

Research Brief

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Using Satellite Data to Monitor Groundwater Levels

Introduction

Since 2012, California and much of the western United States has experienced drought conditions. In response to the stresses placed on water resources in the region from above average temperatures and below average precipitation, states across the West have sought to find ways to conserve water and use and reuse it more efficiently. Actions in California, which has been hard hit by drought, include the 2014 enactment of new groundwater legislation, the Sustainable Groundwater Management Act, which creates a framework for sustainable, local groundwater management. Washington State Governor Jay Inslee declared a statewide drought emergency in 2015. At the federal level, Western state Republicans and Democrats have introduced multiple drought solution bills in both houses of Congress, but as of yet, no compromise has

been reached.

Even as policymakers seek to monitor and regulate water supplies based on best available science, there is recognition that more and better data are needed. Traditionally, groundwater levels have been measured with tapes, acoustic probes, floats and pressure gauges, but more recently, satellite observations have proven to be a valuable tool. However, one of the challenges with the new method has been the use of these observations in agricultural areas, as the growth of crops can obscure images being analyzed, leaving gaps in the measurement of groundwater levels.

To address limitations to satellite data analysis, Stanford researchers developed an algorithm that dramatically improves the time-consuming image analysis process, allowing for characterization of groundwater levels on a larger-than-ever scale. This brief outlines the results of a new study by Rosemary Knight and colleagues, in which the new algorithm is utilized to determine groundwater levels across the agricultural basin of Colorado's San Luis Valley (SLV). They demonstrate that the technique can provide a better resolution — across space and time — of groundwater levels than traditional existing well data.



Photo Courtesy of ESA

Newly launched satellite mission Sentinel-1

About the Author

Rosemary Knight is the George L. Harrington Professor of Earth Sciences in the School of Earth, Energy and Environmental Sciences and Director of the Center for Groundwater Evaluation and Management at Stanford University. Her research focuses on the development of geophysical methods for imaging the top ~500 m of Earth for environmental

applications. Knight, an Affiliate of the Stanford Woods Institute for the Environment, is specifically interested in the use of electromagnetic methods for exploring the properties and processes that control the distribution and movement of groundwater.

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Key Research Findings

The study relied on data from Interferometric Synthetic Aperture Radar (InSAR), a satellite observation method for measuring centimeter-level changes in the elevation of Earth's surface. By measuring the deformation of the ground surface above a confined aquifer over time (between 2007 and 2011), the researchers were able to estimate the changes in water level. The researchers found that InSAR is an effective method for determining groundwater levels and is able to help fill in gaps where data on water levels are unavailable; and that changes in the surface level can lag behind groundwater pumping activity.

An Effective and Reliable Approach

The research suggests that the InSAR data can be used for basin-wide characterization of groundwater levels and aquifer storage capacity over vast regions. InSAR surface deformation measurements can achieve centimeter-scale accuracy in terms of vertical displacement and resolution on the order of tens to hundreds of meters on a regional scale, which are sufficient for groundwater studies in most groundwater basins.

- InSAR data revealed that little water-storage loss occurred in SLV during the period.

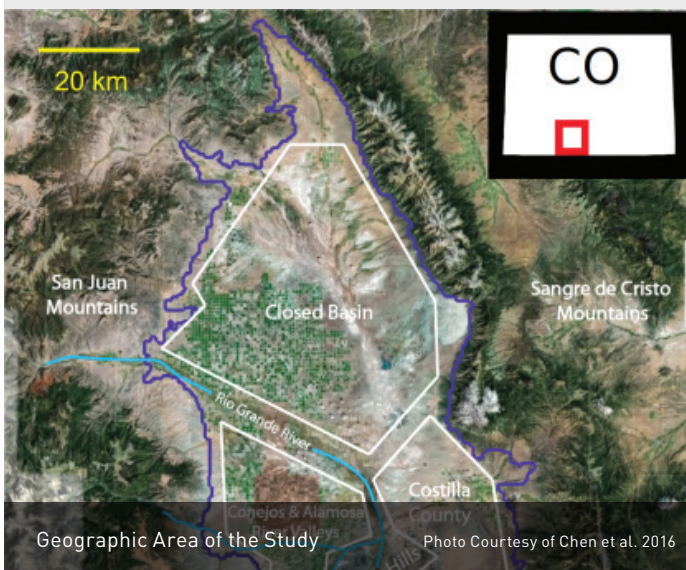
- InSAR data captured the seasonal change in water levels over time (confined aquifer pumping in the summer and recharge in the winter).
- InSAR estimates agreed with existing well data over a broad region of the SLV over the period of the study, which suggests that InSAR data can improve the spatial and temporal resolution of existing well data.

Filling in the Gaps

The method fills in groundwater levels between pixels where high quality InSAR data are not available due, for example, to crops and other vegetation, thus allowing for water level calculations over larger areas. The filling in, or interpolating, is a form of averaging, and is dependent on calibrating the InSAR data from places that are located near monitoring wells where groundwater levels are known. The interpolation approach is potentially applicable to a large number of valleys with extensive agriculture in California, Arizona and New Mexico, if the arrangement of wells is similar to SLV.

Surface Change Takes Time

The researchers observed in the InSAR data a delay between the time when groundwater is pumped out of



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an aquifer and when Earth's surface sinks in response to the removal. Different materials, from clays to sands and gravels, have different lag times between when the water is removed and when the surface deforms. With sandy aquifers, there is no time lag between when water is pumped and when there is surface subsidence, while aquifers containing clay layers often take longer to begin deforming after there has been pumping.

Policy Considerations

1. InSAR provides information that is key to sustainable groundwater management, particularly in agricultural areas by allowing for mapping and monitoring of groundwater levels over large areas. It can also be used to understand characteristics of confined aquifers, specifically changes in their storage properties and long-term capacity.
2. InSAR data should be provided throughout the state, along with the hydrologic studies needed to link InSAR data to water levels. InSAR deformation data alone maps subsidence, which in itself is very useful,

but there is tremendous added value in linking the data to hydrologic properties and processes.

3. In order for InSAR to be more widely adopted for monitoring of groundwater systems, a user-interface that would allow water managers to have access to InSAR data for monitoring subsidence and water levels should be developed. Federal funding is needed for such development and partnerships with the private sector should be considered.

Conclusions

InSAR deformation data provide a new, spatially and temporally dense approach to obtaining information on water levels and storage properties of a confined aquifer without requiring significant disruption of water use practices. The method provides high quality data and allows for measurements of groundwater levels over large areas. InSAR data are likely to play an important role in groundwater monitoring in the future, especially in agricultural regions, where water is needed and groundwater pumping is a concern.

This brief is based on the paper: "Confined aquifer head measurements and storage properties in the San Luis Valley, Colorado, from spaceborne InSAR observations" by Jingyi Chen, Rosemary Knight, Howard A. Zebker, and Willem A. Schreüder, published in *Water Resources Research*, May 2016.

About Water in the West

Water in the West, a joint program of the Stanford Woods Institute for the Environment and the Bill Lane Center for the American West, marshals the resources of one of the world's preeminent research universities to answer one of the most urgent questions about the American West's future—how can the region continue to thrive despite growing water scarcity? Through Water in the West, Stanford University's world-class faculty, researchers and students are working to address the West's growing water crisis and to create new solutions that move the region toward a more sustainable water future. Learn more: waterinthewest.stanford.edu

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