# Deformation on plate boundaries; What it looks like, how we observe it and how we can correct coordinates for its effect: the example of the HTDP software and NAD83.

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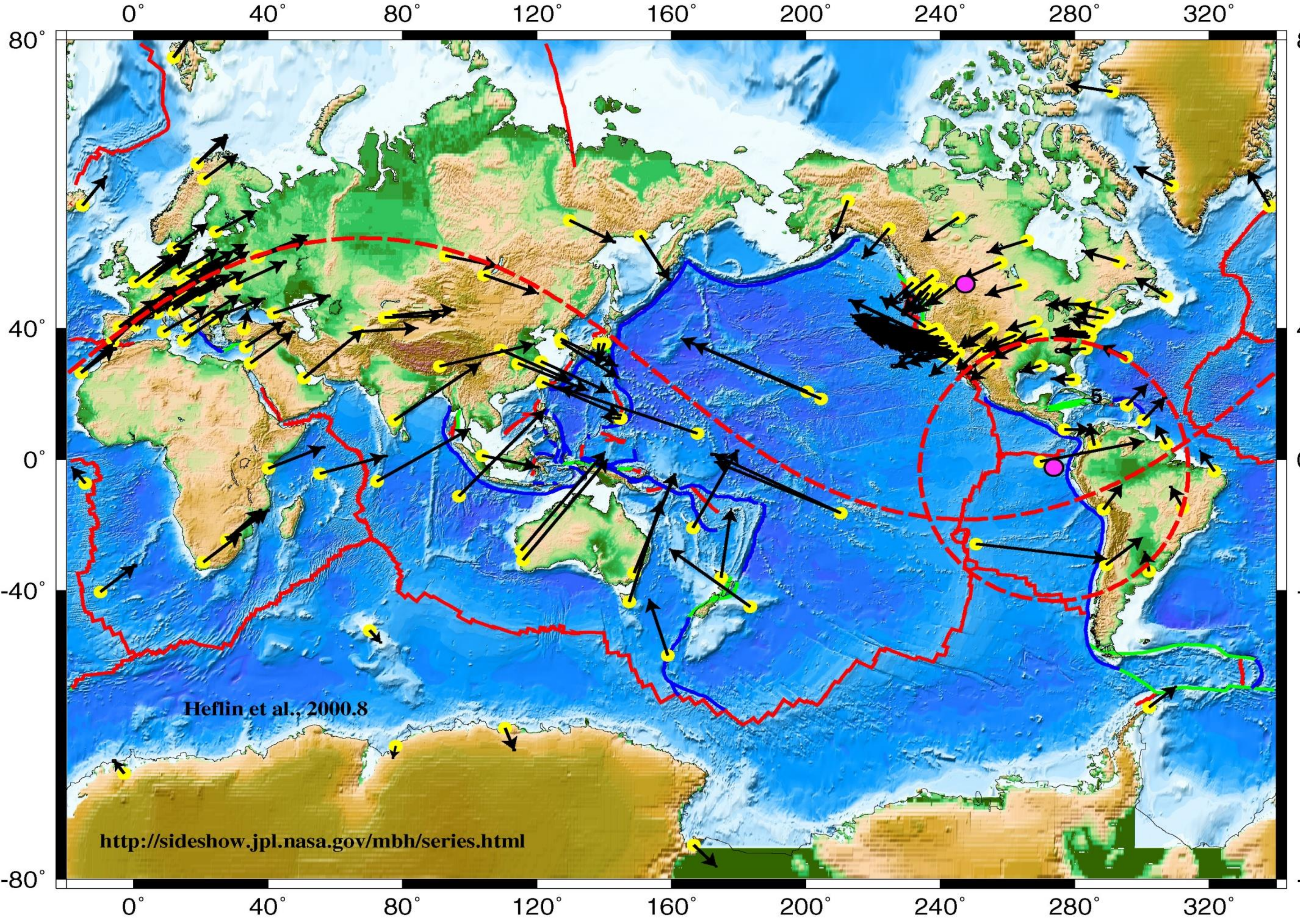
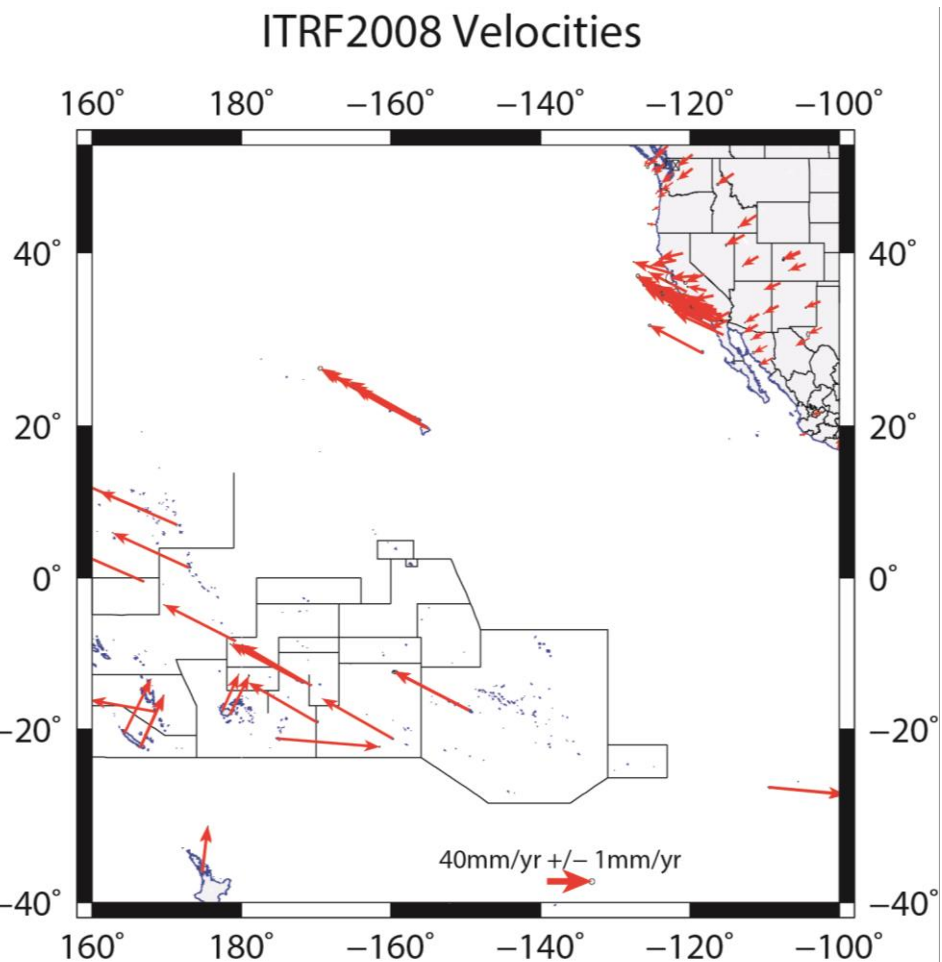
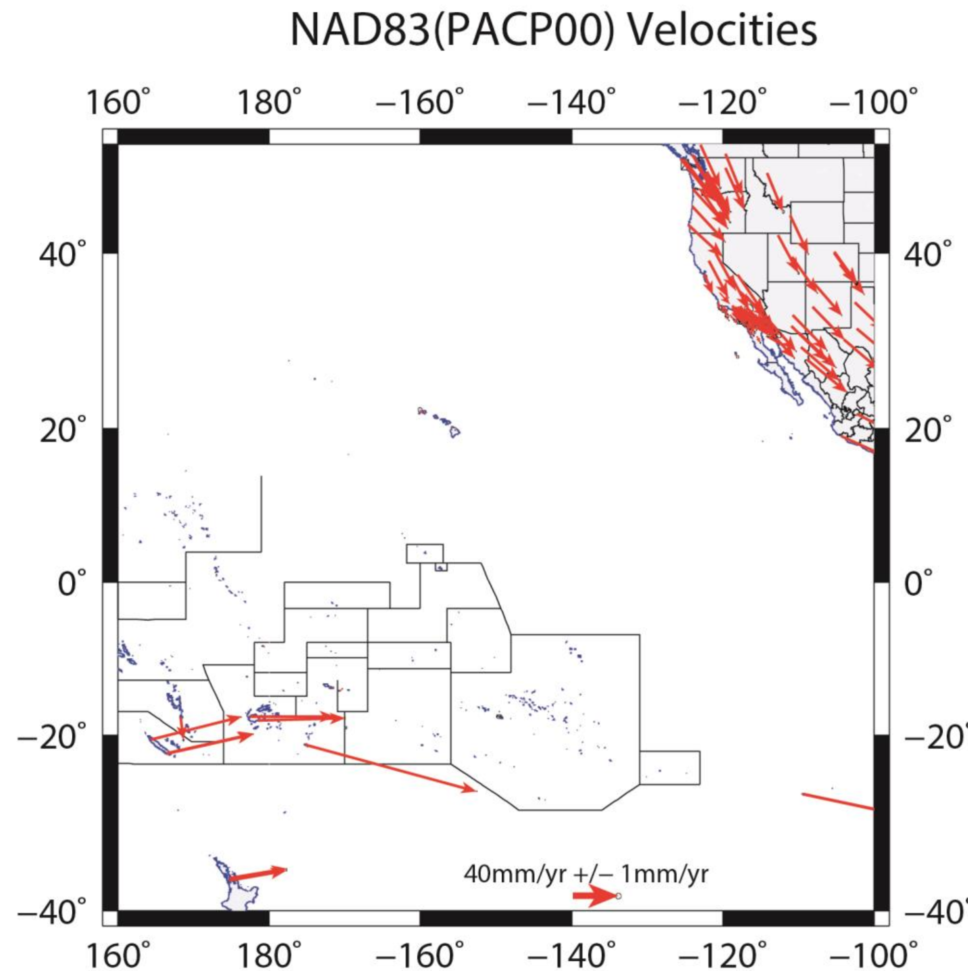
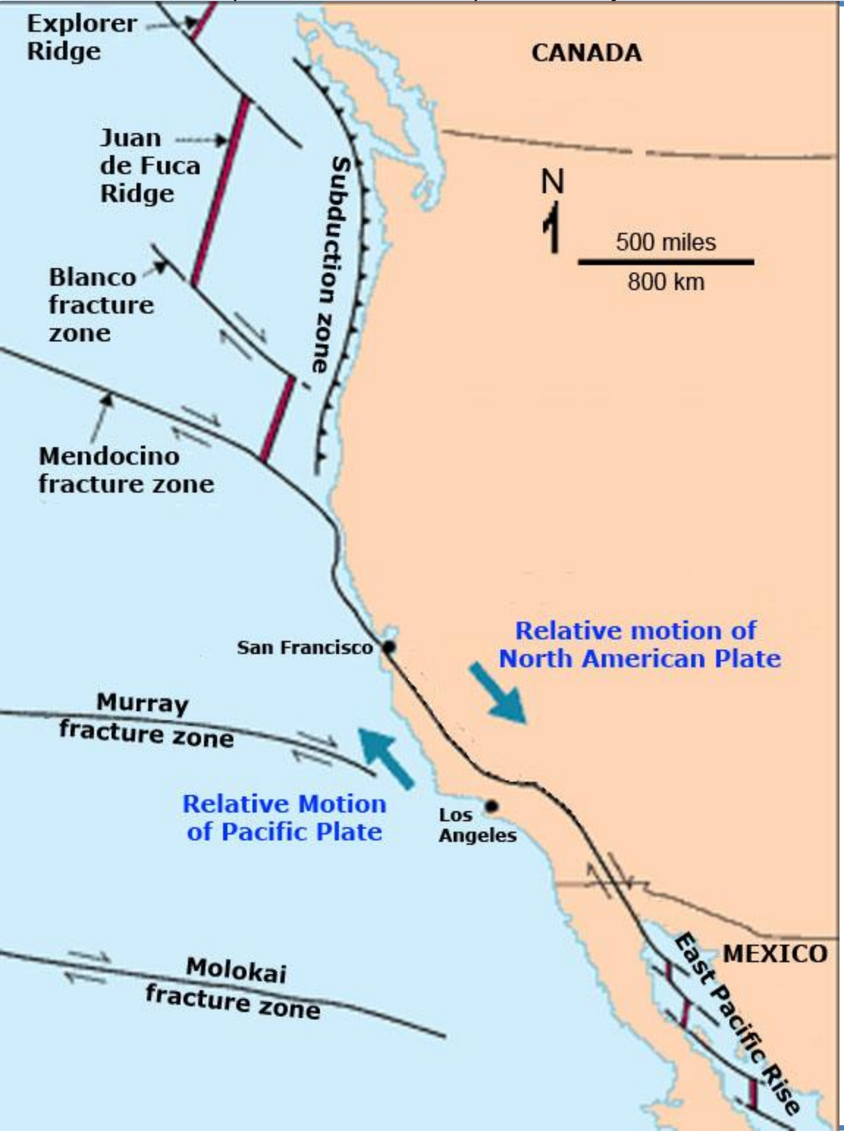


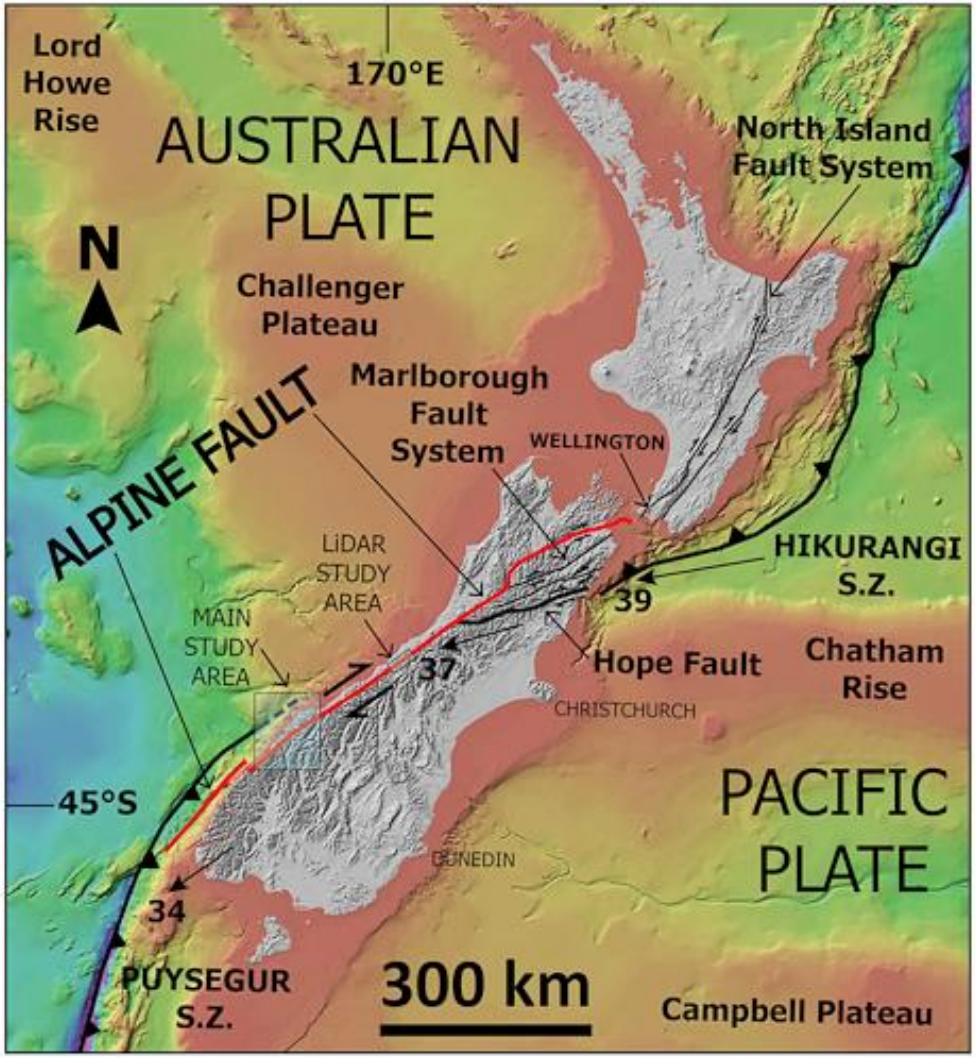

# Small "circles" for N. American pole.

# NAD83(PACP00) aligned with Pacific Plate

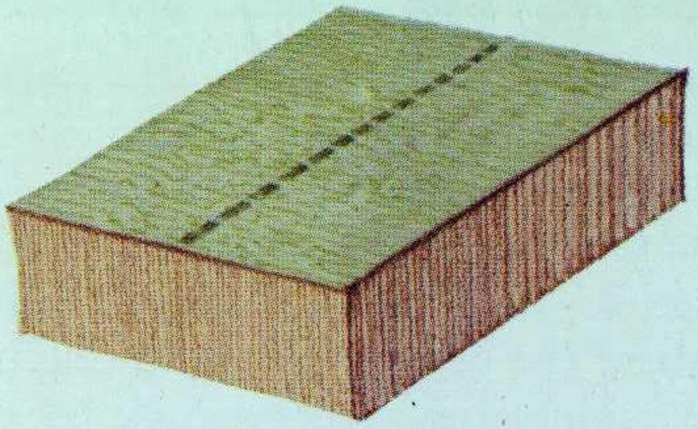


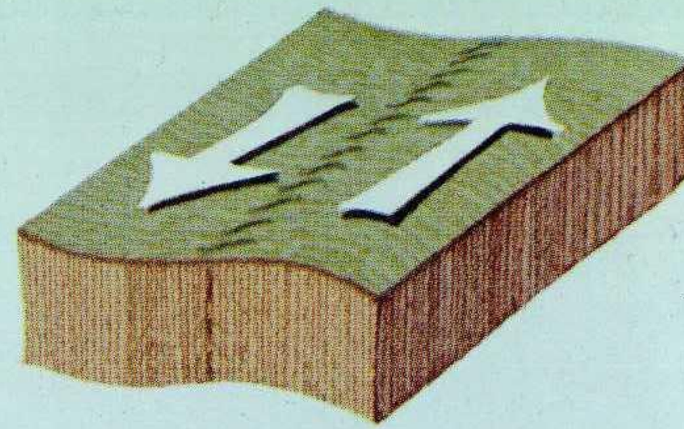

Explorer Ridge
CANADA
Juan de Fuca Ridge
Subduction zone
N
500 miles
800 km
Blanco fracture zone
Mendocino fracture zone
San Francisco
Relative motion of North American Plate
Murray fracture zone
Relative Motion of Pacific Plate
Los Angeles
Molokai fracture zone
MEXICO
East Pacific Rise


Lord Howe Rise
170°E
AUSTRALIAN PLATE
North Island Fault System
N
Challenger Plateau
Marlborough Fault System
WELLINGTON
ALPINE FAULT
LiDAR STUDY AREA
HIKURANGI S.Z.
39
MAIN STUDY AREA
37
Hope Fault
Chatham Rise
CHRISTCHURCH
45°S
PACIFIC PLATE
DUNEDIN
34
PUYSEGUR S.Z.
300 km
Campbell Plateau

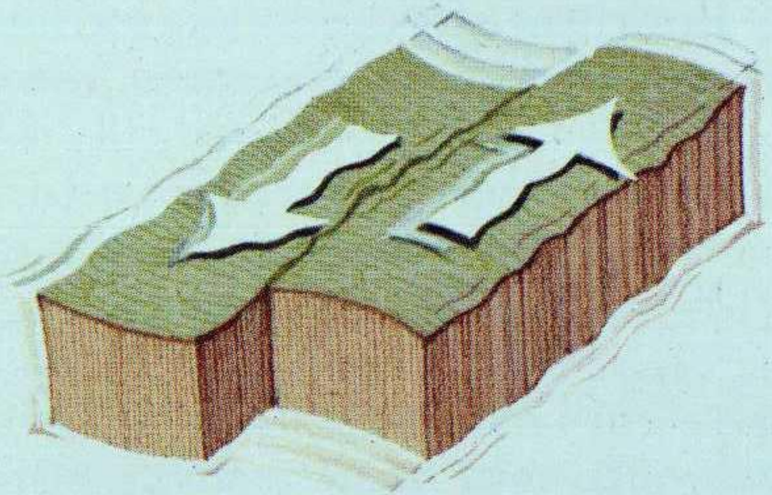
# THE TRIGGERING MECHANISM: SLIPPAGE ALONG A FAULT



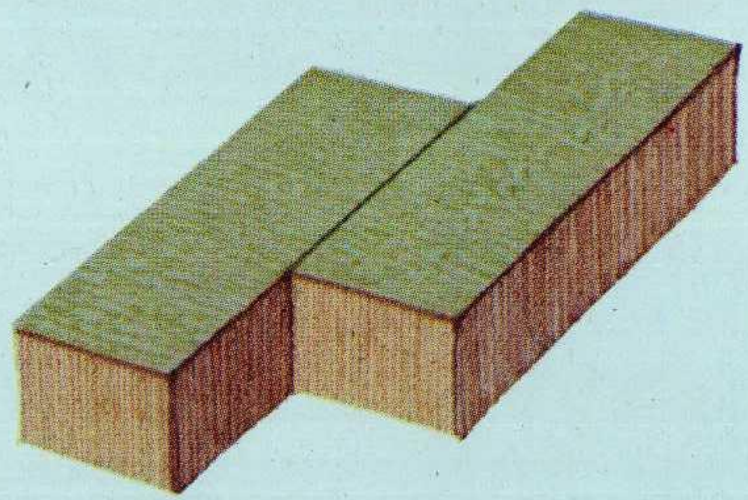
CRUSTAL BLOCKS AT REST



DEFORMATION DURING STRESS BUILD-UP

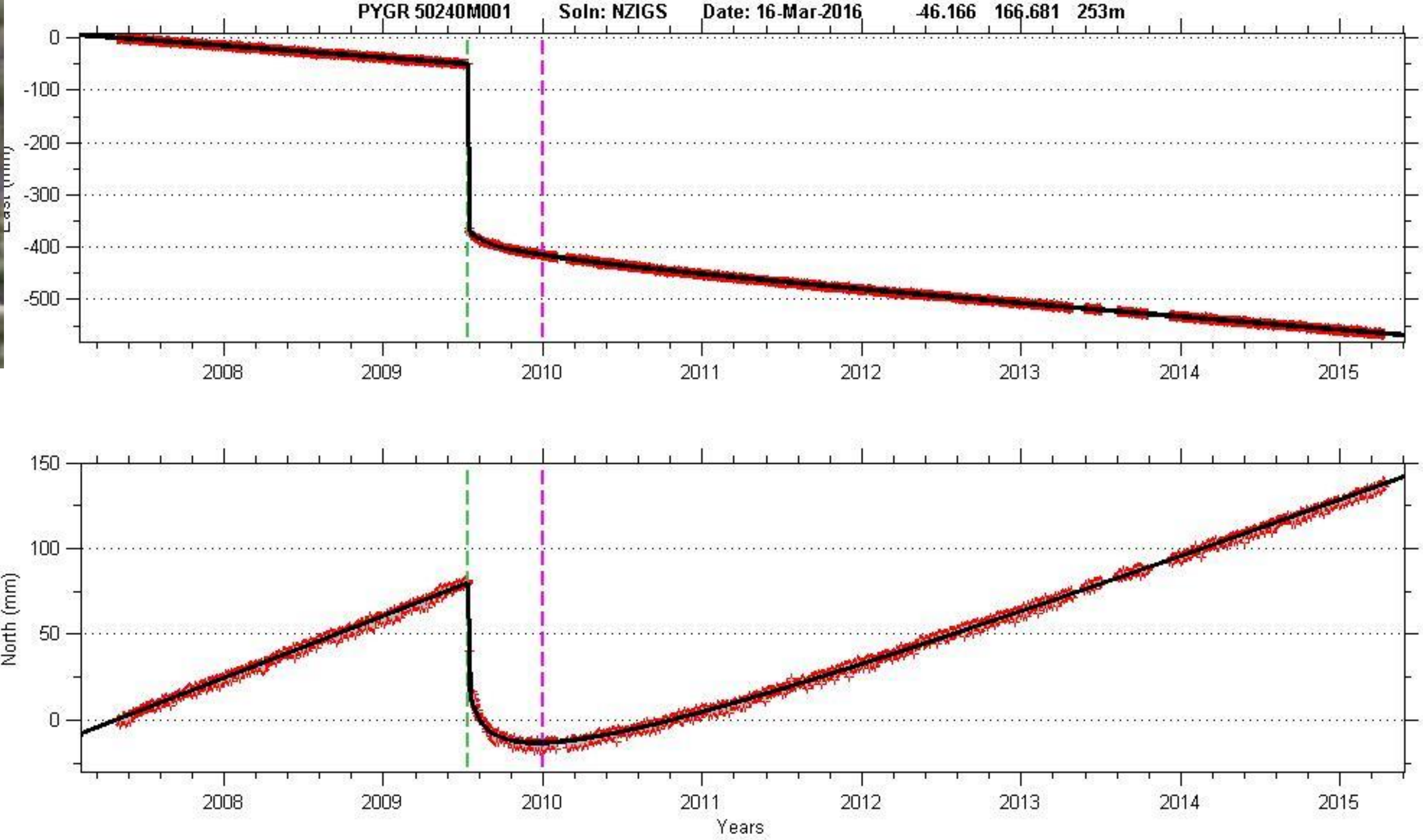


THE INSTANT OF RUPTURE

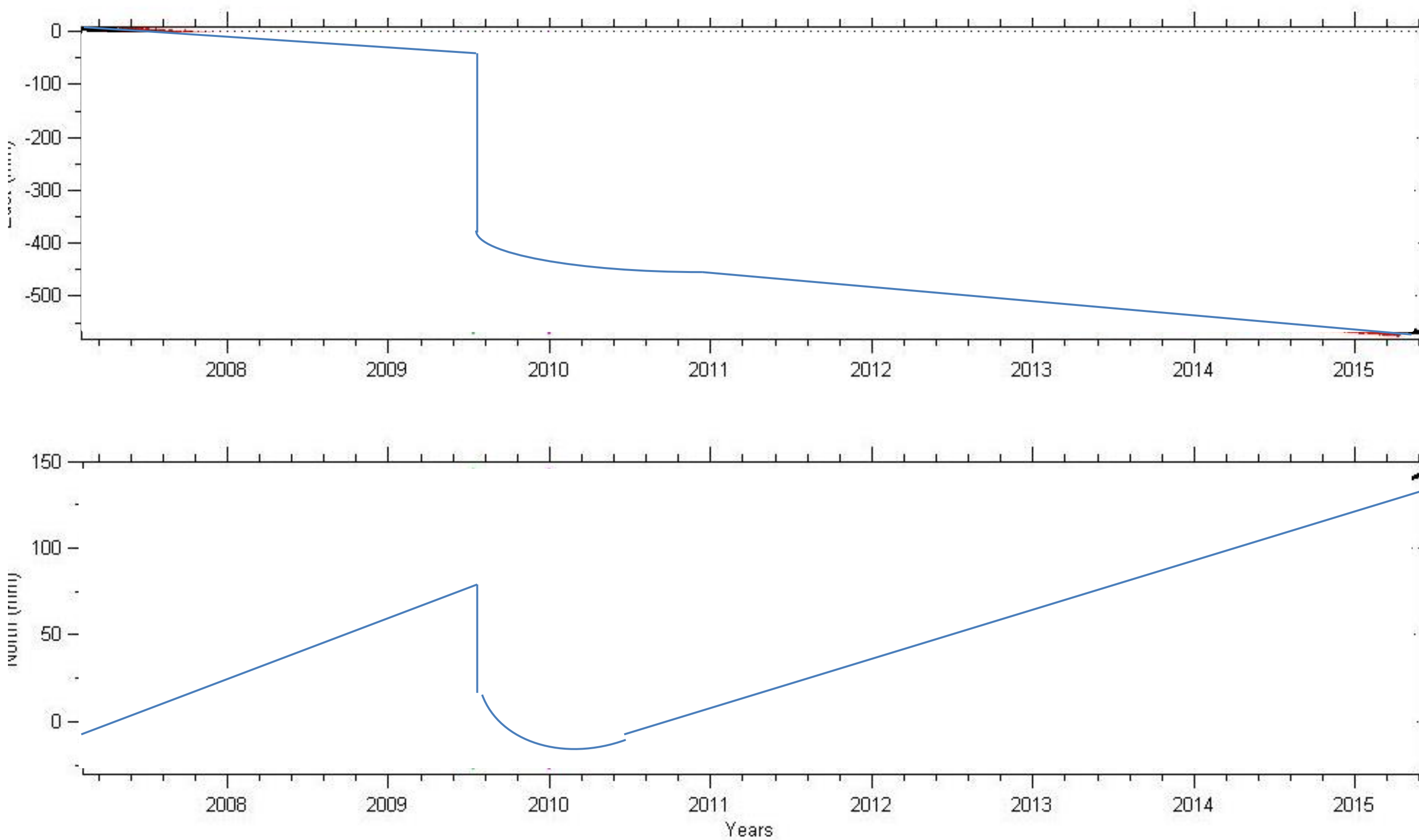


REBOUNDING TO A NEW EQUILIBRIUM

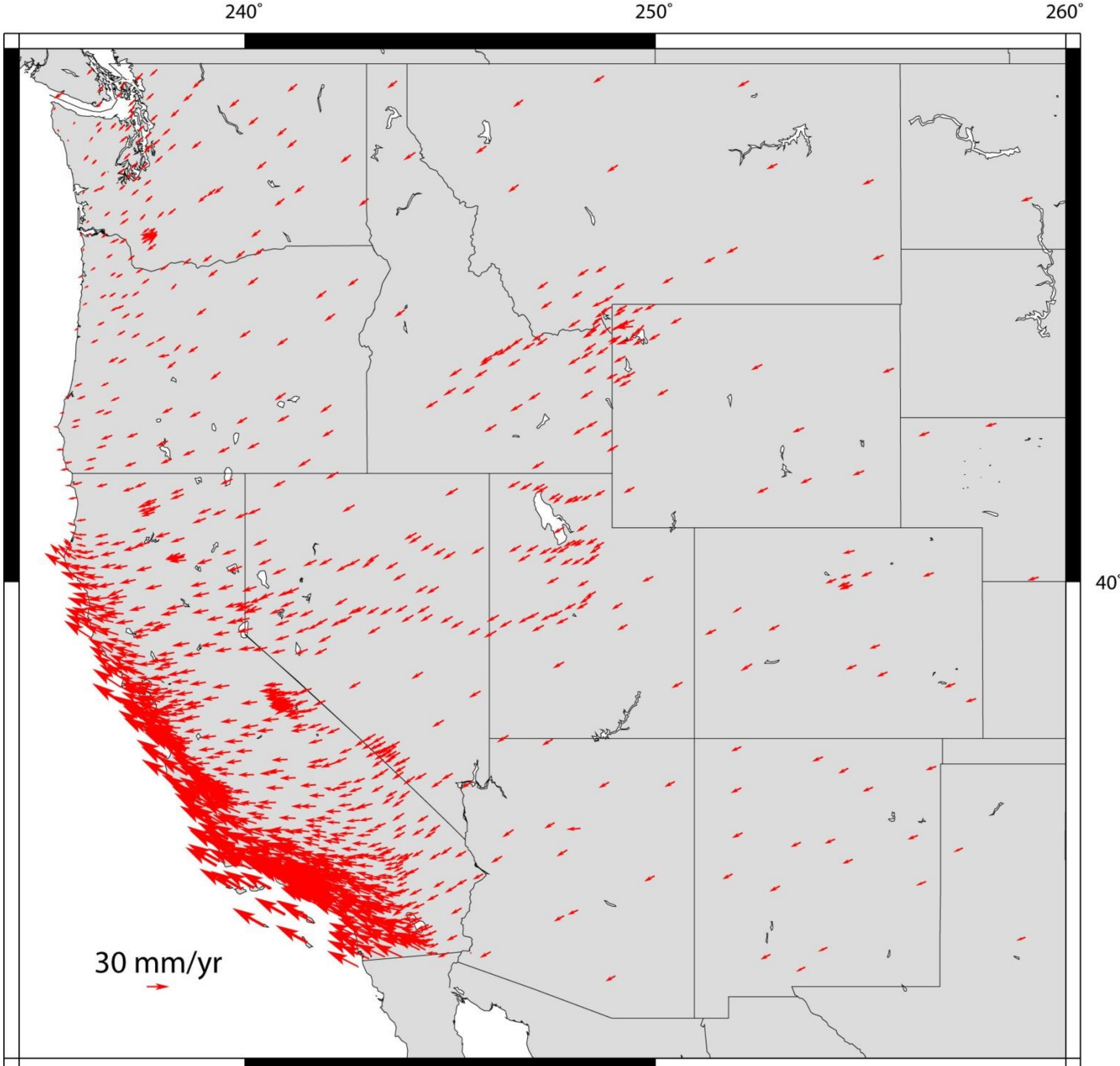
# Time series for PYGR




antenna

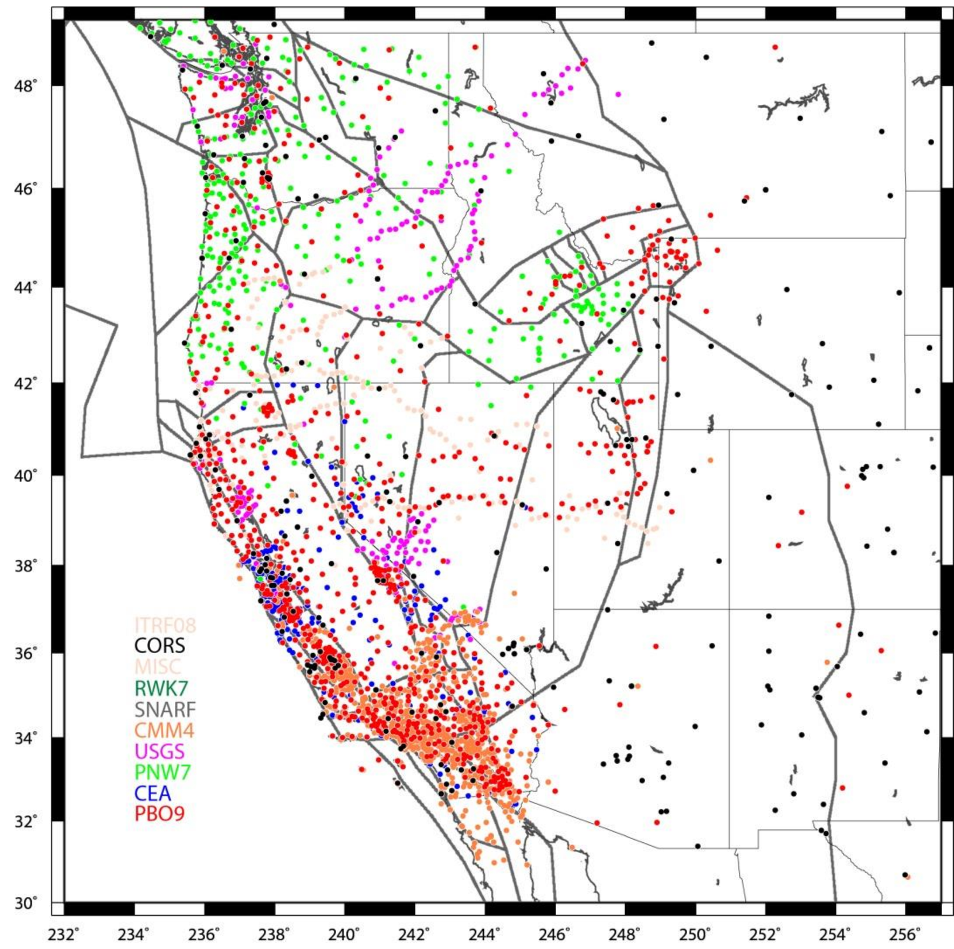

0
-100
-200
-300
-400
-500
2008
2009
2010
2011
2012
2013
2014
2015
150
100
50
0
2008
2009
2010
2011
2012
2013
2014
2015
Years

# Secular velocity field for Western con US



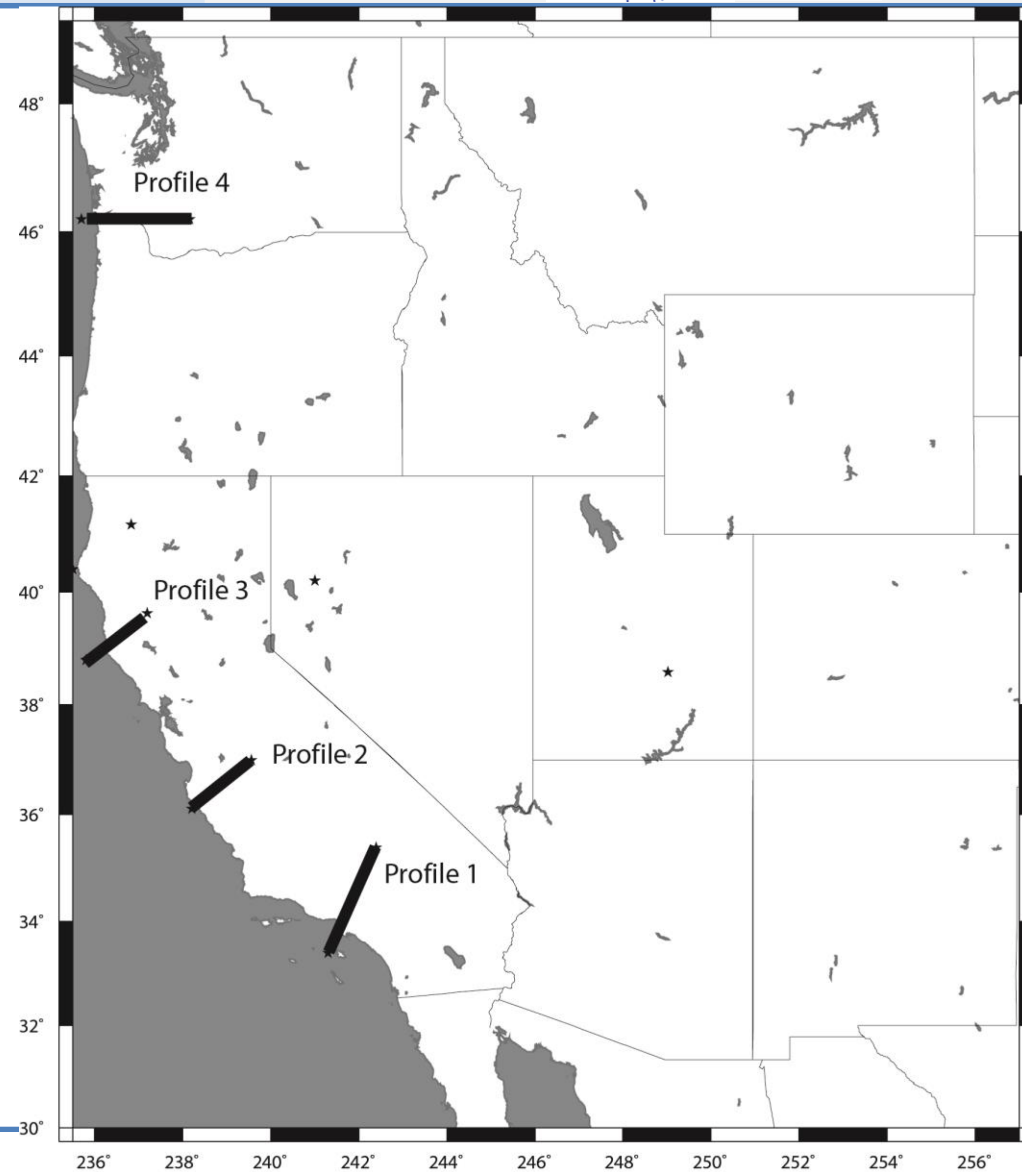
# Secular velocity field for Western con US

- Western US comprised of independently rotating blocks bordered by faults
- Each segment of a fault has a locking coefficient
- Model solves for the Euler pole of each block plus the locking coefficients
- The velocity model is constrained by
  - 4643 GPS vectors
  - 166 slip vector/fault azimuth data
  - 170 fault slip rate measurements

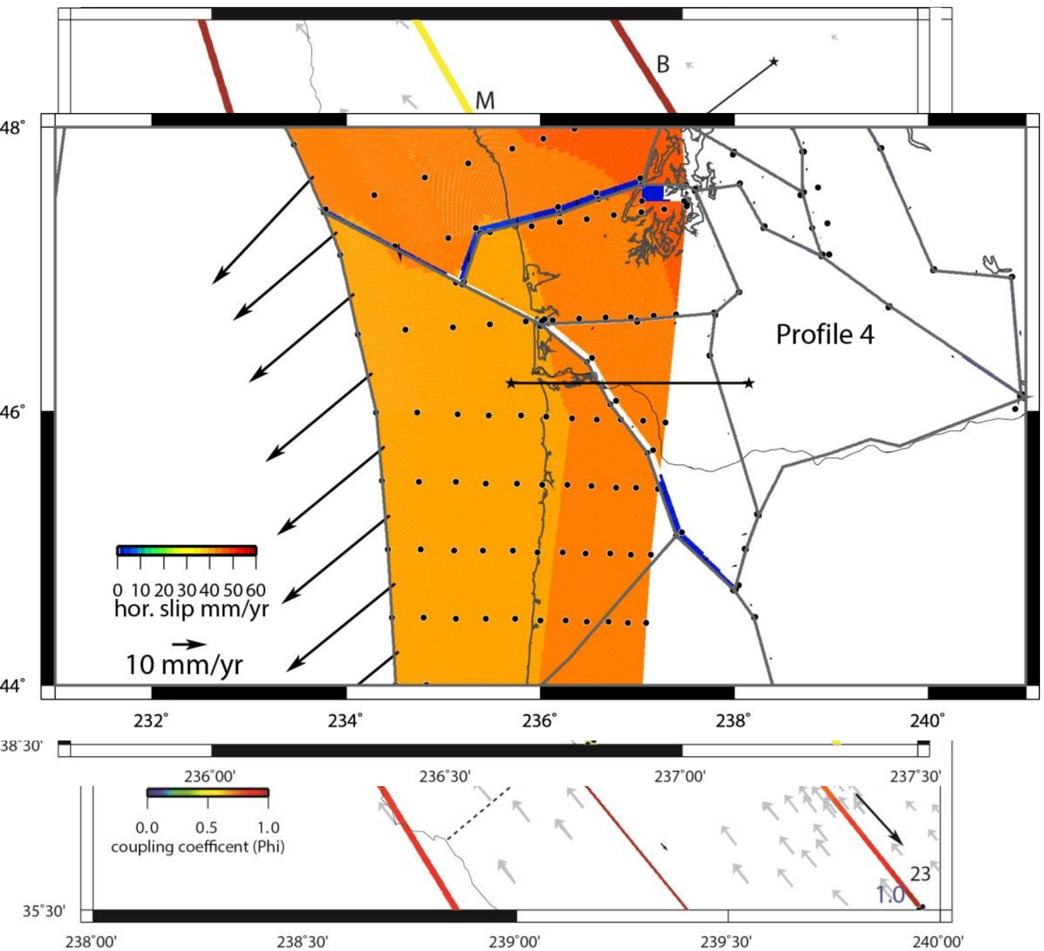


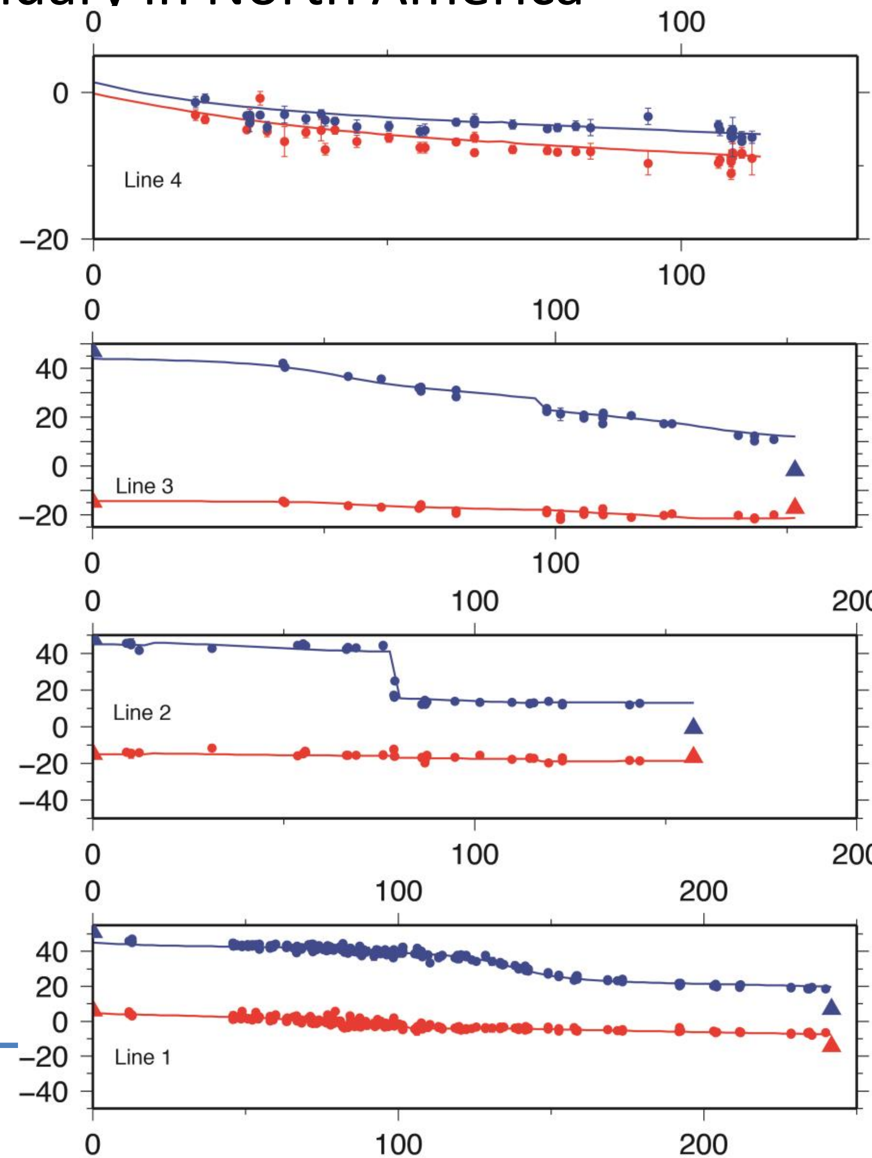
# Profiles

- Profiles 1-3 cross the part of the plate boundary dominated by the San Andreas Fault
- Profile 4 crosses the Cascadia Subduction zone

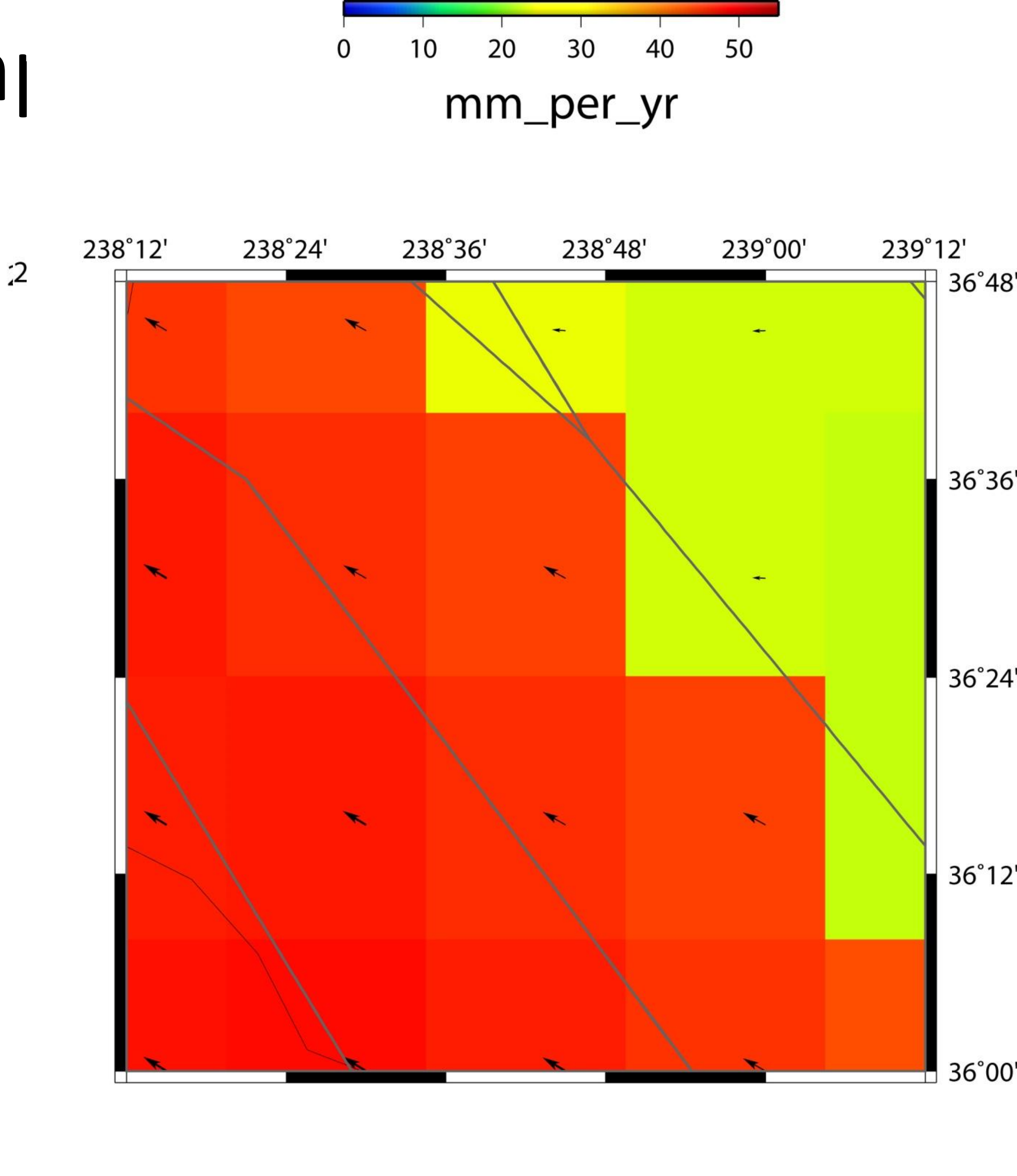


# Secular velocity across the plate boundary in North America

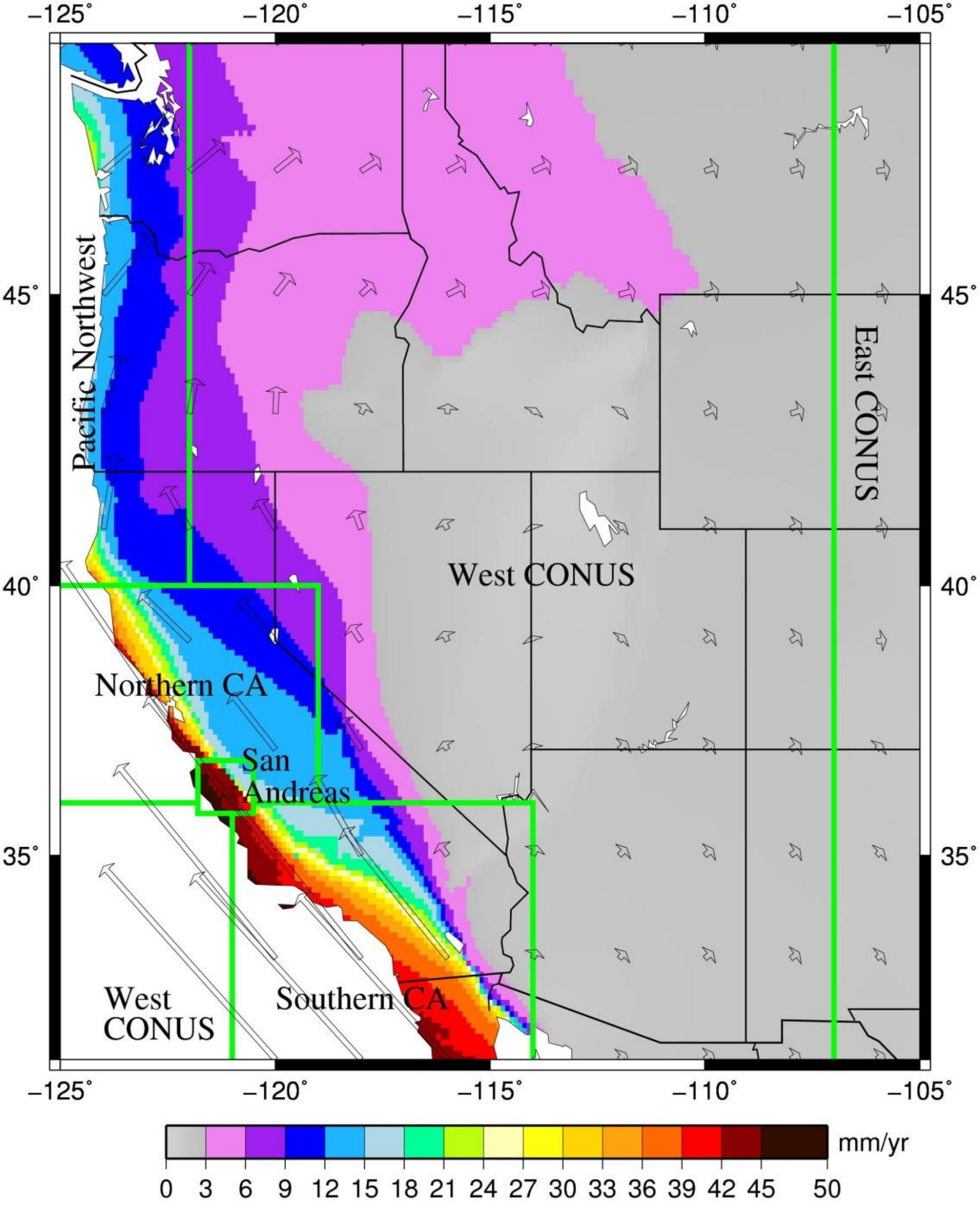


# Im ion


0 10 20 30 40 50
mm_per_yr
238°12' 238°24' 238°36' 238°48' 239°00' 239°12'
36°48'
36°36'
36°24'
36°12'
36°00'

# Western CONUS grids



# Grids

- *HTDP* uses interpolated grid files to calculate the secular velocities.
- These grids cover different regions with different cell sizes in order to obtain higher accuracy in regions of higher velocity gradients

| **Longitude range** | **Latitude range** | **Cell spacing** | **Region** |
|---|---|---|---|
| **West** | **North** | **(minutes)** | |
| 125º to 100º | 31º-49º | 15 | Western CONUS |
| 125º to 122º | 40º-49º | 3.75 | Pacific NW |
| 125º to 119º | 36º-40º | 3.75 | Northern CA |
| 121º to 114º | 31º-36º | 3.75 | Southern CA |
| 120.51° - 121.8° | 35.8° – 36.79 | 0.6 | San Andreas |
| | | | |

# How earthquakes are modeled

Geology and seismology

CORS and campaign GNSS

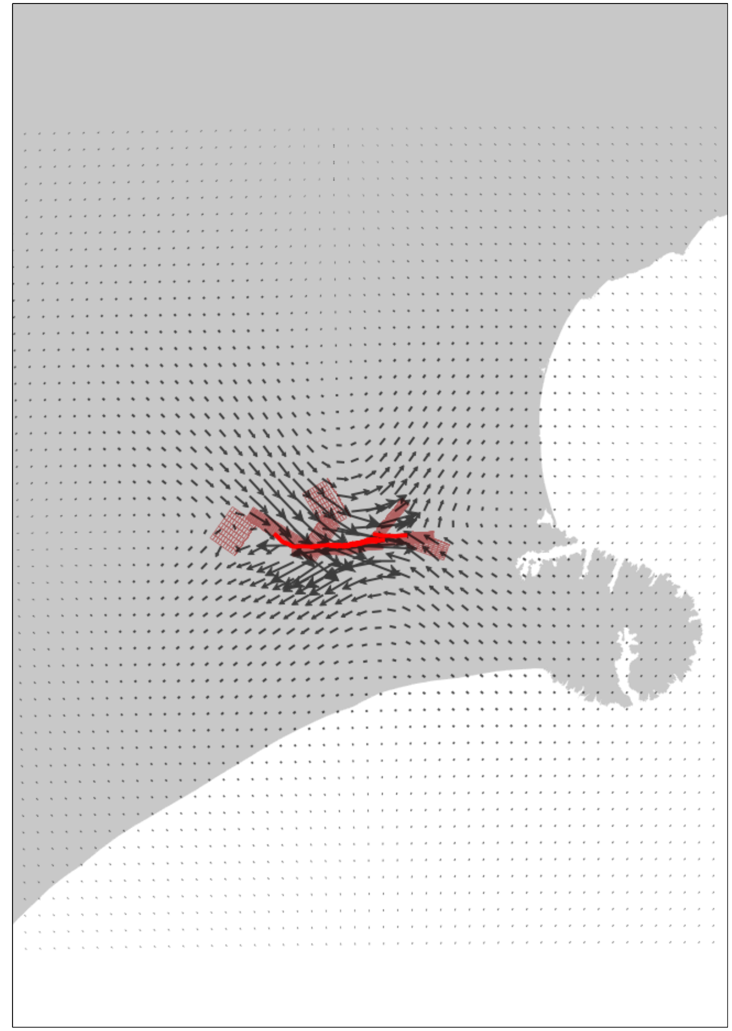
InSAR remote sensing

↓

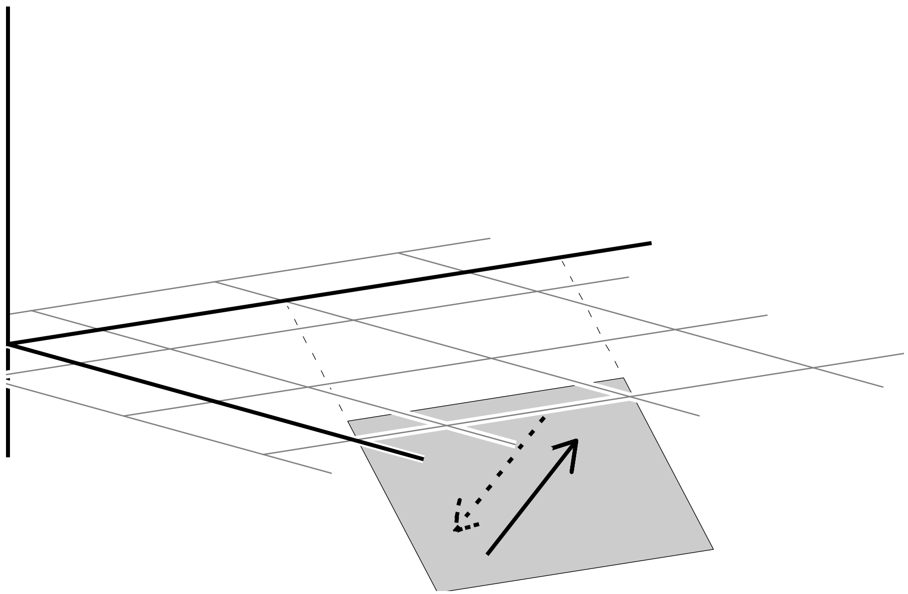
Geophysical fault model

↓

Modeled displacements

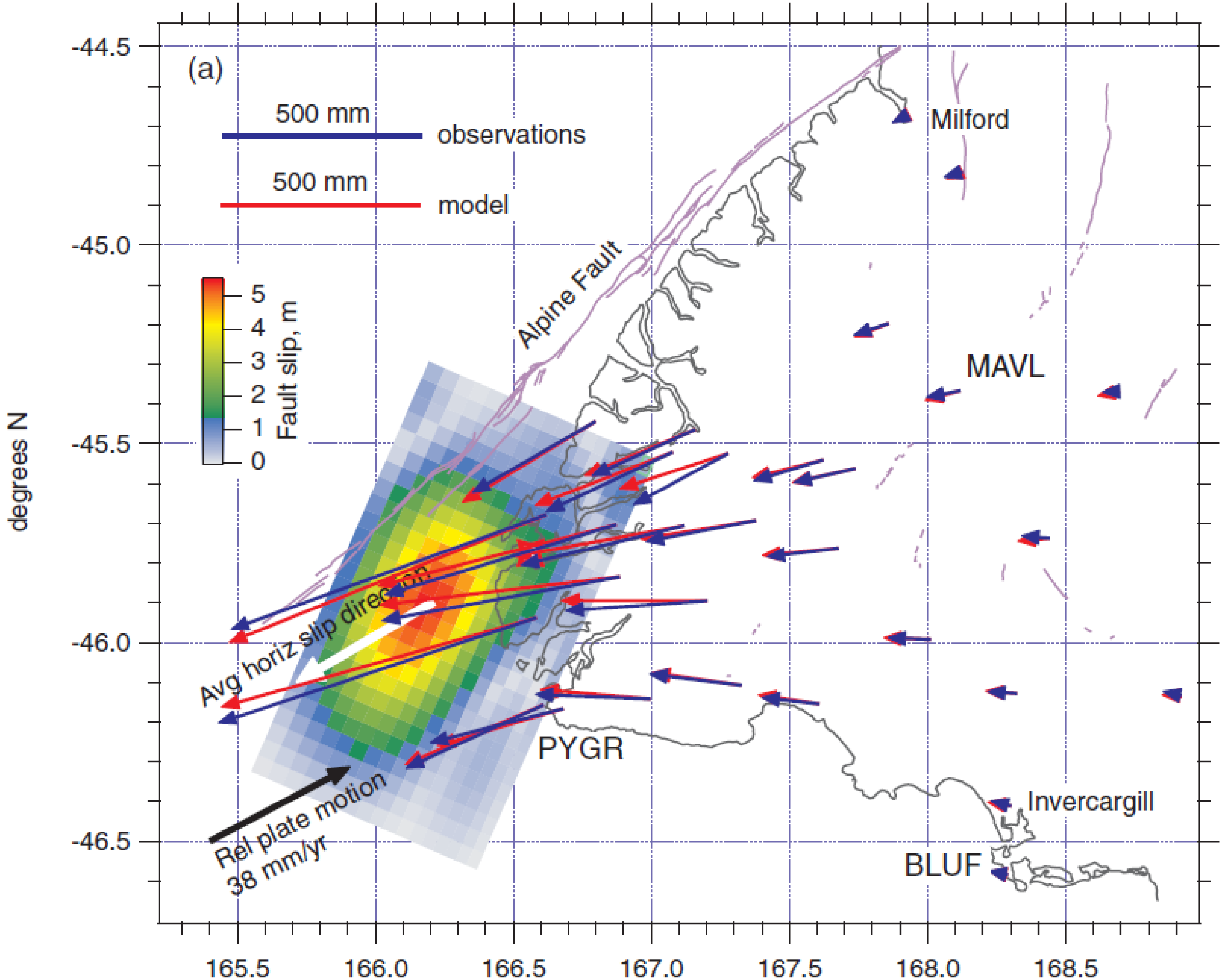


# Dislocations

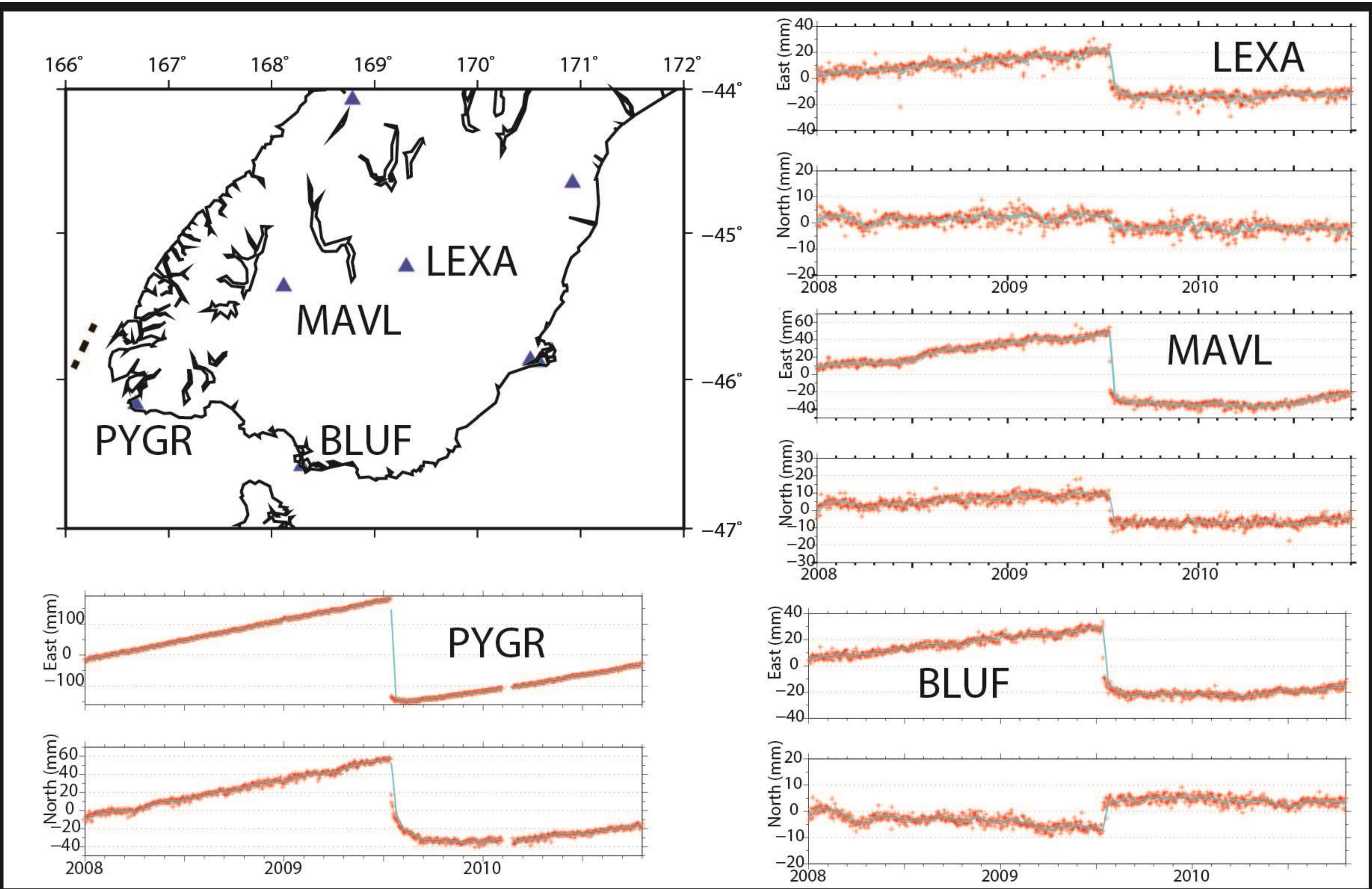


- Each dislocation represents a rectangular patch where one side slips relative to the other
- The name, dislocation, is used because the slip displacement is uniform over the rectangle
- thereby producing a discontinuity along the edges of the patch.

Cl


(a)
500 mm
observations
500 mm
model
Alpine Fault
5
4
3
2
1
0
Fault slip, m
Milford
MAVL
PYGR
Invercargill
BLUF
Avg horiz slip direction
Rel plate motion
38 mm/yr
-44.5
-45.0
-45.5
-46.0
-46.5
degrees N
165.5
166.0
166.5
167.0
167.5
168.0
168.5

# Post-seismic relaxation - 2009 Dusky Sound earthquake



# Post seismic relexation

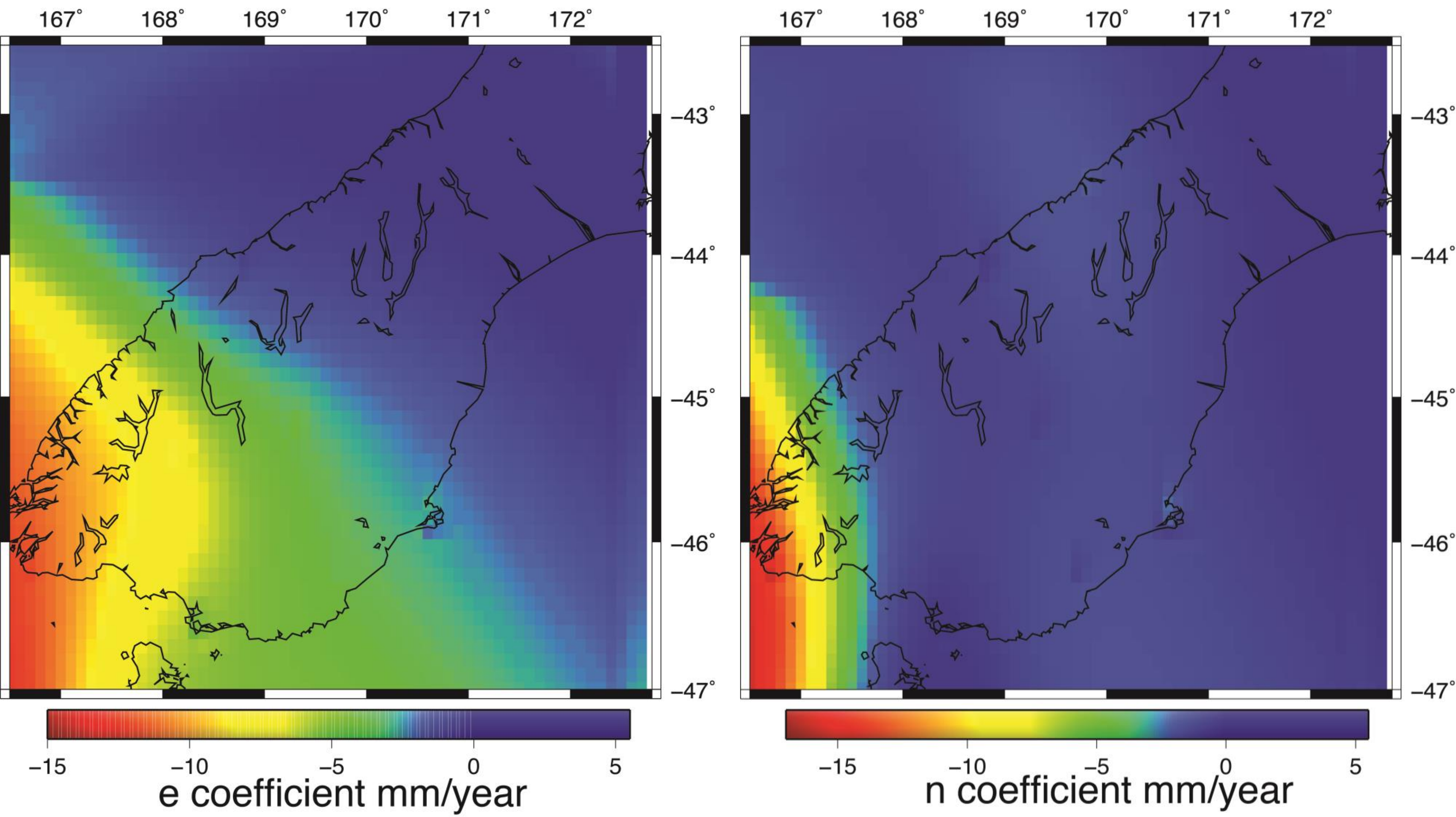
- HTDP uses an exponential decay function to model post-seismic decay for the 2002 Denali Earthquake

$$D_j(\varphi,\lambda,t) = A_j(\varphi,\lambda)\left[1.0 - e^{\left(-\frac{(t-\tau)}{\nu}\right)}\right] \text{if } \tau < t$$

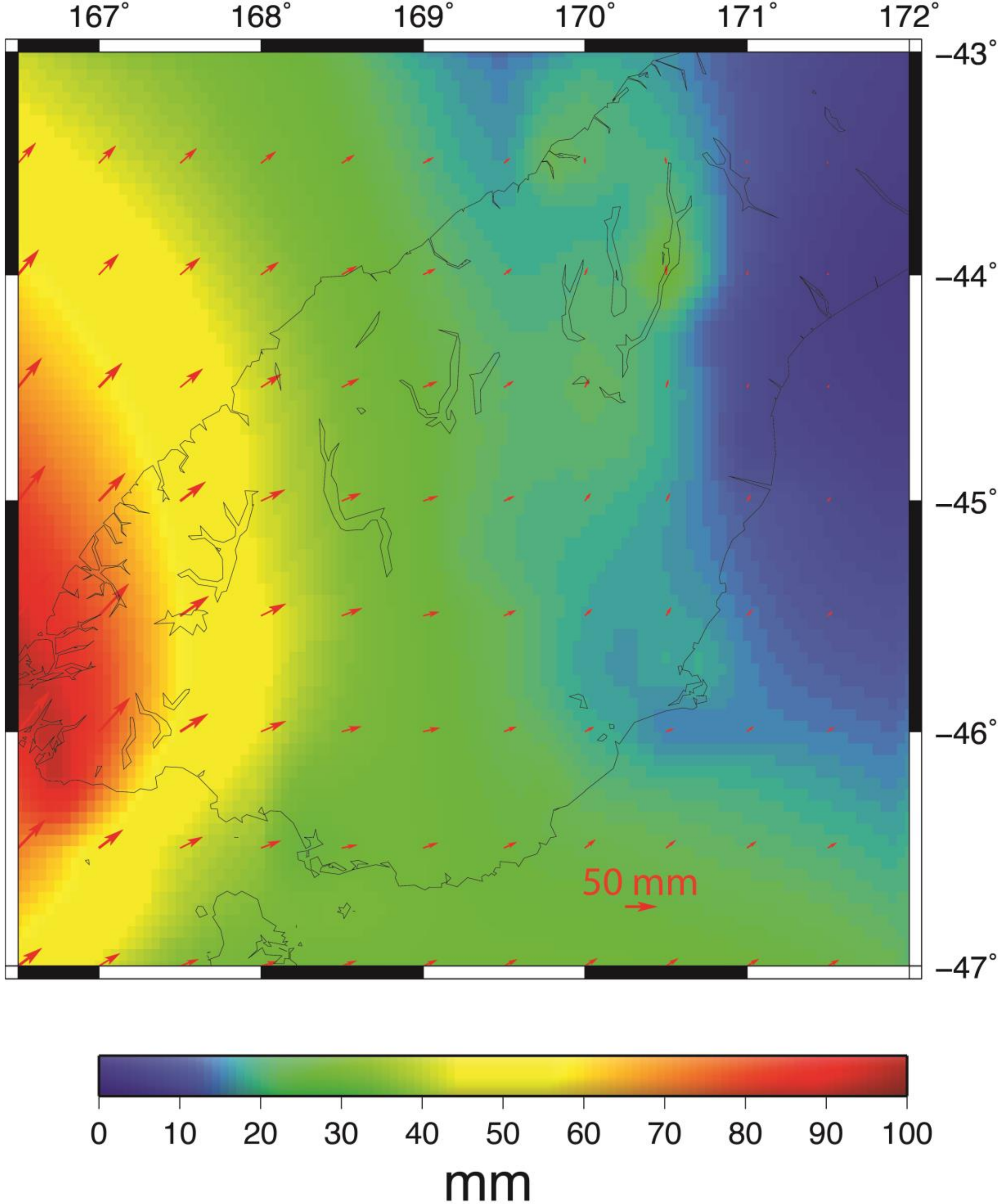
$$D_j(\varphi,\lambda,t) = 0 \text{ if } \tau > t$$

- Where $\nu$= 5 years and $\tau$= 2000.841
-

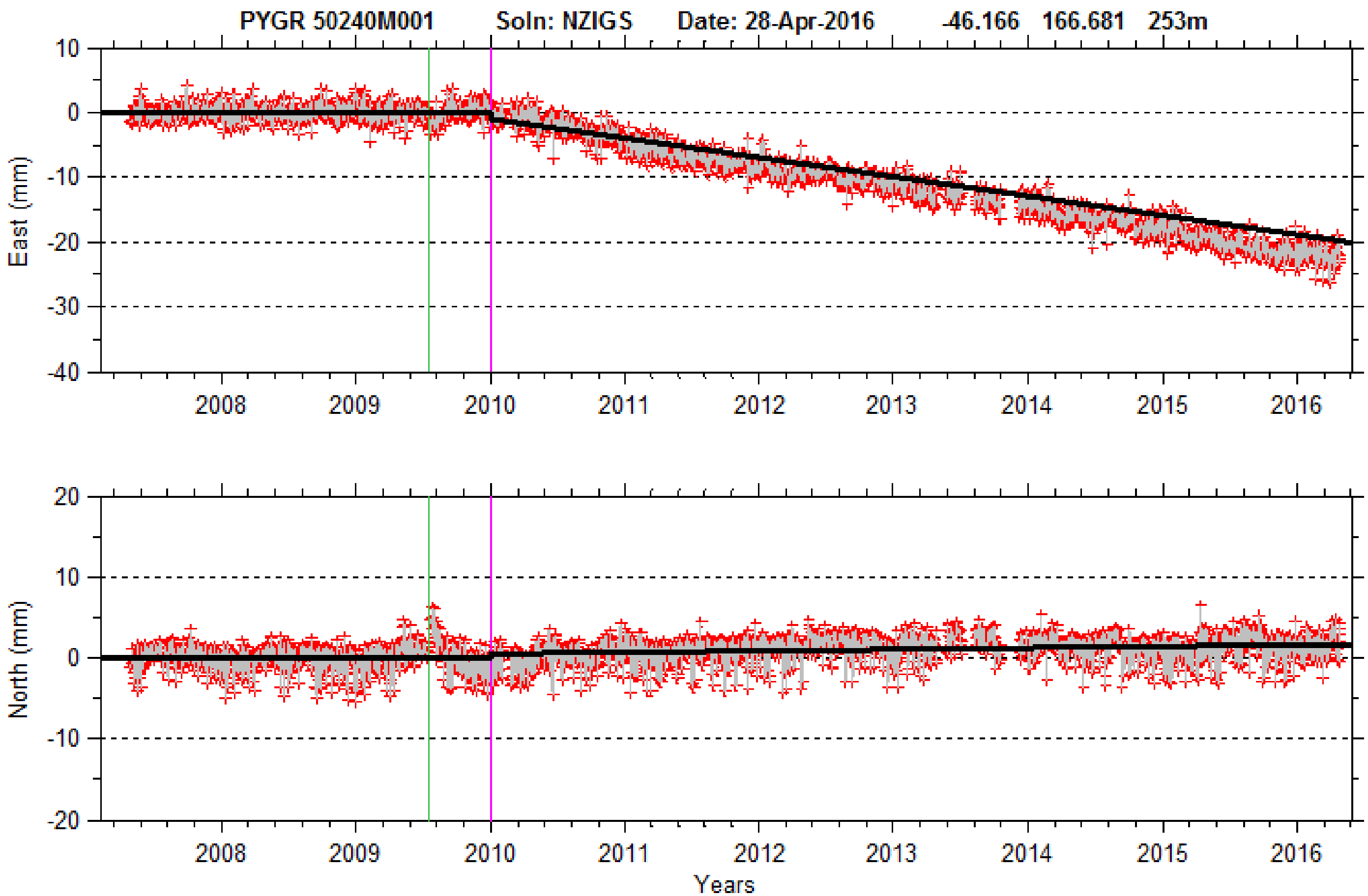
# Post-seismic coefficients



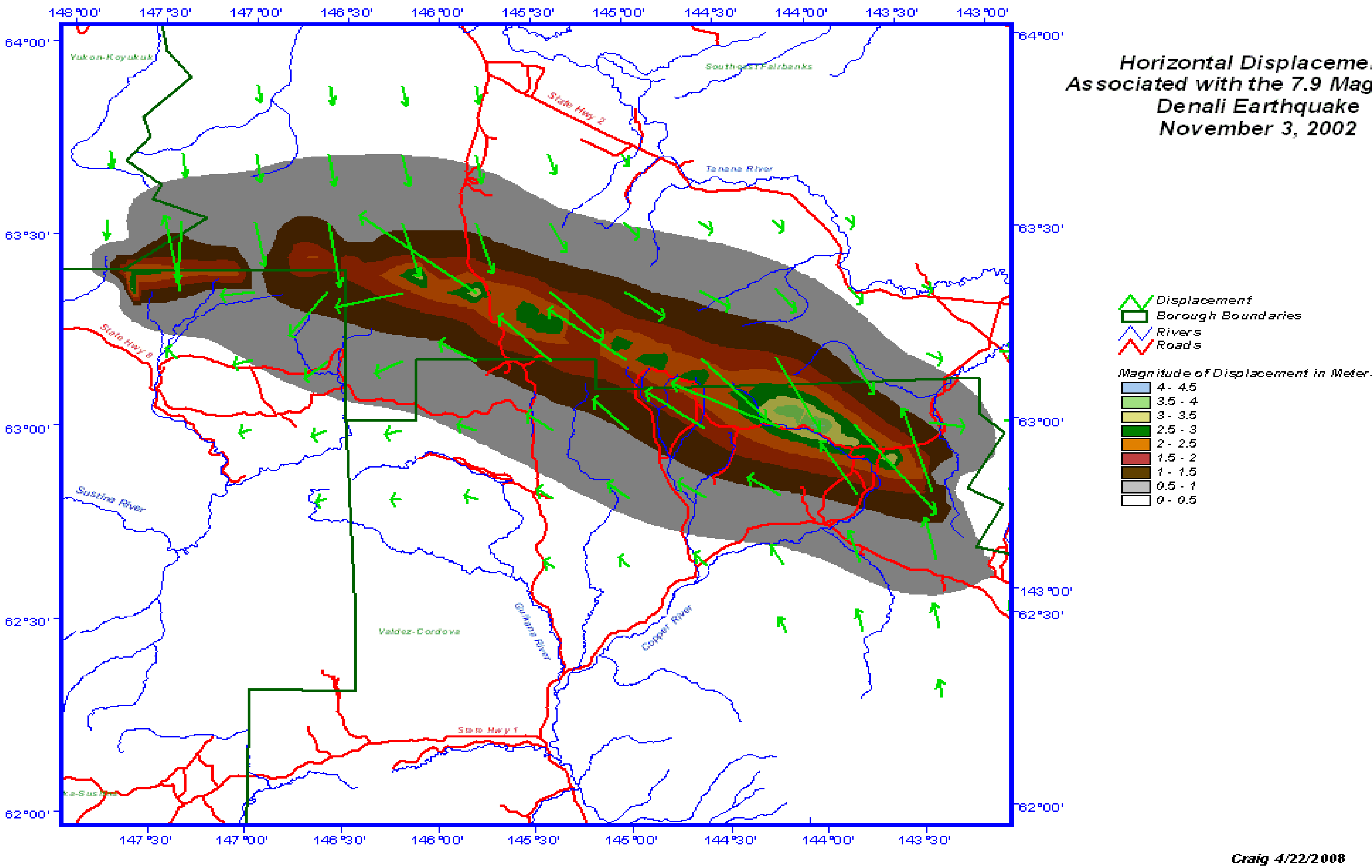
# Post-seismic deformation over 5 years



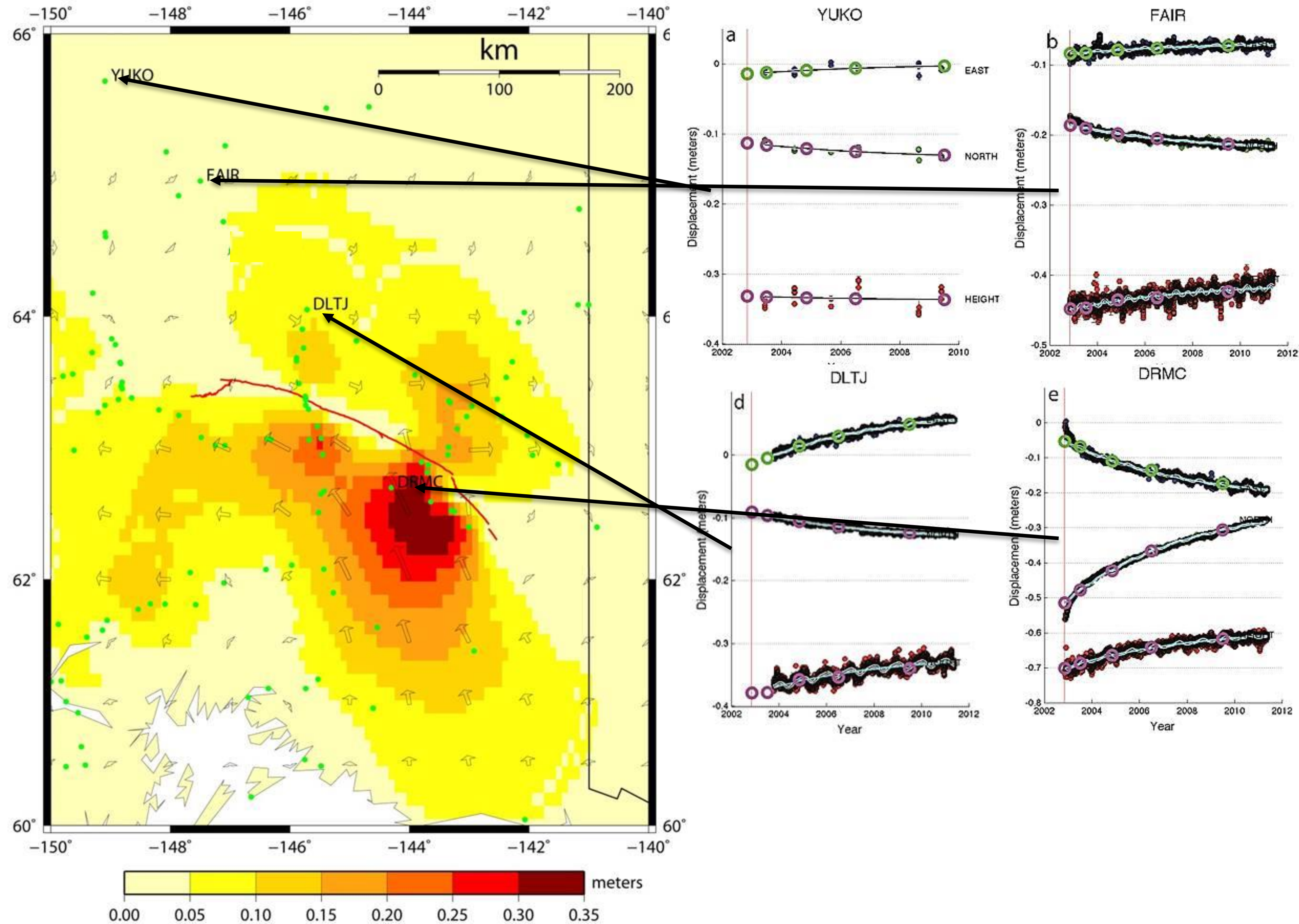
# Velocity change



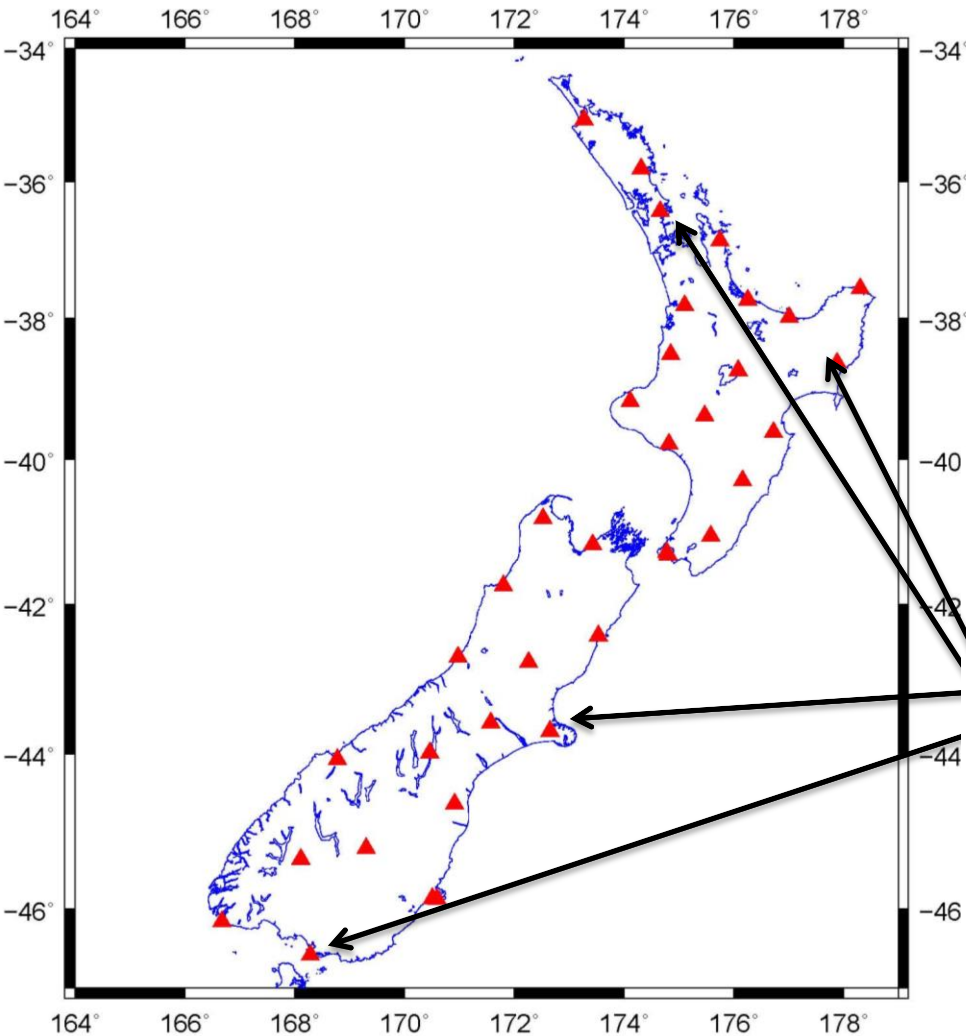
# HTDP, v 3.0 included dislocation model for the 2002 Denali earthquake



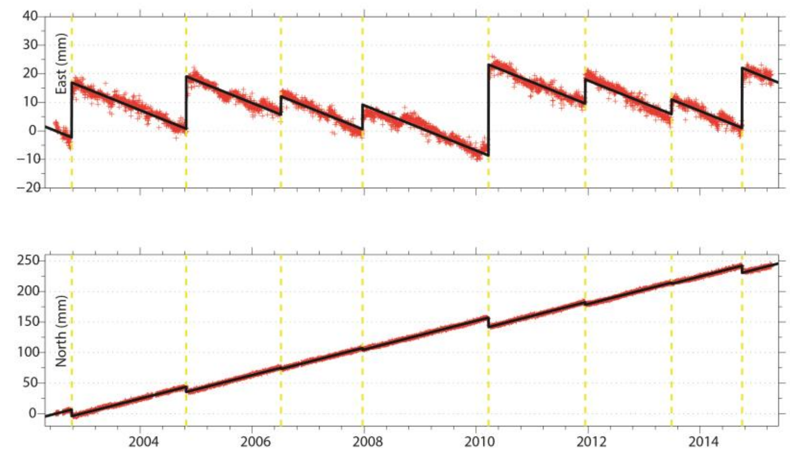

Source: Elliott, J. L., Freymueller J. T., and Rabus B. (2007), Coseismic deformation of the 2002 Denali fault earthquake: Contributions from synthetic aperture radar range offsets, *J. Geophys. Res.*, 112, B06421, doi:10.1029/2006JB004428.

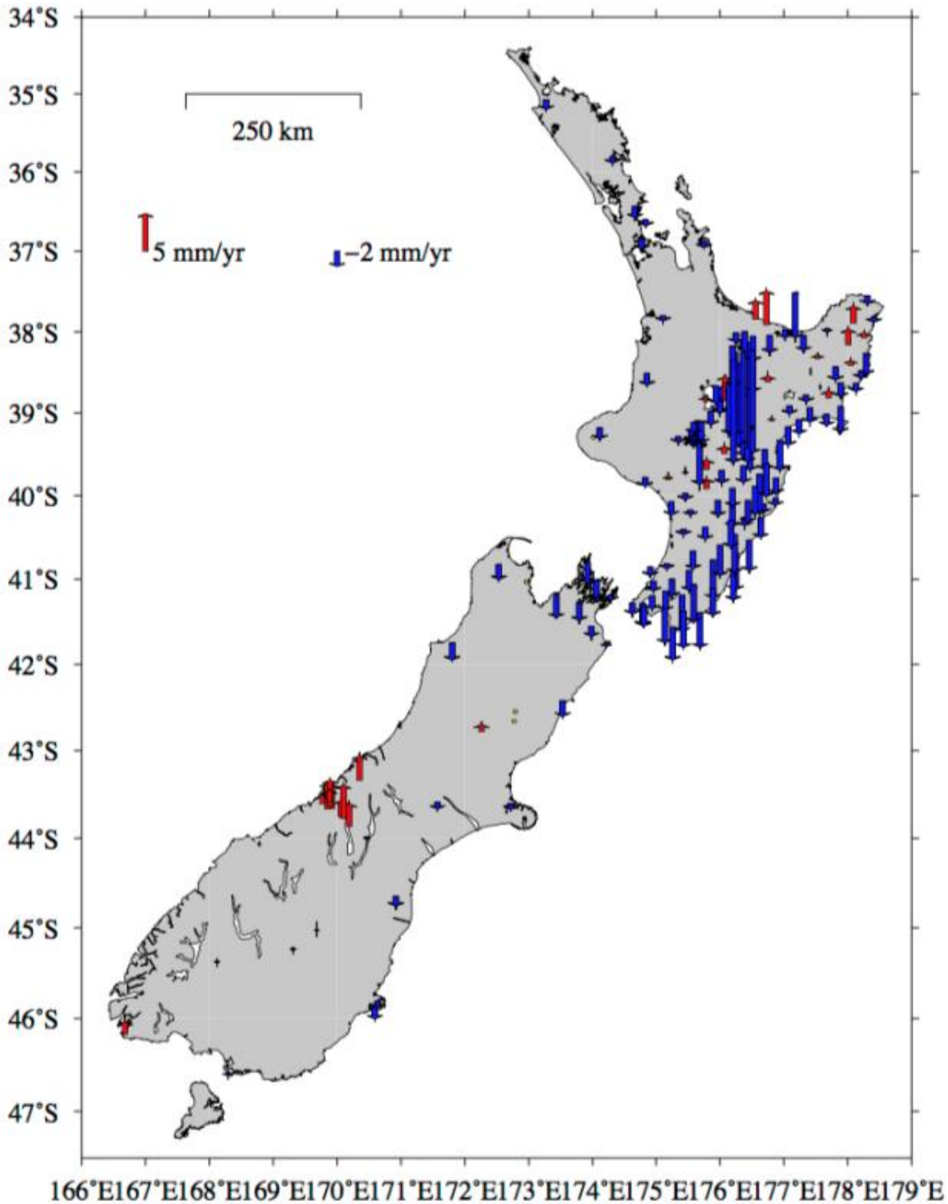


km
0
100
200
YUKO
FAIR
DLTJ
DRMC
−150°
−148°
−146°
−144°
−142°
−140°
66°
64°
62°
60°
meters
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
a
b
d
e
EAST
NORTH
HEIGHT
Displacement (meters)
Year
2002
2004
2006
2008
2010
2012



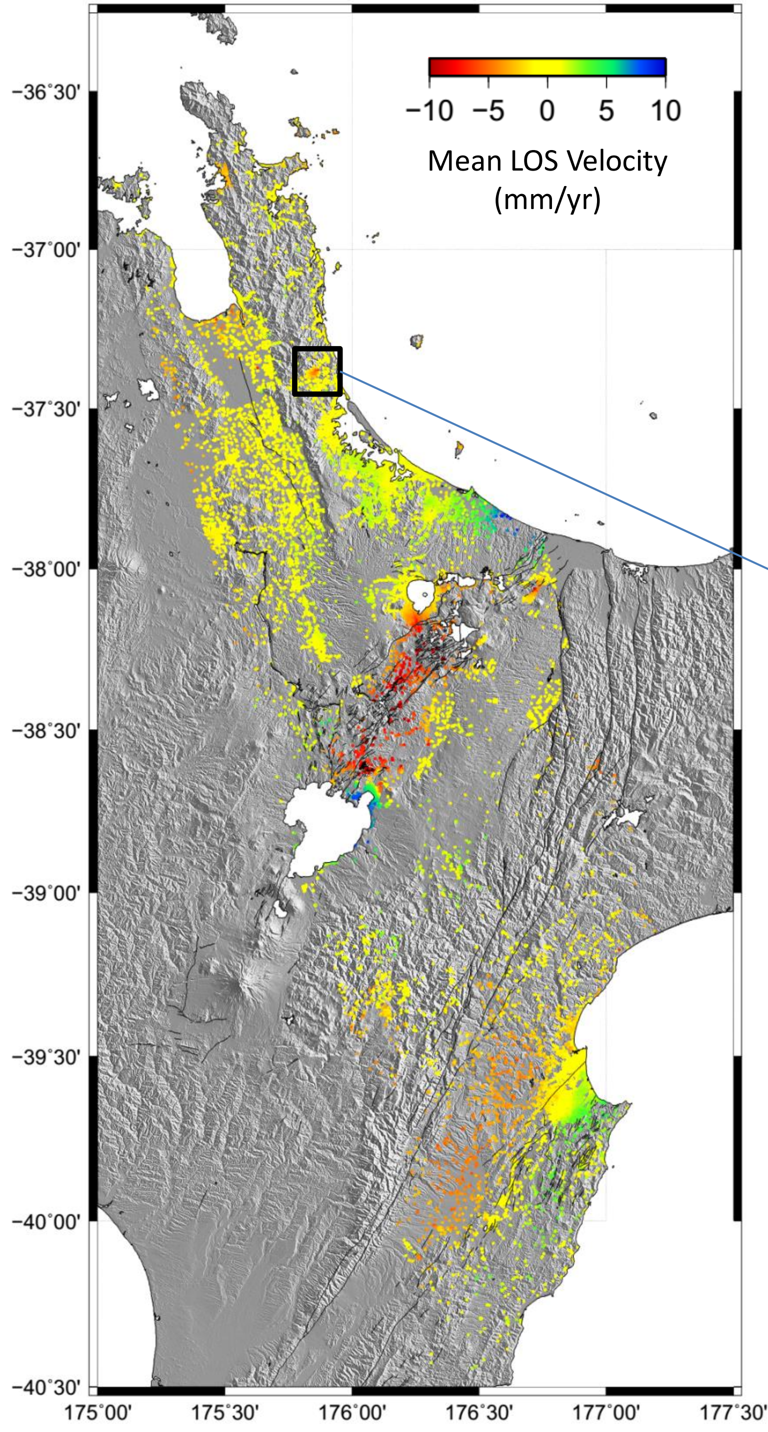

- Secular Velocity
- Earthquake offsets
- Post seismic relexation
- Slow slip events





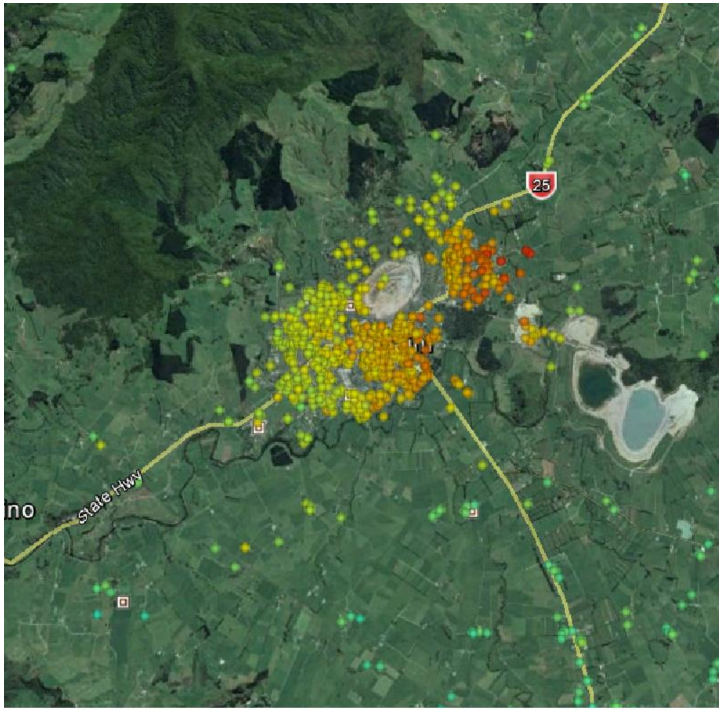

# Vertical velocities in New Zealand

Sigrun Herinsdottir GNS Science

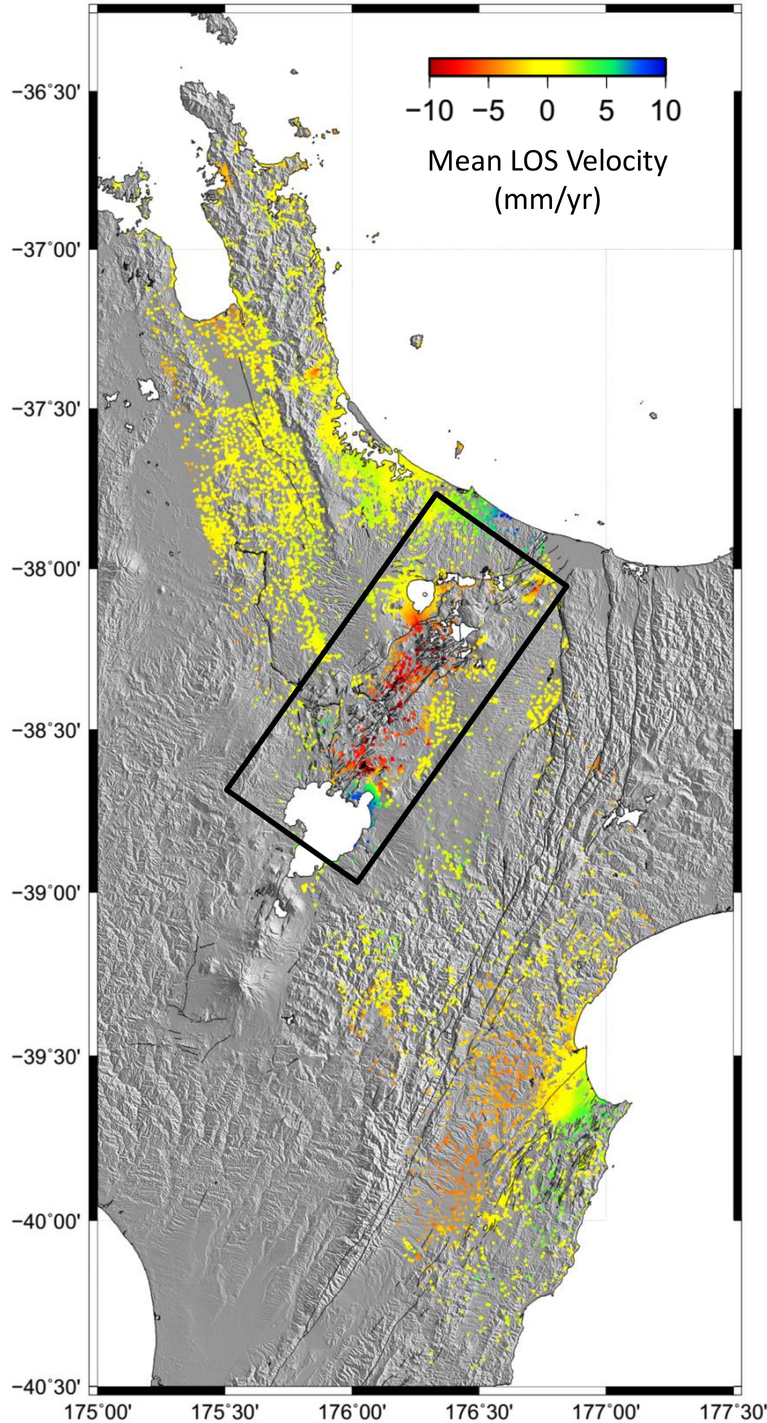



InSAR derived velocity maps from 2003 – 2010 reveal a number of subsiding regions around New Zealand.

Subsidence of up to 10 mm/yr is observed across the Waihi Township. Most likely as a result of past mining activities




Ian Hamling GNS Science




InSAR derived velocity maps from 2003 – 2010 reveal a number of subsiding regions around New Zealand.

Widespread subsidence has been observed along the Taupo Volcanic Zone associated with both geothermal activities and cooling of magma at depth