Tectonic Context and Implications of the Canterbury, New Zealand Earthquake Sequence

Kevin P Furlong
Geodynamics Research Group
Geosciences
Penn State University

Gavin P Hayes
NEIC
US Geological Survey

Mark Quigley
Geological Sciences
University of Canterbury

Harley Benz
NEIC
US Geological Survey

What's the Deal With These Christchurch Earthquakes?

Some Questions:

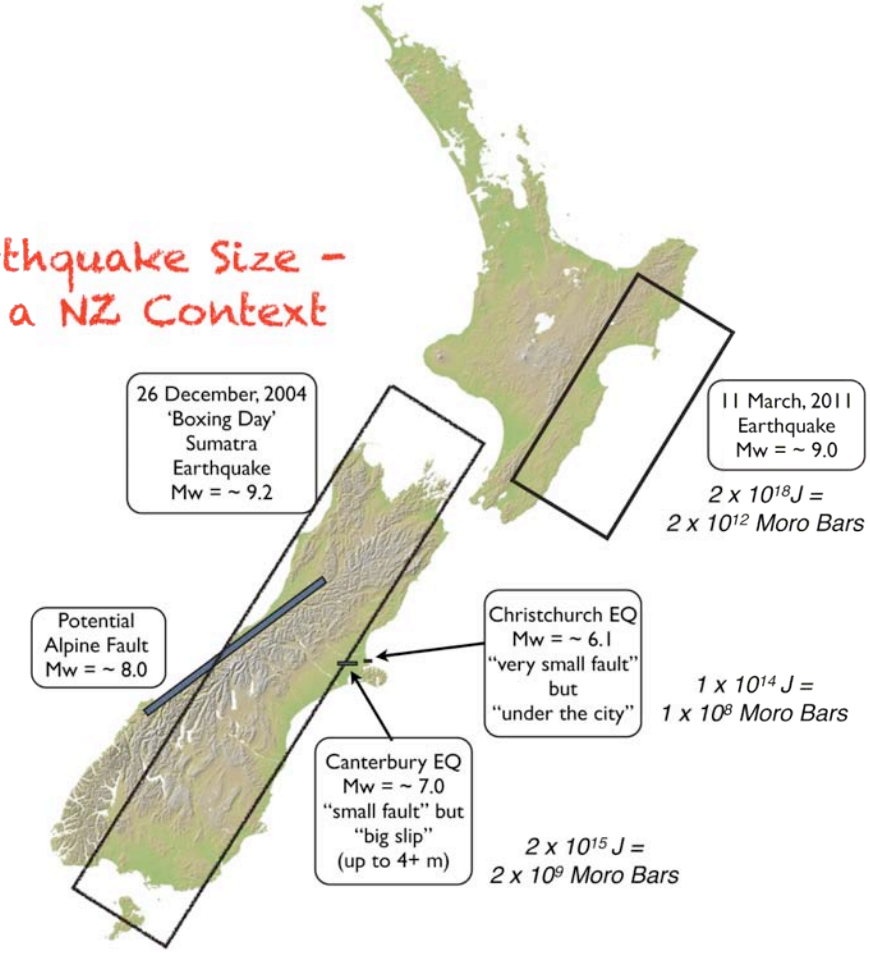
- Why are we having these earthquakes (main event and aftershocks), and when will they stop?

- What about gaps? Can they have big earthquakes?

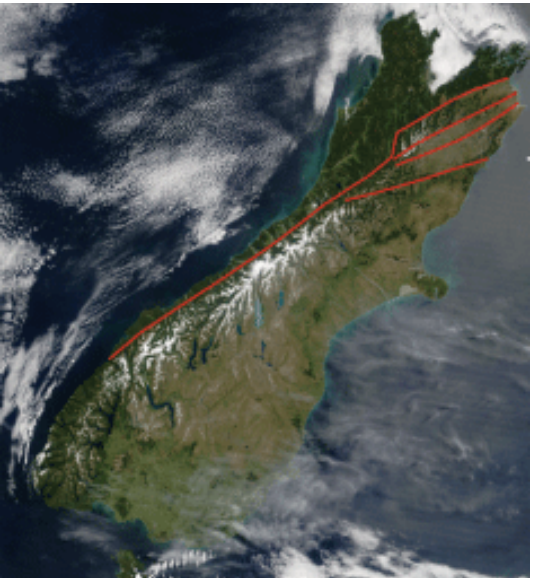
These are questions that Earth Science can help with

The Canterbury Earthquakes reflect intraplate deformation driven by plate boundary interactions

Earthquake Size – in a NZ Context



Background Seismicity - Virtually Nil



-43°

-44°

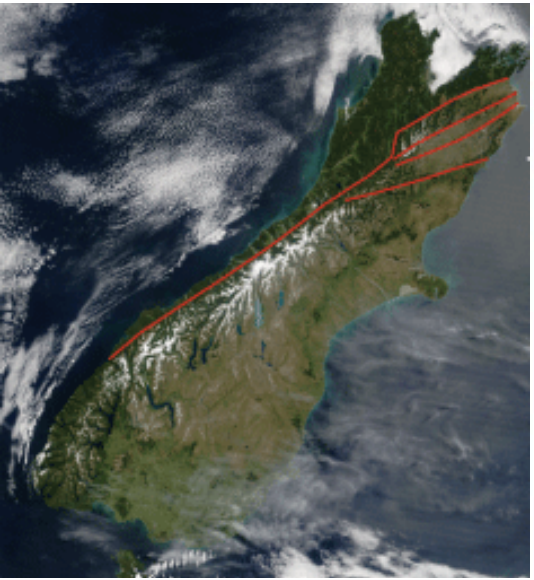
172°

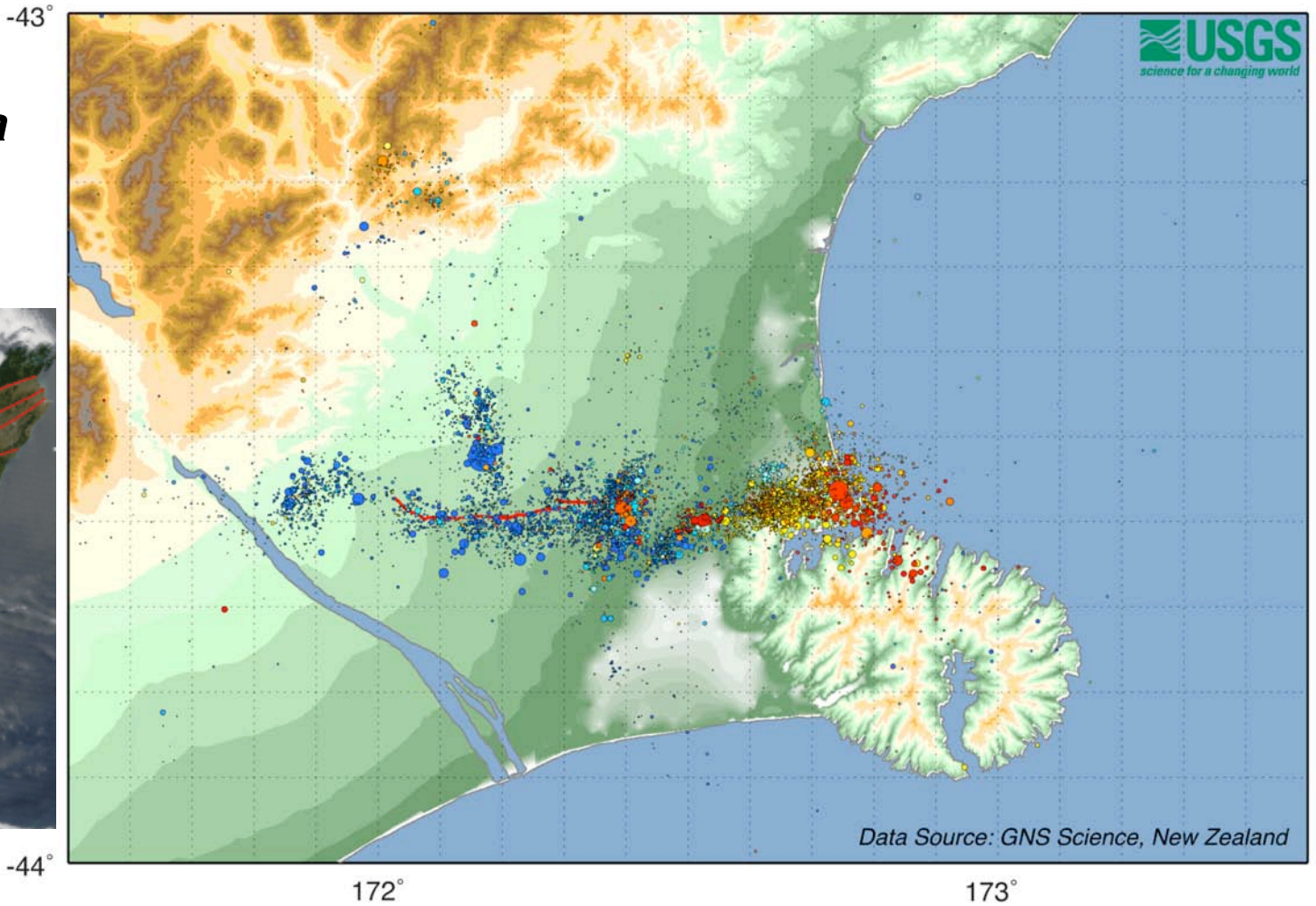
173°

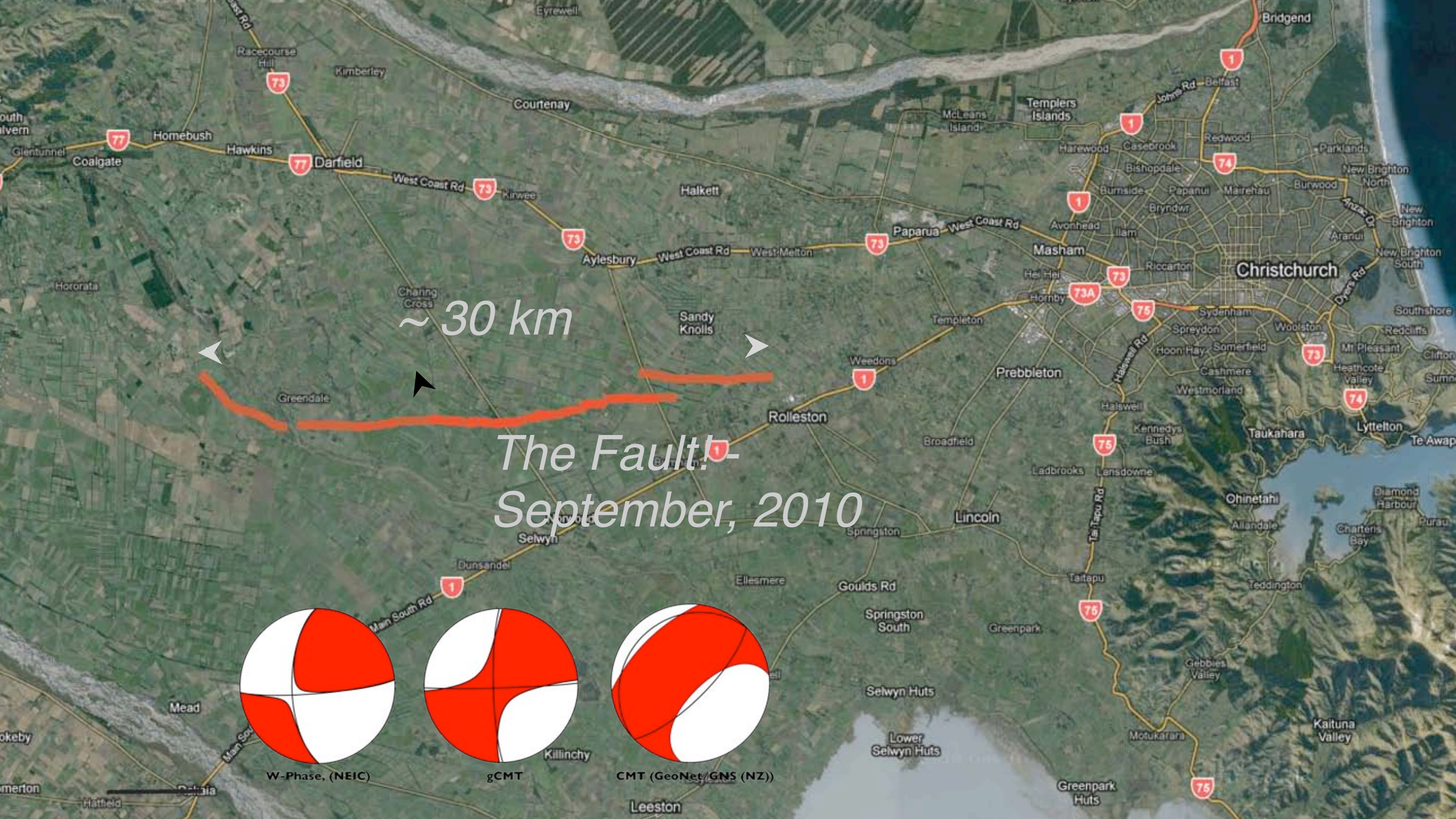
Future Greendale Fault
Surface Rupture

Seismicity :
September 3, 2009, March 31, 2010

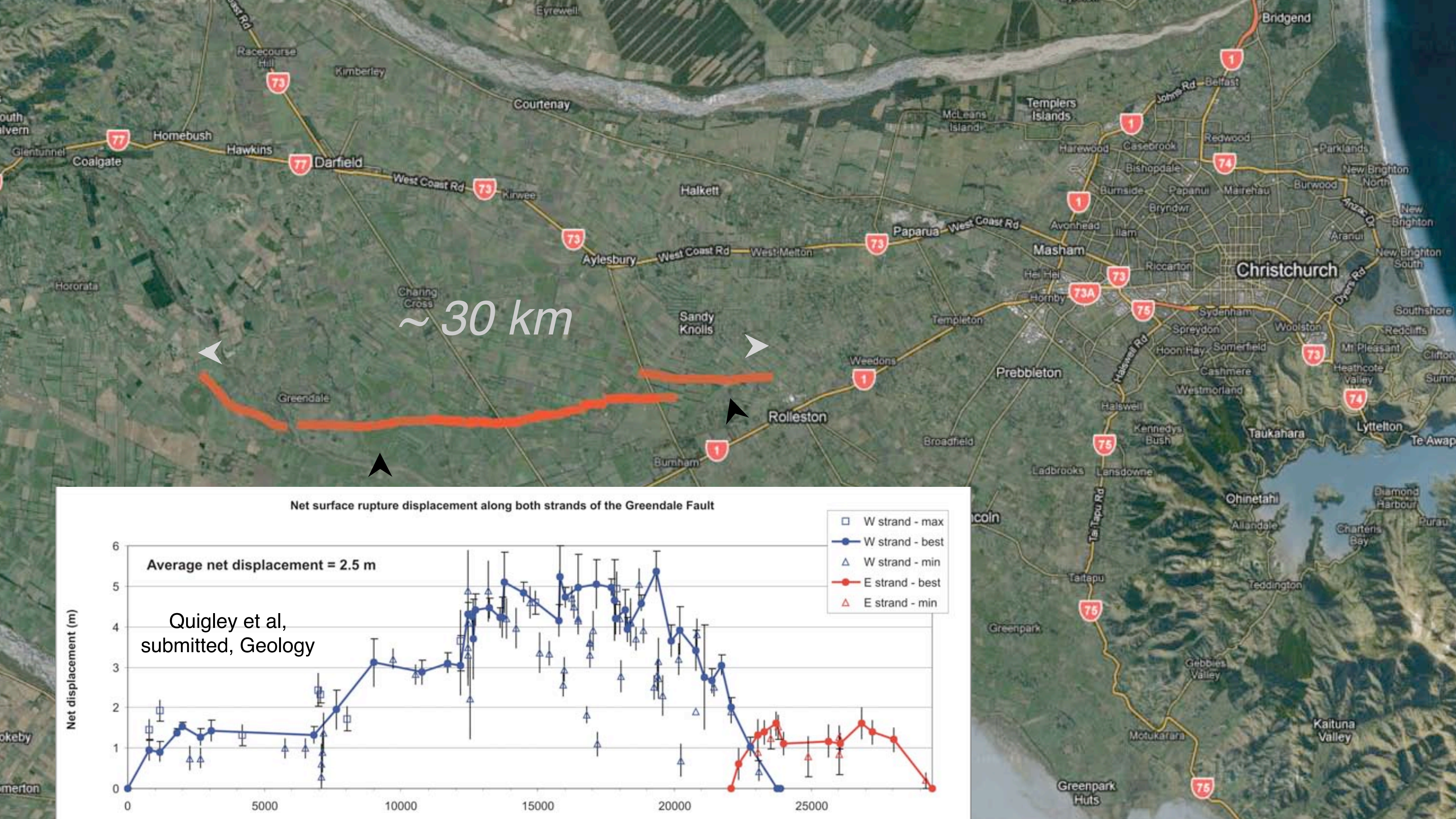
Big Changes in a year

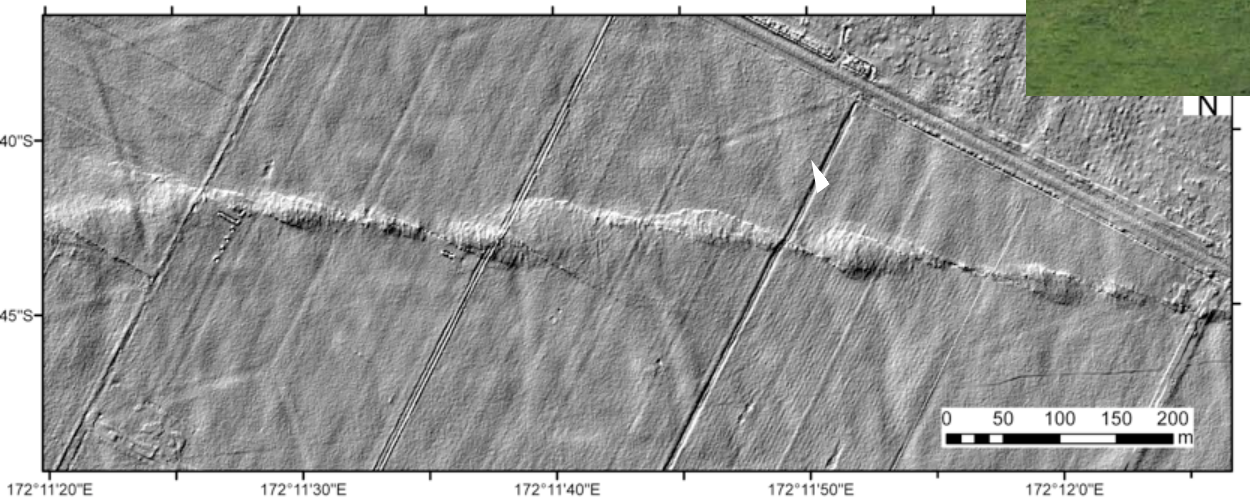





~30 km
The Fault! -
September, 2010
W-Phase, (NEIC)
gCMT
CMT (GeoNet/GNS (NZ))
Christchurch
Darfield
Rolleston
Lincoln
Prebbleton
Templeton
Greendale
Aylesbury
Kirwee
Halkett
Paparua
Masham
Hornby
Sandy Knolls
Charing Cross
Weedons
Courtenay
Kimberley
Hawkins
Homebush
Coalgate
Hororata
Dunsandel
Selwyn
Ellesmere
Springston
Goulds Rd
Leeston
Mead
Killinchy
Lyttelton
Taukahara
Bridgend
Belfast
West Coast Rd
Main South Rd

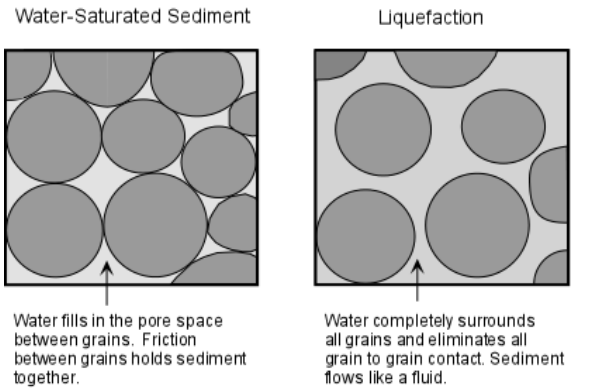
Ephemeral Fault Evidence


~30 km
Net surface rupture displacement along both strands of the Greendale Fault
Average net displacement = 2.5 m
Quigley et al,
submitted, Geology
Net displacement (m)
W strand - max
W strand - best
W strand - min
E strand - best
E strand - min
0
1
2
3
4
5
6
0
5000
10000
15000
20000
25000
Christchurch
Darfield
Rolleston
Greendale
Hororata
Coalgate
Homebush
Hawkins
Kirwee
Aylesbury
West Melton
Halkett
Charing Cross
Sandy Knolls
Weedons
Templeton
Prebbleton
Burnham
Broadfield
Courtenay
Kimberley
Racecourse Hill
Eyrewell
McLeans Island
Templers Islands
Belfast
Bridgend
Hornby
Hei Hei
Masham
Paparua
Avonhead
Halswell
Lyttelton
Taitapu
Motukarara
Greenpark
Greenpark Huts
Ladbrooks
Lansdowne
Taukahara
Ohinetahi
Kaituna Valley
Gebbies Valley
Teddington
Allandale
Diamond Harbour
Charteris Bay
West Coast Rd
Johns Rd
Halswell Rd
Tai Tapu Rd
Dyers Rd
Anzac Dr

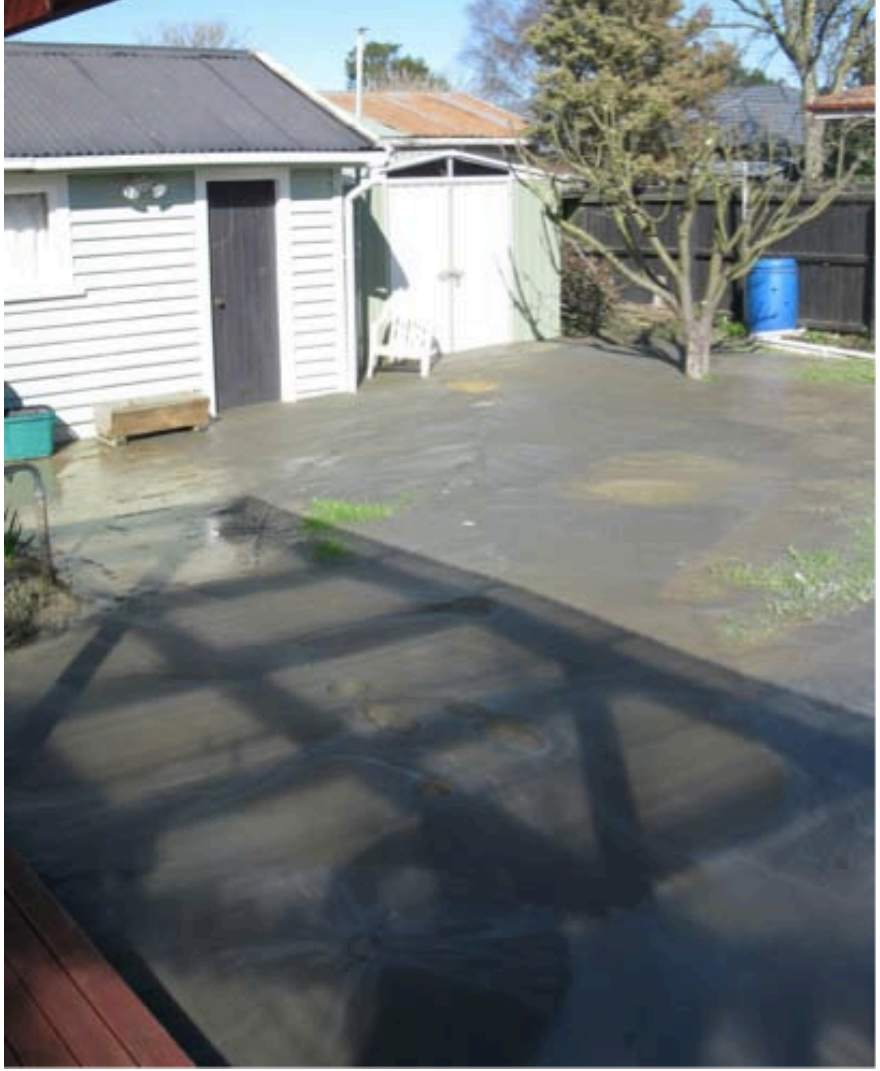


Airborne
LiDAR

Liquefaction and Lateral Spreading

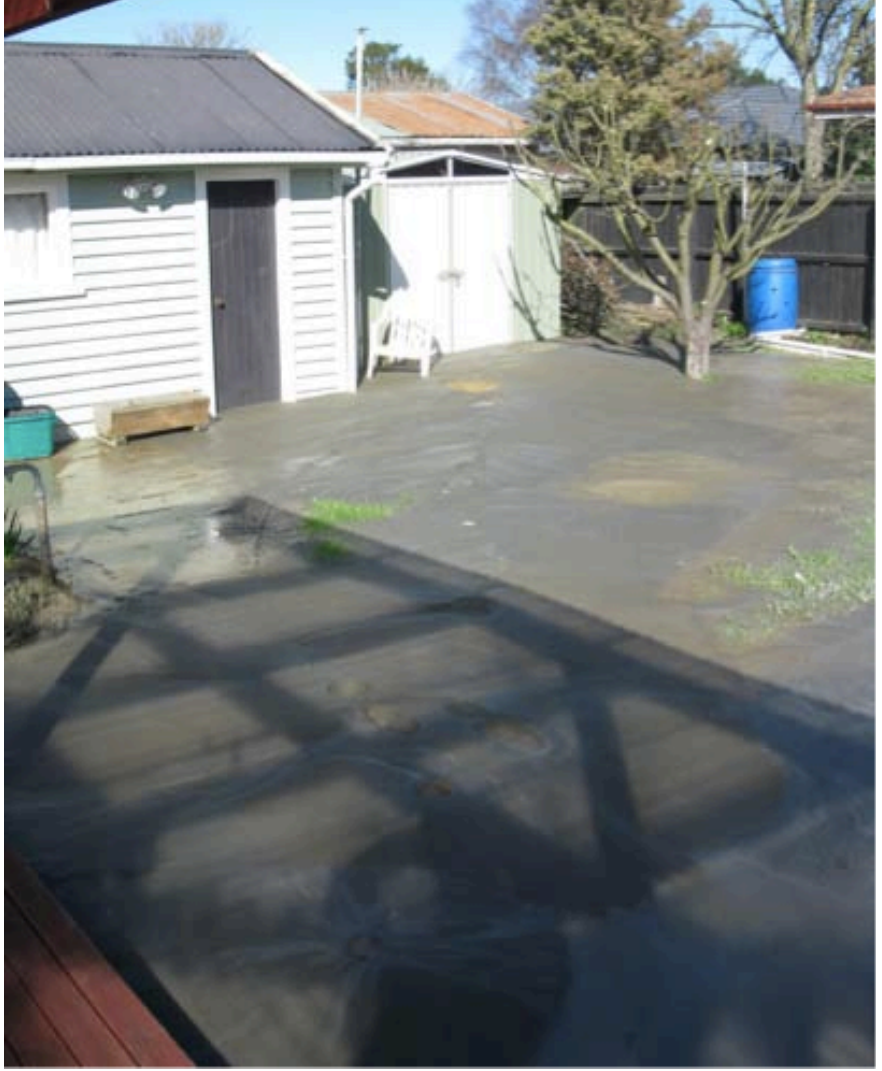

Water-Saturated Sediment
Liquefaction
Water fills in the pore space between grains. Friction between grains holds sediment together.
Water completely surrounds all grains and eliminates all grain to grain contact. Sediment flows like a fluid.

March 2010



September 2010

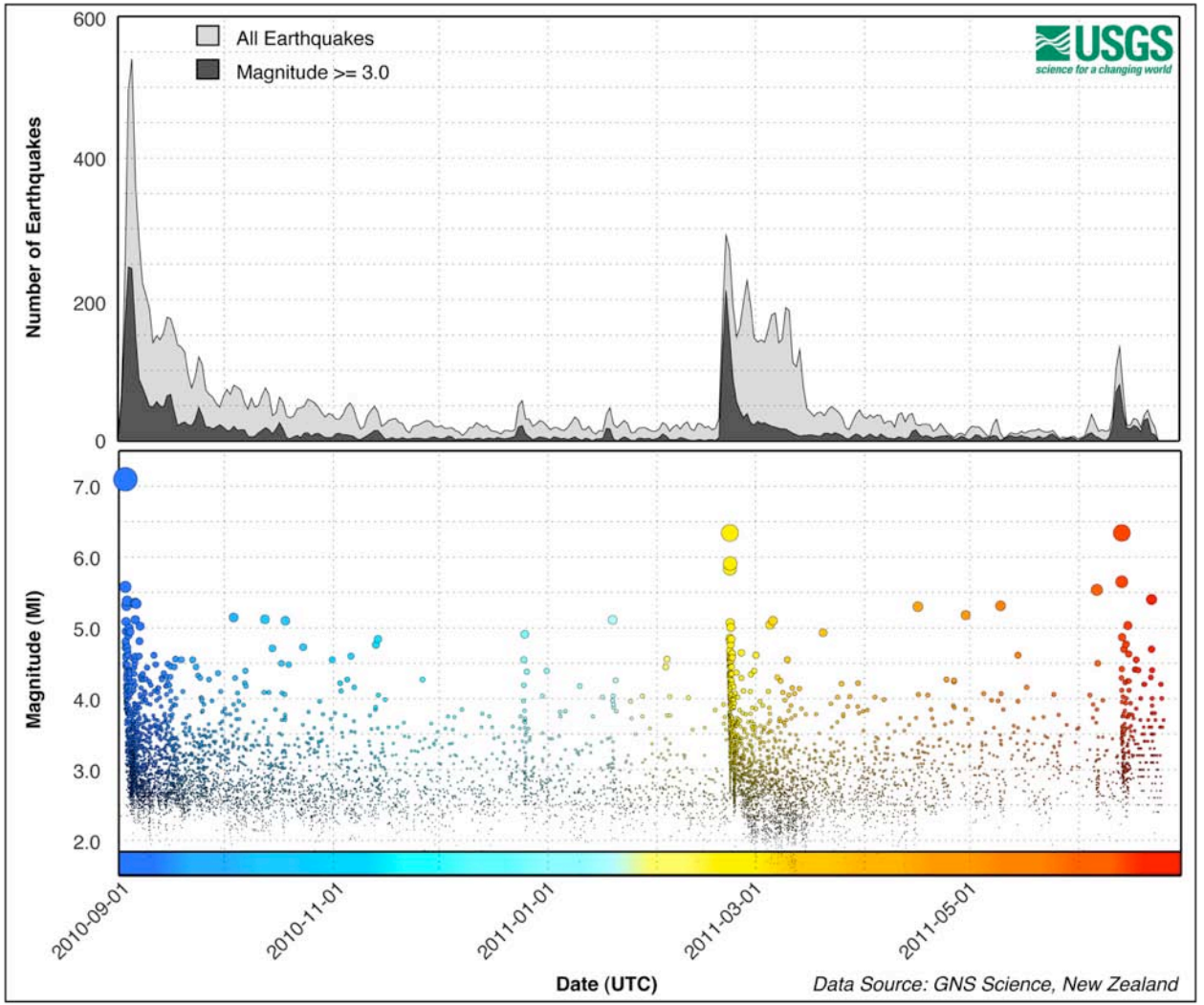
February 2011



September 2010

Liquefaction in the Rural Zone

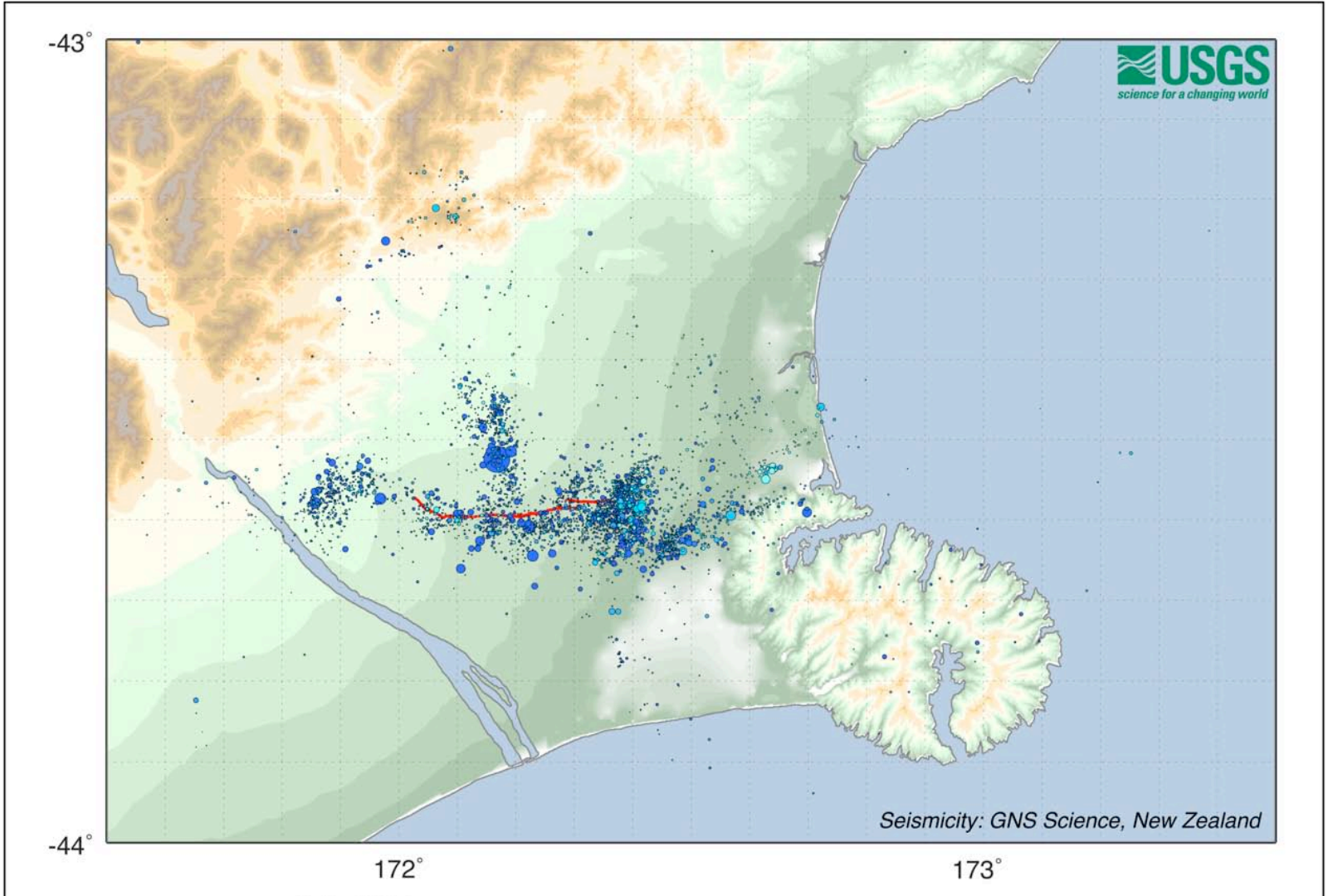
The Earthquake sequence - so far

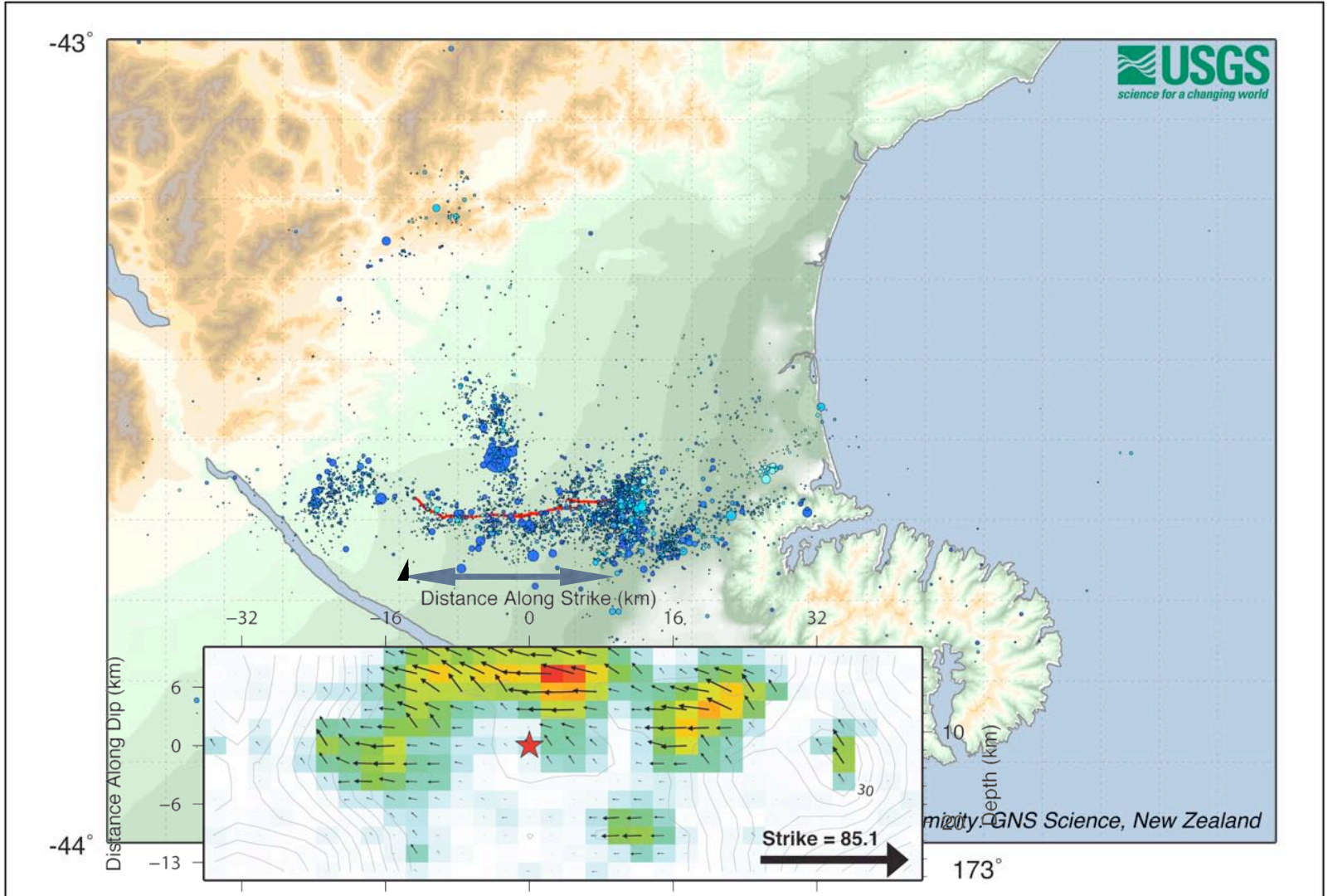


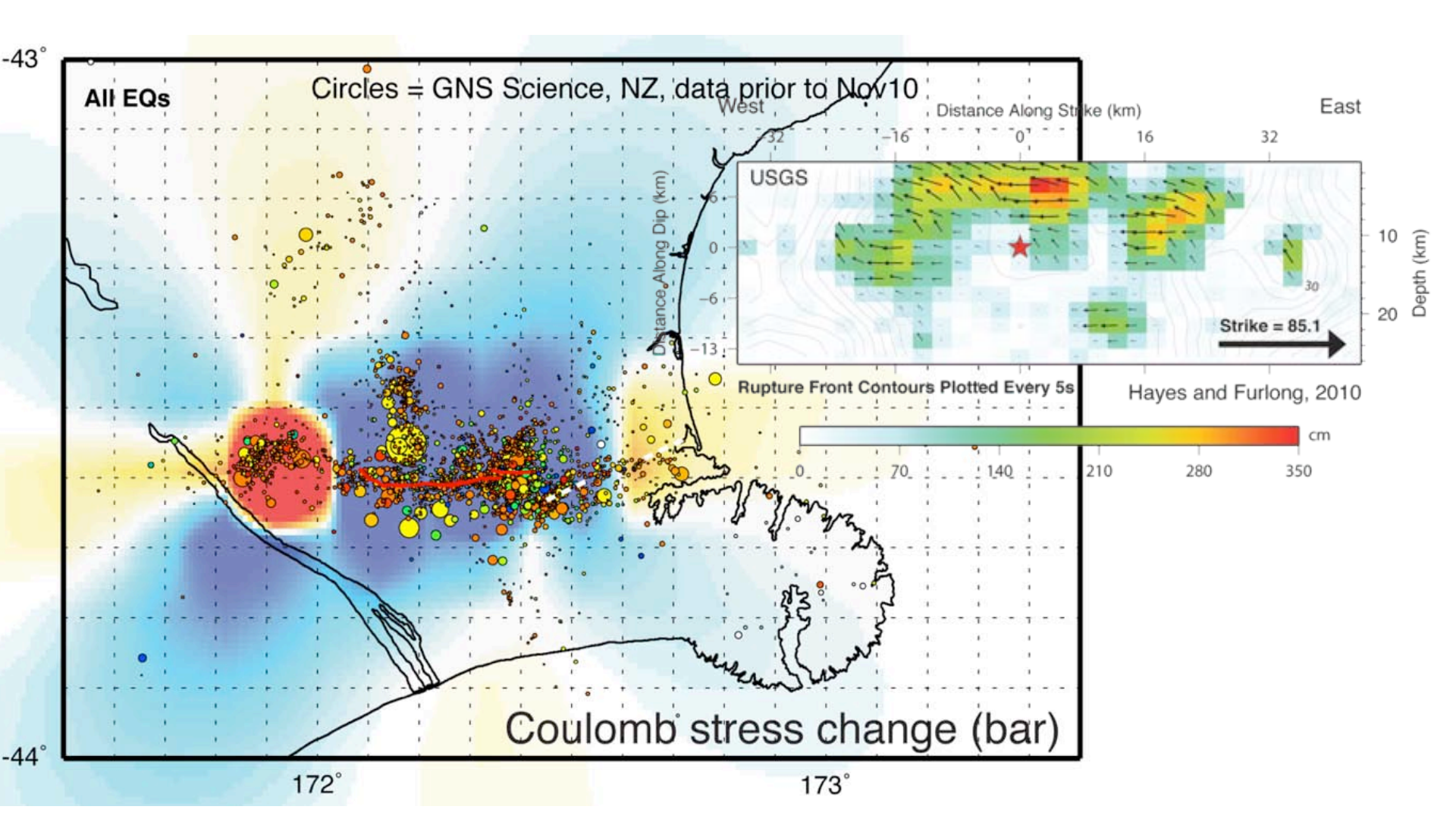
1 Sept 2010

until

31 Dec 2010




-43°
-44°
173°
USGS
science for a changing world
Distance Along Strike (km)
−32
−16
0
16
32
Distance Along Dip (km)
6
0
−6
−13
10
20
30
Depth (km)
Strike = 85.1
mity. GNS Science, New Zealand


All EQs
Circles = GNS Science, NZ, data prior to Nov10
-43°
-44°
172°
173°
Coulomb stress change (bar)
West
East
Distance Along Strike (km)
32
16
0
16
32
Distance Along Dip (km)
6
0
-6
-13
USGS
10
20
Depth (km)
30
Strike = 85.1
Rupture Front Contours Plotted Every 5s
Hayes and Furlong, 2010
cm
0
70
140
210
280
350

31 Dec 2010

until

4 April 2011

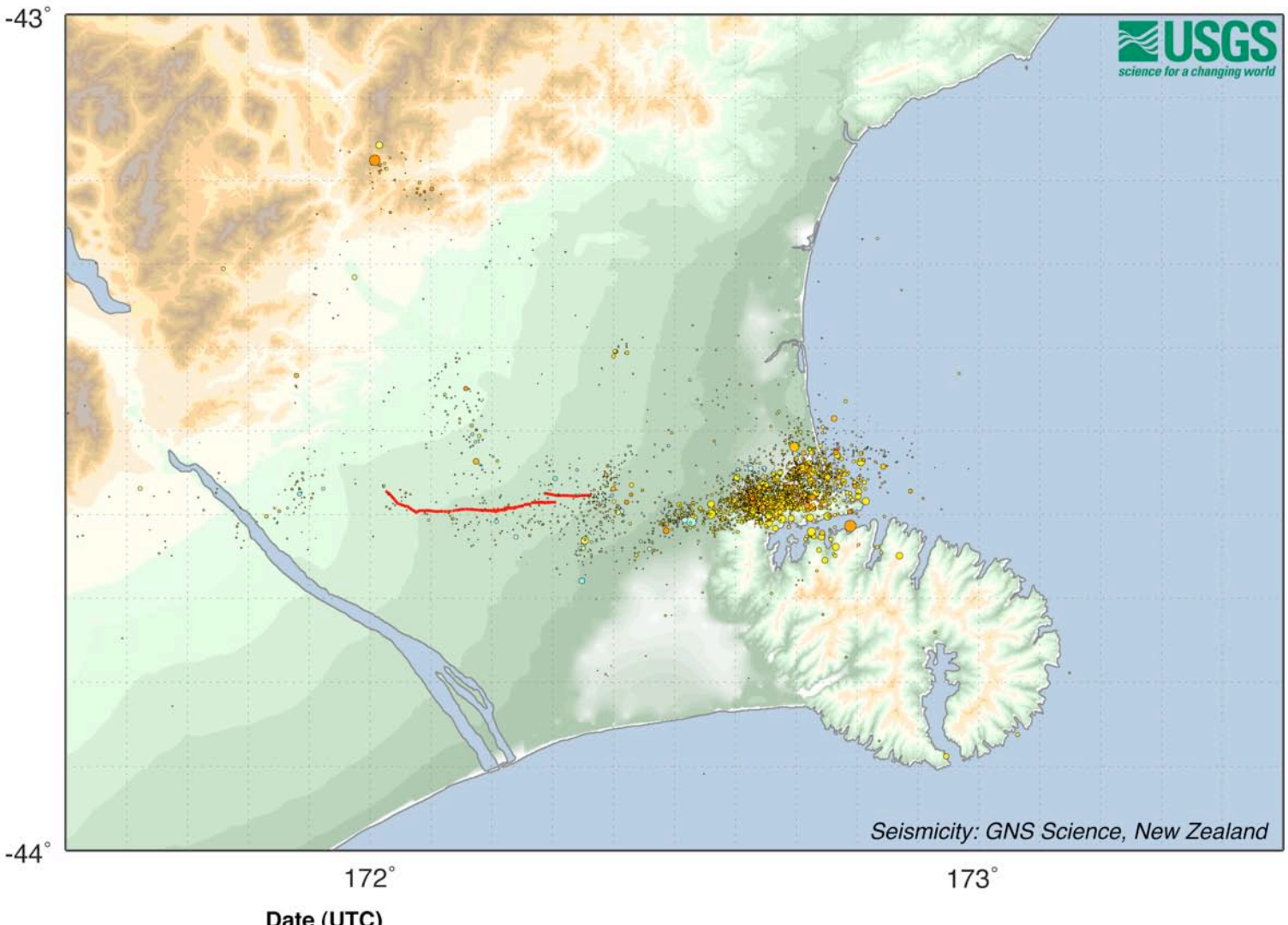
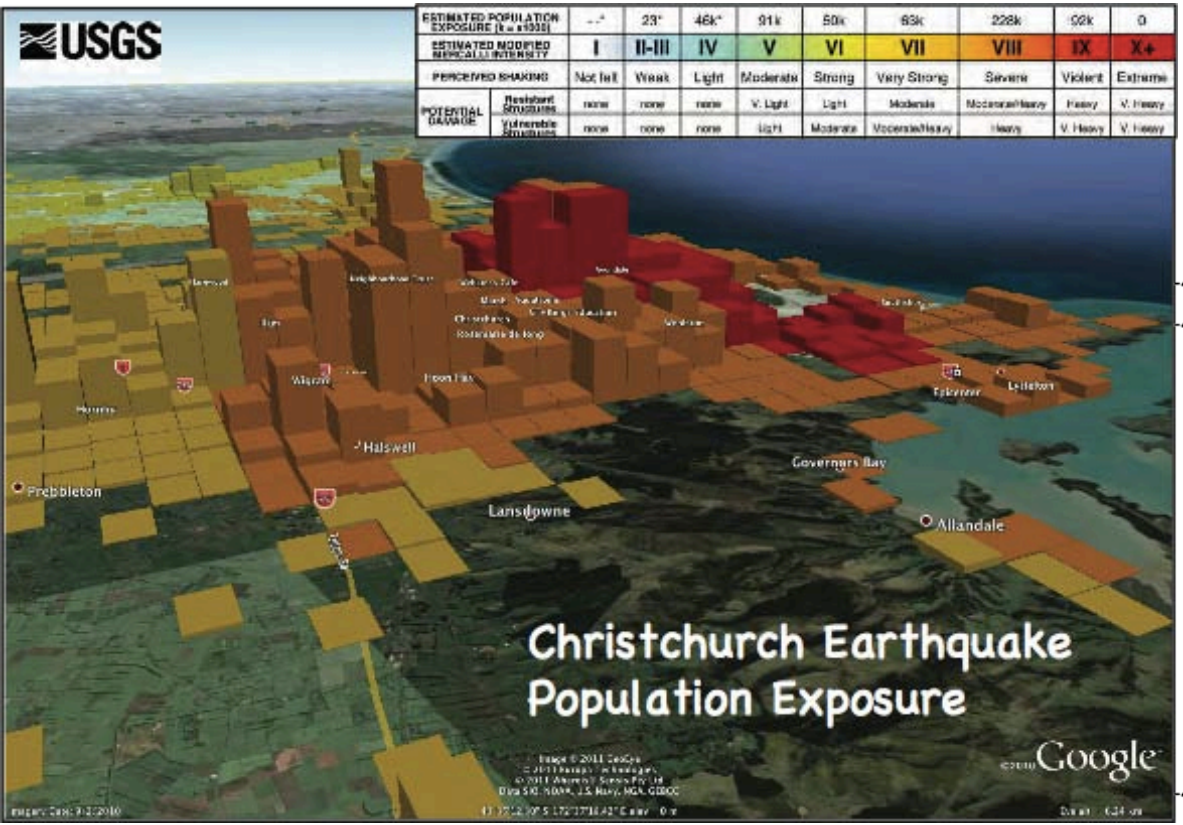
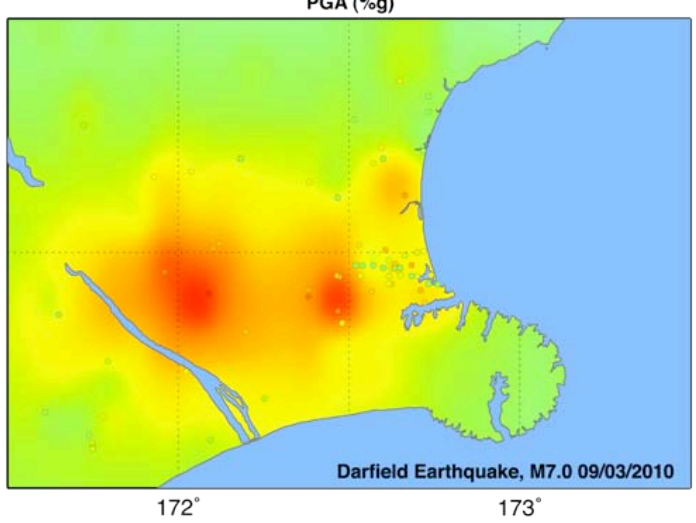
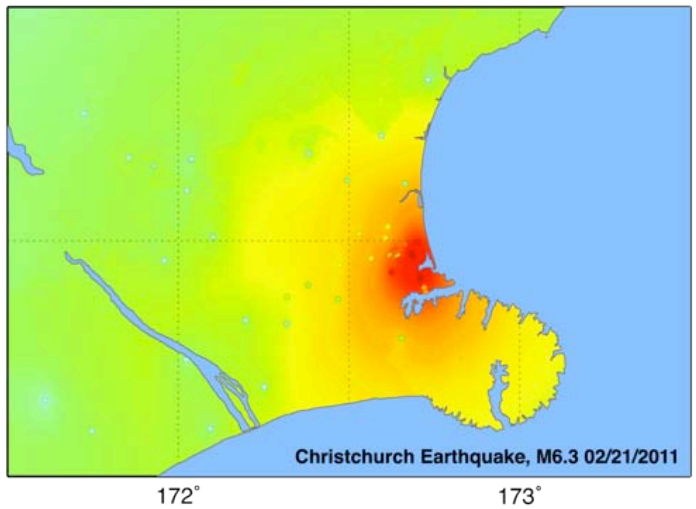



Photo by Richard Hunt


USGS
ESTIMATED POPULATION EXPOSURE (k = x1000)
ESTIMATED MODIFIED MERCALLI INTENSITY
PERCEIVED SHAKING
POTENTIAL DAMAGE
Resistant Structures
Vulnerable Structures
I
II-III
IV
V
VI
VII
VIII
IX
X+
Not felt
Weak
Light
Moderate
Strong
Very Strong
Severe
Violent
Extreme
none
V. Light
Light
Moderate
Moderate/Heavy
Heavy
V. Heavy
Halswell
Prebbleton
Lansdowne
Governors Bay
Allandale
Christchurch Earthquake
Population Exposure
Google


PGA (%g)
-43°
-44°
172°
173°
Darfield Earthquake, M7.0 09/03/2010


-43°
-44°
172°
173°
Christchurch Earthquake, M6.3 02/21/2011

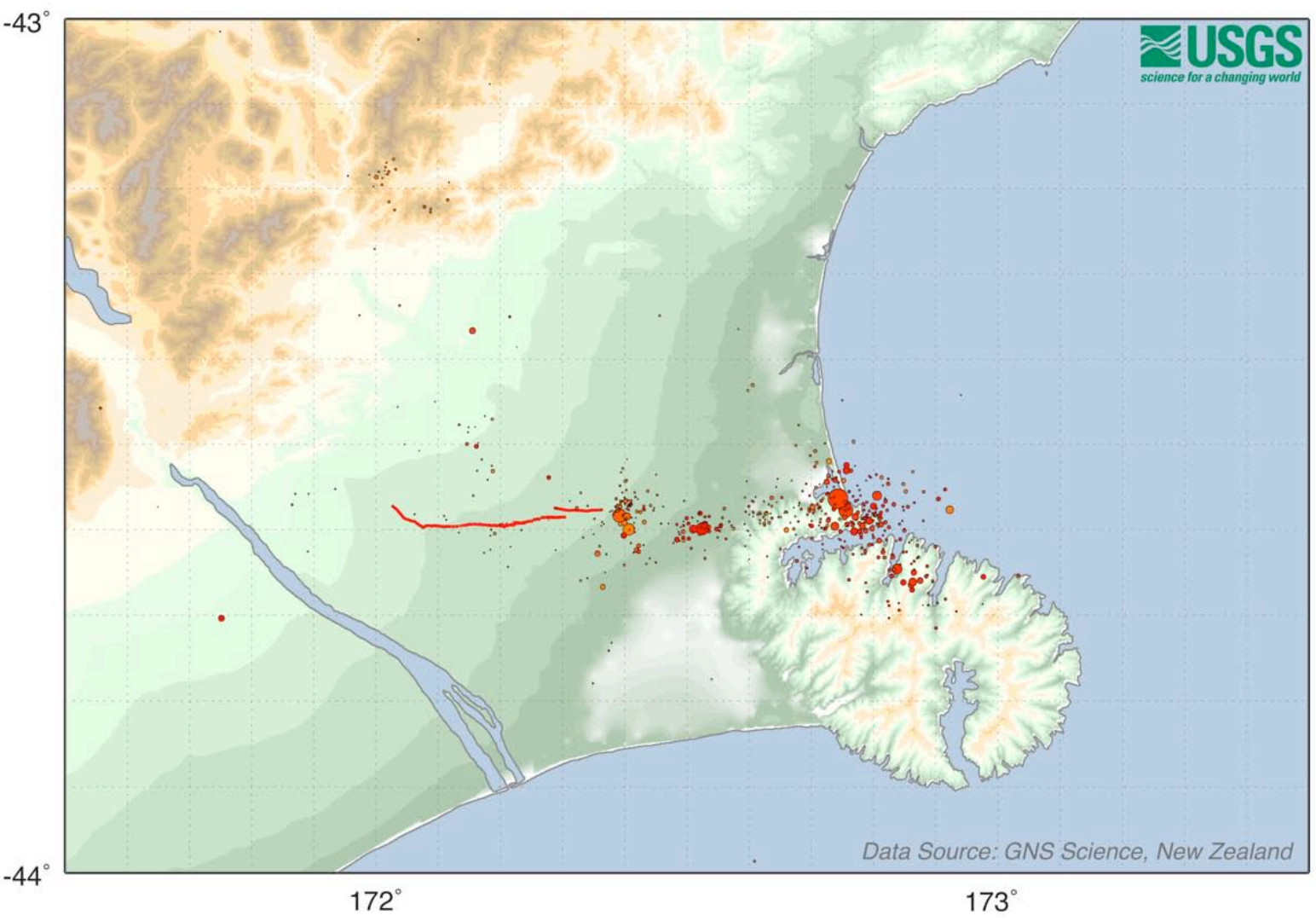
June 13, 2011

The Pain Continues

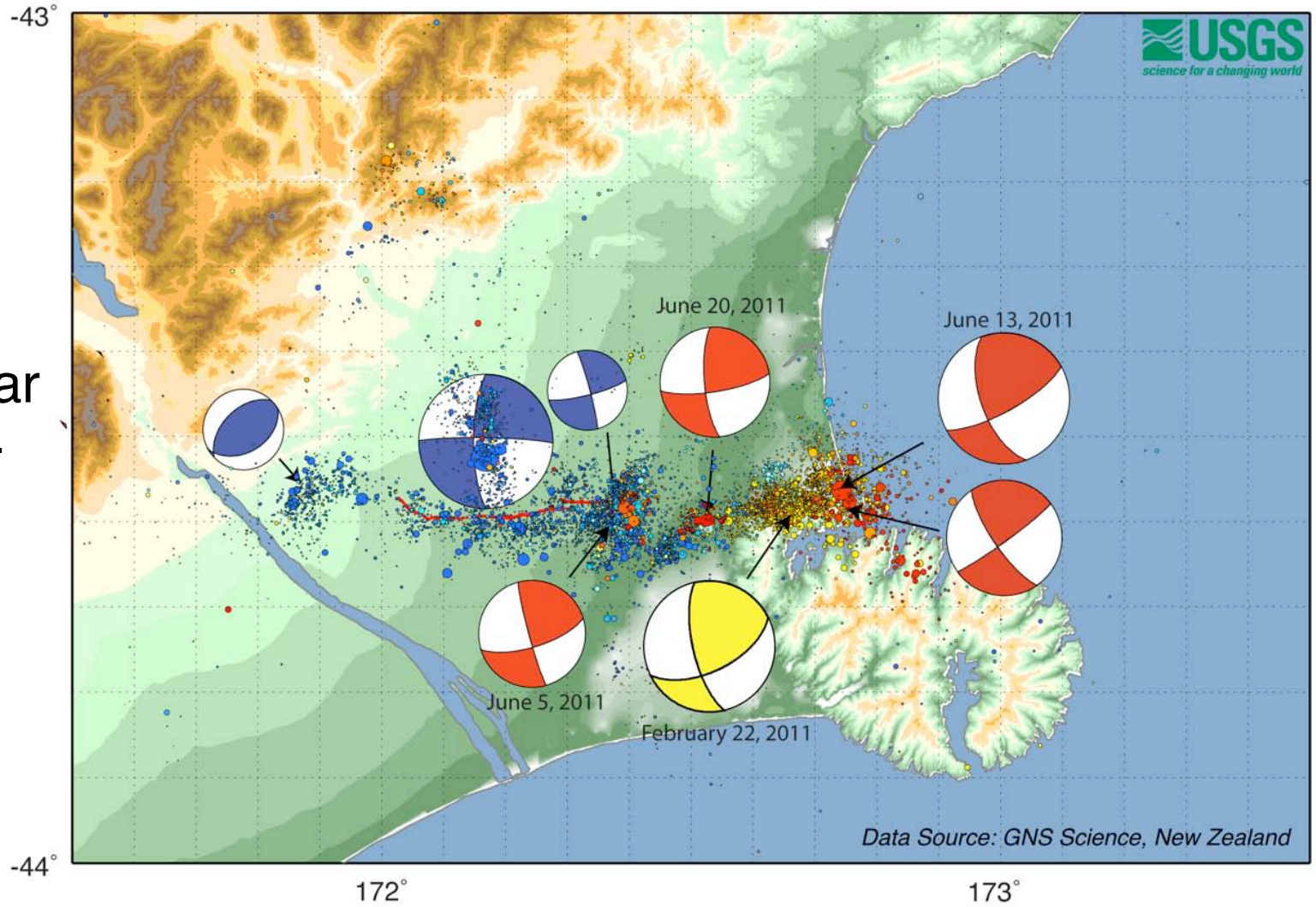
4 April 2011

until

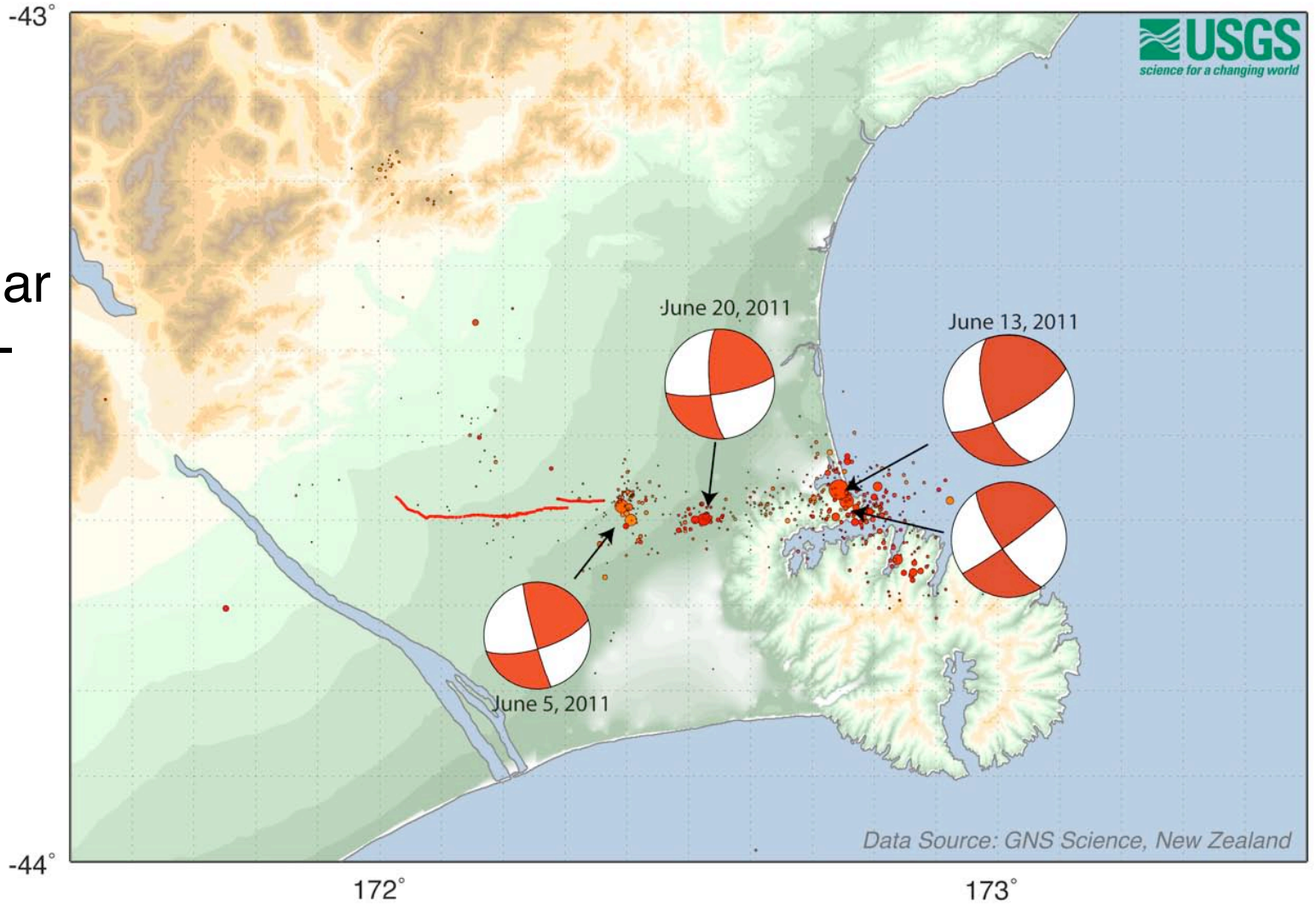
24 June 2011



Very similar faulting - or is it?

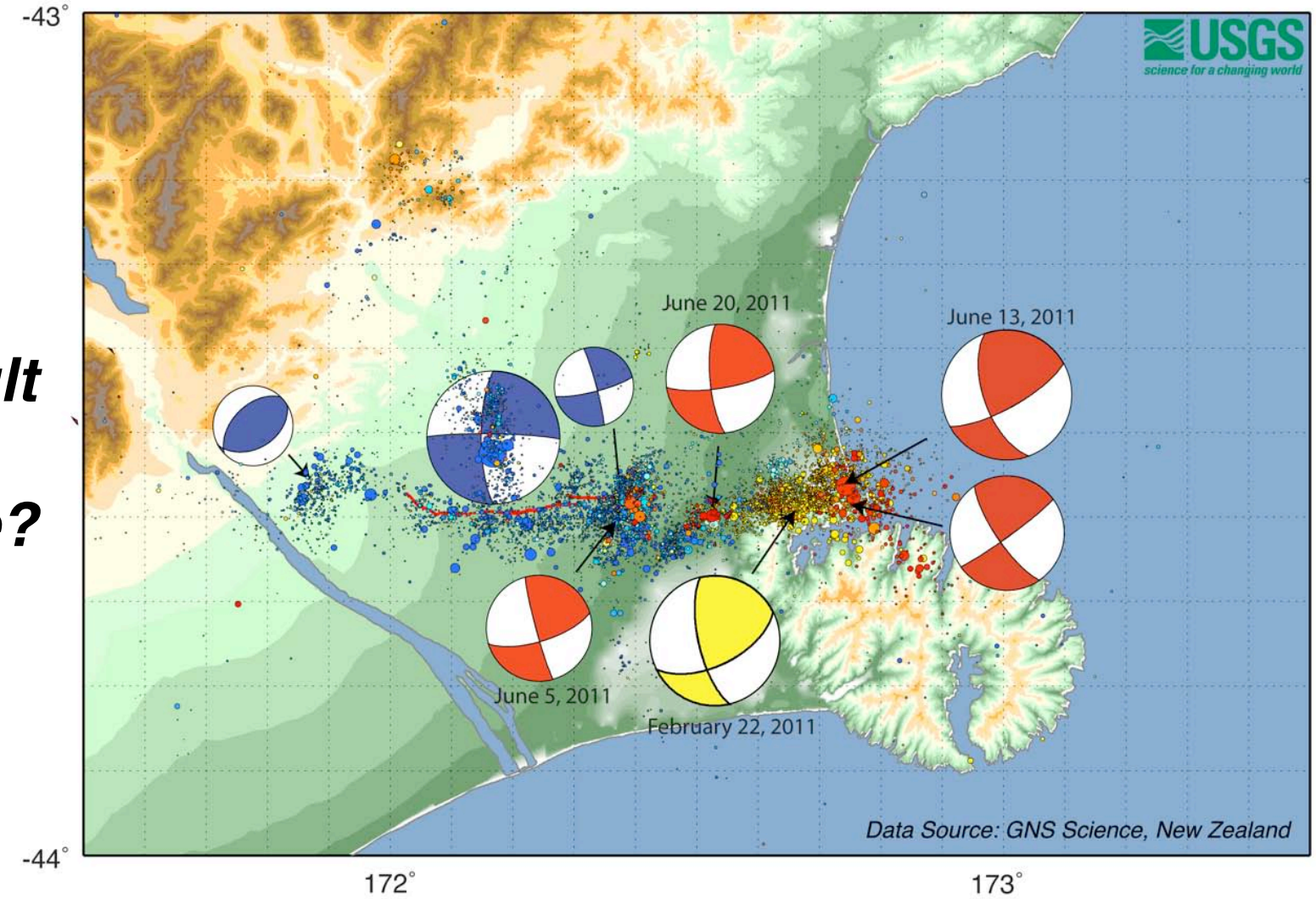


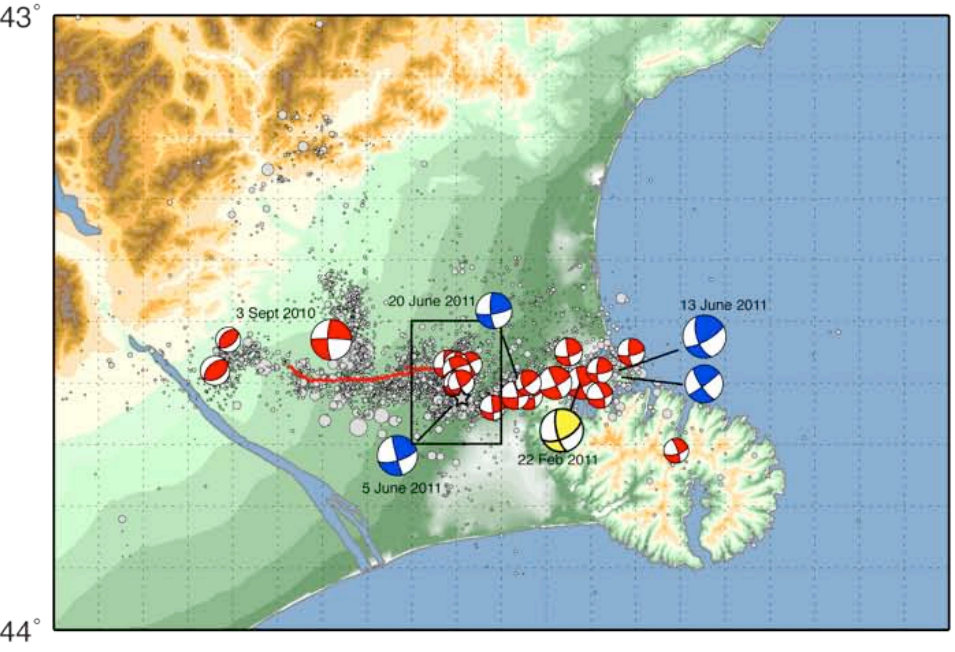
Very similar faulting - or is it?

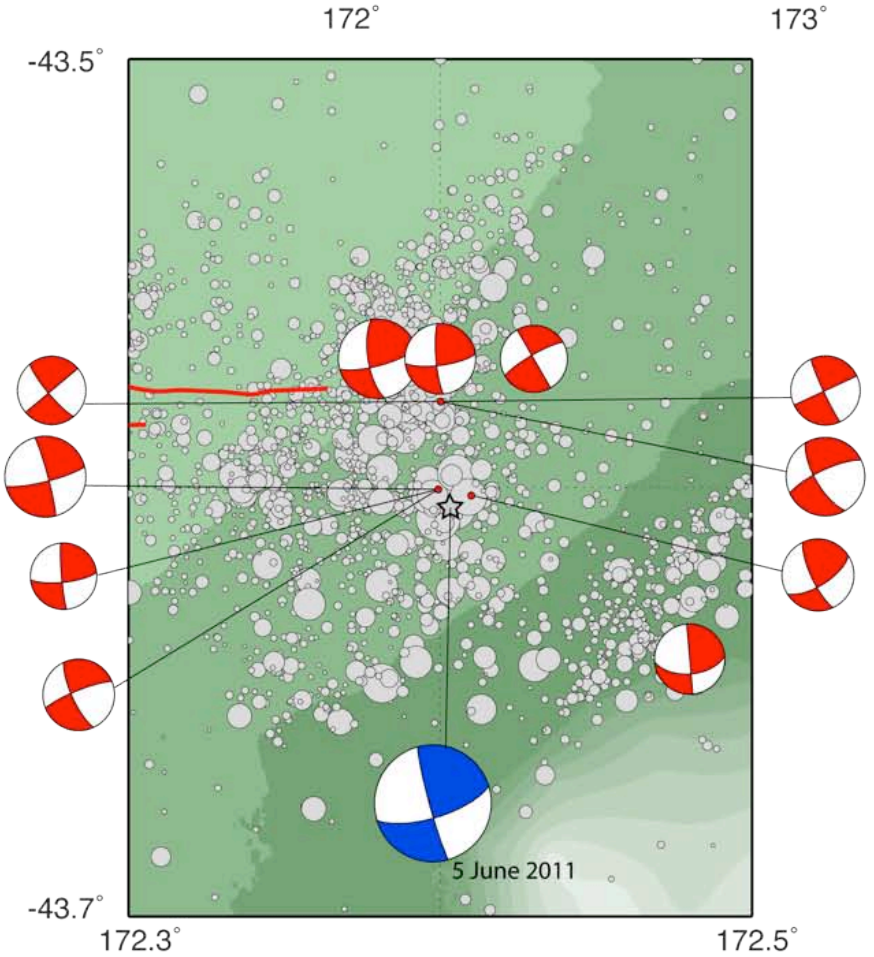


What does the future hold for Christchurch

Is the fault system complete?

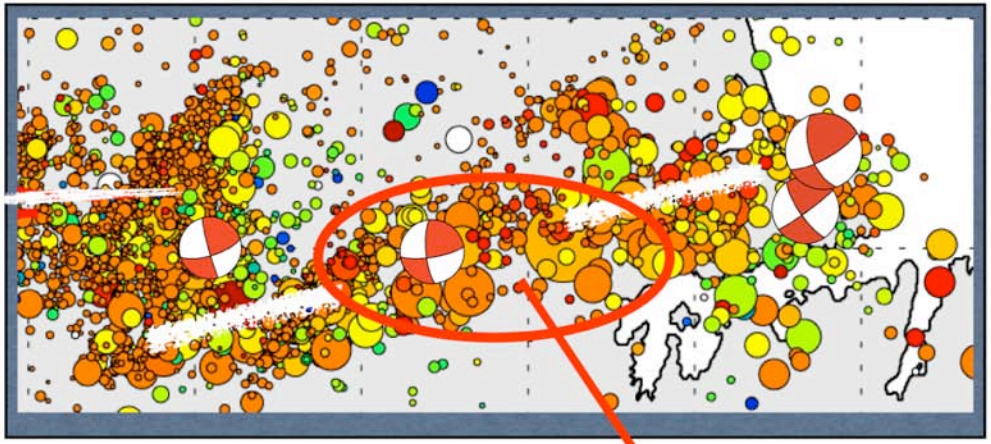




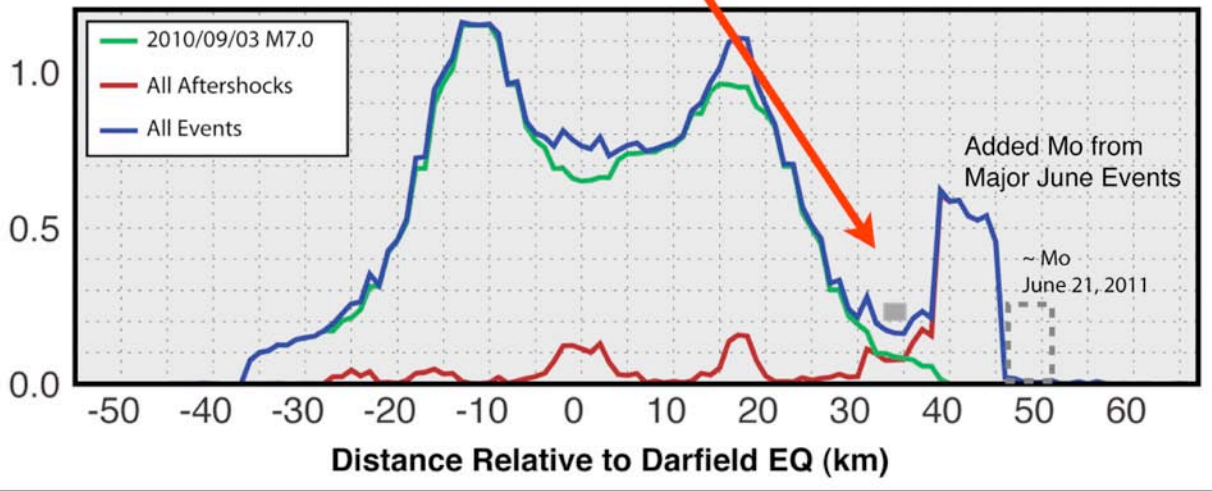


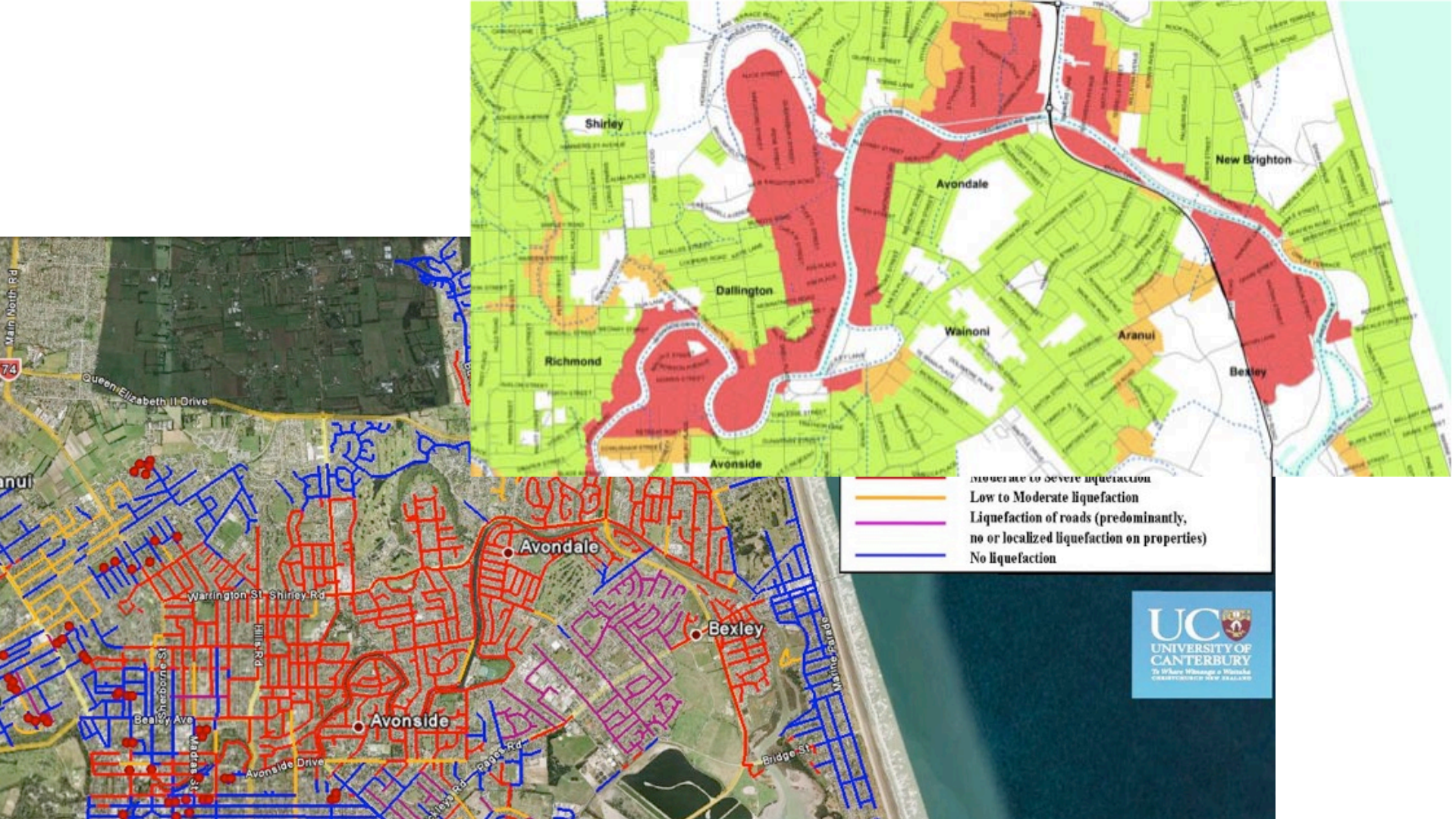
Significance of fault segment complexity?

Is such a minimum in Mo significant ?

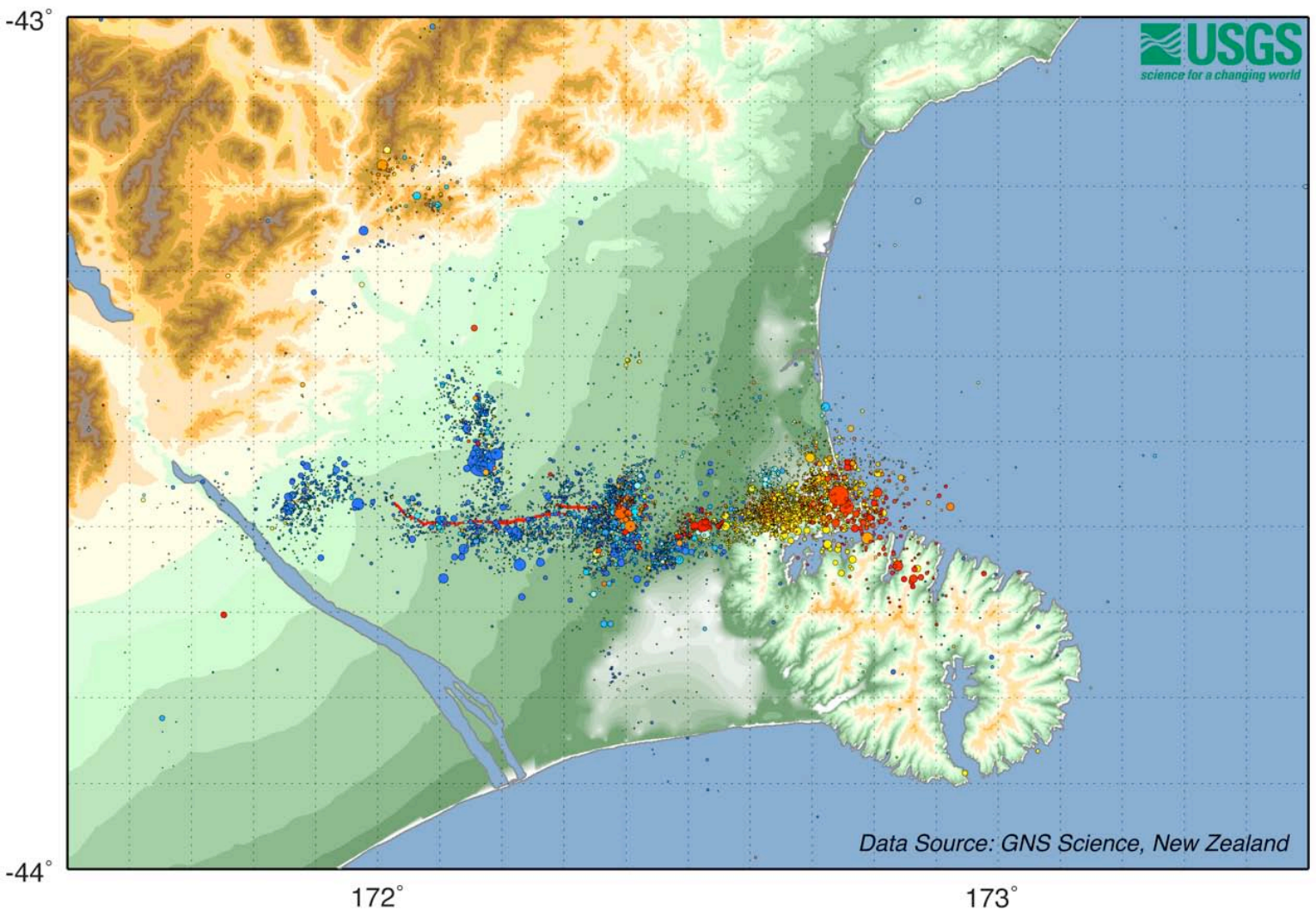


Minimum in Moment Release




Shirley
New Brighton
Avondale
Dallington
Wainoni
Aranui
Richmond
Bexley
Avonside
Moderate to Severe liquefaction
Low to Moderate liquefaction
Liquefaction of roads (predominantly, no or localized liquefaction on properties)
No liquefaction
Queen Elizabeth II Drive
Avondale
Bexley
Avonside
Wardington St
Shirley Rd
Avonside Drive
Bridge St
UC
UNIVERSITY OF CANTERBURY


Is this unique to Christchurch,
or an issue of global significance?


-43°
-44°
172°
173°
USGS
science for a changing world
Data Source: GNS Science, New Zealand