Using near-regional and local earthquake studies to inform seismic hazard assessment in Texas

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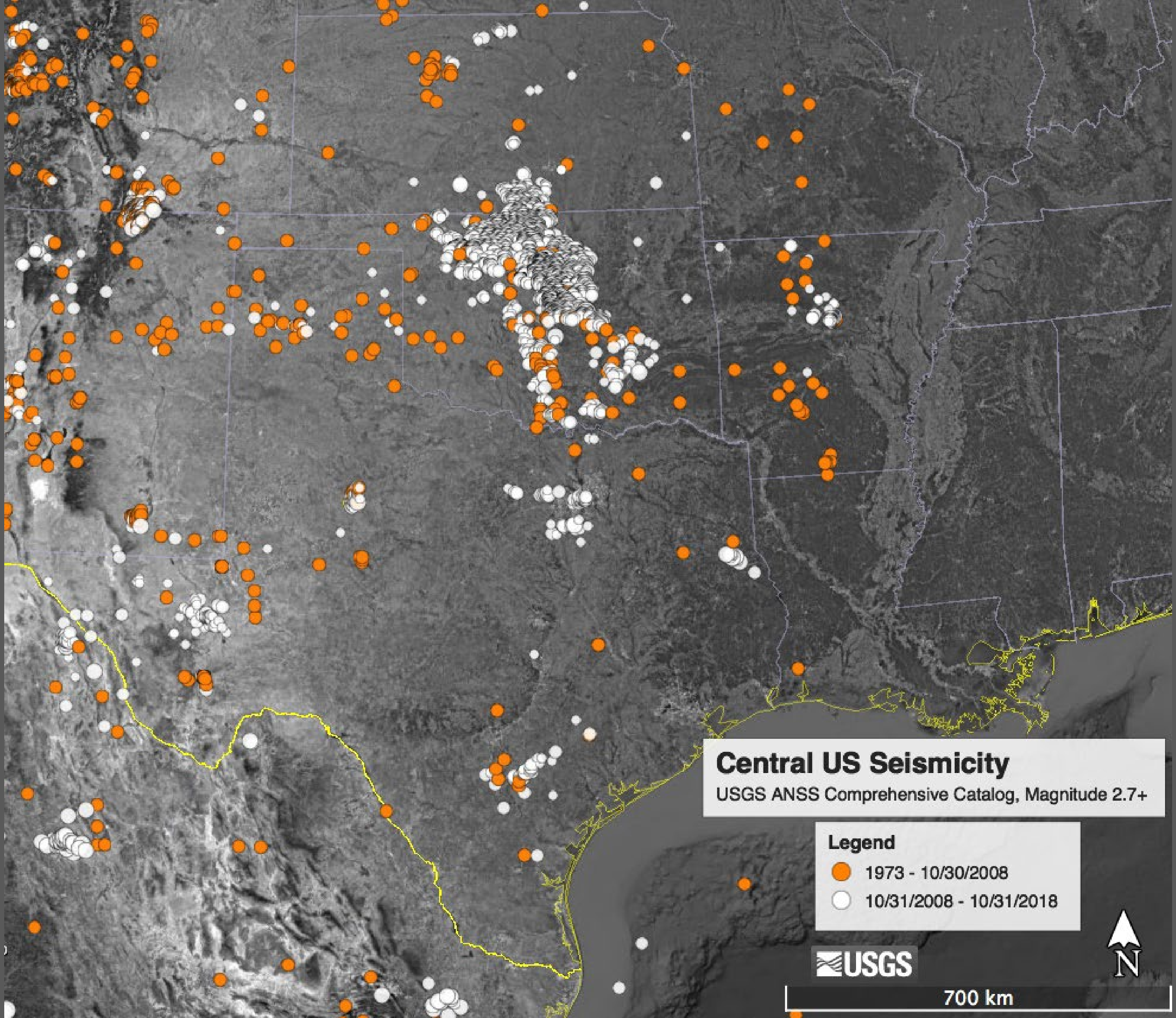
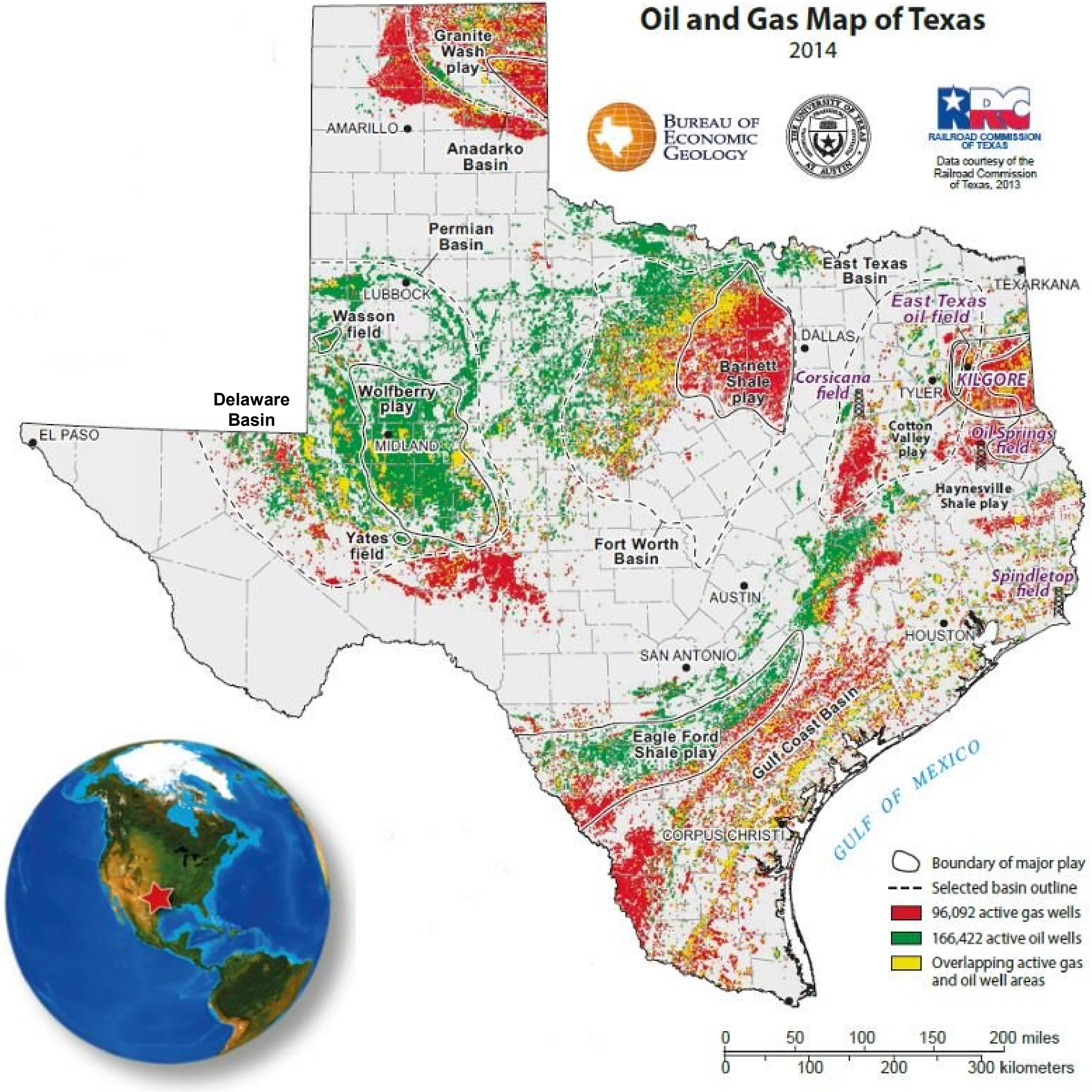
Induced Seismicity & Short-term Hazard
COSG
November 14, 2018

SMU

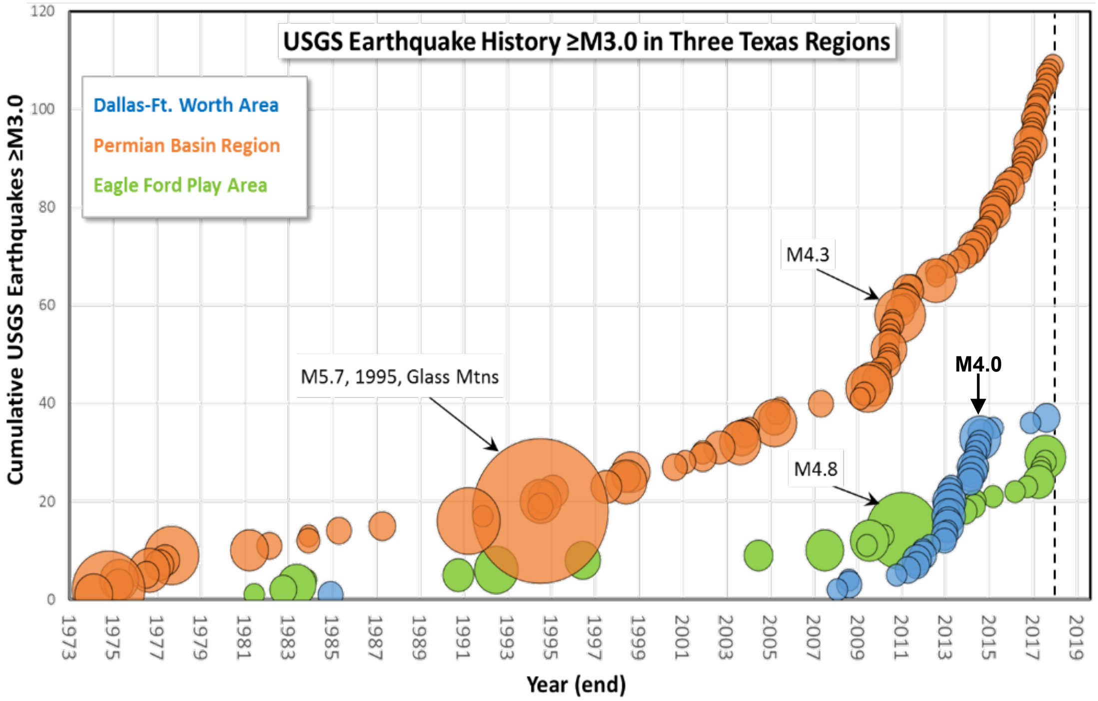


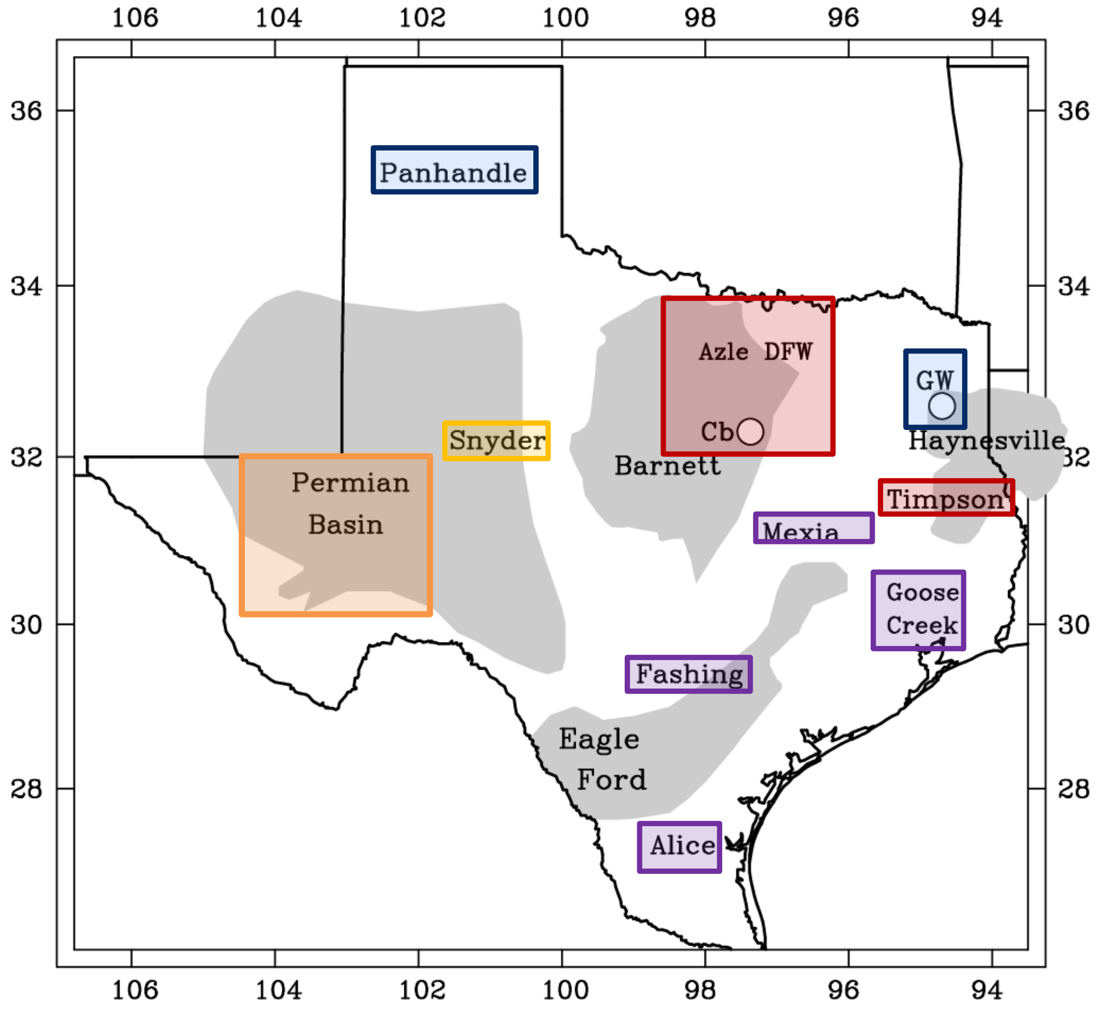
Questions to be addressed

- What do high-resolution local-scale studies reveal about induced earthquakes?
- How do hazard estimates use regional and local network information in areas of induced earthquakes?
- What are the key missing data needed to effectively estimate short-term hazard?
- What are the key missing data needed to effectively design mitigation strategies?



Increased seismicity rates since 2009 & a history of induced earthquakes





Production – Extraction

Production – ?

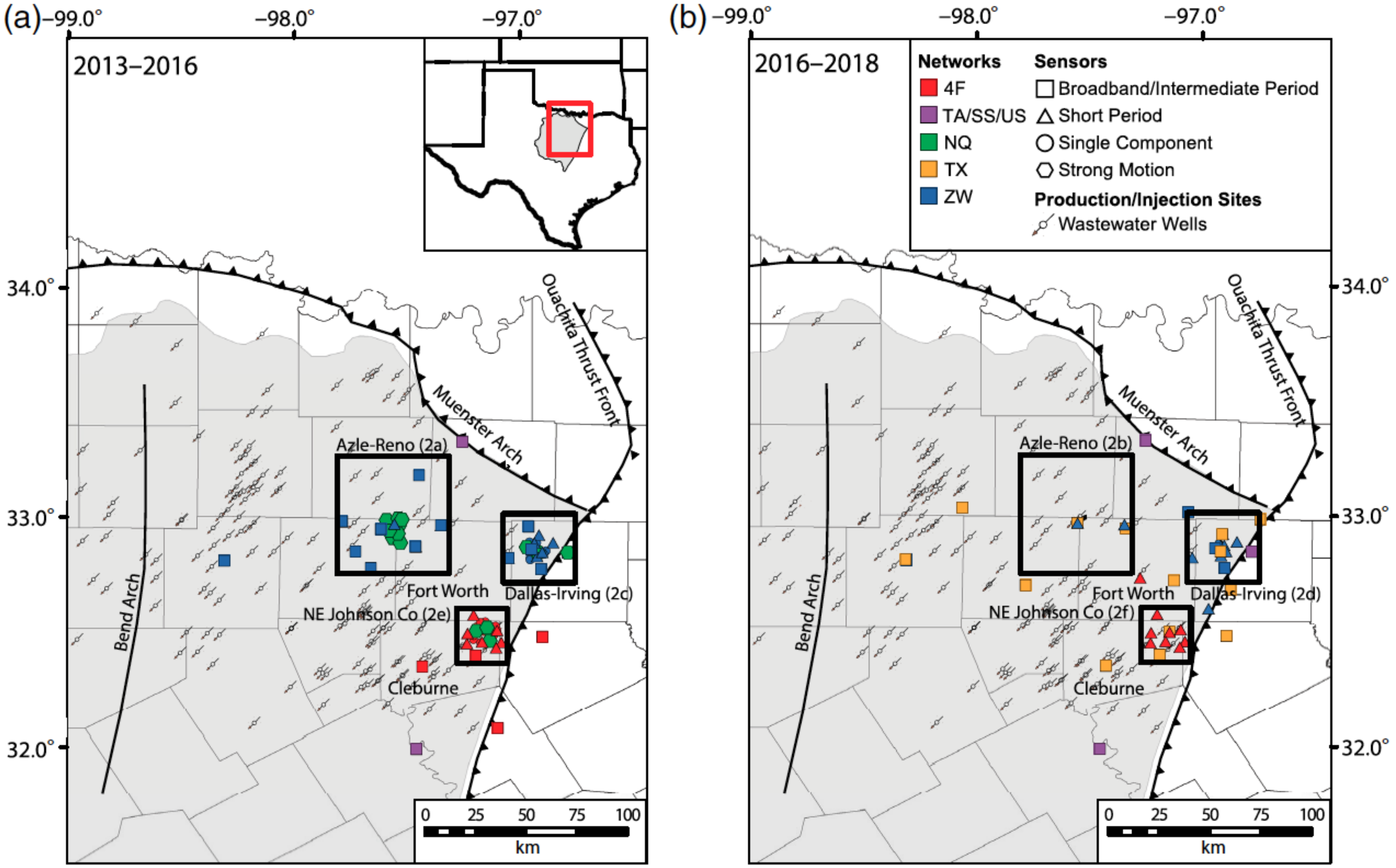
Injection – Enhanced Oil Recovery or CO_2

Injection – Wastewater disposal

Mix of induced and natural

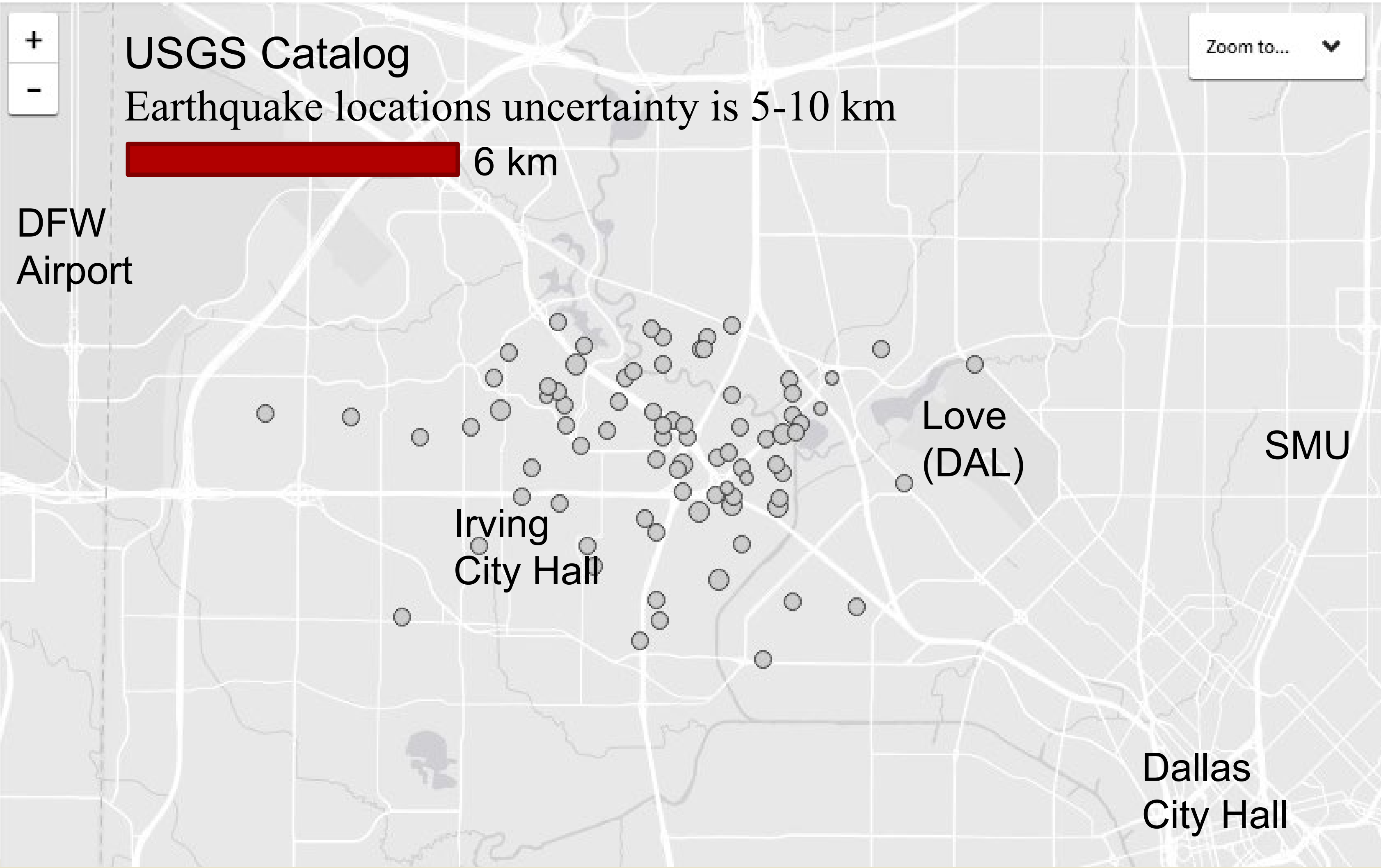
Left: Provided by Alexandros Savvaidis (TexNet); Right: modified from Frohlich et al., 2016

What do local and near-regional studies reveal about induced earthquakes relative to regional networks?



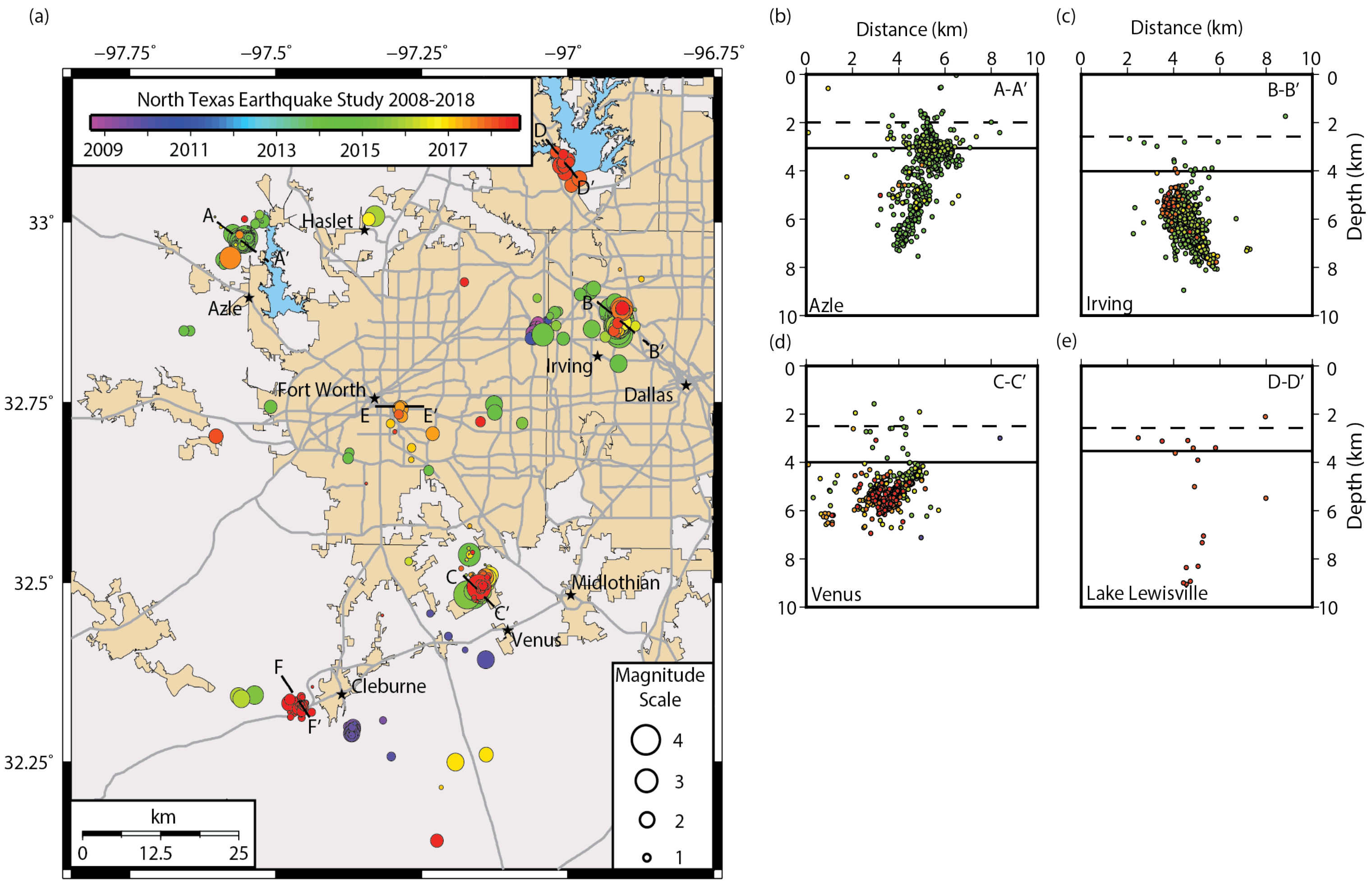
- Earthquakes in space to <1 km epicentral uncertainty
- Earthquake depth
- Earthquake source parameters (stress drop, moment, etc.)
- Earthquake recordings to lower magnitudes
- Ground motions at finer scales

Local seismic data resolves faults and fault behavior



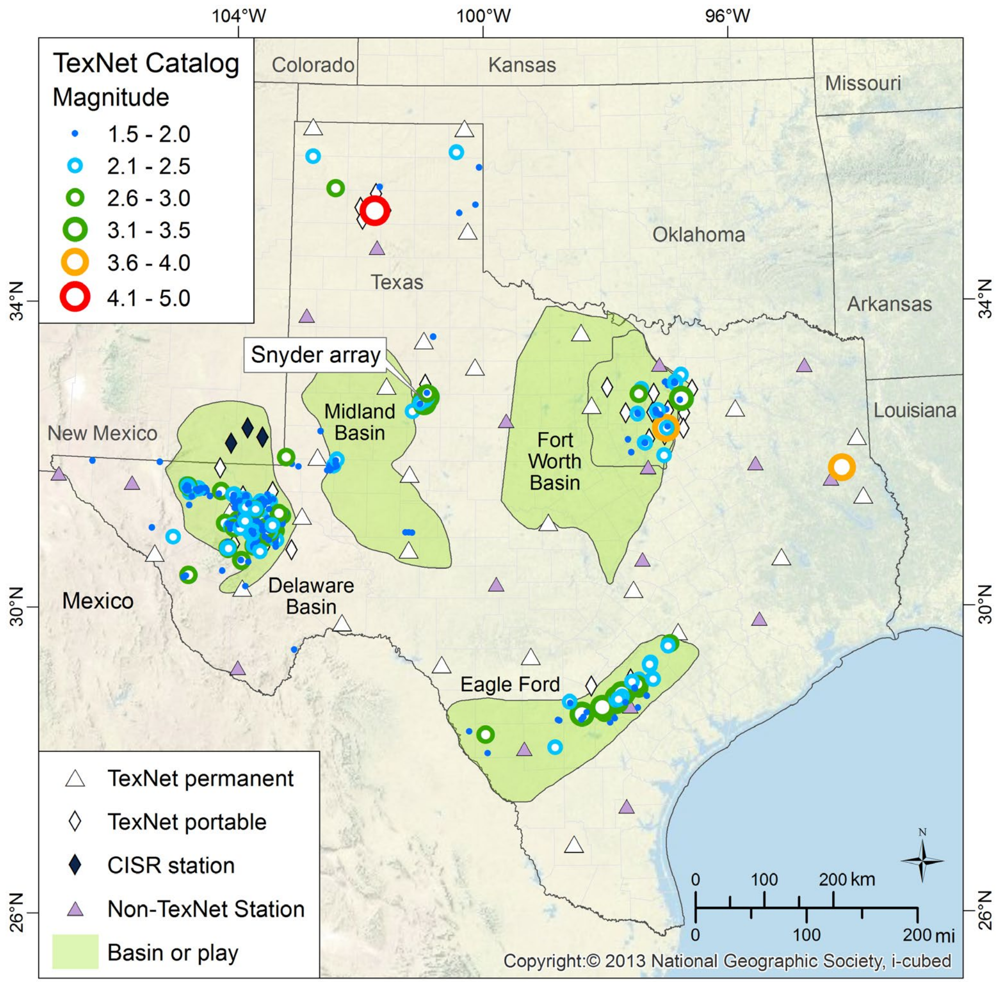
Regulations are triggered based on magnitude and distance from well, so accurate catalogs are required

- Earthquakes occur on individual faults
- Earthquakes are shallow, requiring finer station spacing to resolve depth
- Catalog requires knowledge of subsurface velocity and attenuation
- Improved spatio-temporal history allows comparison to other subsurface processes

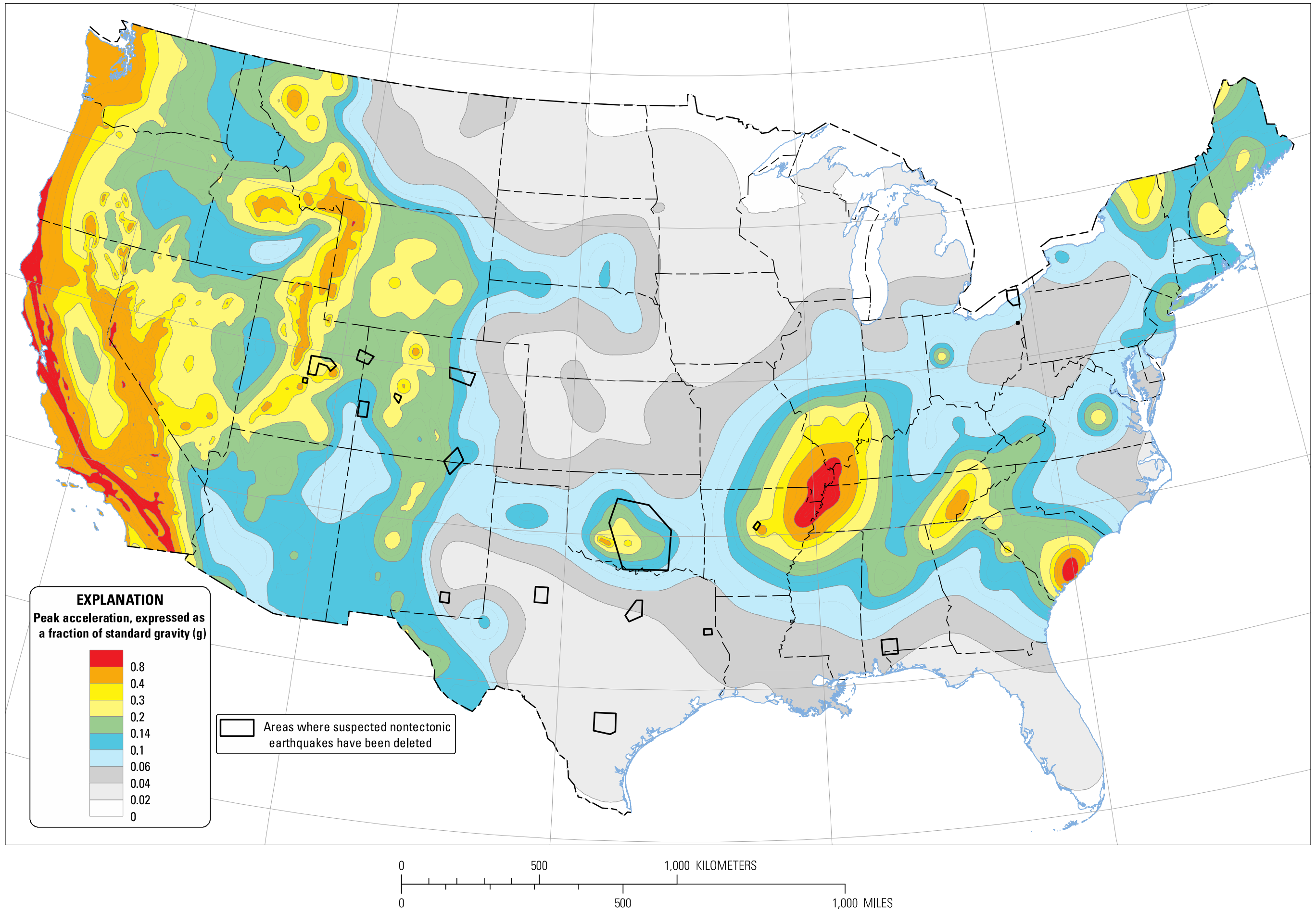


Texas funded a state-wide seismic network in 2015 (TexNet)

- Estimated magnitude of completeness in the USGS ANSS ComCat for Texas is M2.7
- 18 broadband stations in Texas prior to 2017
- By 2017, TexNet added & reduced sensitivity to M1.5
  - 25 permanent broadband seismometers
  - 33 portable systems (broadband+strong motion)
- Current temporary networks include
  - **SMU** (20 stations in FWB)
  - UTEP (nodes in Pecos) and UHouston (Midland)



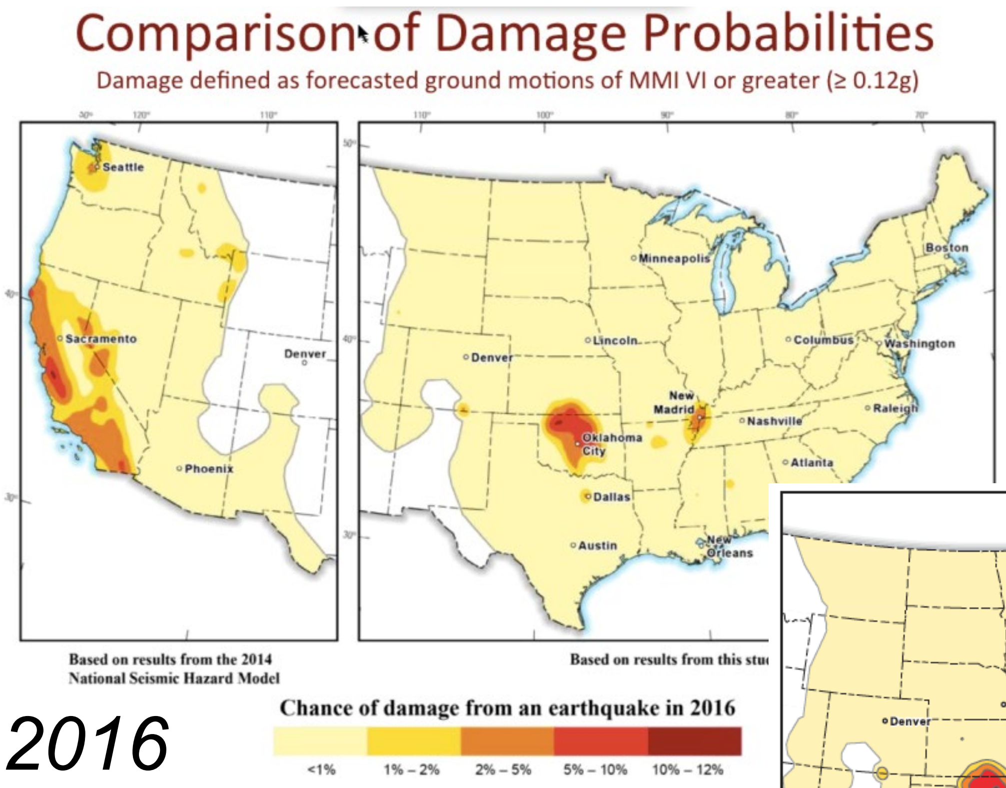
How do hazard estimates use regional and local network information in areas of induced earthquakes?



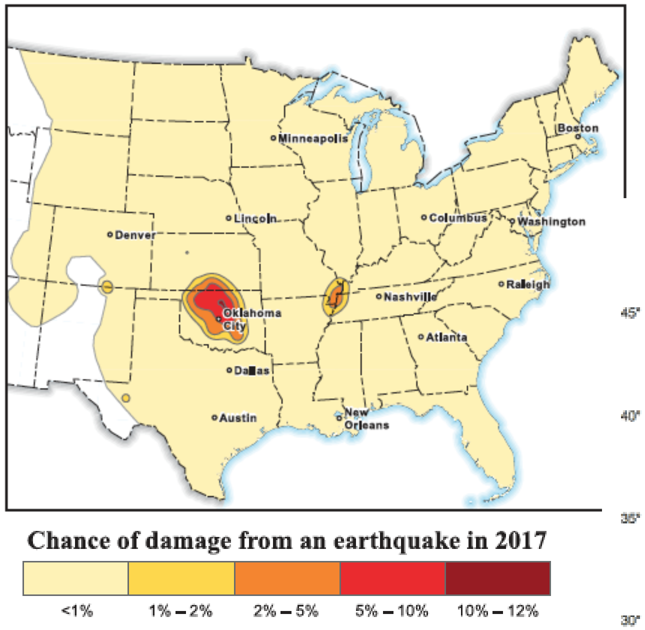
- Telemetered seismic data meeting noise standards can be used by NEIC for earthquake location
- Long-term national hazard maps use peer-reviewed determination of cause
- USGS removes induced earthquakes from the calculation to maintain a map most useful for building codes

Still need to improve the short-term hazard estimates

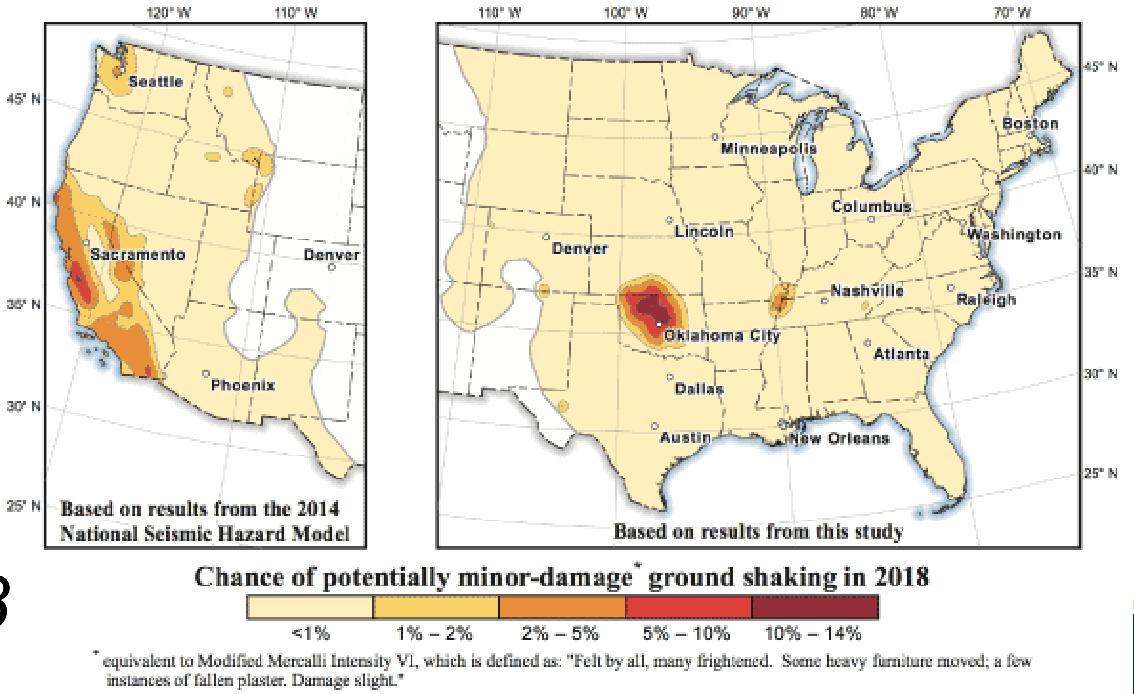
- In 2018, TX has experienced 2 M4.0
  - Amarillo (Panhandle) – MMI IV
  - South Texas (Fashing) – MMI IV
- OK has not experience any M4.0



2016



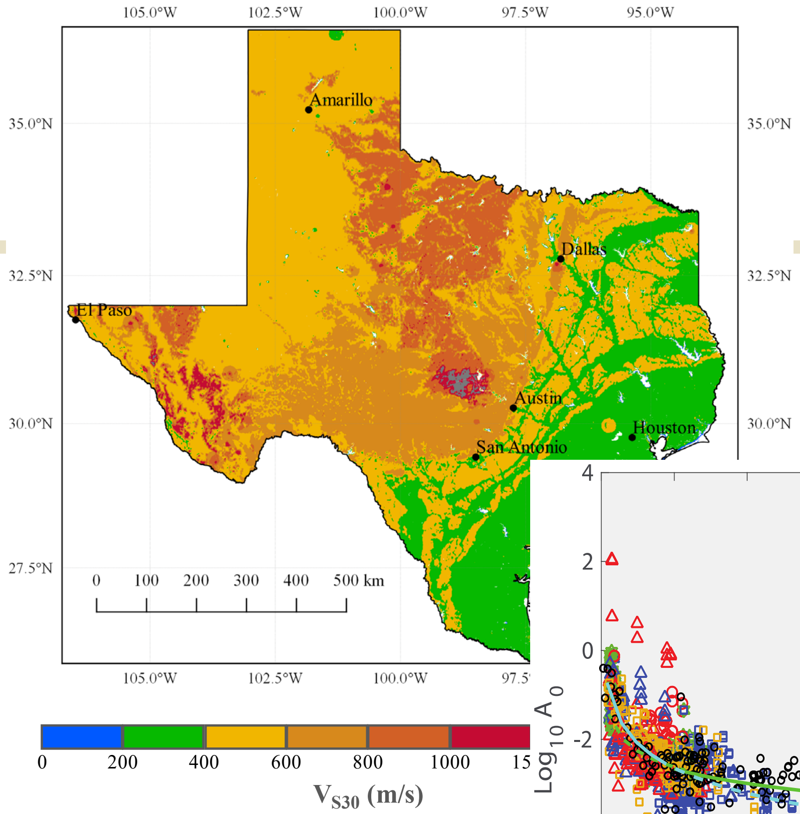
2017



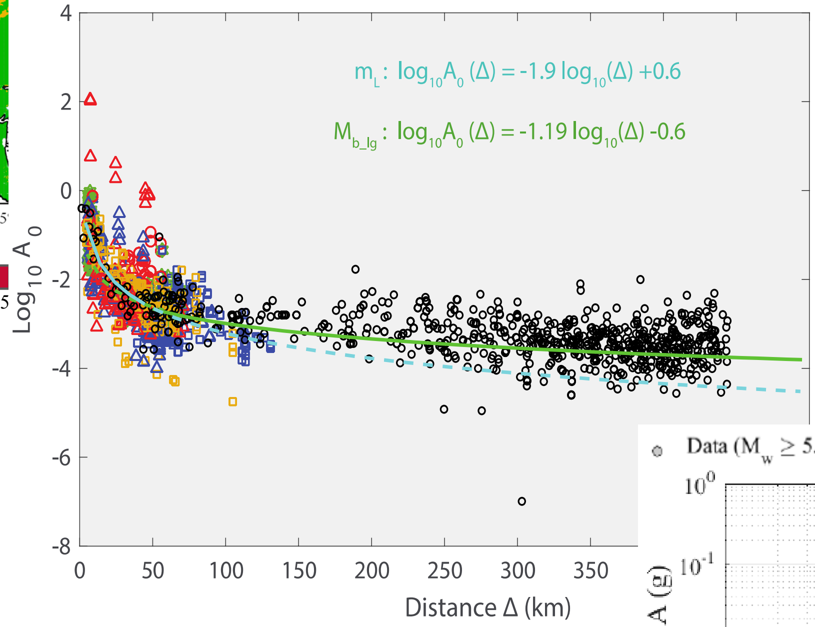
2018

Peterson et al. 2016, 2017, 2018

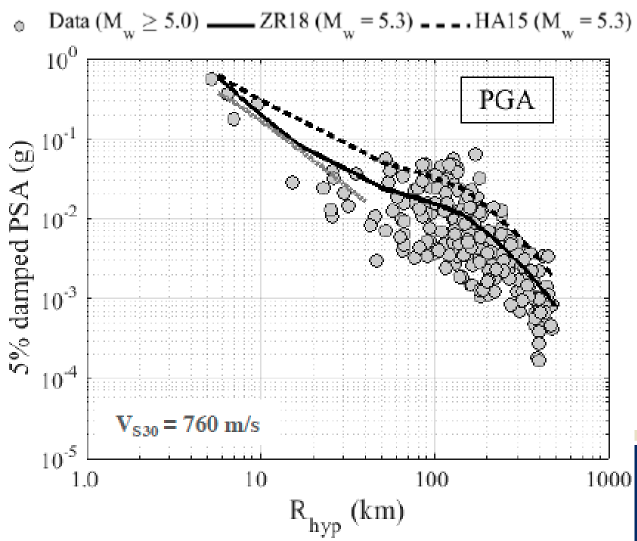
Key Data: Ground motion, near-surface velocity & moments



- V_{S30} for Texas, Oklahoma & Kansas



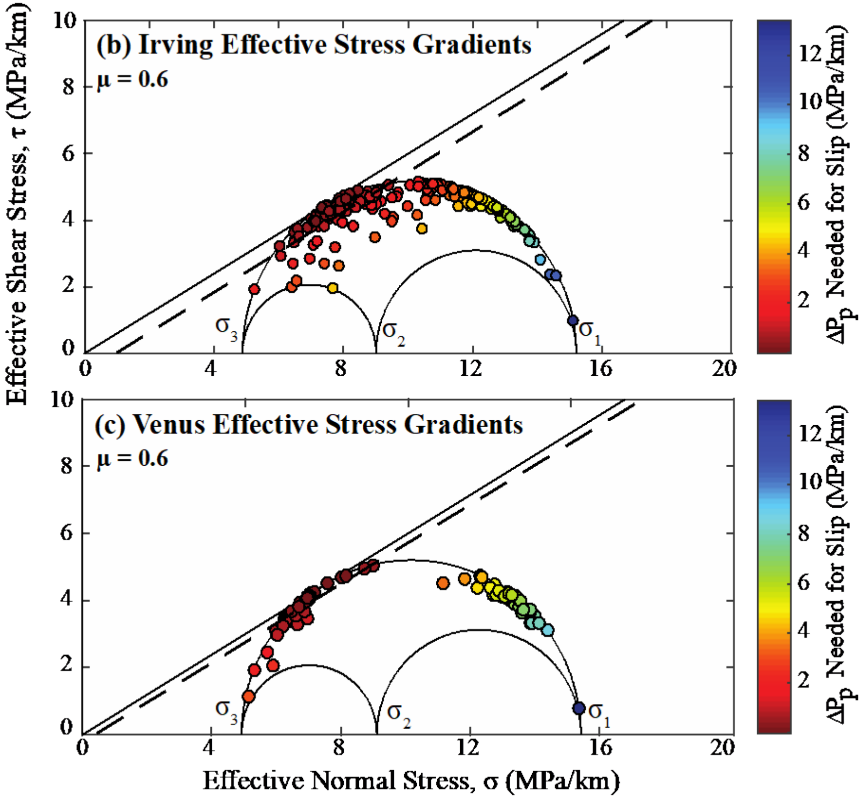
- Attenuation with distance
  - local magnitude in FWB
  - TexNet's m_L & m_{b_lg}
- Stress drops & moments in the FBW



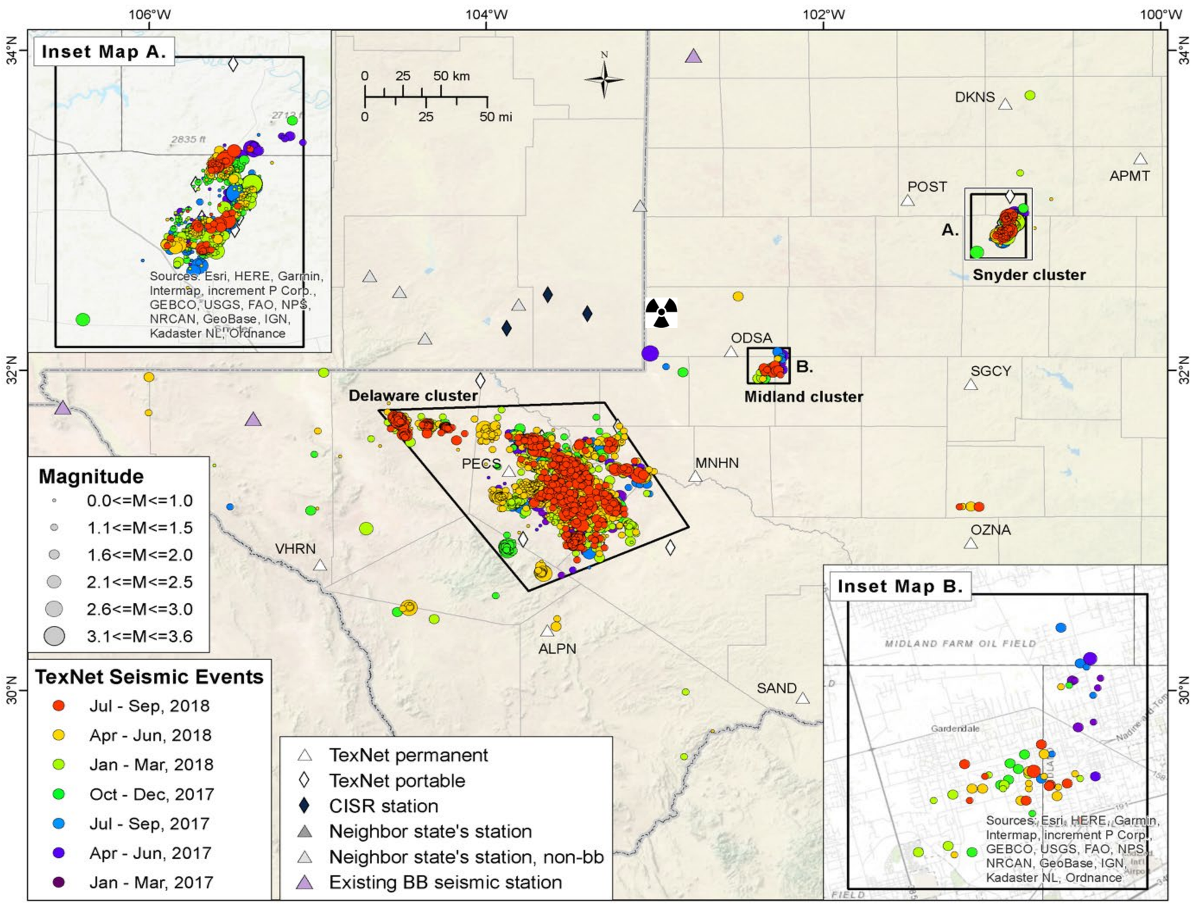
- Ground Motion Models for Texas, Oklahoma & Kansas

What are the key missing data needed to effectively design mitigation strategies and inform regulation?

- Example: 2-5 MPa changes in pore fluid pressures could trigger earthquakes on critically stressed faults in the FWB



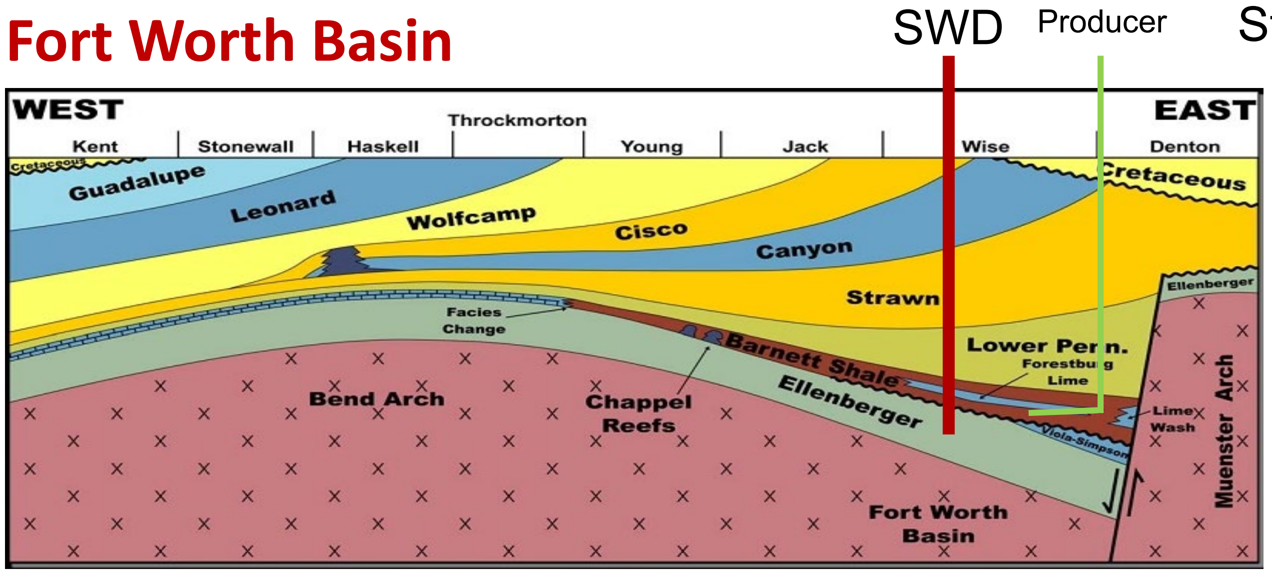
- Do these values hold for the Permian Basin?



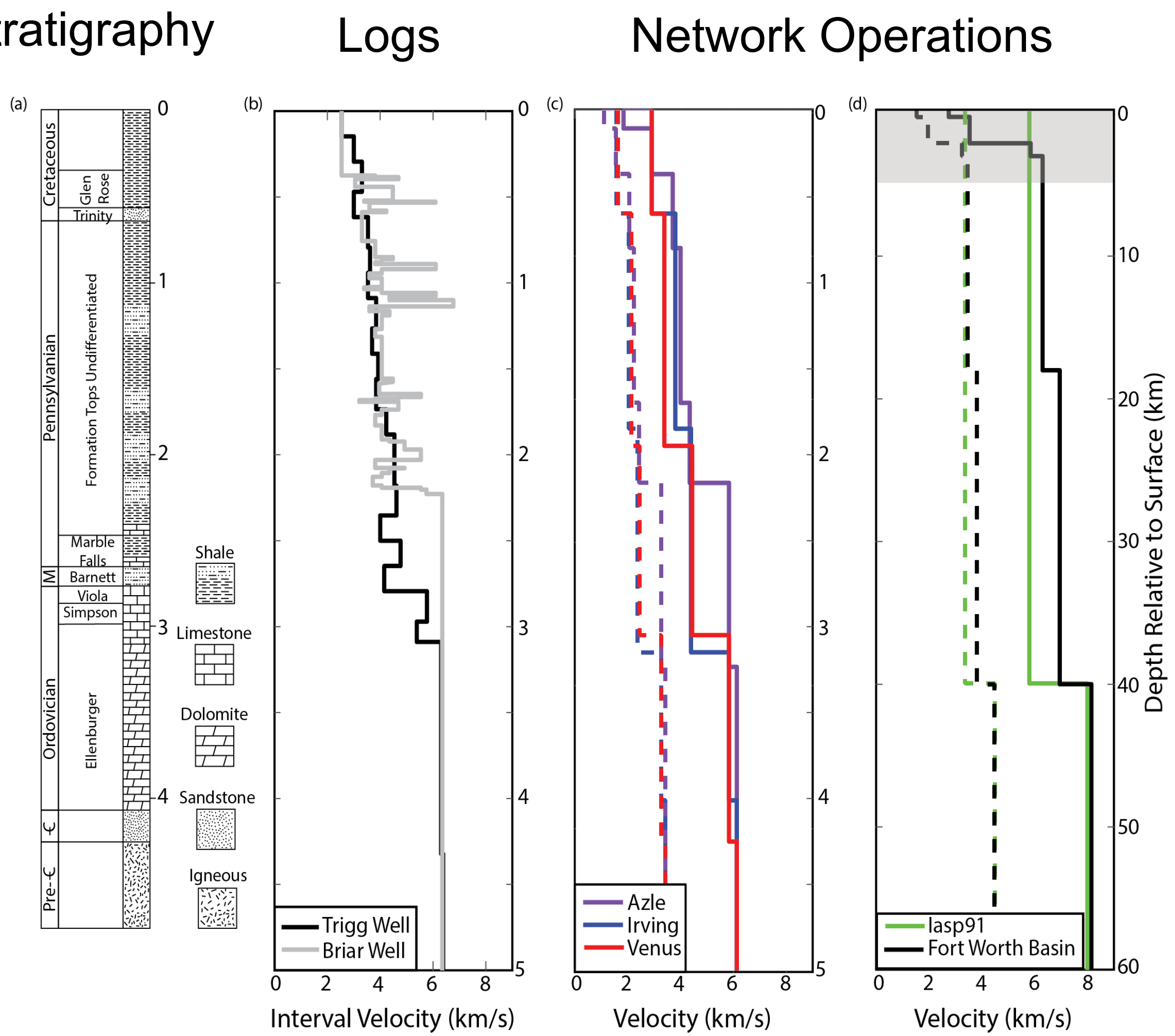
Quinones et al., 2018; provided by Alexandros Savvaidis

Key Data: Subsurface geology and velocity

Fort Worth Basin



- Well log information can inform:
  - 3D petrophysical models
  - Compressional and shear velocity models
  - Pore pressure and poro-elastic modeling



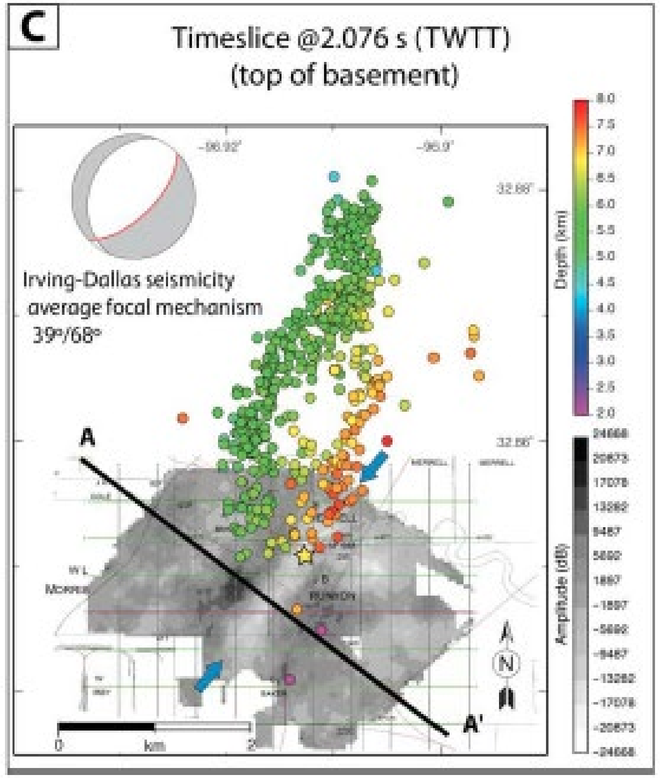
Quinones et al. (in prep)

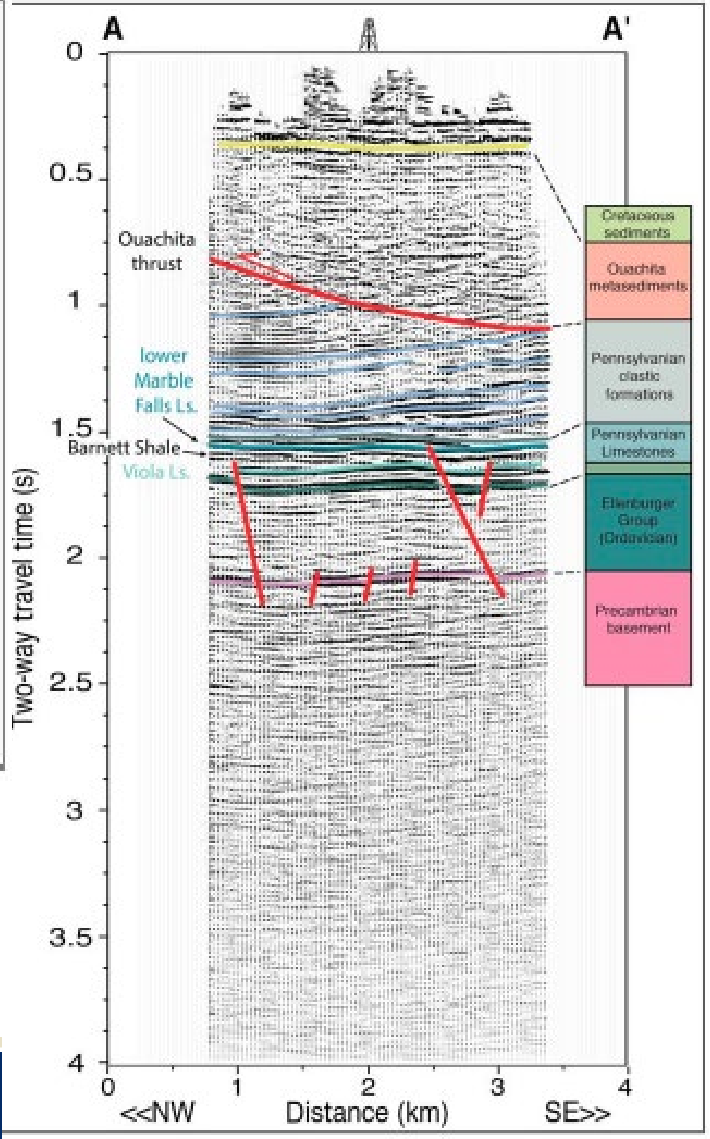
Key Data: Fault locations, areas, and deformation histories

- 3D seismic data is by far the most effective dataset but is largely missing or unavailable for detailed study

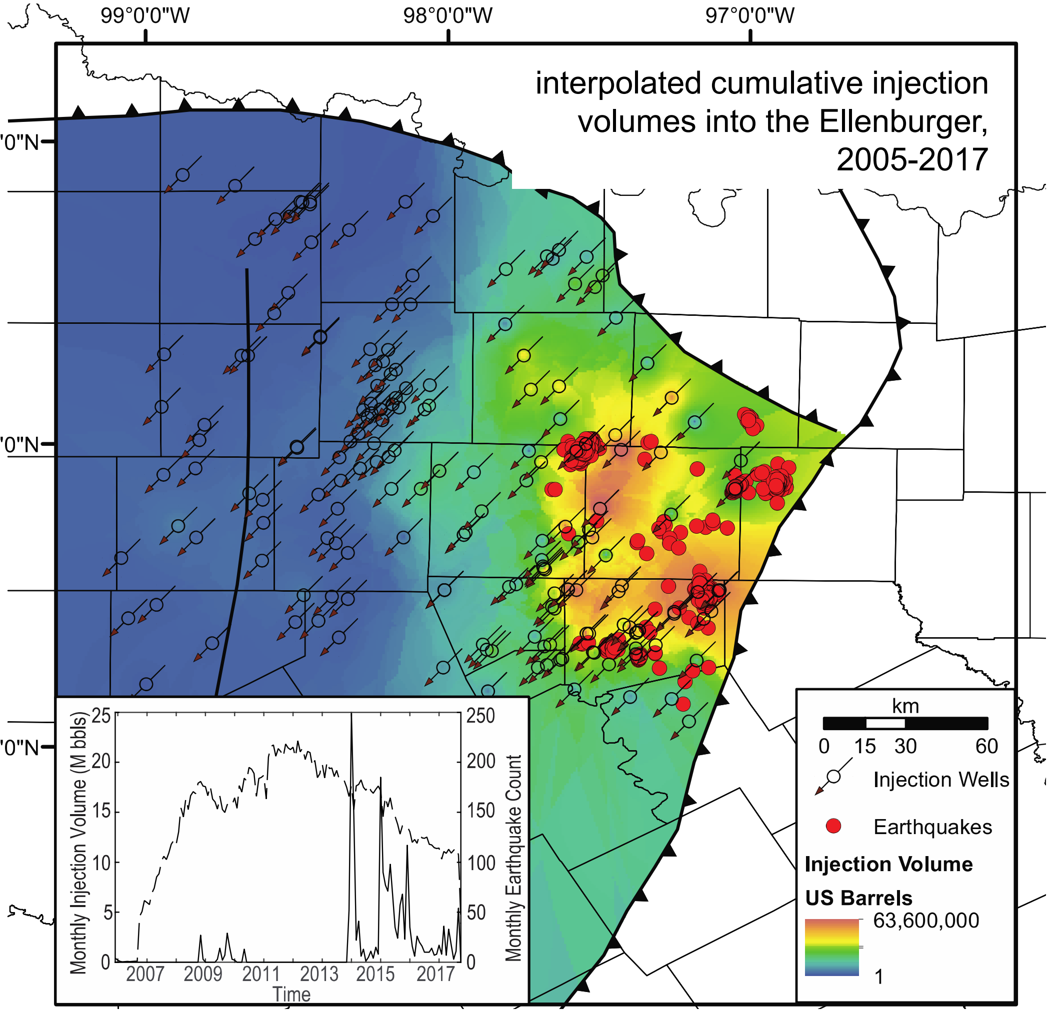
Example Results in the FWB:

- Earthquakes occur on basement rooted faults that have not measurably deformed units younger than 300 MA
- The seismogenic faults are identical to neighboring faults that have no seismicity
- What is the permeability of these faults?





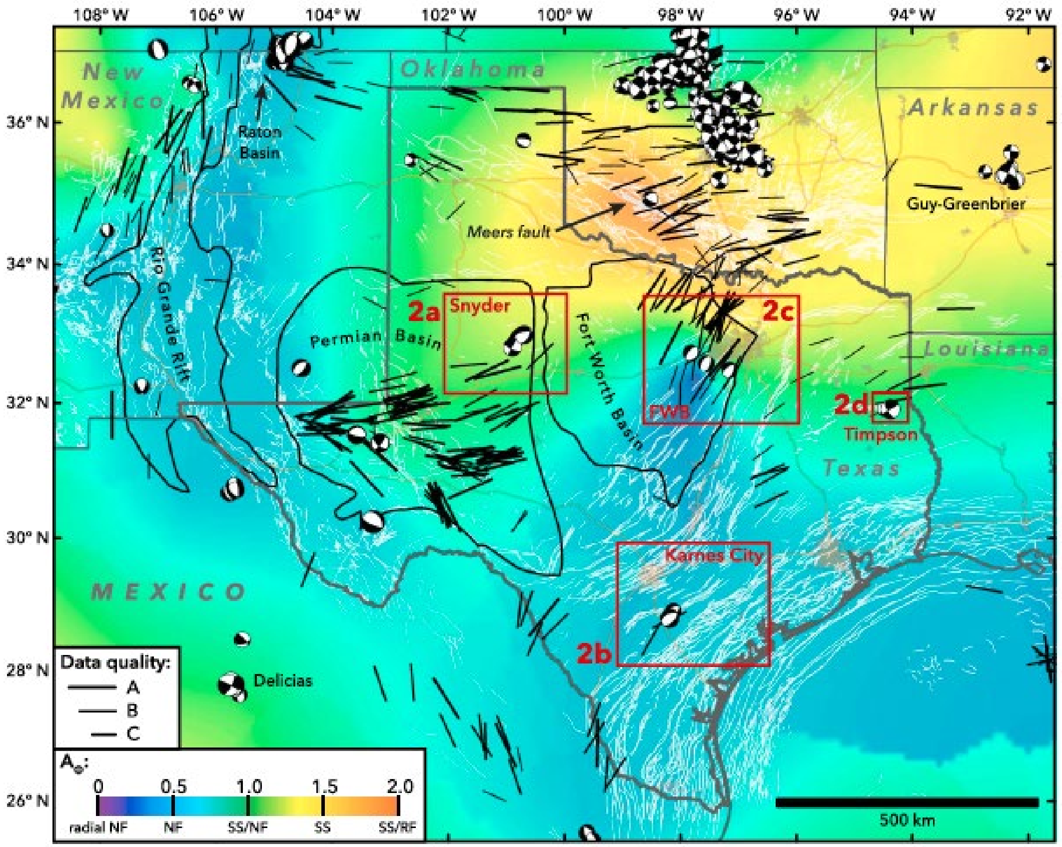
Key Data: Injection and production data



- Time and space correlation is not sufficient to understand physical processes in the subsurface
- Need to track local and regional subsurface pressure changes in both space and time
- Data needs include:
  - Daily injection volumes and pressures
  - Downhole pressure or fall-off tests
  - Fluid production information (oil, gas & water)
  - Properties of the fluids and the source rock

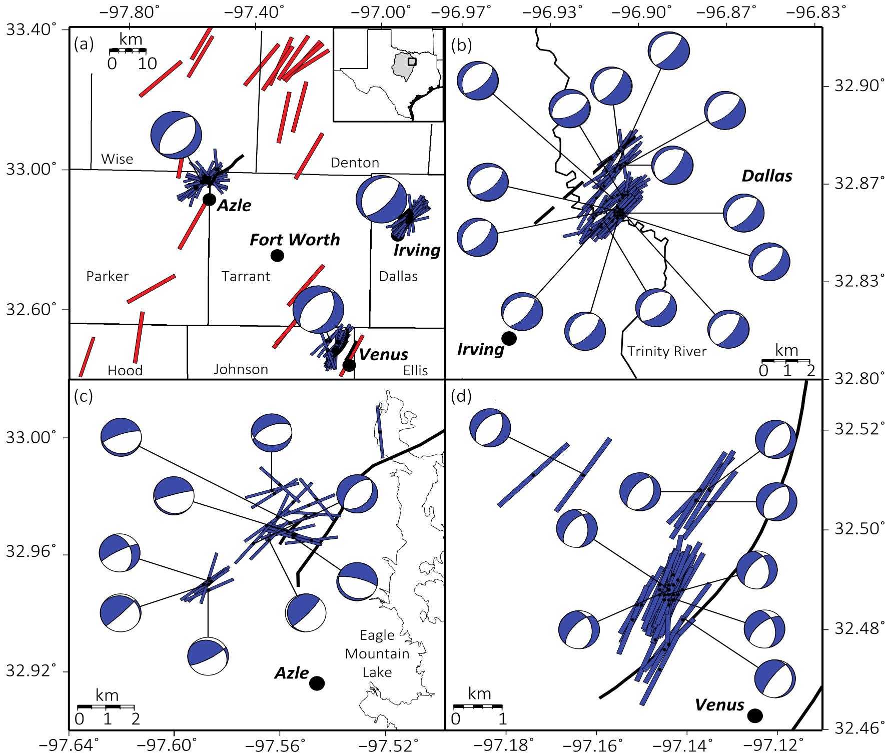
Modified from Hornbach et al., 2016 in Quinones et al. (in prep)

Key Data: Regional and *in situ* stress state



- $A\phi$ estimates preferred faulting style within the stress regime (colors)

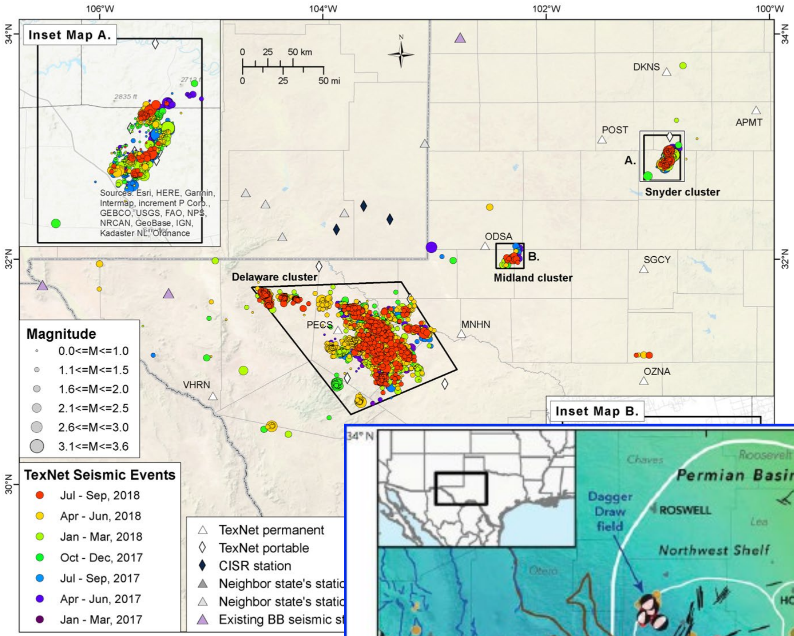
- What faults are critically stressed and what percentage of earthquakes actually occur on those faults?

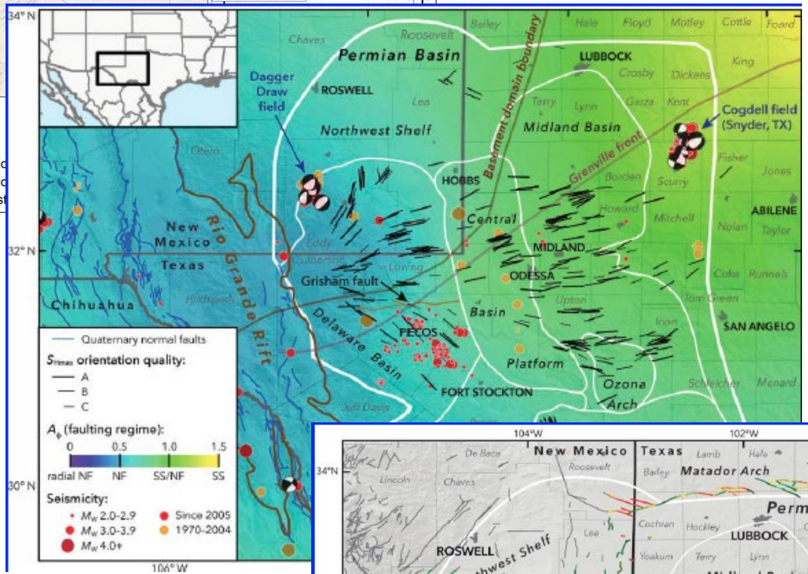


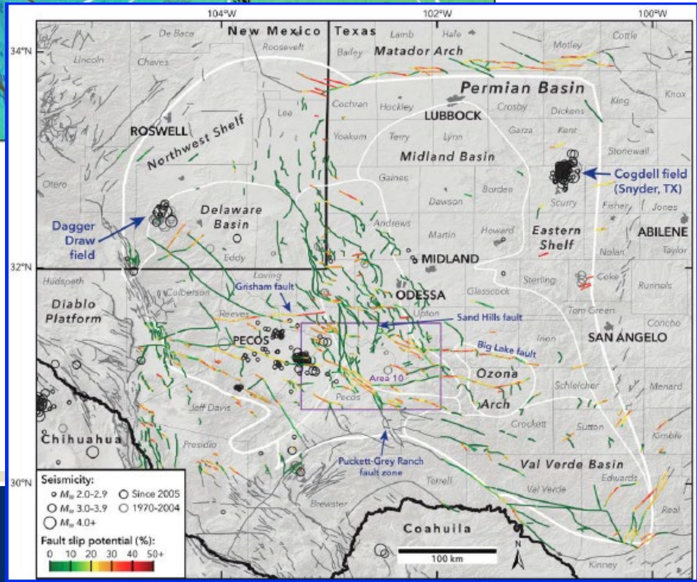
Summary

- Monitor
- Research
- Mitigate

- Near-regional and local datasets are required to provide spatial and temporal resolution necessary to address cause
- We know enough to realize the short-term hazard methodologies are incomplete
- Earthquake mitigation is possible but is DATA limited
- Regulatory agencies and national seismic hazards maps rely on the peer-reviewed publication system







Thank You!

Co-authors of FWB studies
Louis Quinones, Paul Ogwari, Monique Scales, Oner Sufri

Chris Hayward, Matt Hornbach, Beatrice Magnani, Brian Stump,

Jake Walter, Cliff Frohlich, Peter Hennings, Alexandros Savvaidis, Jens Lund Snee

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