Active deformation in eastern North America

Damage from Aug. 23, 2011 Virginia earthquake
From: Bill Barnhart, Cornell grad student

1) Is eastern NA moving?
Who cares?

2) How fast is it moving?

What techniques could detect the movement?

3) What areas are moving?

Matt Pritchard
Rowena Lohman
Cornell

Mostly rigid plate motion

At a broad scale:
GPS similar to that of a rigid plate

But:
regional exception (Glacial Isostatic Rebound)

a few local anomalies

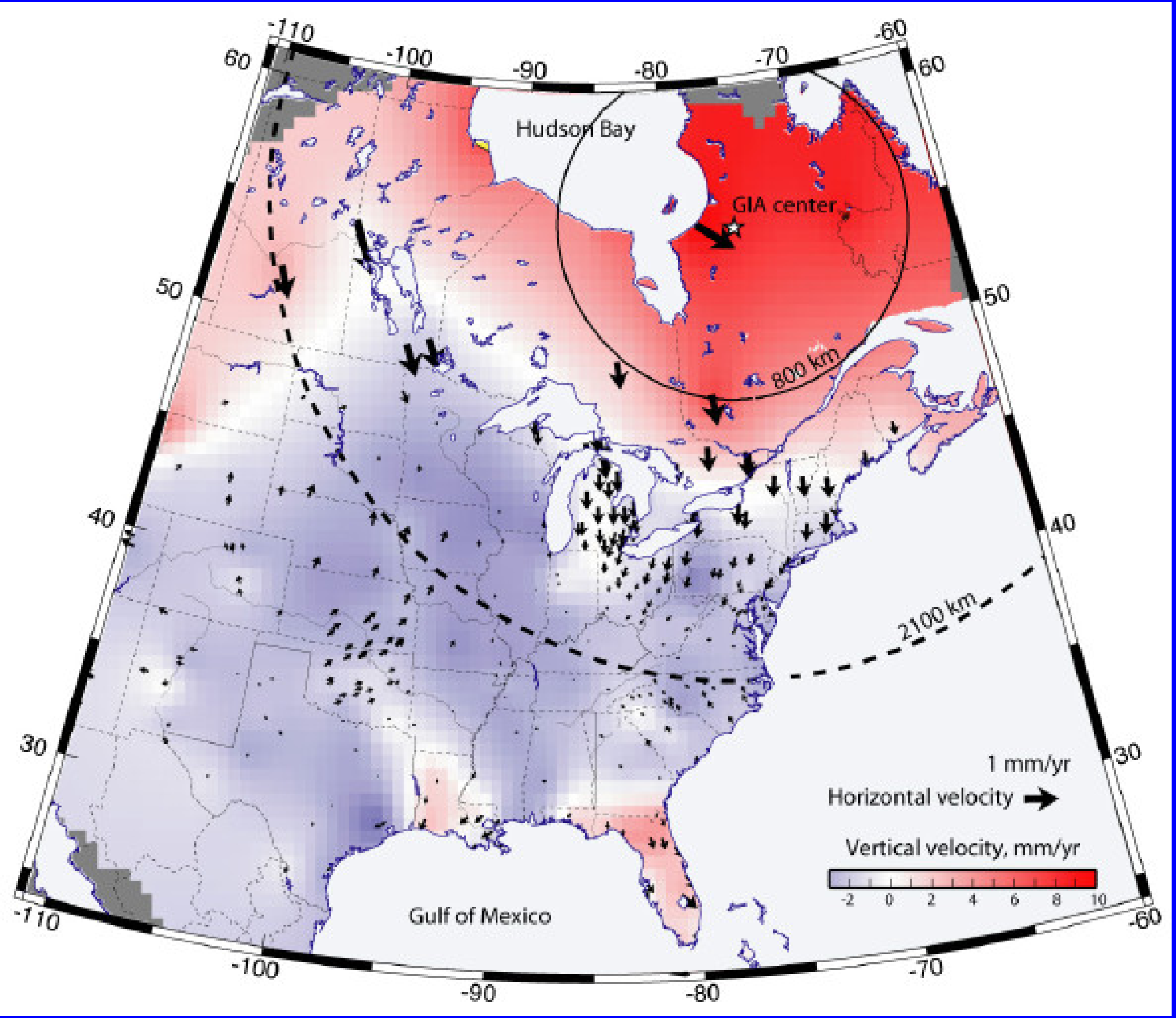
Stein & Sella, 2002

Glacial Isostatic Adjustment

Horizontal & vertical differences from rigid plate observed by GPS

Implications for understanding sea level rise, lateral mantle heterogeneity, & origin of eastern U.S. earthquakes?

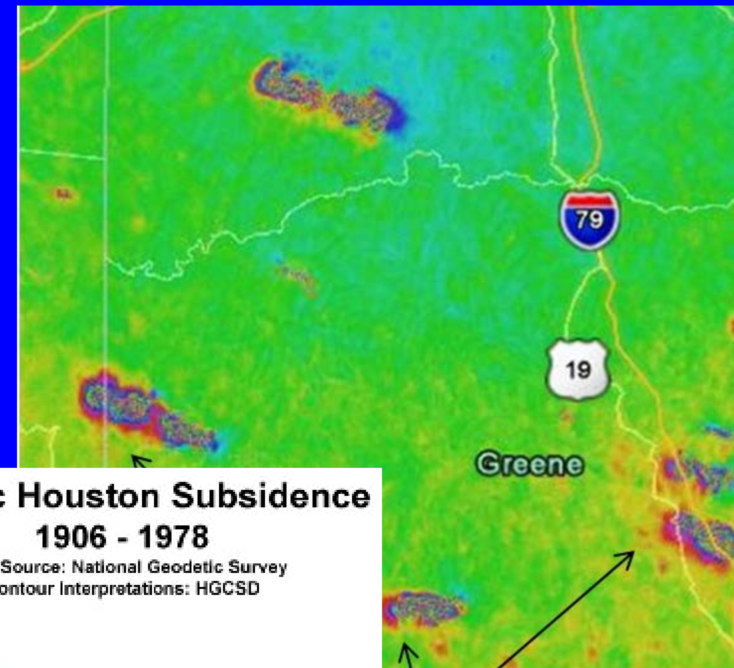
Need denser stations in places



From: Calais et al., 2006

Some other sources of deformation

Landslide: 1995 Quebec
From Geological Survey of Canada



Mining(?) subsidence near Pittsburgh, PA
From: Neva Ridge.com

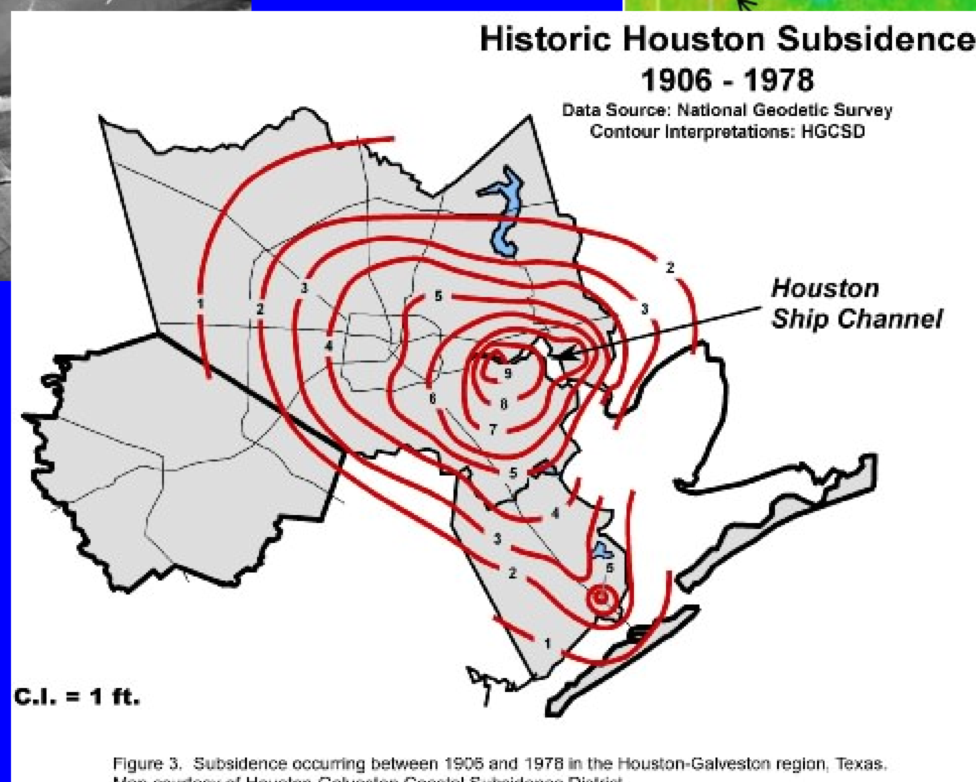


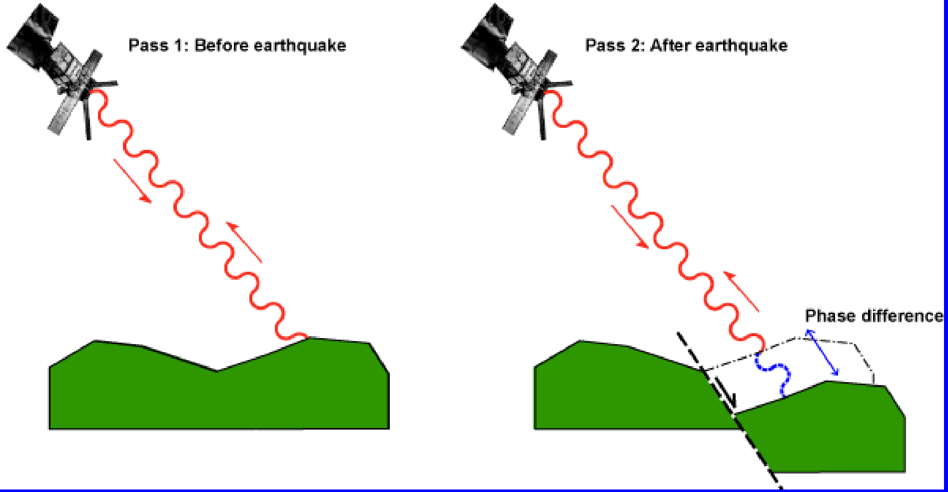
Figure 3. Subsidence occurring between 1906 and 1978 in the Houston-Galveston region, Texas.
Map courtesy of Houston-Galveston Coastal Subsidence District

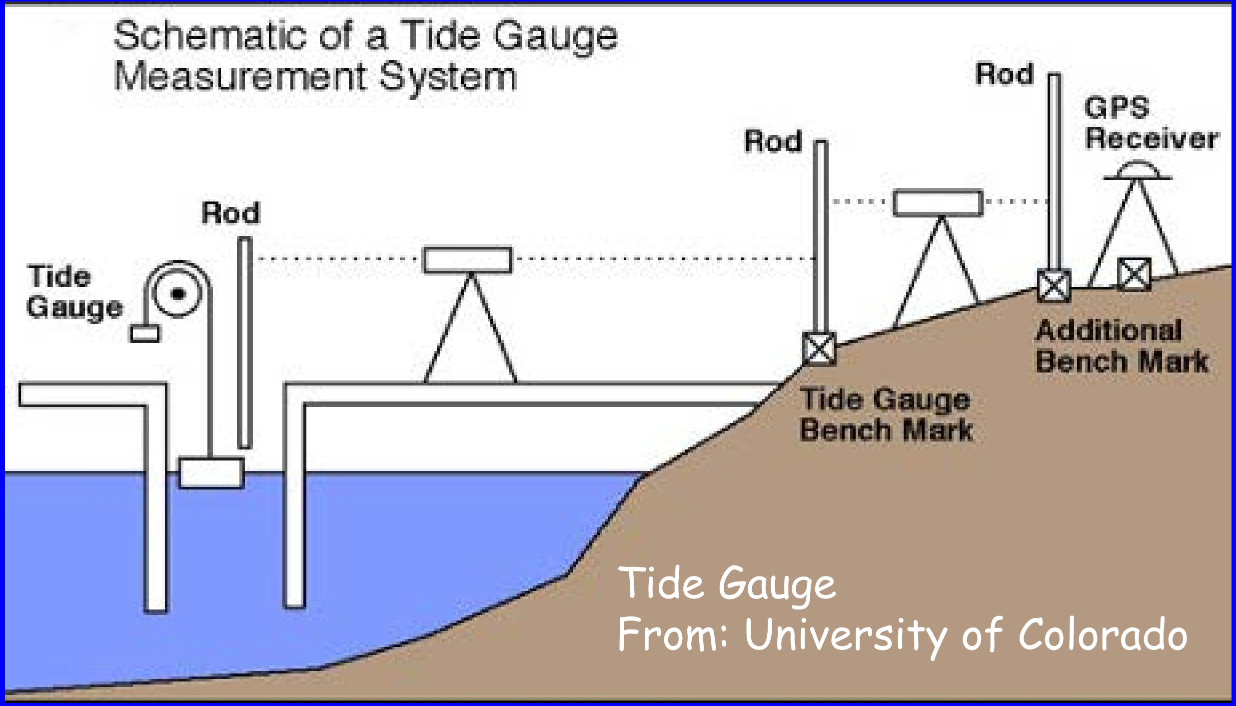
From Houston Geological Society

Some ways to measure deformation

Leveling
From: Geologic Survey of Canada

InSAR
From: Wright, 2002

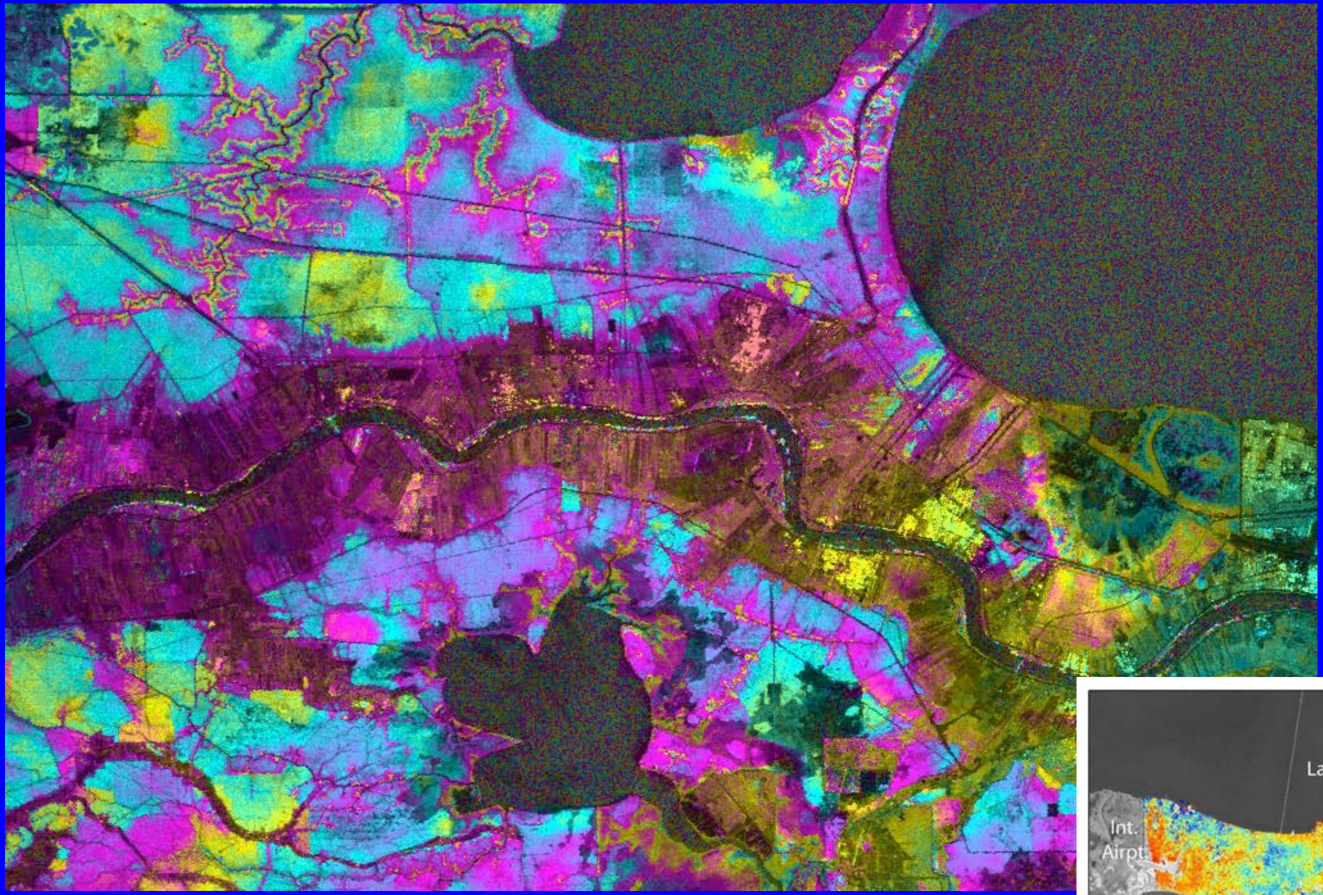




Tide Gauge
From: University of Colorado

GPS
From: JPL

InSAR works in the east! New Orleans example



What is needed:

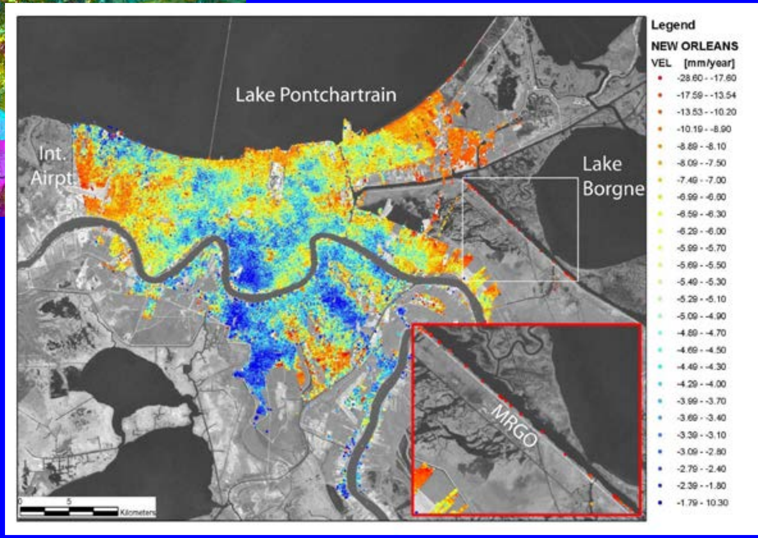
Frequent observations

Long wavelength radar

Enhanced signal processing

NASA's DESDynI mission

23 cm radar interferogram gives good measurements everywhere....



...while 6 cm radar interferogram is good over the urban areas

Dixon, Amelung, Ferretti et al., Nature 2006

InSAR for New York City: It works in winter!

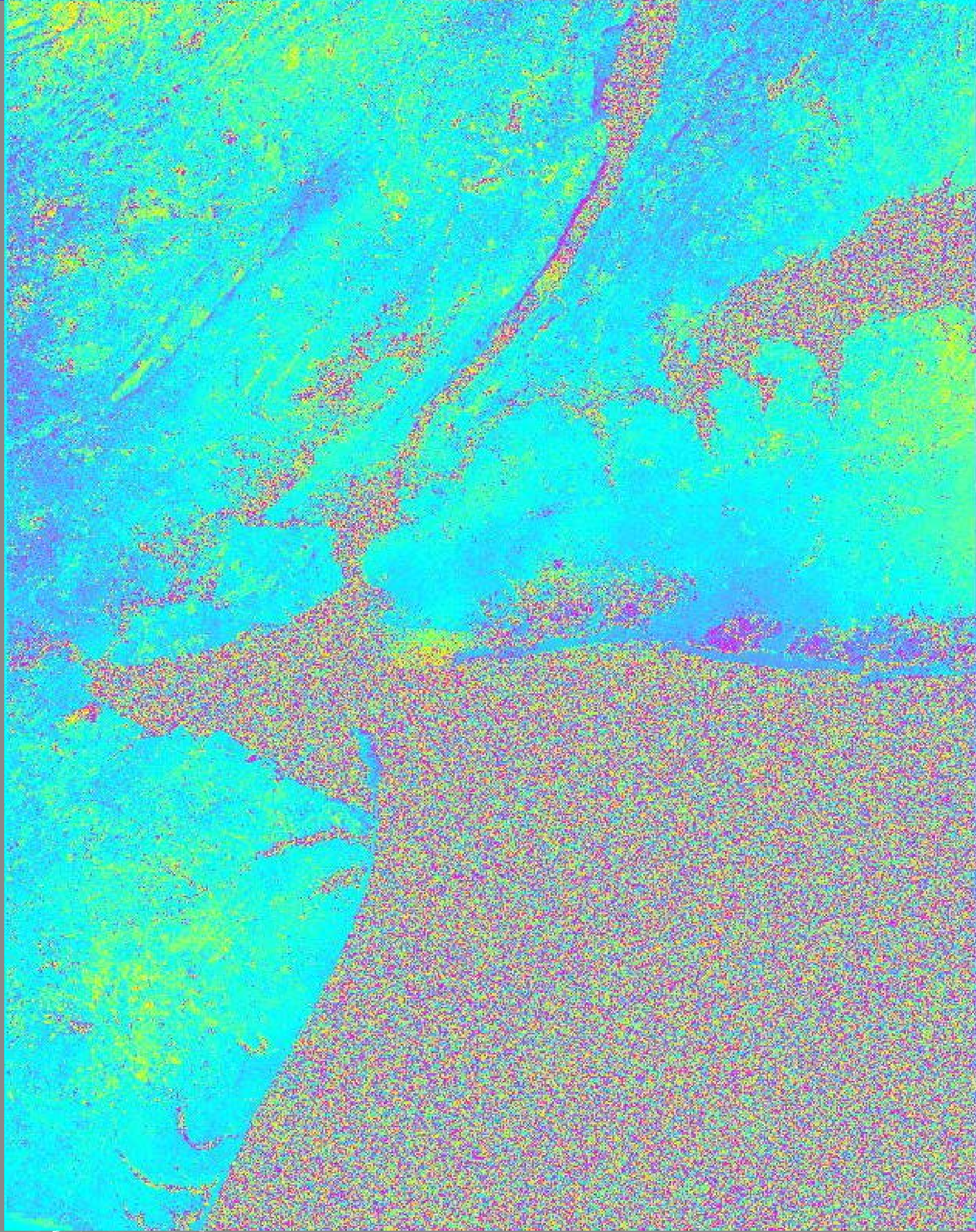
Dec. 23 2010 to Feb. 7 2011

23 cm radar

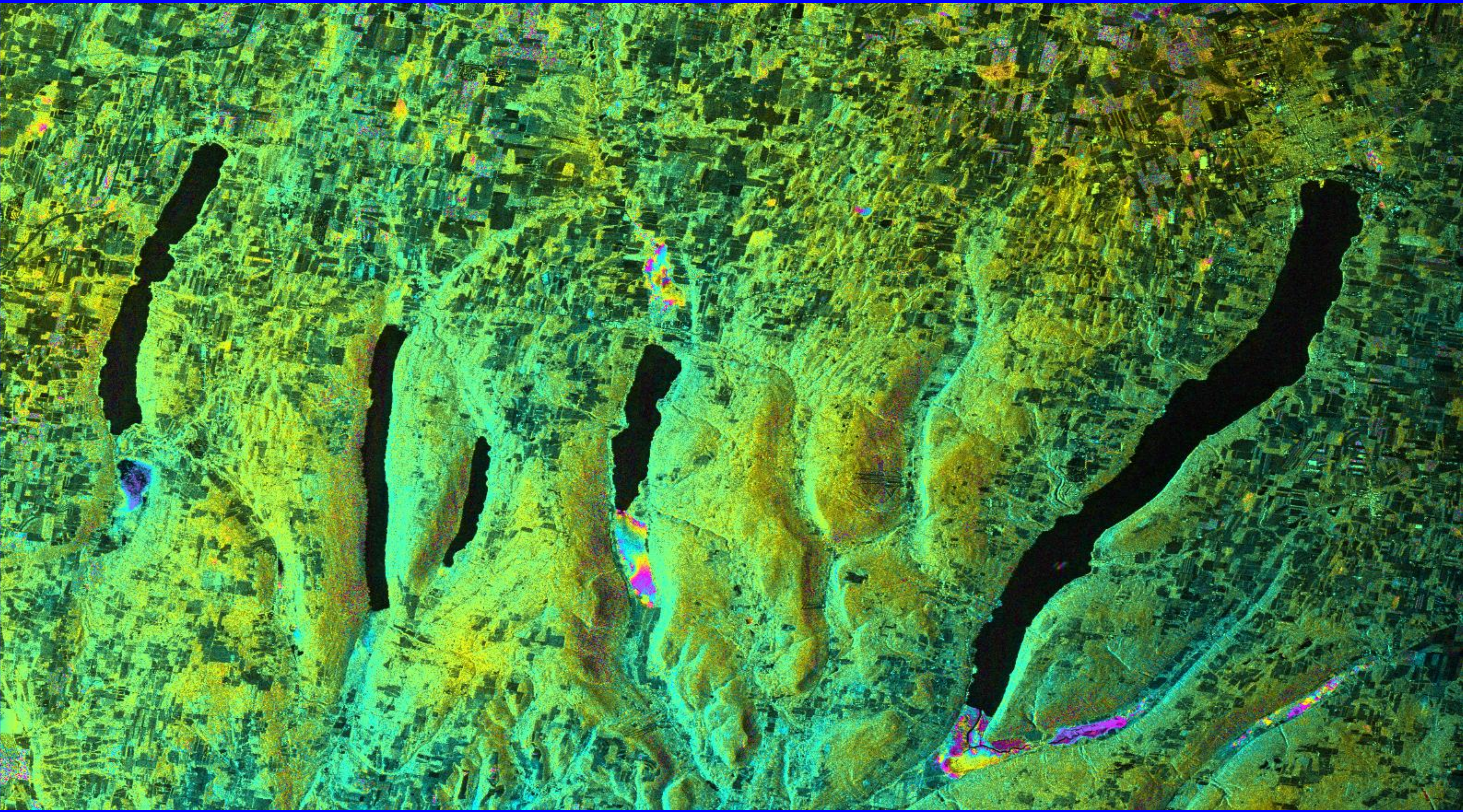
Excellent coherence nearly everywhere

No obvious atmospheric effects

Some potential “signal” along the Hudson River, individual buildings



InSAR for upstate New York: Wetlands



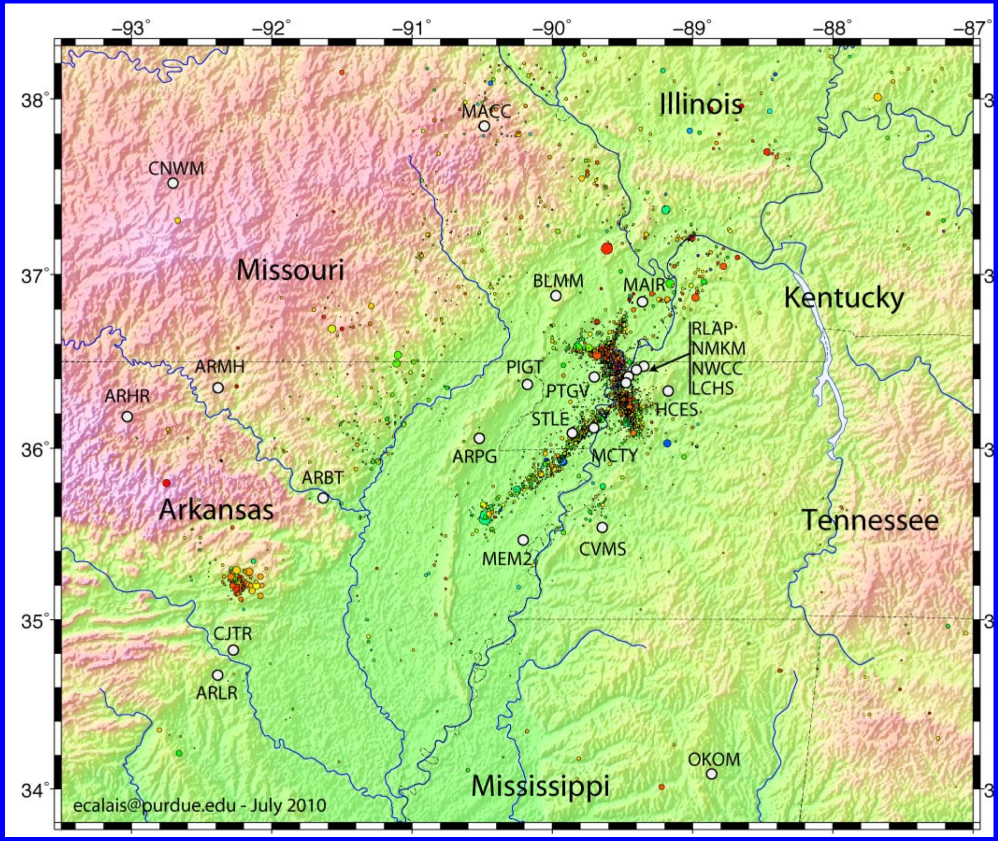
23 cm radar
Oct. 2 2010 to Nov. 17 2010

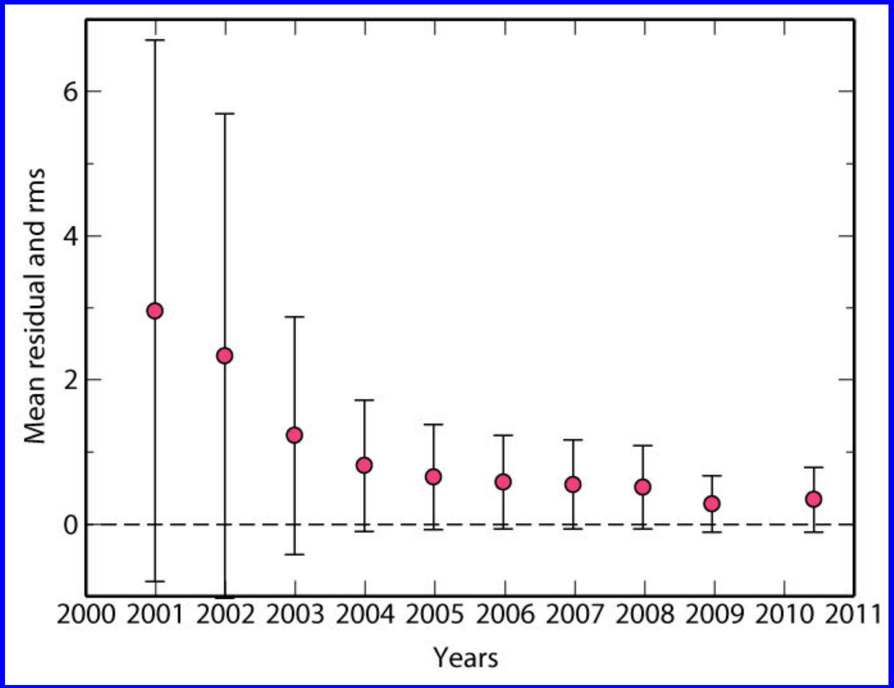
How slow can we resolve?

•It depends: on the length of the time series

•But mm/yr rates are resolvable with all techniques
Worry about GIA corrections (e.g., Mitrovica & Davis, 1996)

Sub mm/yr resolvable with GPS and decade-long time series





GPS in New Madrid Seismic Zone
From: Calais & Stein, 2009

Can we detect tectonic deformation?

- New Madrid:
Very low rates < 1 mm/yr
 (e.g., Calais & Stein, 2009; Smalley et al., 2005; Newman et al., 1999, etc.)

- Charleston: hint of mm/yr
(Talawani & Dura-Gomez, 2009)

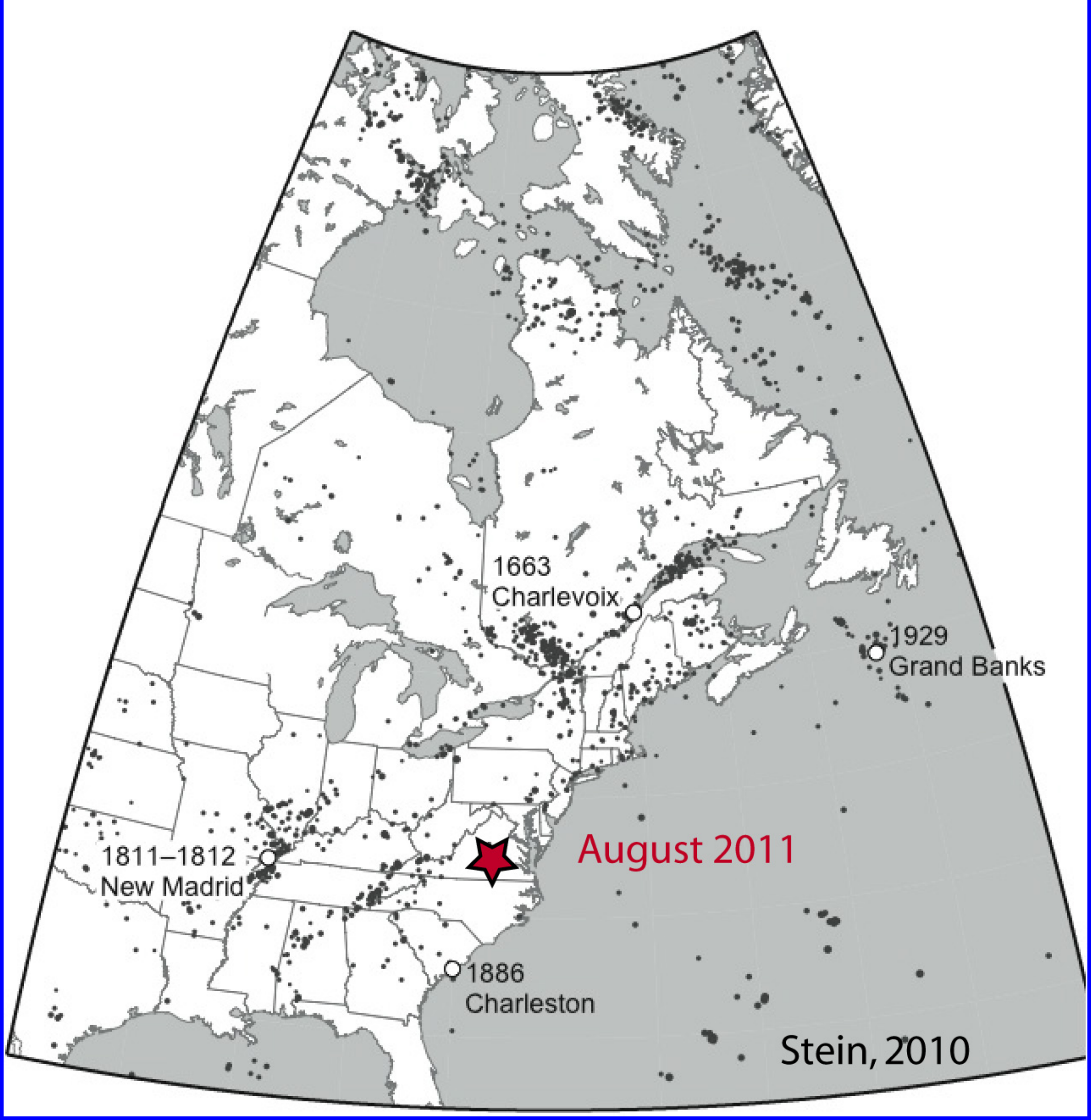
- Wabash Seismic: hint of mm/yr, but complex (Galgana & Hamburger, 2010)

- Charlevoix: strain detected
(Mazzotti et al., 2005)

- Western Quebec, Tennessee, Newark Rift basin, New England seismic zones?

Given low strain rates, we need:

- Decades of measurements
- Dense arrays in the "right" areas



Is there anything moving?

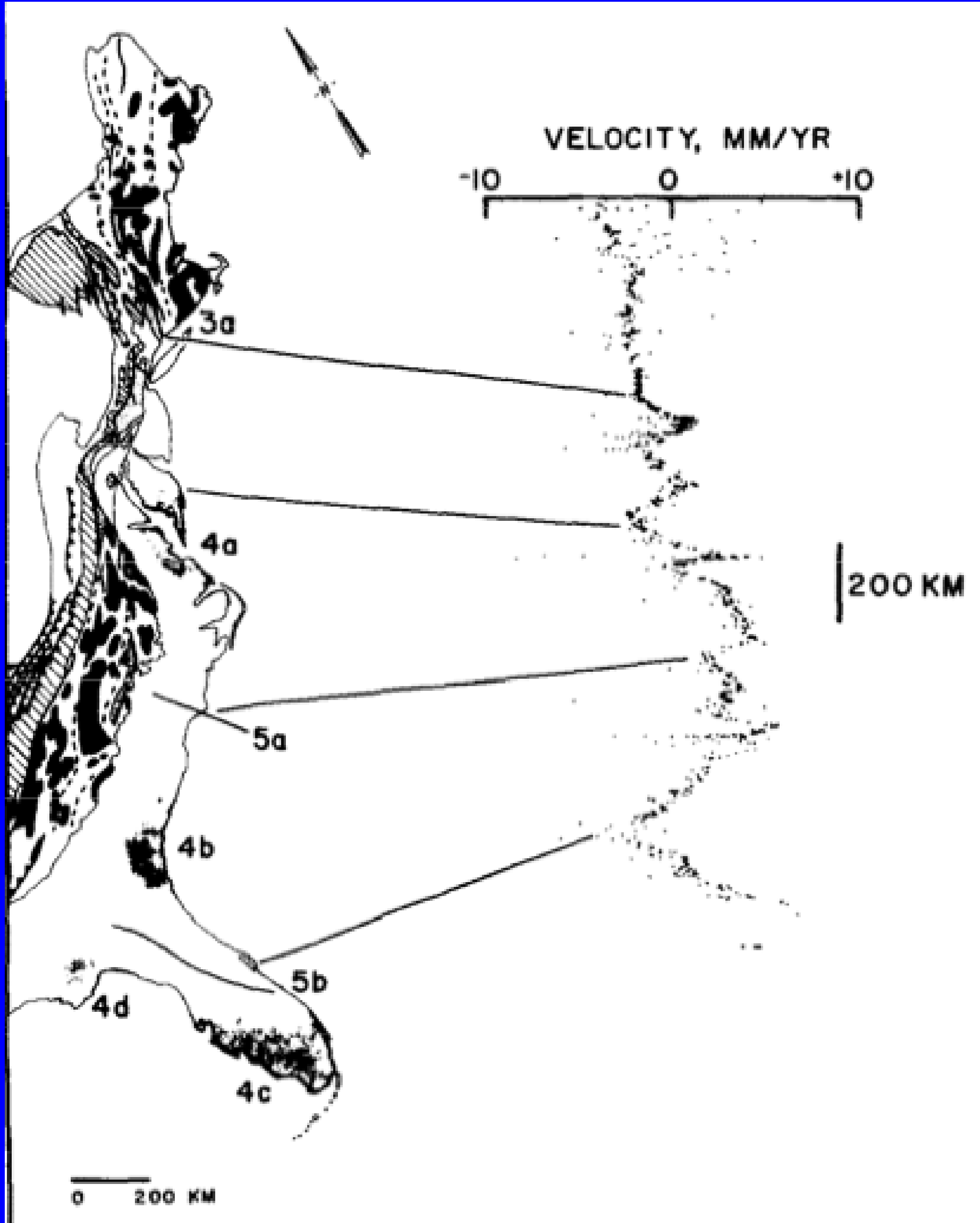
Leveling surveys along the east coast USA

"Corrected" profile

Anomalies at:
Connecticut Valley
Chesapeake Bay
Cape Fear
Cape Canaveral

Are they real?
Is there anything else to detect?

From: Brown, 1978



Key questions for discussion

1) What areas are moving?

Our inventory is incomplete

2) How fast are they moving? What techniques could detect the movement?

Rates of mm/year could be detected with tide gauges, leveling, GPS, InSAR

Lower rates detectable from geomorphology & stratigraphy

3) Why is the area moving? Who cares?

Glacial Isostatic Adjustment (GIA)
Tectonics/earthquake cycle
Pumping/Injection of subsurface fluids: groundwater, carbon sequestration, etc.
Surface water: Lakes, Rivers, Wetlands: Floods, tides, etc.
Landslides
Subsidence: karst, erosion, sediments, etc.
Mining