Study of Movement and Seepage along Levees Using DInSAR and the UAVSAR Instrument

Sacramento Delta / UAVSAR POLSAR / 7 m resolution

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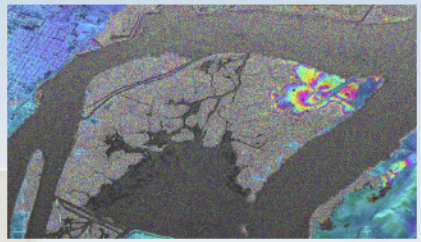
Radar Remote Sensing of the Sacramento Delta Levees

A NASA Applied Science Project

Monitoring Levees and Subsidence in the Sacramento-San Joaquin Delta using UAVSAR



Funding: NASA Research Opportunities in Earth Science

Collaboration: ***Jet Propulsion Laboratory,*** *California Dept. of Water Resources, USGS, HydroFocus, Inc.*

Objectives

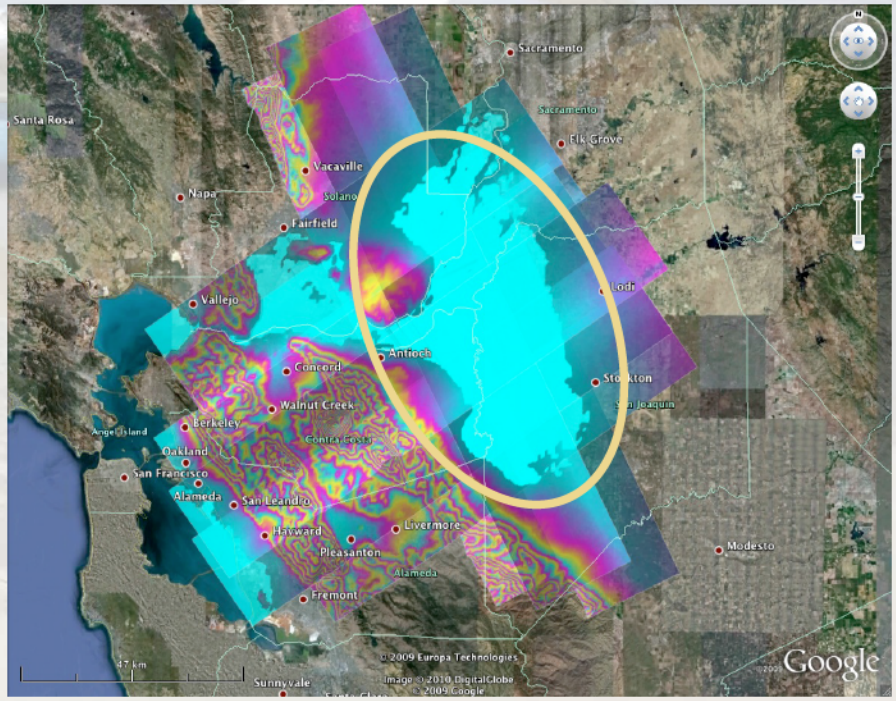
(1) Provide an *independent and verifiable* source of information about levee status with the *spatial extent* needed to cover the 1700 km of levees within the Sacramento Delta and with sufficient *ground resolution* and *temporal frequency* to detect changes indicative of potential levee failure.

(2) Measure subsidence rates across the entire delta at a scale suitable to resolving differential features within islands.

Method:

The area is imaged monthly with UAVSAR and the DInSAR products are monitored for changes along the levees. We are using SBAS techniques to measure long-term subsidence trends and long-term levee deformation from the monthly UAVSAR data.

Nine flight lines have been collected at 1-2 month intervals since July 2009 to image all locations in the Sacramento Delta from 3-4 different look directions.



UAVSAR (Uninhabited Aerial Vehicle Synthetic Aperture Radar)

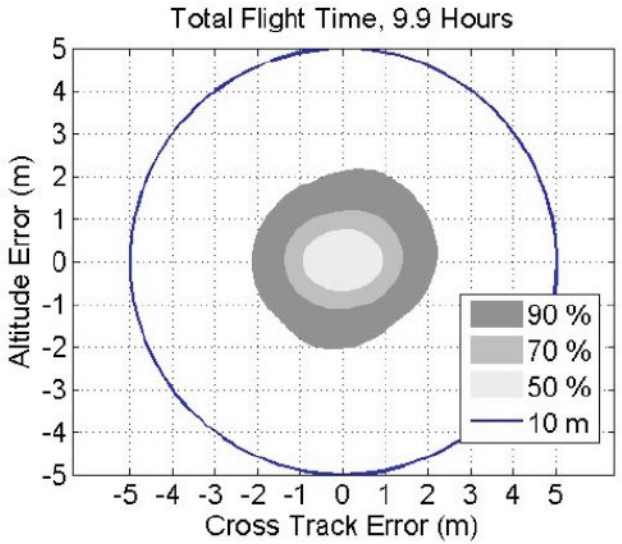
NASA's Airborne Radar for Repeat Track Differential Interferometry

The UAVSAR L-band (23.8 cm wavelength) radar is housed in a pod flown on the NASA G-3 platform, shown here in flight over Edwards Air Force Base, California.

UAVSAR has several unique features to allow high precision DInSAR from an airborne platform:

1. Precision autopilot to maintain the flight track within a 10 meter tube around the desired track.
2. Phased array antenna plus adaptive steering to maintain pointing direction of the radar beam.

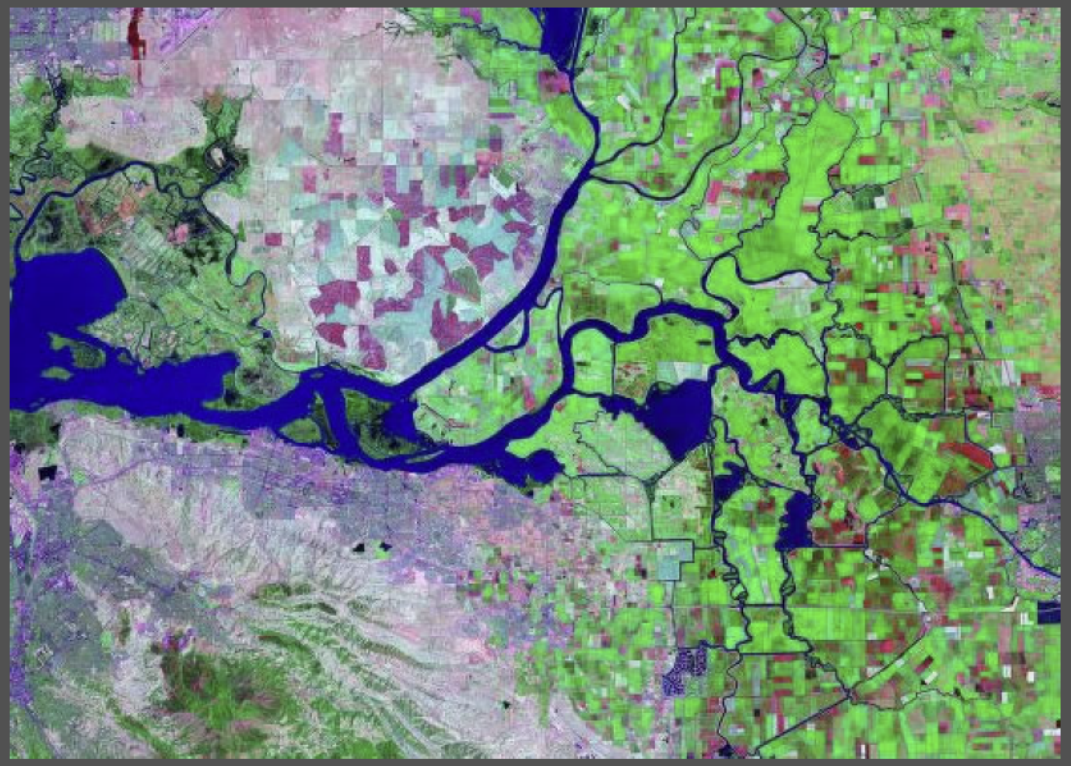
The Precision Autopilot System was designed and developed at Dryden Flight Research Center to provide < 5 meter repeat track capability.



Parameter	Value
Frequency	L-Band 1217.5 to 1297.5 MHz (23.8 cm wavelength)
Bandwidth	80 MHz
Resolution	1.67 m Range, 0.8 m Azimuth
Polarization	Full Quad-Polarization
ADC	12 bit ADC; 180 MHz sampling frequency
Waveform	Nominal Chirp/Arbitrary Waveform
Antenna Aperture	0.5 m range/1.5 m azimuth (electrical)
Azimuth Steering	Greater than ±20°
Transmit Power	> 3.1 kW
Polarization Isolation	<-25 dB

The Sacramento-San Joaquin Delta, California

Critical Water Resource



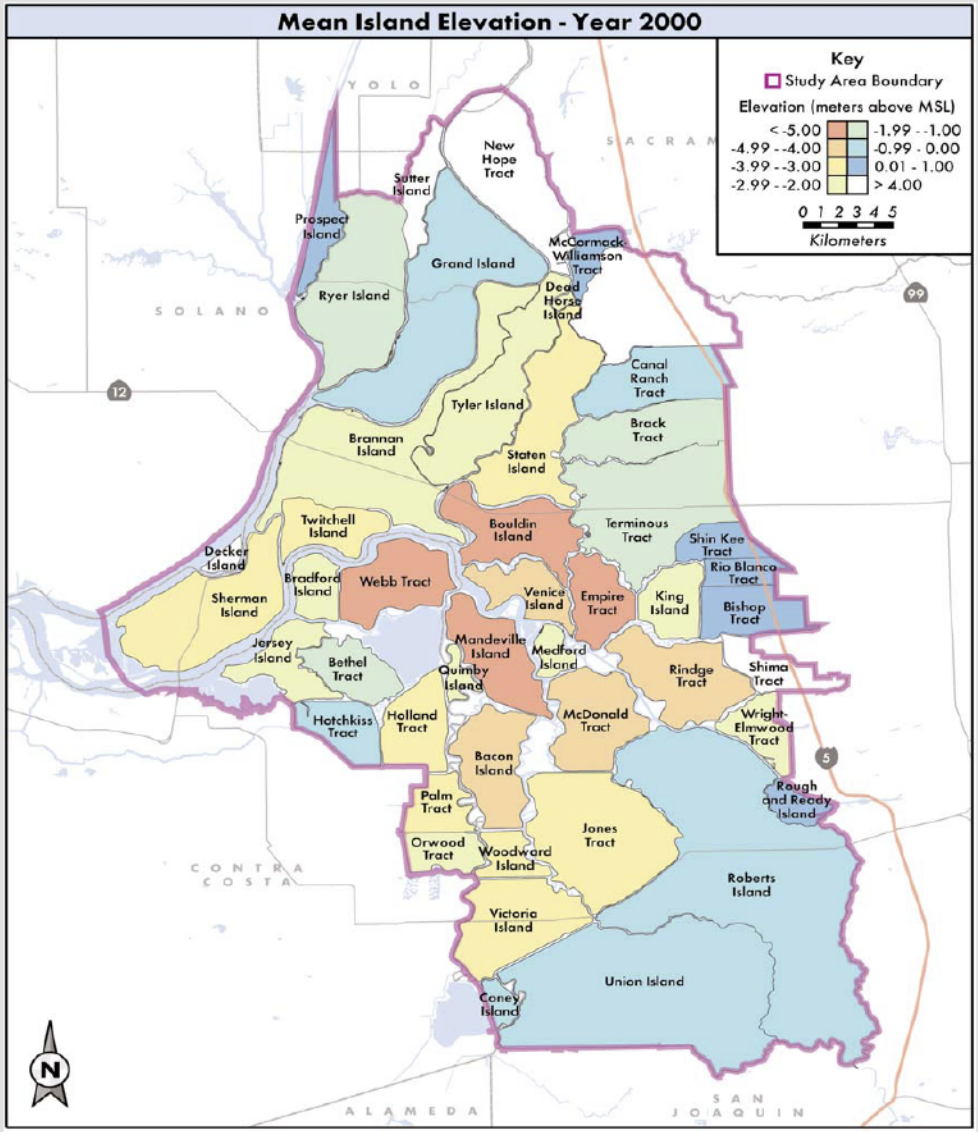
- 60+ reclaimed islands surrounded by 1700 kilometers of levees
- Most islands lie below mean sea level.
- Collects run-off from approximately 2/3 of the state via the Sacramento and San Joaquin rivers.
- Supplies water to ~2/3 of the residents of California and to almost all of the agriculture of the California Central Valley.

THE DELTA IS THE MOST CRITICAL WATER RESOURCE IN CALIFORNIA.

The Islands of the Sacramento – San Joaquin Delta

Land Elevation

Twitchell Island, California



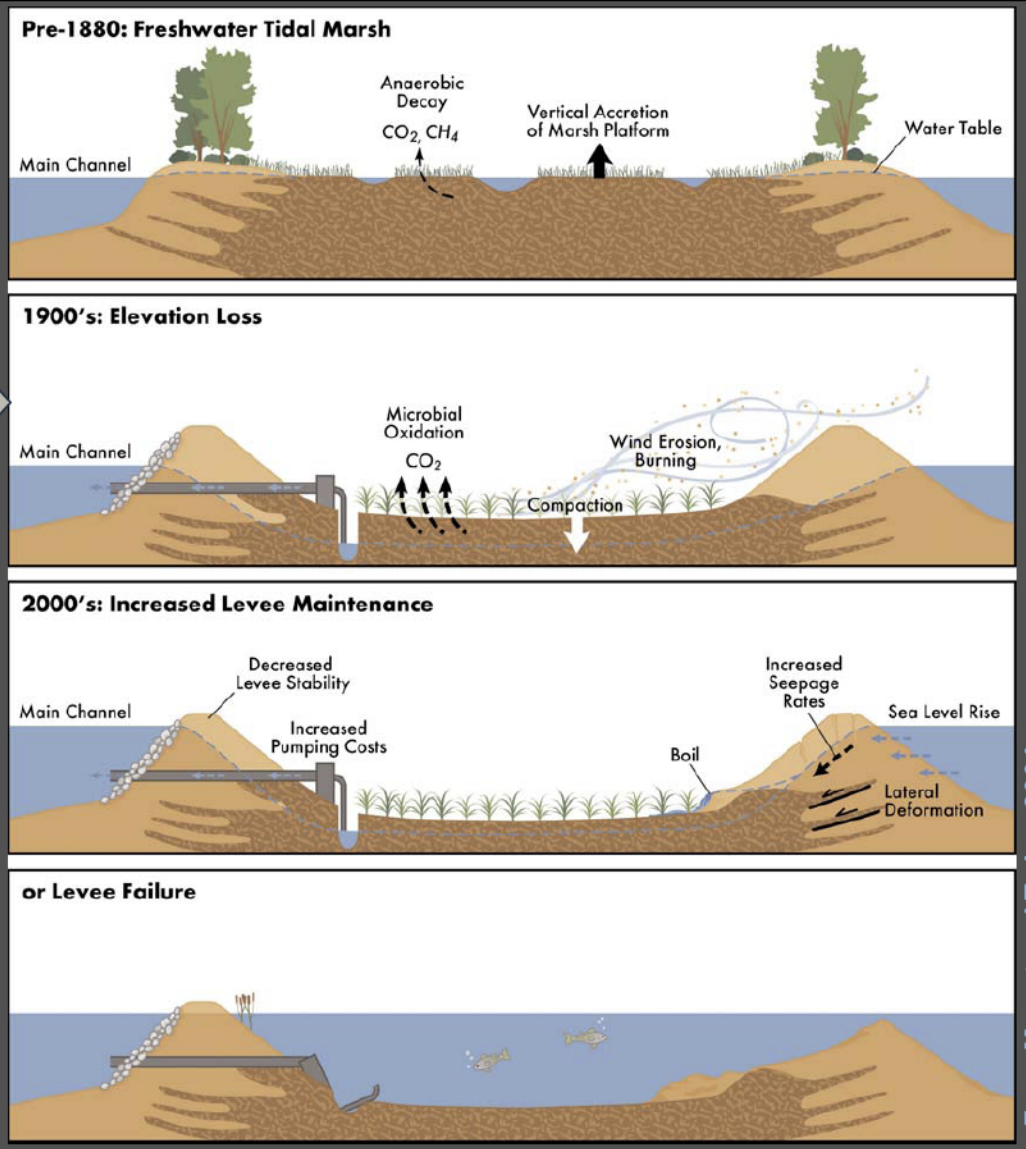
From "Subsidence, Sea Level Rise, and Seismicity in the Sacramento – San Joaquin Delta," Jeffrey Mount and Robert Twiss, San Francisco Estuary & Watershed Science, March 2005.

The Delta at Risk
Subsidence Mechanisms

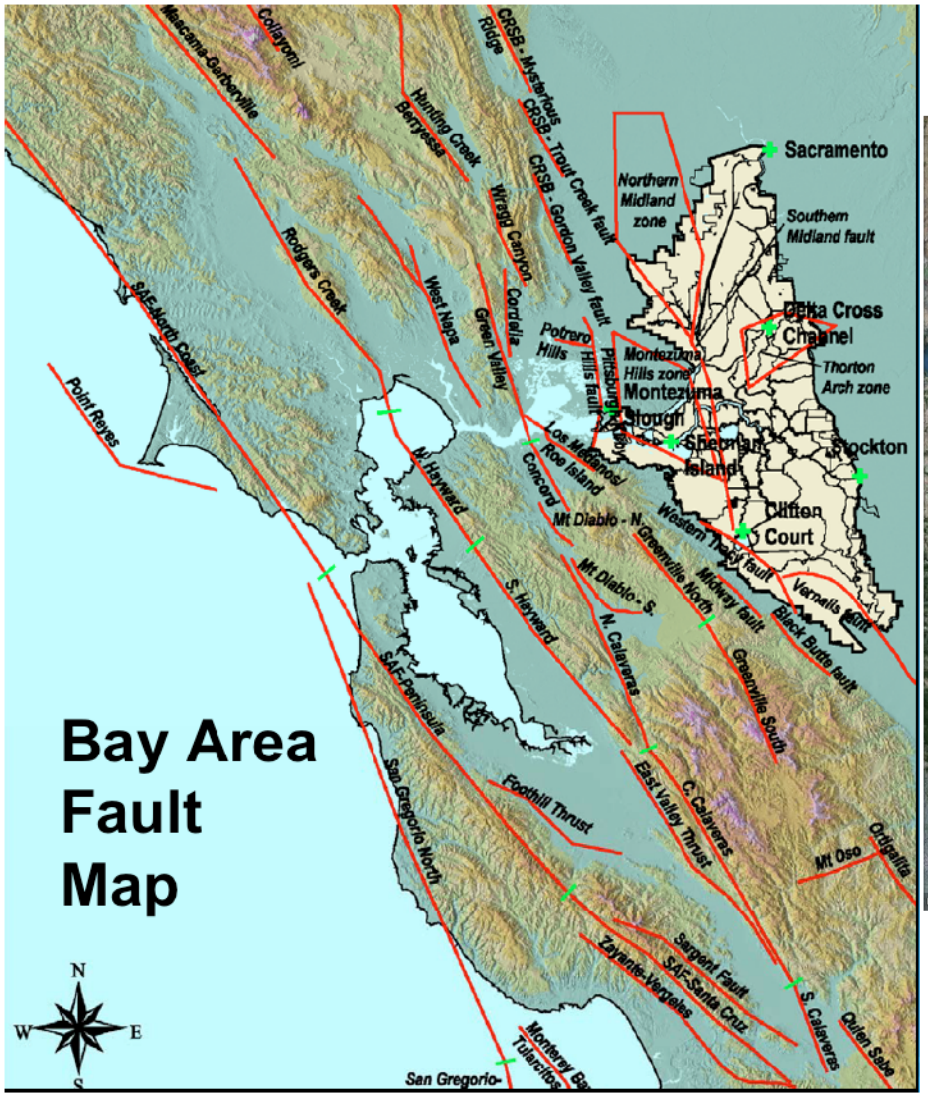
Levees are at risk from constant hydrostatic pressure because of subsidence.

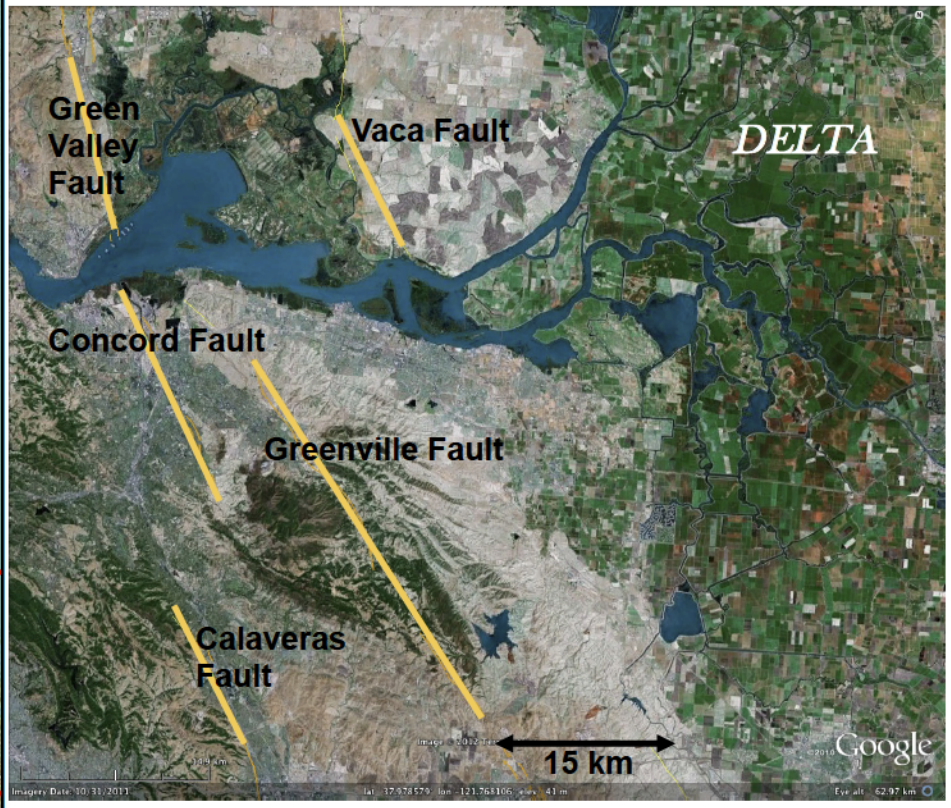
Conceptual diagram illustrating evolution of Delta islands due to levee construction and island subsidence.

Subsidence rates and the dominant subsidence mechanism varies from island to island with the soil type. In high peat soils, the dominant subsidence mechanism is aerobic microbial oxidation, which releases CO_2 as a by-product.



Earthquake Risk
San Francisco Bay Area





Levee Deformation and Island Subsidence (DInSAR)

Radar Remote Sensing of the Sacramento Delta Levees

Damaged Levee Detection and Monitoring

On August 28, 2009 a ship rammed the north levee on Bradford Island. This image was made from an interferogram between UAVSAR data collected on July 17 and Sept. 10, so evidence of the impact and repair are seen in the data.

We have monitored this site monthly since the repair to look for shifts and settling.

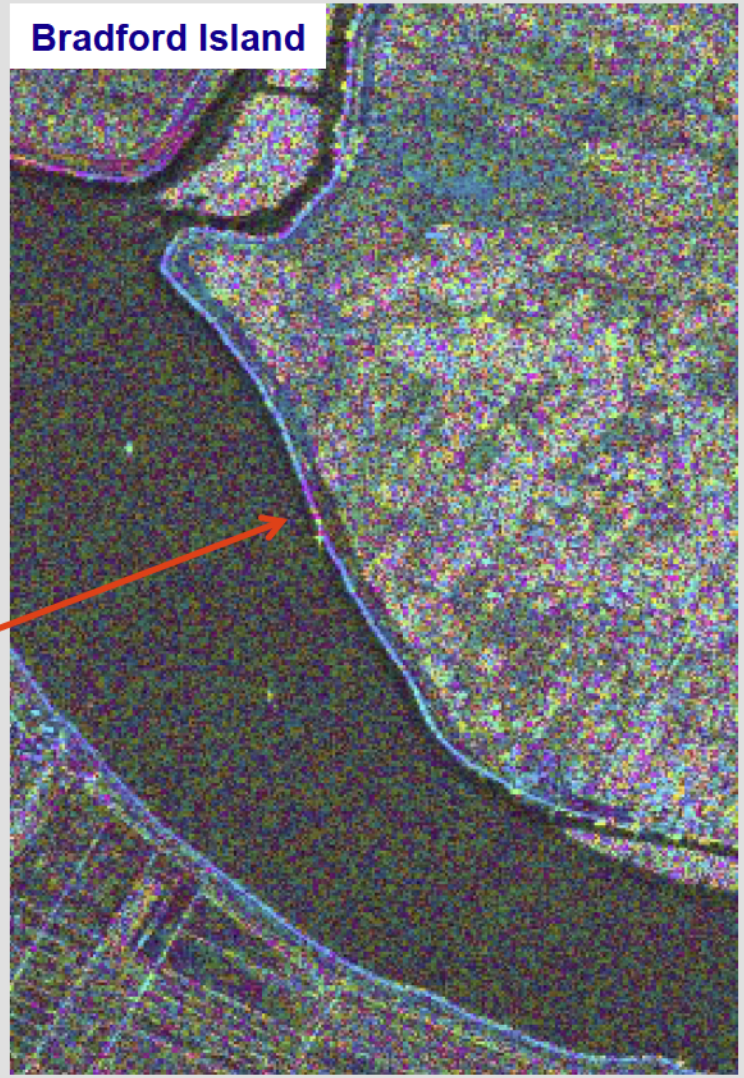
Overlay of interferometric phase and coherence, 46 day temporal baseline

Radar Remote Sensing of the Sacramento Delta Levees

Post-repair settling along levee crown

The DInSAR change map formed from images collected in July 2009 and a year later in July 2010, show that the post-repair settling extended all along the length of the repair site.

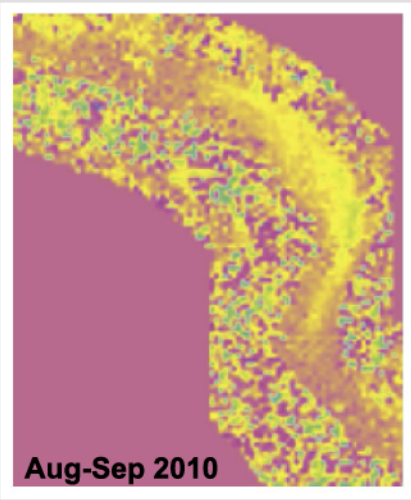
Change along repaired section of the levee

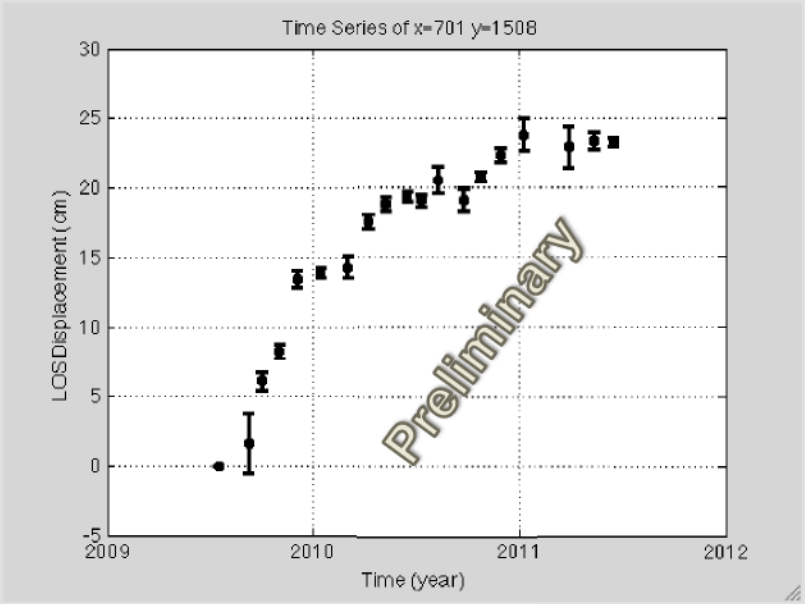


1 year temporal baseline 7/2009 - 7/2010

Radar Remote Sensing of the Sacramento Delta Levees

Subsidence along toe behind repaired levees

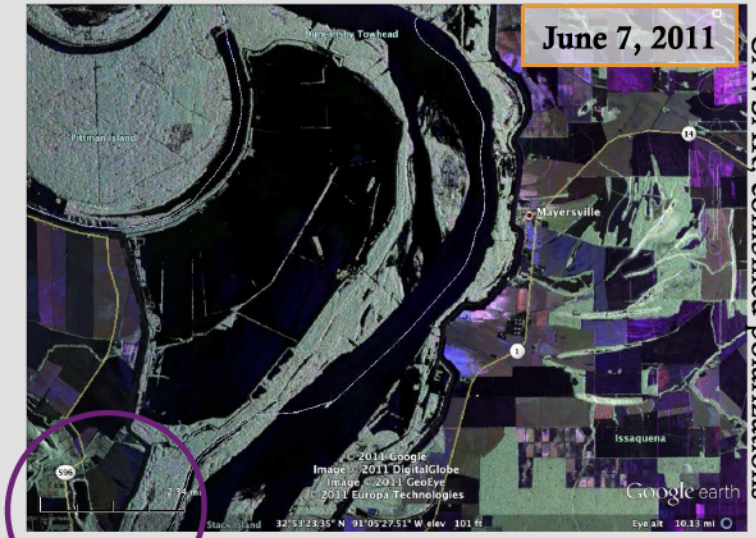




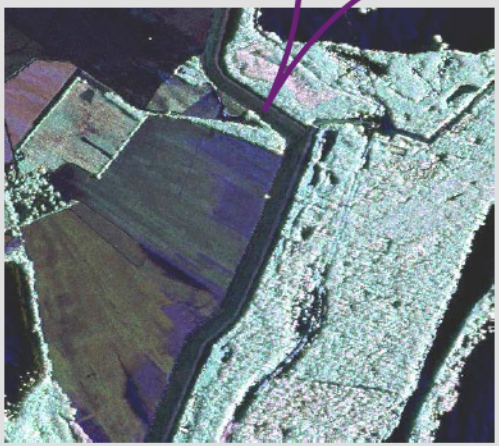
Seepage Detection (DInSAR and POLSAR)

Radar Remote Sensing of the Mississippi River Levees

Mississippi River Flood, Spring 2011



UAVSAR, combined polarizations

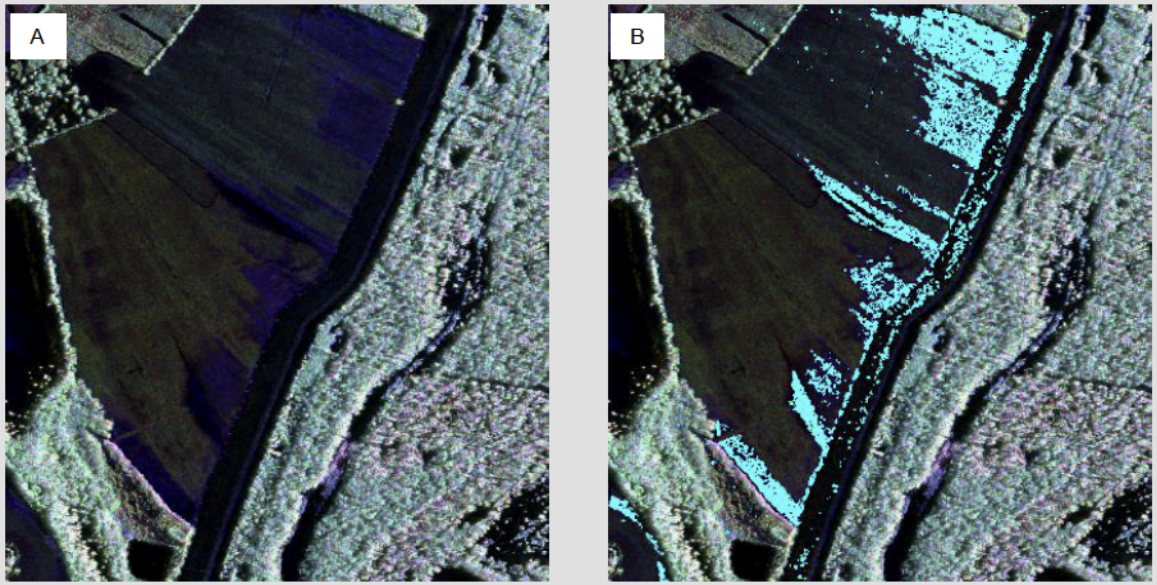


The radar images show that there is a seep through the levee along this section. We used the different polarization data to enhance detection of leaking sections of levees and to automatically classify high-likelihood seepage areas.

Radar Remote Sensing of the Mississippi River Levees

Automatic Classification to Locate Major Seeps

Image A is an RGB = HH, HV, VV color composite UAVSAR image of the area, image B is the same color composite with the high moisture class pixels(cyan) overlaid on top. The seep locations are found by looking for anomalously high values of the co-polarized ratio, VV/HH.

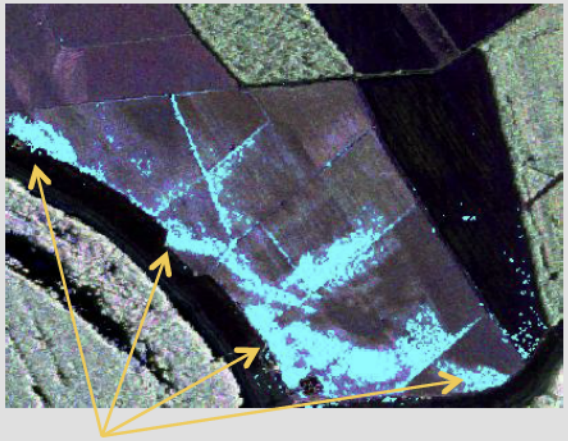


The levee is present in the images running from southwest to northeast. Deep purple striations in image A (high VV backscatter) relate to pixels in the increased moisture class (cyan).

NASA DEVELOP student project
JPL, Spring 2012
(A. Madson, K. O'Connell, K. Laygo)

Radar Remote Sensing of the Mississippi River Levees

Automatic Classification to Locate Major Seeps

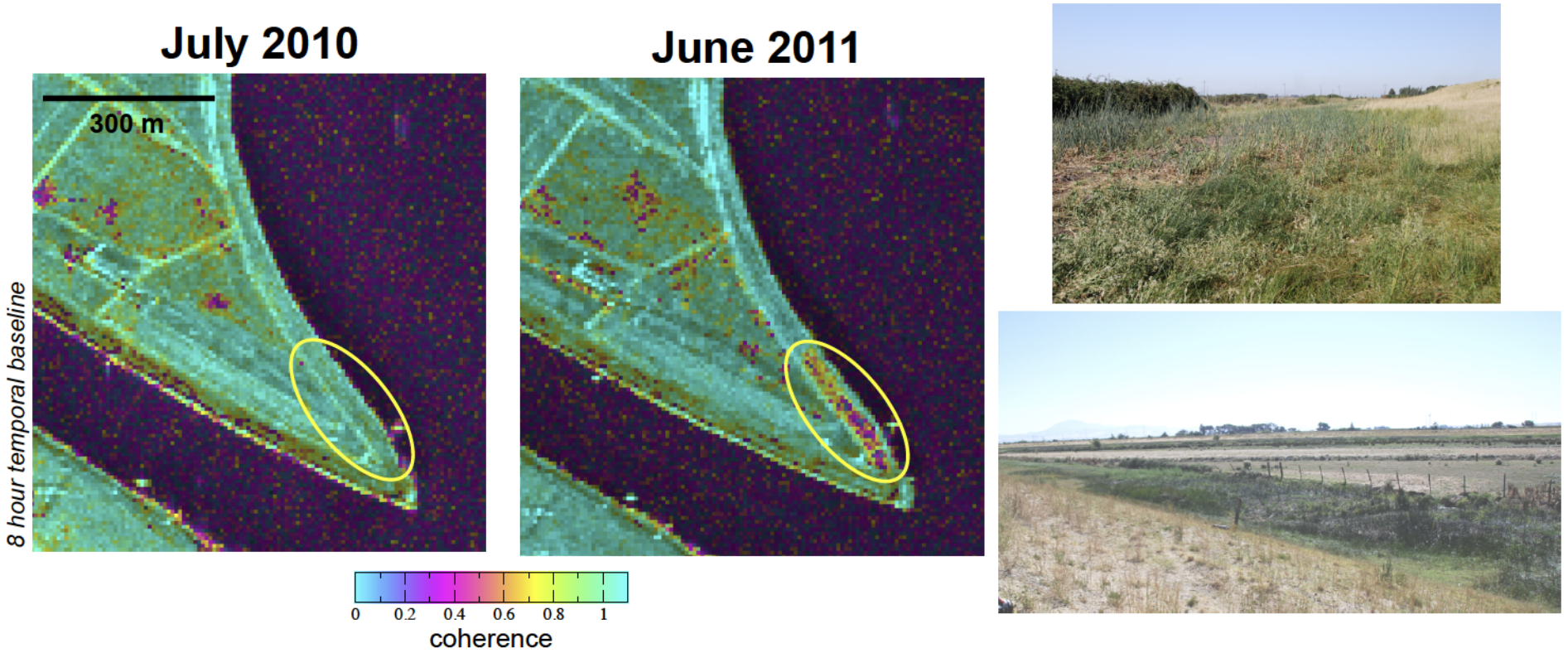


Major seepage through the levee

Radar Remote Sensing of the Sacramento Delta Levees

Levee Seep Detection on a Smaller Scale

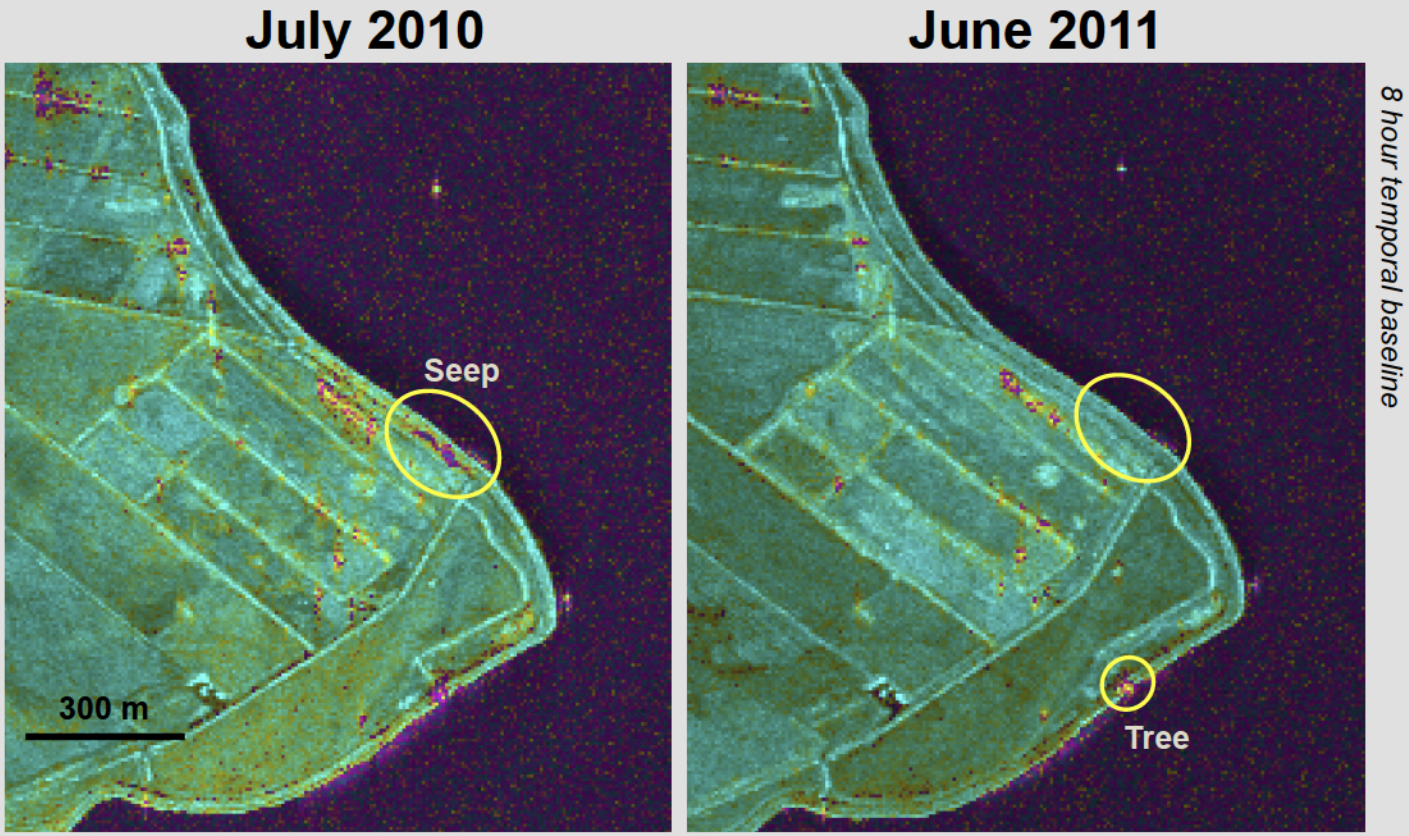
A seep through a levee on a Delta island developed between July 2010 and June 2011. This was found using coherence change detection on repeat pass UAVSAR images collected at high and low tide. There was no change in the interferometric coherence observed along the levee during the high/low tidal cycle in 2010, but a large change was seen in the same location the following year.



Radar Remote Sensing of the Sacramento Delta Levees

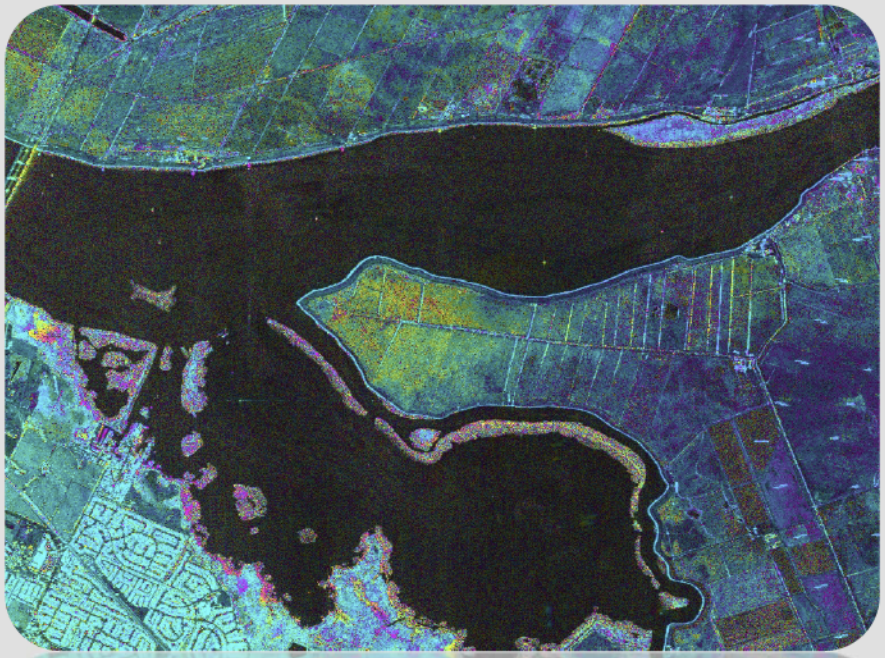
Levee Seep Detection

A seep that had been present in 2010 was repaired in May 2011. The seep was identified the repeat pass data in 2010 but not seen following the repair in 2011.



Radar Remote Sensing for Monitoring Levees

Conclusions



Radar remote sensing offers great potential for high resolution monitoring of ground surface changes over large areas at one time to detect movement on and near levees and for location of seepage through levees.

Our project to develop techniques that use DInSAR to monitor levees in the Sacramento Delta and our study of the Mississippi River levees have shown that radar remotes sensing is useful for levee health monitoring and that UAVSAR offers an unprecedented combination of spatial resolution, temporal coherence, and small interferometric baseline for this application.