NASA Science Mission Directorate
Earth Science Division
Applied Sciences Program

Subsidence Monitoring from Space

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Subsidence Monitoring from Space

Challenges / Opportunities

- As climate changes, groundwater becomes a more important component of water resources in drier regions and deltas
- The western States, particularly California, are experiencing an exceptional drought, causing severe overdraft of groundwater resources, especially in the Central Valley
- The effects include subsidence, new areas subject to flooding, damage to infrastructure (aqueducts, railways, roads), and loss of storage capacity
- As mandated by new laws, the California Department of Water Resources needs to monitor the effects of the drought and propose regulations on groundwater withdrawals.
- Other countries dependent on groundwater need the ability to monitor their aquifers

Partners and Community

- This work is currently funded by the CA DWR
- The AZ DWR has a program in place to furnish subsidence maps; we are working closely with them
- The CA High Speed Rail authority has been working with us to engineer their tracks to account for subsidence
- Other collaborators include USGS, Stanford, and ASU
- A proposal with the King Abdullah Center for Science and Technology in Saudi Arabia to extend the monitoring effort to their aquifers is near signing

Subsidence Monitoring from Space

Future communities

- We are beginning an internal effort to extend our work with the CA DWR to the other western States
- We are planning to work with the Italian Space Agency to use their Cosmo-SkyMed constellation to monitor subsidence in the western US, Italy, and other regions
- We are working with Indian hydrologists in the development of groundwater applications for NISAR
- Other countries with subsidence problems such as Iran, Egypt, Vietnam, Thailand, China, could be assisted via the SERVIR program or USAID
- The entire groundwater resources community would benefit from a readily accessible database of maps of subsidence and desired hydrogeological characteristics

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Datasets, models, tools

- Primary tool is InSAR
  - Currently using free Sentinel-1A data
  - Past satellites are used to generate long time series
  - NISAR will continue the time series
- In situ data is important: Wells (water height, geology), GPS
- GRACE gives important constraints on total water mass removed
  - Requires more research to meet needs of managers
- Groundwater models promote understanding of aquifer system responses and can merge disparate observations. They also can provide predictive capability
- JPL Big Data initiatives are providing unique tools to allow correlations (e.g. drawdown vs. subsidence), use of new observations in models, and visualizations

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Approach

- Applications
  - Update maps of subsidence for use by CA DWR
  - Reports on locations of maximum subsidence, rates, etc.
  - Deliver GIS data sets to DWR hydrologists
- Science
  - Extend applications beyond mapping
  - Correlate subsidence with drawdown (hysteresis)
  - Interpret subsidence in terms of hydrogeology, loss of storage capacity, etc.
  - Predict future problems and provide information for informed decision-making

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Impacts (achieved and anticipated)

- Continued funding from CA DWR has allowed development of maps and reports which have influenced policy
- We hope to expand this to other western States which are experiencing similar subsidence problems
- Additional work needs to be done to make the data and information products more accessible to a wide range of users
- This will impact directly the application of NISAR data to users in the water resources community
- The JPL Western States Water Mission is helping develop the tools necessary for the next step in the use of remote sensing data and information in water resources management

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Transition strategy

- The ARIA Project at JPL will soon produce GIS-ready products for subsidence monitoring in California
- We hope to expand subsidence monitoring from CA and AZ to other western States
- This capability can grow from operational monitoring in the western States to other regions of the world
- We will pursue the scientific understanding of the responses of aquifer systems to groundwater pumping in conjunction with our collaborators at Stanford, ASU, and USGS. This will lead to enhanced capability to predict aquifer responses to stress

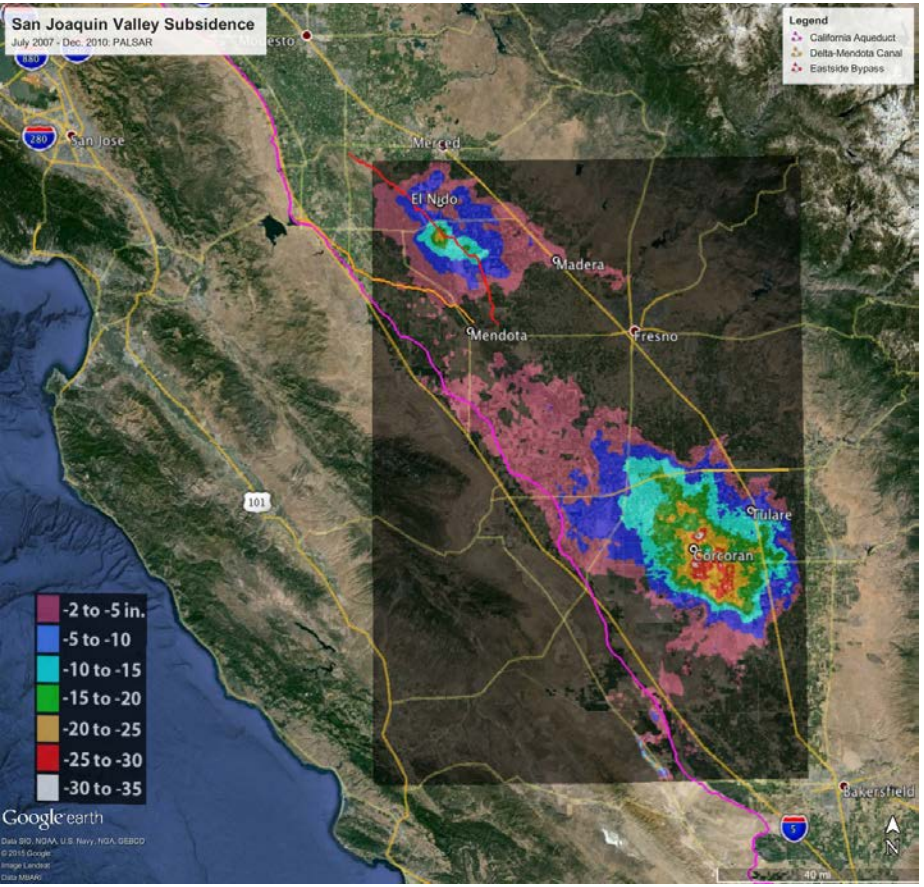
Lessons learned

- It takes a long time (and maybe a crisis) to gain the confidence of an operational agency so that they commit time and money to a new way of doing business
- It requires several iterations to optimize the data and information products they need
- It requires even longer to develop the capacity (and the willingness) for the agency to ingest the new data and information products
- Capturing the interest of ‘Big Data’ developers as a ‘Use Case’ is great!

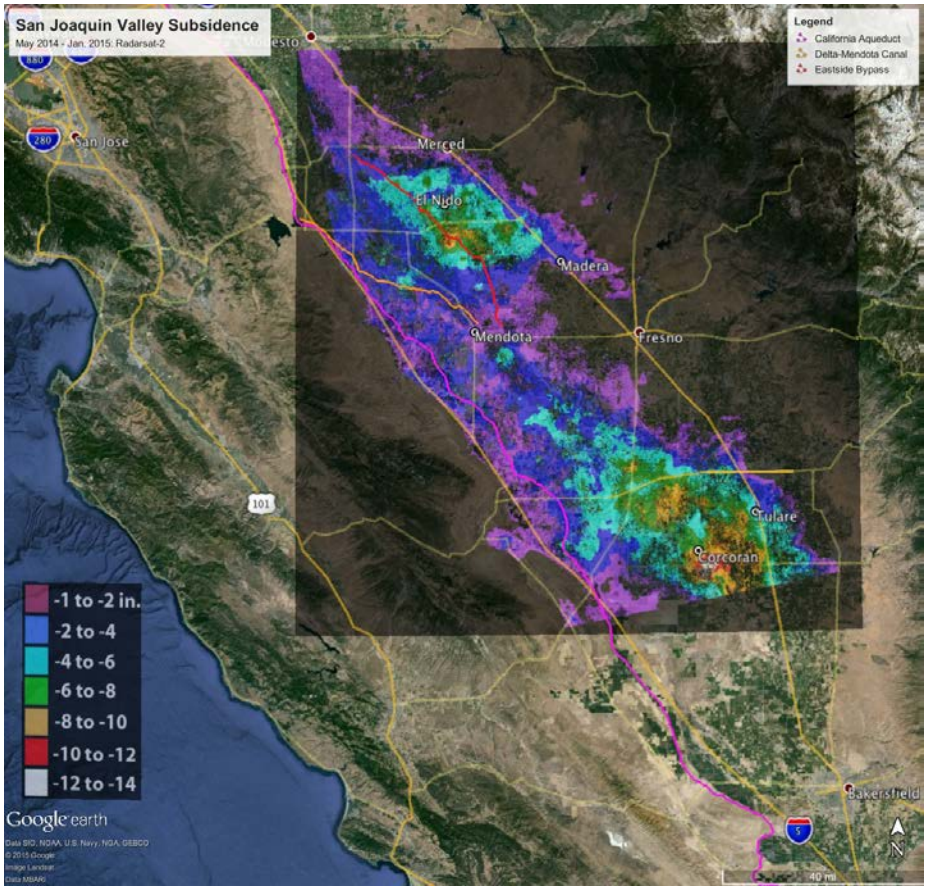
Subsidence in the San Joaquin Valley: PALSAR, 2007-2011

Zhen Liu, Vince Realmuto, Tom Farr, JPL

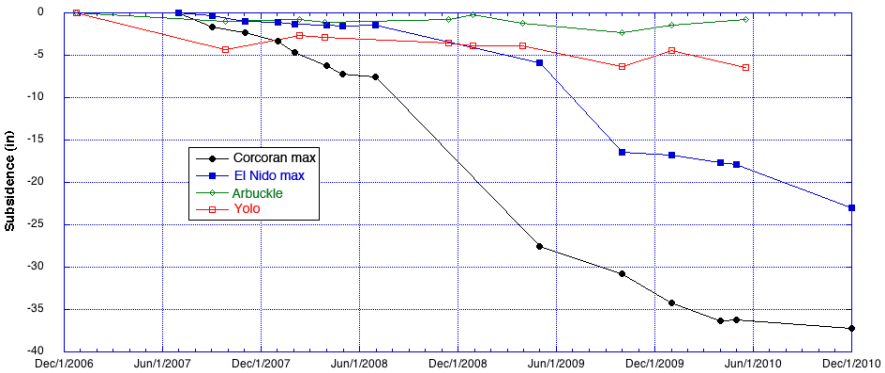
San Joaquin Valley Subsidence

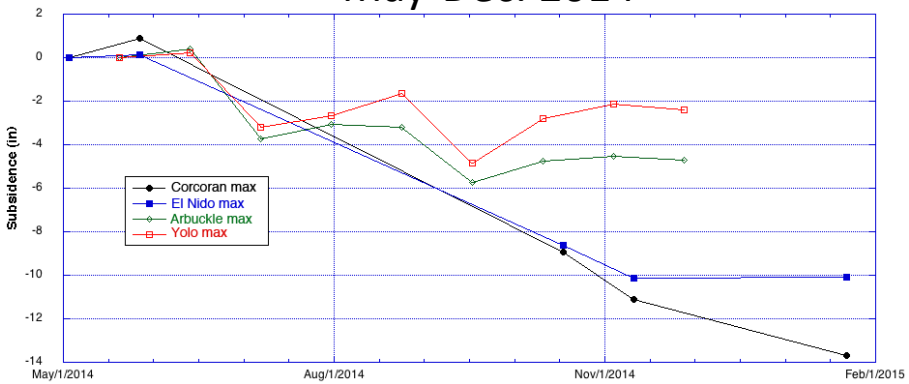


2007 - 2011

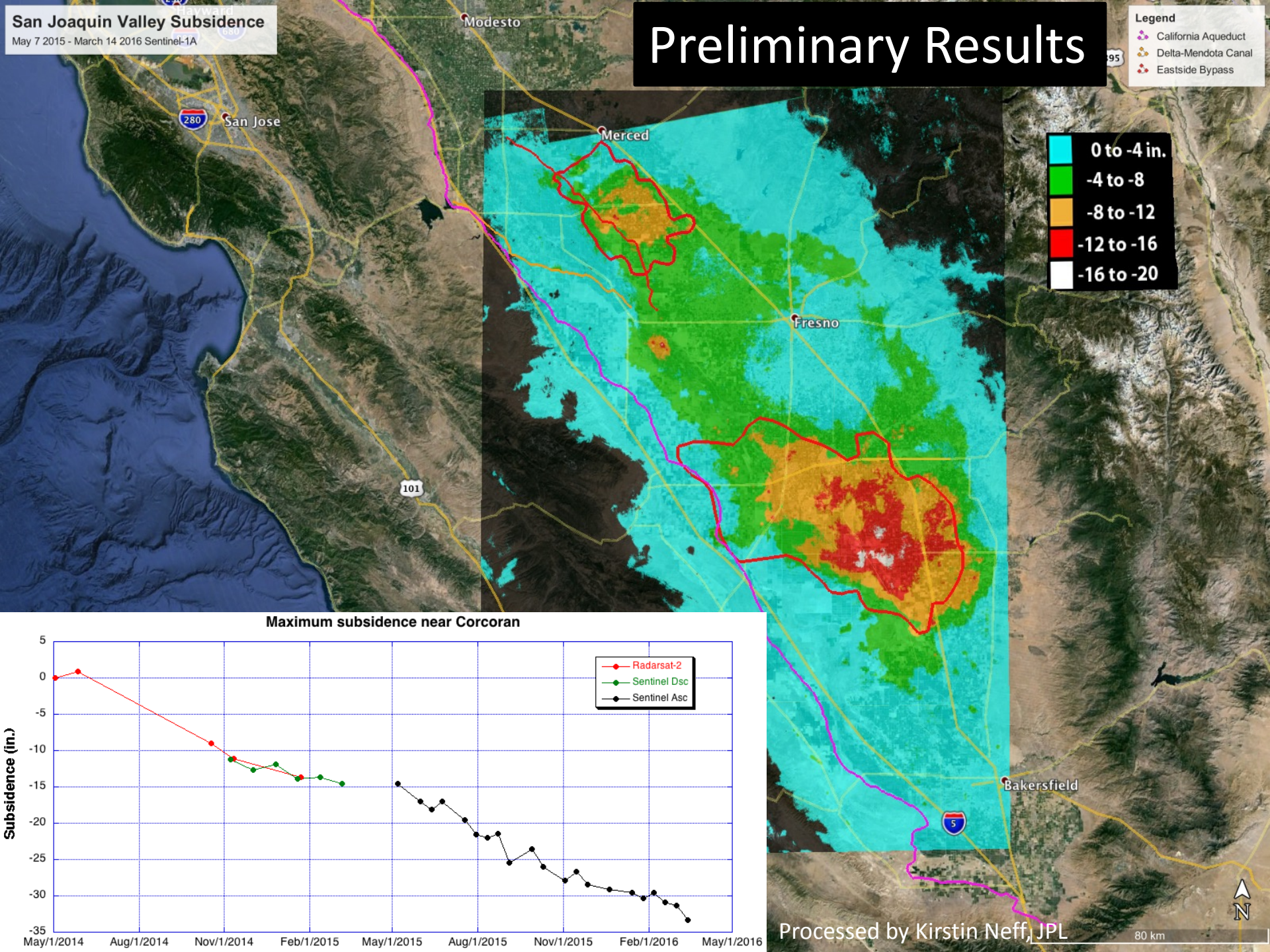


May-Dec. 2014





Preliminary Results



Processed by Kirstin Neff, JPL

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Publications

- **Monitoring Subsidence Associated with Groundwater Dynamics in the Central Valley of California Using Interferometric Radar**
  Tom G. Farr and Zhen Liu. Chapter 24 in: *Remote Sensing of the Terrestrial Water Cycle*, Geophysical Monograph 206. Edited by Venkat Lakshmi. American Geophysical Union, 2015.

- **Progress Report: Subsidence in the Central Valley, California**
  Tom G Farr, Cathleen Jones, Zhen Liu. Report to CA Dept. of Water Resources, 2015. http://www.nasa.gov/jpl/nasa-california-drought-causing-valley-land-to-sink