

MONITORING LANDSLIDES AND VOLCANIC DEFORMATION FROM INSAR TECHNIQUES

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ABSTRACT:

Our research has shown that interferometric SAR techniques can be used to monitor deformation at landslides and volcanoes under specific conditions. Special filtered interferograms are being used to reduce speckle and minimize errors created by vegetation. InSAR images were used to monitor current post slide motion along existing fault lines at the Frank Slide a $30 \times 10^6 \text{ m}^3$ rock avalanche, in the Canadian Rockies. This information is used to understand the post failure mechanism and mobility of the slide. At Miyake-Jima Island in Japan a filtered interferogram was used to monitor post eruption volcanic shrinkage. The volcano erupted in July-August 2000 that led to the total evacuation of inhabitants from the island. Our differential InSAR results show subsidence at the summit after the eruption, and allow us to monitor the post eruption processes, thereby assisting in planning the return of local residents to the island.

INTRODUCTION

SAR interferometric techniques, which uses images acquired with two repeat passes over the same scene, are being used increasingly to monitor landslides and volcanic deformation. (Murphy and Inkpen, 1996; Singhroy et al., 1998; Singhroy and Mattar, 2000; Ohkura and Shimada, 2001; Lundren et al., 2001; Feretti et al., 2001). Recent research has shown that differential SAR interferometry (DIFSAR) is being used to monitor landslide motion under specific conditions (Vietmeier et al., 1999; Rott et al., 1999; Singhroy and Molch, 2004). Provided coherence is maintained, as in non-vegetated areas, surface deformation of a few cm over the acquisition period can be measured. To avoid large spatial decorrelation, data pairs with small perpendicular baselines, and short time intervals between acquisitions are being used. In addition, correcting the effect of topography using GPS information and detailed topographic data are also essential in achieving useful measurements of surface deformation.

MONITORING DEFORMATION AT THE FRANK SLIDE

Our study focused on the Frank Slide, a $30 \times 10^6 \text{ m}^3$ rockslide-avalanche of Paleozoic limestone, which occurred in April 1903 from the east face of Turtle Mountain in the Crownsnest Pass region of southern Alberta, Canada. Seventy fatalities were recorded. Several investigations have focussed on post failure mechanism and mobility (Couture et al., 1998; Cruden and Hungr, 1986). However, a recent 6000 tons rock fall in 2001 has renewed monitoring programs on the Frank slide by the Government of Alberta (Alberta Environment, 2000). Our

InSAR investigation is aimed at assisting in the location of in-situ motion instruments.

ERS data were to be used for the InSAR analysis. In order to select a set of suitable scenes a thorough baseline analysis of all ERS-1 and ERS-2 ascending scenes acquired over the location (track 406, frame 989) during summer between 1992 and 2001 was performed. It was of interest to find as many data pairs as possible during that time period, yet keep the perpendicular baselines below 100 m, thus reducing contributions of topography on differential phase values. Ascending orbit was chosen for the look direction (right) to correspond with the aspect of the slope. We selected an August '95 and August '97 InSAR pair with a perpendicular baseline of 4.5 m to produce the results shown in Figure 1. For all data pairs processed, coherence values were generally high on the slide itself, even for temporal baselines of more than 700 days. Values e.g. for the Aug-95 / Aug-97 pair (736 days) are in the range of 0.73 to 0.91. Singhroy and Molch (2004) published additional details on data selection and InSAR processing.

Our interferometric images show deformation of 2 cm over the 2-year period of along parts of the fault line. This suggests that the failure along the fault line may trigger secondary slides or rockfall and are the target for field instruments. In addition, our InSAR deformation maps are providing a more synoptic view of active areas on the old slide surface. A combination of the synoptic InSAR maps and measurements from field instruments will provide a more integrated monitoring system for these large active slides along strategic transportation routes, and also assist in current investigation on post failure mechanism and mobility at the Frank Slide

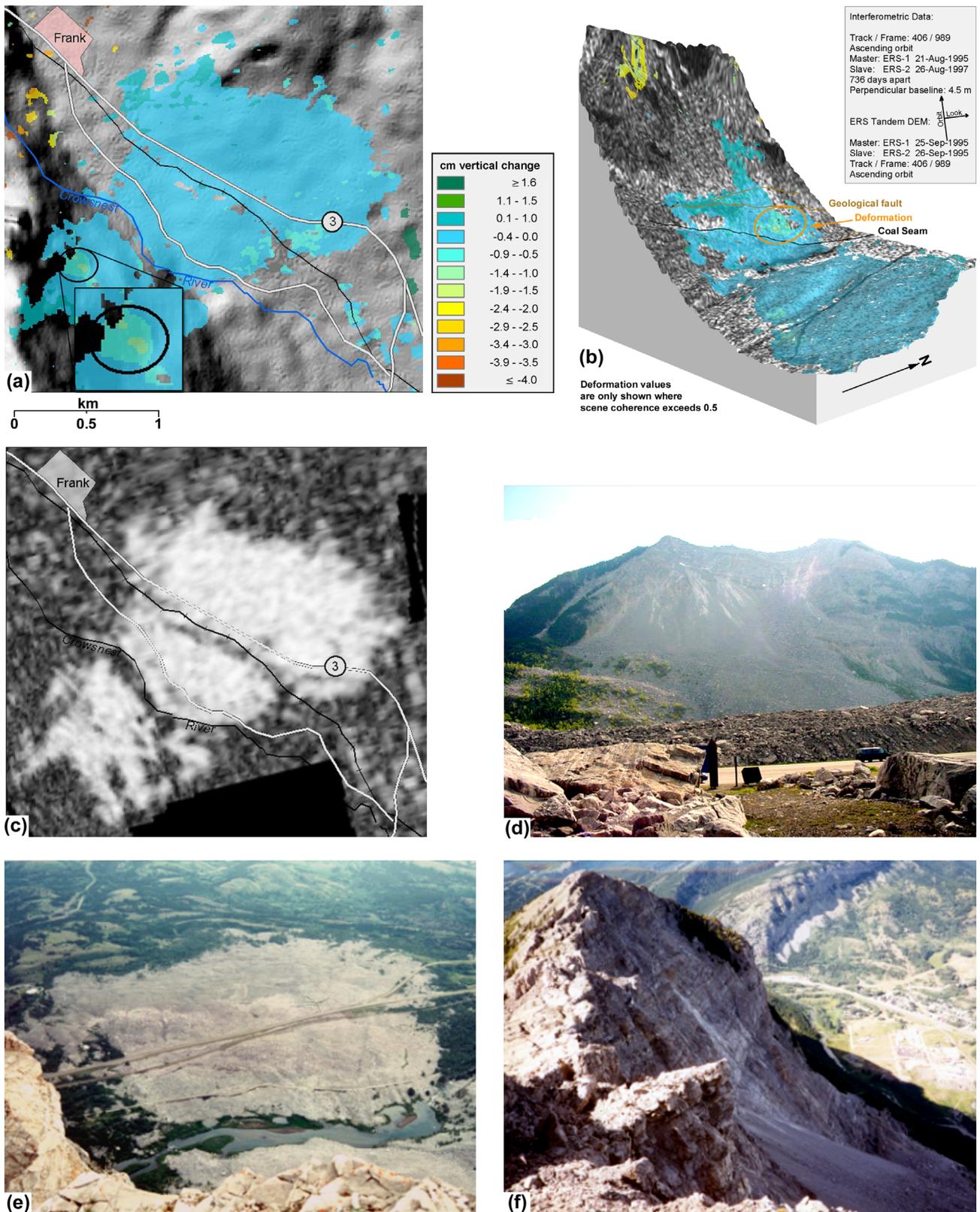


Figure 1. Vertical surface deformation map, generated from differential SAR interferometry (a). Result is draped over a high-resolution elevation model (b). Corresponding coherence image (c), and field photographs (d-f). The deformation is located towards the bottom of the slope, just above a coal seam.

MONITORING DEFORMATION AT MIYAKE-JIMA VOLCANO

Miyakejima is a volcanic island, about 10 km across, located 150 km south of Tokyo on the Izu-Mariana arc (Figure 2a). This basaltic composite volcano has erupted every 15-20 years during the past 500 years. According to the Geological Survey of Japan, the most recent activity started with the collapse of the crater on July 8, 2000. A large eruption occurred on August 18 with a plume height of over 12 km. The crater grew to the size of 1.6 km wide and 500 m deep as of early September. (Kazahya et al., 2001). All residents were evacuated in September 2000. Electrical failures during the eruption resulted in the malfunction of all in-situ monitoring instruments. Under these conditions, SAR interferometry was the only useful technique to monitor surface deformation of the volcano.

Since the eruption volcanic gases have been released intensively. The volcano is still active. Routine monitoring of SO₂ emission is done by the airborne COSPEC Monitoring Team of the Japan Meteorological Agency. SO₂ emissions average about 10,000 tons/day compared to 100,000 tons/day during the late June eruption (Figure 2b). Our InSAR investigation is aimed at providing deformation information related the post eruption behaviour.

Although L-band InSAR produces higher coherence over a vegetated area than C-band SAR imagery, we used RADARSAT C-HH because of its availability, high resolution and suitable viewing geometry. We selected RADARSAT fine mode images (F3f: 41.8-44.3 degrees) with a spatial resolution of 8 m to detect and monitor surface deformation on the small (6 km diameter) island (Figure 2d). Since most of the island is covered with vegetation, a special filter was used to enhance the raw interferogram in areas of poor coherence and speckle. This filter, useful for InSAR analysis in vegetated areas, was developed by Okhura and Shimada (2000). The filter is based on a moving average attached to Atlantis Scientific Inc InSAR software. After each filtering the portion in which the interferogram becomes clear is superposed on the output interferogram. The data of GPS stations installed after the eruption were used for baseline adjustment.

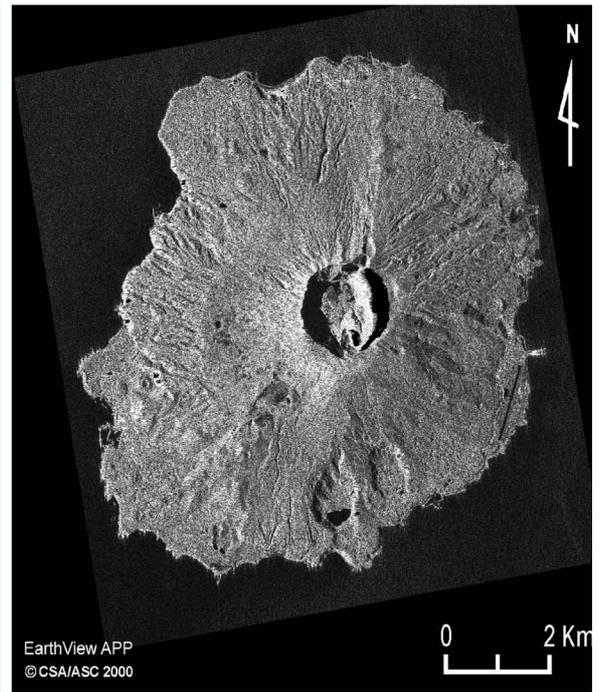
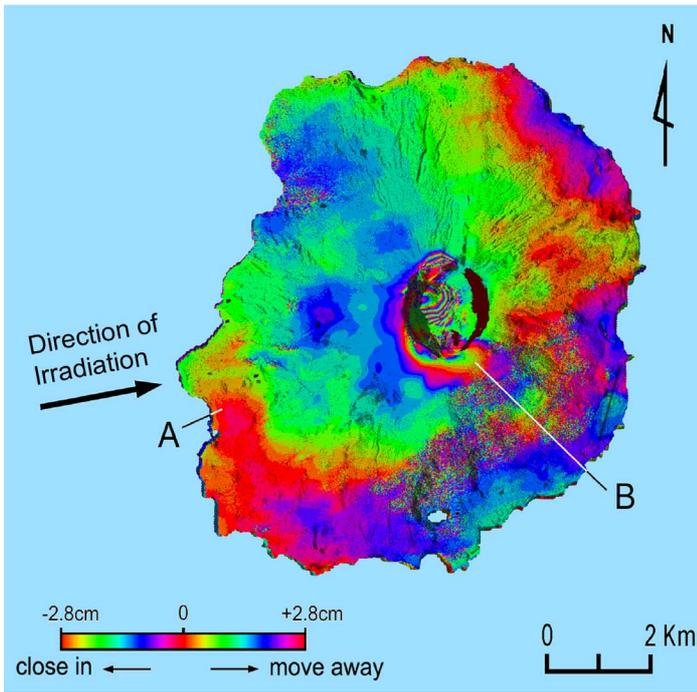
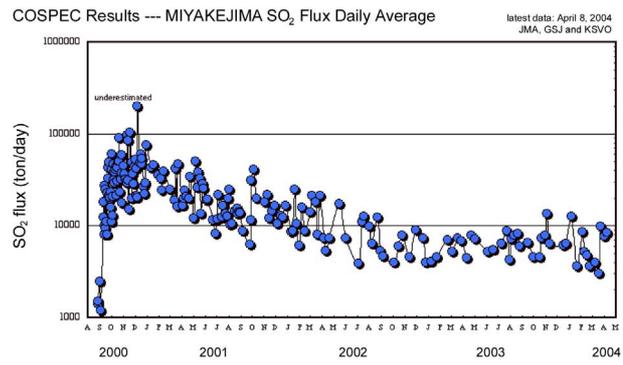
Of the fifteen RADARSAT images acquired from August to December 2000, we selected the November 10th and December 4th InSAR result for this paper (Figure 2c). Our results from the other interferograms (August to December) provided a more complete picture of deformation during this period.

CONCLUSION

- GPS and D-InSAR measurements are providing an integrated monitoring system of post eruption shrinkage rates at the Miyake-Jima volcano, after the severe August 2000 eruption. Our differential InSAR results show Miyake-jima crater subsided 4.7 cm between November 10th to December 4th, 2000.
- The D-InSAR image shows deformation along an existing fault lines at the Frank Slide. This information is used to understand the post failure mechanism and mobility of the slide and target in the location of in-situ monitoring sensors

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RADARSAT D-InSAR 2000 11/10 & 2000 12/04

RADARSAT 42A F3f 2000 11/10

(c) INTERFEROGRAM

(d) MASTER IMAGE

Figure 2. (a) Helicopter view of Miyake-jima Volcano, July 2000. (b) Measurement of SO₂ daily average by the Geological Survey of Japan. (GSJ, 2004). (c) Filtered D-InSAR showing deformation. (d) RADARSAT C-HH fine mode image (8 m) (41.8-44.3 degrees) of Miyake-jima Volcano.