PSI for landslide hazard assessment and monitoring: current issues and under-exploited opportunities

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Motivation

**Big Data** from satellite SAR, including high res. sensors e.g., COSMO-SkyMed and TerraSAR-X, and now SENTINEl-1

→ PSI now more effective for slope hazard detection & monitoring thanks to improved spatio-temporal resolutions & processing

→ Expect greater use of PSI for regular, wide-area & detailed scale landslide assessment

PSI potential is under-exploited in landslide hazard research & applications → raise awareness of current / future opportunities
I. A priori assessments of PSI applicability for landslide study → need detailed land cover & topo information

II. Multi sensor / band, medium and / or high resolution data? → from background medium res. to focused high res. monitoring

III. Under-exploited opportunities

   a) Where? Especially in developing / newly industrialized countries = most landslide hit

   b) X-band high res. PSI can provide useful info on landslides also in the green tropics

   c) Early detection of slope hazards i.e., where, but temporal predictions very difficult
Investigating landslides and unstable slopes with satellite Multi Temporal Interferometry: Current issues and future perspectives

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Multi Temporal Interferometry (MTI) stands for advanced synthetic aperture radar differential interferometry (DInSAR) techniques, which include Permanent/Persistent Scatterers Interferometry — PSI/DInSAR — and similar methods, as well as Small Baseline Subset — SBAS and related/hybrid approaches. These techniques are capable of providing wide-area coverage (thousands of km²) and precise (mm–cm resolution), spatially dense information (from hundreds to thousands of measurement points/km²) on ground surface deformations. New MTI application opportunities are emerging thanks to i) greater data availability from radar satellites, and ii) improved capabilities of the new space radar sensors (X-band Cosmo-SkyMed, C-band RADARSAT-2, TerraSAR-X) in terms of resolution (from 3 to 1 m) and revisit time (from 11 to 4 days for X-band acquisitions). This implies greater quantity and quality information about ground surface displacements and hence improved landslide detection and monitoring capabilities. Even though the applicability of MTI to regional and local-scale investigations of slow landslides has already been demonstrated, the awareness of the MTI utility and its technical limitations among landslide scientists and practitioners is still rather low. By referring to recent works on radar remote sens-
Overview article on remote sensing of landslide motion with emphasis on multi temporal interferometry

Wasowski & Bovenga, 2014, Chapter 11
Remote Sensing of Landslide Motion with Emphasis on Satellite Multitemporal Interferometry Applications: An Overview
p. 345-403
http://dx.doi.org/10.1016/B978-0-12-396452-6.00011-2
A priori feasibility assessment of PSI

1. Landslides are local features, often too “fast” and in harsh environments for PSI (rough topo, vegetation, wet climate)

2. Applicability assessments require suitable resolution info on land cover, topography to get reliable prediction of PS densities

3. With ERS, ENVISAT, RADARSAT-1 usually <10% of landslides suitable for PSI monitoring (review by Wasowski & Bovenga, 2014)

4. Expect better coverage with Sentinel-1 (shorter revisit), but with much slope- and landslide-specific variability

5. Greater PS densities with high res. data e.g., X-band CSK, TSX, but non-uniform distributions (and high costs)
1. Greater SAR data availability → data selection strategy

2. Always good to have Asc. and Desc. datasets (topo visibility, 2-3D deformation field reconstruction, cross-check)

3. Wide-area investigation → medium resolution e.g., Sentinel-1 more cost-effective

4. Urbanized areas & sites with critical facilities at risk (e.g. dams, transport infrastructure) → cost of high res. data justified

5. Ideally, long term, medium resolution background monitoring → focused high res. shorter term monitoring of “hotspots”
From wide-area to local scale investigation – S. Apennines overview of hilltop towns stability with ENVISAT data
Southern Apennines: local scale investigation: town of Bovino – ENVISAT desc. & asc. data
Southern Apennines: **local scale investigation:**
town of Pietramontecorvino – TSX & ENVISAT data
From large slope to site-specific investigation: town of St. Moritz, Switzerland – ENVISAT asc. data
Site-specific investigation: St. Moritz, Switzerland
CSK asc. Stripmap data
Site-specific investigation: St. Moritz
CSK vs ENVISAT asc. data

CSK - shorter time series
28 images 3/2009 - 10/2010

ENV - longer time series
Under-exploited opportunities – where?
Distribution of non-seismic fatal landslides in 2004-2010
(Petley, 2012)
Non-seismic fatal landslides in 2004-2010 (Petley, 2012)
vs PSI-based landslide investigations
High resolution X-band PSI for landslide monitoring in the green tropics?
Non-seismic fatal landslides in 2004-2010 (Petley, 2012)

Haiti case study
Haiti – new SAR data after the deadly Jan 2010 earthquake exploited mainly by geophysicists

Ali et al., 2008
Haiti: coverage of CSK Stripmap imagery
Haiti: PSI results from CSK Stripmap data

~3MM targets
Active slide & local instabilities along the National Route 3
PSI results from CSK data
Early detection of slope hazards
Jan 2014 slope failure & train accident near the town of Marina di Andora, NW Italy
Jan 2014 slope failure & train accident near the town of Marina di Andora, NW Italy
PSI velocity map along the railway near Marina di Andora
CSK Stripmap data
PSI velocity map – zoom at the failed slope area
Time series (2008-2014) of PS from a building just above the failed slope: avg. velocity 9 mm/yr

PS L05734P09339, Vel= -0.9 cm/y, coh=0.86

Failure 17.01.14
Warning signal in time deformation series?

PS L05734P09339, Vel = -0.9 cm/y, coh = 0.86

failure
Lessons from the Andora slope failure & train accident

✓ Small landslide, but big problem → need good spatial resolution

✓ Deformation trends from long-term HR PSI monitoring of slopes → unique opportunity for early detection and warning of hazards i.e. where?

✓ Temporal predictions, i.e. when? very difficult, even via in situ monitoring

See also poster #14 this afternoon (Nutricato et al.)
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