Optimized Radar Remote Sensing for Levee Health Monitoring

Sacramento Delta / false color UAVSAR POLSAR image / 7 m resolution

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Remote Sensing for Levee/Dam Safety Programs

Homeland Security

FEMA, the USACE, and numerous state and local entities currently monitors thousands of dams and thousands of miles of levees throughout the United States.

- **Remote sensing can augment ground-based and visual surveys by:**
  - **providing *consistent monitoring* across all sites**
  - **enabling *rapid data collection* over large areas to give a snapshot of conditions at many sites at the same time**
  - ***detecting* areas that *change* by small amounts or in subtle ways**
  - **informing a *targeted monitoring program* that can *identify potential problem spots* and/or provide continual monitoring of those sites to identify when/how they change**
  - **imaging areas that are *difficult* to *access* on the ground**

Atchison County, Missouri (6/6/2011)

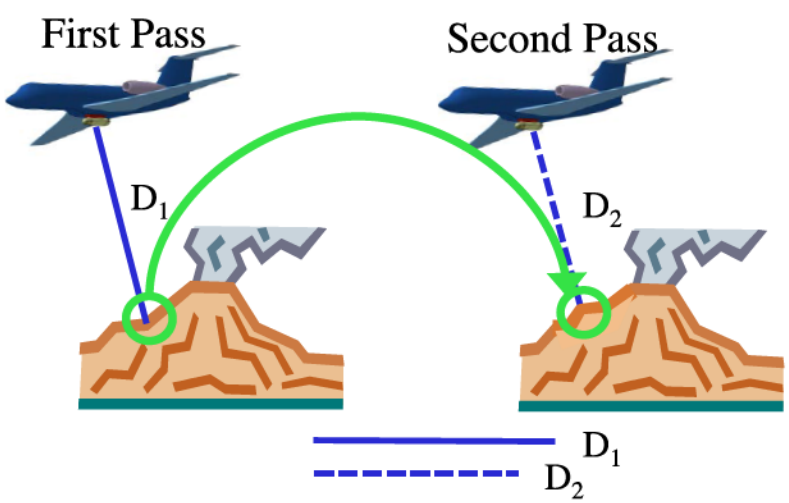
Radar Remote Sensing

Radar remote sensing is used to support a wide range of science topics and an increasing number of applications that derive from the science. Although radar imaging is not the same as photogrammetry or visual surveys, there are certain applications for which it can provide information that is not readily available through other means.

Microwave-band Radar can…

1) See through clouds, smoke, haze.
2) Image the surface of the Earth day or night in any light conditions.
3) Readily identify where there is standing water.
4) Determine the type of surface based upon physical (orientation) and electrical characteristics.
5) Determine whether the surface properties changed (i.e., seep developed, equipment was moved, water level dropped)
6) Detect very small scale (few millimeters) change in the position of hard targets.

Differential Interferometry (DINSAR)



$$\Delta\phi = \frac{4\pi}{\lambda}(D_2 - D_1)$$

$\lambda =$ wavelength of radar

Homeland Security

Optimized Radar Remote Sensing for Levee Health Monitoring

FUNDING: DHS SCIENCE AND TECHNOLOGY DIRECTORATE (Dr. Bruce Davis)
ASSOCIATED FUNDING: NASA and CA. DEPT. OF WATER RESOURCES

Jet Propulsion Laboratory *(Dr. Cathleen Jones)*
Rensselaer Polytechnic Institute *(Civil Engineering Dept., Dr. Victoria Bennett, Dr. Tarek Abdoun)*

Study Objectives:

Optimize methodologies to use existing satellite and airborne radar assets to monitor levee health in order to prevent disasters and more efficiently respond to emergency situations.

- **Develop and validate the capability to efficiently use radar remote sensing for levee status monitoring and emergency response in order to incorporate it into the decision-making process before it is needed in an emergency.**
- **Partnership with end-users and beneficiaries is critical to developing useful methods and products.**

Study Partners:

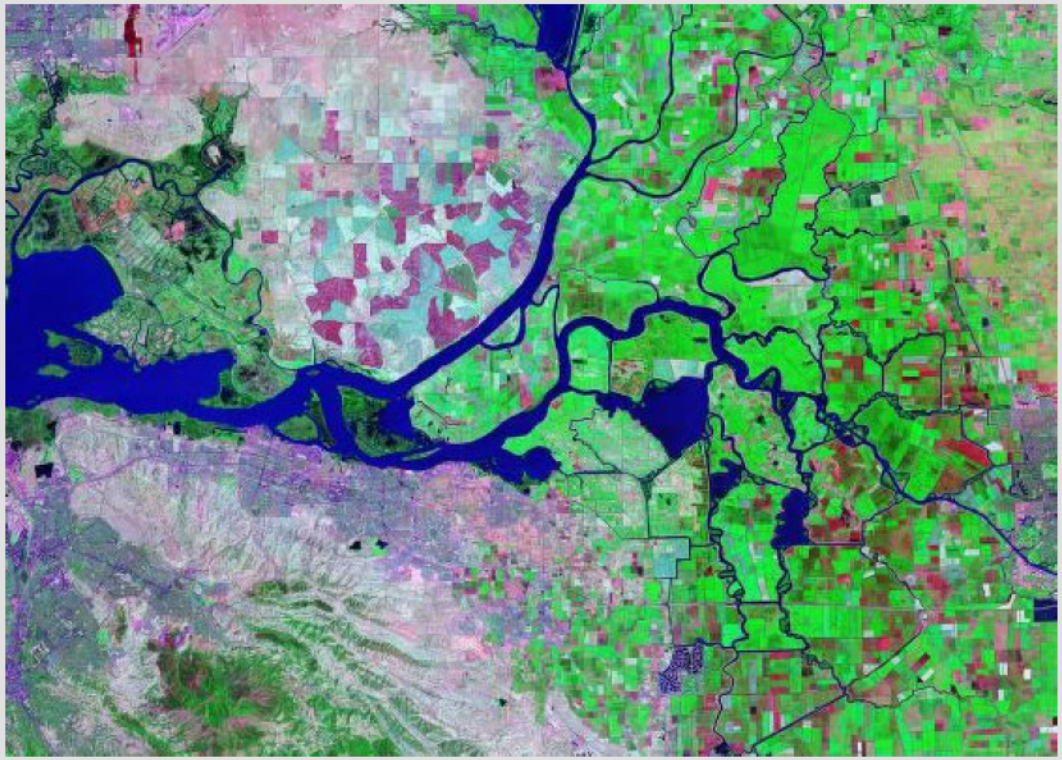
Sacramento Office of Emergency Services
California Dept. of Water Resources, Division of Flood Management

Study Areas:

1. **California's Sacramento-San Joaquin Delta (build on the work done in a NASA multi-year study)**
2. **New Orleans (RPI partner's instrumented levee test site with coverage from multiple radars)**

The Islands of the Sacramento-San Joaquin Delta

Critical Infrastructure: The Levees



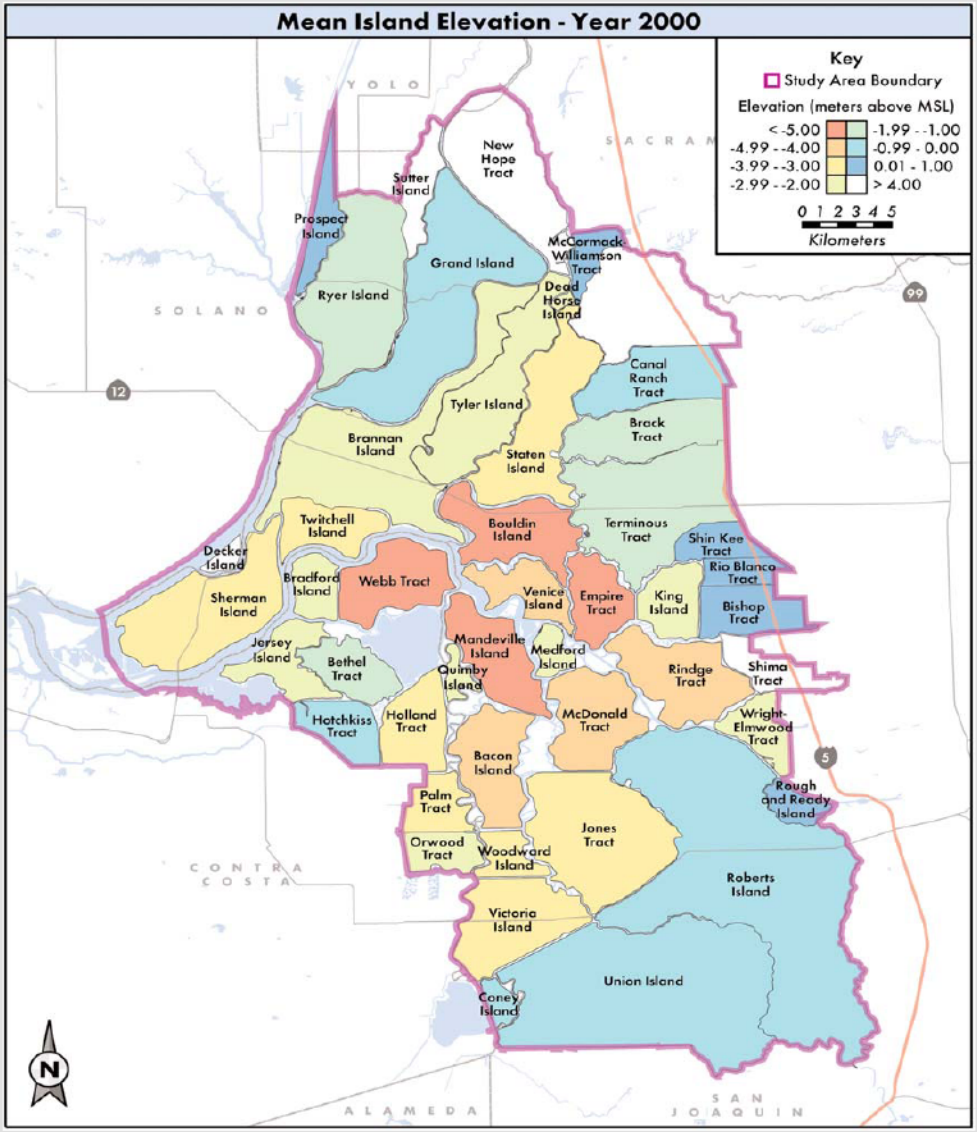
- Over 60 reclaimed islands surrounded by 1100 miles of levees
- Most islands lie below mean sea level.
- Collects run-off from approximately 2/3 of the state via the Sacramento and San Joaquin rivers.
- Supplies water to ~2/3 of the residents of California and to almost all of the agriculture of the Central Valley.

THE DELTA IS THE MOST CRITICAL WATER RESOURCE IN CALIFORNIA.

Subsidence in the Sacramento-San Joaquin Delta

AN ONGOING AND LONG-TERM ISSUE

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.

Subsidence

and

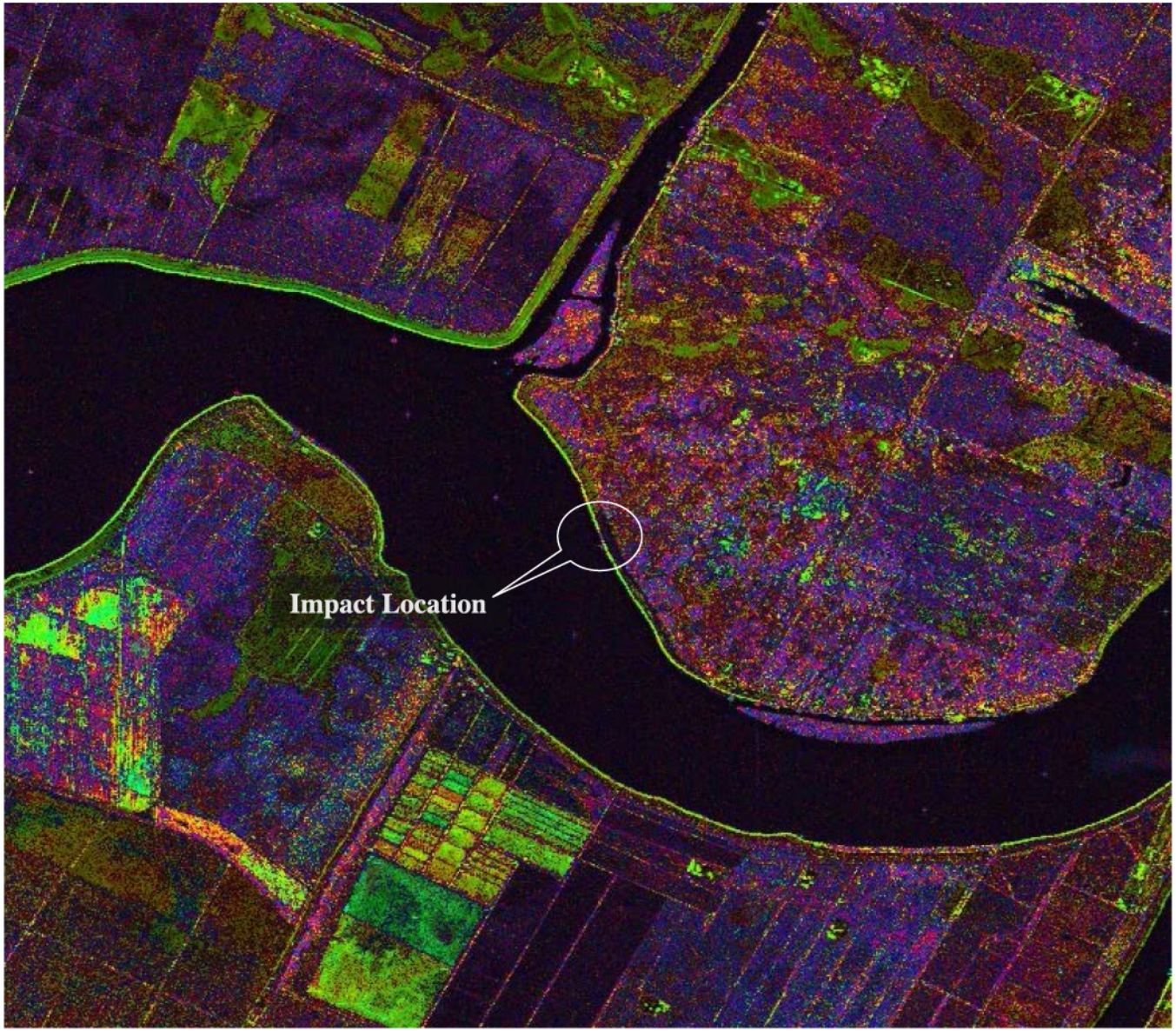
Deformation

Bradford Island Levee Damage

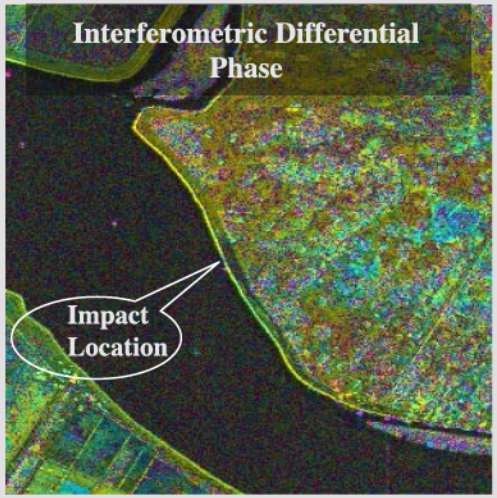
Ship Impact in 2009

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.

The plot shows a false color map overlaying the differential phase and correlation of the interferograms formed using the two data sets.



Damage from ship impact in August 2009 (Bradford Island)



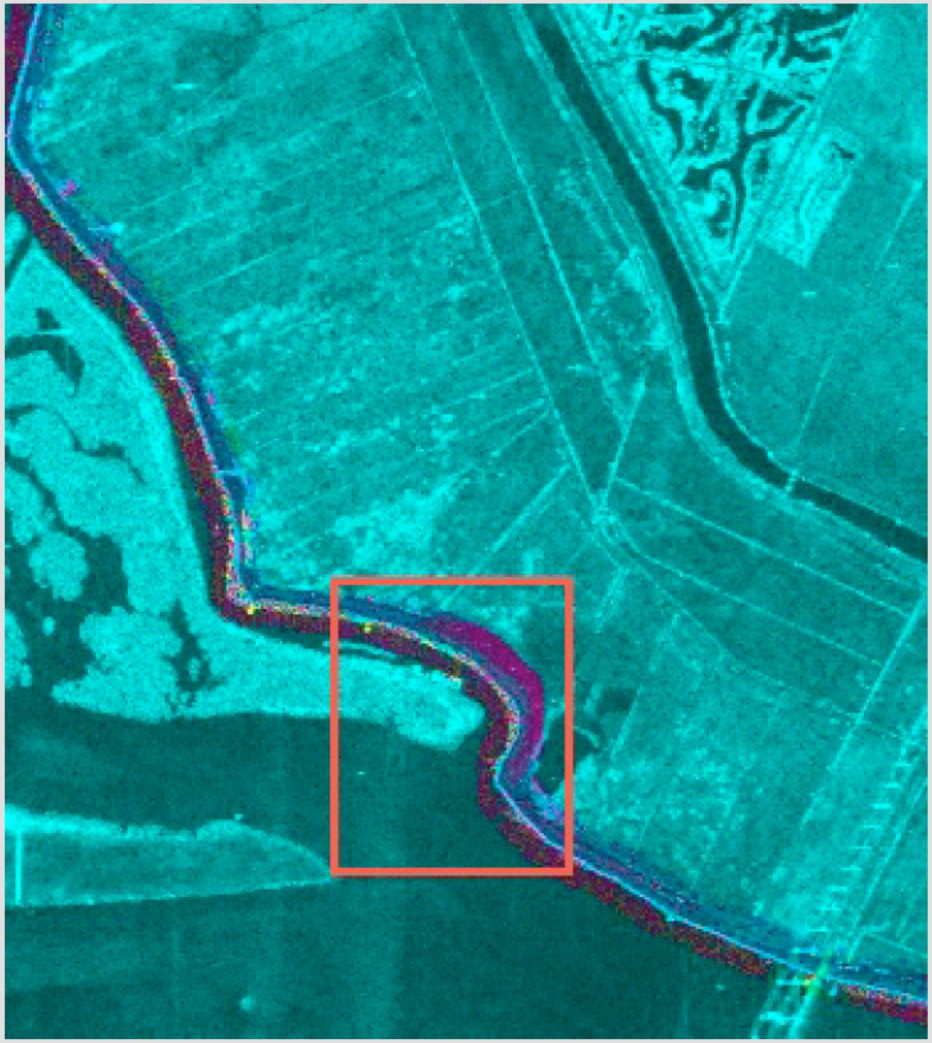
Subsidence occurred only along the repaired section of the levee

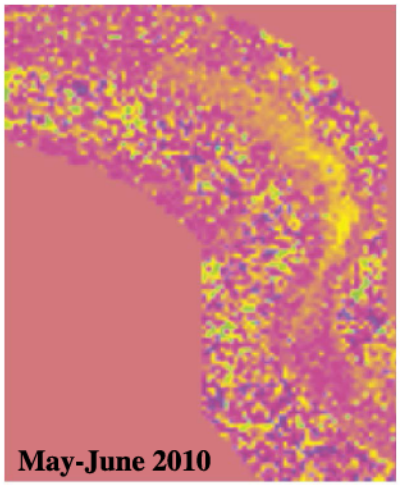
(~3 cm subsidence in the year following repair)

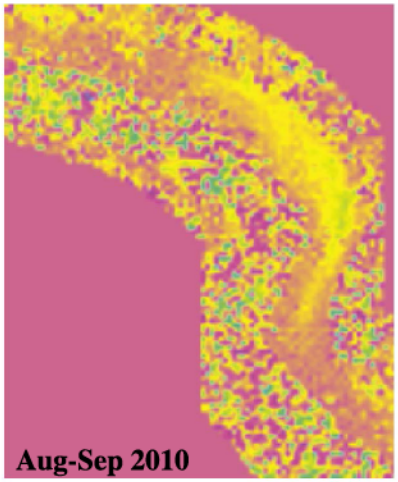
1 year temporal baseline 7/2009 - 7/2010

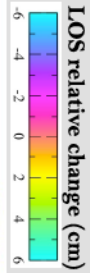
Subsidence Behind New/Repaired Levees

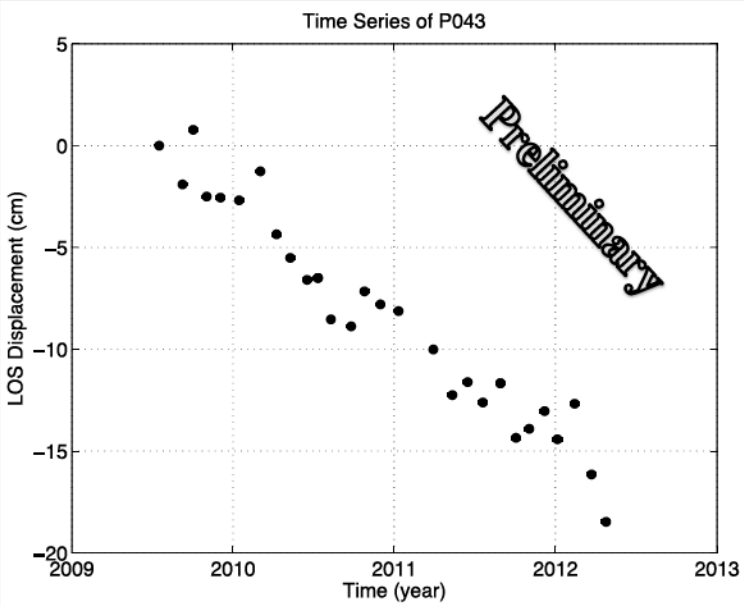
Sherman Island Set-back Levee





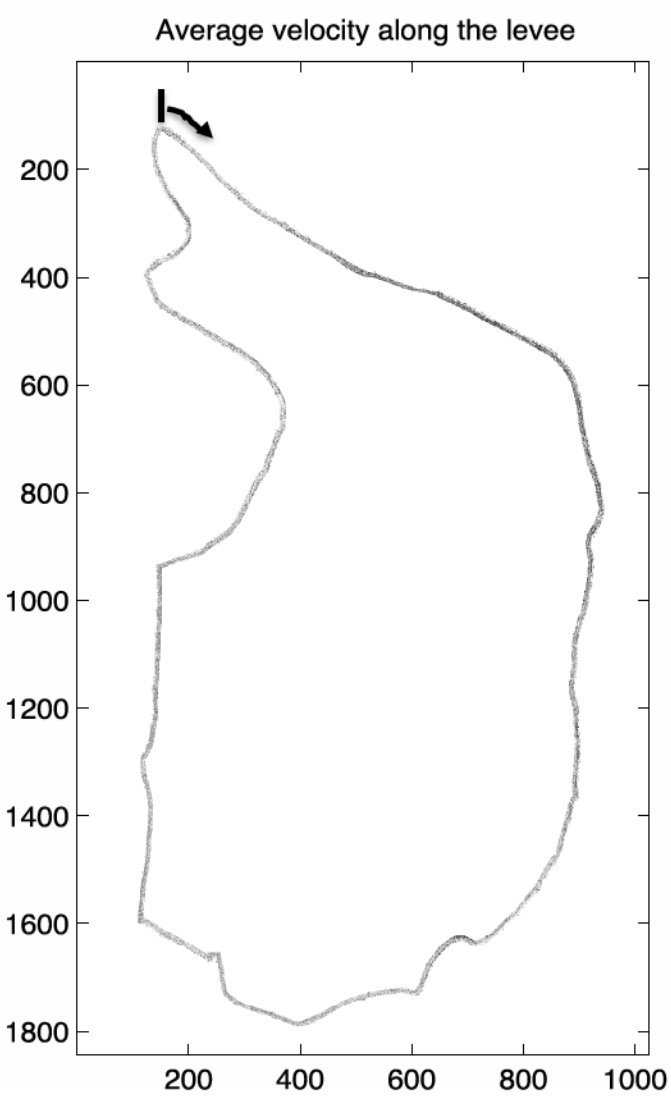


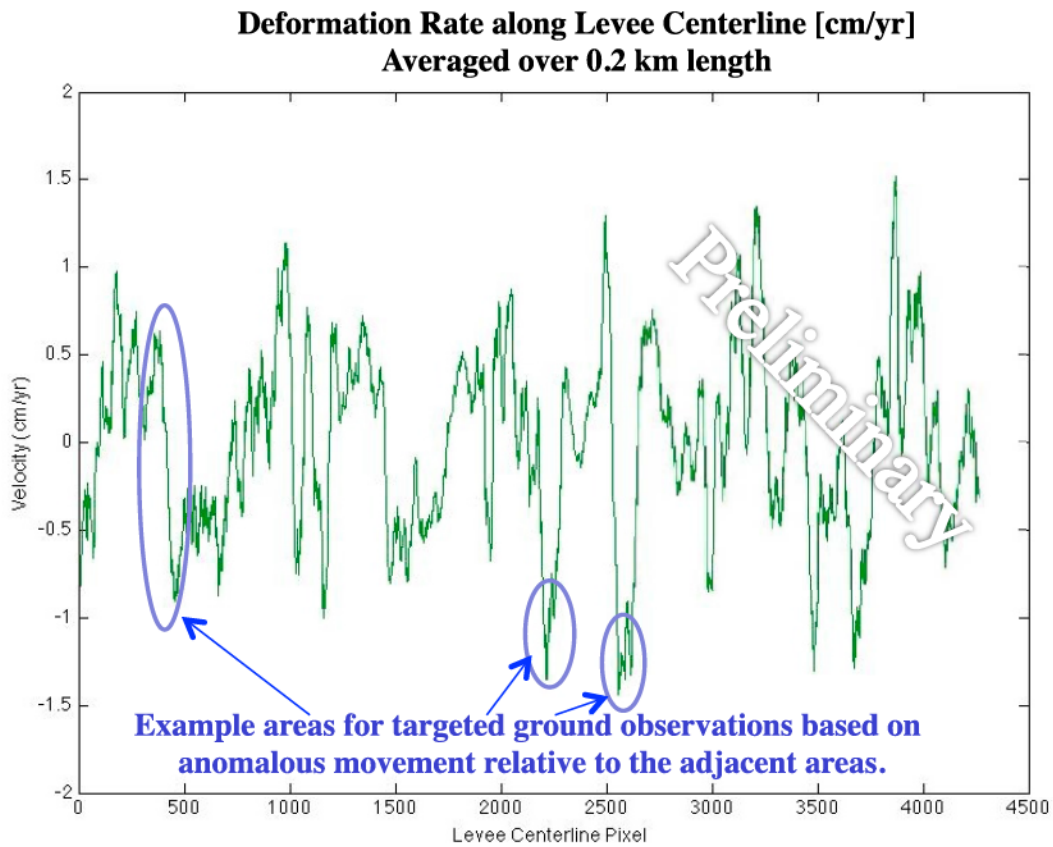




Surface Deformation Along Levee Centerlines

SHERMAN ISLAND



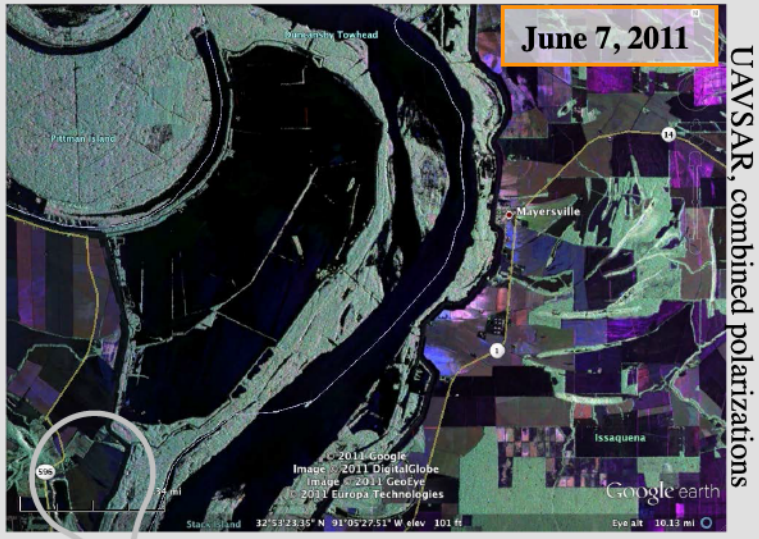


Detection of Seepage

Radar Remote Sensing of the Mississippi River Levees

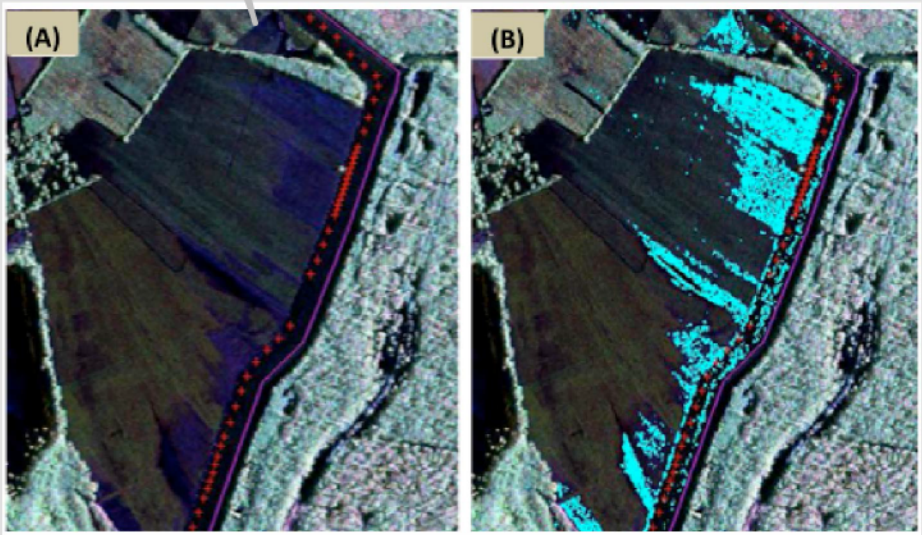
MISSISSIPPI RIVER FLOOD, SPRING 2011

NASA DEVELOP student project : JPL, Fall 2011 – Spring 2012



UAVSAR, combined polarizations

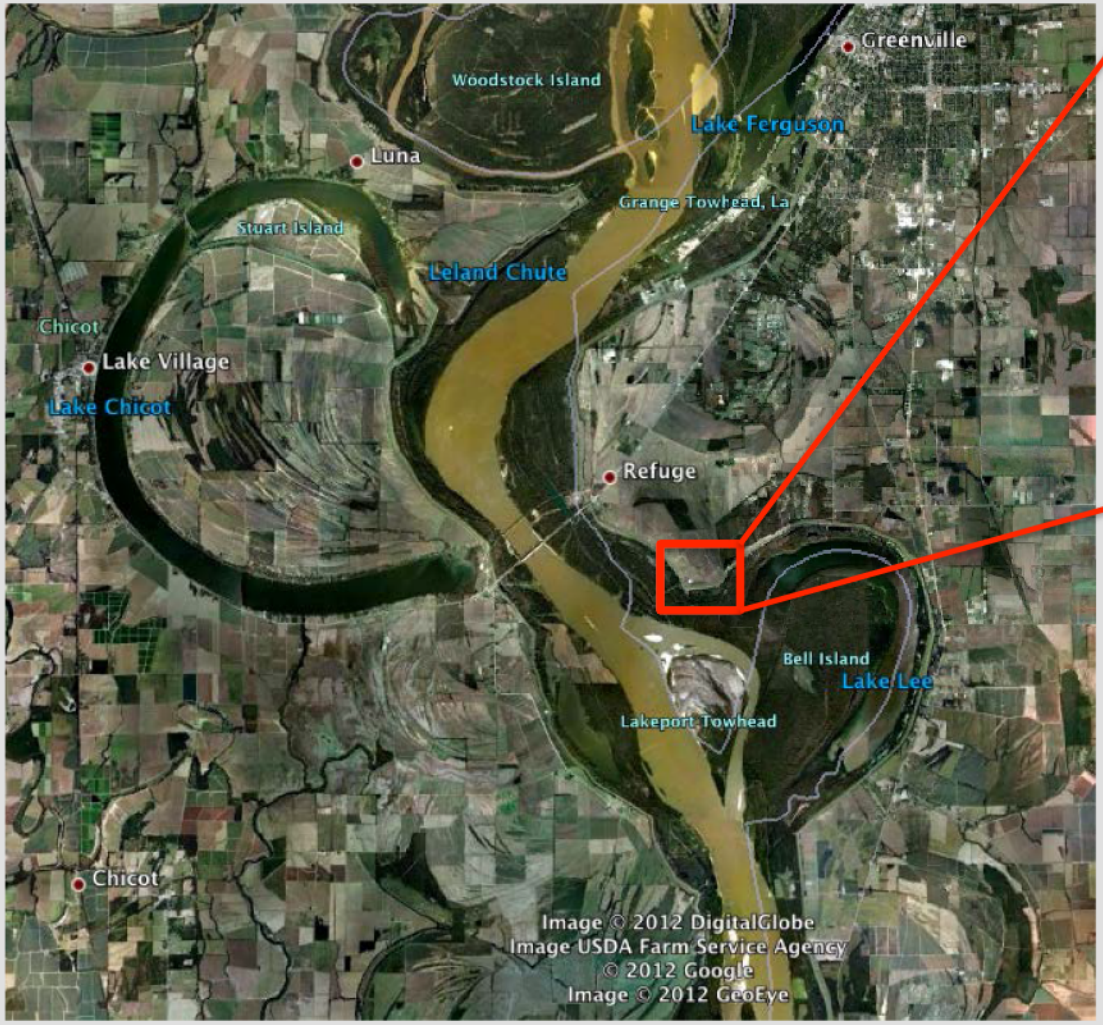
The radar data indicates there is seepage through relief wells along the levee in this area.

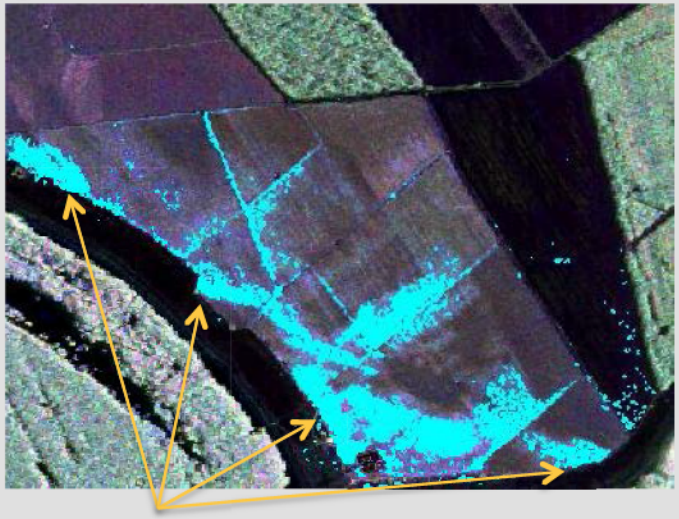


We used the polarization-dependence of the radar return to enhance detection of leaking sections of levees and to automatically classify high-likelihood seepage areas.

Radar Remote Sensing of the Mississippi River Levees

Unsupervised Classification to Locate Major Seeps





Major seepage through the levee in areas without relief wells

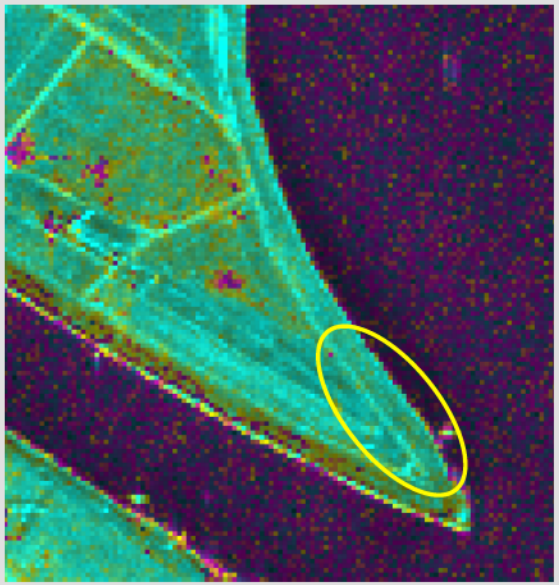
NASA DEVELOP student project :
JPL, Fall 2011 – Spring 2012

Seep Detection Behind Levees

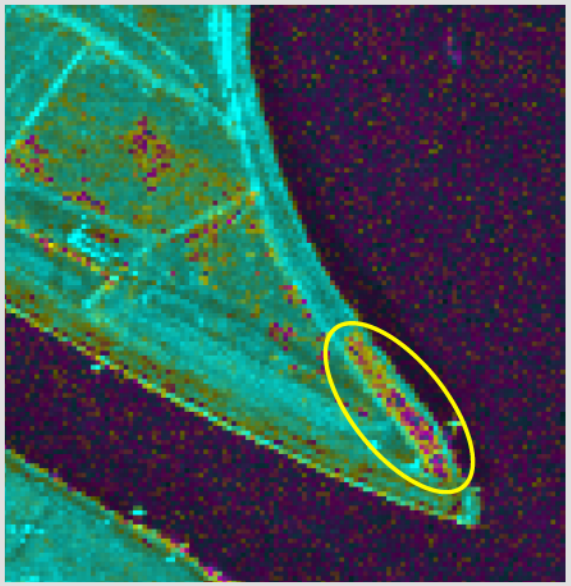
Twitchell Island – Seep Formation

A seep through the levee developed between July 2010 and June 2011. This is detected in the repeat pass interferometric correlation, measured with the UAVSAR L-band radar, which saw no change behind the levee during the high/low tidal cycle in 2010, but detected a large change the following year.

July 2010



June 2011



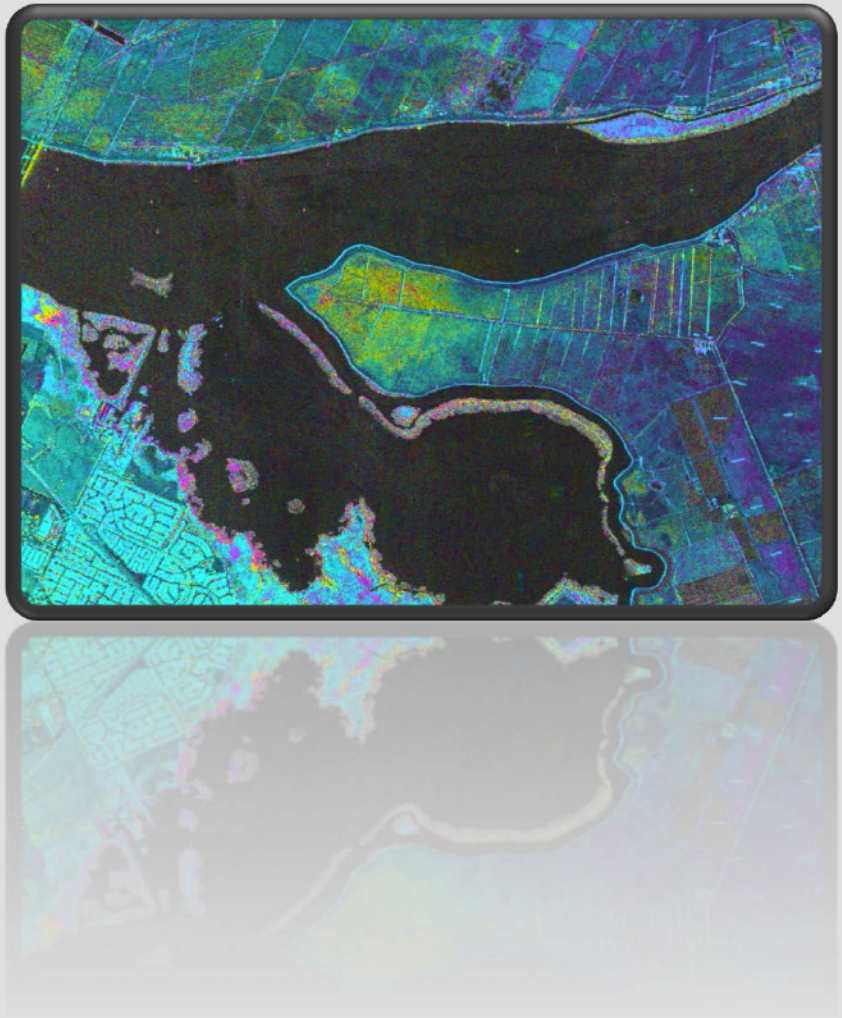
Conclusions

Homeland Security

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 NASA-funded projects to monitor levees in the Sacramento Delta and the Mississippi River have developed and demonstrated methods to use radar remote sensing to measure quantities relevant to levee health and of great value to emergency response.

The DHS-funded project will enable us is to define how to optimally monitor levees in this new way and set the stage for transition to using satellite SAR imaging for better temporal and spatial coverage at lower cost to the end users.



Collaborators on work shown: Mr. Joel Dudas (Ca. DWR); Dr. Sang-Ho Yun, Dr. Scott Hensley, Austin Madson, Kevin O'Connell, Katrina Laygo, (JPL); Dr. Gerald Bawden (USGS); Dr. Steven Deverel (HydroFocus, Inc.)