NASA Helps ADWR Monitor Land Subsidence

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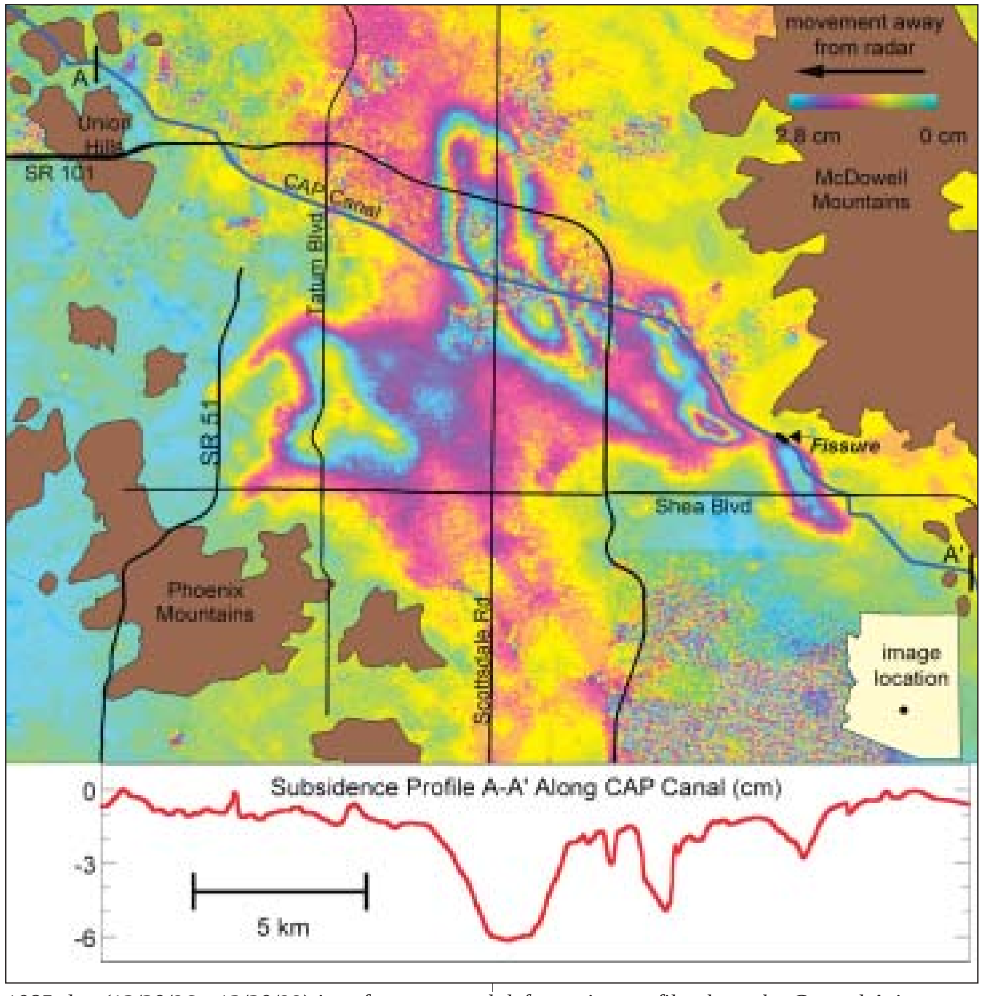
For more than 60 years, scientists have known that the land surface in portions of Arizona is subsiding due to groundwater pumping. Until recently, effective monitoring of the extent and rate of land subsidence has been limited, owing to the cost, time, and resources needed to perform ground-based surveys. Today, however, the Arizona Department of Water Resources is using an emerging satellite technology called “synthetic aperture radar interferometry” (InSAR), a $1.3 million NASA grant, and the technical expertise of the Center for Space Research at the University of Texas at Austin and the Vexcel Corp. in Boulder, Colo., to monitor subsidence in Arizona.

Satellite InSAR provides high-resolution, wide-area mapping of earth-surface topography and deformation. The radar transmits a series of microwave pulses and records both the amplitude and phase of the backscattered responses from the surface. The phase difference between two radar images taken at different times, termed the interferogram, contains signals associated with surface topography and deformation as well as differences in the atmosphere and satellite position at the time of each acquisition. Isolating the deformation signal by applying phase corrections to satellite position and surface topography produces a differential interferogram in which one cycle of phase change represents a half-wavelength (2.8 cm) of surface movement toward or away from the radar. The final image created by the differential InSAR deformation spans approximately100 km by 100 km and can be used to map sub-centimeter deformation at a pixel resolution of roughly 50 meters.



1085-day (12/20/96 - 12/20/99) interferogram and deformation profile along the Central Arizona Project canal in central Arizona.

Variations in the atmosphere and changes in surface properties over time can limit the interpretation of the InSAR deformation measurements, since these variations can appear similar to subsidence phase signatures. As such, it is hard to discern interferometric phase signatures in highly vegetated areas.

The arid environment of Arizona is well-suited for InSAR, and the assembled team has successfully employed the technique to measure subsidence in Phoenix and Tucson with interferograms spanning time periods of up to six years. At least four areas of active subsidence spanning more than eight incorporated areas have been detected in the Phoenix metropolitan area. Maximum subsidence rates of these features are seven centimeters per year (cm/yr). In Tucson,

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two areas of subsidence have been observed within the city limits and a third has been noted 13 km to the south. Maximum subsidence rates in Tucson are 2-3 cm/yr.

The interferograms generated thus far are being used as an integral part of several on-going studies that address the impact of subsidence on Phoenix-area infrastructure and water resources. Two of the subsidence features impact flood retention structures managed by the Maricopa County Flood Control District. The Central Arizona Project canal crosses through multiple features in northeast Phoenix (see figure, page 6). In addition, an interferogram was recently used to predict where fissures, or earth cracks, would likely occur. Subsequently, one previously undocumented fissure (see figure) has been found and is now being monitored.

The utility of InSAR measurements has been demonstrated for the Phoenix and Tucson metropolitan areas. With the support of NASA, ADWR plans to implement an ongoing InSAR monitoring program to generate reliable, routine, and affordable land subsidence measurements for the purpose of water resource management within Arizona.

Contact Maurice Tatlow at matatlow@adwr.state.az.us for more information.
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Tree Rings, Ocean Temperature Shifts Used to Anticipate Megadroughts

From the U.S. Geological Survey

Not long ago, conventional wisdom held that you couldn't predict climate change more than a few days in advance. Then came the awareness of El Niño and La Niña, and forecast windows increased to as much as six to nine months, depending on the region and season. But a recent study in the Geophysical Research Letters suggests that opposing shifts in Tropical Pacific and North Atlantic Ocean temperatures may foretell persistence of disastrous, multiyear droughts across the North American continent.

Forecasts longer than six to nine months rely on two principles. The first is the well-defined relationship between sea surface temperatures and precipitation measurements on land. The second principle is the ocean's thermal inertia. If these slow shifts in ocean regime can be identified in their early stages, then perhaps they can be used to assess the probability of disastrous, multiyear droughts across the North American continent and elsewhere.

In this light, a team of researchers from the U.S. Geological Survey, University of Wyoming, and Middlebury College in Vermont evaluated multidecadal precipitation variability across a network of 750-year-long tree-ring chronologies from the central and southern Rockies. Their study suggests that the Great Plains, the Rockies, and the Southwest are stricken by the same megadrought when both the tropical Pacific turns cold and the North Atlantic warms for multiple years. The geographic scale of such megadroughts is determined by the failure of winter, early summer, and mid- to late-summer precipitation, each of which has specific links to tropical Pacific and North Atlantic sea surface temperatures.

The researchers found that the tree-ring records exhibit significant oscillations in precipitation that last between 40 and 70 years. Generally, multidecadal oscillations in the tree-ring record are not cyclical and are not always in phase across the Rockies, suggesting complex linkages between seasonal precipitation and ocean temperatures.

These oscillations can occasionally synchronize across the Rockies, particularly in times of megadroughts that affect large regions of the country for a decade or more, said Julio Betancourt, of the U.S. Geological Survey and the University of Arizona's Desert Laboratory, one of the authors of the study.

Because no comparable 750-year-long proxy records exist of sea surface temperatures in the tropical Pacific and North Atlantic, the demonstrated link between ocean temperatures and precipitation is limited to the last century. But according to Betancourt, in the context of shifting ocean climate, water and other resource managers in the Rockies and Southwest little cause for optimism about the drought ending any time soon.

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The study could help predict future droughts and their consequences for the Southwest. “Since climate on these time scales is obviously not cyclical, the next best hope for long-term drought prediction lies with identifying precursor states in oceanic climate, similar in fact to the way we use Tropical Atmosphere Ocean moorings to predict and monitor El Niño or La Niña,” said Betancourt.

Information on the relationship between sea surface temperature and North American climate could eventually be used to help guide more effective and long-term water management. For example, the current megadrought is playing a major role in resetting plant demographic clocks across the Rockies through wildfires, insect outbreaks, and tree mortality from physiological stress. Given the longer growing season associated with global warming, the species present in the region now would be more likely to be replaced by other native and non-native species, producing long-term vegetation changes.

The full publication is titled “Patterns and sources of multidecadal oscillations in drought-sensitive tree-ring records from the central and southern Rocky Mountains,” by Steve Gray at the University of Wyoming, Julio Betancourt of the U.S. Geological Survey, Chris Fastie of Middlebury College and Steve Jackson of the University of Wyoming.

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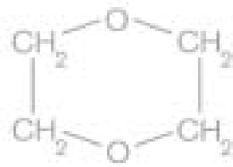
UV-Oxidation Applied to Remove 1,4-Dioxane at California VOC Remediation Site

***Adam D. Festger** – Trojan Technologies*

In the early 1990s, the volatile organic compounds (VOCs) tetrachloroethylene (PCE) and trichloroethylene (TCE) were discovered in the vicinity of several city water supply wells near Stockton, California. An aggressive hydraulic containment/reinjection system was installed to contain the plume and protect the quality of the drinking water. The containment system currently operates at a flowrate of approximately 200 gallons per minute (gpm). This flowrate is sufficient to create a capture zone that protects nearby wells. Contaminants of concern at the site were originally limited to the traditional VOCs such as PCE and TCE. Recently, however, 1,4-dioxane was also discovered in the plume.

A combination of properties makes 1,4-dioxane a potent ground water contaminant. Used primarily as a stabilizer in chlorinated solvents, it is a semi-volatile, colorless liquid with a mild odor. It is also known as diethylene dioxide, diethylene ether, p-dioxane or, simply, dioxane. It is highly soluble in water, has a low affinity for carbon materials and does not readily biodegrade. This combination of properties makes 1,4-dioxane highly mobile in groundwater. In fact, 1,4-dioxane often travels farther and persists longer than the original host solvent.



Dioxane can be found commingled in plumes containing PCE, TCE, and particularly 1,1,1-trichloroethane (TCA). At one time, approximately 90 percent of the 1,4-dioxane produced went into the production of 1,1,1-trichloroethane (TCA), where it is present in concentrations of up to 15 percent by volume. Even though this use of 1,4-dioxane has now been phased out because of TCA's destructive effects on atmospheric ozone, 1,4-dioxane is being detected at a wide variety of solvent contamination sites across the United States. In addition to its use as a solvent stabilizer, 1,4-dioxane is used in the manufacturing of lacquers, plastics, varnishes, cellulose acetate membranes, organic pesticides, personal care products, and paper.

1,4-Dioxane has a moderate chronic toxicity and a low acute toxicity. The U.S. Environmental Protection Agency (EPA) has designated it as a probable human carcinogen of low carcinogenic hazard. In animal testing, 1,4-dioxane increased the incidence of cancer in the liver, lungs, gall bladder, and on the skin. The EPA Integrated Risk Information System (IRIS) Database lists the one-in-a-million cancer risk of 1,4-dioxane at 3 parts per billion (ppb) in drinking water. The California Department of Health Services has set an Action Level of 3 ppb, while other states have set actual standards. Florida and Michigan have 5 ppb and 85 ppb maximum contaminant levels, respectively.

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For several years, a treatment train consisting of granular activated carbon and air stripping was used at Stockton to remove VOCs. However, it was discovered that these systems were not effectively removing 1,4-dioxane. Its low affinity for carbon renders the carbon ineffective and its low vapor pressure and high solubility prevent significant partitioning into the vapor phase in an air stripping system. To remedy the problem, UV-oxidation using UV light and hydrogen peroxide (H_2O_2), was chosen to destroy the 1,4-dioxane. This process relies on the in-situ generation of highly oxidative hydroxyl radicals by way of the UV-photolysis of H_2O_2. In full-scale UV-oxidation, H_2O_2 is injected into the water stream prior to passing through the UV reactor. This technology, provided by Trojan Technologies, has been used in Stockton for more than 18 months, and has successfully reduced the concentrations of 1,4-dioxane from nearly 110 ppb to less than 1.0 ppb.

For more information about 1,4-dioxane, including treatment by Trojan's UV-oxidation systems, contact Adam Festger, Technical Communications Coordinator for Environmental Contaminant Treatment at Trojan Technologies, afestger@trojanuv.com, 520-297-3637.

The Trojan UV-oxidation system at Stockton.