

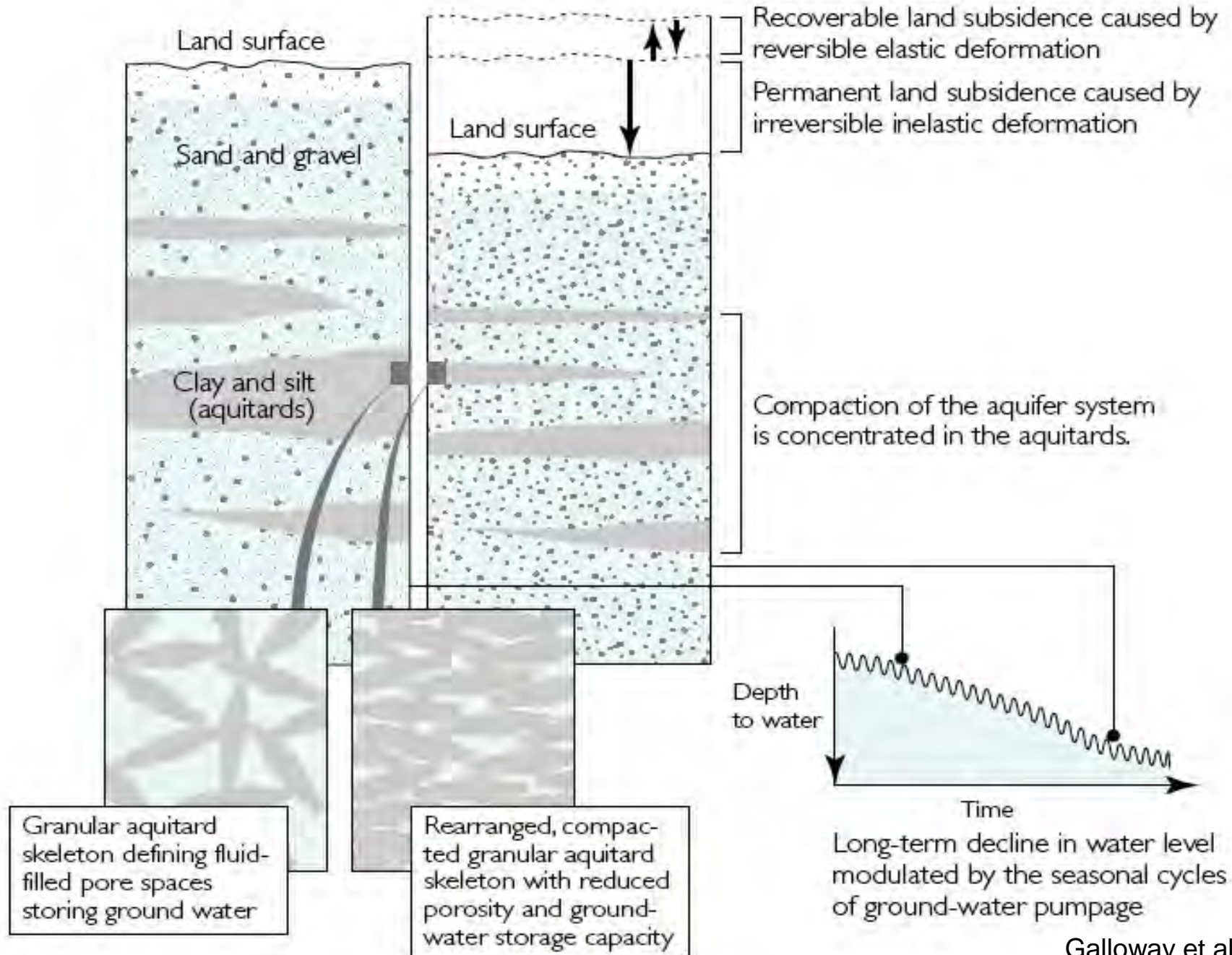
# **Subsidence Monitoring at NASA**

Tom G Farr

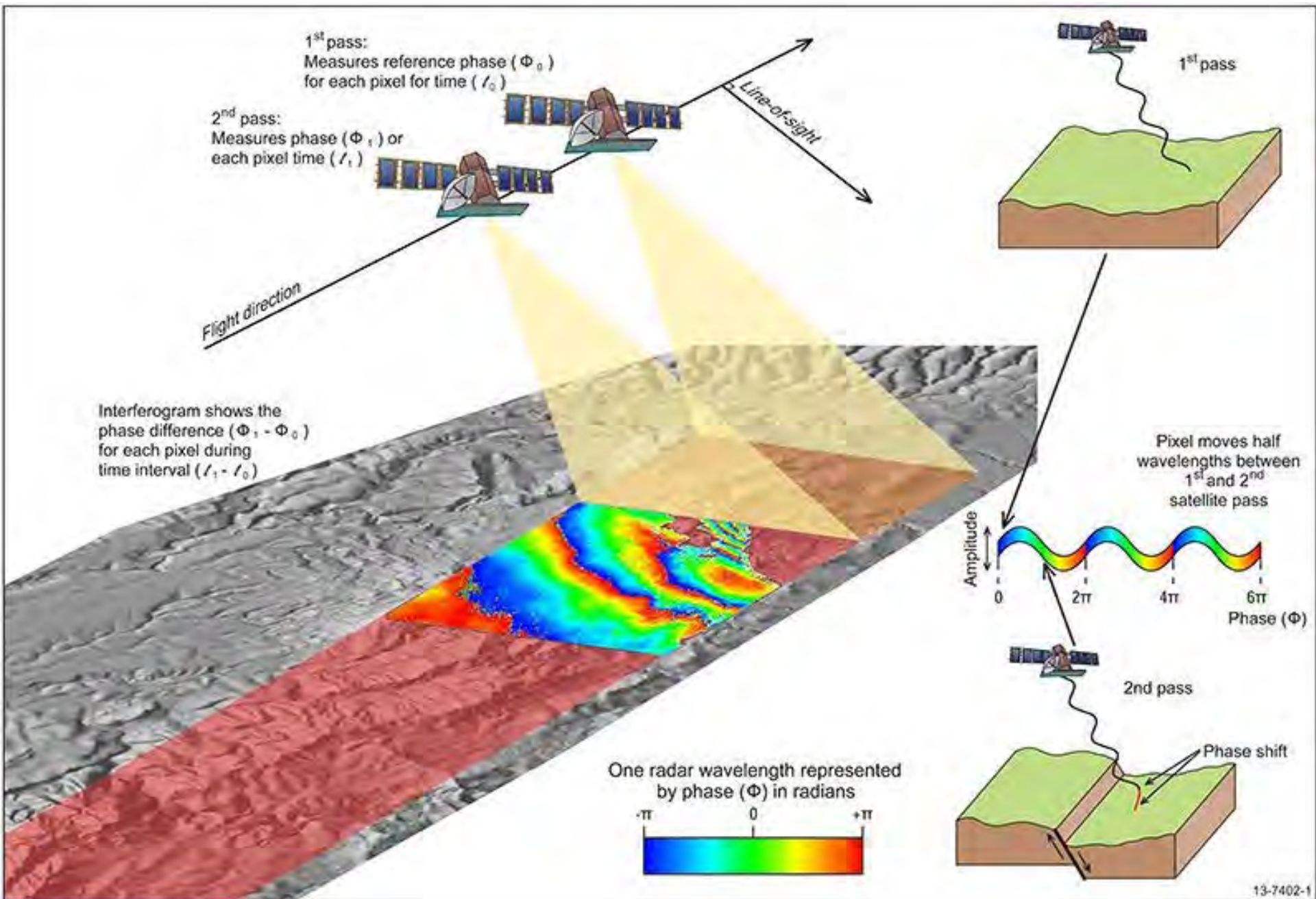
Jet Propulsion Laboratory

[tom.farr@jpl.nasa.gov](mailto:tom.farr@jpl.nasa.gov)

# Hydrology 101: Aquifer compaction



# InSAR 101



# Orbital Radars for Interferometry

Satellite	dates	resolution (m)	swath (km)	incidence angles	minimum revisit (days)	band*/pol
ERS 1,2	1991-2010	25	100	25°	35	CVV
Envisat	2002-2010	25	100	15-45°	35	CVV, CHH
<b>PALSAR</b>	2006-2011	10-100	40-350	10-60°	46	L-quad
Radarsat 1	1995-2013	10-100	45-500	20-49°	24	CHH
<b>Radarsat 2</b>	2008-	3-100	25-500	10-60°	24	C-quad
TerraSAR-X	2007-	1-16	5-100	15-60°	11	X-quad
Cosmo-Skymed	2007-	1-100	10-200	20-60°	<1	X-quad
PALSAR-2	2014-	3-60	50-350	8-70°	14	L-quad
<b>Sentinel-1</b>	2014-	20	250	30-45°	6	C-dual
NISAR	2021	35	350	15-60°	12	L-quad

\* wavelengths: X ~ 3 cm, C ~ 5 cm, L ~25 cm



# Subsidence in the San Joaquin Valley

## Sentinel-1 May 2015 – Jan. 2017





# July 2007 - December 2010

Subsidence from PALSAR-1

### Legend

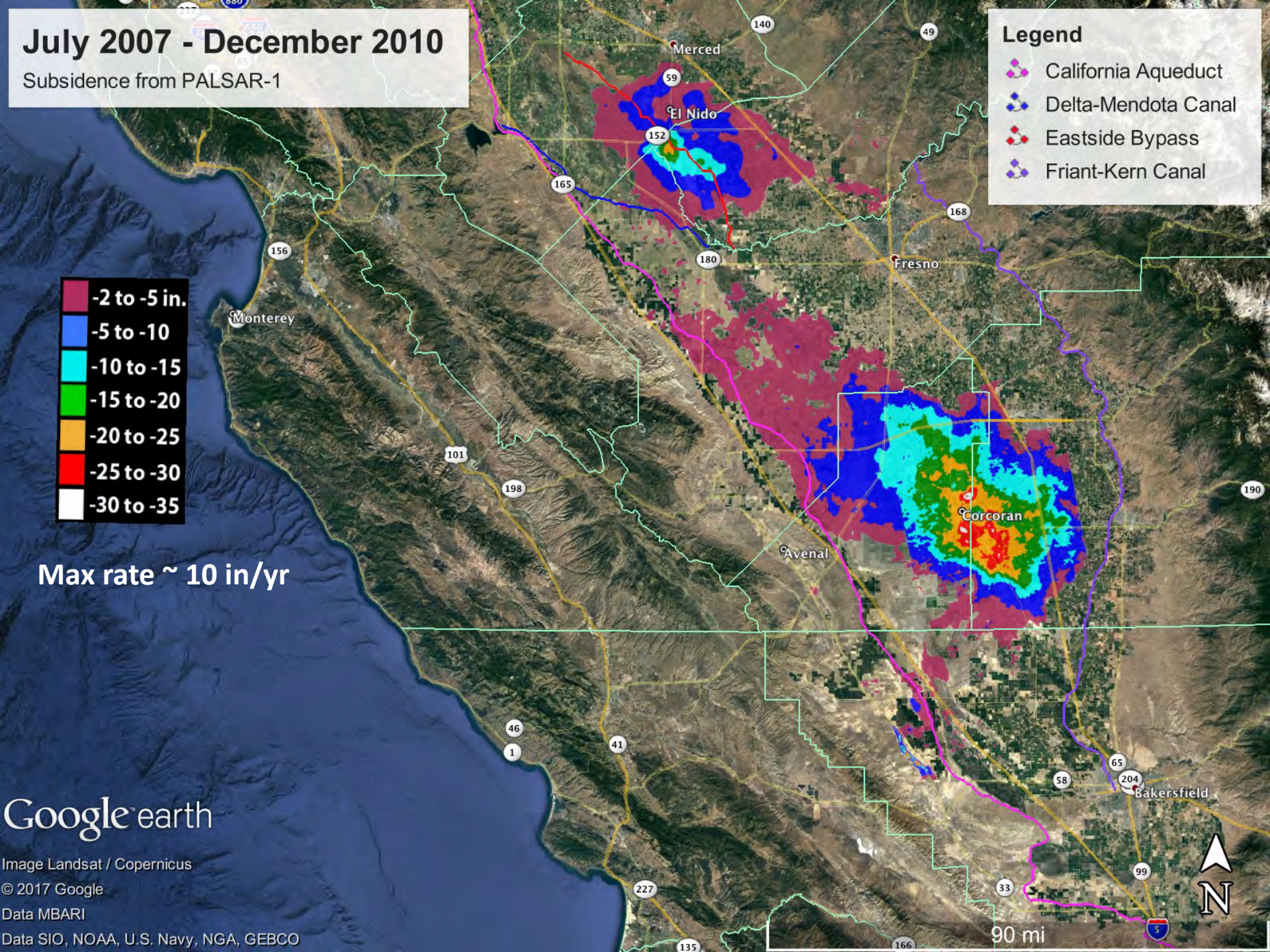
- California Aqueduct
- Delta-Mendota Canal
- Eastside Bypass
- Friant-Kern Canal



Max rate ~ 10 in/yr

Google earth

Image Landsat / Copernicus  
© 2017 Google  
Data MBARI  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO



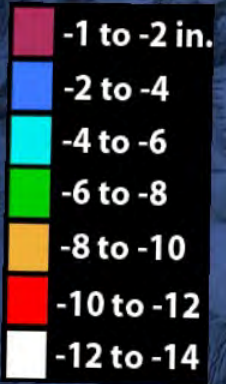


# May 2014 - January 2015

Subsidence from Radarsat-2

### Legend

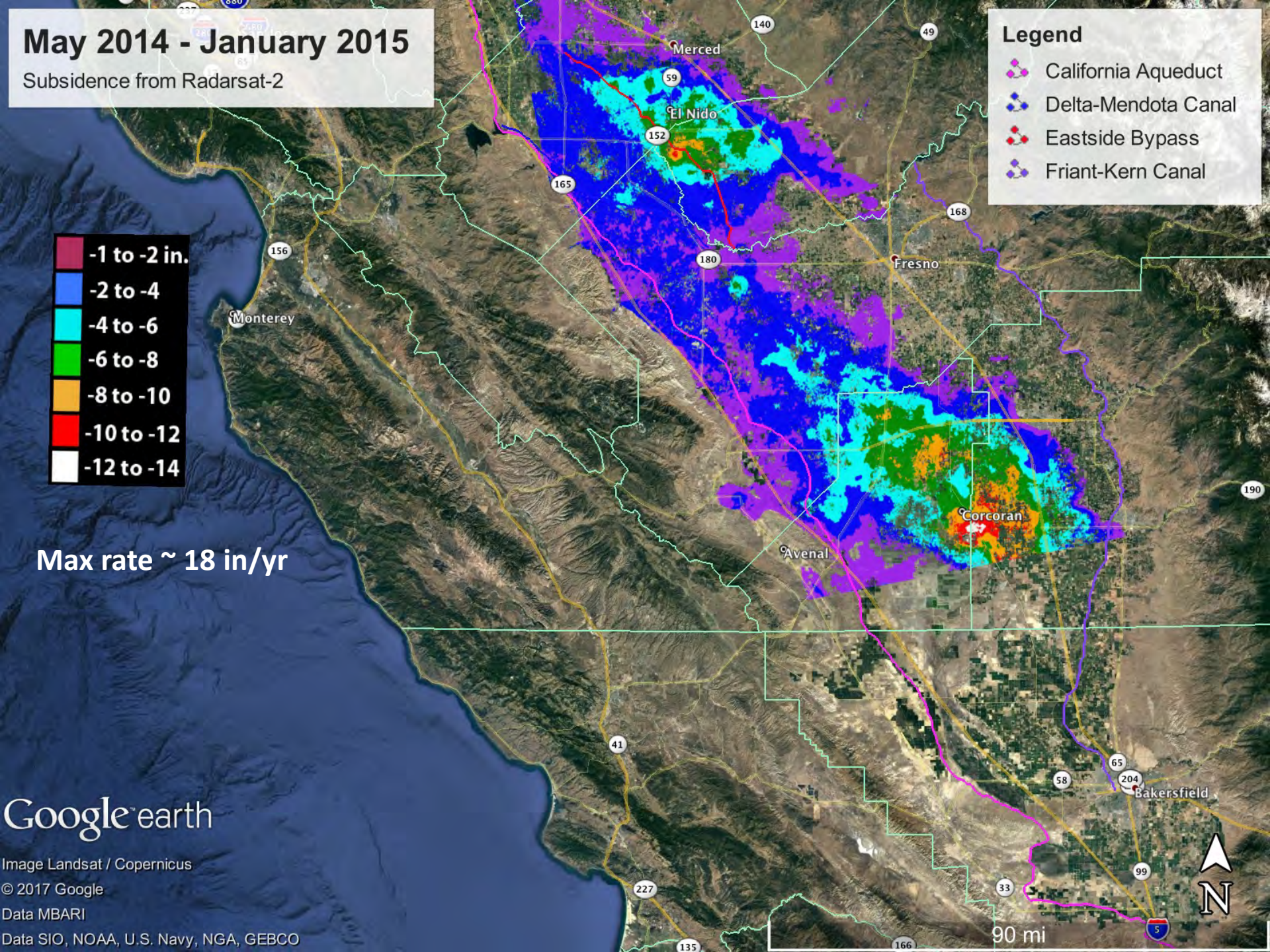
- California Aqueduct
- Delta-Mendota Canal
- Eastside Bypass
- Friant-Kern Canal



Max rate ~ 18 in/yr

Google earth

Image Landsat / Copernicus  
© 2017 Google  
Data MBARI  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO





# May 2015 - Aug 2018 Subsidence from Sentinel-1

**Legend**

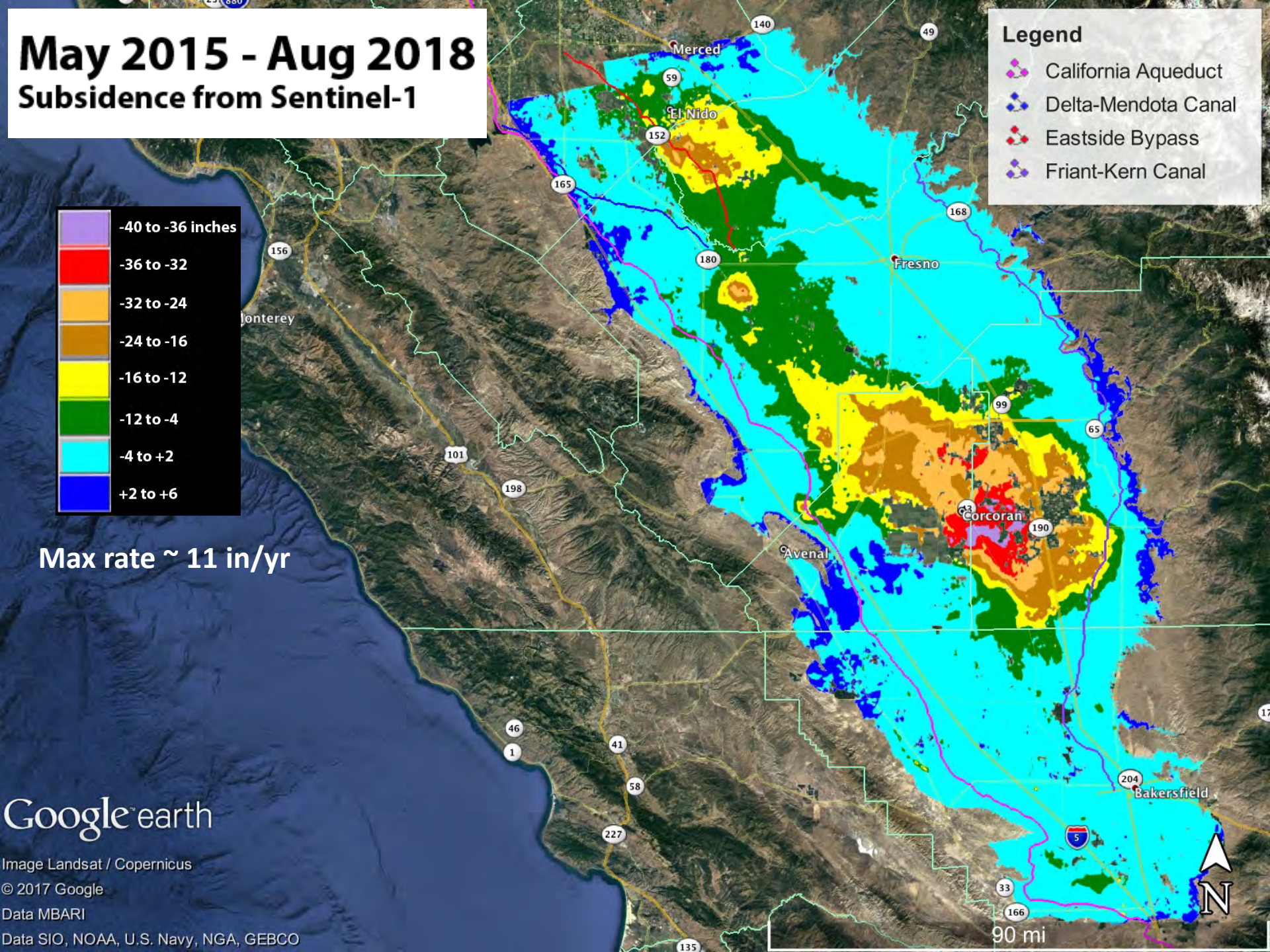
- California Aqueduct
- Delta-Mendota Canal
- Eastside Bypass
- Friant-Kern Canal



Max rate ~ 11 in/yr

Google earth

Image Landsat / Copernicus  
© 2017 Google  
Data MBARI  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO



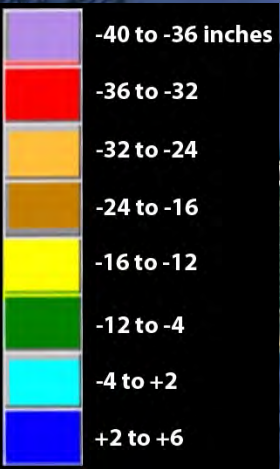


# Jan 2015 - Aug 2018

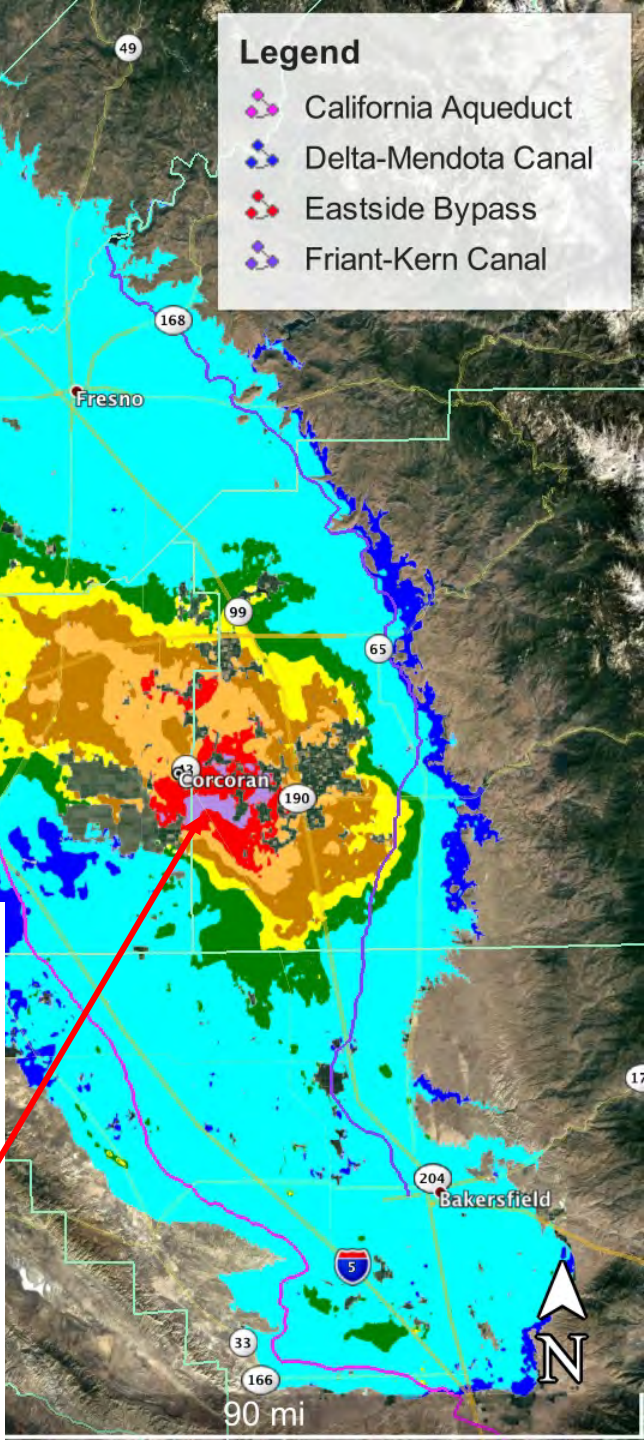
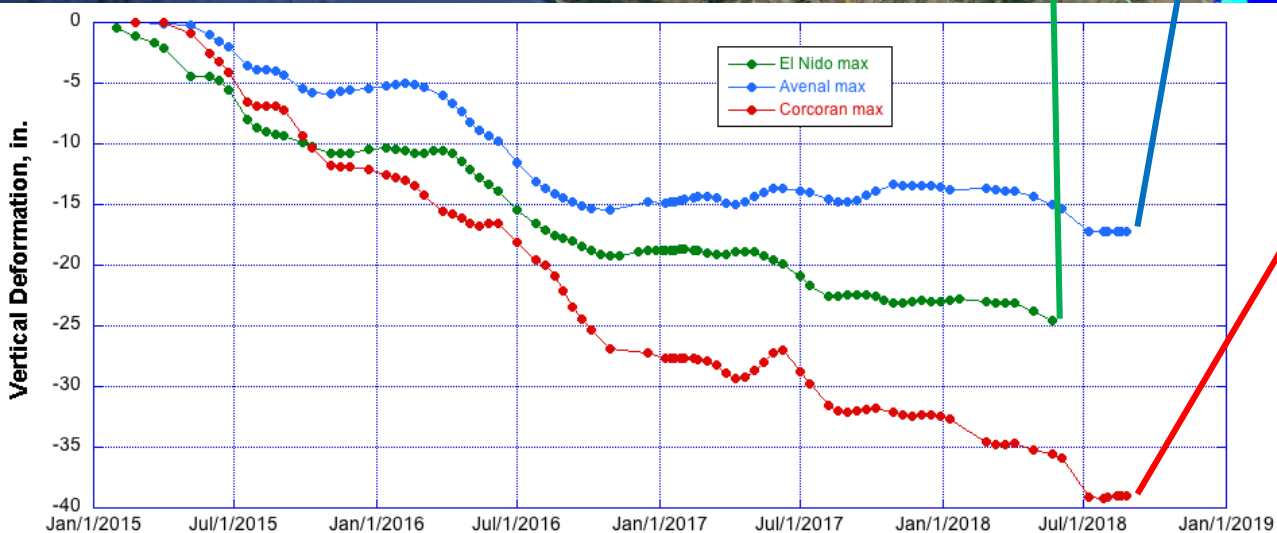
## Subsidence from Sentinel-1

**Legend**

- California Aqueduct
- Delta-Mendota Canal
- Eastside Bypass
- Friant-Kern Canal



Max rate ~ 11 in/yr



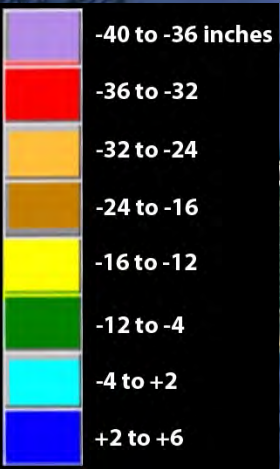


# Jan 2015 - Aug 2018

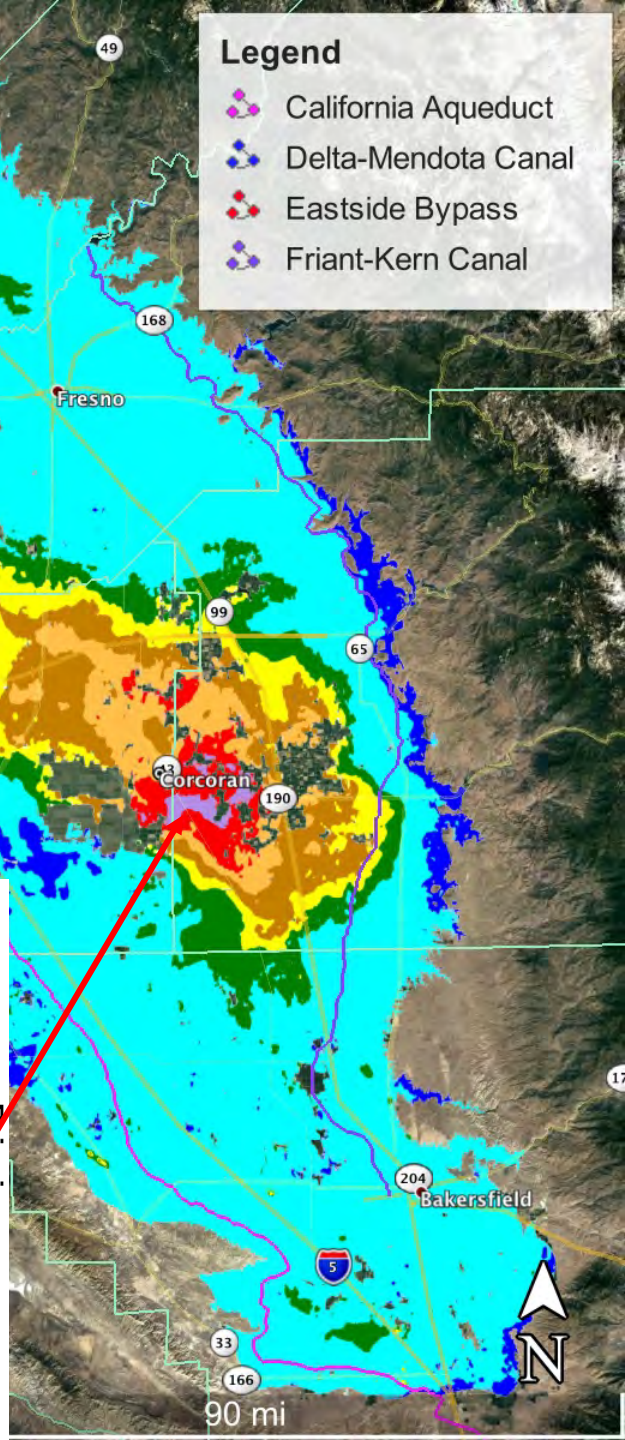
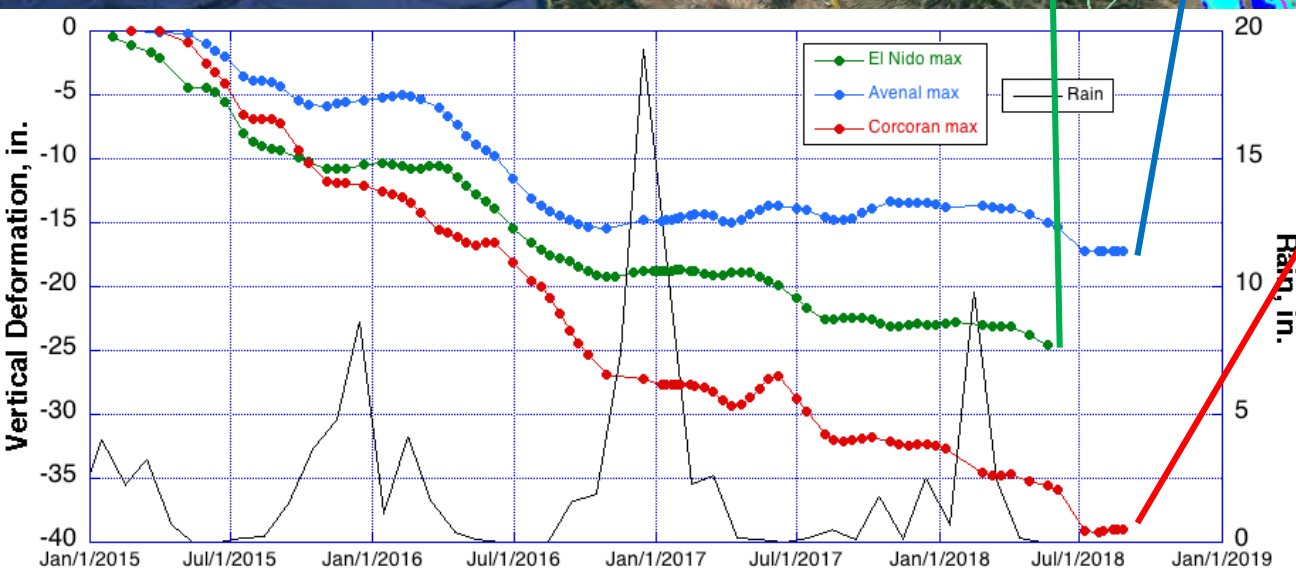
## Subsidence from Sentinel-1

**Legend**

- California Aqueduct
- Delta-Mendota Canal
- Eastside Bypass
- Friant-Kern Canal

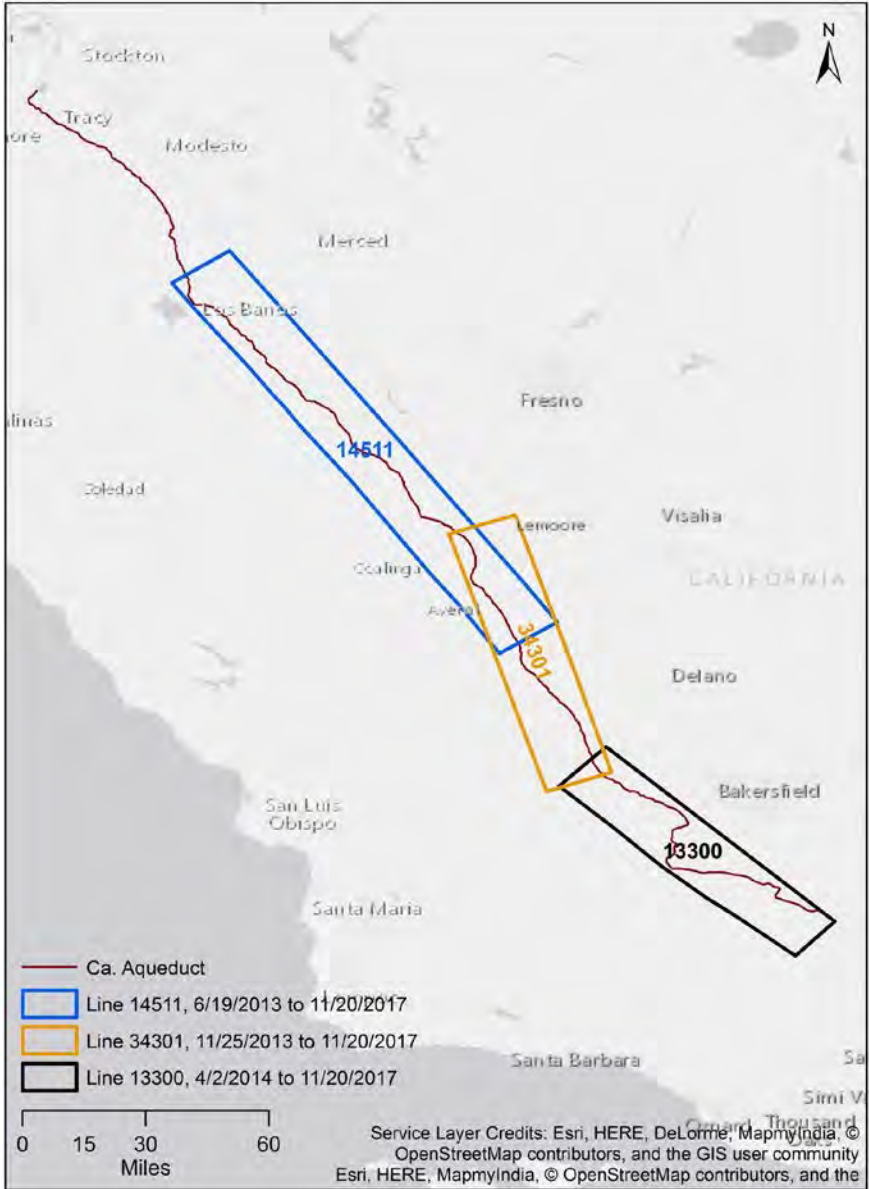


Max rate ~ 11 in/yr





# UAVSAR – West Central Valley Imaging



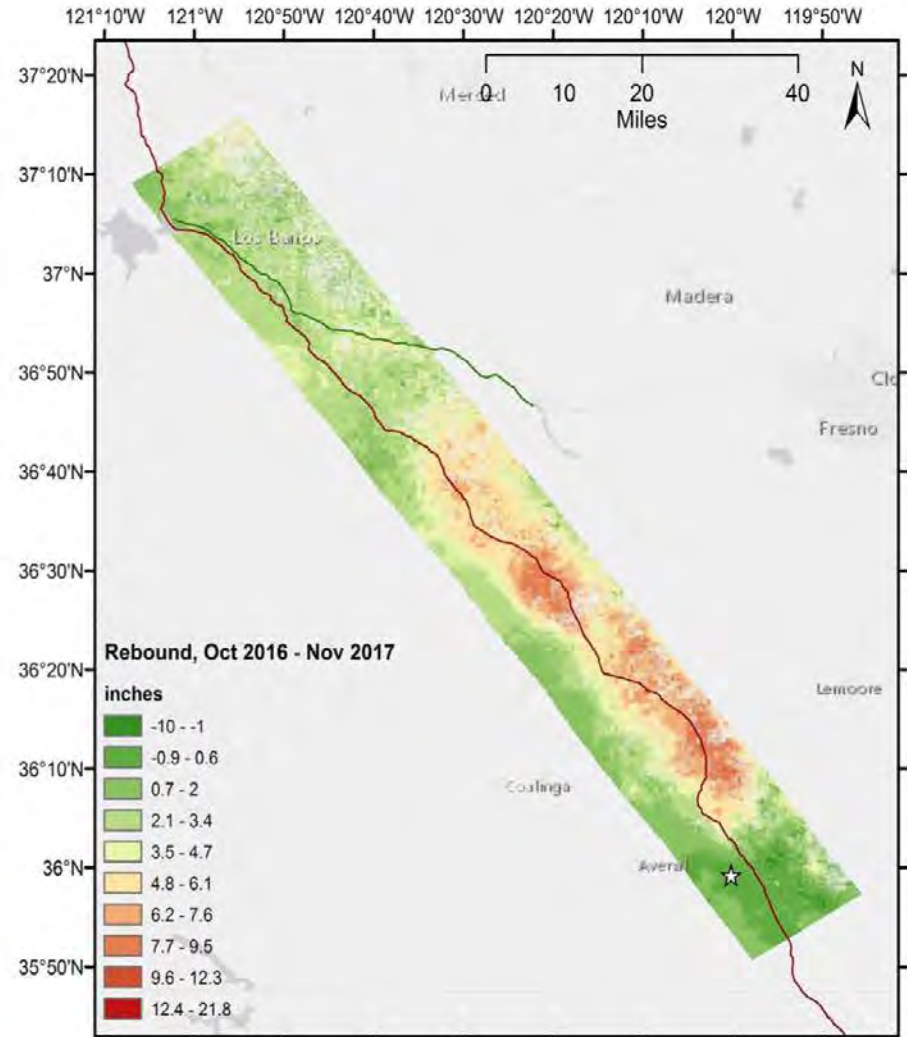
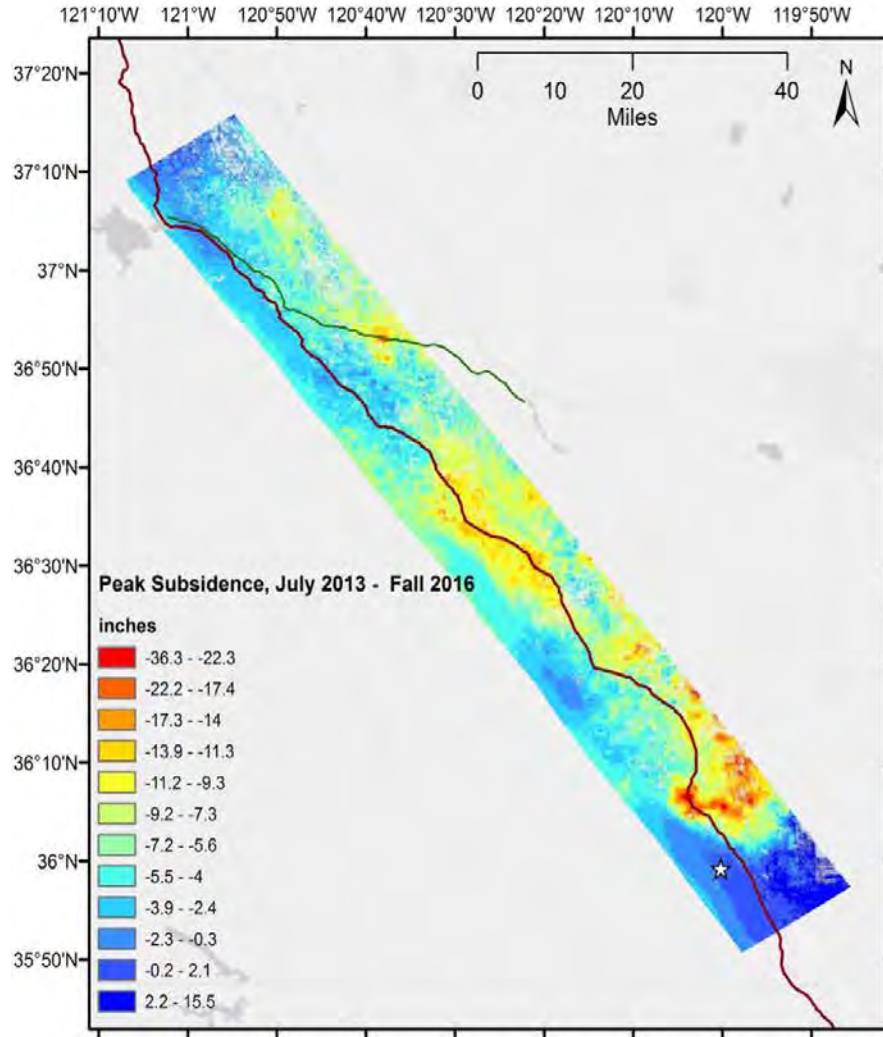
**Number of Acquisitions by Year**

	2013	2014	2015	2016	2017
14511	2	8	4	4	6
34301	1	5	1	1	4
13300	0	6	4	4	6

# Subsidence & Rebound in the West Central Valley, California

Cathleen Jones  
Sept. 26, 2018

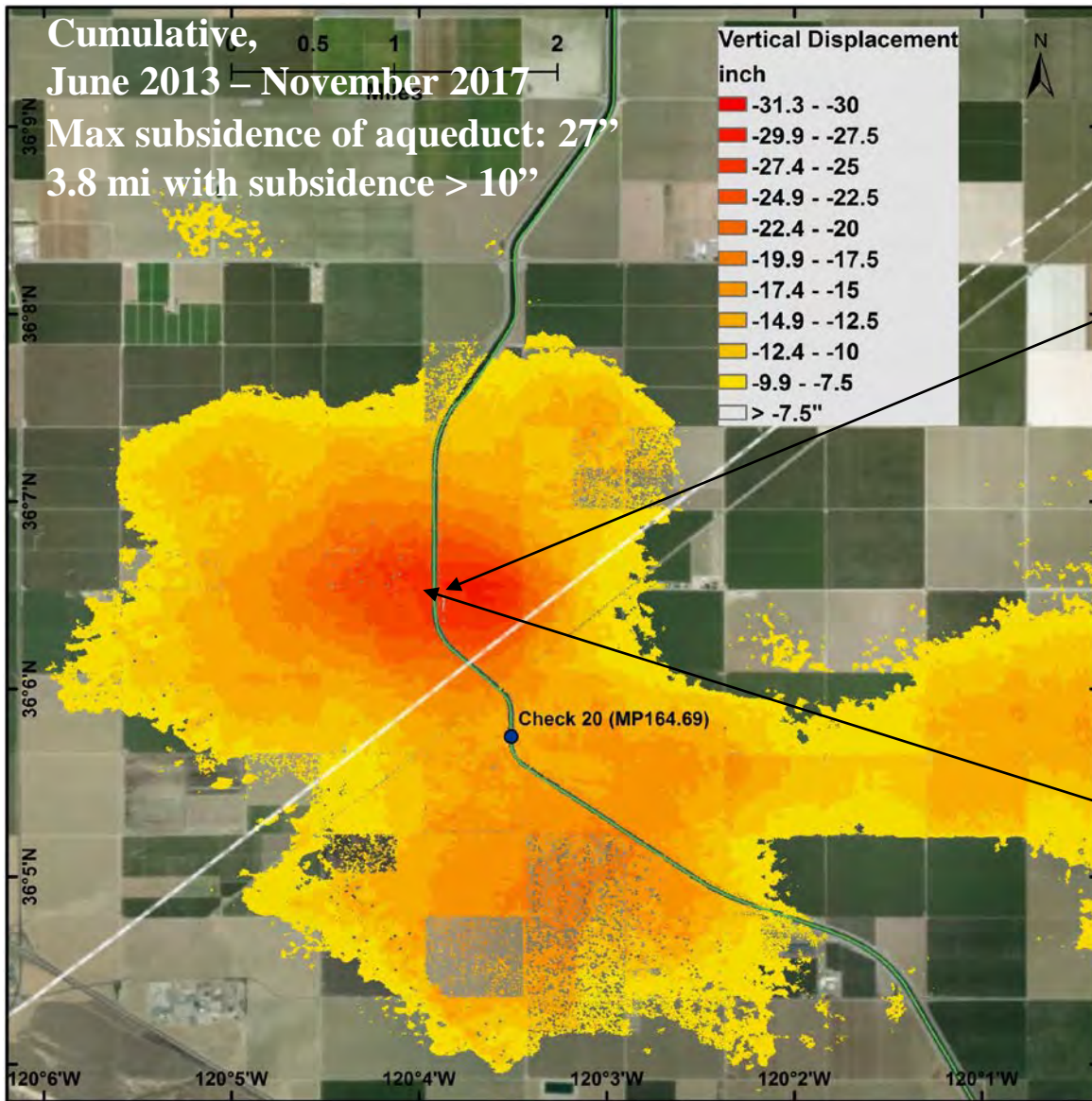
July 2013 – November 2017  
(Northern UAVSAR Scene)



The peak of subsidence (left) occurred in Fall 2016, and highest subsidence centered on groundwater pumping wells. The California Aqueduct (red line) sustained significant subsidence particularly in the south near Avenal. Rebound (right) occurred across much of the area but surface elevation did not recover to near pre-drought levels in the areas that sustained the highest subsidence.

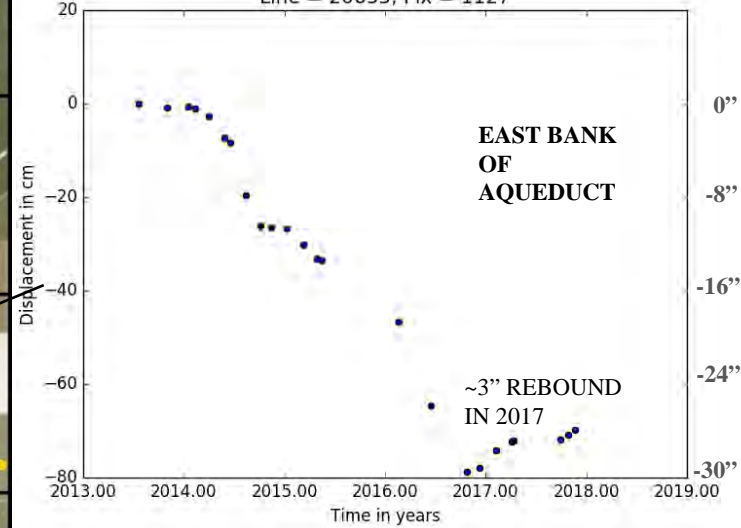


# Avenal Hot Spot – Trends along Aqueduct

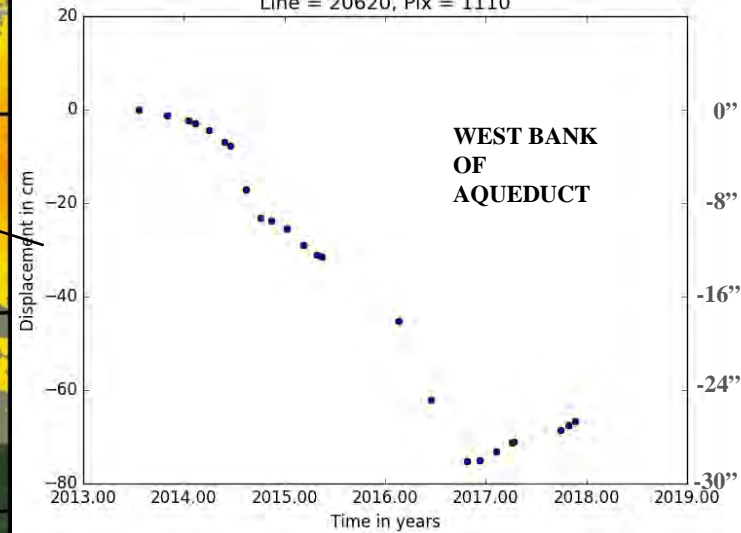


Cumulative, June 2013 – November 2017

Line = 20635, Pix = 1127



Line = 20620, Pix = 1110



✕ ? 10 ↓ order by  ↔

## - platform

? 10 count ↓ OR range

Sentinel-1B (288)

Sentinel-1A (91)

## - user tags

? 10 count ↓ OR range

dwr\_stitched\_137\_test (57)

dwr\_stitched\_137\_full (9)

stitched\_bug (2)

dwr\_partial\_stitch (2)

## + start date

## + stop date

## + temporal span (days)

## - region

? 10 count ↓ OR range

California (314)

Nevada (35)

## - subregion

? 10 count ↓ OR range

Merced County (292)

Fresno County (287)

Stanislaus County (283)

San Joaquin County (274)

Tulare County (262)

Contra Costa County (262)

Alameda County (262)

Madera County (249)

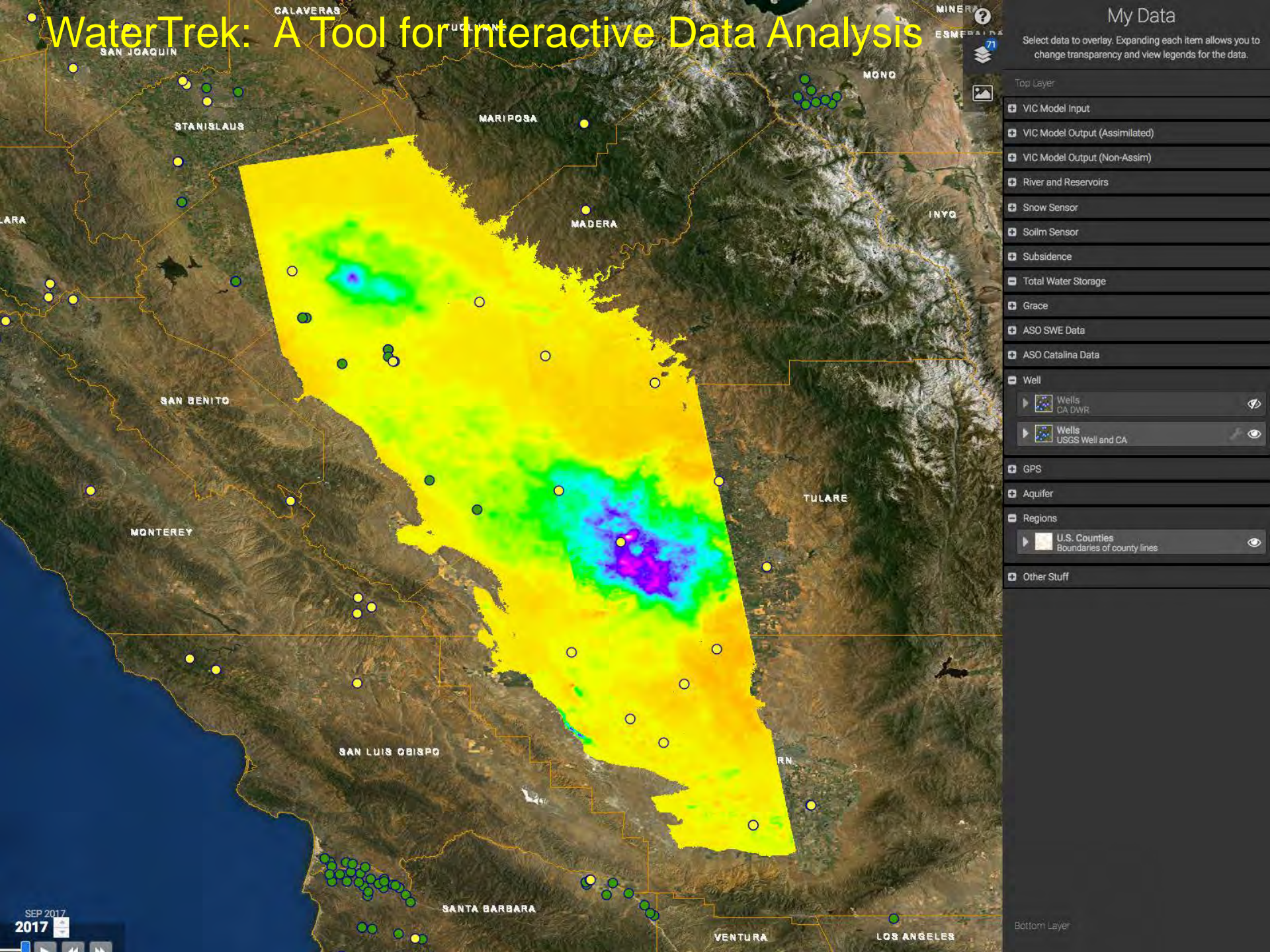
interferogram ✕ California ✕ 137 ✕ S1-IFG-STITCHED ✕

.. 1 - 10 of 314 next » Trigger Rules On-Demand Dataset Downloads





# WaterTrek: A Tool for Interactive Data Analysis



My Data

Select data to overlay. Expanding each item allows you to change transparency and view legends for the data.

Top Layer

- VIC Model Input
- VIC Model Output (Assimilated)
- VIC Model Output (Non-Assim)
- River and Reservoirs
- Snow Sensor
- Soilm Sensor
- Subsidence
- Total Water Storage
- Grace
- ASO SWE Data
- ASO Catalina Data
- Well
  - Wells CA DWR
  - Wells USGS Well and CA
- GPS
- Aquifer
- Regions
  - U.S. Counties
    - Boundaries of county lines
- Other Stuff

Bottom Layer

SEP 2017  
2017