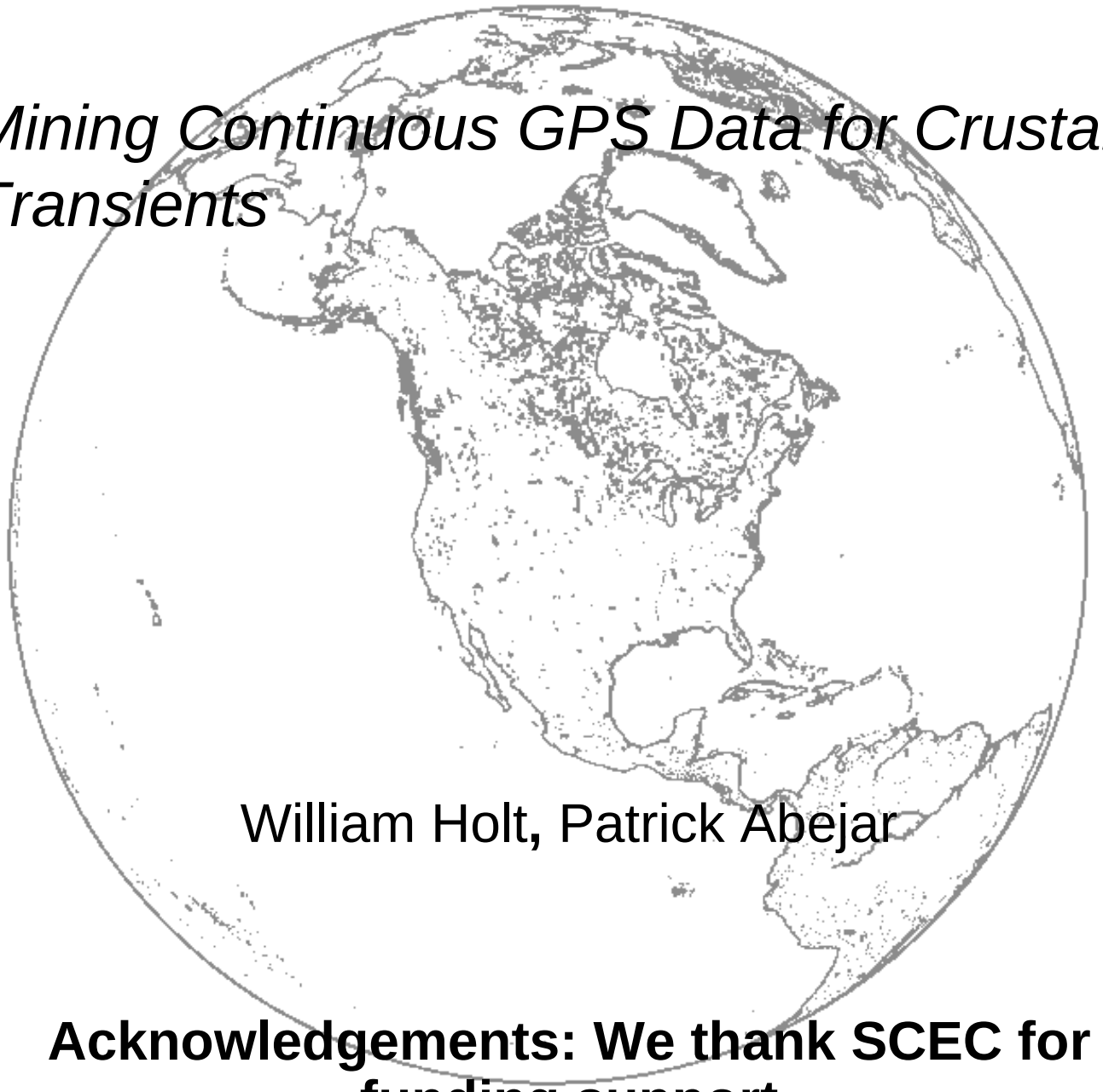
Mining Continuous GPS Data for Crustal Transients



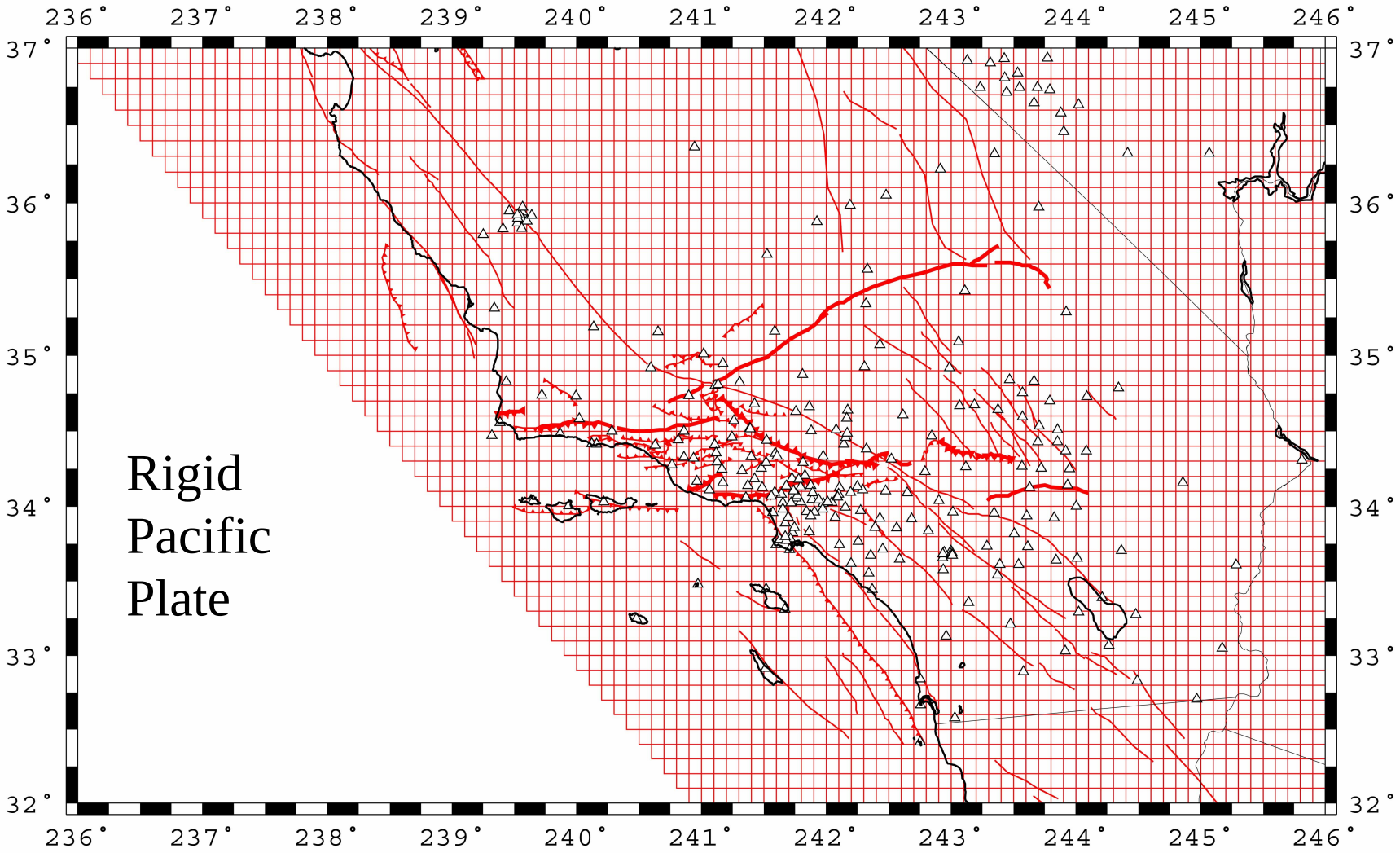
William Holt, Patrick Abejar

Acknowledgements: We thank SCEC for funding support

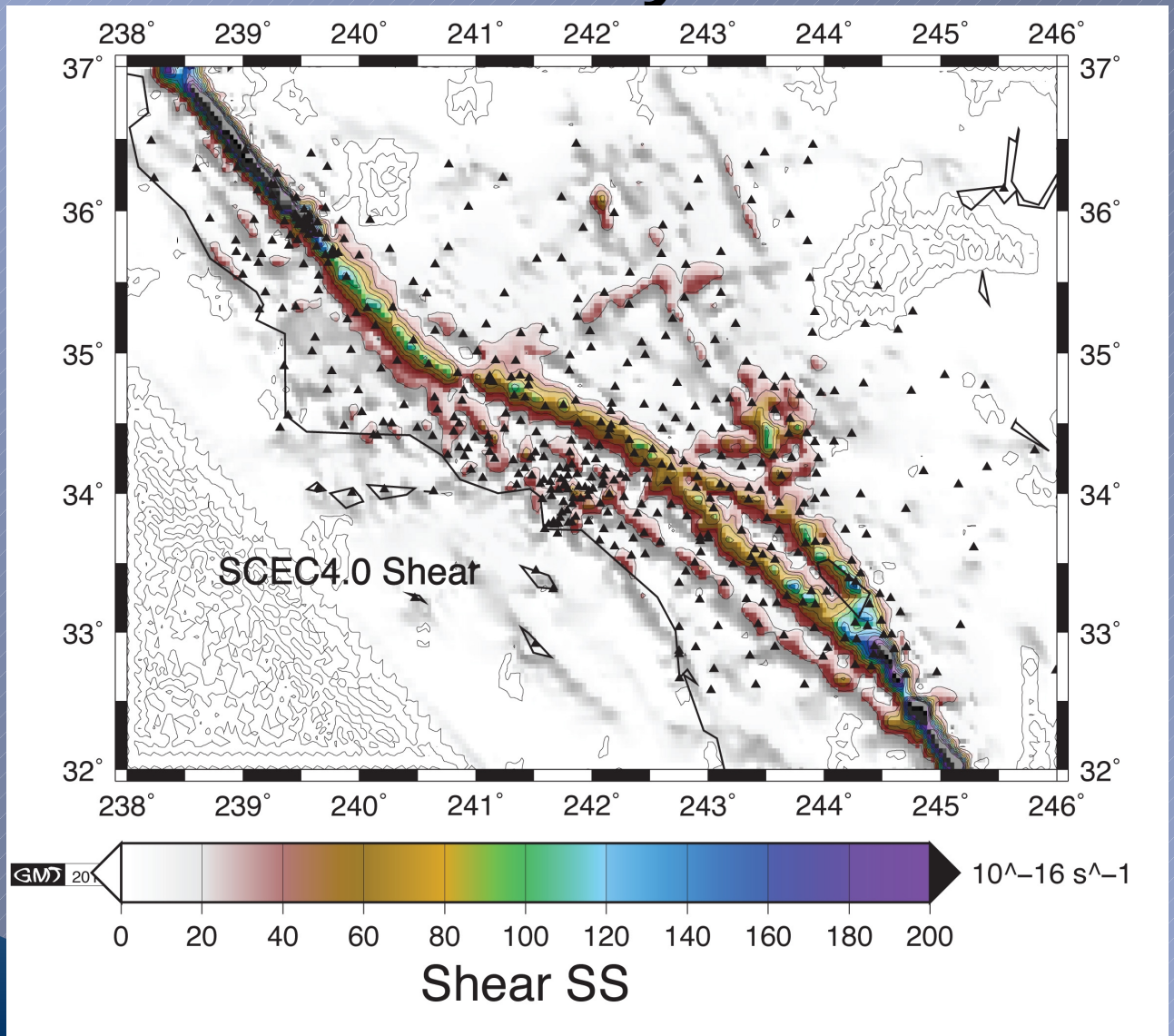
Objectives

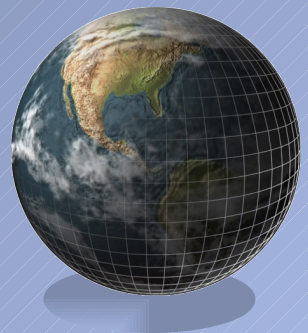
- Map deformation rates as a function of time using CGPS observations. (Finite Element method - spherical)
- Develop tool used to recognize deformation transients.
  - Temporal and spatial changes of deformation rate along with confidence levels
  - Tested through participation in SCEC III Blind Test Exercise

0.1° x 0.1° Grid


236°
237°
238°
239°
240°
241°
242°
243°
244°
245°
246°
37°
36°
35°
34°
33°
32°
Rigid
Pacific
Plate

Model shear strain rates from SCEC4.0 Velocity field





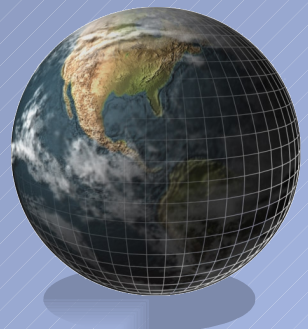
Smoothing or Damping

- Maximize signal associated with GPS
- Achieve Reduced Chi-Squared misfit between model velocity and observed velocity of ~1.0 for all epochs

$$\chi = \sum_{cells\ ij,kl} (\bar{e}_{ij})^T \mathbf{V}_{ij,kl}^{-1} (\bar{e}_{kl}) + \sum_{knots\ i,j} (v_i - \bar{v}_i^{obs})^T \mathbf{V}_{i,j}^{-1} (\bar{v}_j - \bar{v}_j^{obs})$$

Haines, Jackson, Holt, Agnew [1998]

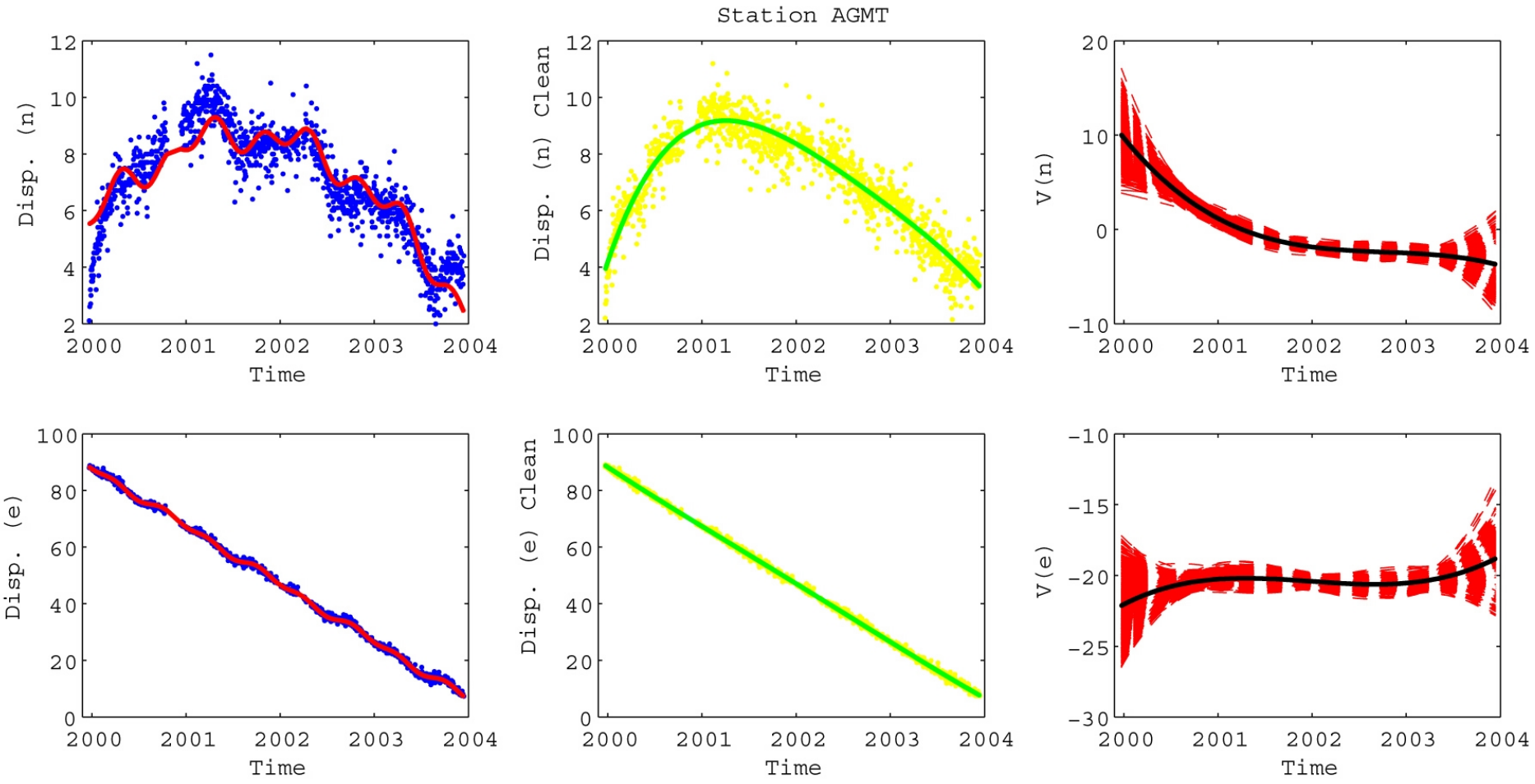
Beavan and Haines [2001]



Least-squares inversion of time series for d(t) and v(t)

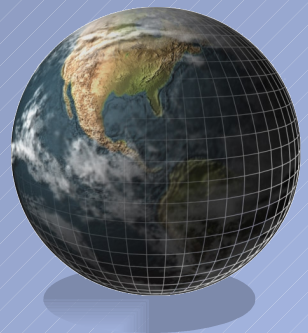
$$d(t) = \frac{1}{24}(a)t^4 + \frac{1}{6}(b)t^3 + \frac{1}{2}(c)t^2 + (d)t + e +$$
$$f\sin(2pt) + g\cos(2pt) + h\sin(4pt) + i\cos(4pt).$$

Time Series Inversion



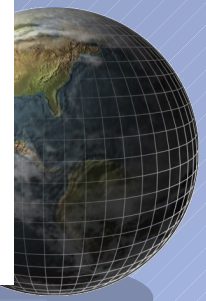
Estimating a Time-Dependent Velocity Field in Southern California

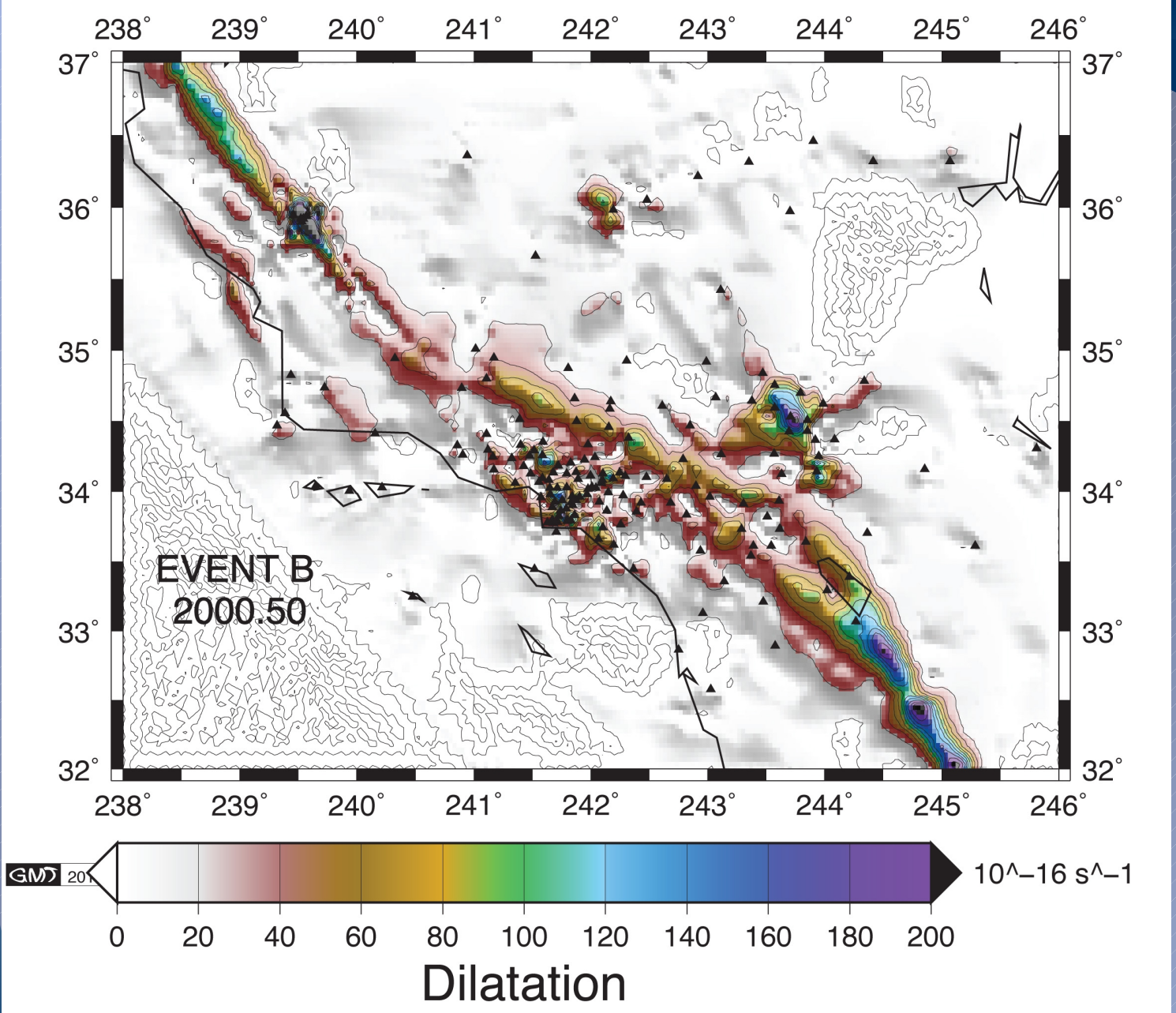
- Using 4th order polynomial fitting with seasonal signals removed, we output time dependent velocities every 0.05 years
- For each epoch we solved for VGTF throughout SCAL (2000.0 – 2010.0).



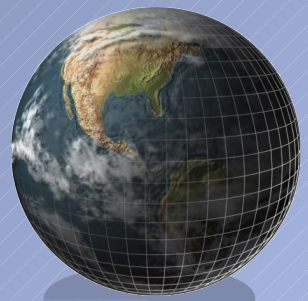
Subtract out ‘master solution’ to estimate signal only from transients

- For real data we used SCEC4.0 solution as a master solution
- For other groups in the SCEC exercise we used time averaged solution (2007 – 2009).

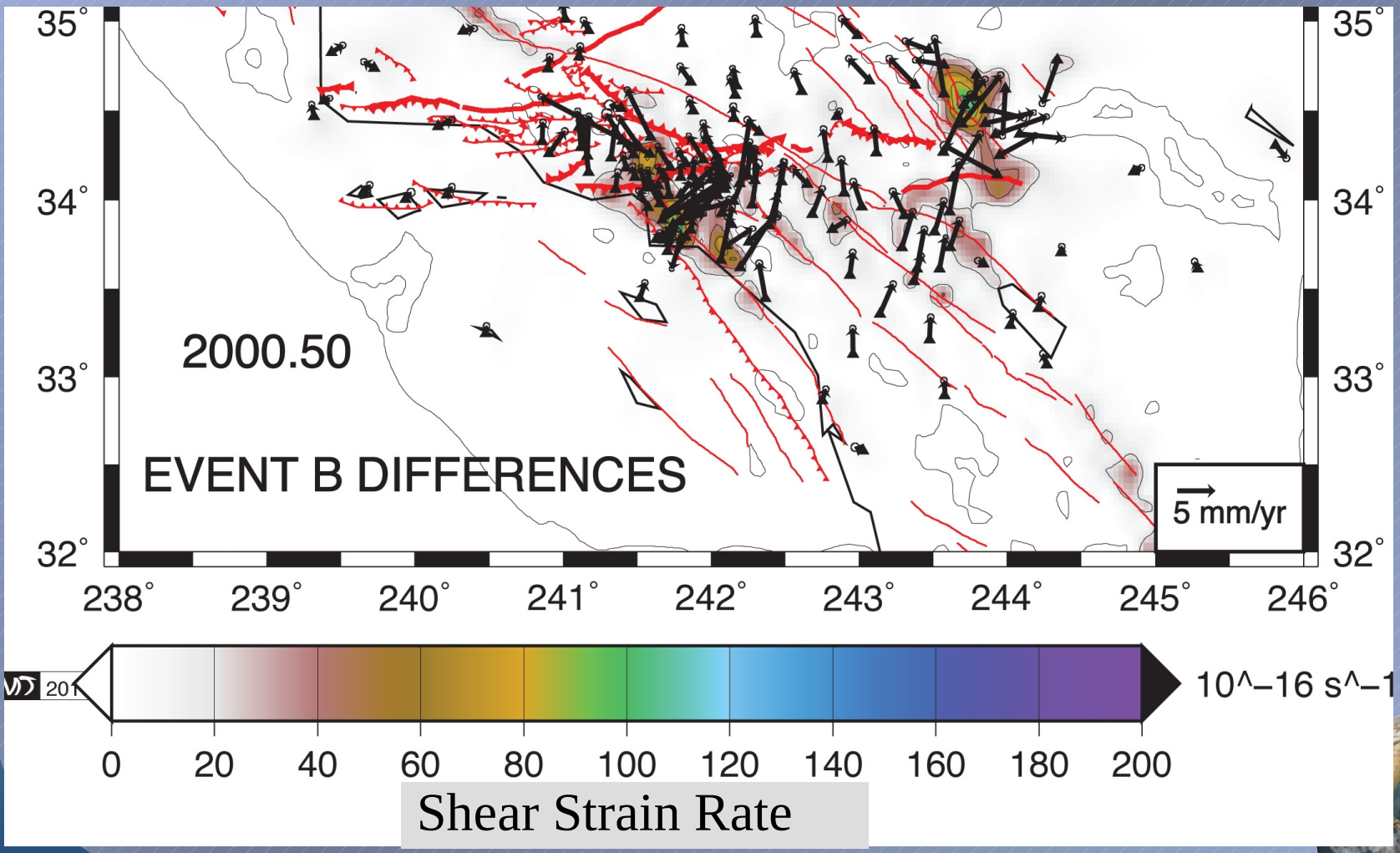




Real data solution at 2000.5

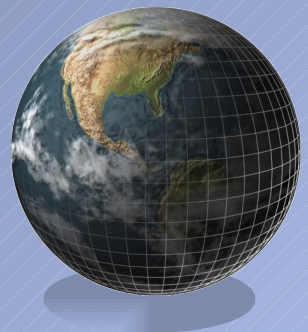


Differences = Epoch – SCEC4.0

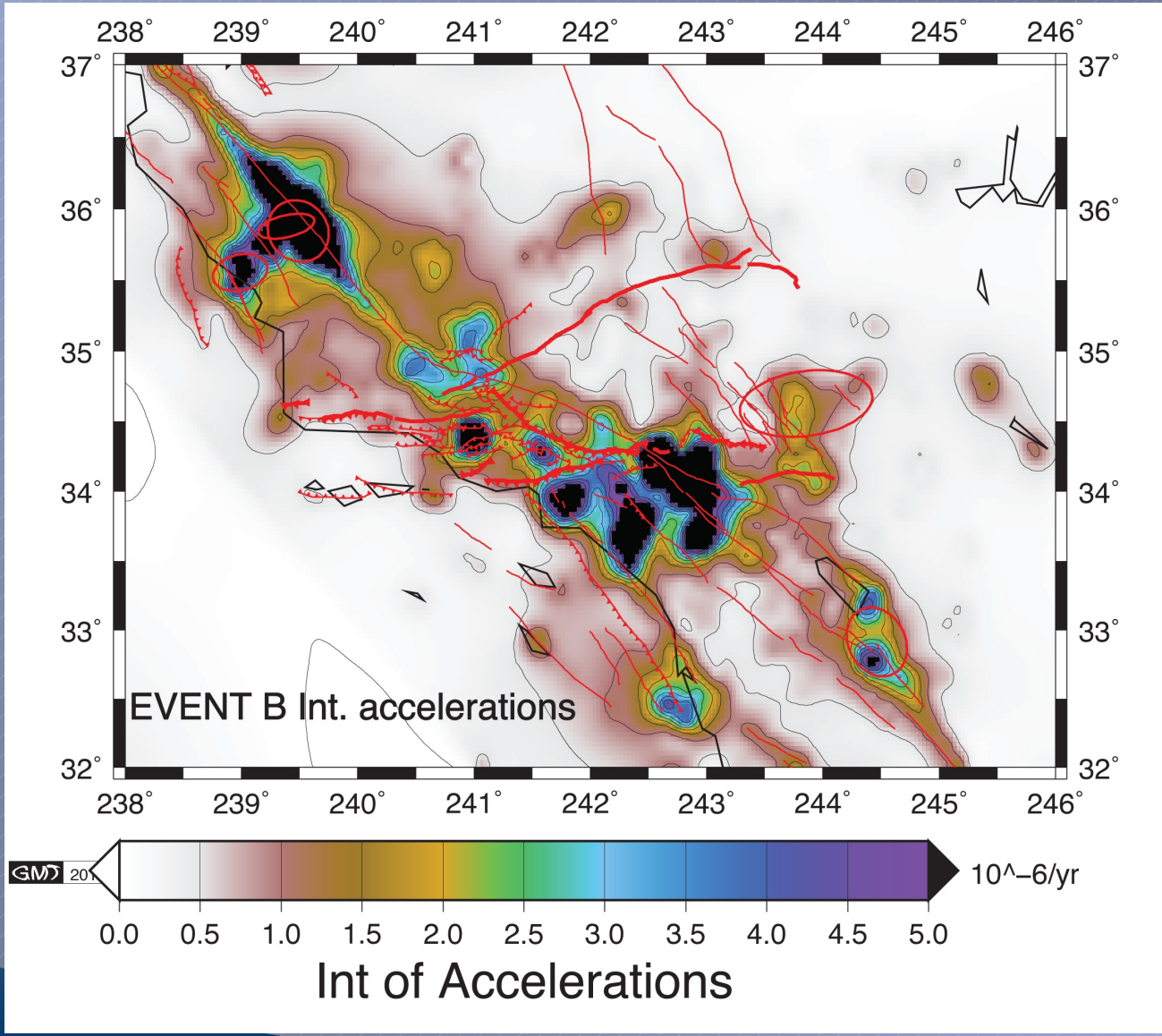


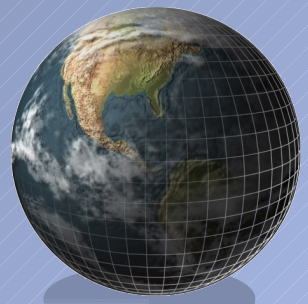
Selecting Potential Transients

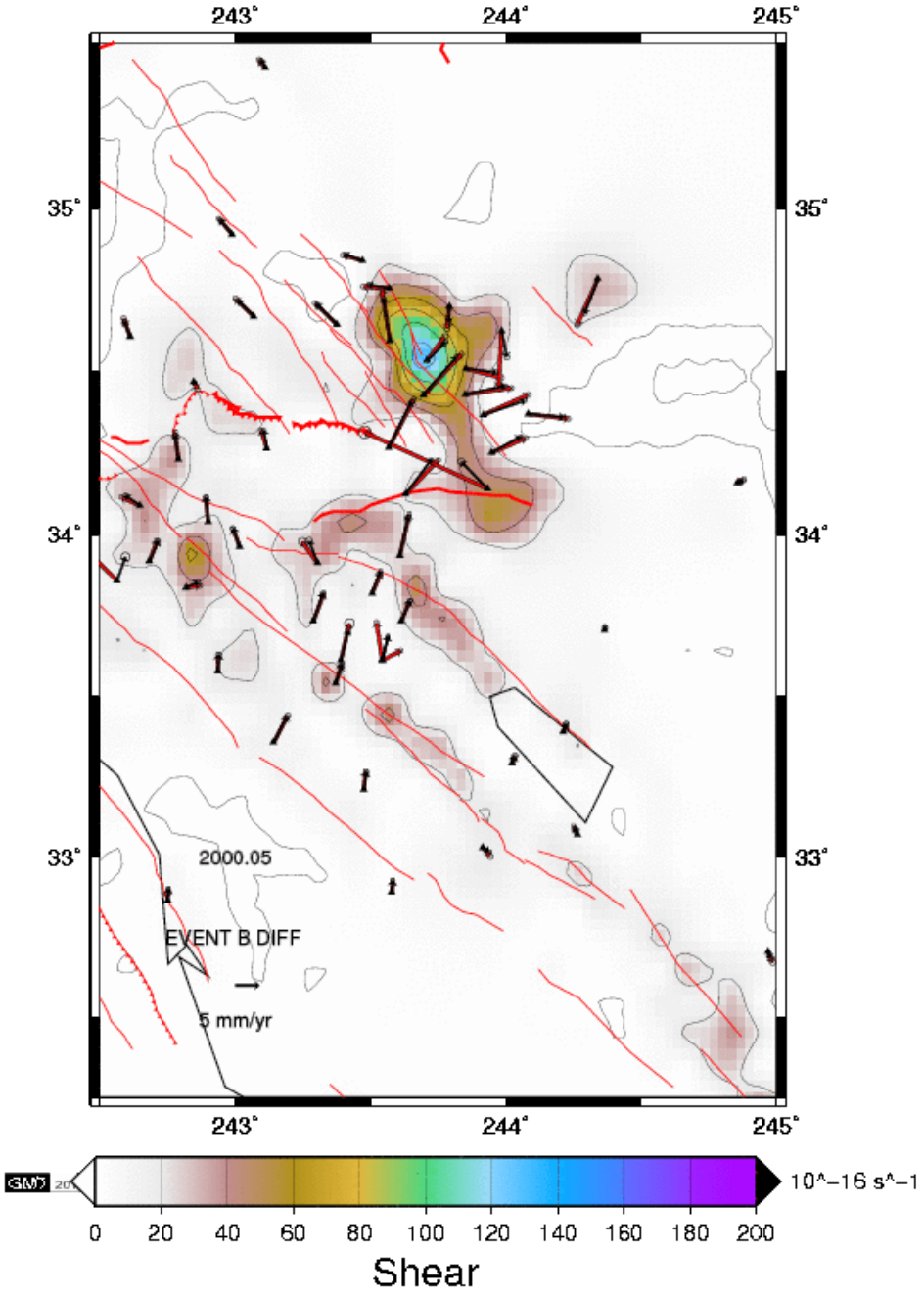
- Accelerations $\frac{d}{dt}(d\dot{E})$
- Finite Strain $\int \delta \dot{E} dt$
- Does signal look tectonic?
- Analysis of finite strain tensor and displacement vector fields



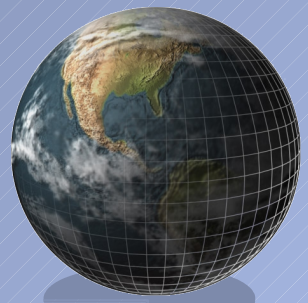
Total Integrated Accelerations



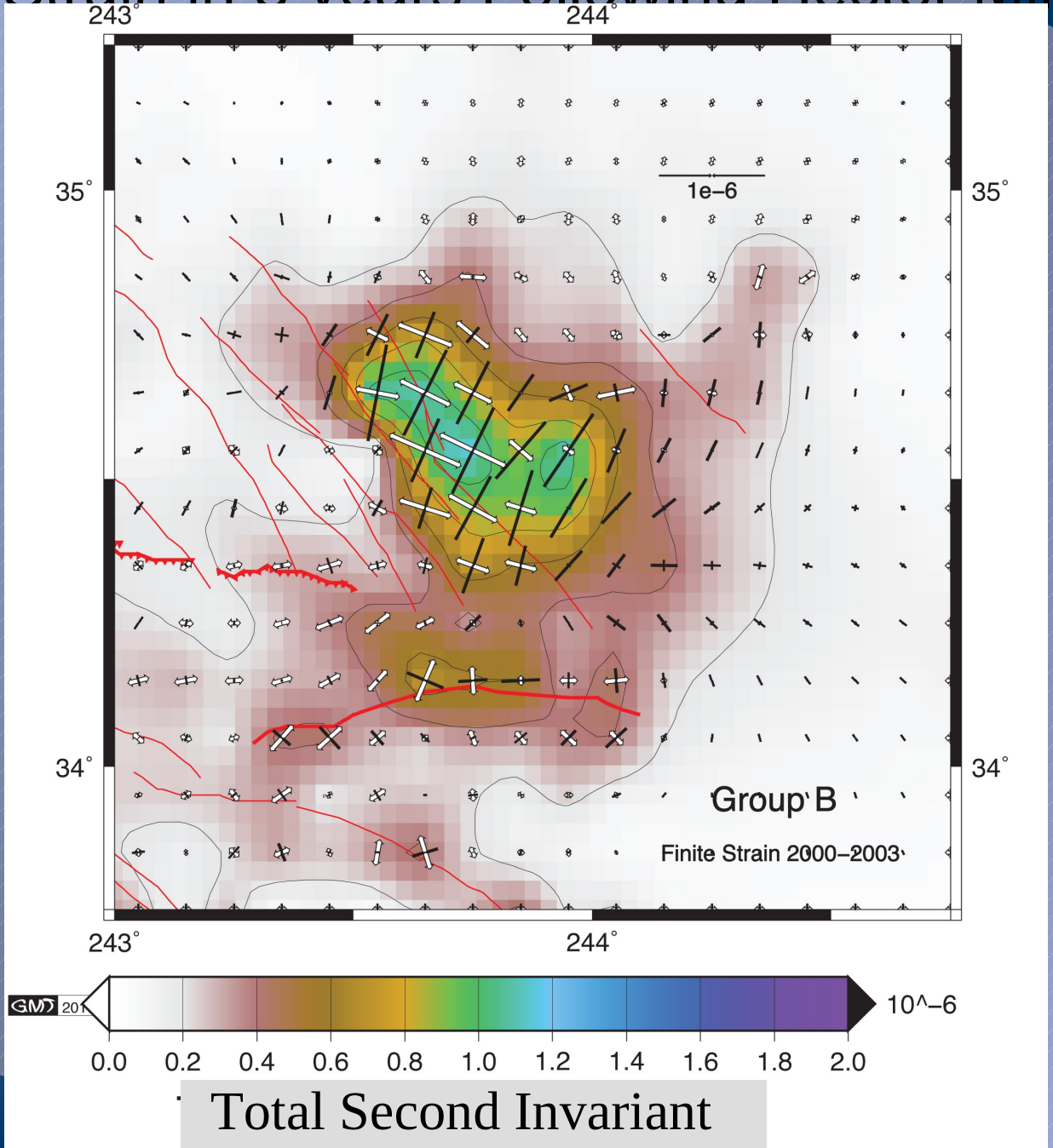




Post-seismic strain rate field evolution following Hector Mine E.Q.

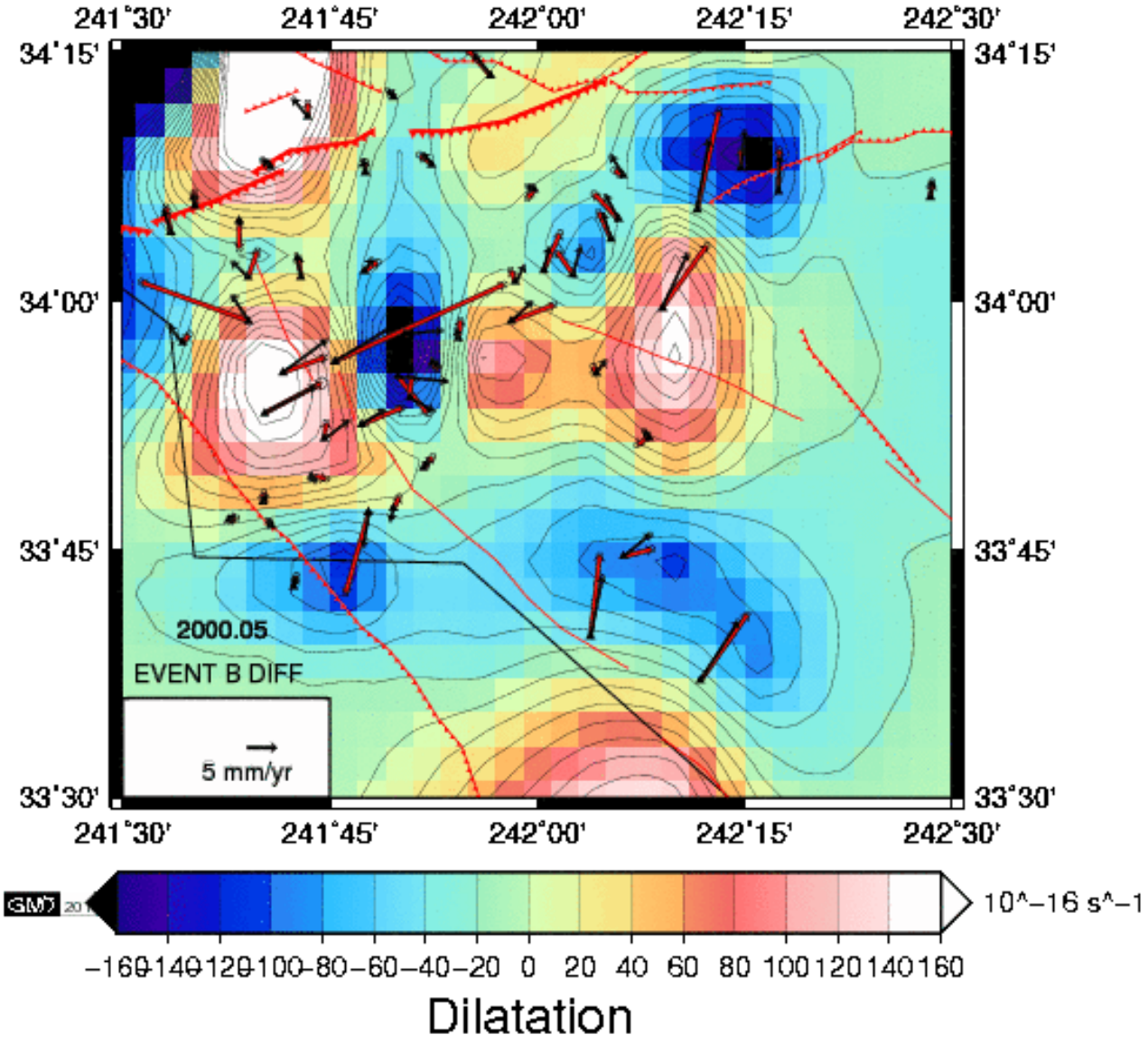


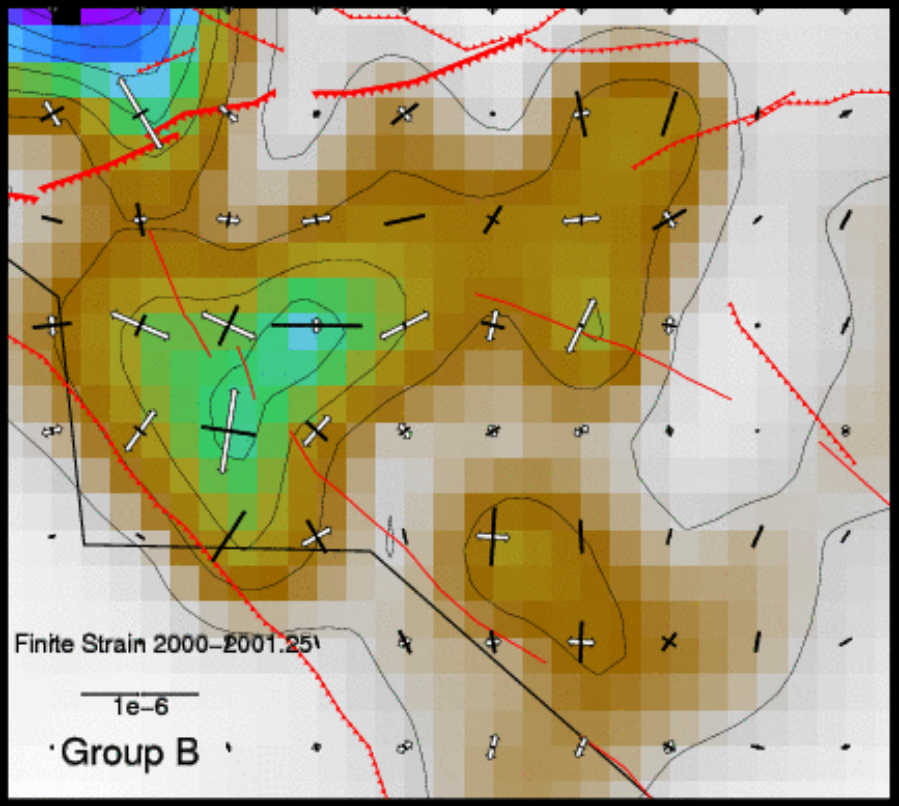
Finite Strain in 3 years Following Hector Mine



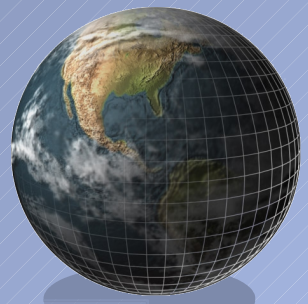
Total Second Invariant

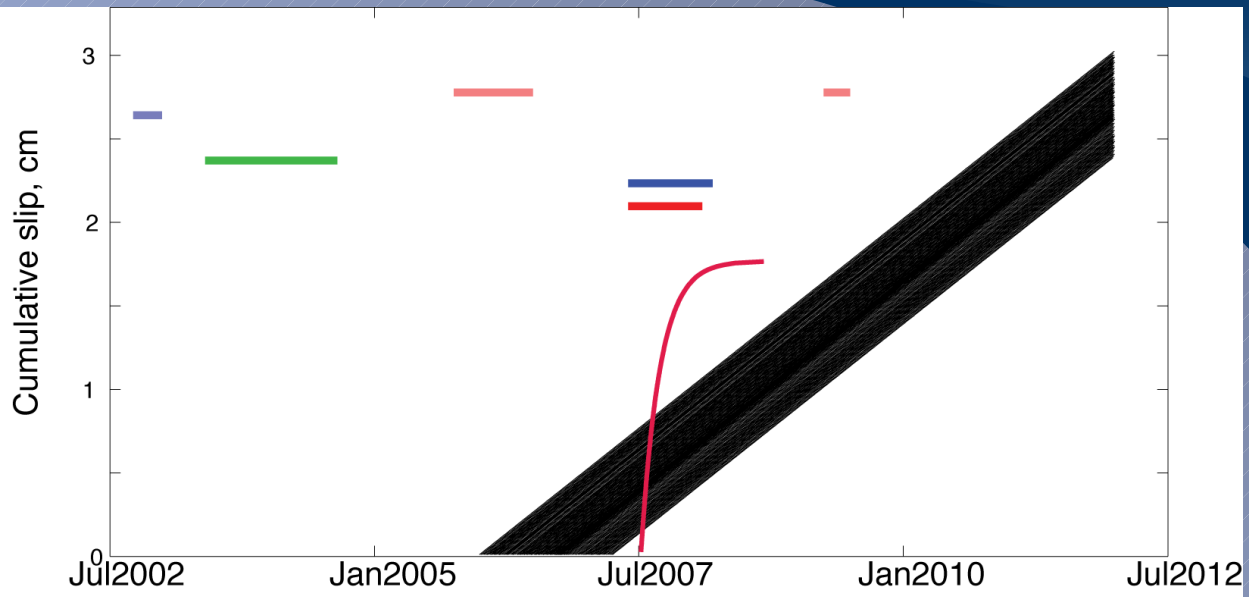
‘Post Seismic’ Strains in LA Basin Region Following Hector Mine EQ

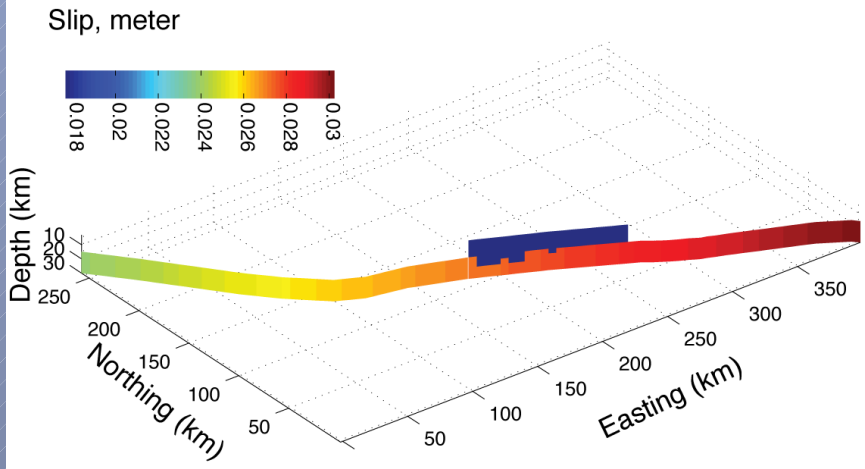



Finite Strain 2000–2001.25
1e–6
Group B


GMT 20



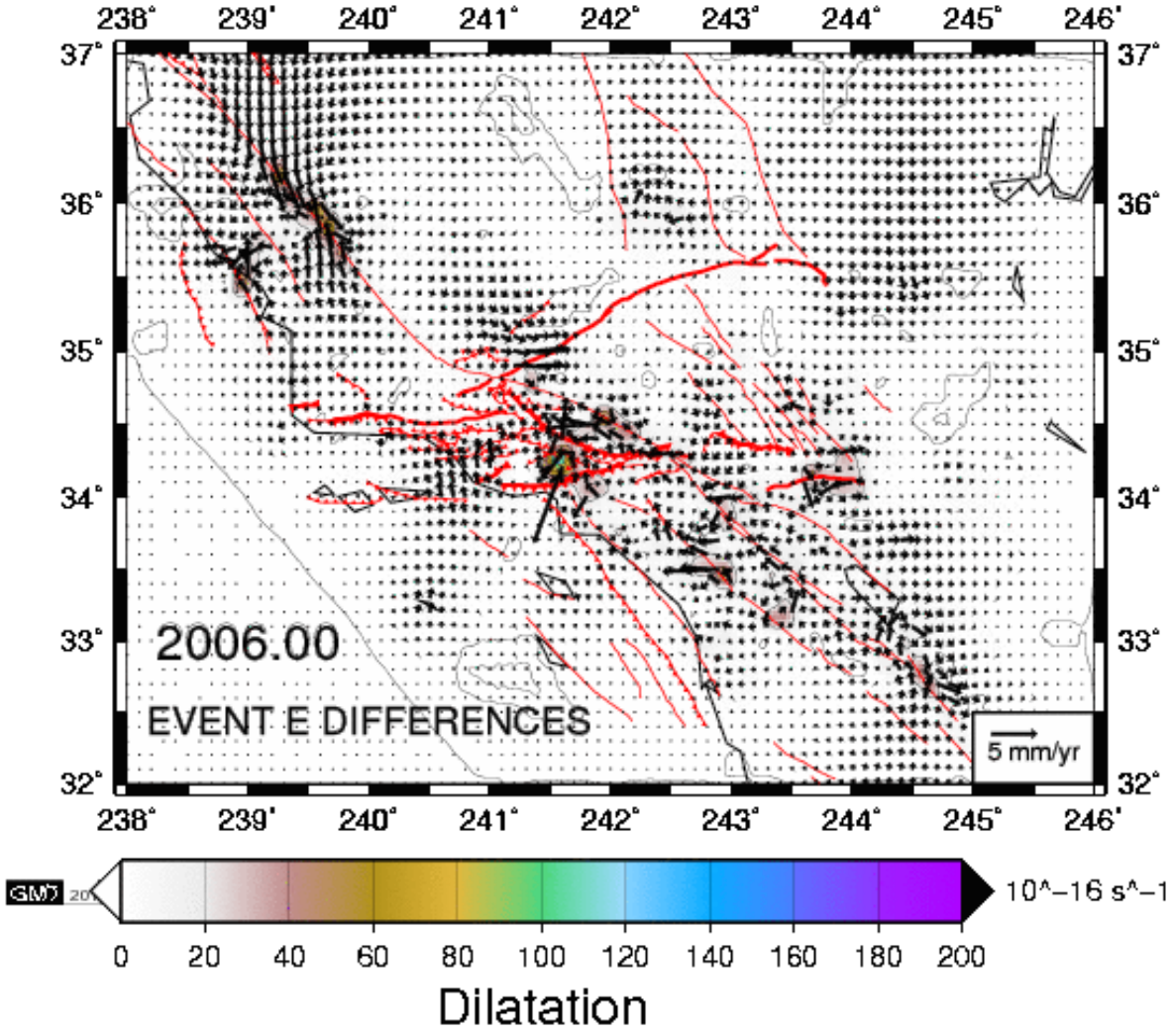




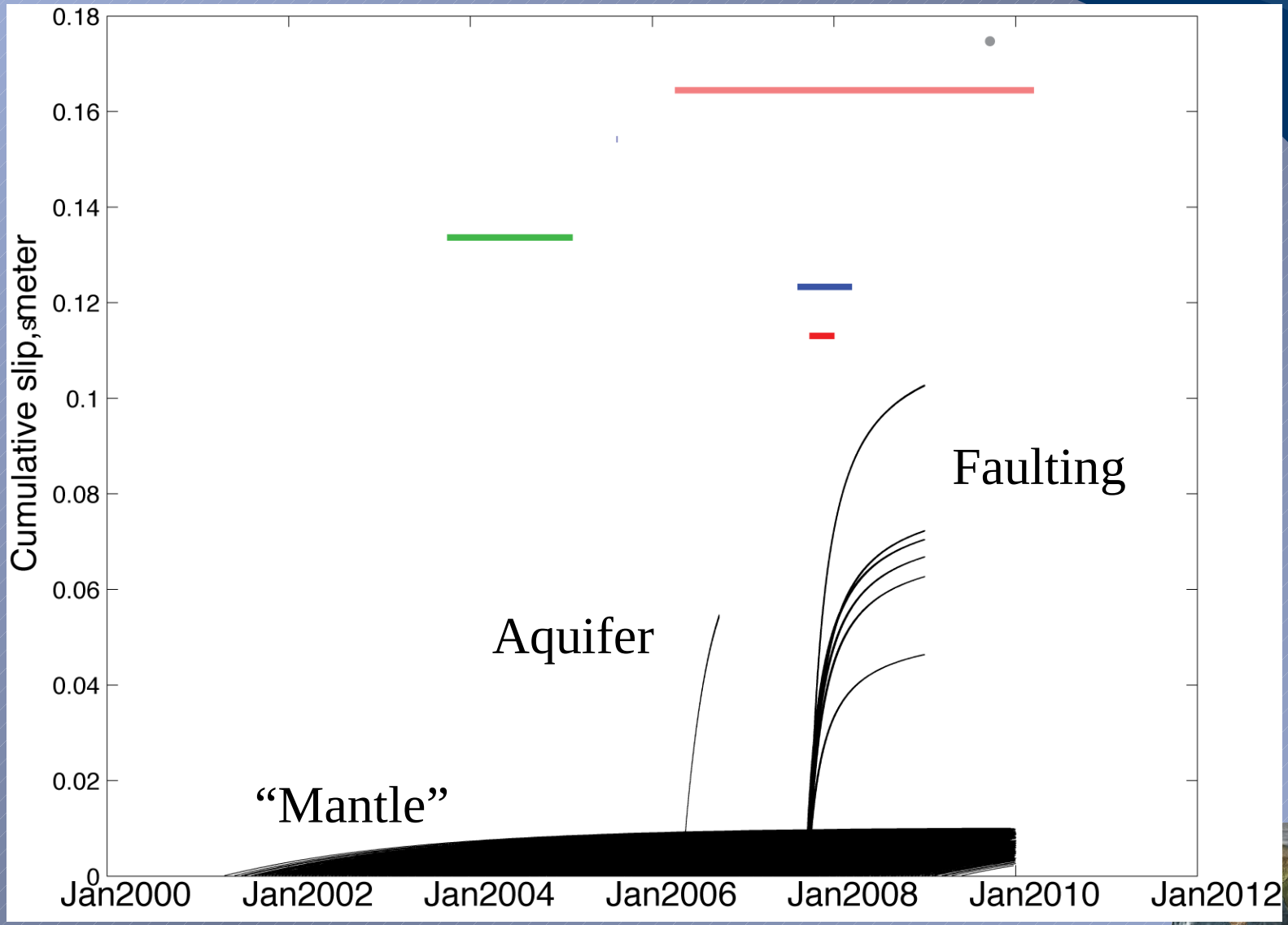
SCEC Transient Group E Sources

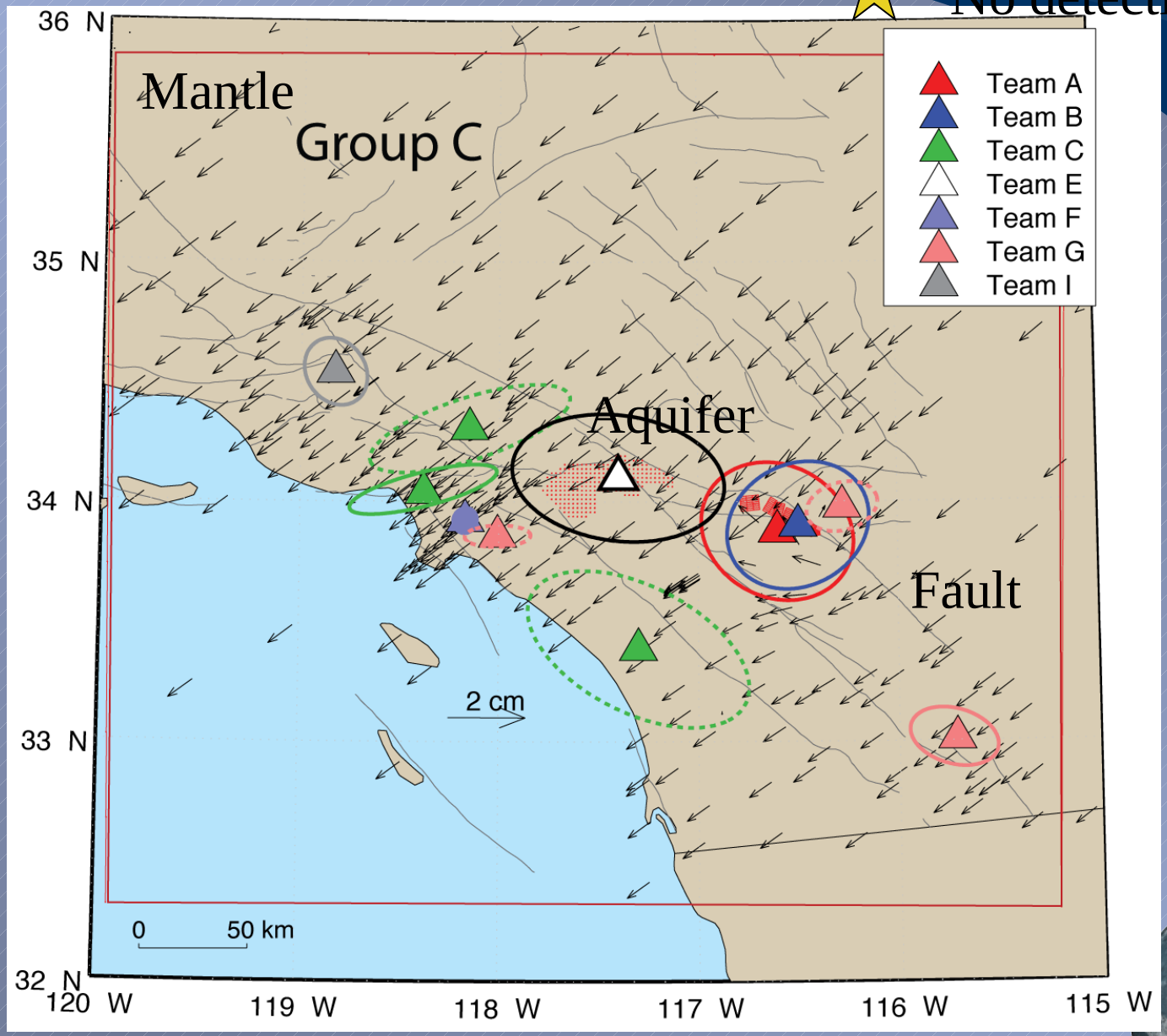
From Group E in SCEC exercise

Event on Big Bend + slip on entire SA captured



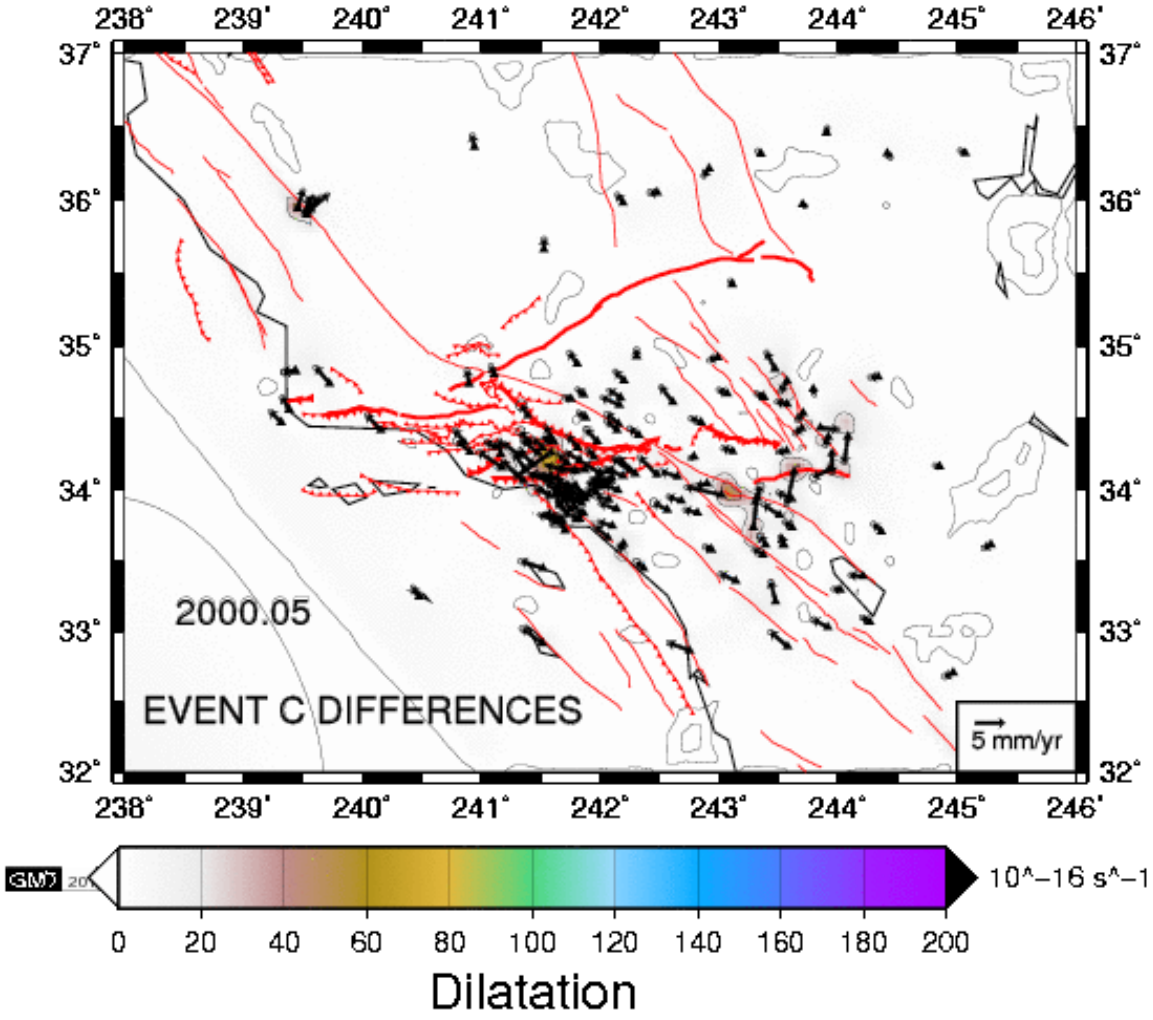
Group C Source

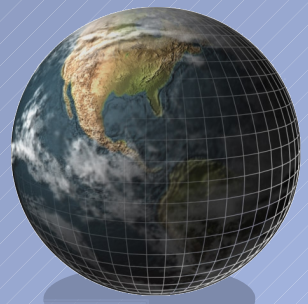



No detection
Mantle
Group C
Aquifer
Fault
Team A
Team B
Team C
Team E
Team F
Team G
Team I
2 cm
0
50 km
36 N
35 N
34 N
33 N
32 N
120 W
119 W
118 W
117 W
116 W
115 W

From Group C in SCEC exercise

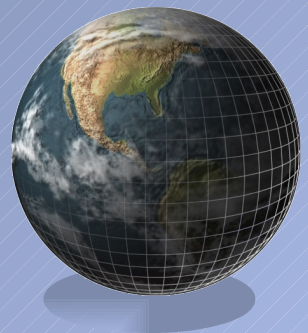
Long wavelength mantle anomaly + event on Southern SA captured



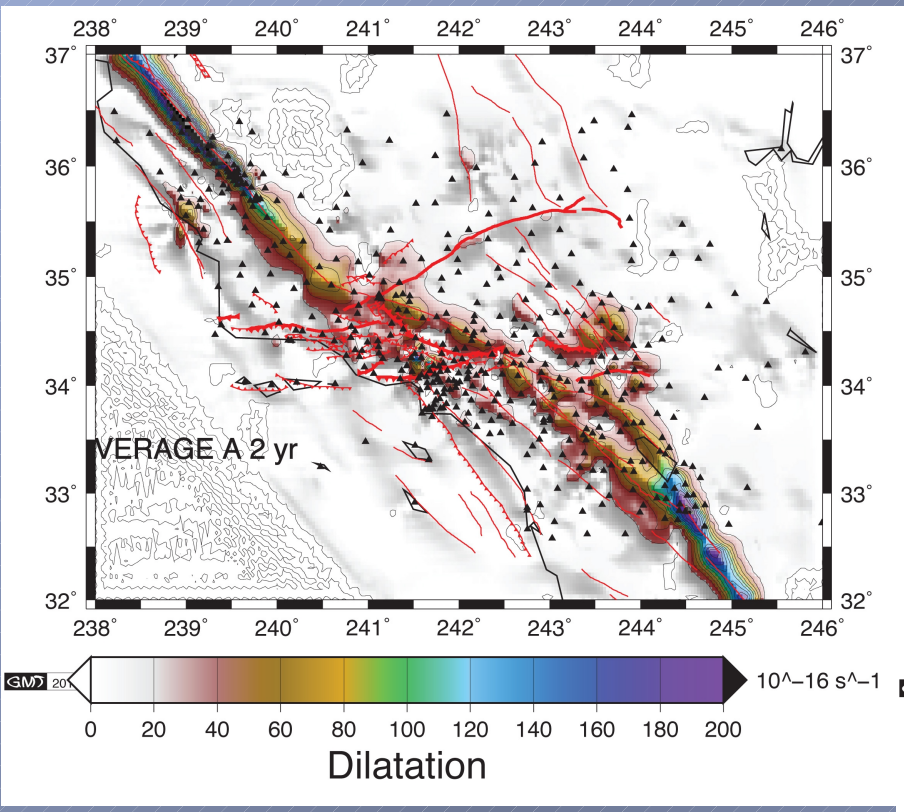


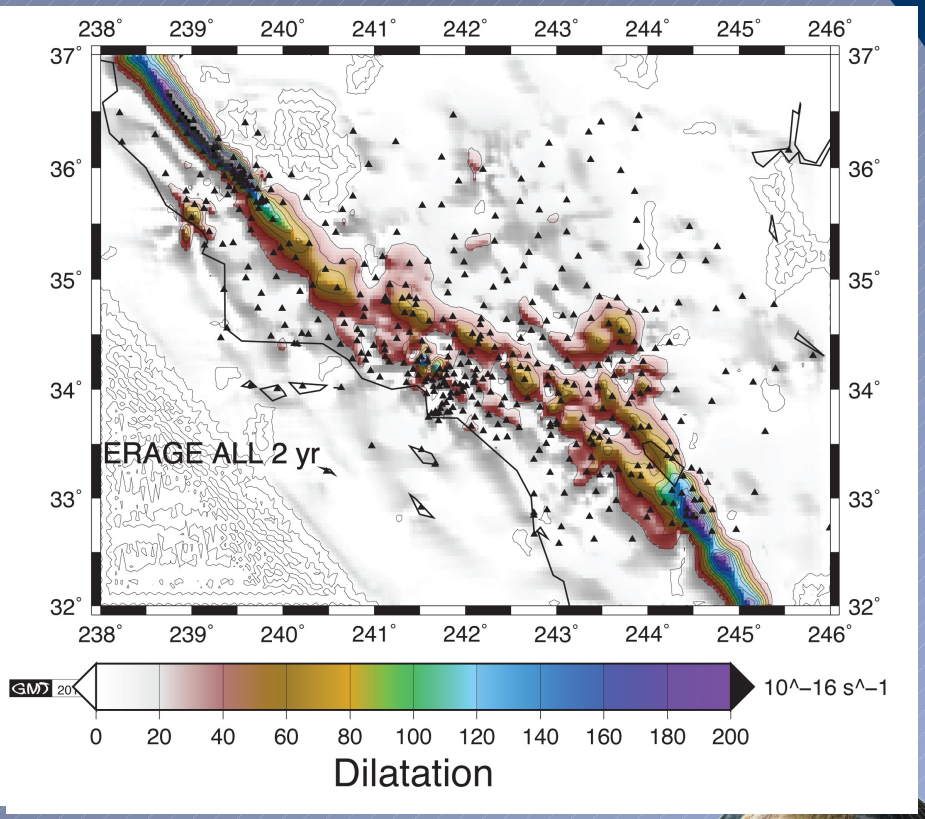
Summary

- Method well-suited to searching for long-wavelength anomalies
- Post Hector Mine is well described in region surrounding EQ
- Anomalies found in LA Basin region during phase of Hector Mine post seismic relaxation
- Anomalies south of Salton Trough
- Shorter time windows (<< 10 yrs) are needed to better delineate/measure anomalies with short temporal duration



Shear Strain Rates for Time-Averaged Solutions

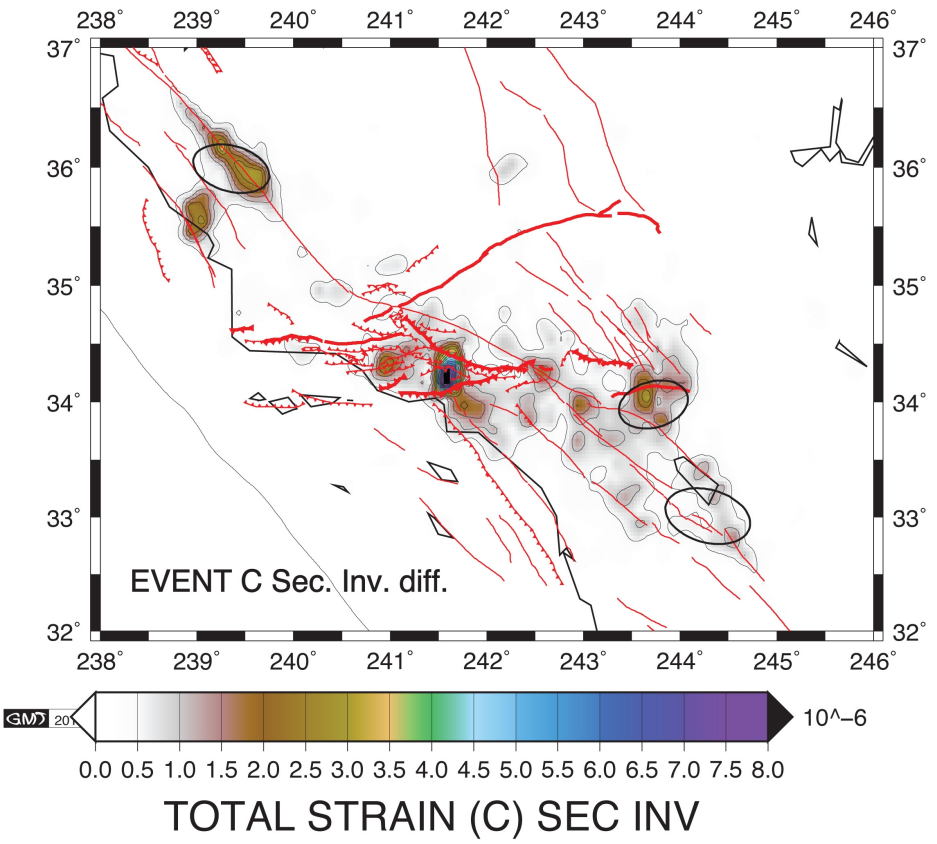


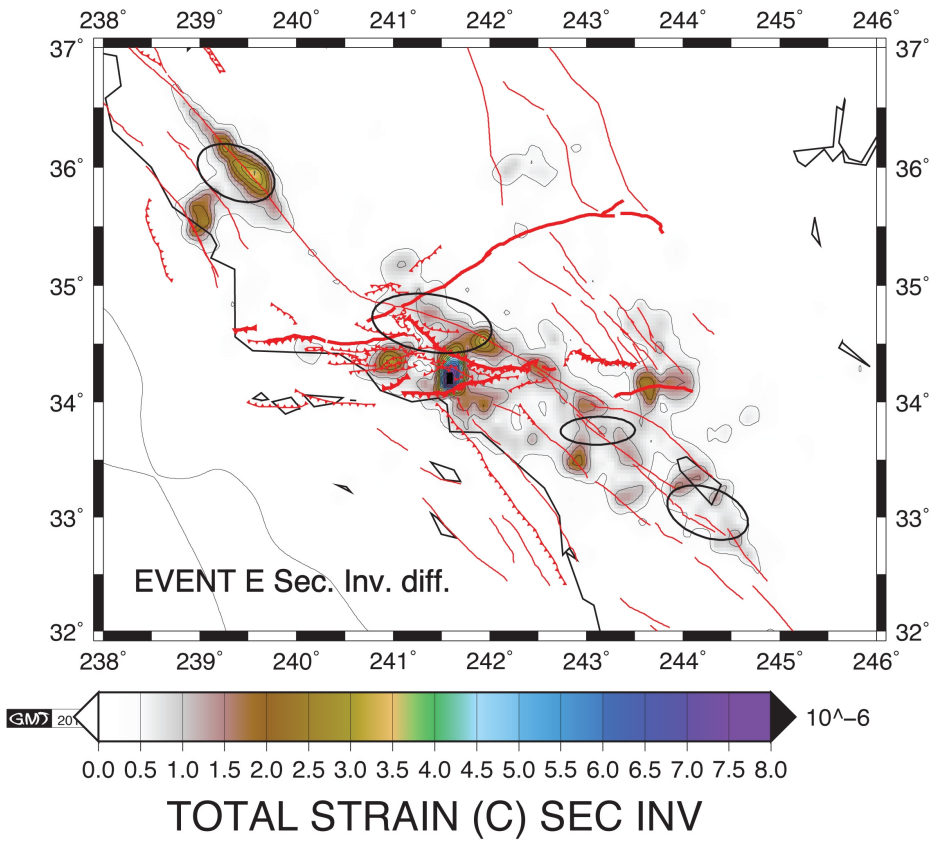


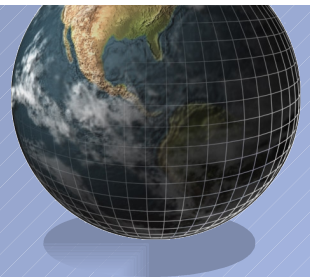
Average for A 2007 - 2009

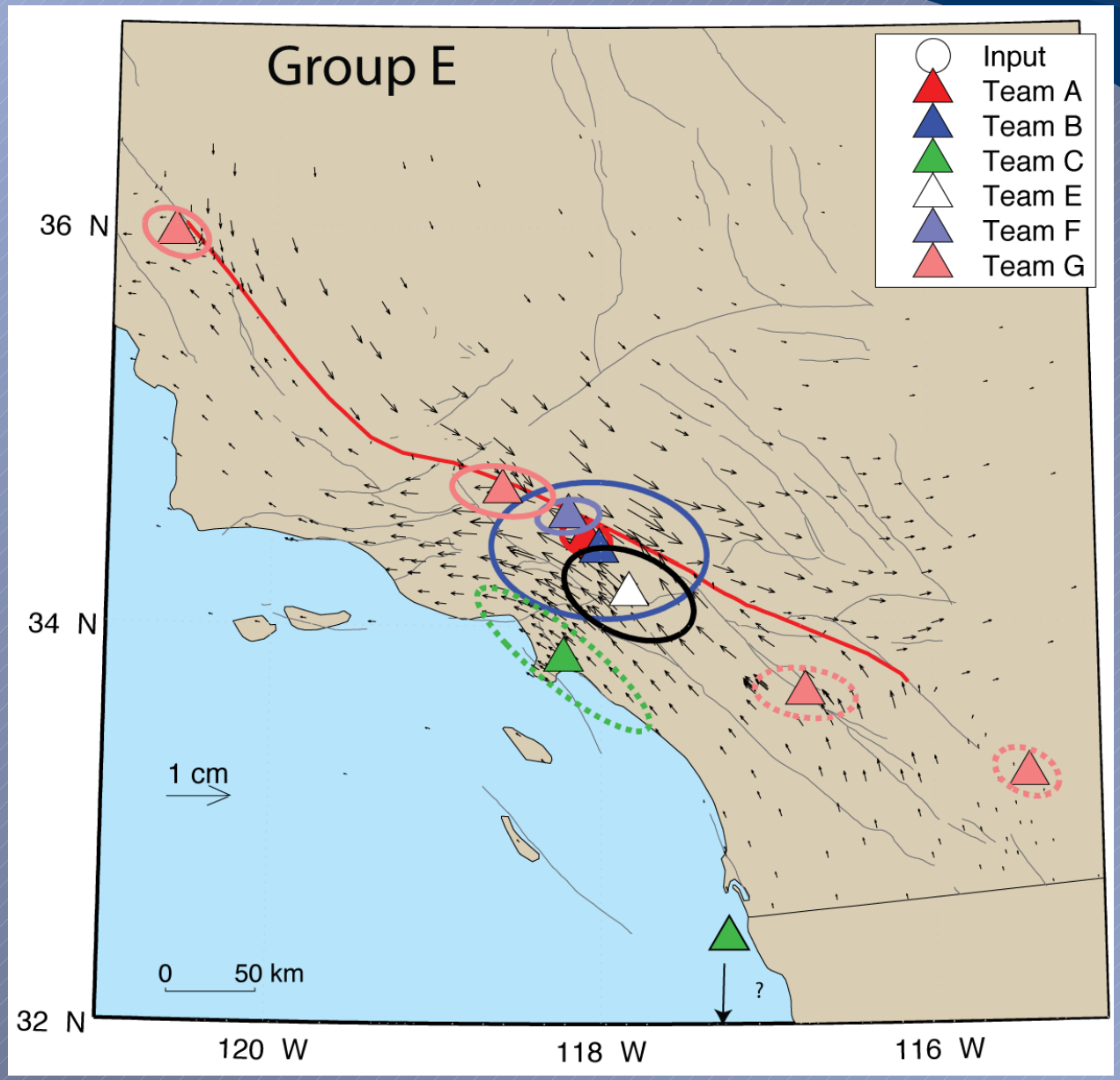
Average for A, C, D E, F, and G (2007 – 2009)

Finite Strain Magnitudes








Group E
Input
Team A
Team B
Team C
Team E
Team F
Team G
36 N
34 N
32 N
120 W
118 W
116 W
1 cm
0
50 km
?