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ICTP SAR Workshop | Trieste | 3rd Sept 13

Landslides and InSAR: Breakthroughs and recent developments

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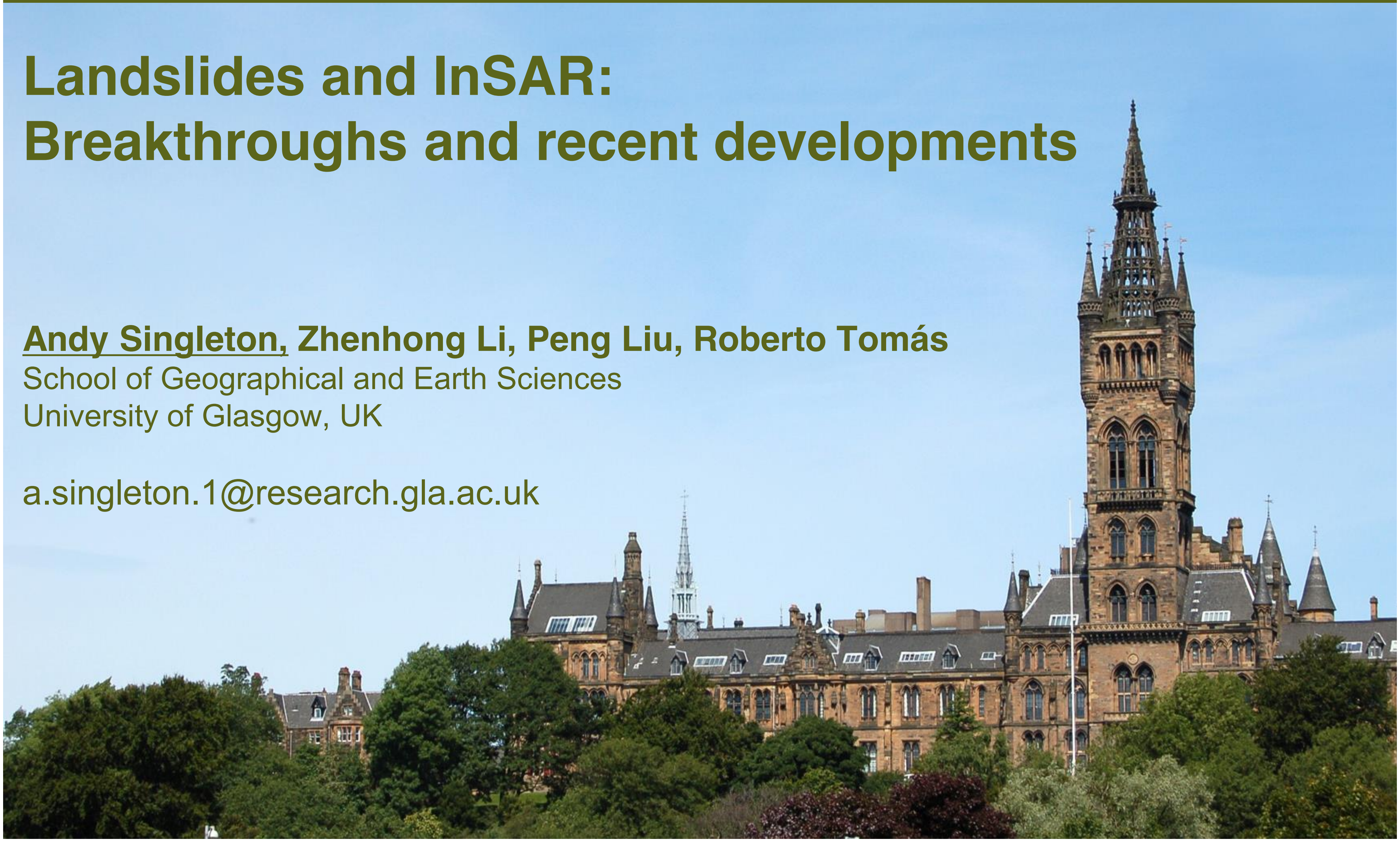
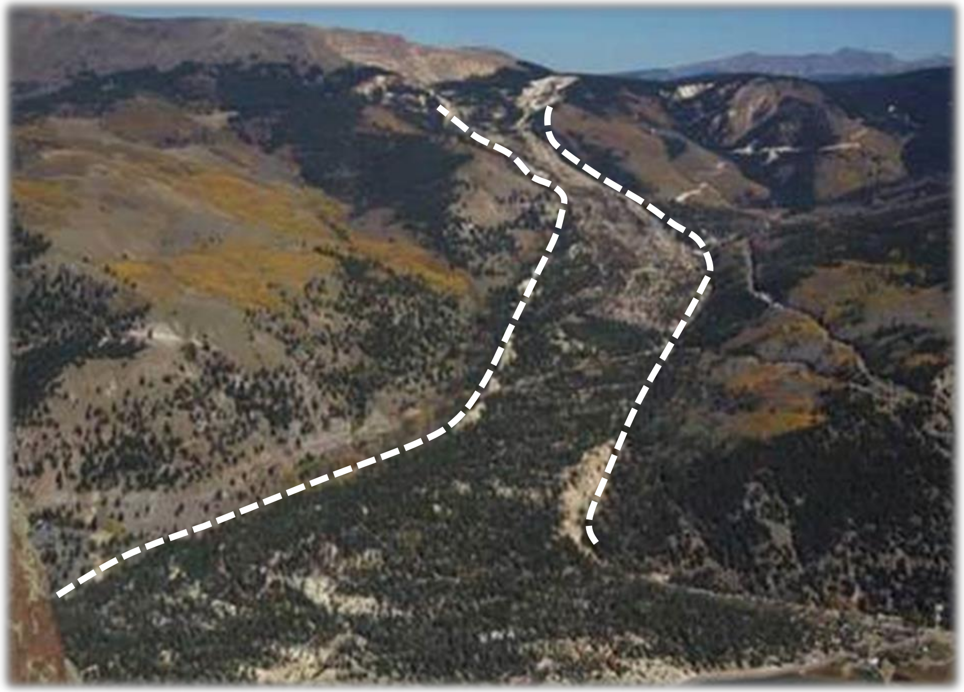


How can InSAR help landslide studies?

Detection → Mapping/Measuring



Long-term monitoring ← Characterisation

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How it all began…

- Fruneau *et al.,* 1996

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Tectonophysics 265 (1996) 181–190

TECTONOPHYSICS

Observation and modelling of the Saint-Étienne-de-Tinée landslide using SAR interferometry

B. Fruneau, J. Achache [*], C. Delacourt

Département Etudes Spatiales, Institut de Physique du Globe de Paris 4, place Jussieu, 75252 Paris, France

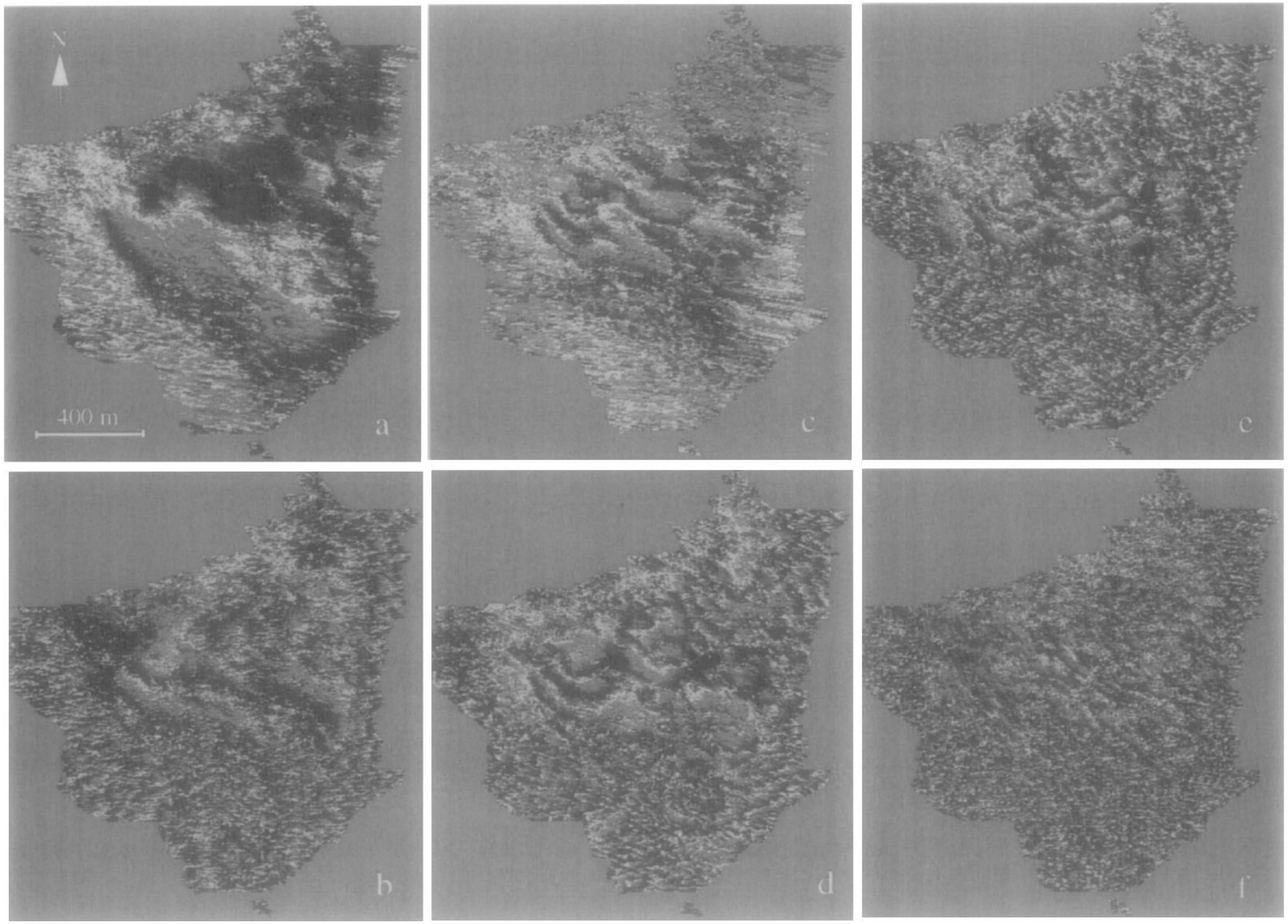
Received 16 October 1995; accepted 11 March 1996

Abstract

Six different interferograms of the ''La Clapière'' landslide were derived from ERS-1 SAR images during the period Aug. 20–Sept. 4, 1991. The coherence of the associated images is shown to remain significant over most of the surface of

How it all began…

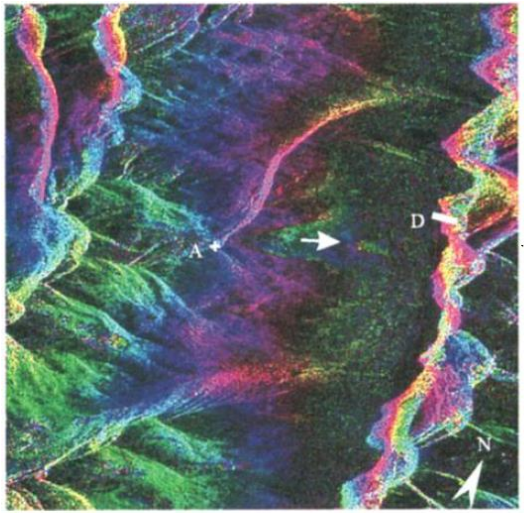
- Fruneau *et al.*, 1996

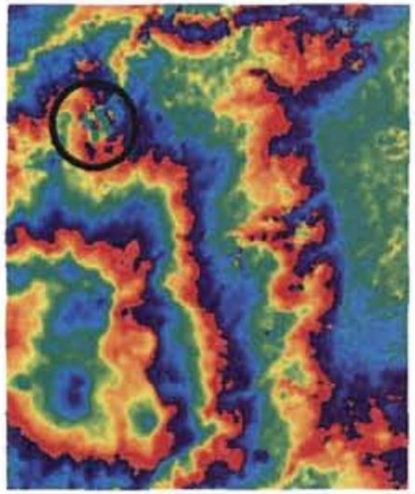


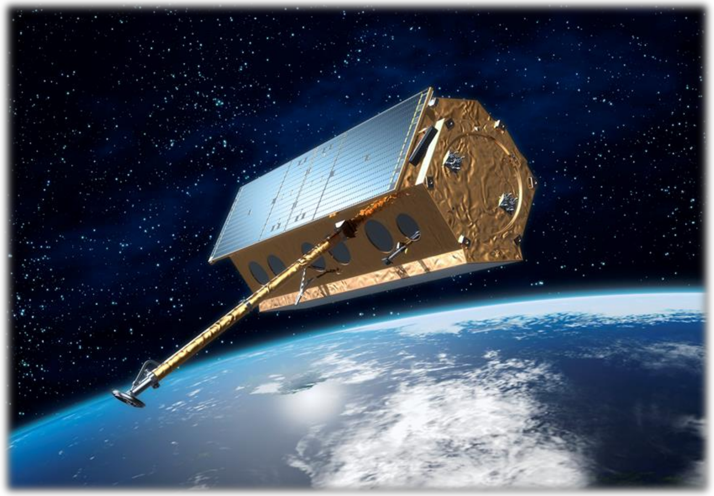
Landslide-related developments

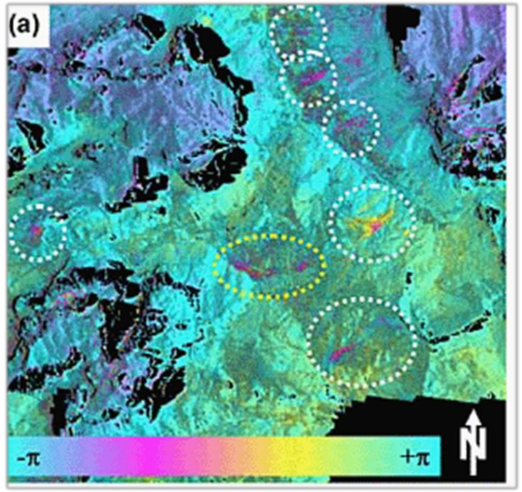
- 1996: Fruneau *et al.*
- 1999: Rott *et al.*
- 2000: Kimura & Yamaguchi (+ SRTM)
- 2001: Ferretti *et al.*
- 2004: Hilley *et al.* Science
- 2005: Strozzi *et al.*
- 2006: Colesanti & Wasowski
- 2007: TerraSAR-X and COSMO SkyMed
- 2011: SAR sub-pixel offsets for landslides

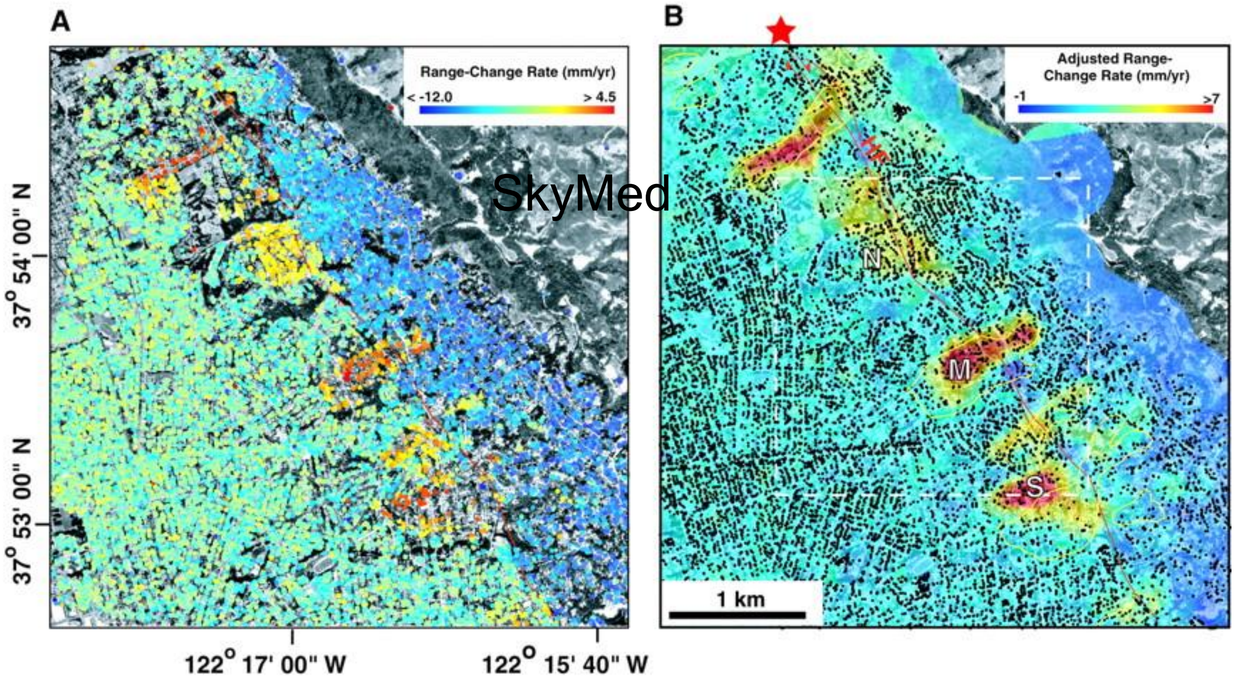
Landslide-related developments











SkyMed

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Landslide-related developments

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Engineering Geology 88 (2006) 173–199

ENGINEERING GEOLOGY

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Investigating landslides with space-borne Synthetic Aperture Radar (SAR) interferometry

Carlo Colesanti [1], Janusz Wasowski [a,*]

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Accepted 11 September 2006
Available online 15 November 2006

8 IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 39, NO. 1, JANUARY 2001

Permanent Scatterers in SAR Interferometry

Alessandro Ferretti, Claudio Prati, and Fabio Rocca

***Abstract*—Temporal and geometrical decorrelation often prevents SAR interferometry from being an operational tool for surface deformation monitoring and topographic profile reconstruction. Moreover, atmospheric disturbances can strongly compromise the accuracy of the results. In this paper, we present a complete procedure for the identification and exploitation of stable natural reflectors or permanent scatterers (PSs) starting from long temporal series of interferometric SAR images. When, as it often happens, the dimension of the PS is smaller than the resolution cell, the coherence is good even for interferograms with baselines larger**

[11], [8], [26], [24]) and cannot be detected and estimated from the coherence map associated with each interferogram [2].

The main goal of this paper is the identification of image pixels, hereafter called permanent scatterers (PSs), coherent over long time intervals [3], [4]. When, as it often happens, the dimension of the PS is smaller than the resolution cell, the coherence is good even for interferograms with baselines larger than the decorrelation one [6], and all the available images of

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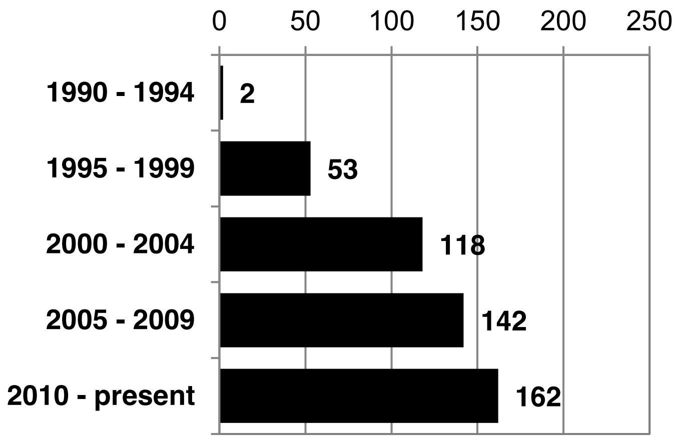
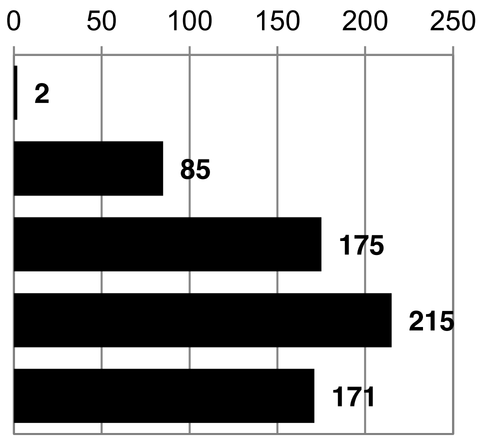
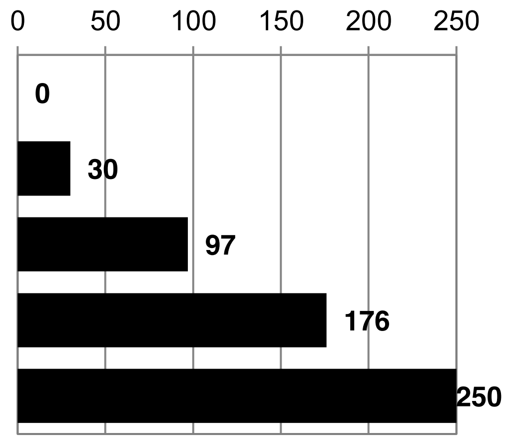
The rise of SAR interferometry



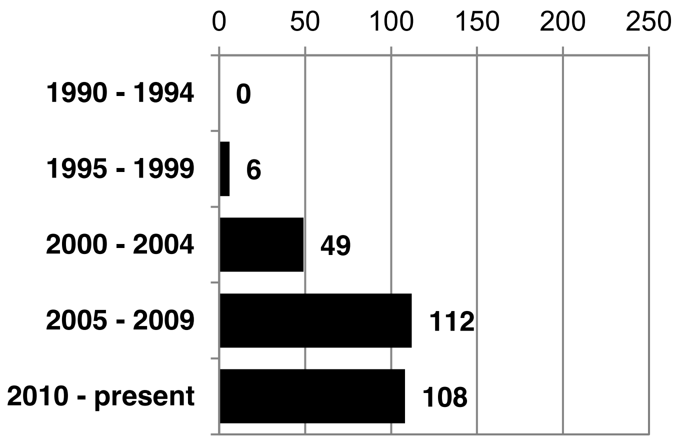
Earthquakes = 477



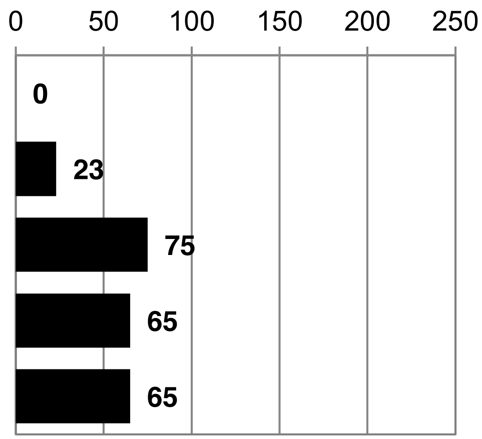
Elevation = 648



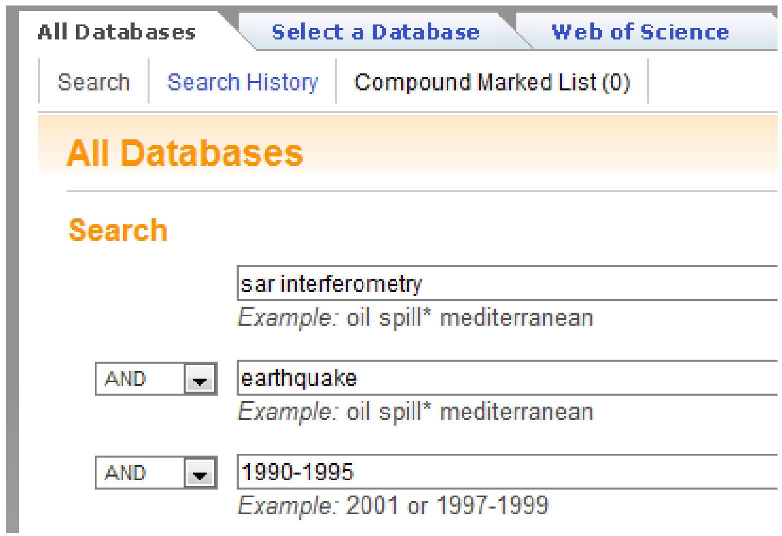
Subsidence = 553



Landslides = 275



Volcanoes = 228

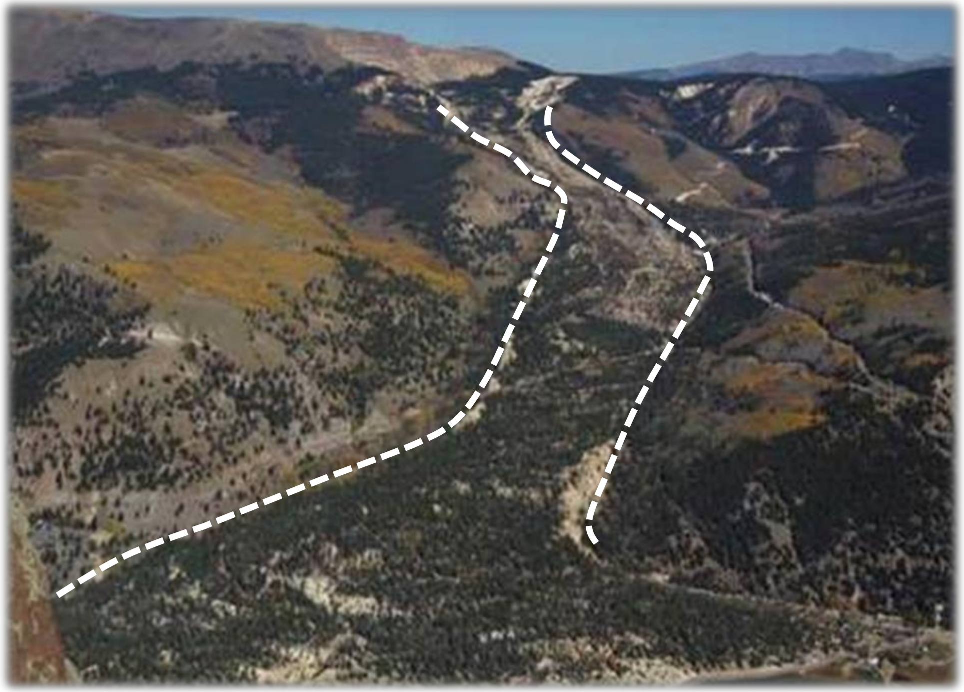


Limitations of InSAR

Detection → Mapping/Measuring

Coherence loss
Bad geometry
Scale

(landcover, landslide speed, orientation, size, SAR resolution, wavelength, baseline and repeat interval)



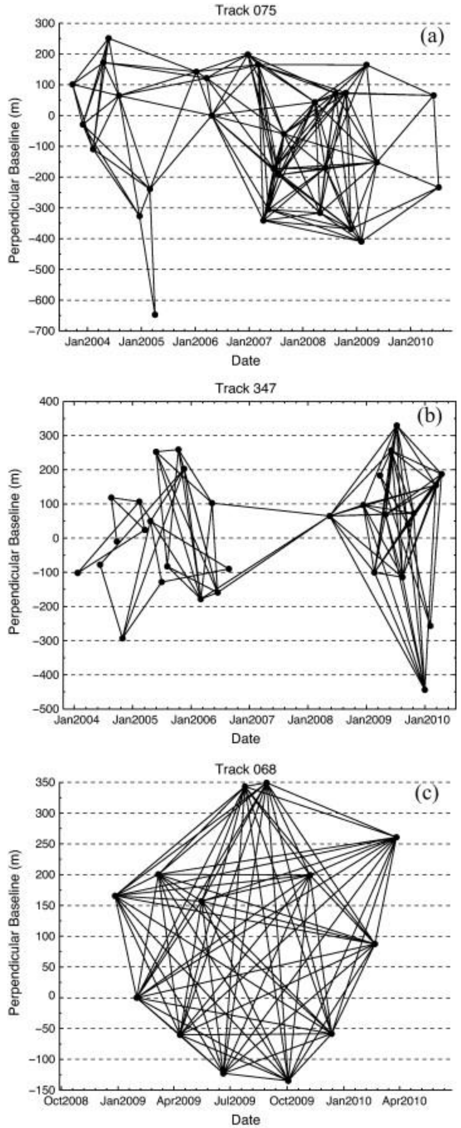
Atmosphere
Ionosphere

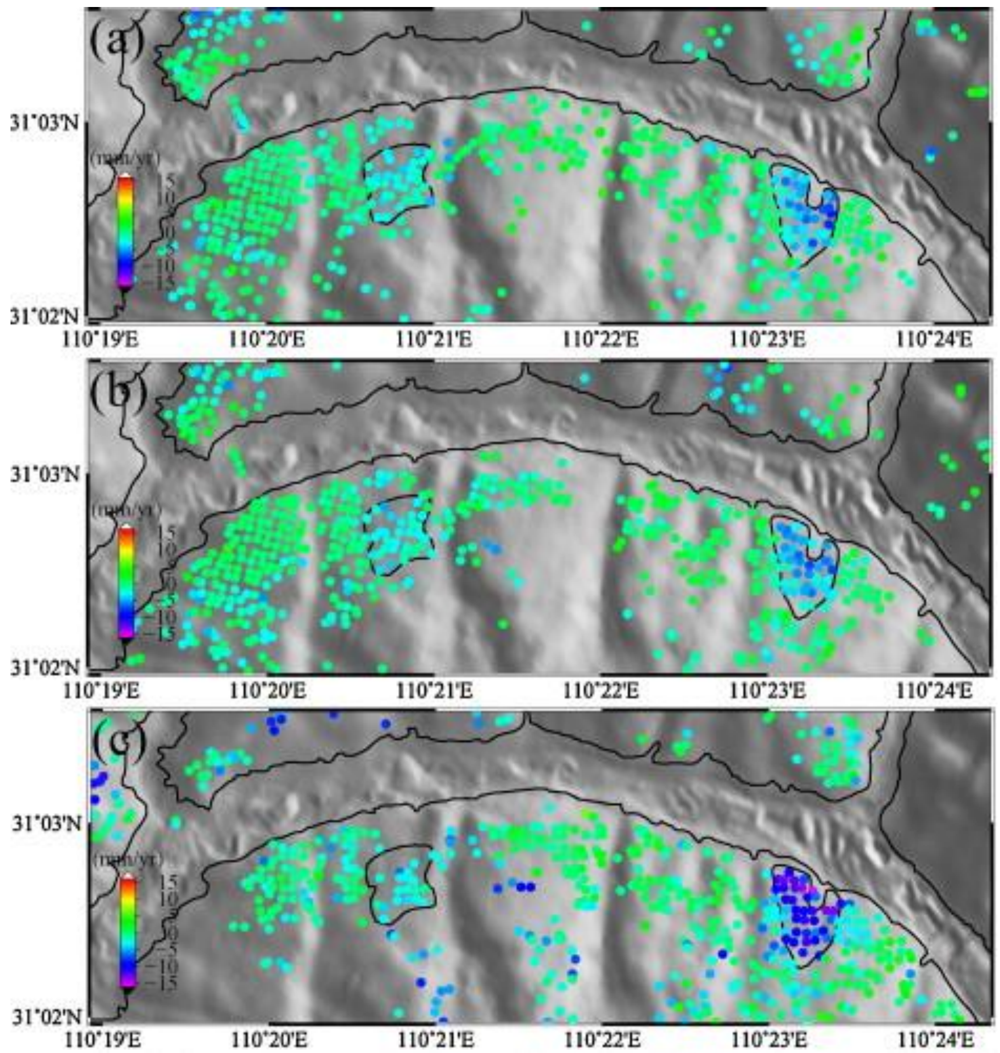
(Rate & scale of movement, SAR wavelength, landslide location)

Long-term monitoring ← Characterisation

1-D sensitivity

InSAR TS results (Badong, China)





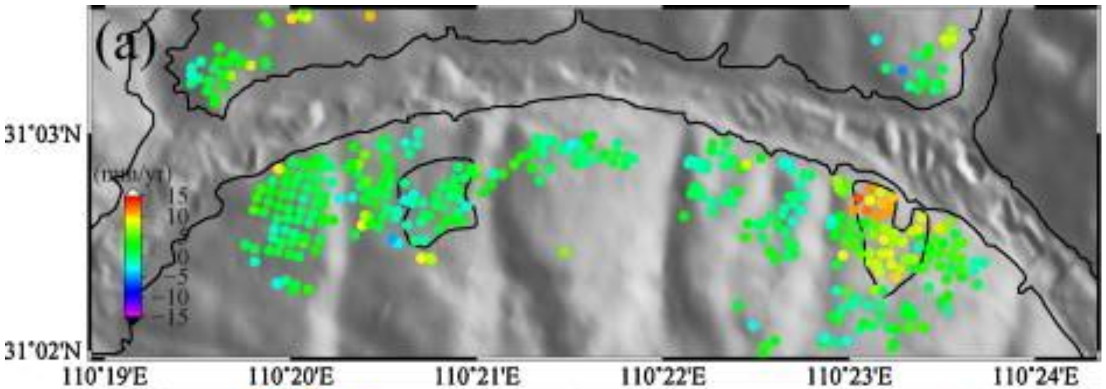
- Liu *et al.*, 2013. *International Journal of Applied Earth Observation and Geoinformation*

Landslide Interpretations

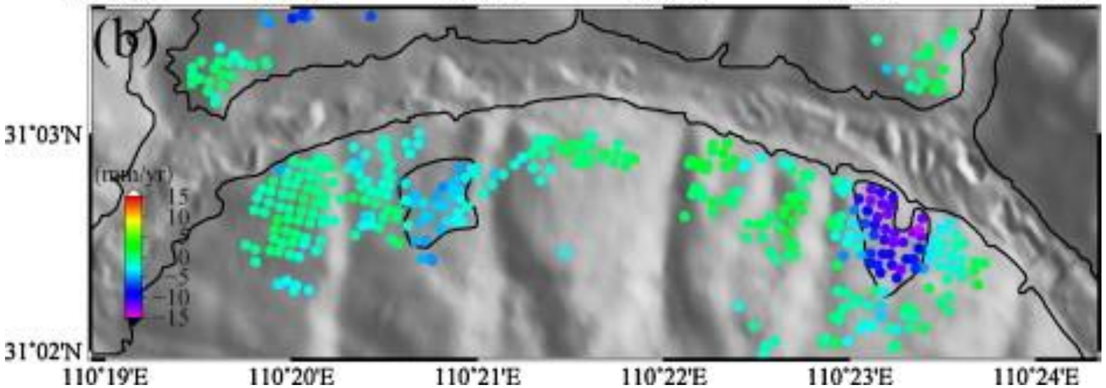
$$\begin{pmatrix} \sin\phi_{075}\sin\theta_{075} & \cos\theta_{075} \\ \sin\phi_{068}\sin\theta_{068} & \cos\theta_{068} \\ \sin\phi_{347}\sin\theta_{347} & \cos\theta_{347} \end{pmatrix} \begin{pmatrix} V_n \\ V_u \end{pmatrix} = \begin{pmatrix} V_{LOS075} \\ V_{LOS068} \\ V_{LOS347} \end{pmatrix}$$

*requires E-W assumption

<u>North:</u>

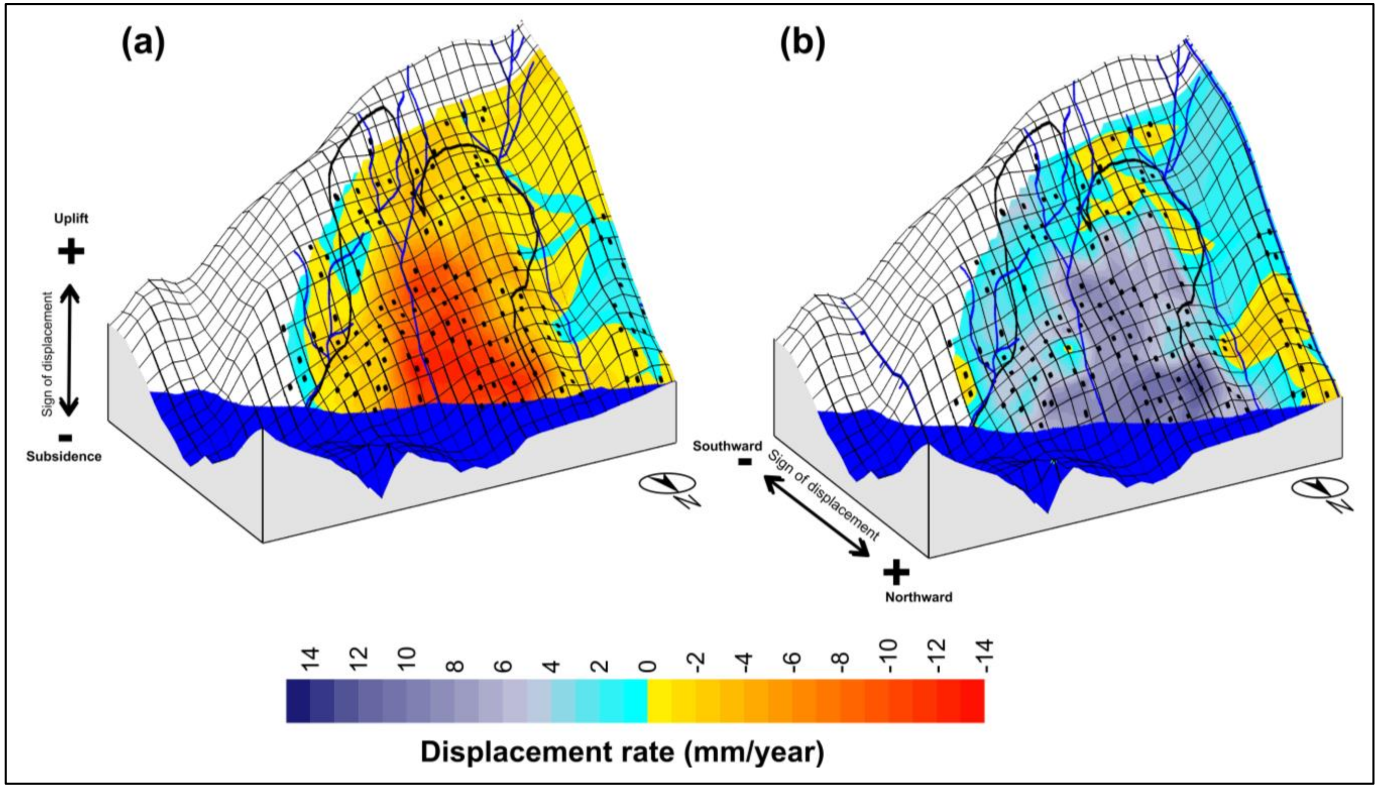


<u>Vertical:</u>



- Tomás *et al.,* submitted. *Geophysical Journal International*
- Liu *et al.,* 2013. *International Journal of Applied Earth Observation and Geoinformation*

Landslide Interpretations



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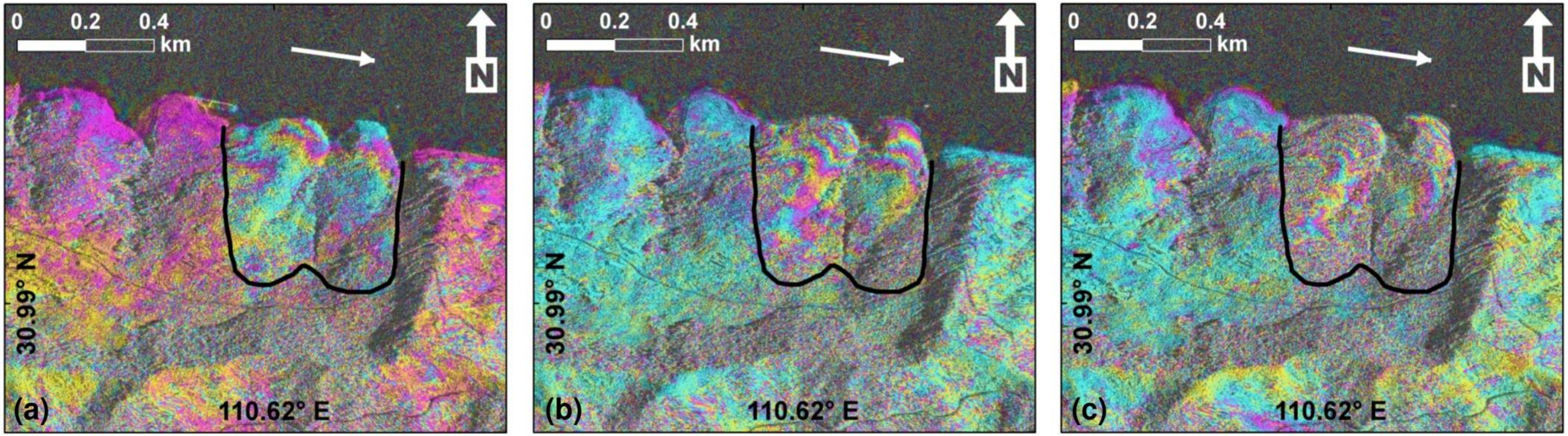
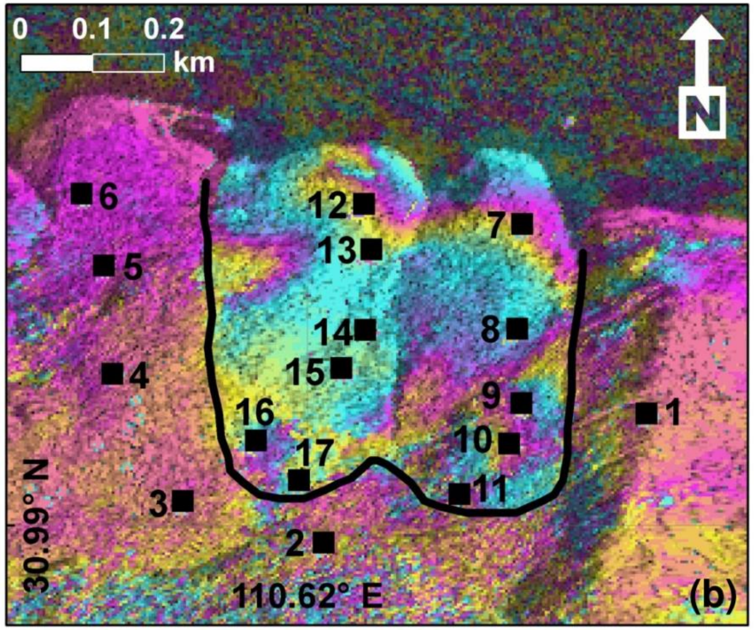
Coherence loss and 1-D sensitivity

Problems of coherence loss

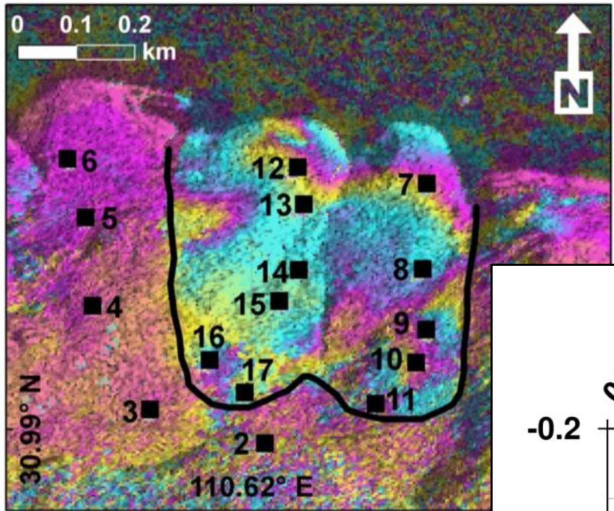
28th Apr – 9th May 2009 | 9th – 20th May 2009 | 20th – 31st May 2009

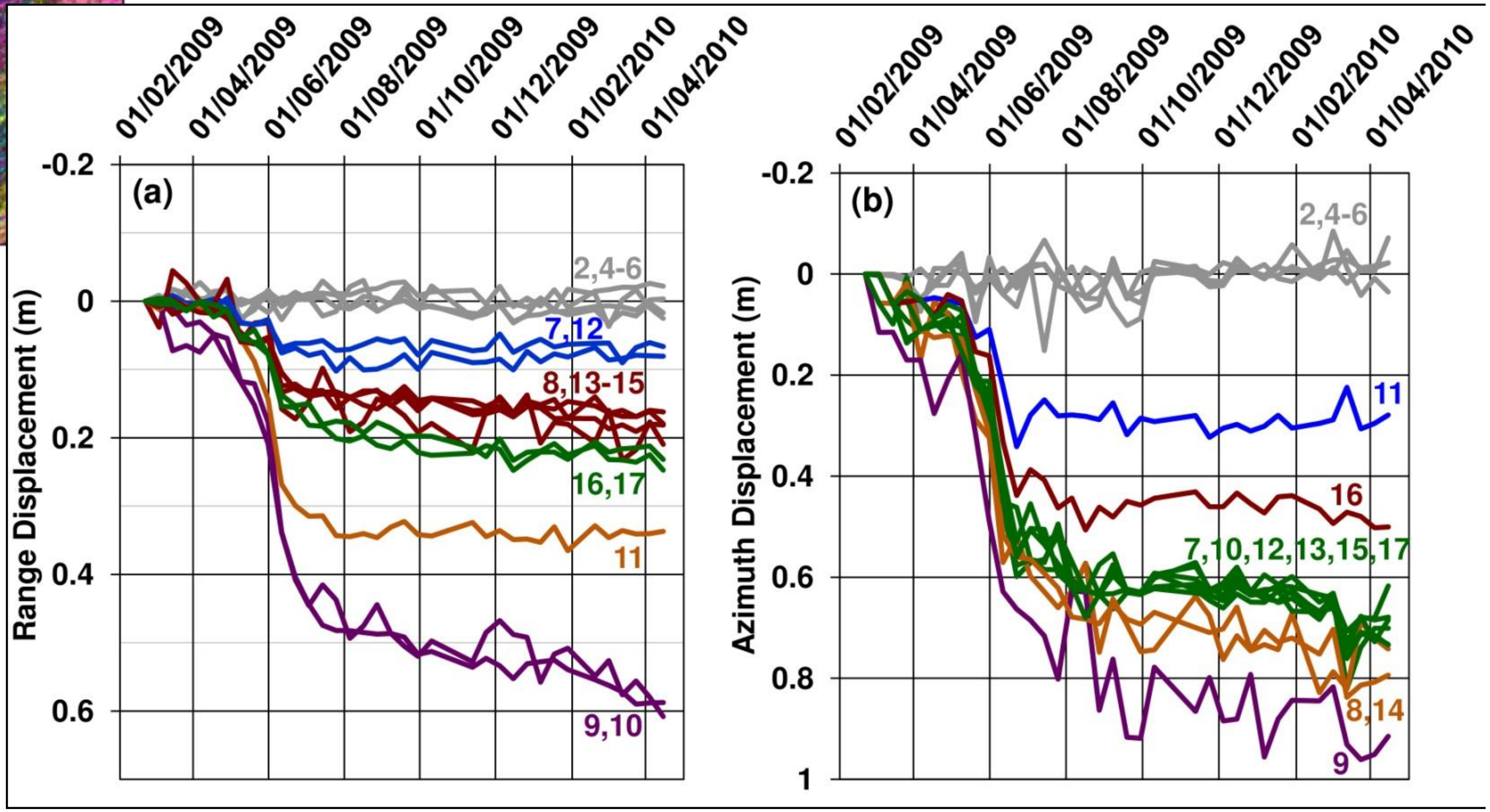


The use of corner reflectors in vegetated terrain



The use of corner reflectors in vegetated terrain





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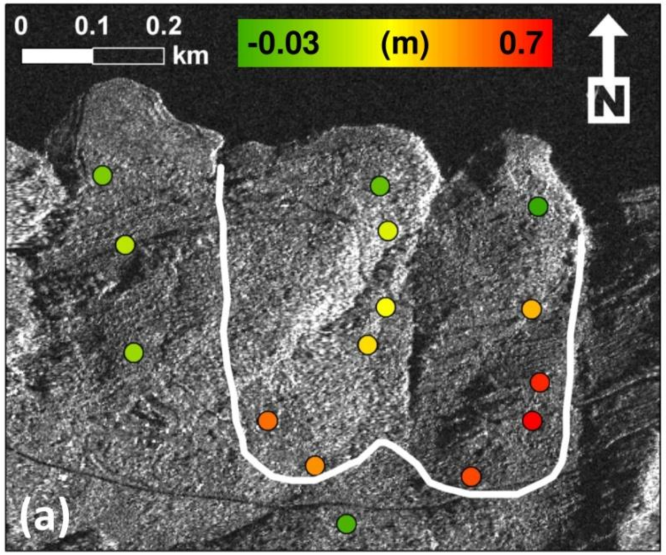
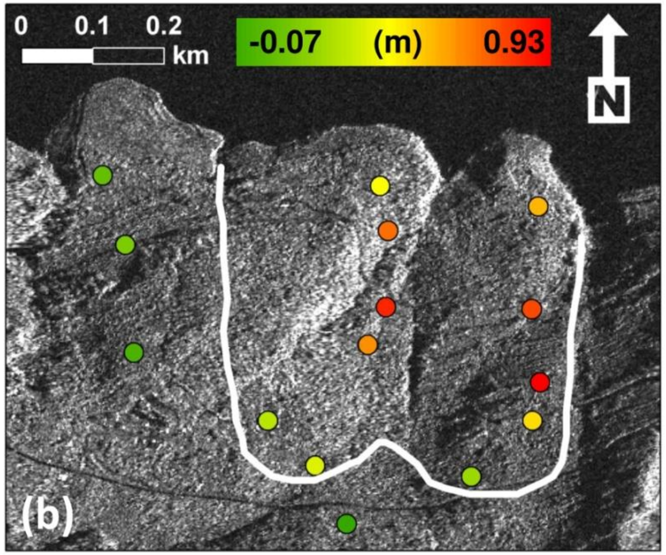
Accuracy assessment

Sensor / Image Mode	Range offsets		Azimuth offsets	
	Mean difference (m)	RMS Error (m)	Mean difference (m)	RMS Error (m)
TSX Spotlight (corner reflectors)	0.012	0.015	0.052	0.057
TSX Spotlight (natural reflectors)	0.466	0.522	0.662	1.122

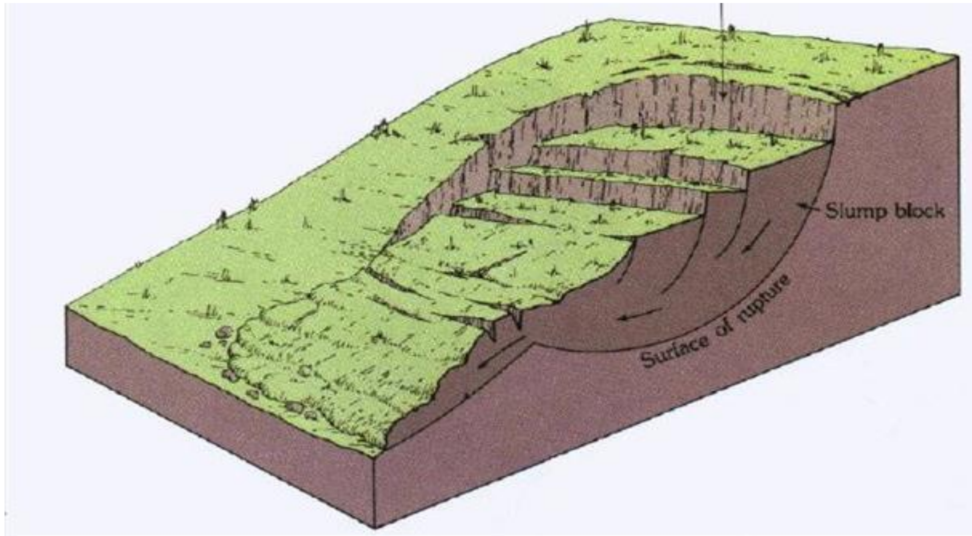
Landslide interpretations



Vertical



North



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Conclusions

- SAR/InSAR techniques have been successfully applied in many examples…
  - …for the detection/delineation of previously unknown landslides.
  - …for regular monitoring of known landslides.

- Current major limitations:
  - Temporal resolution of SAR images (not suitable for early warning systems).
  - Availability of highly reflective objects amongst dense vegetation.

- Comparisons:

X-band (e.g. TerraSAR-X & CSK)	L-band (e.g. ALOS 1-2)
• Shorter repeat interval	• Higher displacement gradients
• High resolution Spotlight mode	• Greater penetration of vegetation
• Transmission rate affected by rain	• More affected by the ionosphere
• Still alive!	• Quad-Polarisation modes

Future developments…?

<u>Systems</u>

- Sentinel-1 satellite(s)
- ALOS 2
- TerraSAR-X2
- Radarsat Constellation

- Airborne SAR
- UAV SAR

- Ground-based SAR for more frequent monitoring

<u>Techniques</u>

- Installation of artificial reflectors for high quality repeat measurements

- Data processing advancements?
- Automated-processing of global(?), regularly acquired data

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Thanks for listening

Comments / Questions?

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