2022-2023 Grand Challenge Award Final Report

Awardee: **Ann Chen, Assistant Professor**
Aerospace Engineering & Engineering Mechanics

Research Award Title: **Aquifer Characterization from Spaceborne Imaging Radar Data**

Research Summary

Spaceborne Interferometric Synthetic Aperture Radar (InSAR) techniques can measure surface deformation due to fluid withdrawal from the subsurface. However, a major noise source for InSAR measurements over vegetated terrain (e.g. agricultural fields) is phase decorrelation, which results from changes in surface scattering properties (e.g., due to vegetation growth) between SAR data acquisitions. Accurate reconstruction of decorrelated interferograms leads to more robust time series solutions.

Our study initially focused on two densely vegetated sites: the southern Central Valley in California and the Carrizo-Wilcox aquifer in Texas, where large subsidence signals associated with confined aquifer pumping or oil and gas production are present. We processed 122 C-Band Sentinel-1 SAR images (2017-2021) over the Central Valley site and 123 SAR images (2017-2021) over the Texas site. To overcome the presence of decorrelation, we identified Persistent Scatterers (PS) based on the similarity of phase observations between near-by pixels, and reconstructed spatially coherent phase patterns through an interpolation between PS pixels. We derived an ensemble of SBAS solutions using varying temporal baselines thresholds from 2 sets of data: (1) original interferograms that suffer from decorrelation, and (2) PS-interpolated interferograms. In the Central Valley case, computing all possible interferograms, interpolating between accurate PS pixels, and selecting interferograms with minimal unwrapping artifacts results in mm-level linear rate misfit based on independent GPS validation. In the Texas case, we observe a region over 100 km long of up to 10 cm of cumulative line of sight (LOS) subsidence overlaying the Carrizo Wilcox aquifer. Conversely, when using unrepaired, decorrelated interferograms, no deformation is detectable in this region.

To demonstrate that our processing strategy is robust, we expanded our analysis over three large oil producing basins in Texas: Delaware, Midland, and Eagle Ford. In the Delaware Basin, we observed areas of up to 13 cm of subsidence and areas of up to 12 cm of uplift, due to production and injection respectively. In the Midland basin, we observed up to 8 cm of cumulative line of sight (LOS) subsidence that increased with production from 2015-2022. In the Eagle Ford basin, we observed a $\sim$900 km2 region of up to 13 cm of cumulative LOS subsidence. We validated the InSAR results using independent GPS data at all 30 available stations and achieved mm-level accuracy. We used additional production and injection data and earthquakes records and found a correlation between deformation and production in all three basins. Specifically, in the Delaware Basin, the magnitude of subsidence is linearly related to production. Rates of subsidence increased from mid 2018-2021. Uplift features, surrounded by subsidence, also increased in 2020-2021. In the Midland Basin, local deformation patterns correlate with production and injection wells. In the Eagle Ford, the observed large subsidence features align with drilling locations and confined aquifer pumping.

Refereed Journal Papers

- Zebker, M., Chen, J., and Hesse, M.A., “Robust Surface Deformation and Tropospheric Noise Characterization from Common-Reference Interferogram Subsets”, IEEE Transactions on Geoscience and Remote Sensing, 2023.
- Zebker, M., and Chen, J., ”A Robust Processing Strategy for Interpreting InSAR Observations Over Densely Vegetated, Decorrelated Terrain”, (in preparation).
- Zebker, M., Chen, A., Staniewicz, S., Smye, K., and Hennings, P., ”Links Between Fluid Injection/Production and Surface Deformation: A Scalable InSAR Processing Strategy Applied to three Texas Basins”, (in preparation).

Conference Presentations

- Zebker, M., J. Chen, T. Oliver Cabrera, C. Jones, K. An, and Y. Lou, ”A Robust PS-SBAS Processing Strategy for Interpreting InSAR Observations over Densely Vegetated, Decorrelated Terrain”, 2023 Fall Meeting, American Geophysical Union, Abstract G21A-02. San Francisco, CA.
- Zebker, M. and J. Chen, ”A Robust and Easy Workflow for Decorrelated Regions”, ESA Fringe 2023 Workshop, Leeds, UK.
- Zebker, M. and J. Chen, ”Land Subsidence over the Densely Vegetated Carrizo-Wilcox Aquifer”, IGARSS 2023, Pasadena, CA.
- Zebker, M., J. Chen, and M.A. Hesse, ”Spaceborne InSAR Deformation Data to Inform Texas Aquifer Properties”, 2022 Fall Meeting, American Geophysical Union, Abstract NS26A-03. Chicago, IL.
- Zebker, M. and Chen, J., ”Land Subsidence over Densely Vegetated Aquifers in Texas and California,” IGARRS 2023-2023 IEEE International Geoscience and Remote Sensing Symposium, Pasadena, CA, USA, 2023, pp 8182-8185.

Awards

- 2022 Outstanding Student Presentation Awards, American Geophysical Union Fall Meeting (Molly Zebker)
- 2022 NASA/Texas Space Grant Consortium Fellow (Molly Zebker)