MONITORING GROUND DEFORMATION ON CARBON SEQUESTRATION RESERVOIRS IN NORTH AMERICA

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1. Introduction

The geological storage of carbon dioxide (CO2) is one of the most important methods for controlling the green house gas. The conception of this kind of storage is injecting large quantities of CO2 (million tons) into deep reservoir like oil field, gas field or saline formation. Part of the use of CO2 for secondary oil recovery suggests that the migration of carbon dioxide can be complicated, and can differ from the movement of injected water or hydrocarbons. Are these reservoirs safe? Will the carbon dioxide remain at depth? Can we know the movement of these flows? Due to these questions, there is a need to monitor the fate of CO2 underground.

Satellite based geodetic method such as InSAR taking advantages of lower cost, high spatial resolution, long-term monitoring, has been applied for ground deformation monitoring in recent two decades. It has been proved to be successful for centimeter level volcanic and earthquake deformation. More recently, InSAR is applied for the low rate deformation in central Nevada for long-term sub-centimeter post-seismic deformation using Small Baseline Subsets algorithm (SBAS). In this paper, we implement InSAR techniques to our carbon sequestration project in North America. Using JAXA's Alos-Palsar synthetic aperture radar image from 2007 to 2010, we generate ground motion time series at 4 carbon sequestration test sites. Some of them show clear ground uplift information.

2. The carbon sequestration projects

Previous researches demonstrate some initial result in Insalah, Algeria. Constrained by InSAR data, the volume and pressure changes are produced based on a linear inversion algorithm. This is the first completed study which using InSAR data to monitor the fate of CO2 in the storage.

In this paper, we select 4 sites in North America, which have large quantity of injection. Due to different geological conditions, the responses of injection detected by InSAR are different. Figure one shows the distribution of the selected sites. Because the projects are operated by private companies, some information of these projects is not available which makes the research more difficult.

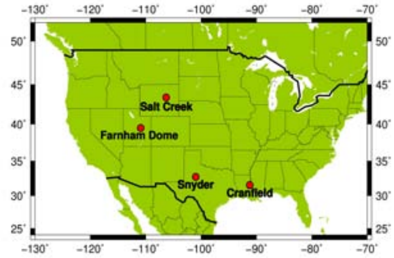

Fig1: CCS injection sites distribution in North America. They are Sal Creek in Wyoming, Farnham Dome in Utah, Snyder in Texas and Cranfield in Mississippi.

3. InSAR and InSAR Time Series

Applied to earthquake deformation monitoring in early 1990s, InSAR has been proved as one of the best tools to obtain large-scale ground movement. Its relatively low cost makes it possible to be used in more applications such as volcano eruption, glacial rebound, urban subsidence. InSAR time series analysis came out in early 2000, known as permanent scatterers InSAR (PS-INSAR) and small baseline subsets InSAR (SBAS-INSAR). PS-InSAR uses multiple wrapped phases, and chooses a series of PS candidates, which are considered with reliable characteristic during time, for atmospheric filtering and phase unwrapping. SBAS-InSAR uses multiple unwrapped phases and applies singular value decomposition (SVD) based assessment to minimize the influence of all the error sources.

In this paper, we use GAMMA software to produce single look complex (SLC) images. Repeat Orbit Interferometry Package (ROIPAC) from Jet Propulsion Laboratory (JPL) is used for Interferogram generation in which Snaphu software is used for phase unwrapping. Finally, we use Time Series InSAR (TSSAR) package written by the InSAR group of the University of Miami to implement SBAS processing. The whole processing runs in a highly automatic environment.

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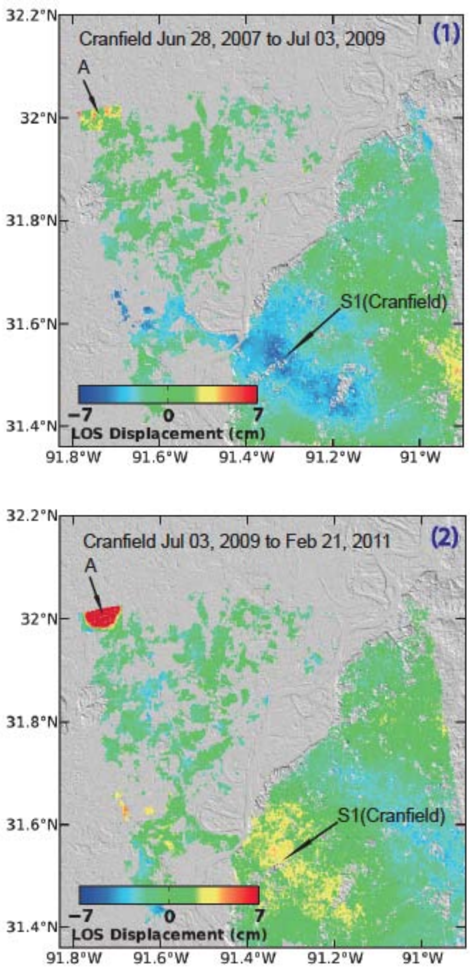
4. Results

4.1 Cranfield

Cranfield locates at Cranfield oil field, Natchez, Mississippi. The first phase of injection started in 2008 with the rate of 1 Mt/yr. In 2011, the rate increased to 1.5 Mt/yr. We choose Alos-Palsar data from Jun. 2007 to Feb. 2011 to generate the time series. Due to the lack of data and the decorrelation caused by vegetation, the result is noisy. We are waiting for more data after the new phase (phase 3, 1.5 Mt/yr injection).

17 Alos-Palsar data from Jun 2007 to Feb 2011, (track 167, frame 620) is used for processing. SRTM-3 DEM is chosen for a 2-pass differential process. The interferograms are multi-looked by 8 and the DEM is multi-looked by 2 so that both pixel of interferogram and DEM match with each other.



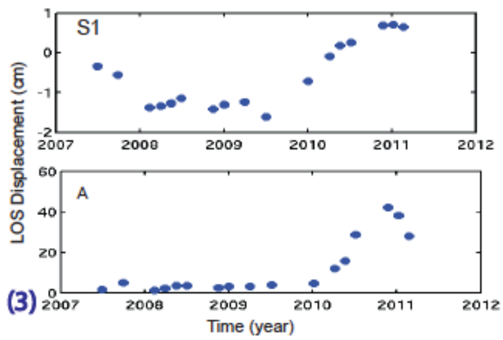


Figure 2: Ground displacement & Time series at Cranfield

Figure 2 shows the ground displacement in Cranfield area. To see the variation more clear, we divide the whole period into two parts. From middle 2007 to middle 2009 (Fig 2(1)), because of oil extraction, this area was generally subsiding. After 2009 (Fig 2(2)), when CO_2 has been injected, we see uplift in this area. However, due to large decorrelation in vegatation area, the result is noisy and it still contains some large scale long wavelength residue which should be related to atmospheric delay. Approximately, we see a maximum 1.5 cm/yr (Fig 2(3), S1) uplift in line-of-sight (LOS) direction in this area after injection. More efforts to overcome the noise should be involved in next step. Moreover, to the north of this site, we find a place with large uplift rate in 2010 (fig 2(3), A). The maximum rate at the center can be 50 cm/yr (LOS). The reason for this uplift is still unknown.

4.2 Salt Creek

Salt Creek field locates in Natrona County, Wyoming, near the town of Midwest. It was an oil field since 1800s. Since 1971, water flooding has been used to improve the production of oil. Enhanced oil recovery (EOR) project started in this field in 2004 using CO2 injection. By 2010, 174 billion cubic feet CO2 has been injected into Salt Creek, which leads to 10 million incremental barrels of oil.

Ascending track 190 frame 860 from JAXA Alos-Palsar data covers Salt Creek field. We use data from Jan. 2007 to Mar. 2011. 15 SLCs and 80 interferograms generated.

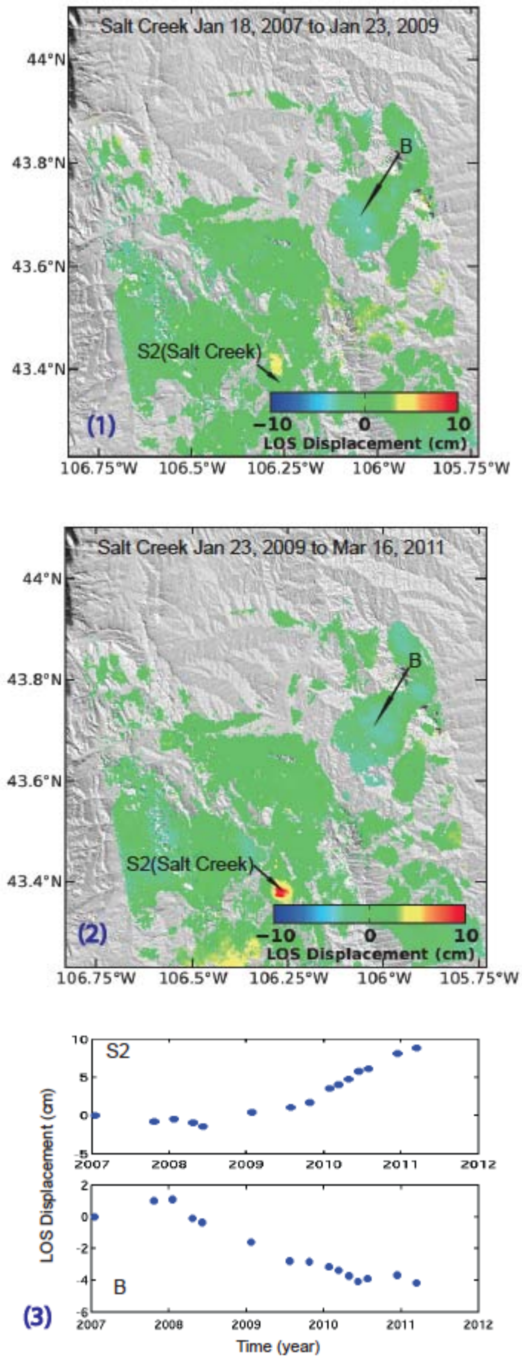


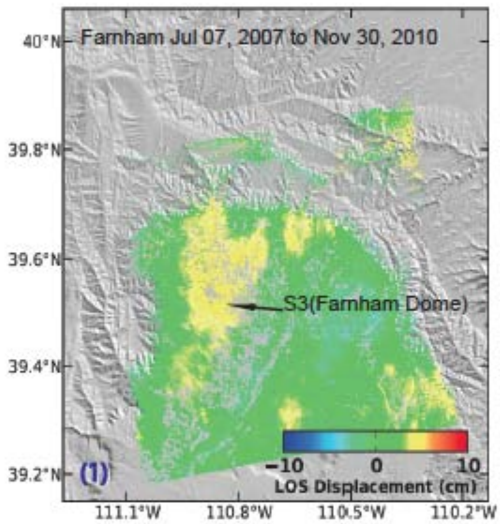
Fig 3: Ground displacement & Time Series at Salt Creek

The injection information of this site is unknown. But from Figure 3, we can see before 2009 (Fig 3(1)), there is almost no any deformation at Salt Creek. After 2009 (Fig 3(2)), we see a regular penny shaded uplift signal in this site. The maximum rate (Fig 3(3), S2) is about 6 cm/yr (LOS). The signal we get is very clear and large. We plan to get more information of this site to confirm if the whole signal is related to CCS. Ers data before 2007 also can help us to understand the geological history of this area. To the north west of this site, we see a continuous subsidence signal which maybe due to some mining activity in Wyoming (Fig 3(3), B).

4.3 Farnham Dome

The Farnham Dome injection site locates at southwest of the Uinta basin near Price, Utah, 120 miles to the south of Salt Lake City. Drilling along the crest of Farnham Dome in the 1920s and 1930s resulted in the discovery of significant deposits of CO2 in the Jurassic Navajo Sandstone and small shows of CO2 in Triassic, Permian, and Pennsylvanian reservoirs. Given that the more shallow Jurassic units appear promising with respect to large CO2 capacities and low risk with respect to leakage. The area provides an excellent deployment test opportunity for analysis of high injection rates and high resolution monitoring of CO2 in multiple rock layer horizons. The target formations are deep saline units. These saline formations are major targets for commercial-scale sequestration associated with future coal-fired power plants planned for the area.

15 Alos-Palsar SLCs are acquired from July 2007 to Nov 2010. In the interferometric proceesing, most interferograms have relatively low coherence, which may be due to the snow in the winter. We do not get too many good interferograms for time series analysis. However, an initial result shows that there is a maximum of 3 cm uplift exists to the north of Drunkards Wash. More data is expected in this area in the future study.



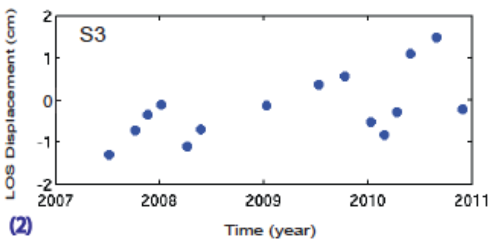


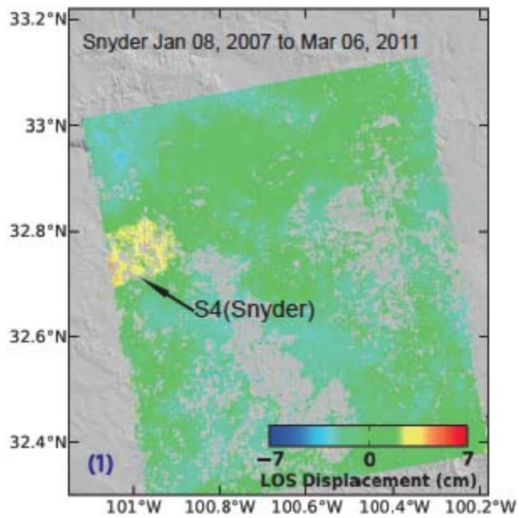
Fig 4: Ground displacement & Time series at Farnham Dome

Figure 4 shows the ground displacement at Farnham Dome. There is uplift signal exists at this site. But from the time series we can see it is not clear. We believe it is due to some long wavelength residue such as atmospheric error. Till now we cannot confirm signal due to CCS at this site.

4.4 Snyder

Snyder located in Texas. It was also an oil field and was subsiding before injection. More detail about this site is still unavailable. Alos-Palsar data track 184 frame 640 covers this area. 13 SLC and 57 interferogram generated after processing.

From the time series, we can see about 1 cm/yr (Fig 5(2)) linear uplift at this site. The result shows a penny shaded uplift signal. But there is also some noise exists. In the next step, we are going to reduce the influence of noise and try the adjacent track which also covers Snyder area to see if we can find similar signal.



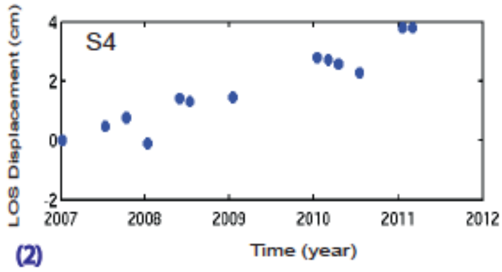


Fig 5: Ground displacement and Time series at Snyder

5. Conclusion

Uplift due to carbon sequestration is able to be detected by InSAR time series. In this poster, we choose Alos-Palsar data for processing. After SBAS analysis, some of the site shows clear ground uplift signal, which is believed to be related to CCS. However, because of the long wavelength of Alos data and relative small deformation rate, the influences of different noises cannot be cancelled easily. For Salt Creek and Cranfield, uplifts are significant. To model the deformation requires more constraint such as GPS or seismic data. Especially for Cranfield area, the result is noisy. Processing should be very careful and permantnant scatterer(PS) may be more suitable for this site. For Farnham Dome, the influence of the error of the elevation model can not be ignored. More precise DEM is going to be used. Both Farnham and Snyder need more data (short wavelength longer period data) to make sure if the signal is true.

Reference:

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