ETH zürich

How is space borne SAR useful to investigate rapid mass movements?

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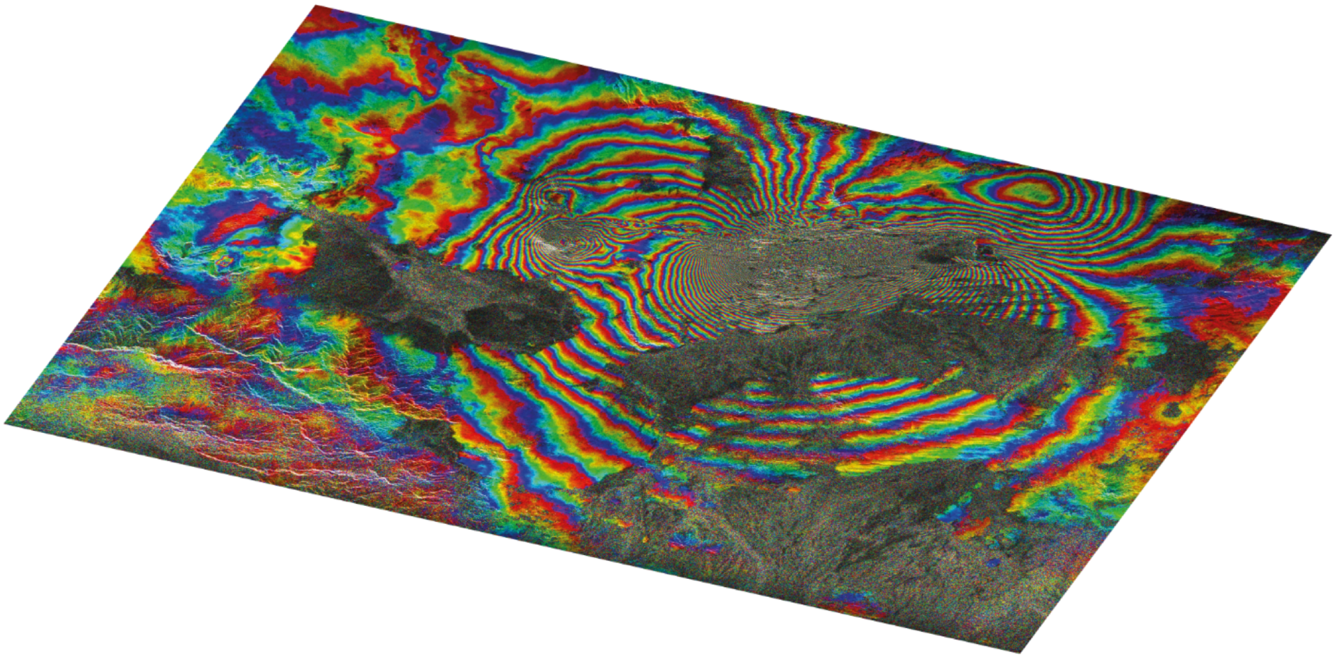
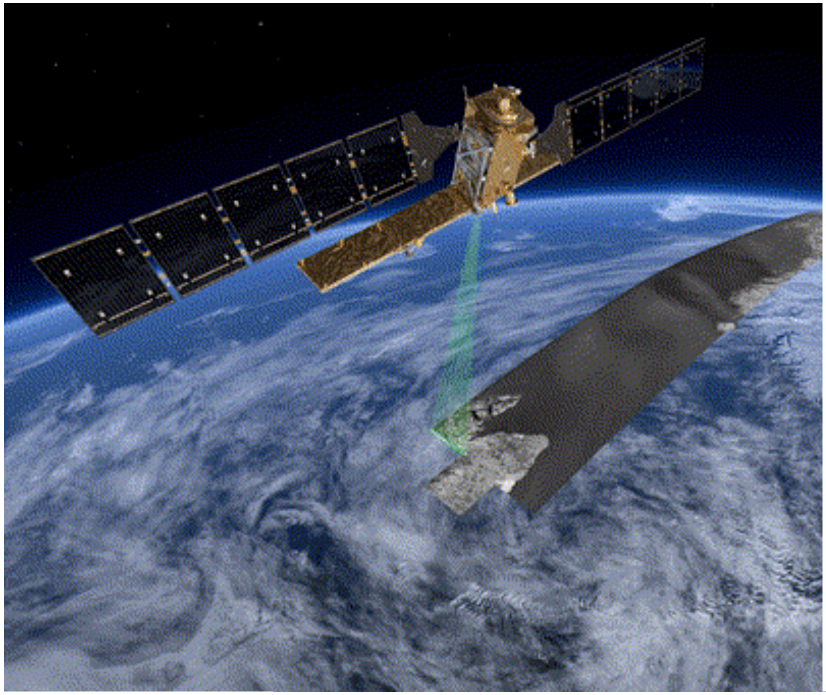
DERDW
EARTH SCIENCES



SAR to study mass movements: Why?



- Day & Night, all weather conditions: suitable for rapid change detection assessments also during emergencies
- Measurements with large spatial coverage (regional scales)
- Differential interferometry (DInSAR) can provide information on long-term and short term) surface deformation

Main SAR products to detect/map/monitor changes due to mass movements

- Amplitude (measures intensity of backscattering, depends mainly on roughness and water content)
- Phase (InSAR to generate DEMs or DInSAR to measure surface displacements between subsequent acquistions)
- Coherence (i.e., correlation of the phase of the signal between two or more SAR acquisitions, indication of quality of the signal)

Rapid mass movements

Varnes, 1978
Cruden, & Varnes,1996
Hungr et al., 2014

Table 1 A summary of Varnes' 1978 classification system (based on Varnes 1978, Fig. 2.1)

Movement type	Rock	Debris	Earth
Fall	1. Rock fall	2. Debris fall	3. Earth fall
Topple	4. Rock topple	5. Debris topple	6. Earth topple
Rotational sliding	7. Rock slump	8. Debris slump	9. Earth slump
Translational sliding	10. Block slide	11. Debris slide	12. Earth slide
Lateral spreading	13. Rock spread	–	14. Earth spread
Flow	15. Rock creep	16. Talus flow	21. Dry sand flow
		17. Debris flow	22. Wet sand flow
		18. Debris avalanche	23. Quick clay flow
		19. Solifluction	24. Earth flow
		20. Soil creep	25. Rapid earth flow
			26. Loess flow
Complex	27. Rock slide-debris avalanche	28. Cambering, valley bulging	29. Earth slump-earth flow

Table 2 Landslide velocity scale (WP/WLI 1995 and Cruden and Varnes 1996)

Velocity class	Description	Velocity (mm/s)	Typical velocity	Response[a]
7	Extremely rapid	5×10^{3}	5 m/s	Nil
6	Very rapid	5×10^{1}	3 m/min	Nil
5	Rapid	5×10^{-1}	1.8 m/h	Evacuation
4	Moderate	5×10^{-3}	13 m/month	Evacuation
3	Slow	5×10^{-5}	1.6 m/year	Maintenance
2	Very slow	5×10^{-7}	16 mm/year	Maintenance
1	Extremely Slow			Nil

[a] Based on Hungr (1981)

Space borne SAR & Rapid mass movements

Description	Velocity (mm/s)	Typical velocity	
Extremely rapid	5×10^{3}	5 m/s	Amplitude & Coherence
Very rapid	5×10^{1}	3 m/min	
Rapid	5×10^{-1}	1.8 m/h	
Moderate	5×10^{-3}	13 m/month	
Slow	5×10^{-5}	1.6 m/year	Phase
Very slow	5×10^{-7}	16 mm/year	
Extremely Slow			

Intrinsic limitations: space borne SAR is a great tool, BUT…

→ Relatively poor spatial / temporal sampling

→ Geometric distortions / viewing geometry

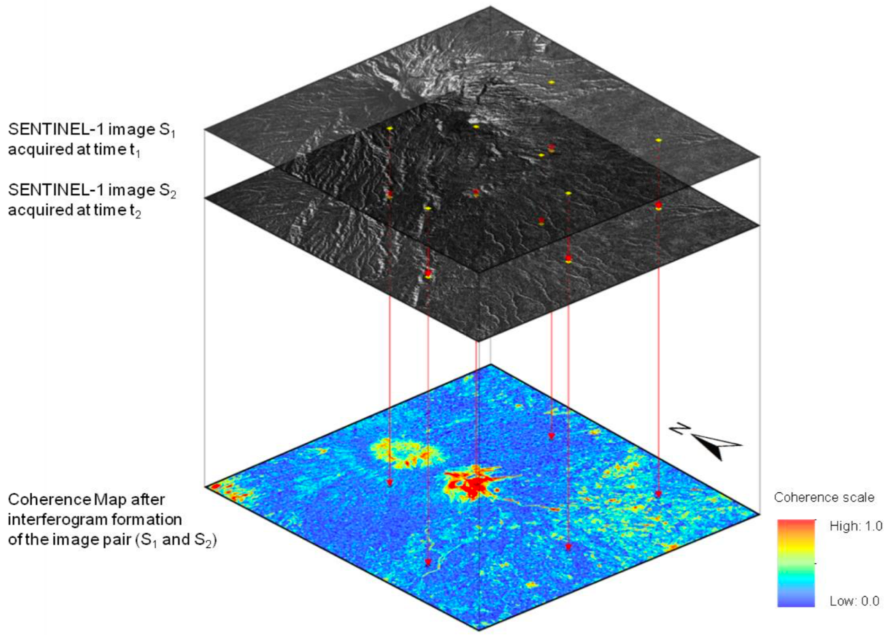
→ Atmospheric disturbances

Volcàn de Colima, Mexico

Montegrande ravine, regularly affected by lahars. After the large explosive event in July 2015 (and a subsequent pyroclastic flow) we aimed at studying the potential of Sentinel-1 to detect changes associated to erosion/deposition processes in the ravine.

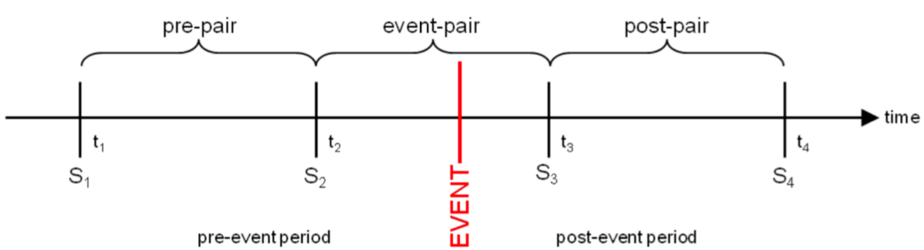
Analysis of the changes in coherence due to lahars in the Montegrande ravine

B. Ruf, MSc thesis ETH, 2018

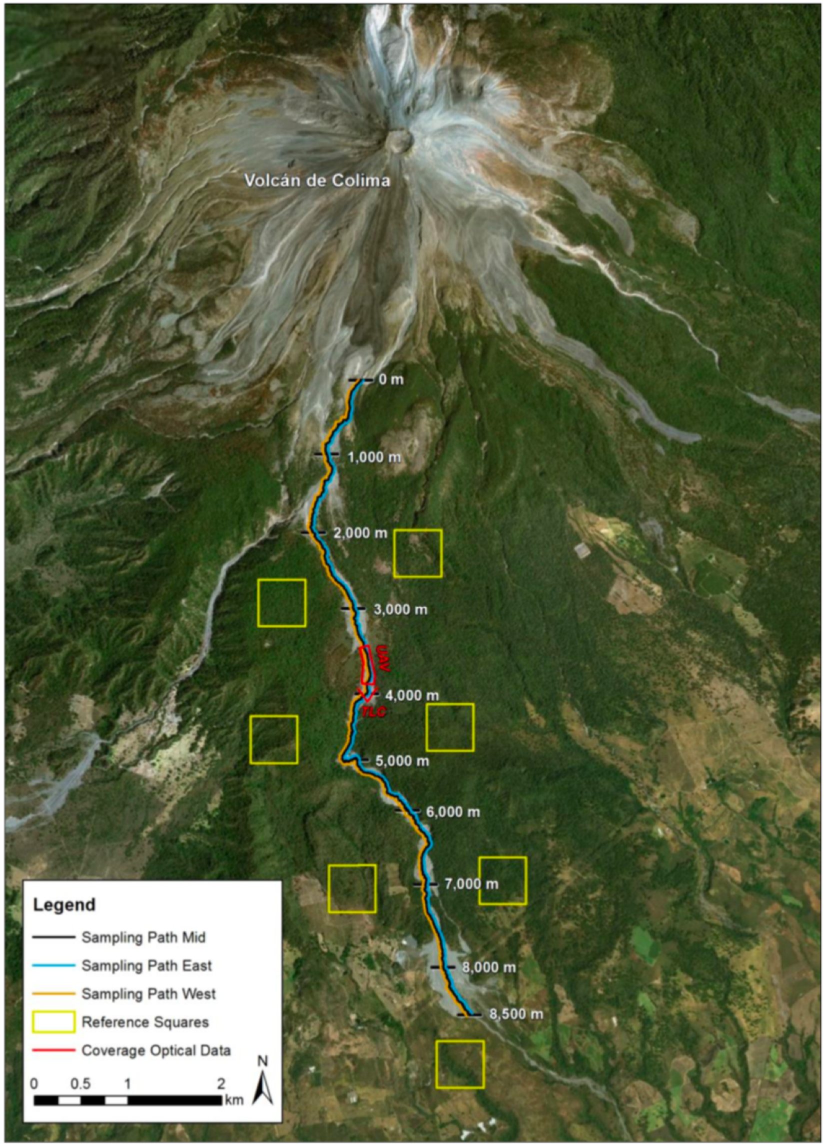


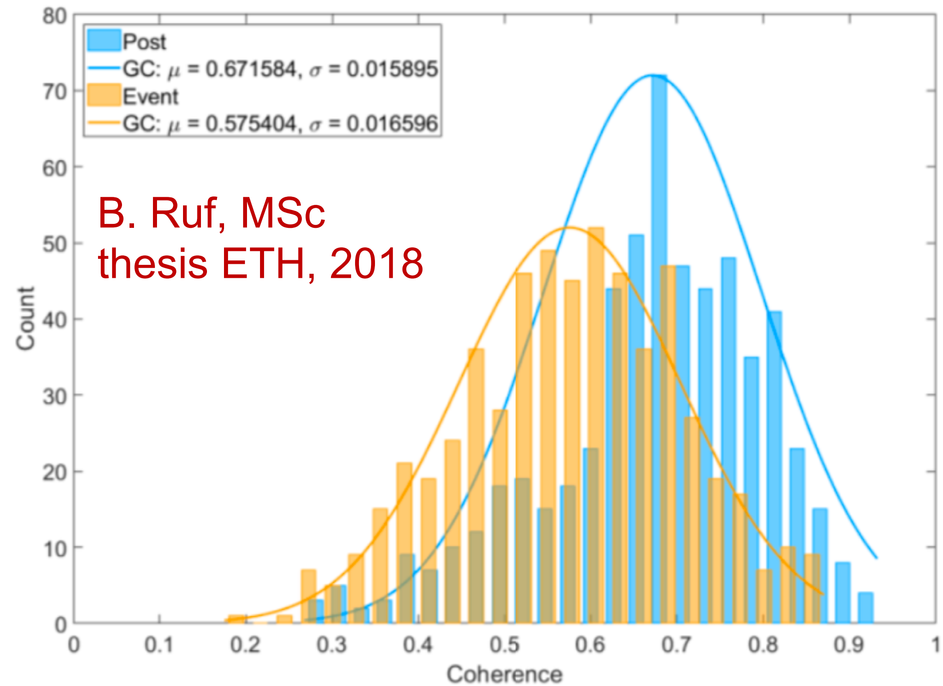
Analysis of the period after the pyroclastic flow (2015-2017)

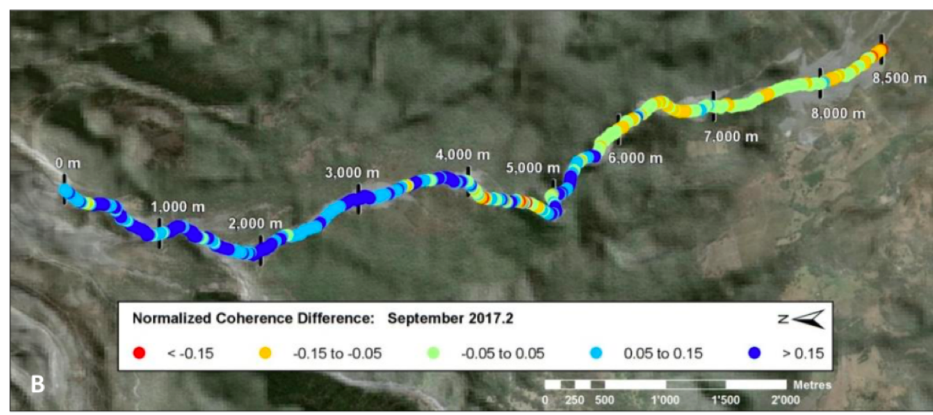
Constraints on lahars timing provided from seismic stations and optical terrestrial imagery



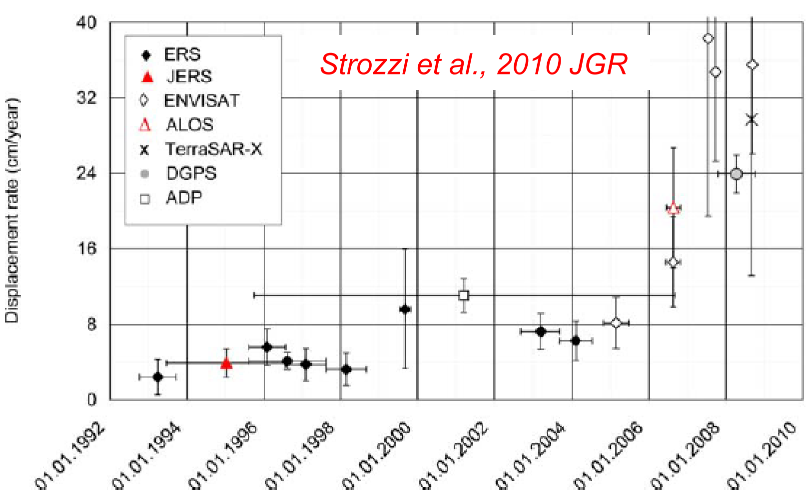
$$ND_\gamma = \frac{\gamma_{pre/post} - \gamma_{event}}{\gamma_{pre/post} + \gamma_{event}}$$


Volcán de Colima
0 m
1,000 m
2,000 m
3,000 m
UAV
4,000 m
TLC
5,000 m
6,000 m
7,000 m
8,000 m
8,500 m
Legend
Sampling Path Mid
Sampling Path East
Sampling Path West
Reference Squares
Coverage Optical Data
0 0.5 1 2 km
N


Post
GC: μ = 0.671584, σ = 0.015895
Event
GC: μ = 0.575404, σ = 0.016596
B. Ruf, MSc
thesis ETH, 2018
Count
Coherence
0 10 20 30 40 50 60 70 80
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1


0 m
1,000 m
2,000 m
3,000 m
4,000 m
5,000 m
6,000 m
7,000 m
8,000 m
8,500 m
Normalized Coherence Difference: September 2017.2
N
< -0.15
-0.15 to -0.05
-0.05 to 0.05
0.05 to 0.15
> 0.15
B
Metres
0 250 500 1'000 1'500 2'000

Surface deformation in the Great Aletsch Glacier valley, Switzerland



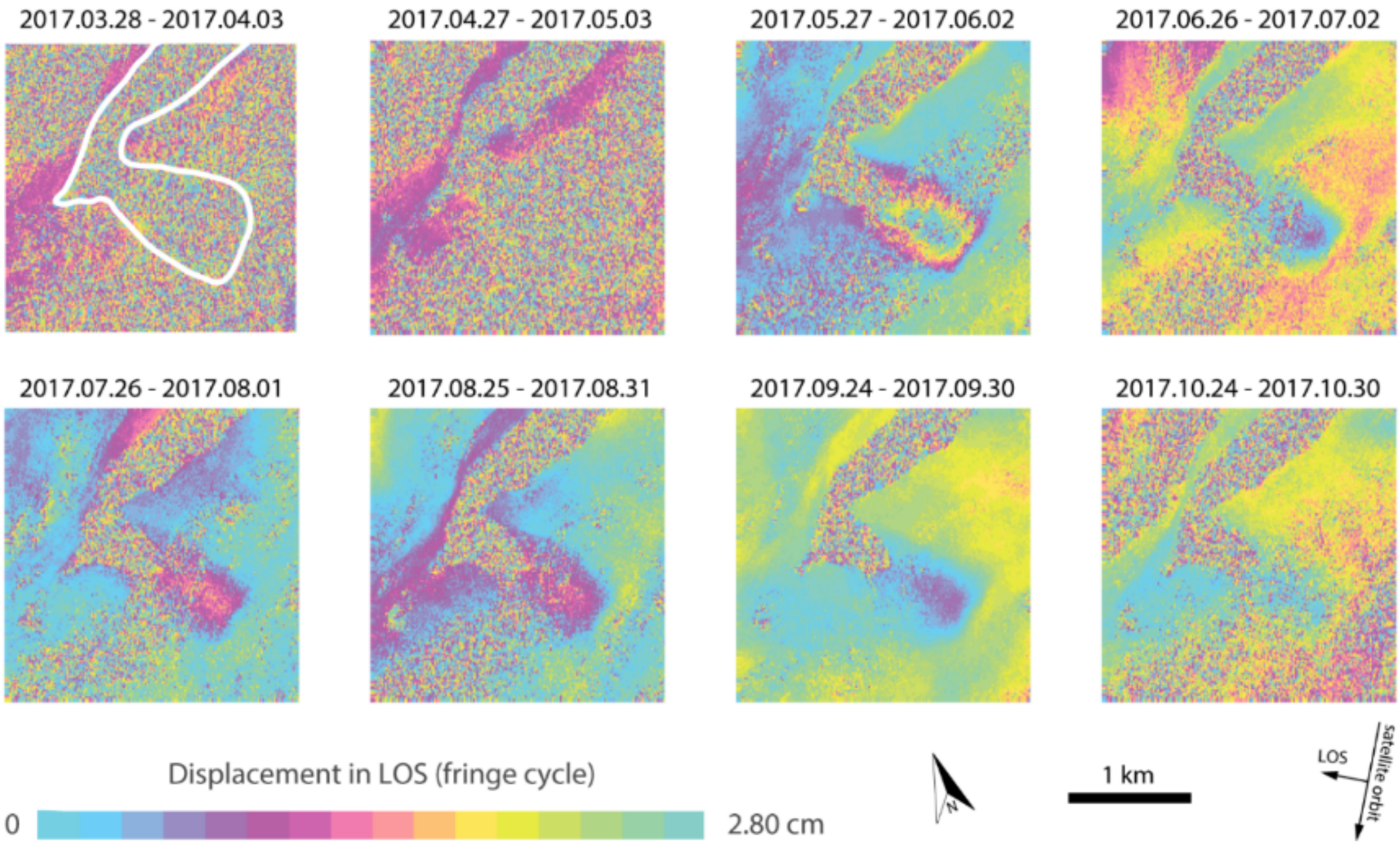
https://www.youtube.com/watch?v=_SefC58kE-s

Friday, Session NH 3.1

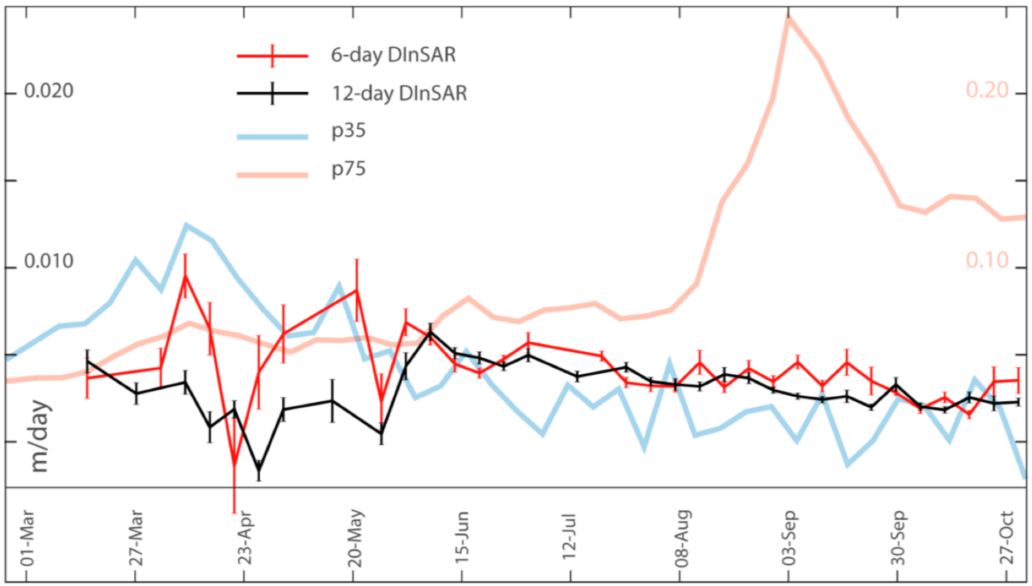
Talk: EGU2019-14762 h 11:45
Poster: EGU2019-7442 Hall X3

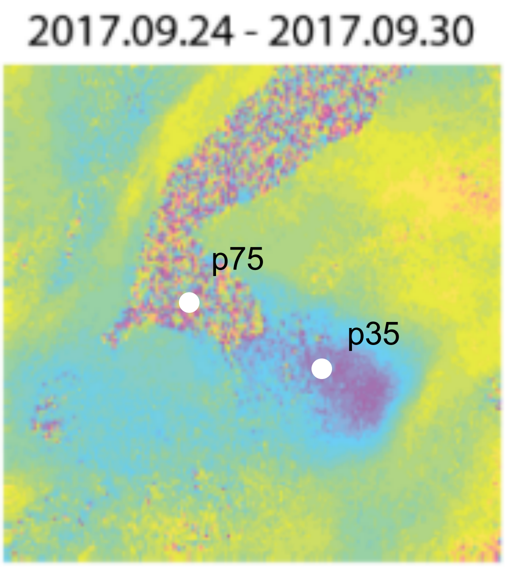
Systematic monitoring with satellite DInSAR?

Manconi et al., 2018, Remote Sensing



Manconi et al., 2018, Remote Sensing

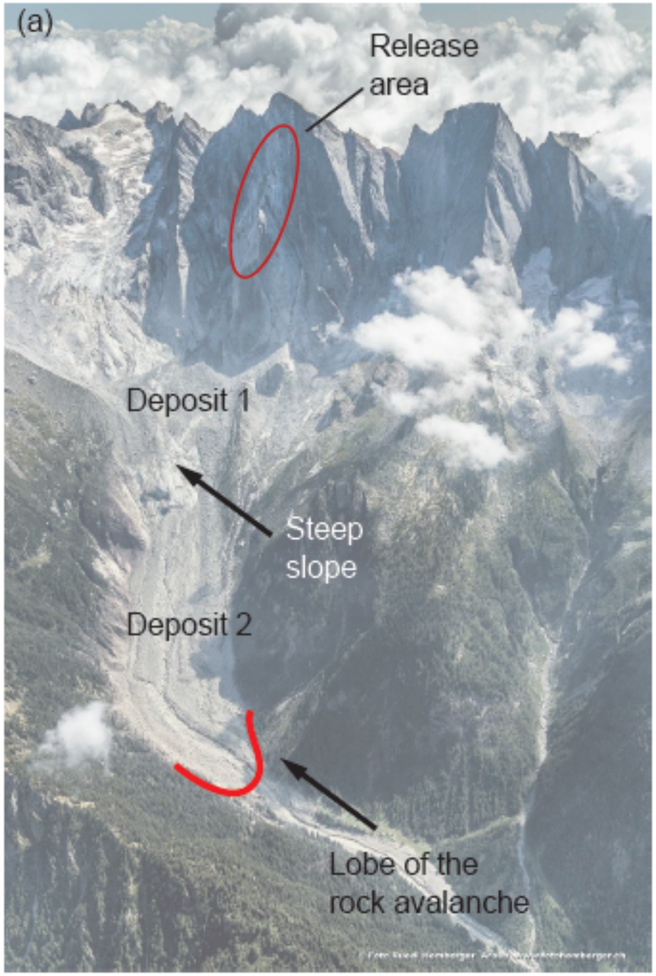




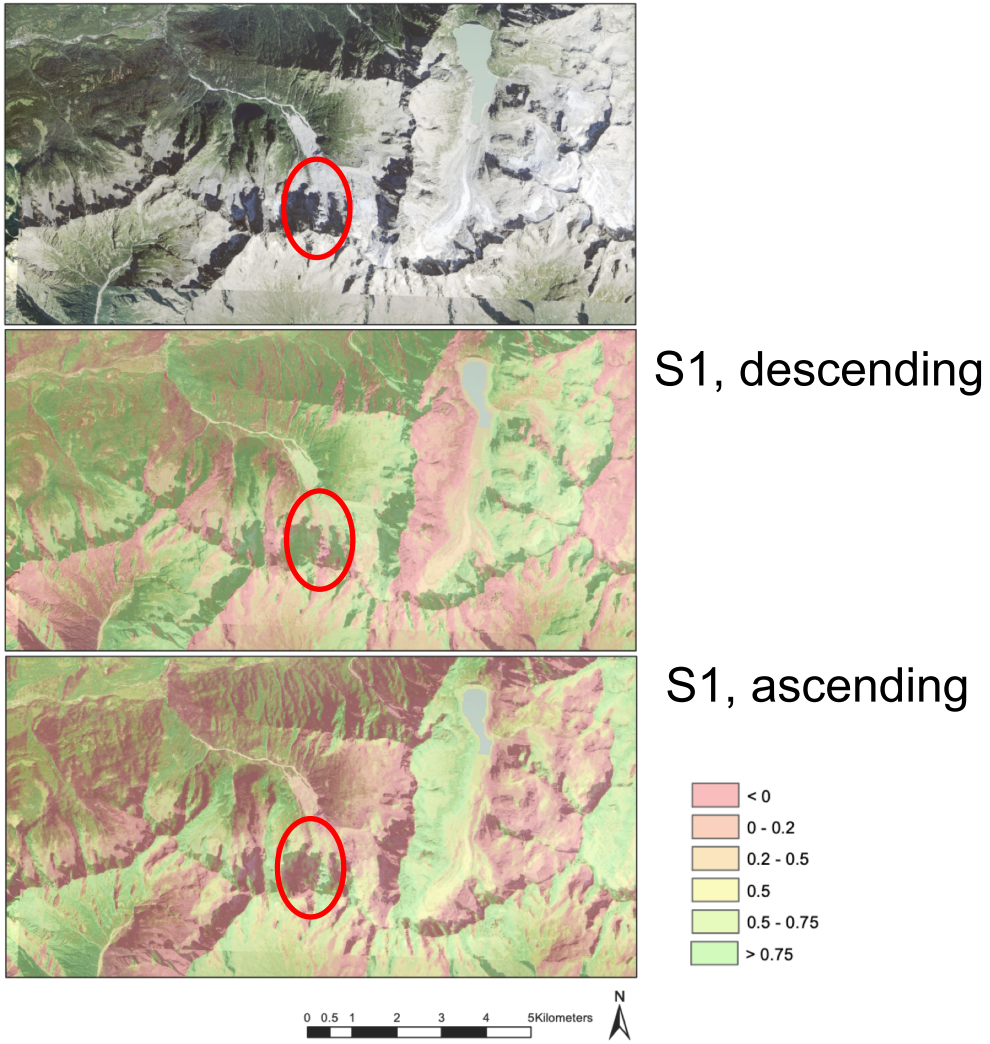
It is difficult to catch the important acceleration phases in Alpine areas because they usually happen when snow is still covering the slope…

If velocities of some portions of the slope (kinematic domains) overcome the intrinsic limitations of DInSAR, they cannot be accurately monitored (and their evolution cannot be then predicted…)

Piz Cengalo, rock avalanche in August 2017



Amann et al., 2017



Summary

Space borne SAR is more and more used in operational activities to detect / map / monitor mass movements

- Rapid mass movements, before failure: detect and map potential initiation with DInSAR, monitoring only when they are very slow or slow…
- Rapid mass movements, after failure: map areas hit by the event (amplitude and/or coherence CD), and to some extent monitor post-failure phases with DInSAR

Thanks for your attention!

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