

Monitoring Surface Deformation at an Enhanced Oil Recovery Site

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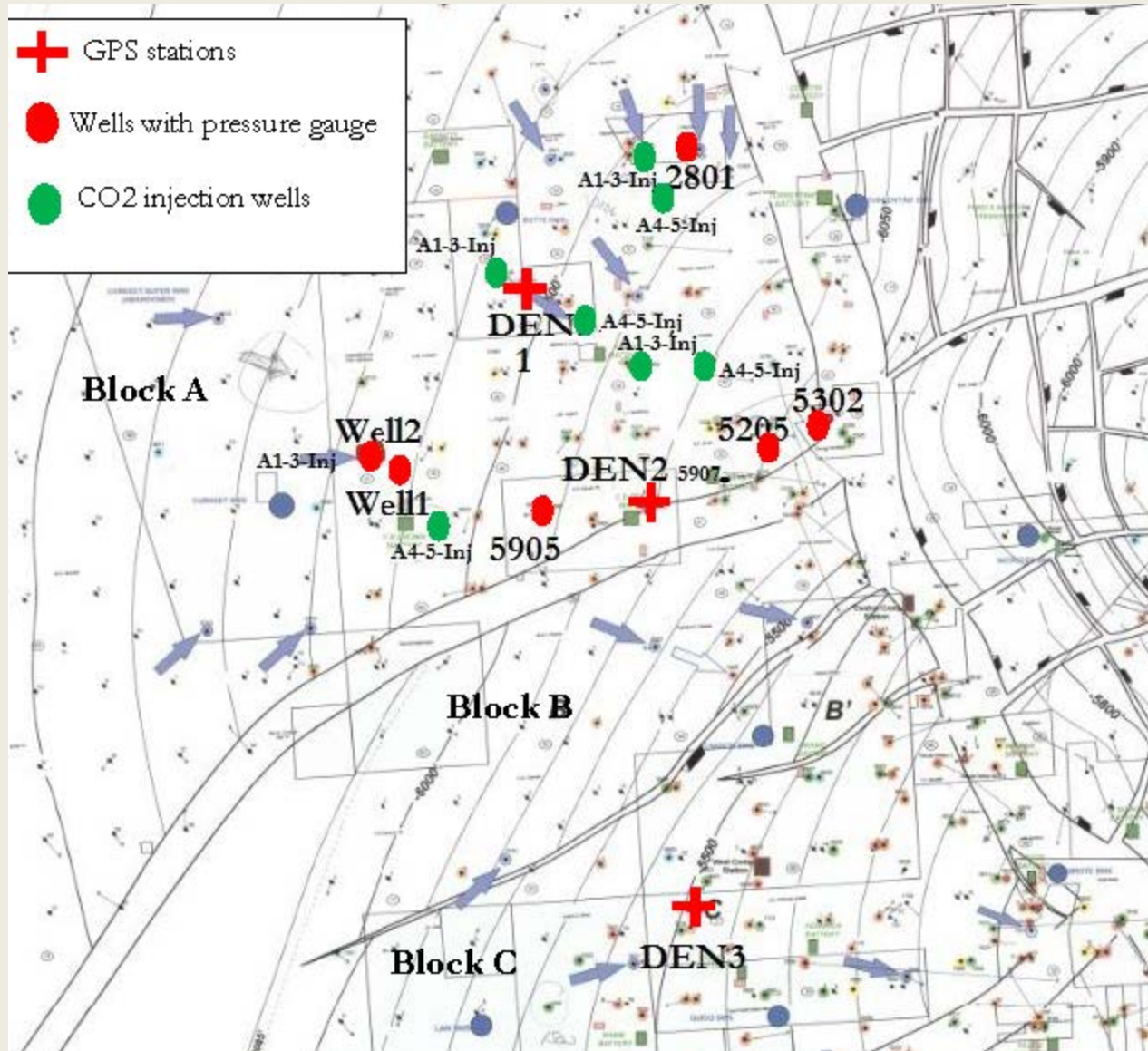
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Surface Deformation - Background

- Surface deformation (eg measured by GPS or InSAR) is sensitive to pressure changes in the reservoir at depth
- Potentially useful as a low cost tool for monitoring, verification, accounting for CO₂ injection and storage (non-invasive)
- Surrogate for downhole pressure monitoring?
- Challenge – separating signal from a variety of noise sources

Study Site: Hastings, Texas



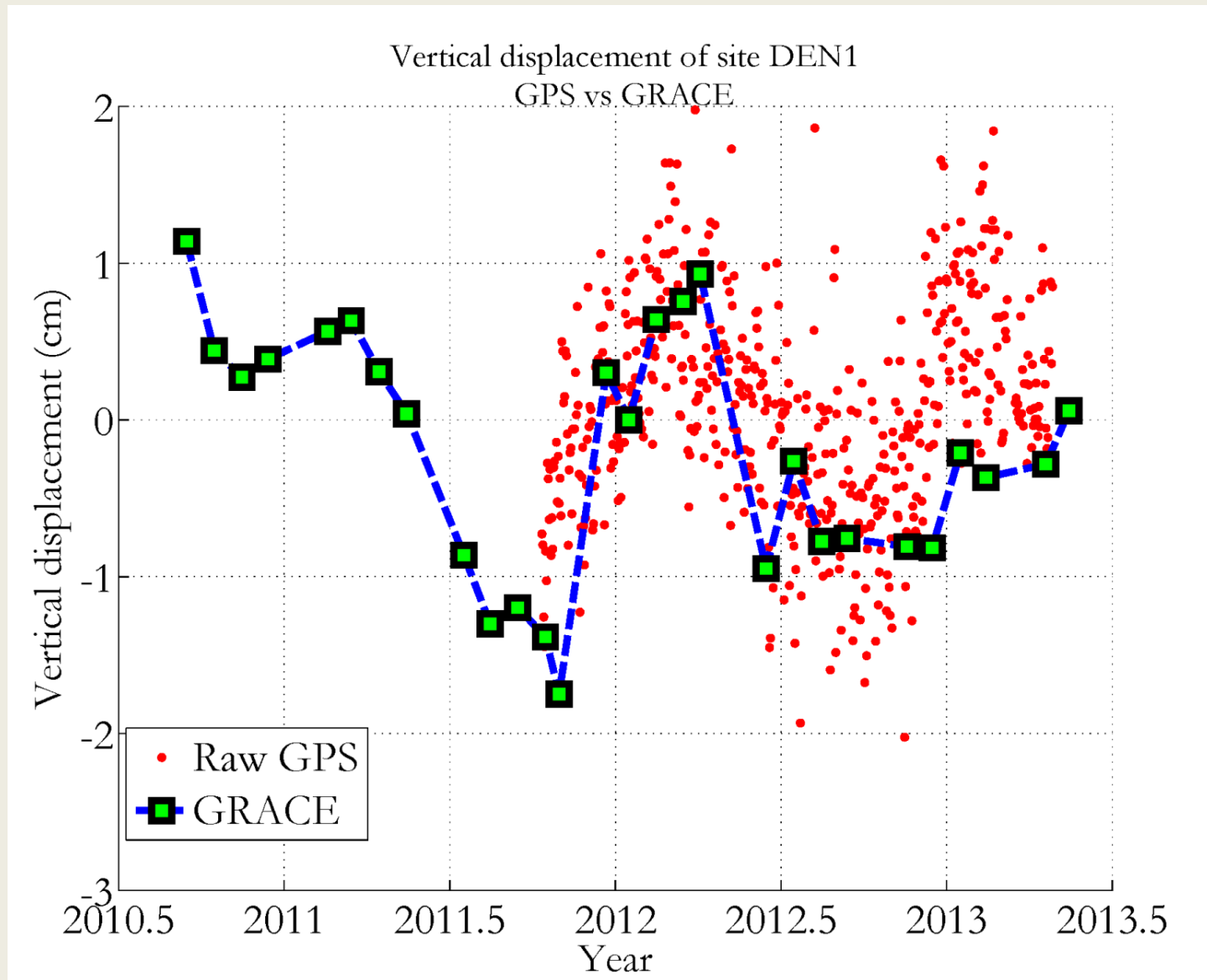
Deformation sources in the Gulf Coast

- CO₂ or saline water injection, oil extraction at the site of interest
- Regional ground water table variation associated with wet/dry season
- Local ground water variation due to pumping
- Extraction of oil, natural gas from adjacent fields
- Salt tectonics

Other Challenges

- In addition to multiple deformation sources, microwave techniques (InSAR, GPS) are highly sensitive to atmospheric water vapor (major noise source)
- Bottom line: Gulf Coast is not an optimum place for surface deformation monitoring

Comparison of GPS and GRACE time series

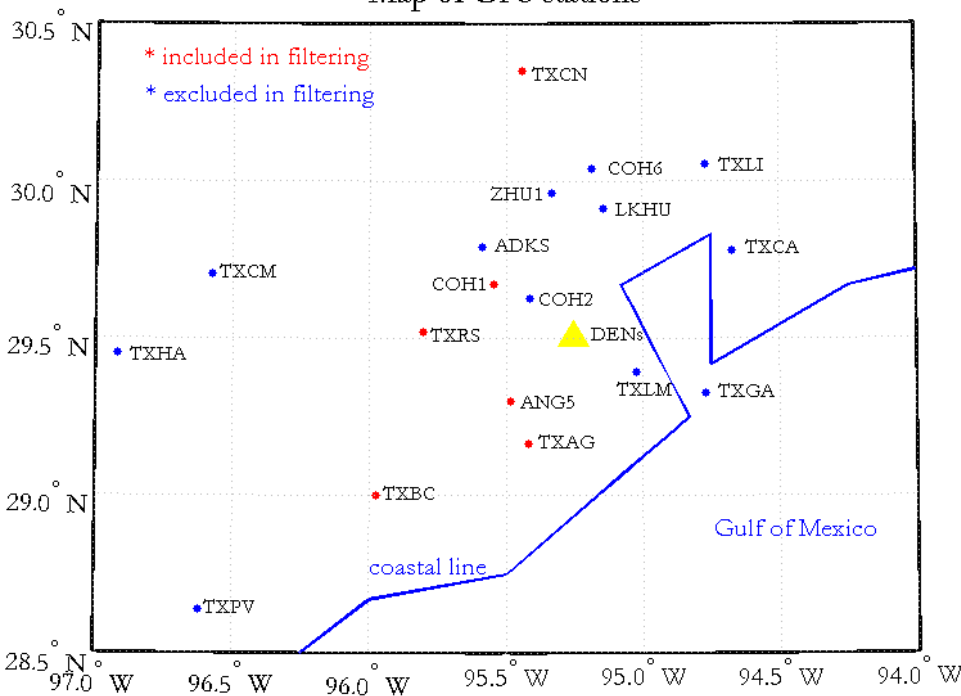


Approach

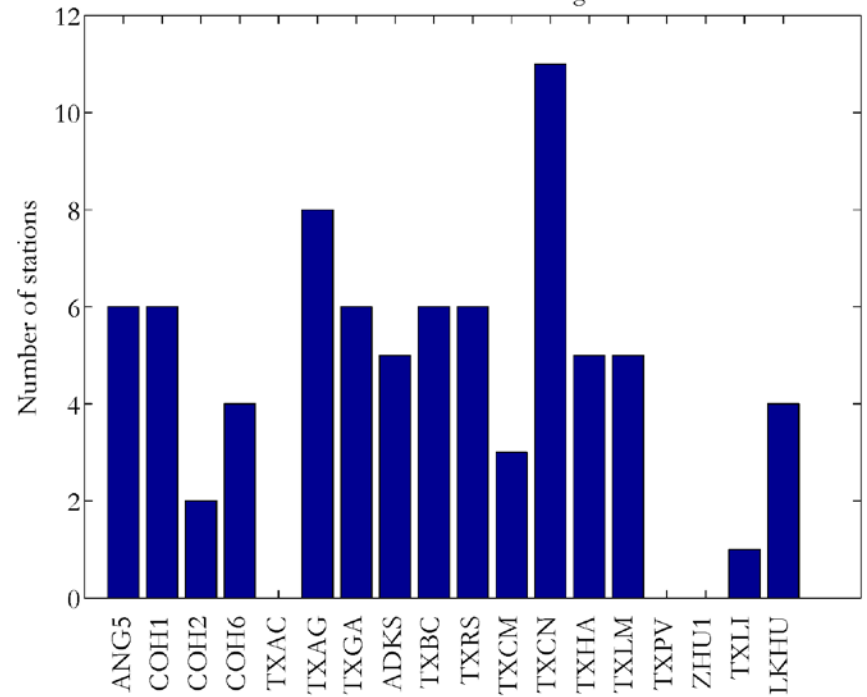
- Use nearby stations as reference to define and subtract common mode (regional) signal
- Problem: some nearby stations also respond to local deformation sources (eg groundwater pumping)
- Solution: correlation analysis distinguishes local and regional signals

Correlation analysis of potential reference stations

Map of GPS stations

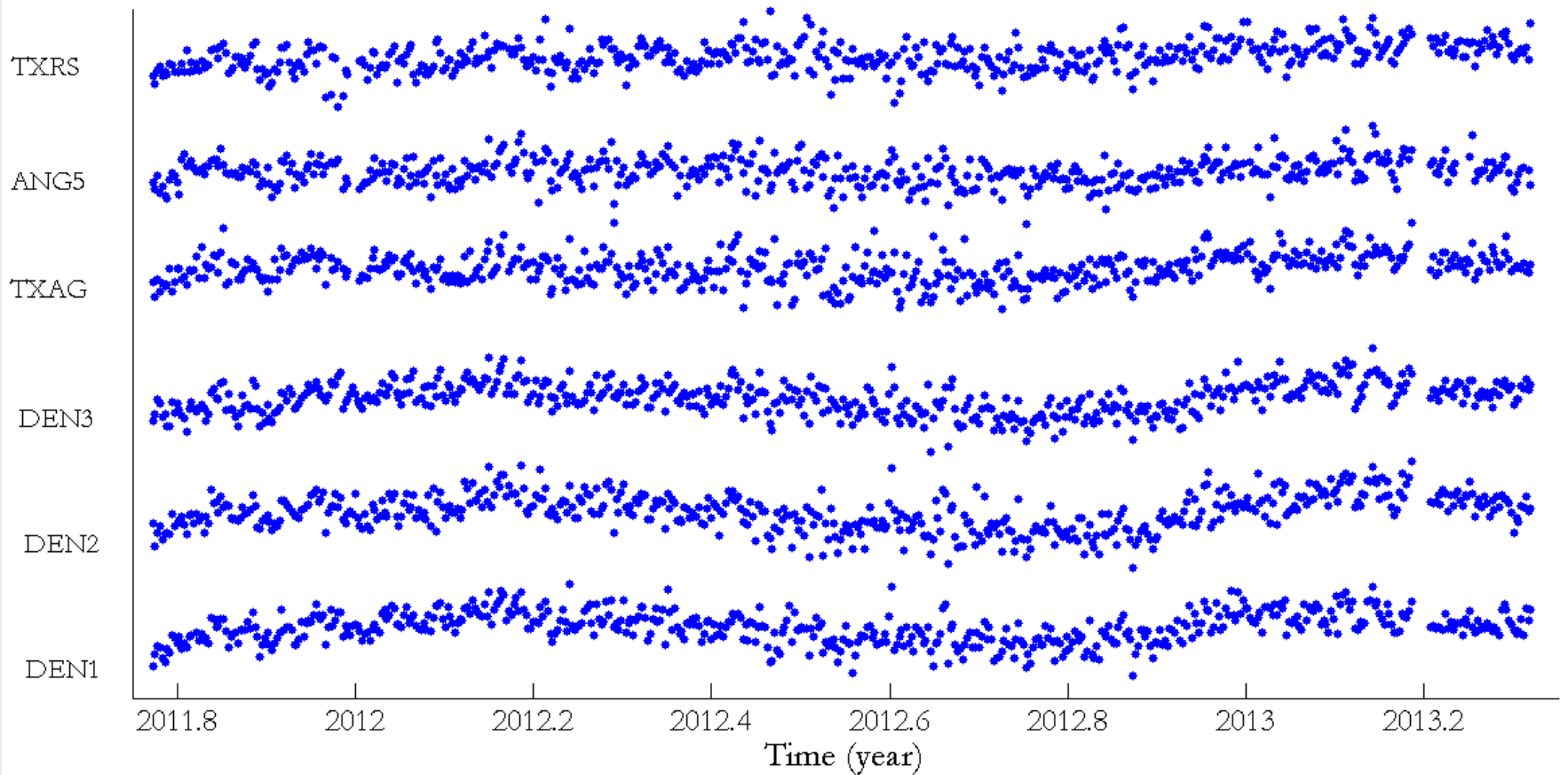


Number of stations with correlation greater than 0.5



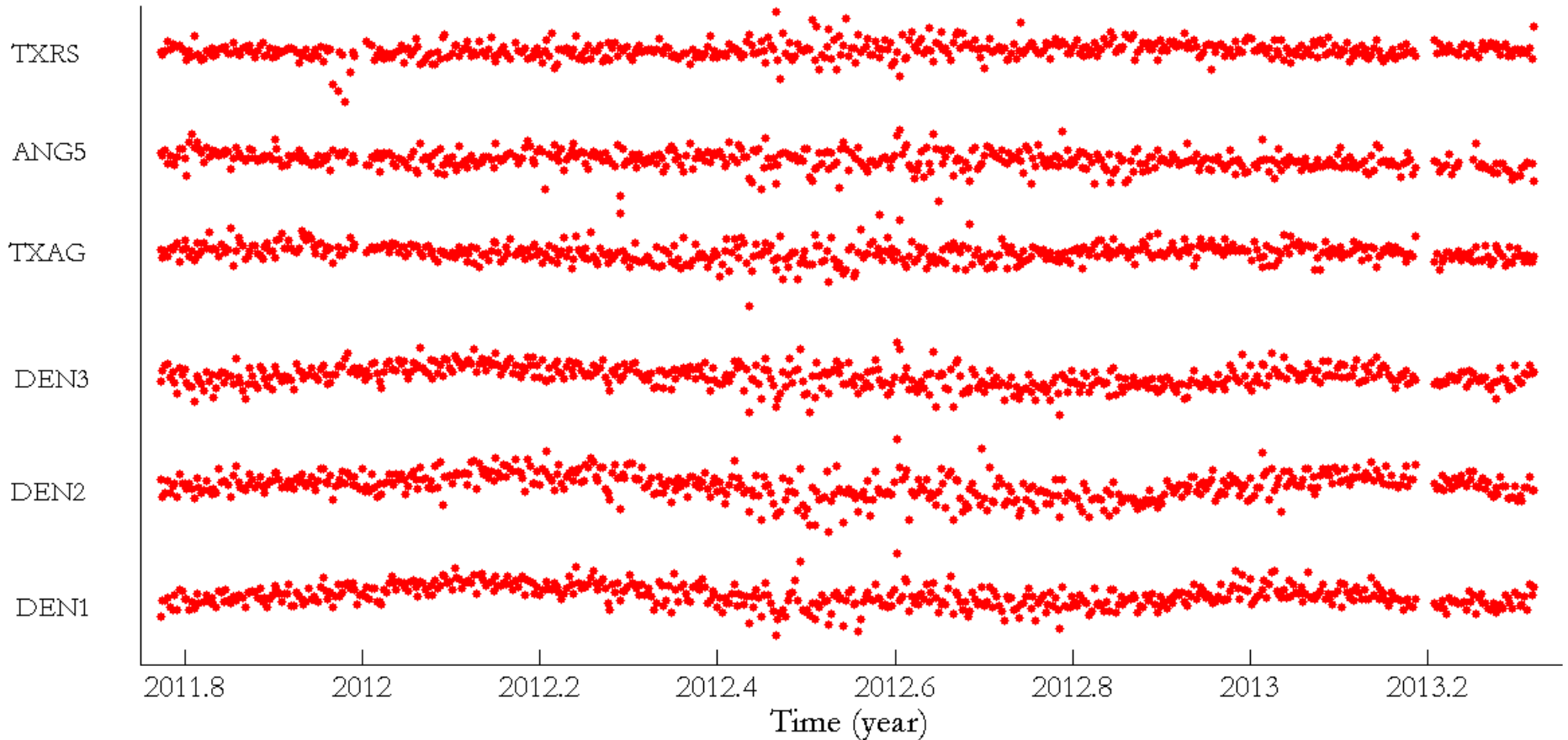
Raw time series

raw time series, vertical component

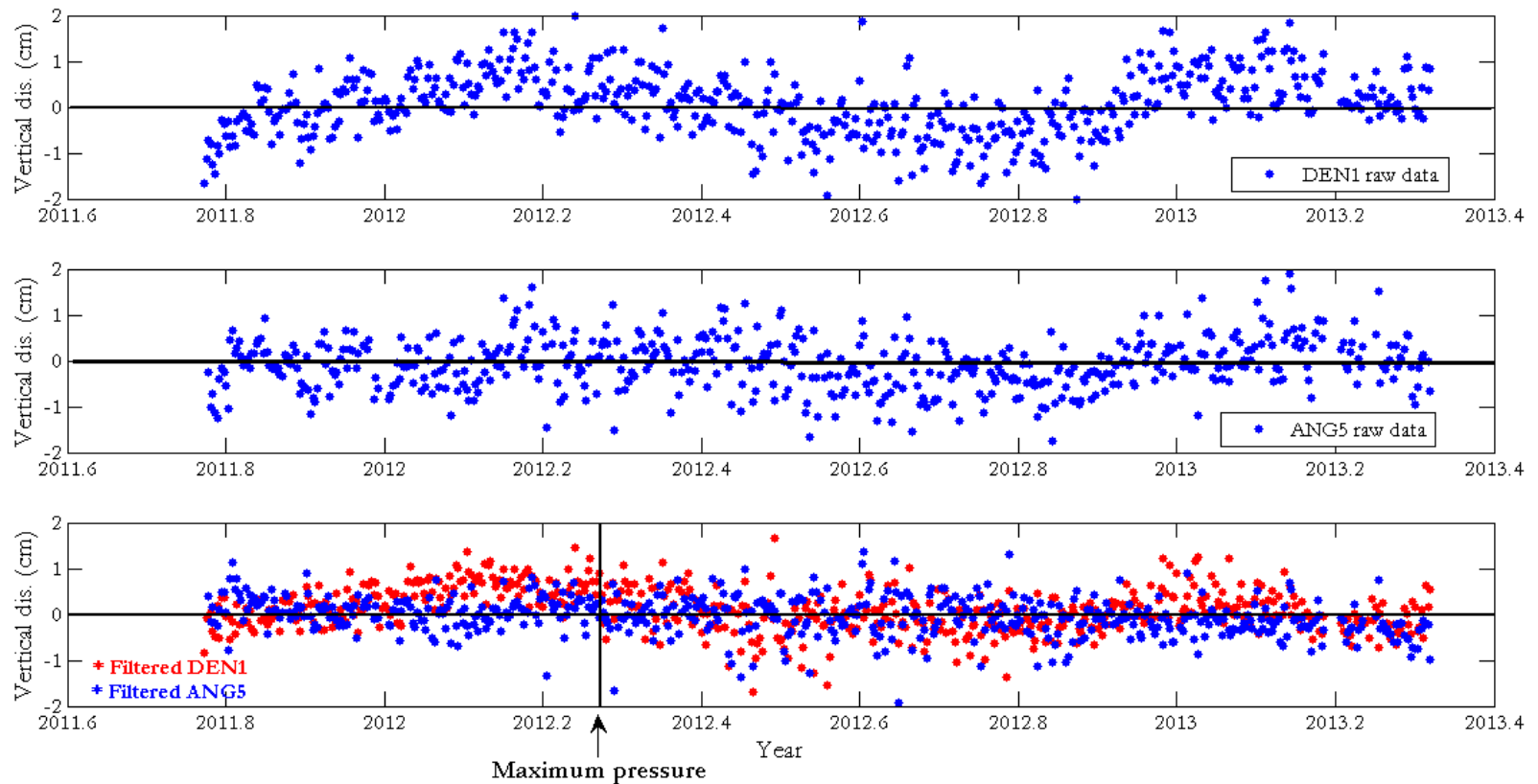


Filtered time series

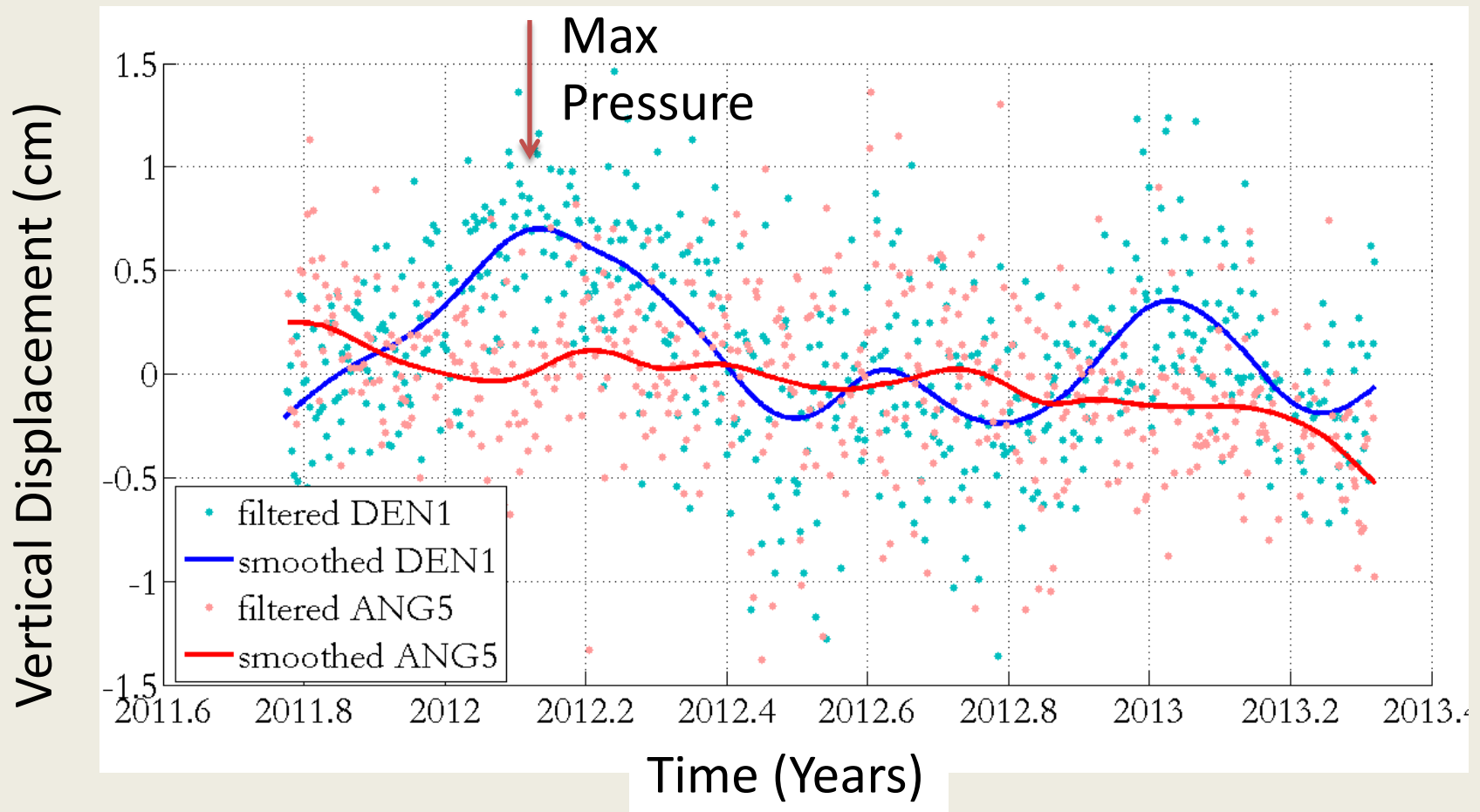
filtered time series, vertical component



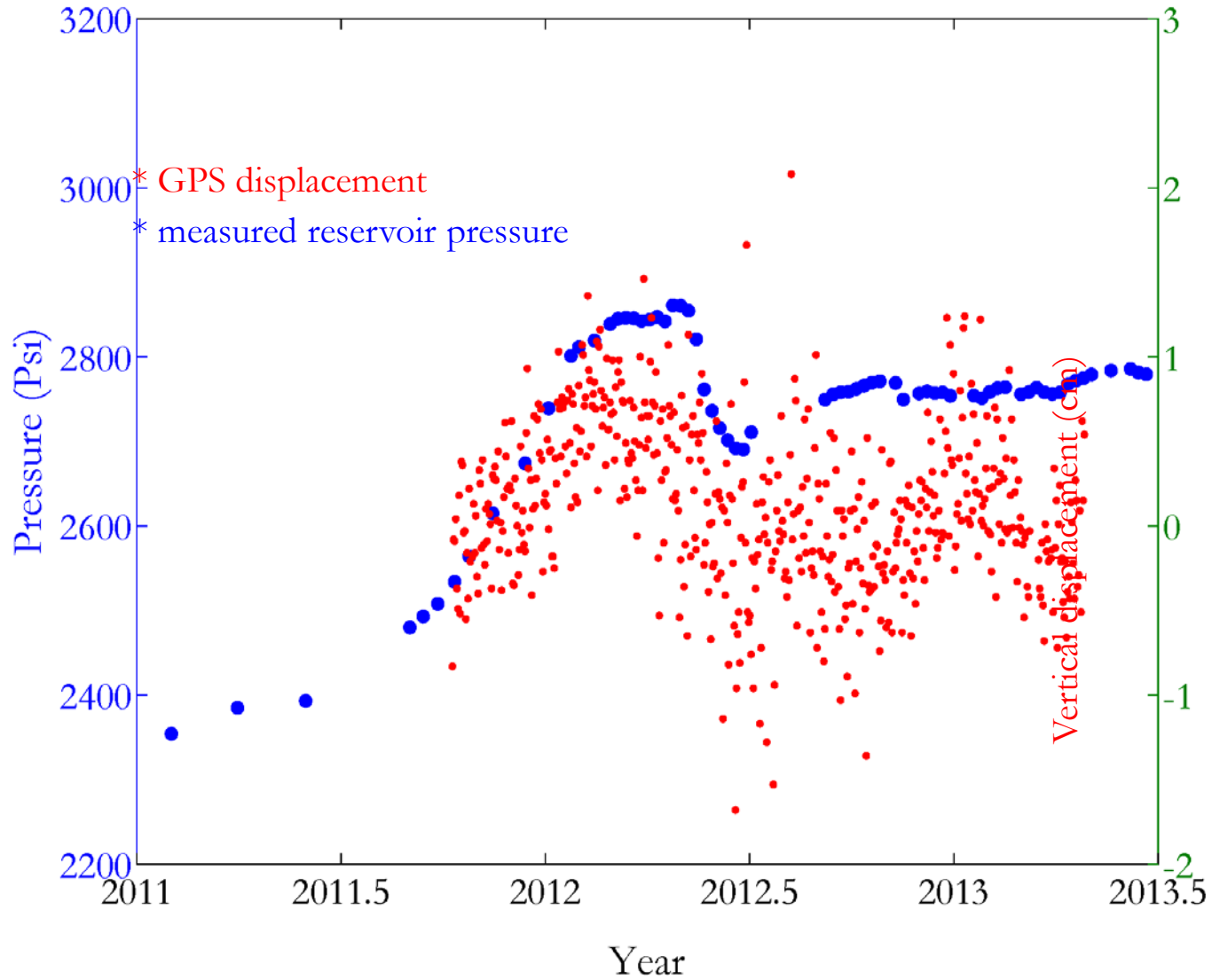
Filter example-compare EOR and non-EOR site



Surface Deformation vs Reservoir Pressure

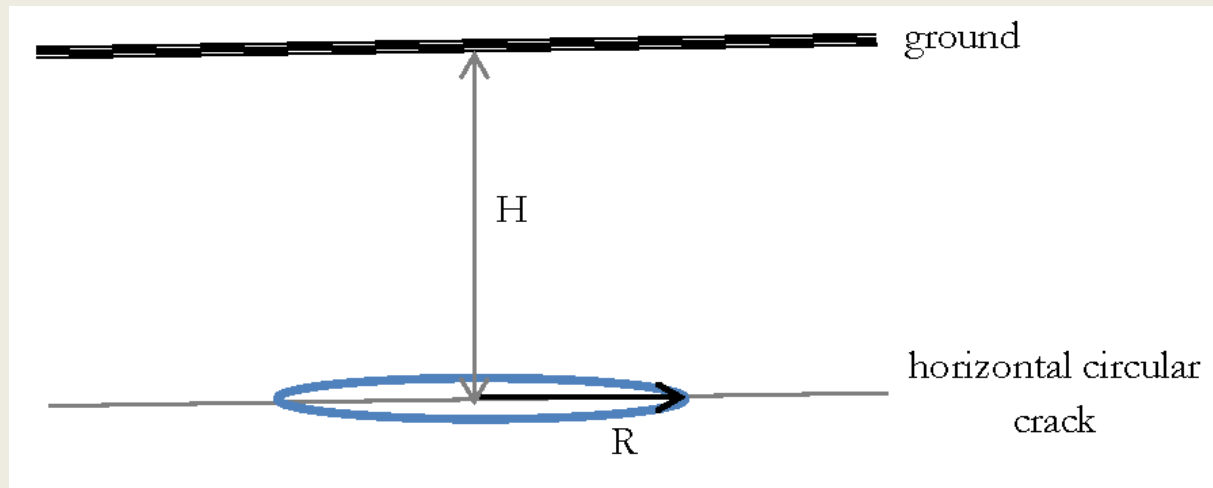


Displacement vs. reservoir pressure



Forward modeling of surface displacement

Simple elastic half space model



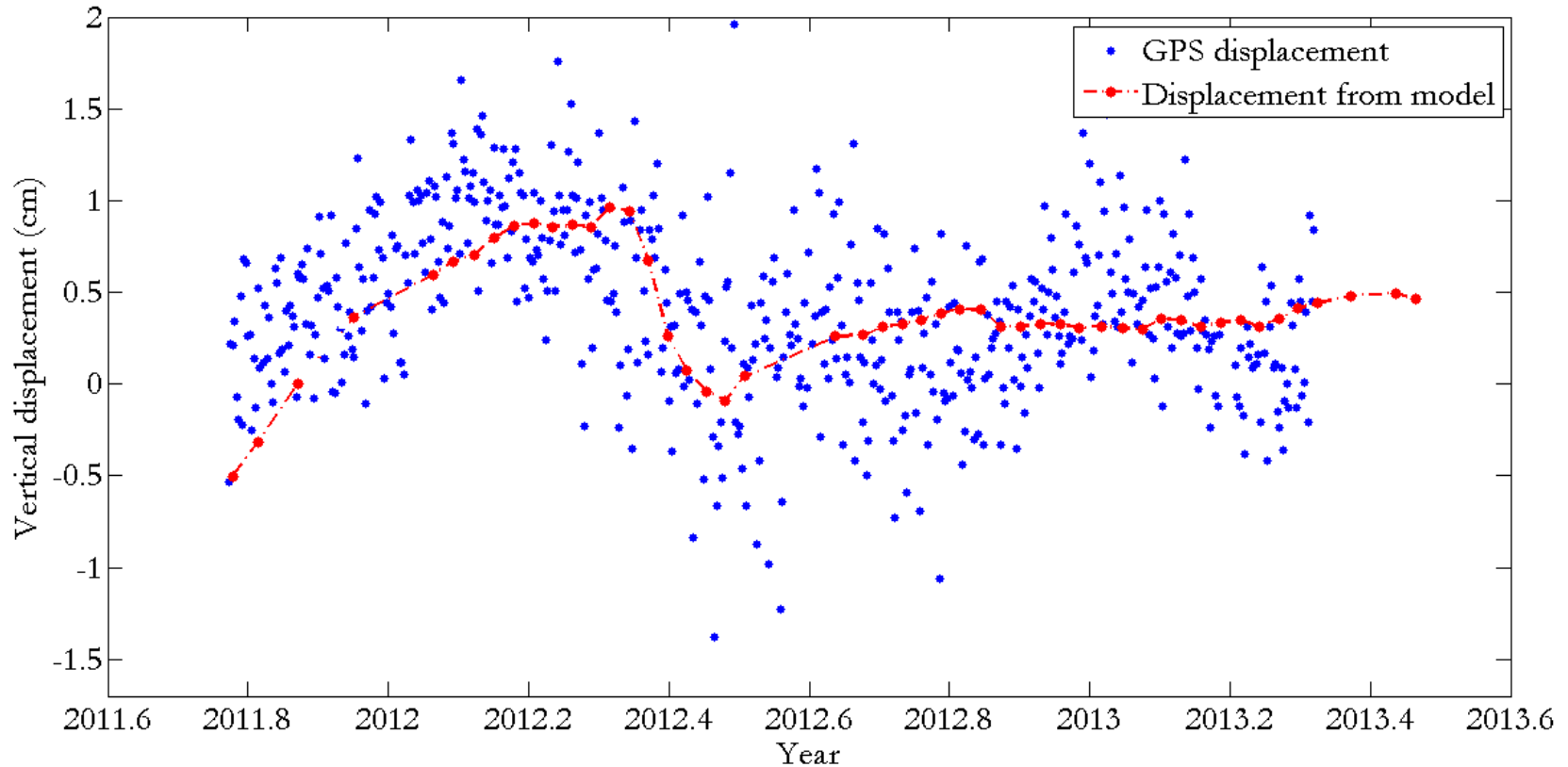
radius of crack = 750 ~ 800 m

depth of reservoir = 1600 m

shear modulus = 15 GPa

Poisson's ratio = 0.25

Forward modeling of surface displacement



Next Steps

- Continue tests of alternate regional filtering strategies
- Refine analytical deformation model:
 - Incorporate horizontal data
 - Explore sensitivity to reservoir dimensions
- Finite Element Model: incorporate stratigraphy & realistic rheology, multiple injection/extraction sites

Preliminary Conclusions

- Surface deformation is a useful tool for MVA, and is a viable surrogate for reservoir pressure monitoring – it is non-invasive and hence low cost compared to downhole techniques
- Caveats:
 - Annual signal can be large; two yrs of baseline data is useful
 - Need to integrate with geomechanical model
 - Ancillary/multiple data sources very useful

Questions?