AIOS-PALSAR data for Landslide Monitoring and Geological Mapping

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Objectives

• InSAR monitoring of failure and post failure mechanism and mobility of several landslides in different climatic and geologic environments, affecting strategic transportation and energy corridors.

• Integrate ALOS images within current geological mapping programs
InSAR Monitoring of Landslides

• **Geological Setting**
  – Rock Avalanche
  – Retrogressive thaw slide
  – Deep-seated slide:

   - Frank Landslide & coal mine subsidence
   - Retrogressive thaw slide on permafrost affecting pipeline route- Thunder River

Road realignment and maintenance
Little Smokey
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Frank Slide: Rock Avalanche
90 fatalities in 1903: 6000 tons rock fall in 04
View from Interpretive Centre

East

Crest of Turtle Mountain Fold

Limestone (Livingstone Formation)

Muddy Limestone (Banff Formation)

Limestone (Livingstone Formation)

West

Slide Deposit

Sandstone and Mudstone (Kootenay Formation)

Coal Seam

Turtle Mtn. Fault
Monitoring Frank Slide, Alberta from RADARSAT-2 and ALOS

28-Apr-04 / 2-Jun-04
IS4 ascending orbit
Perpendicular Baseline: 351 m
Acquisitions 35 days apart

24-Oct-03 / 17-Nov-03
Ascending orbit
Perpendicular Baseline: 332 m
Acquisitions 35 days apart

Singhroy 2007
Frank Slide – ALOS and RADARSAT InSAR Results
ALOS Deformation map along Line of Sight Frank Slide

Incidence angle of ~37° (June Aug07)

Incidence angle of ~40° (June Aug07)

Deformation in slant direction (mm)

-30 0 30
D-InSAR monitoring of Permafrost melt landslides
Mackenzie Valley, Canadian Arctic
July – August 2006
F3F Desc. Rsat-1

Deformation in slant direction (mm)
-20 toward satellite 20 away
Incoherent data

Mackenzie River
Thunder River
ALOS: Snow Accumulation
(Dec 24-Feb8/08) related to Permafrost melt and Landslides

Ascending Image
Sensor Mode: Fine Beam Single polarization HH
Off Nadir Angle: 34.3
Perpendicular baseline 921m
InSAR monitoring of Little Smoky Landslide
ALOAS Little Smoky Landslide
13/06/07-29/-07/07 (414m baseline)

Enhanced interferogram

Magnitude of phase

Coherence
Geological Mapping with ALOS
Sudbury Basin

- World’s oldest, largest, and best-exposed meteorite impact site
  - 1.8 billion years old
  - 200-300 km original diameter
- World class mineral deposits
  - over 100 years of production worth more than $150 billion (contained metal in 2008 dollars)
  - Current production worth close to $3 billion per year
  - Significant new discoveries continue to be made

- Large mining cluster:

- CCRS developed several image integration tools that are being used by the mining industry.
Sudbury mine locations

Figure 1: Location map of Ni-Cu-PGE and Zn-Pb-Cu deposits and occurrences, Sudbury, Ontario, Canada. OF = Onaping Formation, SIC = Sudbury Igneous Complex
Sudbury Basin - North

RADARSAT 1 – SAR
C band – Beam Mode: Fine - HH polarization – ascending orbit
The image filtered and enhanced for visual interpretation

ALOS – PALSAR
L band – Beam Mode: Fine - HH polarization – ascending orbit
The image filtered and enhanced for visual interpretation

Singhroy 2007-CCRS
Sudbury High Resolution Image Integration

Both RADAR sensors integrated with magnetic vertical gradient and shaded relief

Integrated Bedrock Geology-RADARSAT-Digital Elevation Data
Sudbury High Resolution Image Integration

Both RADAR sensors integrated with magnetic vertical gradient and shaded relief

Integrated Bedrock Geology-RADARSAT-Digital Elevation Data
Merged Surficial Geology and shaded DEM, Sudbury Region

Legend
- Fill
- Modern Fluvial Deposits
- Wetland Areas
- Fluvial Deposits: sand, gravel in terraces
- Eolian Deposits: sand
- Glaciolacustrine Deposits: sand
- Glaciolacustrine Deposits: silt and sand
- Glaciolacustrine Deposits: clay and silt
- Outwash Deposits
- Ice-contact Stratified Deposits
- Till, associated with moraines
- Till
- Bedrock at or near surface
RADARSAT 1 – SAR
C band – Beam Mode: Fine
HH polarization – ascending orbit

ALOS – PALSAR
L band – Beam Mode: Fine
HH polarization – ascending orbit

Image Map Integration Steps:

+ Surficial Geology
+ Hill-shaded Digital Elevation Model
+ Landsat 7 bands 4, 5, 7
The ASAR-SHR-ETM+ image map provides structural/3D and color information of land cover.
Summary

Landslide Monitoring:
- ALOS PALSAR InSAR have assisted in mapping landslides in vegetated areas.
- The ALOS PALSAR InSAR results show deformation on rock and vegetated slopes on the Frank Slide. This was not observed on RADARSAT InSAR results over the same time period.

Geological Mapping:
- Our results show that in vegetated mineral belts in Canada the ALOS (L-HH) images are providing the same litho-structural information as RADARSAT-1 (C-HH) images. ALOS fused images maps are providing the baseline terrain information for surficial geologic mapping in Canadian mineral belts.
Landslide Studies: Key Questions

1. **Identification, mapping and monitoring of landslides**: which parameters can be best derived from PRISM, AVNIR-2 and PALSAR?

2. Which is the ideal **PALSAR configuration** (polarisation / incidence angle...) for mapping landslide features?

3. Compared to existing C-band/X-band sensors and related observation cycles, what are the advantages/disadvantages of **ALOS PALSAR for landslide monitoring**? How best can research benefit of multi-band observations?

4. Does L band InSAR provide any additional information for monitoring **landslide motion on vegetated slopes**?
Landslide Studies: Key Findings

1. Identification, mapping and monitoring of landslides: Which parameters can be best derived from PRISM, AVNIR-2 and PALSAR?

- **PRISM, AVNIR-2 and PALSAR are all useful** for landslide identification, mapping and monitoring

- The stereo capability of PRISM, like other high resolution stereo optical images, provides the geomorphological characterization of landslides to assist in the classification of landslides. To date there are limited examples exist.

- More convincing case studies using high resolution PRISM are needed for landslide inventory mapping.

- Based on a few examples, to date, **ALOS PALSAR InSAR monitoring results show deformation on rock and vegetated slopes** and compliments InSAR monitoring results from C and X band satellites.

- **Polarimetric InSAR capabilities of ALOS for landslide motion have not been fully explored to date**

- Given that landslide motion activities are increased during frequent wet periods, the current 46 day repeat cycle is limiting to monitor landslide motion. **Small baselines and weekly revisits are the requirements for landslide monitoring.**

2. Which is the ideal PALSAR configuration (polarisation / incidence angle...) for mapping landslide features?

- This has not yet been determined. However, early results have shown that **40 degrees fine mode** are useful to monitor motion on steep slopes.

3. Compared to existing C-band/X-band sensors and related observation cycles, what are the advantages/disadvantages of ALOS PALSAR for landslide monitoring? How best can research benefit of multi-band observations?

- With the current lack of SAR constellations to date, InSAR motion monitoring from separate C, X and L are useful for landslide motion monitoring and mitigation.

- Early results have shown that **L band InSAR do map very slow motion on sparsely vegetated slopes**, not seen by other SAR satellites.

- The 46 day repeat cycle is limiting factor.

- **INSAR images with similar viewing geometry are seriously lacking for landslide motion monitoring**, and there convincing case studies are not readily available.

4. Does L band InSAR provide any additional information for monitoring landslide motion on vegetated slopes?

- Early results have shown that **L band InSAR do map very slow motion on sparsely vegetated slopes**, not seen by other SAR satellites. More case studies are required.