Solution Mining Research Institute Spring 2023 Technical Conference

Detroit, Michigan, USA 23-26 April 2023

Satellite Radar Data and Machine Learning to Locate and Quantify Creep of a Salt Cavern

Timothy Masterlark[1], Scyller J. Borglum[2], Victoria Karnes[1], Sophie Minas[2], and Nils Skaug[2]

[1]South Dakota School of Mines and Technology, Rapid City, USA
[2] WSP USA, Houston, USA

Abstract

The Napoleonville Salt Dome, Louisiana, USA, hosts an assembly of more than 50 storage caverns with volumes ranging from 1 million to 70 million barrels (bbl). It is important to monitor the physical integrity of these caverns, as they are used to store critical energy resources. A salt cavern is mechanically equivalent to a pressurized cavity. The salt that hosts a cavern will creep in response to deviatoric stress conditions caused by the presence of the cavern and variations in its pressurization. This creep results in losses in cavern volume (ΔV) over timescales of months to years. Downhole tools, such as sonar or pressure and gas flux measurements, are the most precise and reliable techniques to measure cavern deformation and are used during cavern maintenance workovers separated by multi-year intervals. It is cost prohibitive to survey caverns with downhole tools more frequently than for scheduled maintenance purposes. We demonstrate a proof-of-concept for using satellite radar data, geophysical deformation models, and machine learning to estimate the location and volumetric losses due to creep within a salt dome. This concept is intended to inform downhole surveys for scheduled maintenance workovers or provide early warning to help focus cost-intensive resources for monitoring ΔV in caverns between workovers. The method may also be used to prospect for creep in caverns globally, due to the global coverage of satellite radar data. For this proof-of-concept, we create Interferometric Synthetic Aperture Radar (InSAR) data with anticipated characteristics of the upcoming NASA-ISRO NISAR satellite radar mission expected to launch in 2024. The synthetic InSAR data map a swath of deformation over a 6 km $\times$ 8 km (3.7 mi $\times$ 5.0 mi) footprint centered on the Napoleonville Salt Dome cavern assembly. The data simulate a deformation anomaly that is co-located with the Occidental Brine Well No. 2 (OB2) cavern. Four deformation scenarios span ΔV equivalent to 10%, 5%, 1%, and 0.1% of the total OB2 cavern volume. The data include a characteristic phase ramp associated with satellite orbital errors and conservative instrument uncertainties. We calculate three pixel spacing configurations (10, 50, and 100 m) for each of the four deformation scenarios to investigate sensitivities to the spatial resolution of the data. We treat these synthetic deformation data for each combination as actual data and use a machine learning algorithm to characterize the corresponding location and ΔV, as if it were a source of creep. Estimations for the $\Delta V_{10\%}$ scenario and 10 m pixel spacing configuration accurately predict the creep to within 1 m of the true location of OB2 and ΔV to within 1% of the true value of $\Delta V_{10\%}$. Parameter uncertainties are sufficient to attribute this source of creep to a unique cavern at the 95% confidence level. Accuracy is robust if the deformation exceeds data uncertainties. Precision decays with both the diminishing ratio of deformation to data uncertainty and increasing sample sparsity.

Keywords: Cavern Monitoring, Salt Creep, Machine Learning, Remote Sensing, Subsidence