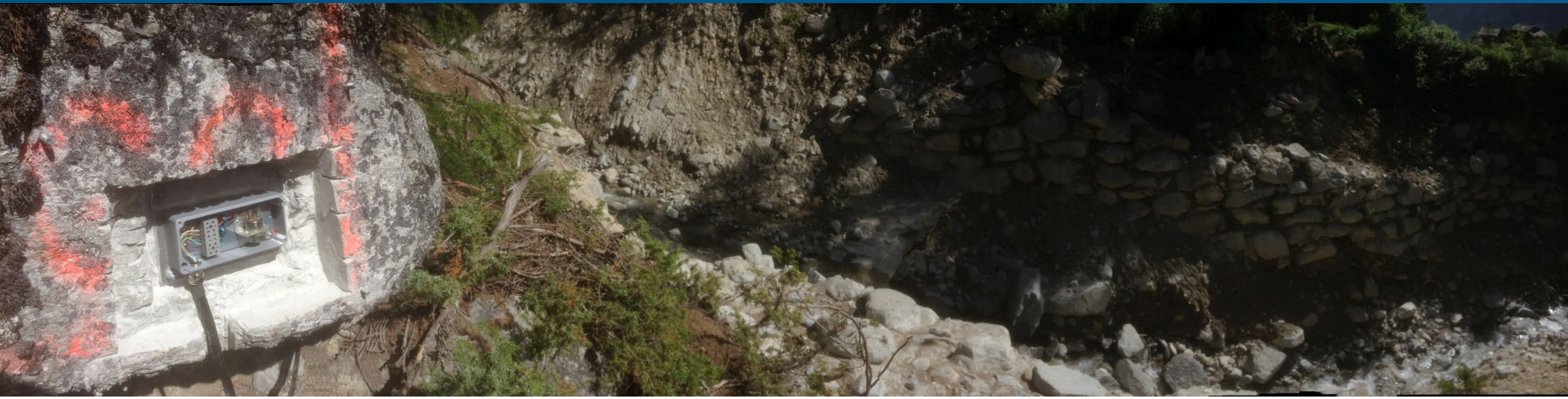


Early Warning Systems – Concepts and Technologies

GLOFCA Workshop Almaty – October 23, 2024 – Andreas Hasler and Martin Zimmerli, SensAlpin

Intro

SensAlpin

- Small company funded 2003
- Close collaboration with ALPUG
- Together 30 years of experience
- Monitoring, warning and alarm systems

Martin Zimmerli

Hansueli Gubler

Intro

SensAlpin

- Provide technical solutions for natural hazard and climate monitoring
- Operate about 600 Stations
- Active in mountain regions in Switzerland and internationally (10%)
- Engineering: System integration and sensor development
- Provide full service from planning and production to installation and operation

Intro

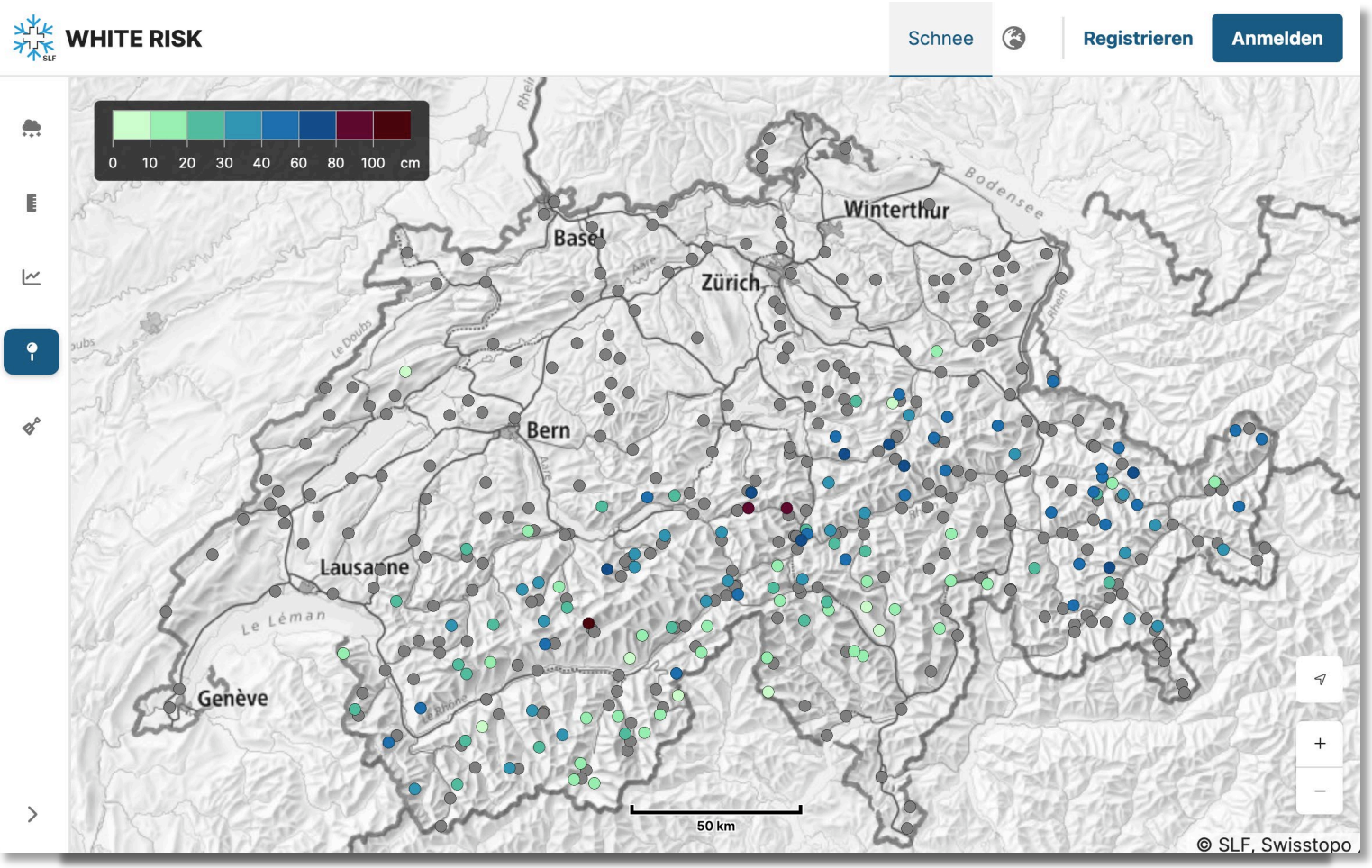
- Our expertise is mainly on technical aspects of Early Warning Systems (EWS, ***Monitoring and Warning Services***)
- Process expertise (***Risk Knowledge***) needed for proper design of EWS
- ***Dissemination and Communication*** to some extent implemented in our systems
- ***Response Capability*** managed by external companies and authorities

Intro

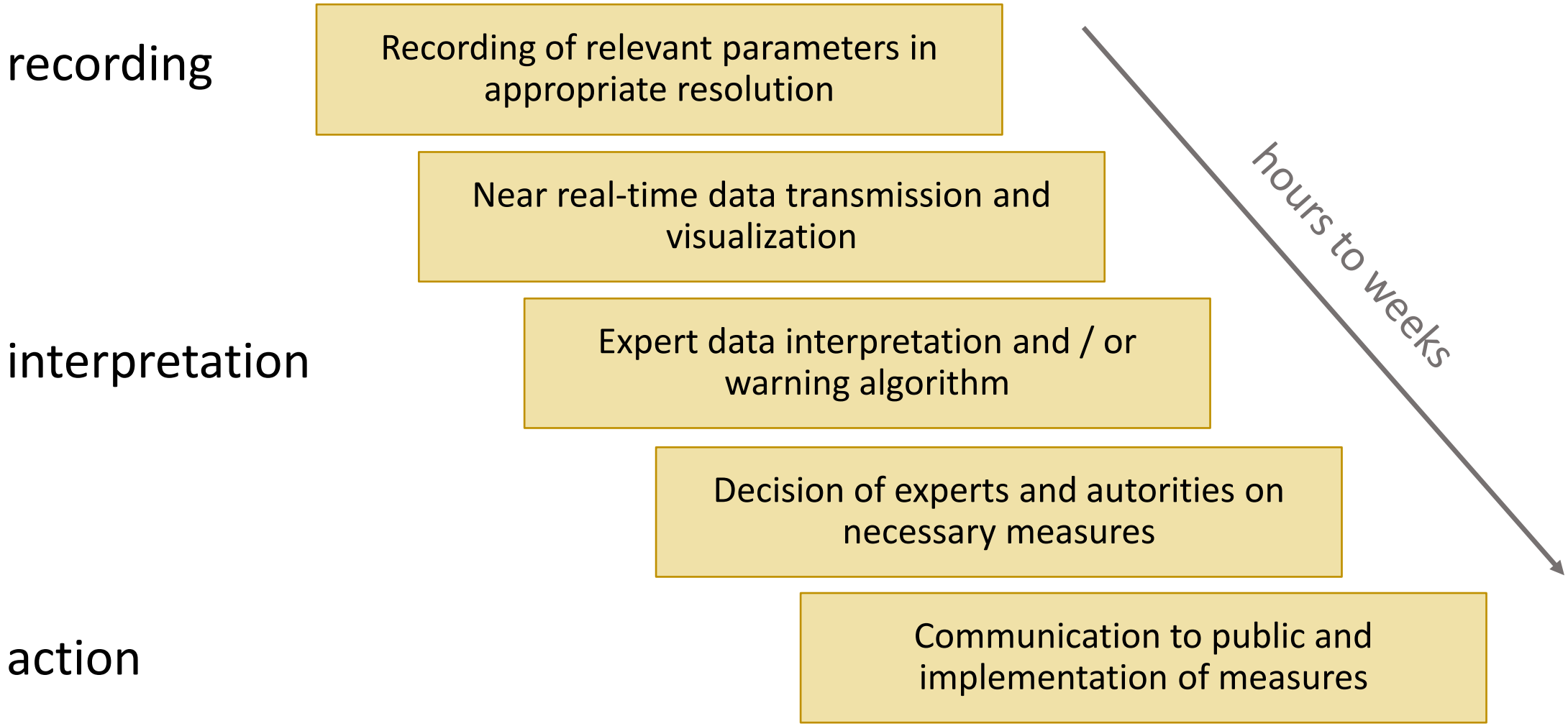
- Personally 9 years at SensAlpin
- Before monitoring projects with universities and authorities (Switzerland, Canada)
- Project lead avalanche warning systems
- Project lead debris flow alarm system “Chamoson” (session 2; case 2)
- Technical stuff for installation and maintenance of our systems
- Programming of stations, data management and visualization
- Experience in Canada, Chili and Central Asia

Intro: EWS = Warning and Alarm Systems

Avalanche warning (IMIS)



Concept of warning systems



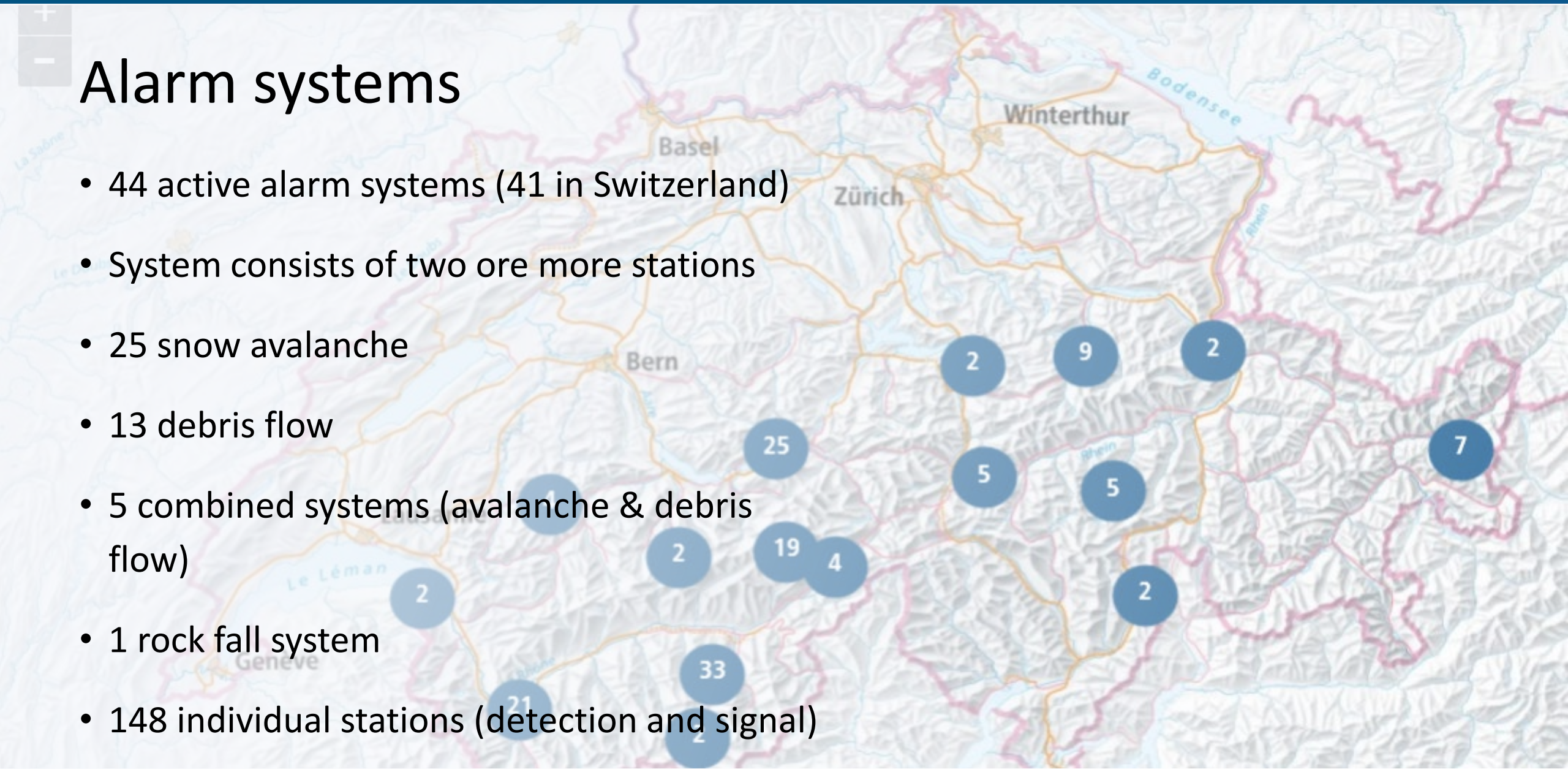
Examples of our warning systems

- Rain / water level / discharge monitoring → flood / debris flow warning
- Snow measurements → avalanche warning
- Regular images of glaciers, lakes and other objects of interest



Alarm systems

- 44 active alarm systems (41 in Switzerland)
- System consists of two ore more stations
- 25 snow avalanche
- 13 debris flow
- 5 combined systems (avalanche & debris flow)
- 1 rock fall system
- 148 individual stations (detection and signal)



Concept of alarm systems

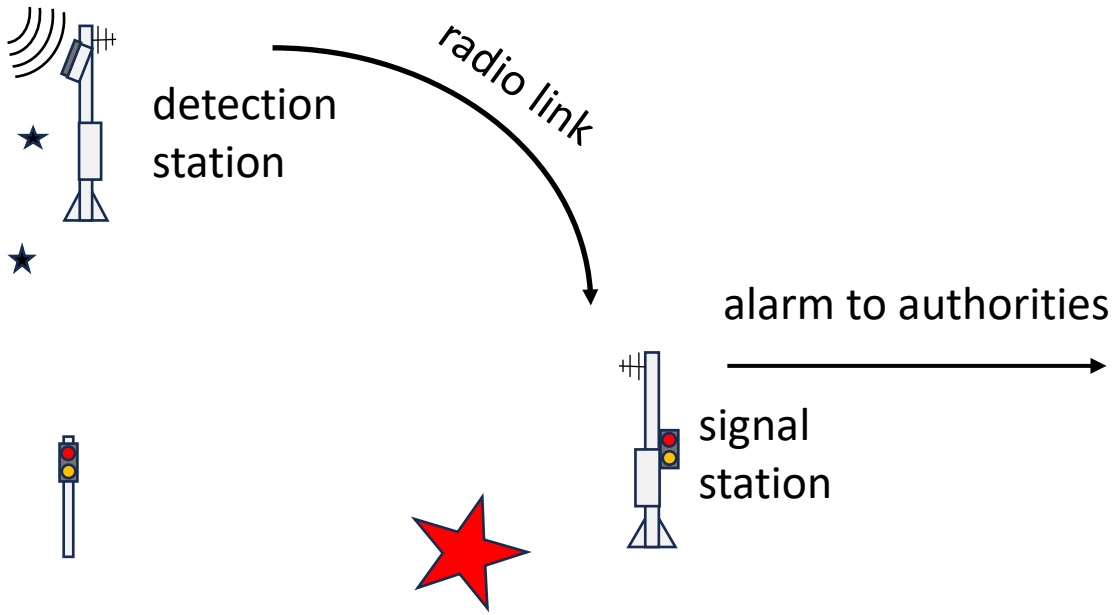
- detection of rapid mass movements
- immediate decision and action
- alarm mainly for events that reach the protection goal (process and size)


starting zone
transition zone
impact zone

starting zone

transition zone

impact zone



Concept of our alarm systems

detection

detection of rapid mass movement by continuous monitoring of flow path

automated decision by algorithm at the detection station

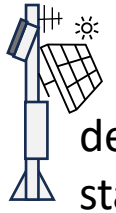
alarm

Immediate alarm transmission to signal station via radio link

Signal control and alarm propagation to authorities and system operator

action

Decision of authorities on following measures and event analysis



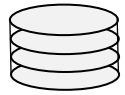
detection station

seconds

signal station

hours to days

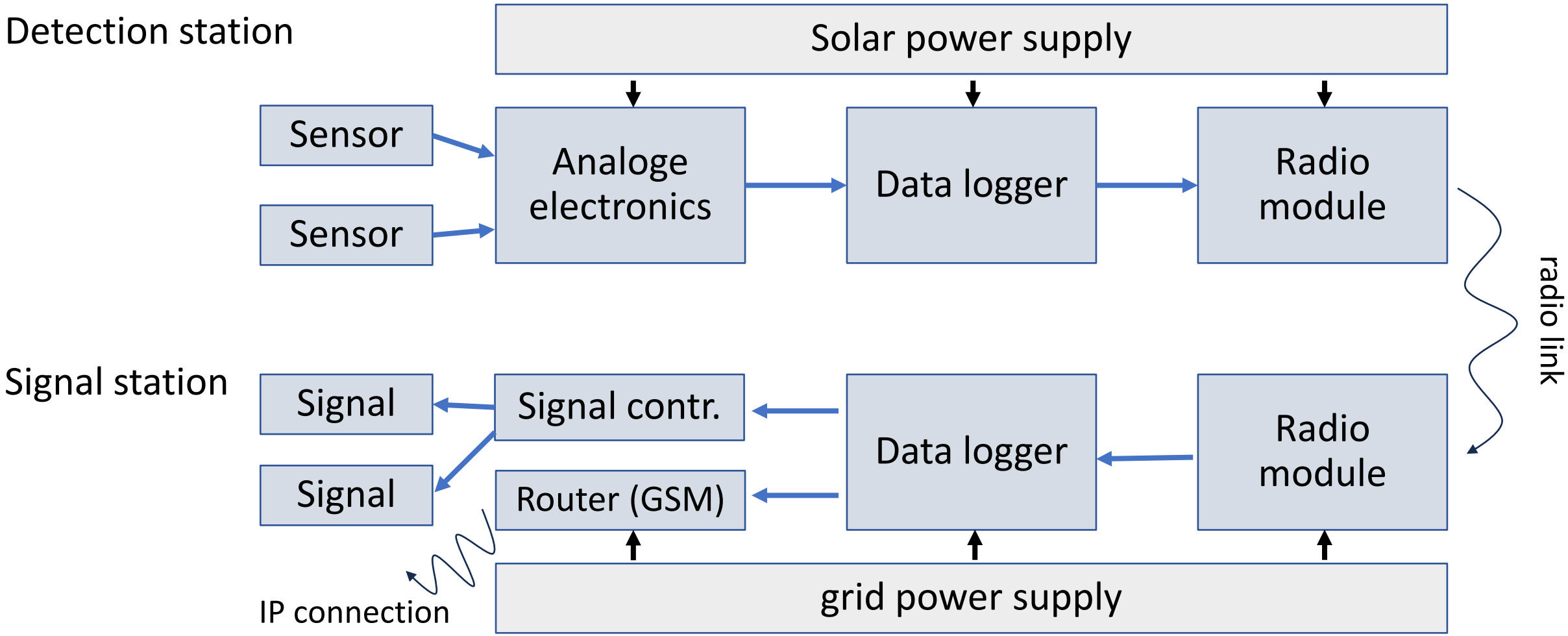
data server / operator



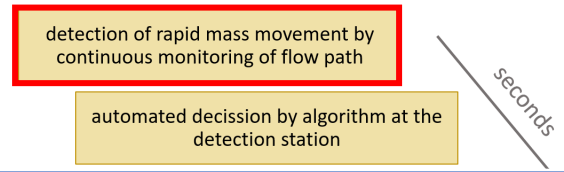
Overview of technical setup

- Autonomous operation by solar power supply and batteries (detection stations)
- Both station types based on Campbell Sci loggers
- Costumized electronics for sensor and signal interfaces
- UHF radio for full control on transmission protocols
- Alarm server by external provider (eAlarm emergency)
- Monitoring and controlling server and software

Overview of technical setup



Sensors for detection and monitoring



phenomenon	physical parameter	sensor
Flood	Liquid precipitation	pluviometer
	Water level (static = lakes, river barriers)	pressure sensor (difference to P_{air})
Debris flow	Flow height	distance / level sensor (radar, laser, ultrasonic)
		tilt sensor, pull rope, rip cord
Snow and ice avalanche	Vibration (seismic energy)	geophones
	Flow velocity	doppler radar
	Infrasound emission	infrasound microphones

Sensors for detection and monitoring

sensor
pluviometer
pressure sensor (difference to P_{air})
distance sensor (radar)
tilt sensor, pull sensor, rip cord
geophones
doppler radar
webcam (communication, power!)

Event detection – decision on alarm

- local processing on station
- relevant process and size
- multiple sensors used

→ redundancy

- complementary physical principles

→ not similar error sources

→ low false-alarm rate

- alarm criteria strongly depend on situation

→ training needed

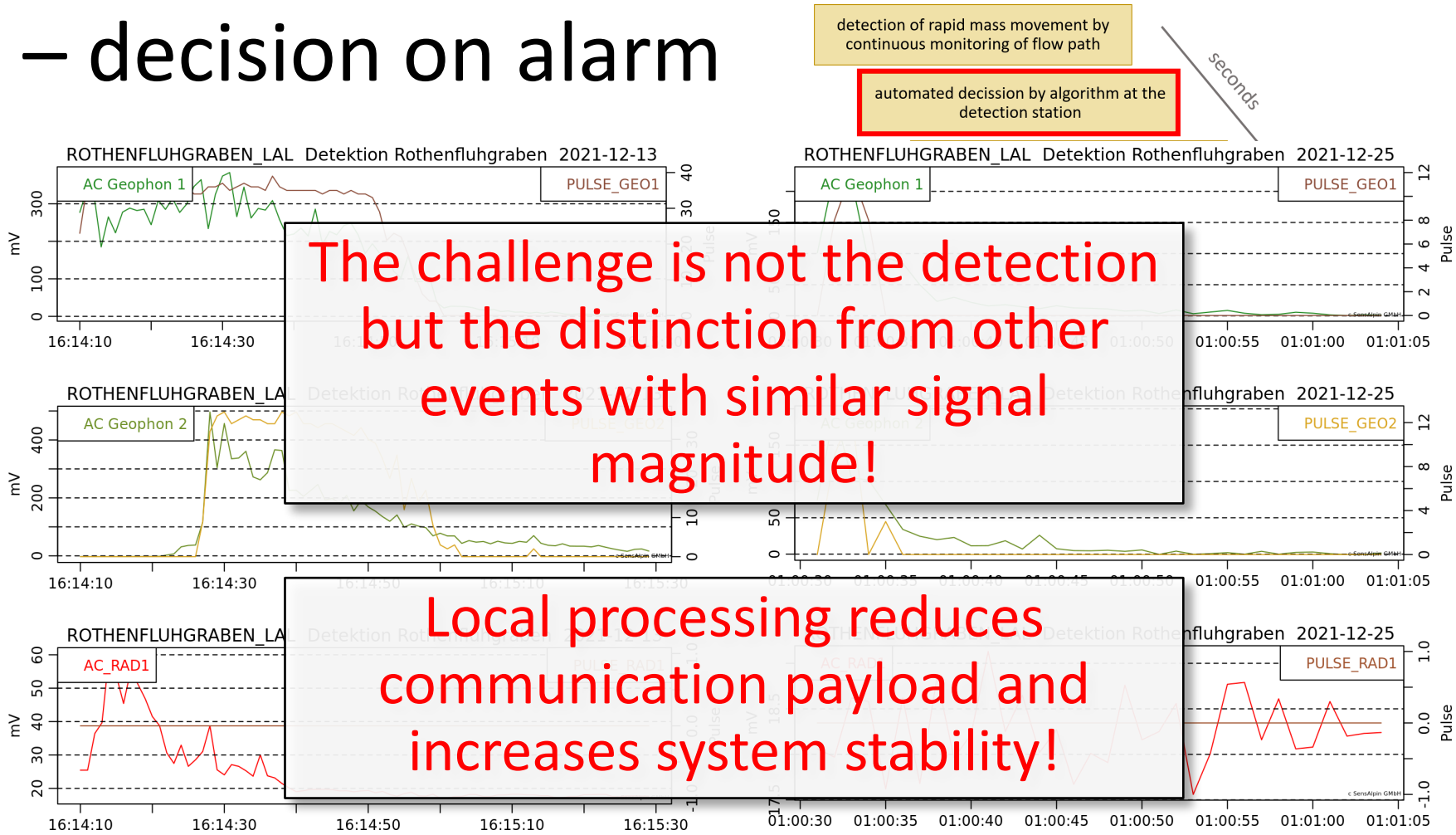
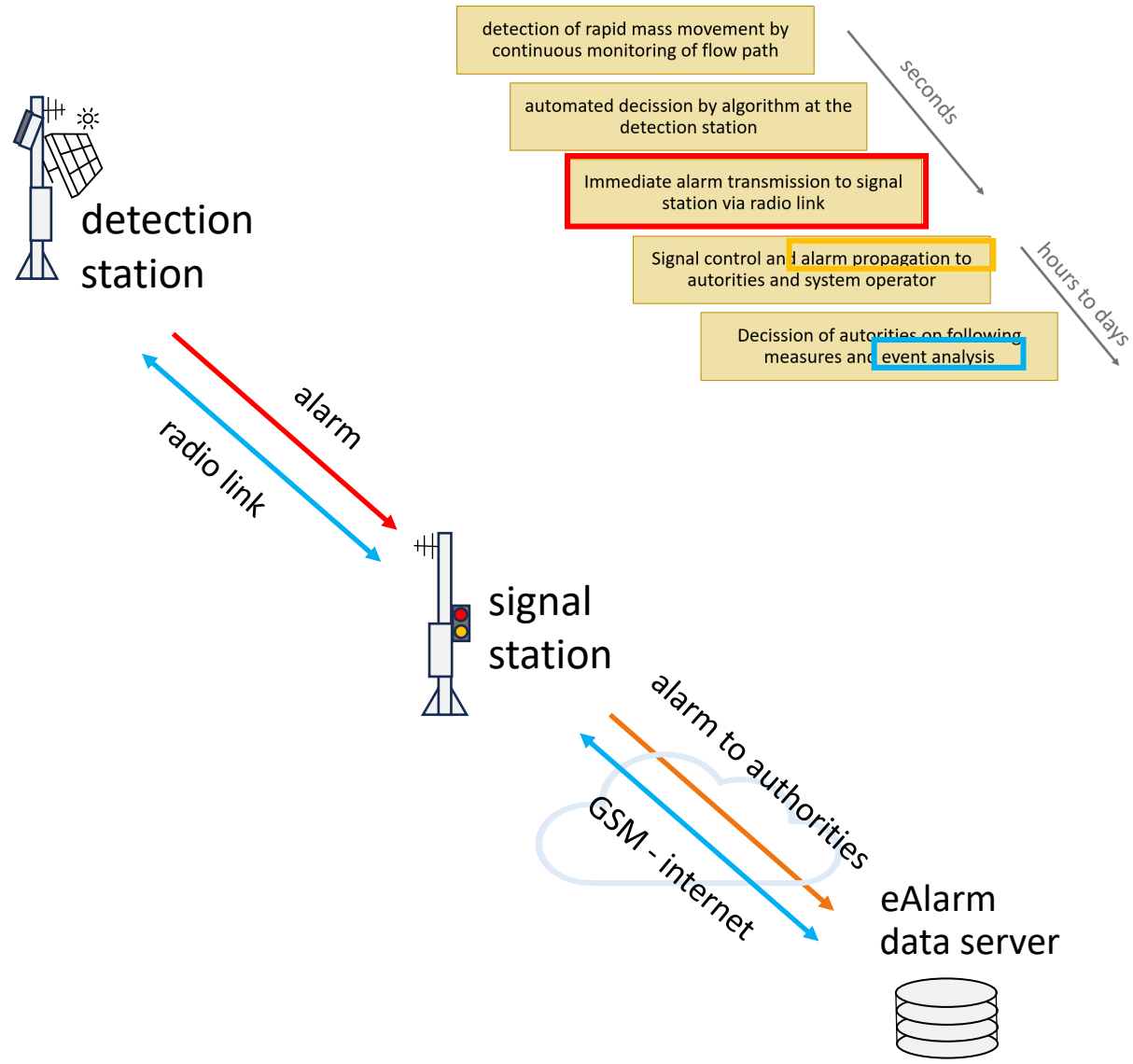


Figure 4 *Detection signals (2 geophones, 1 doppler radar)* ***left:*** *snow avalanche;* ***right:*** *earthquake*

Communication

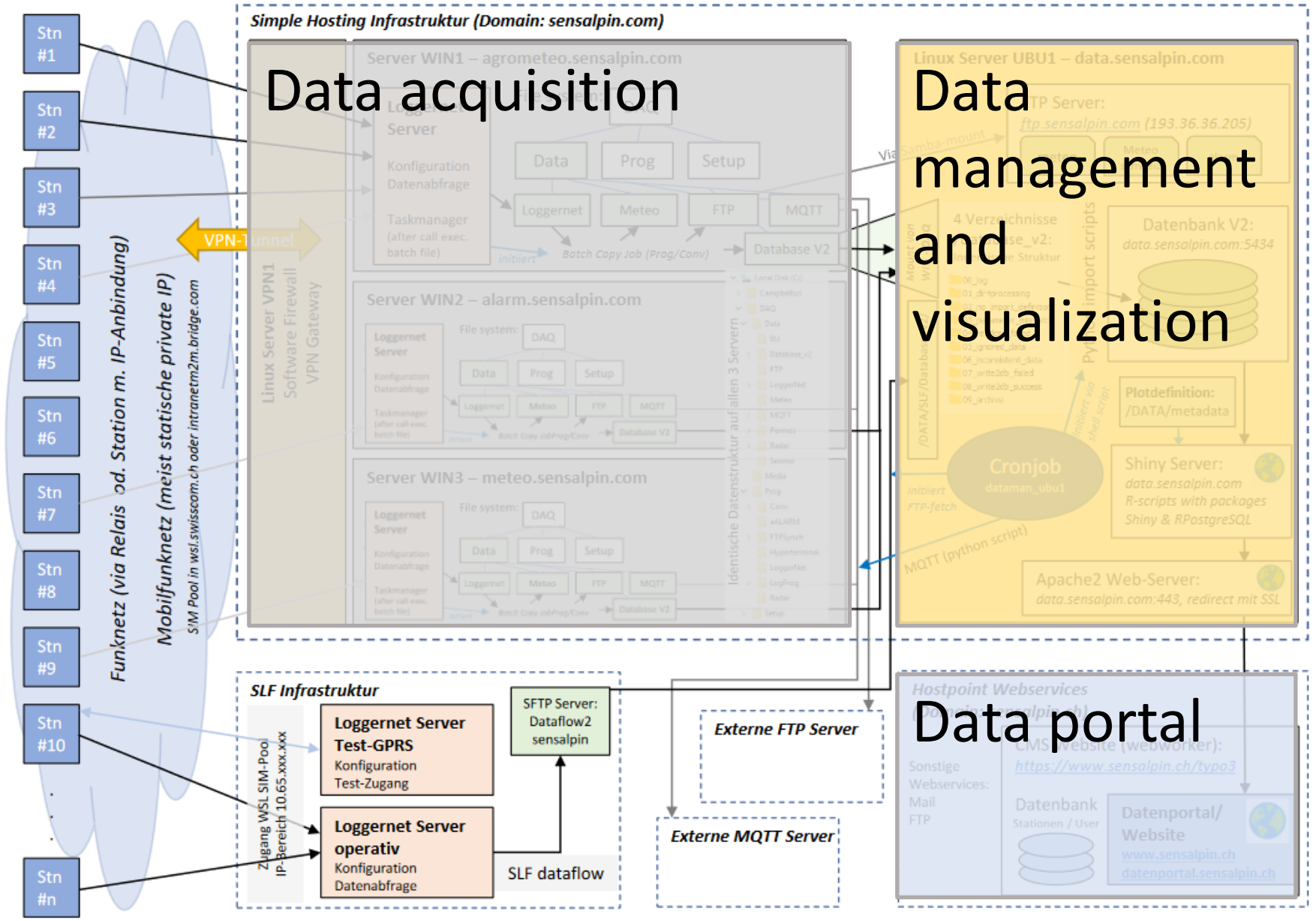
- Radio link *detection to signal*:
  - UHF radio for full control on transmission protocols
  - Very robust alarm call (alarm code)
- Weblink from signal to alarm server (eAlarm emergency)
- Communication link to station for event analysis, maintenance and system monitoring



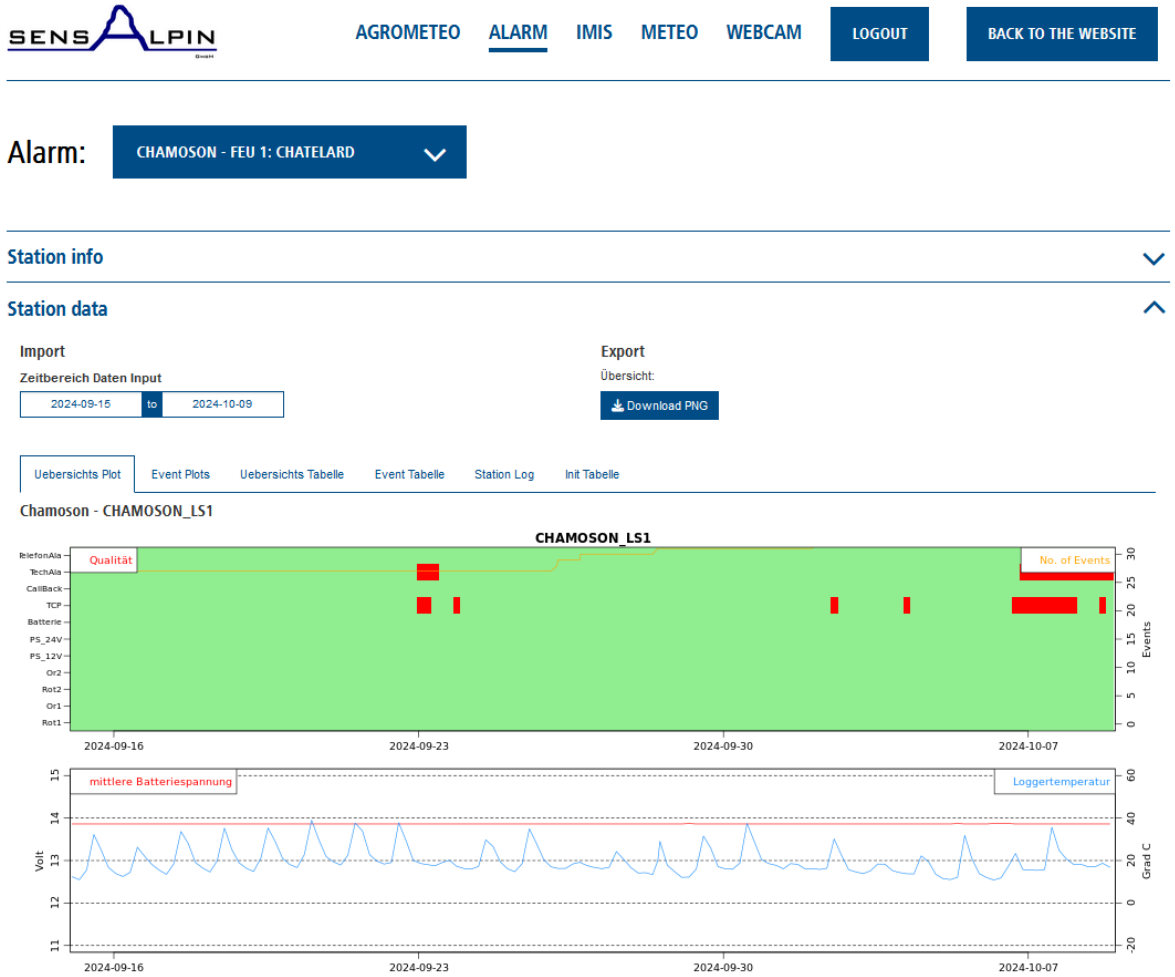
Alarm interface

- local alarm by traffic lights, flashlights, sirens etc.
- alerting of authorities by automated phone calls, text messages and interfaces to their control centers
- hardware interfaces at the signalizing stations
- web interfaces to reset alarms and control traffic lights
- desktop control tool “alarm manager”

Data flow and data management infrastructure



Data portal and system monitoring

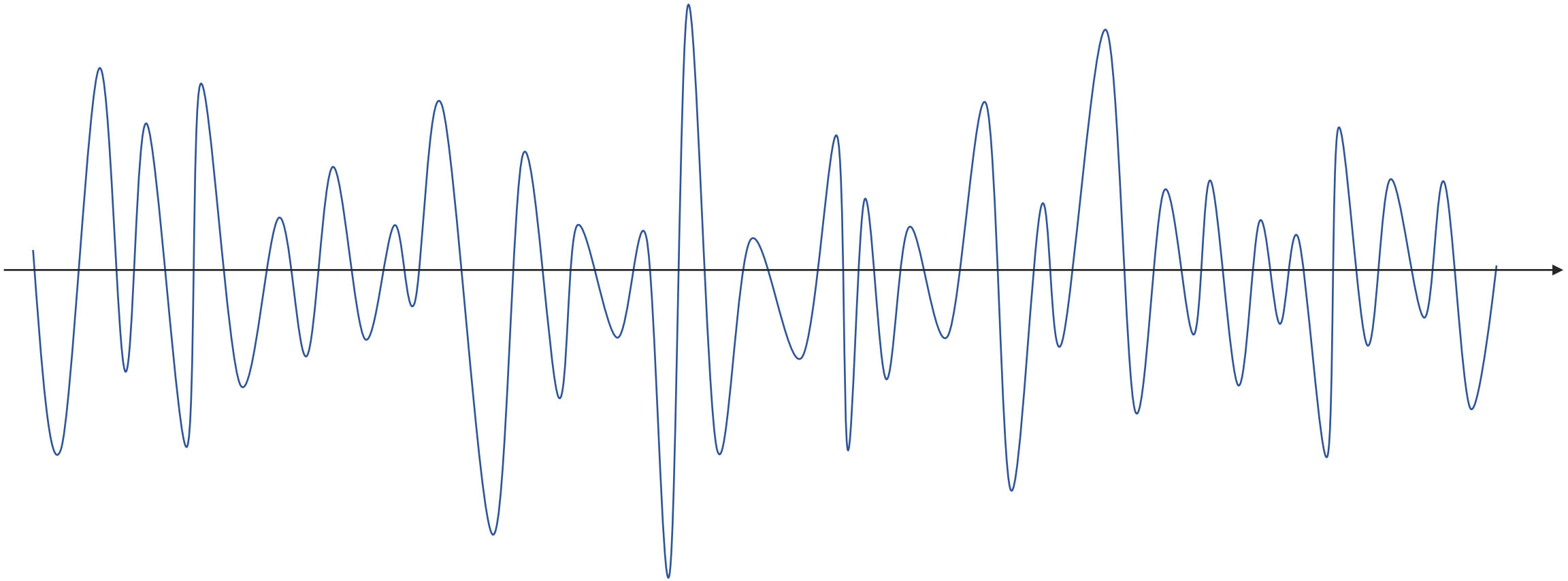


Geophones

- Sensitive to frequencies 1-100 Hz
- 5-50 meters from flow channel
- Redundancy by multiple sensors
- Alternative seismic signals: earth quakes, thunder, rockfall, human activity,…
- Manual triggering impossible (for large debris flows)
- Size and flow velocity estimation in post processing
- Signal processing required for alarm

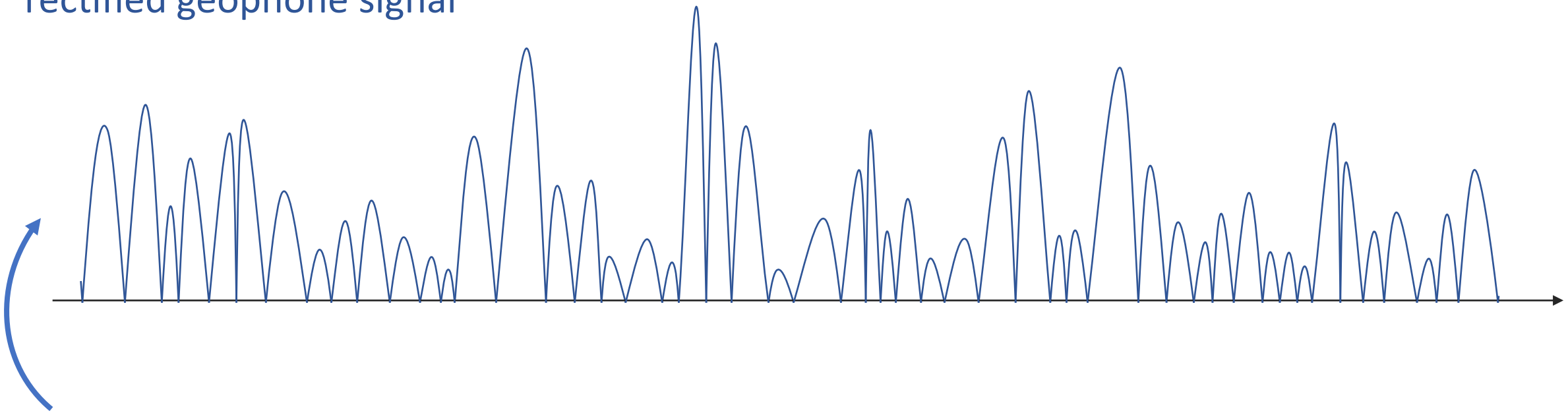
Geophone signal processing

raw geophone signal (ground vibration)



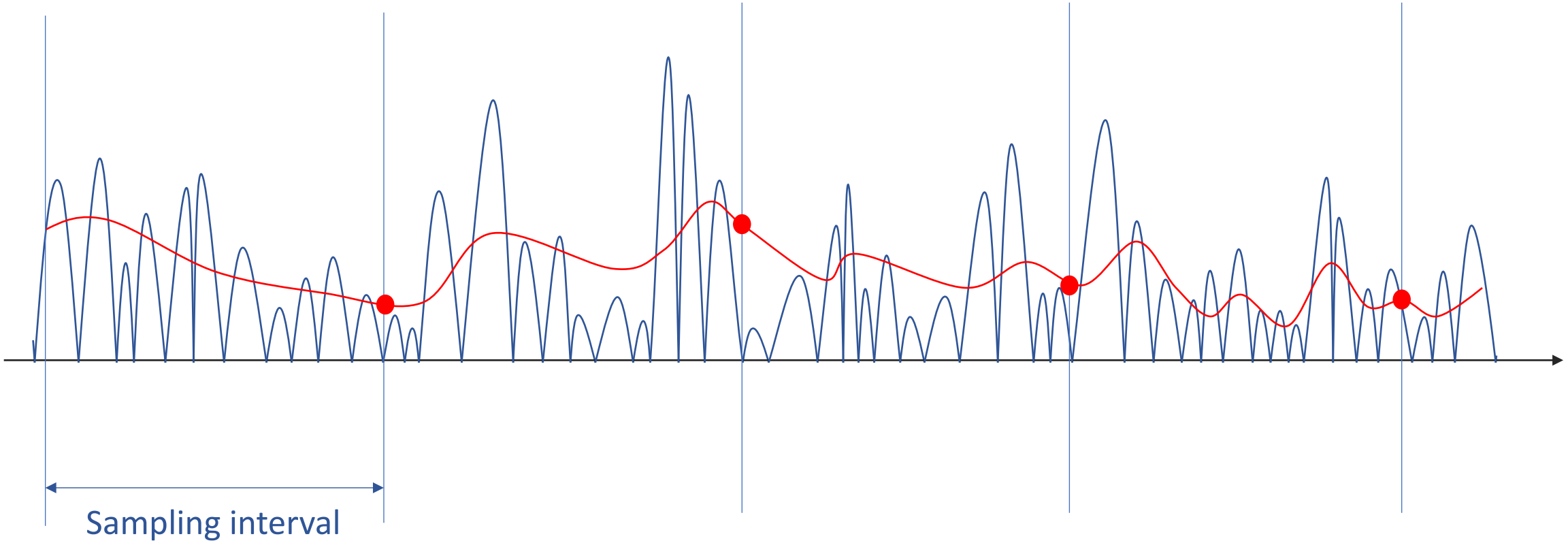
Geophone signal processing

rectified geophone signal



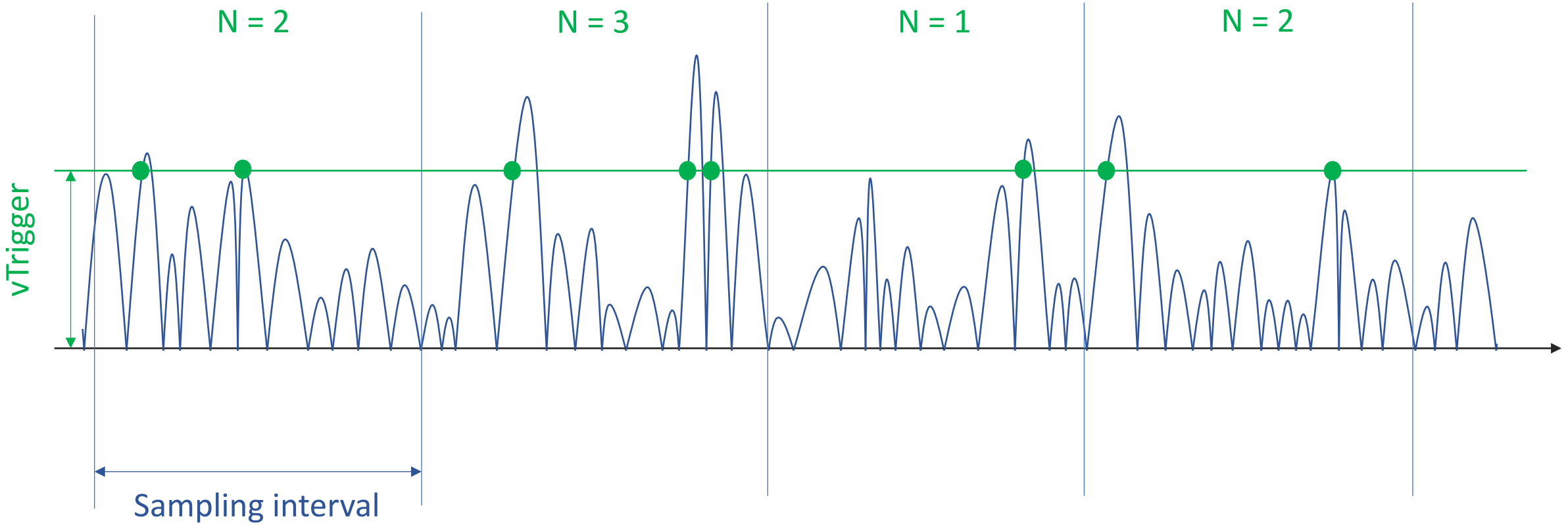
Geophone signal processing

AC (running effective value ≈ amplitude)



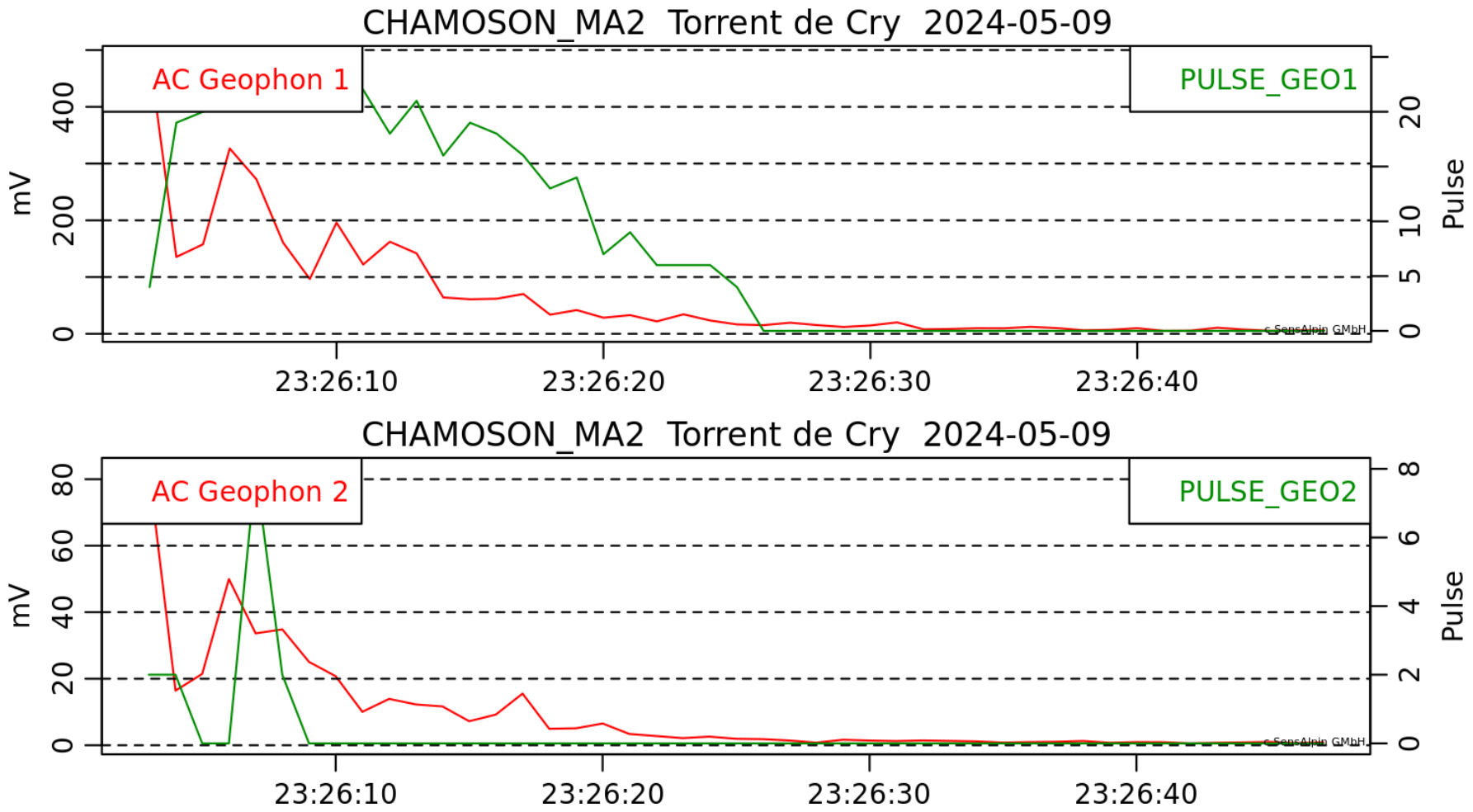
Geophone signal processing

PULSE (discrimination circuit)



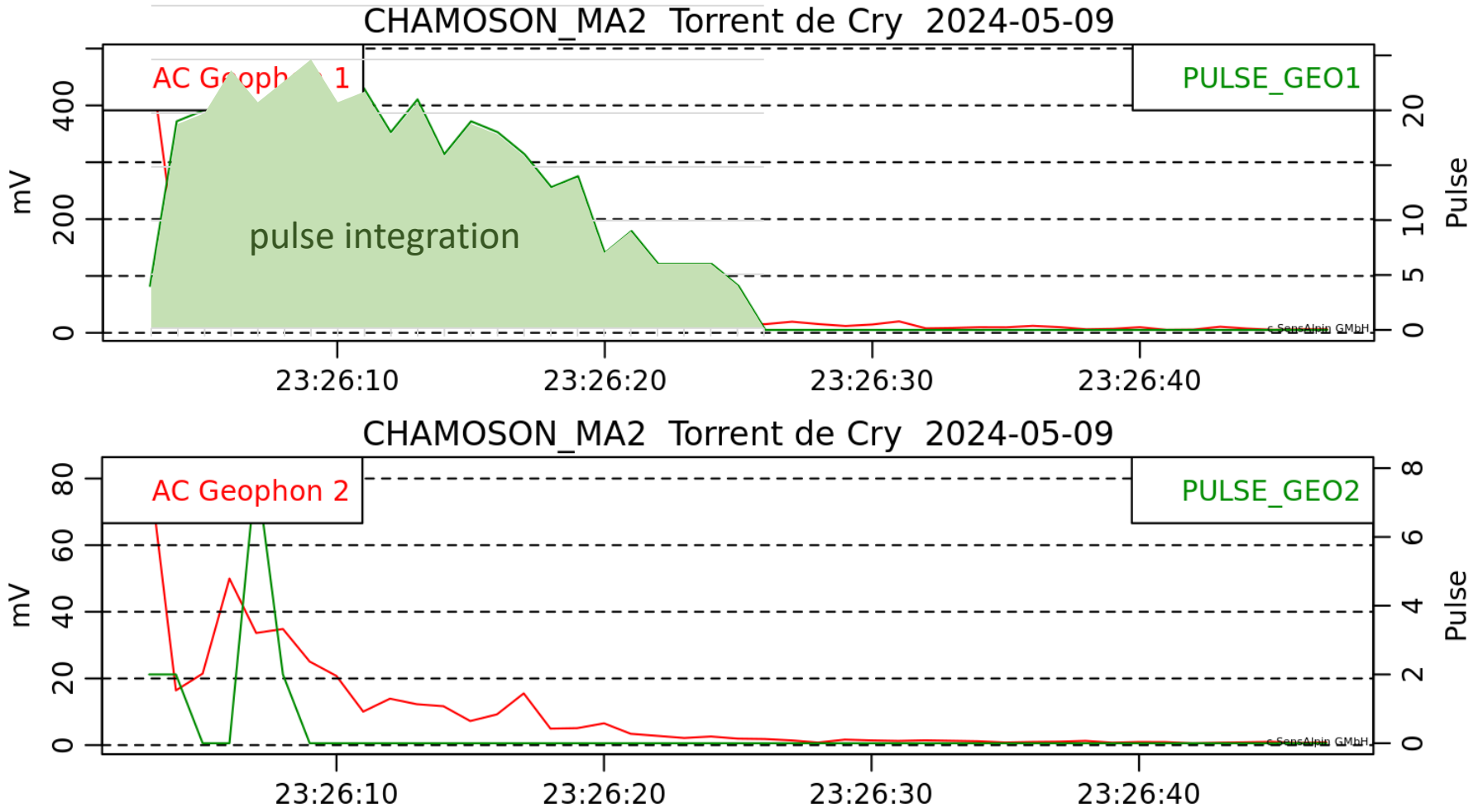
Geophone signal processing

- digitized signals with 1 sec resolution

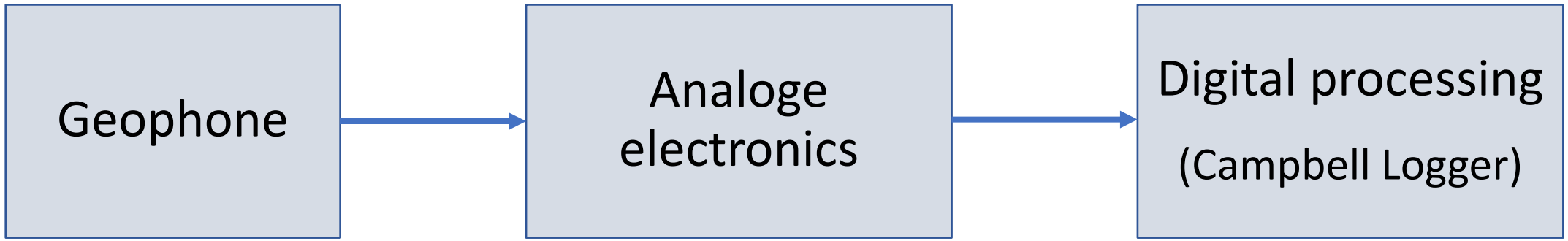


Geophone signal processing

- digitized signals with 1 sec resolution
- digital integration of pulse sum of event over pulse threashold



Geophone signal processing

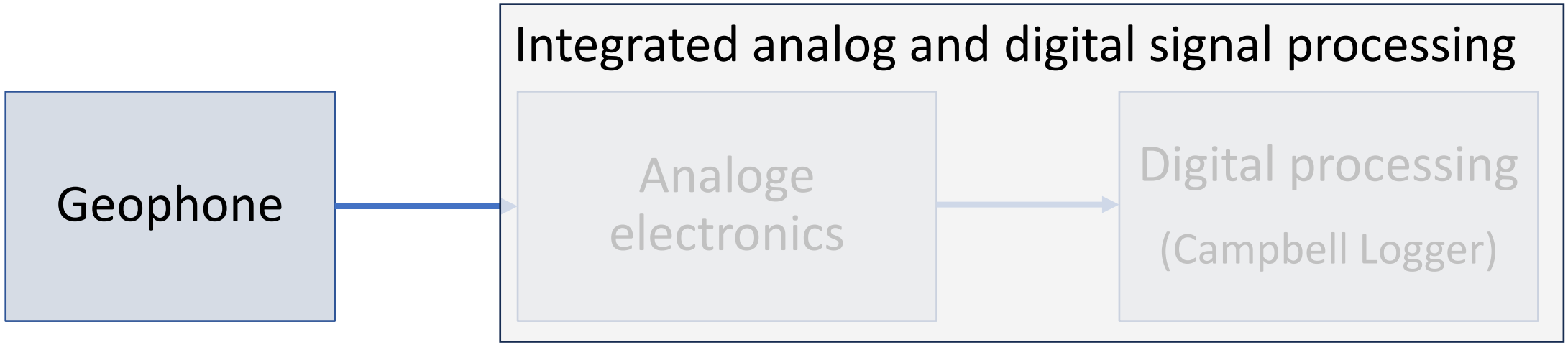


- relevant location
- good seismic coupling

- AC: analog averaging circuit
- PULSE: analog discrimination circuit

- pulse counting
- pulse integration
- alarm

Geophone signal processing



- relevant location
- good seismic coupling

- technically easier application
- platform independent
- short training phase

Conclusion geophones

- Other algorithms may have similar or even better results, but training events needed
- Our signal processing based on some 10‘000 registered events
- We can provide our experience with the integrated signal processing unit
- About 6 months develoment needed on our side
- We can support local suppliers with the integration in their detection system
- However, basic station concept (on station processing) has to match

Key messages

System reliability as a key factor

- Proven simple technology preferred over latest high-tech!
- High robustness of technology and algorithms
  - → low failure rate and low costs of operation
  - → low power consumption
- Combination of different sensors
  - → low false alarm rate
- Redundancy where necessary
- Time critical communication with “own” radio (no GSM)
- Calibration phase for system training
- System monitoring and maintenance

Links

www.sensalpin.ch

https://www.sensalpin.ch/en/applications/natural-hazards-alerting/

swisstopo-map-sensalpin

data-portal-sensalpin