New Madrid Geodesy

The Quest for Strain

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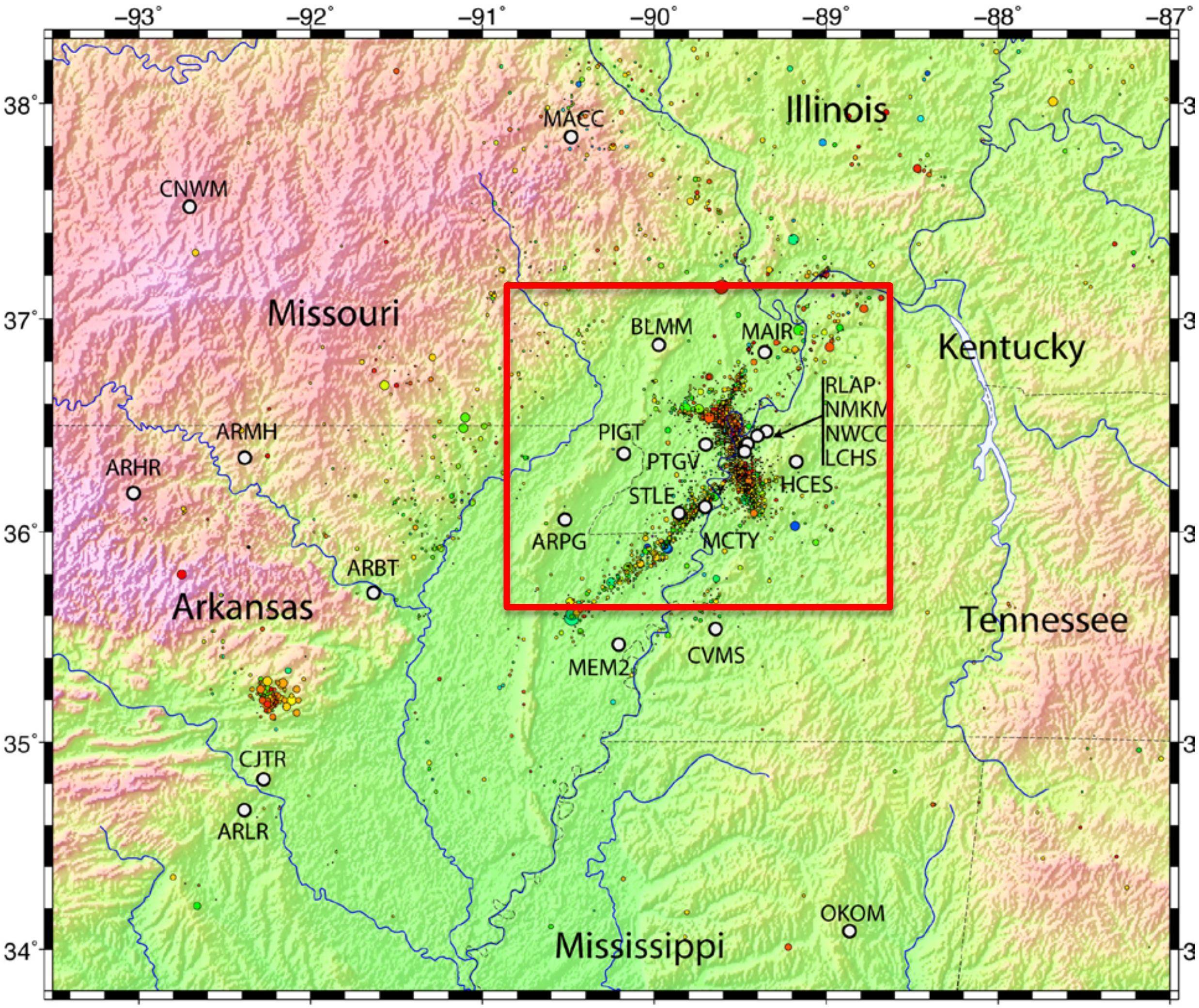
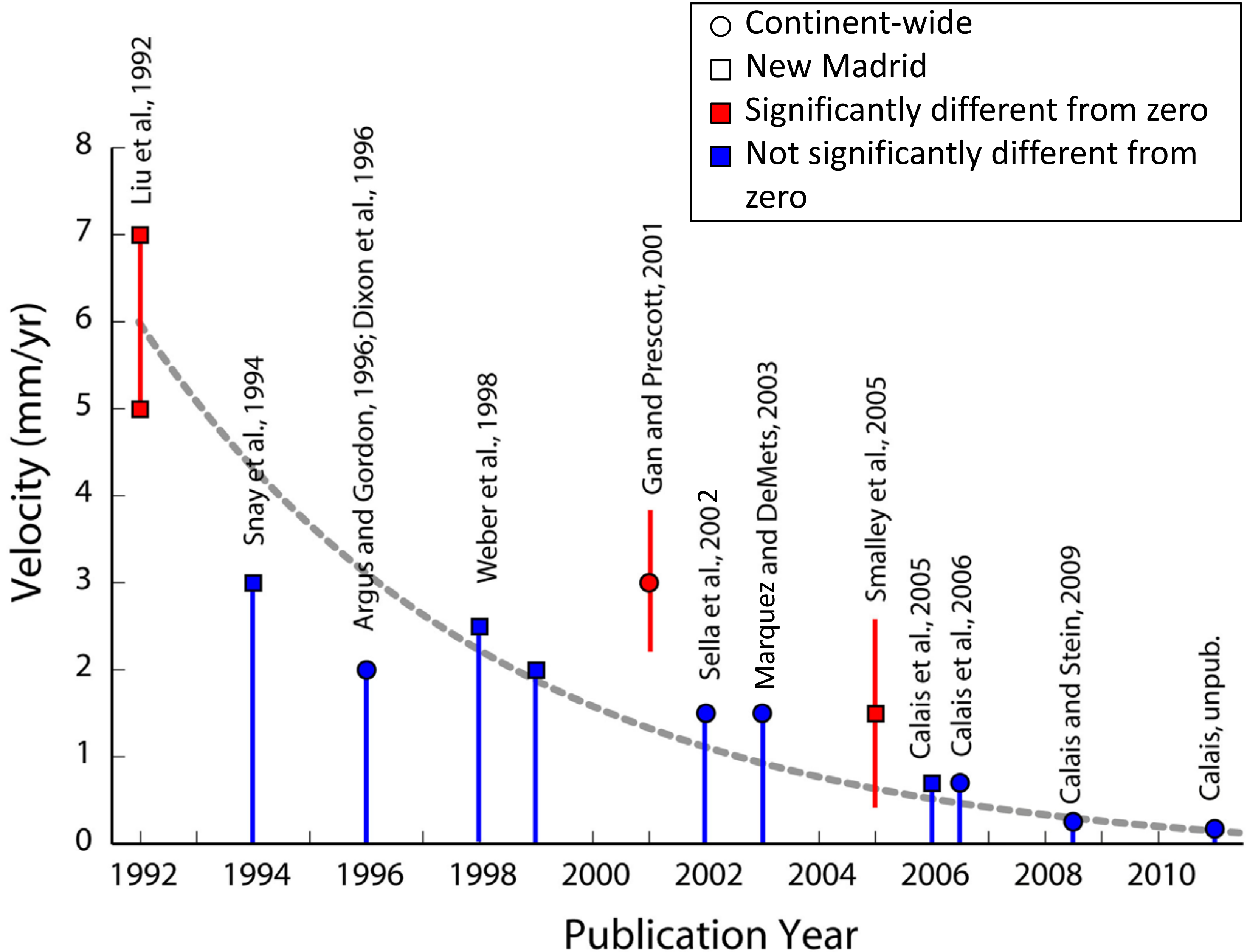


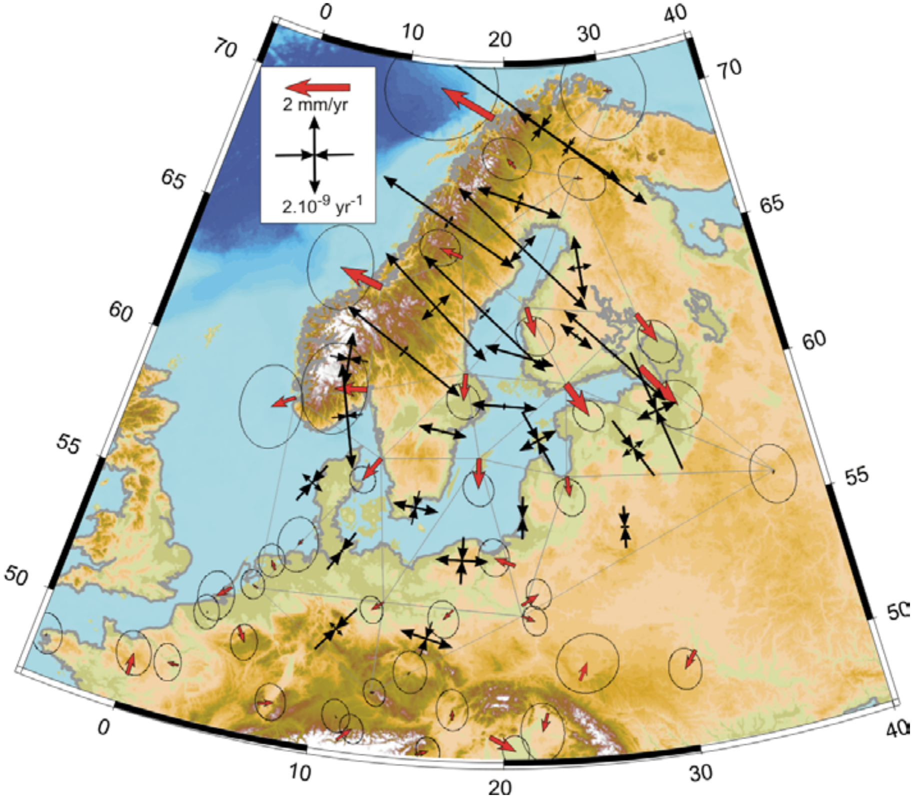
Only "active" intraplate system where a local continuous GPS network is available:

- GAMA network (CERI, Univ. Memphis): H-beam + deep-drilled braced
- CORS stations (states, surveyors, etc.): buildings, masts, pillars
- NOAA/FSL (BLMM, CNWN, OKOM): buildings, fence posts

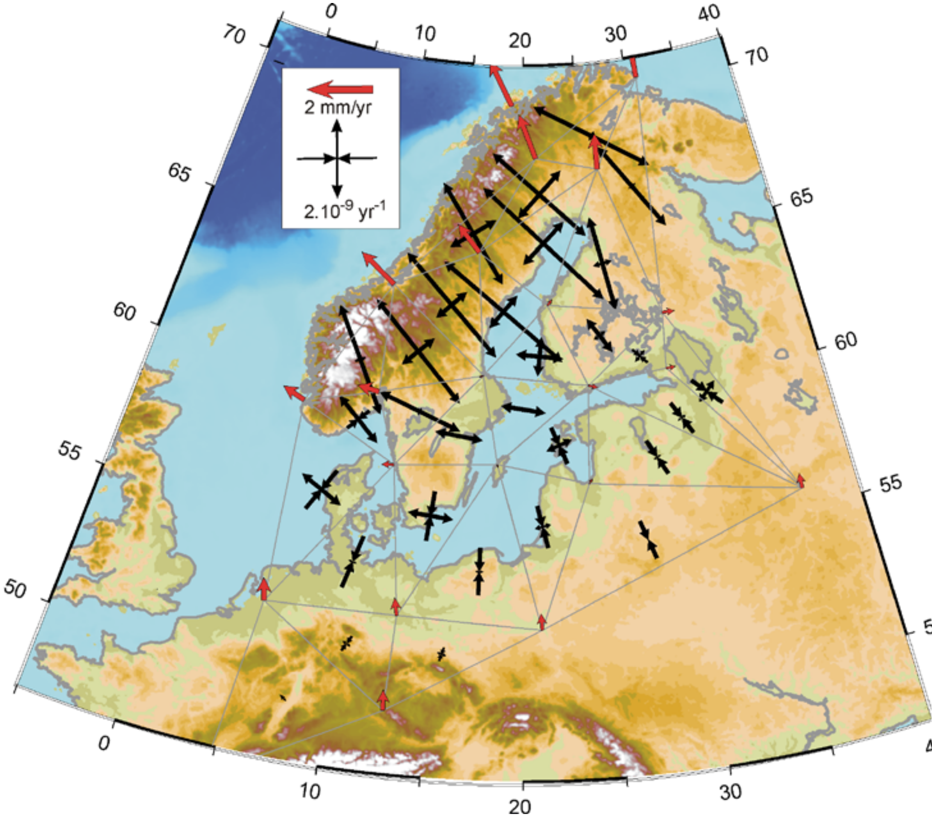


Continent-wide
New Madrid
Significantly different from zero
Not significantly different from zero
Velocity (mm/yr)
0
1
2
3
4
5
6
7
8
Liu et al., 1992
Snay et al., 1994
Argus and Gordon, 1996; Dixon et al., 1996
Weber et al., 1998
Gan and Prescott, 2001
Sella et al., 2002
Marquez and DeMets, 2003
Smalley et al., 2005
Calais et al., 2005
Calais et al., 2006
Calais and Stein, 2009
Calais, unpub.
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Publication Year

CGPS measurements
(Nocquet et al., 2005)



GIA model
(Milne et al., 2001)

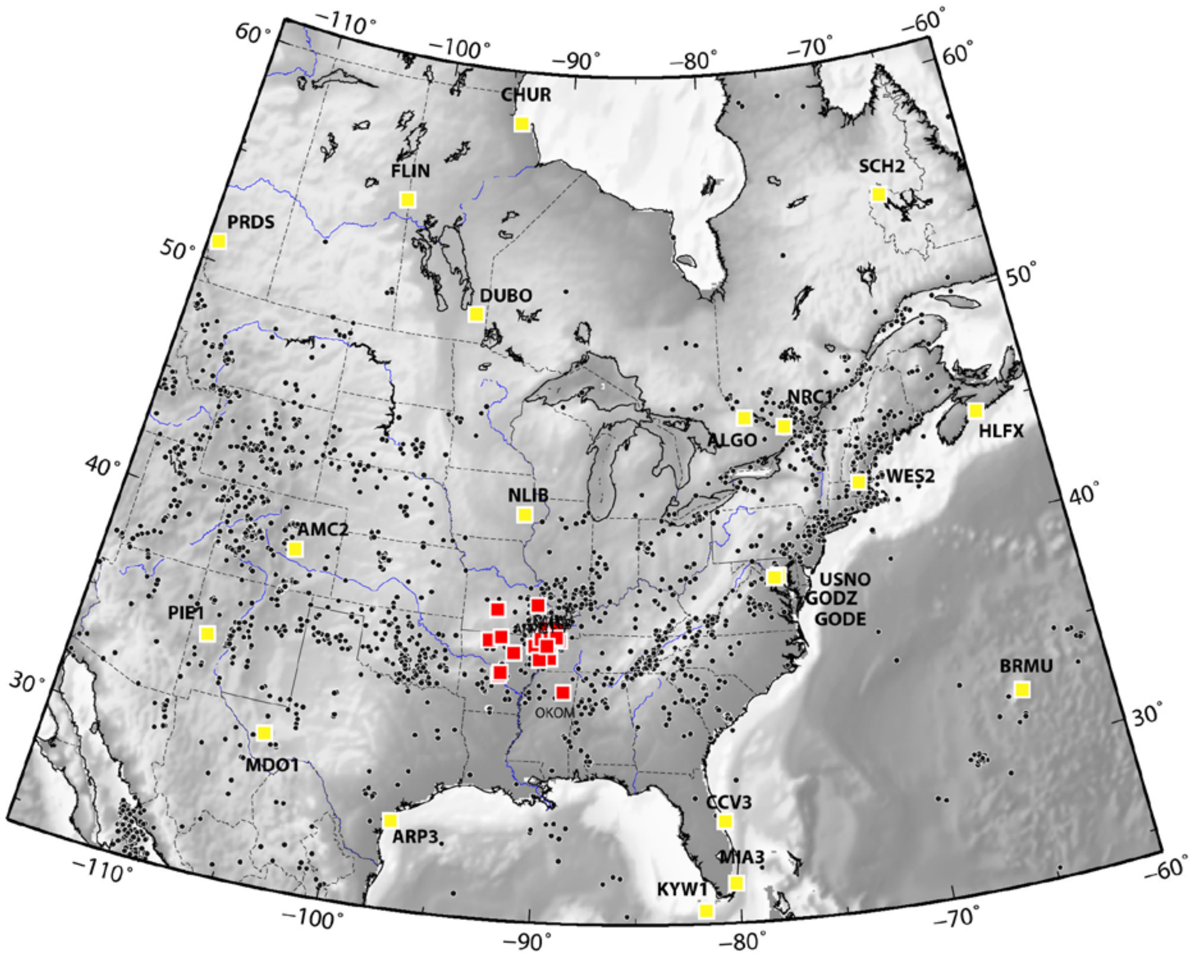


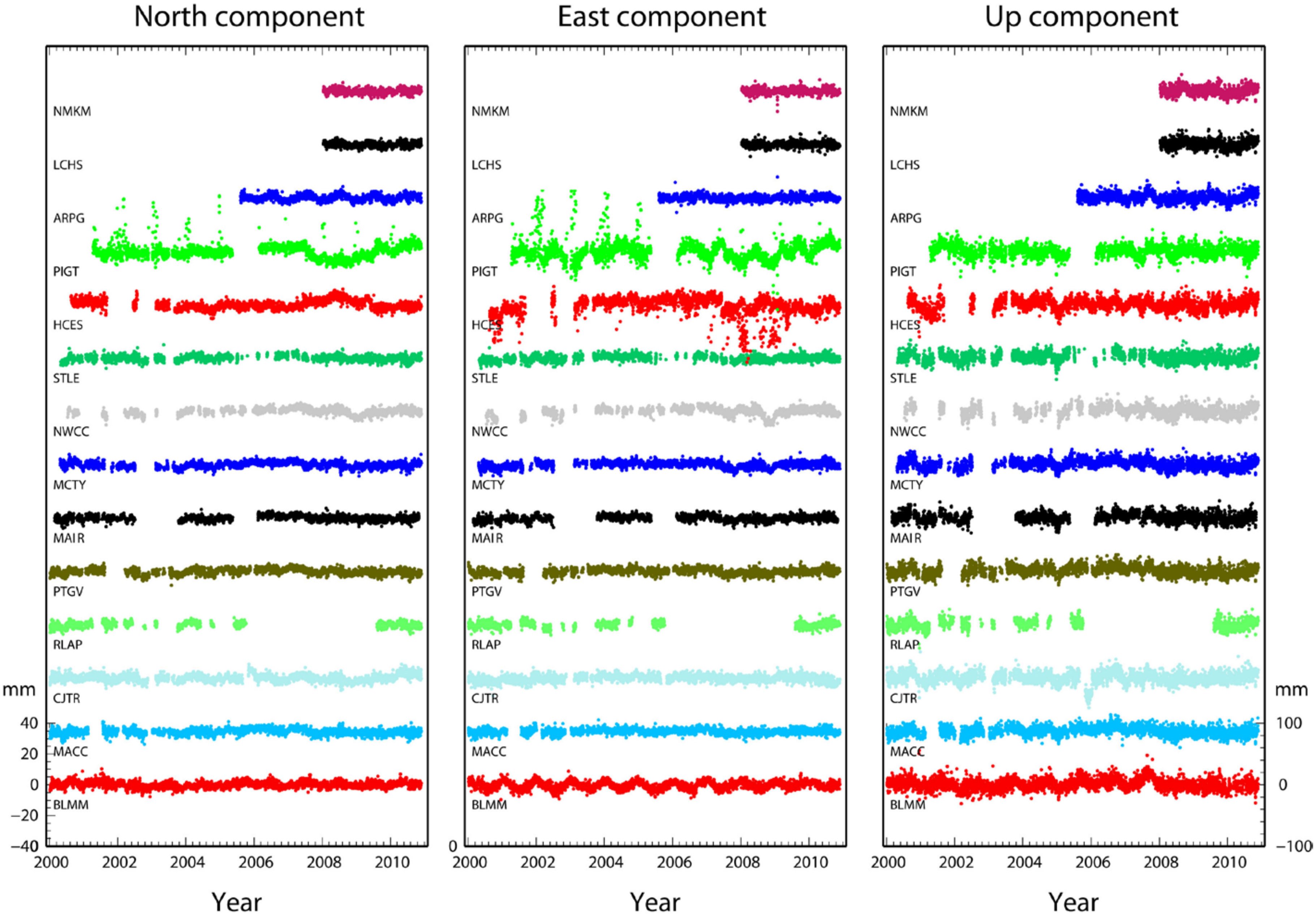
GPS detects with confidence:
Velocities ~1 mm/yr or less
Strain rates ~10^{-9} /yr

(Note that GPS velocities today are consistent with 10,000 year time scale process)

CGPS data processing "recipe":

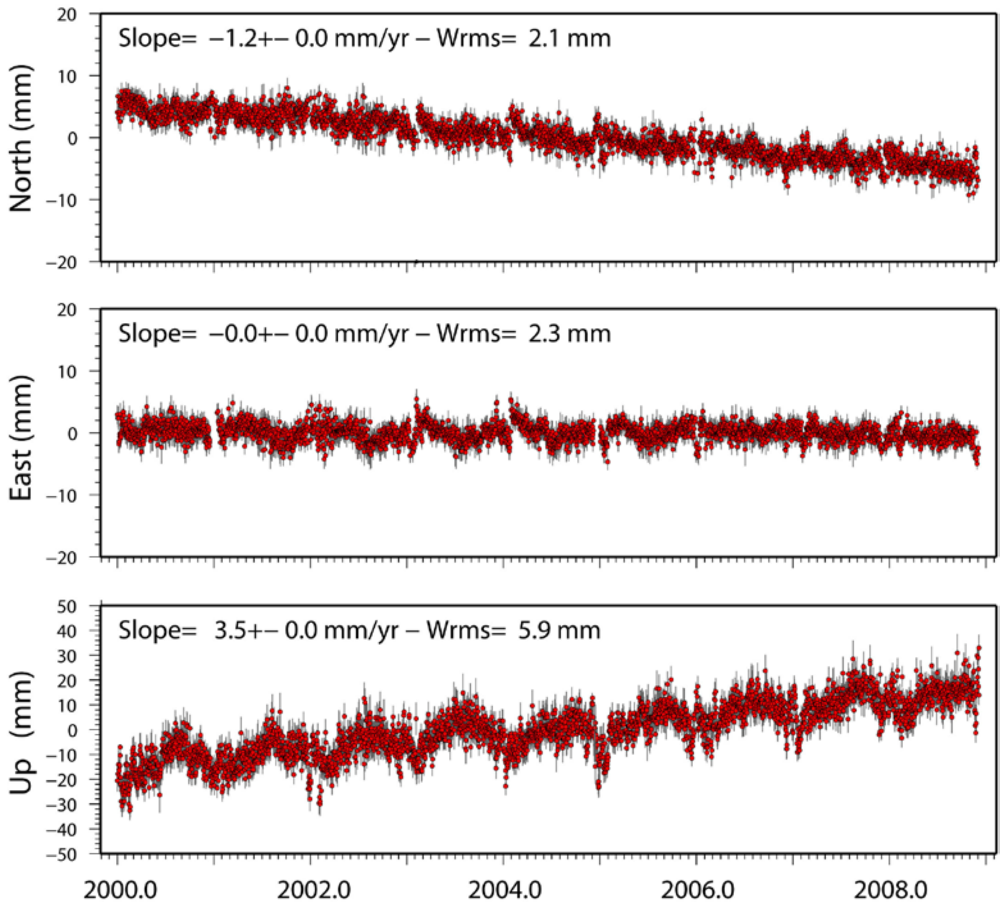
- Phase data processed with GAMIT (incl. absolute APC models, reprocessed IGS orbits, ITRF2008).
- Position time series, used for outliers/jumps detection and calculating WN+colored noise model ("realistic sigma" algorithm, T. Herring).
- Daily solutions combined into weekly position solutions.
- Weekly solutions combined with weekly IGS solutions from MIT into one cumulative position/velocity solution (loosely constrained).
- ITRF2008 reference frame implemented by minimizing position/velocity deviation from core group of globally-distributed IGS stations.
- NOAM-plate frame implemented by removing rigid plate rotation based on stable NOAM sites.





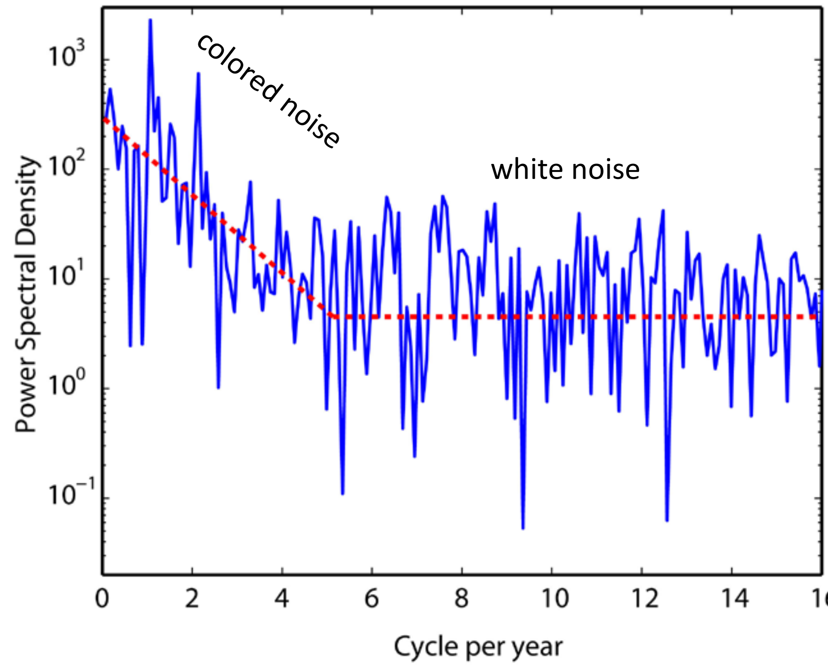
The “data”: **detrended** daily position time series

The good (many), the bad (RLAP, NWCC) and the ugly (HCES, PIGT)



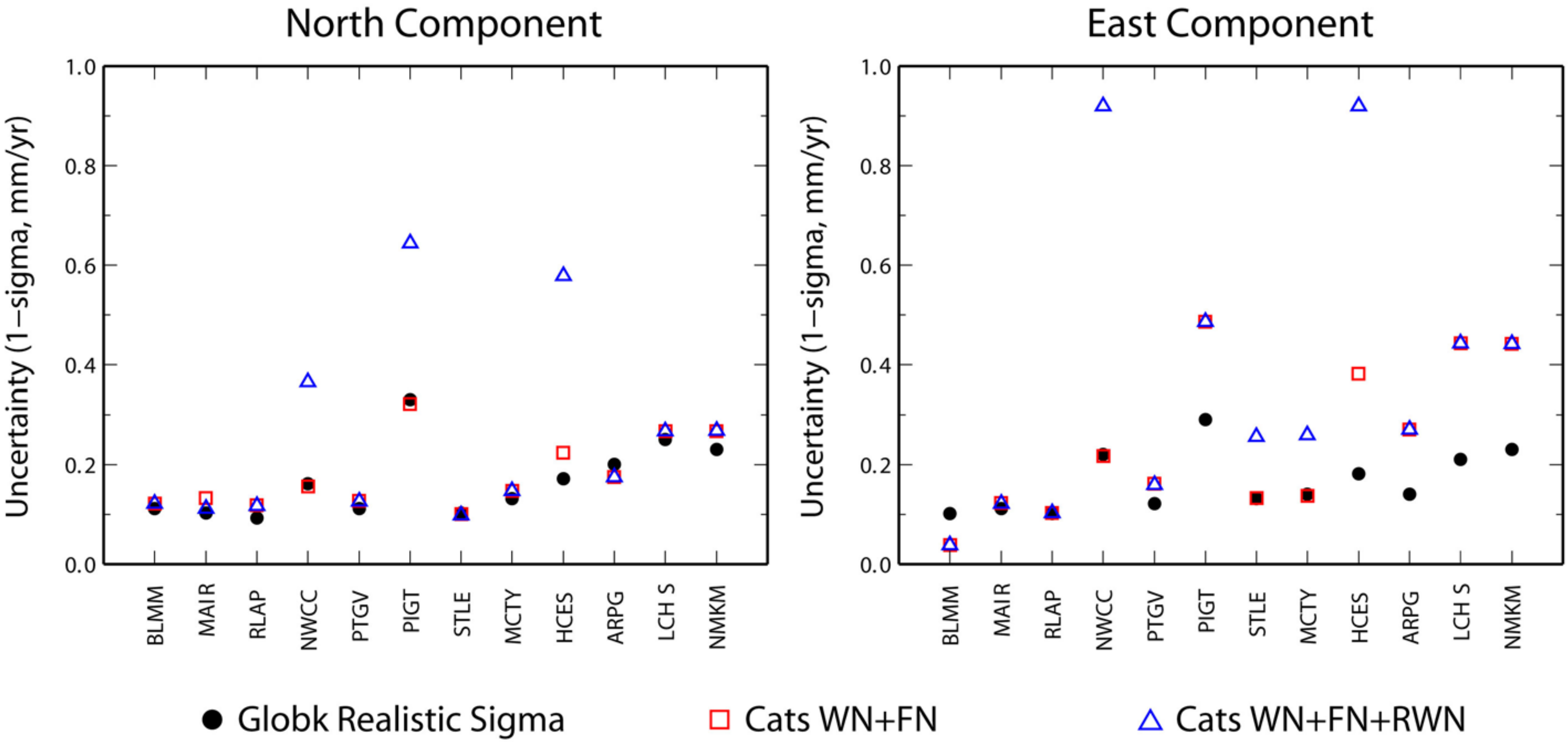
Time series of daily GPS positions, Algonquin (ALGO). Note:

- Wrms scatter: 2 mm horizontal
- S-ward + up motion = GIA
- Seasonal on vertical snow loading
- Formal velocity uncertainties = 0.0 mm/yr?

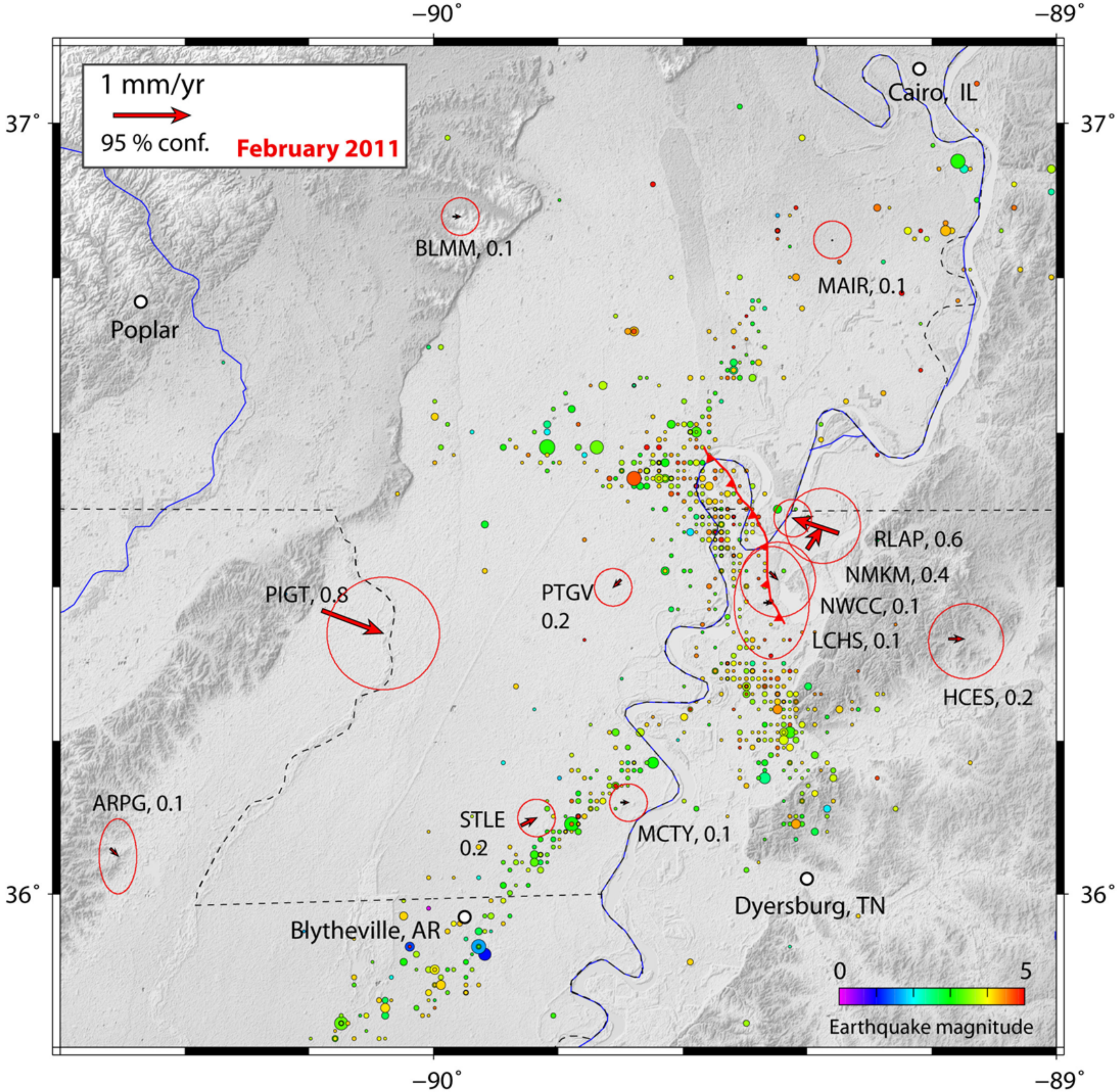


Spectral analysis of GPS time series:

- White + colored noise: origin unclear but process can be accounted for in precision estimates
- Amplitude is site dependent
- Realistic uncertainty estimates must account for colored noise
- Uncertainties x 4 to 10 compared to WN only

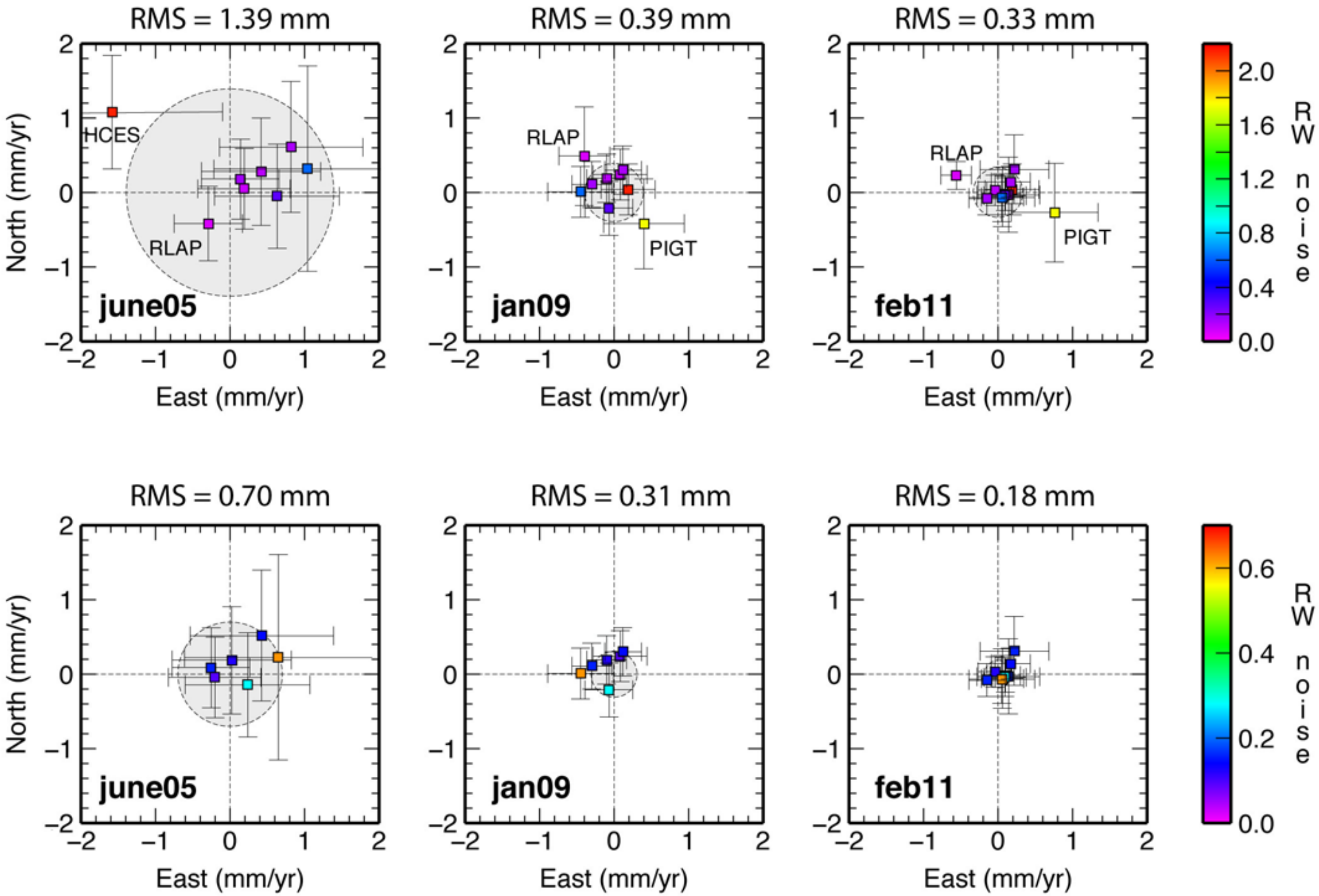


- CATS (Williams, 2008) : at most sites, WN+FN fits data equally well as WN+FN+RW.
- GLOBK RS algorithm: average positions over increasing time periods => WRMS decreases => find noise characteristics for infinite frequency = velocity uncertainty
- CATS uncertainty estimates generally consistent with GLOBK RS algorithm.
- If anything, RS slightly underestimates uncertainties => conclusions of this talk optimistic?

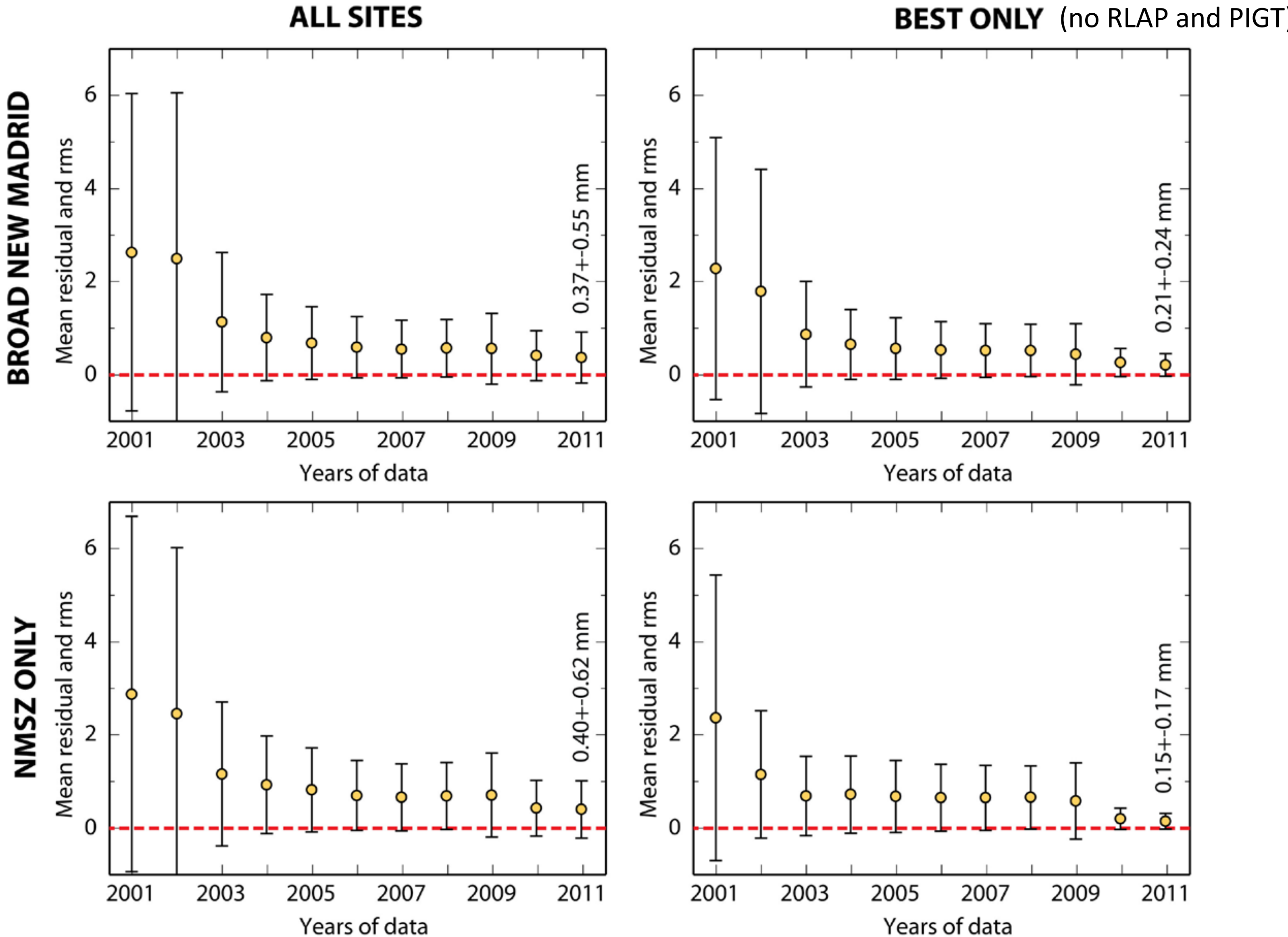


−90°
−89°
37°
36°
1 mm/yr
95 % conf.
February 2011
Cairo, IL
Poplar
BLMM, 0.1
MAIR, 0.1
RLAP, 0.6
NMKM, 0.4
NWCC, 0.1
LCHS, 0.1
PIGT, 0.8
PTGV
0.2
HCES, 0.2
ARPG, 0.1
STLE
0.2
MCTY, 0.1
Dyersburg, TN
Blytheville, AR
0
5
Earthquake magnitude

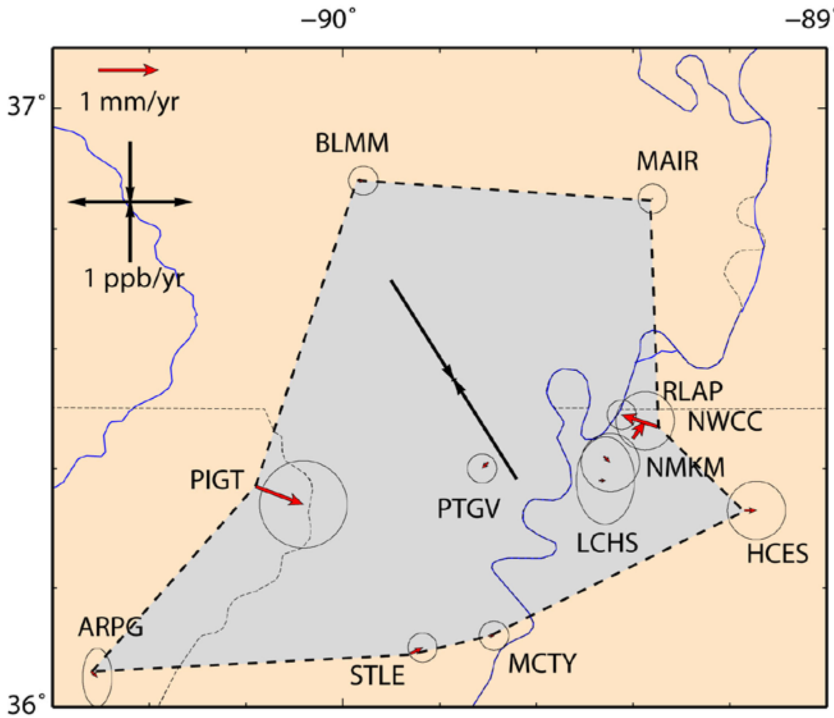
NMSZ only



- Velocity uncertainties have decreased by at least a factor of ~2 at all sites
- Residual velocities have decreased by a factor of ~3
- PIGT and RLAP are consistent outliers:
  - PIGT = high colored noise
  - RLAP = large gaps in time series

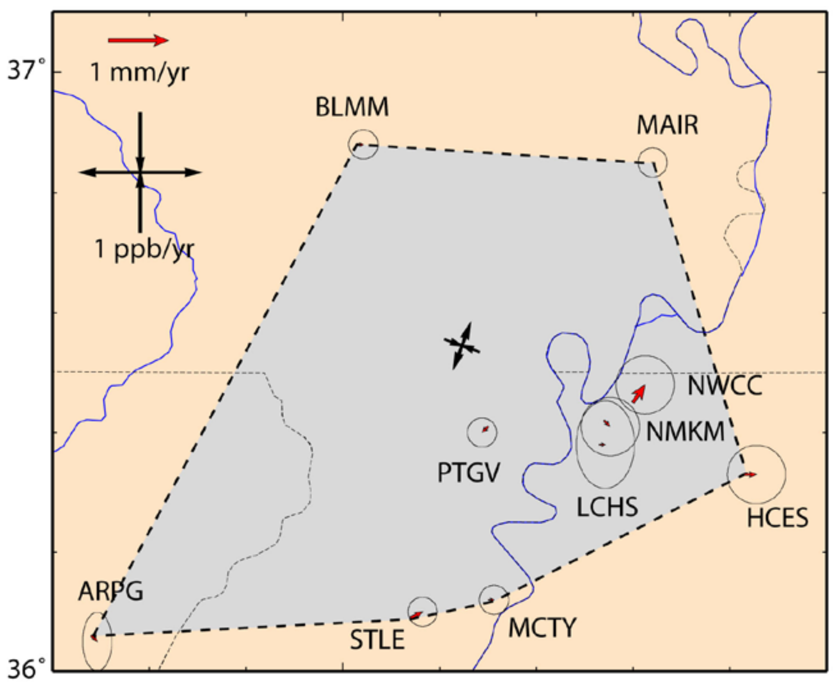


- Residuals decrease with time
- RMS decreases with time, keeps including zero

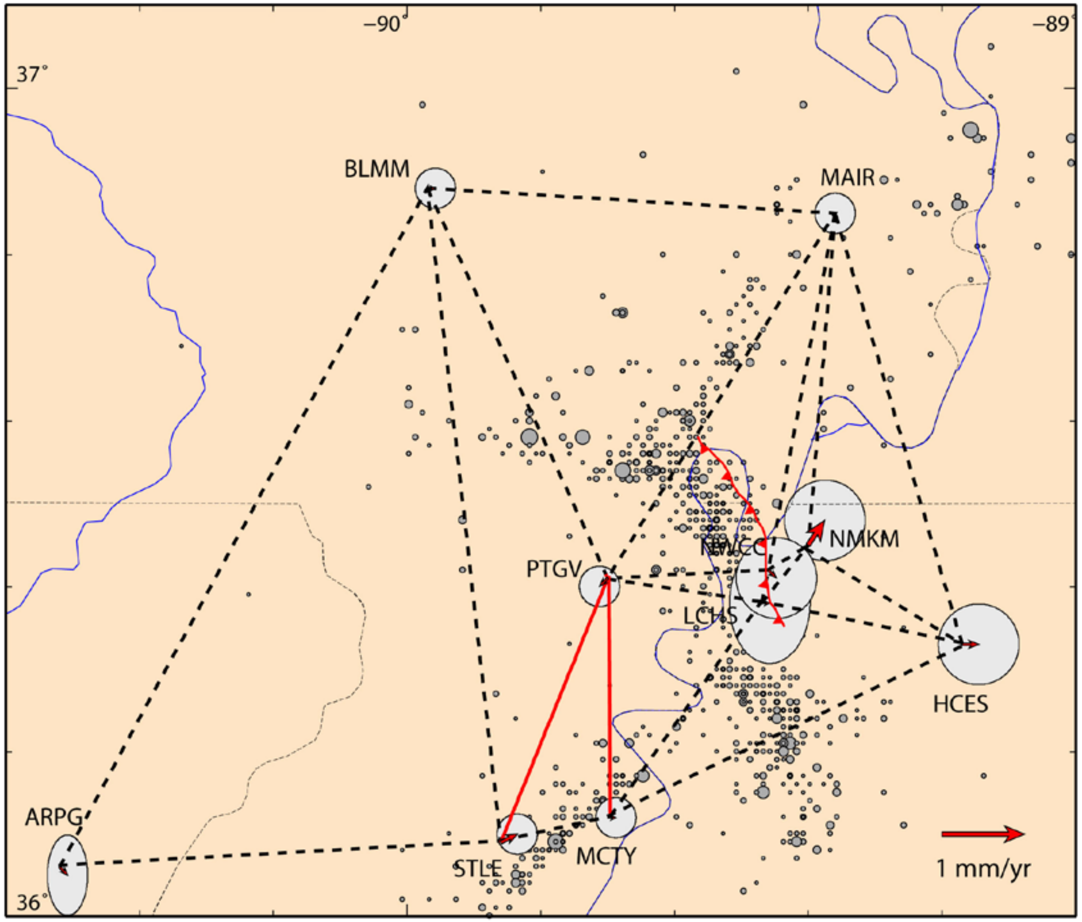


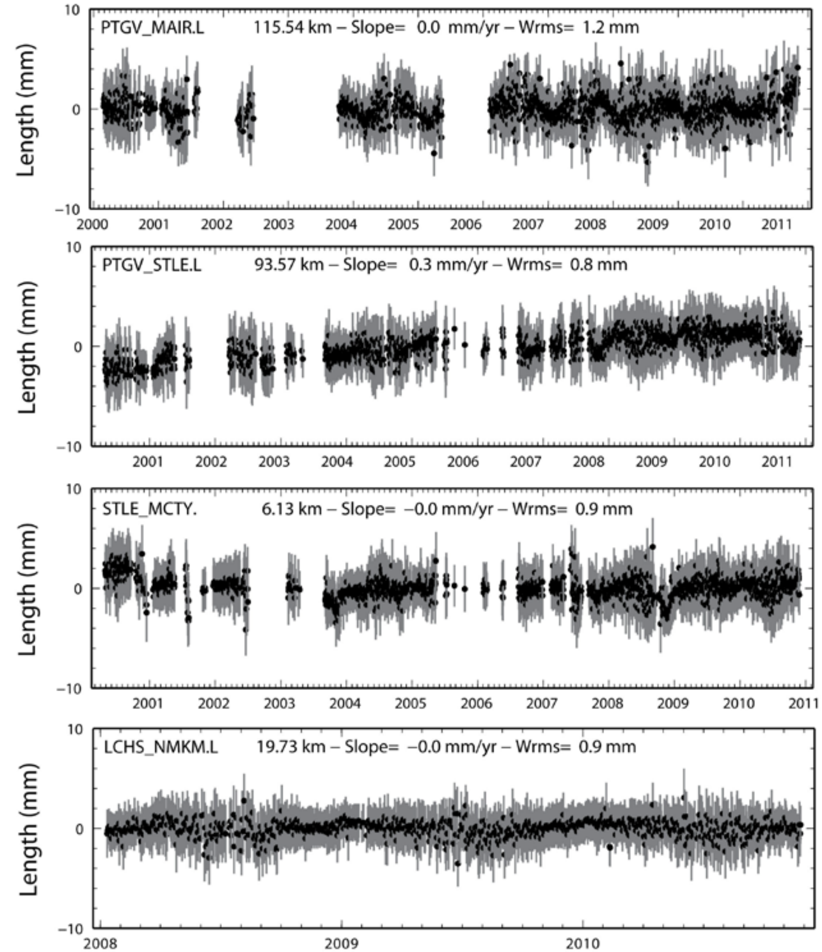
2011 estimates, configuration 1
Strain rate tensor:
epsxx = -1.40 +- 1.01 ppb/yr
epsxy = 0.90 +- 1.10 ppb/yr
epsyy = -0.54 +- 2.47 ppb/yr
Second invariant:
snd = 0.89 +- 0.15 ppb/yr
Principal strains:
eps1 = 0.03 +- 0.78 ppb/yr
eps2 = -1.97 +- 0.78 ppb/yr
azimuth = -57.78(eps1, CW from north)

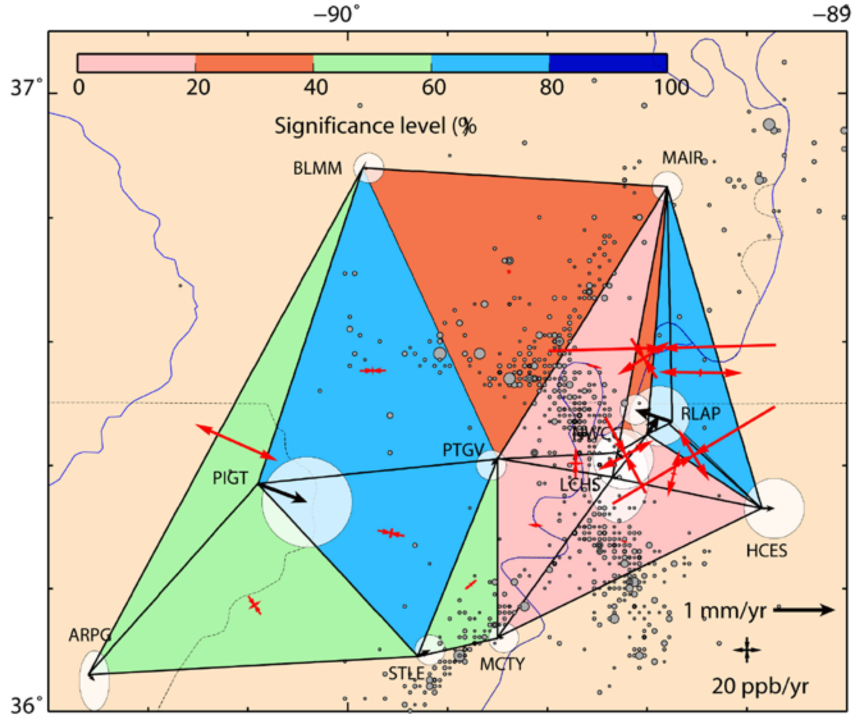
2008 estimates:
Strain rate tensor:
epsxx = -4.55 +- 5.39 ppb/yr
epsxy = 0.88 +- 3.64 ppb/yr
epsyy = 4.12 +- 4.40 ppb/yr
Second invariant:
snd = 0.30 +- 1.30 ppb/yr
Principal strains:
eps1 = 4.20 +- 5.34 ppb/yr
eps2 = -4.64 +- 5.34 ppb/yr



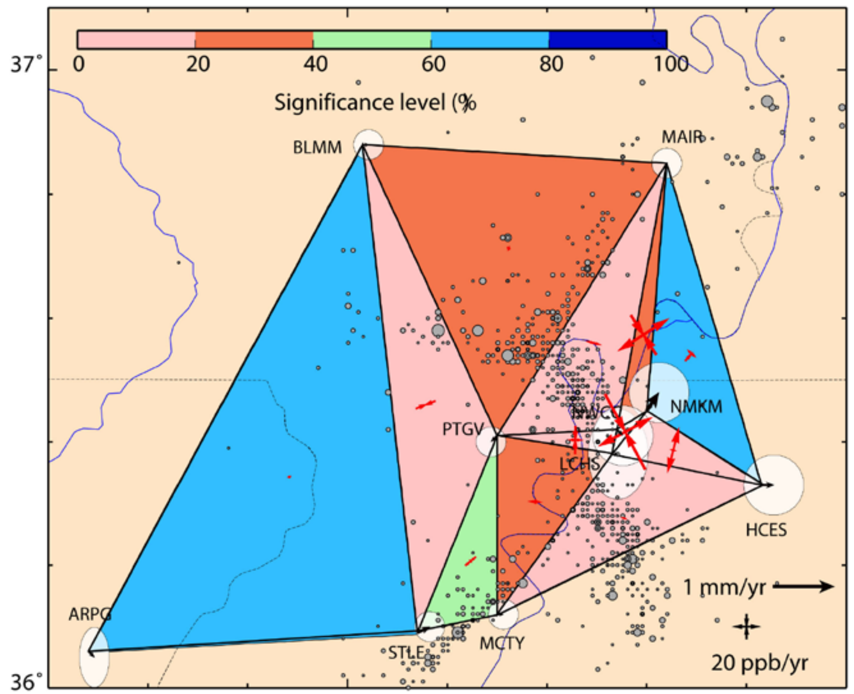
2011 estimates, configuration 2
Strain rate tensor:
epsxx = 0.31 +- 1.07 ppb/yr
epsxy = 0.22 +- 1.13 ppb/yr
epsyy = -0.22 +- 2.50 ppb/yr
Second invariant:
snd = 0.09 +- 0.64 ppb/yr
Principal strains:
eps1 = 0.39 +- 0.95 ppb/yr
eps2 = -0.30 +- 0.95 ppb/yr
azimuth = -20.24(eps1, CW from north)


–90°
–89°
37°
36°
BLMM
MAIR
PTGV
NMKM
LCHS
HCES
ARPG
STLE
MCTY
1 mm/yr


PTGV_MAIR.L 115.54 km – Slope= 0.0 mm/yr – Wrms= 1.2 mm
PTGV_STLE.L 93.57 km – Slope= 0.3 mm/yr – Wrms= 0.8 mm
STLE_MCTY. 6.13 km – Slope= –0.0 mm/yr – Wrms= 0.9 mm
LCHS_NMKM.L 19.73 km – Slope= –0.0 mm/yr – Wrms= 0.9 mm
Length (mm)



	EPS1 (ppb/yr)	EPS2 (ppb/yr)
MAIR NWCC PTGV	10.0 +- 23.6	1.6 +- 8.0
ARPG PIGT STLE	8.5 +- 11.1	-17.2 +- 16.5
MAIR NMKM NWCC	46.8 +- 88.7	-37.7 +- 75.4
BLMM MAIR PTGV	2.6 +- 4.9	-2.3 +- 5.2
HCES LCHS MCTY	3.6 +- 23.1	-0.4 +- 26.2
HCES LCHS NMKM	35.0 +- 72.3	3.5 +- 20.0
HCES MAIR RLAP	64.4 +- 30.9	-5.1 +- 7.3
ARPG BLMM PIGT	**70.0 +- 59.0**	0.4 +- 5.6
LCHS NMKM NWCC	47.1 +- 100.1	-68.7 +- 250.5
LCHS MCTY PTGV	8.8 +- 21.4	-3.2 +- 8.6
BLMM PIGT PTGV	3.9 +- 7.1	**-20.4 +- 14.3**
LCHS NWCC PTGV	9.4 +- 17.1	-22.7 +- 161.9
HCES NMKM RLAP	**45.6 +- 35.7**	**-153.2 +- 91.8**
MAIR NMKM RLAP	-5.0 +- 6.9	**-184.0 +- 99.9**
MCTY PTGV STLE	2.0 +- 17.9	-10.6 +- 13.6
PIGT PTGV STLE	-7.3 +- 7.9	**-21.4 +- 15.8**



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LCHS NWCC PTGV	9.4 +- 17.1	-22.7 +- 161.9
ARPG BLMM STLE	2.2 +- 4.7	-1.3 +- 4.1
BLMM PTGV STLE	0.2 +- 4.4	**-16.5 +- 13.2**

EPS1: most extensional eigenvalue of strain rate tensor
EPS2: most compressional eigenvalue of strain rate tensor
Extension positive

Concluding remarks

Main results:

- The longer we measure, the lower residual velocities and strain rates become.
- Current status: ~0 +- 0.2 mm/yr, < 1 ppb/yr
- Are RLAP and PIGT showing reliable tectonic signals?
- Surface strain too small to sustain M7 every 500 years – if one assumes plate boundary, steady-state model.

Some open questions:

- Does zero strain rate mean zero hazard?
- If there is strain (rate), where is it?
  - Under the NMSZ, decoupled from surface?
  - Spread out and currently undetectable?
- We can only measure current strain **rates** – what if the NMSZ (or midcontinent) had been loaded long ago?