RADARSAT InSar Monitoring of an Active Rock Avalanche

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Abstract – In this study, we used RADARSAT interferometrically derived images to monitor current post slide motion at the Frank Slide, a 30x $10^6 m^3$ rock avalanche, in the Canadian Rockies. The images cover the period from September 2000 to April 2004. Our results show that the Frank slide is still active and the deformation process is localized and related to seasonal and local weather conditions. This information is useful in assisting to locate in-situ field monitoring at specific locations, and to plan mitigation strategies. The combination of satellite differential InSAR techniques, covering large areas, and site-specific GPS monitors can produce an integrated monitoring system of active slopes.

Keywords: Landslide motion, InSAR, landslide mapping.

1. INTRODUCTION

Remote sensing techniques are increasingly being used in slope stability assessment. (Murphy & Inkpen, 1996, Singhroy et al. 1998, Singhroy & Mattar 2000, Singhroy & Molch 2004). Recent research has shown that differential interferometric SAR techniques can be used to monitor landslide motion under specific conditions (Vietmeier et al. 1999, Rott et al. 1999). Provided coherence is maintained over longer periods, as is possible e.g. in non-vegetated areas, surface displacement of a few cm per year can be detected. Using data pairs with short perpendicular baselines, short time intervals between acquisitions, and correcting the effect of topography on the differential interferogram, reliable measurements of surface displacement can be achieved.

Our study focused on the Frank Slide, a 30x $10^6 m^3$ rockslide-avalanche of Paleozoic limestone, which occurred in April 1903 from the east face of Turtle mountain in the Crowsnest Pass region of southern Alberta, Canada. Seventy fatalities were recorded.

Several investigations have focused on characterizing grain size and distribution of this rock avalanche, in order to understand post failure mechanism and mobility (Couture et al. 1998, Cruden & Hungr 1986). "Factors contributing to the slide have been identified as the geological structure of the mountain, subsidence from coal mining at the toe of the mountain, blast induced seismicity, above-average precipitation in years prior to the slide, and freeze-thaw cycles" (Alberta Environment, 2000). In 2001, 6000 tons of rock fell from the north slope of the Frank slide which led to our InSAR investigation. Currently, the Government of Alberta is installing GPS stations to monitor post slide activity at specific locations. Our InSAR results will assist in locating in-situ monitors, as well as providing a regional and seasonal view of gravitational mass movement.

2. DATA ACQUISITION AND PROCESSING

RADARSAT data were used for InSAR analysis. In order to select a set of suitable RADARSAT scenes, a thorough baseline analysis was performed. Twenty archival and new scenes were acquired over the location between September 2000 and November 2004. It was of interest to find as many data pairs as possible during this time period, yet keep the perpendicular baselines ideally below 100 m, thus reducing contributions of topography on differential phase values as much as possible. Ascending orbit was chosen since its look direction corresponds to the aspect of the slope. The suitable RADARSAT-1 SLC data were interferometrically processed to geocoded vertical displacement maps using Vexcel's EV-InSAR software. Figure 1 shows selected results, displayed over an elevation model. The data were processed using the ephemeris data provided. Within the differential interferometry processing sequence it was ensured that Master-to-Slave coregistration was precise to an RMS of better than 0.1 pixels in range and azimuth at the tie points. Employing a simulated SAR image generated from the external DEM, the DEM-to-Master coregistration was refined to below 1 pixel RMS, ensuring the best fit possible. Topographic phase contribution was removed using a CDED 1:50,000 DEM. Azimuth spectral overlap and baseline decorrelation filtering were performed where spectral overlaps fell below 90%. Residual topographic phase was removed from the differential interferogam through baseline refinement by iteratively adjusting the slave state vector. Especially for data pairs with longer baselines this led to an improved differential interferogram. The phase was unwrapped using an iterative disk masking algorithm. The unwrapped phase was then translated to vertical height change values and subsequently geocoded. Table A lists the selected datsets presented in Figure 1.

Table A. RADARSAT-1 Data Pairs Presented Here

Date Master	Date Slave	Time between acquisitions [days]	Perpendicular baseline [m]
24 Oct 03	17 Nov 03	24	332
24 Oct 03	09 Apr 04	168	76
21 Sep 00	24 Oct 03	1128	3

For all data pairs processed, coherence values are generally high on the slide itself, even for temporal baselines of more than two years. This can be attributed primarily to the lack of vegetation on the slide and indicates a general stability of the individual scatterers on the slope.

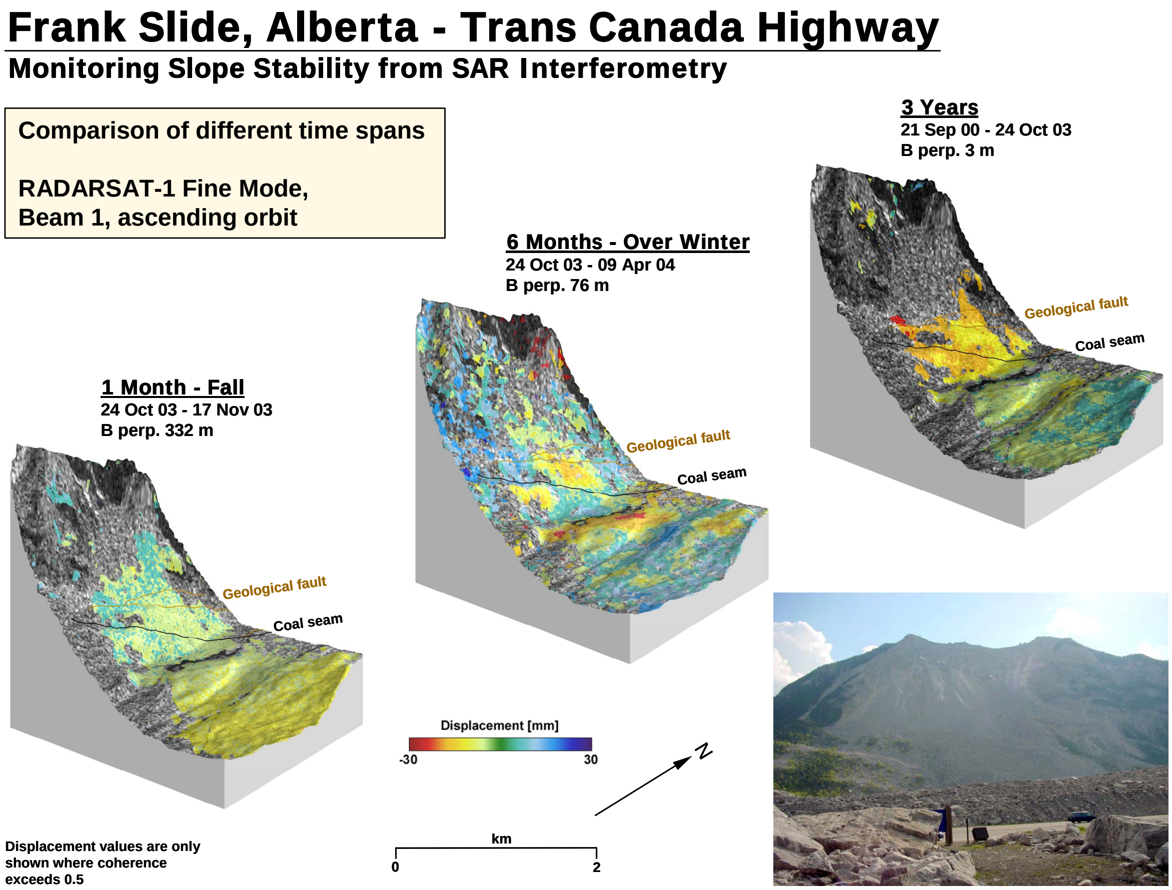

Figure 1. RADARSAT-1 InSAR displacement maps for three different time spans between 2000 and 2004.

3. . DISCUSSION

In this study we analyse RADARSAT InSAR images over differerent time periods. Interpretation of these images (Figure 1) is presented below. In general, there are active processes in the middle part of the slide as shown from the September 2000 to October 2003 period. The InSAR deformation map shows negative vertical surficial deformation above the coal seam and below the regional fault and its splay. The localized slope deformation may be the result of a local surficial slope failure within the colluvium (e.g. old and recent rock fall debris) accumulated at the base of the slope. Deformation associated to the fault is doubtful, as the measured deformation is localized, well below the fault and not linear, as it would be expected if it were related to the regional fault.

In addition, InSAR results shows differential motion of the landslide at different periods. This is based on the freeze-thaw processes and the availibility of moisture from spring melt and rainfall. The increased activity from October 2003 to April 2004 period is mainly due to the availibility of extensive moisture from springtime snow melt which triggers active surficial motion processes resulting in numerous zones of significant vertical surface displacement, both positive and negative vertical displacement. During the winter months, the slide is generally inactive. In the spring time, the surficial processes increase significantly. All the surface deformation situated at the base of the mountain slopes present a negative value and therefore would be mostly associated to settlement of colluvium and rock avalanche debris. This settlement often follows snow melting and ground thawing. It is difficult to identify which portion of the deformation is associated to gravitational mass movements since there is no positive vertical surface movement in the mountain slope that would be indicative of material transfer from the source area to the deposition area. The zones of deformation in the uppermost parts of the slopes are associated to failures in the bedrock that had caused rockfalls. This is typical, during the springtime, since the higher frequency of freeze-thaw cycles are responsible for failures along rock fractures. During the fall period for example from October to Novomber 2003, there seems very little activity, because of the lack of heavy rainfall events which sometimes triggers surficial motion.

4. CONCLUSION

Our investigation has shown that RADARSAT InSAR can continuously monitor large active slopes. The series of InSAR images indicates the different level of activity of the slopes (high and low) during different periods of the year. It is clear, that gravitational mass movement activity is localized and related to weather and seasonal conditions, with the springtime being the most active time period.

5. REFERENCES

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