Arizona Department of Water Resources
Land Subsidence Monitoring Program

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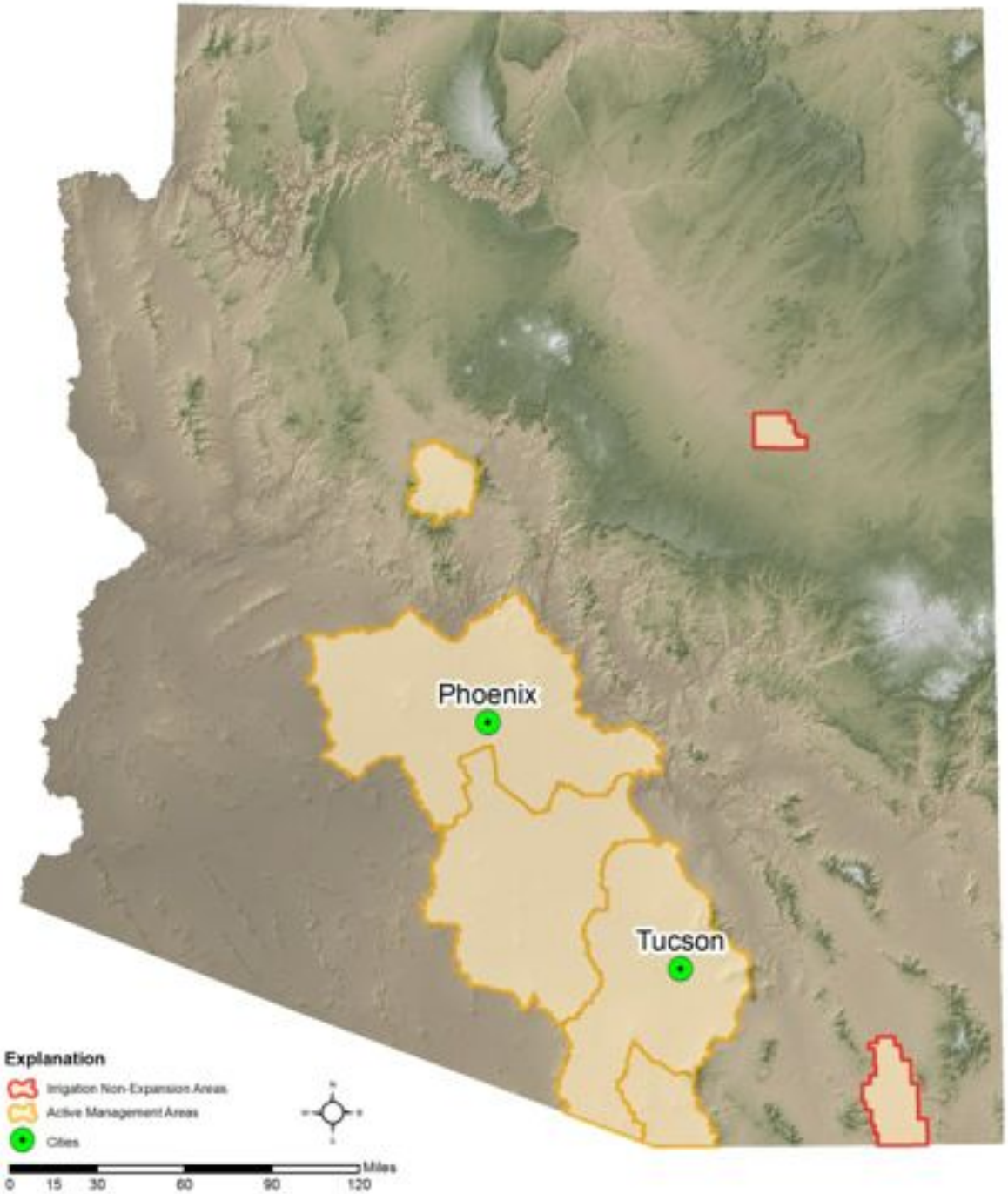
ADWR'S Land Subsidence Monitoring Program

ADWR's authority to collect or require the collection of land subsidence and/or earth fissure data is established in statutes and rules related to:

- Determining whether an Active Management Area (AMA) should be established (in part) to reduce the impacts of land subsidence or earth fissures.
- Determining whether new non-exempt (pumps more than 35 gpm) or recovery wells in AMAs or other wells used for inner-basin groundwater transfers may cause unreasonable increasing harm due to regional land subsidence.
- Determining if land subsidence or earth fissures are a potential concern for regulated dam projects.

Active Management Areas

- Prescott
- Phoenix
- Pinal
- Tucson
- Santa Cruz



ADWR'S Land Subsidence Monitoring Program

- In 1997 numerous non-exempt wells were proposed in the Apache Junction and Luke Air Force Base areas, both areas noted for significant historic land subsidence and earth fissuring.
- Concerns over the potential for the new wells to cause unreasonable increasing harm led to a Directorate level decision to begin a land subsidence monitoring program.

Historical Land Subsidence

- Land subsidence totals based on historical leveling and GPS survey data and InSAR data.

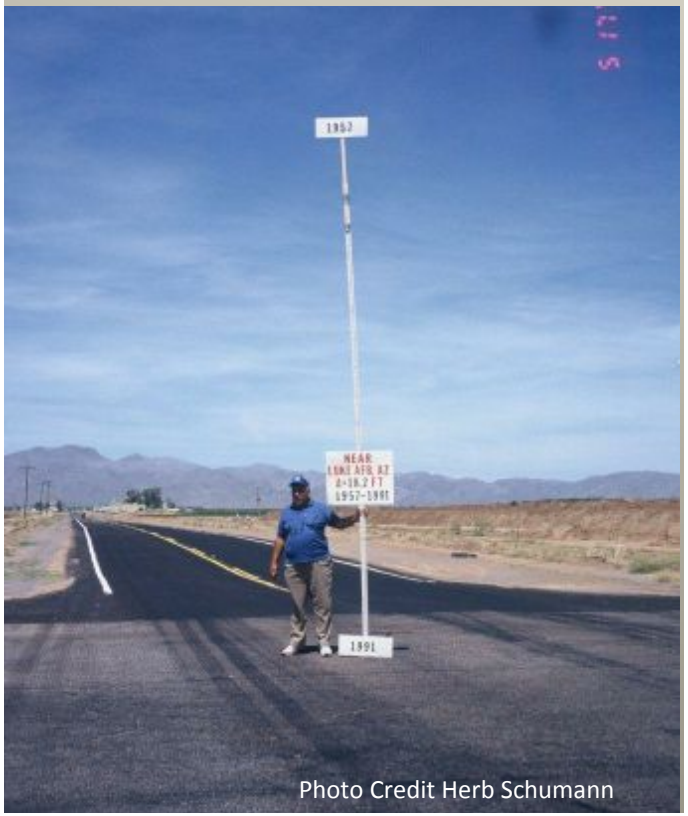
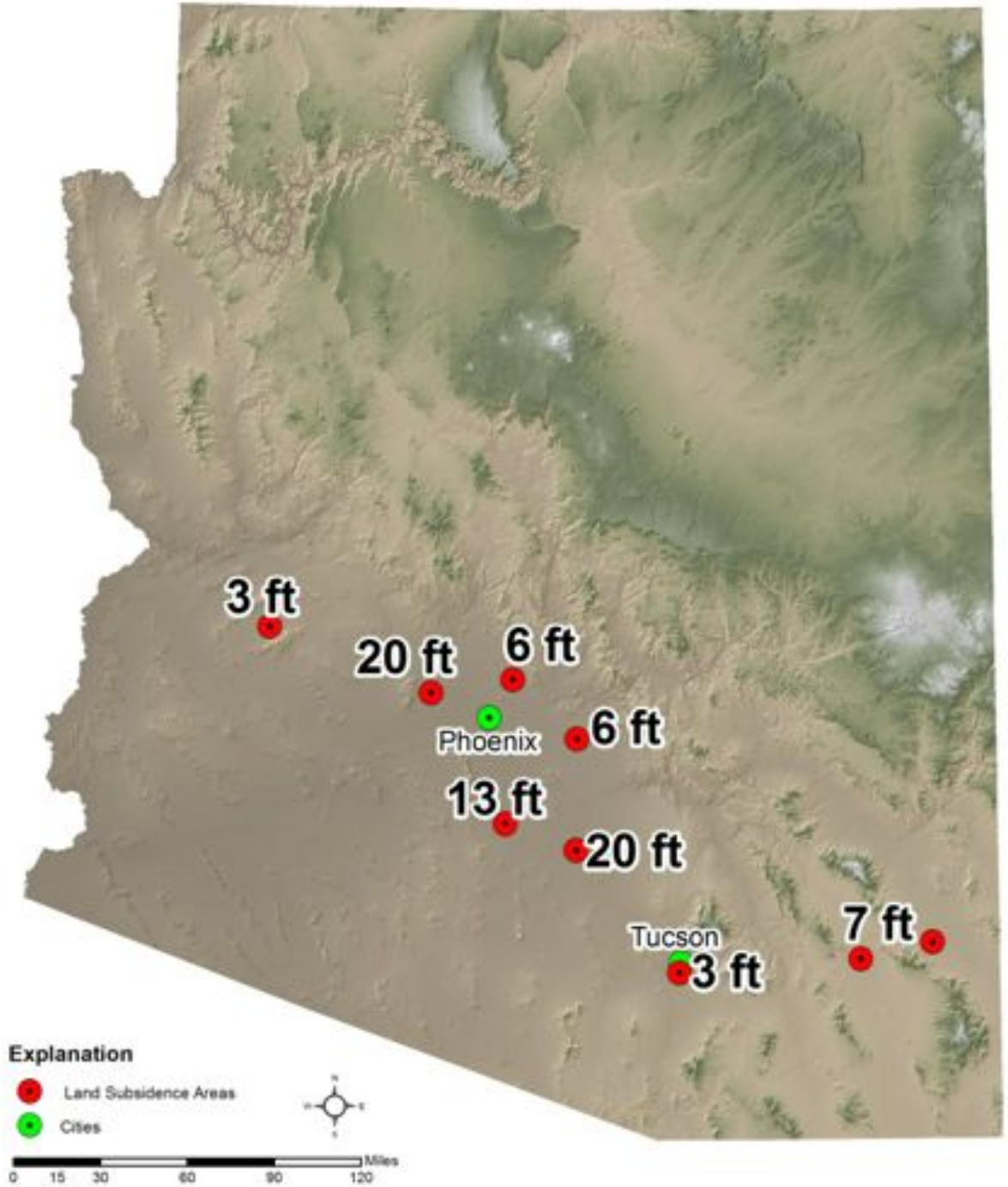


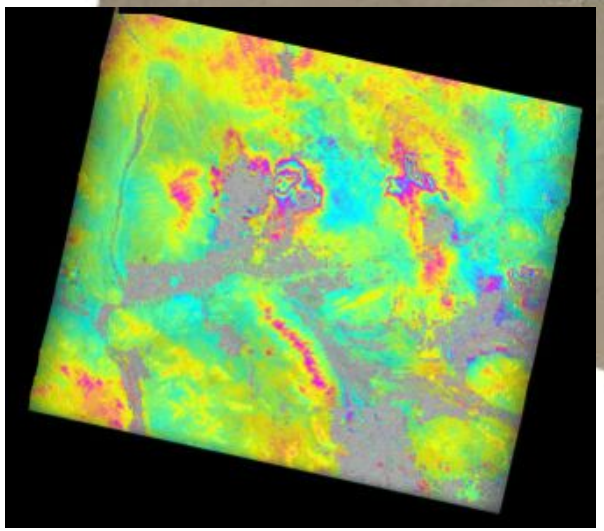
Photo Credit Herb Schumann

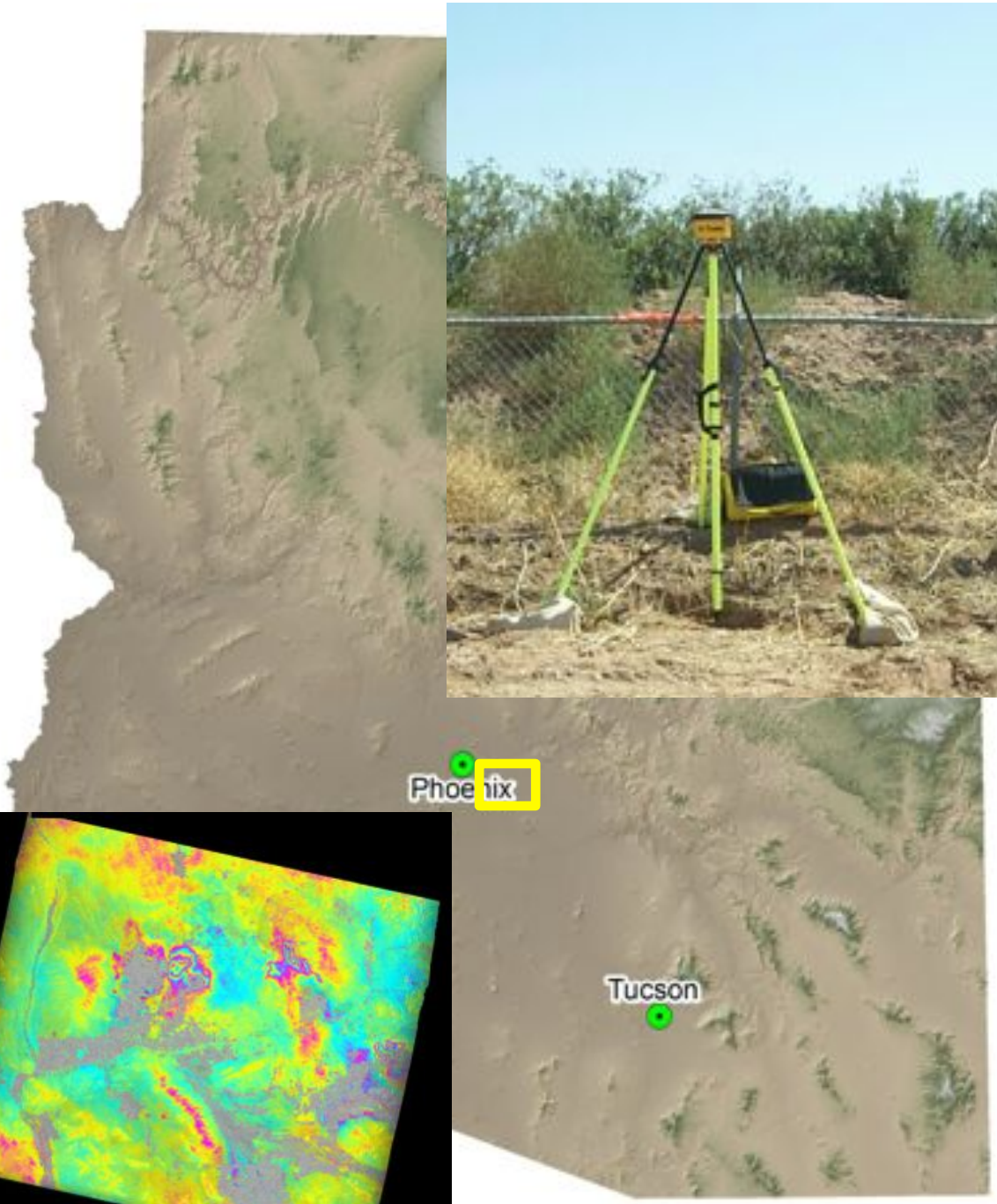



planetvid.com

ADWR'S Land Subsidence Monitoring Program

- Program started in 1998, collected static GPS measurements over a small regional network in the eastern part of the Phoenix Metropolitan Area.
- Funded a pilot InSAR program in 2001 through the Center for Space Research to test the InSAR technology in Arizona.
- Awarded a $1.3 million NASA grant in 2002 to develop ADWR's InSAR program over 3 years.

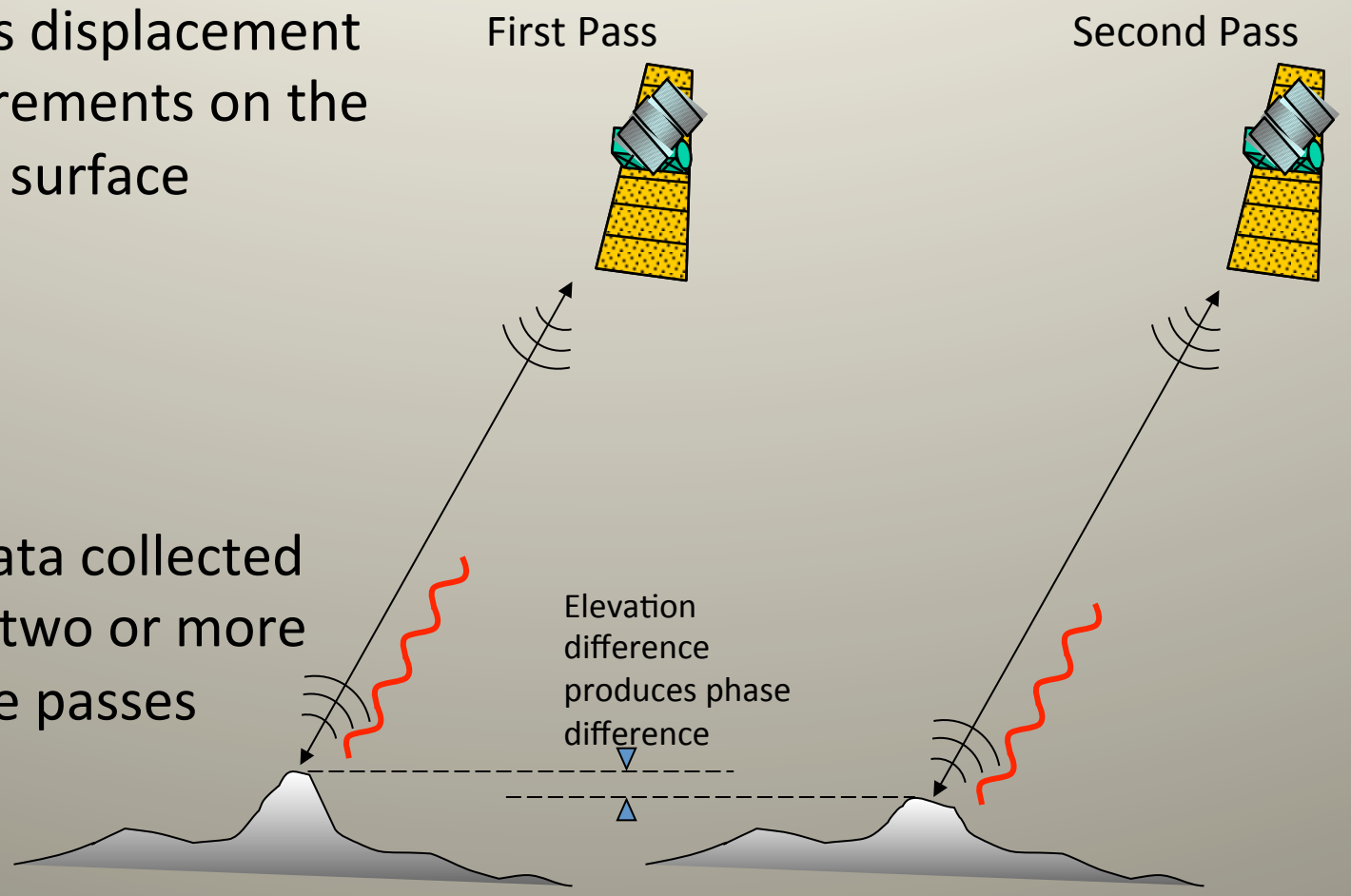




Synthetic Aperture Radar Interferometry (InSAR)

Enables displacement measurements on the Earth's surface

Uses data collected during two or more satellite passes

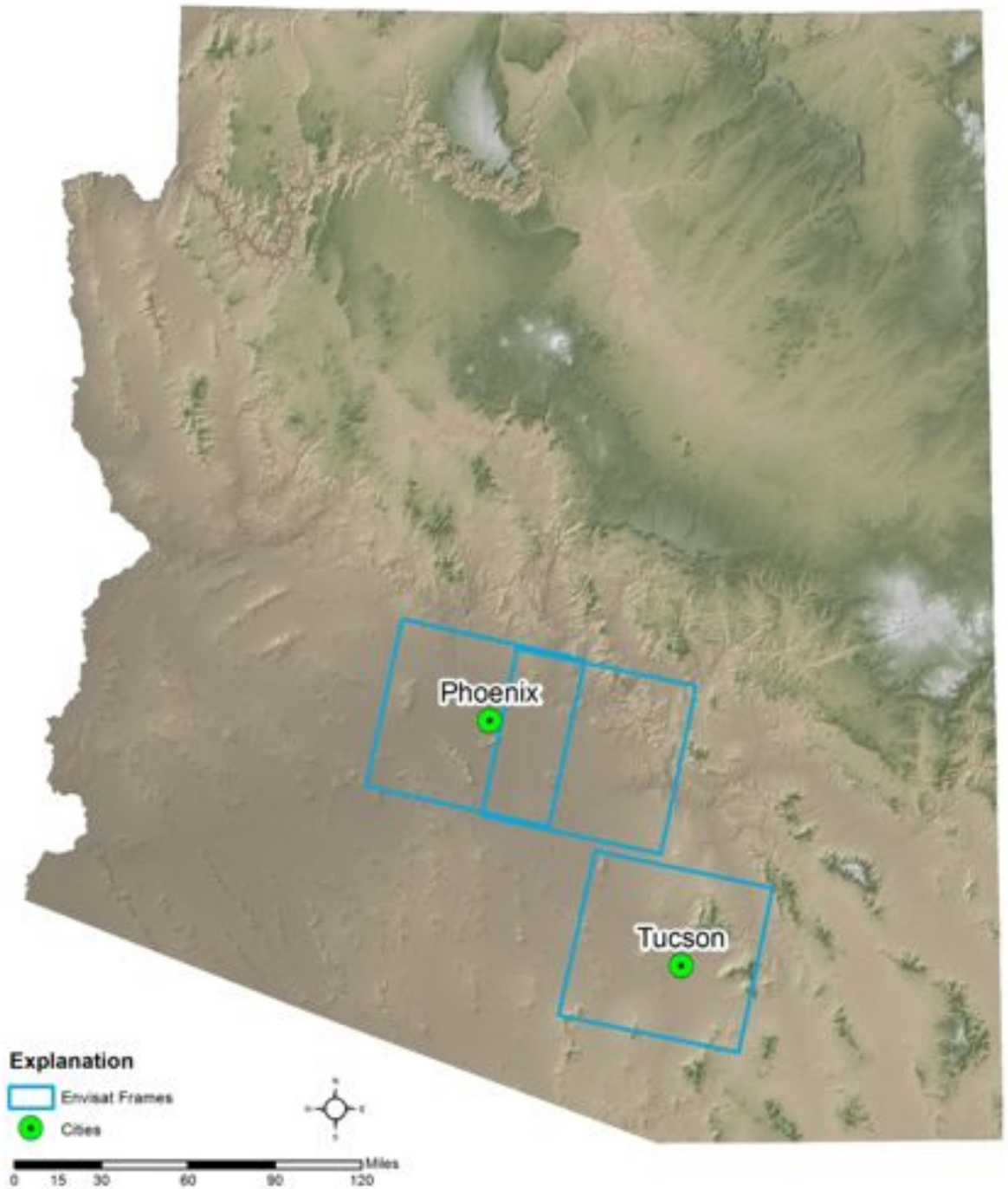


Applications of InSAR in Arizona

- Land subsidence monitoring.
- Monitoring seasonal deformation (subsidence and uplift).
- Monitoring natural and artificial recharge events.
- Geological mapping and investigations for landslides and other features.
- Locating earth fissures and areas where conditions may exist for earth fissure formation.
- Dam hazard mitigation and land subsidence modeling.
- Monitoring changes to floodplains and natural drainage slopes.

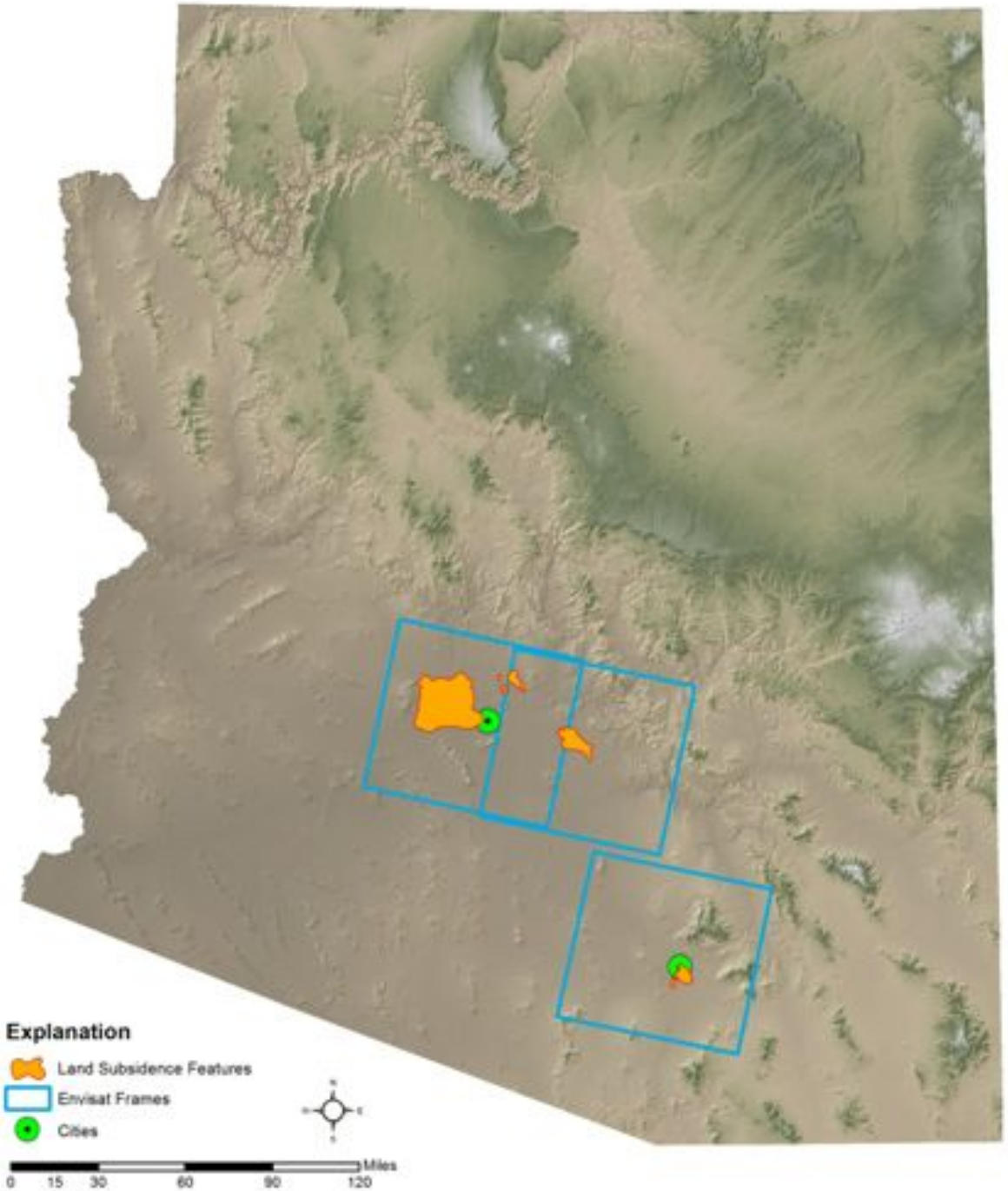
ADWR'S InSAR Program

- Started collecting 3 satellite frames in 2004.
- Collected 2 frames covering the Phoenix Metropolitan Area.
- Collected 1 frame covering the Tucson Metropolitan Area.



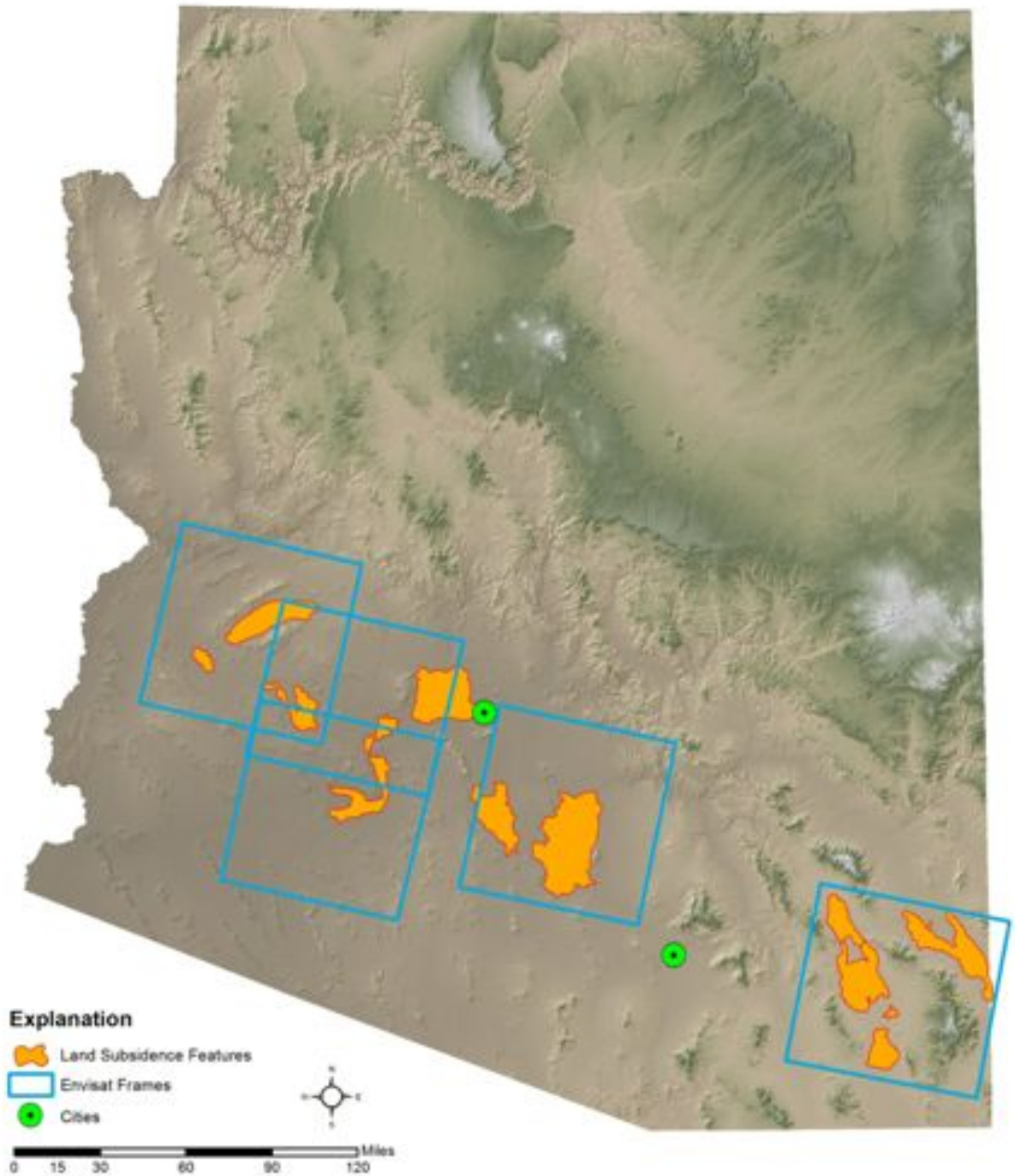
ADWR'S InSAR Program

- Identified 5 land subsidence features
- 3 in the Phoenix Area
  - West Valley
  - NE PHX/Scottsdale
  - Hawk Rock
- 2 in the Tucson Area
  - Valencia
  - Central Well Field



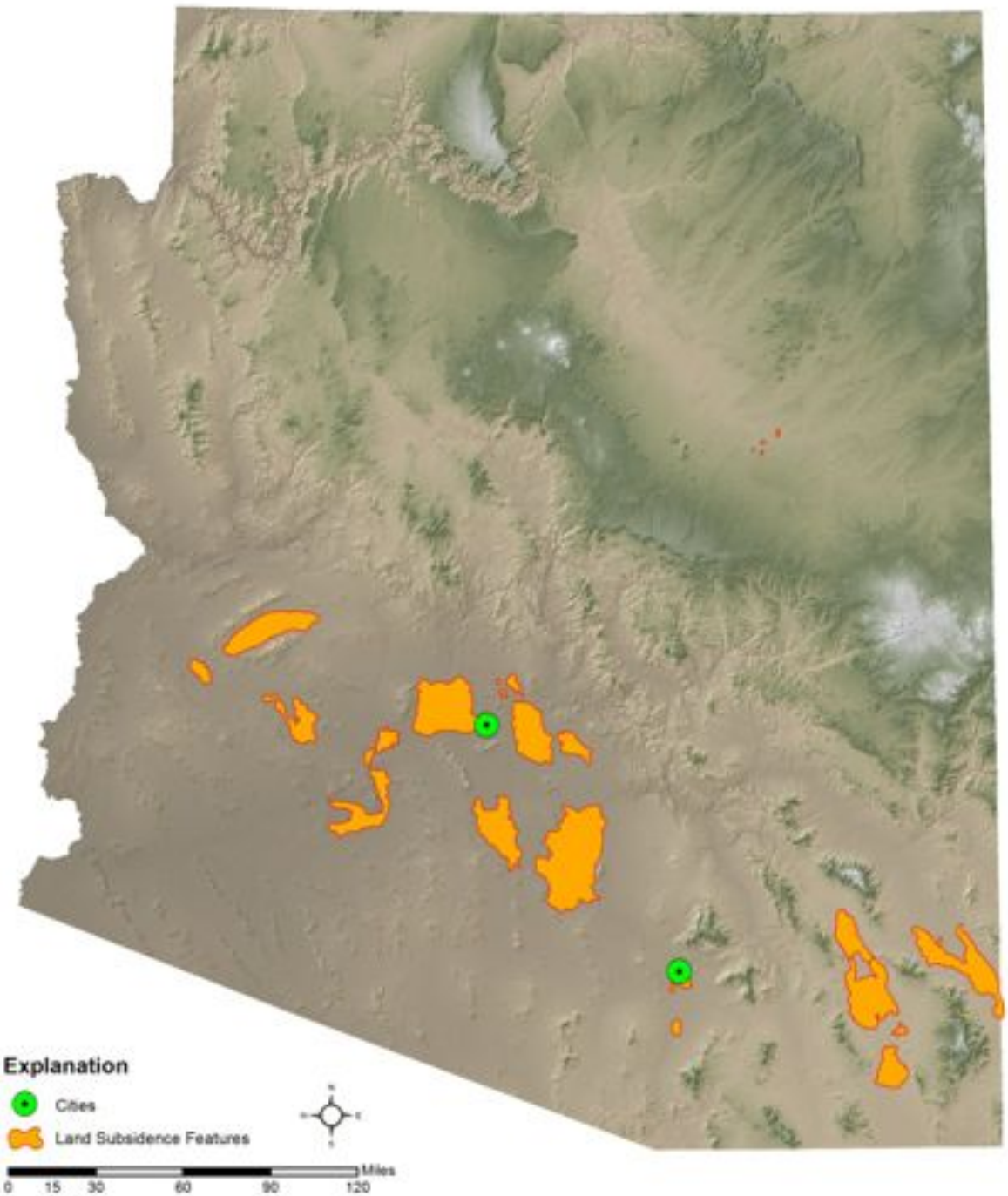
ADWR'S InSAR Program

- By 2009, InSAR program was greatly expanded to cover other areas of the State in order to investigate other potential land subsidence areas where there have been historical groundwater declines.
- Identified thirteen additional land subsidence features.



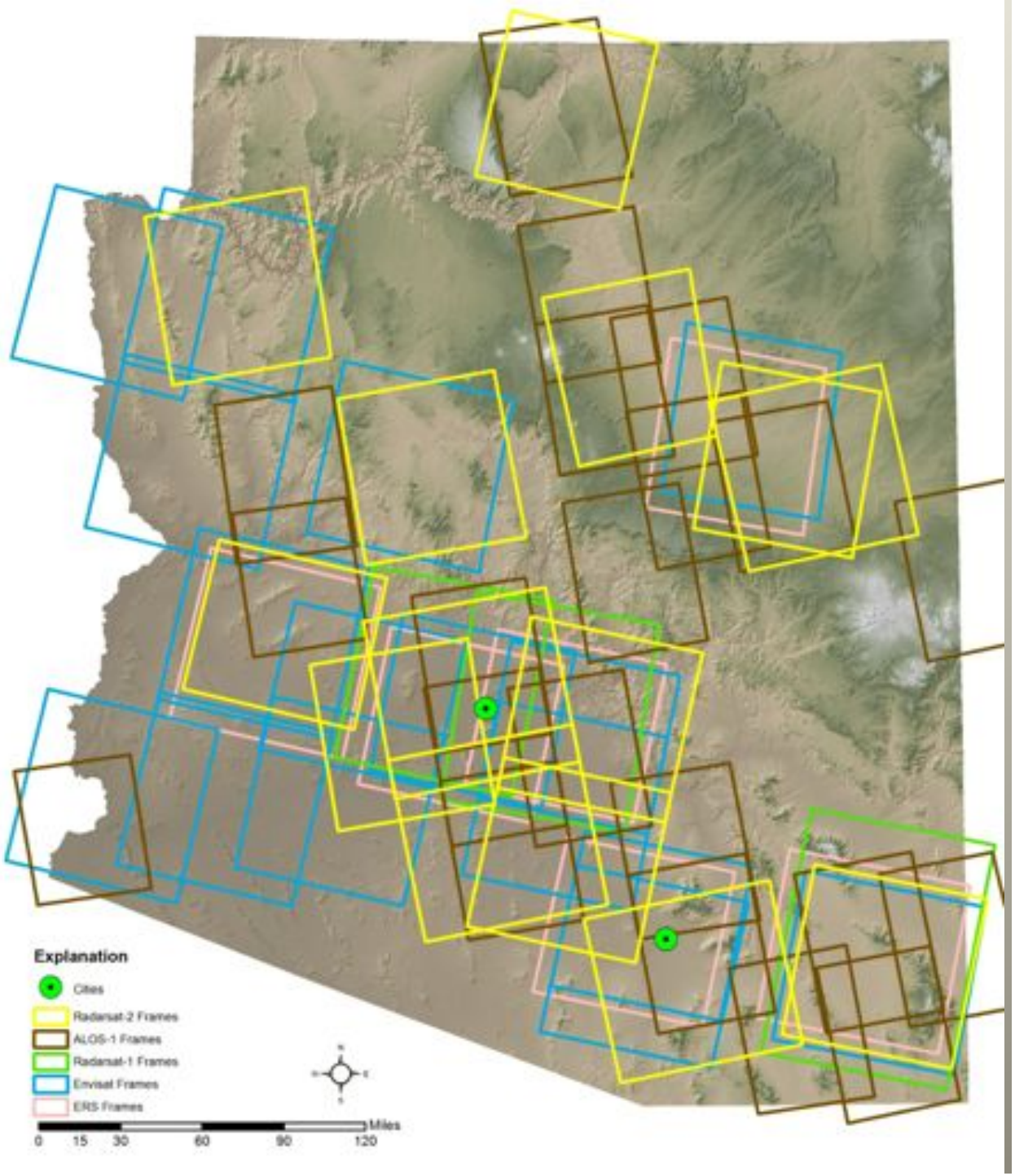
ADWR'S InSAR Program

- By 2014, identified 25 individual land subsidence features.
- ADWR cooperates with fourteen different federal, state, county, and local agencies and private water companies to help fund the InSAR program.



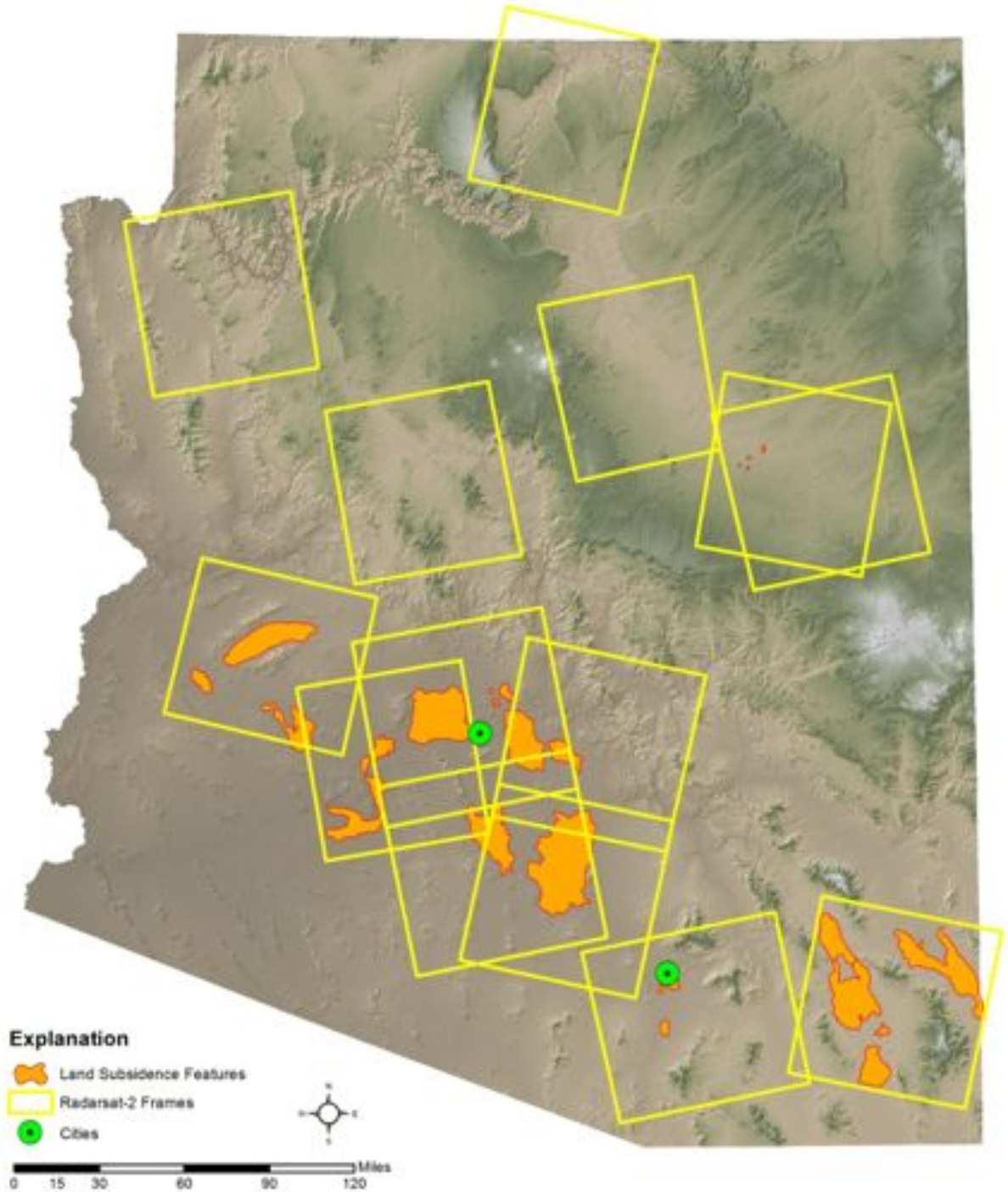
ADWR'S InSAR Program

- Have an extensive InSAR library of more than 1,300 collects.
- Collected more than 150,000 square miles of InSAR data.
- Cost of the InSAR data has exceeded $1 million dollars, predominantly paid through grants and InSAR cooperator funds.



ADWR'S InSAR Program

- Currently collecting more than 50,000 square miles of InSAR data.
- Collect InSAR data throughout the year to capture seasonal signals.



ADWR'S InSAR Program

- Currently receive Radarsat-2 InSAR data within 12 hours of data collection.
- ADWR uses primarily conventional InSAR processing techniques, but has recently started using PS-InSAR.
- Interferograms and xyz files are freely available by request to other agencies, consultants, cooperators, and the public.

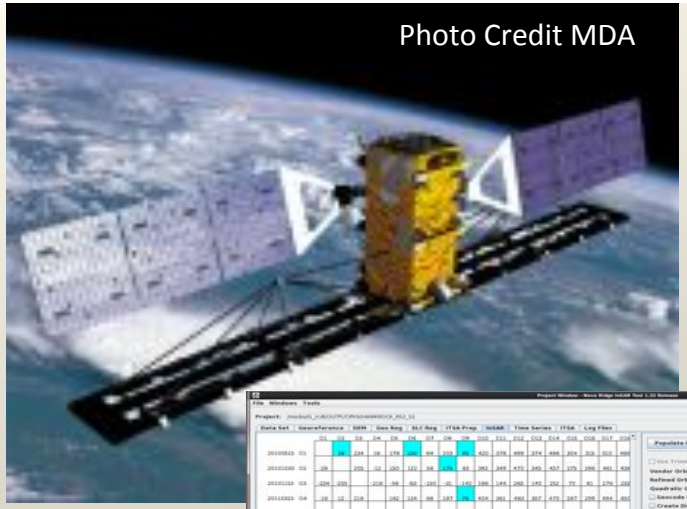
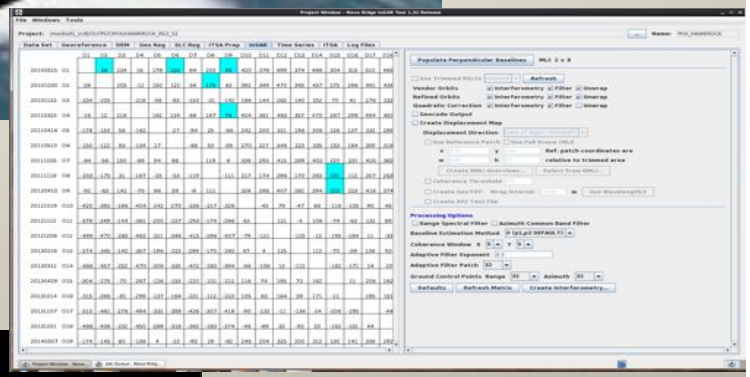
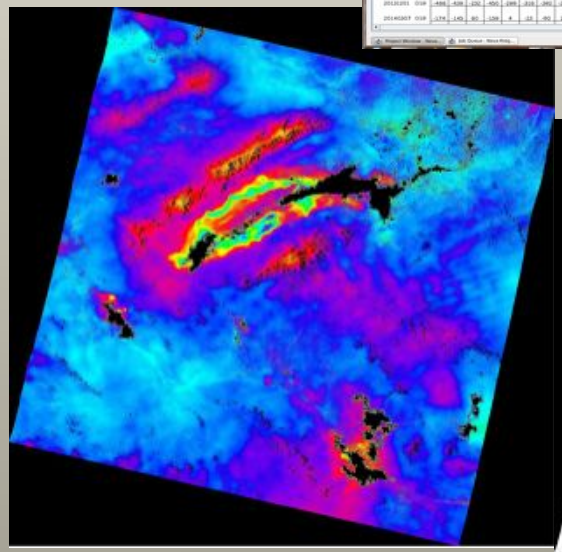
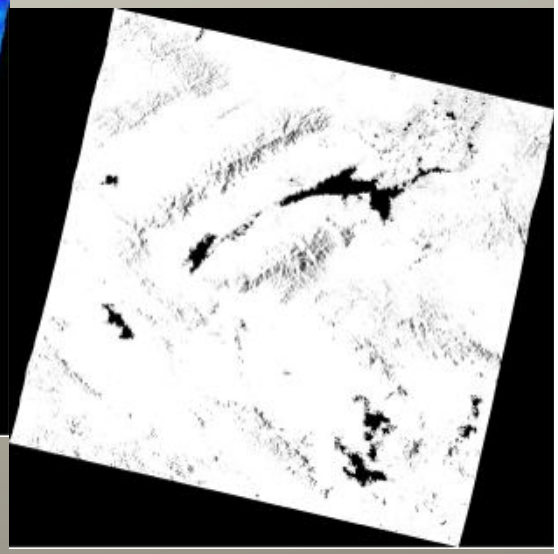


Photo Credit MDA




Interferogram


xyz file

ADWR'S Land Subsidence Website

- ADWR's website has a dedicated land subsidence section.
- Able to access an interactive land subsidence map using a Google Maps interface.

ADWR'S Land Subsidence Website

- Using the Interactive Map, click on any land subsidence feature inside the map or on left.
- Lists the land subsidence feature name and a link to access the website for that particular land subsidence feature.

ADWR'S Land Subsidence Website

- Each land subsidence features has it's own dedicated webpage.
- A total of 199 land subsidence maps are available for download.
- The maps cover various periods of time between 1992 and 2000, 2004 to 2010, and 2010 to present.

Interactive Arizona Land Subsidence Map

Arizona Land Subsidence Areas

Scottsdale/NE Phoenix	McMullen Valley	Picacho/Eloy	Fort Grant Rd
West Valley	Hassayampa Valley	Maricopa Standfield	Kansas Settlement
Hawk Rock	Ranegras Valley	Tucson	Elfrida
Buckeye	Gila Bend	Green Valley	Bowie/San Simon
Holbrook Sinks	Lost Valley		

What is Land Subsidence

Land subsidence has been occurring across Arizona since the early 1900's. Millions of people around the world live in active land subsidence areas and are unaware. Most of the time, there is no clear and identifiable sign that land subsidence has occurred in an area. Areas in Maricopa and Pinal Counties have subsided more than eighteen feet since the early 1900's.

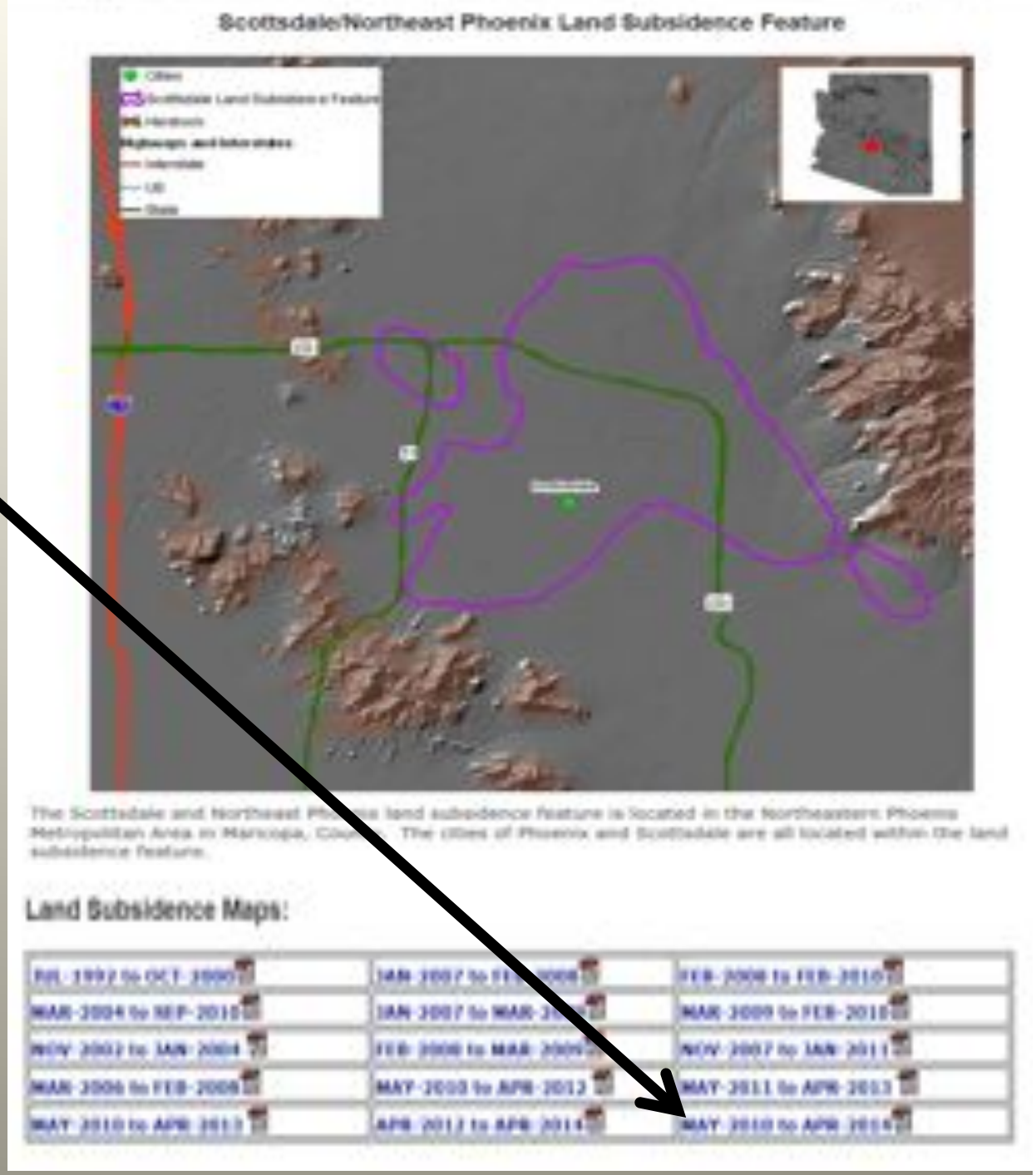
Land subsidence in the basins of Arizona is generally due to compaction of the alluvium caused by lowering of the water table. As the water table declines, pores in the alluvium once held open by water pressure are no longer supported and collapse. Collapse and subsequent lowering in elevation of the land surface is defined as land subsidence. This subsidence is generally not recoverable. If this subsidence occurs over areas of bedrock, differential subsidence can occur.

Differential subsidence is when adjacent areas subside at different rates. Bedrock will not compress like the surrounding alluvium, creating a subsurface platform. Differential subsidence occurs where shallow bedrock and deep bedrock are adjacent to each other, creating a zone of differential change in surface elevation. Because of these different amounts of subsidence, tension can build in the alluvium layer at this differential subsidence zone, forming an earth fissure.

ADWR Land Subsidence in Arizona Fact Sheet [< 1 MB]

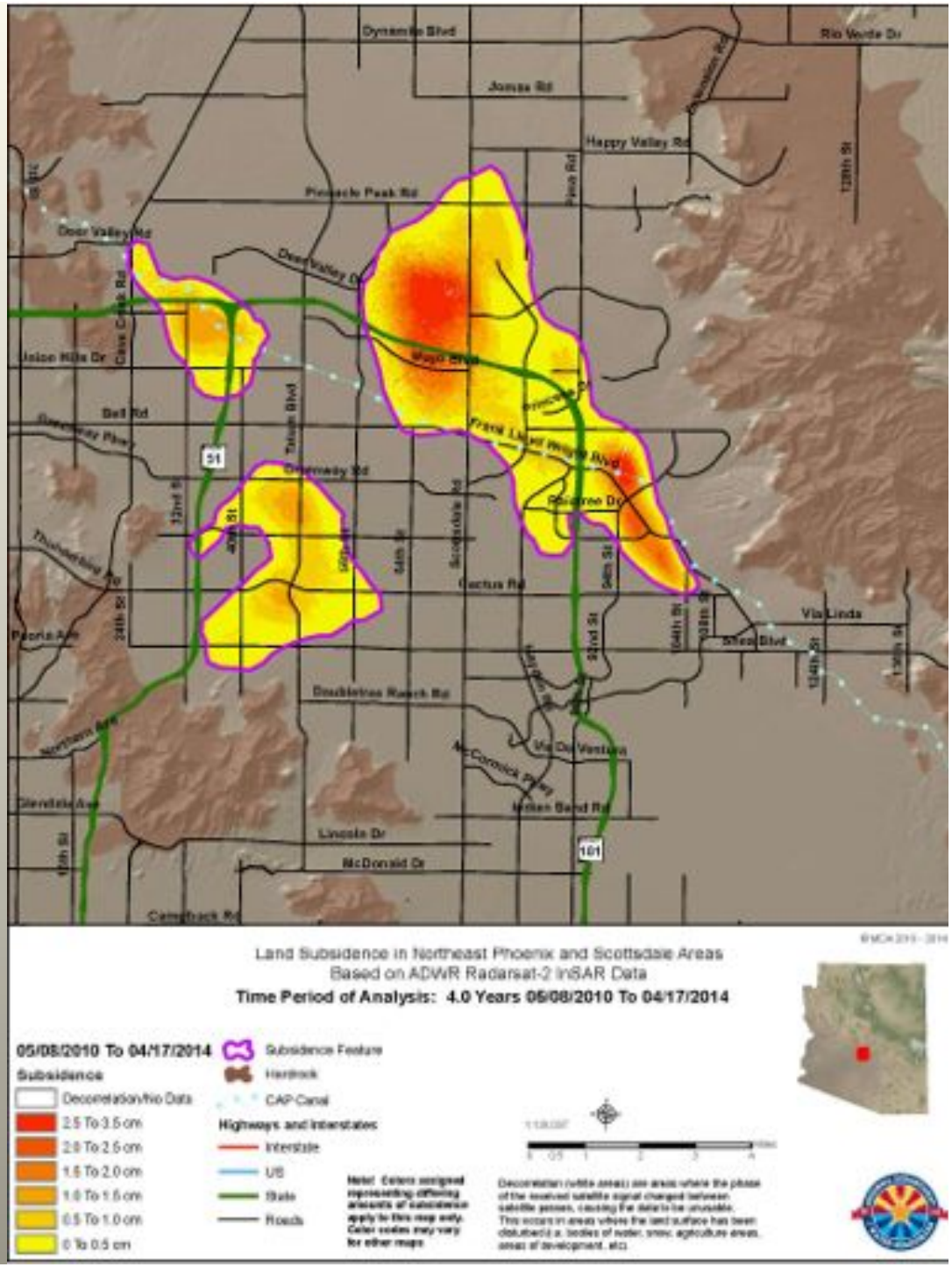
ADWR'S Land Subsidence Website

- Clicking any period of time will open up a pdf land subsidence map displaying the magnitude of land subsidence for that time-period.



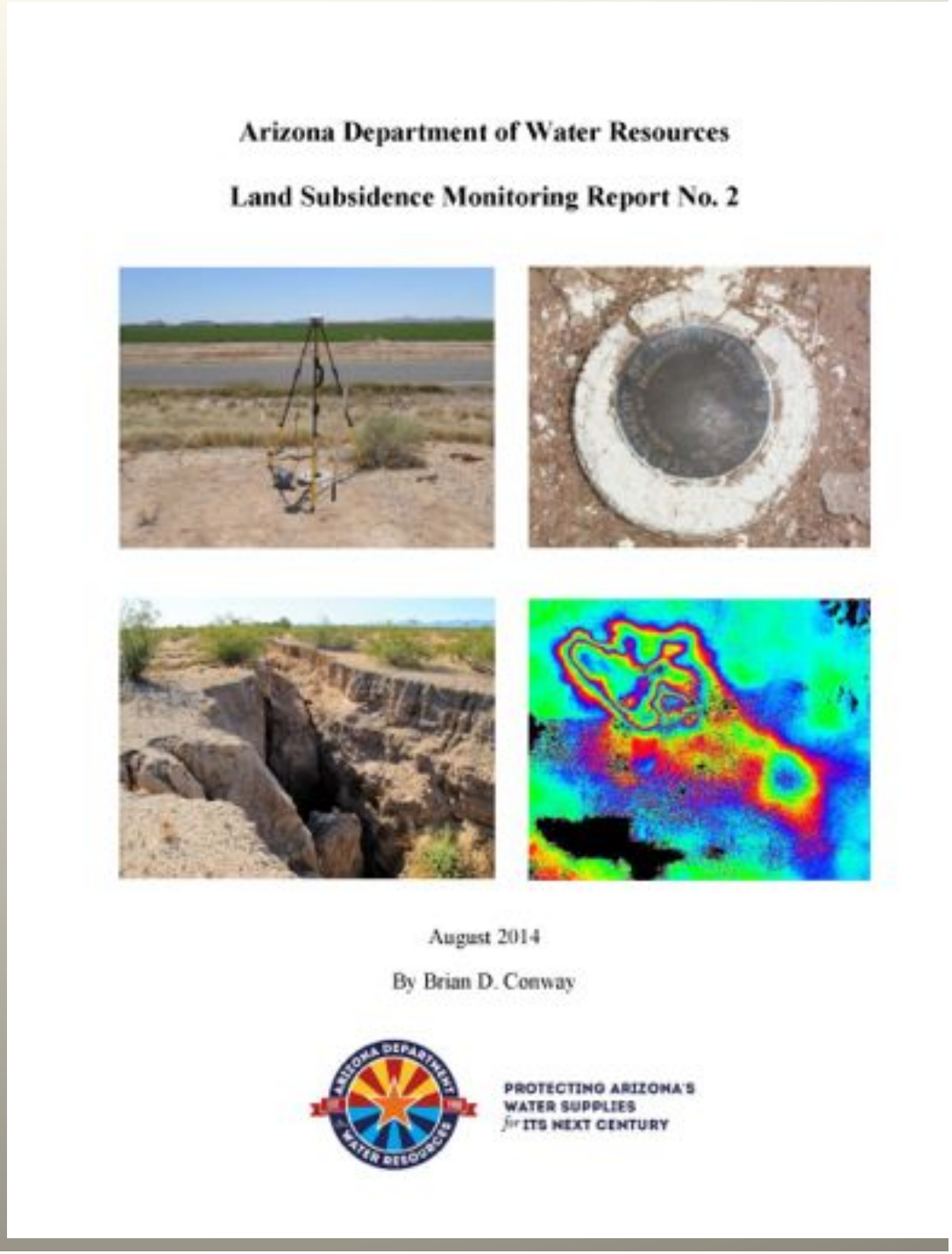
ADWR'S Land Subsidence Website

- Land subsidence map for the Northeast Phoenix/Scottsdale land subsidence feature between May 2010 and April 2014.



ADWR'S Land Subsidence Reports

- Provide land subsidence monitoring reports that discuss recent results throughout the State.



Arizona Department of Water Resources

Land Subsidence Monitoring Report No. 2

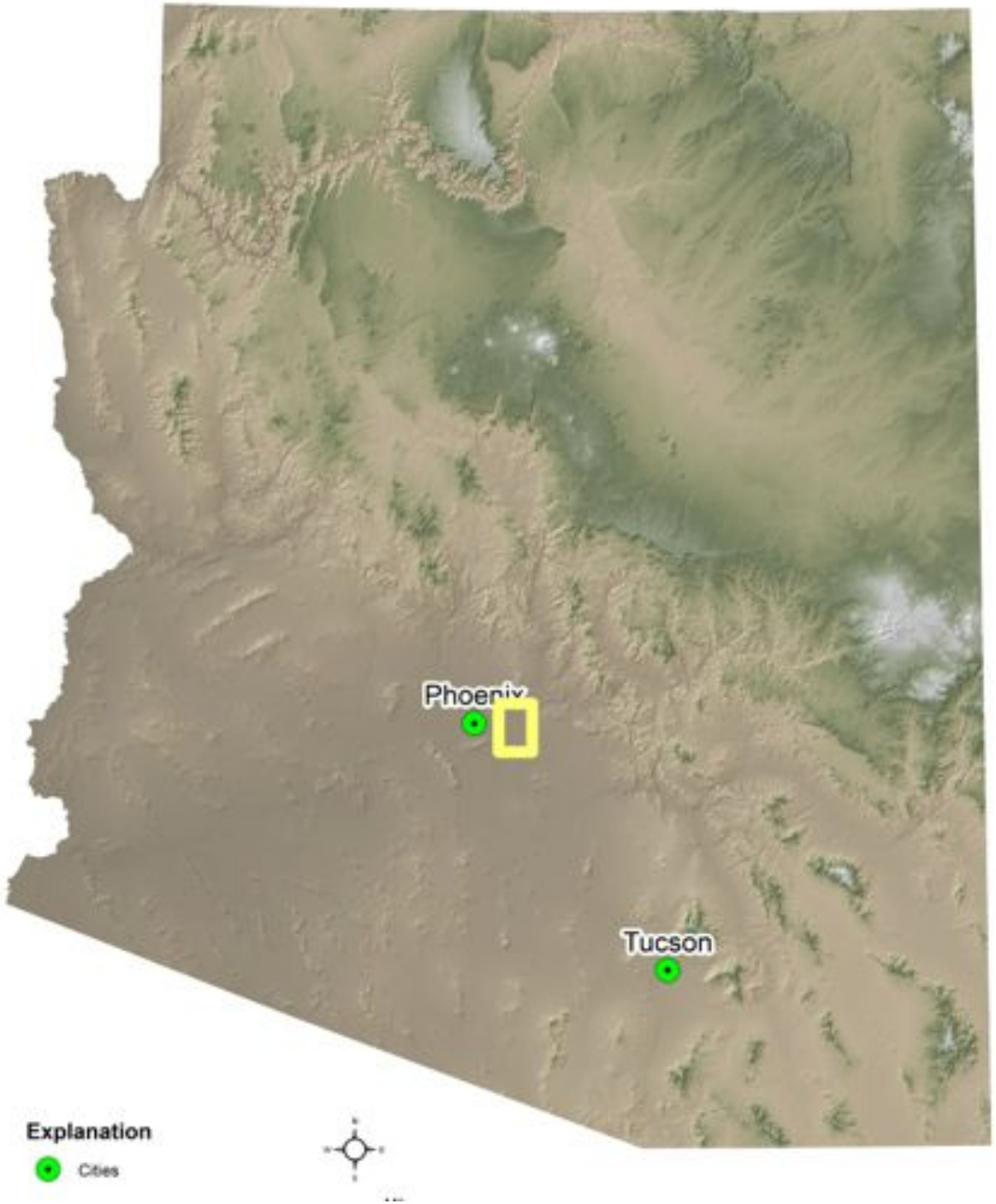
August 2014

By Brian D. Conway

PROTECTING ARIZONA'S WATER SUPPLIES *for* ITS NEXT CENTURY

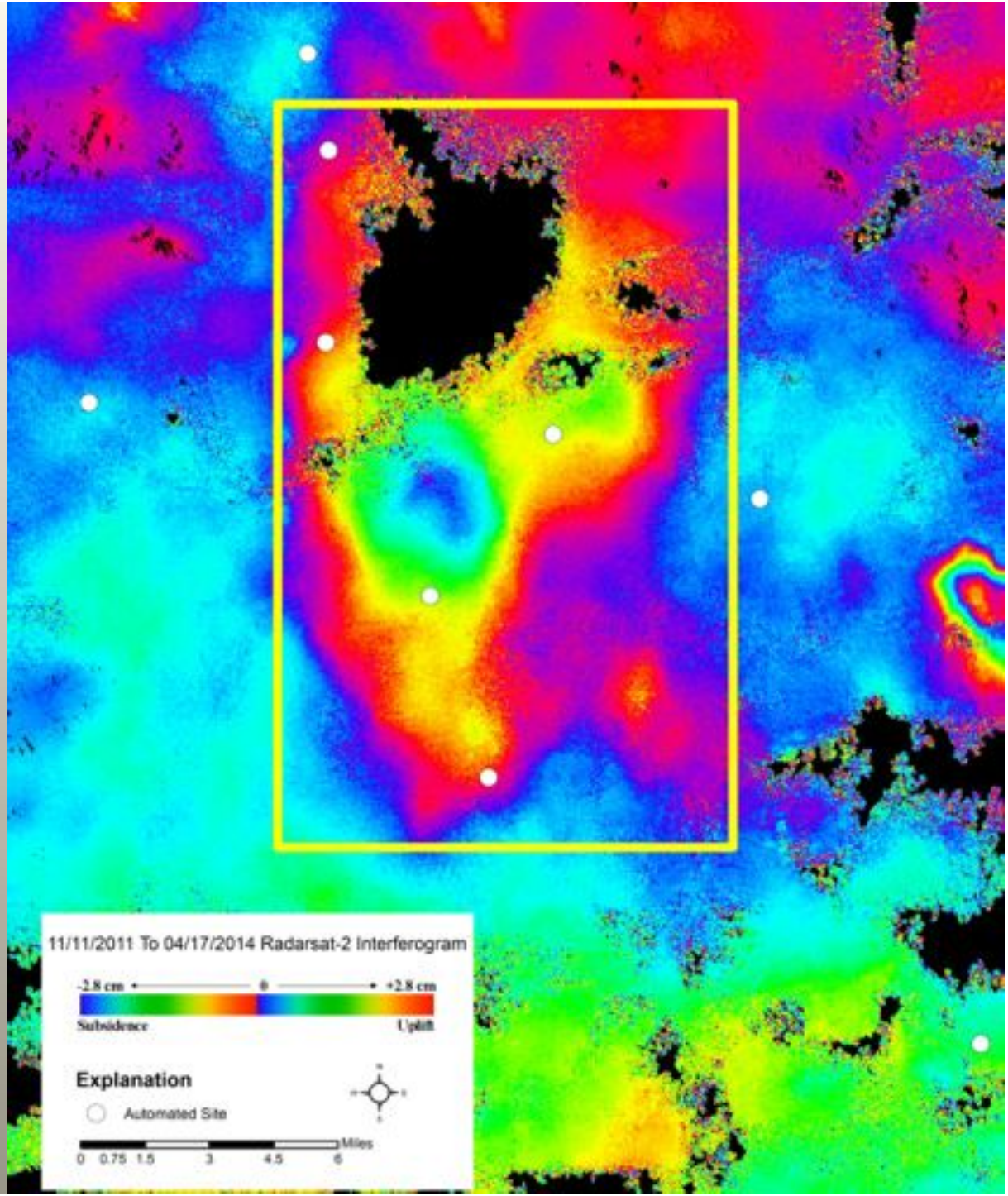
Identifying New Land Subsidence Features

- InSAR data provides ADWR with real-time deformation monitoring with the ability to detect sudden changes.
- An example of this recently occurred in the eastern part of Metropolitan Phoenix.



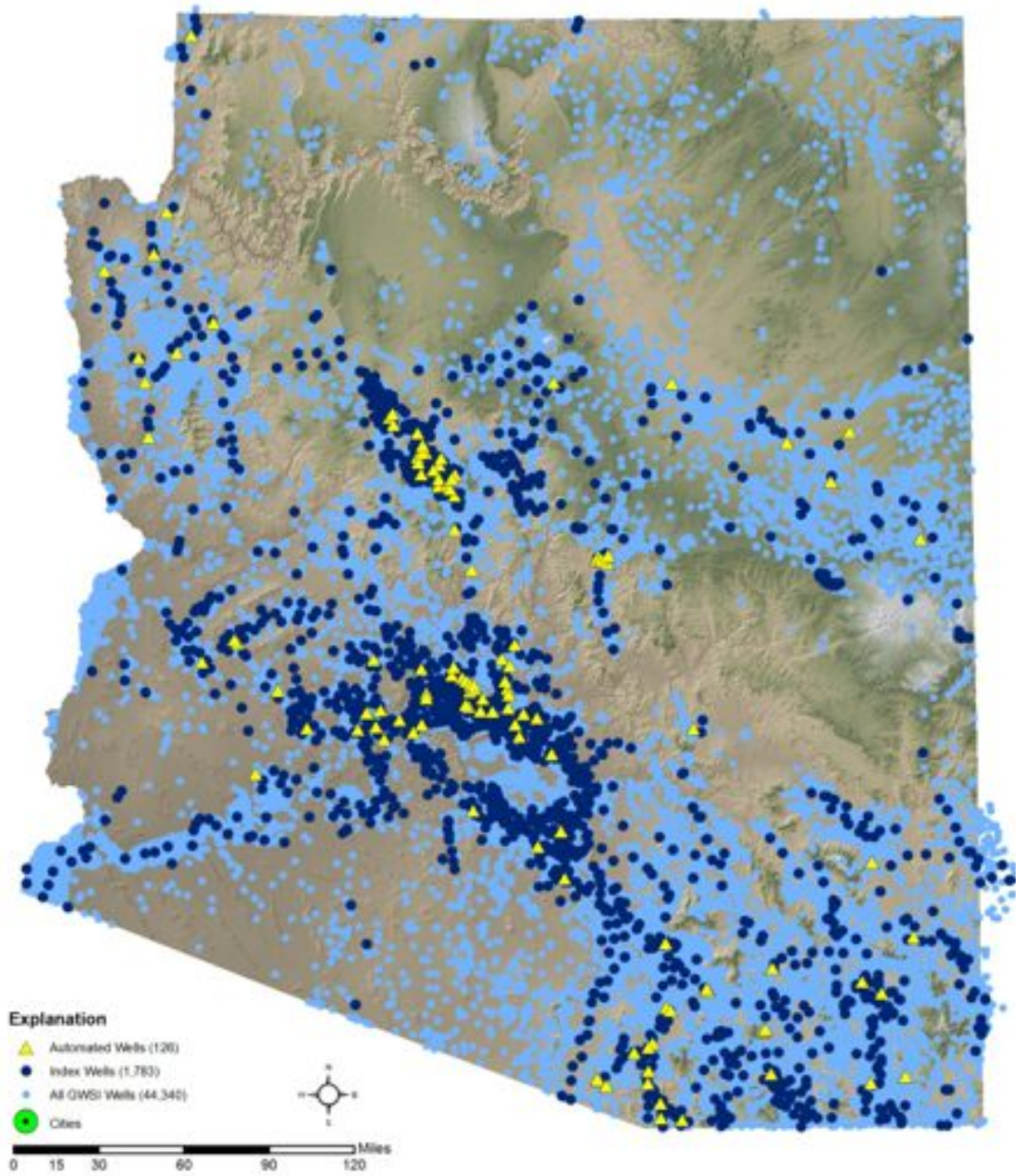
Identifying New Land Subsidence Features

- Identified a new land subsidence features in 2012.
- Started researching internally into what caused this new land subsidence feature.



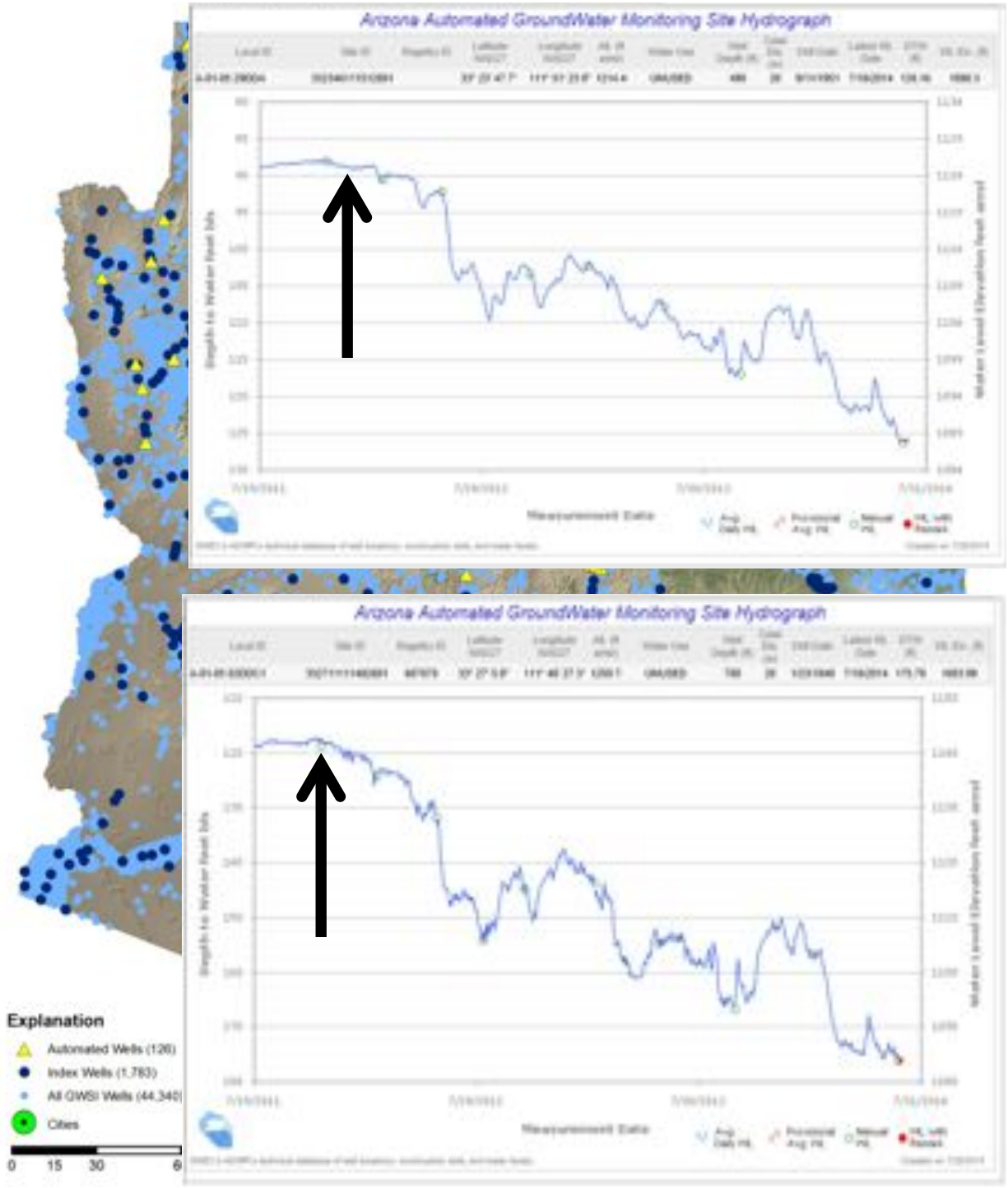
Identifying New Land Subsidence Features

- Examined groundwater levels, groundwater pumping volumes, and well logs (all publicly available on ADWR's website) for the area.



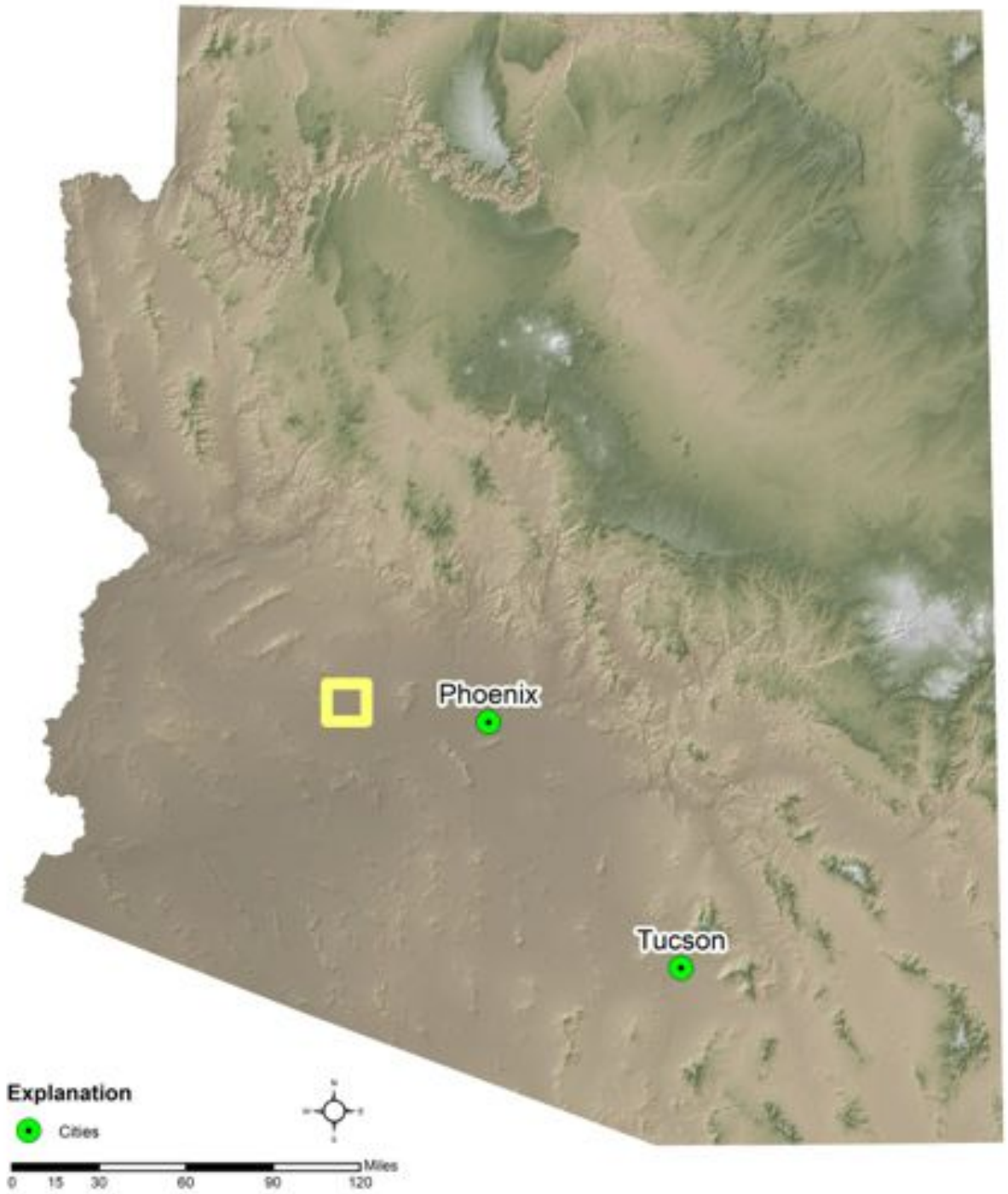
Identifying New Land Subsidence Features

- Groundwater levels showed that groundwater declines had started in 2011.
- Pumping data showed that pumping increased more than 30,000 acre-feet in 2011 due to a decrease in surface water deliveries.
- The new land subsidence feature is a result of declining groundwater levels because of increased groundwater pumping to offset a decreased in surface water deliveries.



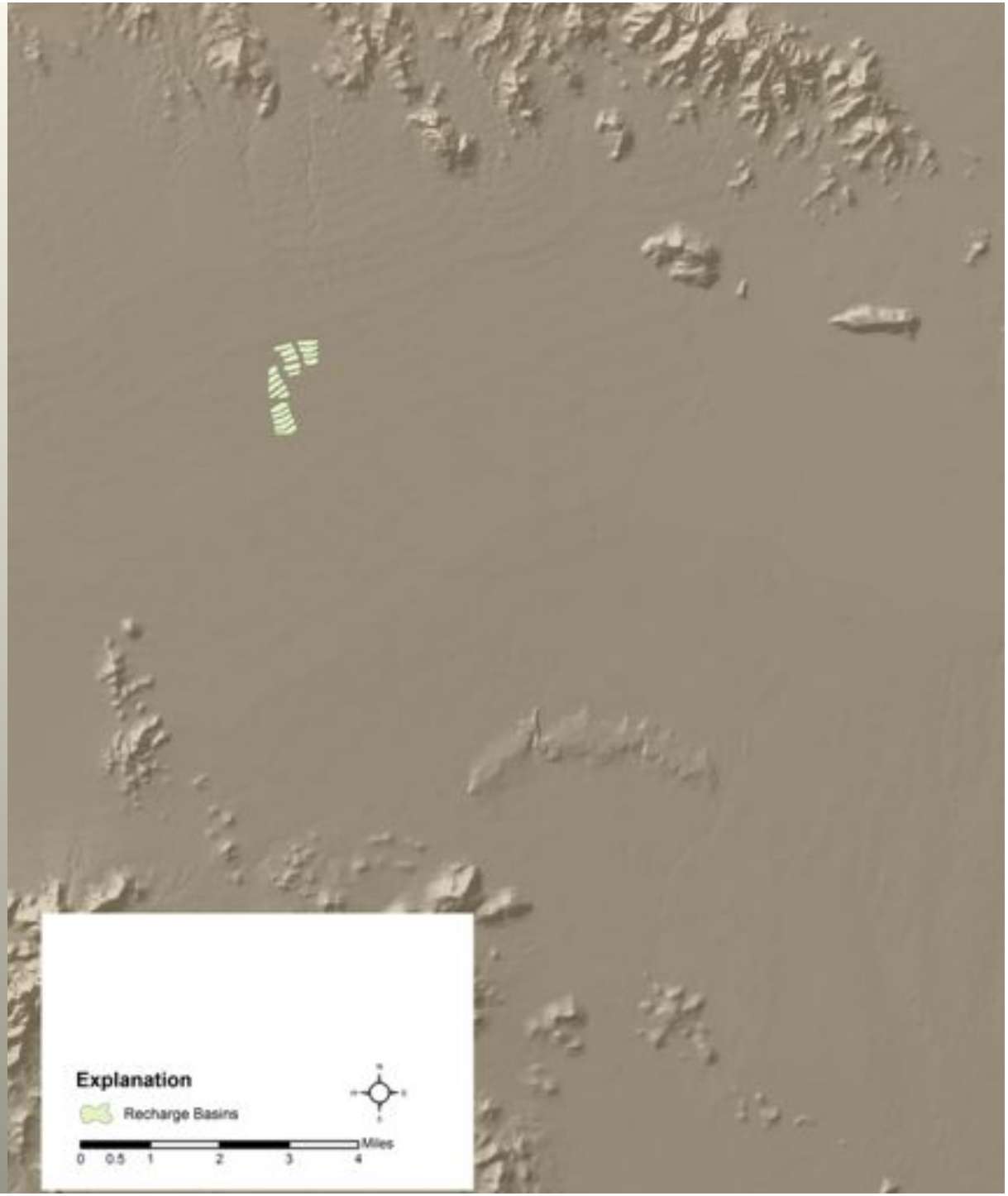
Using InSAR Data to Monitor Land Uplift

- ADWR uses InSAR data for monitoring surface uplift related to groundwater recharge facilities.
- Recharge facility about 40 miles west of Phoenix.



Using InSAR Data to Monitor Land Uplift

- Central Arizona Water Conservation District (CAWCD) Tonopah Recharge Facility began recharging 150,000 acre-feet of water/year in 2006 using recharge basins.



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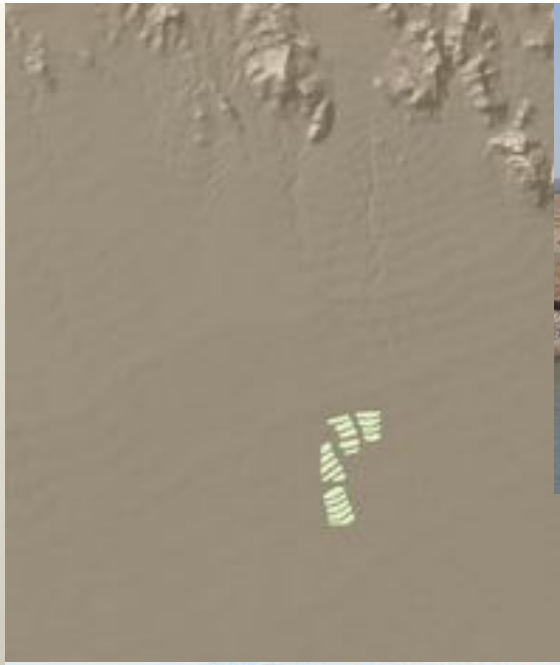
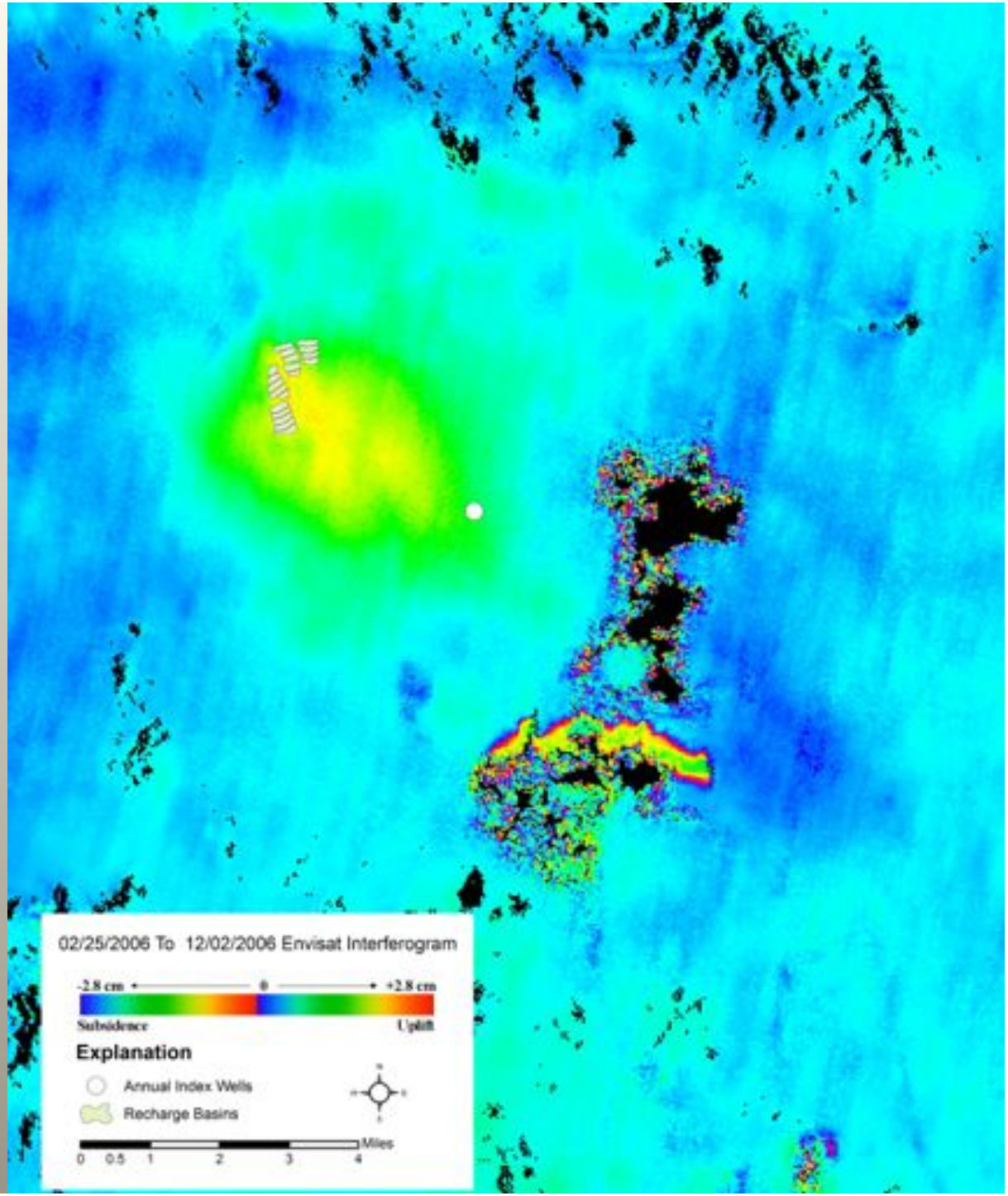


Photo Credit CAWCD

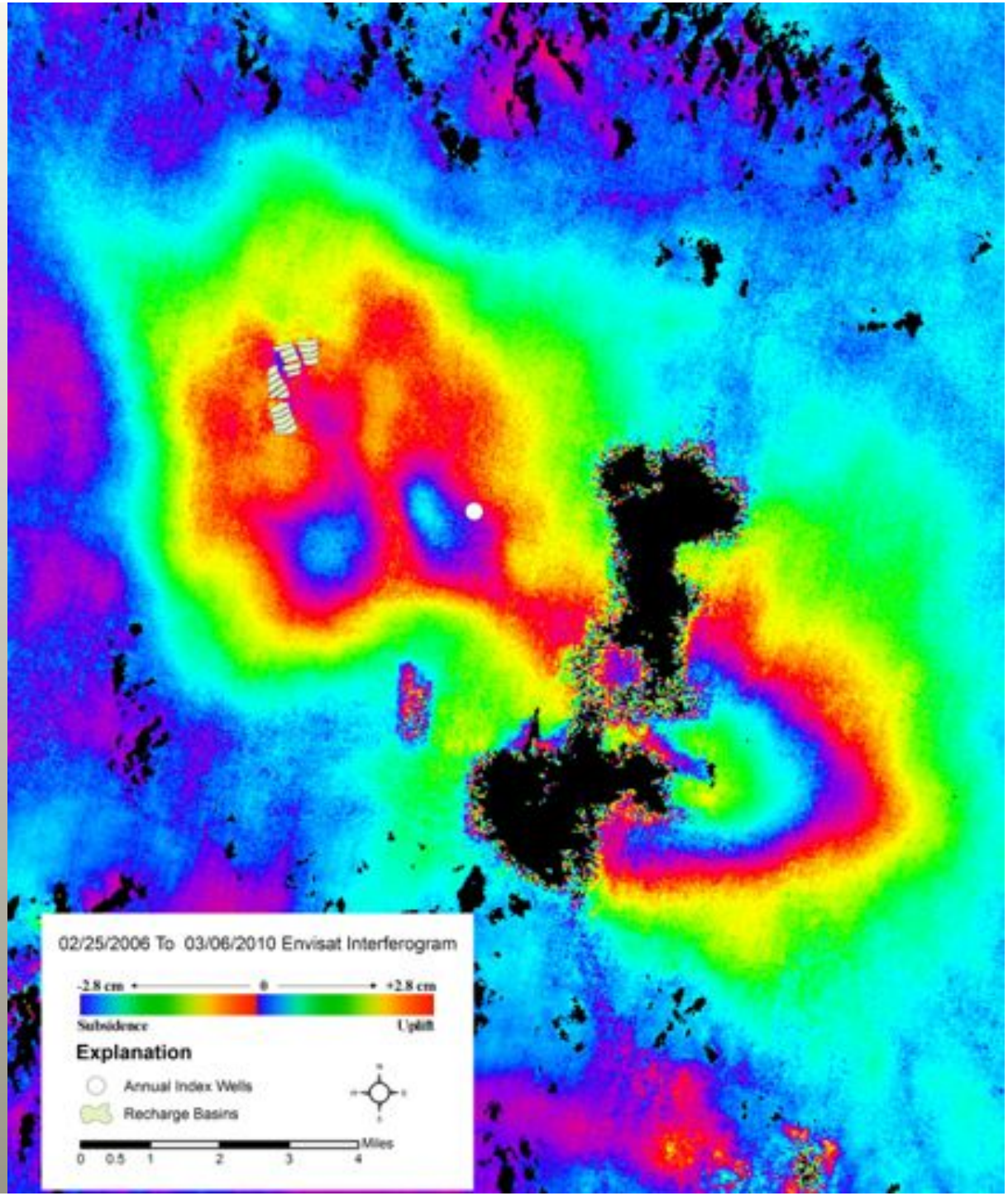
Using InSAR Data to Monitor Land Uplift

- Within a few months of recharge, uplift was detected in the InSAR data.
- The uplift is a result of the rising groundwater levels from the groundwater recharge.



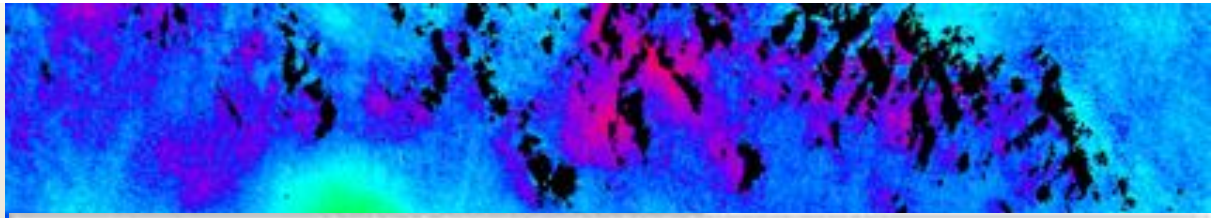
Using InSAR Data to Monitor Land Uplift

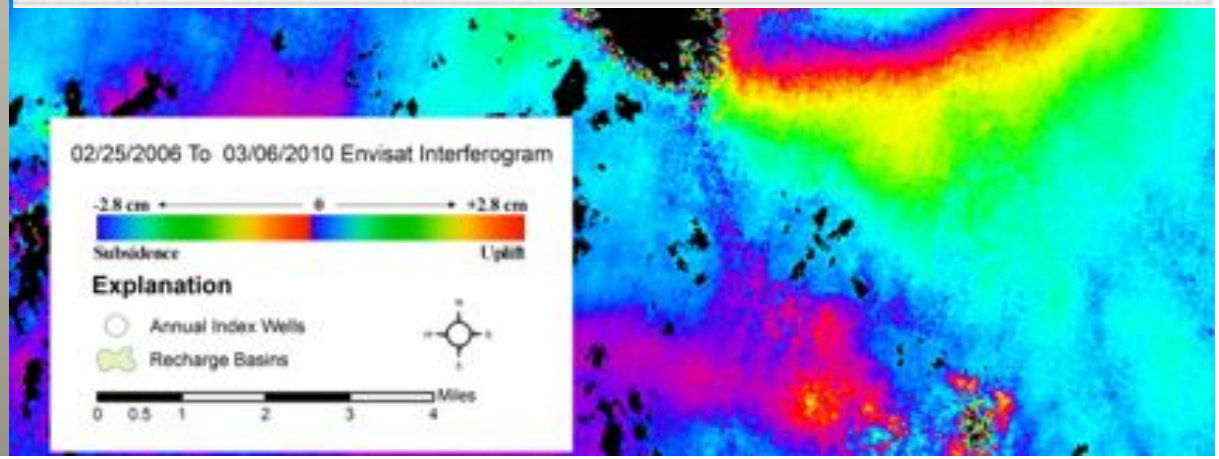
- After four years of more than 640,000 acre-feet of recharge, the InSAR data shows a significant area of uplift that has not only mounded but also extended to the southeast.
- The area of uplift covers an area greater than 50 square miles.
- Maximum uplift for the feature is 3.2 centimeters.



Using InSAR Data to Monitor Land Uplift

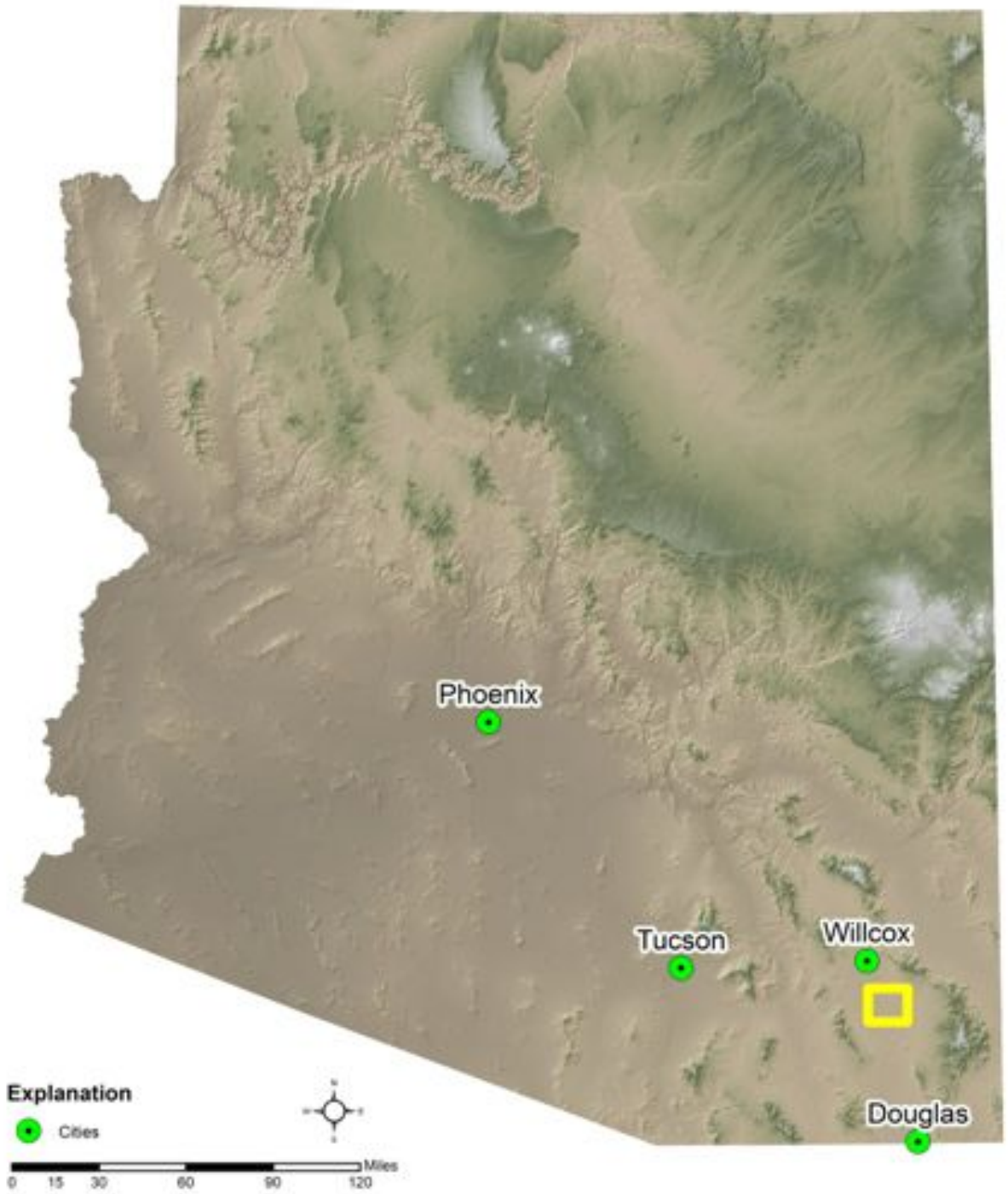
- When the area of uplift first reached the annual index well in 2006, the groundwater level rose 110 feet and continued to rise a total of 203 feet by 2011.
- The groundwater level has slightly dropped since its peak in 2011. This is due to decreased recharge at the facility.





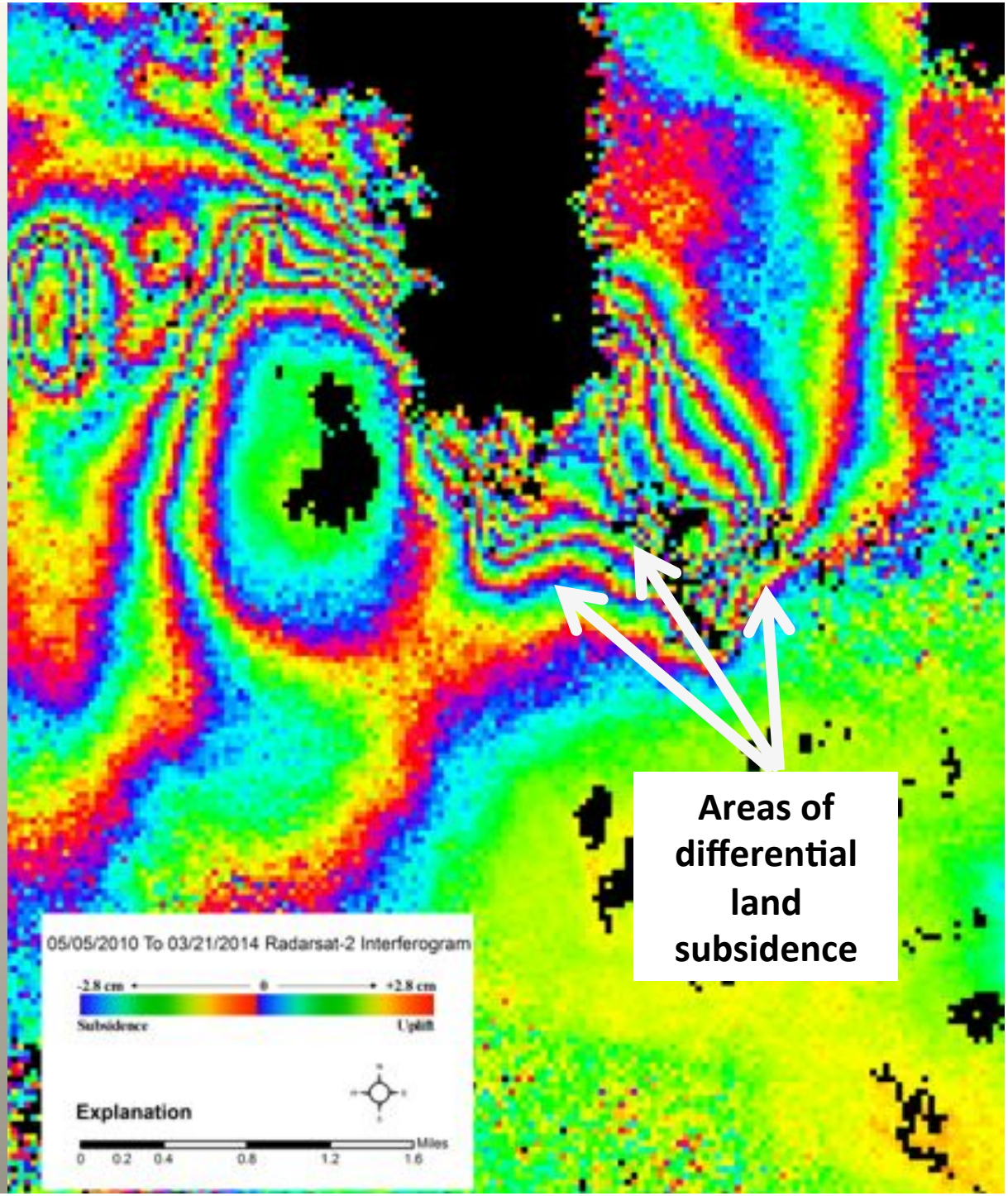
Using InSAR Data to Monitor Earth Fissures

- InSAR is also used for monitoring and identifying areas of potential earth fissuring.
- ADWR works closely with the Arizona Geological Survey (AZGS) which is responsible for mapping all the earth fissures in the State.



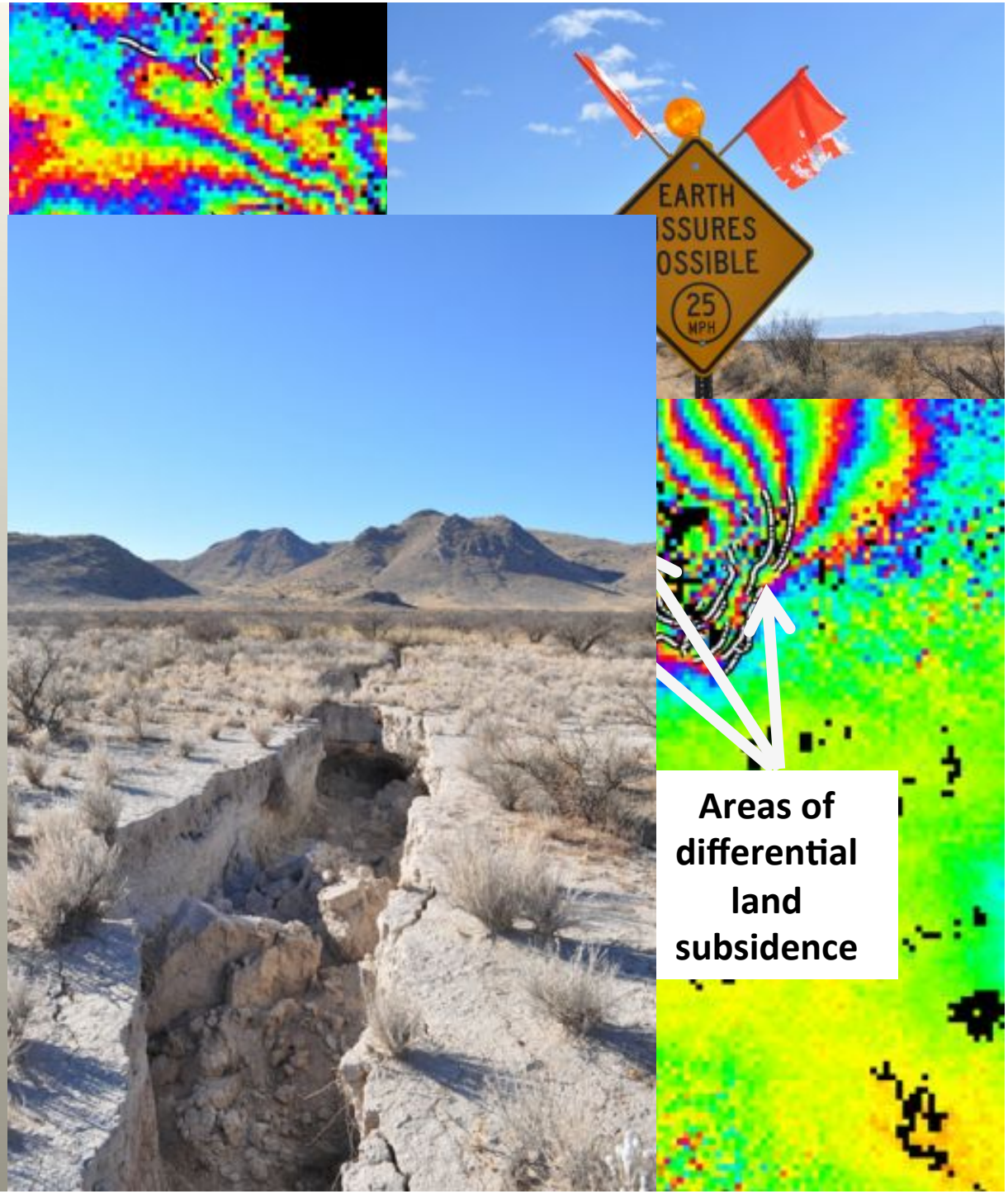
Using InSAR Data to Monitor Earth Fissures

- Cochise County is home to the largest magnitude of land subsidence/year in Arizona.
- Subsidence rates between ½ and 1 foot/year have been recorded.
- InSAR data is used to not only monitor earth fissure activity, but to also identify areas for potential earth fissuring where differential land subsidence is occurring in the InSAR data.



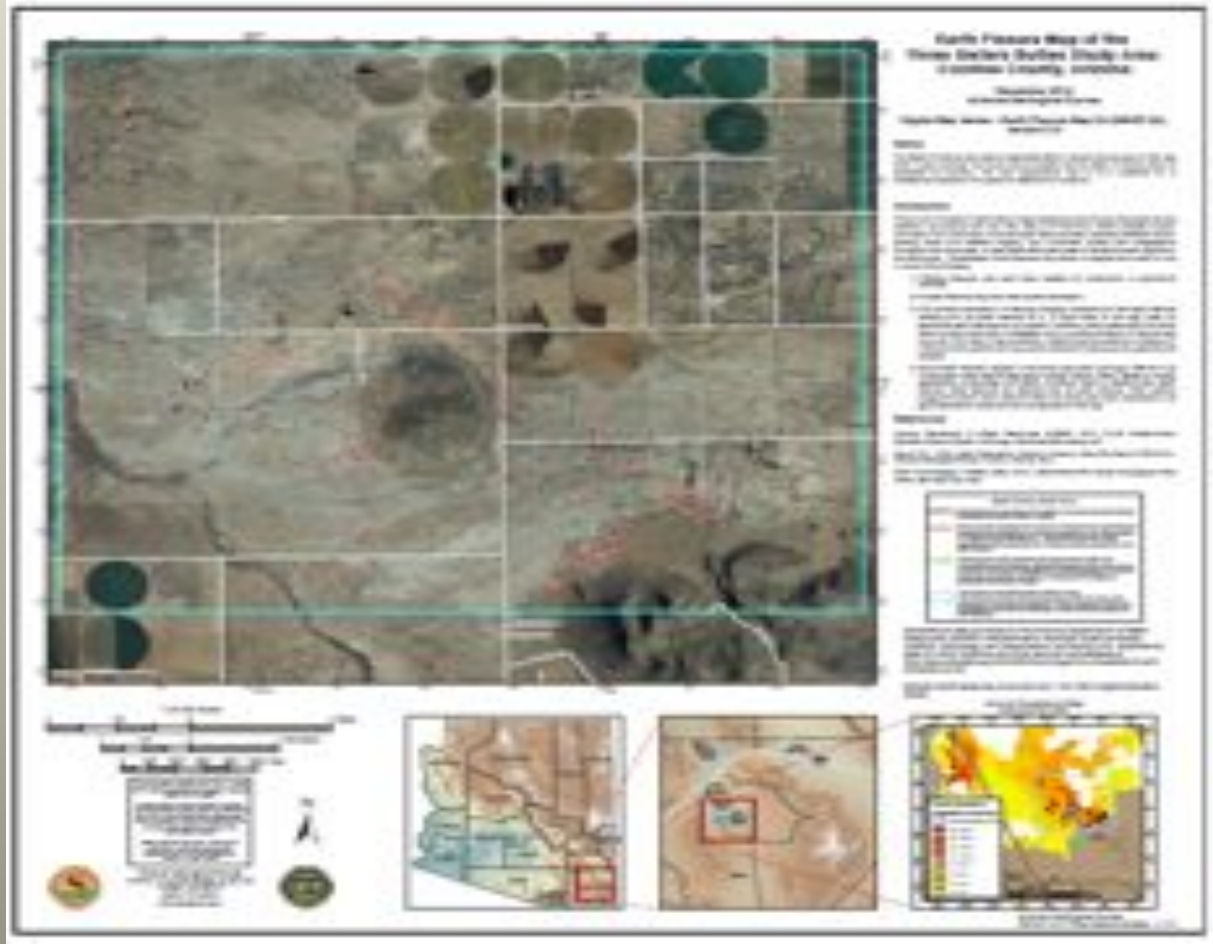
Using InSAR Data to Monitor Earth Fissures

- AZGS has identified and mapped more than 100 earth fissures in this area that cover a distance of 19.5 miles.



Arizona Geological Survey Earth Fissure Mapping Program

- AZGS has identified and mapped more than 153 miles of earth fissures Statewide.
- Using InSAR data has allowed both the AZGS and ADWR to concentrate earth fissure monitoring efforts.
- There are 24 earth fissure study area maps.
- AZGS publishes earth fissure maps for each earth fissure study area and can be downloaded from their website (www.azgs.az.gov).



Land Subsidence Monitoring in Arizona

- A major step with the land subsidence monitoring program is providing the data to those who need it for their own monitoring, mitigation, planning, and design projects.
- Land subsidence maps are updated every spring which reflect the past 12 months of InSAR data collection.
- InSAR data (interferogram and xyz file) can be requested by anyone (consultant, public, other agency, etc.) and will be provided free of charge.
- The land subsidence maps/InSAR data, earth fissure maps, groundwater level data, groundwater pumping data, and well-log data are all critical datasets that are needed to properly monitor, investigate, and mitigate land subsidence.
- ADWR and the AZGS make these datasets readily available through their websites and the datasets are constantly being updated with current data.

Benefits From InSAR in Arizona

- Greatly improved land subsidence monitoring efforts across Arizona.
- Developed important partnerships with other federal, state, county, and local agencies providing land subsidence data for their monitoring efforts.
- Developed and published land subsidence maps for the State of Arizona.
- Greatly improved awareness of land subsidence and the potential problems caused by land subsidence.

Future of ADWR's Land Subsidence Monitoring Program

- Continue to monitor land subsidence throughout the State and add additional areas as needed.
- Continue to provide InSAR data and land subsidence maps to the public, consultants, other government agencies, and the InSAR cooperators.
- Continue to educate about land subsidence and earth fissures and the problems that each can cause.
- Continue to build the InSAR program as new processing techniques become available and collect data using new satellites (ALOS-2, Sentinel-1, SAOCOM, NI-SAR, etc).

Questions?

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