Space Geodesy in the intraplate New Madrid Seismic Zone and Central US

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and the
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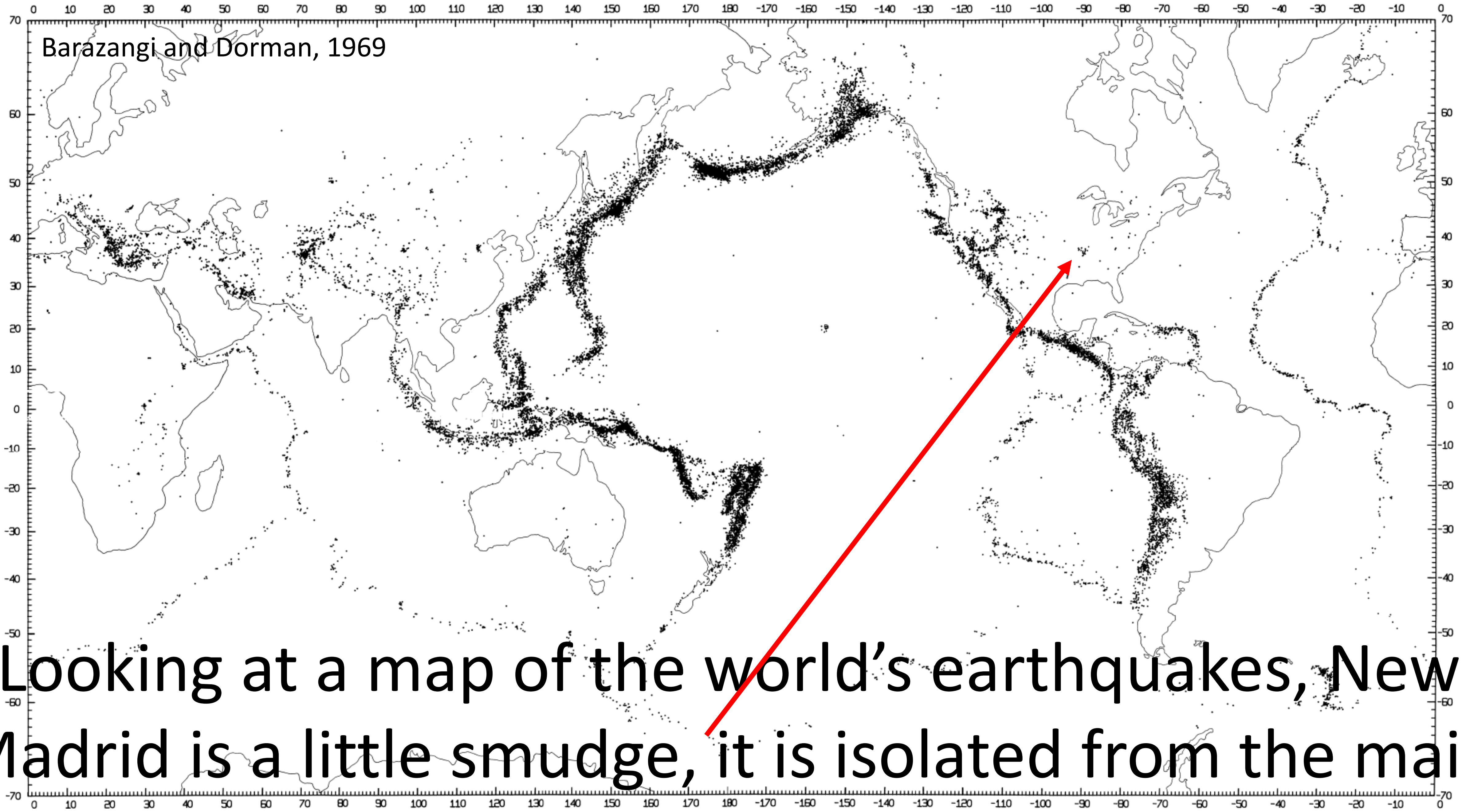
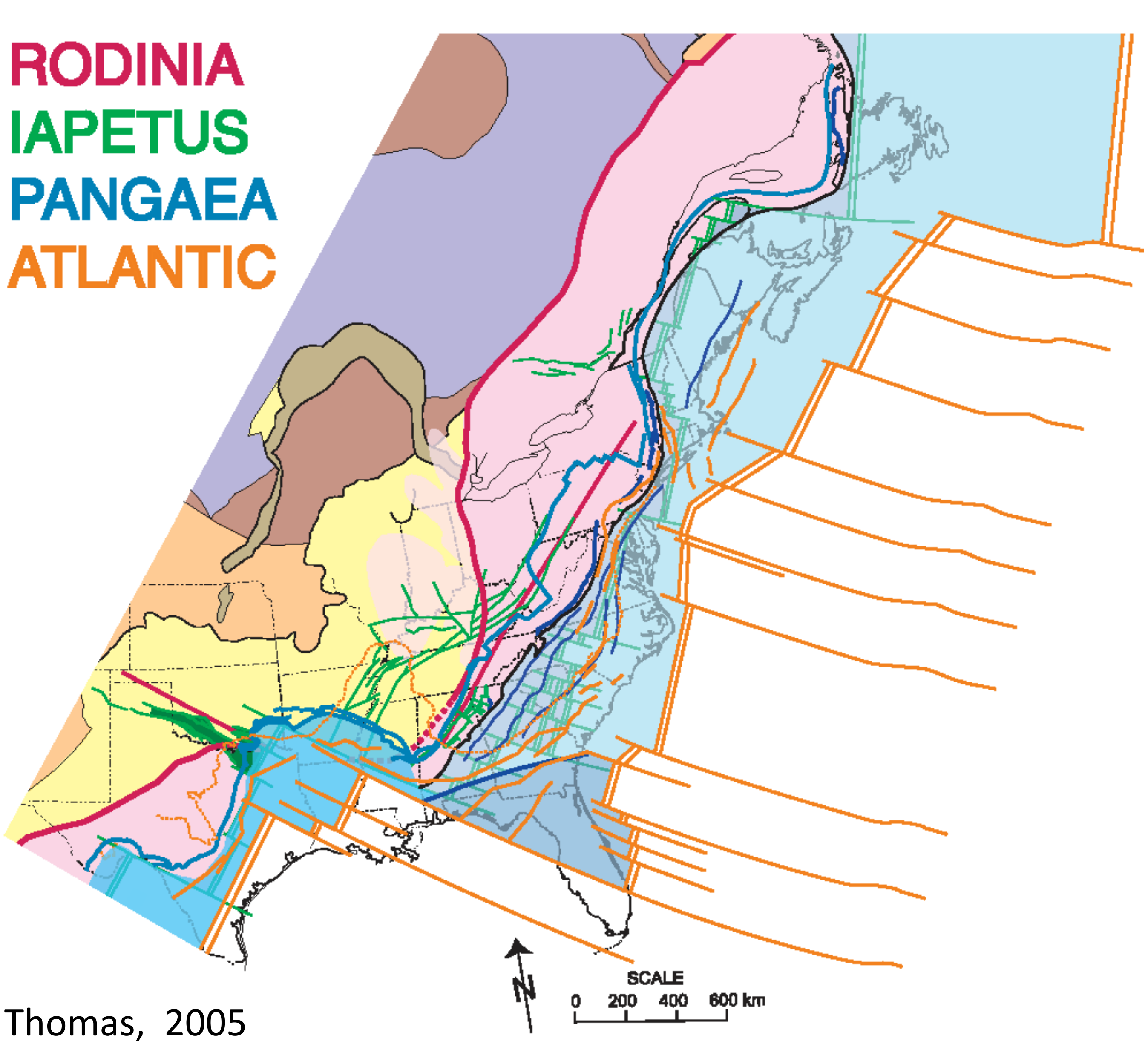
Robert Smalley, Jr.

Center for Earthquake Research & Information (CERI), The University of Memphis

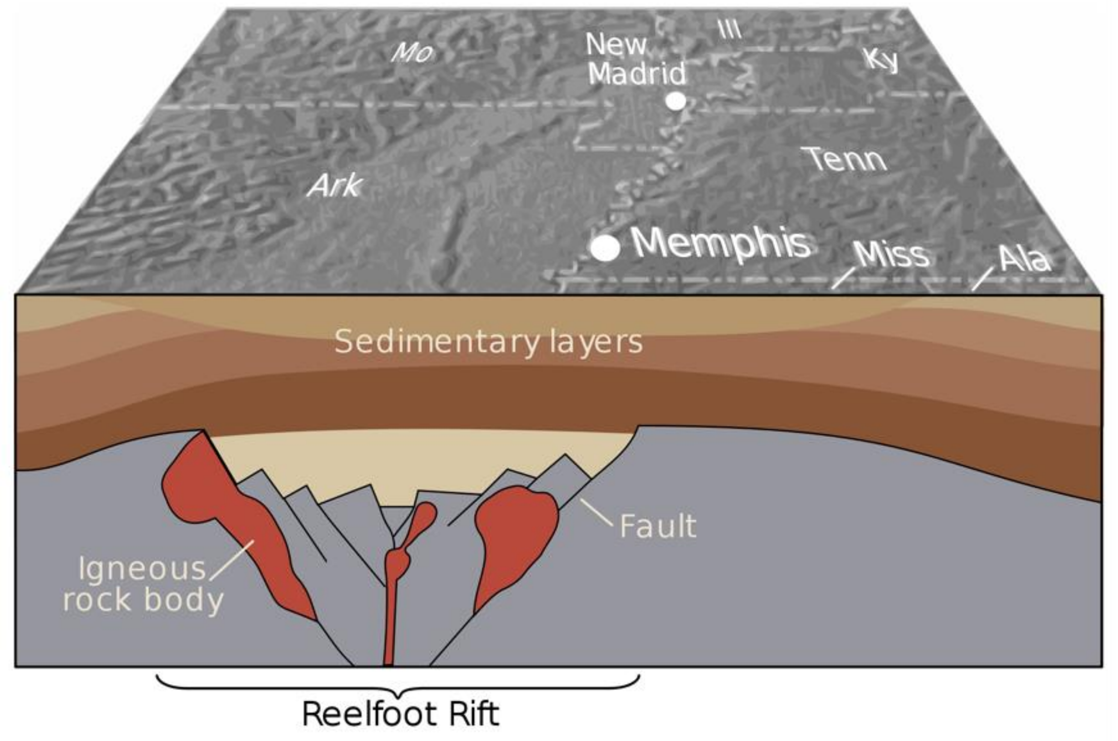


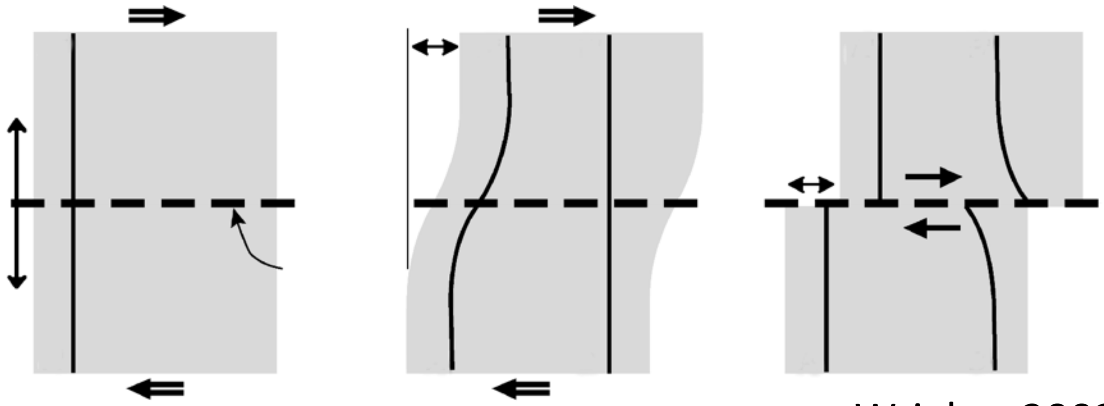
Looking at a map of the world's earthquakes, New Madrid is a little smudge, it is isolated from the main belts of activity.

So, why do we have earthquakes in New Madrid?



Thomas, 2005

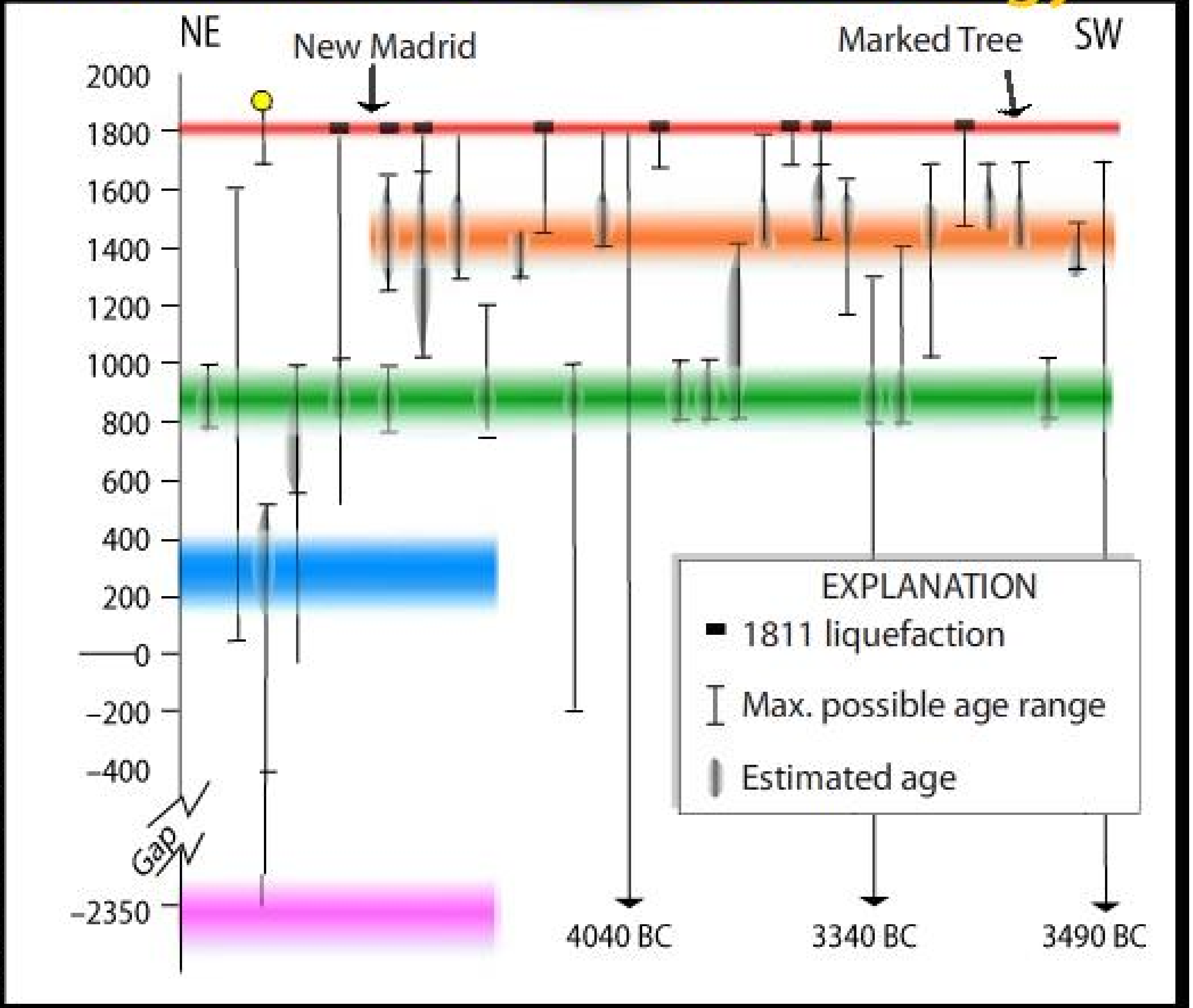




Wright, 2002

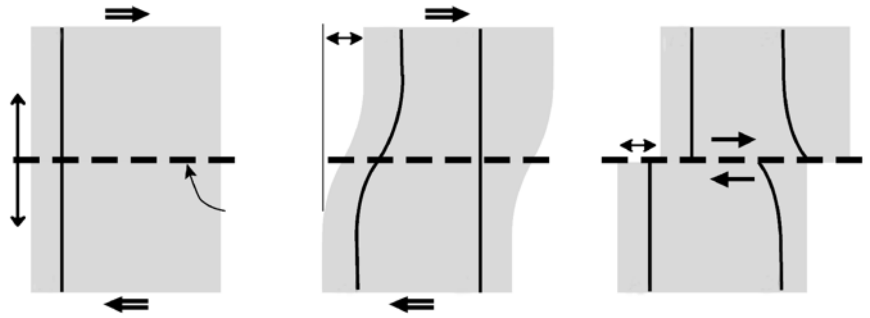
New Madrid Paleoseismology

Graph from M.P. Tuttle (http://mptuttle.com/newmadrid5.html)



There is evidence for earthquake "cycle" behavior at the few thousand-year time scale.

Is there an elastic rebound deformation cycle happening there?

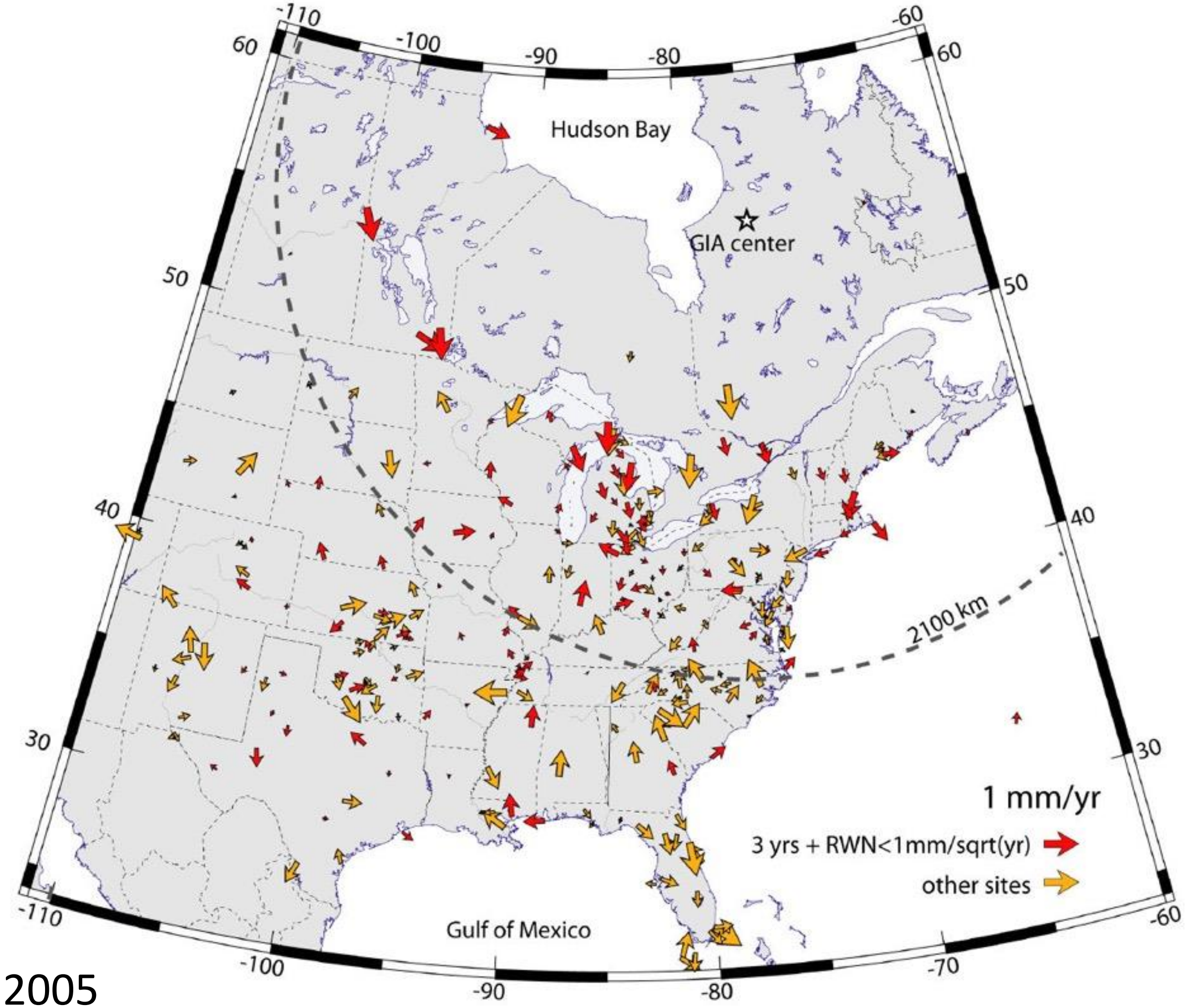


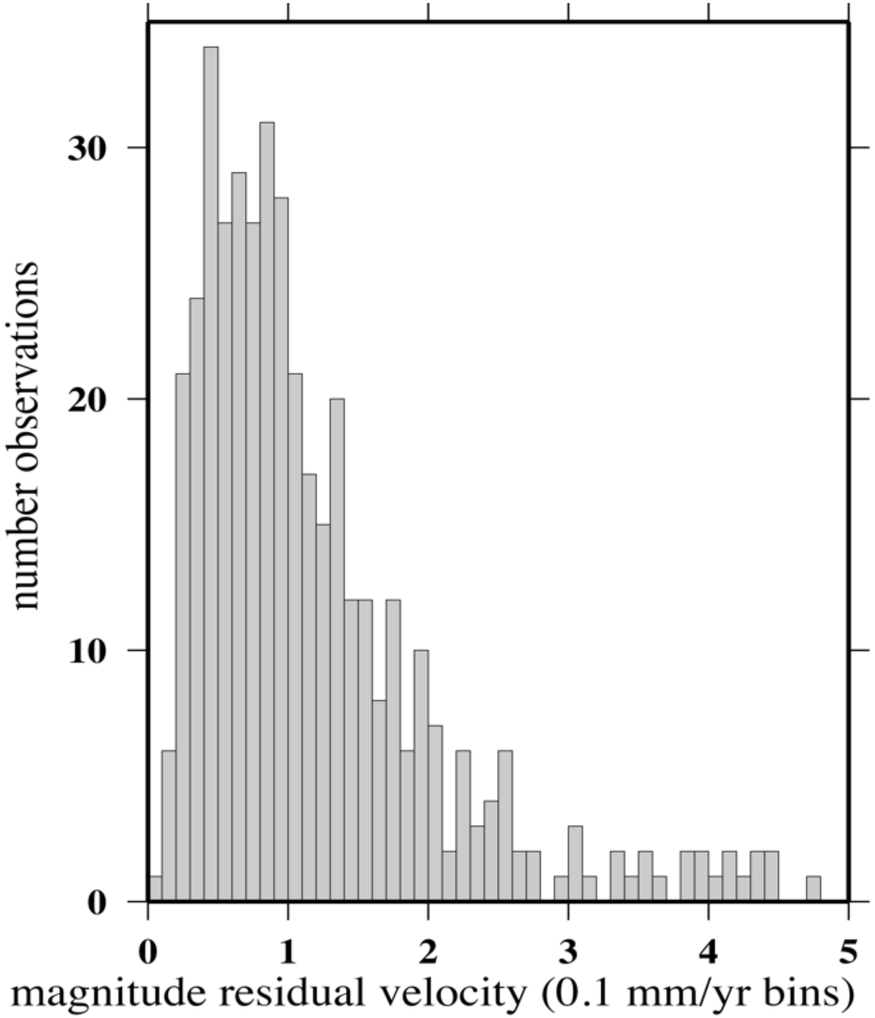
Wright, 2002

Is the New Madrid seismic zone deforming with respect to the plate tectonic stable N. America plate?

How can one tell?

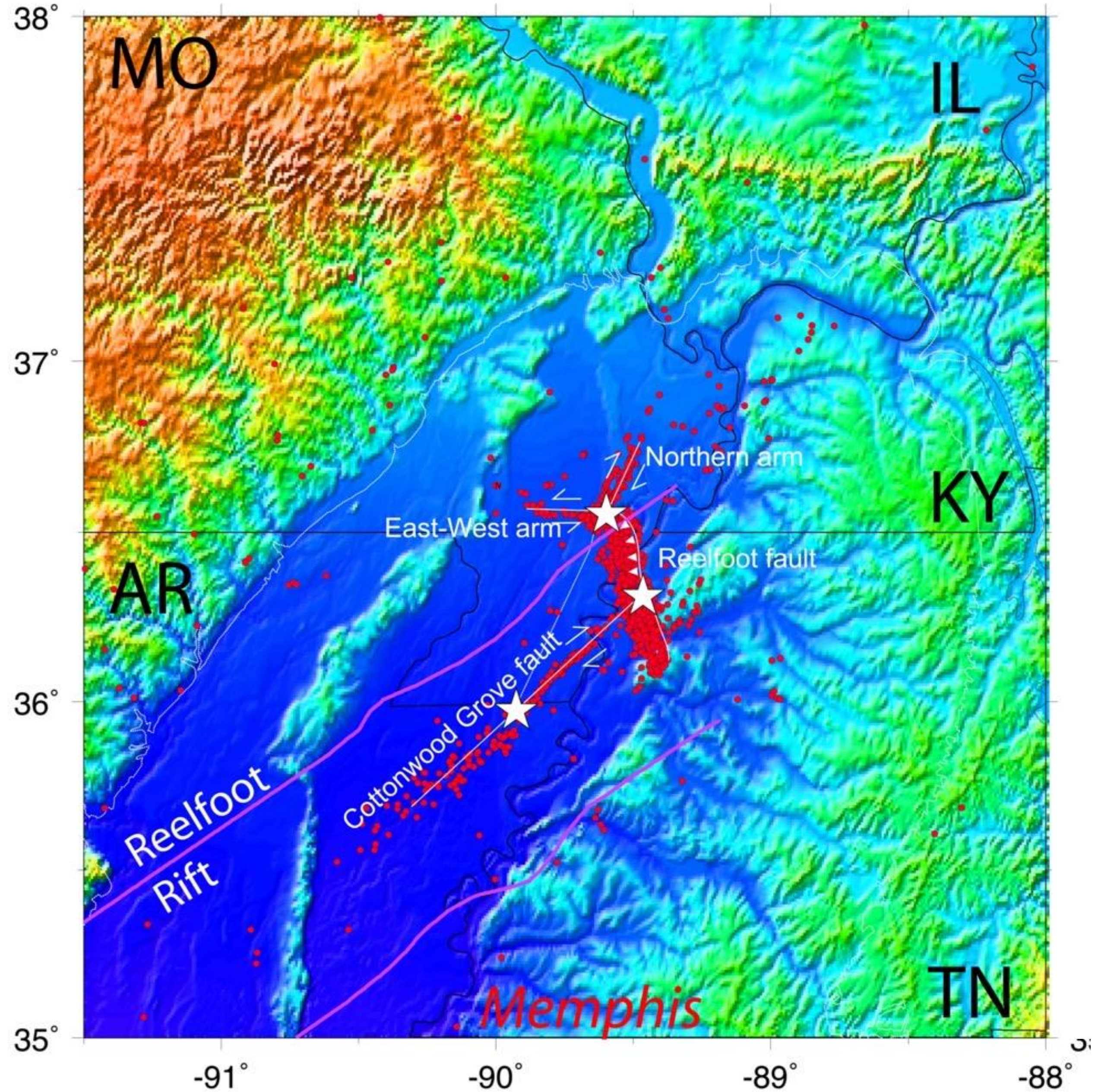
In N. America we have an additional consideration due to GIA.

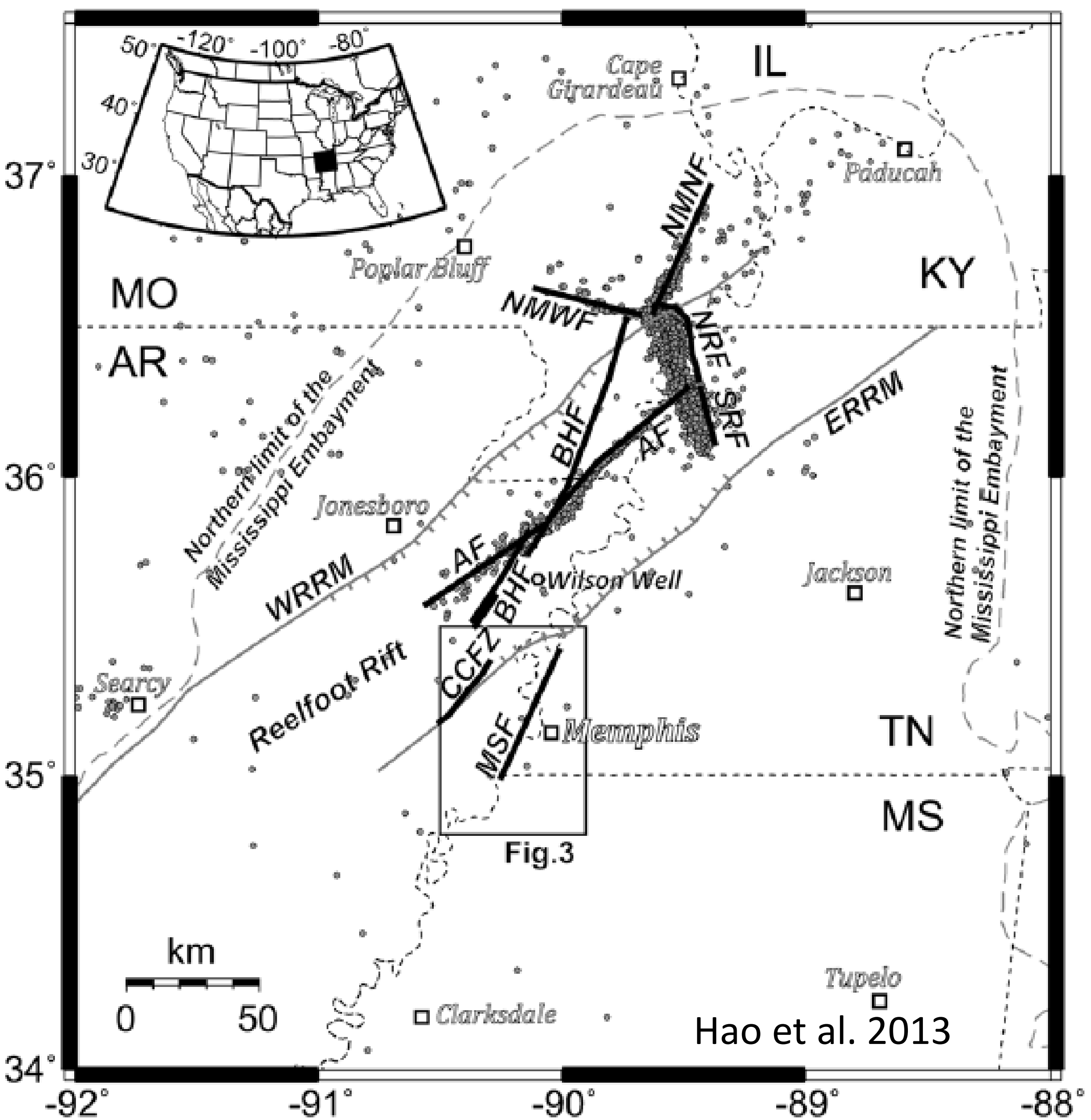




Calais, 2005

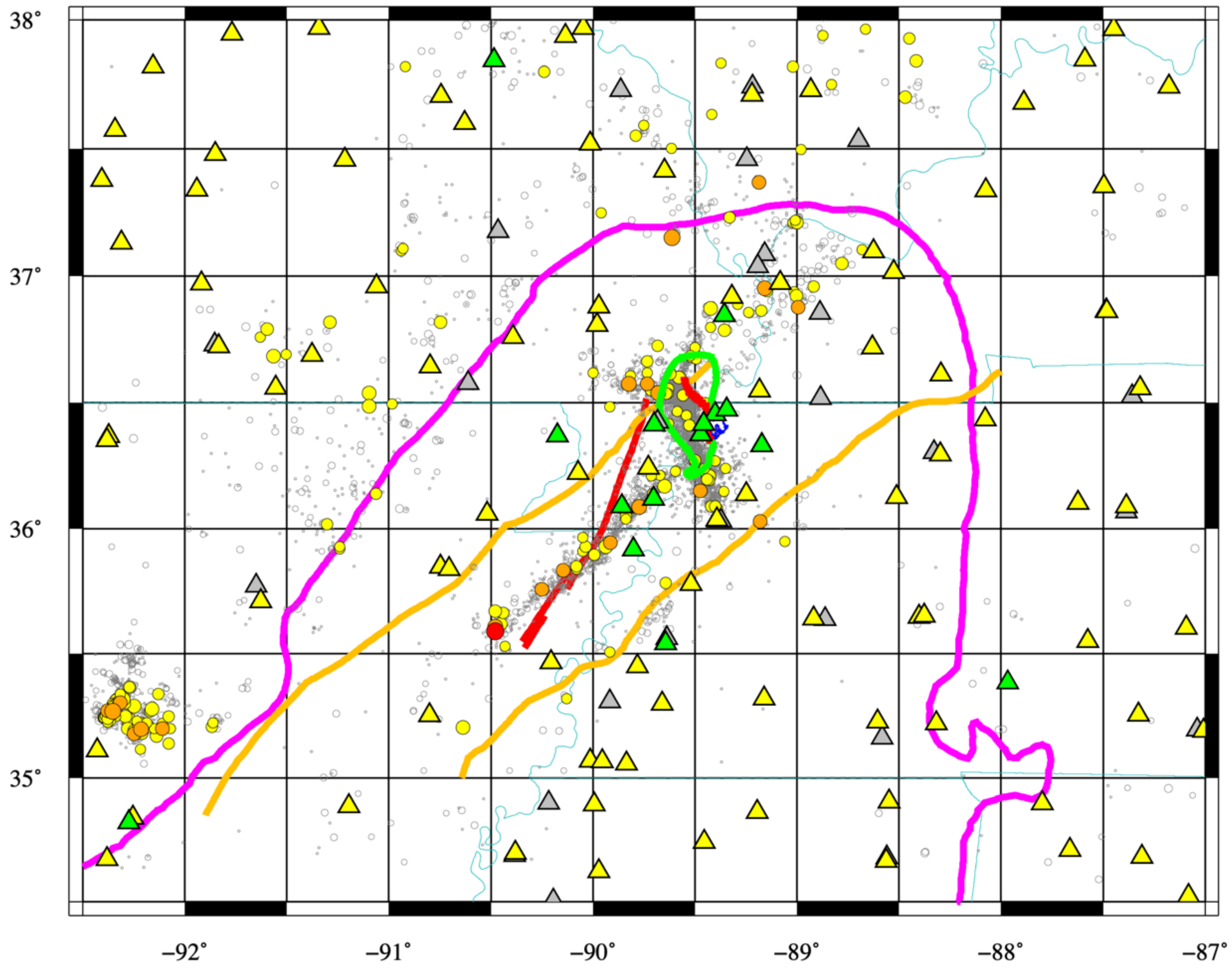
New Madrid Seismic zone – most active seismic zone east of Rockies





Hao et al. 2013

Space Geodetic Infrastructure in the New Madrid Seismic Zone and surrounding mid-continent.

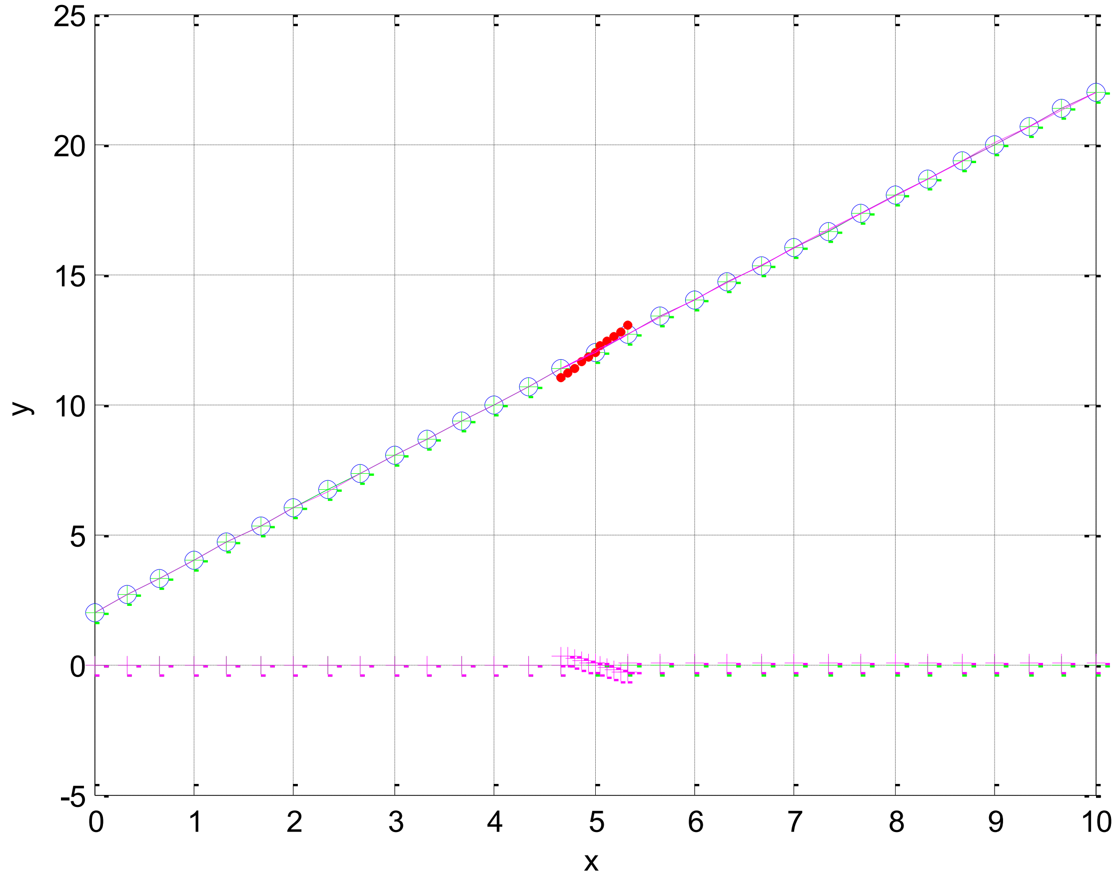


GNSS sites ▲ – stably monumented antennas (green, GAMA).

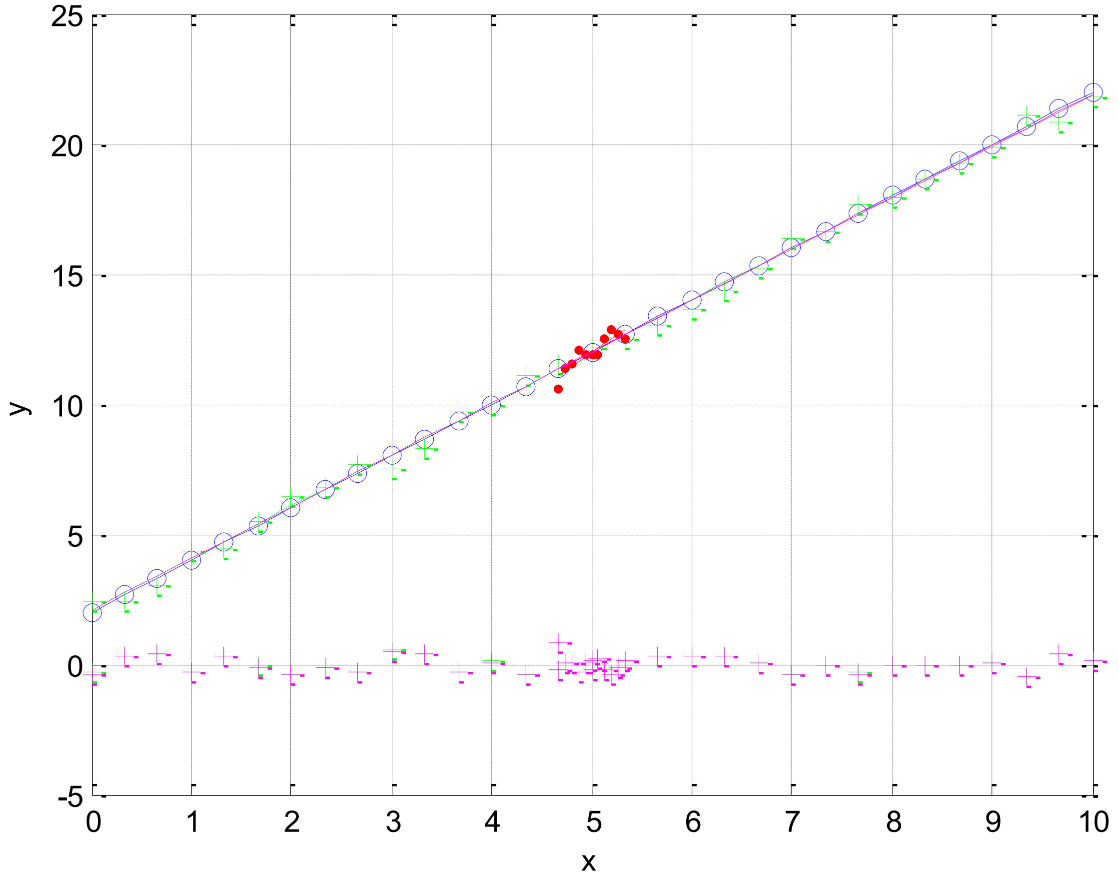
Most antennas mounted on buildings and other unstable structures, yellow/gray w/ & w/out velocity solution.

Seismicity and geologic structures also shown.

Separating two signals:
New Madrid – a small region with a small signal.
SNR≤1?
Pushing the limits of GNSS.

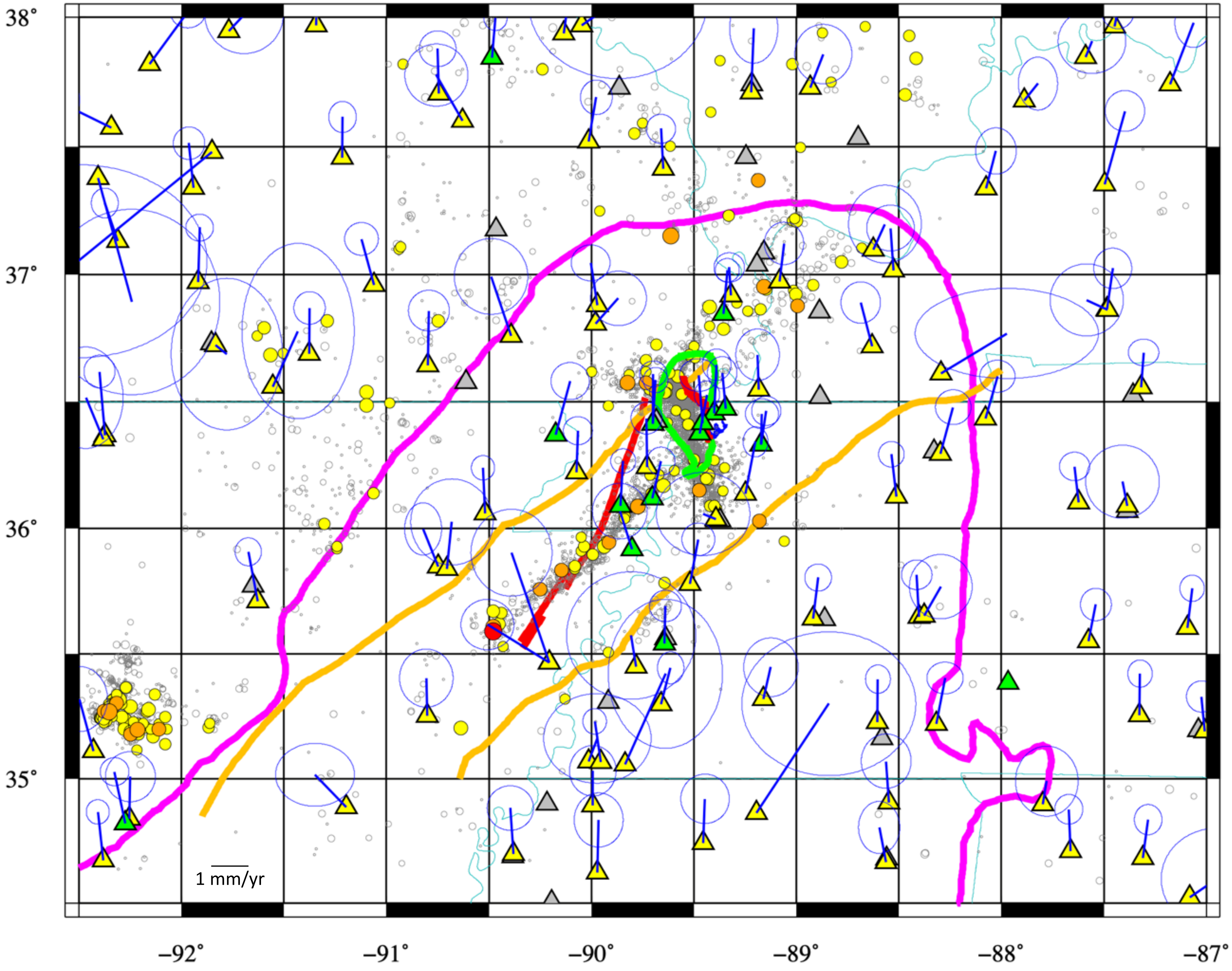


no noise



with noise

Site velocities with respect to a stable North America Plate Reference frame.

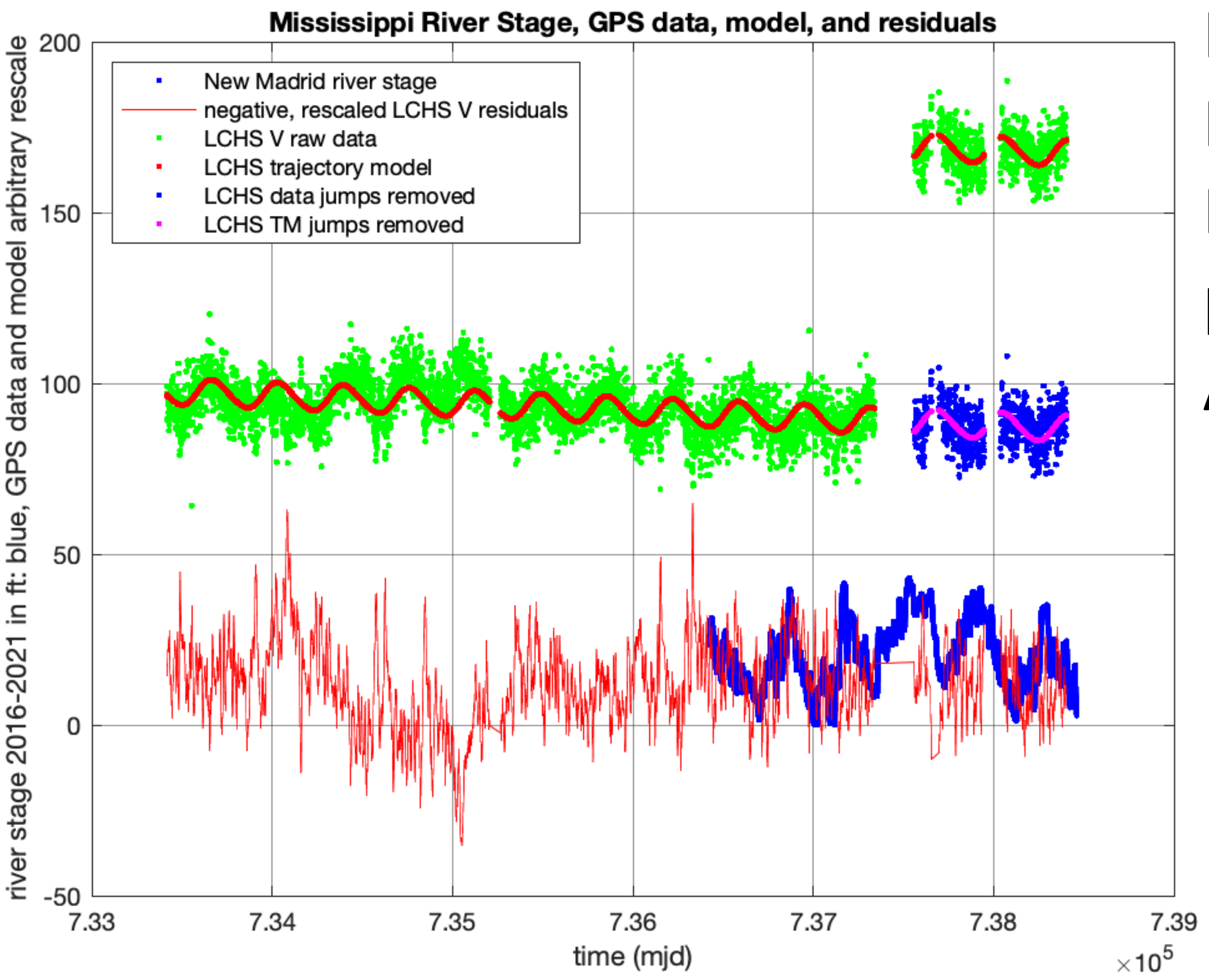


Left - velocities with respect to a Stable N. America Plate.

After 20 years, GAMA velocities ~1-1.5 mm/yr with error ellipse radii ~1/3 of magnitude, but difference in velocities (strain) is less than the errors.

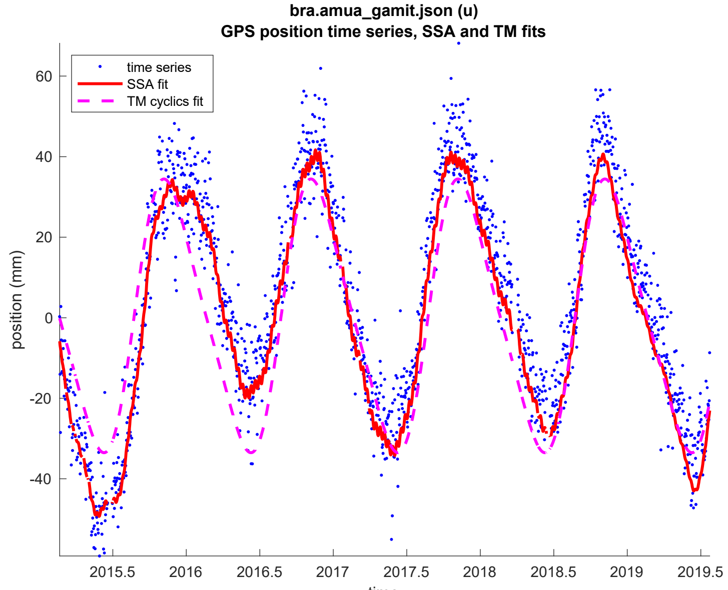
Elastic response of Earth's crust to loads.

In addition to isostatic adjustment, the crust responds elastically to applied loads and GPS can estimate this response to determine the elastic properties of the crust or "weigh" the load.



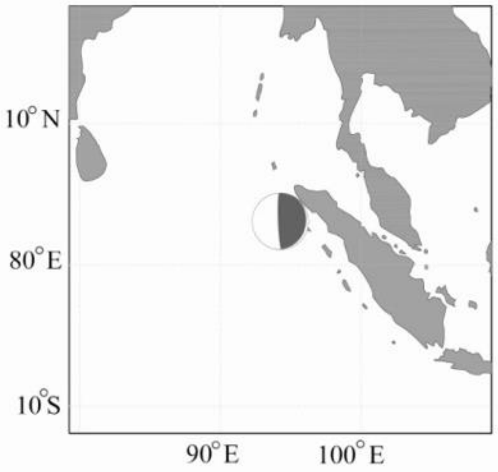
Left – response to Mississippi River floods.

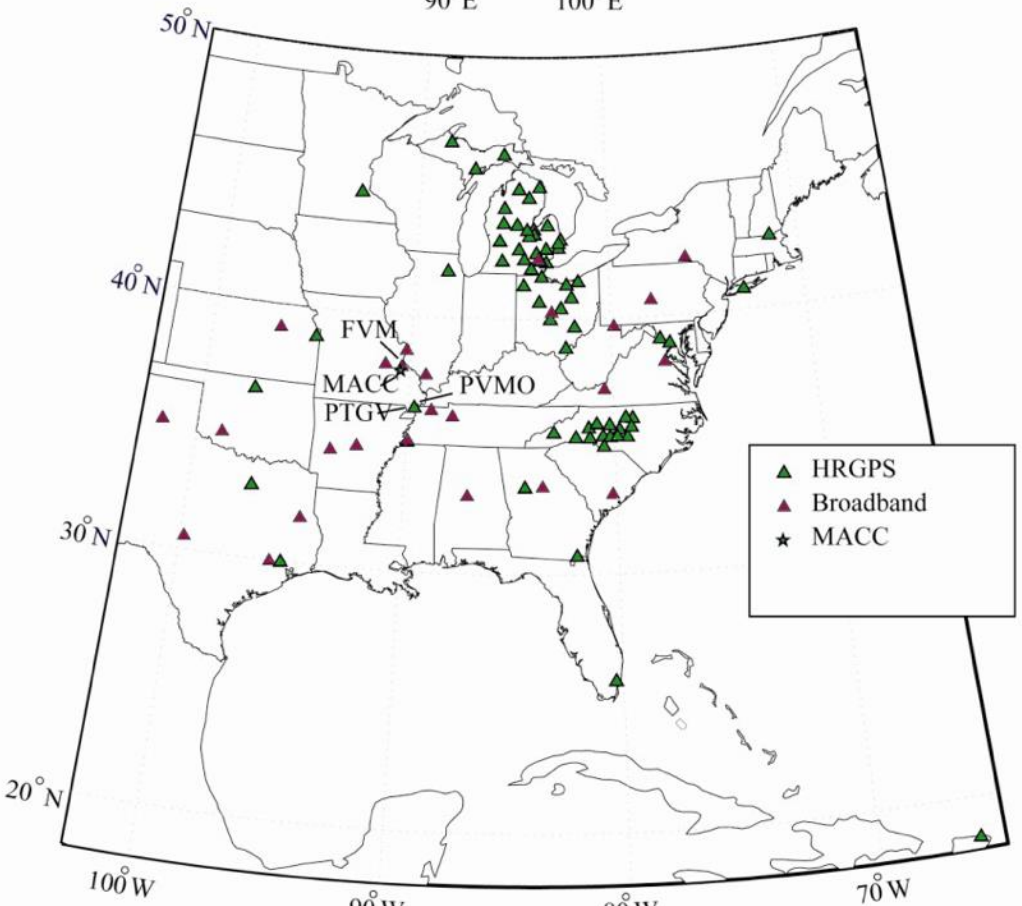
Below – 10 cm peak to peak vertical response to Amazon river loading.

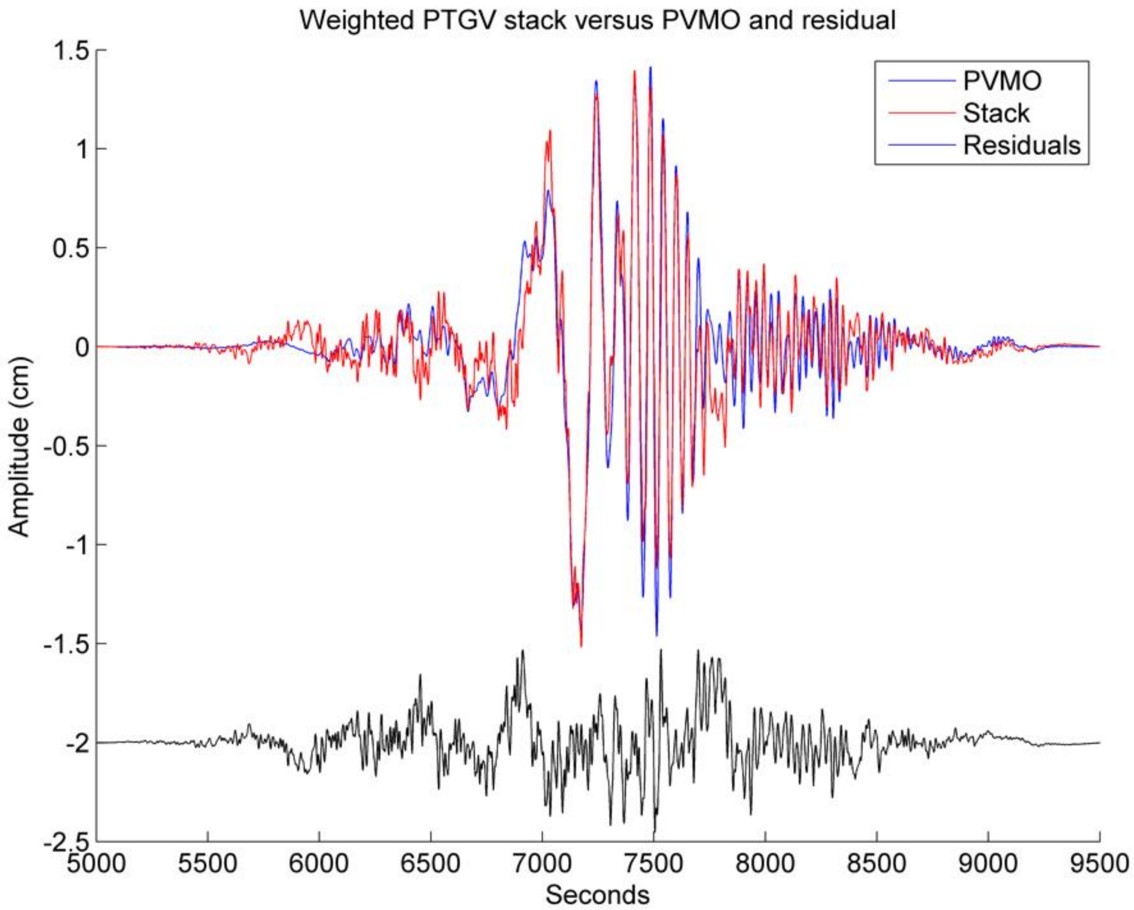


High Rate - Kinematic GPS

GPS absolute displacement seismograms and co-located broadband seismic recording of – Love wave of 2004 M9.0, Sumatra-Andaman earthquake in Portageville, AR., at 14,000 km distance.

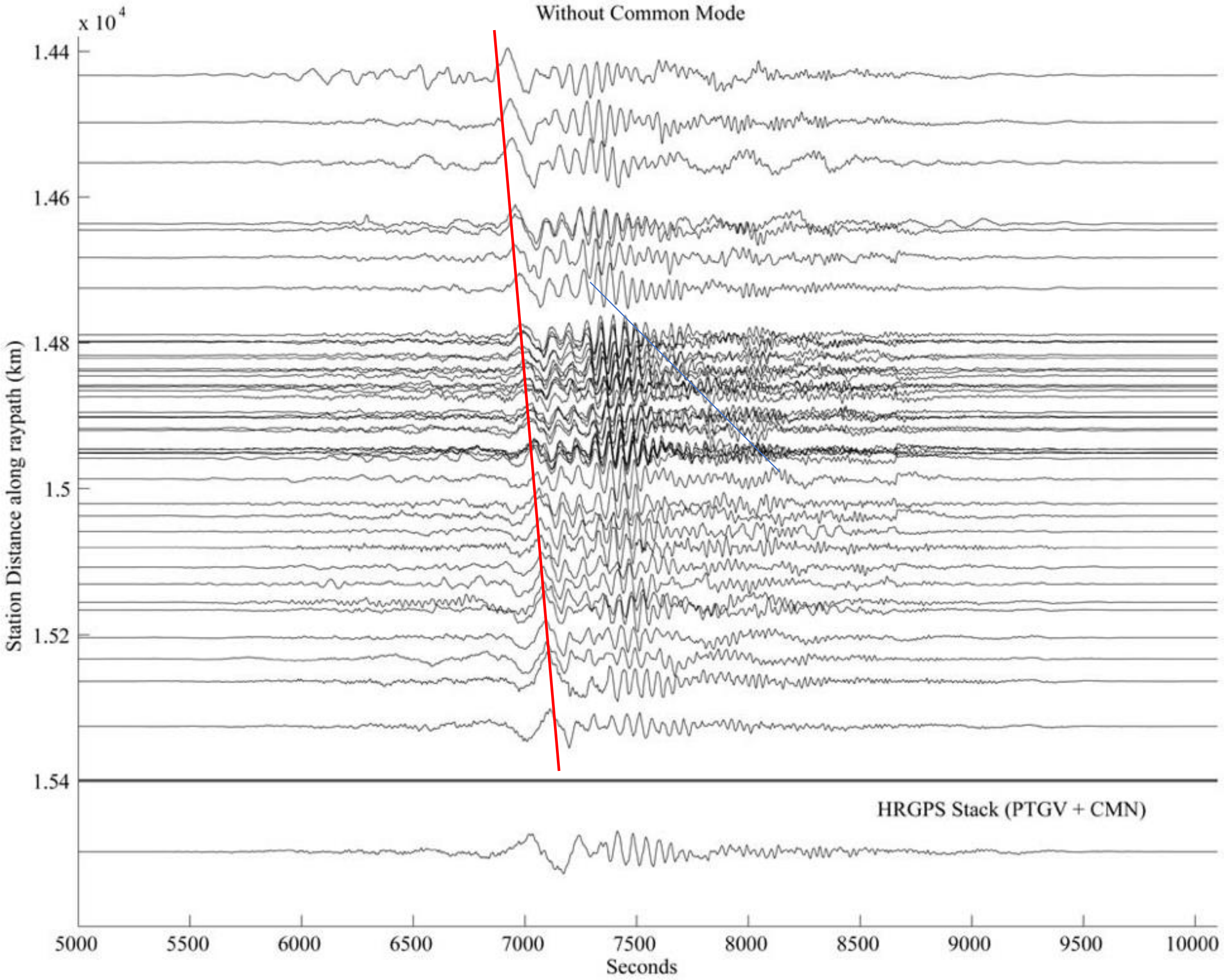


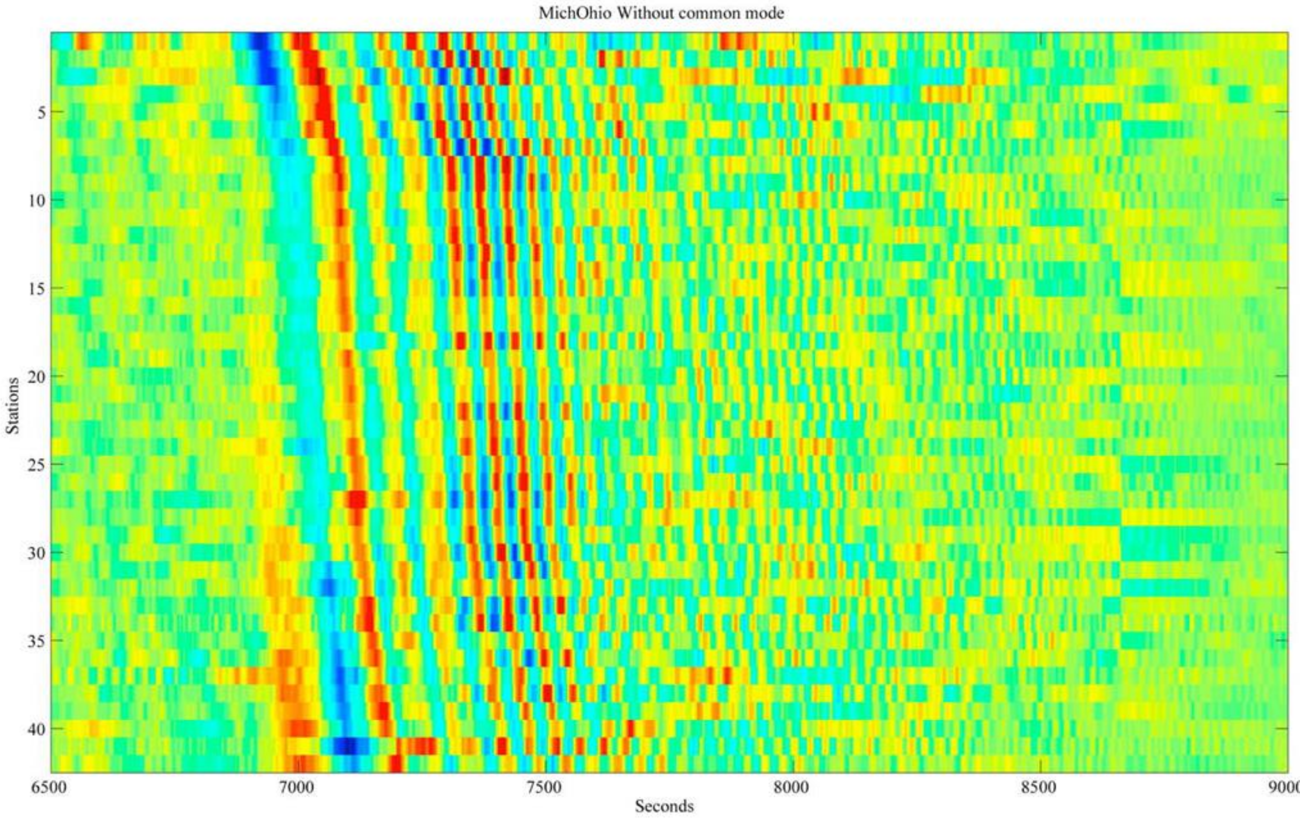




Davis and Smalley, 2009

~100 Absolute displacement, sidereally filtered seismograms.
Left side, record section where the slope, “move-out”, gives the velocity of the surface waves.
Right side, same data displayed as surface (not a record section, slope not meaningful).

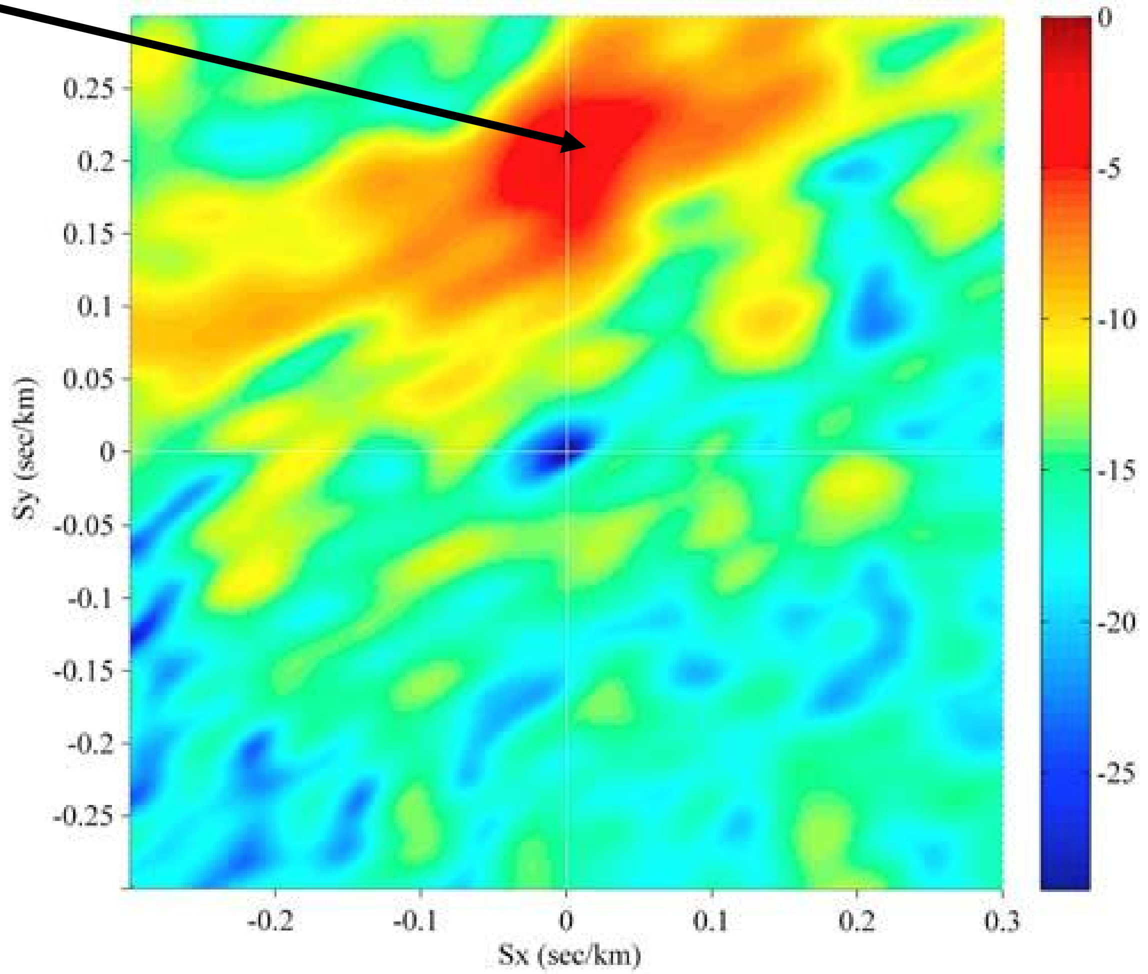




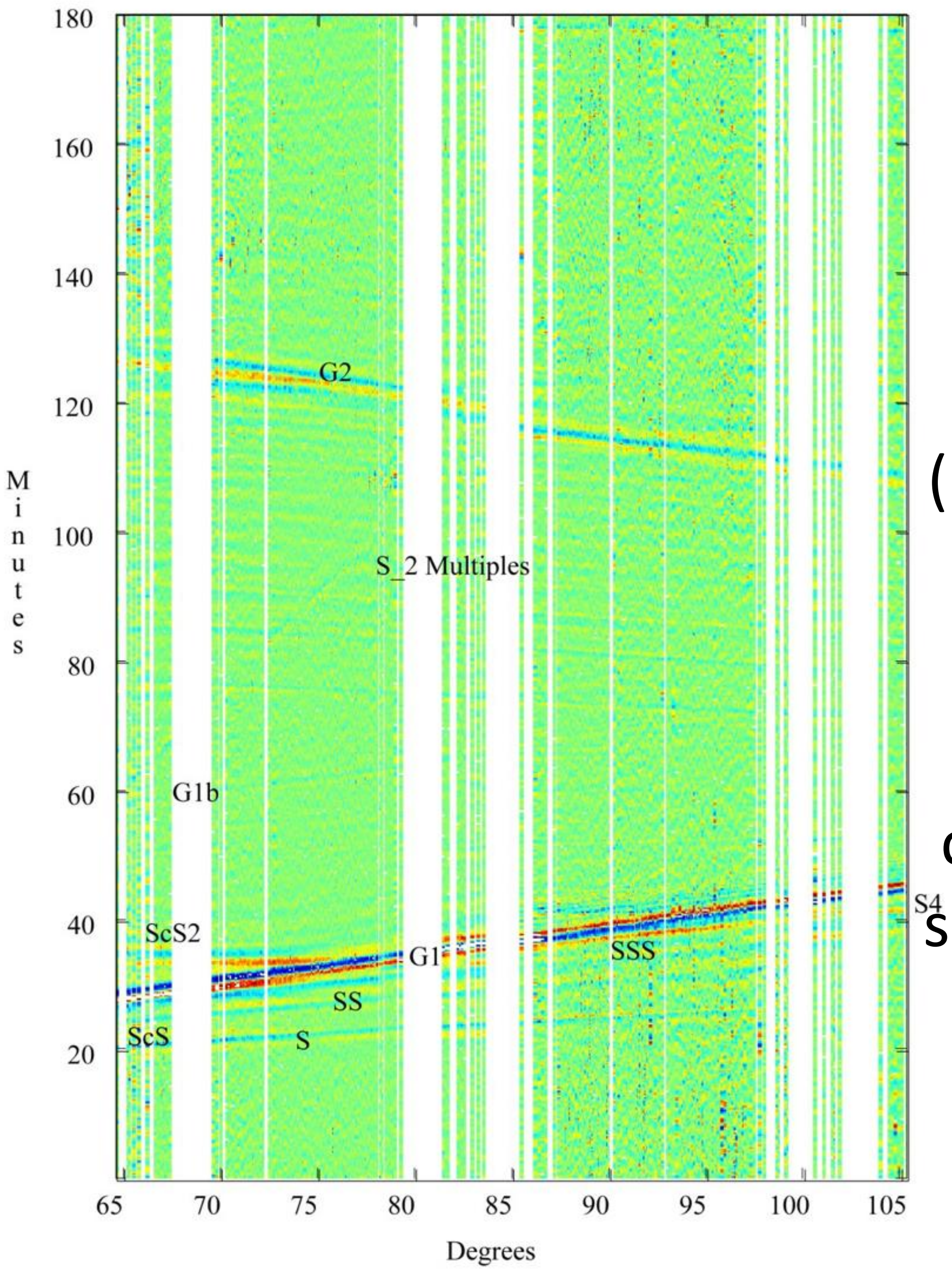
Davis and Smalley, 2009

We can estimate wave properties such as apparent velocity and azimuth by array processing (beam steering, f**k** filtering).

Peak position provides estimate of azimuth and slowness of plane (surface) waves crossing array.

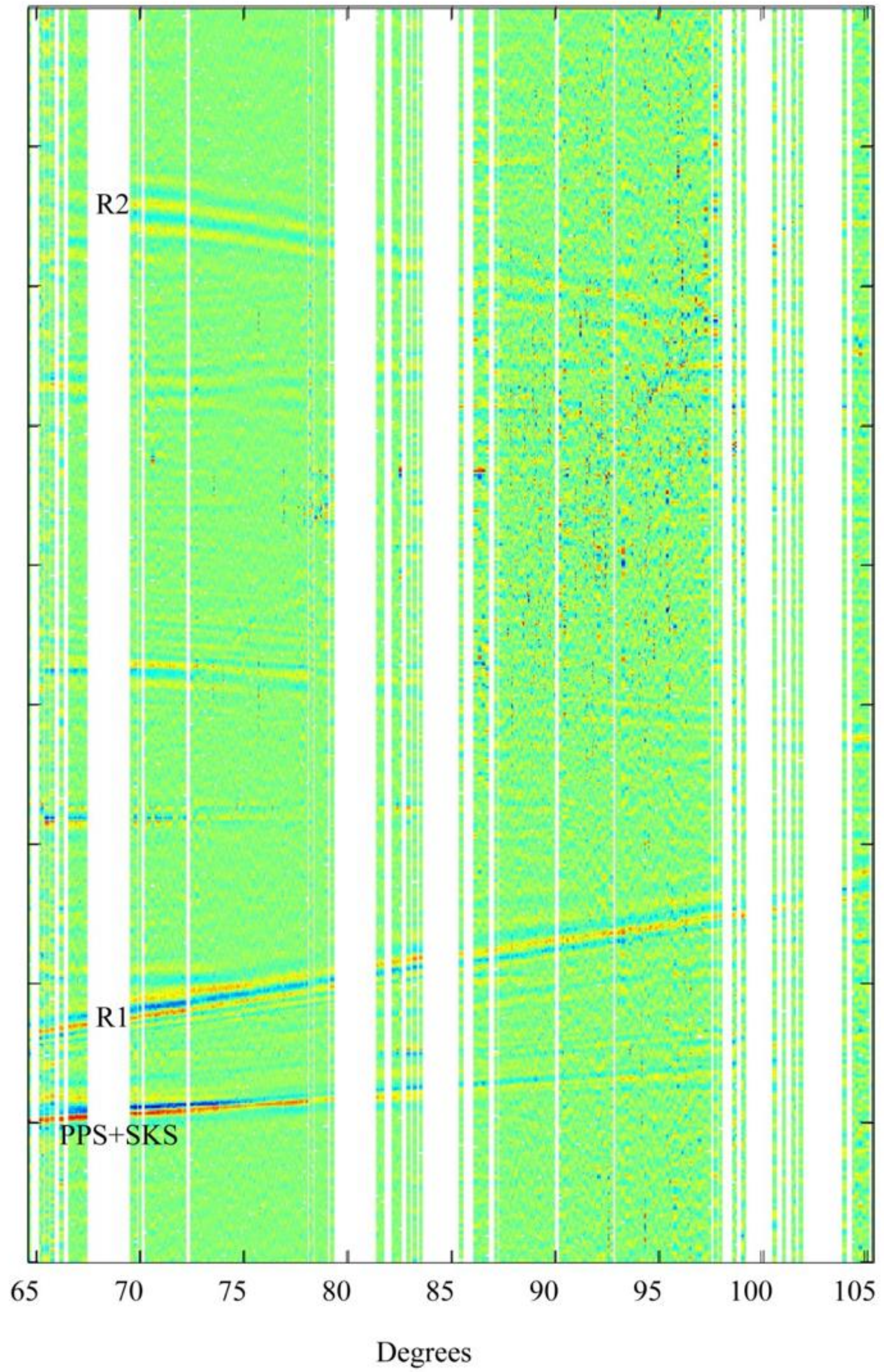


Davis and Smalley, 2009

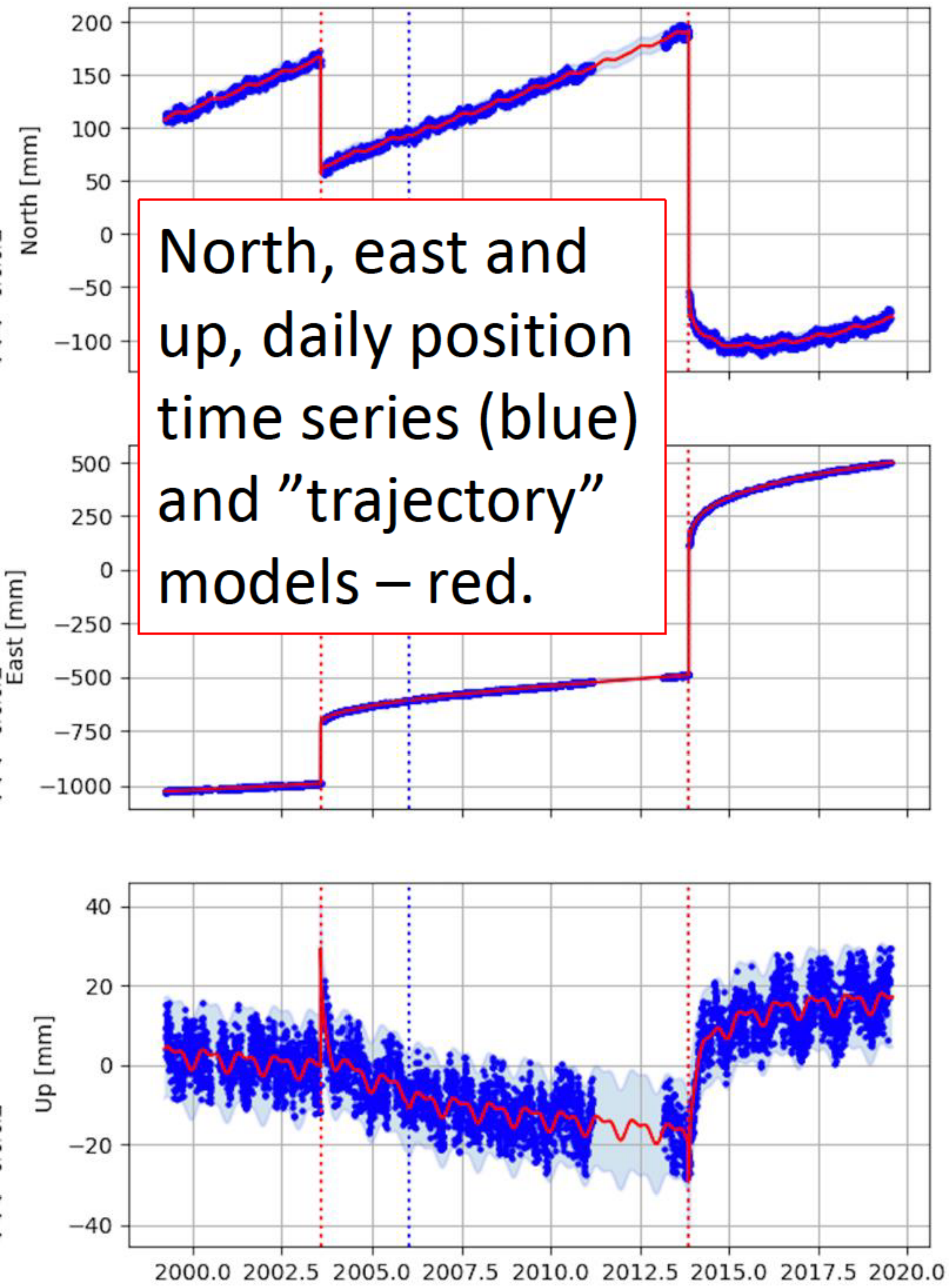


High-rate GPS seismograms from Tohoku-Oki, $M_w 9$, earthquake recorded in the US (PBO, CORS, GAMA).

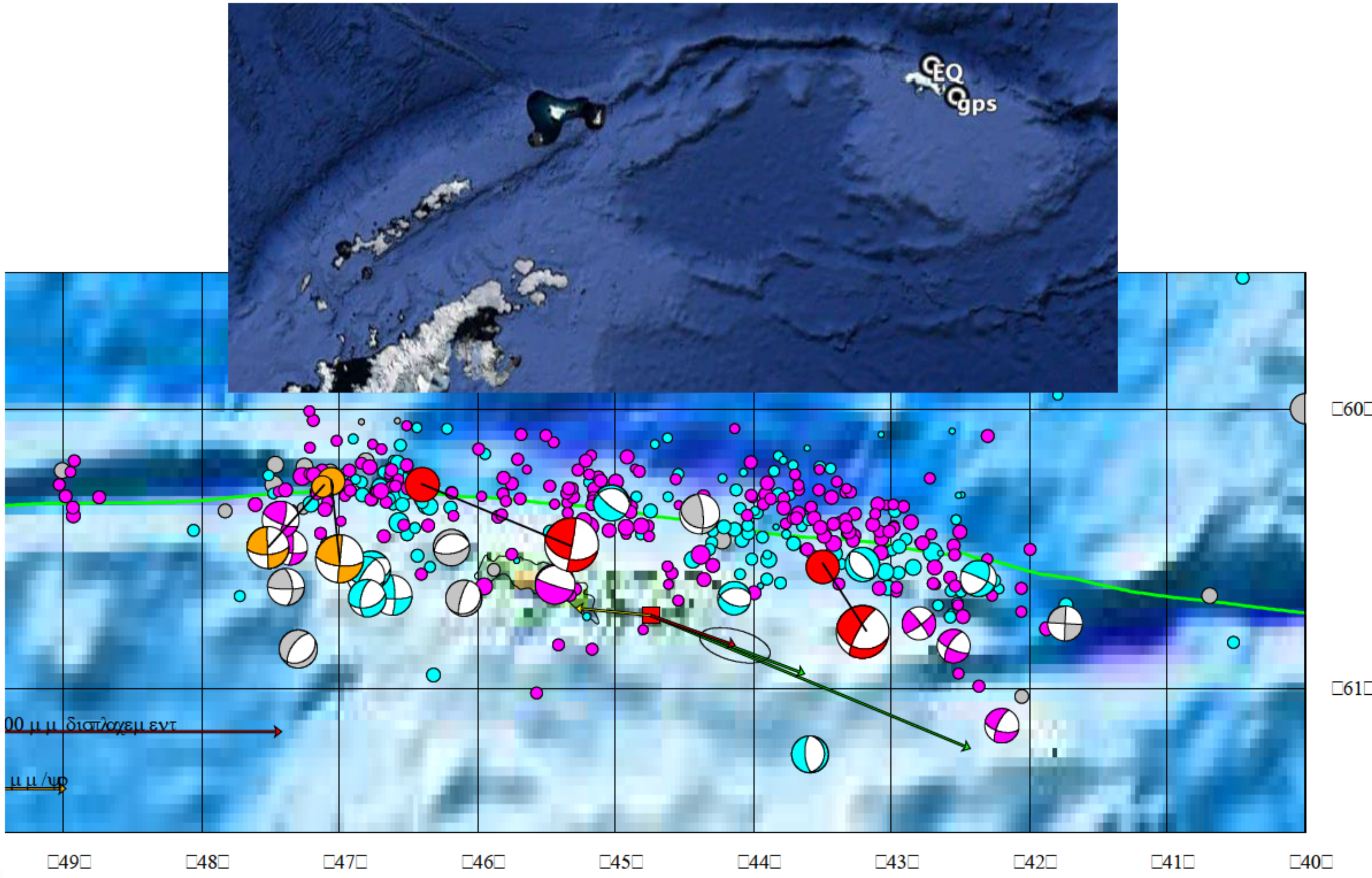
Transversely (left) and radially (right) polarized components of GPS seismograms shown. Both body (S) and surface waves observed.



Seismicity of S. Orkney Islands since installation of a continuous GPS station in 1999. Large earthquakes – east – 2003, M7.6, west – 2013, M7.8: inter-, co-, and post-seismic signals.

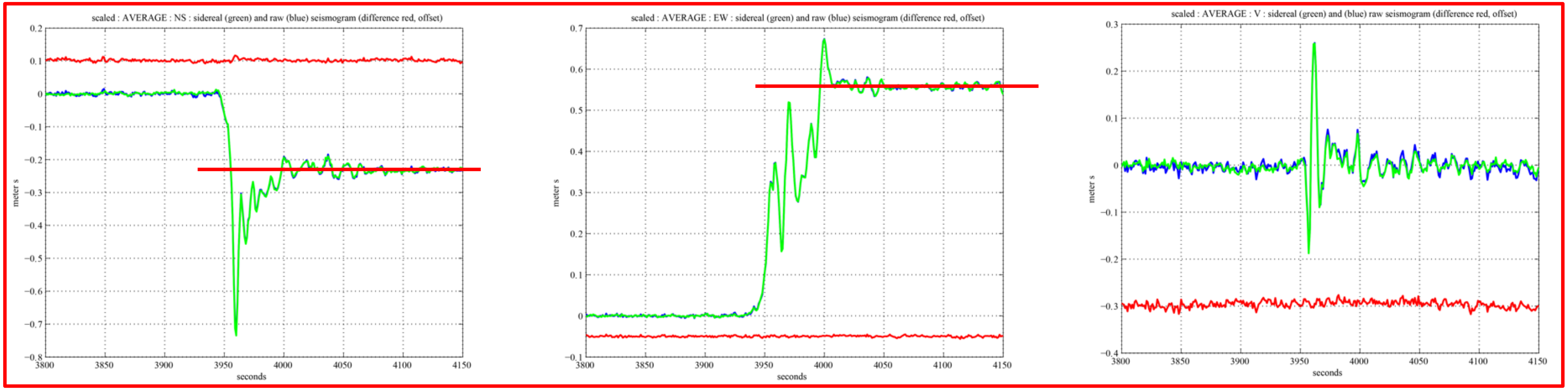


North, east and up, daily position time series (blue) and ”trajectory” models – red.



1 Hz GPS seismograms

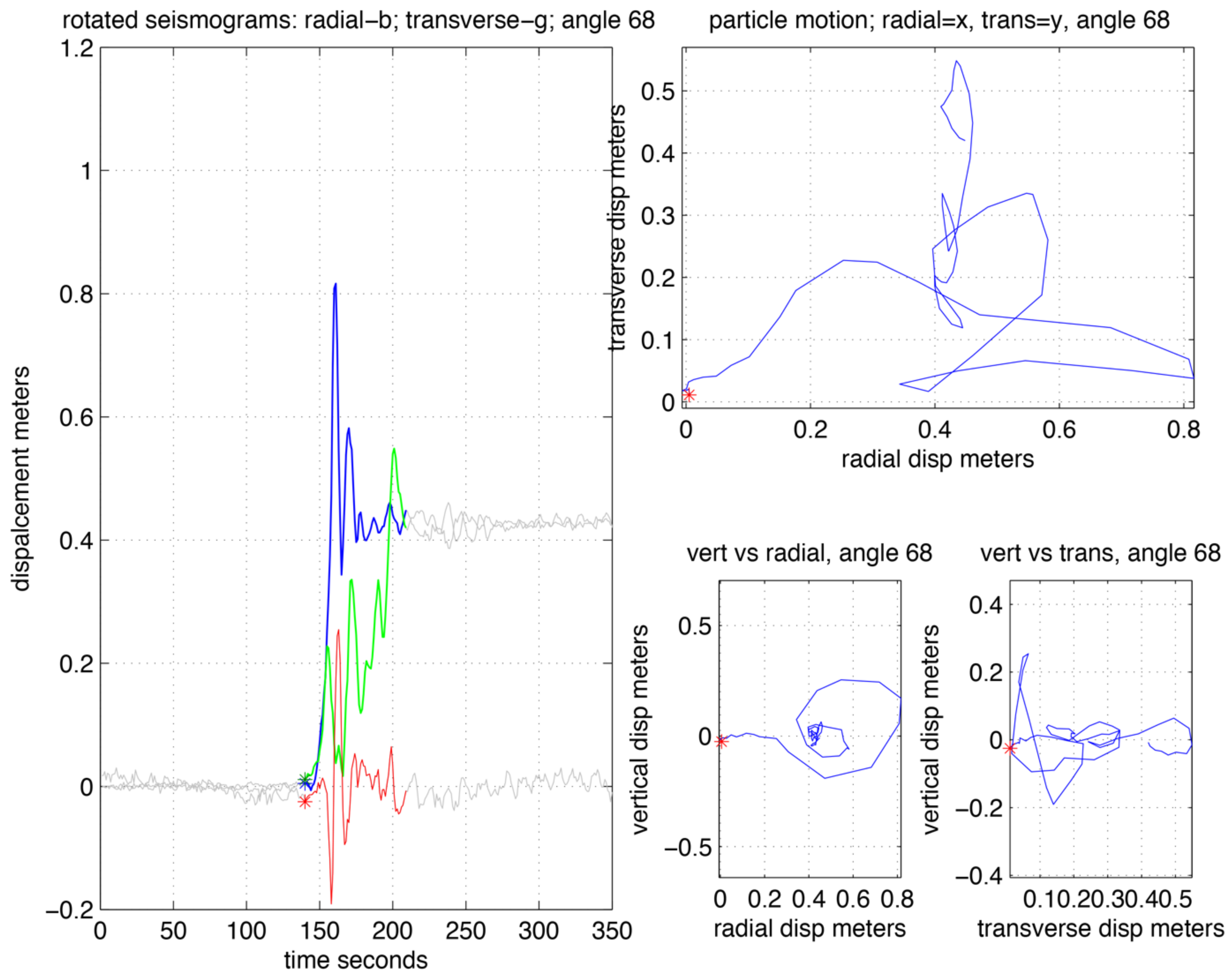
NS E W UD



Before this event a common question was what were the overshoots?

Static coseismic displacements were N~-0.325 m, E~0.56 m, U~0 m.

Raw seismogram in blue.
Sidereally filtered seismogram in green, sidereal filter in red.



Rotate horizontals for maximum polarization into Radially and Transversely polarized waves.

H1 vs H2 now radial & transverse (=Love wave) directions.

V vs H1 – retrograde elliptical particle motion (= Rayleigh wave).

Surface waves pass DURING development of the coseismic offset.

GPS/GNSS Space Geodesy is continuing to improve in terms of the hardware (satellites and receivers) and processing.

The slow signals will require more time, and we might not personally live to see it (think of it like the building of the famous Cathedrals in Europe), but Space Geodesy will contribute to solving the enigma of the New Madrid Seismic Zone.

Thank you.