Using InSAR to study aquifer properties in the Los Angeles Basin

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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
- Environmental satellite (Envisat)
  - 60 SAR images combined into 358 interferograms
  - Sep 2003 to Sep 2010
- Almost monthly observations
- Processed with GIAnT toolbox
  - [http://earthdef.caltech.edu](http://earthdef.caltech.edu)
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

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

\[ \Delta b = S_{ke} \Delta h. \]

- 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

- 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

- 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.