Assessing Geomechanical Risks in CCUS Projects: Utilizing Surface Deformation to Monitor Underground Pressure Changes

Yan Jiang
University of Victoria, School of Earth and Ocean Sciences
Natural Resources Canada

Yunjun Zhang
California Institute of Technology
Now at Chinese Academy of Science

Lindsay Gammon
University of Victoria

Yaser Sadeghi
Geoscience BC

Summary

Surface deformation is a direct manifestation of the underground pressure state. Injecting carbon into the underground geological reservoirs disturbs the pore pressures and causing local stress buildup in the surrounding area, which may cause geohazards that will raise environmental concerns and societal unease. It is essential to monitor and assess these geomechanical risks promptly in order to uphold public support for Carbon Capture, Utilization, and Storage (CCUS) initiatives. This study utilizes surface deformation as a proxy to infer variations in reservoir pore pressure. Our objective is to demonstrate the practicality of using accurate and low-cost geodetic data to monitor the long-term health of injection wells and to ensure integrity. The presentation includes initial results from both simulated predictions and observations collected from operational CCUS stations, assessing the effectiveness of current monitoring strategies. Furthermore, we will discuss the successes and limitations of these approaches, proposing future improvements towards developing a comprehensive Monitoring, Measurement, and Verification (MMV) methodology using geodetic observations.

Theory / Method / Workflow

Injecting or withdrawing fluid from a reservoir leads to changes in fluid pressure within the reservoir, which in turn can cause surface strain and deformation in the surrounding strata. If the deformation is large enough, it can be detected using geodetic tools. In theory, with knowledge of the geomechanical properties of the cap rock, it's possible to invert the underground stress distribution at the base of the cap rock and quantify the spatial and temporal variations of the injected fluid. Space geodetic techniques have been utilized to investigate various types of surface deformation related to underground fluid movement. These applications include assessing volcanic hazards (Hooper et al., 2004), subsidence due to groundwater withdrawal (Amelung et al., 1999), and earthquakes induced by fluid injection (Wang et al., 2020). This study focuses on employing space geodetic techniques to constrain the location and migration of the injected CO2 at operational CCUS sites. We will show preliminary findings from using Interferometric SAR to monitor selected operational carbon injection sites, evaluating the potential of space geodetic tools for long-term monitoring. Additionally, we will present results from analytical poroelastic deformation models to validate InSAR observations.

Results, Observations, Conclusions

We will present InSAR ground deformation measurements, using Sentinel 1 observations, along with modeling results that consider the actual injection rates and the geomechanical conditions of the site. Our discussion will cover the successes and challenges encountered in detecting ground deformation using InSAR, along with strategies that could improve future geodetic monitoring efforts. Our modeling indicates localized and generally small deformation rates, which poses a challenge for InSAR detection (e.g., a few centimeters over several kilometers), especially under current injection conditions, such as those in the Quest project. Incorporating more precise in-situ measurements, e.g. GNSS, can enhance the accuracy of ground deformation measurements and provide essential constraints using horizontal components which is crucial for inverting underground plume migration.

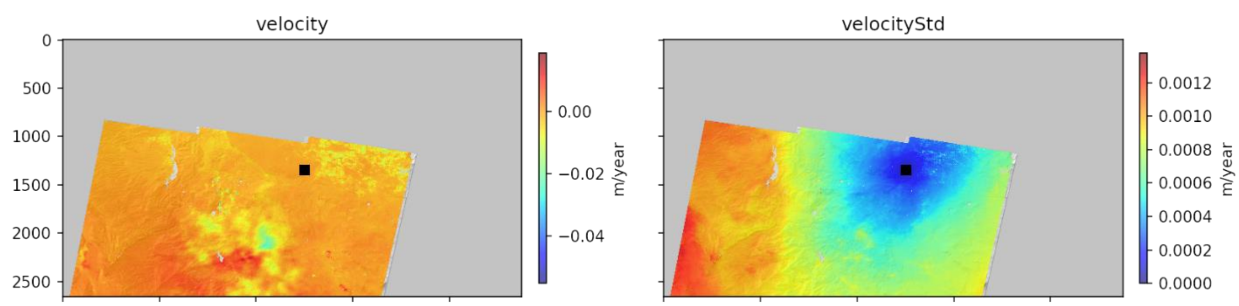

Figure1. The average deformation rate at a CCUS-EOR site in West Texas. The rate is determined using Sentinel-1 interferograms spanning from 2014 to 2022. The black dot indicates the location of the CCUS injection sites. Notably, the high deformation rate observed in the southwest area of the map is associated with oil/gas operations and wastewater injection.

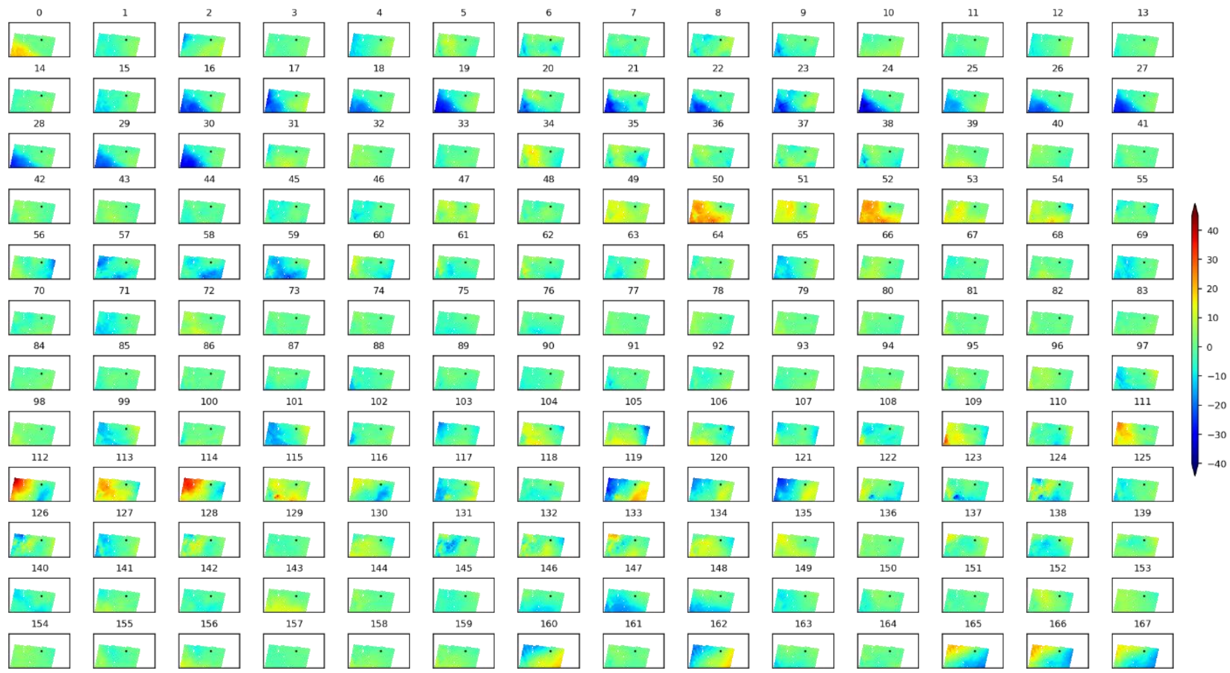

Figure2. Deformation history of the above velocity plot.

References

Hooper, A., Zebker, H., Segall, P., & Kampes, B. (2004). A new method for measuring deformation on volcanoes and other natural terrains using InSAR persistent scatterers. Geophysical research letters, 31(23).

Amelung, F., Galloway, D. L., Bell, J. W., Zebker, H. A., & Laczniak, R. J. (1999). Sensing the ups and downs of Las Vegas: InSAR reveals structural control of land subsidence and aquifer-system deformation. Geology, 27(6), 483-486.

Wang, S., Jiang, G., Weingarten, M., & Niu, Y. (2020). InSAR evidence indicates a link between fluid injection for salt mining and the 2019 Changning (China) earthquake sequence. Geophysical Research Letters, 47(16), e2020GL087603.