Semi-automated regional classification of the style of activity of slow rock-slope deformations using PS InSAR and SqueeSAR velocity data

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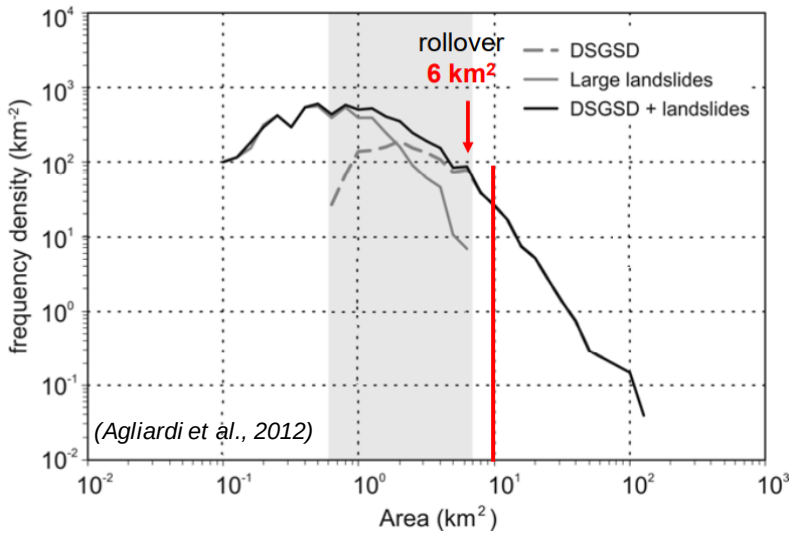
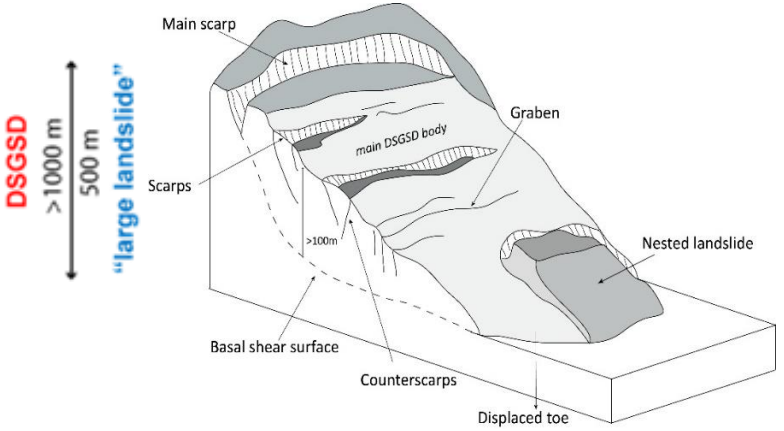
Springer Link **Crippa et al., Landslides (2021)** **open access**

DSGSD and large landslides

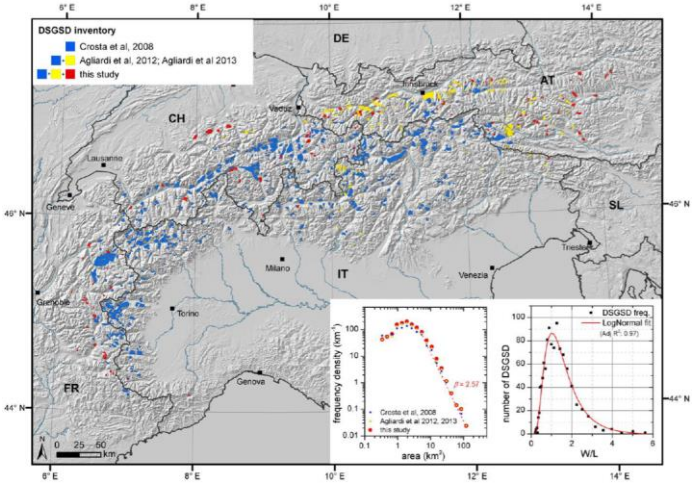




Slow rock slope deformations:

continuum between DSGSDs and Large Landslides

DSGSD	Large Landslides (LL)
> 6 – 10 km²	> 1 km²
Limited cumulative strain	Higher cumulative strain
Creep behaviour	Hidrological sensitivty
Morphostructures	Topographic expression



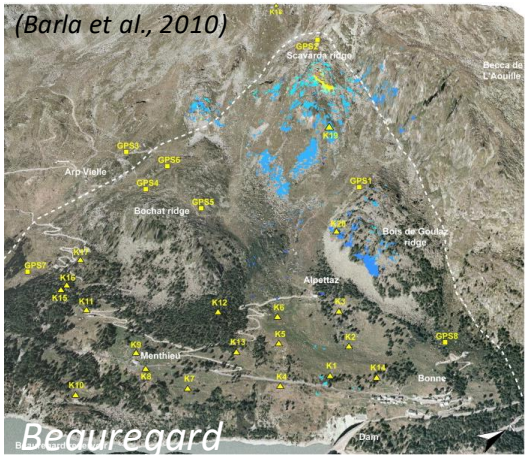
(Crosta et al., 2013)

- Recently recognized as active landslides
- Widespread (>1300 in the Alps)
- Complex displacement pattern → different damage potential

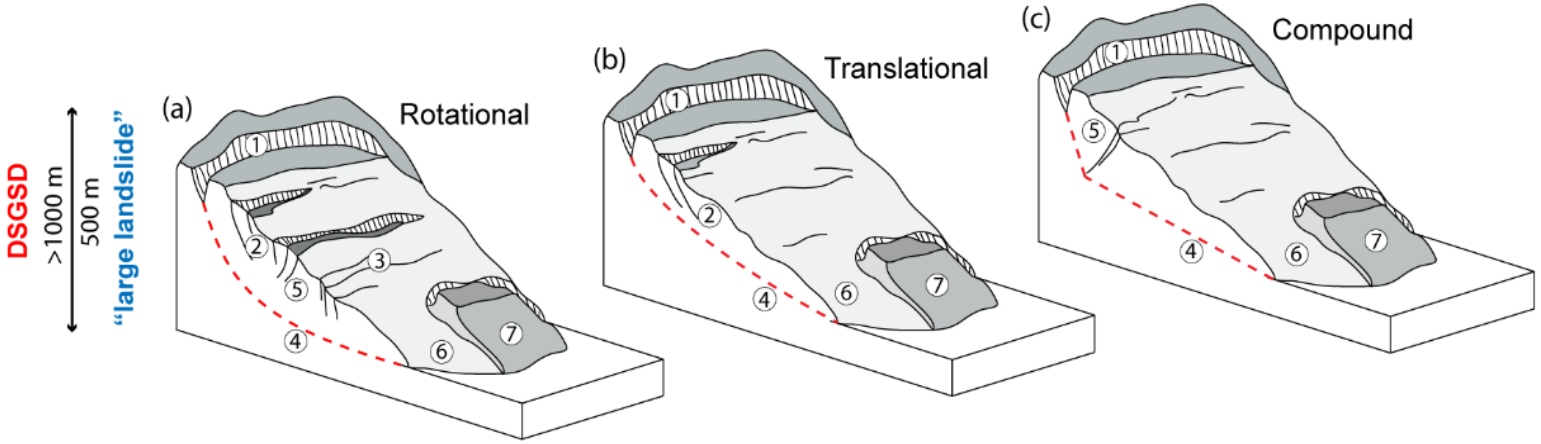
Style of activity of slow rock slope deformations

Slow rock slope deformations ***style of activity*** = complex combination of:

1) Segmentation, heterogenous activity
2) Displacement rate (mm-cm/yr)



3) Kinematics



Research needs and methods

Main issues:

- Many
- Complex: ≠ style of activity and stages of evolution
- Threaten infrastructures

Study approach:

- InSAR and morphostructural data integration
- Multi-technique approach
- Multi-scale approach

Regional scale

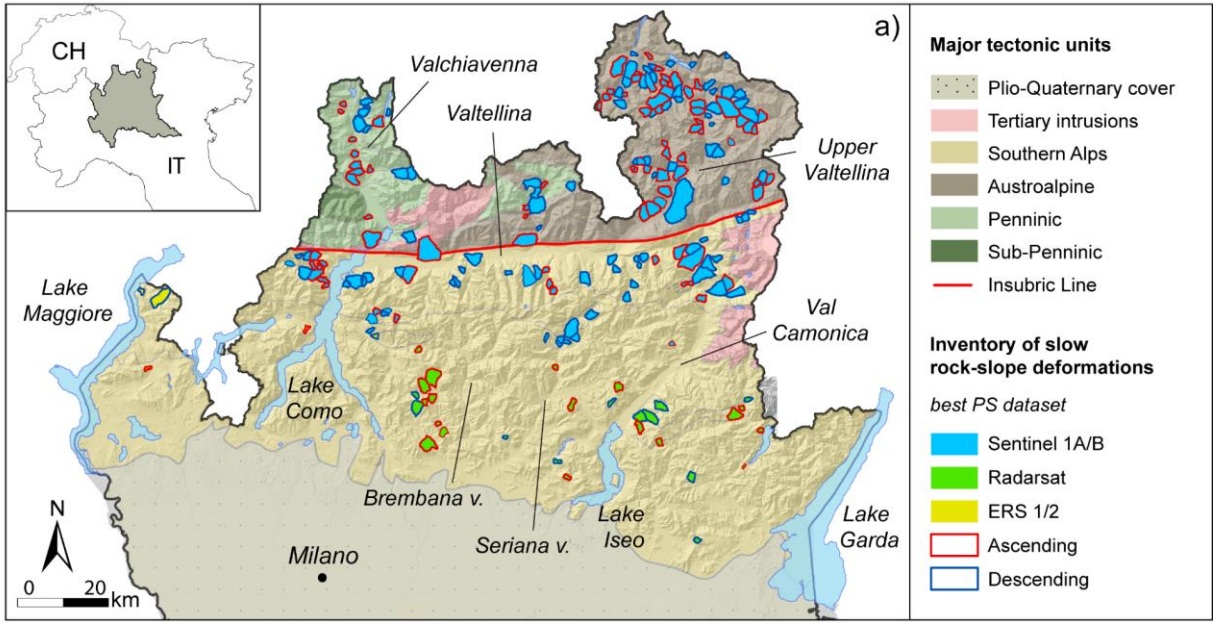
Screening: semi-automated classification

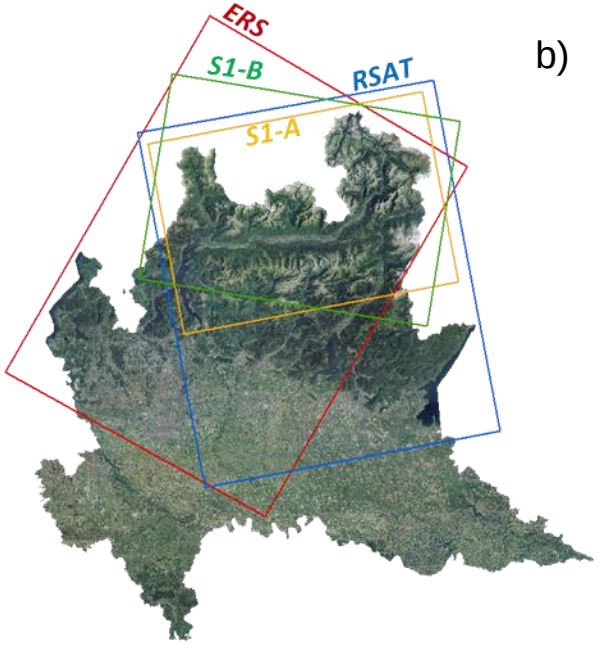
Semi detailed mapping + PSI dataset

Improved PSI analysis

→ segmentation and heterogeneity
→ kinematics

- Austroalpine, Penninic and Southalpine domains
- Alpine sector: high elevation, steep topography, medium strength foliated metamorphics
- Southalpine sector: less steep, stratigraphic control



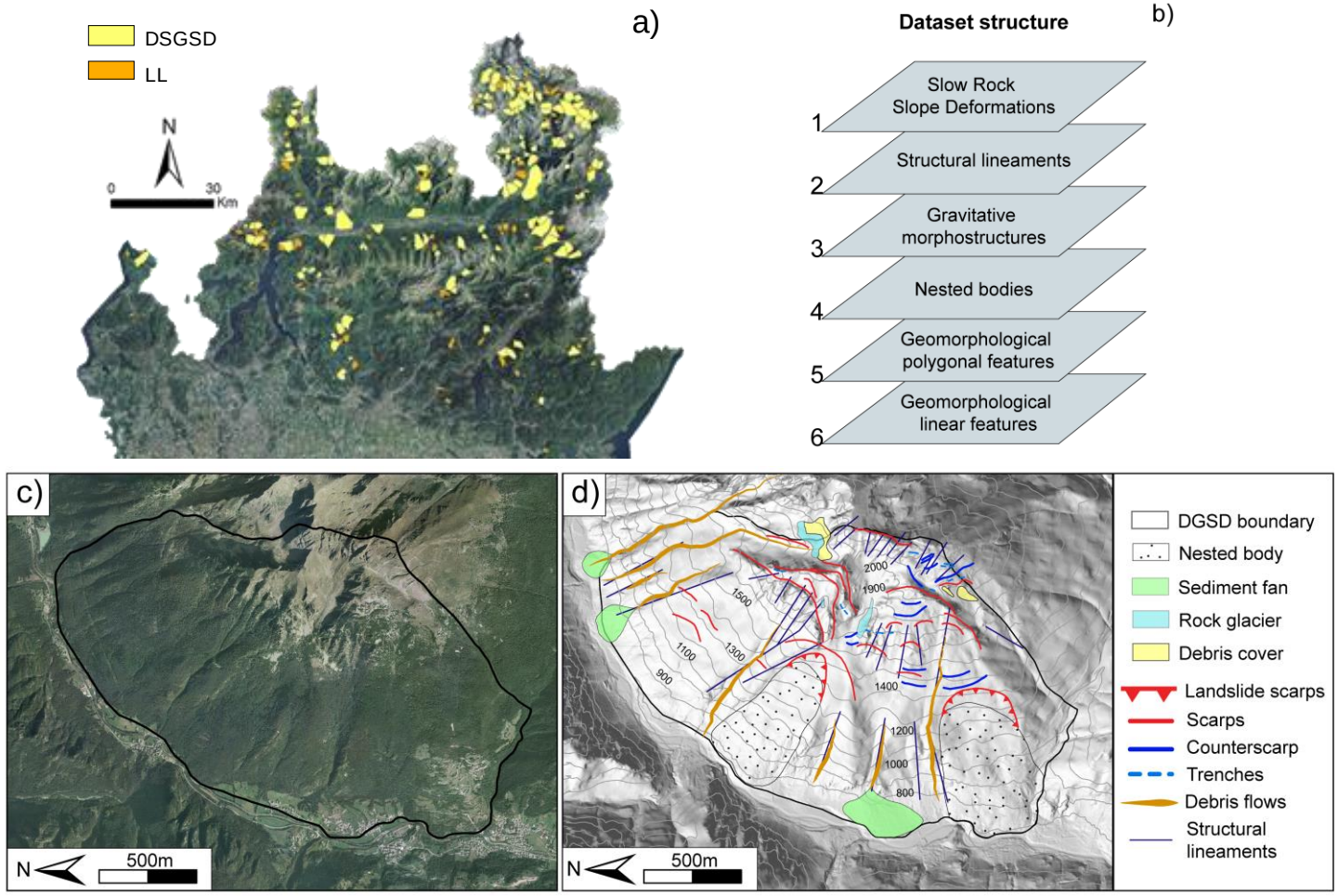


Available PSI datasets:

Satellite	PSI technique	Mode	Θ(°)	δ(°)	Revisit time(days)	Time interval(yr)
ERS 1/2	PSInSAR™	Ascending	23.20	~13.00	35	1992-2003
ERS 1/2	PSInSAR™	Descending	23.09	~12.00		1992-2000
RADARSAT-S3	SqueeSAR™	Ascending	32.49	12.12	24	2003-2007
RADARSAT-S3	SqueeSAR™	Descending	36.27	9.60		
Sentinel1 A/B	SqueeSAR™	Ascending	41.99	10.23	12 (6 after 2016)	2015-2017
Sentinel1 A/B	SqueeSAR™	Descending	41.78	8.89		

Landslide dataset

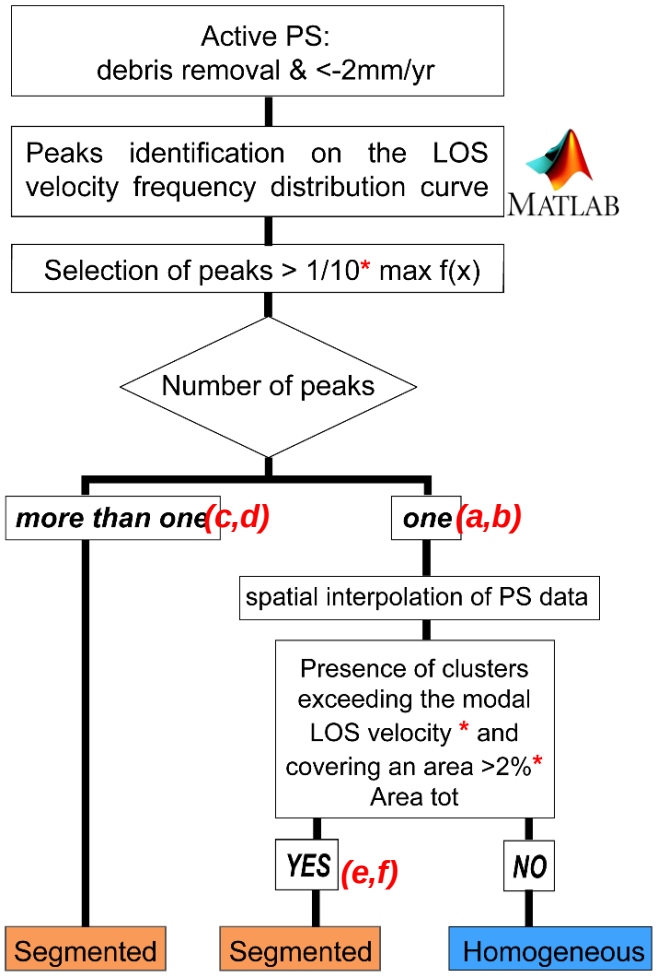
- 208 mapped slow rock slope deformations: 134 DSGSDs+ 74 LL uniformly mapped
- Semi detailed mapping: 3 polygonal layers + 3 linear layers



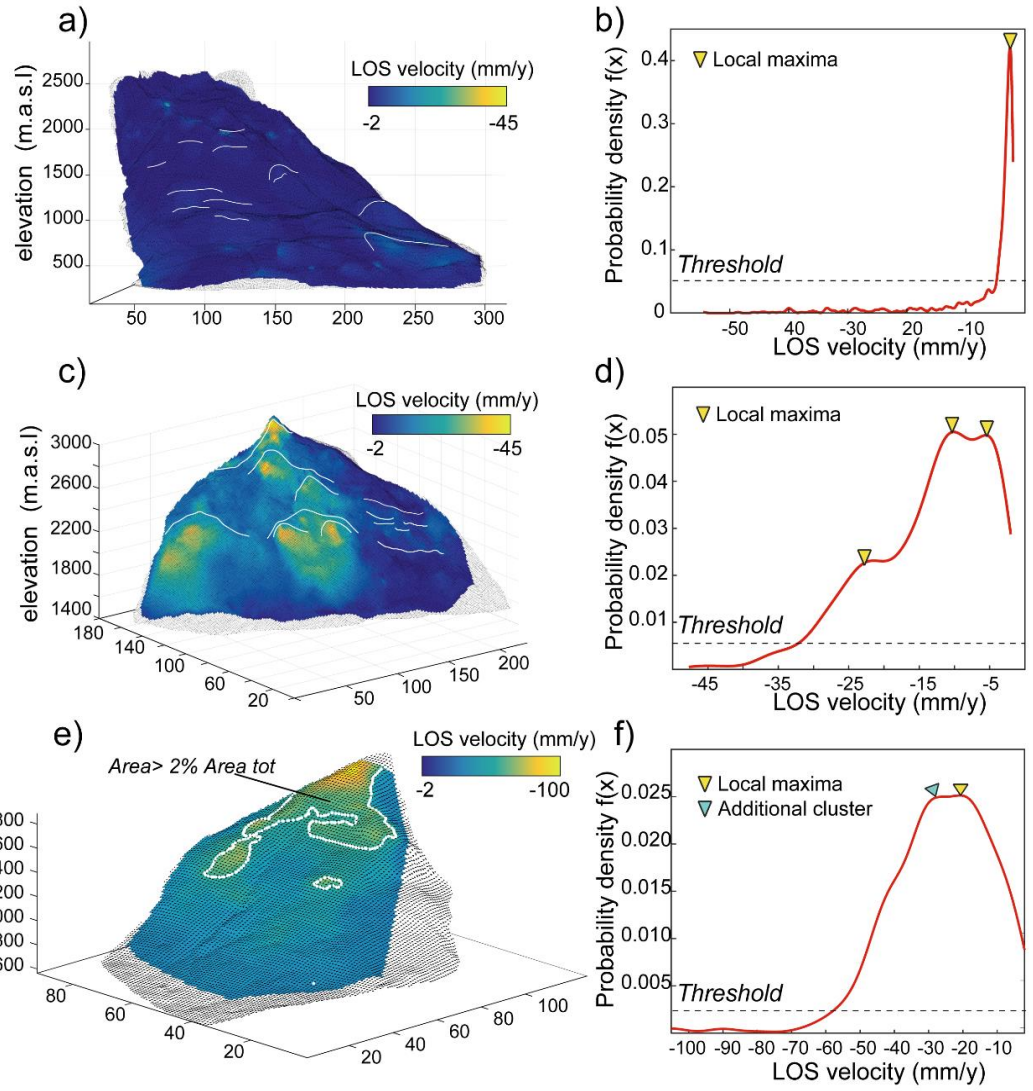
- Descriptive morphostructural and morphometric variables for each landslide

Activity and segmentation

- Mean LOS velocity : ineffective in representing the state of activity
- Automated discrimination of homogenous/segmented landslides through peak analysis implemented in an original Matlab tool

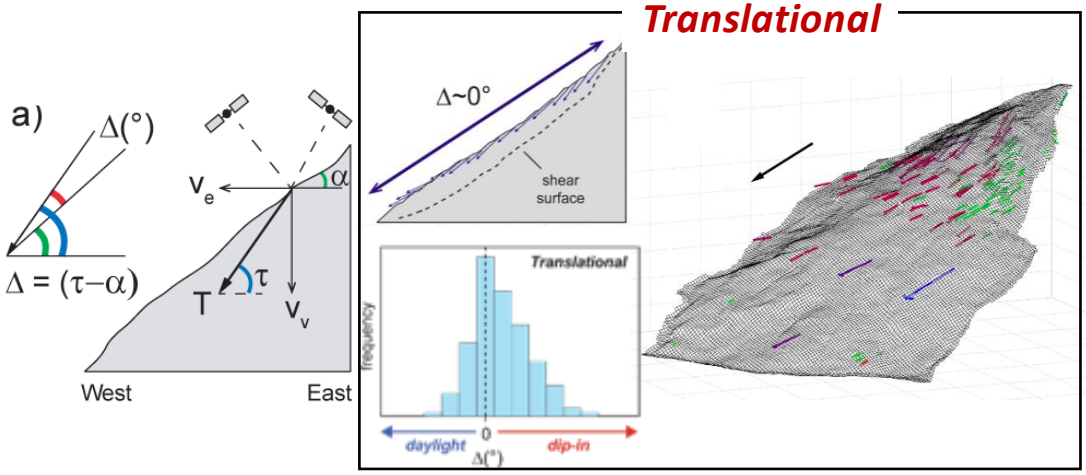


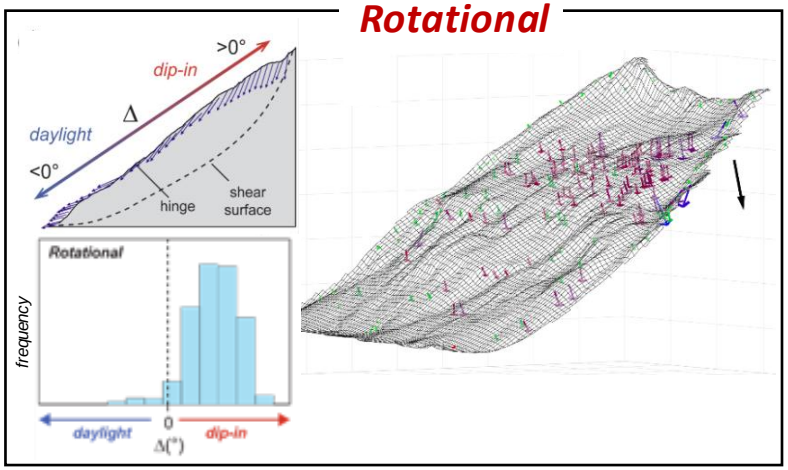
* user defined values



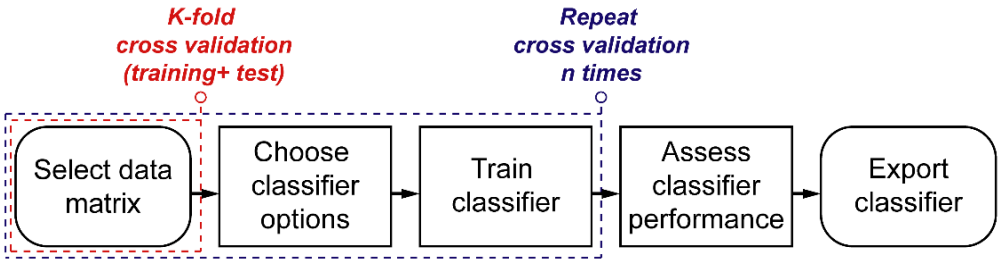
Regional scale kinematics

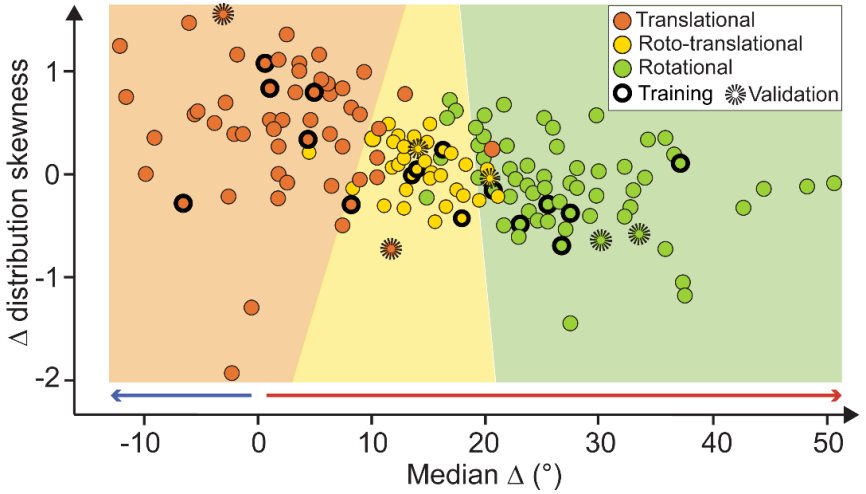
- Δ parameter → changes in the 2D displacement vector orientation along slope
- Asymmetry of Δ frequency as predictor of kinematics → signature of landslide kinematics





- Δ mean, mode, median, skewness, kurtosis = inputs of a supervised machine learning analysis





- Linear discriminant resulted the best predictive model with an accuracy higher than 80%.

Multivariate analysis and classification

- Multivariate analysis= PCA + cluster analysis (K-medoids)

Variable type	Label	Variable name
Morphostructural	***DB***	Deformed nested landslides density
	NB	Immature nested landslide density
	LS	Landslide scarp sector density
	DM	Morpho-structures density
Morphometrical	***Hi***	Hypsometric integral
	L/W	Elongation ratio
	A/2p	Shape factor
	Δh	Relief
	Aspect	Northerness
InSAR derived	***v_PM***	Velocity of major peak
	v_Pm	Velocity of minor peak
	Q_dev	Quartile deviation
	Δ_SK	Skewness of Δ distribution
	Δ_M	Median of Δ distribution

- **Combined** (mapping+ InSAR derived variables)

1) Bulk inventory
2) DSGSDs
3) Large Landslides

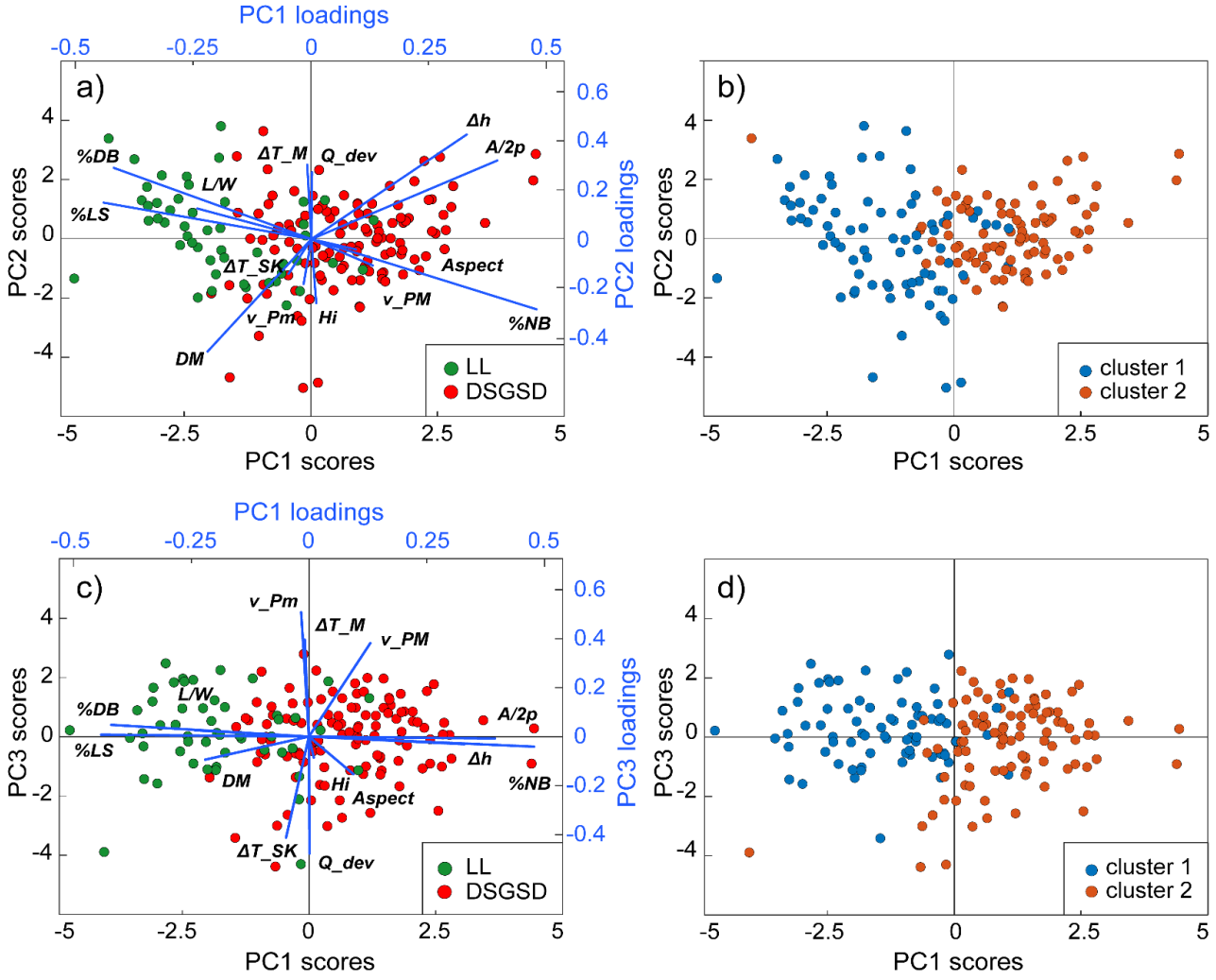
} SAR covered → 166 cases

- **Morphometric** (mapping derived variables)

3) Bulk inventory (with SAR blind) → 208 cases

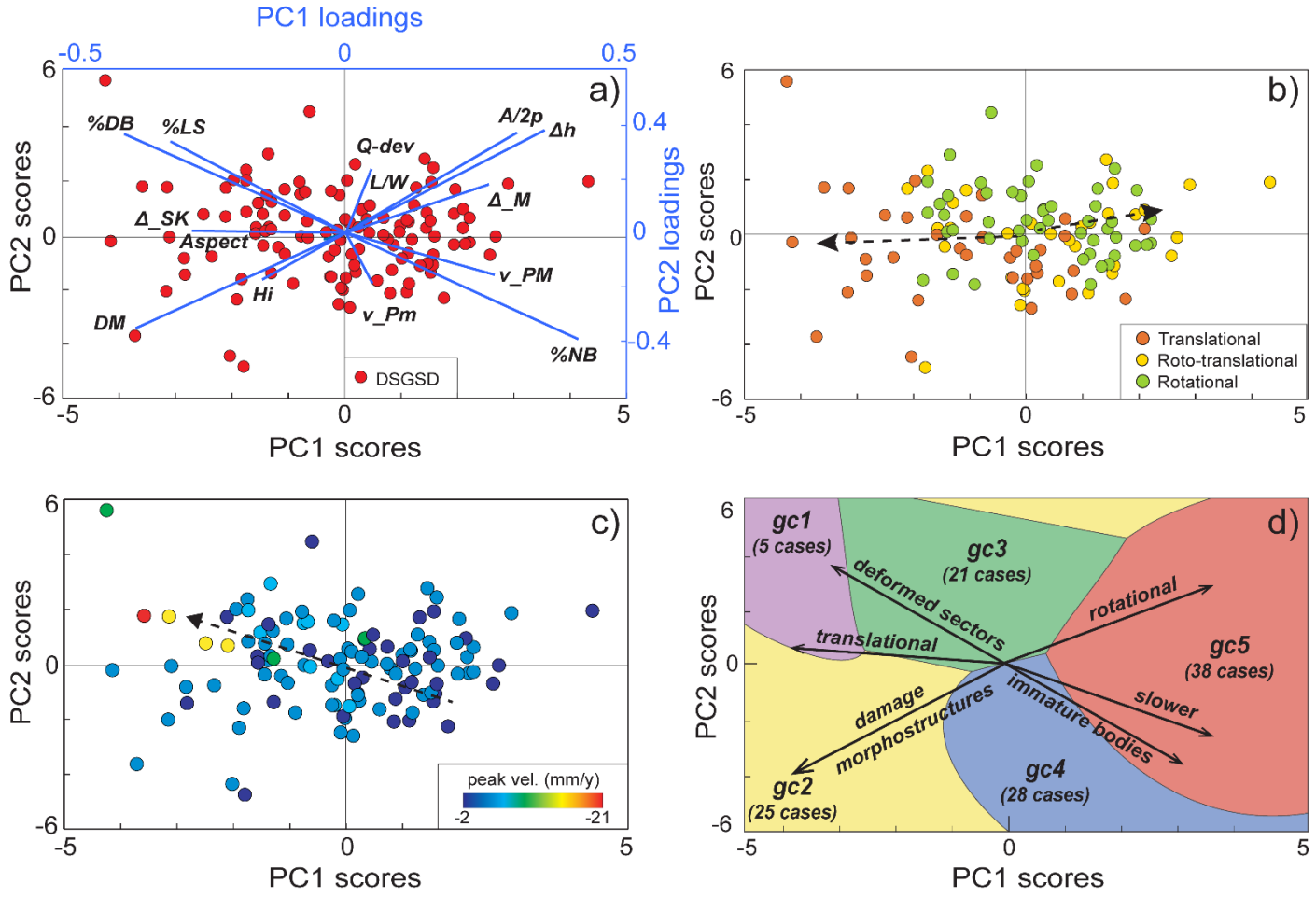
DSGSD and LL covered by InSAR data, all variables

- PCA and cluster analysis on the bulk inventory (SAR covered): ***different statistical signatures of DSGSD and LL*** → **morphological differences** (e.g. L/W: more elongated shape for large landslides; density of DB: higher accumulated internal deformation for LL ; energy relief: > for DSGSD)



Combined PCA & Cluster Analysis: DSGSDs

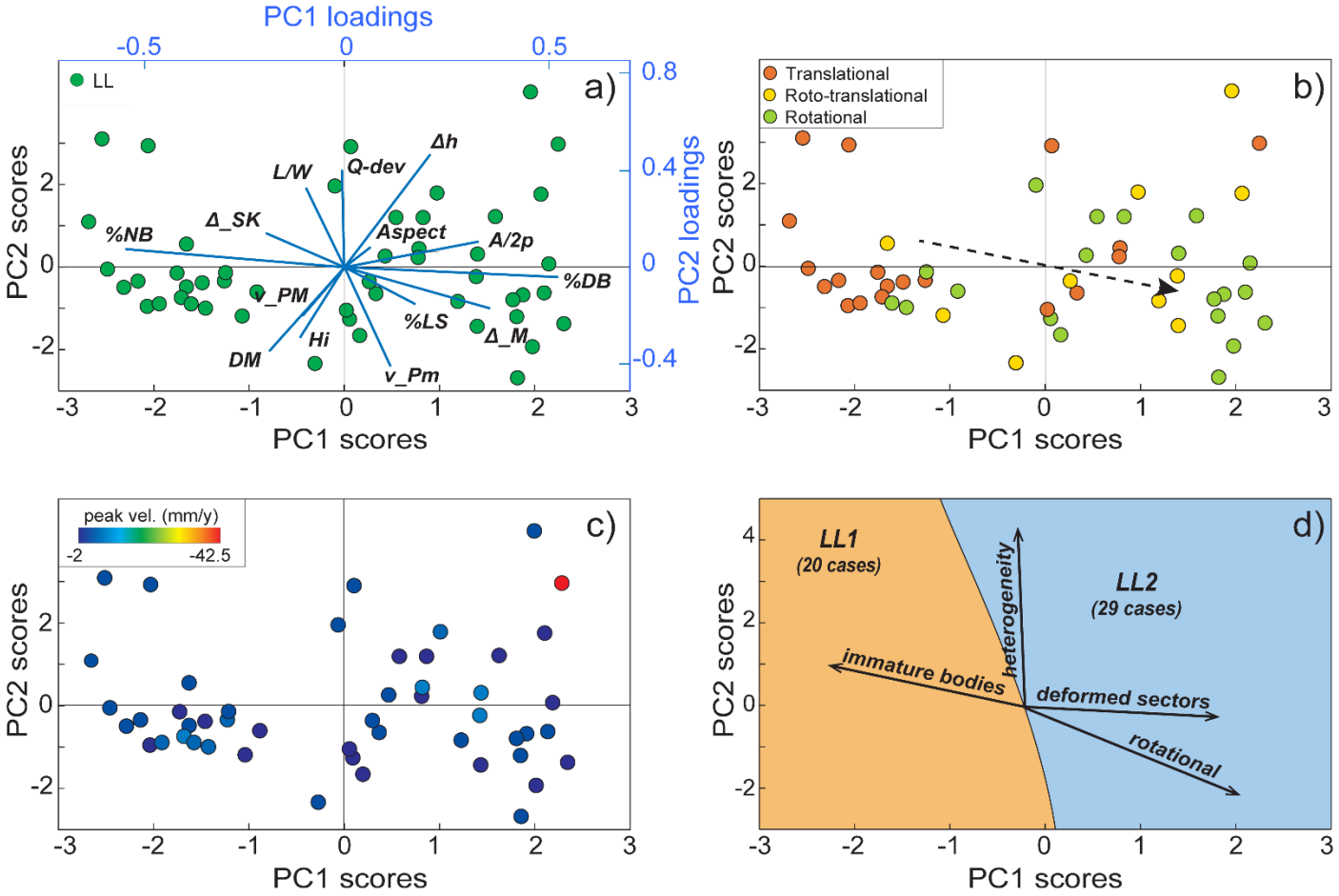
- **Combined PCA on SAR covered DSGSDs** (117)
- 5 cluster analysis on the PCs scores
- PC1-PC2-PC3: 50.2% of the variance



- *gc1-gc5* groups: representative **rate + kinematics + morphostructural expression**

Combined PCA & Cluster Analysis: LL

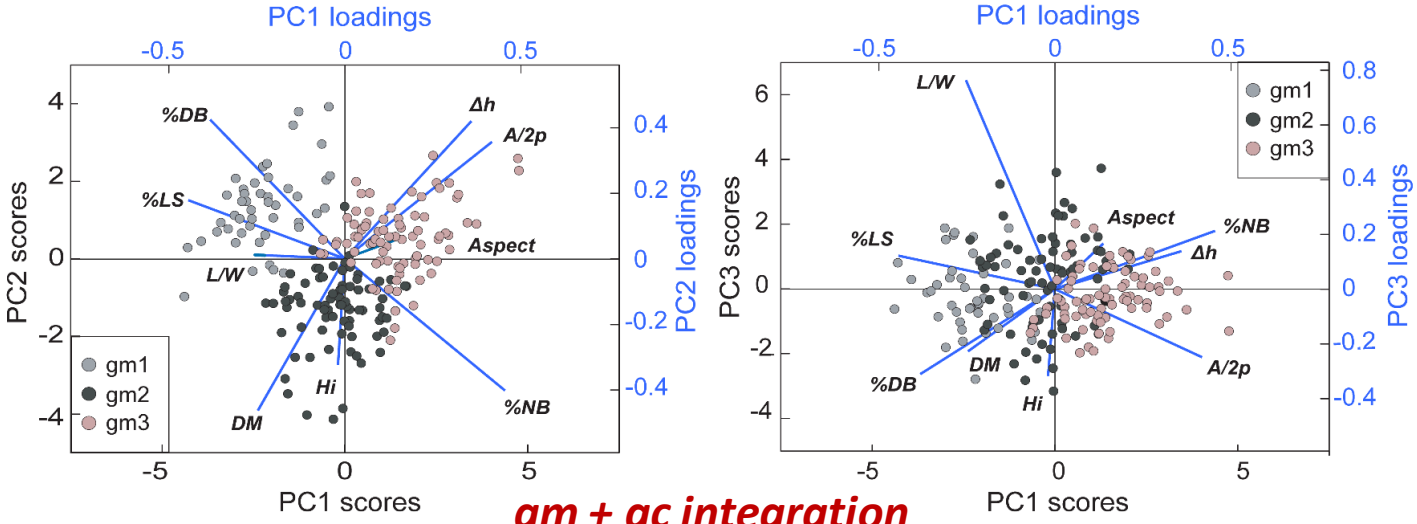
- **Combined PCA on SAR covered Large Landslides** (49)
- 2 cluster K-medoids analysis on the PCs scores
- PC1-PC2-PC3: 47.2% of the variance



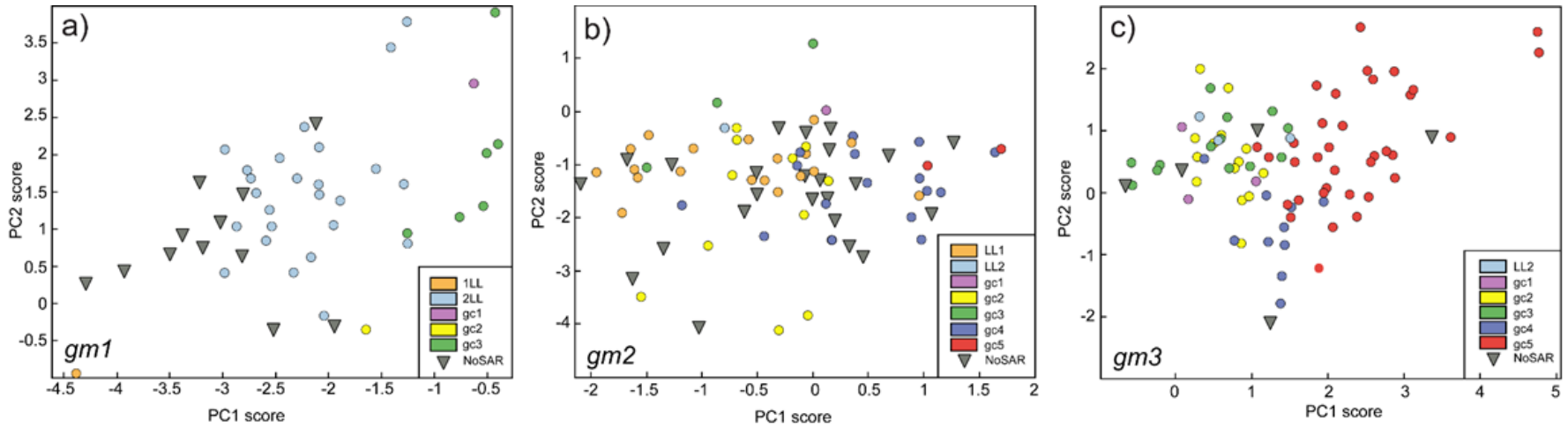
- LL1-LL2: **≠ morphostructural expression** → ≠ maturity and accumulated deformation

All DSGSD and LL: morphometric and morpho-structural variables

- **Landslides with no SAR data** (42)→ listwise exclusion from combined PCA
- PCA & cluster on mapping derived variables+ proximity analysis
- PC1-PC2-PC3: 67% of variance

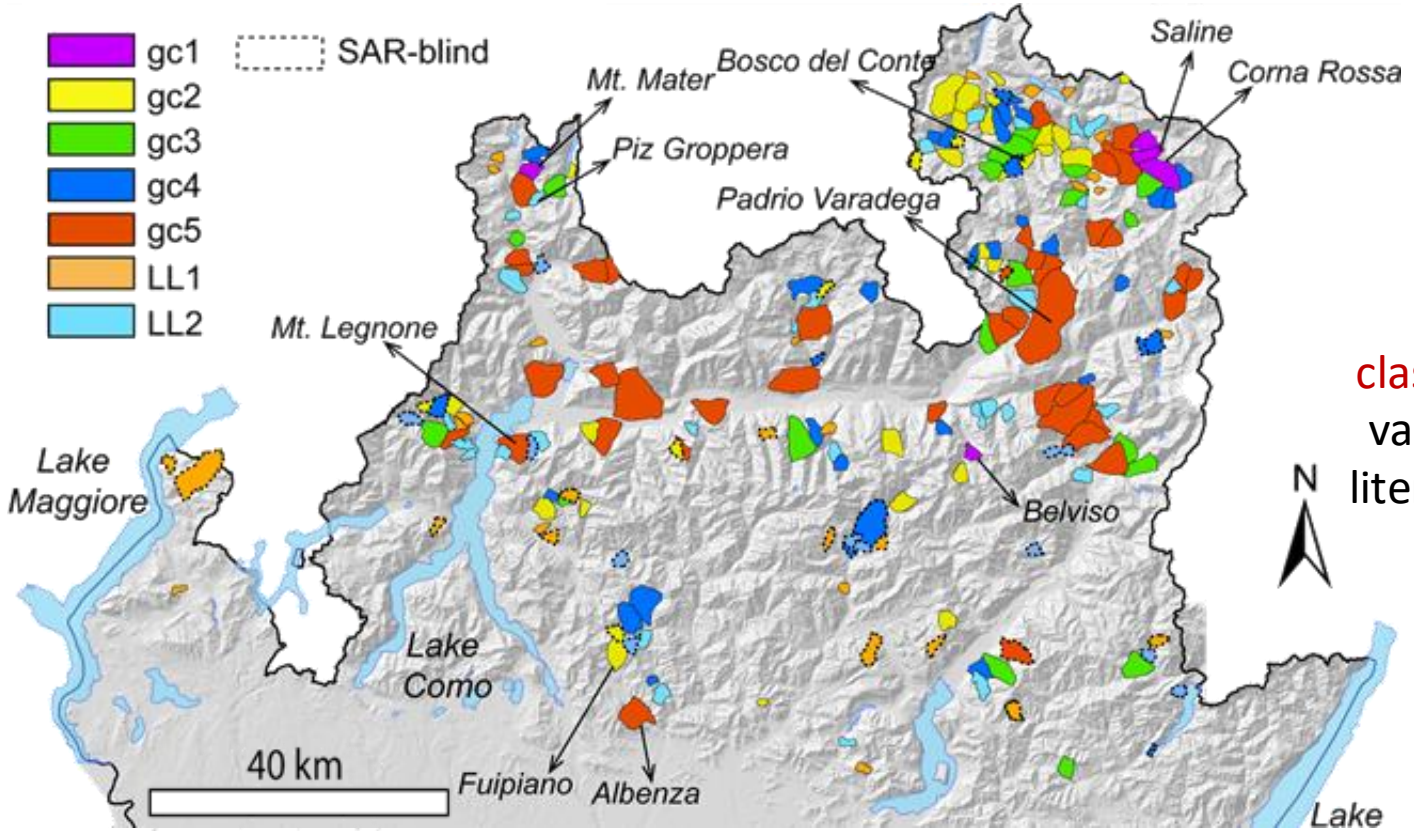


gm + gc integration



gc attribution to SAR blind landslides

Groups definition



Groups classification: validated on literature case studies

	Classes	Kin	DM	DB	Median V_{LOS} (mm/yr)	Vel heterogeneity
DSGSD	Gc1	T	High	Medium	13.5	High
	Gc2	T	High	Medium	4.4	Low
	Gc3	R-RT	Medium	High	3.9	Low
	Gc4	T-RT	Medium	Low	6.1	High
	Gc5	R-RT	Low	Low	3.7	Medium
LL	LL1	T	High	Low	4.5	Low
	LL2	R-RT	Medium	High	4.3	Medium

Style of activity of slow rock-slope deformations:

interplay between displacement rates, kinematics and complexity (e.g. segmentation, heterogeneity, internal damage, structural controls)

Slow rock slope deformations: ***main characteristics***

- DSGSD and large landslides: different expression, mechanisms, evolutionary stages
- Similar displacement rates may correspond to ≠ kinematics and damage potential
- Statistically-based classification → style of activity groups

Slow rock slope deformations: ***implications***

- Screening of slow rock slope deformations → *through replicable semi automated tools*
- Identification of critical case studies
- Prioritization of detailed site-specific mapping, monitoring and modelling studies