InSAR Land Subsidence Monitoring

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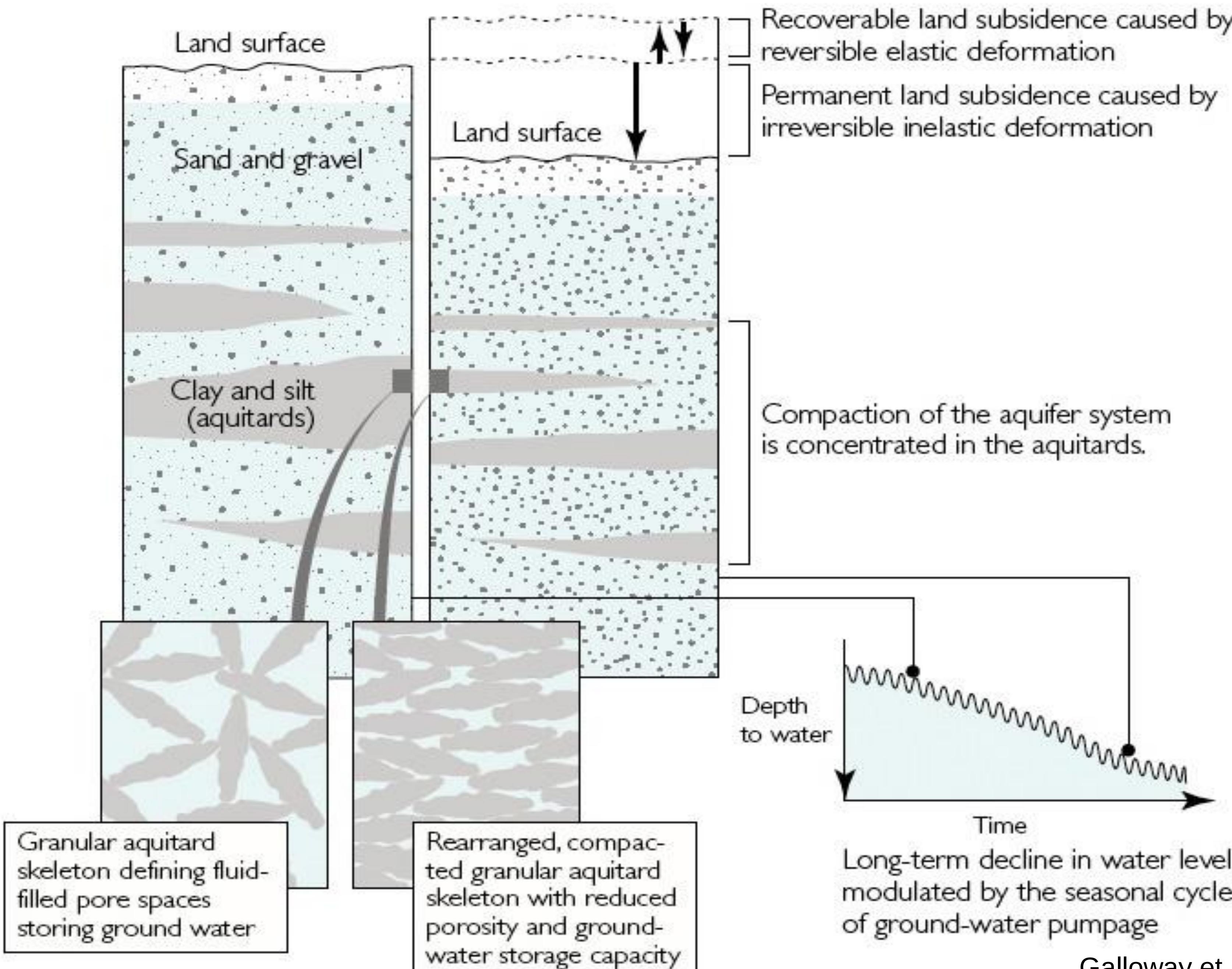
Subsidence from Space

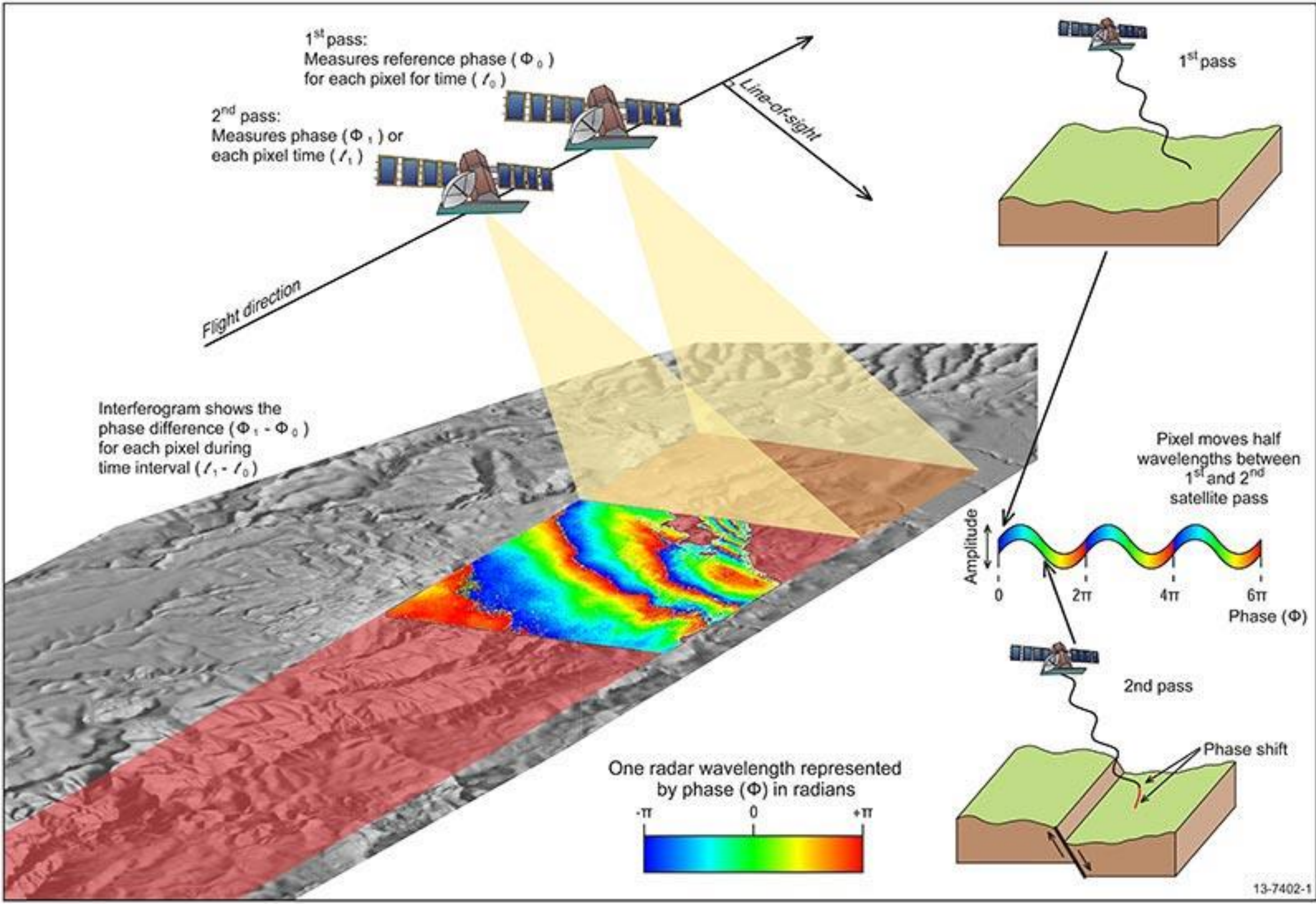
- Groundwater is becoming a more important part of water resources
- But knowledge of the groundwater level is not uniformly available
- Wells provide some monitoring capability, but there are political and practical difficulties
- Interferometric Synthetic Aperture Radar (InSAR) can provide information on groundwater levels by measuring surface deformation caused by withdrawal and recharge of aquifers
- Subsidence also causes problems for infrastructure such as roads, aqueducts, and trains
- We are developing information products for water managers, the public, and hydrologists including animations, maps of ‘hot spots’, pixel histories, and regional maps of subsidence
- Most of the work has been done for the Central Valley and LA basin, but we are also processing data for other basins and coastal areas of California

Hydrology 101: Aquifer compaction



Galloway et al., 1999

InSAR 101



1st pass:
Measures reference phase (Φ_0) for each pixel for time (t_0)
2nd pass:
Measures phase (Φ_1) or each pixel time (t_1)
Line-of-sight
Flight direction
Interferogram shows the phase difference ($\Phi_1 - \Phi_0$) for each pixel during time interval ($t_1 - t_0$)
1st pass
Pixel moves half wavelengths between 1st and 2nd satellite pass
Amplitude
0
2π
4π
6π
Phase (Φ)
2nd pass
Phase shift
One radar wavelength represented by phase (Φ) in radians
-π
0
+π
13-7402-1

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
PALSAR	2006-2011	10-100	40-350	10-60°	46	L-quad
Radarsat 1	1995-2013	10-100	45-500	20-49°	24	CHH
Radarsat 2	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
Sentinel-1	2014-	20	250	30-45°	12	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: PALSAR, 2007-2011

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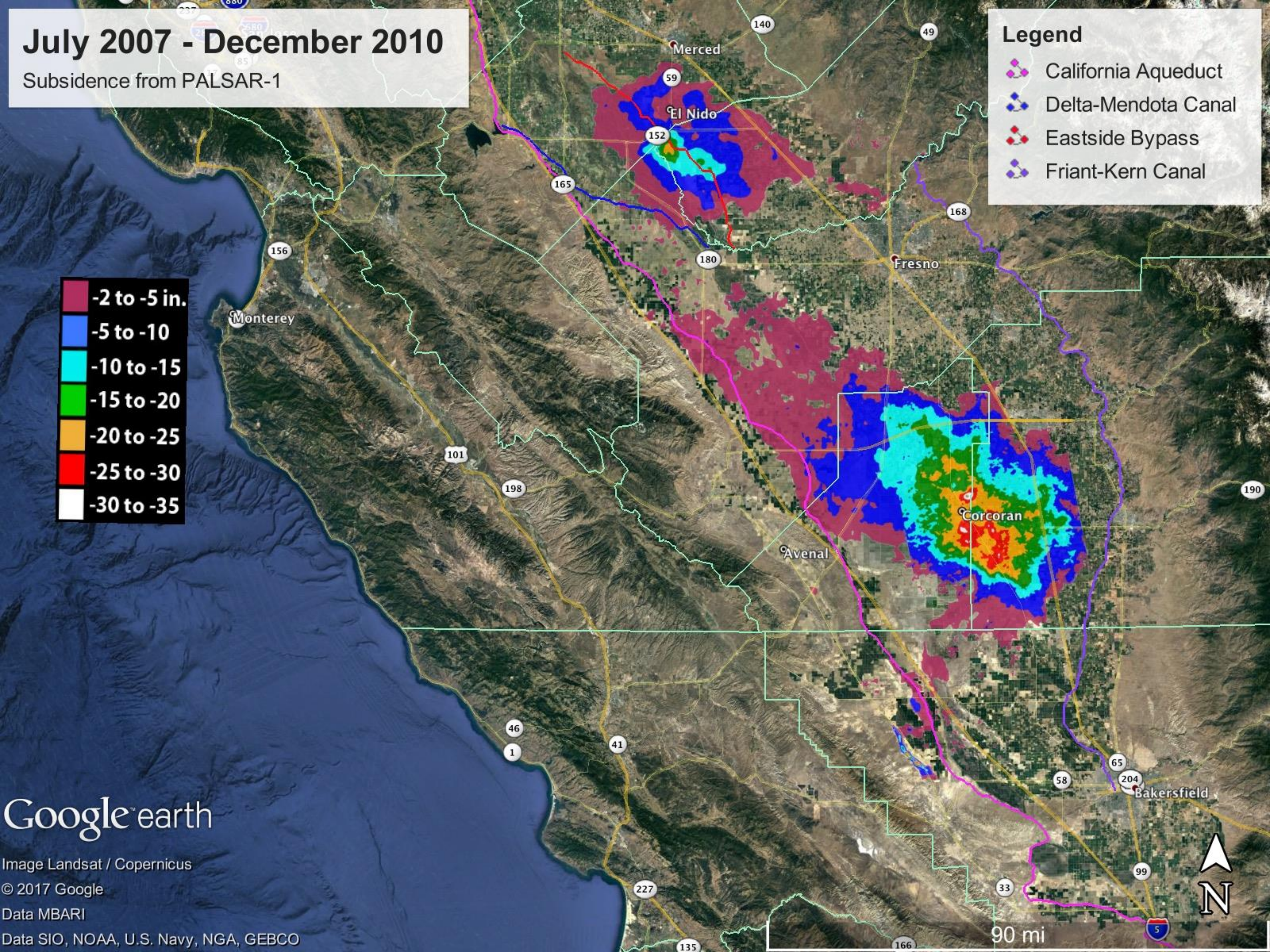
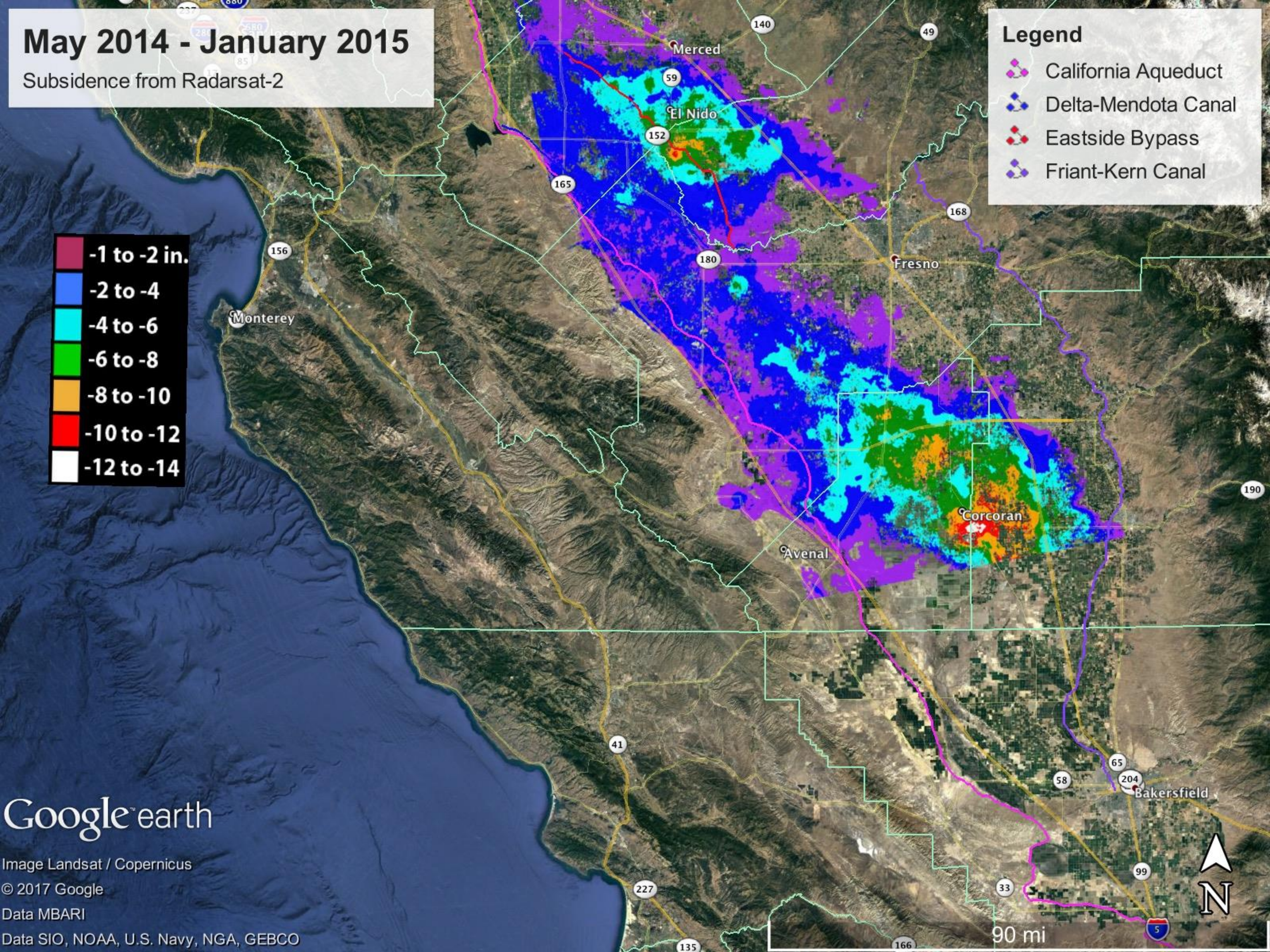

July 2007 - December 2010
Subsidence from PALSAR-1
Legend
California Aqueduct
Delta-Mendota Canal
Eastside Bypass
Friant-Kern Canal
-2 to -5 in.
-5 to -10
-10 to -15
-15 to -20
-20 to -25
-25 to -30
-30 to -35
Merced
El Nido
Fresno
Monterey
Corcoran
Avenal
Bakersfield
Google earth
Image Landsat / Copernicus
© 2017 Google
Data MBARI
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
90 mi
N


May 2014 - January 2015
Subsidence from Radarsat-2
Legend
California Aqueduct
Delta-Mendota Canal
Eastside Bypass
Friant-Kern Canal
-1 to -2 in.
-2 to -4
-4 to -6
-6 to -8
-8 to -10
-10 to -12
-12 to -14
Merced
El Nido
Fresno
Monterey
Corcoran
Avenal
Bakersfield
Google earth
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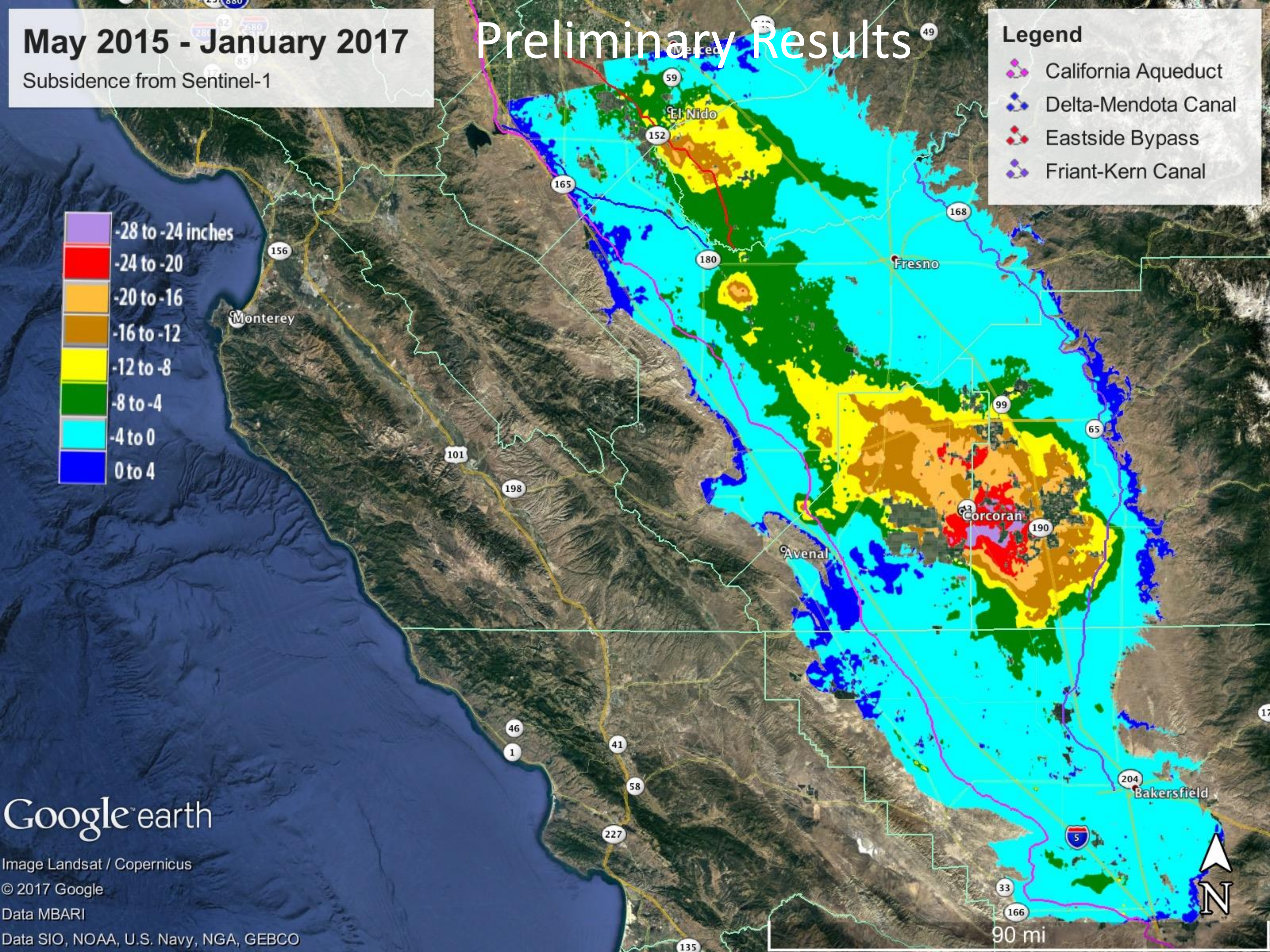
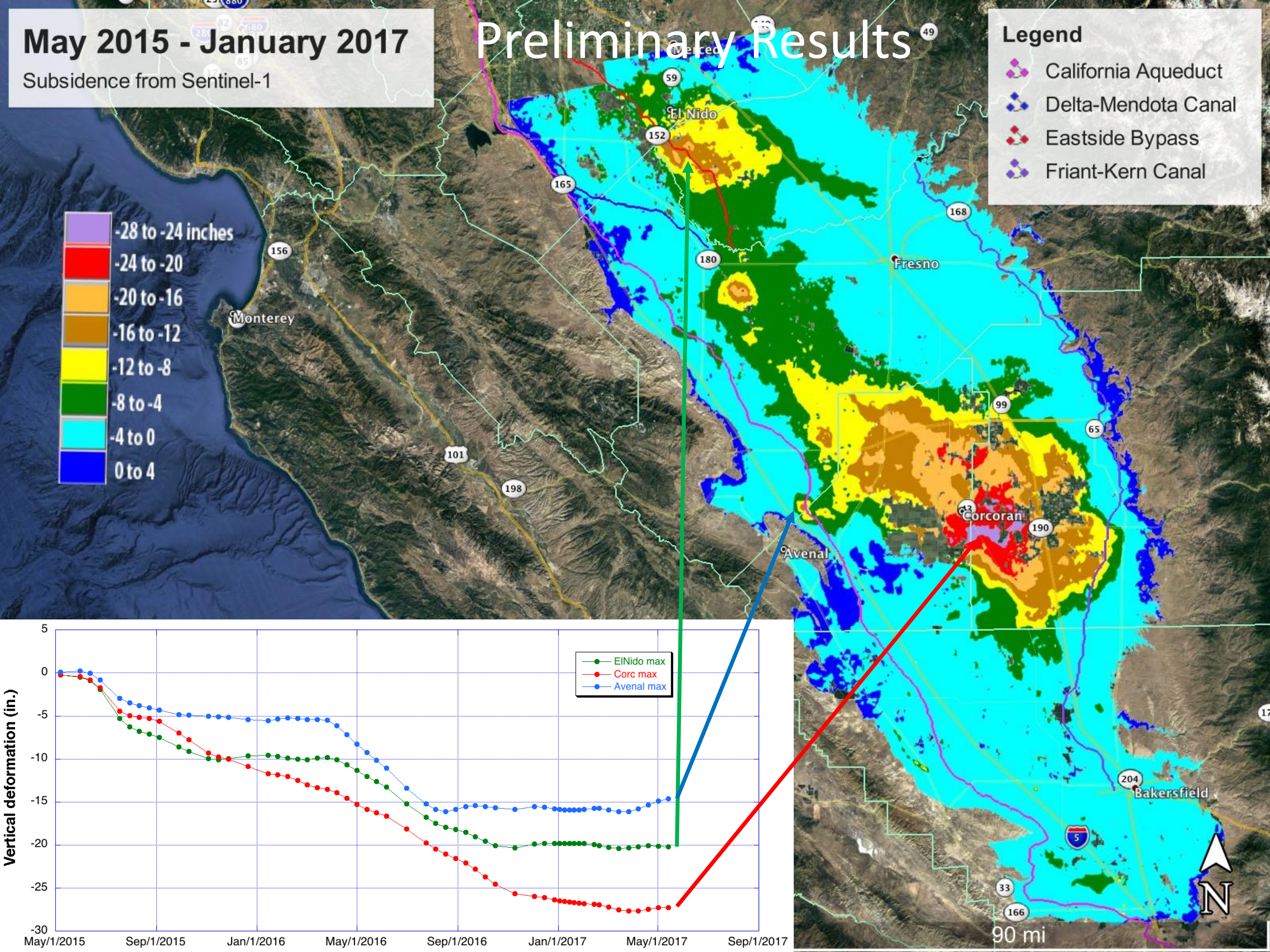
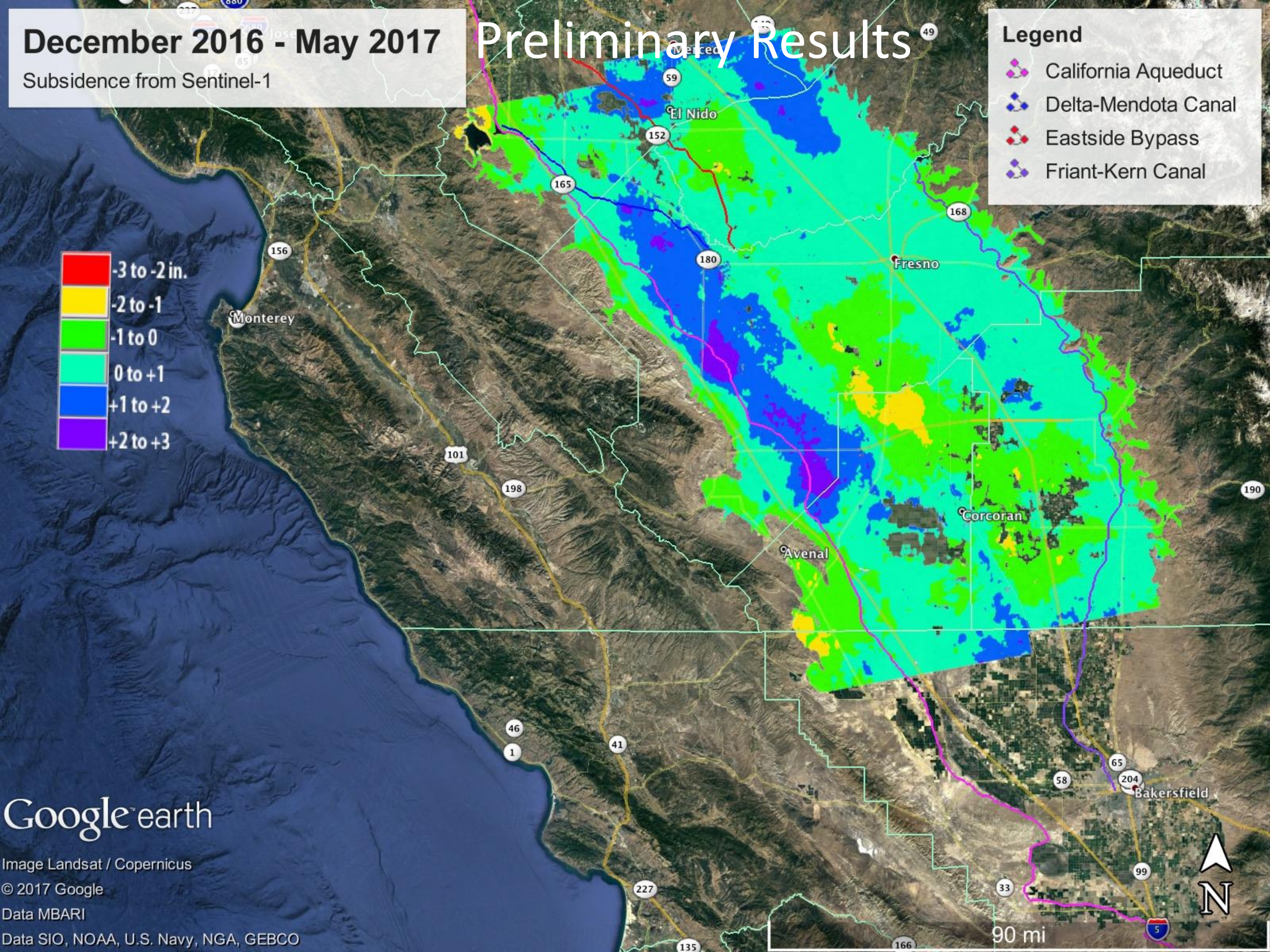
Data MBARI
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
90 mi
N

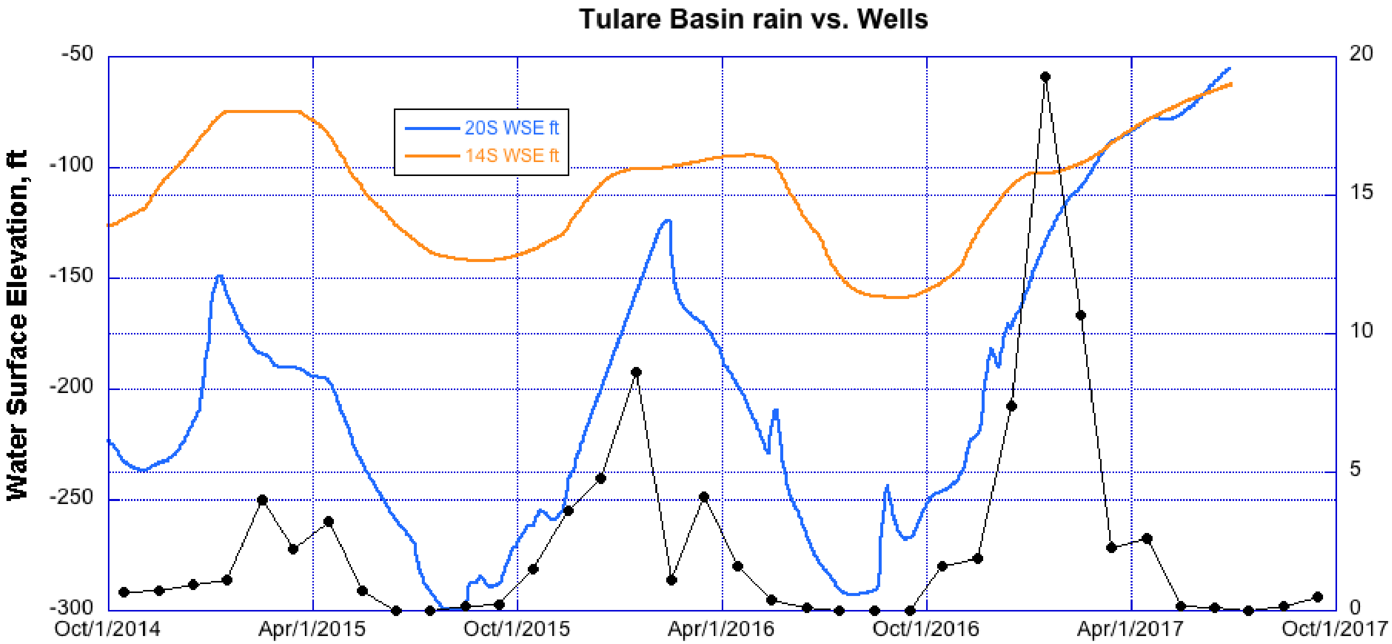


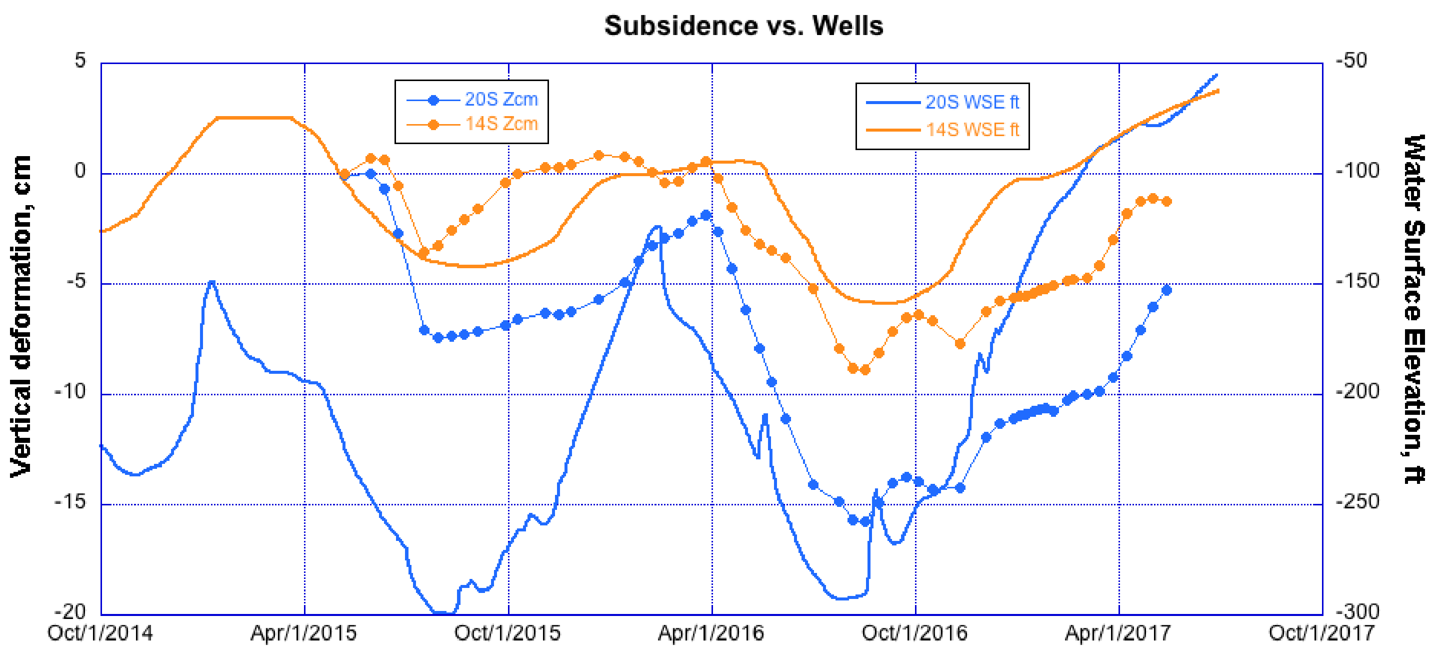
May 2015 - January 2017
Subsidence from Sentinel-1
Preliminary Results
Legend
California Aqueduct
Delta-Mendota Canal
Eastside Bypass
Friant-Kern Canal
-28 to -24 inches
-24 to -20
-20 to -16
-16 to -12
-12 to -8
-8 to -4
-4 to 0
0 to 4
Merced
El Nido
Fresno
Monterey
Corcoran
Avenal
Bakersfield
Google earth
Image Landsat / Copernicus
© 2017 Google
Data MBARI
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
90 mi
N


May 2015 - January 2017
Subsidence from Sentinel-1
Preliminary Results
Legend
California Aqueduct
Delta-Mendota Canal
Eastside Bypass
Friant-Kern Canal
-28 to -24 inches
-24 to -20
-20 to -16
-16 to -12
-12 to -8
-8 to -4
-4 to 0
0 to 4
El Nido
Fresno
Monterey
Corcoran
Avenal
Bakersfield
90 mi
ElNido max
Corc max
Avenal max
Vertical deformation (in.)
May/1/2015
Sep/1/2015
Jan/1/2016
May/1/2016
Sep/1/2016
Jan/1/2017
May/1/2017
Sep/1/2017

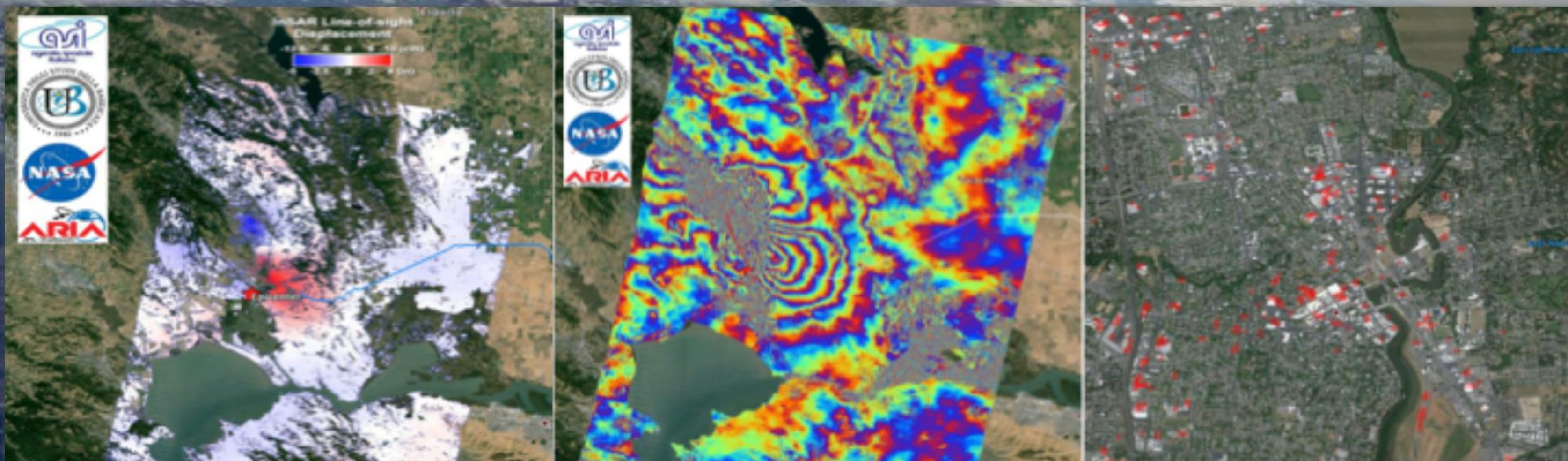

December 2016 - May 2017
Subsidence from Sentinel-1
Preliminary Results
Legend
California Aqueduct
Delta-Mendota Canal
Eastside Bypass
Friant-Kern Canal
-3 to -2 in.
-2 to -1
-1 to 0
0 to +1
+1 to +2
+2 to +3
Merced
El Nido
Fresno
Monterey
Corcoran
Avenal
Bakersfield
Google earth
Image Landsat / Copernicus
© 2017 Google
Data MBARI
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
90 mi
N

Response of Wells and Subsidence to Rainfall





Advanced Rapid Imaging and Analysis (ARIA) Project for Natural Hazards



JPL-Caltech in collaboration with ASI/CIDOT responded to the M6.0 earthquake in California's Napa Valley by generating rapid GPS and SAR products, including radar based deformation and damage maps. More details and links to products can be found here.

Overview

ARIA is a collaboration between JPL and Caltech to exploit radar and optical remote sensing, GPS, and seismic observations for hazard science and response

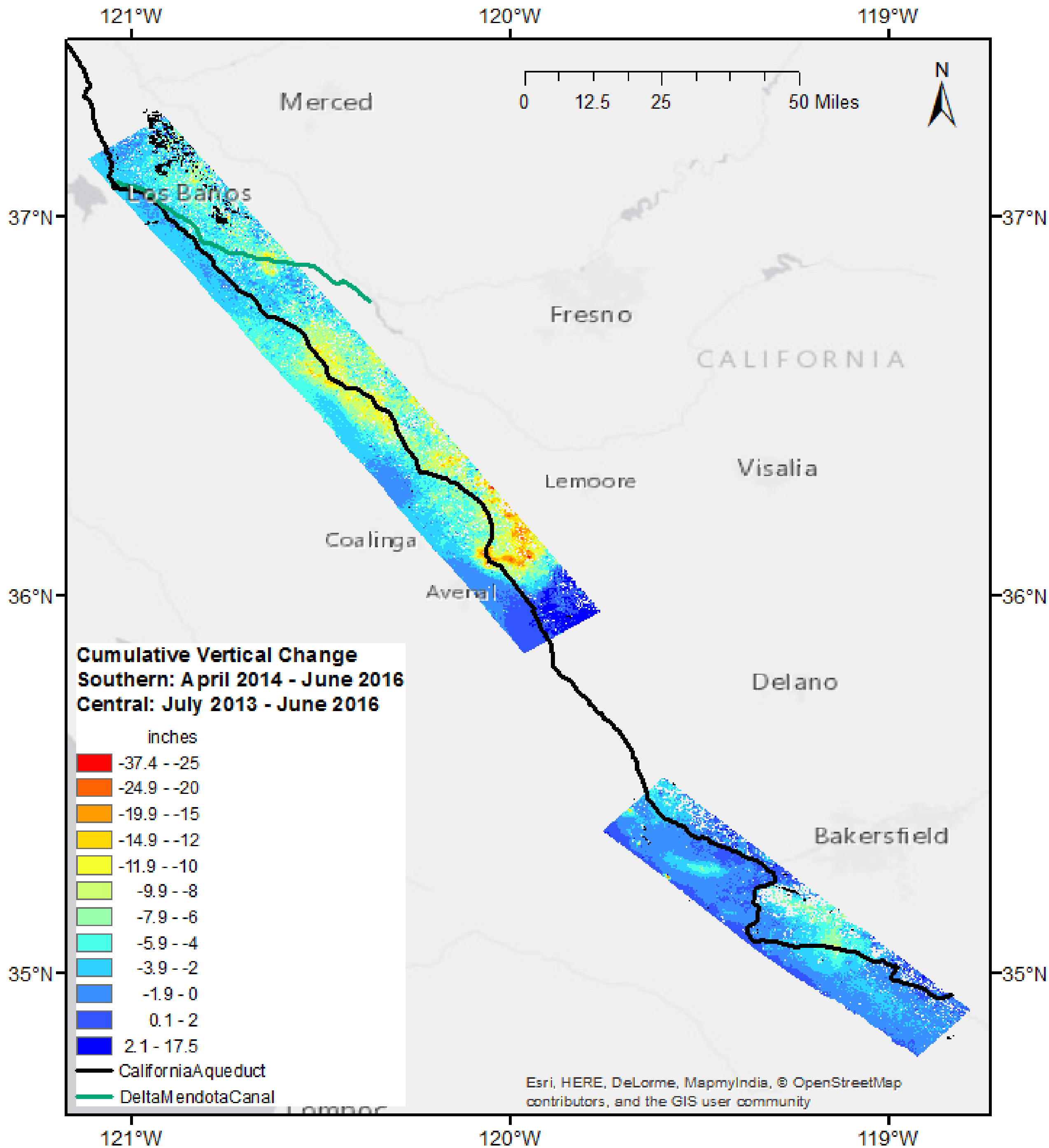
Science & Research

ARIA investigates the processes and impacts of earthquakes, volcanoes, landslides, fires, subsurface fluid movement and other natural hazards by applying modern geodesy, merged with

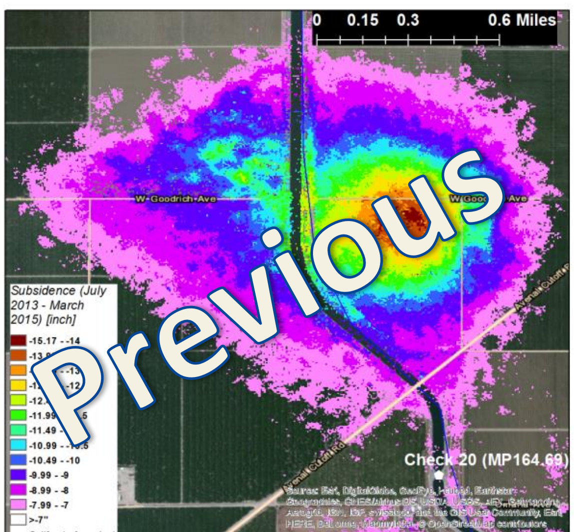
Monitoring & Response

As populations grow, response to natural disasters is becoming an increasingly important part of link between science and society. We are

Subsidence along the California Aqueduct



Avenal Subsidence Hot Spot



NOTE CHANGE IN SCALE

- Previously had seen 13” max subsidence of the aqueduct in July 2013 - March 2015.

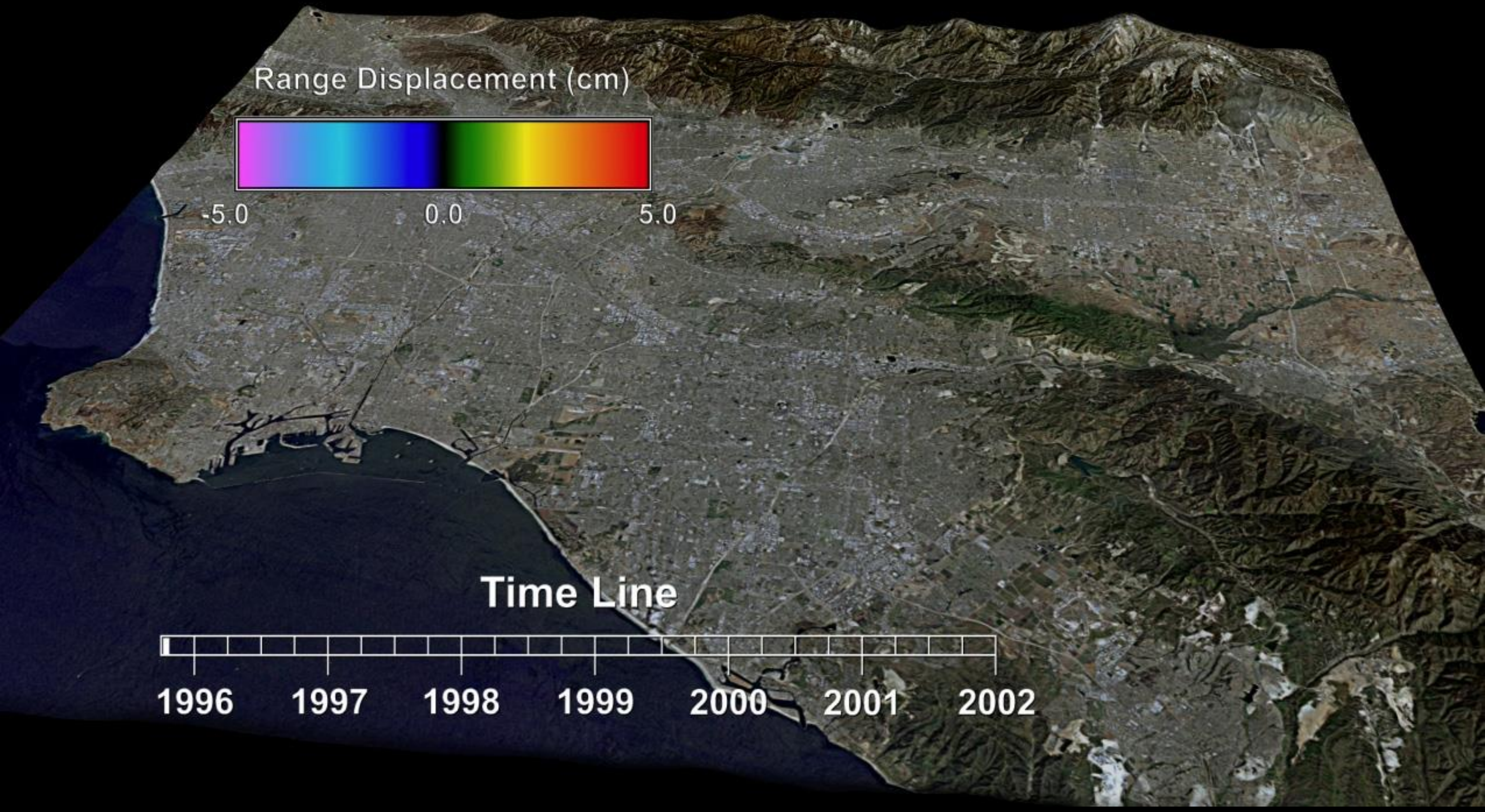
owed 25”

l > 10”.

5’x25’, so
obably

flow here
struction

Monitoring LA Basin



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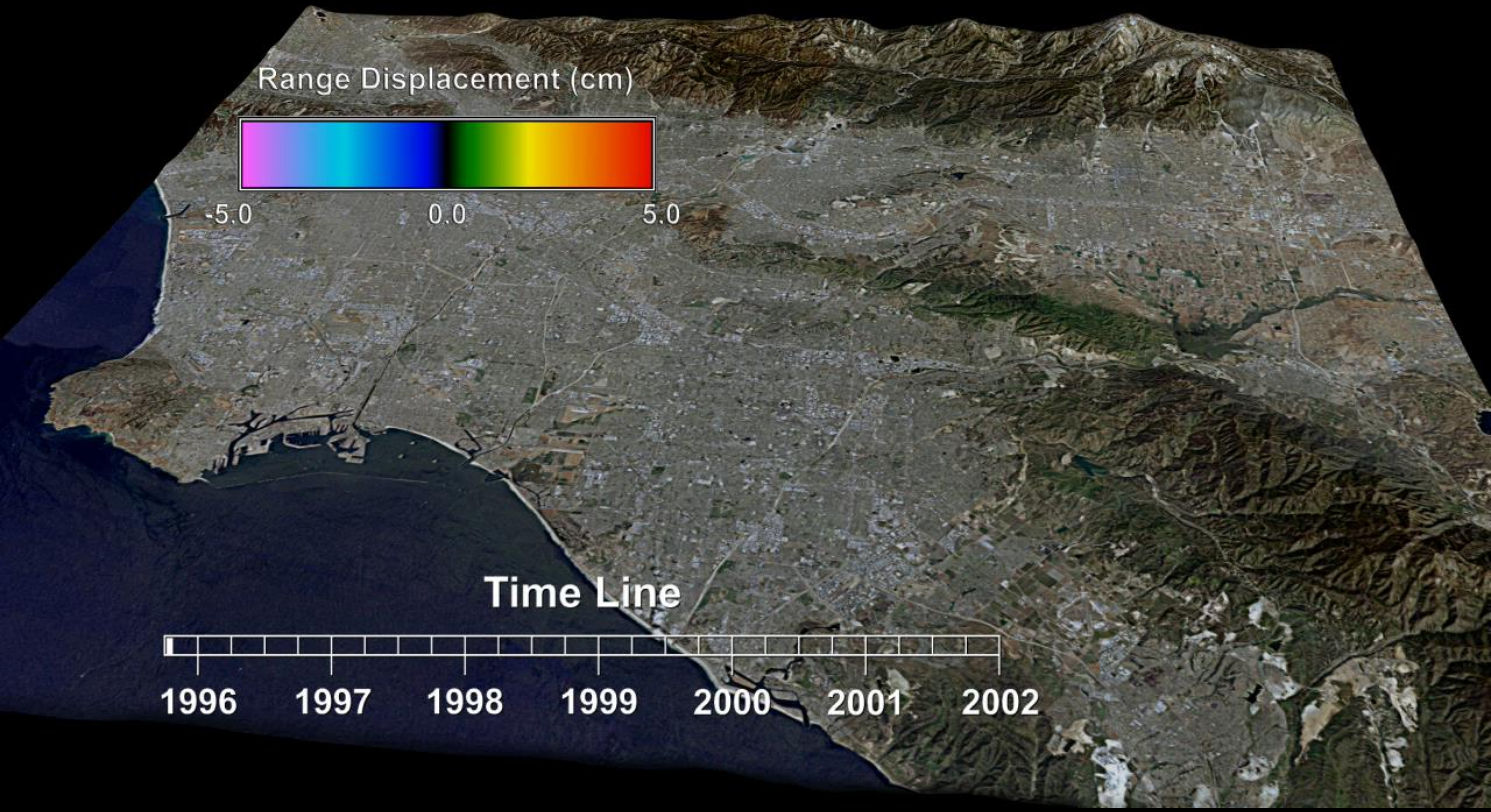
Monitoring LA Basin



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