Monitoring Ground Deformation at the Aquistore CO2 Storage Site in SE Saskatchewan, Canada

G51B-1113

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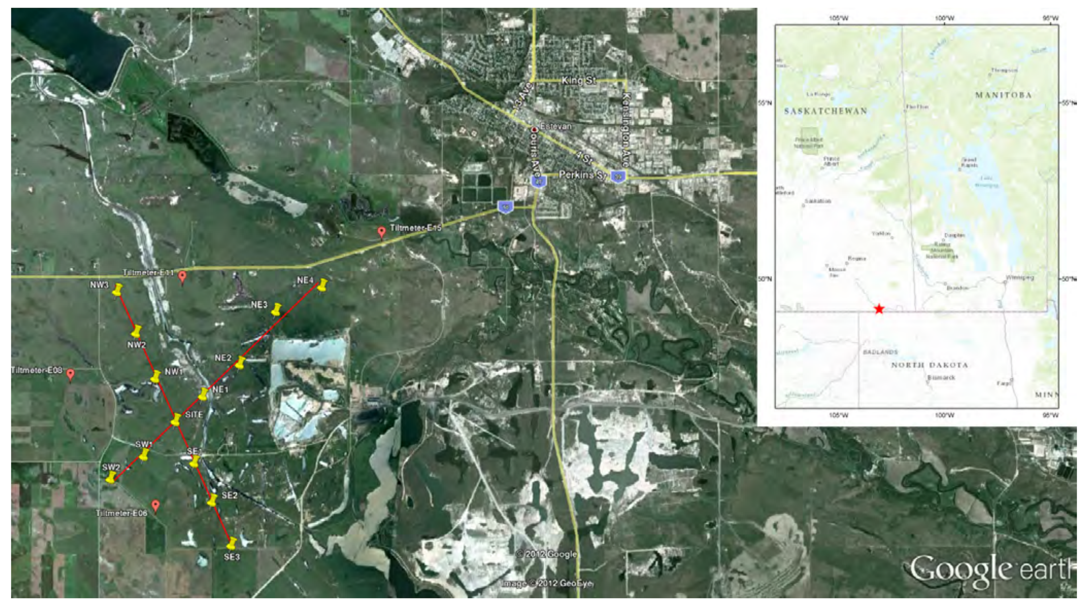
ABSTRACT

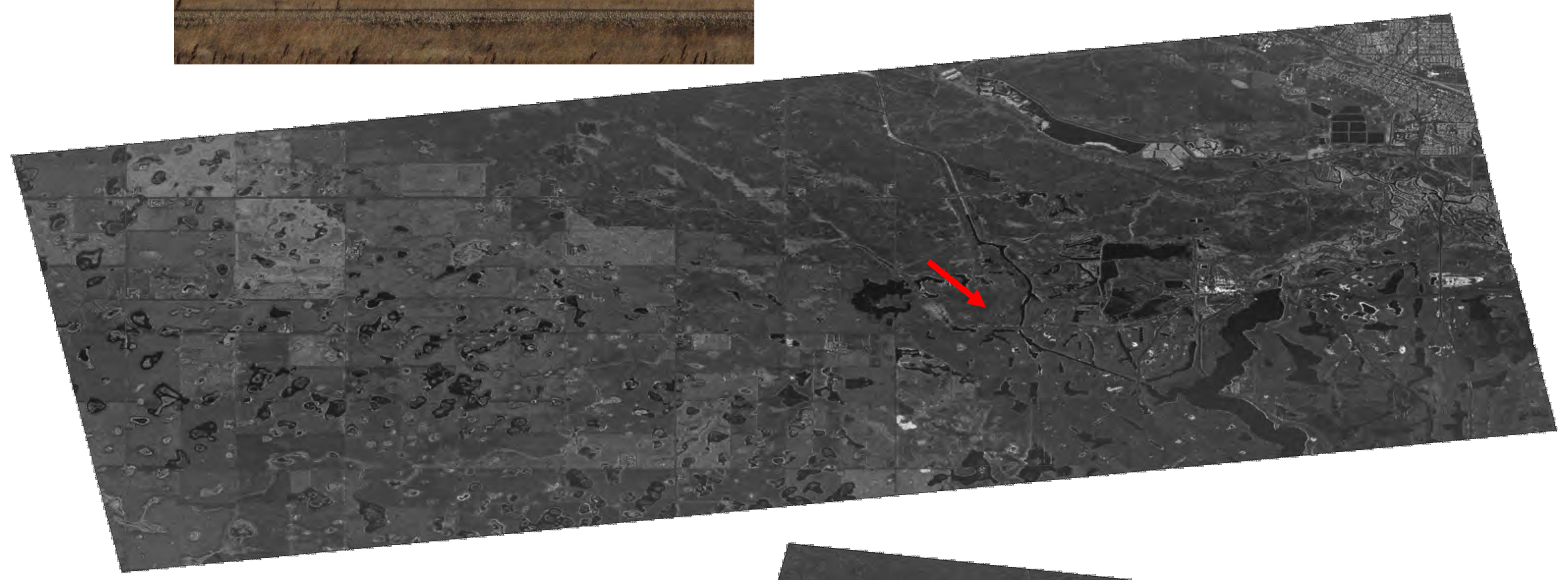
The scientific objectives of the Aquistore CO2 storage project is to design, adapt, and test non-seismic monitoring methods that have not been systematically utilized to date for monitoring CO2 storage, and to integrate the data from these various monitoring tools to obtain quantitative estimates of the change in subsurface fluid distributions, pressure changes and associated surface deformation. For this an array of monitoring methodologies will be tested, including satellite-, surface- and wellbore-based monitoring systems. Interferometric Synthetic Aperture Radar (InSAR), GPS and tiltmeter monitoring will be used for measuring any ground deformation caused by CO2 injection and the associated subsurface pressure perturbation. In the spring-summer of 2012 we started collecting C-band SAR data from the Canadian Radarsat-2 satellite to provide baseline data over the study site. The Radarsat-2 data is acquired about every six days on average in five different geometries in order to achieve nearly uninterrupted coverage. We acquire ascending and descending spotlight data with sub-meter resolution (1.6x0.8 m), ascending and descending wide ultra fine data with moderate resolution (1.6x2.8 m) and descending fine quad-pol data with coarse resolution (5.2x7.6 m). Over the project life, this SAR coverage will be supplemented by X-band TerraSAR-X data, C-band Sentinel, and L-band ALOS-2 data. Availability of SAR data from all three wave-band sensors should allow us to measure ground deformation with a precision of a few mm/year. For mitigating temporal de-correlation and for improving precision during the winter when there will be snow cover, we will install 6 paired corner reflectors suitable for ascending and descending imaging. Multidimensional time series of ground deformation will be produced using MSBAS techniques (Samsonov and d'Oreye, 2012). PolInSAR methodology will be tested on fine quad-pol data. To obtain higher precision spatial and higher resolution temporal ground motion measurements we will install 13 continuous Global Positioning Systems (cGPS), and 15 tiltmeters in 2012-2013. Various geodetic data will be integrated using the methodology of Samsonov et al., 2007 and resultant ground deformation maps will be used for validation of the geomechanical modelling. Here we will present maps of the injection site showing the locations and installation design of various geodetic sensors and provide initial results of InSAR measurements.

Location Map, SE Saskatchewan



Site Name	Piezometer Depth m	Tiltmeter Depth m	GPS Depth m	InSAR Depth m
SITE	14; 35; 42		30	4.5
NE01	13; 33		30	4.5
NE02		30	30	
NE03		30	30	
NE04		30	30	
NW01	9	30	24	4.5
NW02		20-30	20-30	
NW03		20-30	20-30	4.5
SE01	15	30	30	4.5
SE02			30	
SE03		30	30	
SW01	20; 35	30	30	4.5
SW02		30	30	
TL05		30		
TL06		30		
TL08		30		
TL11		30		
TL15		30		

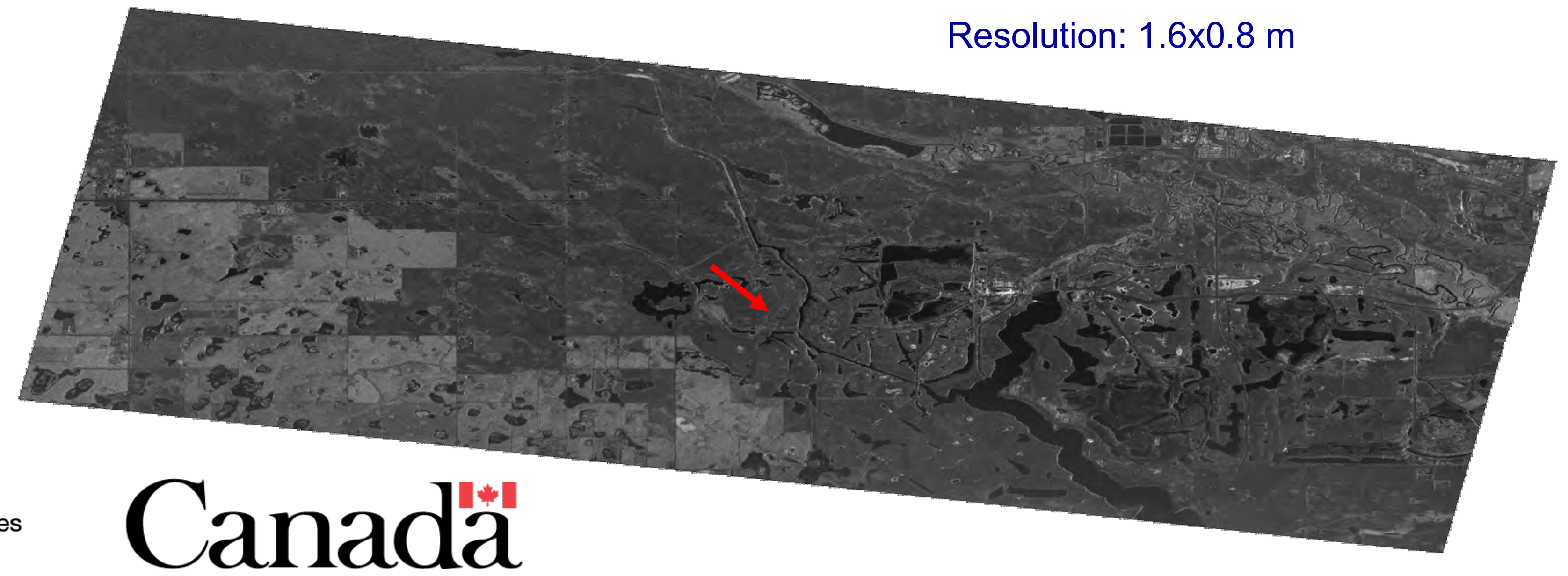
Injection-well 4B5-06-02-08W2M to the Winnipeg and Deadwood Formations at ~3350 m depth



Radarsat-2 descending SpotLight 18 image

Coverage: 18x8 km

Resolution: 1.6x0.8 m



Radarsat-2 ascending SpotLight 12 image

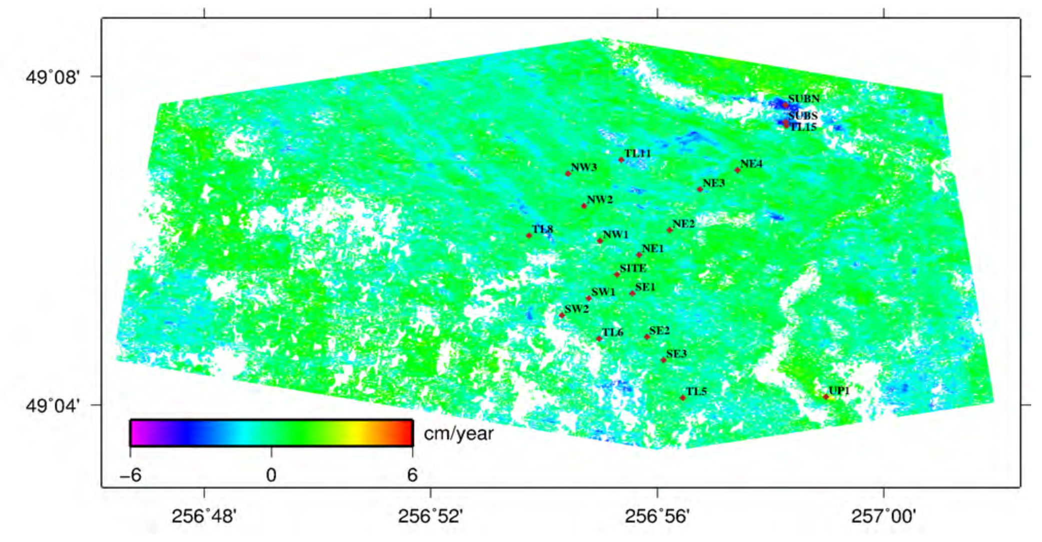
Coverage: 18x8 km

Resolution: 1.6x0.8 m

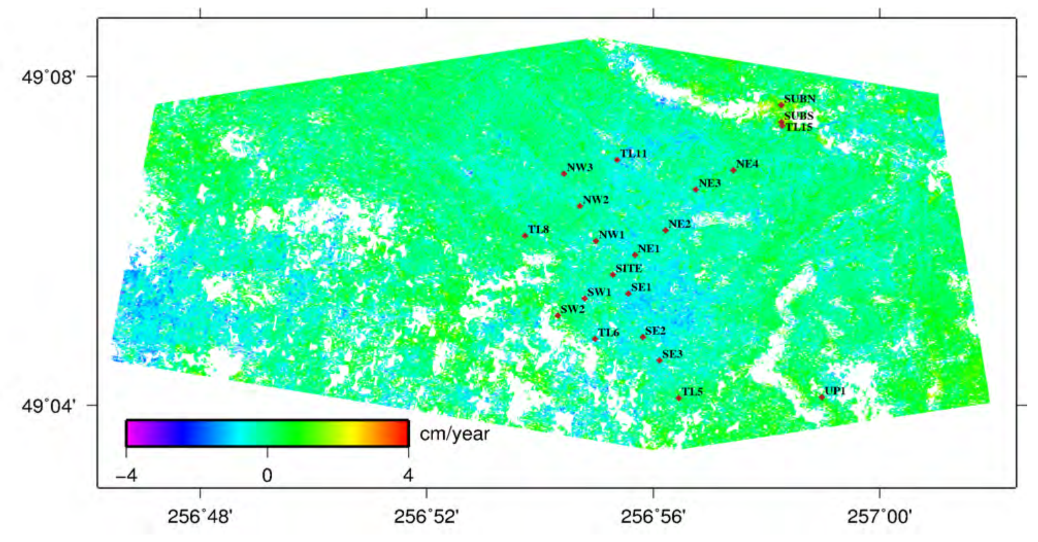
*Red arrow shows location of injection well

Vertical and horizontal east-west linear deformation rate maps calculated from InSAR data using MSBAS methodology from Samsonov and d'Oreye, 2012

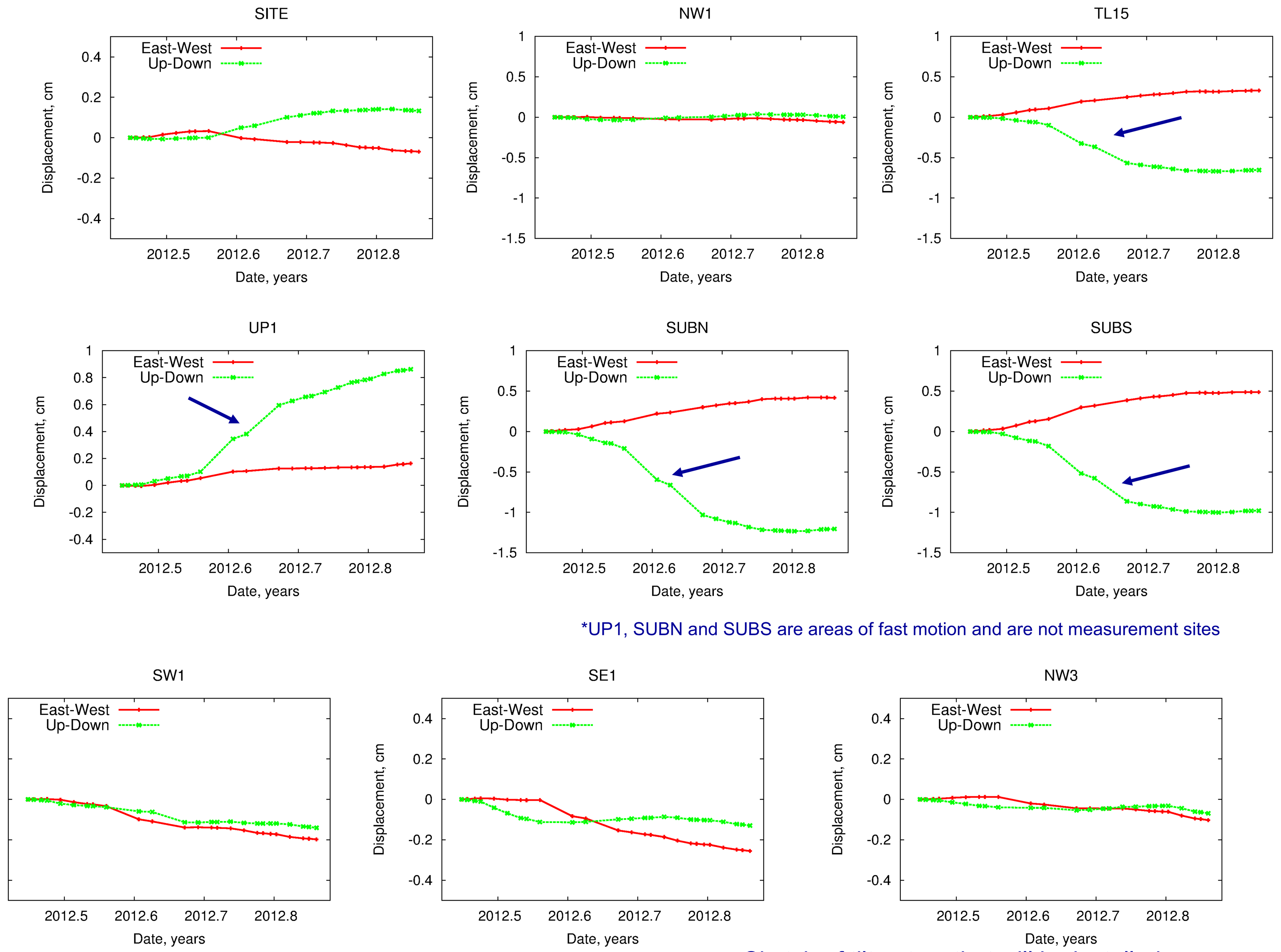
Vertical deformation rate



Horizontal east-west deformation rate

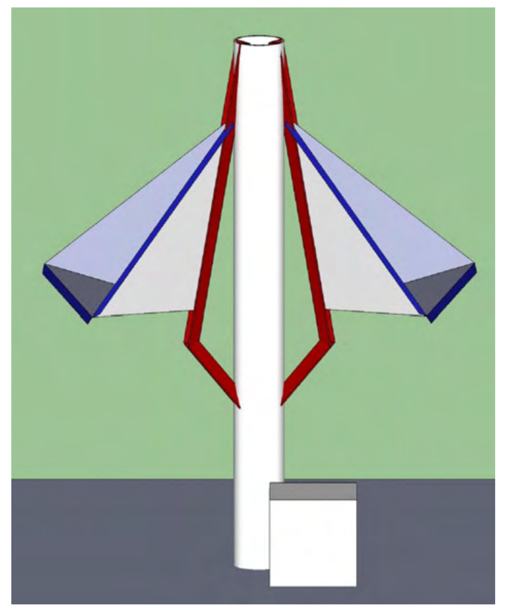


Time series of ground deformation at selected sites. Measurement noise is ~0.5 cm/year. Uplift at UP1 and subsidence at SUBN, SUBS and TL15 sites is clearly above the noise level.

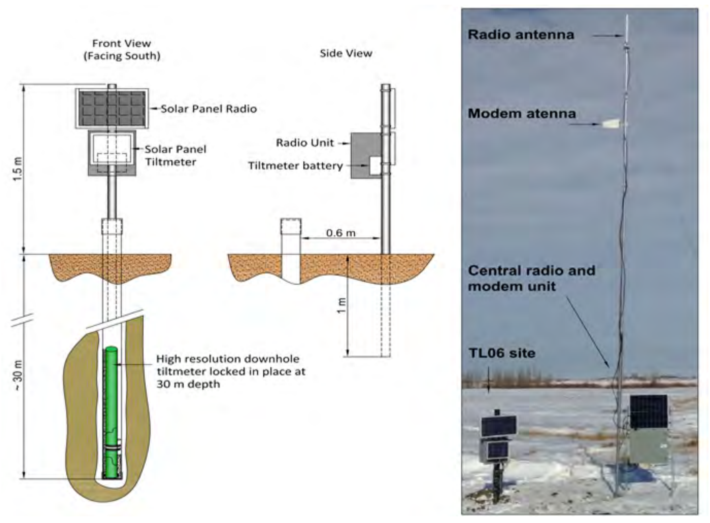


*UP1, SUBN and SUBS are areas of fast motion and are not measurement sites

Sketch of corner reflector that will be installed at six sites: SITE, NW1, NE1, SW1, SE1, NW3.

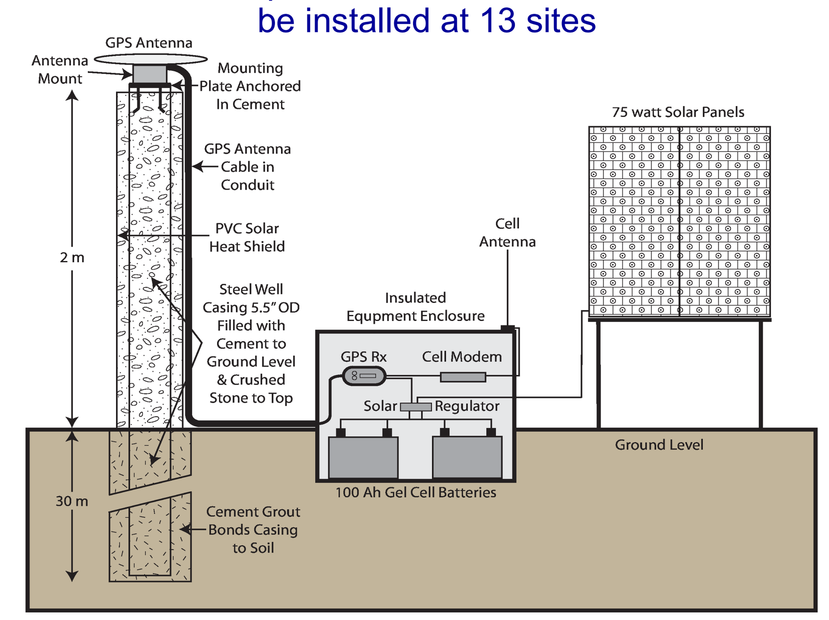


Sketch of tiltmeters that will be installed at 15 sites



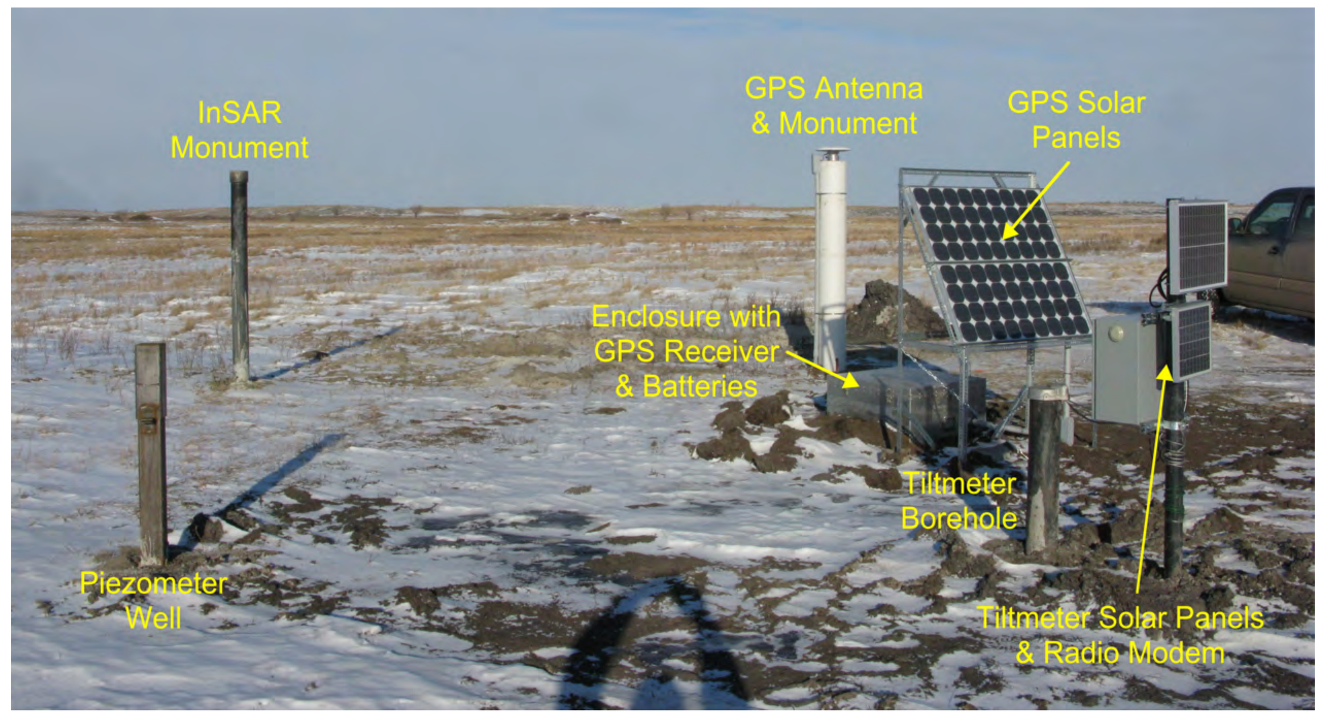
An array of 15 downhole tiltmeters will be deployed and locked in place at 30 m depth. The sensing element at the core of each tiltmeter is a pair of orthogonal bubble levels, in which electrodes detect movements of the air bubble within a conductive fluid as the fluid seeks the lowest spot in the sensor. It can resolve tilt to as little as one billionth of a radian (500 nanodegrees). The tiltmeter data is recorded every 4 minutes and download daily to GeoREF backup system.

Sketch and photo of GPS monument that will be installed at 13 sites



The GPS surface deformation monitoring component consists of 13 monitoring sites with continuously operating, geodetic-grade GPS receivers (Trimble NetR9) and antennas (Trimble Zephyr Geodetic 2) mounted on a steel well casings anchored to a depth of 30 m. GPS data will be transmitted on a daily basis to NRCan servers for daily processing and analysis.

Long term subsidence rates of 3-4 mm/year in southern Saskatchewan have been determined from 17 years of GPS measurements (Craymer et al., 2011).



Current installation at NW01 site. Six sites were successfully installed in November 2012, 5 with GPS and 2 with tiltmeters. Corner reflectors will be installed at 5 sites in December 2012. The remainder of the 18 sites will be installed in 2013.

SUMMARY

- By 2014 injection rates at the Aquistore CO2 injection site should reach 0.5 - 1.0 M tonnes per annum.
- CO2 injection will cause redistribution of stress at the injection depth ~3350 m that may manifest as a measurable uplift at the surface.
- For monitoring temporal and spatial distribution of ground deformation, a variety of instruments will be installed, including 13 continuously operating GPS receivers and 15 tiltmeters.
- SAR data from Radarsat-2 satellite acquired approximately once a week is used for InSAR analysis. Six corner reflectors will be installed to provide high-precision measurements.
- Initial InSAR analysis suggests that localized natural and anthropogenic ground deformation is ongoing in the region, for example uplift at UP1 and subsidence at SUBN, SUBS and TL15 sites.

References

1. Samsonov S. and d'Oreye N., Multidimensional time series analysis of ground deformation from multiple InSAR data sets applied to Virunga Volcanic Province, Geophysical Journal International, DOI: 10.1111/j.1365-246X.2012.05669.x
2. Samsonov S., Tiampo K., Rundle J., and Li Z., 2007, Application of DInSAR-GPS optimization for derivation of fine scale surface motion maps of southern California. IEEE Transactions on Geoscience and Remote Sensing, 45(2), 512-522
3. Craymer, M., J. Henton, M. Piraszewski, E. Lapelle. An updated GPS velocity field for Canada. Eos Transactions, AGU, 92(51), Fall Meeting Supplement, Abstract G21A-0793, 2011.

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