INTERFEROMETRIC SYNTHETIC APERTURE RADAR (INSAR)

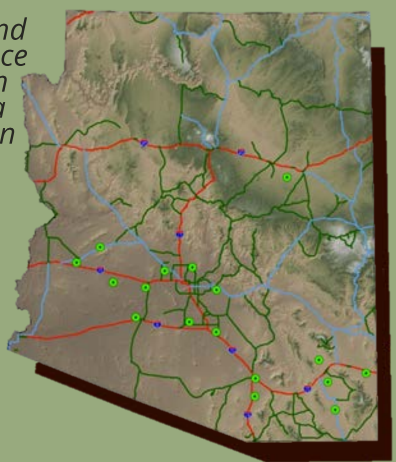
LAND SUBSIDENCE AND EARTH FISSURES

WHAT'S INCLUDED IN THIS FACT SHEET?

INTERFEROMETRIC SYNTHETIC APERTURE RADAR (INSAR) PROGRAM

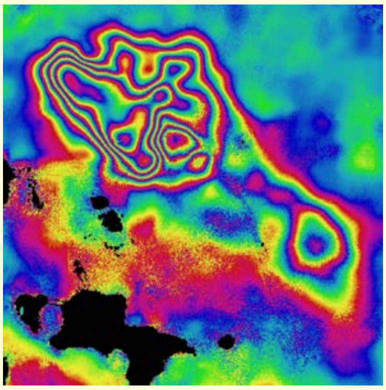
The Arizona Department of Water Resources' (ADWR) InSAR program started in 2002 with the awarding of a 3-yr NASA Earth Science grant in cooperation with the University of Texas at Austin Center for Space Research and the Vexel Corporation. ADWR and its cooperators developed the InSAR program during the three years of the grant. In 2005, ADWR began collecting and processing monthly level 0 raw SAR data from the European Space Agency (ESA) and Canadian Space Agency SAR satellites, producing time-series interferograms for the greater Phoenix and Tucson metropolitan areas. The InSAR coverage has been greatly enhanced around Central and Southern Arizona, collecting regularly scheduled SAR data for Maricopa, Pinal, Pima, La Paz, Navajo, and Cochise counties. Through these efforts, ADWR has identified and now monitors more than twenty-five individual land subsidence features around Arizona, which cover an area greater than 1,200 square miles. Numerous state, county, and local government entities understand the importance of InSAR and utilize the data as an important resource into their own monitoring efforts. As a result, these groups have entered into agreements with ADWR, providing annual contributions to the InSAR program, ensuring that SAR data are collected, processed, and analyzed for those areas critical to each group's monitoring efforts.

Active land subsidence areas in Arizona based on ADWR InSAR (Right)



SYNTHETIC APERTURE RADAR (SAR)

Synthetic Aperture Radar (SAR) is a side-looking, active (produces its own illumination) radar imaging system that transmits a pulsed microwave signal towards the earth and records both the amplitude and phase of the back-scattered signal that returns to the antenna. Interferometric Synthetic Aperture Radar (InSAR) is a technique that utilizes interferometric processing that compares the amplitude and phase signals received during one pass of the SAR platform over a specific geographic area with the amplitude and phase signals received during a second pass of the platform over the same area but at a different time. In SAR techniques, using satellite based SAR platform data, can be used to produce land surface deformation products with centimeter scale vertical resolution, 30 meter pixel resolution, and covering areas of 100 square kilometers.



Hawk Rock 2010 - 2018 Interferogram (Above)

MDA Radarsat-2 Satellite (Above)

ADWR'S USE OF INSAR

ADWR has been using InSAR to determine the spatial extent, deformation rates, and time-series history of land subsidence features identified around the state. InSAR is very cost effective due to its resoulation and the large area covered by each satellite frame. Engineers, hydrologists, geologists, and scientists greatly benefit from the InSAR data to identify and evaluate areas of subsidence, uplift, earth fissures, faults and many other geologic features. InSAR data are used by those involved in the fields of water resources, structural engineering, geological engineering, hydrological engineering, land planning, and surveying.

SATELLITES AND DATA

ADWR uses SAR data from the ESA's ERS-1, ERS-2, Envisat, and Sentinel-1 satellites, the MDA/Canadian Space Agency's RadarSat-1 and RadarSat-2 satellites, the Japanese Aerospace Exploration Agency's ALOS-1 and ALOS-2 satellites, and MDA's Radarsat-2 satellite. These satellites utilize the C and L band wavelengths. One possible limitation of the SAR data is that, in areas where the land surface has been disturbed (i.e. bodies of water, snow, agriculture areas, areas of development, etc.), there may be poor coherence and decorrelation problems.

DECORRELATION AND COHERENCE

Decorrelation occurs when the phase of the received satellite signal changed between satellite passes, causing the data to be unusable. The ALOS-1 and 2 satellites use the L band wavelength (26 centimeters), which helps improve coherence and reduce the amount of decorrelation.

ESA's Sentinel-1A Satellite (Above)

COOPERATION AND AGREEMENTS

ADWR has entered into Inter-Government Agreements with the following government entities to help fund the costs (satellite programming and acquisition costs, InSAR processing software maintenance, and upgrade/support of the required servers and storage devices) associated with the InSAR program:

- Maricopa Flood Control Dist.
- Pinal Flood Control Dist.
- Metopolitan Domestic Water Improvement Dist.
- Arizona Dept. of Transportation
- Arizona State land Dept.
- Central Arizona Project

ADWR would also like to thank the following groups for making donations to the InSAR program:

- Salt River Project
- City of Phoenix
- City of Scottsdale
- Cochise Flood Control Dist.
- City of Glendale
- City of Mesa
- Community Water Company of Green Valley
- Petrified Forest Nat. Park
- Arizona Geological Survey

LAND SUBSIDENCE

Land subsidence has been occurring across Arizona since the 1940's. Thousands of people 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 areas. Areas in Maricopa and Pinal counties have subsided more than eighteen feet since 1940. Land subsidence in the basins of Arizona is generally due to compaction of 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 built in the alluvium layer at this differential subsidence zone, forming an earth fissure.

Subsidence, leaving well head exposed above ground (Above)

Pot hole resulting from an earth fissure, Apache Junction, Pinal County (Left)

EARTH FISSURES

Earth fissures are cracks at or near earth's surface that are the result of differential subsidence. Earth fissures start out as small cracks and may not bevisible on the surface. They grow and widen from surface water flowing into the crack, eroding material from the sides. Earth fissures have caused millions of dollars in property and infrastructure damage, damaging pipelines, roads, canals, flood retention structures, bridges, buildings, and private property. There are unanswered questions about how earth fissures interact with groundwater pollution.

Earth fissure near Tator Hills, Pinal County, Feb. 2017 (Above)

EARTH FISSURE MONITORING AND MAPPING

Earth fissures are identified by using on the ground and aerial monitoring techniques. The Arizona Geological Survey (AZGS) started an intensive earth fissure mapping program in 2006. The goal of this program is to survey and record each known earth fissure around the state and to provide this data to the public.

Warning sign located in Cochise County (Above)

IMPACTS OF LAND SUBSIDENCE AND EARTH FISSURES

There are many consequences of land subsidence and earth fissures: elevation and slope change affecting the natural flood plain drainage, flow within canals and drains, damaging intermodal infrastructure (roads, bridges, railways, etc.), damaging water retention and retarding structures (dams, levees, floodways, etc.), and damaging private property (homes, driveways, fences, etc.)