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**where**  
drives NZ's success



**Presented at the FIG Working Week 2016,  
May 2-6, 2016 in Christchurch, New Zealand**



# The Evolution of Geodetic Crustal Deformation Monitoring in New Zealand for Datum Definition

Graeme Blick | Chief Geodesist



# What we'll cover

Tectonic setting of New Zealand

Early surveys in New Zealand

Early deformation surveys

The age of GPS and increased precision

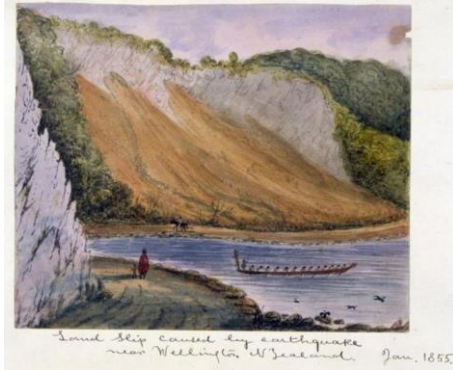
Refining the datum

The future





# Significant historic earthquakes



West Wairarapa 1855



Napier 1931



Edgecumbe 1987



Murchison 1929



Inangahua 1968



Christchurch 2011

# Significant volcanic events



White Island



Mt Tarawera 1886



Mt Ruapehu



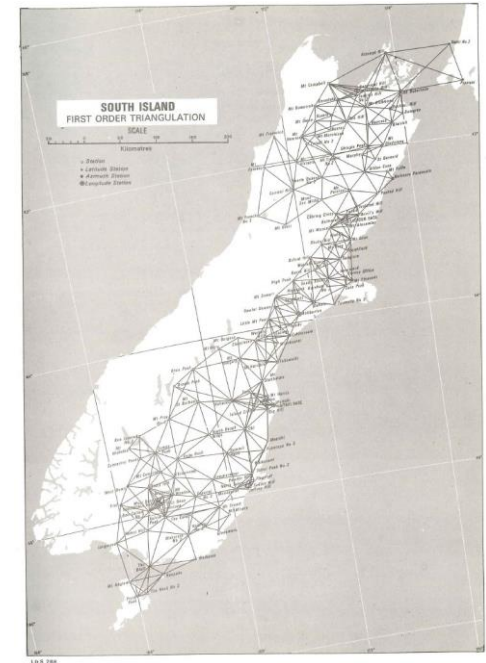
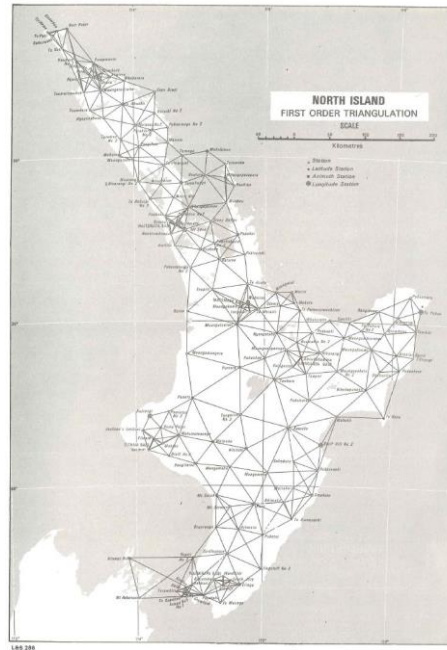
Mt Ngauruhoe

# Early triangulation surveys

Commenced in the 1880s

1st order control completed 1940s for NZGD49

Provided a foundation for measuring crustal deformation





# Recognition of plate tectonics



**Professor Harold Wellman**



# Post 1973 deformation surveys

Ad-hoc deformation surveys carried out by Lands and Survey, Otago University, Victoria University, Ministry of Works and NZ Geological Survey but programme uncoordinated

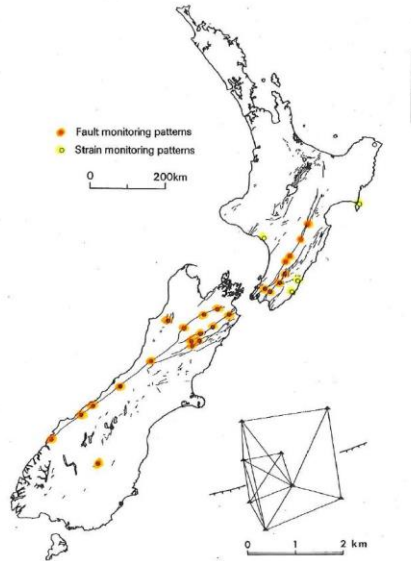


Fig. 1: Distribution of fault (FMP) and strain (SMP) monitoring patterns in both the North and South Island. Active faults are from Officers of the Geological Survey (1983), and those discussed in this paper are labelled on Fig. 2. A typical FMP is also shown.

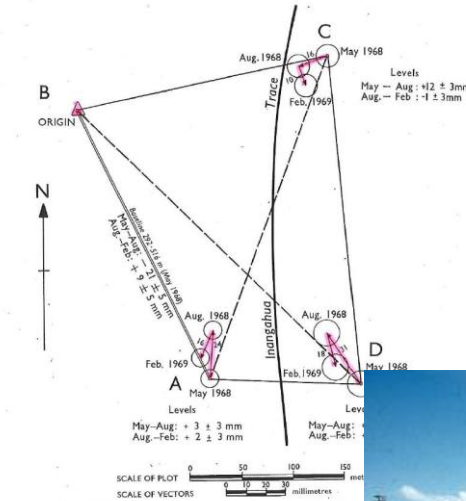


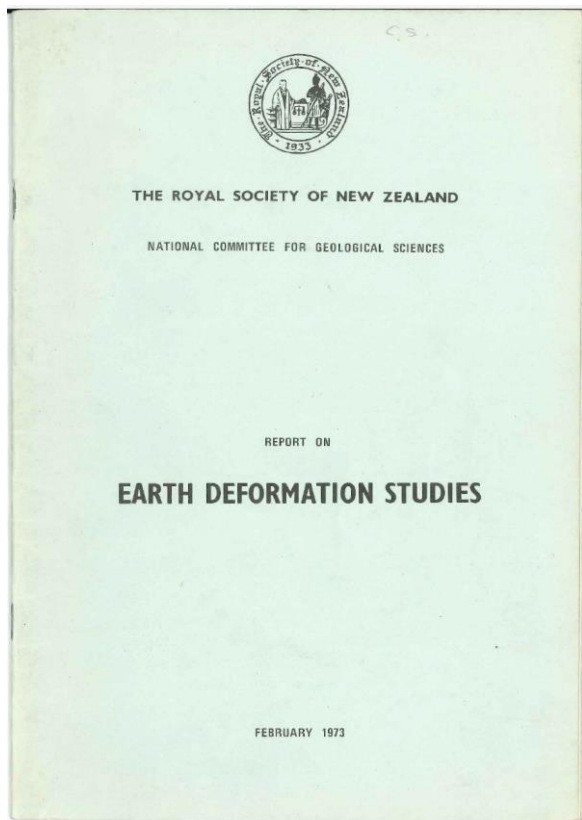
Fig. 6.—Post-earthquake deformation demonstrated by braced quadrilateral structure.

Post-seismic deformation measured following the 1968 Inangahua earthquake





# Royal Society Report on Earth Deformation Studies 1973



14A

DEPARTMENT OF LANDS AND SURVEY

OUR FILE: 17/137/2                      YOUR FILE:  
From            HEAD OFFICE                      Date: 2 April 1974  
To                All Chief Surveyors.  
Ref.: Ours/Yours of

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EARTH DEFORMATION SURVEYS

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You will be aware of the suggestion of the N.Z. Institute of Surveyors to practising surveyors to forward any evidence of Earth Deformation obtained in the course of their work, to the Chief Surveyors. This arose out of the Royal Society of New Zealand's report on Earth Deformation Surveys, a copy of which is enclosed for your information.

You should instruct your own survey staff to report on any earth deformation proved by recent resurveys, particularly in control work. Where survey control is required in an area known to be geologically active, it would also be advisable, while still working within the general requirements of the control survey, to include additional rays, and extra measurements to provide a basis for future resurvey or monitoring of any movement.

You should forward any such information received to this office where it will be collated.

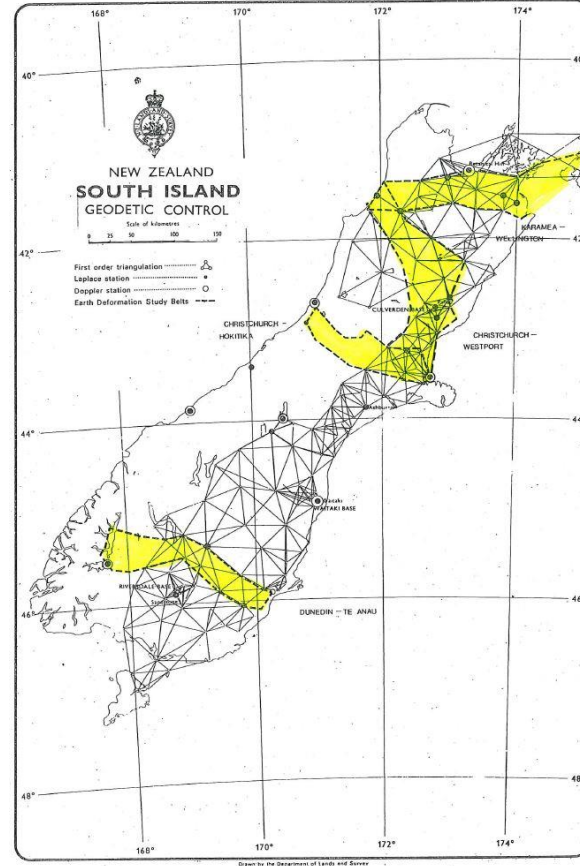
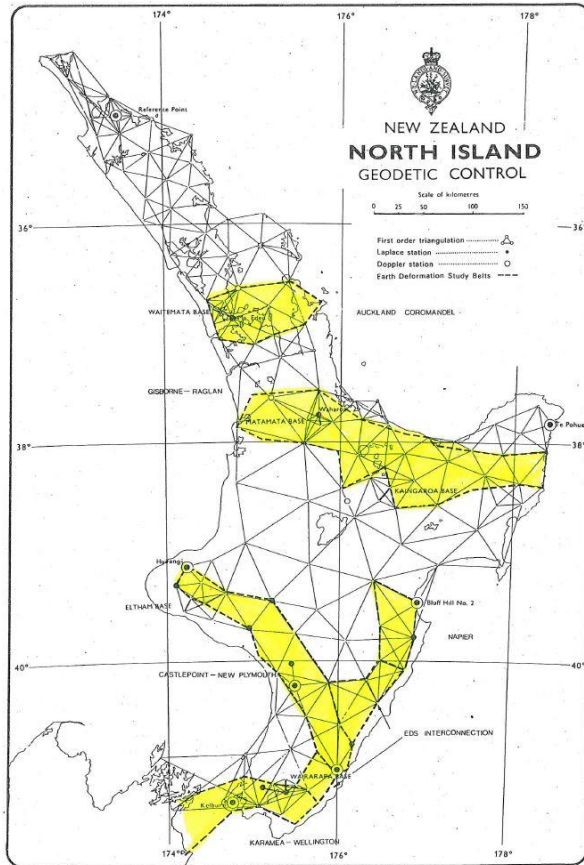
I.F. Stirling,  
Surveyor-General

per:



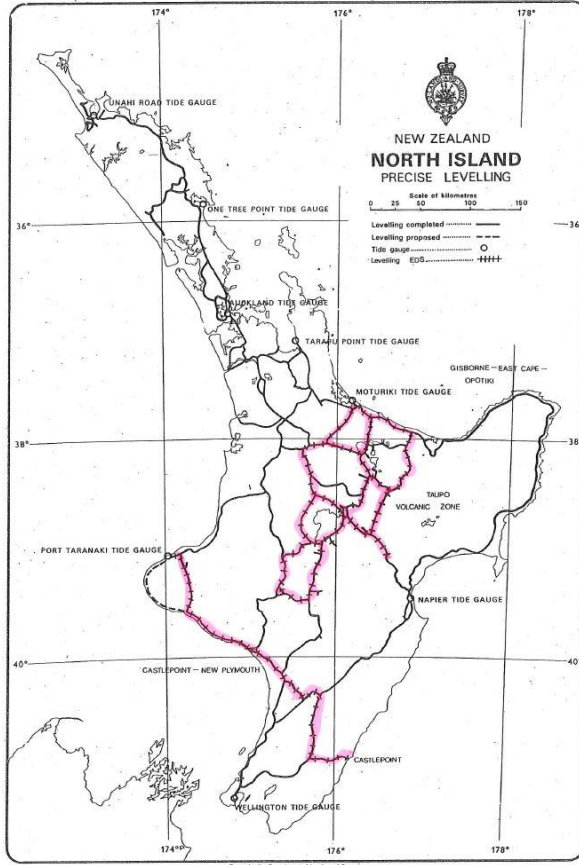
# EDS Regional Triangulation Belts

NZ Royal Society Misc Series 13

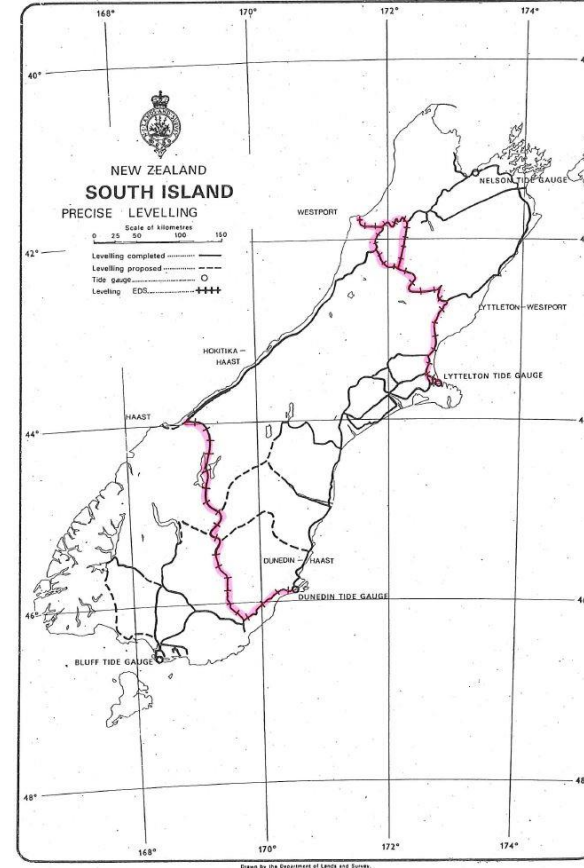


# EDS Regional Levelling Routes

NZ Royal Society Misc Series 13



Drawn by the Department of Lands and Surveys.



Drawn by the Department of Lands and Surveys.



# Regional Survey Methods







# FMP results

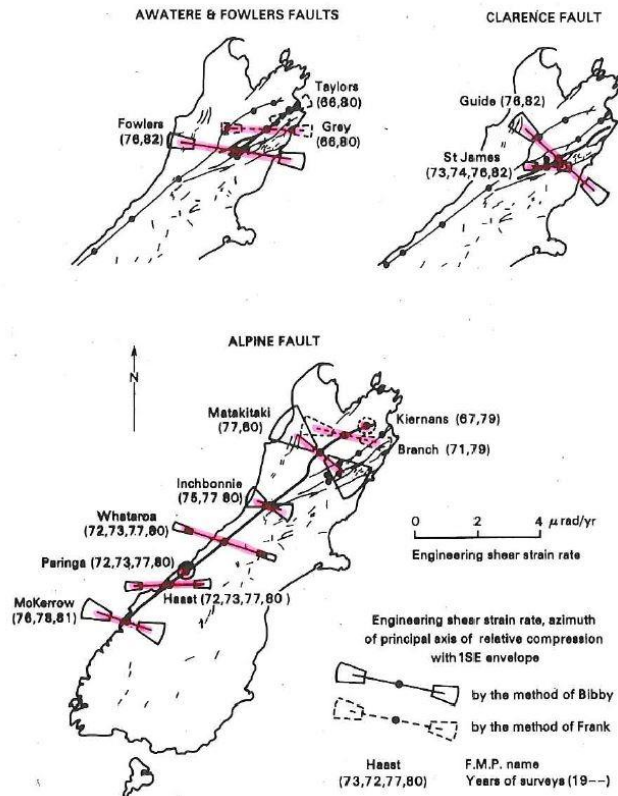
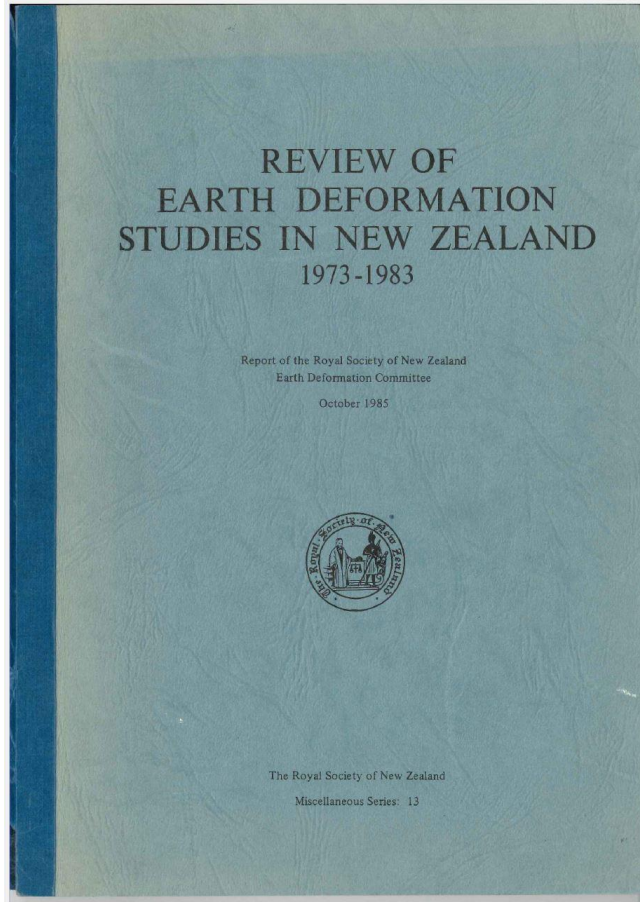


Fig. 2: Shear strain determined from repeated surveys of fault monitoring patterns in the South Island on the Alpine, Awatere, Clarence and Fowlers Faults. Symbols show, for each FMP analysed, the orientation of the principal axis of compression and the shear strain rate with 1SE envelopes. Results are derived by the method of either Bibby (1973, 1982)-solid symbols, or Frank (1966)-dashed symbols.



# 10 year review of EDS 1973 - 83



## The Report made 10 recommendations

### Of note:

Recommendation 3 - Particular emphasis in geodetic work should be on the local extension of the repetition of the 1<sup>st</sup> order triangulation outside the narrow belts, to follow up patterns of detected strain, and to re-observe the narrow belts, which provide a datum for further studies. Observations of local geodetic patterns should be continued, with particular attention to temporal variations of deformation.

Recommendation 5 - A collaborative programme, based on comprehensive data bases, should be established for the interpretation of geodetically- determined deformation in relation to geological structure, seismicity and geodynamic phenomena.

Recommendation 8 – The developments in satellite-based techniques for geodetic work should be closely monitored and investigated for further application.

# The 1980s and 90s GPS revolution

By analysing repeated historical survey measurements, a map of how New Zealand deformed was completed – based on limited repeats

Survey results from local Fault Monitoring Patterns indicated time variability of deformation

Limitations with NZGD49 were recognised – regional distortions of up to 5m

The development of GPS in the late 1980s allowed repeated surveys to be made more accurately and efficiently

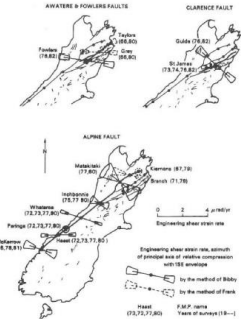
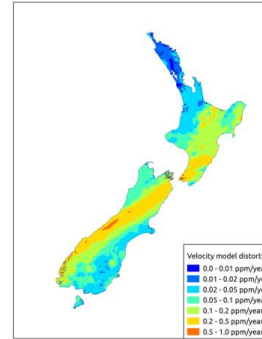
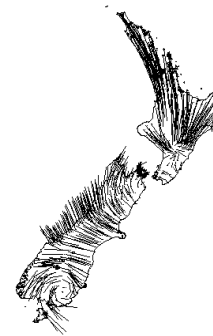


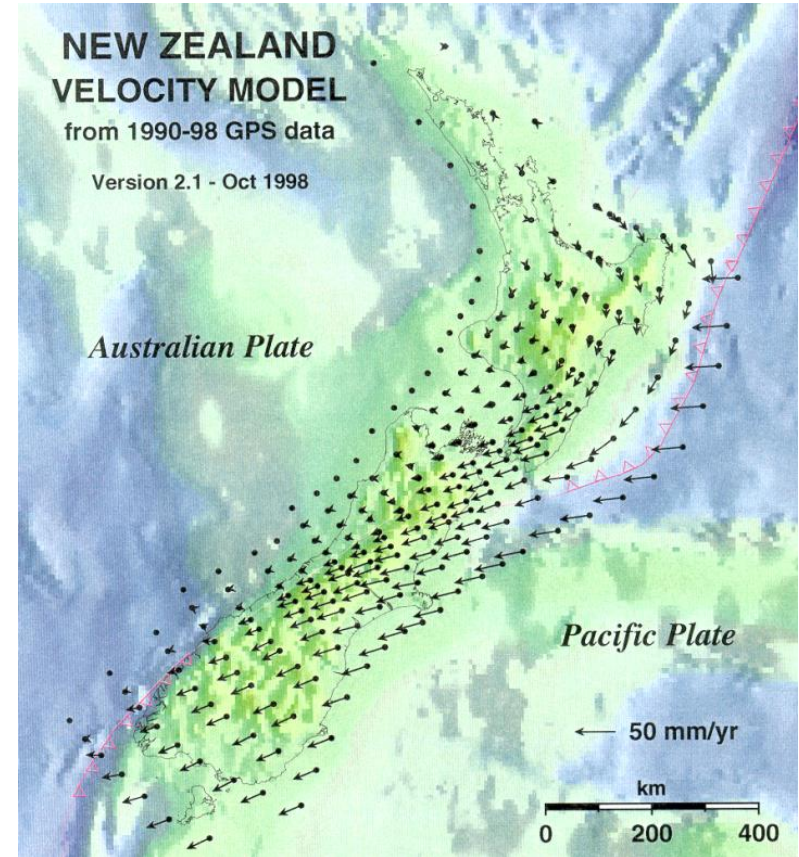
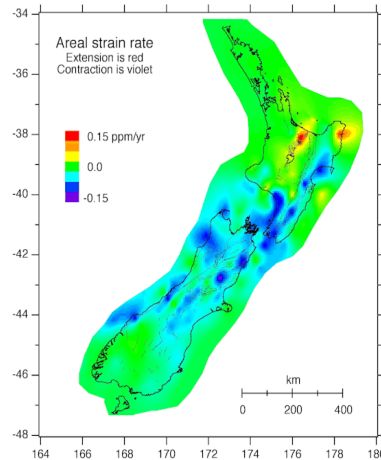
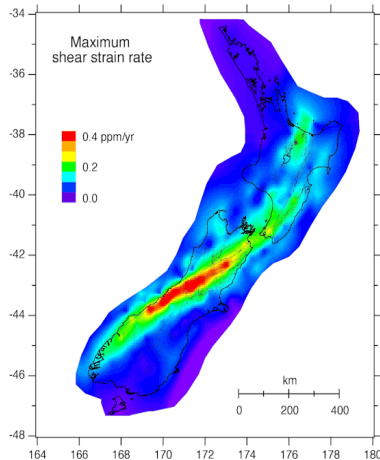
Fig. 2. Shear rates determined from repeated surveys of fault monitoring systems in the South Island on the Alpine, Awatere, Clarence and Fowlers Faults. Symbols show, for each FMP analysed, the orientation of the principal axes of compression and the shear strain rate with 1SE envelopes. Results are shown by the method of Bibby (1997), 1982 radial symbols, on Frank (1984) shaded symbols.



# Implementation of NZGD2000

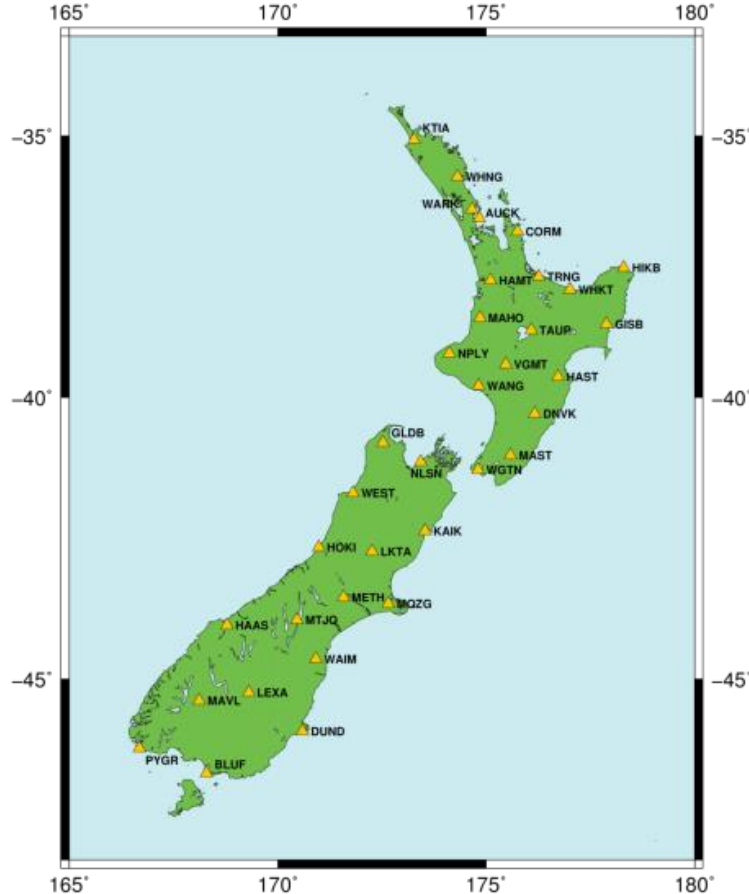
## Semi-dynamic datum

Incorporation of a deformation model derived from repeated GPS surveys made between 1990 and 1998





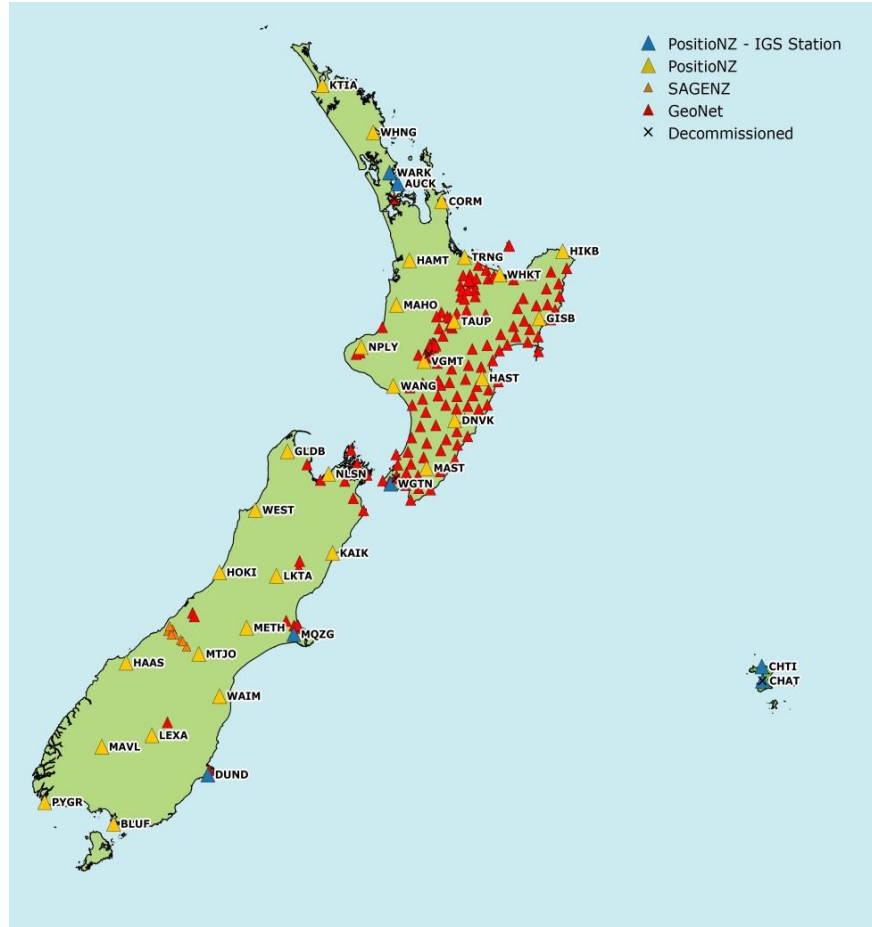
# Since 2000 - the evolution of CORs



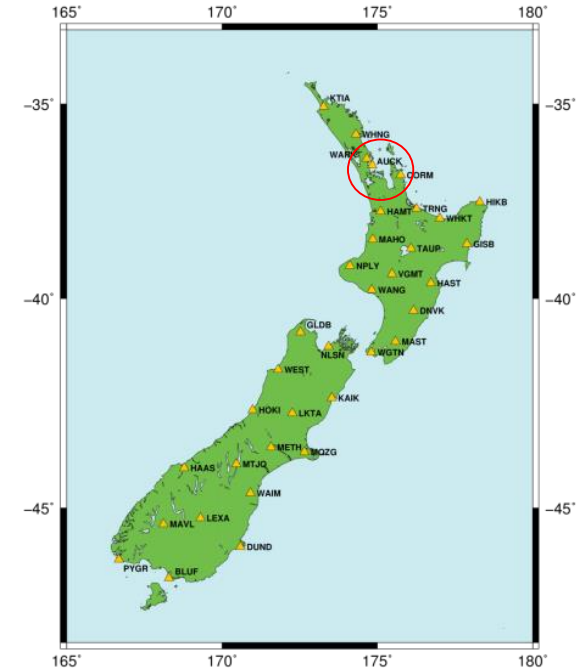
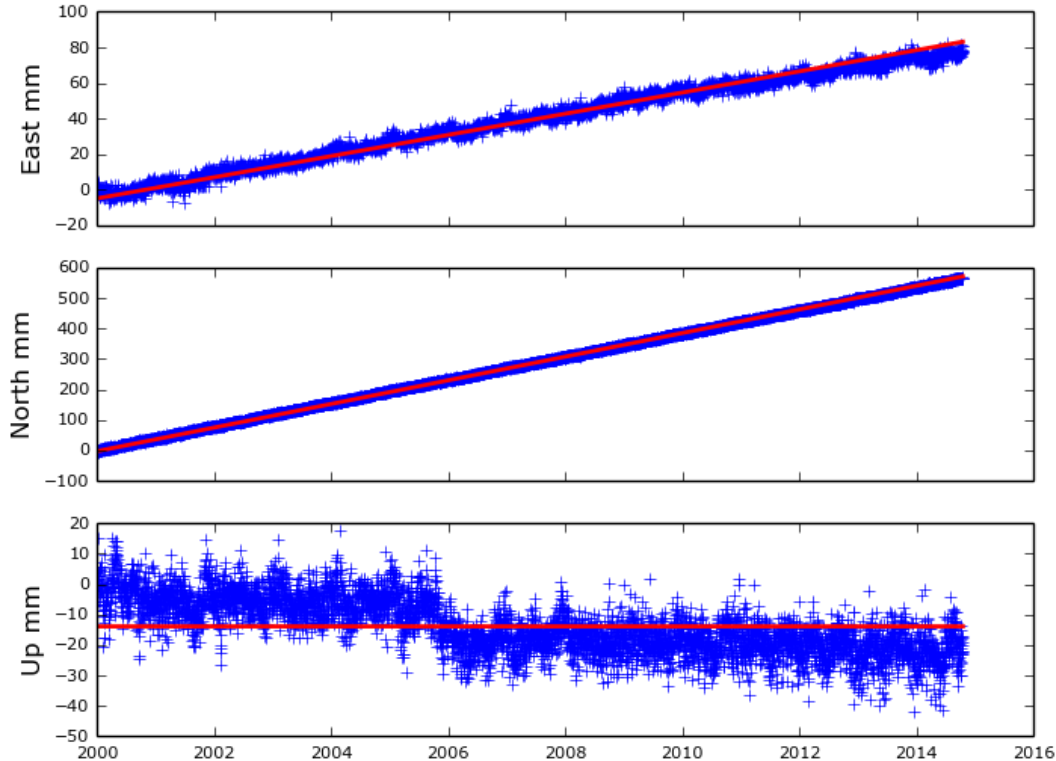
## PositionNZ Network

35 on the mainland of NZ  
1 on the Chatham Islands  
3 in Antarctica

# Genet established in 2001 - 190 stns

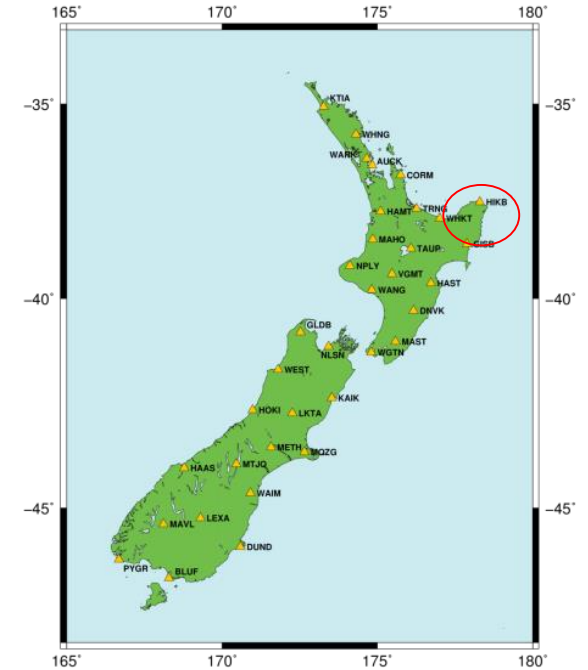
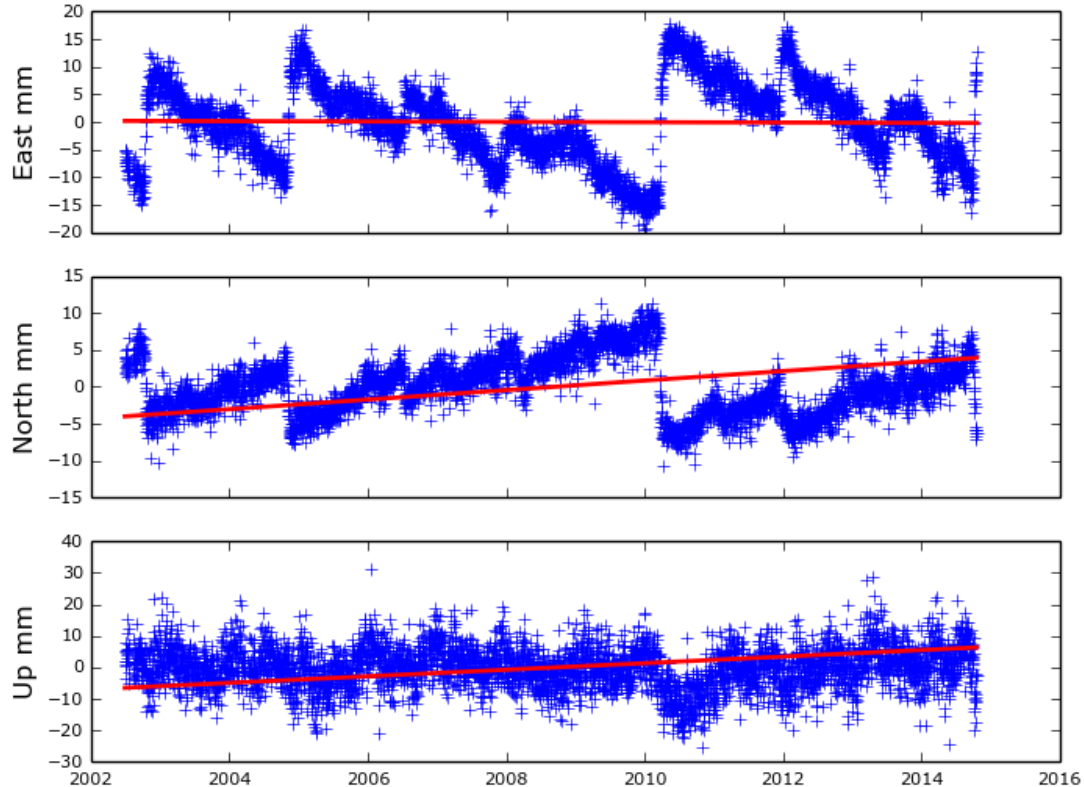


# Auckland - stable

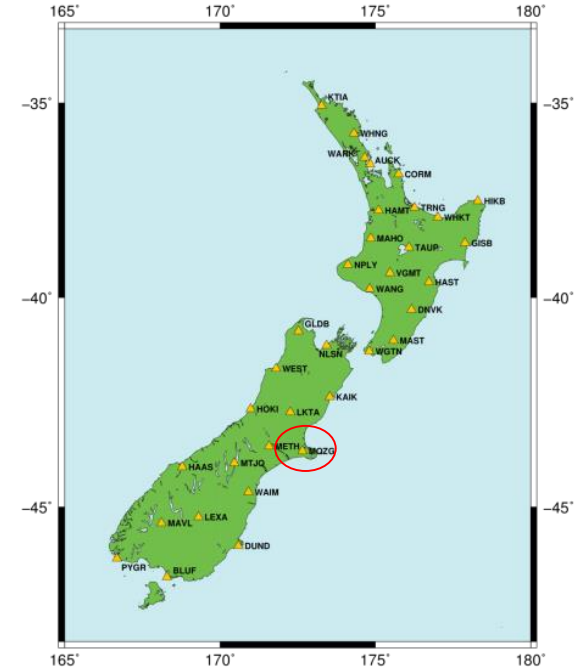
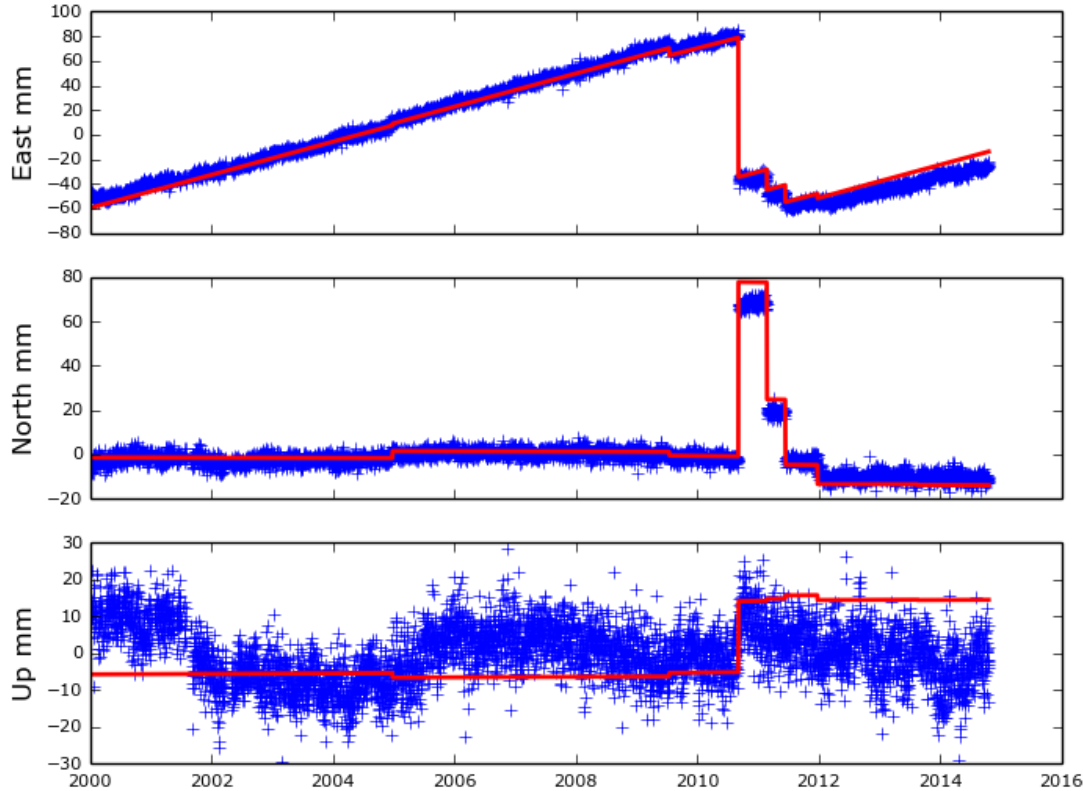




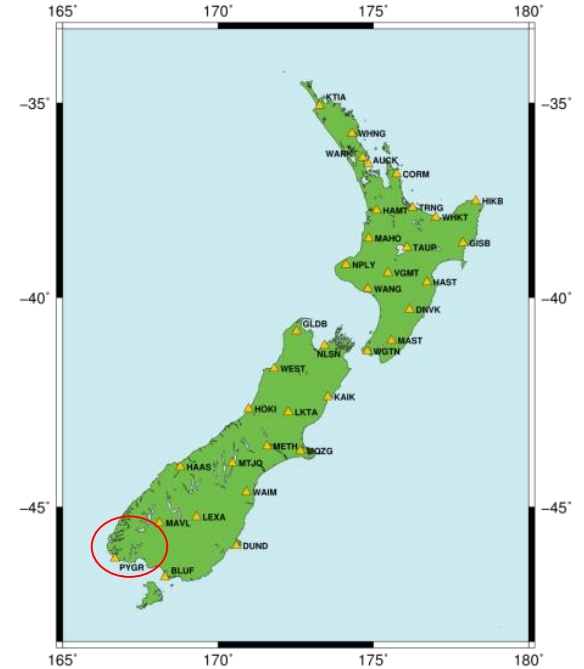
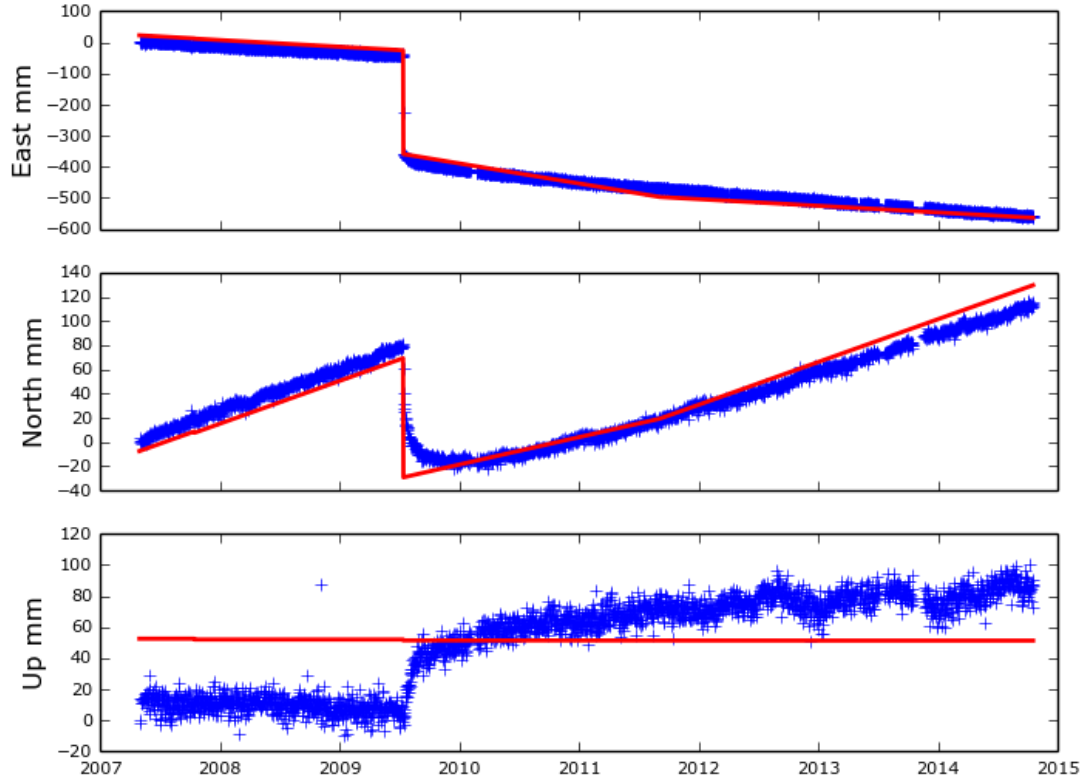
# Gisborne – slow earthquakes



# Christchurch – Canterbury earthquakes

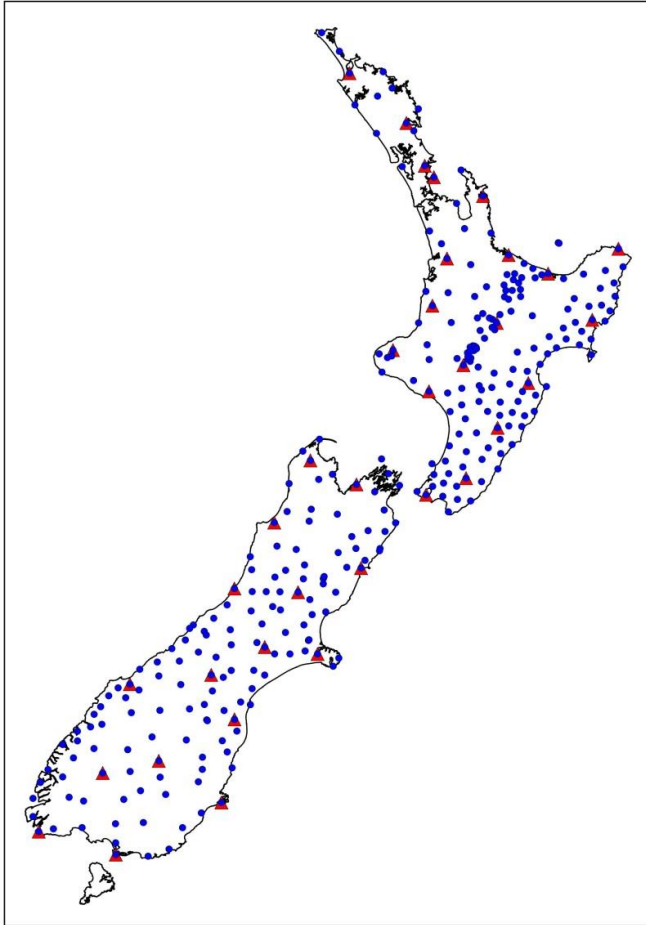


# Fiordland postseismic recovery



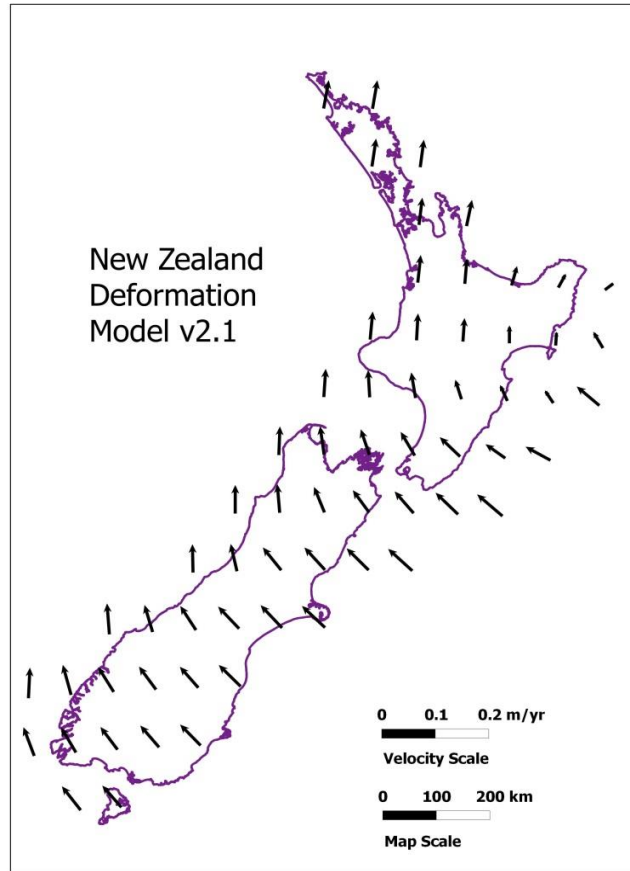


# National deformation monitoring network



National Deformation Monitoring Network (NDMN), - campaign stations measured every 8 years.

# Enhancing the Deformation Model



Horizontal model only

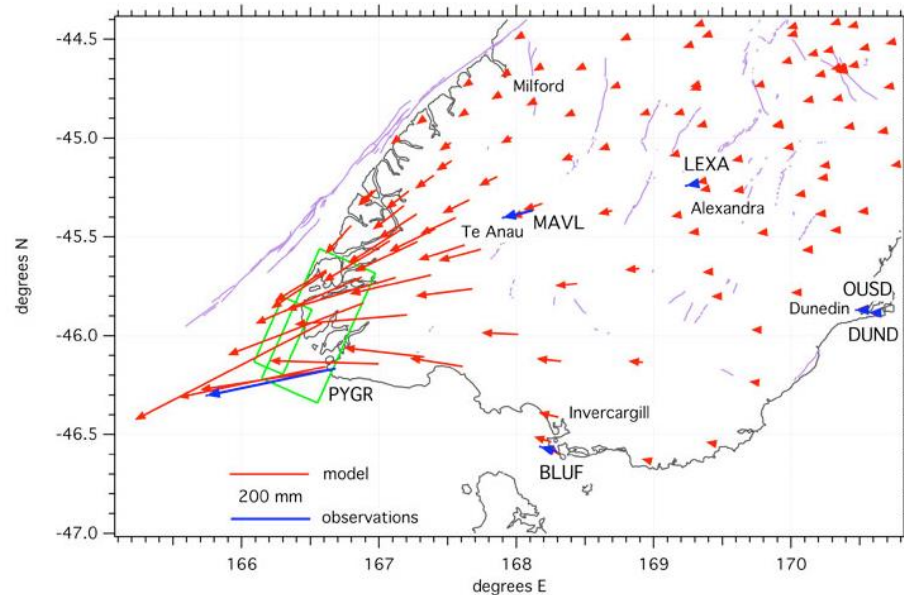
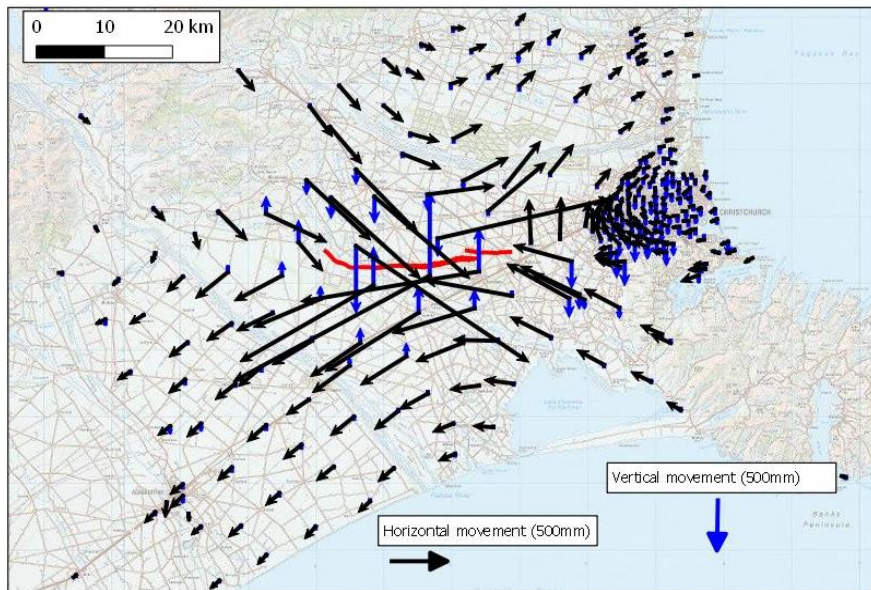
Continuously updated and refining

# Earthquake!!

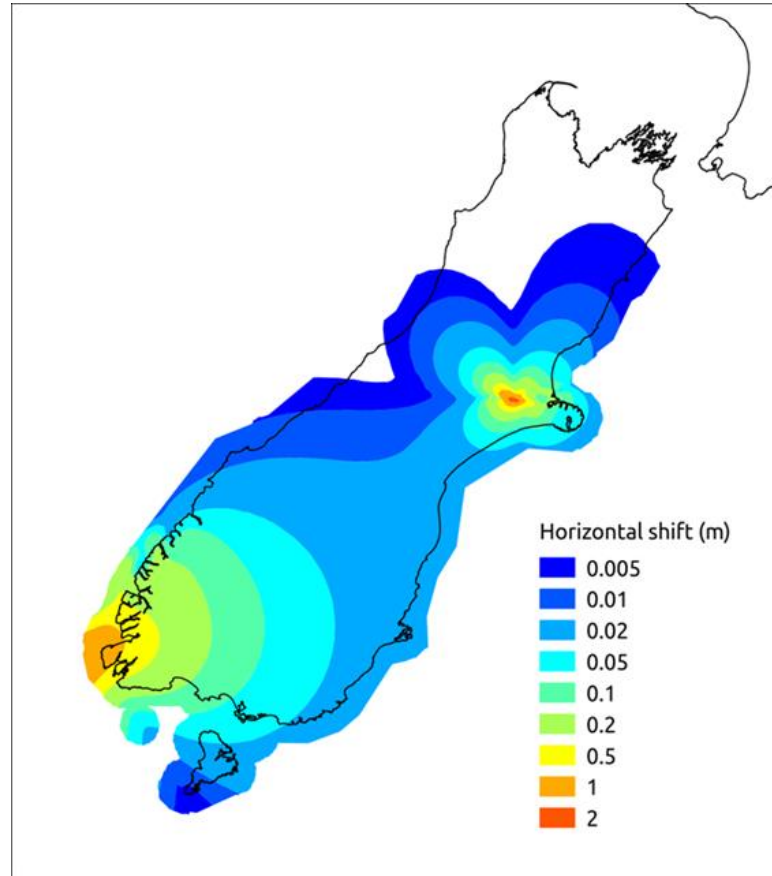




# Deformation due to earthquake

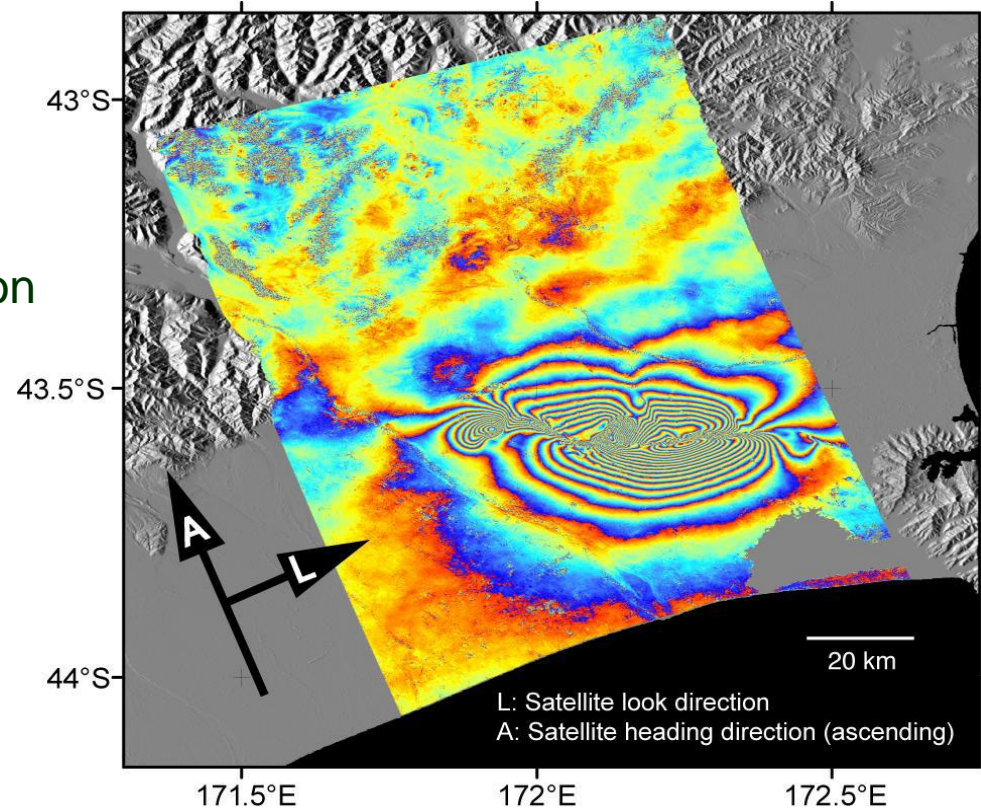


# Adding patches



# The future

New technologies to monitor deformation  
Vertical deformation model





the power of  
**where**  
drives NZ's success



# Questions?

