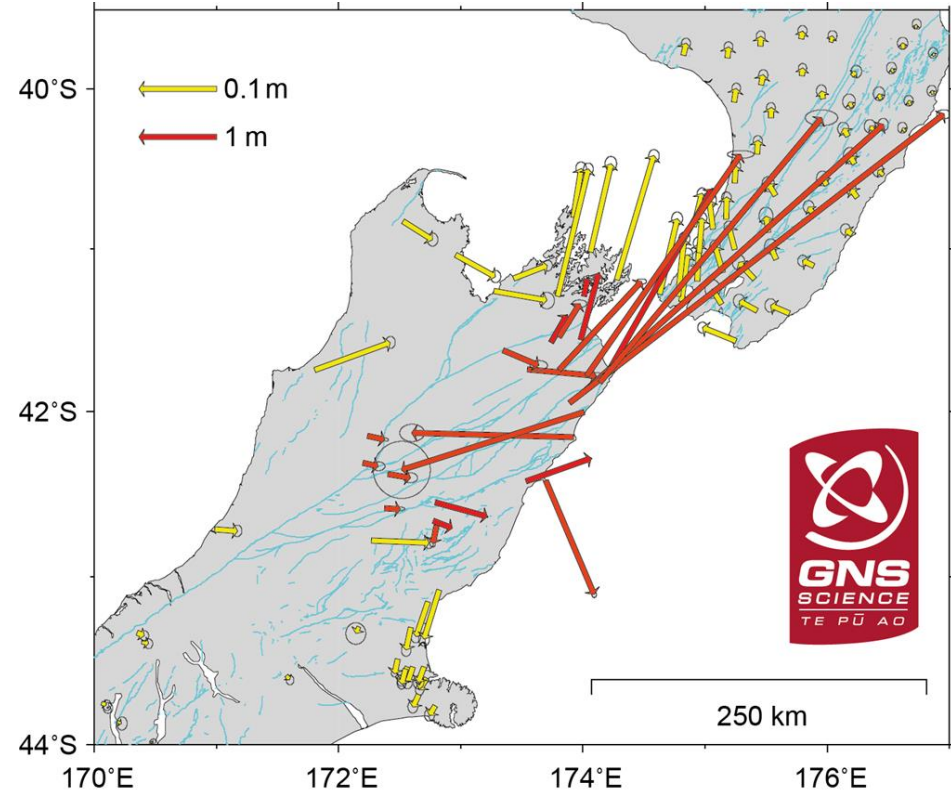
Fig. 6. Best fitting slip model including an interface source. (A) Best fitting slip models for the Kaikōura earthquake with the inclusion of an interface source. **(B)** Observed and modeled surface displacements at continuous and campaign GPS based on the interface model. **(C)** Slip distribution for only the interface, black lines show the location of the corresponding crustal faults shown in (A). **(D)** Difference in slip on the crustal faults when including the subduction interface as a source. Blue colors show areas where more slip is predicted by the interface model and red areas where more slip is predicted by the crustal only model. Moment tensors are for USGS CMT and two fault models for comparison.

Kaikoura Earthquake

Aftershocks, Nov 13th - 30th, depth <25 km

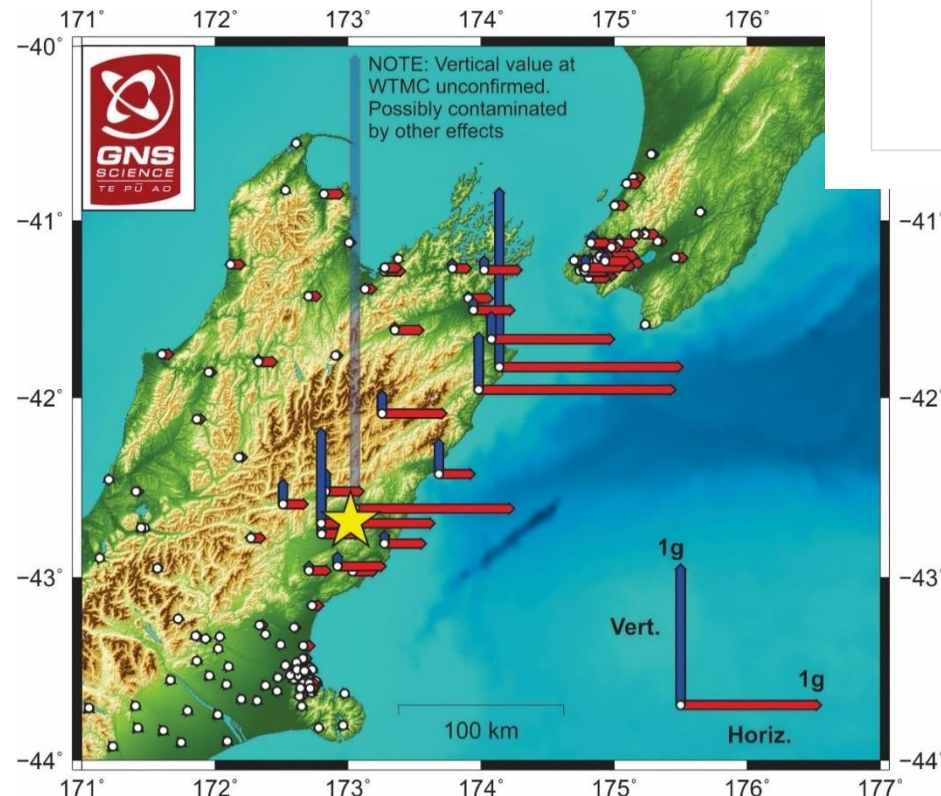
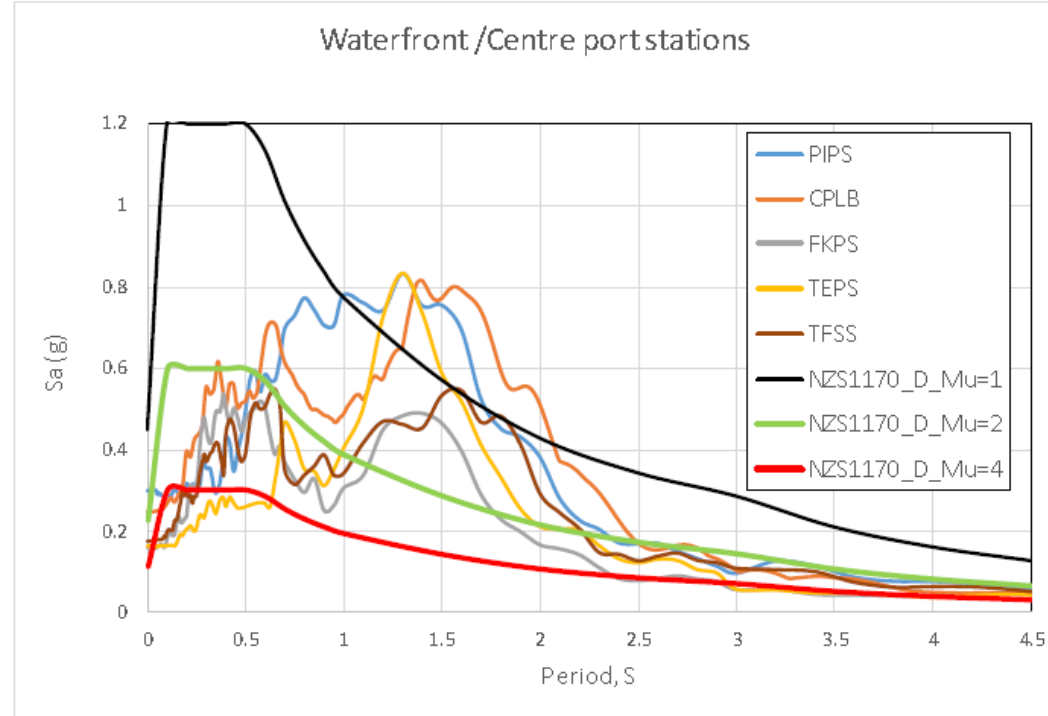


Geodetic station displacements
Hmax: 6m; Vmax: 2m



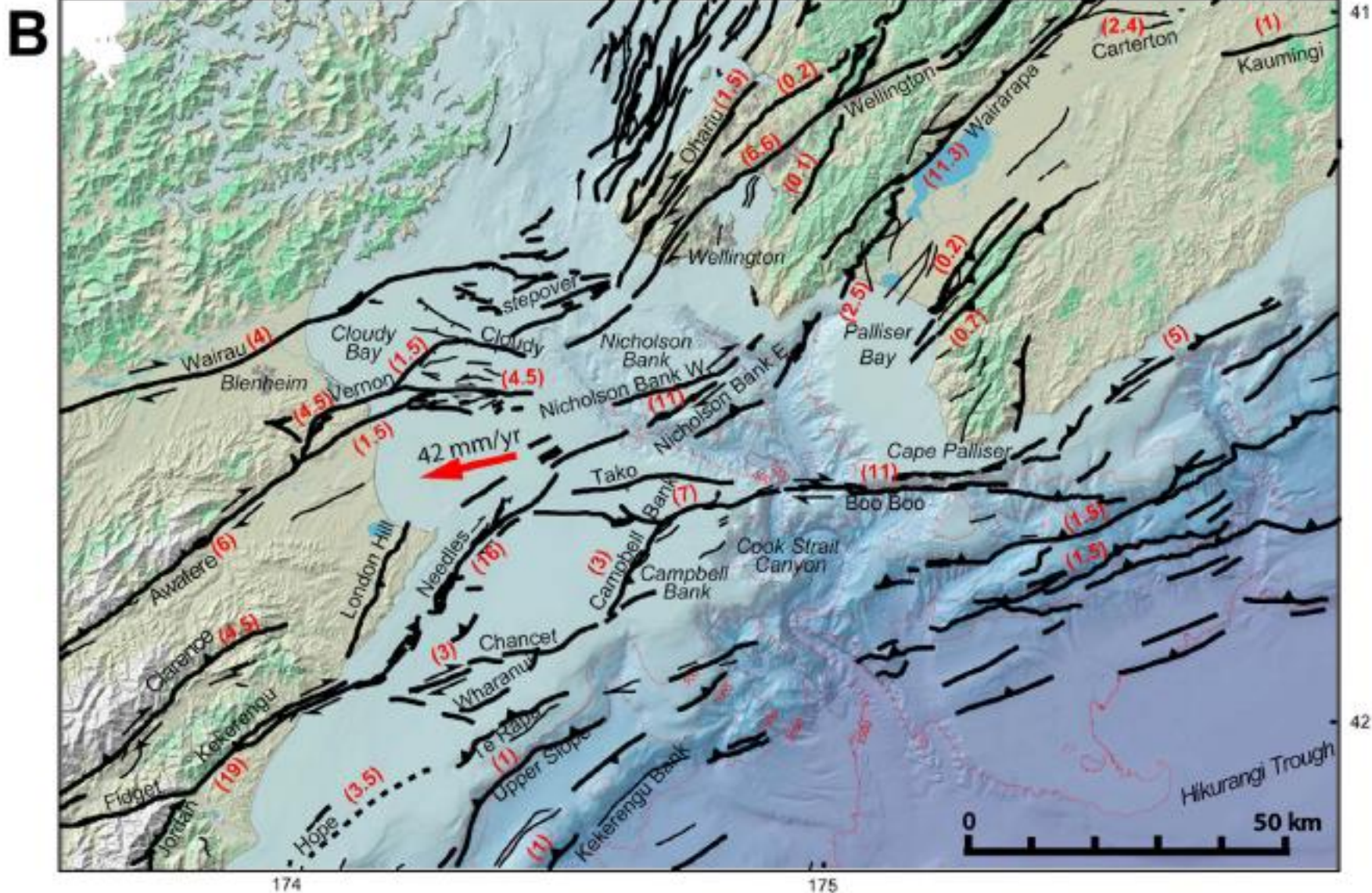
Ground Motions

- Two 'nodes' of large motions – epicentre and northeast
- Similar ($>1g$) to Christchurch
- Because of directivity effects in Wellington $>$ Christchurch



- In Wellington shaking damage dependent on ground conditions and building height
- Motions exceeded earthquake-prone criteria
- For taller buildings especially on weak soils or at basin edges motions exceeded building code

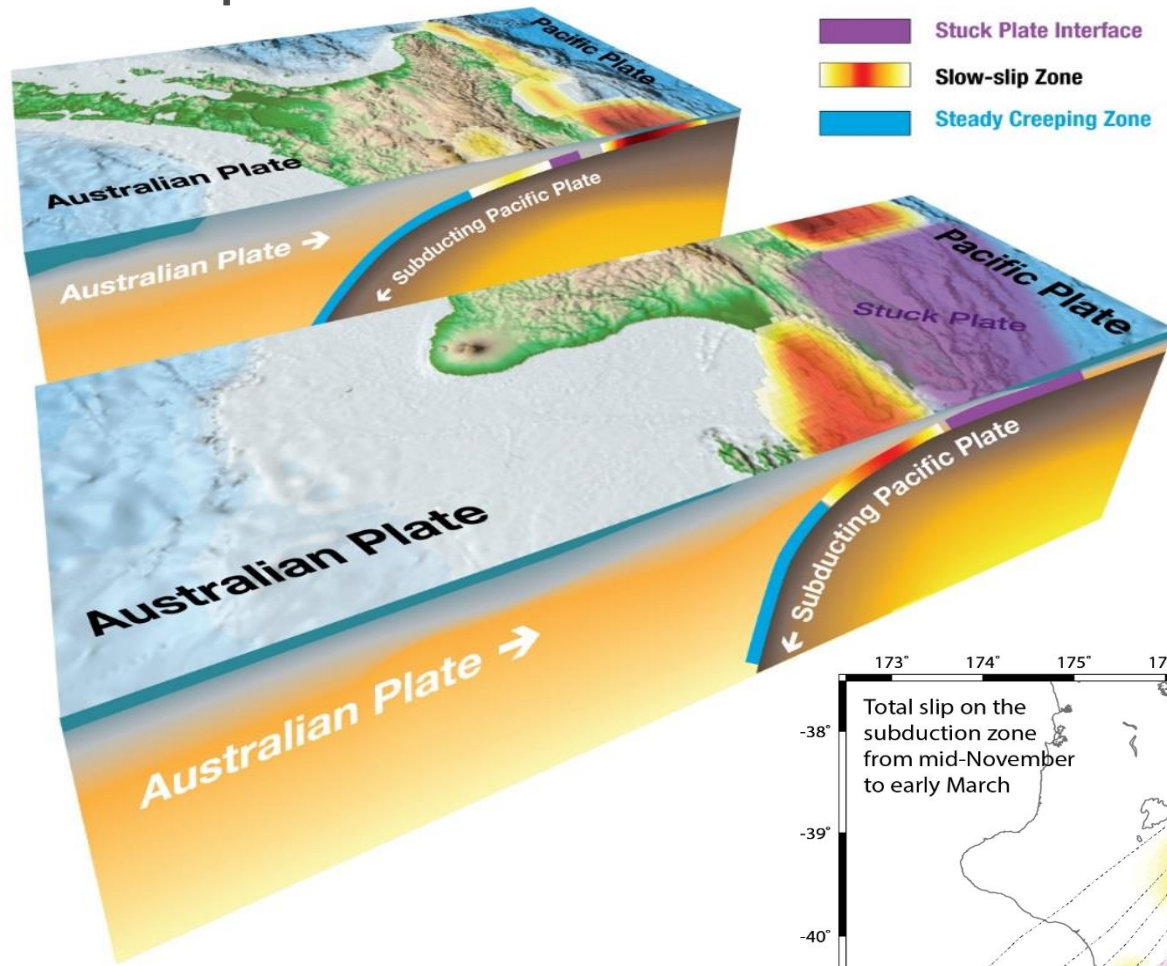
Kinematics in the transition zone



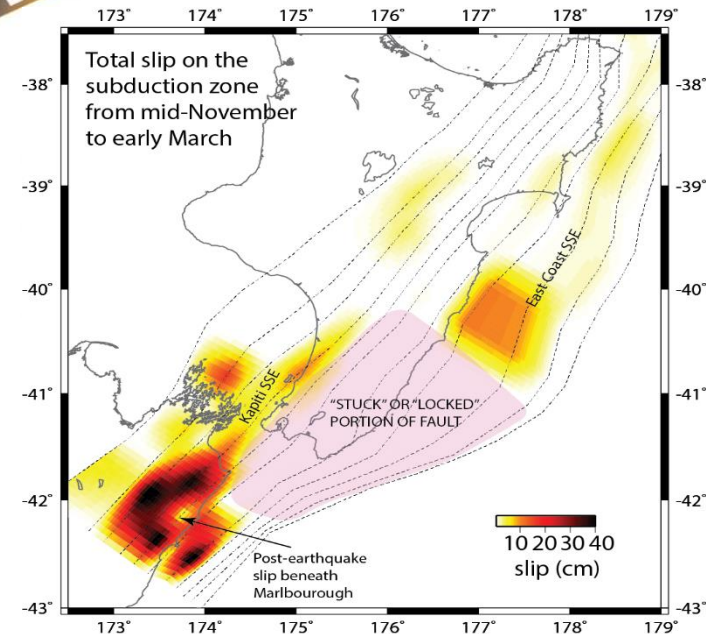
Wallace et al., 2012

2. Kaikōura Earthquake

Kaikōura earthquake & slow slip



Slow slip events started along the whole margin within 1 week of Kaikōura EQ

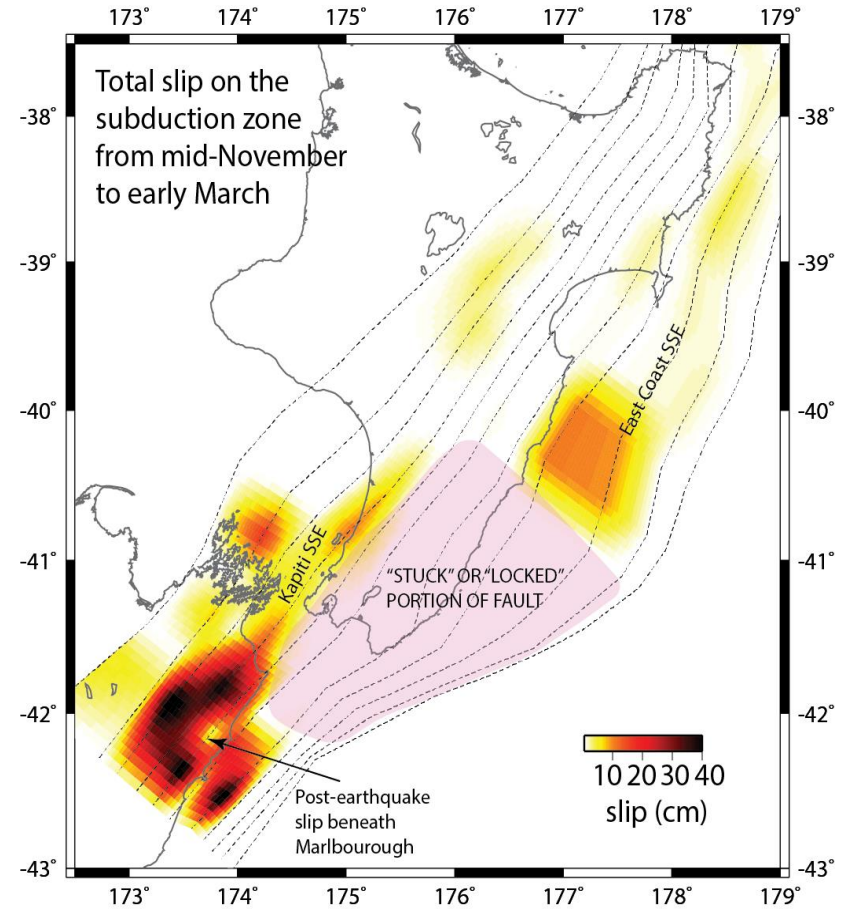
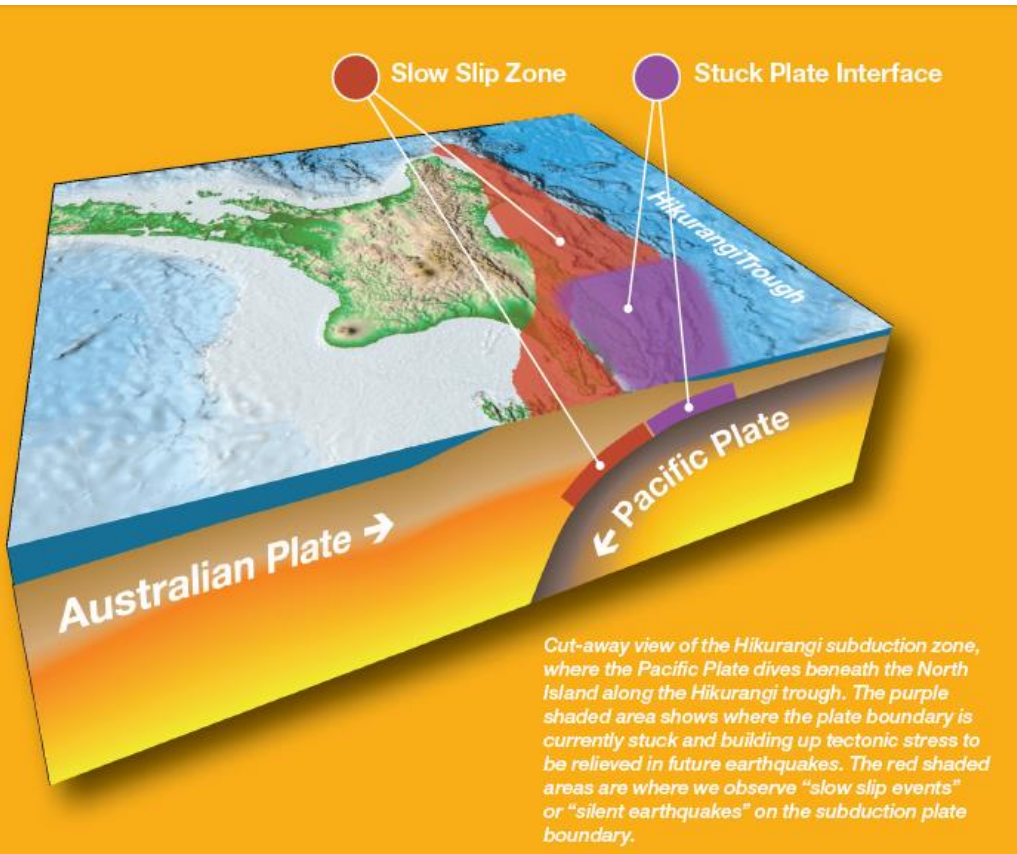


What are the scenarios following the Kaikōura Earthquake?

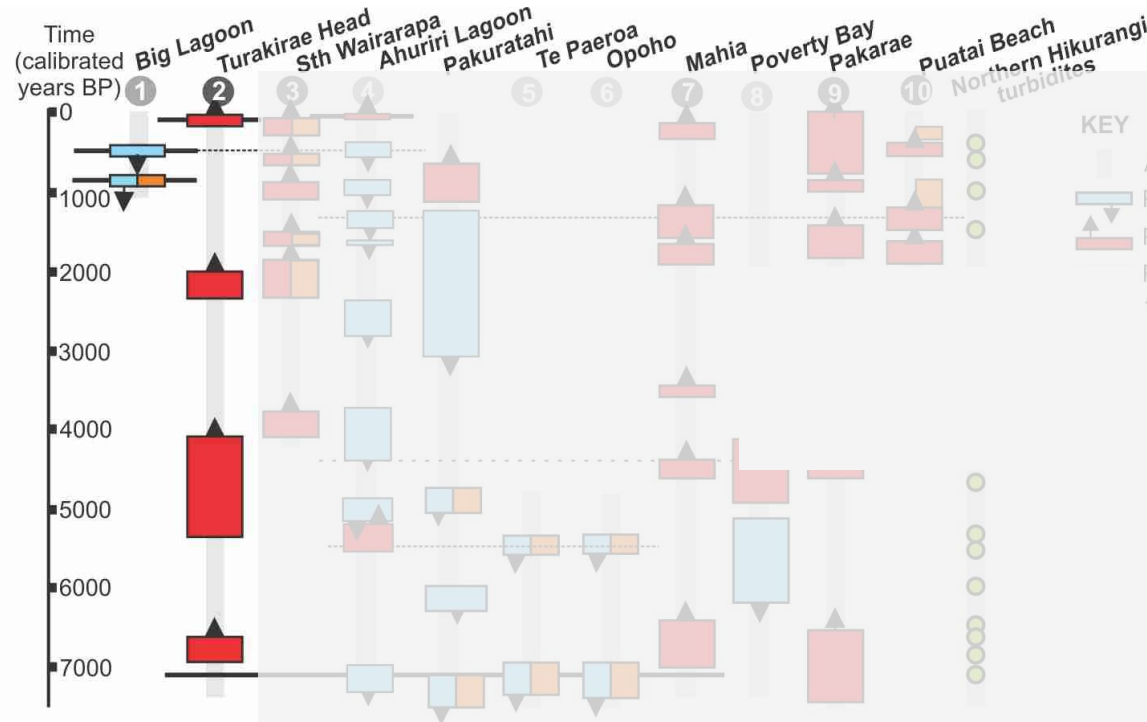
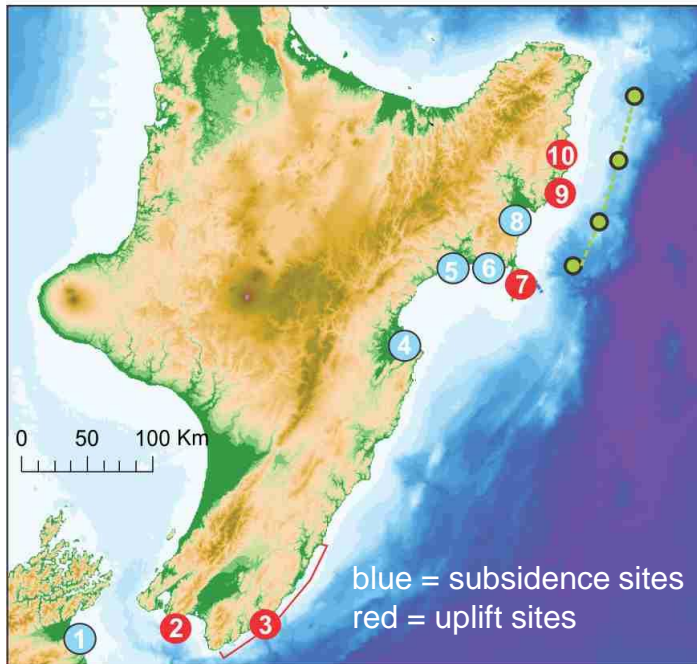
- **Scenario One: Likely (70% within the next year)**
 - Aftershocks will continue to decrease in frequency over the next year and no aftershocks of M7 or larger will occur, but a M6+ is very likely.
- **Scenario Two: Unlikely (approximately 25% within the next year)**
 - An earthquake smaller than the main shock but between M7.0 and M7.8 will occur (*a fault in Cook Strait is one of the possibilities*)

Scenario Three

- Could we have a mega earthquake here?
- Current thinking is about a 1 in 20 chance of a M8+ in the coming year



Past Hikurangi margin earthquake activity



Most Recent Subduction EQ's in Wellington region

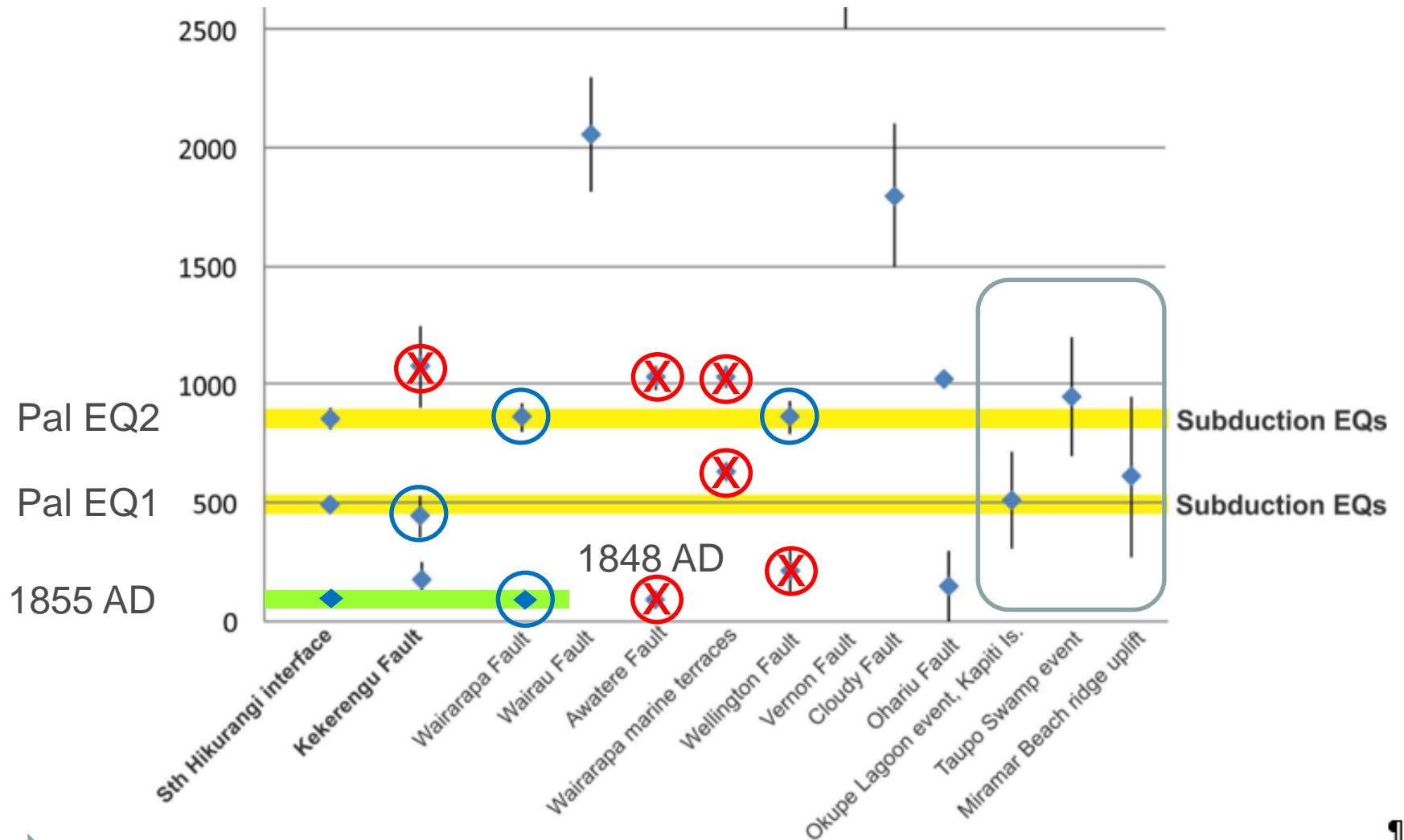
1855 AD


EQ1 – 520-470 cal yBP

EQ2 – 880-800 cal yBP

- Broad pattern on inboard subsidence & outboard uplift
- Some sites uplift and subside
- Major contributions to uplift (& subsidence??) from upper plate faults
- Untangling the upper plate & interface records is the main challenge

Correlation of major shallow events with subduction mega-quakes




 a partial correlation exists – subduction earthquakes have sometimes occurred at the same time, or before, or after, upper plate fault rupture

More Broadly – what should we be preparing for ?

Event	Likelihood in next 50 yrs	Possible economic loss (2015 estimates)
• Alpine fault - M8 earthquake	30%	>> \$10bn
• Ruapehu/Tongariro/Ngauruhoe White Island major eruption	almost certain	> \$1bn
• Taranaki eruption	20%	> \$10bn
• Hikurangi subduction zone M8+ and tsunami	30%	\$30-40bn
• Hope fault M7.2 earthquake	50%	~\$1bn?
• South America M9+ earthquake & NZ tsunami	50%	>\$1bn?
• Taupo region major eruption	10%	>> \$10bn
• Auckland volcanic eruption	5%	~ \$30bn
• NZ earthquake sequence like 1929-1942	50%	>> \$10bn
• Wellington fault earthquake	5%	\$40-60bn

Note: New Zealand GDP 277B NZD (2013)

What can be done?

- Continue research to extend and refine past record of major events
- Evaluate consequences of those events and judge levels of acceptable risk
- Use available risk management options – accept, reduce, avoid, transfer
- Plan, exercise, develop contingency plans – personal, family, community, city, country



Drop, Cover and Hold is still the right action to take



Drop, Cover and Hold



long or strong, get gone