

# Using InSAR to study aquifer properties in the Los Angeles Basin

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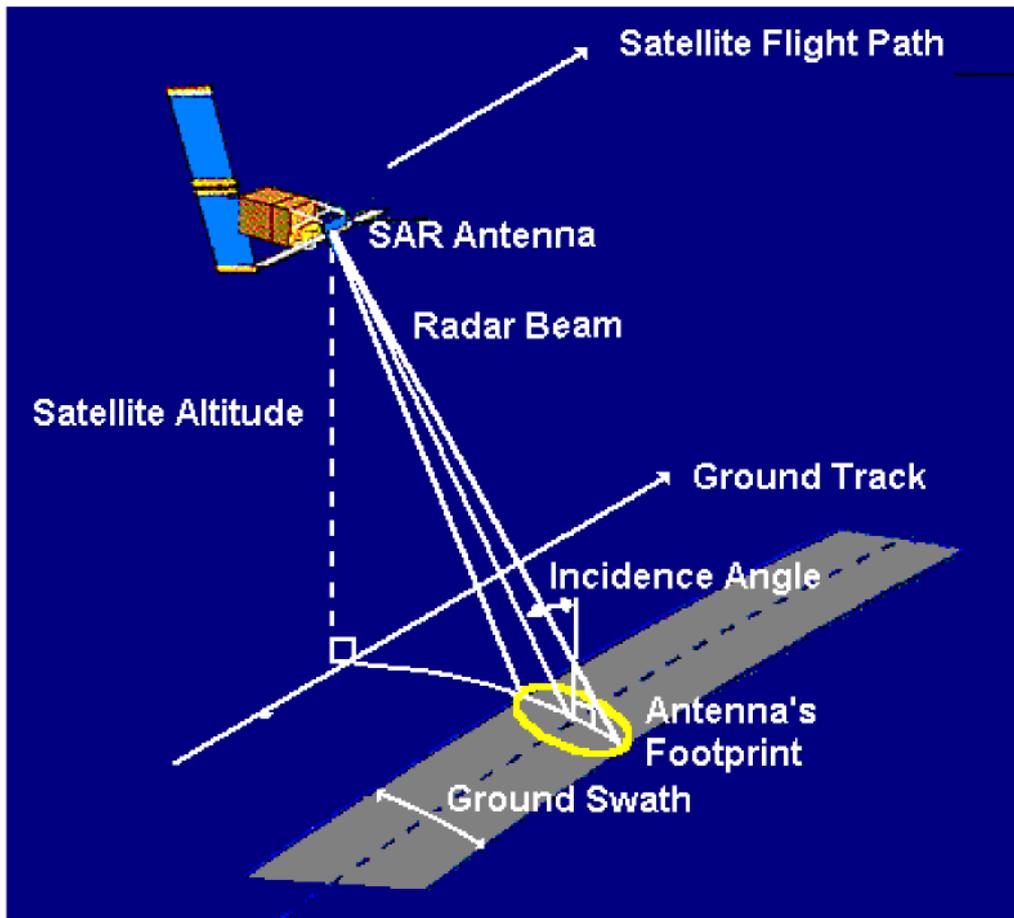
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# Synthetic Aperture Radar (SAR)



- Satellite or airplane based active imaging system.
- Typical satellite system.
  - 100 km x 100 km at a resolution of 25m.
  - Orbit repeat time of 1 month.
- Can image through clouds and without sunlight.



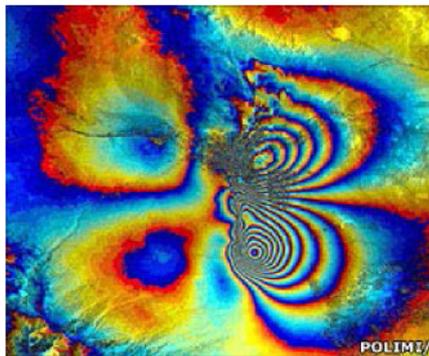
## Optical Image

- Multi-chromatic
- Amplitude information only
- Needs sunlight



## SAR Image

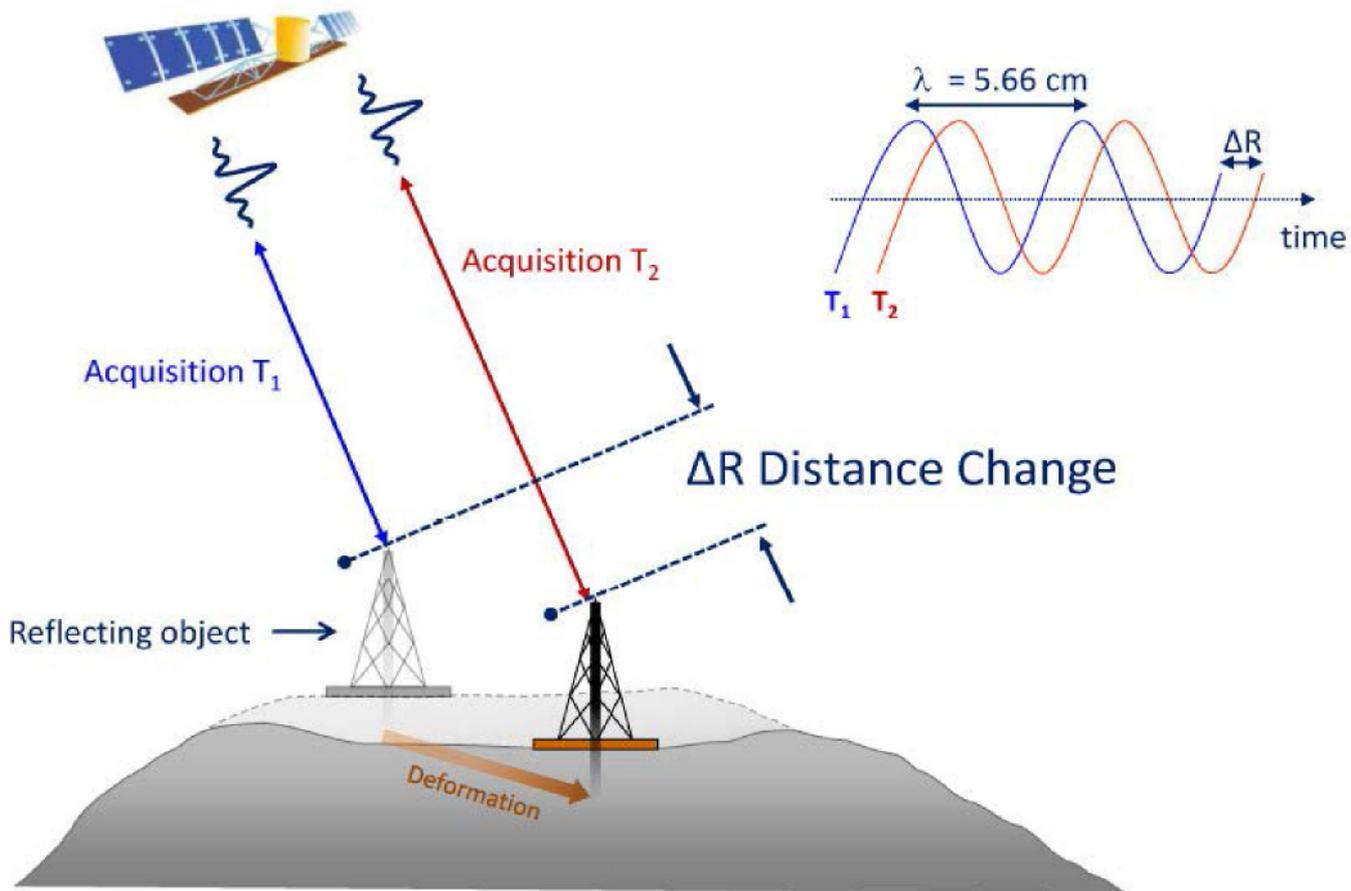
- Monochromatic
- Amplitude and phase
- Active system



## InSAR Image

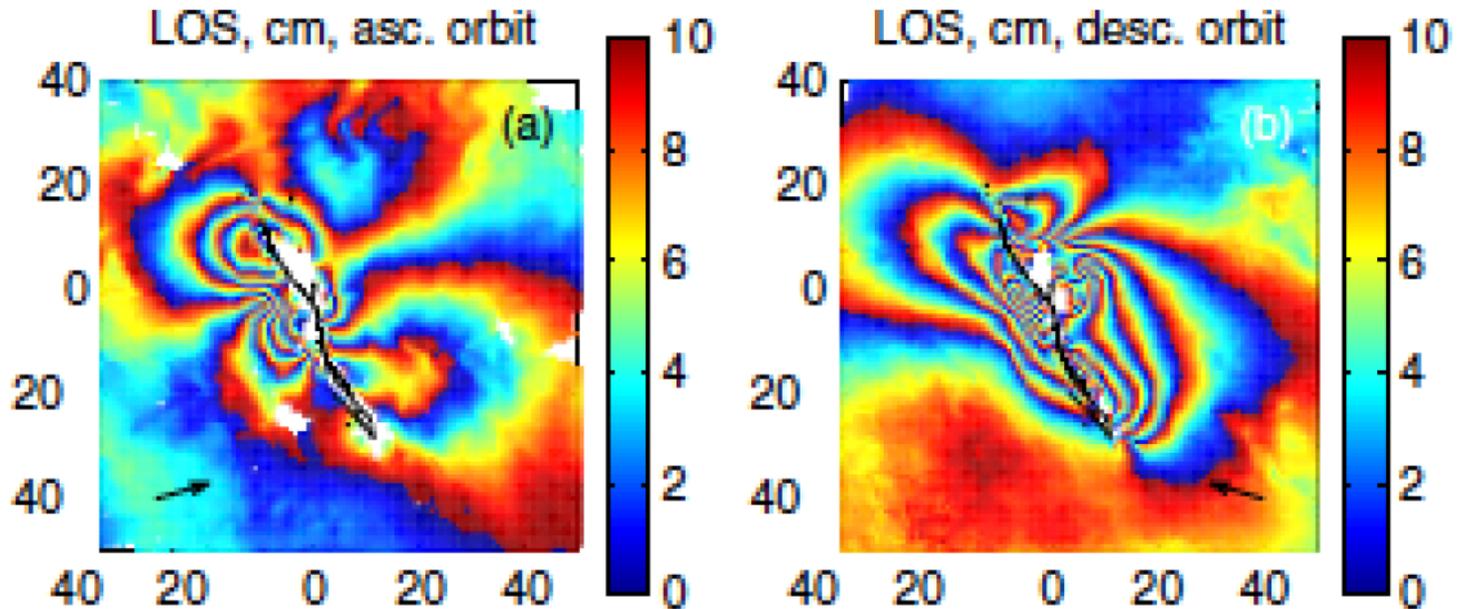
- Phase difference of two SAR images
- Sensitive to deformation

# Interferometric SAR



Phase change can be related to deformation

# Large deformation events



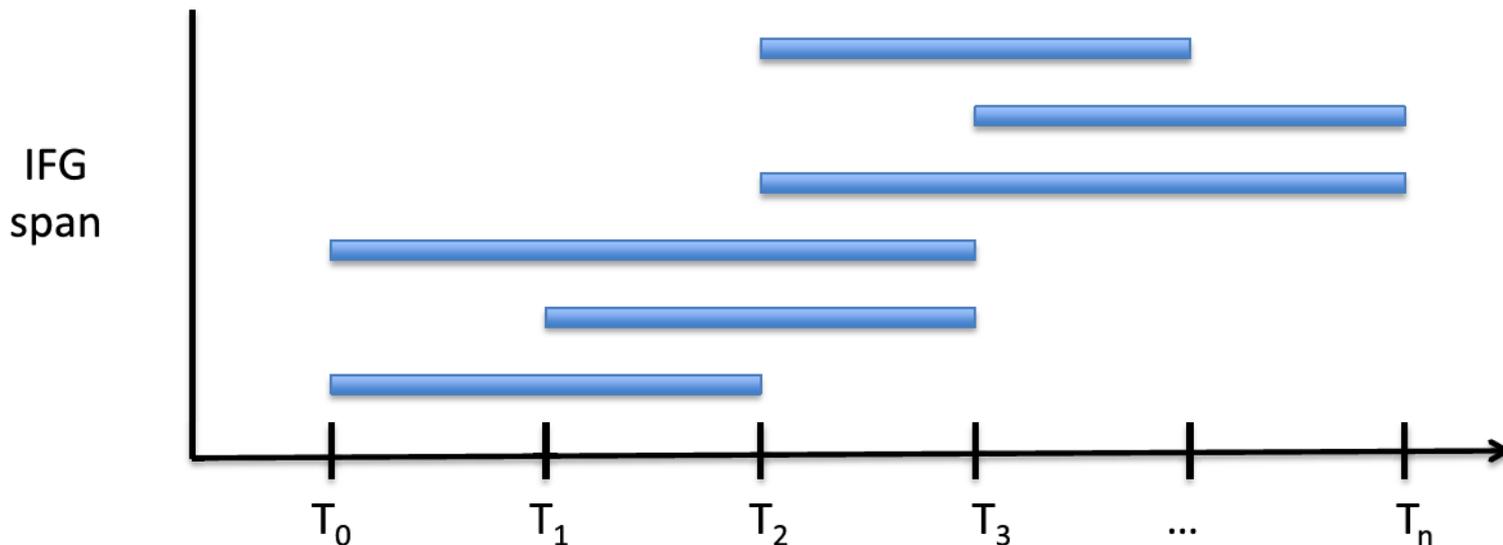
Fialko et al. (2001), Hector Mine EQ

Deformation typically much larger than noise sources

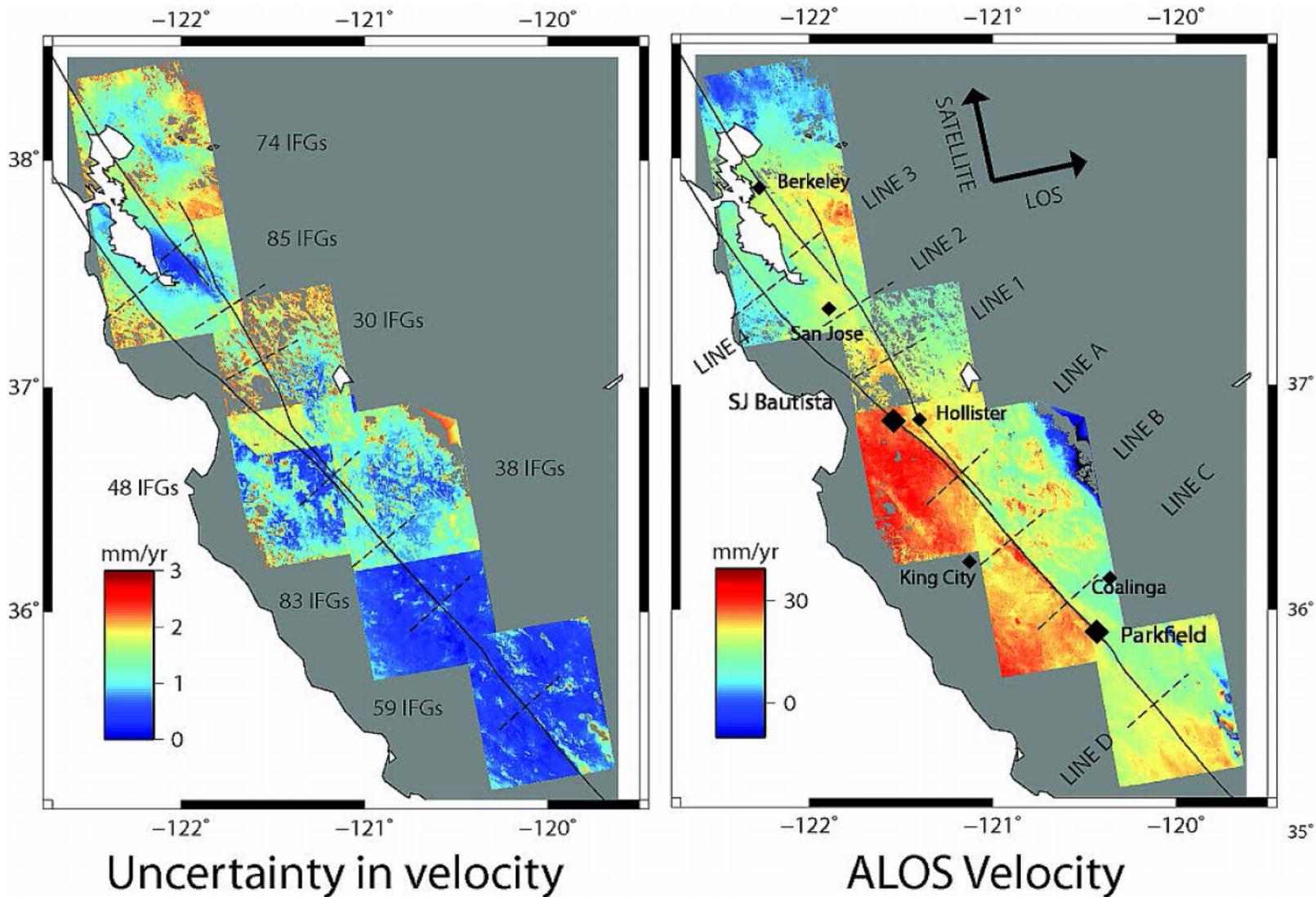
- Atmospheric contributions - few mm to few cm
- Orbital errors introduce long wavelength features

# For sensitive measurements

- Time-series InSAR
  - Combine multiple observations
  - Atmospheric signal is uncorrelated over time
  - Orbital errors are random in time



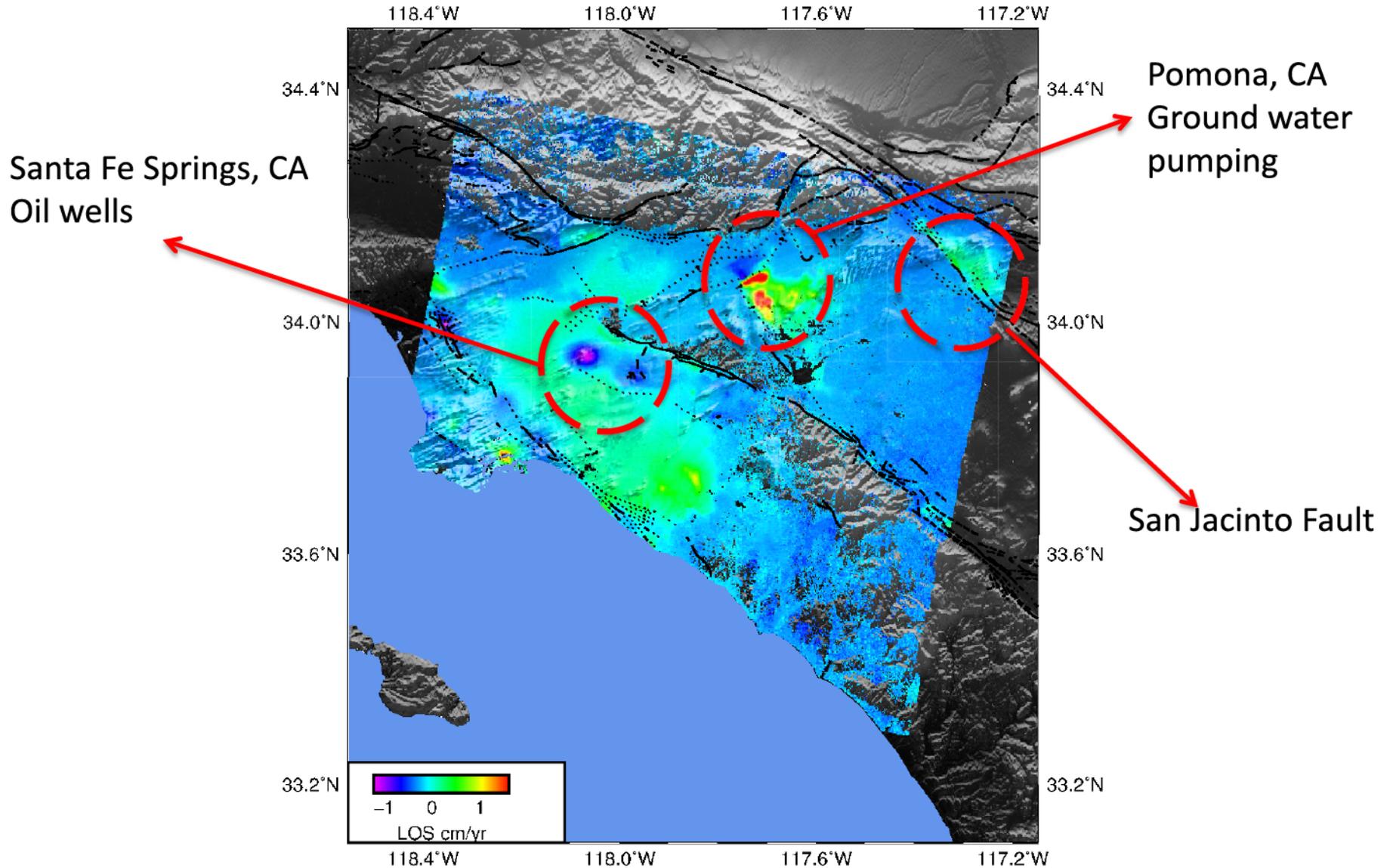
# Example: ALOS stacks over SAF



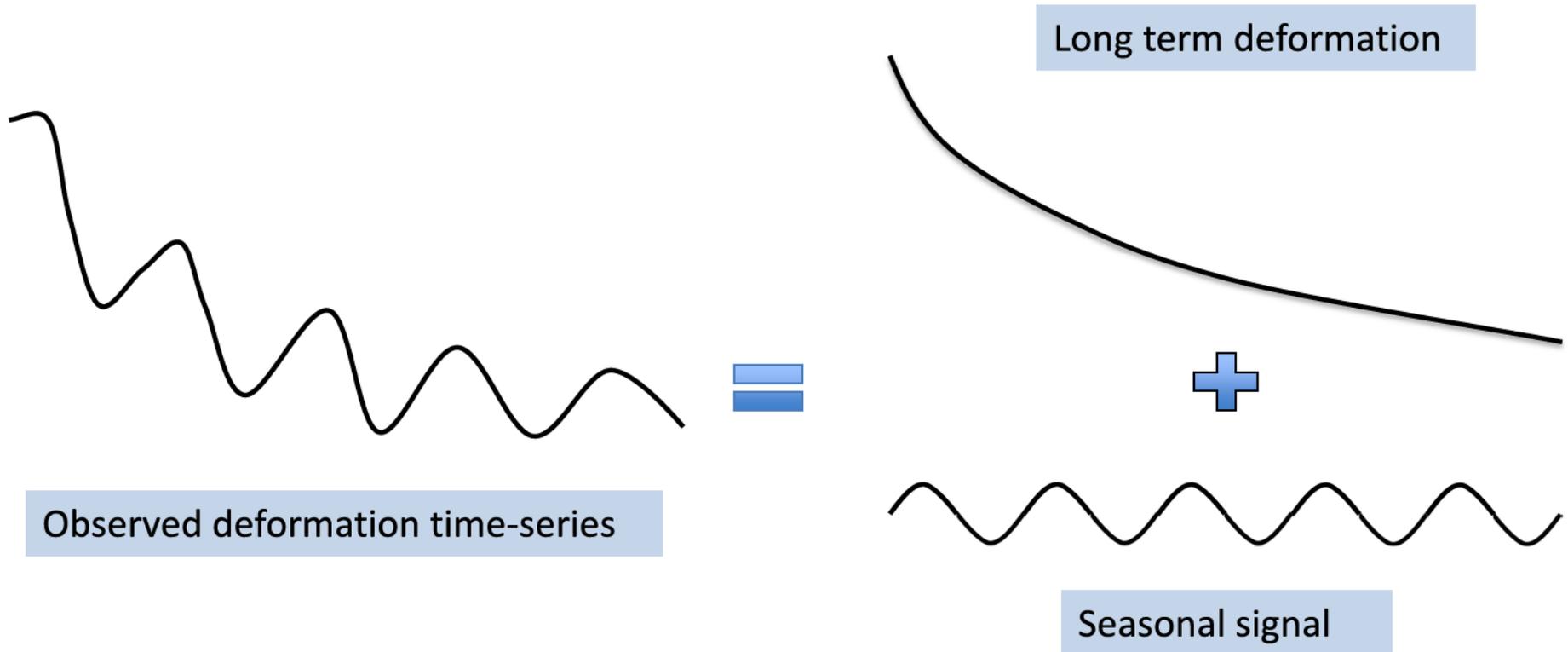
# Data set over Los Angeles

- 18 years of SAR data
- European Remote-Sensing Satellite (ERS)
  - 105 SAR images combined into 523 interferograms
  - Aug 1992 to Mar 2007
- Environmental satellite (Envisat)
  - 60 SAR images combined into 358 interferograms
  - Sep 2003 to Sep 2010
- Almost monthly observations
- Processed with GIAN-T toolbox
  - <http://earthdef.caltech.edu>

# Average LOS velocity

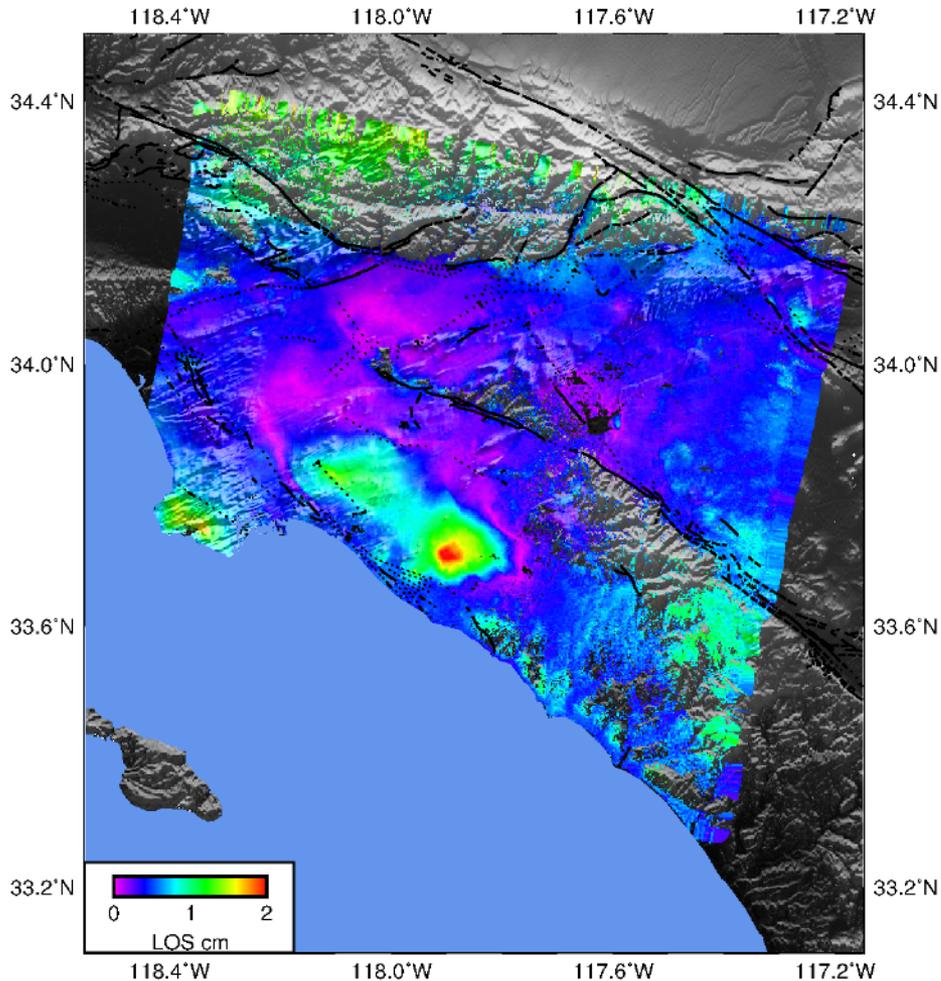


# Decoupling the seasonal signal



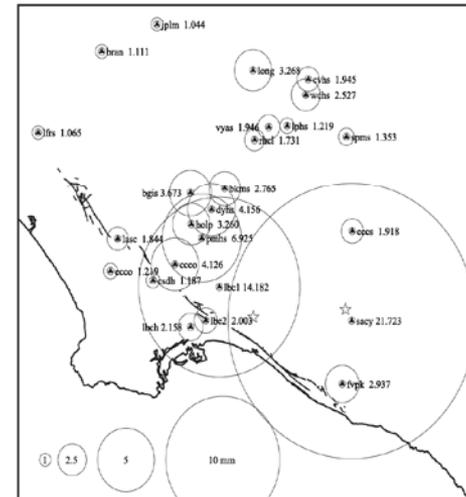
- 18 years of data allows us to decouple the seasonal signal
- Monthly data increases the reliability of our seasonal estimates
- We estimate the average seasonal cycle over 18 years

# Seasonal Amplitude



InSAR time-series

## SOPAC GPS

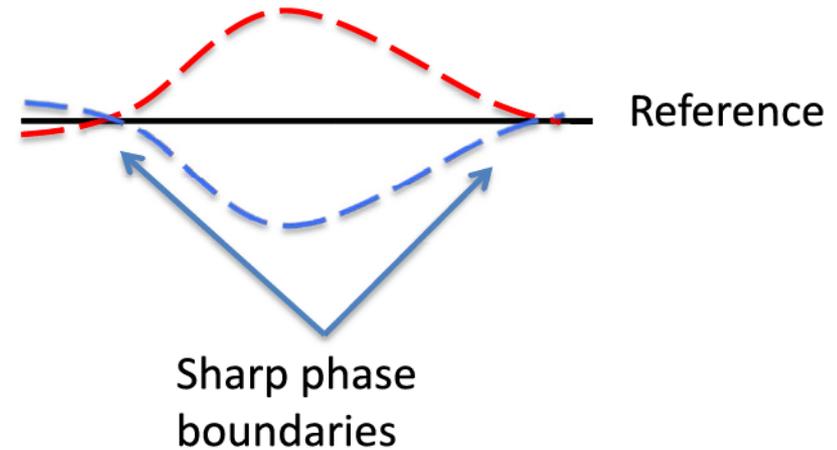
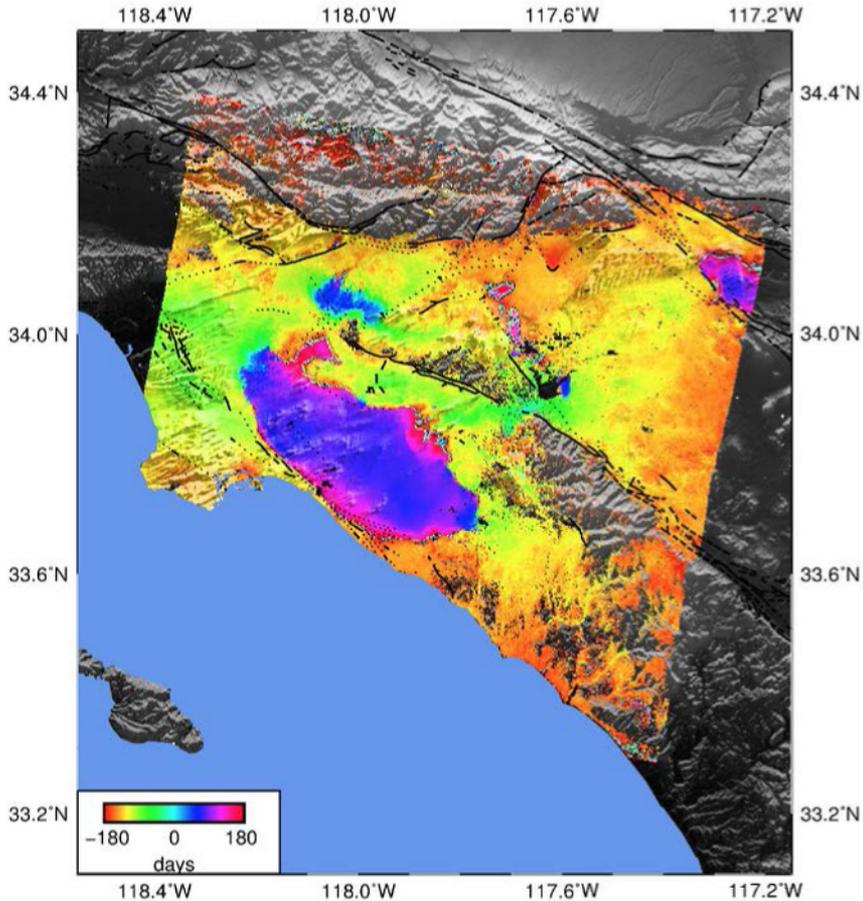


Watson et al., (2002)

- Two localized regions of deformation are clearly identified.
- InSAR - a better contiguous image



# Seasonal phase in days



- Barriers are clearly identified.
- Lines up with known faults.

# Using the amplitude information

$$\Delta b = S_{ke} \Delta h$$

Deformation  
magnitude



Skeletal  
Compressibility

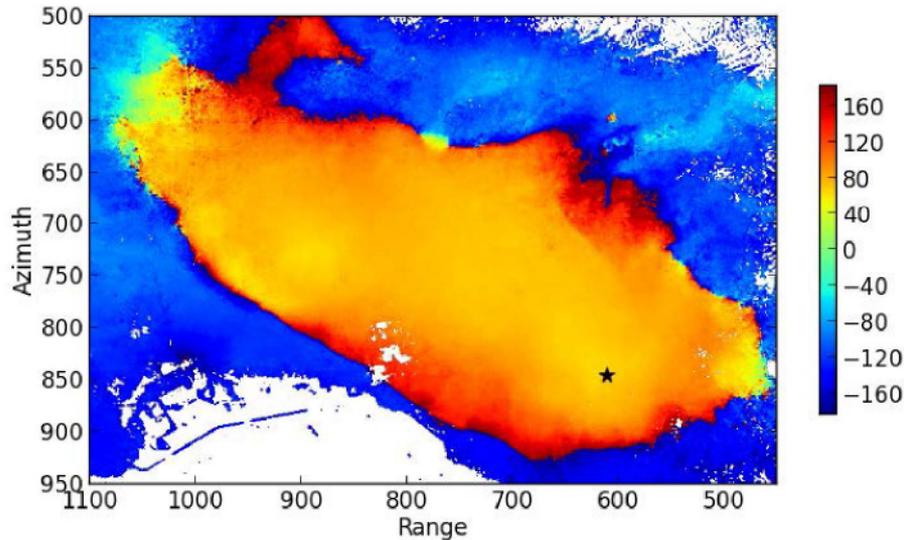


Change in  
hydraulic head

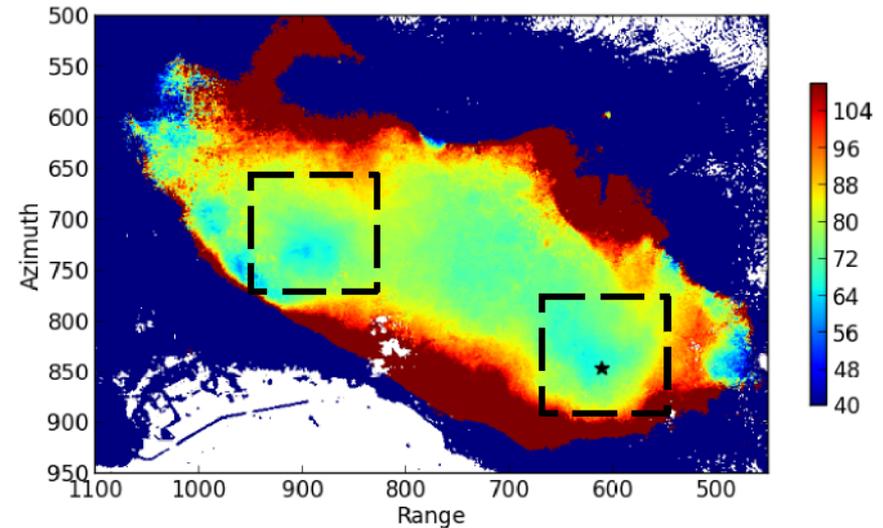
- Reeves (2013), Stanford University
- Simple linear relationship for confined aquifers
- All deformation is assumed to be elastic
- Allows for direct comparison between InSAR and GPS observations with hydraulic head measurements from wells.

# Time lag in detail

Full scale

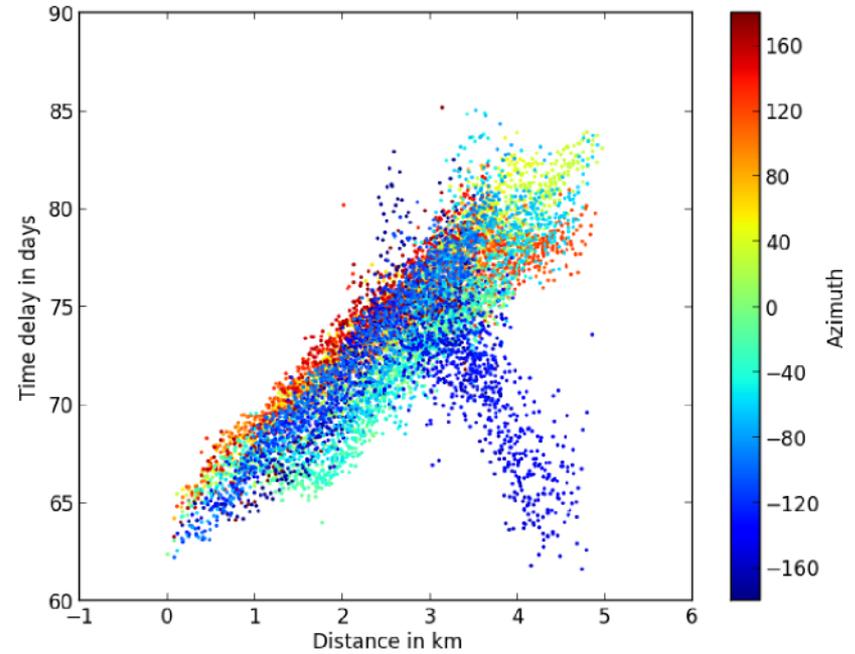
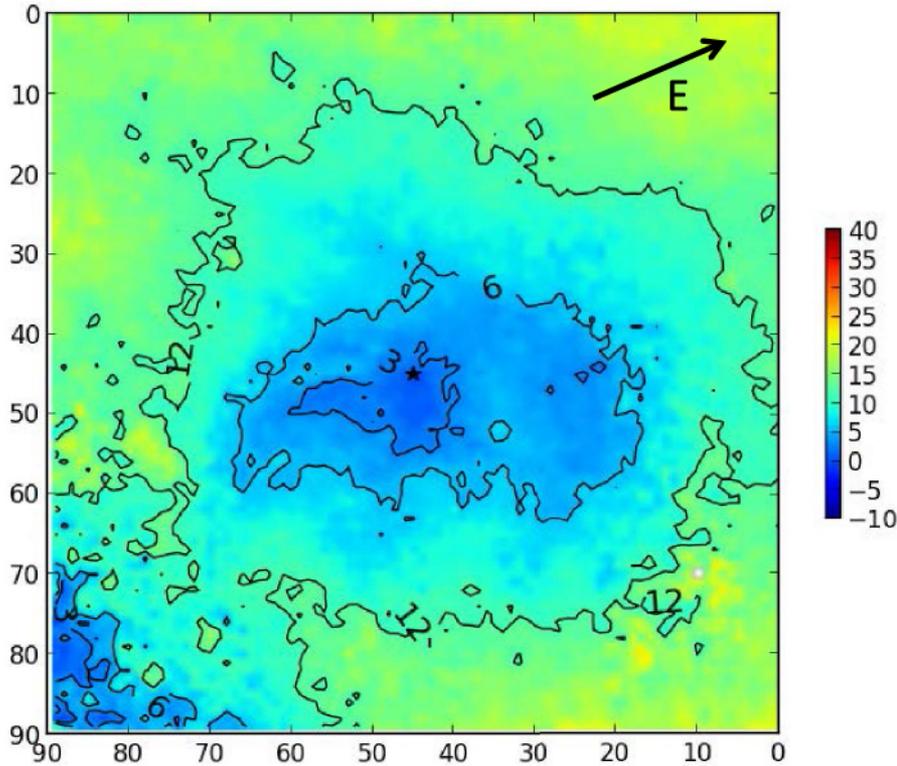


Reduced Dynamic Range



- Time lag in days and \* marks maximum seasonal amplitude location
- Spatial variation in lateral conductivity
- Relationship with distance?

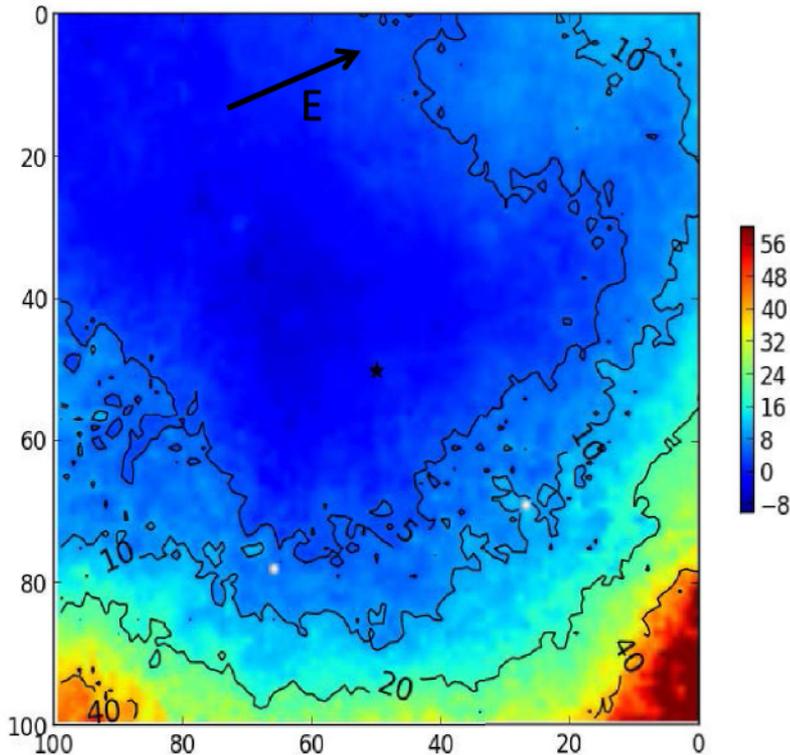
# Time lag vs Distance



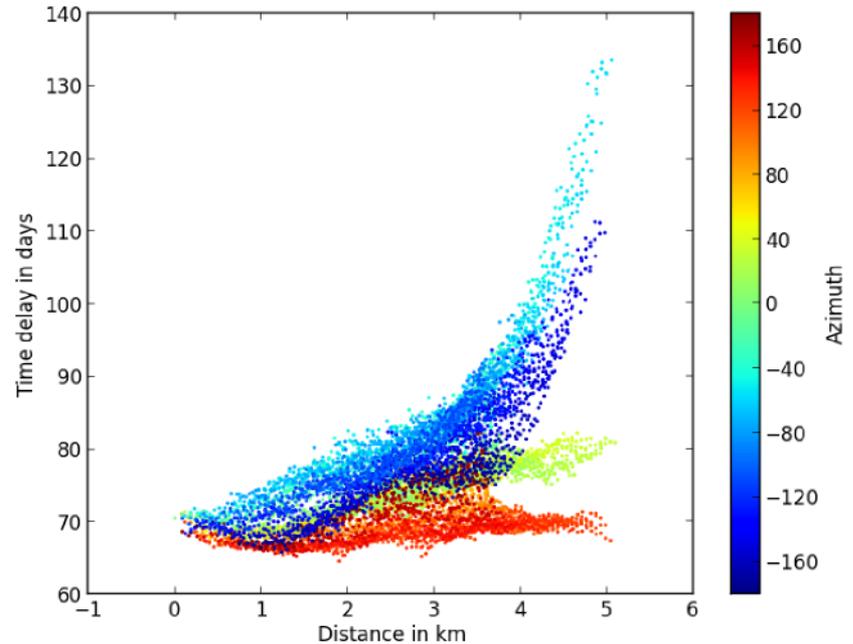
Zoom of the northern box  
(All distances w.r.t \*)

- Single source assumption appears to be reasonable
- Linear relationship
- Roughly 0.27 Km/ day

# Time lag vs Distance



Zoom of the southern box



- Directional dependence.
- Blue curves -> exponential relationship?
- Red curve suggests a distributed source

# Conclusion

- InSAR time-series techniques can provide unique datasets for studying aquifer properties.
- Spatial pattern of amplitude and phase at higher resolution than other techniques.
- 18 year archives of SAR data over California and other parts of the US, available for analysis.
- Newer sensors with shorter repeat periods (TSX, CSK, ALOS-II) will allow for better monitoring of the seasonal cycle.