Early Warning and Alarm Systems for Natural Hazards

Richard Steinacher

Overview

1. Presentation block: Overview
   - Introduction
   - Types of early warning systems
   - Local measurements/remote measurements (remote sensing)
   - Short examples of various sensors

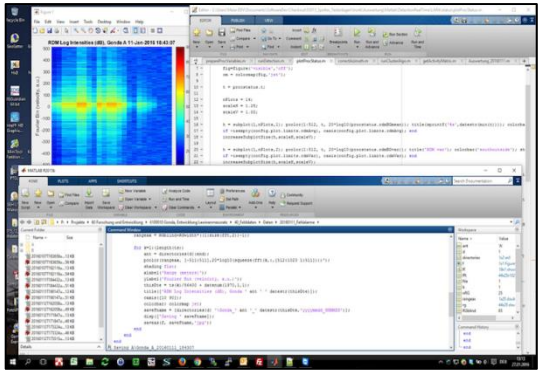
2. Presentation block
   - Image analysis
   - Interferometric radar
   - Doppler radar

3. Discussion

Geopraevent

develops, **installs** and **operates**

electronic **detection systems** for natural hazards.



Natural hazards?

drought

earthquakes

avalanches

storms

gravitational natural hazards

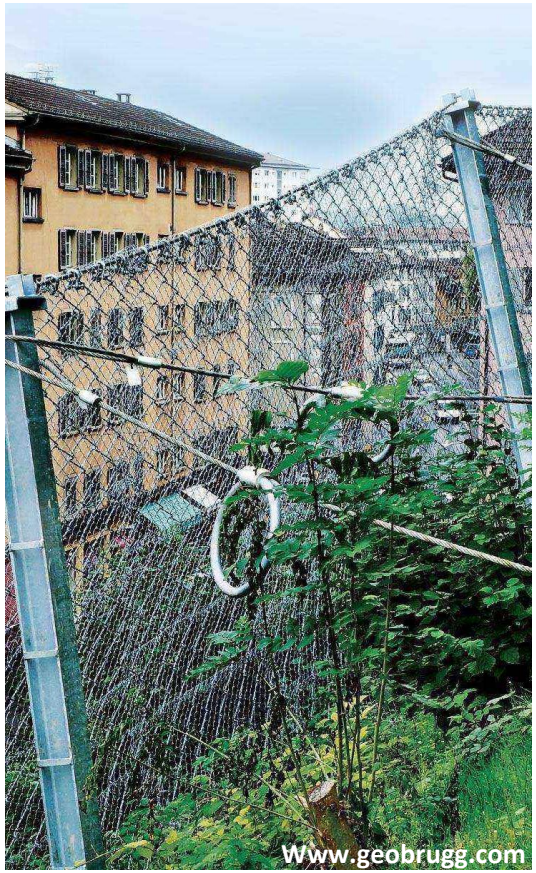
landslides/rockfall
rock avalanche

$$F = \frac{GM_1M_2}{r^2}$$

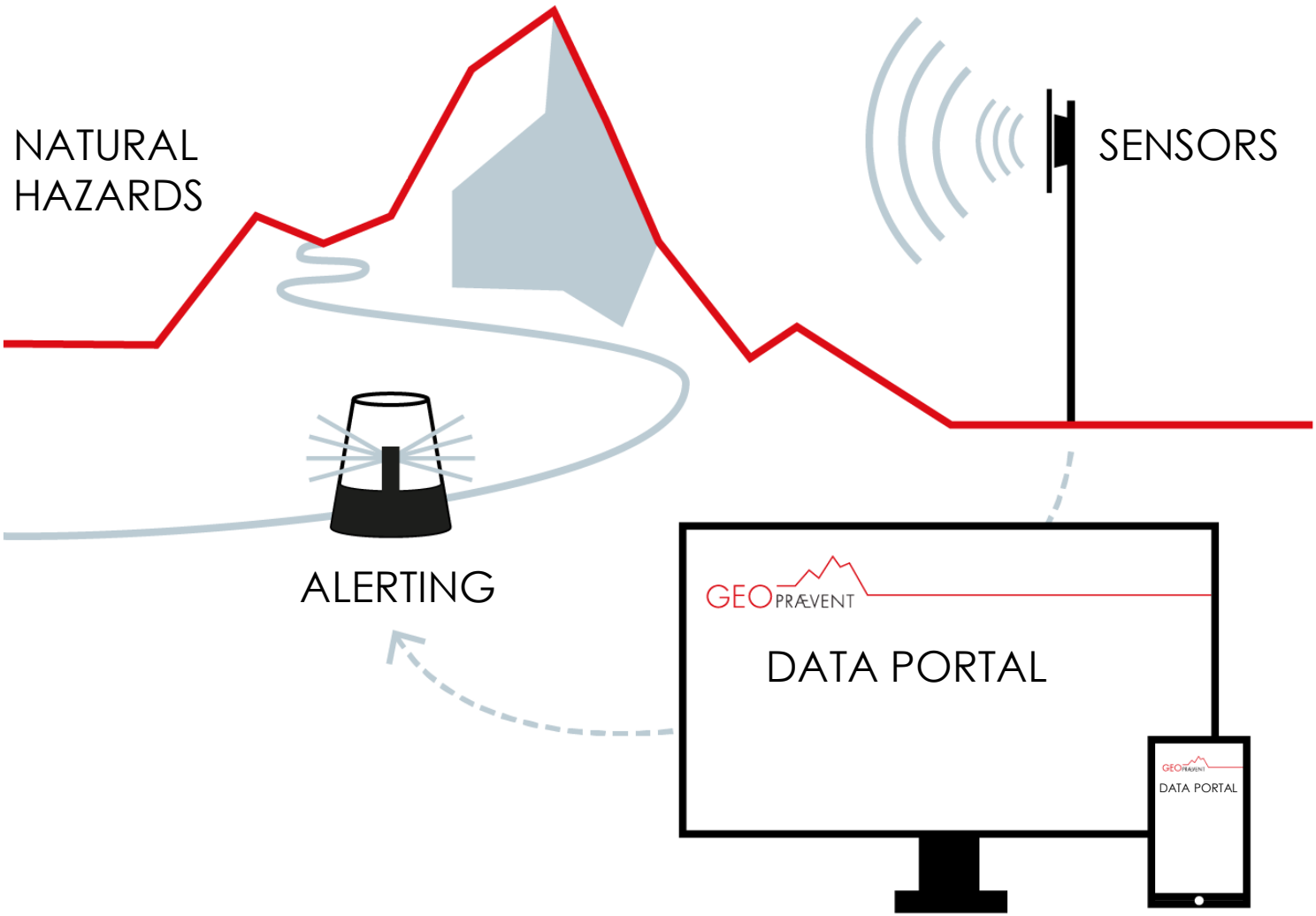
floods

debris flows

Permanent structural measures



Organizational measures



What do we monitor?

Rockfall

Floods

Glaciers

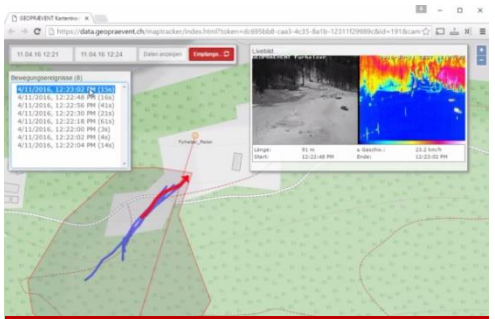
Landslides

Glacial Lakes

Avalanches

Debris flows

Rockfall nets



People

About

80

permanent stations

200

projects

in

Switzerland
Austria
Germany
Italy
Norway
Georgia
Canada
China
Chile

All photos are from operational GEOPRAEVENT installations.

www.geopraevent.ch

How we work, who we are...

Project flow (days to months)

Situation/Risk Analysis

Proposal measures

Specification monitoring requirements

Detailed specifications/
System integration

Planning/construction of system hardware, software

System installation

operation/monitoring of system

Data interpretation, organisational measures

Engineering offices

various offices

customer directly (e.g. cantons)

15 employees

8 electric/software engineers

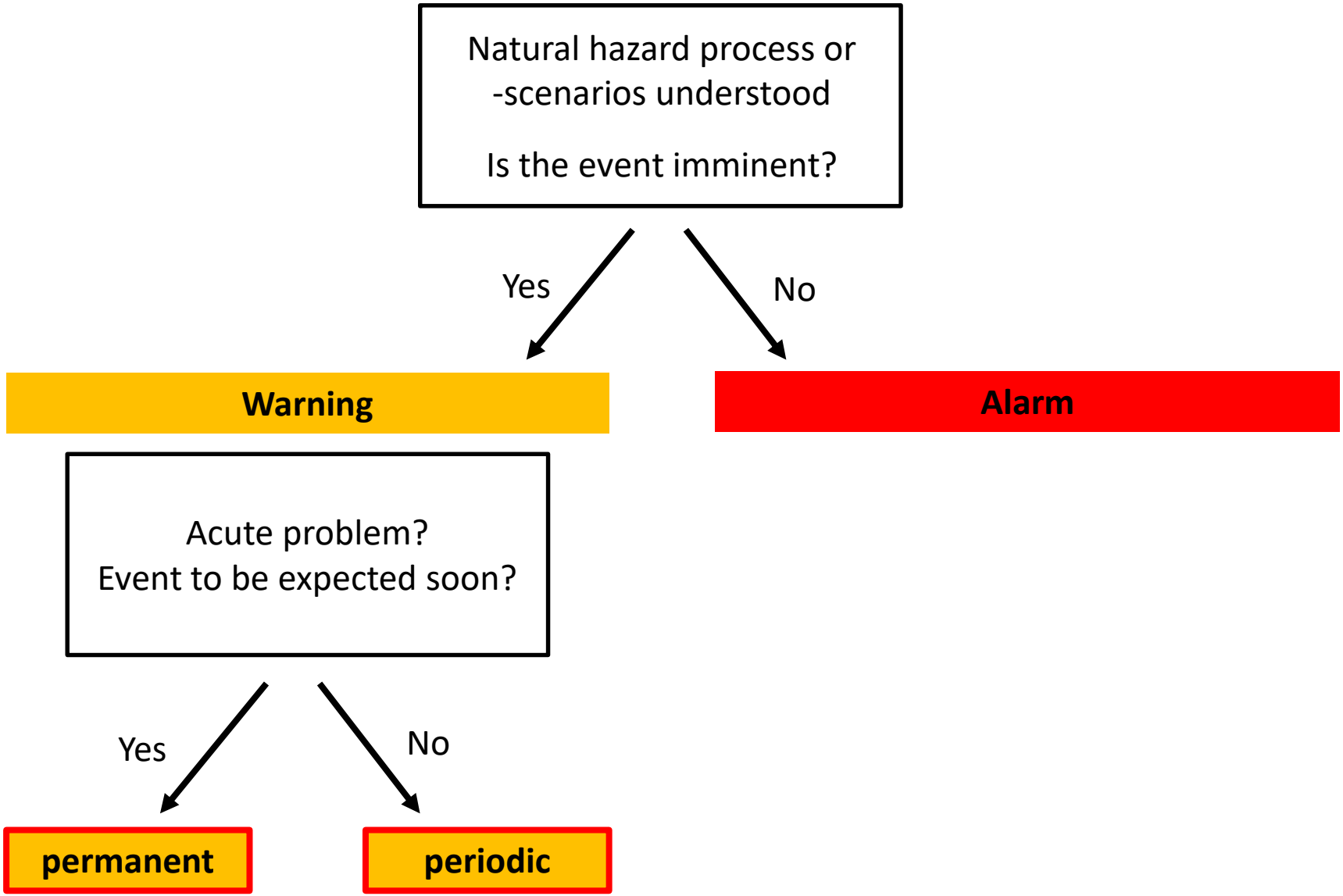
5 Technicians/Administration

2 Physicists

Approx. 70 systems CH/NO/AT/GE/CN/CL

TECHNOPARK® ZÜRICH

Project schedule



Types of measuring systems

	A **Alarm system**	W **Warning system**
	measures actual event	measures event precursors
Measurement	velocity, pressure, level, deformation...	precipitation, snow depth, level, deformation, temperature...
Action	direct and automatic alerting	Interpretation of data by experts. Automatic model integration individual cases (e.g. tsunami warning system)

See for example Practical assistance for the use of early warning systems for gravitational natural hazards by Babs/SLF

Setting up an early warning system

Sensors

Measurement of primary physical parameters

Data logger

Digitization of measured values, calculations, alarm triggering

Communication

Data transfer to servers or for alerting

Alerting

Information of the persons concerned, evacuation of areas, road closures

Setting up an early warning system

Sensors | Data logger | Communication | Alerting

Technologies

GEO PRÆVENT

Sensors | Data logger | Communication | Alerting

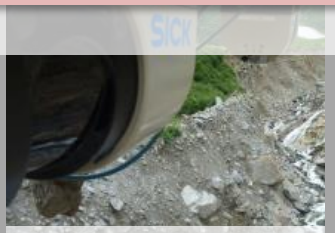
Local measurements


Distance (Laser)


Distance (Radar)


Force


Geophones


Profile Scanner


Cleft measurements/Extensometer

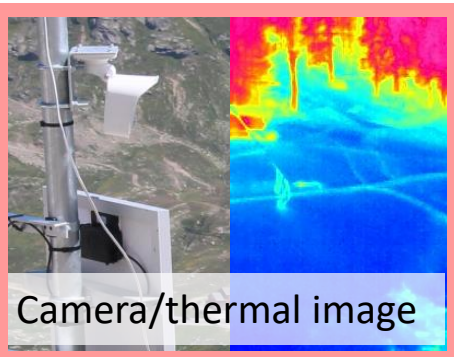

Radio


Weather


Pressure

etc....

Remote Sensing


Camera/thermal image


Laser scans

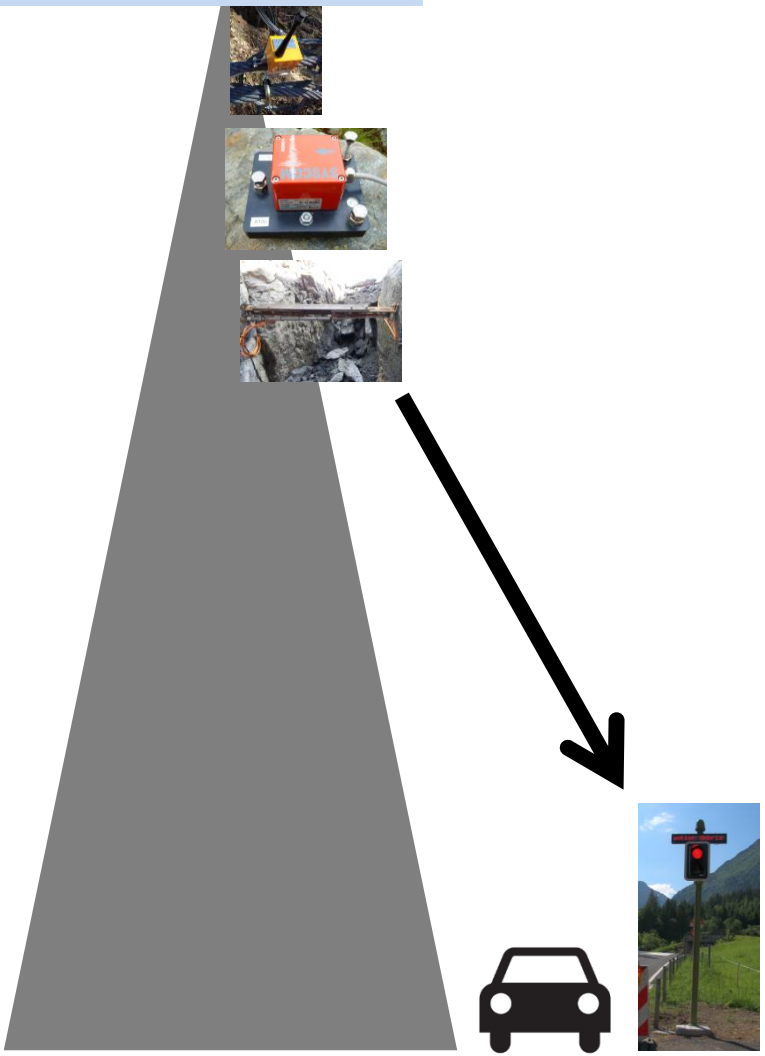

Interferom. radar


Doppler radar

All photos are from operational GEOPRAEVENT installations.

Local Monitoring

Sensors



Sensors on the mountain – alerting in the valley

Benefits

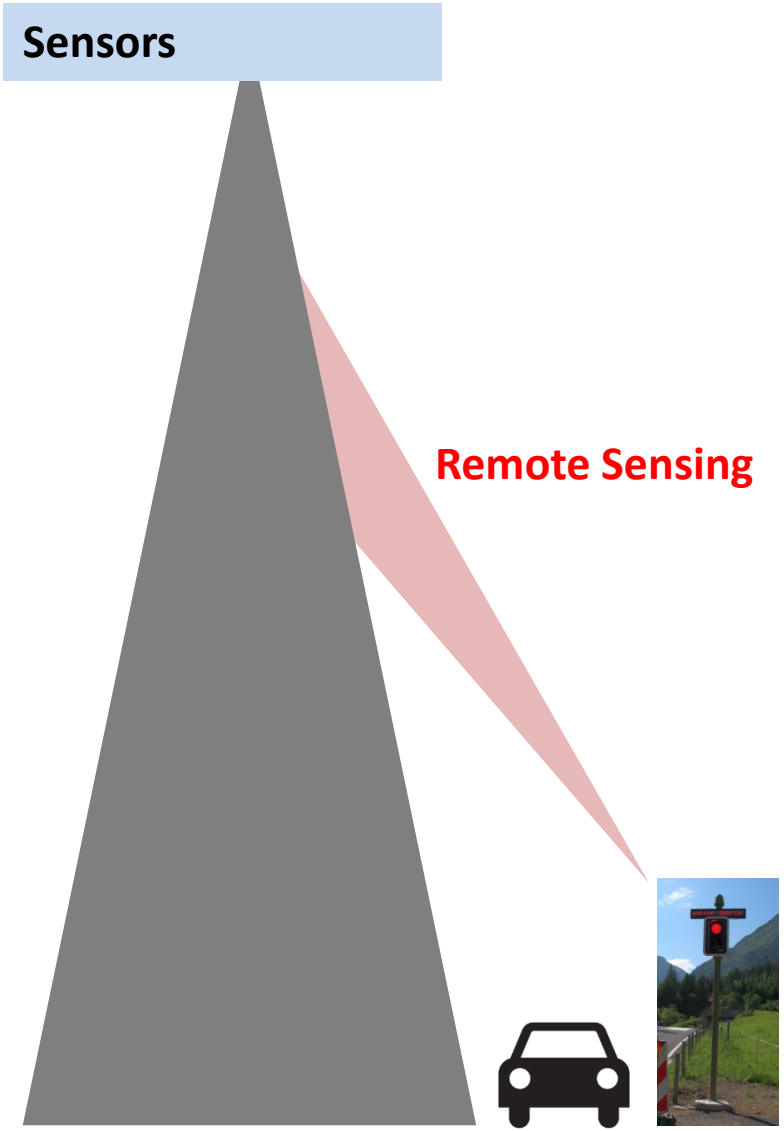
- Simple, inexpensive sensors
- Straightforward algorithms/threshold values

Disadvantages

- Reliable data transmission required
- Expensive, ev. dangerous installation
- Autonomous power supply
- Partly high maintenance costs
- Limited measuring range
- Inflexible if danger changes


2018-01-22 CET 12:02:01
GEO PRÆVENT
ZERMATT
EINWOHNERGEMEINDE
CANTON DU VALAIS
KANTON WALLIS
Https://youtu.be/bTA1oPih7so
2018-01-22 12:02:01
001864 ETH Event UC

Remote Monitoring



Sensors in the valley – alerting in the valley

Benefits

- Large and flexible coverage area
- Simple, safe installation
- Cheaper (at least per monitored m^2)
- Smooth data/alarm transmission

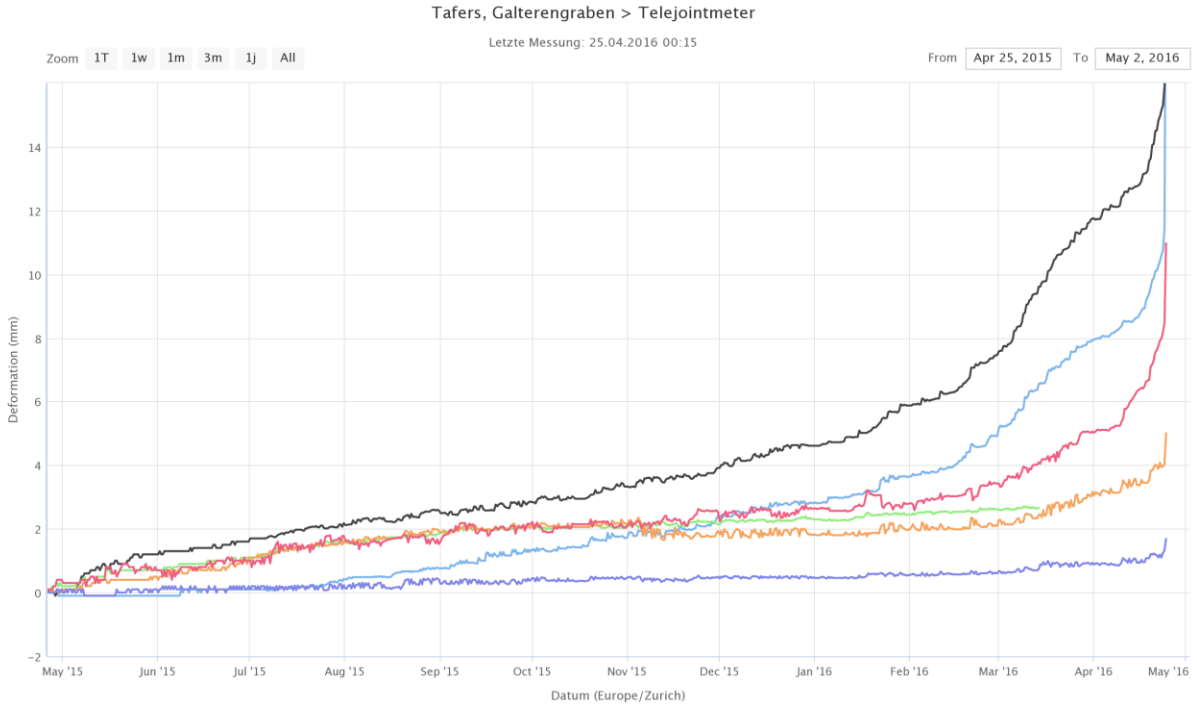
Disadvantages

- Visibility not always guaranteed
- In extreme cases disturbances due to weather
- Costly for ' little ' problems

Extensometer

Deformation measurement
Extensive? No
Remote measurement? No
All weather? Yes
Accuracy Sub-mm
Costs Low (# of sites)

Example
Tafers, Galterengraben 2015
Prediction break-off approx. 2500 m^3
Total deformation before break-off: approx. 20 mm



Tachymeter/Total Station

Deformation measurement

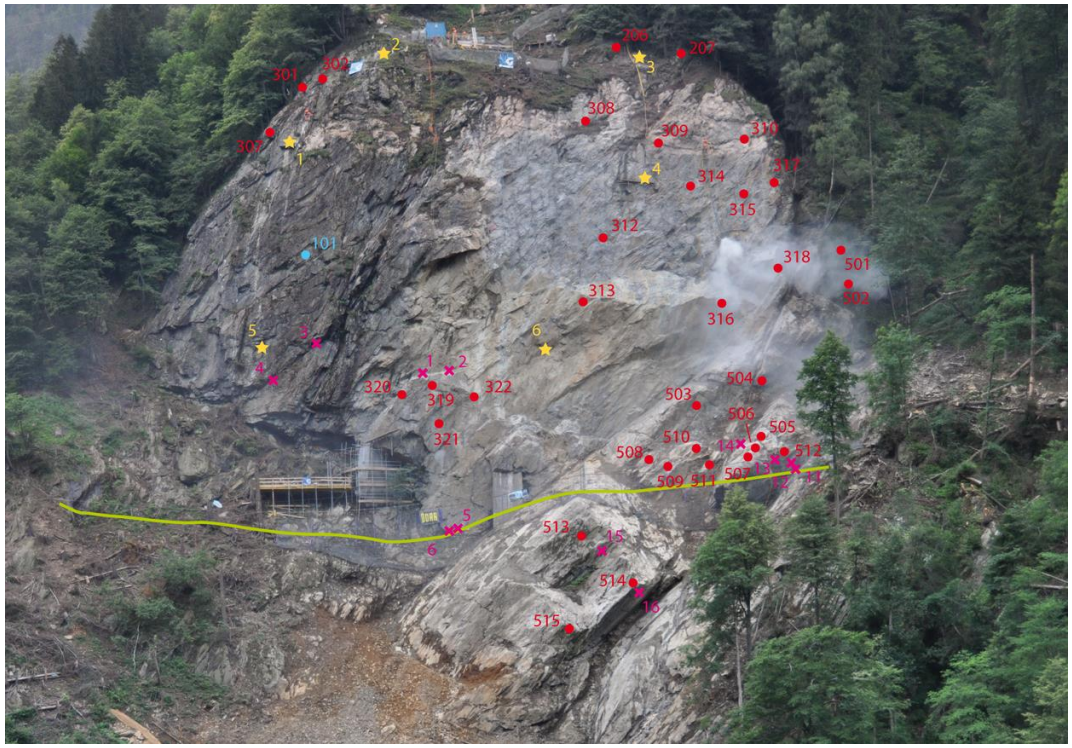
Extensive?	No
Remote measurement?	No
All weather?	No

Accuracy a few mm

Costs low

Example

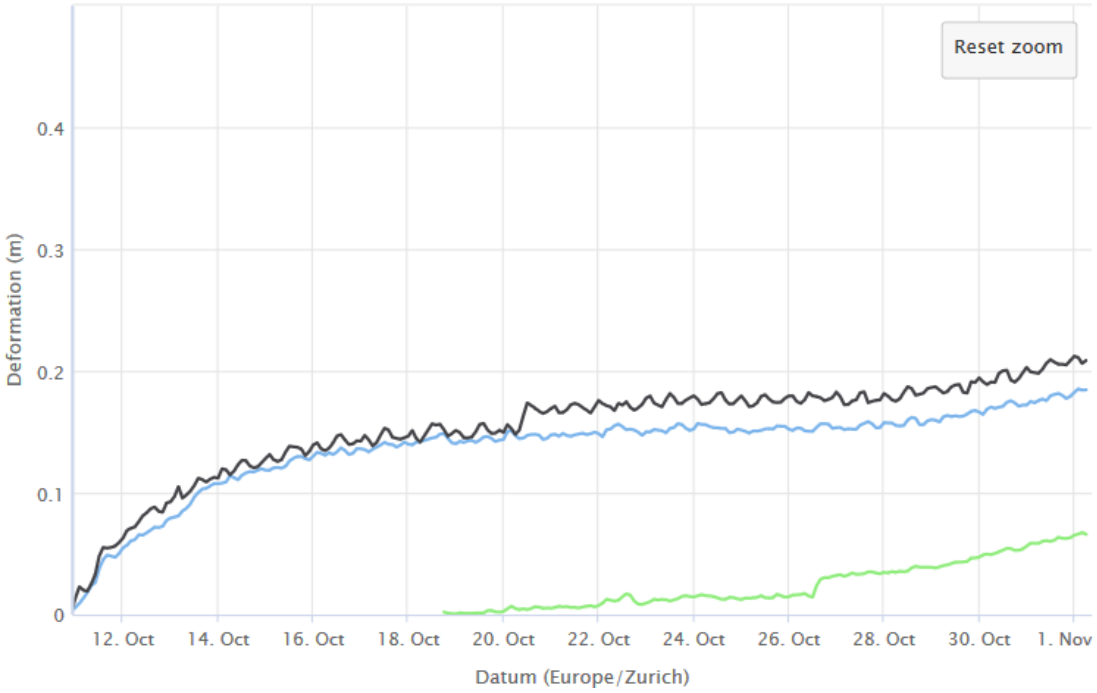
Gurtnellen, Rockfall SBB 2012
redundant measuring setup
with approx. 50 mirrors
10 telejointmeters, 5 extensometers, trigger lines, interferom. Radar, local alerting



GNSS (Geosat GPS)

Deformation measurement
Extensive? No
Remote measurement? No
All weather? Yes
Accuracy Some mm to cm
Costs Medium-High (number)

Example
Landslide Malbun FL 2017
3 GPS + 1 reference station. approx. 1 cm/day
Several predefined threshold for Sms



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Deformation measurement
Extensive? No
Remote measurement? No
All weather? Yes
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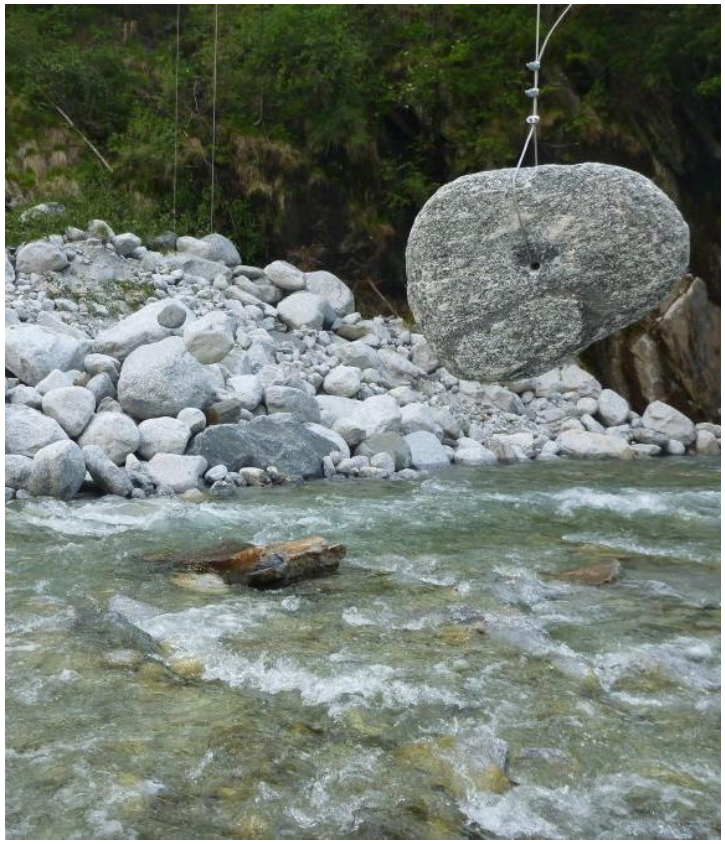
Costs Medium-High (number)

Example
Landslide Zongling, China 2018
7 GPS + 1 reference station

Trigger lines

Fast mass movement
Type local
Costs low

Example
Bondo, Val Bondasca
3 trigger lines close the road on 23.8.2017



Force measurement

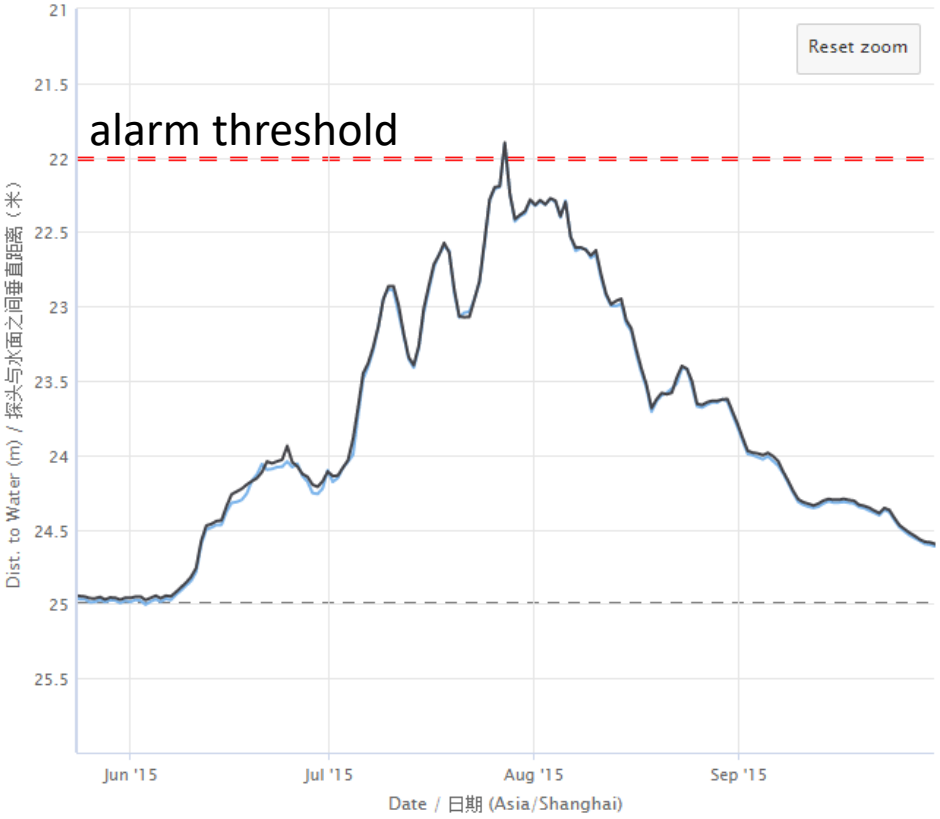
Safety switch

Predetermined breaking point

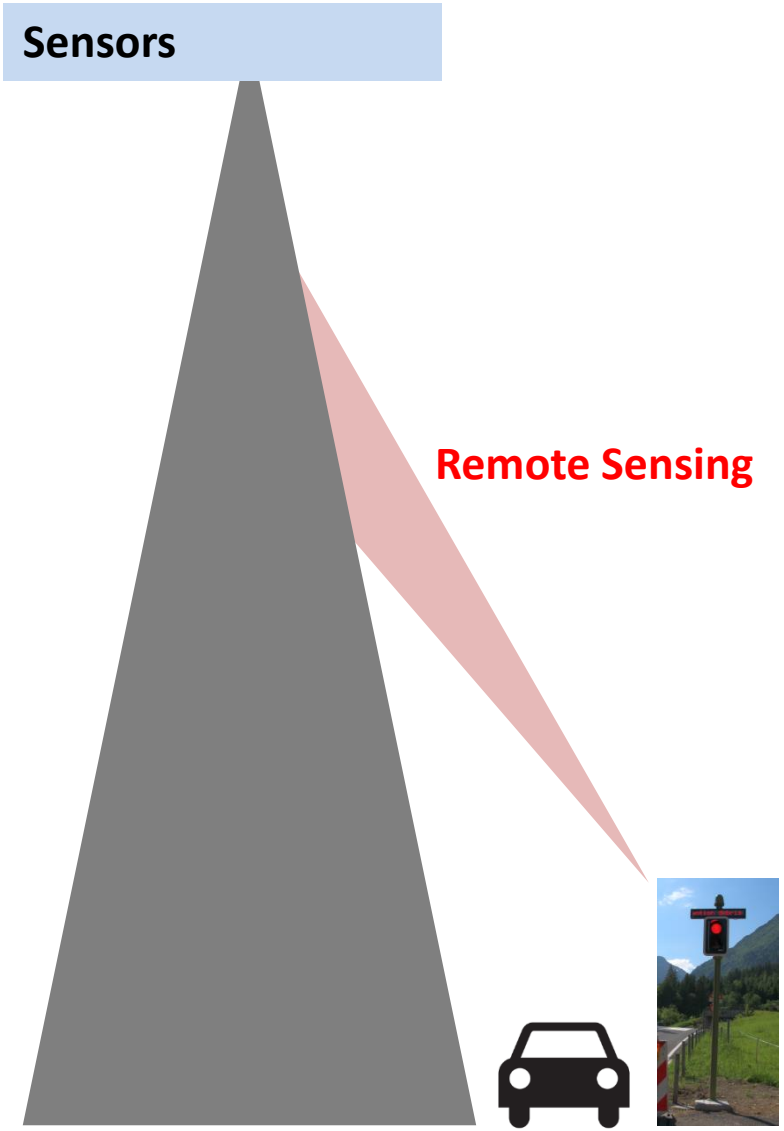
Level measurement

Fast mass movement
Type Local
Costs Low-Medium

Example
China, Hekou, Kelequin River monitoring
2 gauge radars, 2 cams, weather station



Remote Monitoring



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- Smooth data/alarm transmission

Disadvantages

- Visibility not always guaranteed
- In extreme cases disturbances due to weather
- Costly for ' little ' problems

Image analysis

Deformation measurement

Extensive?	Yes
Remote measurement?	Yes
All weather?	No
Accuracy Some cm	
Costs Low to Medium	

HD Camera with up to 42 Mpix
local processing of difficult light conditions
server processing of image analysis

Image analysis

Deformation measurement	
Extensive?	Yes
Remote measurement?	Yes
All weather?	No
Accuracy Some cm	
Costs Low to Medium	

Example

Saas Grund, Trift Glacier/Weissmies

Glacier collapse approx. 300'000 m^3 on 10.09.2017

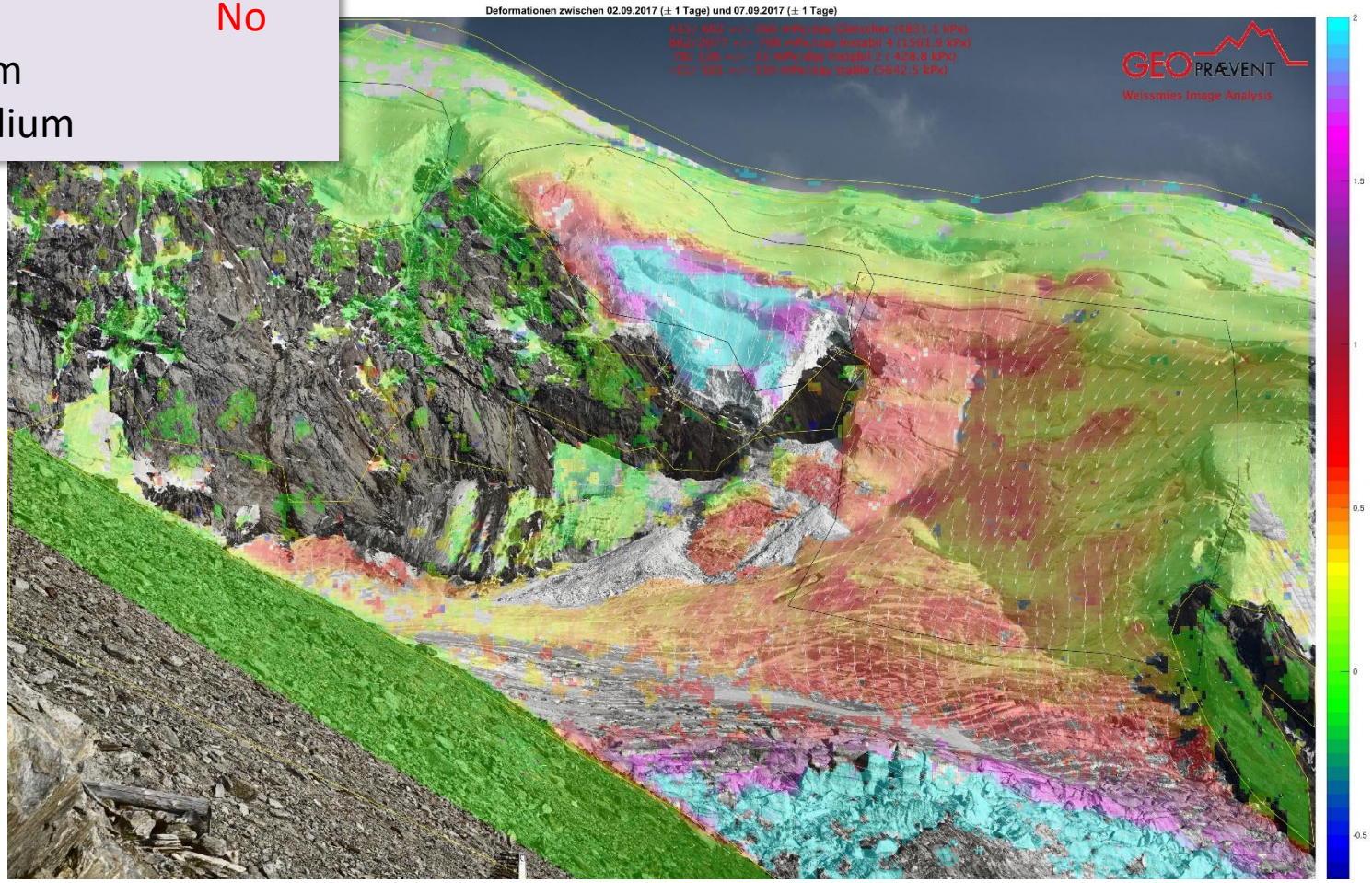


Image analysis

Deformation measurement

Extensive? Yes

Remote measurement? Yes

All weather? No

Accuracy Some cm

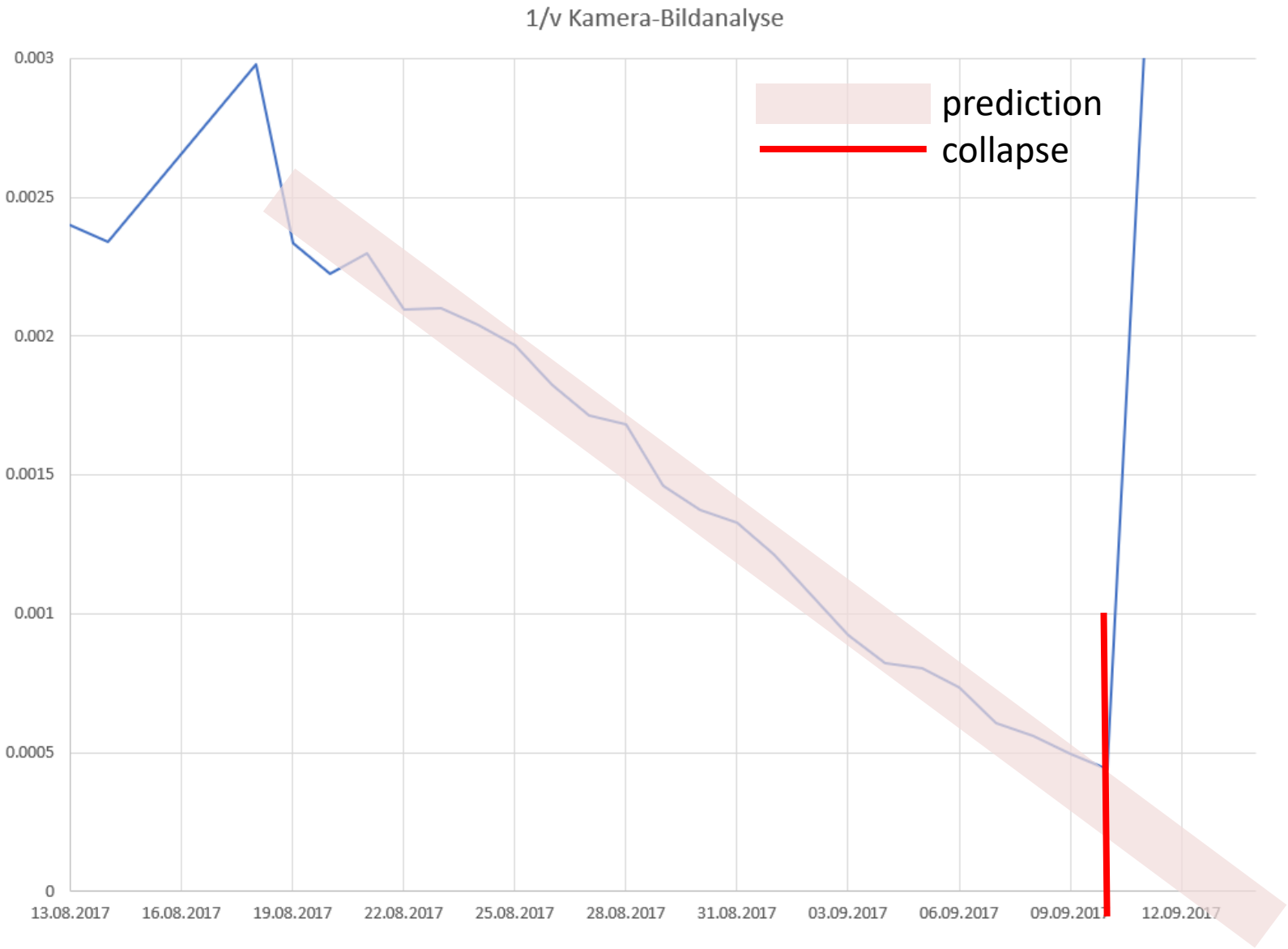
Costs Low to Medium

Example

Saas Grund, Trift Glacier/Weissmies

Glacier collapse approx. 300'000 m^3 on 10.09.2017

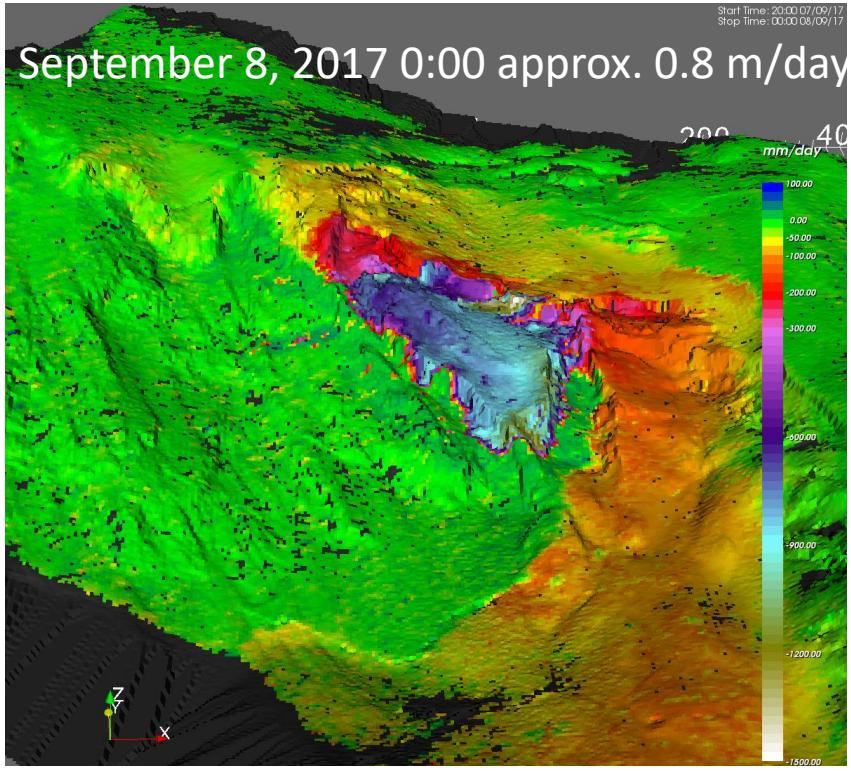
Image analysis

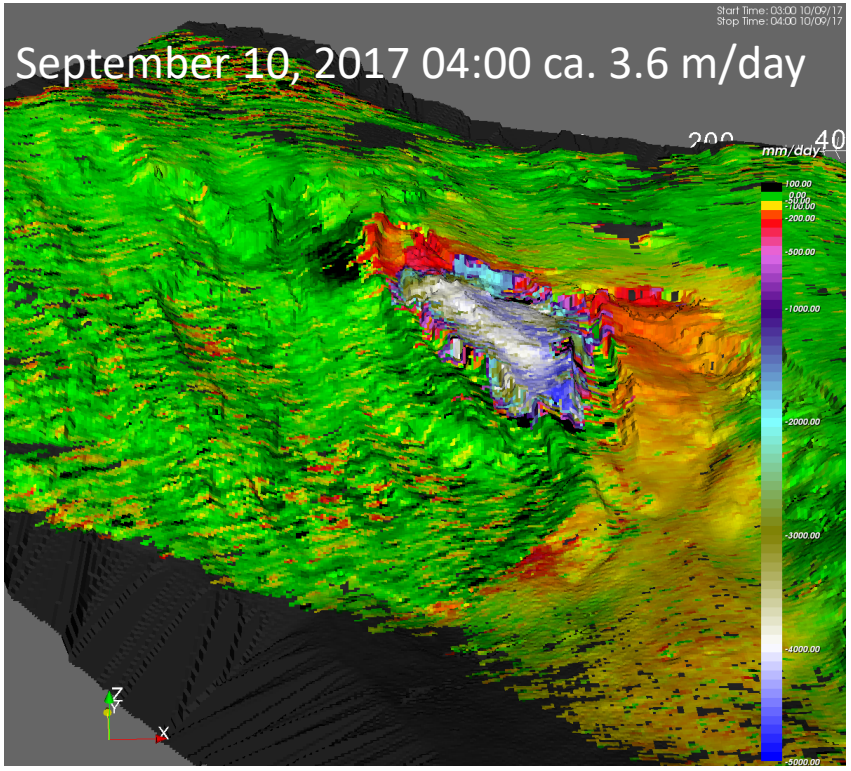


Interferometric Radar

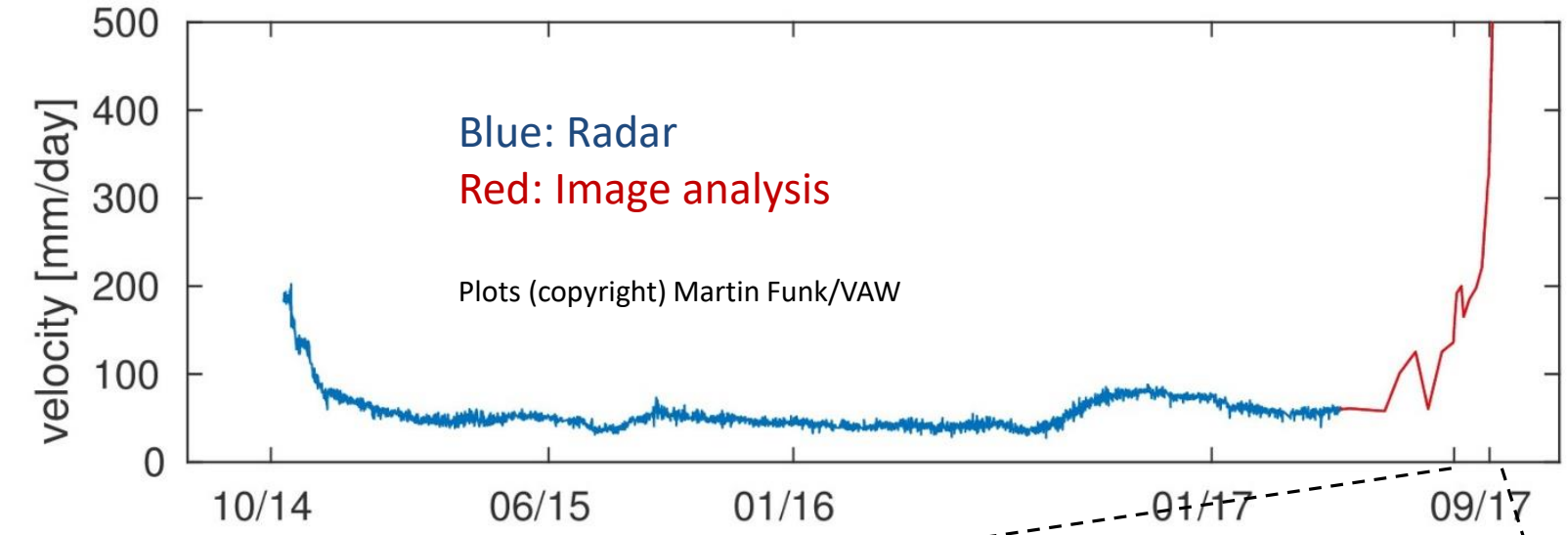
Deformation measurement
Extensive? Yes
Remote measurement? Yes
All weather? Yes
Accuracy Sub-mm to mm
Costs Medium to high

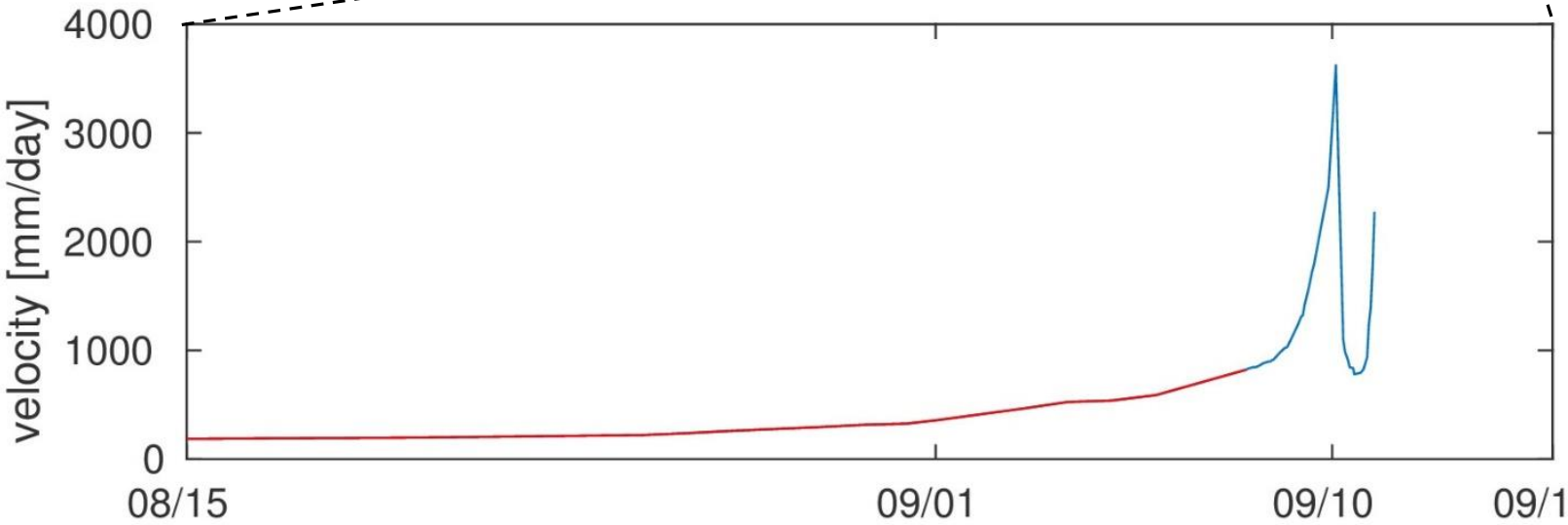
Example
Saas Grund, Trift Glacier/Weissmies
Glacier collapse approx. 300'000 m^3 on 10.09.2017





Weissmies: interferometric radar/image analysis

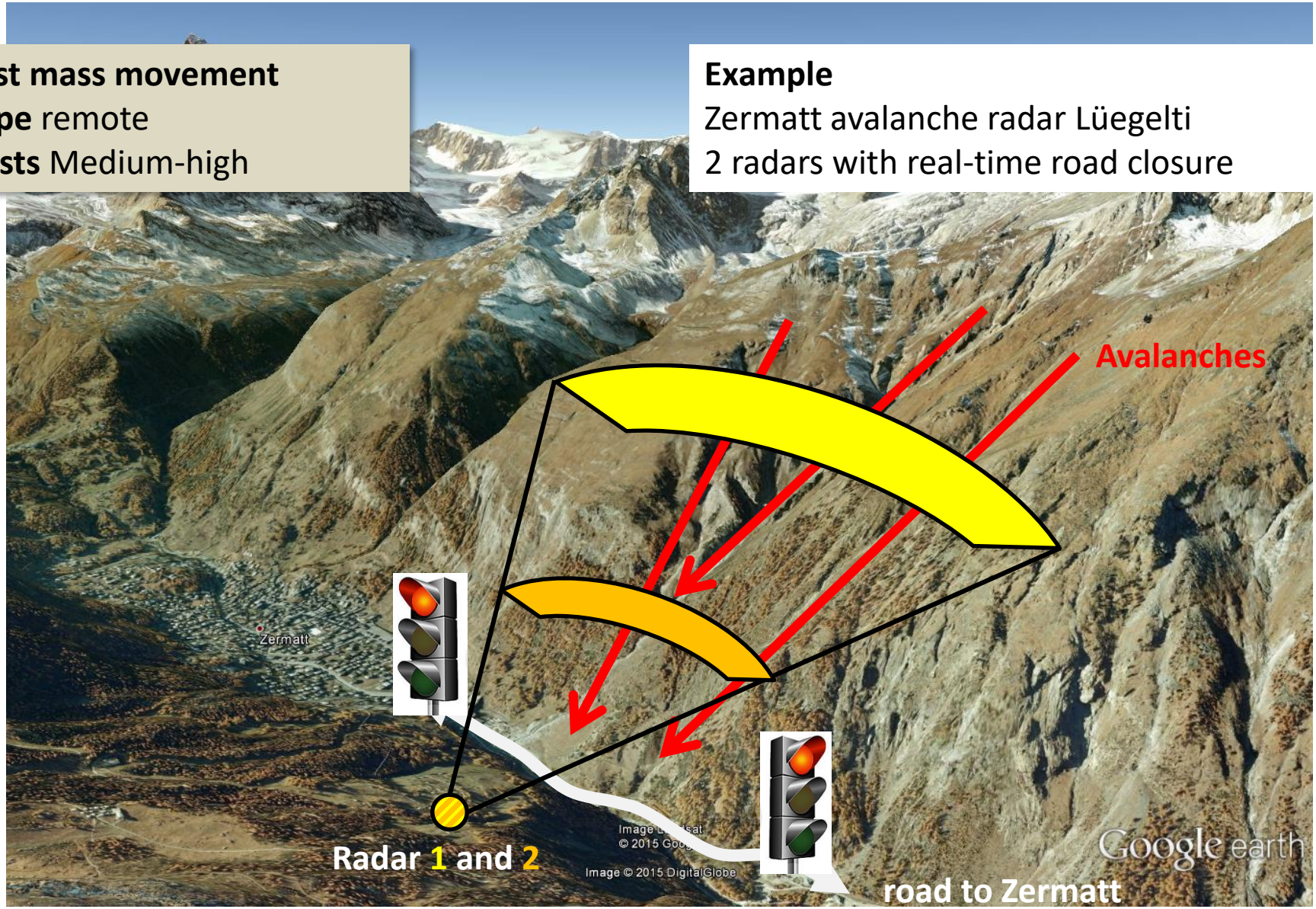




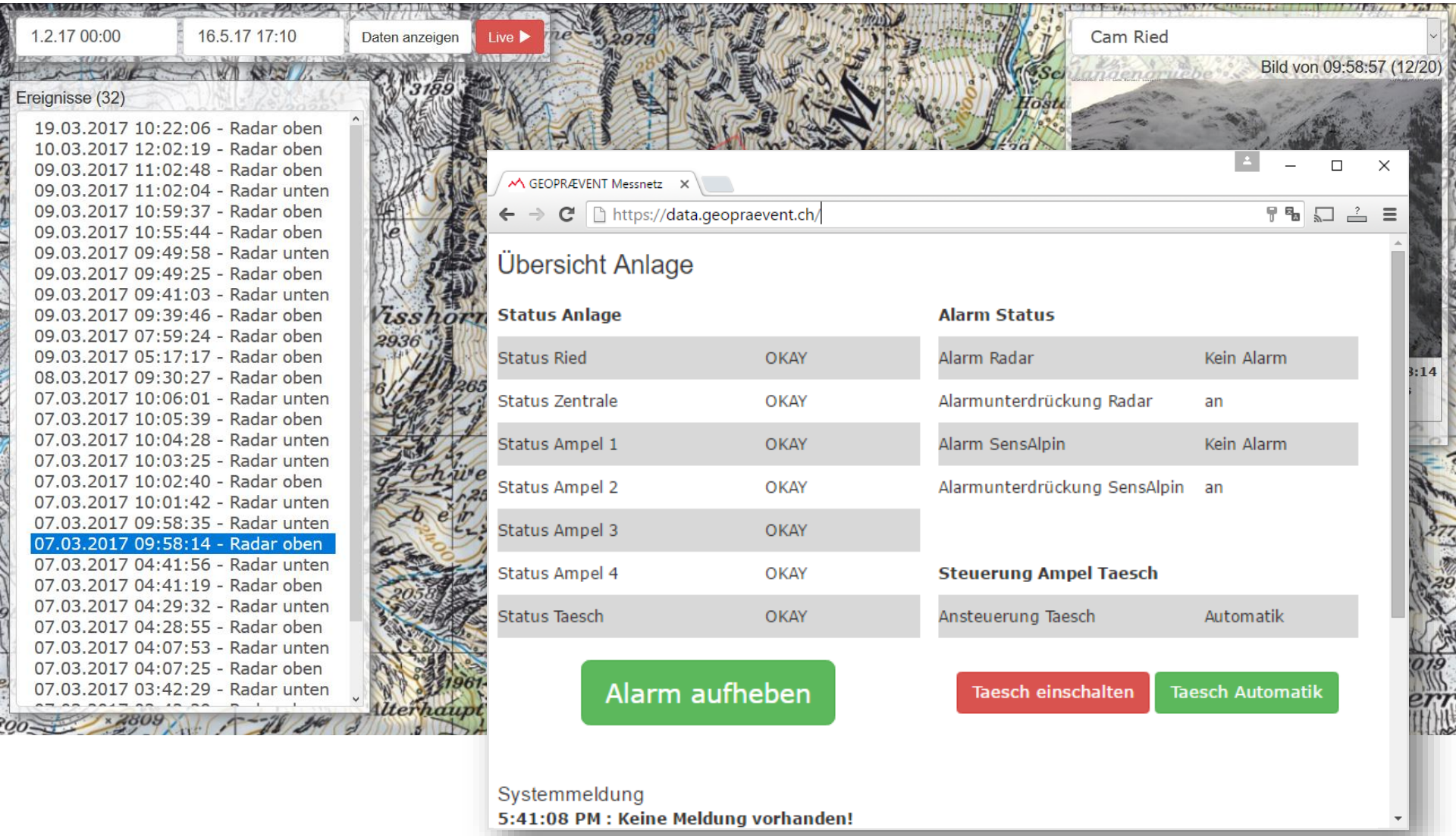
Doppler radars

Fast mass movement
Type remote
Costs Medium-high

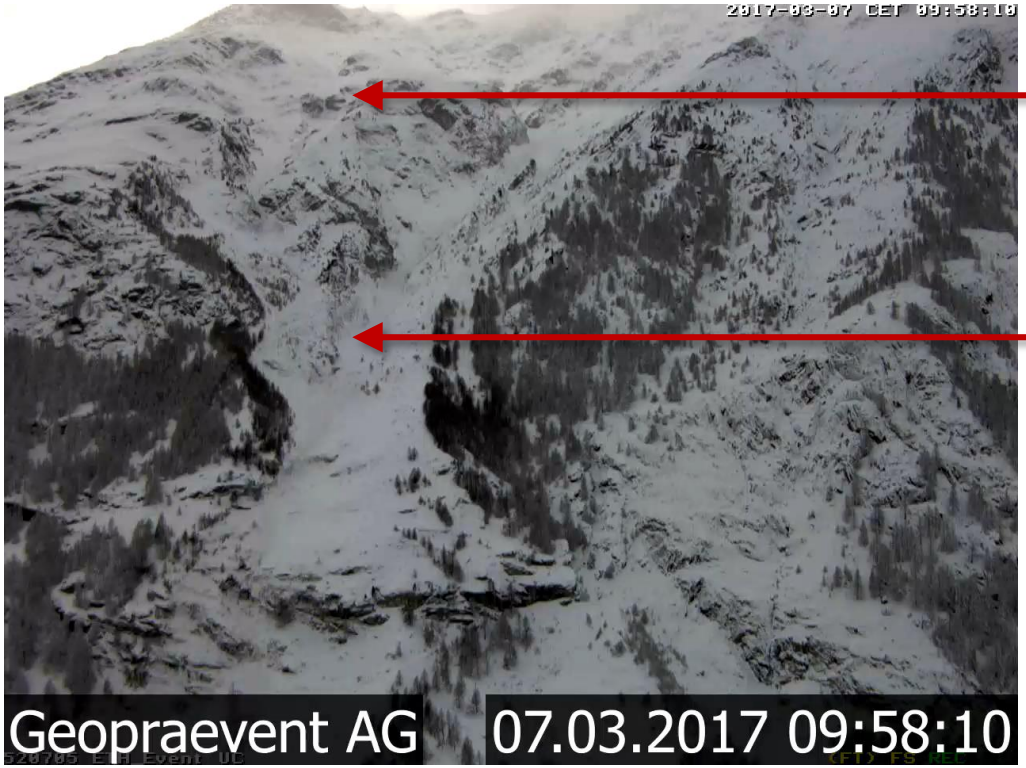
Example
Zermatt avalanche radar Lüegelti
2 radars with real-time road closure



Avalanche alarm system Zermatt



Zermatt: avalanche of 7 March 2017



Detection upper radar
→ Automatic road closure

Time: 09:58:20

Detection lower Radar
→ Big avalanche confirmed

Time: 09:58:41

Powder cloud at road

Time: 09:59:07

Street had been closed since

47 seconds

Https://youtu.be/h5eFnWq4BD0

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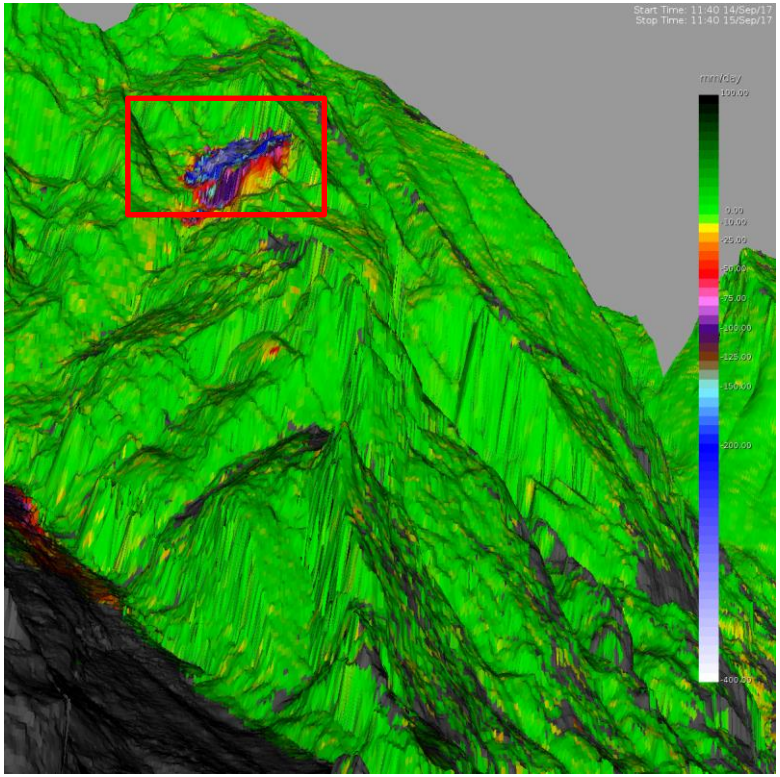
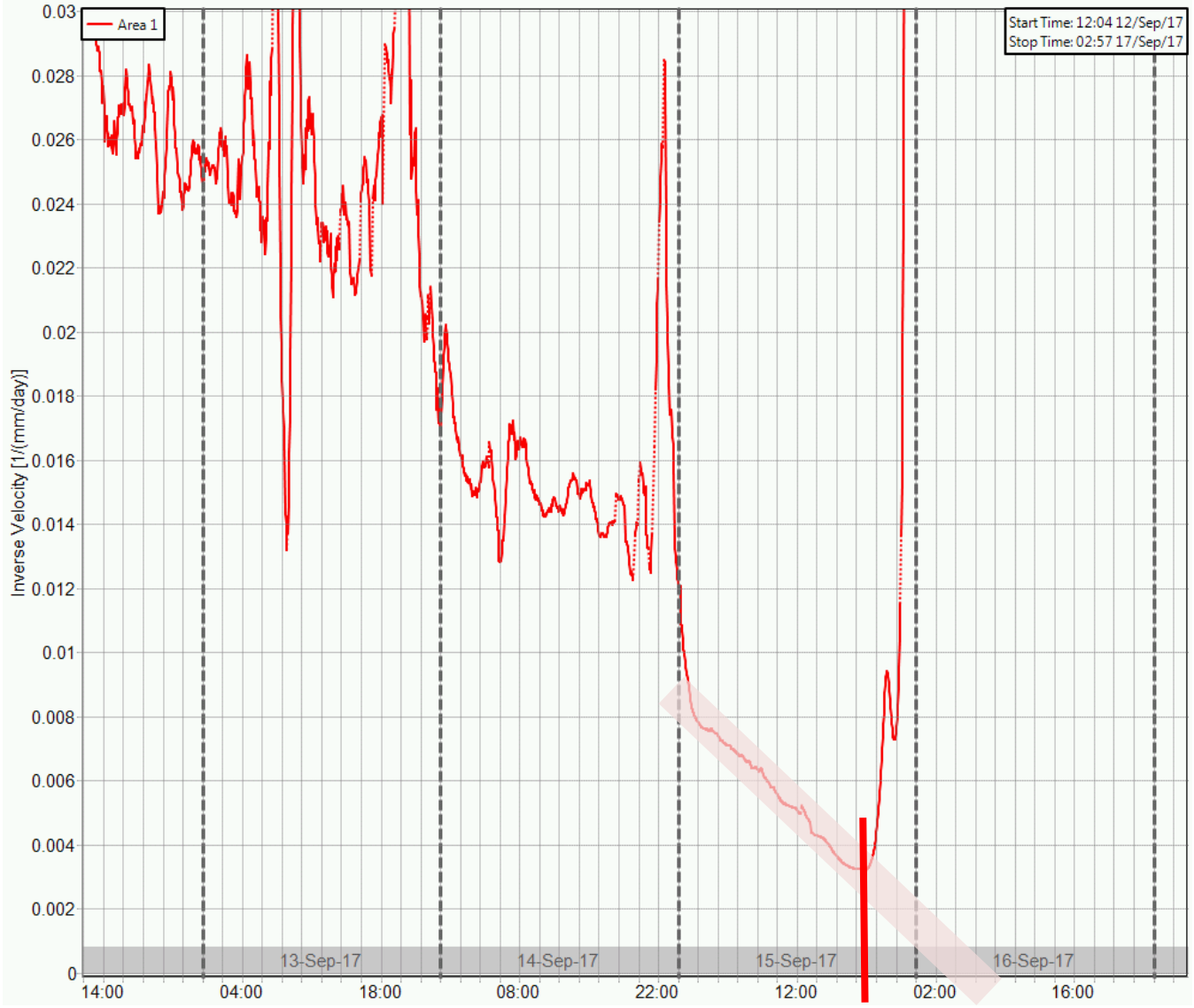
Radar/Camera Sciora


GEOPRÆVENT
GEOPRAEVENT Radar Cengalo

Radar Sciora: Real-time analysis



Radar Sciora: Real-time analysis



Prediction

Event

Radar Sciora

Permanent radar measurements

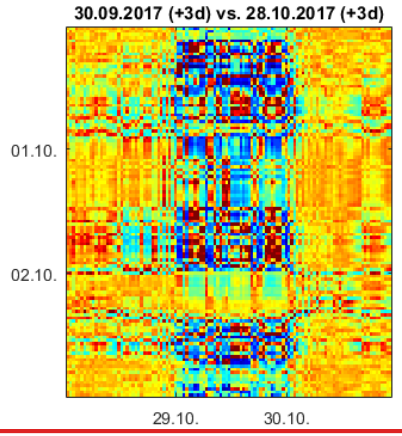
Approx. 400 measurements per day, approx. 10 GB data/day

Real-time analysis

Detection of mm movements within about 1 hour

Long-term analysis

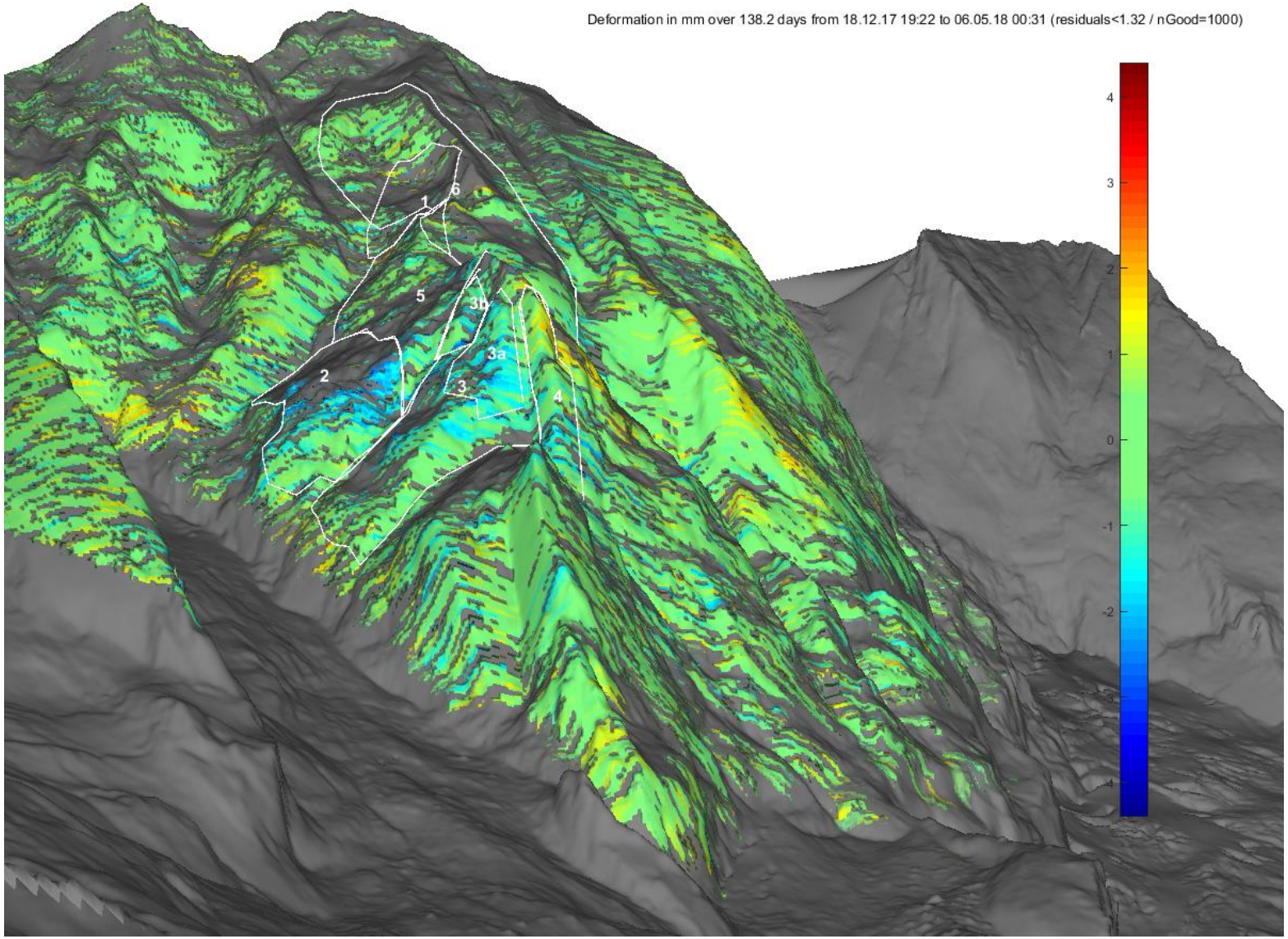
Detection of mm movements within days, weeks, months, years...



e.g. comparison of all measurements October with September:

72 million possible pairs:
-> smart algorithms needed

Special analysis 140 days (Dez 2017 – Mai 2018)



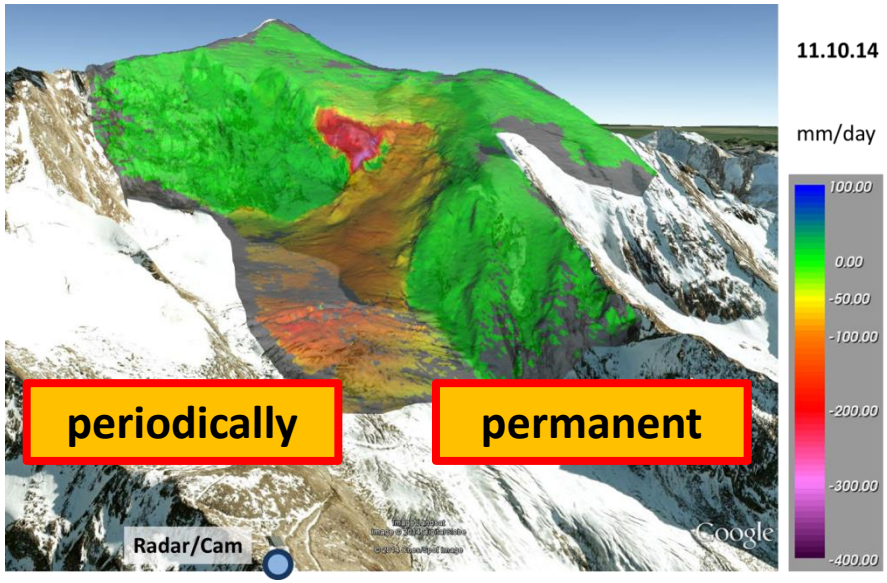
Event detection with radar

Benefits:

Large monitored area (km^2)
No installation in dangerous area
Relatively weather resistant

Interferometric radar

Warning

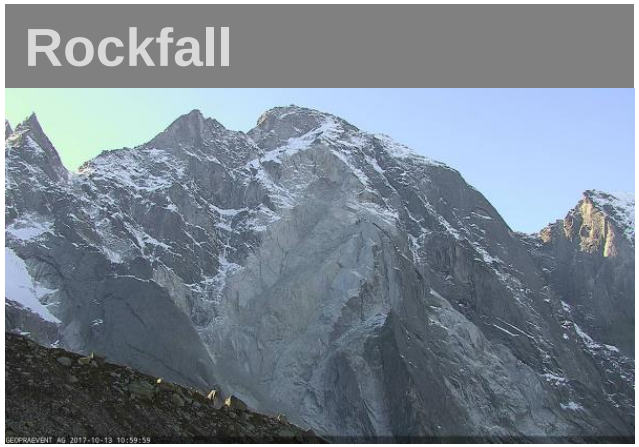


Slow (mm per minute or year)
Rock instabilities, landslides, glaciers

Doppler radar

Alarm

Rapid (meters per second)
Avalanches, rock fall, debris flows



Example: Rockfall/debris flow val Bondasca

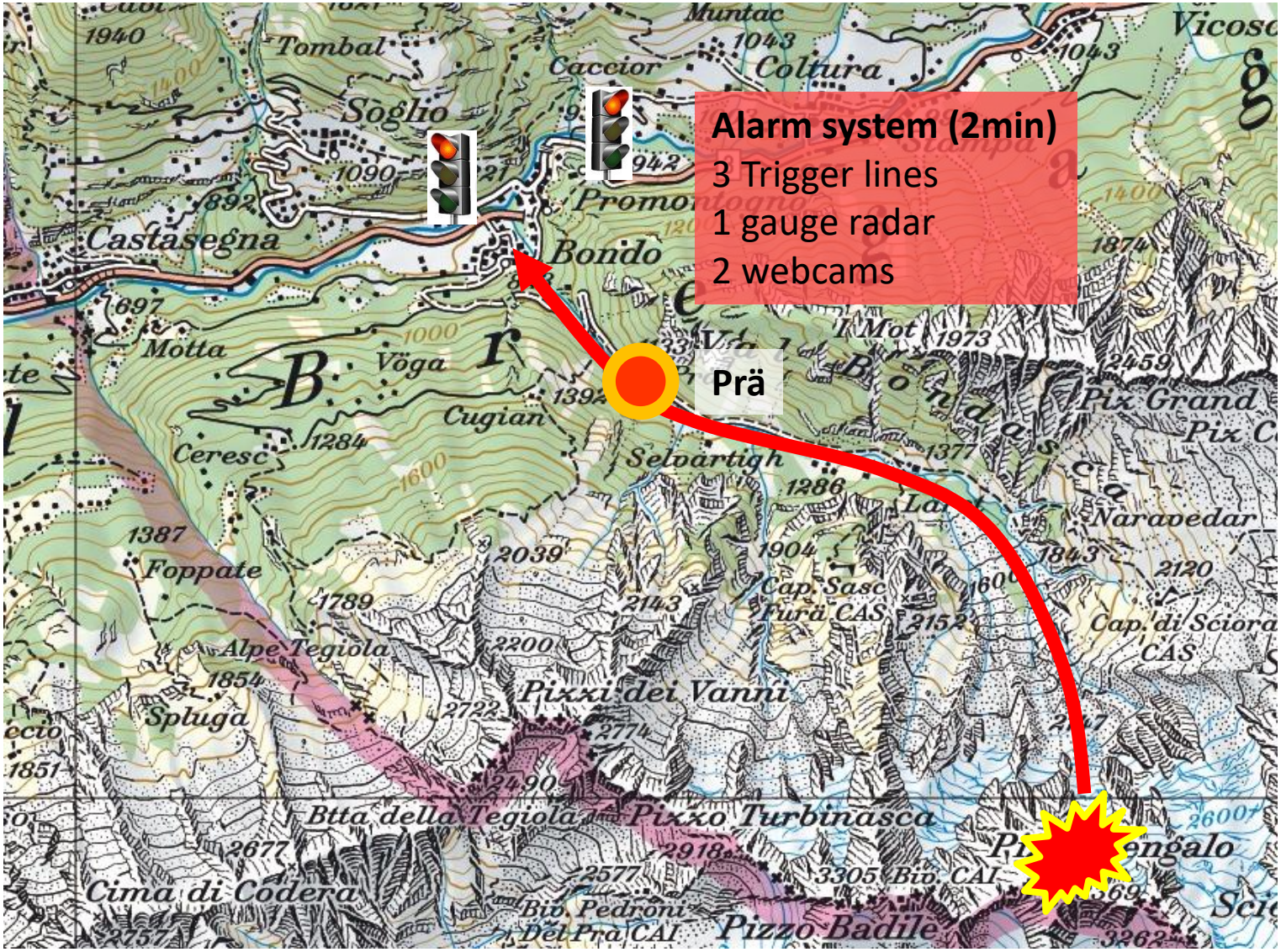
Customer: Community Bregaglia, Canton of Graubünden

23.08.2017: Rock avalanche 3 Mio m^3 on Pizzo Cengalo

© Sciorahütte

© SLF Davos

23 August 2017



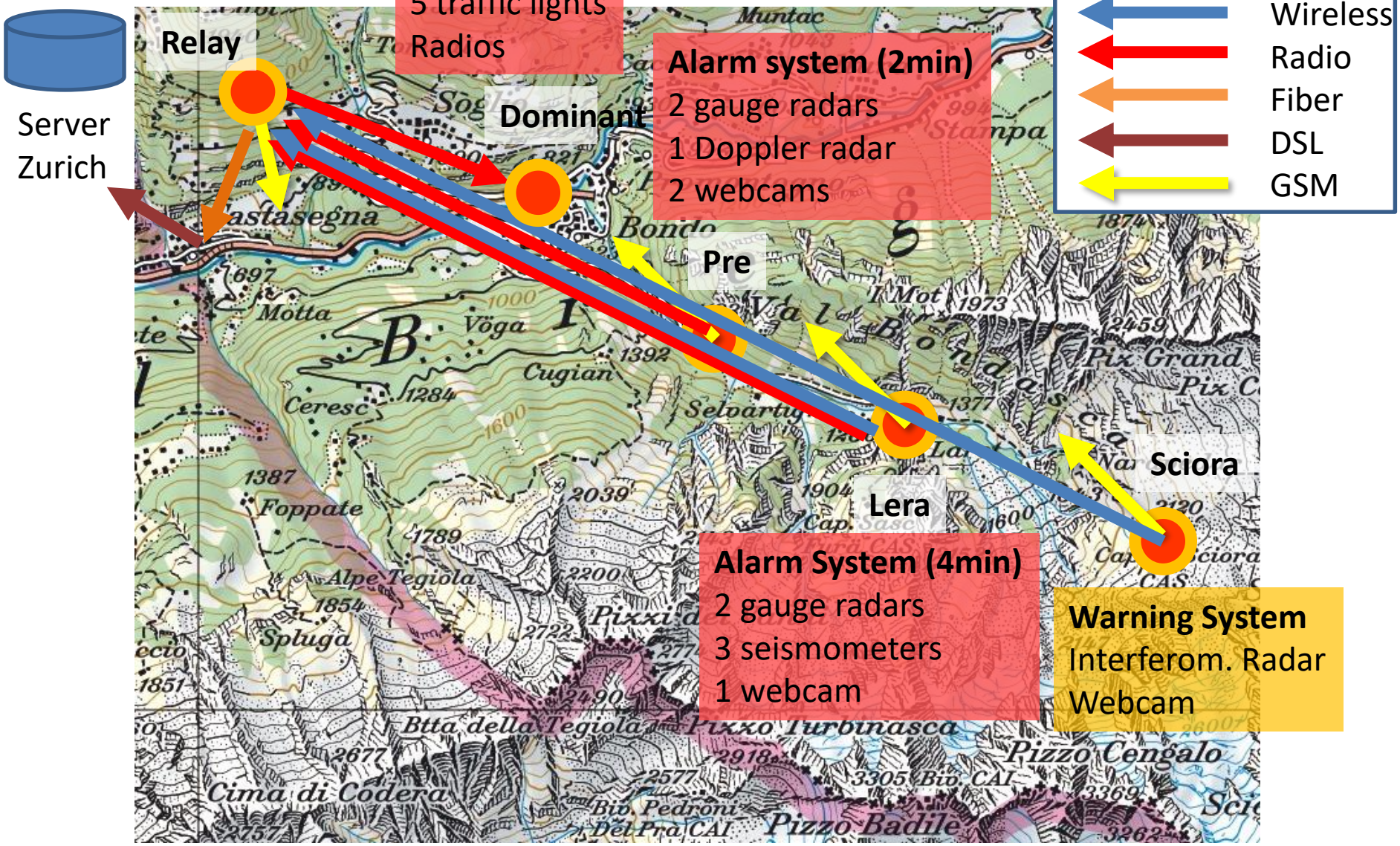
Detection Prä

Detection Prä

Bondo: One of several debris flows

Bondo

Bondo: Monitoring Val Bondasca

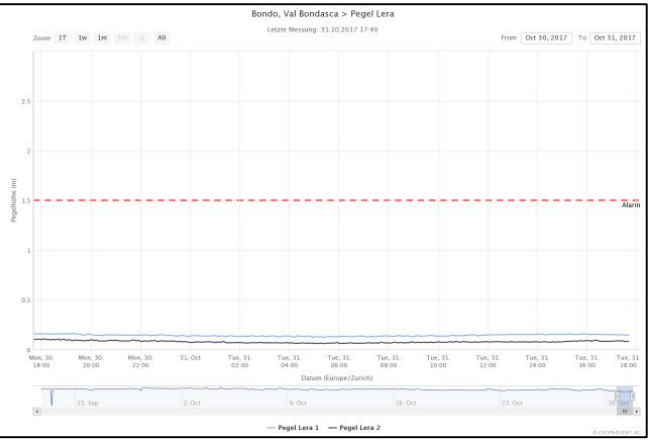


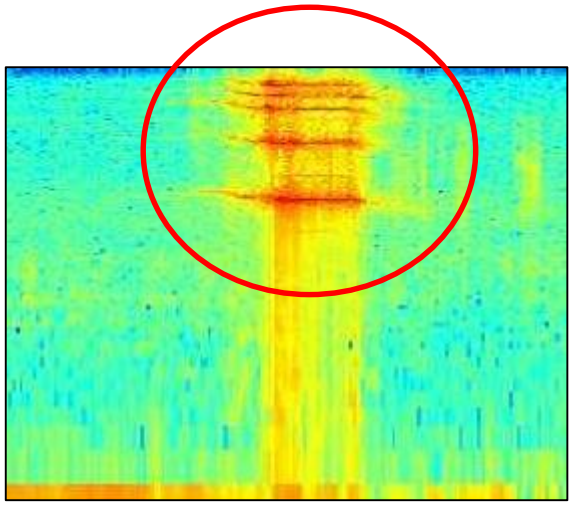
Radar/Camera Sciora

Lera

Lera

Helicopter flies over station





2 gauge radars

alerting

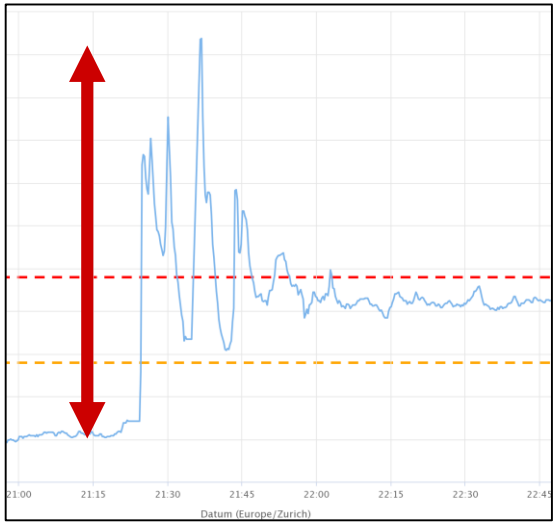
3 seismometers

redundant alarm
detection of rockfall activity

1 webcam

verification, overview

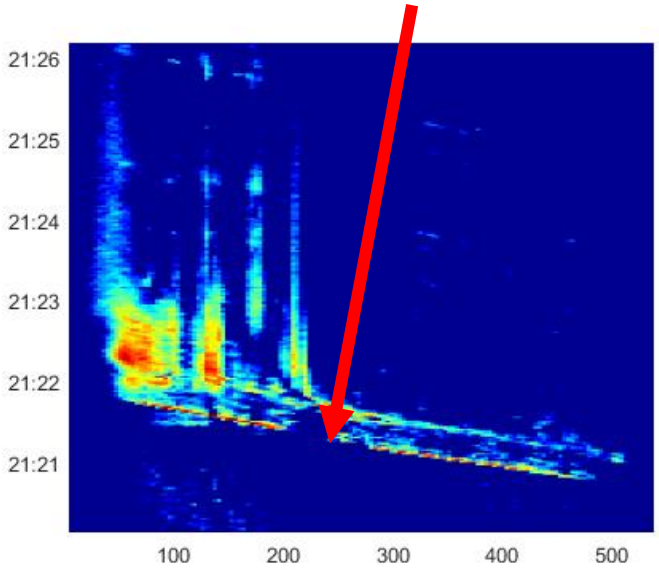
5m level increase by debris flow of 31.8.17



2 gauge radars

Alerting

Measured front speed above 500m from 10 m/s



1 Doppler radar

redundant alarm

2 webcams

verification, overview

Spino

Thanks for your attention!

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Ph. + 41 44 419 91 10

Https://youtu.be/Zo66mNTXqag