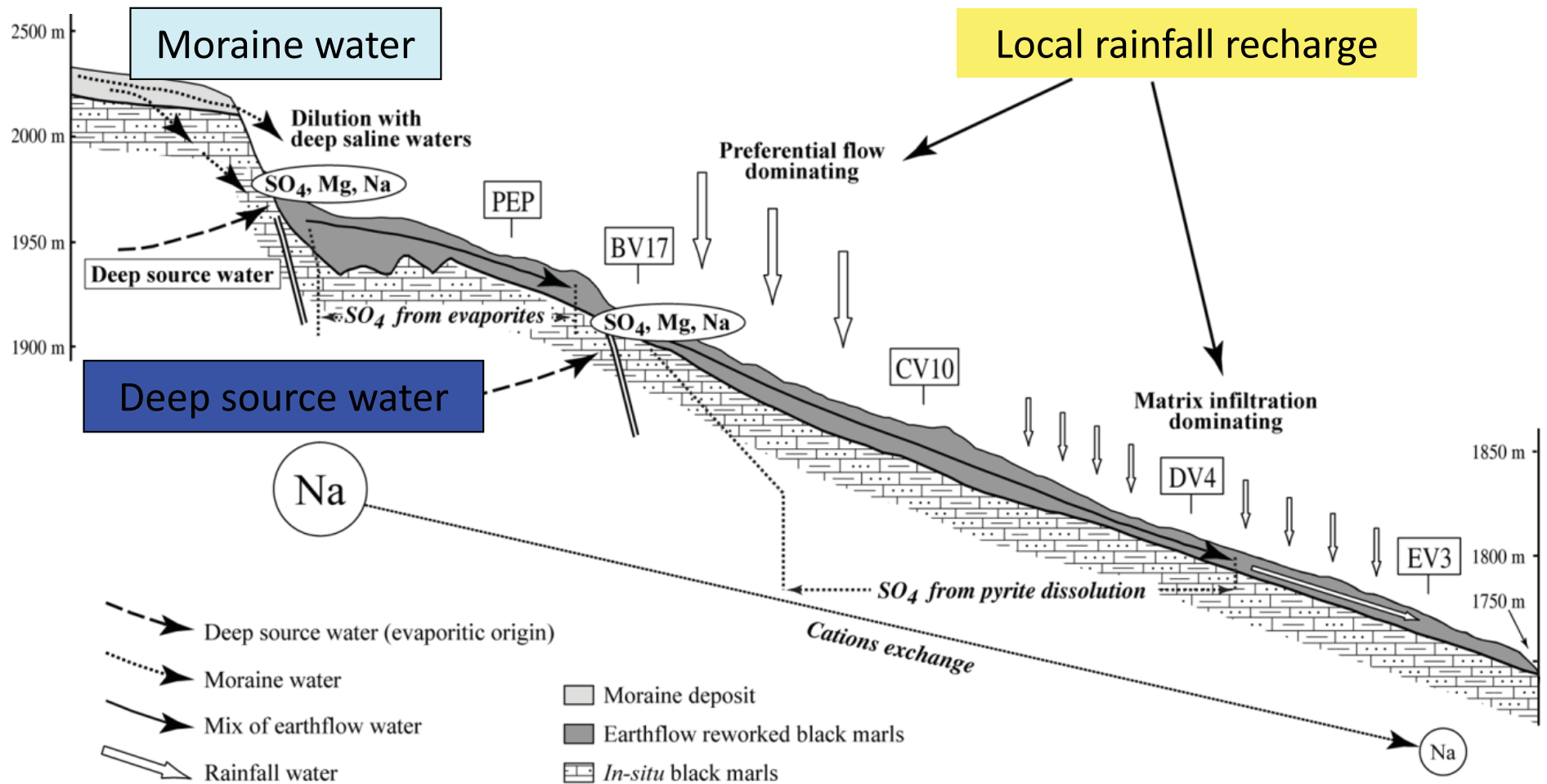


Monitoring landslide hydro-meteorology

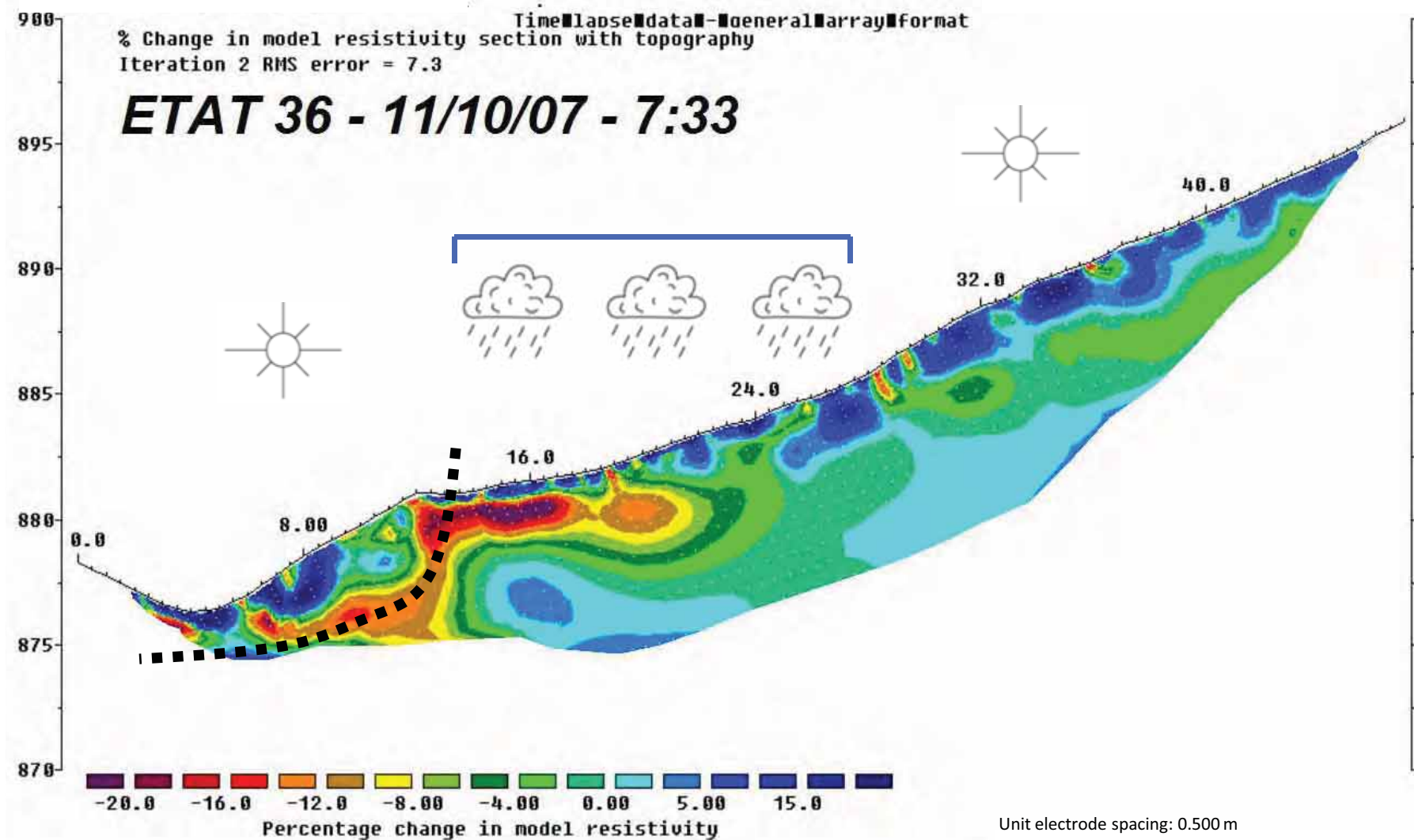
Hydrogeochemistry – Surface and sub-surface water quality



Monitoring landslide hydro-meteorology

Time-lapse hydrogeophysics (e.g. ERT)

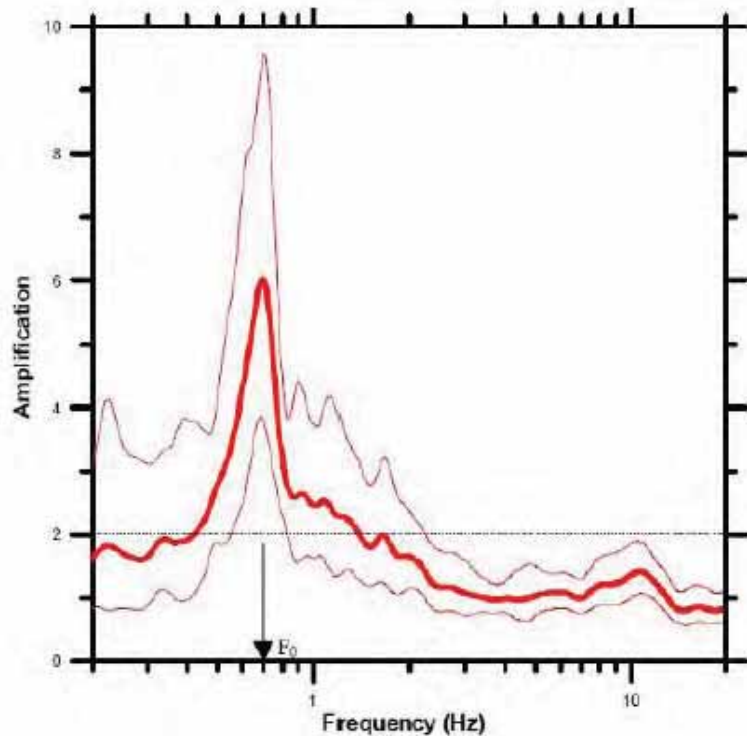
Travelletti et al. (2012)



Monitoring landslide seismology (micro-seismicity)

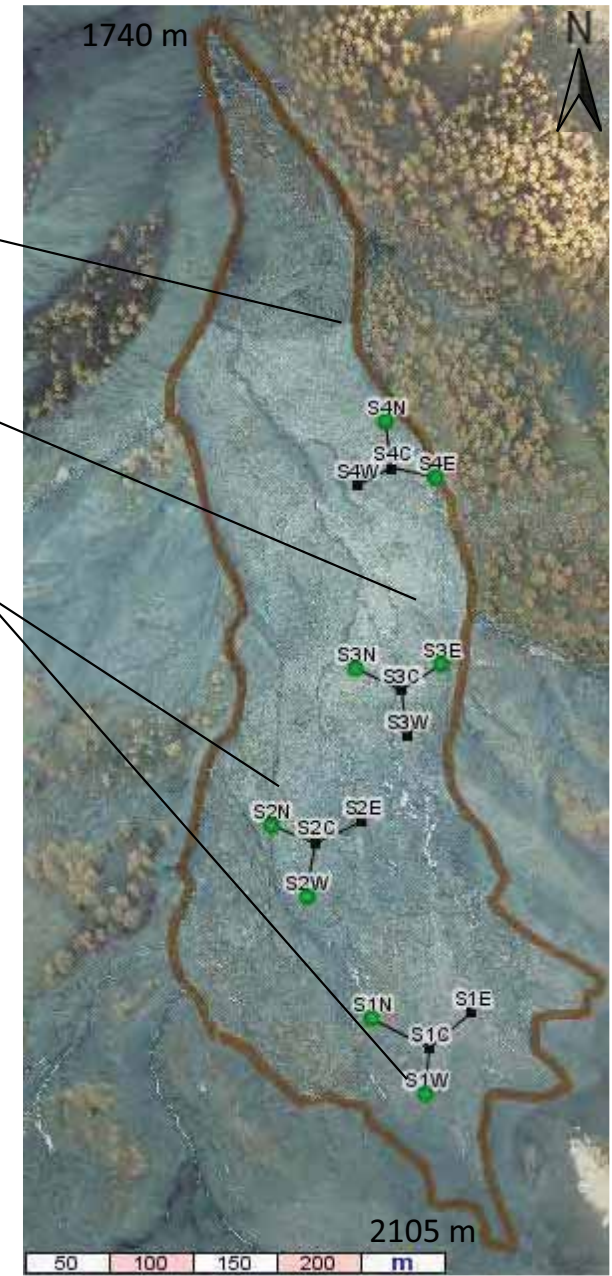
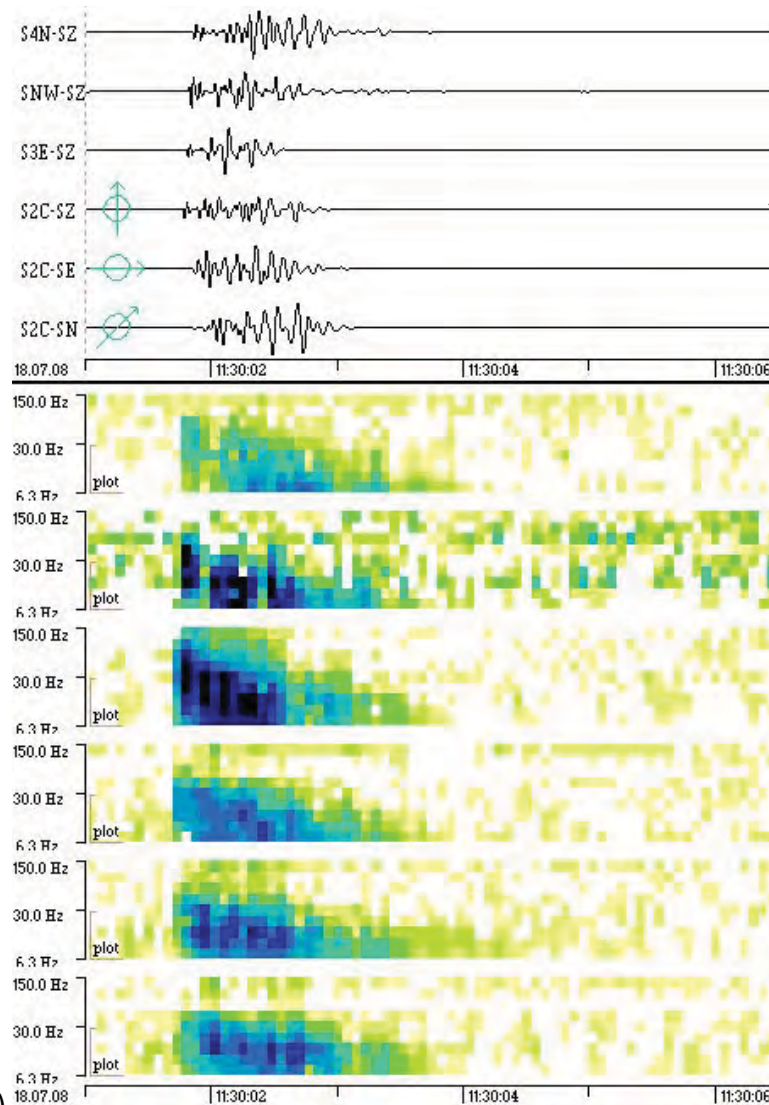
Seismic noise tomography

H/V ratio and fundamental frequency (0.7 Hz)
at Séchilienne



Monitoring landslide seismology (micro-seismicity)

Micro-seismicity monitoring – Identification of slidequakes



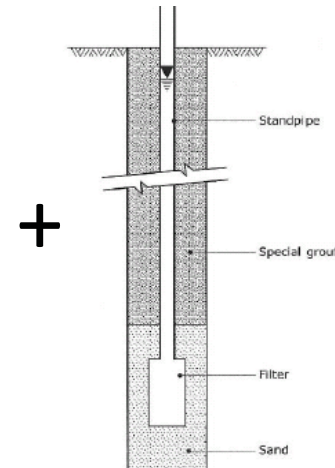
Criteria for the selection of the appropriate techniques

- Is the landslide type a sufficient condition for the selection of the optimal technique?



Rotational landslide

?
=



- More criteria need to be considered!
- Guidelines have been proposed in the SafeLand EC Project
→ Deliverable D4.4, Leaders: CNRS & ITC



Criteria for the selection of the appropriate techniques

- Spatial resolution
- Temporal resolution
- Costs of input data
- Accuracy
-

Technological
Constrains

Selection

- Type (style of movement)
- Displacement rate
- Scale
- Event history
-

Characteristics of the
Landslide & Area

Task

- Detection
- Characterization
- Rapid mapping
- Long-term monitoring

Criteria for the selection of the appropriate techniques

- Spatial resolution
- Temporal resolution
- Costs of input data
- Accuracy
-

Technological
Constraints

Selection

- Type (style of movement)
- Displacement rate
- Scale
- Event history
-

Characteristics of the
Landslide & Area

Task

- Detection
- Characterization
- Rapid mapping
- Long-term monitoring

Criteria for the selection of the appropriate techniques

- What are the technological constraints? More details

Ground-based sensors

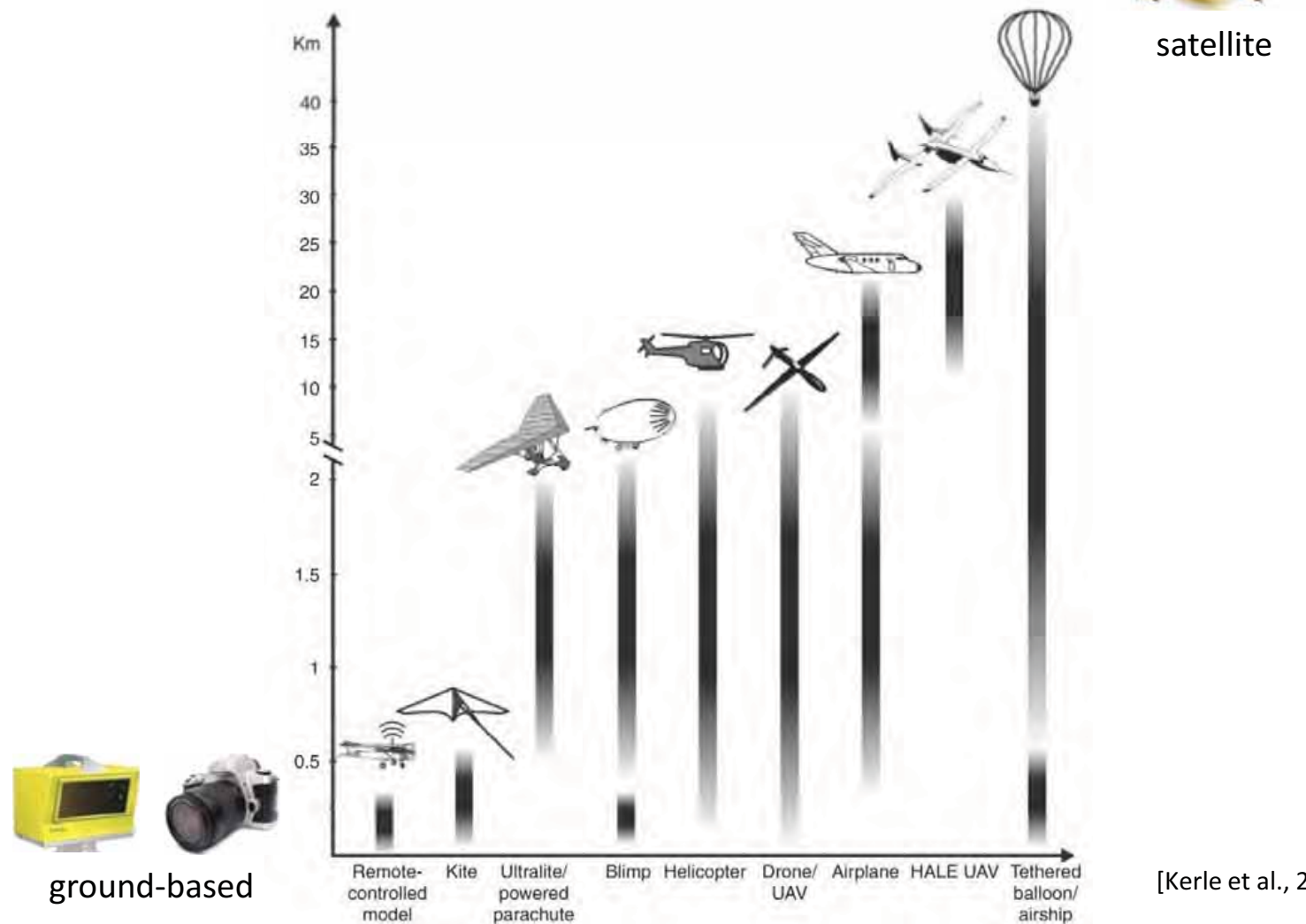
- Spatial resolution
- Temporal resolution
- Accuracy
- Costs of input data
- Additional costs for processing
- Additional costs for EW
- Development status
- Elaboration time

Remote-based sensors

- Data product
- Spatial resolution
- Temporal resolution
- Accuracy level
- Costs of input data
- Availability of alternatives
- Spatial Coverage
- Sensor type
- Platform

Criteria for the selection of the appropriate techniques

- Availability of different ground-based, airborne and satellite platforms and approximate operating altitudes



[Kerle et al., 2008]

Criteria for the selection of the appropriate techniques

- Spatial resolution
- Temporal resolution
- Costs of input data
- Accuracy
-

Technological
Constrains

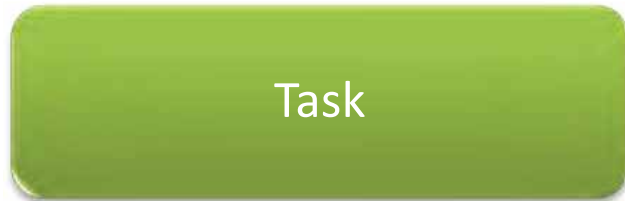
Selection

- Type (style of movement)
- Displacement rate
- Scale
- Event history
-

- Detection
- Characterization
- Rapid mapping
- Long-term monitoring

Task

Characteristics of the
Landslide & Area



- Landslide type

	Detection			Fast Characterization			Rapid mapping			Long-term monitoring		
Landslide types	suitable in few cases	suitable in some cases	suitable in many cases	suitable in few cases	suitable in some cases	suitable in many cases	suitable in few cases	suitable in some cases	suitable in many cases	suitable in few cases	suitable in some cases	suitable in many cases
Fall												
Topple												
Rotational slide												

- Displacement rates

[illegible]

- Observation scale

[illegible]

Methodology for the setup of the guidelines

- Collaborative online tables fulfilled by scientists for different:

- *techniques*

- Passive optical
- Active optical
- Microwave
- Other (airborne geophysics, offshore methods)

- *platforms*

- Ground-based
- Airborne
- Satellite



- Tables fulfilled according to:

- *the expertise of the scientist*
- *the necessity of providing as much quantitative information as possible*
- *the necessity of providing at least relative qualitative approximations*



Examples of tables used for each technique

Accuracy level				
very low (e.g. 1 00 m)	low (e.g. m)	medium (dm)	high(cm)	very high (mm)

- description of the accuracy achievable with the technique
- qualitative and/or in spatial units (e.g. m, m², m³)

Alternatives				
almost none	few	a couple	several	many

- qualitative statement about the possibilities to derive extracted information with other remote sensing techniques or in-situ measurements

Coverage				
site specific	local	regional	continental	global

- q
- co

Costs of input data				
very high	high	medium	low	very low

- p
- es
- co
- co

Additional costs for rapid response				
very high	high	medium	low	very low

- co
- h
- q

Additional costs for processing				
very high	high	medium	low	very low

- costs of operator, additional software and/or specialised hardware
- quantitative or qualitative

Development status				
concept design	tested prototype	multiple studies	commercial use	well established

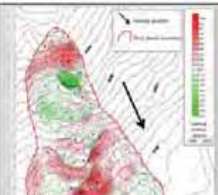
- Maturity of the technology
- Expressing also the possibility to obtain access to the technology and the degree of expertise needed for operation


Estimated elaboration time				
more	month-years	days-month	hours-days	near real time-hours

- Semi- quantitative description including data acquisition and processing time

Organisation of the guidelines


- Example of tables for passive observation techniques

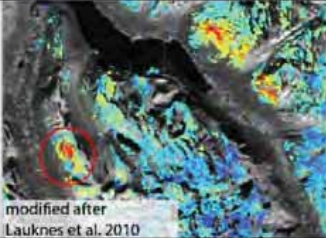
Surface reconstruction with close range photogrammetry					 modified after Ladstaedter and Kaufmann 2004		A1	
Sensor type	Platform	Recording system	System names	Contributing institution	Applicable analysis methods	Method Nr.	Data product	
Passive optical sensors	Ground – based, Low-altitude aerial	Metric cameras		ITC	Close range photogrammetric DSM generation (D4.1 Part A:2-3)	A1 (see also A7)	Historical volume budgets, vertical deformation, surface displacement	
Accuracy level			Alternatives			Coverage		
		dm historic	cm with recent systems		Terrestrial LIDAR	Close range, up to 1km distance	Site specific	
Spatial resolution		Temporal resolution		Costs of input data				
10-50 cm		Historical images usually only recorded every few years					Nil as historical imagery is used	
Additional costs for rapid response		Additional costs for processing			Development status			
Not assessed				Scanning	Camera calibration			
Estimated elaboration time		Advantages			Limitations			
		<ul style="list-style-type: none">• Exploitation of already historical imagery• One of the few sources for quantitative historic information on displacement and volumes• Relatively low costs			<ul style="list-style-type: none">• Constrains on viewing geometry and gaps in occluded areas• Historic reconstruction only possible where regular surveys had been carried out• Increasingly difficult with low view angles• Inhomogeneous accuracies dependent on the image depth			

Visual image interpretation							A7	
Sensor type	Platform	Recording system	System names)	Contributing institution	Applicable analysis methods	Method Nr.	Data product	
Passive optical sensors	Airborne	Metric cameras - multispectral		ITC	Visual interpretation (high resolution and at least colour information is desirable, D4.1, Part A: 2.2, 3.4, 4.2)	A7 (see also A1-14)	Landslide area, number of landslides, landslide types	
Accuracy level			Alternatives			Coverage		
Dependent on the interpreter	m	Sometimes dm			VHR satellite imagery		5-25 km ²	Local Regional
Spatial resolution		Temporal resolution		Costs of input data				
25-50 cm		More frequently available since 1990s				More recent 5-10 €/km ²		Low costs for historical imagery, <100 € per scene
Additional costs for rapid response			Additional costs for processing			Development status		
Flight crew, airplane, ...				Work hours of expert				
Estimated elaboration time				Advantages		Limitations		
Month-years				• Established method for the creation of landslide inventories • No advanced image processing techniques needed for the analysis		• Subjective, time-consuming		

Organisation of the guidelines

- Example of tables for active observation techniques

Airborne LiDAR scanning							B3	
modified after Van Der Eeckhaut et al. 2011								
Sensor type	Platform	Recording system	System names	Contributing institution	Applicable analysis methods	Method Nr.	Data product	
Active optical sensor	Airborne	LIDAR	e.g. Optech ALTM	JRC	Visual interpretation, morphostructural analysis (D4.1 Part B: 4), Object-oriented analysis (D4.3: 3.3 and 3.4)	B3	x, y and z coordinates of million points, areas, volumes, displacement	
Accuracy level			Alternatives			Coverage		
	dm	cm			Max. range up to 6 km (typically from 1 up to 3 km)	Local	Regional scale	
Spatial resolution	Temporal resolution		Costs of input data					
0.1- >30 points/m ²	(month) typically years		Higher point densities	for higher point densities	0.5 points/ m ² over large areas, around 100- 300 €/ m ²			
Additional costs for rapid response			Additional costs for processing			Development status		
	Plane	Crew		Large datasets	Highly specialised software		Analysis	Data acquisition
Estimated elaboration time			Advantages			Limitations		
	Expert interpretation		Point-cloud processing	Hours for scanning	<ul style="list-style-type: none">• High accuracy• Near nadir viewing• Software tools for post-processing widely available• Useful in vegetated areas (LiDAR pulses may penetrate through canopy)• Major teething problems have been solved by now		<ul style="list-style-type: none">• Rather expensive• Data collection can occur beneath clouds and in some haze, but because water absorbs most near infrared light, it will not operate correctly during fog, rain, or snow.• Bad coverage in steep terrain (e.g. cliffs)	

Small baseline spaceborne SAR (C-band)					 modified after Lauknes et al. 2010		C9	
Sensor type	Platform	Recording system	System names	Contributing institution	Applicable analysis methods	Method Nr.	Data product	
Active micro-wave sensors	Satellite	InSAR (C-band)	ERS-1/2, ENVISAT SAR	UNISA	SBAS - Small baseline subset (D4.1: 4.3.1 and Case study 11)	C9	3D reconstruction of landslide displacements	
Accuracy level			Alternatives			Coverage		
		mm			Swath width: 50-100 km			
Spatial resolution	Temporal resolution		Costs of input data					
80 x 80 m ² for full-resolution data; 10 x 10 m ² for high-resolution data	35 days						Min. 15 scenes, 0.6 €/km ² (ERS, archive)	
Additional costs for rapid response		Additional costs for processing				Development status		
	2 €/ km ² 0.2 €/ km ²							
Estimated elaboration time			Advantages			Limitations		
		3 weeks for a 30 image data-set	<ul style="list-style-type: none">• Fast data processing / low user interaction• High point density in urban areas• High accuracy• Cost-effective, regular updates over large areas• Easy data-integration in standard GIS			<ul style="list-style-type: none">• Not applicable in densely vegetated and forested areas• costly for specific local analysis• Low-reflectivity areas (e.g. smooth surfaces and certain materials).• Temporal sampling limited by satellite repeat-cycles• Only “slow” deformation can be measured (<10 cm/yr in LOS)• difficult anticipation of PS distribution in an area• SAR data must be acquired by the same satellite		

Organisation of the guidelines

→ Synthetic tables for the selection of suitable methods

- *for different landslide types*
- *according to their expected velocity and their activity state*
(pre-failure, failure, post-failure)
- *the tasks in risk management*

Remote sensing techniques for landslide investigation	Landslide displacement rates (mm/sec)						
	Extremely slow	Very slow	Slow	Moderate	Rapid	Very rapid	Extremely rapid
	5×10^{-7}		5×10^{-5}	5×10^{-3}	5×10^{-1}	5×10^1	5×10^3
	16 mm/year	1.6 m/year	13 m/month	1.8 m/hr	3 m/min	5 m/sec	> 5 m/sec
	Velocity range of common types of landslides						
	Slide and flow in clayey materials (including mudslide and earthflow)				Rockfall		
					Slide in hard rocks and fragile overconsolidated clays		
Shallow slide and debris flow							
Detection	Satellite InSAR ^f						
			ALS ^{pf}				
Fast characterization			High resolution satellite image analysis ^{pf}				
	Satellite InSAR ^f						
	GB-InSAR ^f						
	TLS & ALS ^f						
Rapid mapping			Ground based cameras ^f				
	Satellite InSAR ^f						
	GB-InSAR ^f						
	Radar distance-meter ^f		Radar distance-meter ^f				
	TLS ^f						
Long-term monitoring			Ground based video and non-metric cameras ^f				
	GB-InSAR, Satellite InSAR ^f						
	TLS, ALS ^f						
	GB video, metric cameras		non-metric cameras ^f				

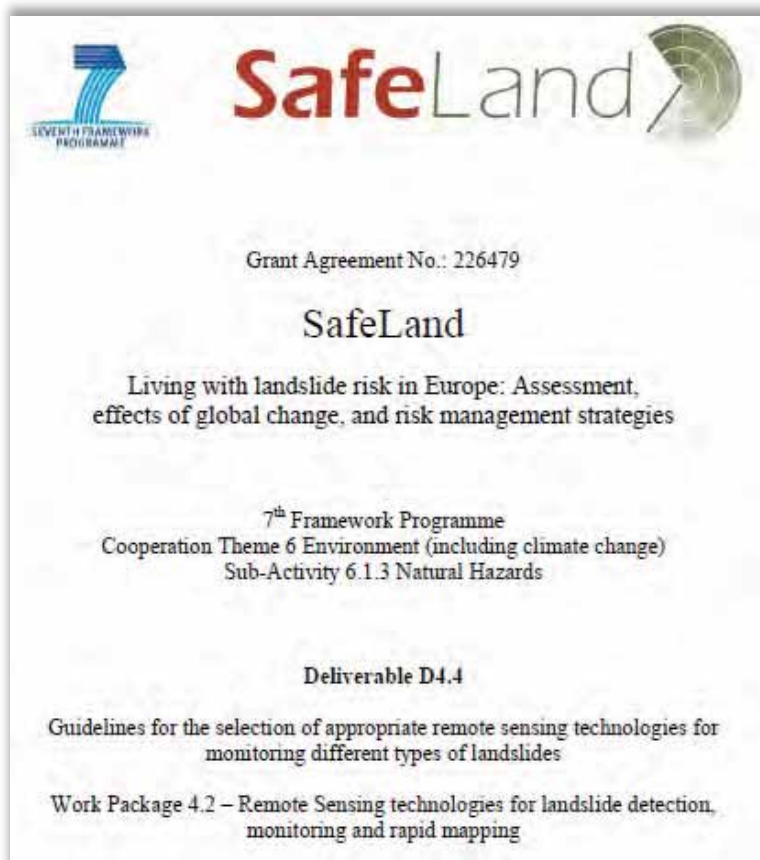
Conclusion



- Comprehensive base for the comparison of relevant monitoring techniques
- Guidelines and checklist for scientists and stakeholders to select among the most relevant / suitable techniques according to criteria
- A guidepost to experts and relevant websites for specific services (e.g. Safer, Doris, GMES, Pléiades, Sentinel, etc) and processing softwares (commercial, open source)

Conclusion

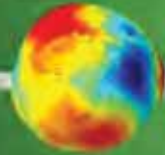
- Guidelines presented and discussed at ESA Forum in May 2012, Santorini



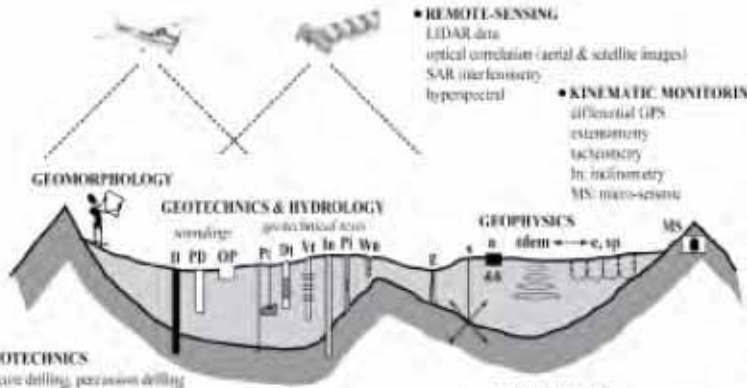
- Guidelines presented in a manuscript submitted to *ESR – Earth Science Reviews* (Stumpf, Malet, Kerle, Michoud, Jaboyedoff & Casagli)

Conclusion: towards “Landslide Observatories”

omiv.osug.fr



Service des Observatoires des Instabilités de Versants

Organisation / Team	<p style="color: red; text-align: center;">Welcome to the 'Observatoire Multidisciplinaire des Instabilités de Versants' (OMIV)</p> <p>The primary duties of the French Observatory OMIV on landslide processes are to conduct geomorphologic, geologic, hydrologic, geophysical and seismic studies related to long-term monitoring, understanding of processes, and assessment of hazards at several active landslides characteristics of several types of activity, and to maintain a freely accessible multi-parameter database on these landslides.</p> <div style="text-align: center;">  </div> <div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> <p>• GEOTECHNICS D: core drilling, percussion drilling PD: portable hand-aux drilling OP: open pit and trench Pt: dynamic or static penetrometer test (DPT, SPT), cone penetration test (CPT) Dt: dilatation test (Menard pressurometry) Vt: vane shear test Pt: piezometer and interstitial pressure cell Wt: volumetric water content</p> </div> <div style="width: 30%;"> <p>• REMOTE-SENSING LIDAR data optical correlation (aerial & satellite images) SAR (interferometry) hyperspectral</p> </div> <div style="width: 30%;"> <p>• KINEMATIC MONITORING differential GPS extensometry tachymetry In: inclinometry MS: micro-seismic</p> </div> </div> <div style="display: flex; justify-content: space-between; margin-top: 10px;"> <div style="width: 30%;"> <p>• GEOPHYSICS e: seismic tomography (reflection, refraction, SASW) c: electric tomography sp: self-potential item: electro-magnetic sounding g: ground geophysics a: acoustic measurement (seismic noise, HVV, network)</p> </div> <div style="width: 30%;"> <p>• HYDROLOGY permeability test hydrogeochimistry</p> </div> </div>
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Conclusion: towards “Landslide Observatories”

Observatoire Multidisciplinaire des Instabilités de Versants

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Autres sites étudiés par les partenaires OMIV:

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Chamousset



Chamousset 2



Trièves



La Praz



La Valette



Villerville



Utiku, New Zealand



Sharing 'long-term' landslide data for research

Home > Data Access > Super-Sauze mudslide		INSU CNRS OSUG EOST LGIT GeoAzur LST DO	
Organisation / Team	Data Access - Super-Sauze mudslide		
Super-Sauze mudslide	Geomorphology Geometry and structure Displacement Meteorology Hydrology Seismology Aerial and satellite remote sensing		
La Valette mudslide	Data download: click on document name (#): restricted use For any question: Jean-Philippe Malet		
Villerville landslide			
Barcelonnette area			
Data access			
• Super-Sauze • La Valette • Villerville • Barcelonnette area			
Publications			
Links			

Meteorology

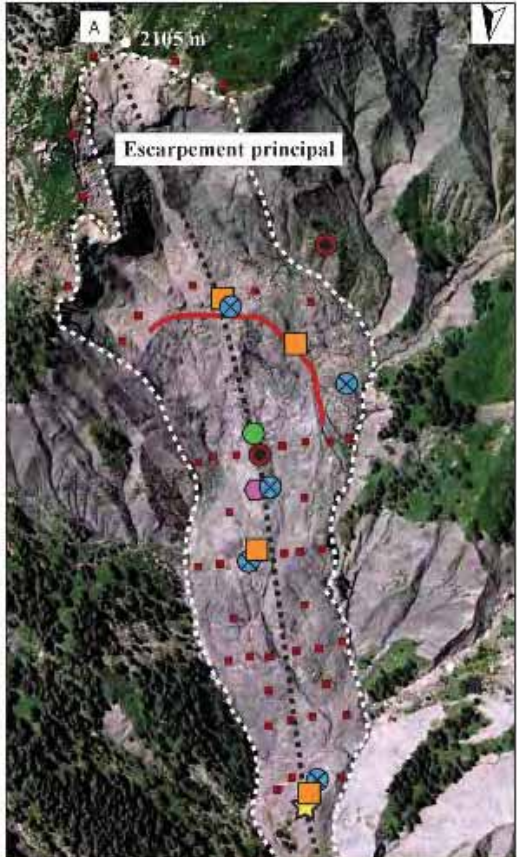
- Meteo station & snow depth

Hydrology & hydrodynamics

- ⊗ Pore water pressure
- Hydrology & inclinometry (Geobeads)
- Temperature (DTS)

Kinematics

- Seismometer (June/July 2009)
- ◆ Extensometer
- ★ GPS
- Topo benchmark
- Hut with VHR optical camera



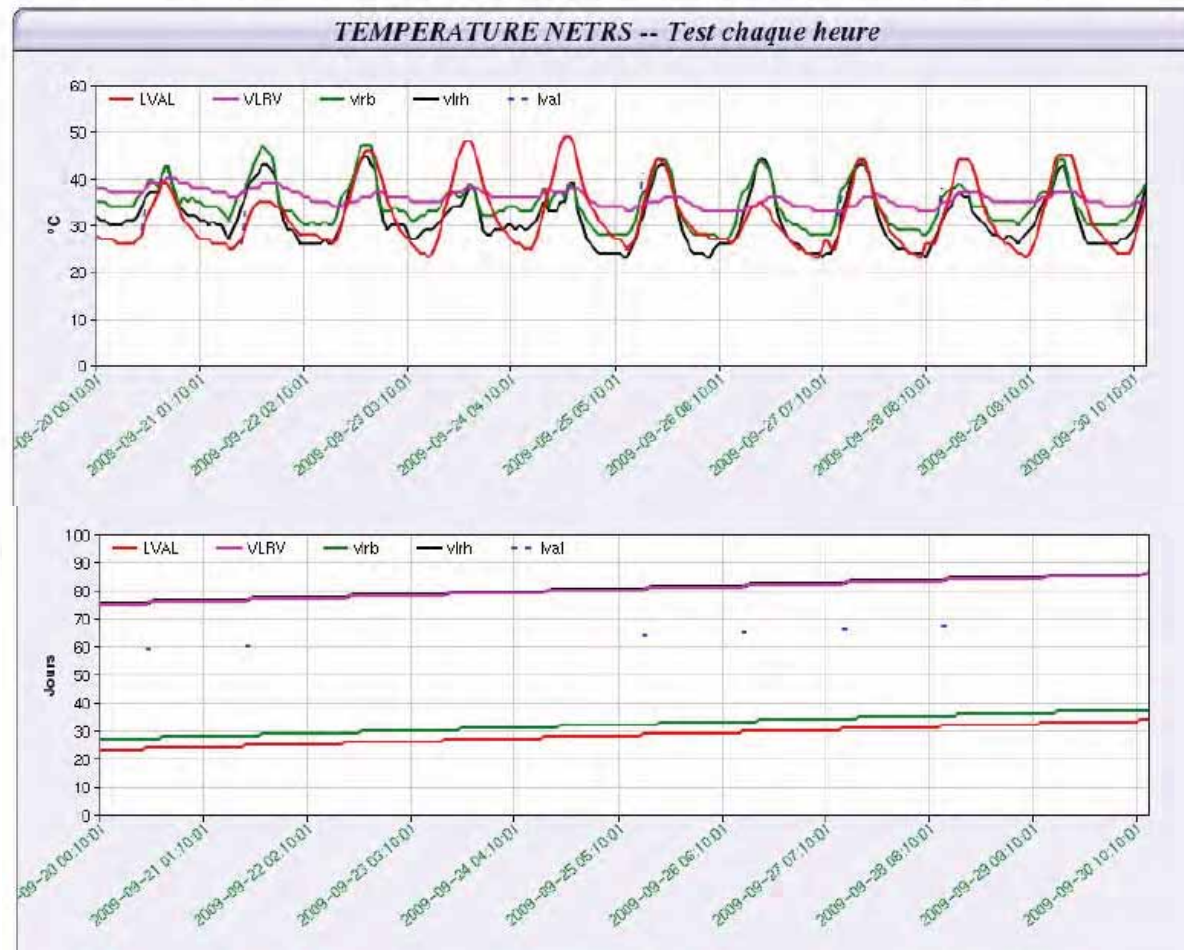
The aerial photograph shows a steep, rocky mountain slope. A dashed white line outlines the 'Escarpement principal'. Various monitoring points are marked on the slope: a green circle for a meteorological station, several blue circles with an 'X' for pore water pressure, orange squares for hydrology and inclinometry, a red line for DTS temperature, a brown circle for a seismometer, a purple diamond for an extensometer, a yellow star for a GPS station, and a blue square for a hut with a VHR optical camera. A topographic benchmark is also marked with a small red square. The elevation at the top left is 2105 m.

Sharing 'long-term' landslide data for research

Année	Mois	Jour	Heure		Année	Mois	Jour	Heu
2009	06	01	00	<DEBUT-----FIN>	2009	09	30	14

Envoyer Annuler

Status des NetRS de 2009-09-20, 00 heure(s) à 2009-09-30, 14 heure(s)



Continuous monitoring by dGPS and baseline processing at Day+1

Questions, suggestions, remarks?

