

LONG TERM, OPERATIONAL MONITORING OF ENHANCED OIL RECOVERY IN HARSH ENVIRONMENTS WITH INSAR

S. Sato and M.D. Henschel

*MDA Geospatial Services Inc.
57 Auriga Drive, Suite 201
Ottawa, Ontario K2E 8B2 CANADA
email: ssato@mdacorporation.com*

ABSTRACT

Since 2004, MDA GSI has provided ground deformation measurements for an oil field in northern Alberta, Canada using InSAR technology. During this period, the monitoring has reliably shown the slow rise of the oil field due to enhanced oil recovery operations. The InSAR monitoring solution is essentially based on the observation of point and point-like targets in the field. Ground conditions in the area are almost continuously changing (in their reflectivity characteristics) making it difficult to observe coherent patterns from the ground. The extended duration of the oil operations has allowed us to continue InSAR monitoring and transition from RADARSAT-1 to RADARSAT-2. With RADARSAT-2 and the enhancement of the satellite resolution capability has provided more targets of opportunity as identified by a differential coherence method. This poster provides an overview of the long term monitoring of the oil field in northern Alberta, Canada.

Key words: InSAR; Point Scatterer; Enhanced Oil Recovery.

1. INTRODUCTION

The use of InSAR technology to provide monitoring of ground deformation is a well demonstrated (Rosen et al. 2000; Ferretti et al. 2001). This paper presents an example of the use of corner reflectors and coherent scatterers (Hopper et al. 2004; Hooper 2006; Kampes & Van der Kooij 2008) to show the long term observation of ground deformation over an enhanced oil recovery site in Northern Alberta, Canada.

The region is characterized by large changes in soil moisture, tree canopy, and vegetation on a continuing basis. This leads to large changes in the spatial coherence of the region as shown in Figure 1. Clearly the wide variation in coherence precludes the use of wide area differential InSAR. The goal of the construction of an InSAR

monitoring program therefore must be the efficient use of existing target points that can provide persistent measurements of phase along with a sparse field of installed point locations. Ideally the field of existing and installed targets will be dense enough that the extent of the ground signal can be well understood (for a brief discussion see Henschel & Lehrbass (2011)).

The oil field presented in these results uses a steam assisted gravity drainage (SAGD) method for oil recovery. The expected surface expression is expected to be a slow, continuous surface deformation. Typically, the deformation is less than two centimetres per year in the vertical direction.

The site presented was monitored from March 2006 with RADARSAT-1. A total of 24 Corner Reflectors at that time. In the first quarter of 2009, the site was monitored with both RADARSAT-1 and RADARSAT-2, and a transition to monitoring solely with RADARSAT-2 was accomplished in March 2009.

Figure 2 shows an illustration of the site with the location of corner reflectors and a time series of observations from two of the reflectors. The graphic shows the period from March 2006 to April 2011. The cumulative deformation is shown as colour coded circles labeled with corner reflector number. The analysis shows an essentially linear, upward trend in the observations. The unwrapping of the corner reflector field is accomplished in a spatial sense first and no linear trend over time is assumed in the temporal analysis. A seamless transition from RADARSAT-1 to RADARSAT-2 was accomplished by providing a linear offset from the results observed between May 2008 and March 2009 with both sensors. A smooth linear trend was observed in both RADARSAT-1 and RADARSAT-2 over that time period. The fact that the trend was the same and linear in both sets of observations provided for a seamless integration of the two over the corner reflectors.

The existing scatters, our so called CTM points, are not as easily considered. While the corner reflector locations can be used to ensure an accurate coregistration between the RADARSAT-1 and RADARSAT-2 data, the nature of the coherent targets over the area makes the transition

more difficult. The higher resolution of RADARSAT-2 means that more individual scatterers can be identified in the set. The RADARSAT-2 data, for instance, makes the identification of point scatterers on pipeline infrastructure possible. Furthermore, a much higher density of well behaved scatterers is available over the oil field itself. The change in distribution of the point scatterers (and the naturally higher variability as compared to installed corner reflectors) precludes chaining the CTM results together between RADARSAT-1 and RADARSAT-2 in this example. Figure 3 shows the same region of the oil field but this time with colour coded cumulative deformation as observed by the CTM points from RADARSAT-2. The time series shows a comparable trend with the corner reflector analysis shown in Figure 2. The results shown in Figure 3 are derived from all of the imagery available from RADARSAT-2 between May 2009 and April 2011.

Both the corner reflector measurements and the CTM points are measured with respect to a plane through the reference corner reflectors.

2. CONCLUSION

This paper has shown an example of a long term monitoring project over an enhanced oil recovery site in a region that is difficult to monitor with standard InSAR techniques. The work also provides an example of a smooth transition from one satellite system to the subsequent mission; that is the transition from monitoring with RADARSAT-1 to RADARSAT-2.

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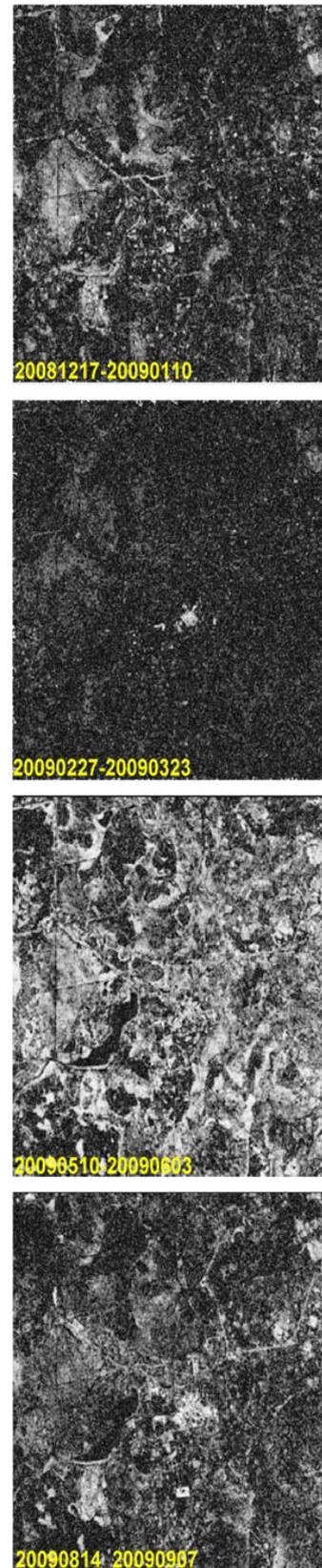


Figure 1. Changes in spatial coherence over the region at different times during the year (with Figure 1).

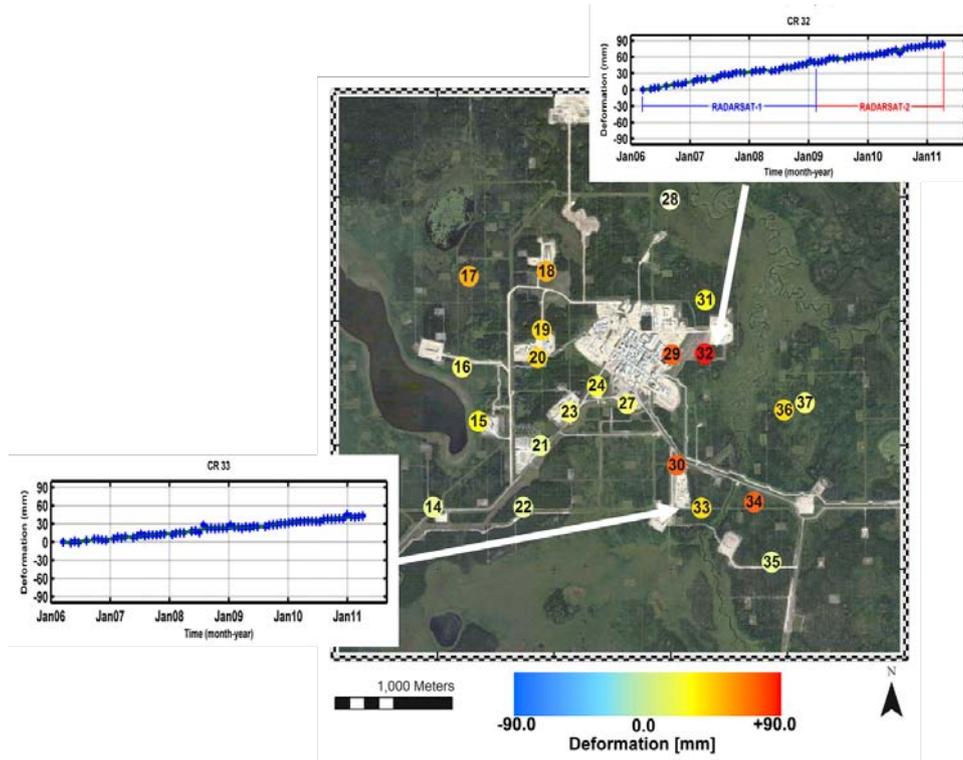


Figure 2. Time series of select corner reflector points from both RADARSAT-1 and RADARSAT-2 over an enhanced oil recovery site.

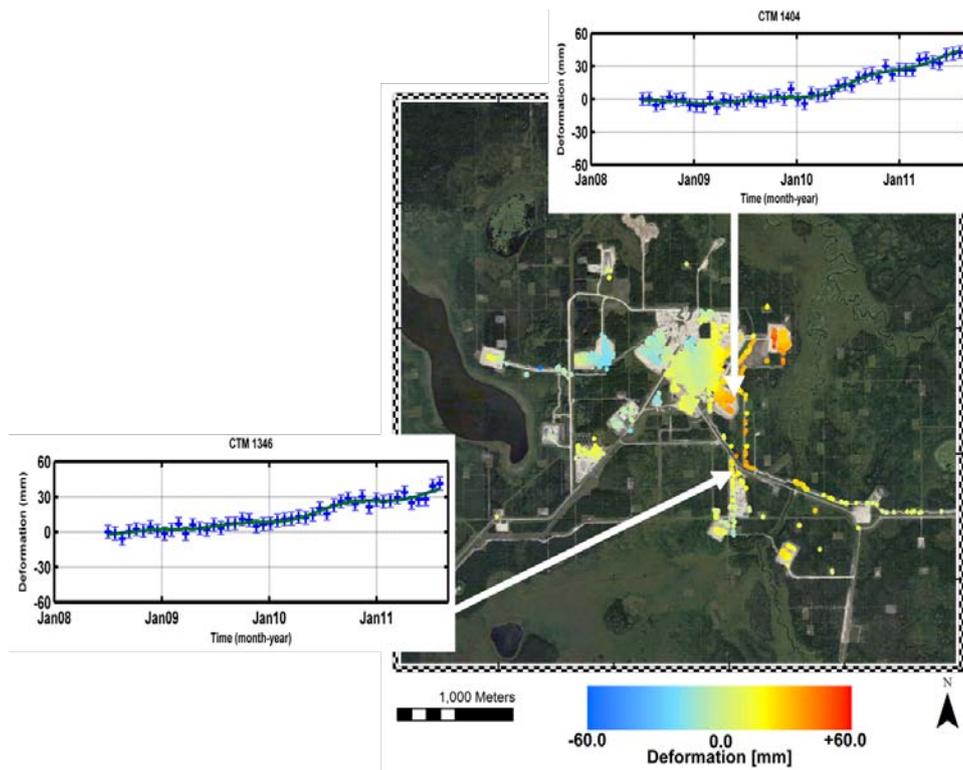


Figure 3. Time series of select points with colour coded cumulative deformation from persistently coherent (CTM) targets over an enhanced oil recovery site.