

Subsidence Monitoring Using Synthetic Aperture Radar

Maurice Tatlow – Arizona Department of Water Resources

Synthetic Aperture Radar (SAR) images have been used to measure a variety of surface water and groundwater hydrologic parameters. The Arizona Department of Water Resources (ADWR) is using the technology to monitor land subsidence in areas of extensive groundwater extraction.

SAR is a type of imaging radar that uses a small antenna to achieve the effects of a very large one by combining or synthesizing signals as the platform moves along its flight path. SAR products can be generated from a satellite or airborne SAR system. Satellite platforms employ a side-looking, active radar system that transmits a pulsed, microwave signal toward Earth and measures the intensity and phase of signal that is scattered back to the platform's antenna. SAR data can be collected day or night, and through cloud cover. The high altitude (roughly 800 km) polar orbits of the platforms allow much of the earth to be imaged with normal repeat visit times of 24 to 35 days. One standard frame roughly covers an area 100 km by 100 km with a 30-m processed pixel resolution. Finer resolution products are available.

SAR Interferometry

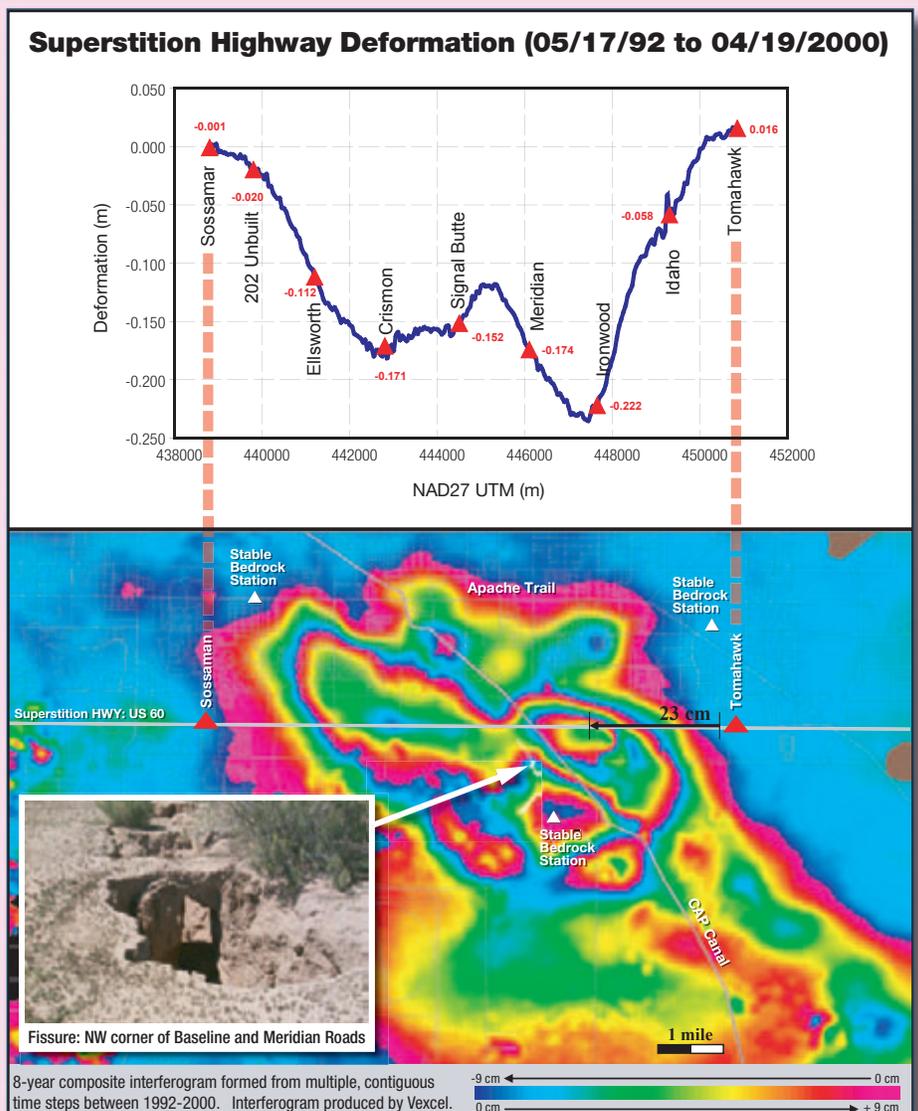
Radar phase difference products, or interferograms, are produced by comparing the phase difference between two SAR scenes of the same area at different times. Using existing satellites, time differences are in increments of roughly one month. After processing to remove the effects of different orbital geometry, topography, and to properly georeference each scene, the phase difference that remains (discounting atmospheric perturbations) is a measurement of the surface deformation that occurred during the time interval between satellite passes. If additional data, such as change in depth-to-water and fluid flux, are available over the same time interval, then the deformation can be used to calculate aquifer parameters such as elastic and inelastic storage coefficients and compaction time constants (see Hoffmann et al., 2003), valuable for groundwater modeling.

The figure at right shows a composite interferogram that clearly defines a large deformation feature that impacts the Superstition Highway and the CAP canal in the cities of Mesa and Apache Junction, Arizona. The accompanying profile shows the magnitude of land subsidence that occurred along the Superstition Highway from the Sossaman Road interchange to the Tomahawk Road interchange from 1992 to 2000.

Acquiring Data Is the First Step

Radar phase difference products may be obtained several ways. First one must determine whether raw data have been or can be collected in the area of interest. If so, they may be processed by the user or a third party. Both Eurimage (www.eurimage.com) and Radarsat International (www.rsi.ca) distribute data for current and past satellite sensors. Many parts of the Southwest have archived imagery (some as far back as 1992) and are being imaged today.

Processing software ranges in price from nearly free for the publicly available ROI_PAC package (developed at JPL/Caltech) to several thousand dollars for some commonly used commercial packages, and up to \$50,000 for high-end, high-volume packages. The learning curve is steep with these programs, which commonly operate in UNIX or LINUX, and the identification of problems and interpretation of results requires some expertise. In addition, other software may be needed for display purposes. If you don't



plan on consistently producing products for the long-term, purchasing phase difference products from a third party is probably your best choice. Before doing this, do a thorough search to determine if other investigators are producing SAR products in your area of interest (see contacts at end of article). The cost of a third party producing interferograms of an area 100 km by 100 km is roughly \$10,000 to \$20,000, including the data. Commercial providers of these products include Vexcel Corporation (www.vexcel.com) and NPA (www.npa.com).

Coverage Is Only One Issue...

Coverage of an area by a SAR platform's footprint does not guarantee a useful product. Commonly available C-band raw data (wavelength = 5.6 cm) are strongly affected by vegetation, the presence of which can make interferometry nearly impossible. Changing atmospheric conditions, especially active storm cells during radar acquisition, also can produce perturbations that are very difficult to remove. The optimum conditions for interferometry are areas with a relatively dry climate, land with sparse vegetation, or urban environments, all of which exist in many parts of the Southwest.

ADWR will begin processing SAR data in Arizona this year. With funding assistance from NASA during the past three years and technical support from the Center for Space Research at the University of Texas in Austin and Vexcel Corporation, ADWR has determined SAR technology to be the only practical and cost-effective method to monitor the occurrence of pumping-related ground subsidence in many areas of the state. The agency plans to use these data to improve both its groundwater models and groundwater management practices.

Contact Maurice Tatlow at matatlow@adwr.state.az.us. Other users of SAR data in the Southwest include John Bell (Nevada): jbelle@unr.edu; Gerald Bawden (California): gbawden@usgs.gov; and Sean Buckley (Texas and Arizona): buckley@csr.utexas.edu.

Reference

Hoffman, J., D.L. Galloway, and H.A. Zebker, 2003. Inverse modeling of interbed storage parameters using land subsidence observations, Antelope Valley, California. Water Resources Research, 39(2), 13p.