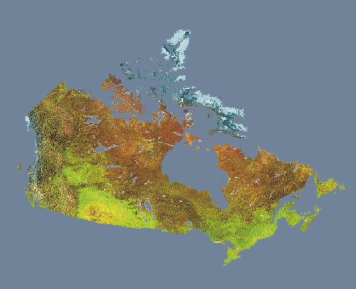
Geomatics Canada
Scientific Presentation 1

GROUND DEFORMATION DUE TO STEAM-ASSISTED GRAVITY DRAINAGE AND CYCLIC STEAM STIMULATION OBSERVED BY RADARSAT-2 IN ALBERTA'S OIL SANDS



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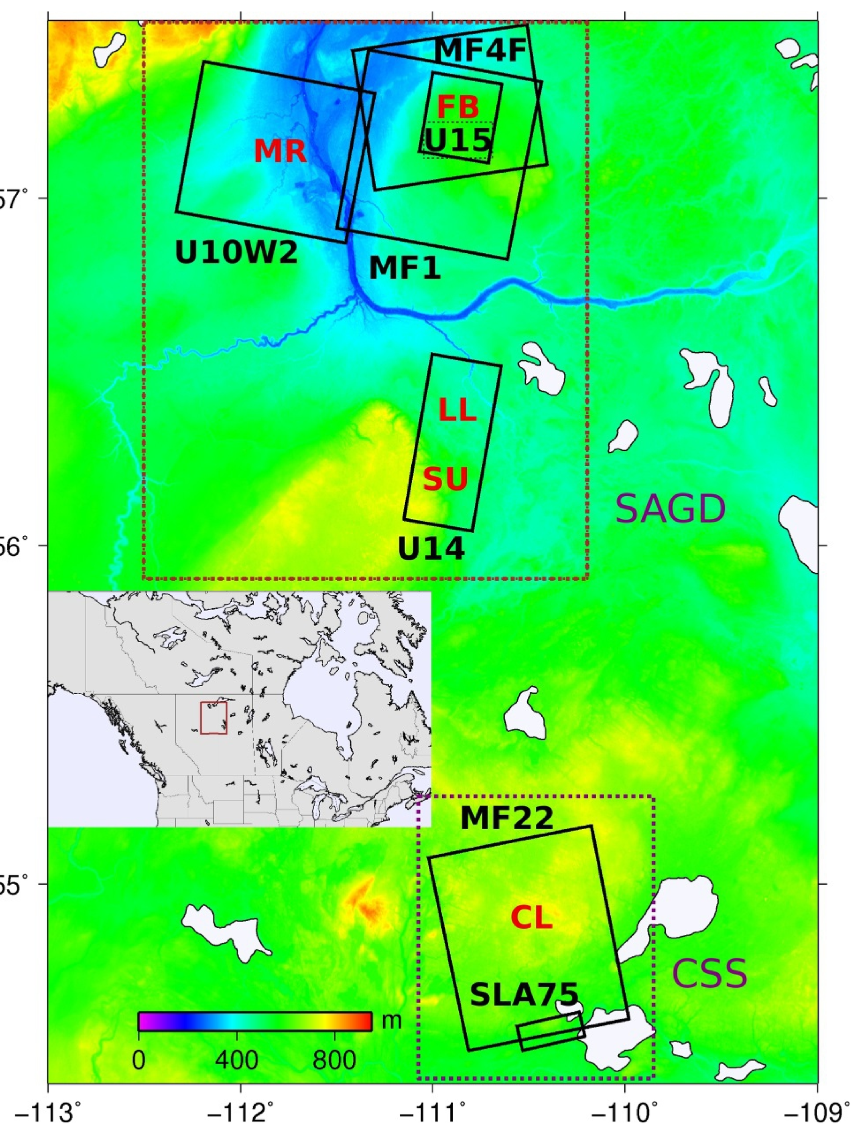
ABSTRACT

Ground deformation in Alberta's oil sand in Canada was observed with RADARSAT-2 Differential Interferometric Synthetic Aperture Radar (DInSAR). Canadian RADARSAT-2 satellite is capable of acquiring SAR data with 24 day repeat cycle with beams of various resolution, coverage and polarization. In this work we used data from various RADARSAT-2 beams acquired over the Steam Assisted Gravity Drainage (SAGD) and the Cyclic Steam Simulation (CSS) enhanced oil recovery mining sites. We employed the Small Baseline Subset (SBAS) technique for measuring linear deformation rates and time series of deformation when coherence of individual interferograms was favorable. In case of very fast deformation observed at some sites the accurate phase unwrapping for a large number of interferograms was impossible so for these sites we computed individual interferograms only. Presented here results demonstrate that CSS enhanced oil recovery method produces significantly larger ground deformation than SAGD method.

Figure 1. Digital Elevation Model (from ASTER 30 m). RADARSAT-2 frames are outlined in black: U14 , U15 – Ultrafine, U 10W2 – Wide Ultrafine, MF4F, MF1, MF22 – Multi-look Fine, SLA75 - Spotlight. SAGD sites are labelled as LL (Long Lake), SU (Surmont), MR (MacKay River) and FB (Firebag). CSS site is labeled as CL (Cold Lake). Regions of SAGD and CSS operation are outlined in brown dashed line.



ALBERTA'S OIL SANDS AND ENHANCED OIL RECOVERY METHODS

Alberta's oil sands represent one of the largest deposits of crude oil in the world. They form viscous bitumen embedded within uncemented sand in the Lower Cretaceous McMurray Formation [1, 2]. According to the Energy Resources Conservation Board the main four oil sand deposits widely spread over an area of Northern Alberta, with total initial in-place reserves estimated at about 1.8 trillion barrels. The largest of these deposits is the Athabasca, which outcrops along the Athabasca River and gradually dips down towards the south-west [3].

About 20% of the recoverable bitumen is close to the surface and is accessed through the open pit mining. Extraction of the remaining 80% of deposits, located at depth greater than 65 meters, is performed using two enhanced oil recovery methods: the Steam Assisted Gravity Drainage (SAGD) and the Cyclic Steam Simulation (CSS). In the SAGD operation a pair of wells separated by a few meters vertically is drilled horizontally into the oil reservoir. Then high pressure steam is injected continuously into the upper well, which heats the oil and reduces its viscosity and causes the heated oil to drain into the lower well, from which it is pumped out. In the CSS operation only one well is drilled, which is periodically used for injection and production. During the injection phase steam is injected for several weeks to months and then flow is reversed and oil is extracted to the surface.

Figure 3. Schematic of Steam Assisted Gravity Drainage (SAGD) site.

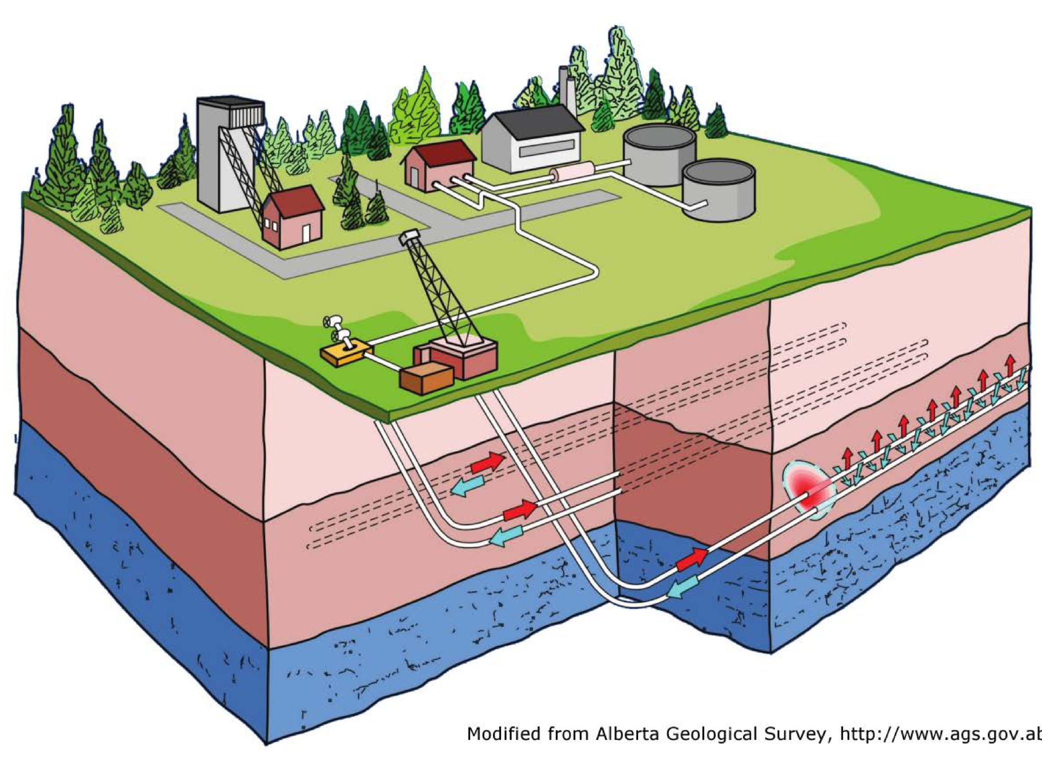
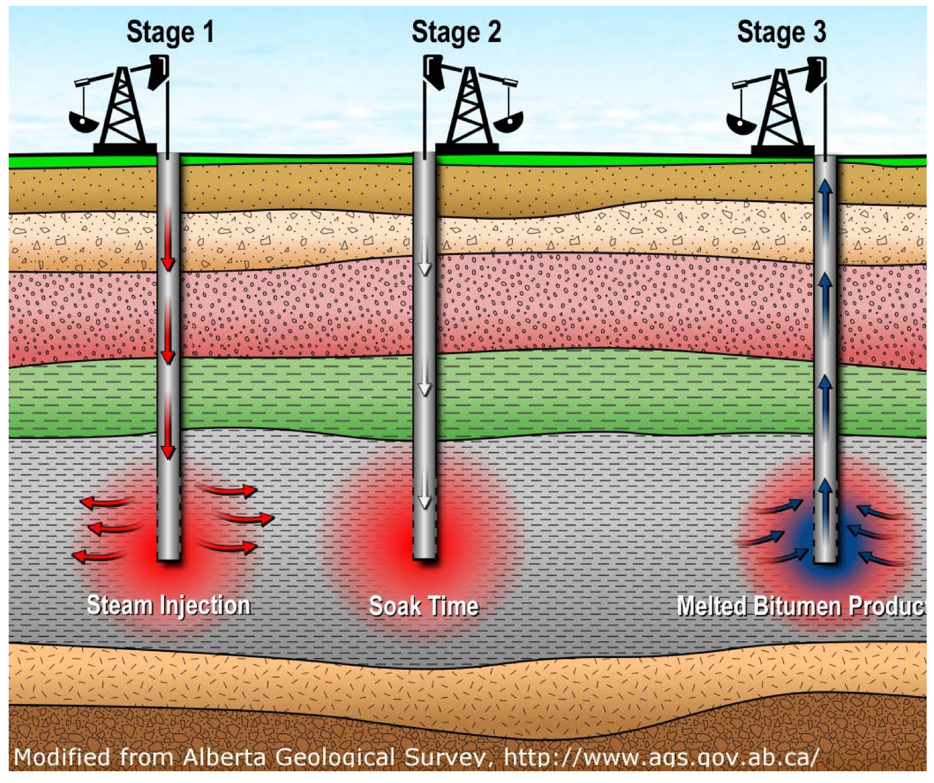


Figure 4. Schematic of Cyclic Steam Simulation (CSS) site.



CONCLUSIONS

With DInSAR we observed ground deformation at both SAGD and CSS sites, but the rate and temporal pattern of deformation was significantly different. At SAGD sites the linear deformation rate measured with SBAS DInSAR (Figure 5) showed uplift with the maximum rate of about 2 cm/year [5]. At CSS sites (Figure 6) deformation was extremely high reaching up to 30 cm over 24 day cycle or 450 cm/year [6].

Figure 2. Schematic geological cross section.

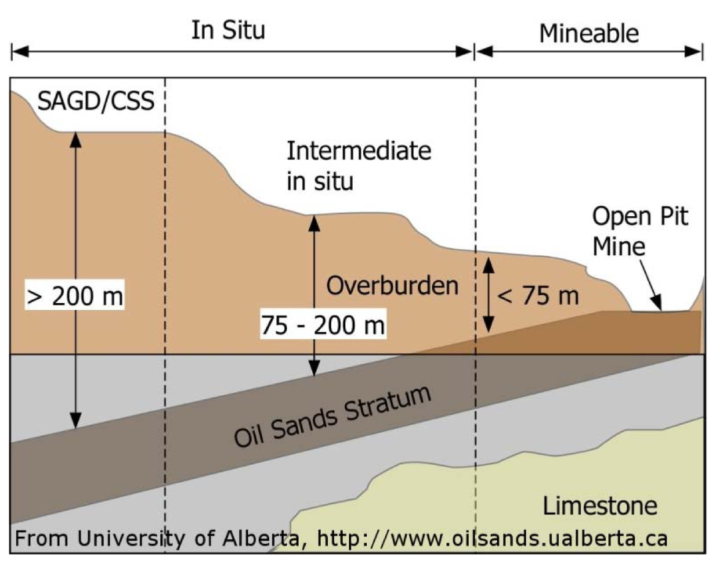
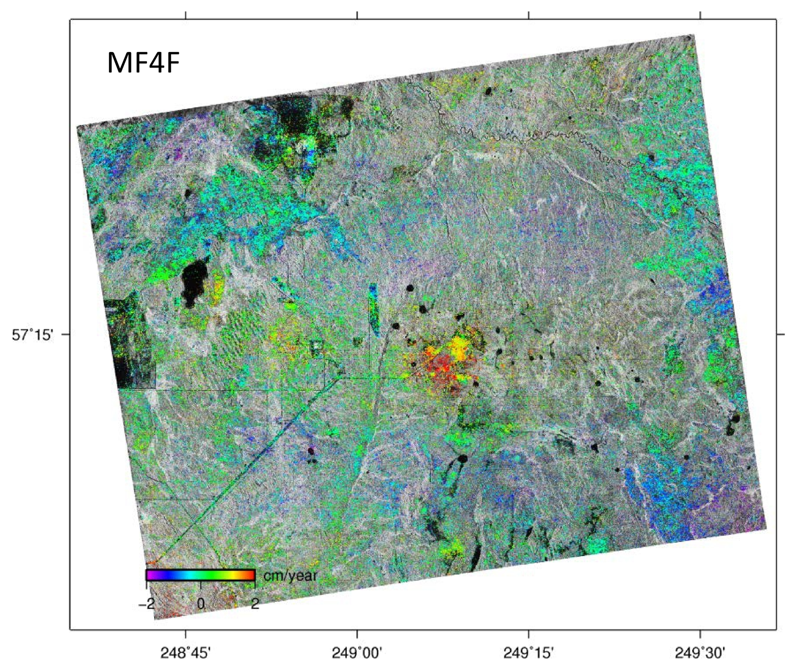
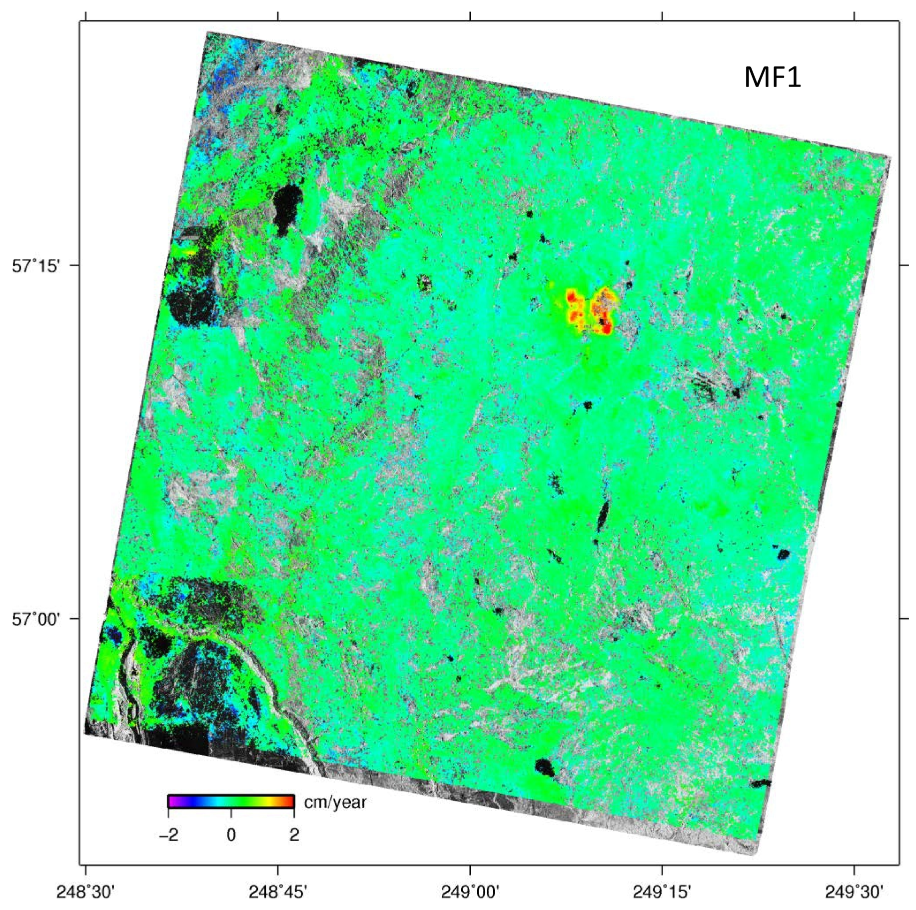
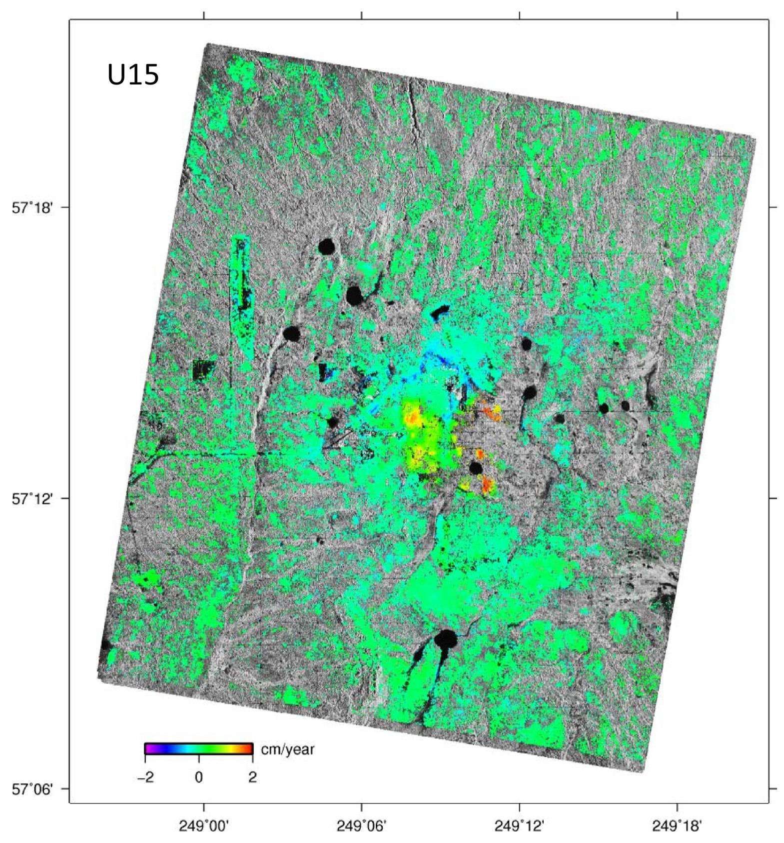
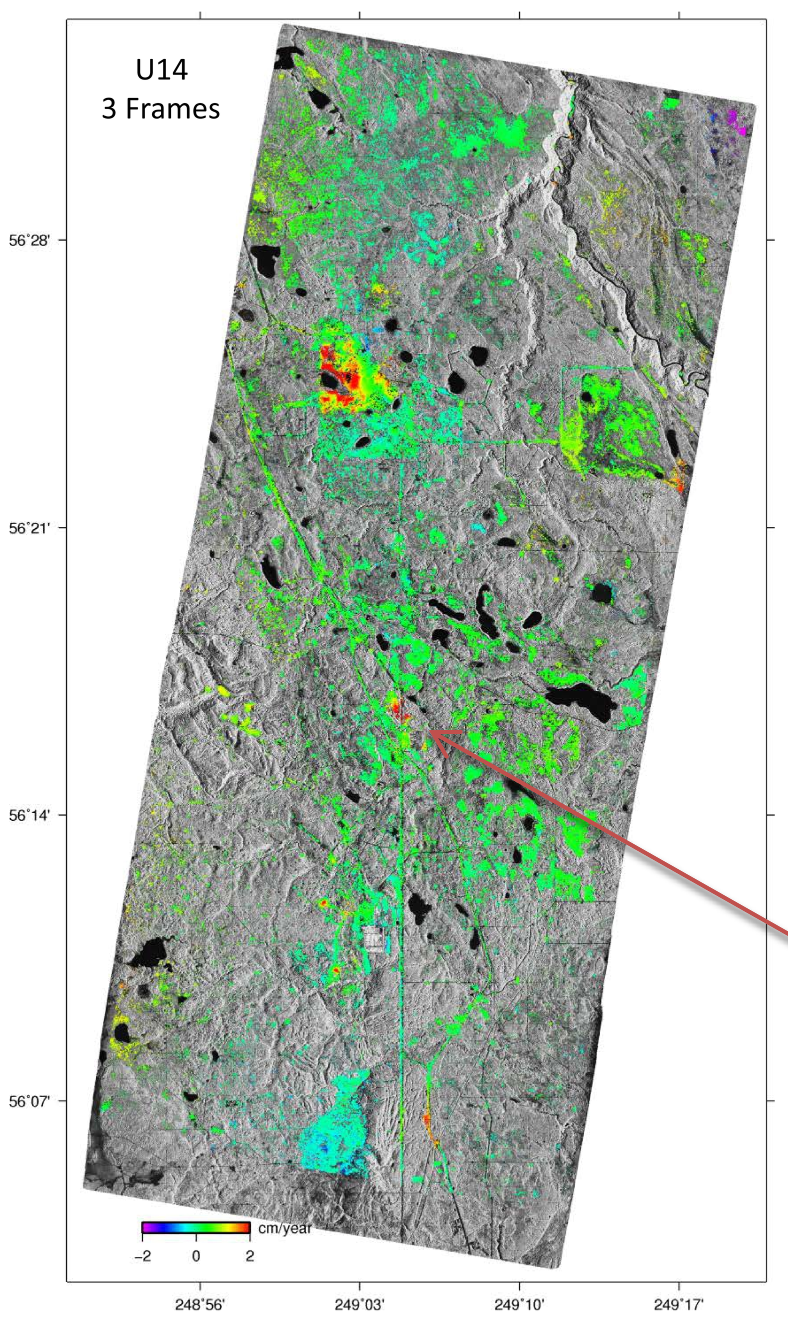


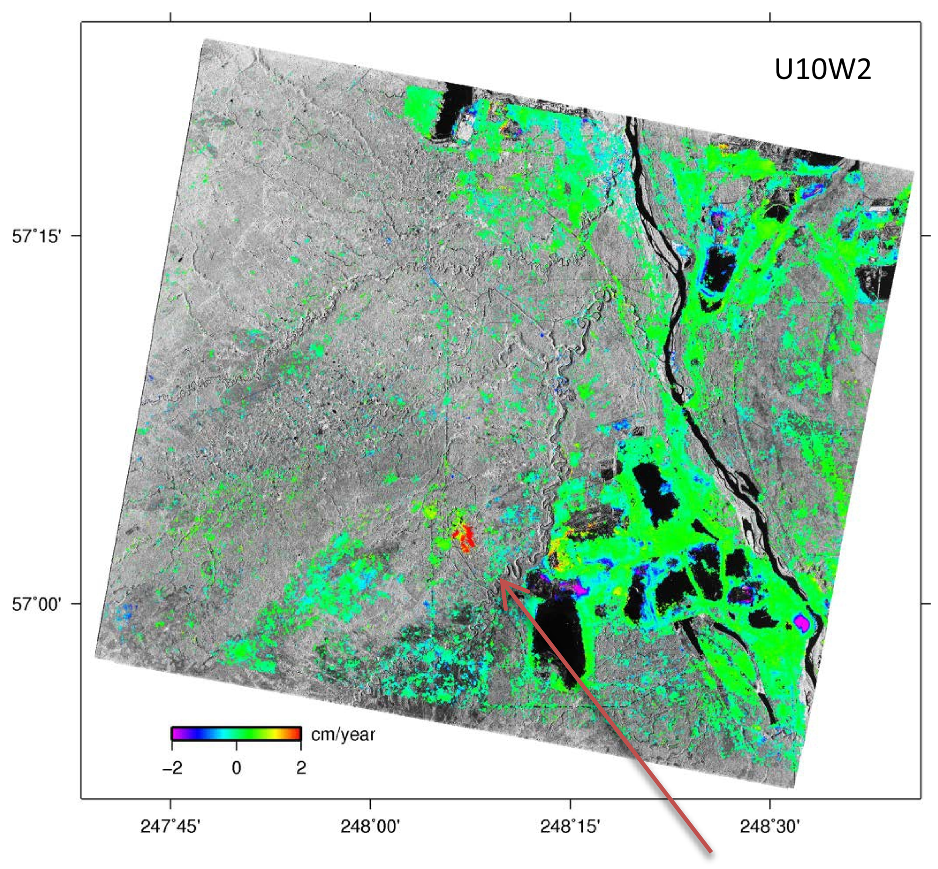
Figure 5. 2008-2013 linear deformation rates and time series for SAGD sites computed with Small Baseline Subset (SBAS) method [4]. In background, SAR intensity image reveals areas of lower coherence, for which deformation rate was not estimated.











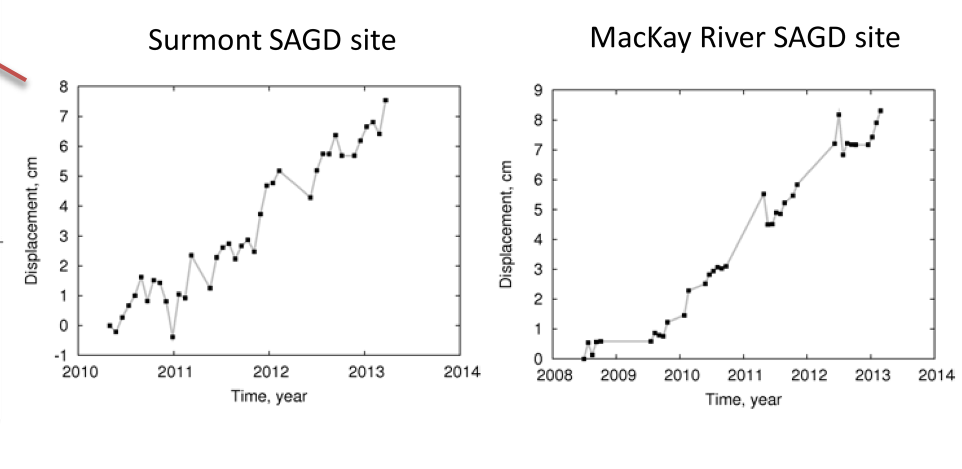
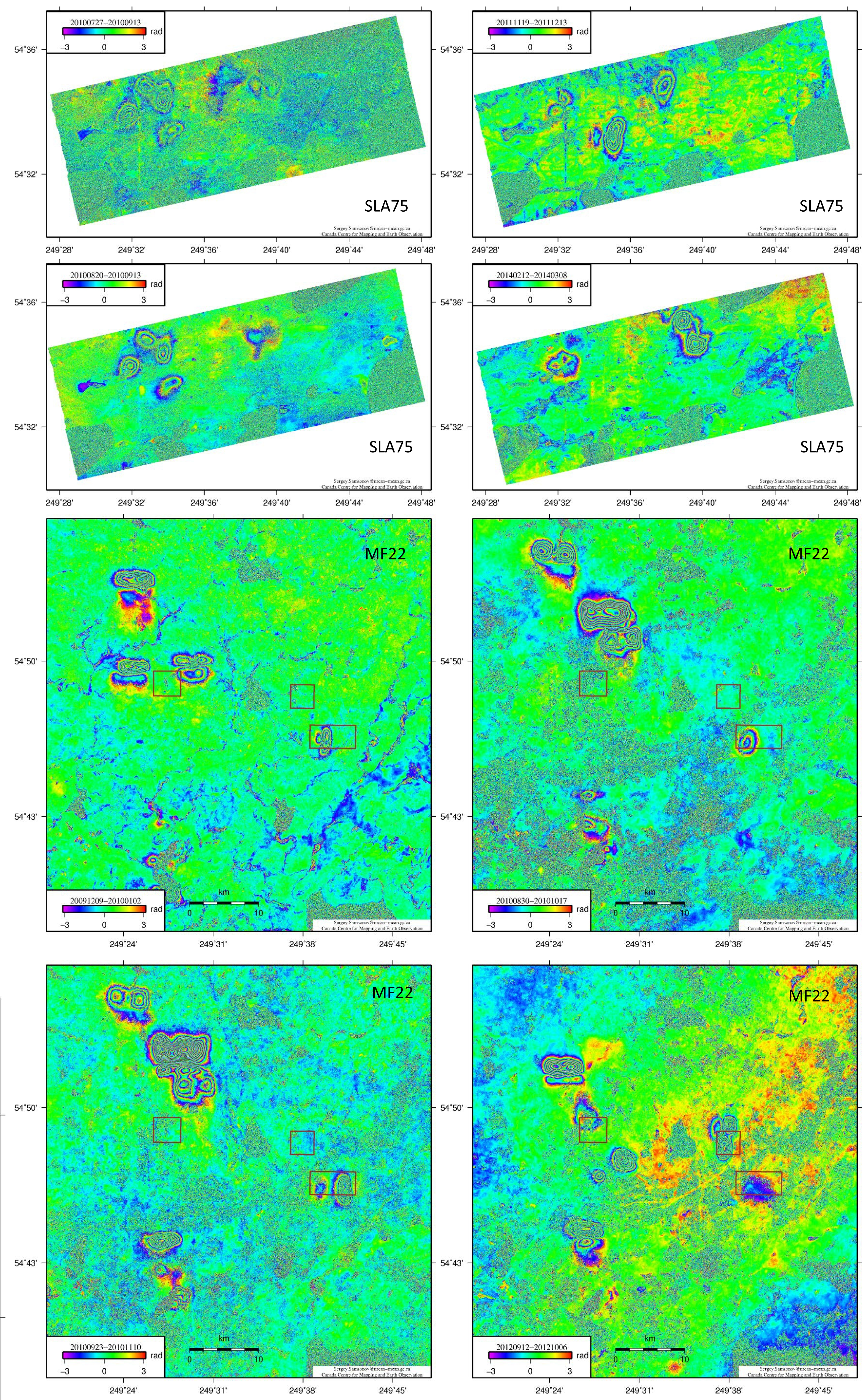


Figure 6. Wrapped DInSAR interferograms for CSS sites from SLA75 and MF22 RADARSAT-2 data. Regions were oil leak was reported near Cold Lake site is outlined in brown. One fringe corresponds to 2.8 cm line-of-sight motion.



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