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Multi-Image Radar Interferometry for Monitoring CO2 Sequestration

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The geological sequestration of CO2 is rapidly becoming recognized as the quickest method to reduce GHG emissions. While research is ongoing regarding the most efficient ways to capture CO2 from gas streams the decades old experience of the oil industry with EOR means that tested injection technology is already available.

However, public opinion demands that rigorous monitoring methods be used to ascertain that injected CO2 stay permanently stored. Utmost importance must be given, therefore, to the identification and use of tools capable of monitoring plume development. Given the depths involved and the often heterogeneous nature of the subsurface this is a challenging task that requires integration of numerous techniques.

A Joint Venture between BP, Sonatrach and StatoilHydro has been injecting CO2 at the In Salah gas field in Algeria since 2004 at a rate of almost 1 million tons of CO2 per year [1]. To demonstrate best-practice application of CO2 storage monitoring, integrity and verification technologies, the In Salah Gas CO2 Storage Assurance Joint Industry Project was also set up in 2004. Participants include academia, the US DoE and the EU.

The use of PSInSAR™ as a viable monitoring tool was demonstrated within this framework. PSInSAR™ is a radar satellite technique that detects and measures ground movement with a high degree of precision. Compared to differential interferometry (DInSAR), which uses only two radar images, PSInSAR™ significantly increases the accuracy of movement measurement by processing an entire stack of radar images. This allows atmospheric effects to be removed from the results and in ideal conditions average ground deformation rates can be measured with an error of less than 1 mm/yr [2]. Several other characteristics of the technique make it a valuable tool for CO2 injection monitoring:

1) It can produce a high spatial density of measurement points (PS) on the ground;
2) It can cover large areas, extending to thousands of square kilometers, without loss of precision;
3) It is a time lapse technique.

At In Salah two overlapping descending orbit radar datasets, covering the period from 12 July 2003 to 19 March 2007 and acquired by the ENVISAT satellite, were used to measure surface deformation [3].

Uplift was detected around all three injection wells with rates of up to 5 mm/yr. Ground heave, although mostly centered on the injection wells, also followed a NE-SW trend at injection well KB-502 (Figure 1). This information was instrumental in reconstructing plume development following a minor leak that was detected at KB-5, a suspended appraisal well [1]. Modeling of the subsurface pressure increase due to CO2 injection demonstrates that the measured surface deformation is consistent with geomechanical data [4].

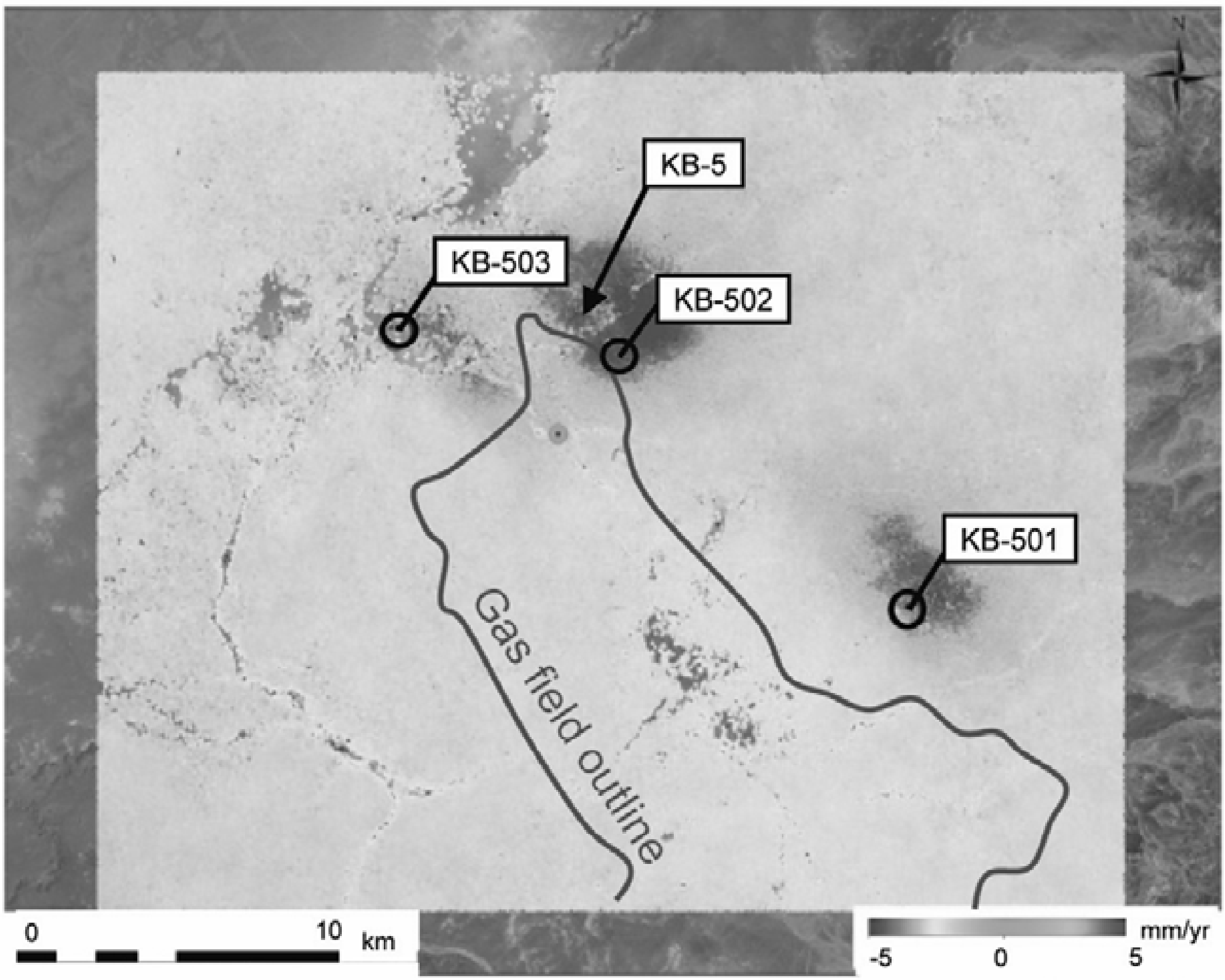

Figure 1: Surface uplift measured by the PSInSAR technique at the 3 injection wells of the In Salah CCS site (image from Ringrose et al, 2009).

The satellite monitoring produced results that exceeded expectations [1;5]. The high spatial density of measurement points and the time lapse nature of the technology made it possible to indirectly "image' the subsurface plume migration. These results were achieved with a relatively old satellite. Currently the satellite monitoring over In Salah is being carried out with a newer generation of high resolution, short revisiting time satellites that will likely lead to even more exciting results.

REFERENCES

1. Ringrose, P., Atbi, M., Mason, D., Espinassous, M., Myhrer, O., Iding, M. et al. Plume Development Around Well KB-502 at the In Salah CO2 Storage Site. First Break 27, 85-89 (2009).
2. Ferretti, A., Prati, C. & Rocca, F. Permanent Scatterers in SAR Interferometry. IEEE Transactions on Geoscience and Remote Sensing 39, 8-20 (2001).
3. Vasco, D., Ferretti, A. & Novali, F. Estimating permeability from quasi-static deformation: temporal vatiations and arrival-time inversion. Geophysics 73, 037-052 (2008).
4. Rutqvist, J., Vasco, D. & Myer, L. Coupled reservoir-geomechanical analysis of CO2 injection at In Salah, Algeria. (2009).
5. Mathieson, A., Wright, I., Roberts, D. & Ringrose, P. Satellite Imaging to Monitor CO2 Movement at Krechba, Algeria. Energy Procedia GHGT-9 Paper 307, (2009).