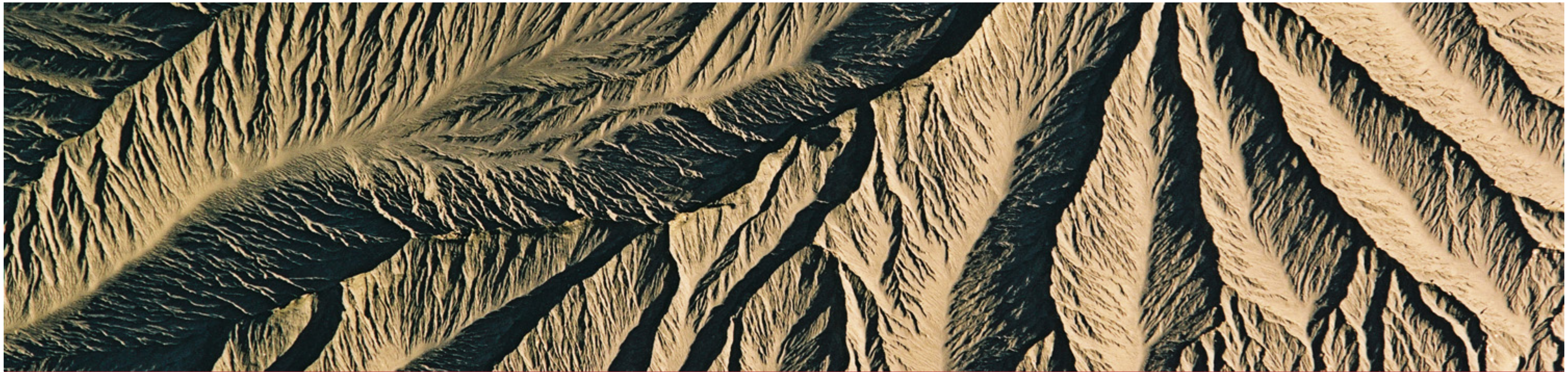
Guidelines for better science advice: Examples from applications in natural hazard assessments

Annemarie Christophersen

COST meeting, Delft 3 – 5 July 2017

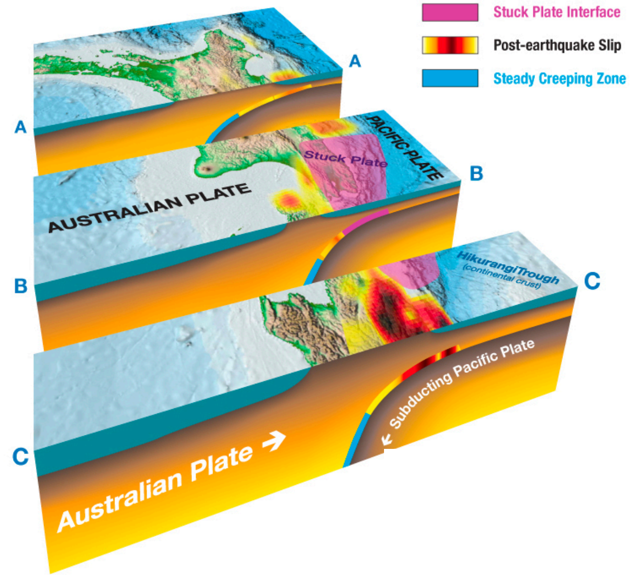
Our challenges

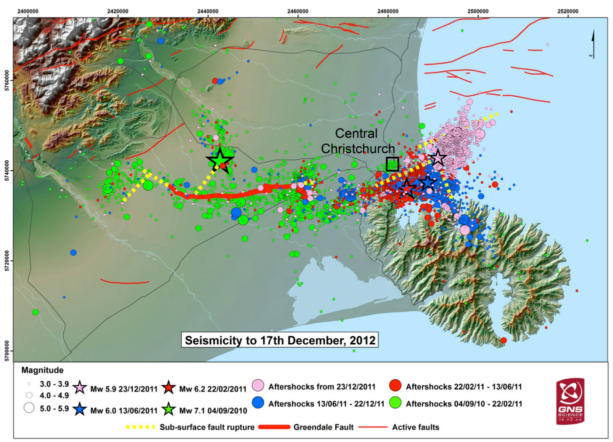
- How to conduct unbiased and defensible model development?
- How to develop appropriate calibration questions?
- How to ease the elicitation burden, especially for many probabilities in Bayesian network?
- What is the minimum in procedures/processes to get a defensible answer?

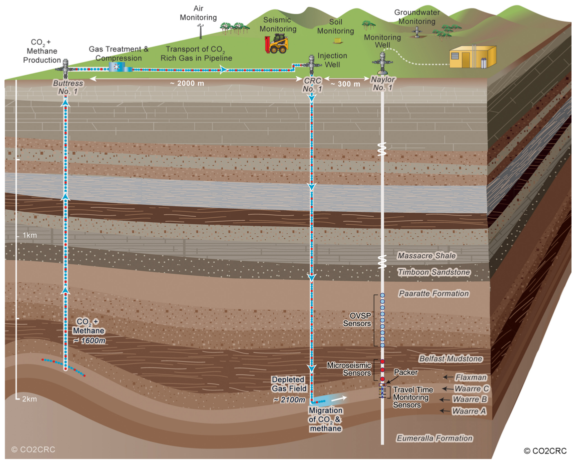


Outline

- Probabilistic Seismic Hazard Assessment
- Risk assessment for carbon capture and storage
- The probability of a volcanic eruption
- The probability of another very large earthquake
- Summary







Probabilistic seismic hazard model for Christchurch

The aim and use

Informing rebuilt of Christchurch
Setting building code standards

Model

Probabilistic Seismic Hazard

- Smoothed seismicity model
- Fault model
- Ground motion prediction equations

The topics

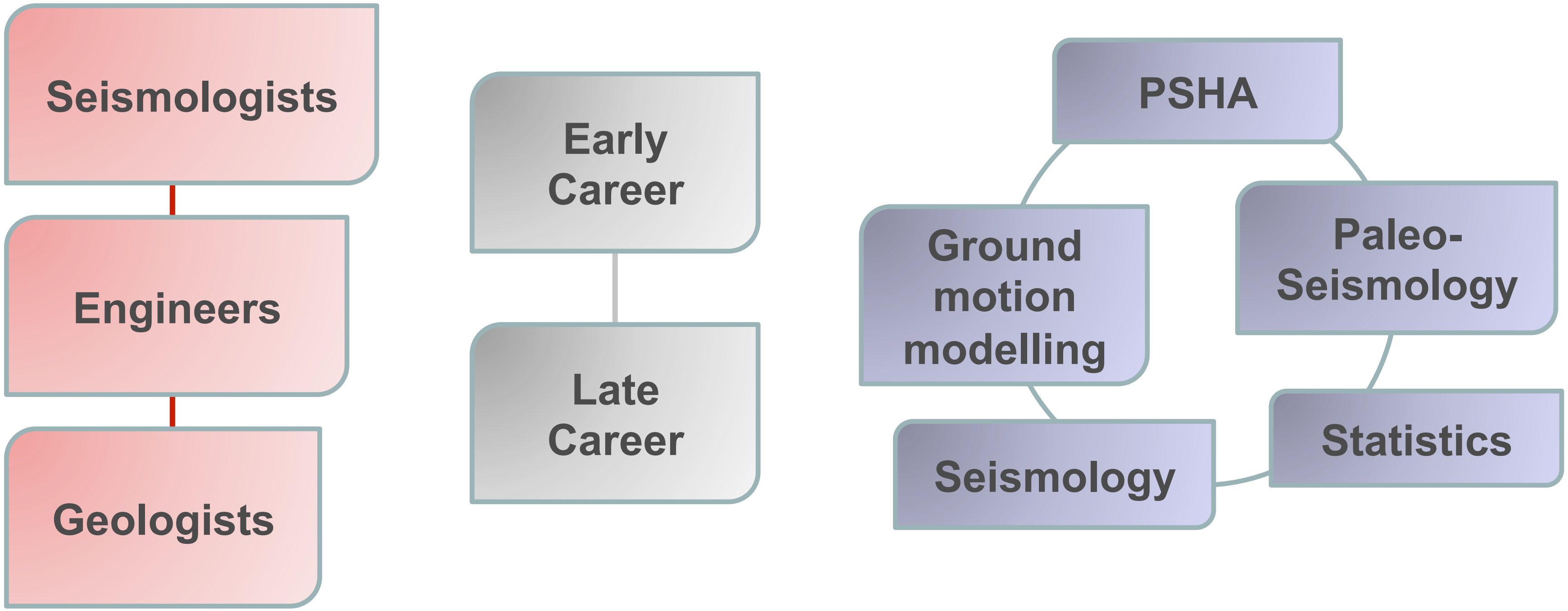
Geology, seismology, statistical seismology, PSHA, ground motion prediction

The Experts

Carefully selected

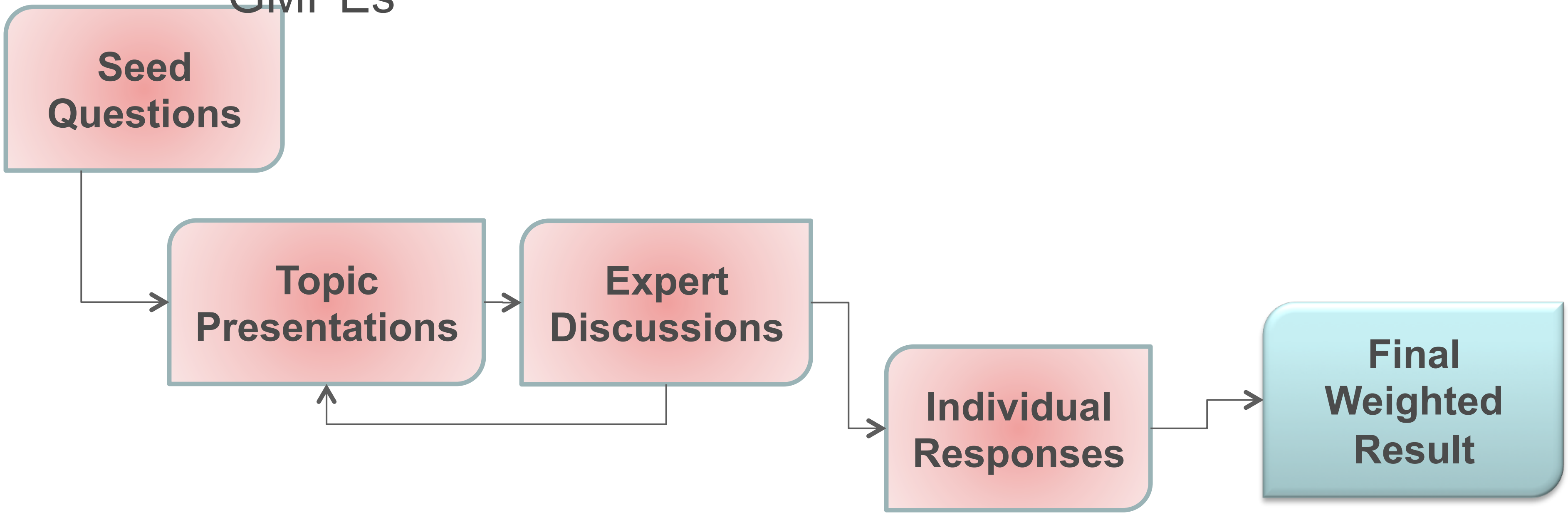
The Experts

- Covering a similar & broad range of expertise, experience and point in career



Elicitation

- Model development: Informal discussion in a series of conference call with and without screen sharing and video
- Model quantification: 2 workshops
  - Workshop 1: 3 days, 12 Experts & 50 target questions covering source models to GMPEs
  - Workshop 2: 1 day, 5 experts & 12 target questions on GMPEs



Issues

- Experts had no involvement in the model development
- Calibration questions useful to set the scene and establish thought processes for answering the target questions but concept challenging for some experts and time-consuming to develop
- Analysts uncomfortable that one experts got nearly all the weight

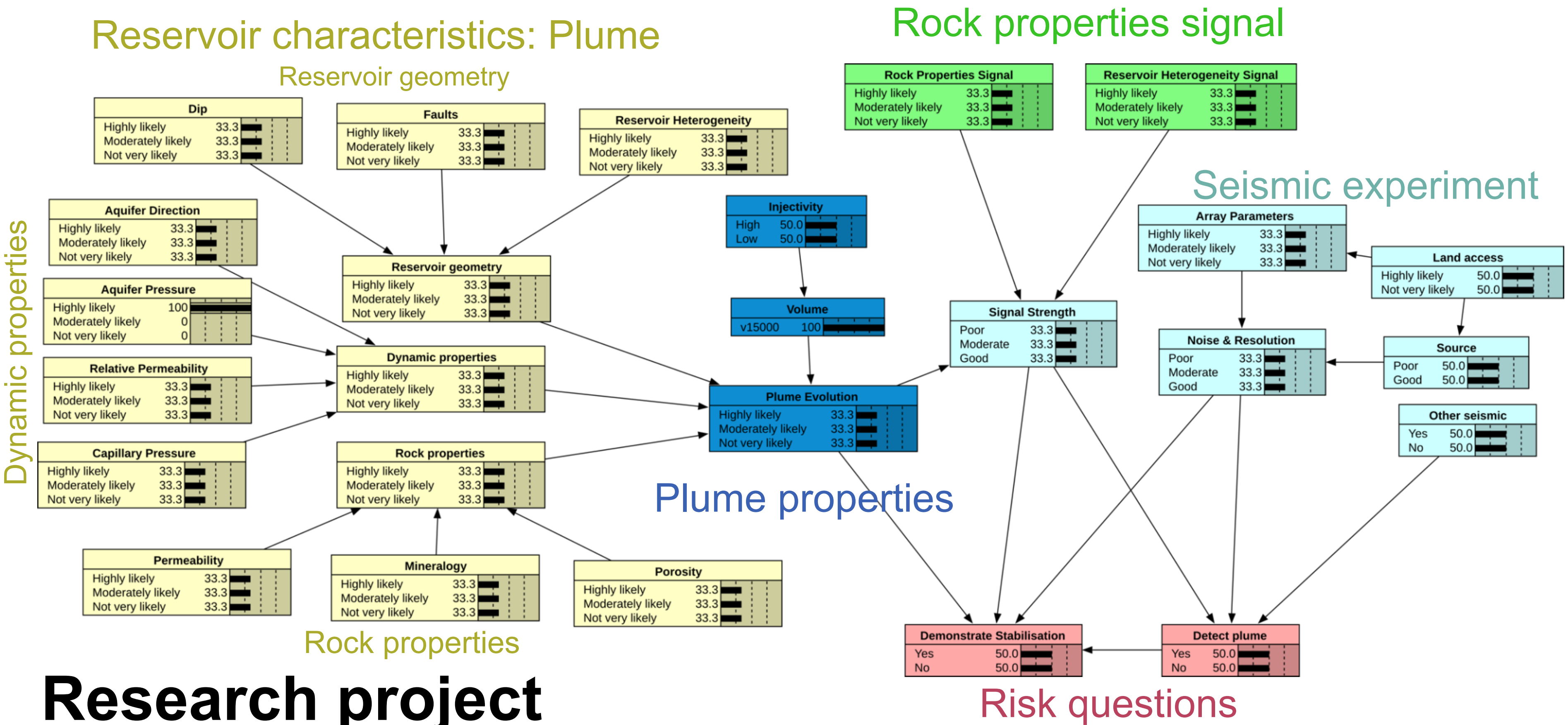
Publications

- Gerstenberger MC, McVerry G, Rhoades DA, Stirling M. 2014. Seismic Hazard Modelling for the Recovery of Christchurch, New Zealand. Earthquake Spectra. 30(1):17-29. doi: 10.1193/021913EQS037M.
- Gerstenberger MC, Rhoades DA, McVerry GH. 2016. A hybrid time-dependent probabilistic seismic-hazard model for Canterbury, New Zealand. Seismological Research Letters. 87(6):1311-1318. doi:10.1785/0220160084.

Risk assessment in carbon capture and storage

The aim and use

Detecting CO_2 plume with 4D seismic experiment



Research project

Model

Bayesian network to determine the probability that a CO_2 plume can be imaged by seismic survey and that the plume will stabilise over time.

The topics

Geology, geophysics, reservoir modelling

The Experts

Mainly from within the project

Expert elicitation

- Model development: Informal discussion in a series of conference call with and without screen sharing and video
- Model quantification: Workshop for 2 half days, 12 Experts; ~130 probabilities to assess

Issues

- Challenge to develop the model structure and get agreement
- Challenge to get acceptance of calibration questions and very time consuming to develop calibration questions
- Initial reluctance, both to BBN as well as structured expert elicitation but positive feedback afterwards.

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A Bayesian network and structured expert elicitation for Otway Stage 2C: Detection of injected CO_2 in a saline aquifer

M.C. Gerstenberger[a,b], A. Christophersen[a,b,*]

[a] GNS Science, Lower Hutt, New Zealand
[b] CO2CRC Limited, Melbourne, Australia[1]

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ABSTRACT

This paper describes, to our knowledge, the first application of a Bayesian network (BN) with structured expert elicitation in risk assessment of carbon storage. The BN estimates the probability that the CO2CRC Otway Stage 2C experiment is successful in detecting a CO_2 plume injected into a saline aquifer and in confirming stabilisation of the plume using a 4D seismic survey. To develop the BN structure, Otway Stage 2C scientists and managers identified the key variables impacting the success of the experiment and their relations. To estimate the conditional probabilities required to quantify the BN, we applied the Classical Model. This is a non-consensus procedure for combining expert judgement that involves weighting a group of experts according to their ability to judge uncertainties accurately and informatively. The experts participated in open discussion about the BN and provided, individually, all probabilities required to complete the BN. The primary result was a 74% probability of detecting the plume, and a 57% probability that there will be consistency between the model-predicted plume behaviour and the observations.

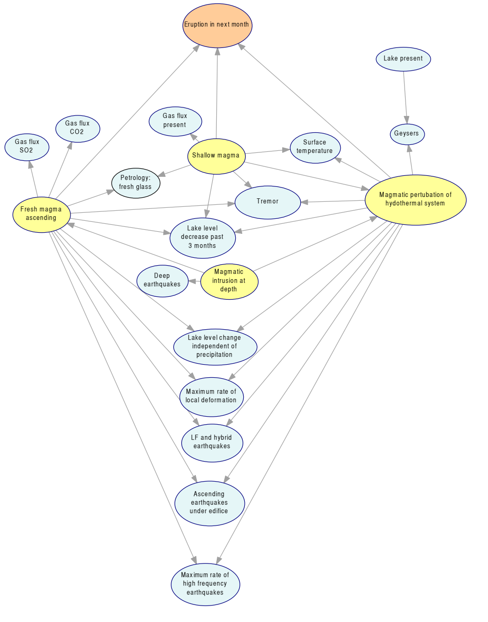
Forecasting volcanic eruptions on White Island

The aim and use

Apply the tools and methods that we learned so much about in previous two projects to other areas

Contribute our methods of risk assessment to the life-risk question for visiting volcanoes.

Research project



The model

Bayesian network based on published work

The topics

Seismology, geology, geochemistry, volcano hazard modelling

The Experts

Mostly from within volcano monitoring team; two external experts from New Zealand universities attended workshop

Expert elicitation

- Model development: Informal discussion with some key members of volcano monitoring team
- Model quantification: Workshop for 2 half days, 11 Experts; ~100 probabilities plus their uncertainties assessed

Issues

- Challenge to develop the model structure and get agreement; every experts wanted changes; different disciplines have different conceptual model
- Challenge to develop calibration questions; only the concept introduced in workshop
- Volcanologists not keen on hard boundaries; setting thresholds

Issues continued

- 11 White Island models that mostly overpredict the eruption probability in the next month
- Struggle to secure funding for the work
- Challenging to get engagement from some; and near impossible to get group times

Highlights and outlook

- Bayesian network great communication tool
- Many new learnings and insights
- Volanologists primed for calibration
- Preparing manuscript on the experience so far
- Started work on continuous BN with head of department volcanology

Kaikoura earthquake: Tectonic setting

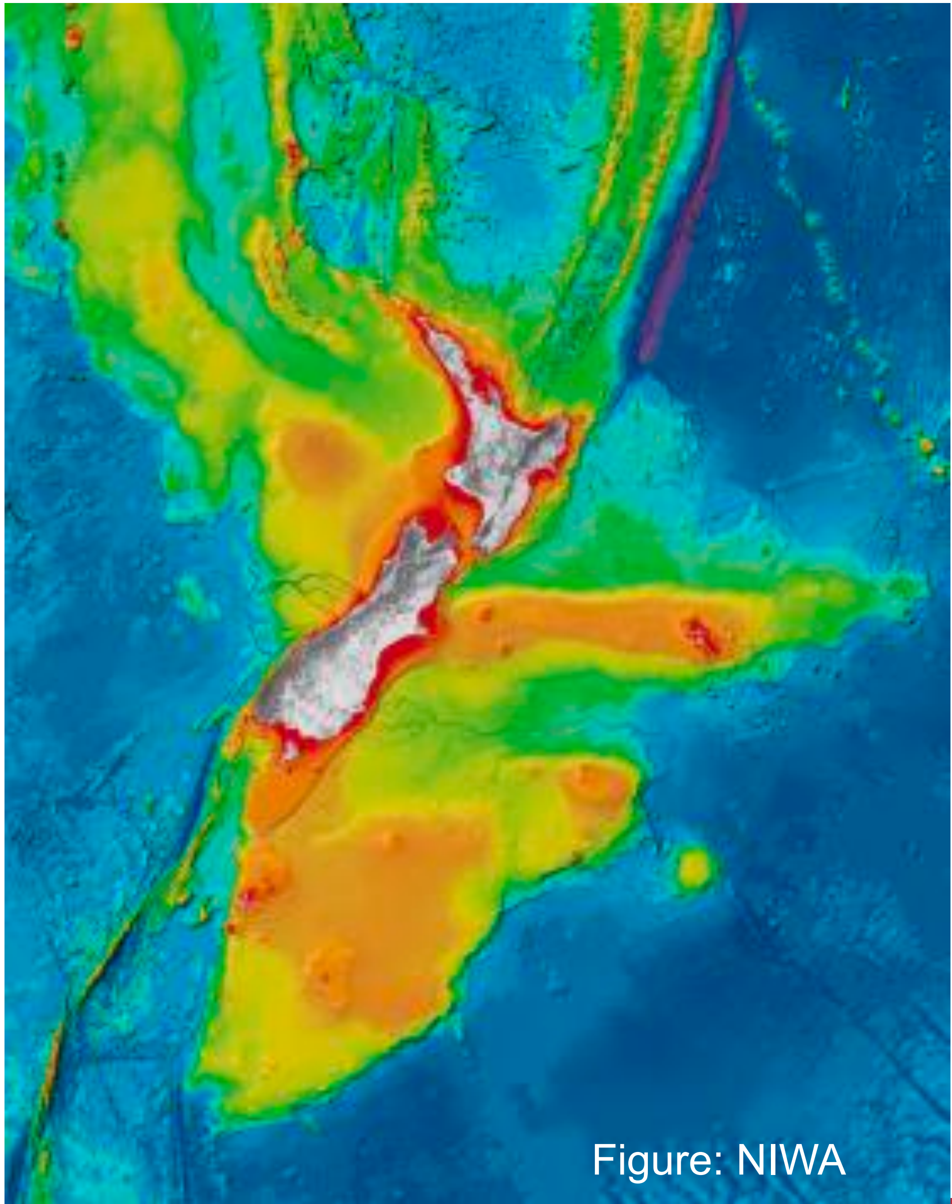


Figure: NIWA

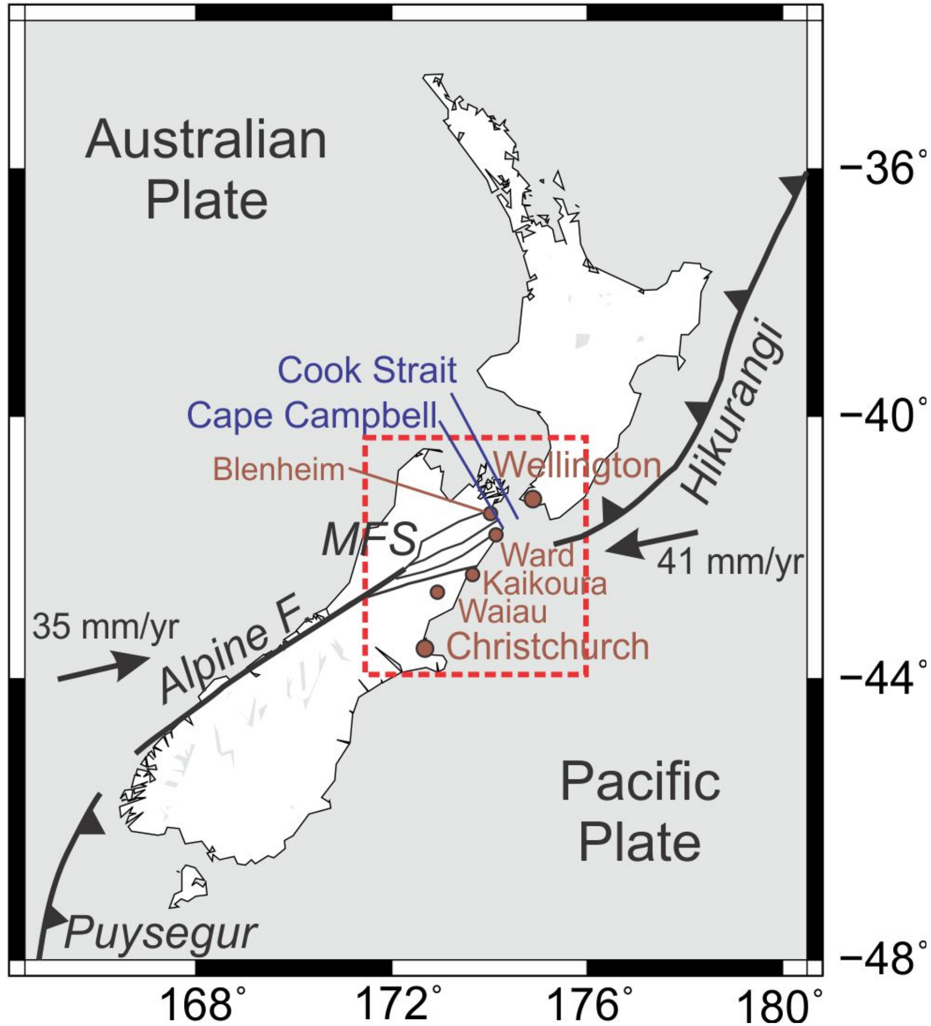
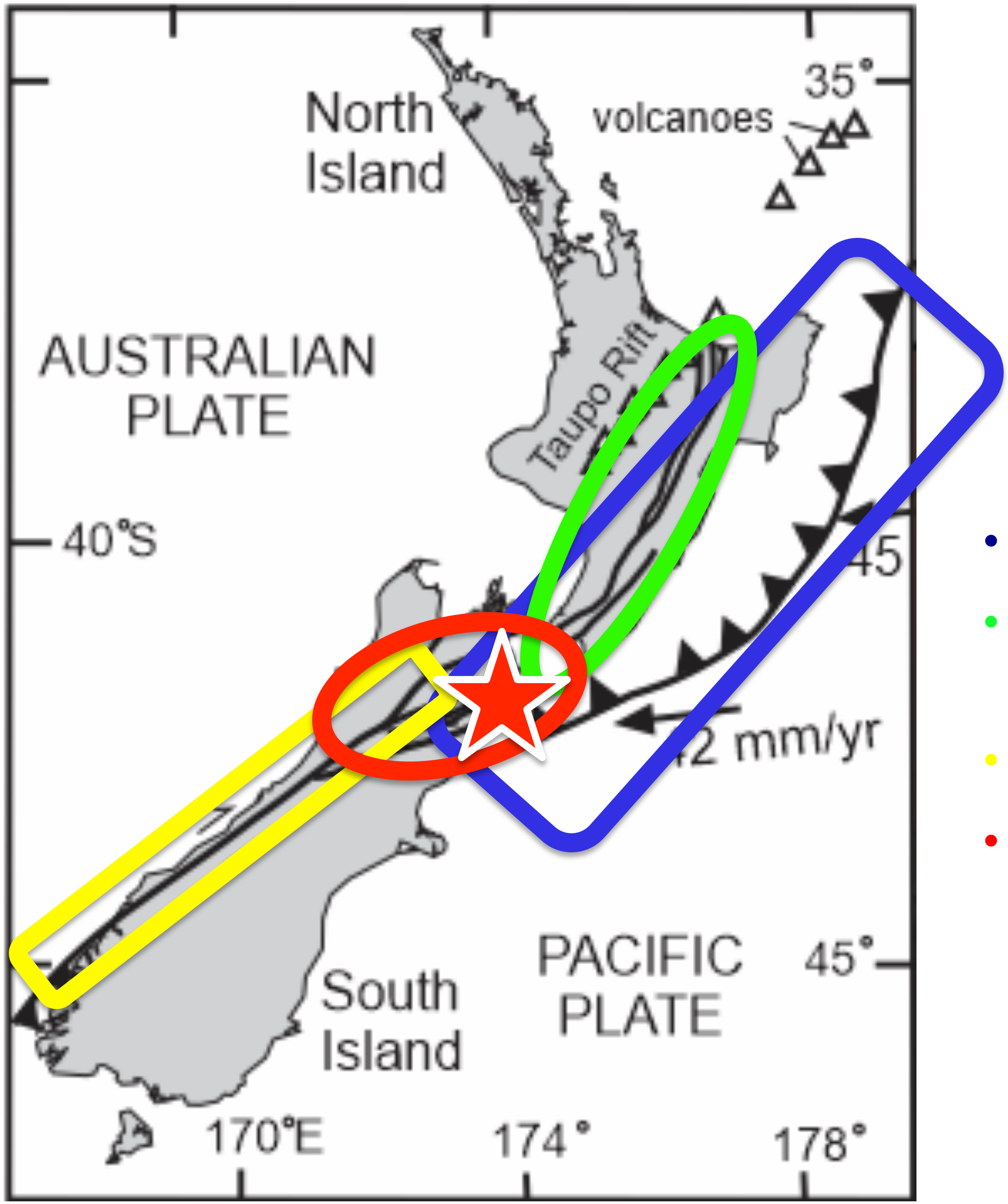


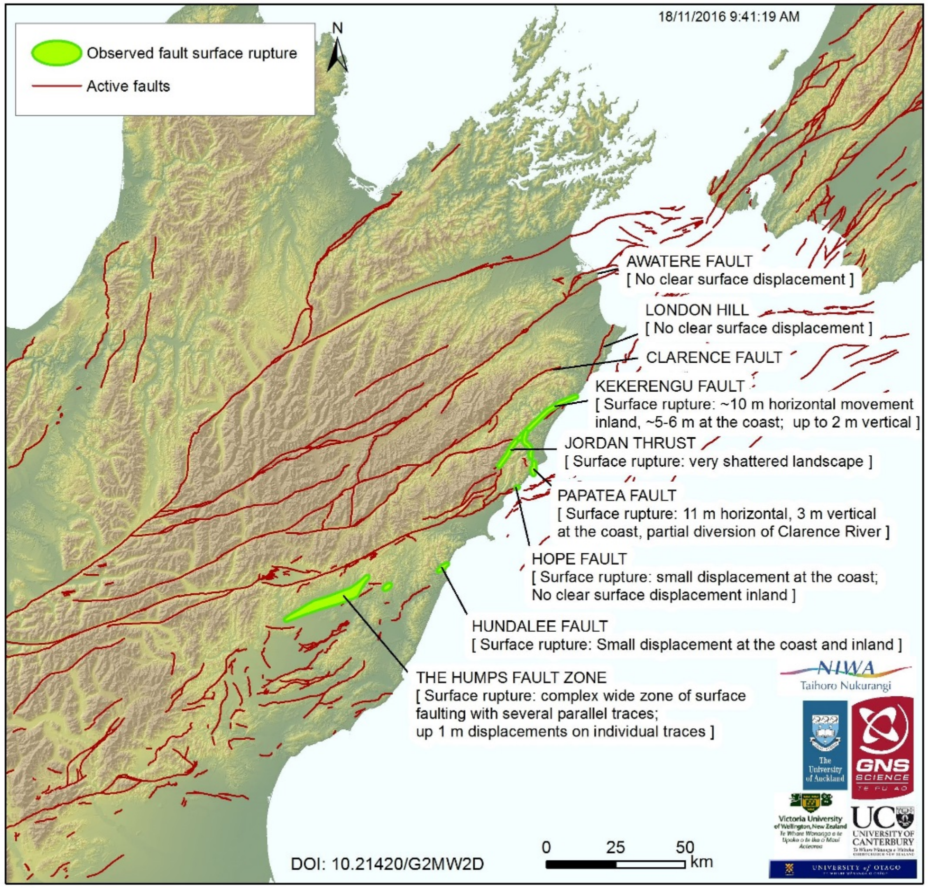
Figure: GNS Science

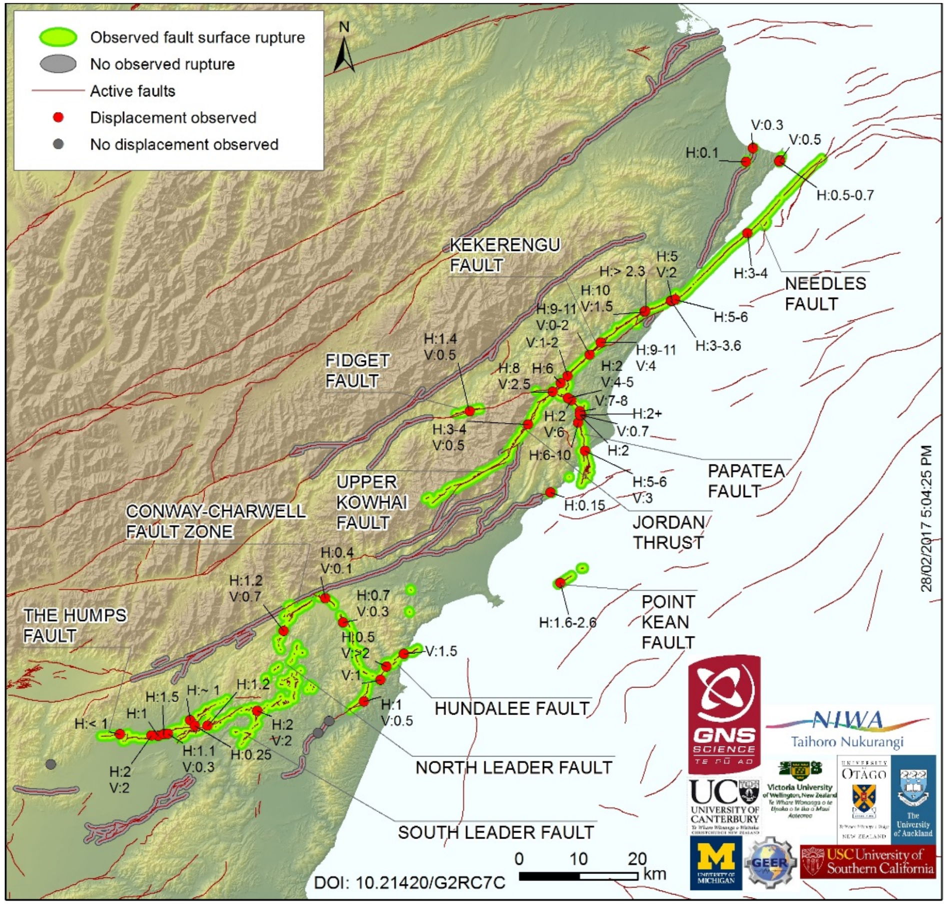


Major elements of New Zealand Plate Boundary

- Hikurangi Subduction Zone
- North Island Dextral Fault Belt
- Alpine Fault
- Marlborough Fault System

Fault ruptures



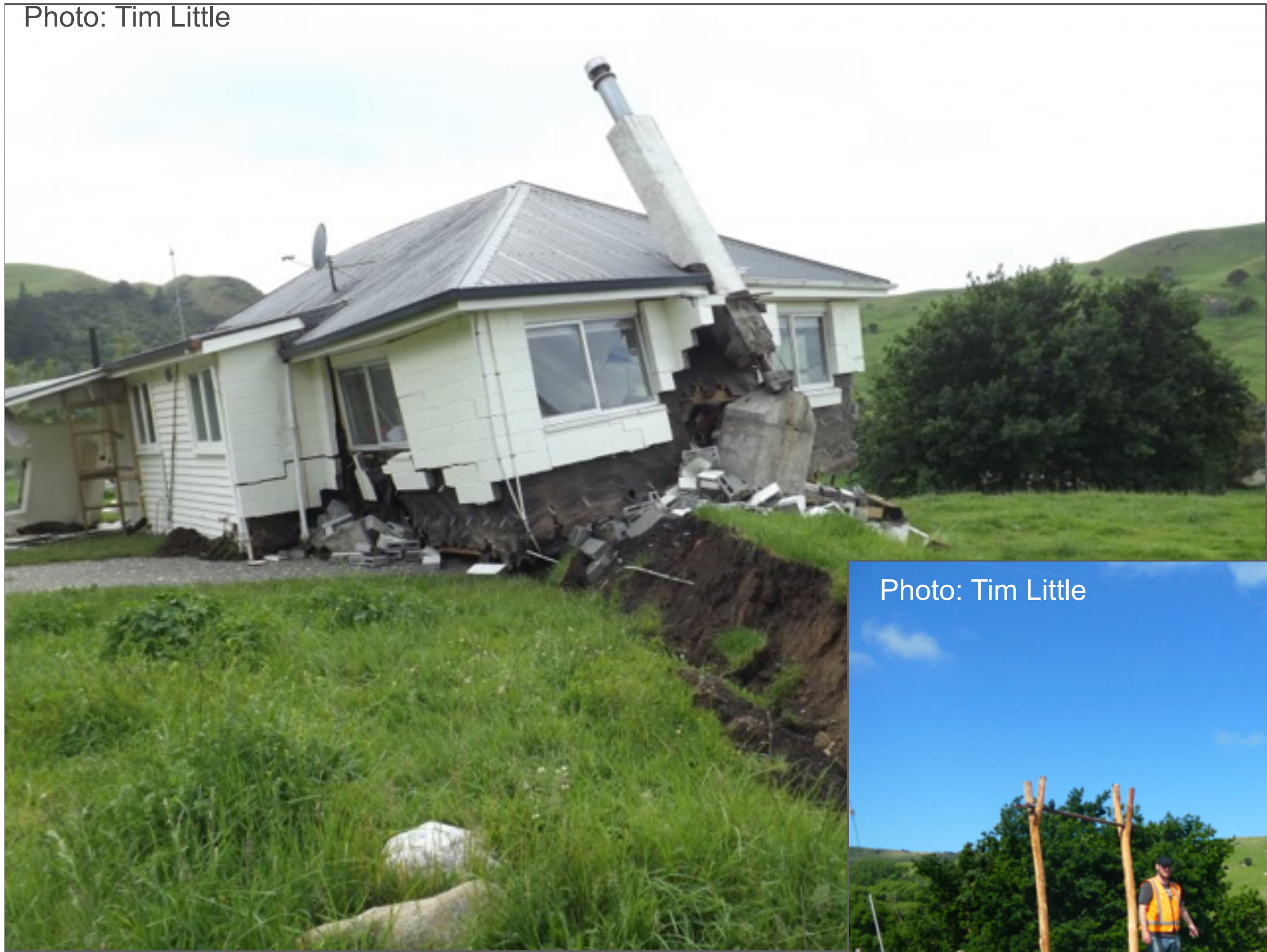


5 fault ruptures

– we thought that was a lot!

21 faults, 180 km of surface rupture

Kekerengu Fault: Bluff Station Cottage

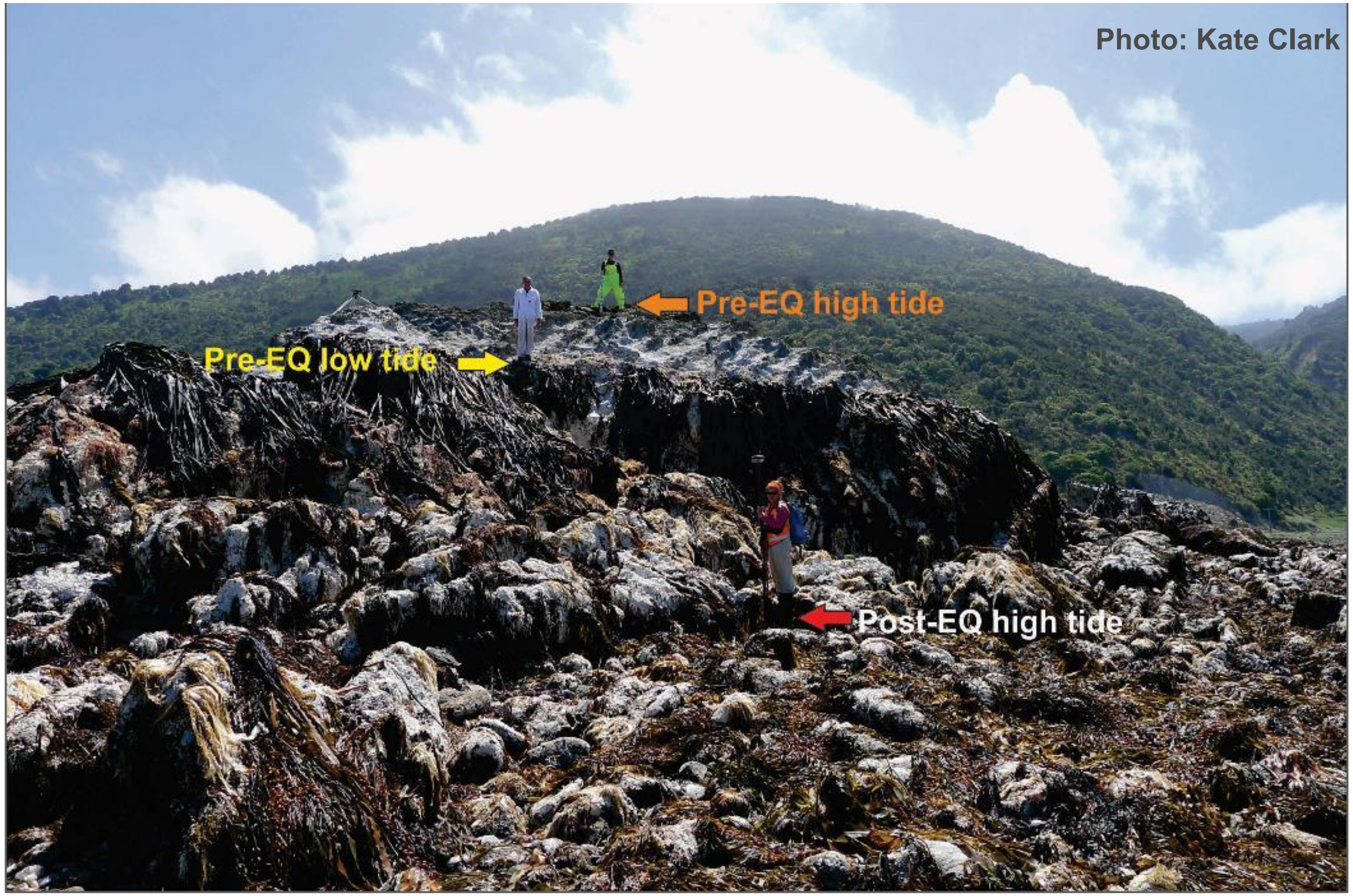


Bluff Station Cottage

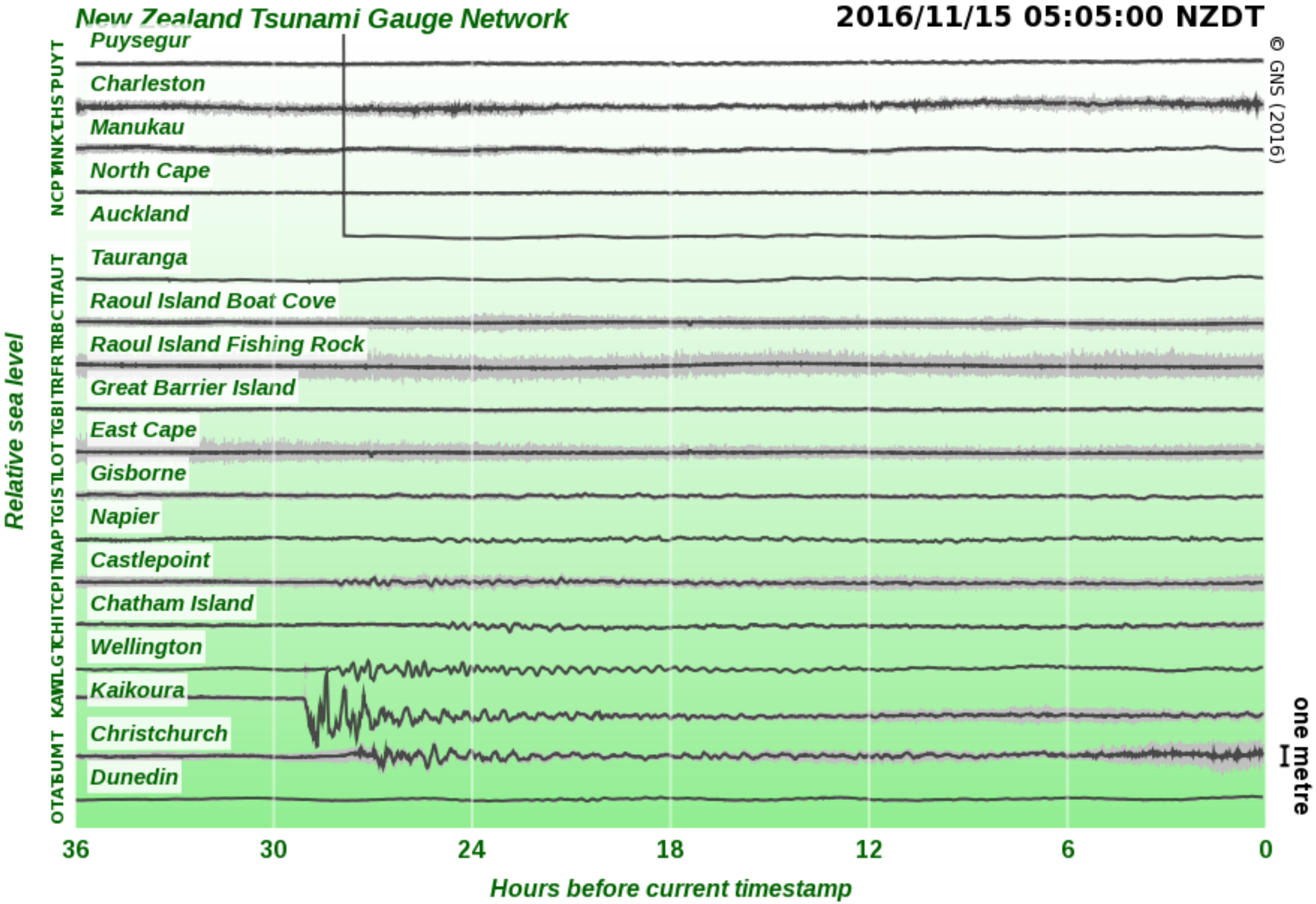
Photo: Julian Thomson

- Four large earthquakes in the last ~1,200 years now including the 2016 Kaikoura earthquake

Coastal Uplift



Tsunami



New Zealand Tsunami Gauge Network
2016/11/15 05:05:00 NZDT
Puysegur
Charleston
Manukau
North Cape
Auckland
Tauranga
Raoul Island Boat Cove
Raoul Island Fishing Rock
Great Barrier Island
East Cape
Gisborne
Napier
Castlepoint
Chatham Island
Wellington
Kaikoura
Christchurch
Dunedin
PUYT
CHST
MNKT
NCPT
AUCT
TAUT
RBCT
RFRT
GBIT
LOTT
GIST
NAPT
CPIT
CHIT
WLGT
KAIT
SUMT
OTAT
Relative sea level
© GNS (2016)
one metre
36
30
24
18
12
6
0
Hours before current timestamp

Landslides

- ~100,000 landslides were triggered by the earthquake and subsequent aftershocks.

- ~50 of them yielded significant landslide dams (lakes & ponds)

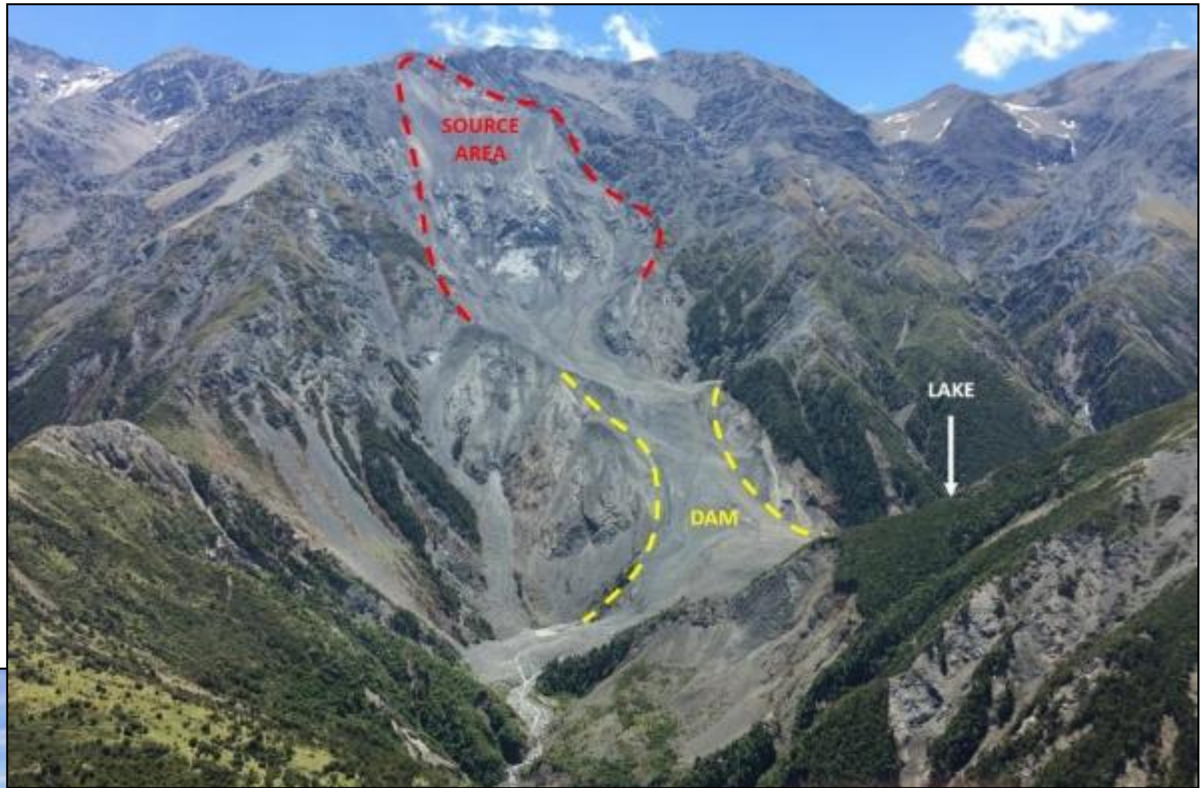
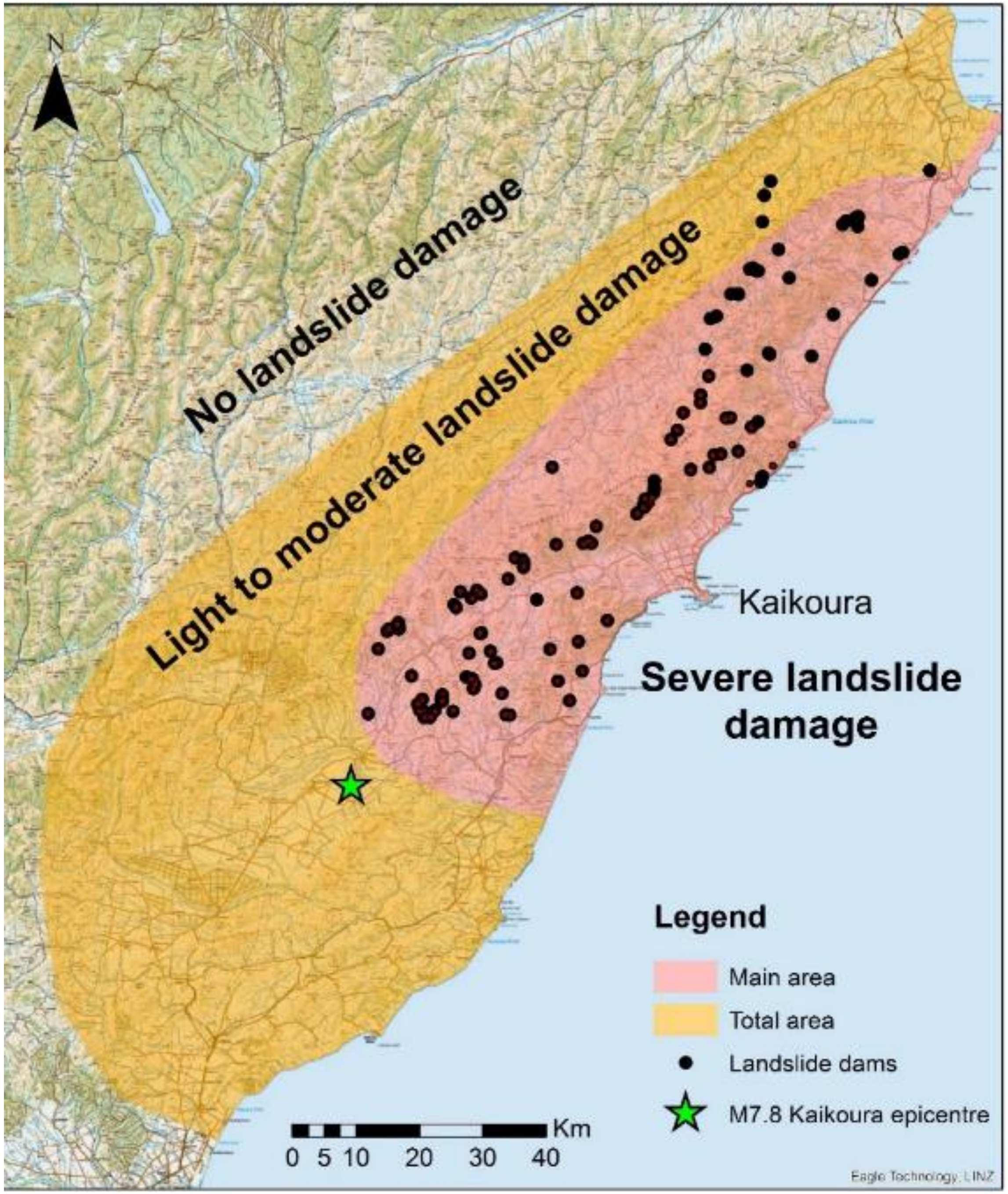
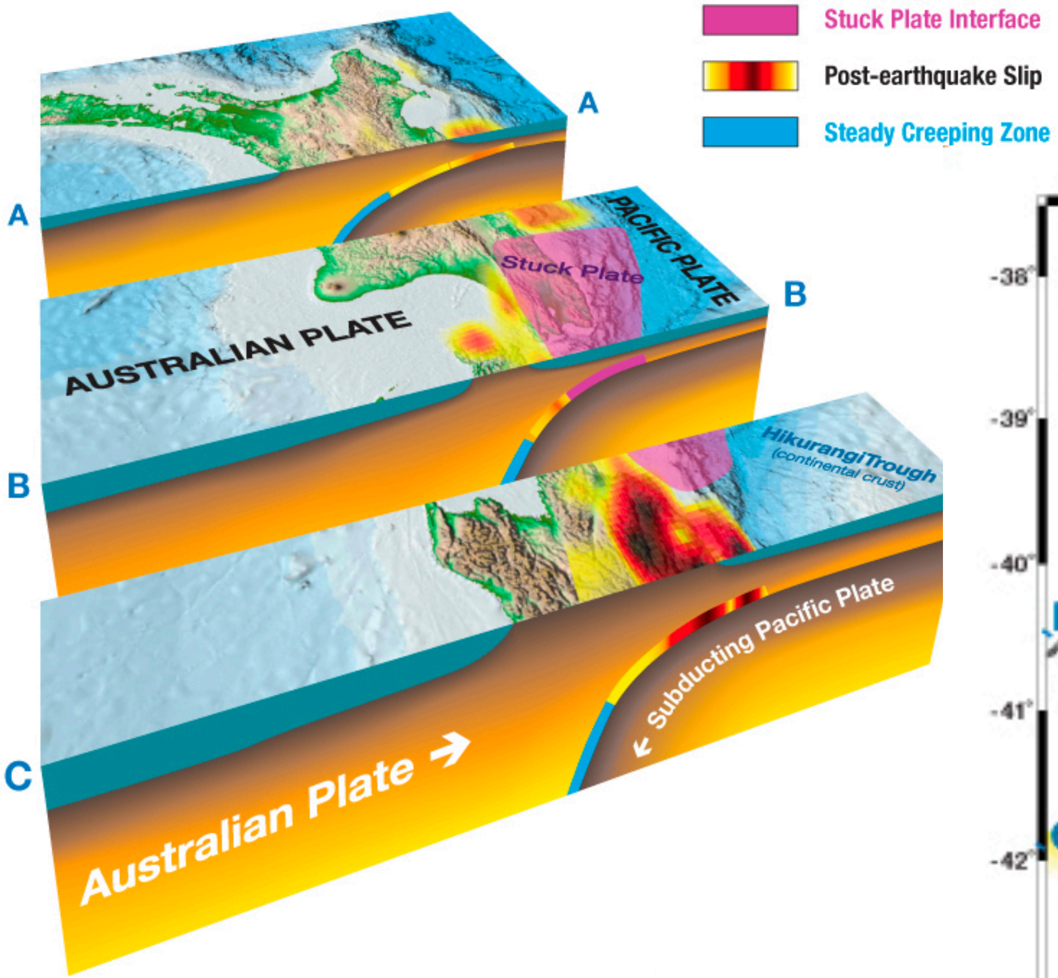


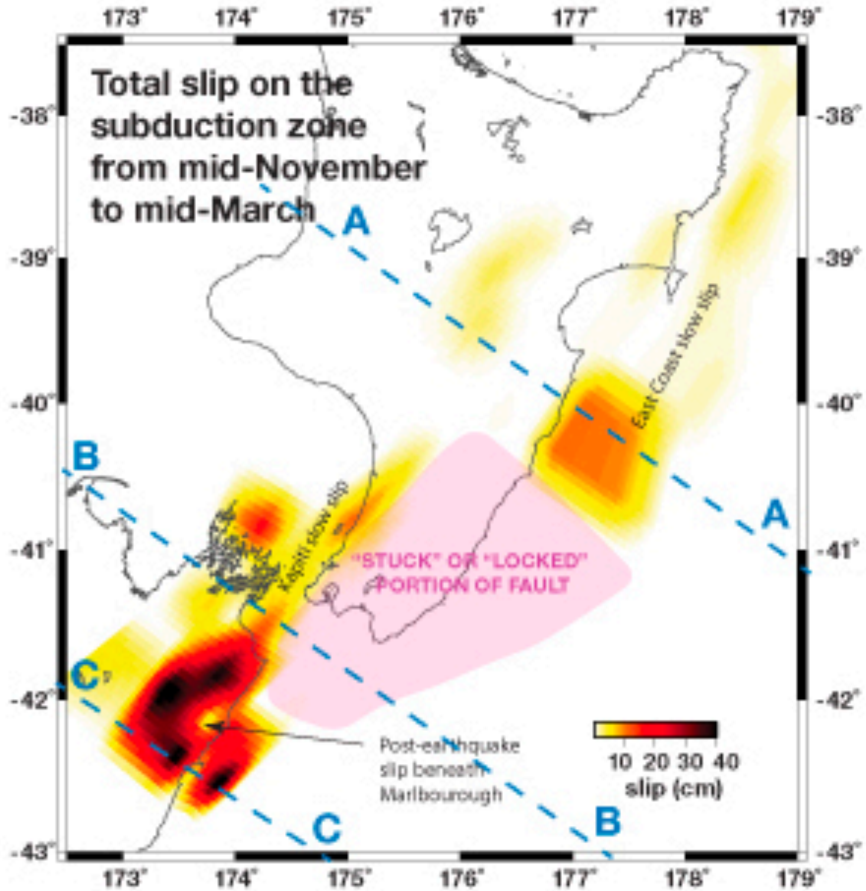
Image: Canterbury Maps

Landslide distribution



Slow-slip events

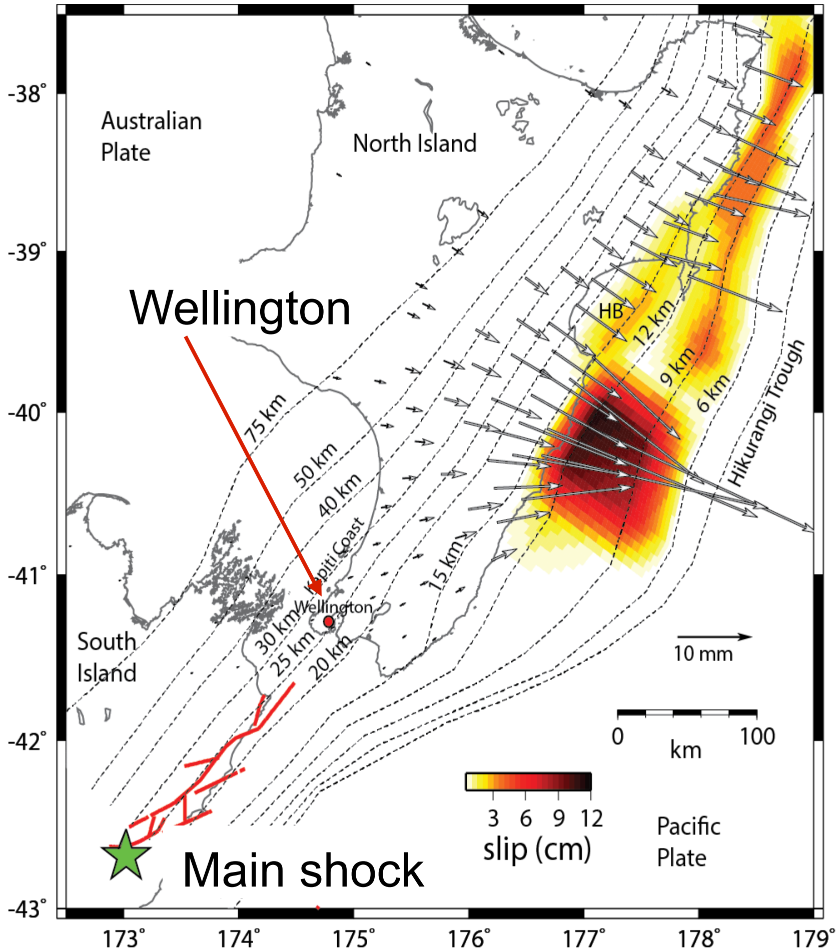




Modelling: Laura Wallace, figures: GeoNet

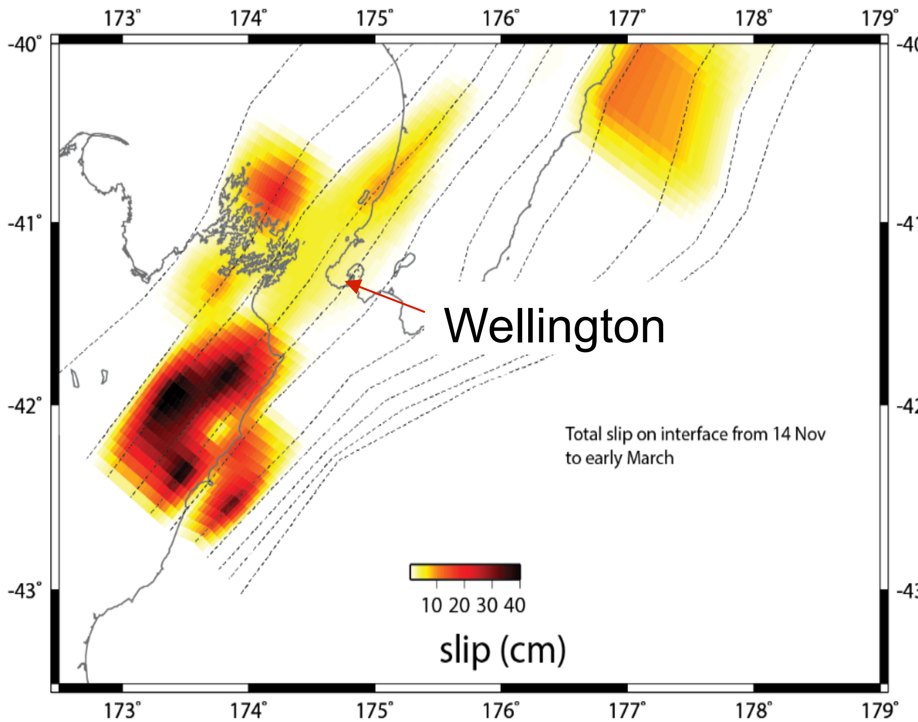
Slow slip and afterslip on the Hikurangi subduction interface following Kaikoura

East Coast SSE



Wallace et al., in review

Kapiti SSE & northern South Island afterslip



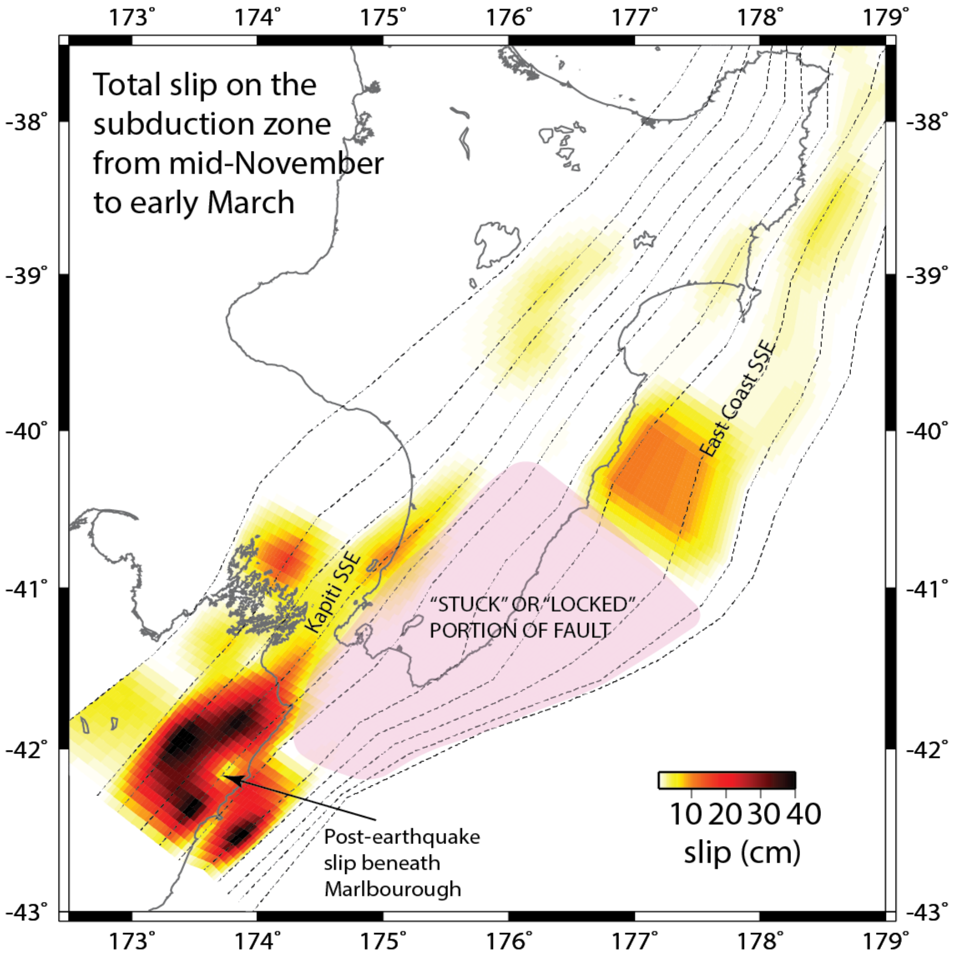
East coast SSE lasted 1-2 weeks

Southern Hikurangi (Kapiti, Marlborough) SSEs/afterslip still ongoing

What does this mean for future seismicity

- *Only ~20 years of SSE observations* with 23 events
- No observations of slip up dip from Wellington
  - i.e., it's locked, and is it getting loaded?
- No existing models of SSE→ future rates
- Lots of concern, but what does it mean...
- Government demanded numbers

Decisions about fast-tracking major roading & infrastructure works, response planning for Wellington, etc



Cumulative slip to date

Evidence available to estimate probability

EEPAS (+STEP)	Rate increase during past NZ SSE	ARTs: R. Robinson's Earthquake simulator	Paleoseismic data	National Seismic Hazard Model
Statistical clustering models based on past catalog observations Implicitly contain SSE, but how much?	Observations of triggered seismicity during and following SSE. Rate changes and MFD	Central NZ Using ~100 2D fault sources, including random off fault seismicity >M6.5 Includes Hikurangi Static Coloumb + pseudo-dynamic Includes temporal clustering Simple stats and Spiking Neural Networks	Observations of clustered crustal and megathrust earthquakes	Long-term rates of large events as modelled in the NSHM

Evidence available to estimate probability of M>=7.8 in the next year

EEPAS (+STEP)	Rate increase during past NZ SSE	ARTS: R. Robinson's earthquake simulator	Paeloseismic Data	National Seismic Hazard Model
Large rate increase over 10 years 30% prob of M>7 in 1 year 3% prob of M>7.8 in 1 year	~2 times increase on average. As large as 15, as little as ½ 1/3 had significantly increased rates (southern SSE) Mostly GR-ish but some odd shapes Largest triggered in NZ: M6.1 (11/17)	2% probability of M>7.8 following another M7.8	Paleoseismic data illustrate a temporal correlation (±30-50yrs) between **some** past large earthquakes on crustal faults and subduction earthquakes Direction of correlation? Large uncertainties	~0.5-0.8% M7.8+/ year in the region

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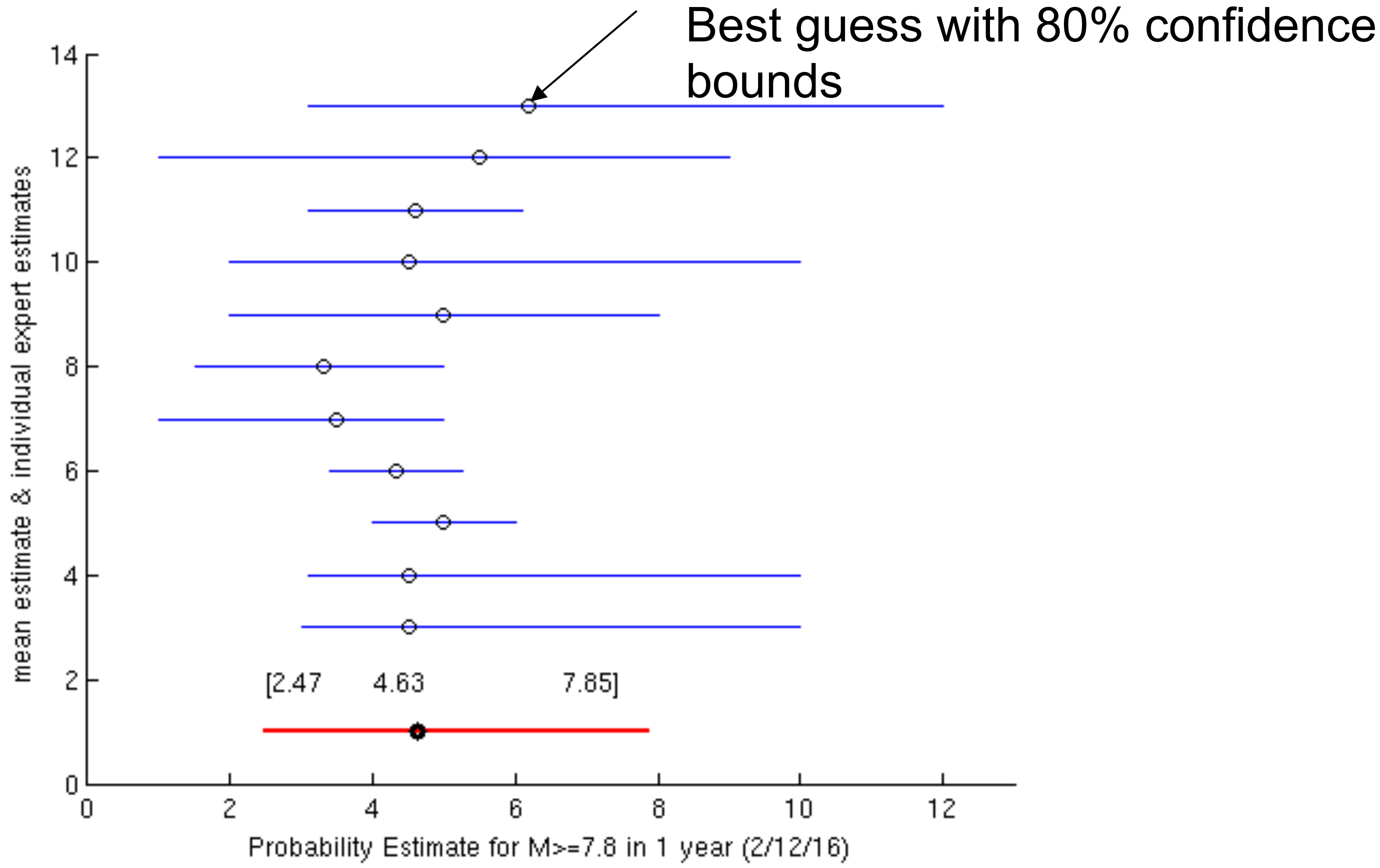
A 5% probability of M7.8+ in 1-year was assessed based on expert judgement



Variability across expert

Model

No model

The topics

Geology, geophysics, geodesy, statistics

The Experts

Mainly from within GNS Science; one colleague from a New Zealand university attended workshop discussion on the phone

Overnight calls with international colleagues for feedback

Expert elicitation

- Gathering material: Driven by mainly two people with contributions from anyone who had something to contribute
- Probability estimation: Workshop for 2 hours, 12 Experts; one probability and uncertainty assessed.

Issues

- Enormous time pressure
- Some experts more than one hat/role
- Everyone overtired
- Challenge to follow‘best practice’
- Concerns about anchoring
- Concerns about “minimising” and “exaggerating”

Summary and outlook

- Many problems that lend themselves to expert elicitation
- Various expertise required that is often available in-house
- So far always workshop style elicitation for experts to discuss
- Challenges with calibration
  - Only one or two experts per specialty
  - “ethics” of weighting an existing team
- Challenges with roles in the process
- Preparing “guidelines for better science advice”
- Keen to hear your feedback and suggestions!
- Looking for reviewers