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Quantifying the success of onshore carbon capture and storage from surface deformation measurement and geo-mechanical modeling

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Although Carbon capture and storage (CCS) is an attractive technology in the drive to mitigate global warming, the approach is controversial because long-term containment and accounting of the stored CO_2 have yet to be demonstrated. Options for monitoring CO_2 storage are varied and range from discrete chemical well sampling programs to full field time-lapse seismic surveys. Crucial for any monitoring program is that it be as cost effective as possible yet yielding sufficiently accurate measurement. Time-lapse seismics has generally proven to be a sufficiently accurate means of monitoring CO_2 in the subsurface. However, there is debate as to whether seismics is the most cost effective approach in the quantitative measurement of CO_2 flow and containment. The cost of monitoring is compounded potentially further by the various international regulations related to CO_2 sequestration, where, for example, it can be argued that CO_2 storage monitoring requirements are much stricter than those for natural gas storage.

For on-shore sequestration, there has been a significant drive to integrate satellite interferometric synthetic aperture radar (InSAR) with geomechanical modeling to link surface deformation with the movement and storage of injected CO_2. At the In Salah CO_2 storage project, export gas specifications require the removal of CO_2 from the produced natural gas with strict long term monitoring requirements to ensure that CO_2 is contained indefinitely. Thus there has been significant research into linking geomechanical modeling with InSAR observations (e.g., Rutqvist et al., 2010; Vasco et al., 2010).

We analyze the surface deformation resulting from CO_2 storage at In Salah in order to provide constraints on the temporal and spatial evolution of CO_2 within the reservoir. Specifically, we process InSAR from the pre-injection period 1992-2004 and the injection period 2004-2009 and combine the InSAR observations with geomechanical modeling of reservoir deformation to determine the volume of CO_2 stored. The results using a simple yet fast geomechanical model (Geertsma, 1973) indicate that, between 2004 and 2008, 97 $\pm$ 9 % of the 1157 x 106 m3 of CO_2 injected into the reservoir has been stored. This value is close to the stringent 99 % target for CO_2 storage permanence set by the Intergovernmental Panel on Climate Change. Our study provides the first practical assessment of CO_2 storage and demonstrates that it is possible to develop independent, fast and cost-effective assessments of future schemes in the absence of ground-based surveys. The strength of this approach is that very little field data is needed to provide a sufficiently accurate initial assessment of CO_2 storage at relatively very little cost. The ability to scrutinize CCS sites globally based on limited input data and cost effectively will be crucial for implementation of international monitoring of CO_2 sequestration agreements.