INTERACTION BETWEEN SSE, EARTHQUAKES, AND SEISMIC RADIATION AT THE HIKURANGI MEGATHRUST

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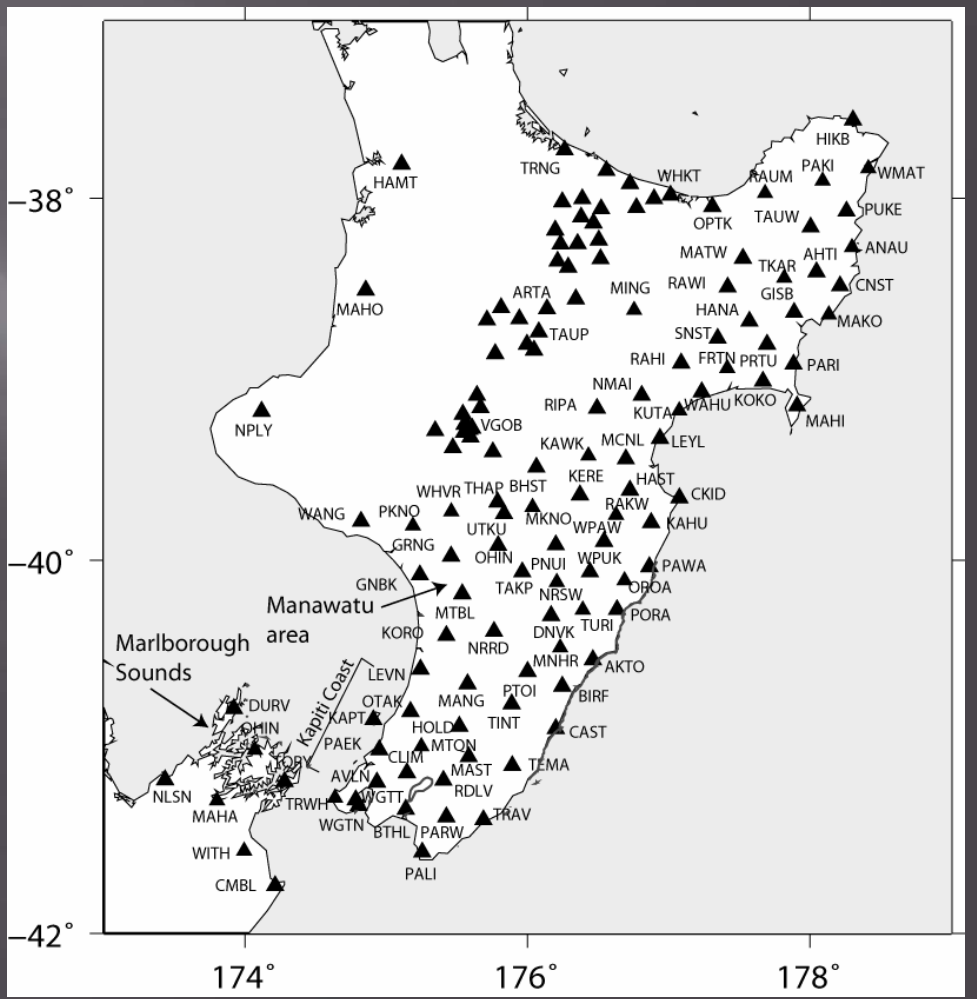
Continuous GPS network

Since 2002, we have observed more than 20 distinct slow slip events at CGPS sites in the North Island

Current CGPS network configuration
Data available at www.geonet.org.nz



My goals for this talk:

- 1) Describe temporal variability of megathrust strain (interevent) – convince you that time-dependent hazard forecasting is important
- Linking thoughts including discussion on informing probabilistic seismic hazard with geodetic measurements and possibly synthetic seismicity

What we do now in our National Seismic Hazard Model

Wallace et al (2009) used as basis for development of recurrence parameters for Hikurangi interface sources

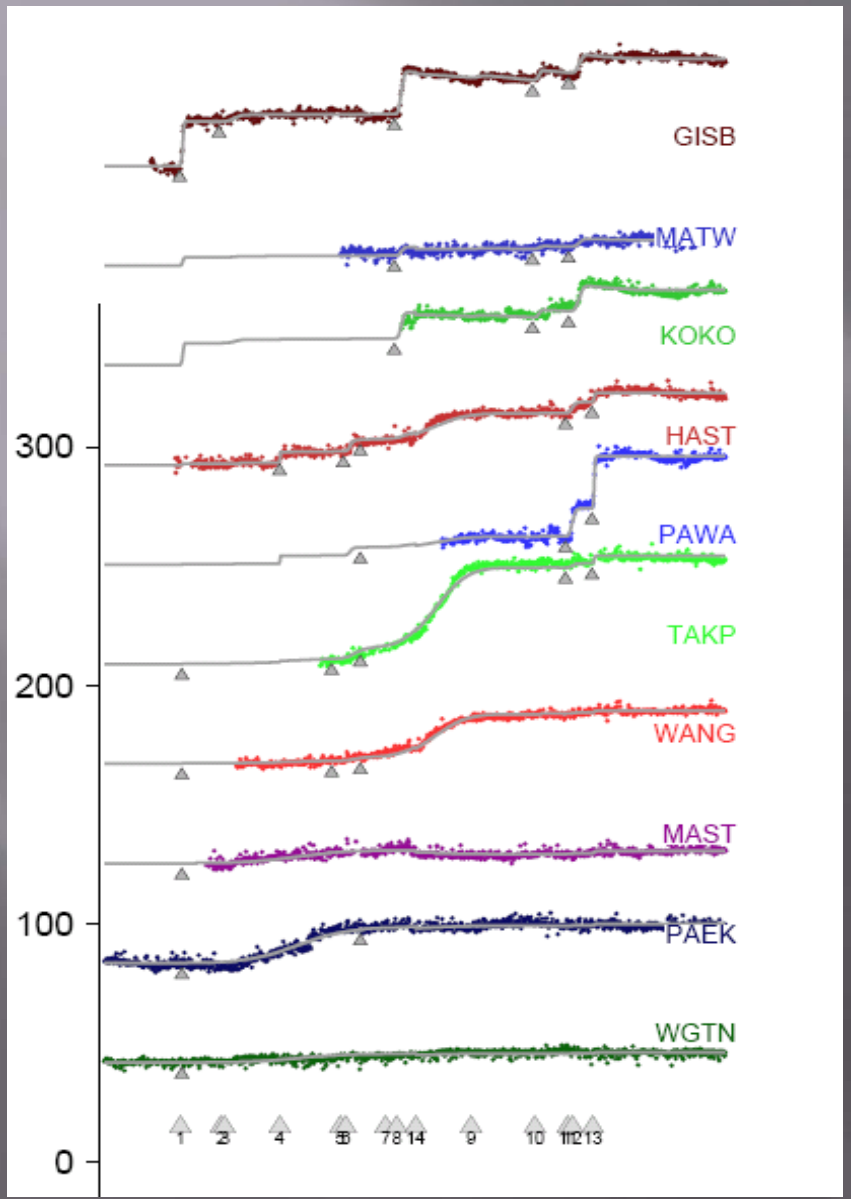
3 segments modelled (Wellington, Hawkes Bay, Raukumara) joint rupture also considered.

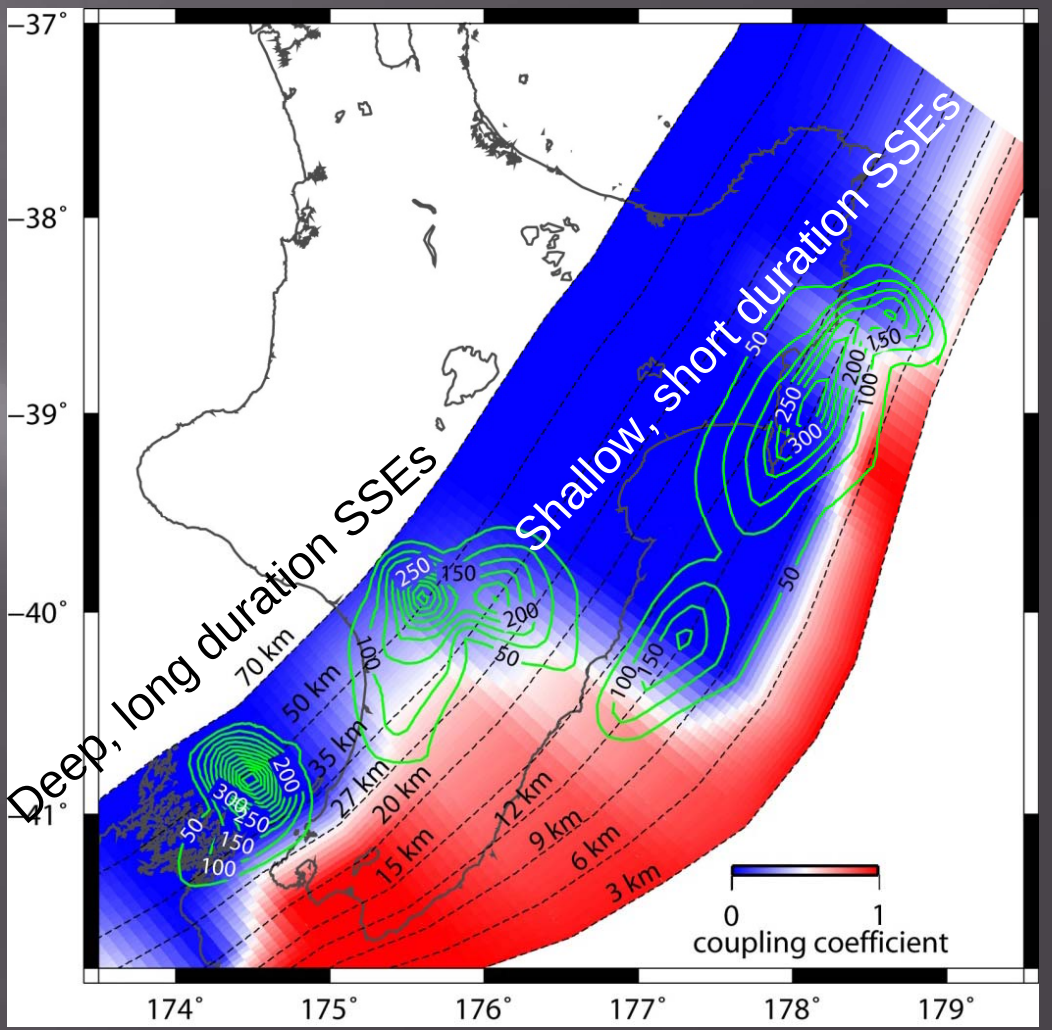
Mw for ruptures based on McCaffrey (2008), Aki & Richards (1980) and Hanks & Kanamori (1979). Magnitude range from Mw~8 to Mw9.

Geodetically defined strain budgets and coupling are used to calculate recurrence intervals for megathrust earthquakes.

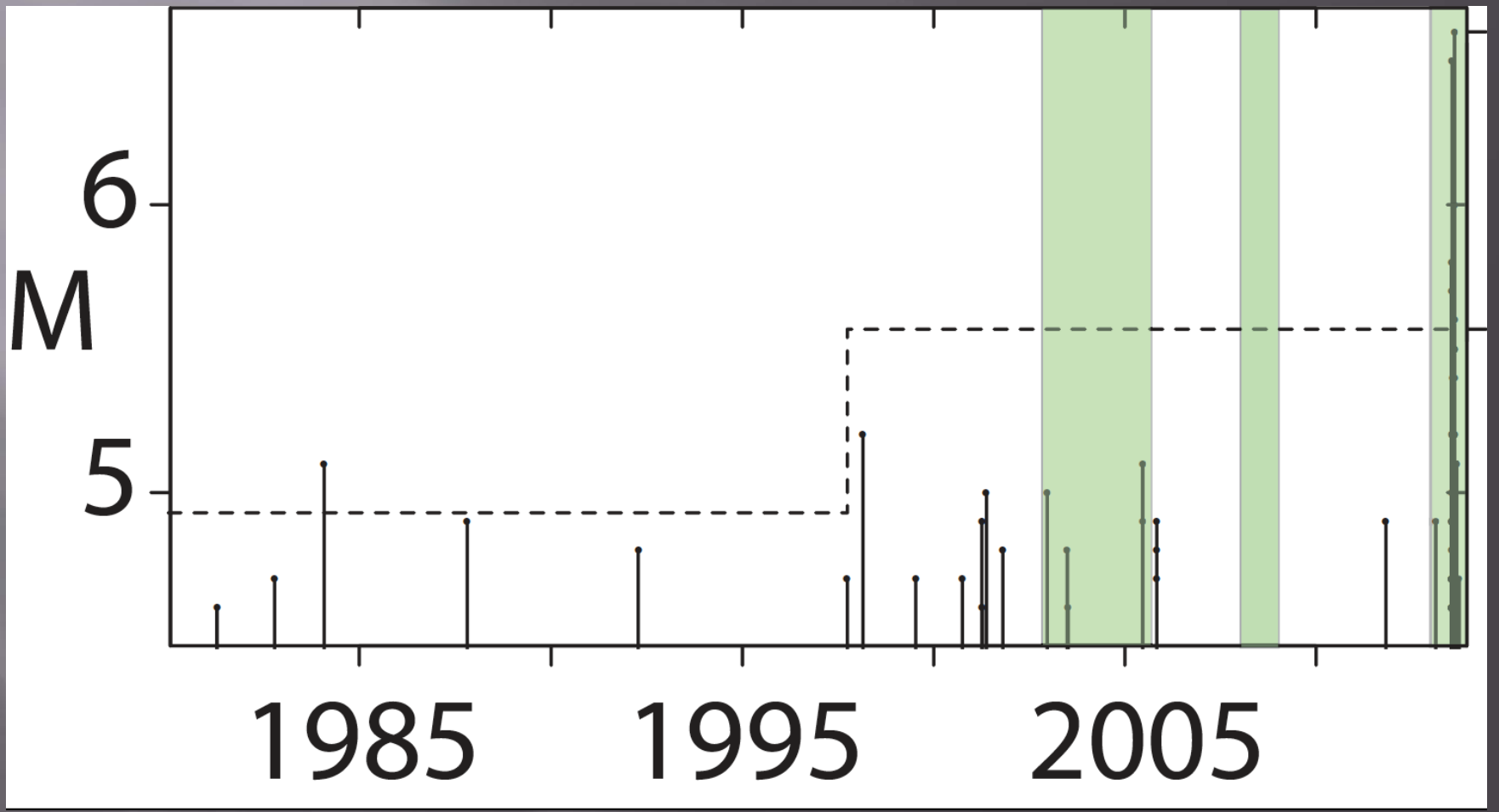
The 3 sizes of interface earthquakes are finally assumed to be Gutenberg-Richter-distributed ie. M~8, M~8.5 and M9. Corresponding recurrence intervals are in the range of 500, 1000 and 7000 years, respectively

We observe a huge variety of slow slip behavior and earthquake behavior at the Hikurangi margin

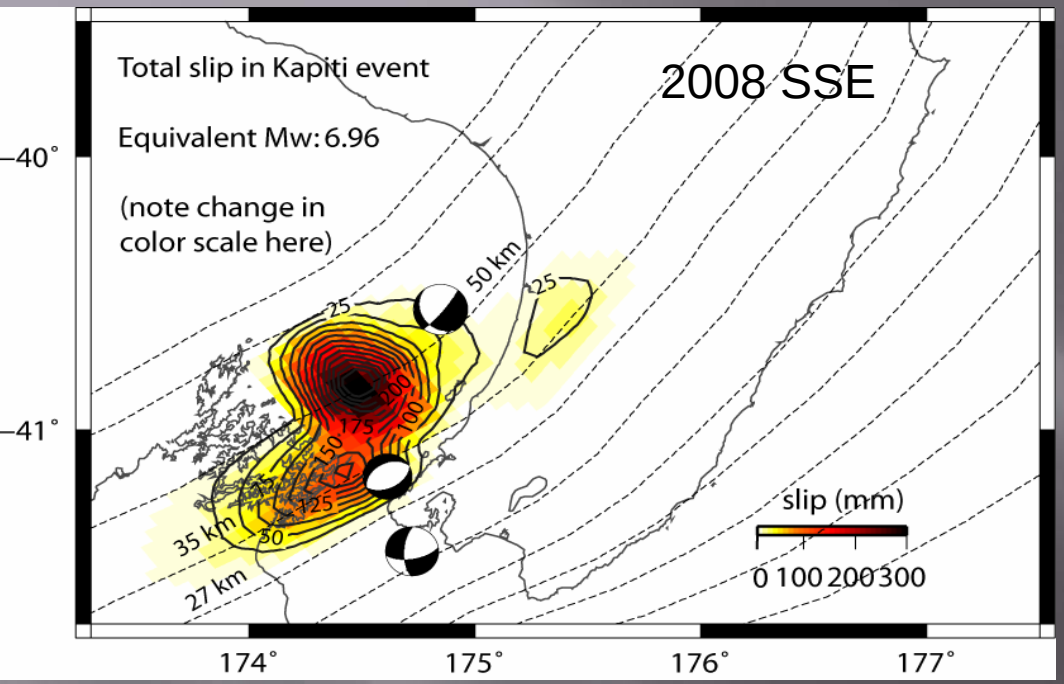




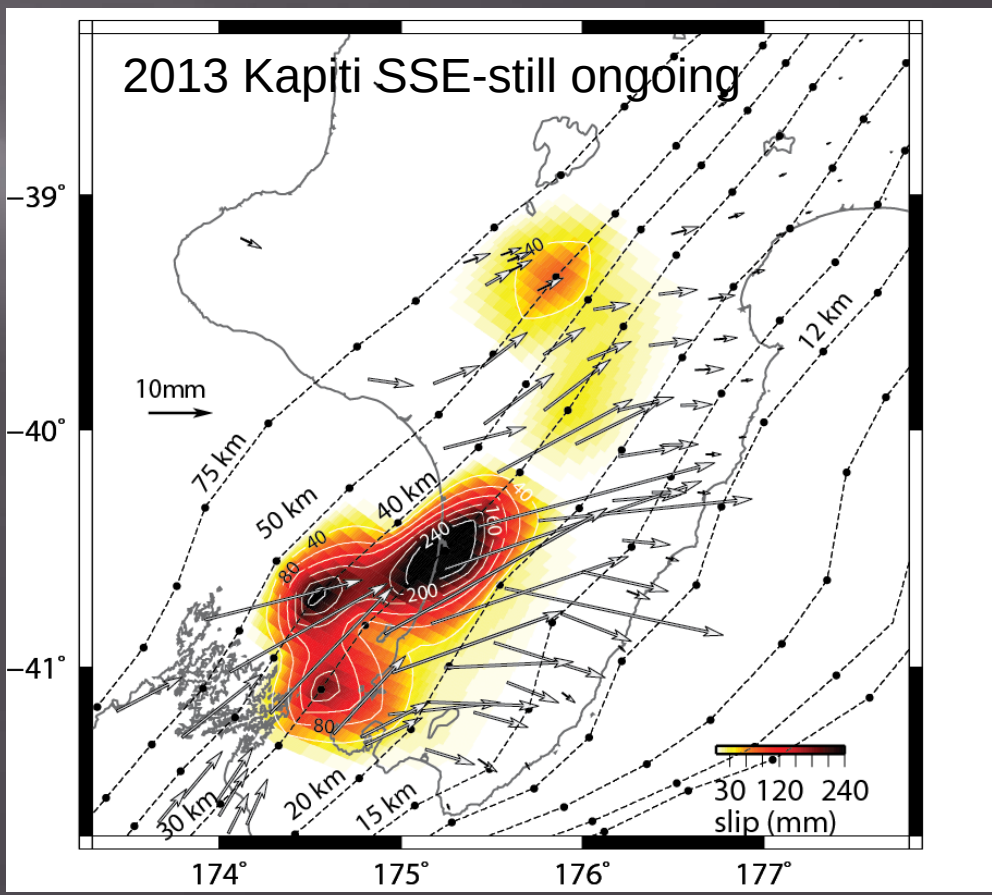
SSE and large crustal EQs



In 2003, 2008, and 2013 a long-term SSE has been recurring ~ every 5 years just west of Wellington



Kapiti SSEs appear to have a 5-yearly recurrence interval

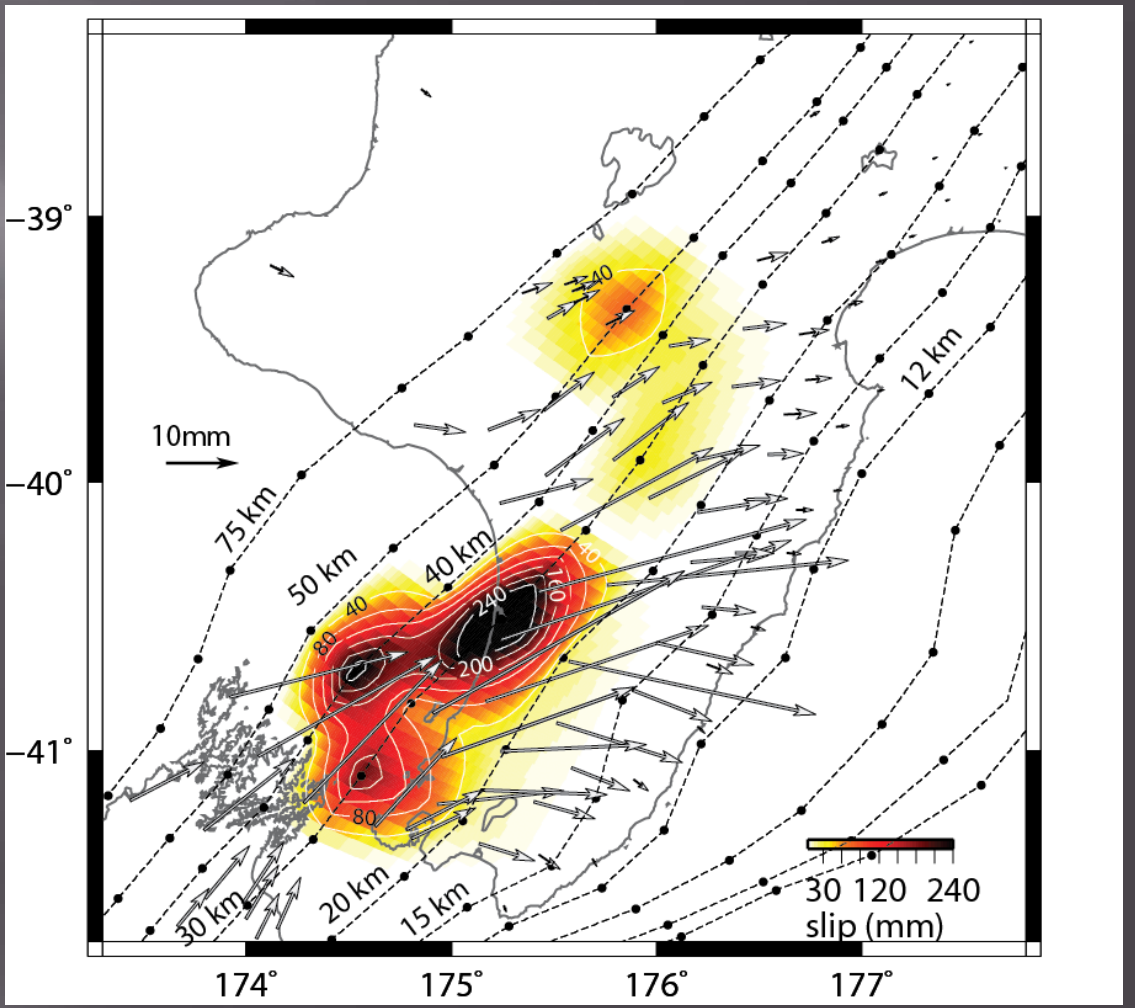


The 2008 event lasted 18 months, and was equivalent to Mw ~7.0

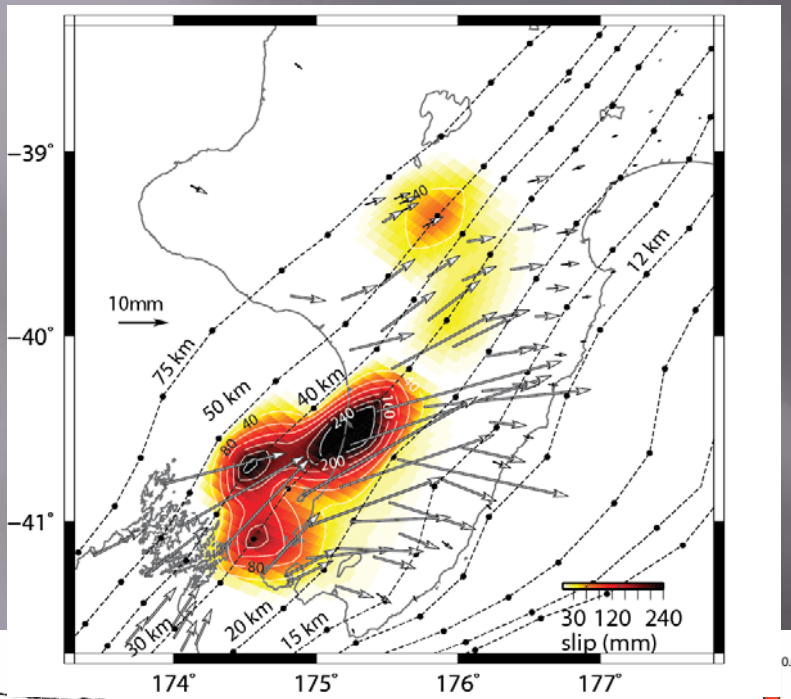
Elevated levels of seismicity in the Wellington region often occur during, or just following the Kapiti SSEs

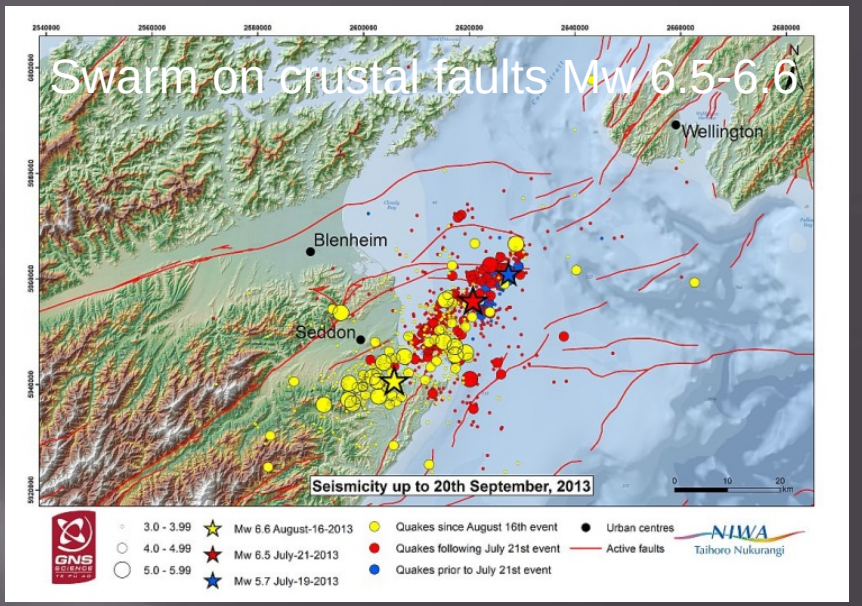
2013 Kapiti SSE

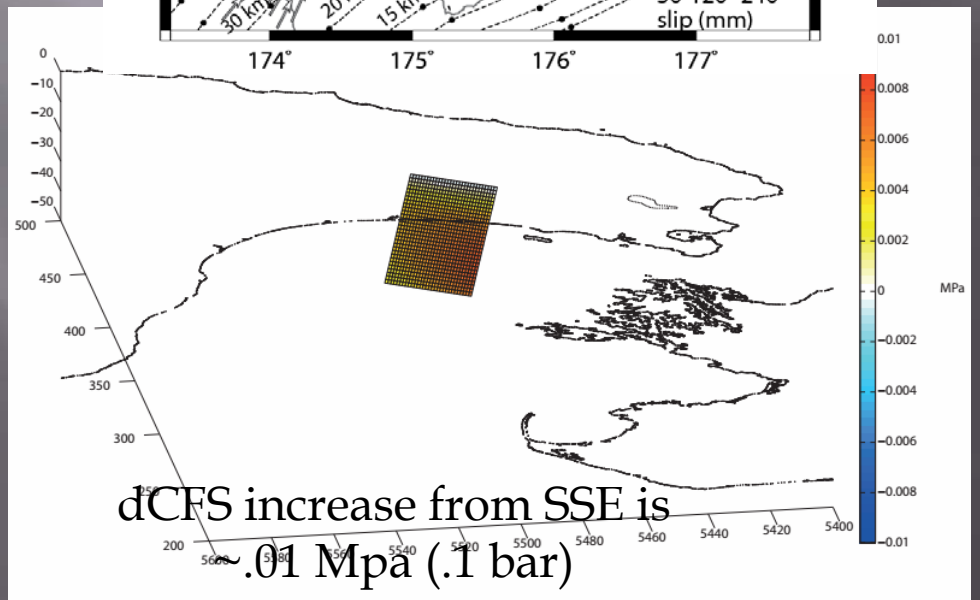
- Kapiti SSE all of 2013 and early 2014
- Equivalent Mw ~7.1
- A much larger amount of slip has occurred north of the main 2008 slip area.



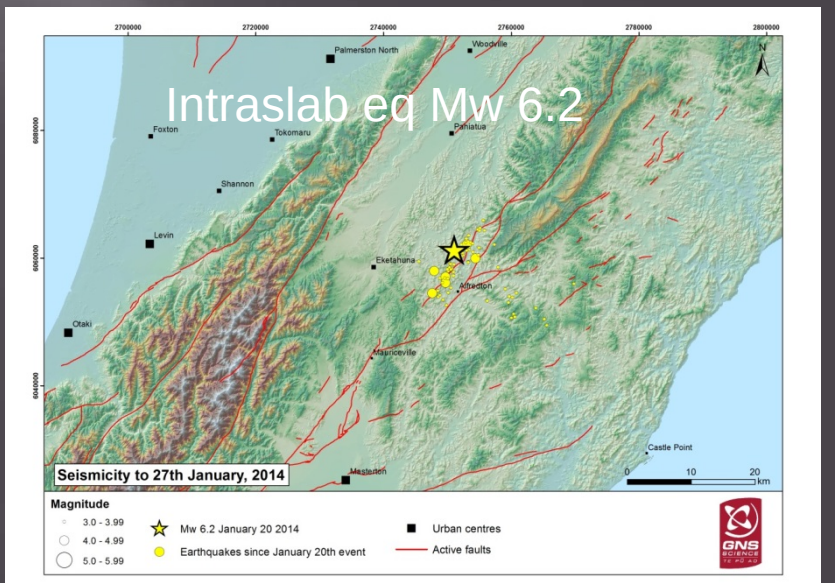
The latest repeat of the Kapiti SSE may have triggered significant seismicity in 2013/2014



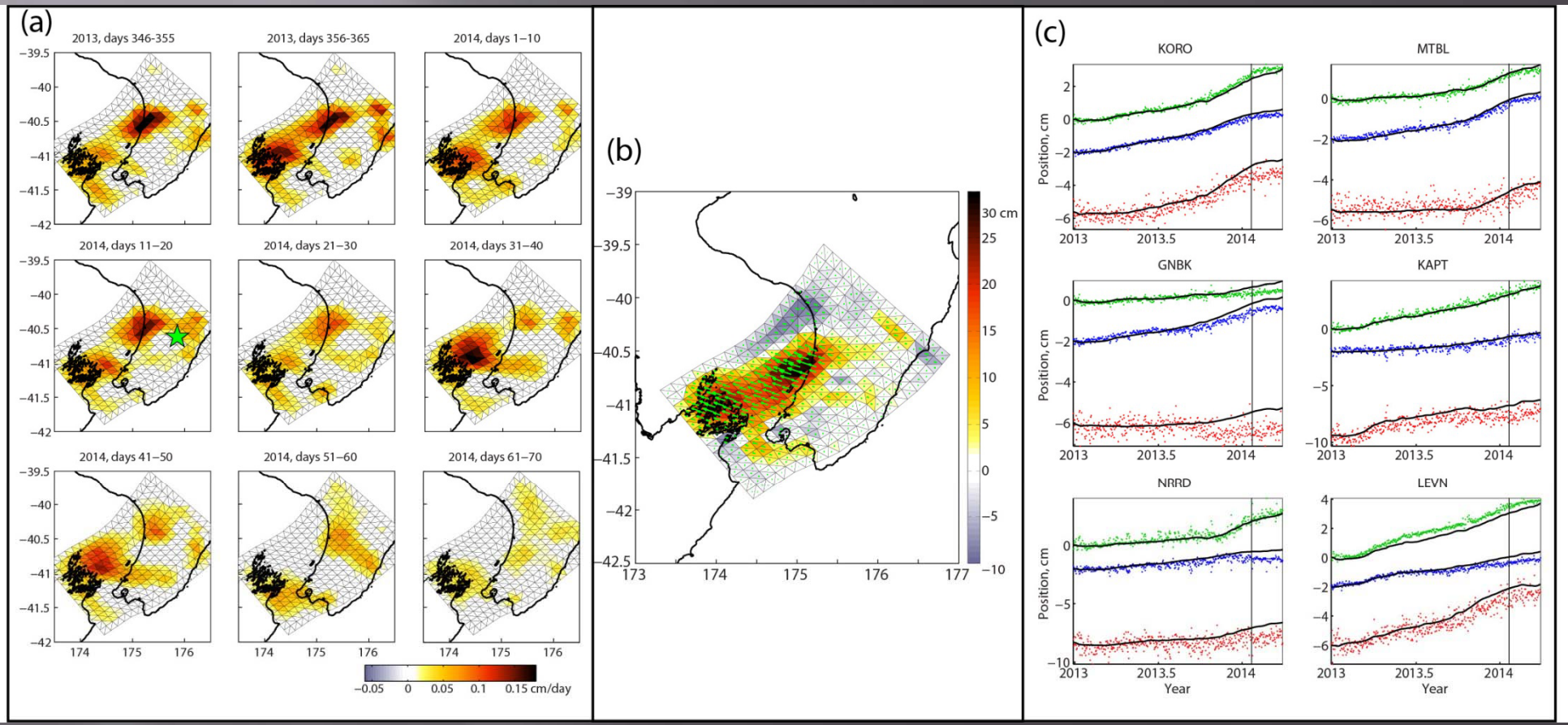




dCFS increase from SSE is ~.01 Mpa (.1 bar)

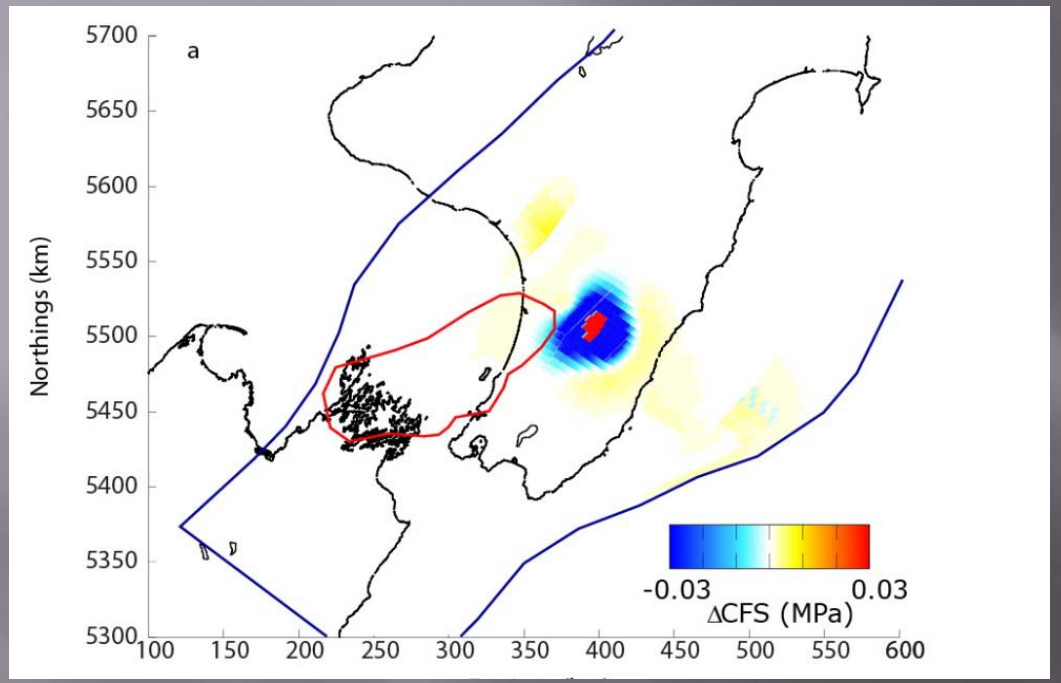


A time dependent inversion of cGPS timeseries for SSE slip



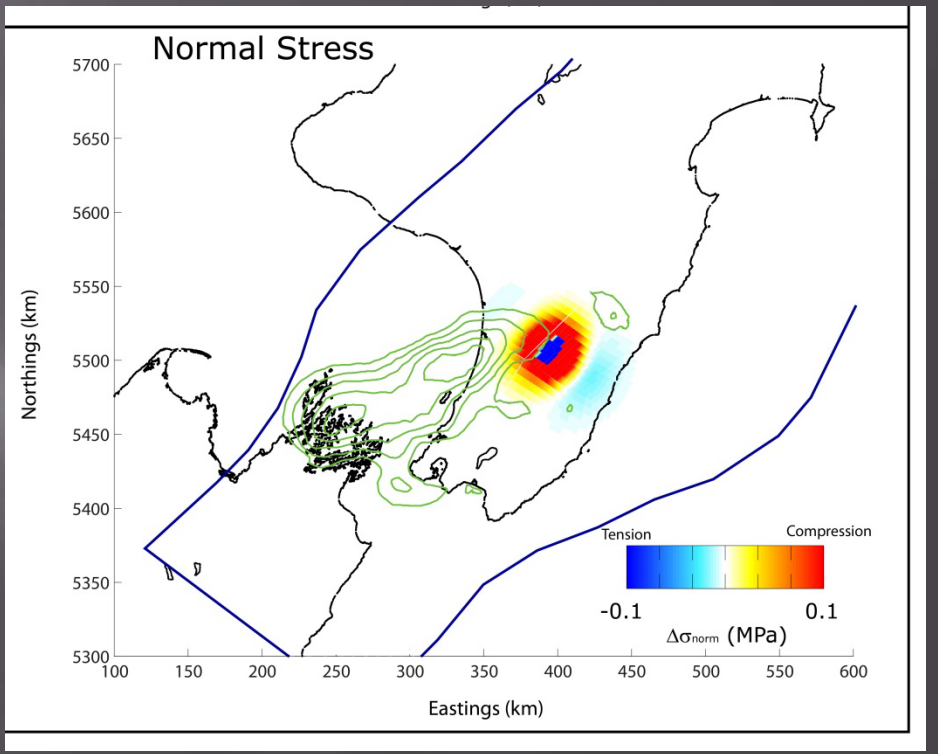
Slip rate in SSE down-dip of the January earthquake decreased by >50% in the weeks following the earthquake. Time dependent inversion by Noel Bartlow, using the network inversion filter

A decrease in Coulomb stress and an increase in normal stress from the intraslab earthquake may have arrested the Kapiti SSE



A decrease in SSE slip rate due to an increase in normal stress is consistent with Rate and State Friction:

$$\mu = \frac{\tau}{\sigma_n} = \mu_o + a \ln \frac{V}{V_o} + b \ln \frac{V_o \theta}{L},$$

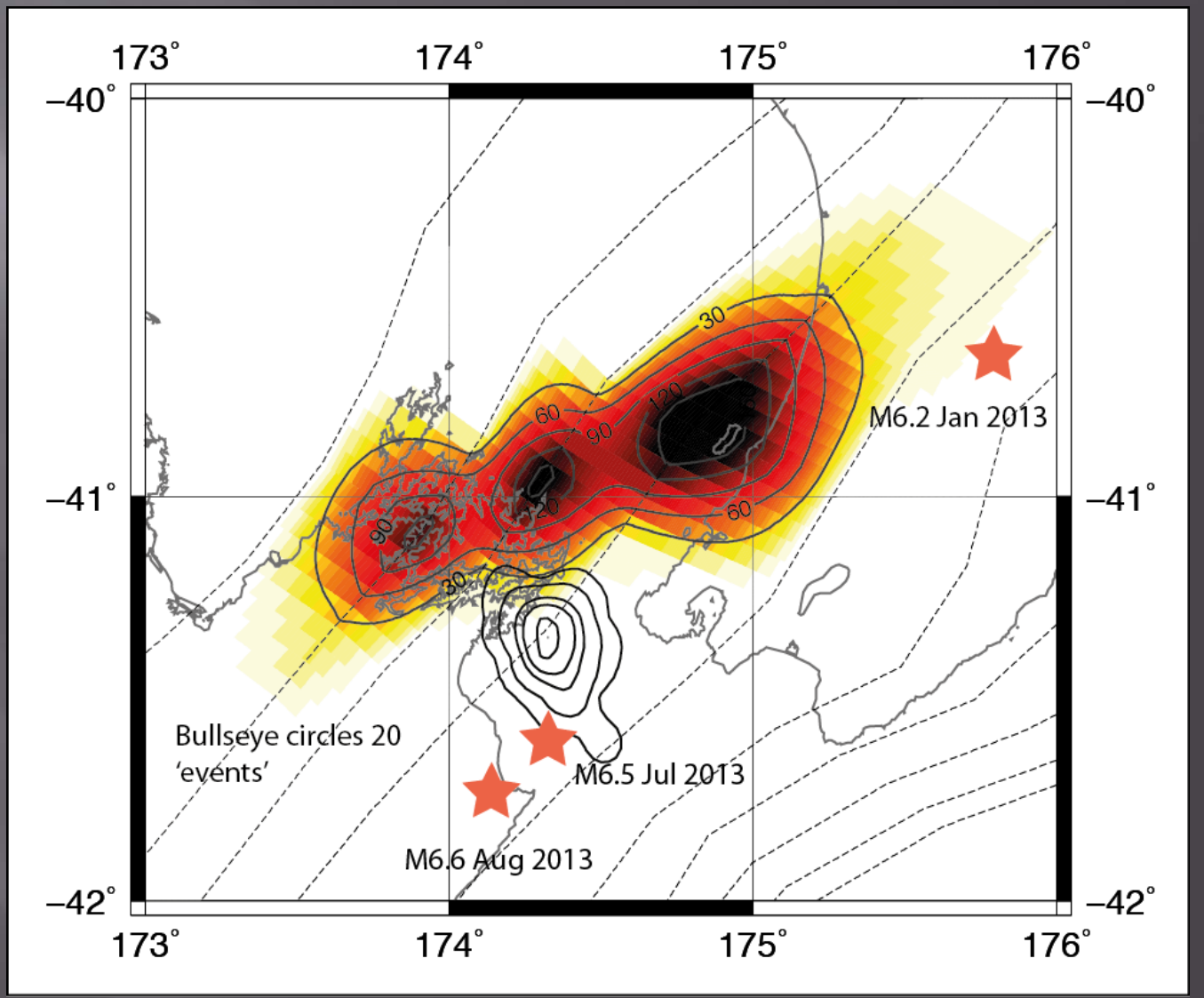


Change in SSE slip rate due to small stress changes also consistent with low effective stress in SSE source

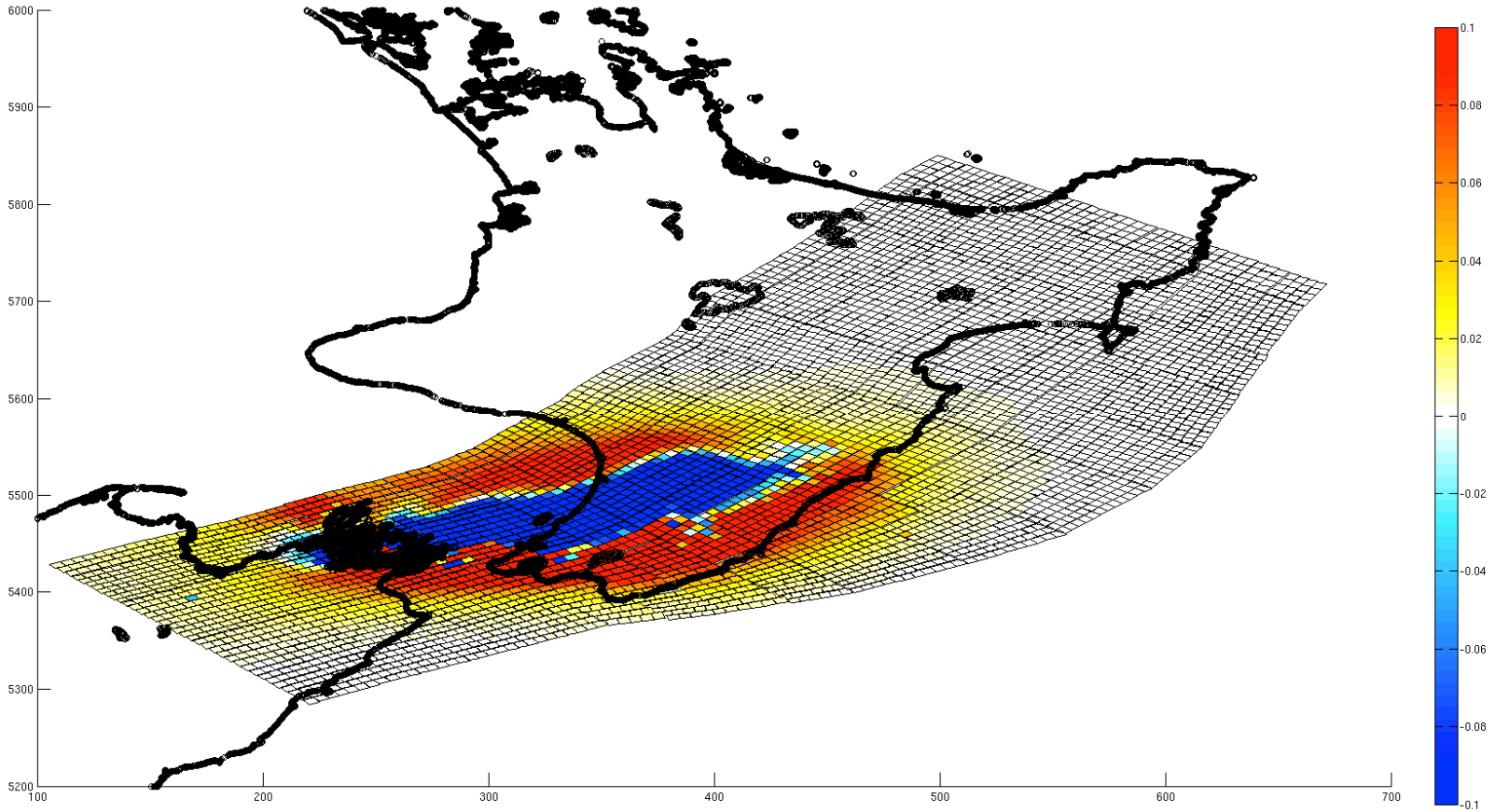
Stress change models by Ian Hamling

Search for tremor

- Manually choose envelope template to calculate moving cross correlations
- Locate with nonlinloc in SC3 using a 3D velocity model
- Very labour intensive and obviously dependent on template selection
- Cluster of events between mid-January and mid-March

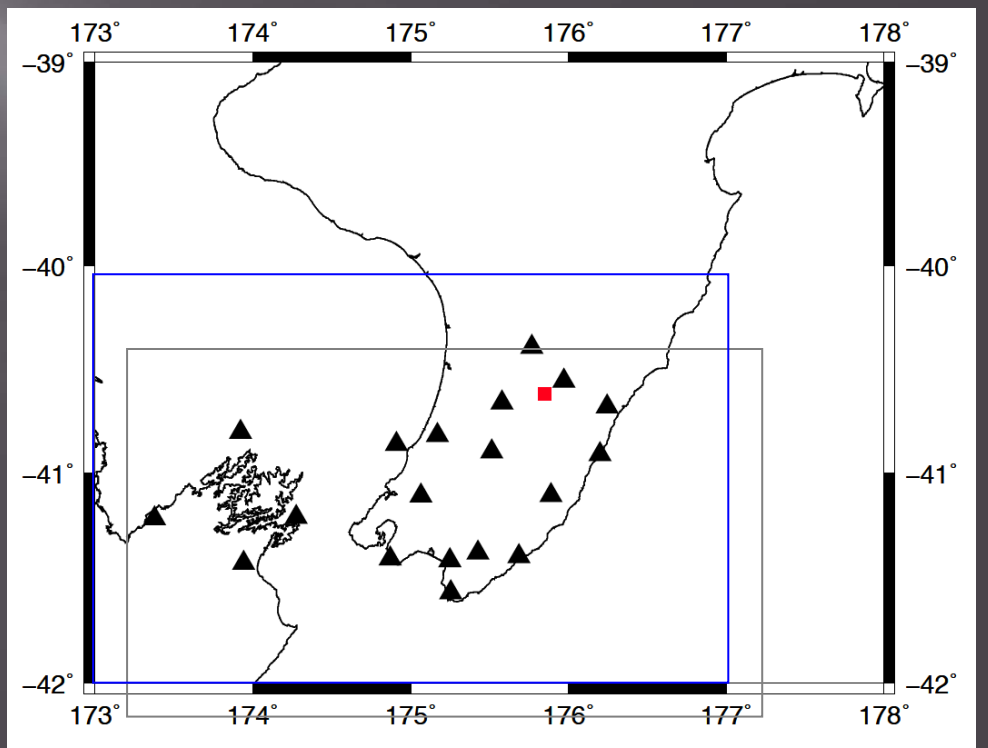


dCFS projected onto plate interface



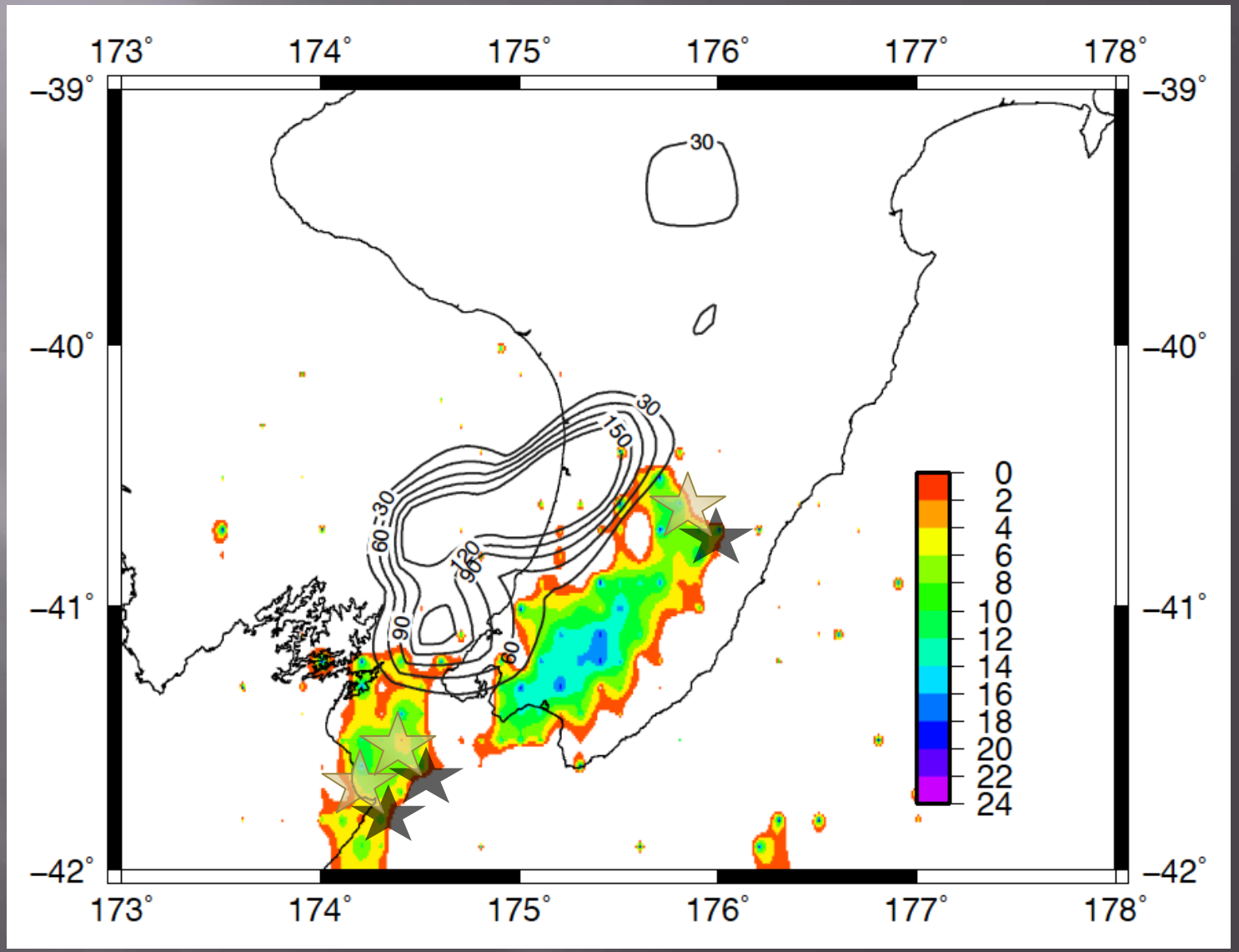
Approach #2, Source Scanning from method of Honn Kao

$$br(\eta_{x,y,z}, \tau) = \frac{1}{N}\sum_{n=1}^{N}\left|u_n(\tau + t_{\eta n})\right|$$



Kao and Shan, 2004;
Liao et al., 2012

July-September – Are we mapping an asperity on the interface?



Near future implementation: SSE as a source in aftershock models

- Near future work is to incorporate patch-discretized interface slip (from geodetic/SSE inversions) as sources for probabilistic earthquake models (ETAS, EEPAS, STEP)
- We currently issue operational forecasts with ensemble models of aftershocks, we hope to also do this with the subduction megathrust

SSE in synthetic catalogues

- Work planned to use earthquake simulators to model SSE/tremor/EQ system including time-variable rate-state friction as well as static and dynamic fatigue

Conclusions

- Seismic hazard and megathrust earthquake potential is highly time-dependent yet our NSHM does not account for this
- We hope to incorporate operational forecasting for subduction system earthquakes using probabilistic models (with SSE) in the near future
- We have a long way to go and welcome any help/input from international colleagues

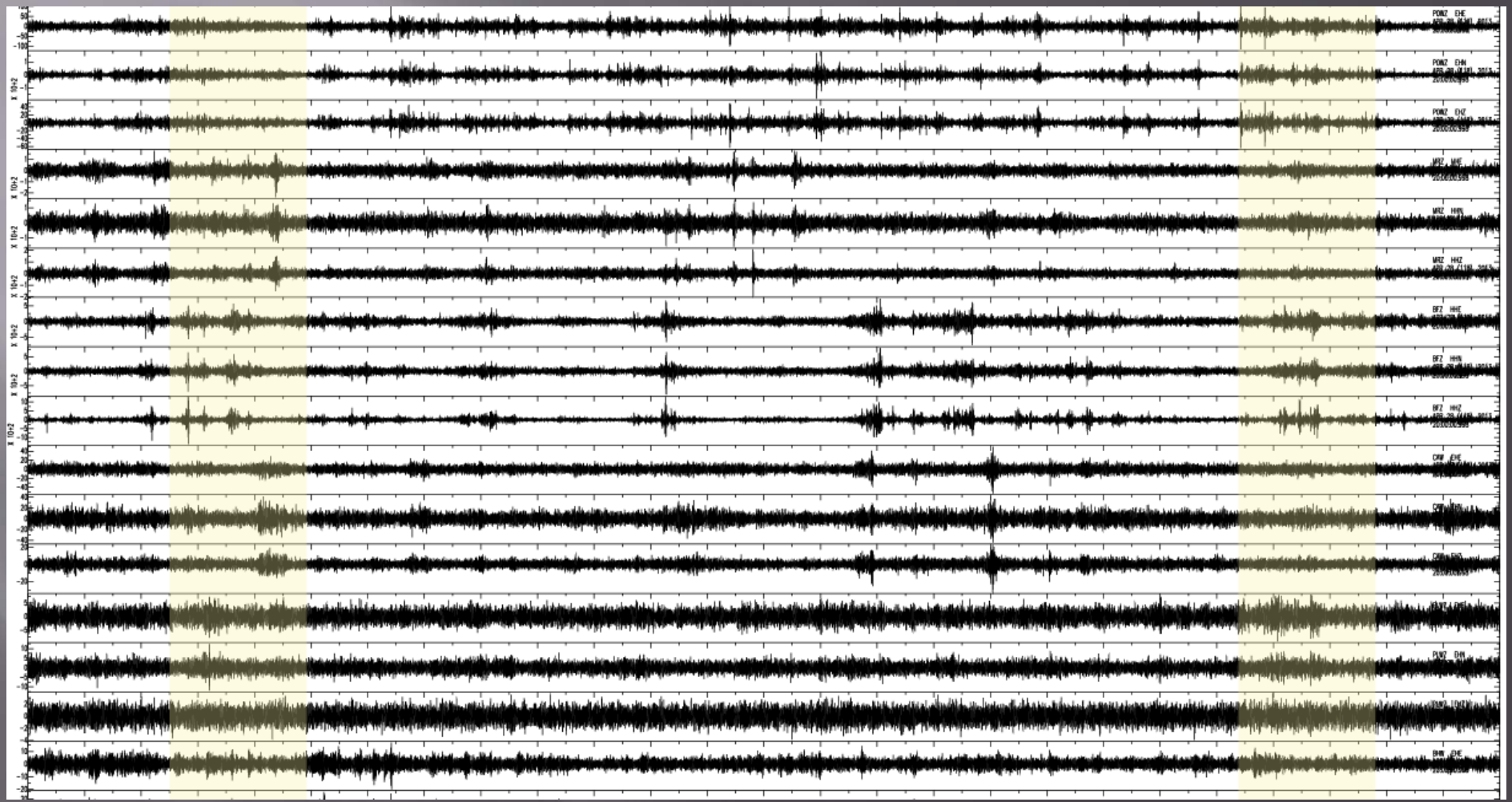
Future directions 2: strain budgets, stress tensors, and crustal anisotropy

- Earthquake simulators with real-world geometries and dynamics
- Can we couple geodetically defined estimates of stress and strain together with seismically defined pervasive seismic ‘fabric’ to modify our probabilistic hazard estimates? More on this later…

Closing thoughts

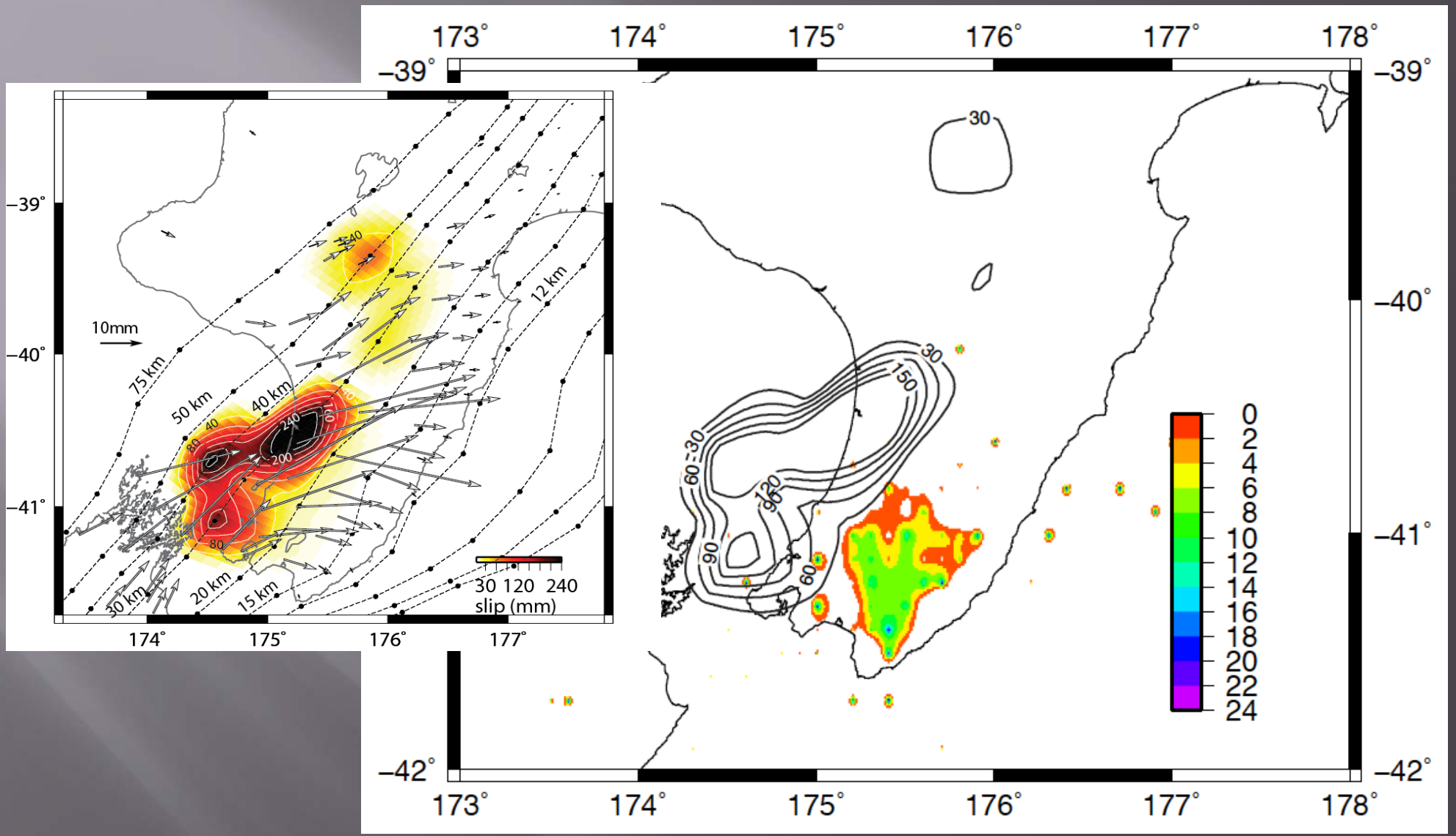
- We have a robust and ever-growing catalogue of SSE on the Hikurangi margin; we must utilize these data for both probabilistic and scenario-based hazard modeling.
- We see a link between SSE and seismic radiation in both space and time, suggesting a causal link and providing further evidence that large-scale movement on the subduction interface can drive upper plate tectonics
- SSE/tremor/earthquakes are not separated by rigid boundaries in wavespace

Template matching

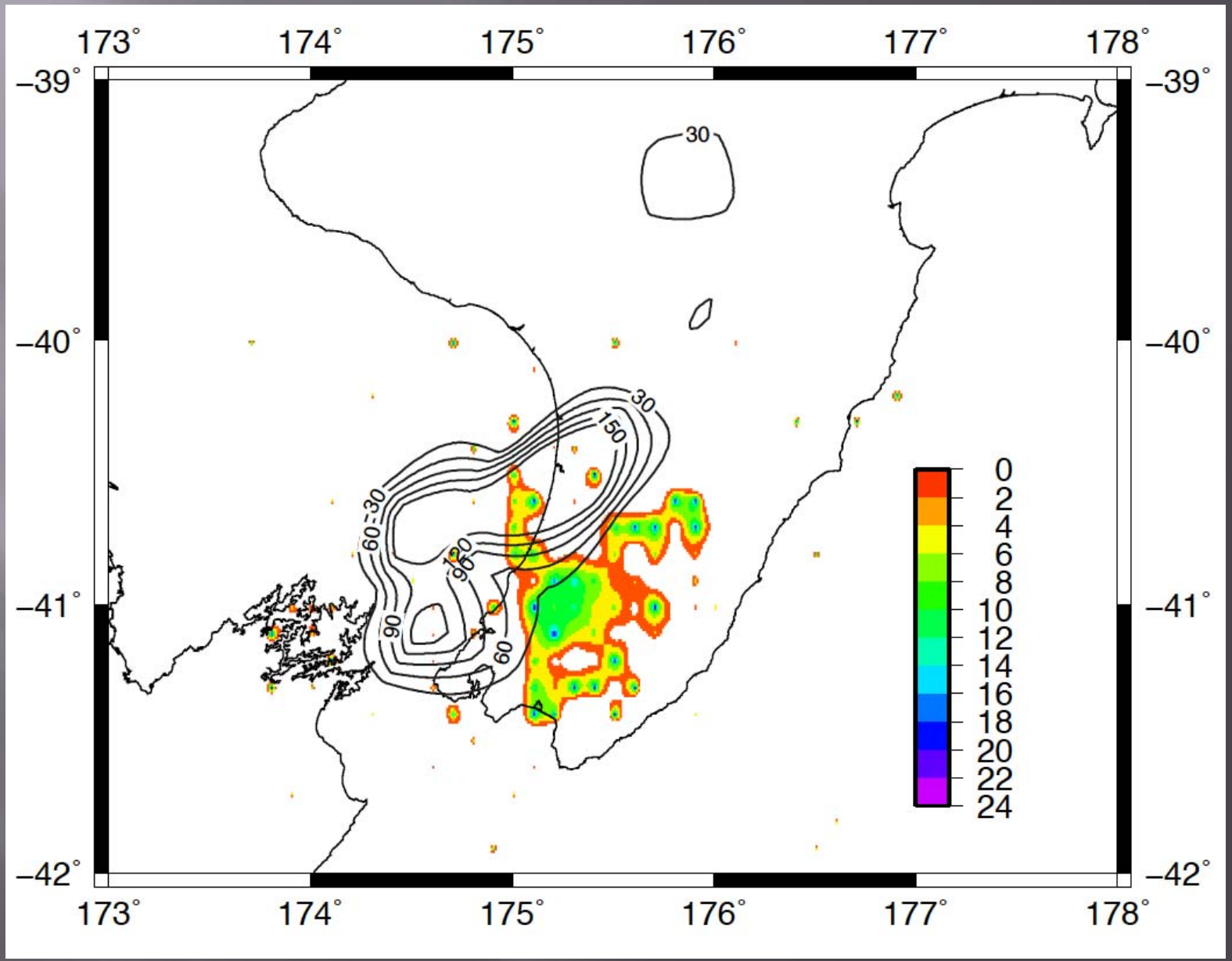


50 seconds between annotations, 1-10Hz

“bright” patches Jan-Mar



March-May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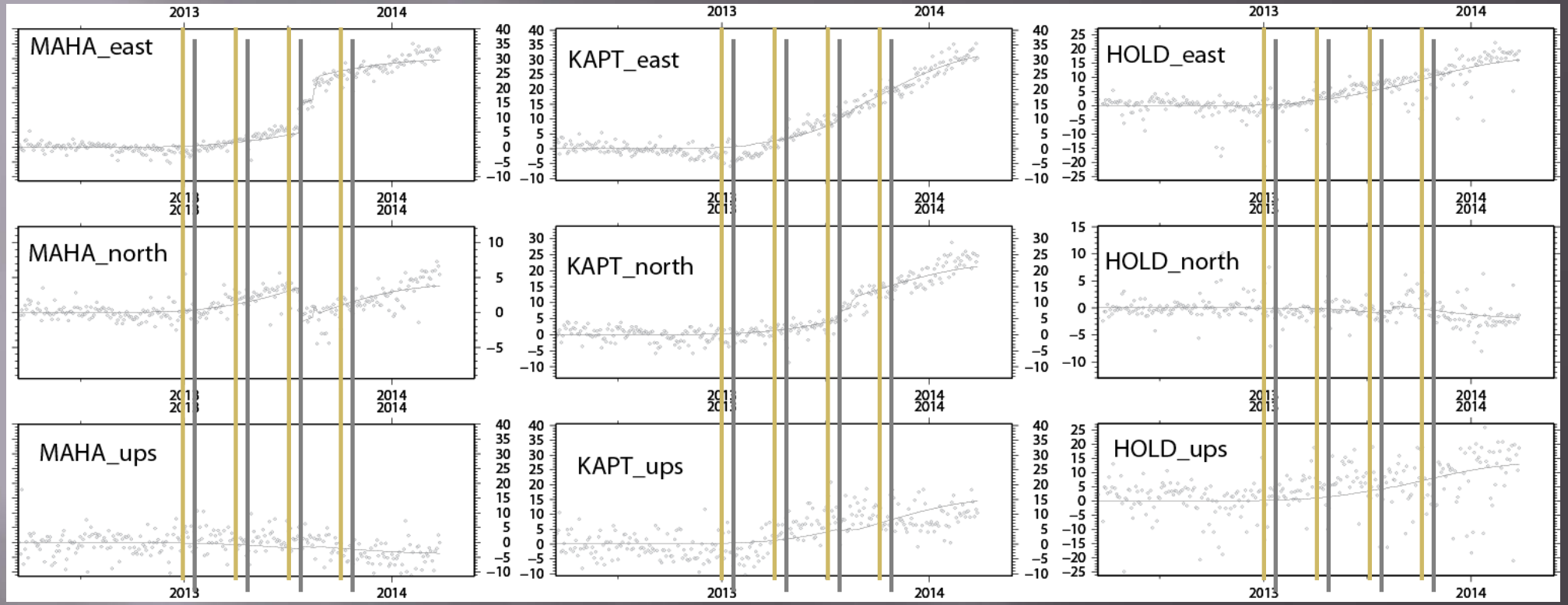
MAHA_east
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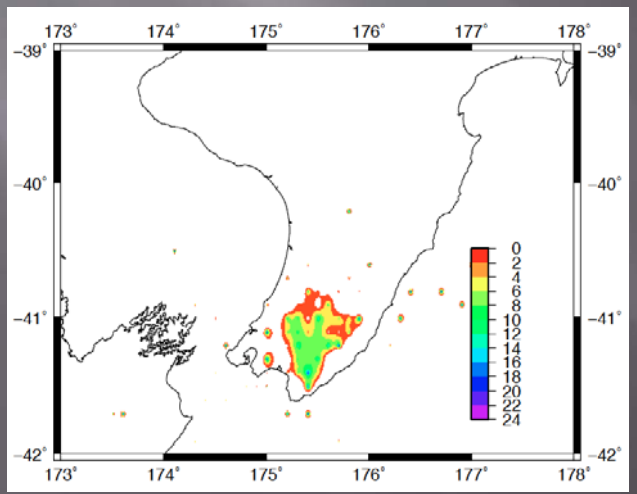
HOLD_ups
2013
2014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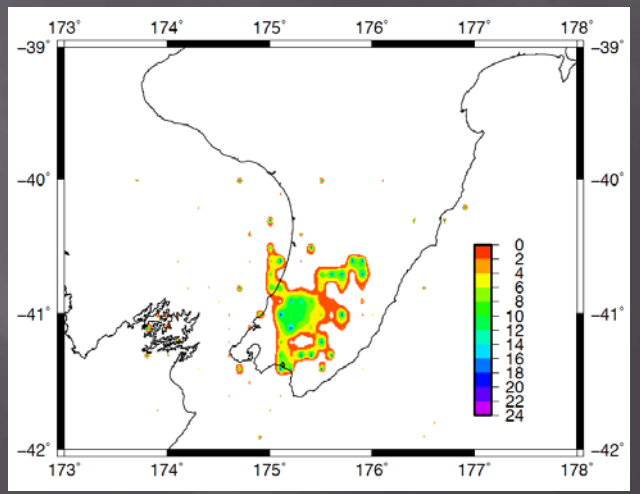
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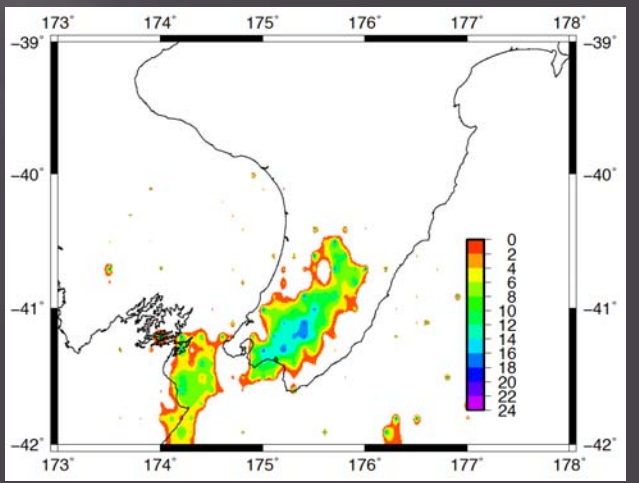
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