
Improvement of process identification and discharge measurement by the combination of different sensors
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Overview
Monitoring site Lattenbach
Debris flow 09.08.15
Debris flow 10.08.15
Debris flow 16.08.15
Warning System AMM-Detection

Monitoring site Lattenbach

Lattenbach:

Grins, Tyrol; Catchment area 5,3 km²
Debris flow monitoring since 2004
Instrumentation:
ultrasonic sensors, weighing precipitation gauge, seismometer, video cameras, 2D laser scanner, debris flow radar, infrasonic sensors, geophones,…

Monitoring site Lattenbach

New installations on the test site:

Debris flow Radar

→ surface velocity of a debris flow

2D-Laser Scanner

→ cross sectional wetted area

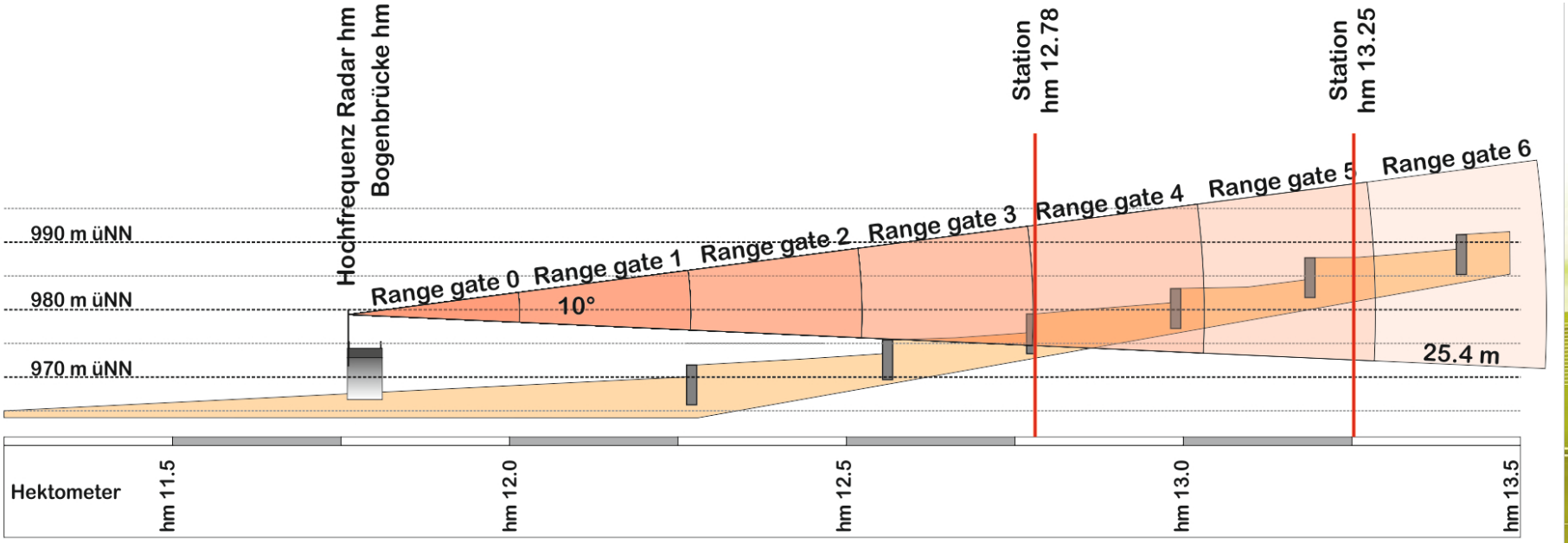
AMM-Detection

→ automatic detection of debris flows based on infrasound and seismic data

Debris flow Radar

High frequency pulse Doppler Radar

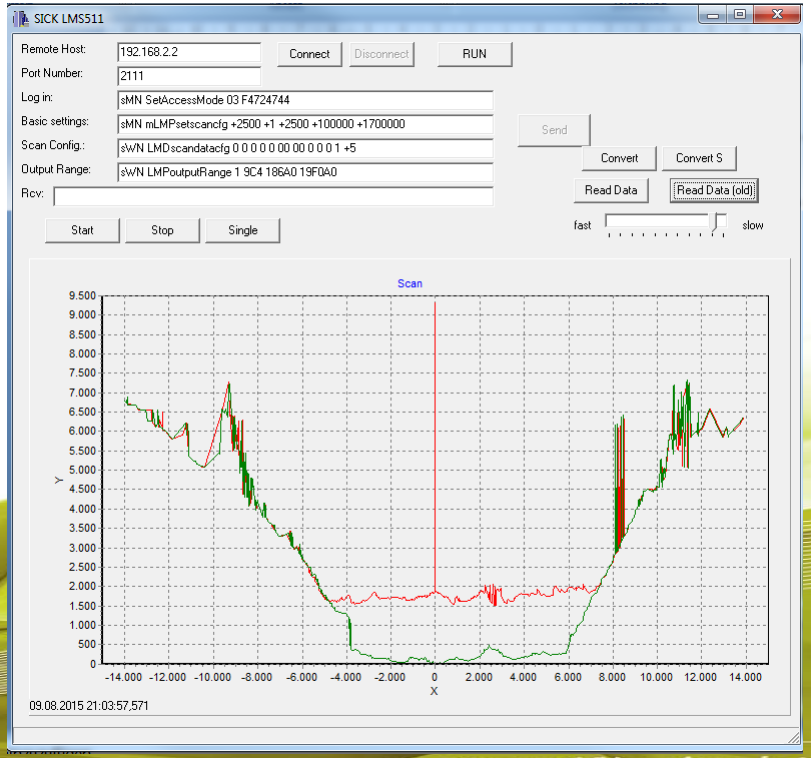
- Max. measurement distance 2,5 km
- Range gate length 15-250 m
- Velocities up to 300 km/h
- Alarming trigger in case of an event



2D-Laser Scanner

SICK Laser-Scanner LMS511

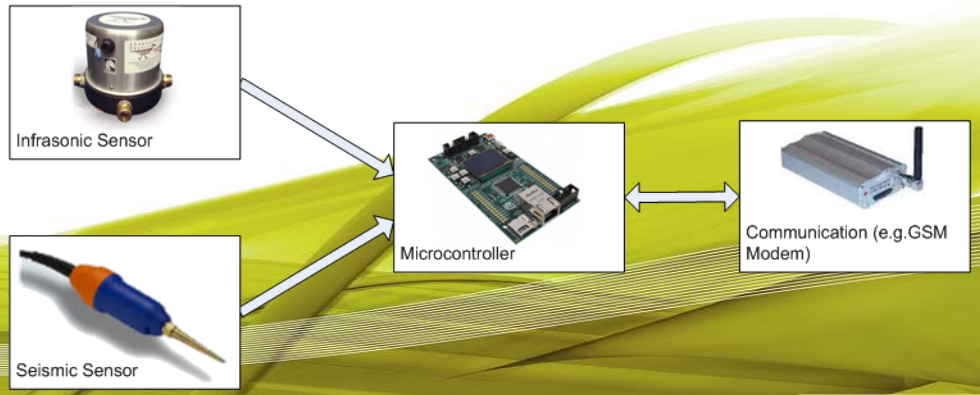
- Resolution: 0,25°
- Sample frequency: 5 Hz
- Data acquisition and configuration: Raspberry PI 1 Model B



AMM-Detection

Automatic detection based on infrasound and seismic data

- System which detects alpin mass movements in real time directly at the sensor site and comes along with only one seismic sensor, one infrasound sensor and a microcontroller
- Warning system for debris flows / debris floods and snow avalanches
- Combination of seismic and infrasound sensors to get advantages of both technologies
- Identify magnitude and process type based on the seismic and infrasound signals



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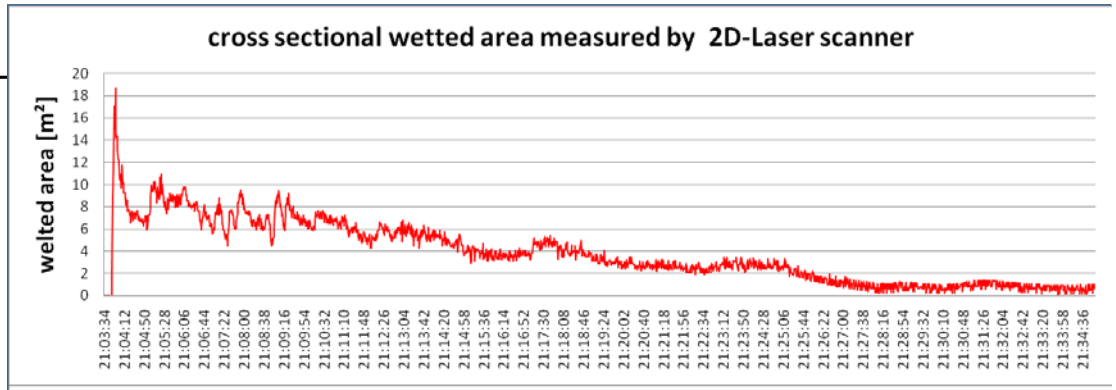
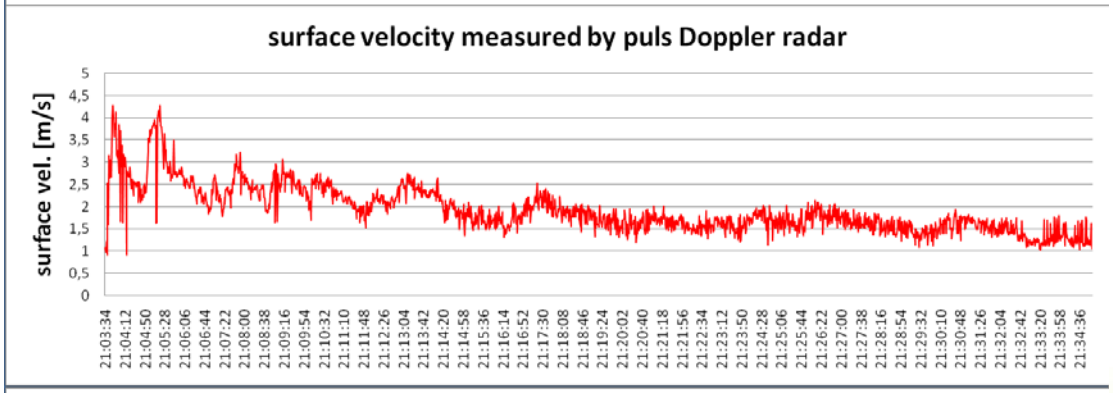
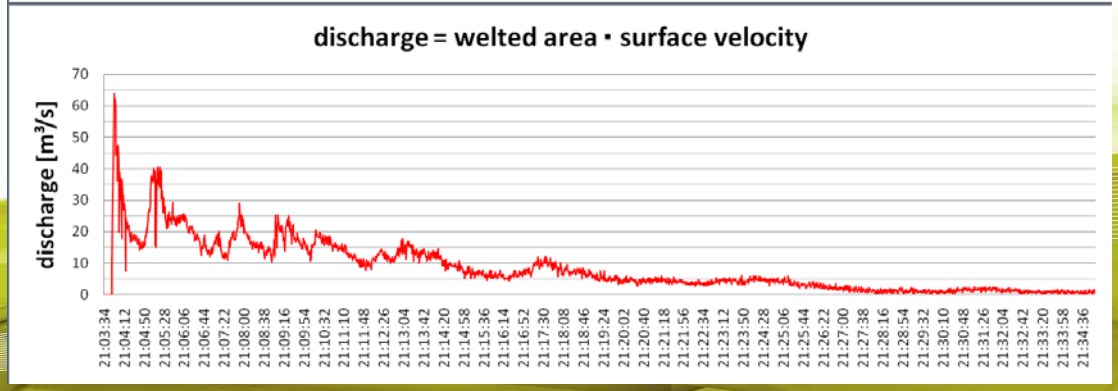
Debris Flow on 09.08.2015

Overall volume:16000 m³
Max. discharge: 64 m³/s
Av. discharge: 4,5 m³/s
Max. velocity: 4,3 m/s
Average velocity: 1,9 m/s

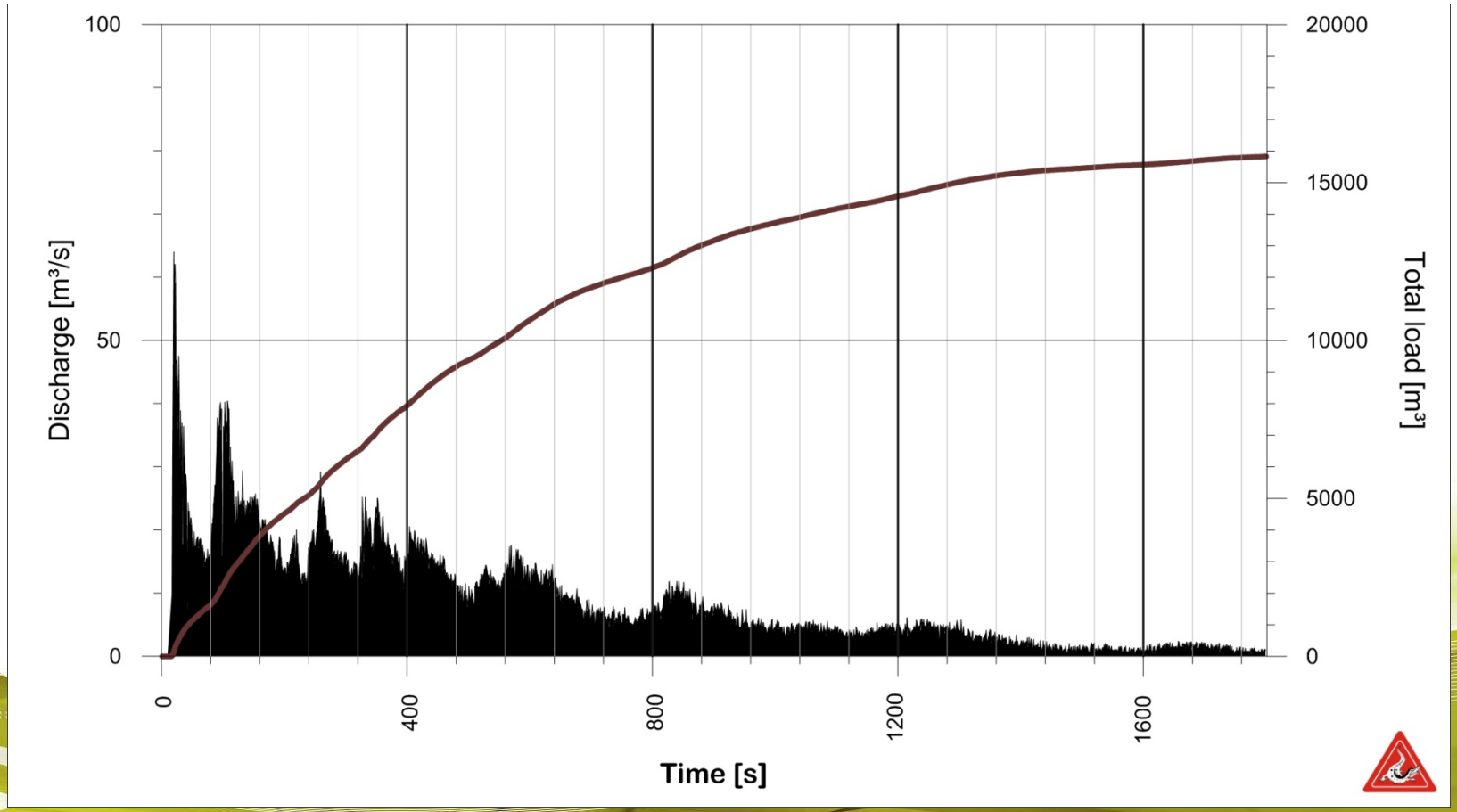




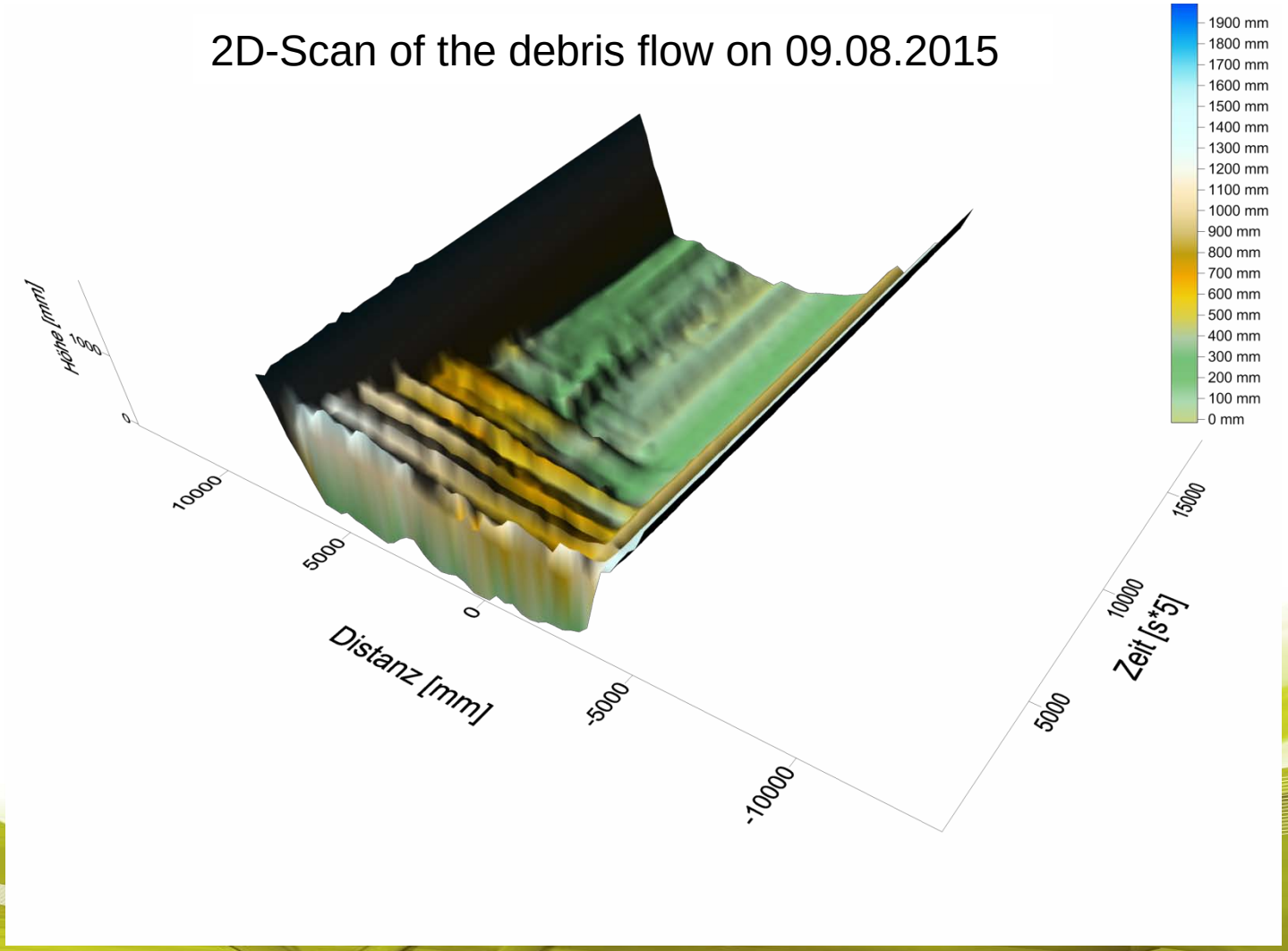


Debris Flow on 09.08.2015

Discharge and total load of the debris flow on 09.08.2015



Debris Flow on 09.08.2015



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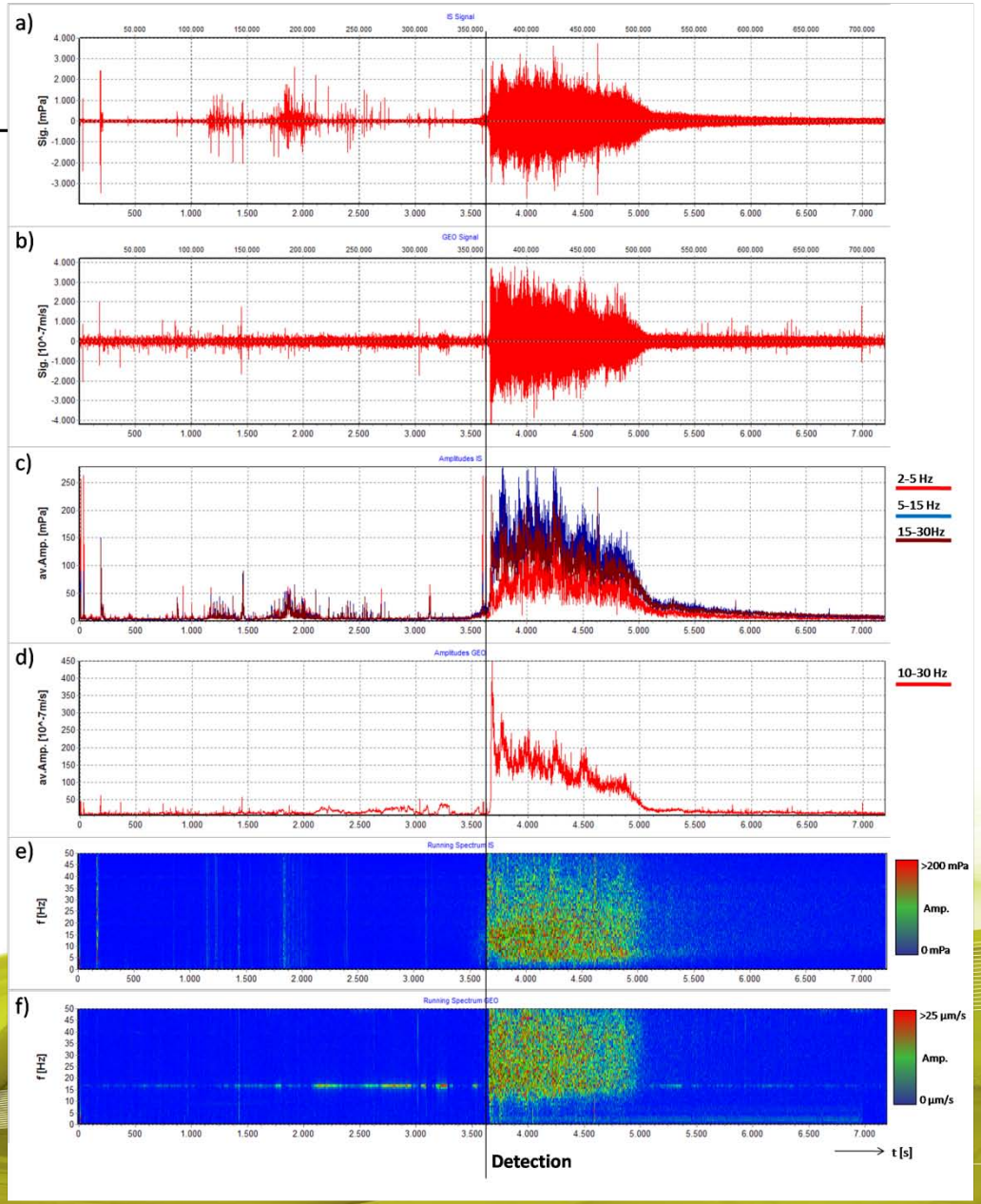
Debris Flow on 09.08.2015

AMM-Detection:

Early detection: 53 s

Max. infrasound amp.: 776 mPa
Max. seismic amp.: 113 µm/s
Duration of event: 2671 s
Peak-frequency band: 5-15 Hz



(a) Infrasound time series; (b) Seismogram; (c) Average amplitude of the frequency bands of the infrasound signal; (d) Average amplitude of the frequency band of the seismic signal; (e) Running spectrum of the infrasound signal; (f) Running spectrum of the seismic signal;
Lines: time of first detection based on infrasound and seismic data. Signals are represented with a common base of time.

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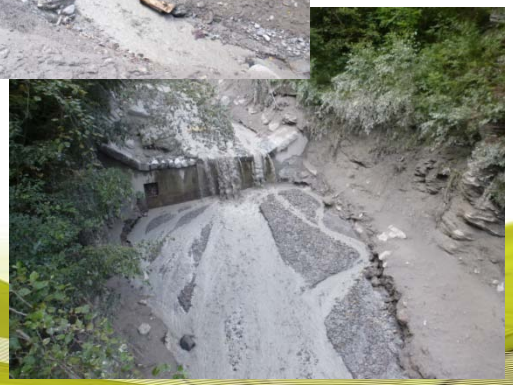
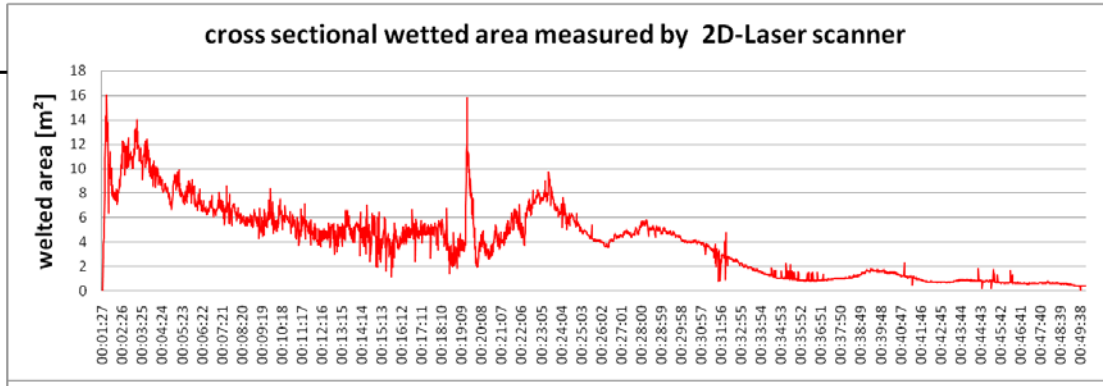
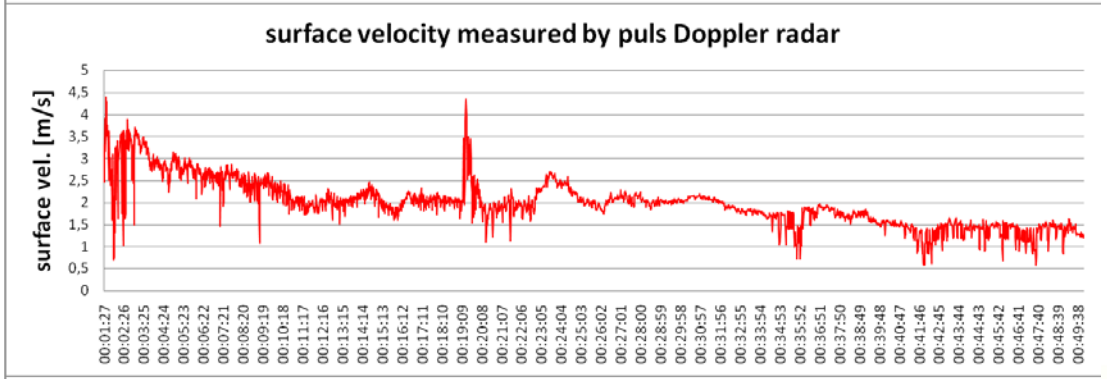
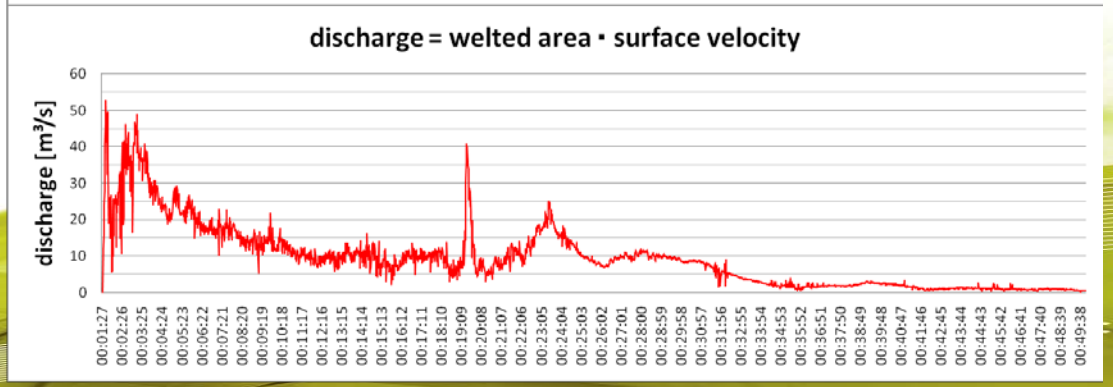
Debris Flow on 10.08.2015

Overall volume: 26800 m³
Max. discharge: 53 m³/s
Av. discharge: 7,4 m³/s
Max. velocity: 4,4 m/s
Average velocity: 2 m/s



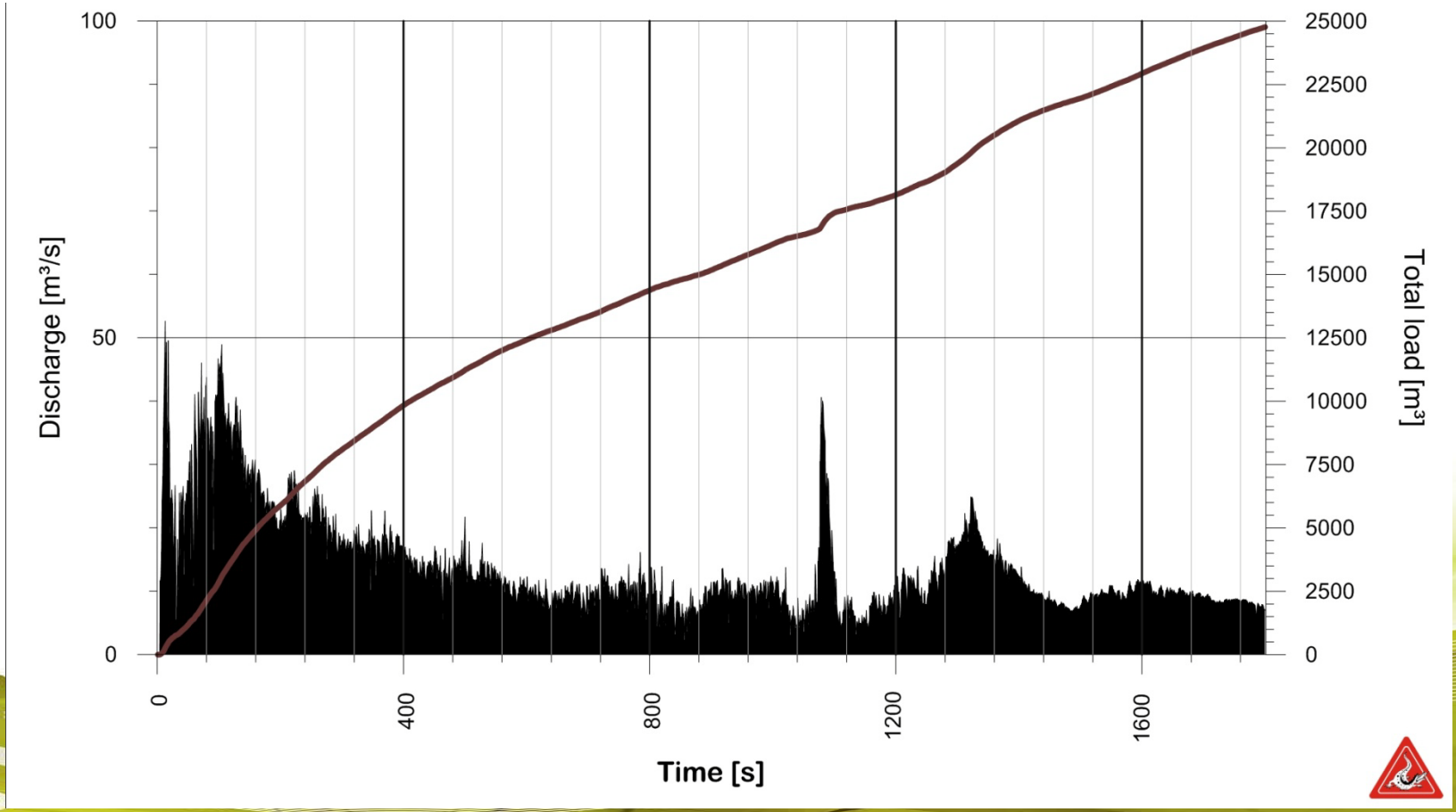






Debris Flow on 10.08.2015

Discharge and total load of the debris flow on 10.08.2015



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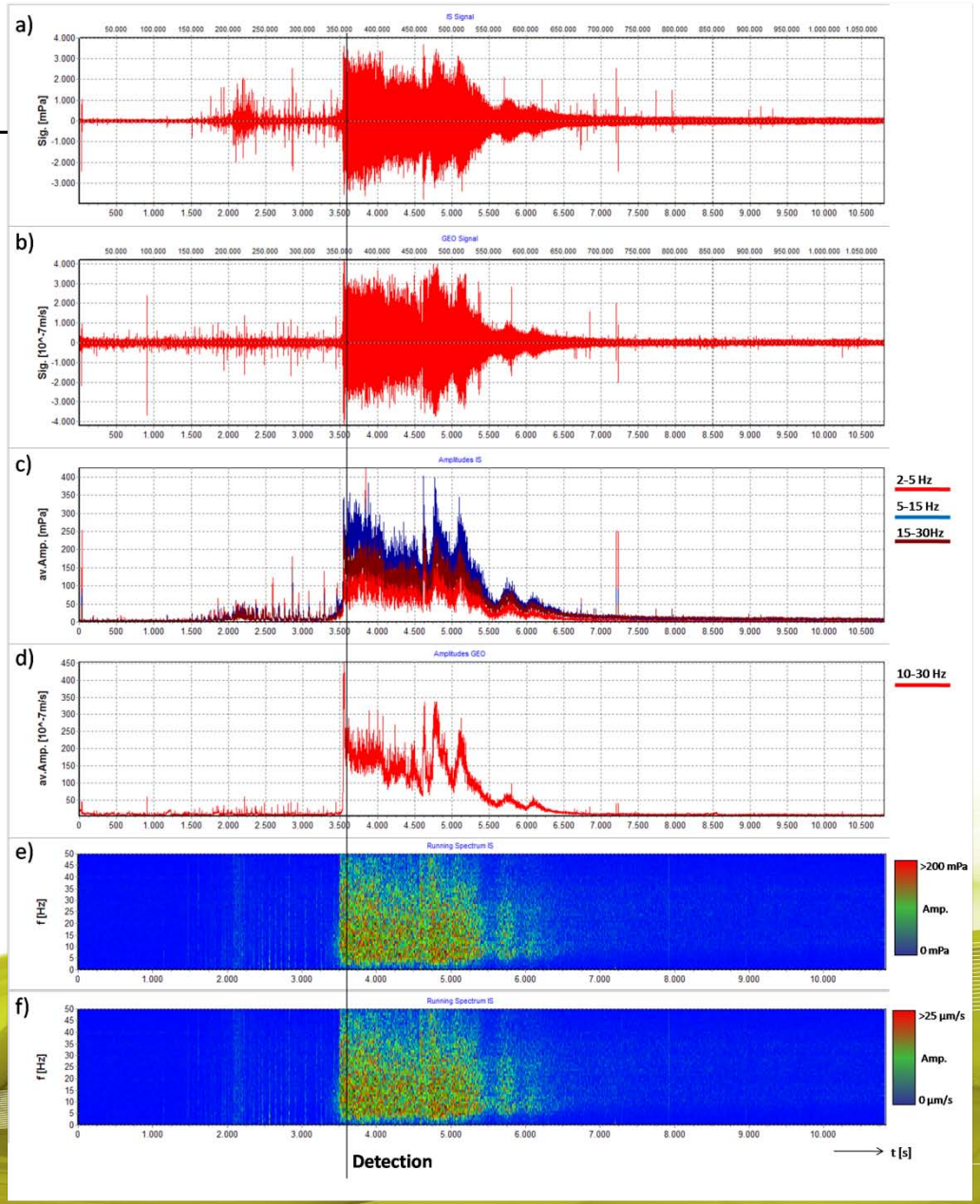
Debris Flow on 10.08.2015

AMM-Detection:

Early detection: -14 s

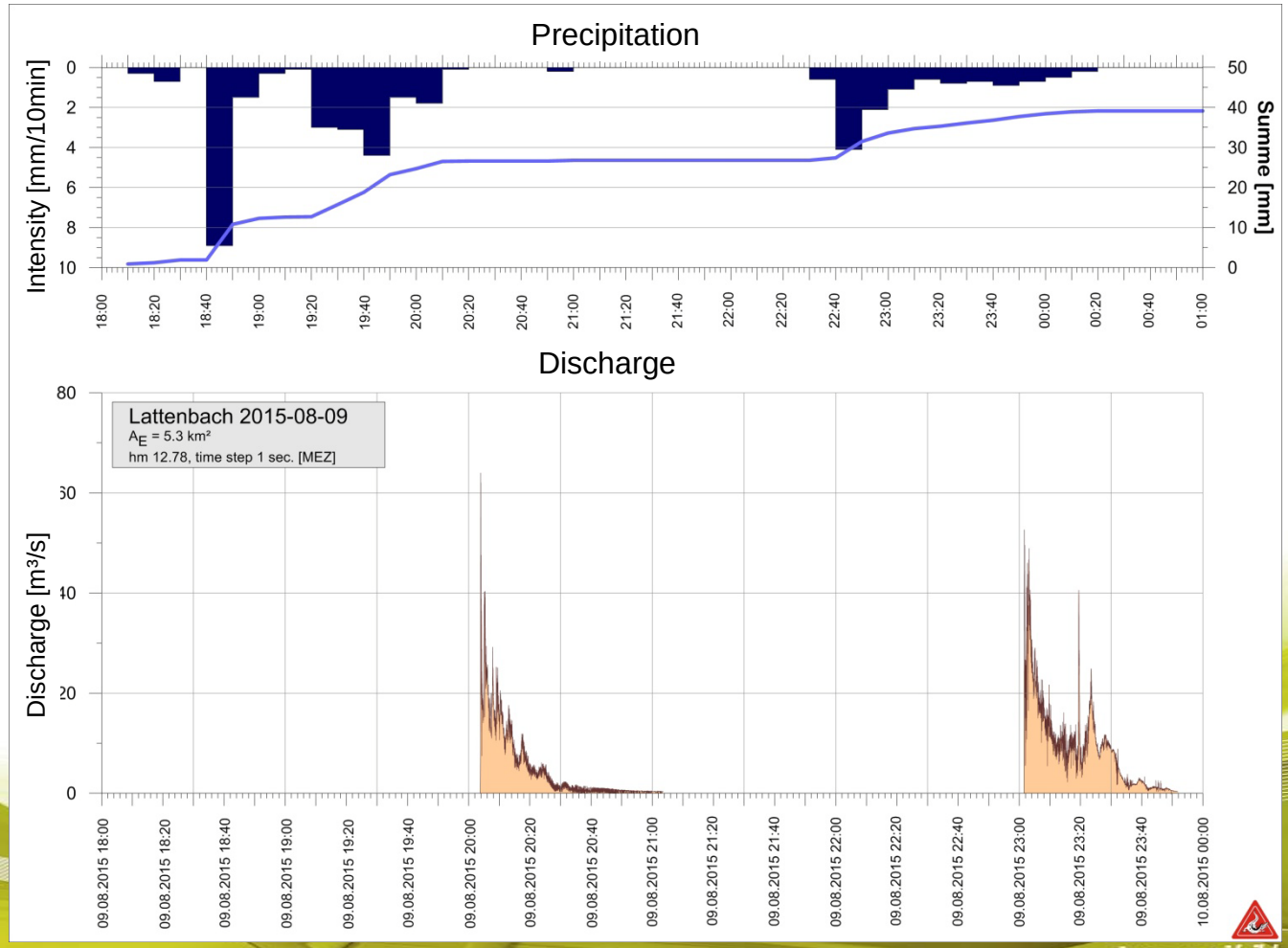
Max. infrasound amp.: 859 mPa
Max. seismic amp.: 134 µm/s
Duration of event: 4561 s
Peak-frequency band: 5-15 Hz



(a) Infrasound time series; (b) Seismogram; (c) Average amplitude of the frequency bands of the infrasound signal; (d) Average amplitude of the frequency band of the seismic signal; (e) Running spectrum of the infrasound signal; (f) Running spectrum of the seismic signal;
Lines: time of first detection based on infrasound and seismic data. Signals are represented with a common base of time.

Debris Flow on 09.08. / 10.08.2015

Precipitation and discharge of the debris flows on 09.08. and 10.08.2015



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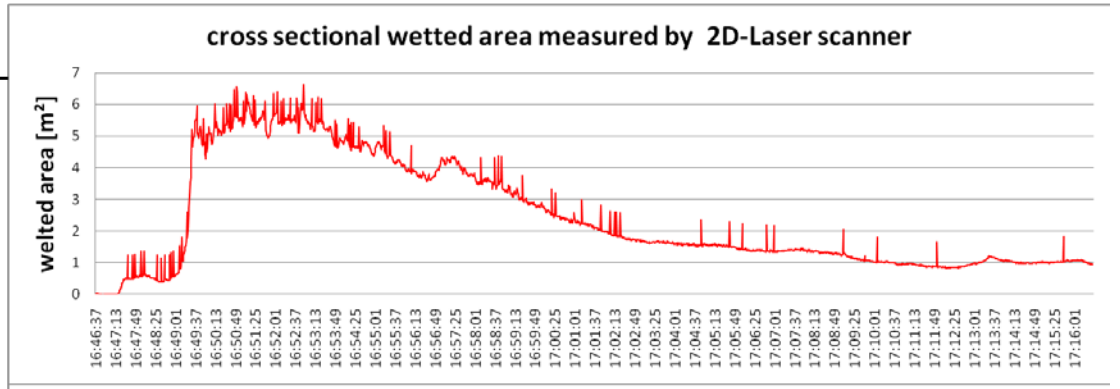
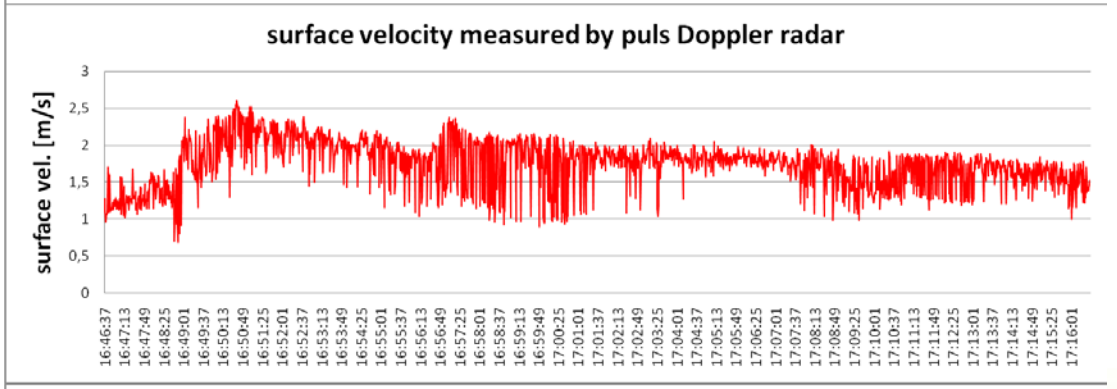
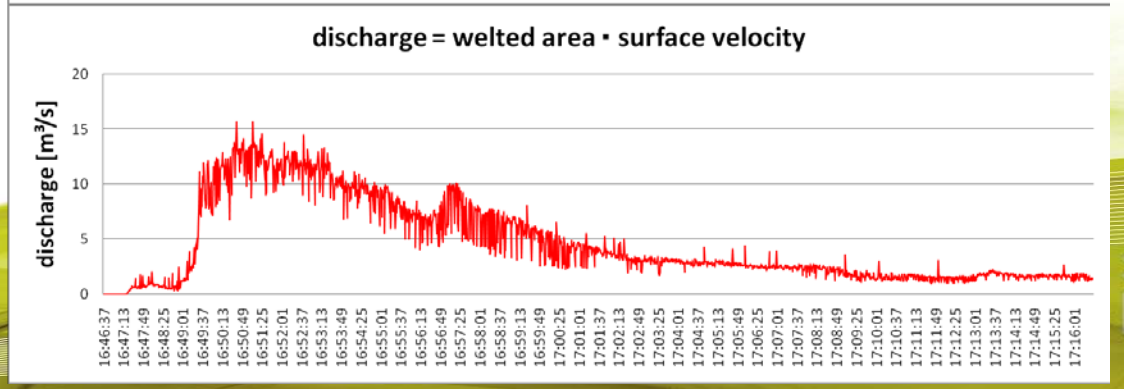
Debris Flow on 16.08.2015

Overall volume: 10000 m³
Max. discharge: 16 m³/s
Av. discharge: 2,8 m³/s
Max. velocity: 2,6 m/s
Average velocity: 1,6 m/s

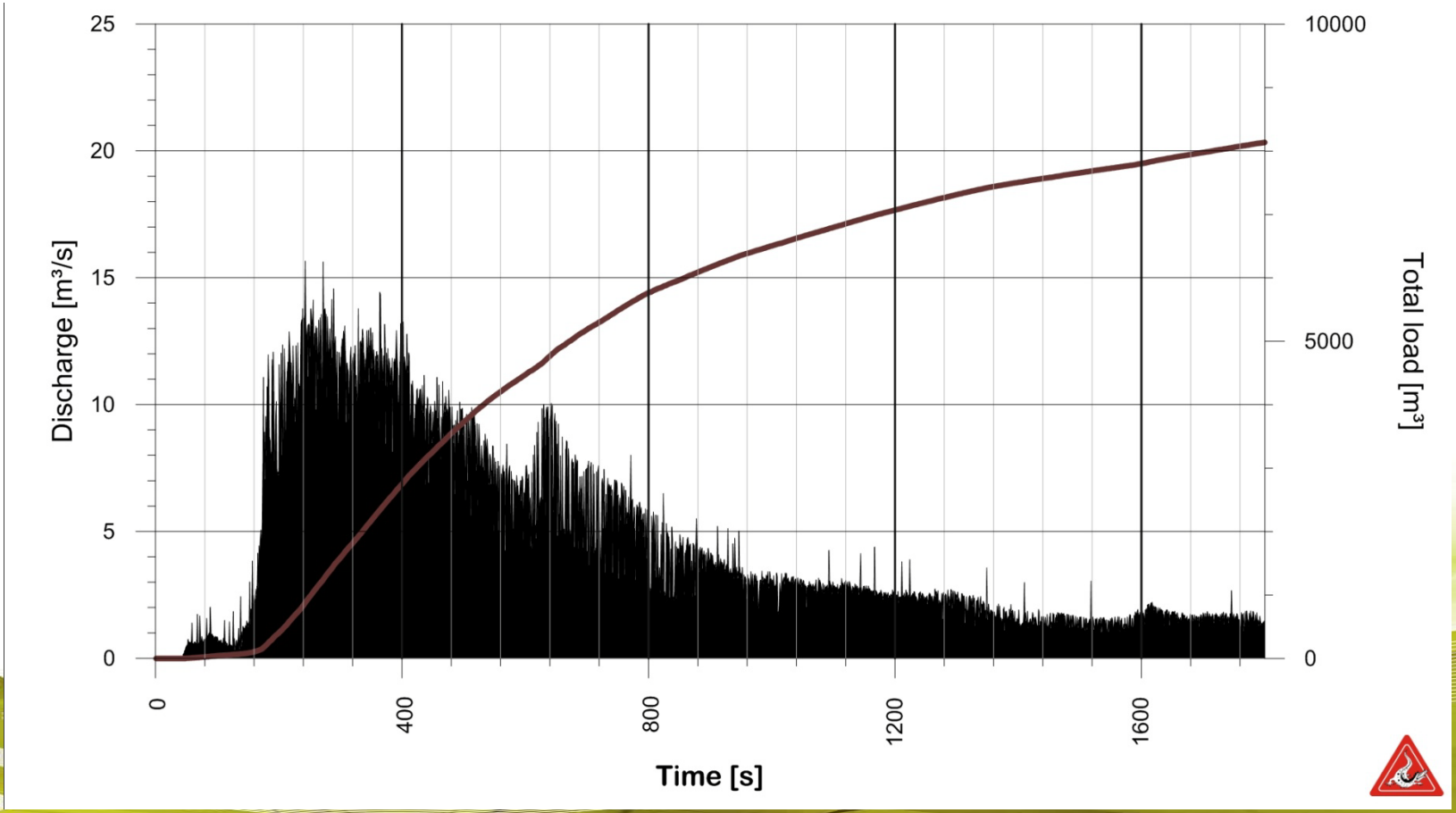






Debris Flow on 16.08.2015

Discharge and total load of the debris flow on 16.08.2015



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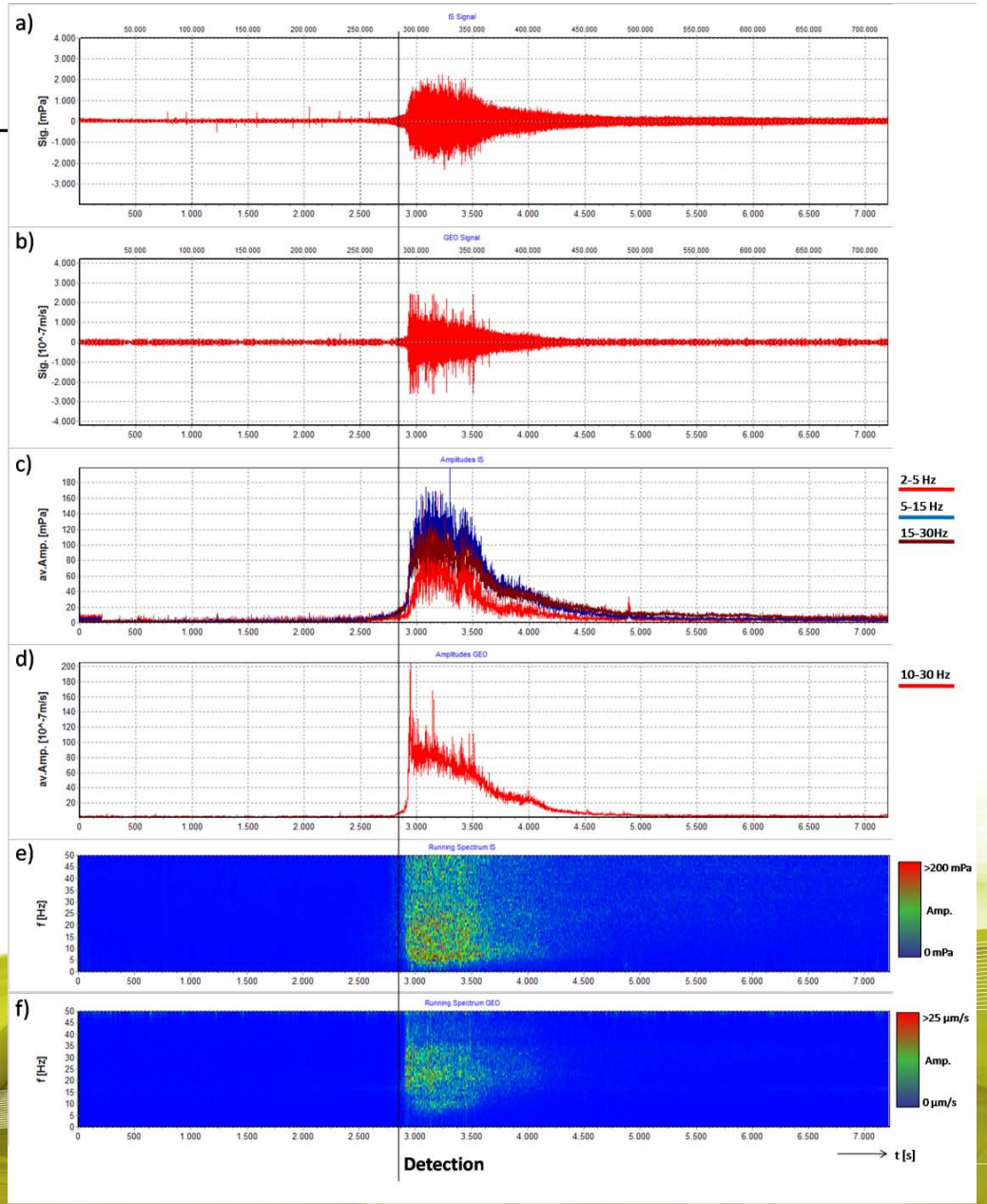
Debris Flow on 16.08.2015

AMM-Detection:

Early detection: 12 s

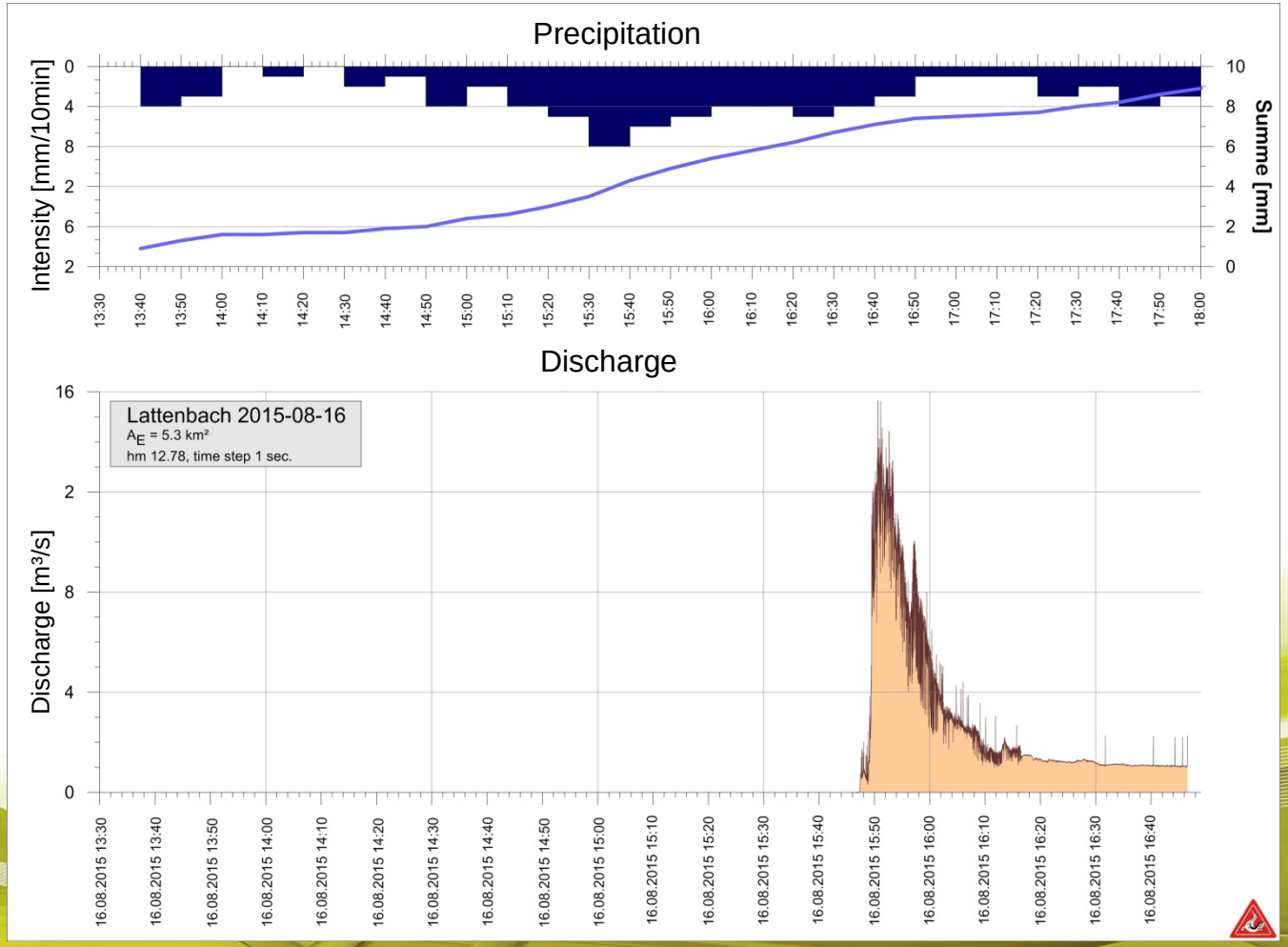
Max. infrasound amp.: 561 mPa
Max. seismic amp.: 75 µm/s
Duration of event: 2099 s
Peak-frequency band: 5-15 Hz

(a) Infrasound time series; (b) Seismogram; (c) Average amplitude of the frequency bands of the infrasound signal; (d) Average amplitude of the frequency band of the seismic signal; (e) Running spectrum of the infrasound signal; (f) Running spectrum of the seismic signal;
Lines: time of first detection based on infrasound and seismic data. Signals are represented with a common base of time.



Debris Flow on 16.08.2015

Precipitation and discharge of the debris flows on 16.08.2015



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AMM-Detection

"Automatic Detection and Identification of Alpine Mass Movements based on Infrasound and Seismic Signals"

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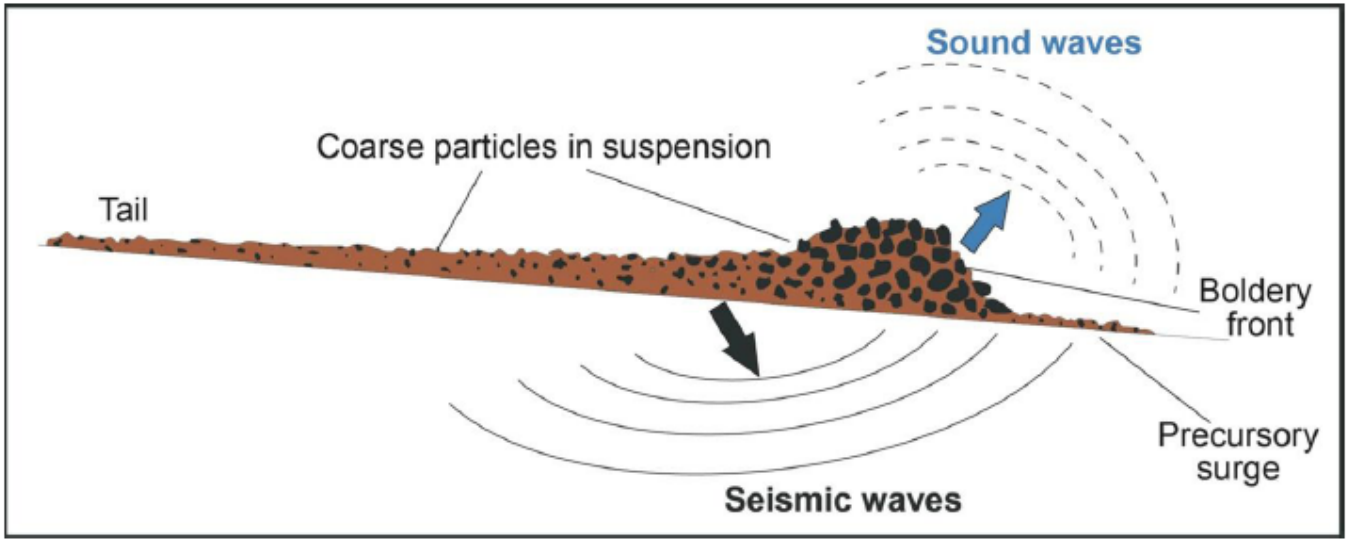
Infrasound and seismic waves of debris flows



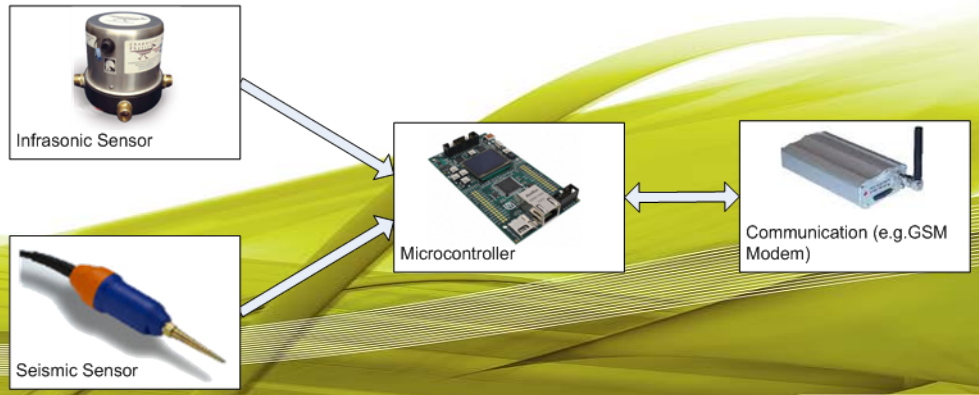
(Kogelnig 2012)

Infrasound:
- Signal source is the collision of stones (vibrations)
- Sound pressure between 0,1-10 Pa
- Peak frequencies
  5-15 Hz (debris flow)
  15-30 Hz (debris flood)

Seismic waves:
- Signal source is the collision of stones with the channel
- Amplitudes between 5-500 µm/s
- Peak frequencies 10-30 Hz

Used components

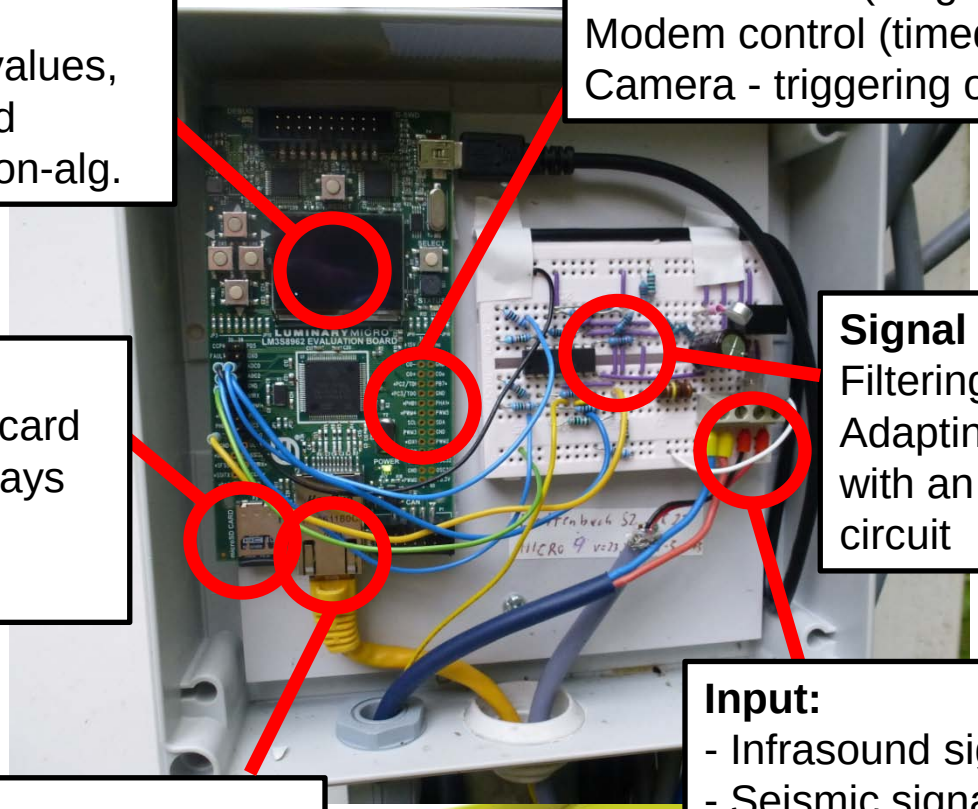
- **Microcontroller: Luminary LM3S8962**
  50 MHz ARM-Cortex-M3 Processor
  4 ADC-Channels – 100 Samples/s
- **Infraschall sensor: Chaparral Model 24**
  Sensitivity 2 V/Pa, frequency range 0,1 Hz – 50 Hz
  or **MK-224**
  Sensitivity 50 mV/Pa, frequency range 3 Hz – 200 Hz
  or **Electret Condenser Micophone** KECG2742WBL-25-L
  Sensitivity -42±3 dB, frequency range ~20-20000 Hz
- **Seismic sensor: Geophone Sercel SG-5**
  Sensitivity 80 Vs/m, Natural frequency 5 Hz



Functions of the warning system

Output:
Alarm 3 V (relay control)
2 Alarm levels (magnitude)
Modem control (timed switch on/off)
Camera - triggering on alarm

Display:
Display of current values, system settings and parameters detection-alg.



SD-Card:
Max. 16 GB memory card
Recording time 148 days (3560 hours-files)
Log-Files (3 types)

Signal adaptation:
Filtering by RC-network
Adapting the input signals with an inverting amplifier circuit

Input:
- Infrasound signal
- Seismic signal
- Level (ultrasonic or radar gauge)

Power supply (12 V, consumption <1.5W!; supervision possible)

Network:
100 Mbit Ethernet
Web server (remote control)
Time from time server
E-Mail alert

Signal processing

- Removing the DC-component by RC-high-pass with a cutoff frequency of ~1 Hz
- Adaptation of the signal to ADC input with an inverting amplifier circuit → Infrasound: 400 mV/Pa; Seismic: 8 mV/µm/s
- Sampling at 100 samples/s, transforming into physical dimensions (Anti-aliasing: 32x Hardware oversampling)
- Calculation of the frequency spectrum using Fast Fourier Transformation per second, 100 FFT samples (FFT Bluestein algorithm)
- Detection-Algorithm

Current Detection-Algorithm

Infrasound Signal:

Amplitude-Criteria - Level 1 / Level 2:

Amplitude of the debris flow / debris flood frequency band exceeds a limit for a certain time-period

$$avAmp_{DFlow} \geq AmpLimitL1 \quad \text{or} \quad avAmp_{DFlood} \geq AmpLimitL1$$
$$avAmp_{DFlow} \geq AmpLimitL2 \quad \text{or} \quad avAmp_{DFlood} \geq AmpLimitL2$$

Distribution-Criteria:

Amplitude of the debris flow / debris flood frequency band is greater than the amplitudes of the frequency bands above and below

$$avAmp_{DFlow} > \begin{matrix} avAmp_{high} \\ avAmp_{low} \end{matrix} \quad \text{or} \quad avAmp_{DFlood} > \begin{matrix} avAmp_{high} \\ avAmp_{low} \end{matrix}$$

Variance-Criteria:

Variance of the amplitudes below a certain value (to eliminate artificial noise)

$$AmpVar_{DFlow} \leq VarLimit \quad \text{or} \quad AmpVar_{DFlood} \leq VarLimit$$

Current Detection-Algorithm

Seismic Signals:

Amplitude-Criteria - Level 1 / Level 2:

Amplitude of the debris flow / debris flood frequency band exceeds a limit for a certain time-period

$$avAmp_{DFlow/DFlood} \geq AmpLimitL2$$
$$avAmp_{DFlow/DFlood} \geq AmpLimitL1$$

Variance-Criteria:

Variance of the amplitudes below a certain value (eliminate artificial noise)

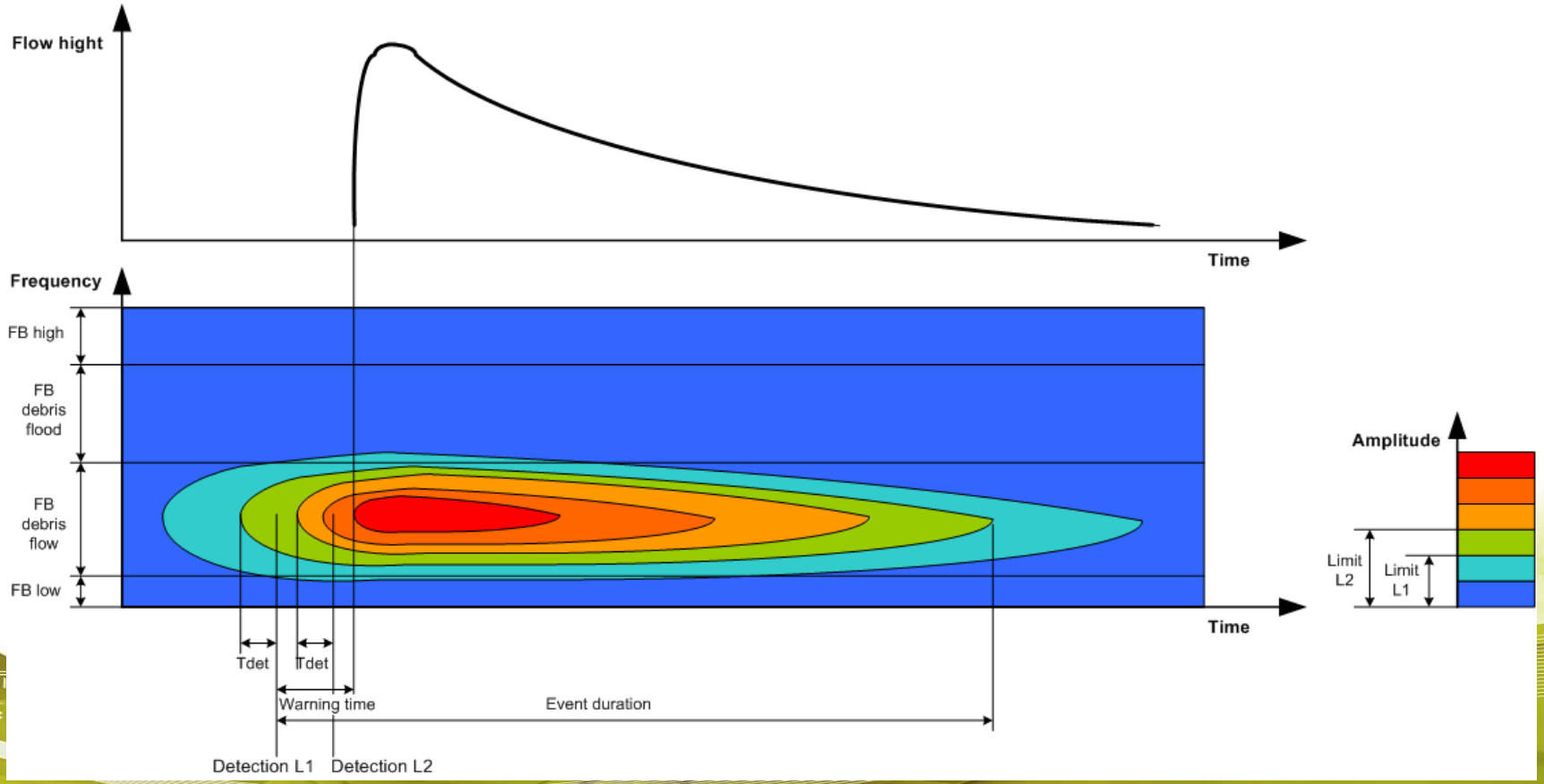
$$AmpVar_{DFlow/Flood} \leq VarLimit$$

Detection:

All criteria for both signals (seismic and infrasound) are met.

Current Detection-Algorithm

Scheme of the event detection - debris flow infrasound signal:



Current Detection-Algorithm

Current parameter values:

		Infrasound signal	Seismic signal
Frequency band 1	$FB1_{low}$ - $FB1_{high}$	3 to 5 Hz	-
Frequency band 2 - debris flow	$FB2_{low}$ - $FB2_{high}$	5 to 15 Hz	10 to 30 Hz
Frequency band 3 – debris flood	$FB3_{low}$ - $FB3_{high}$	15 to 35 Hz	10 to 30 Hz
Frequency band 4	$FB4_{low}$ - $FB4_{high}$	35 to 50 Hz	-
Limit for Amplitudes - Level 1	AmpLimitL1	10 mPa	0,4 µm/s
Limit for Amplitudes - Level 2	AmpLimitL2	30 mPa	1,2 µm/s
Limit for Variance	VarLimit	0,6	0,6
Time span for detection	T_{det}	12 s	12 s

Test sites since 2013

- **Debris flow** (Illgraben, Marderello since 2015)
- **Avalanches**

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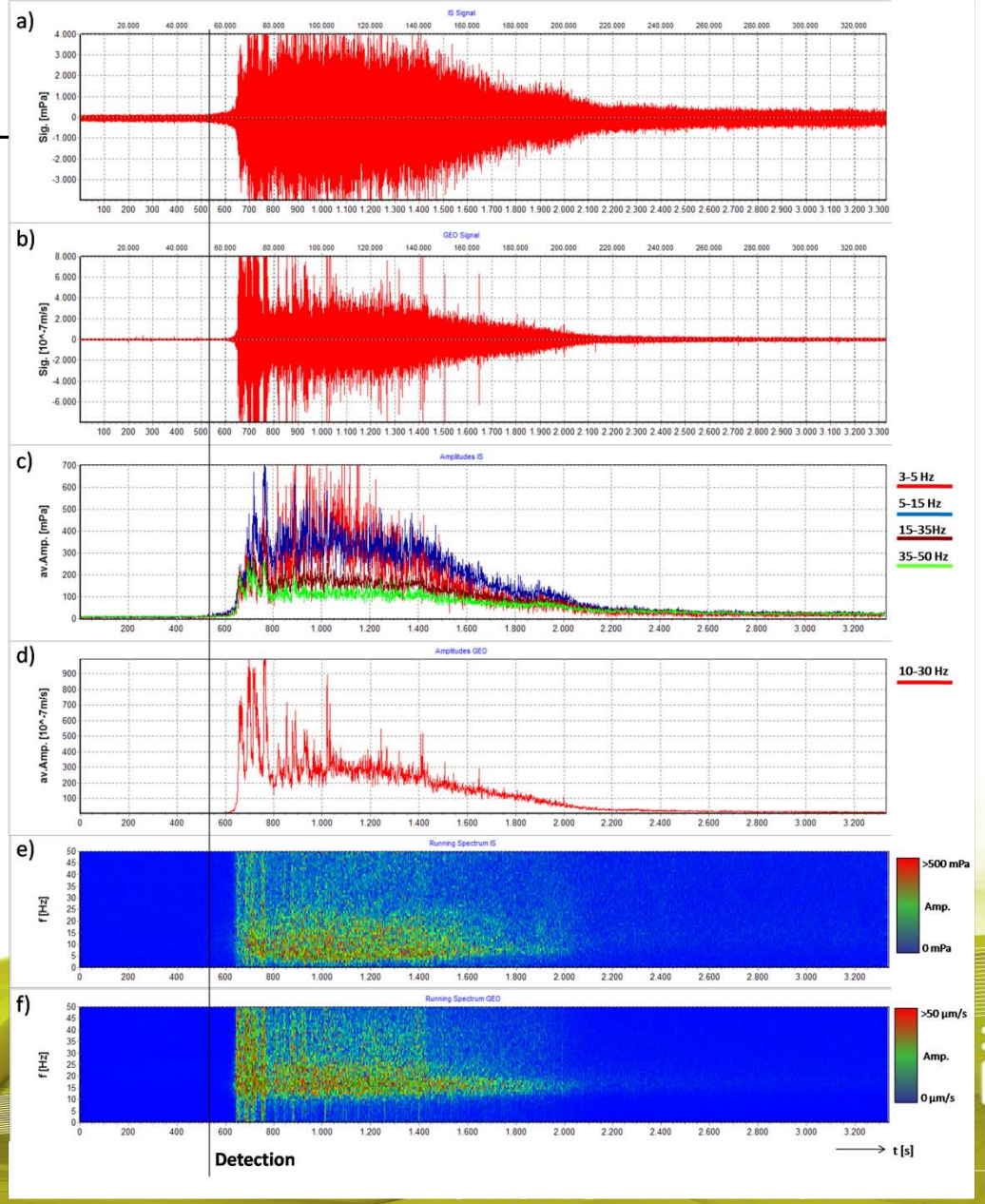
Example for detection

Debris flow on 1.9.2008
Lattenbach (Tyrol)
Early detection: 111 s



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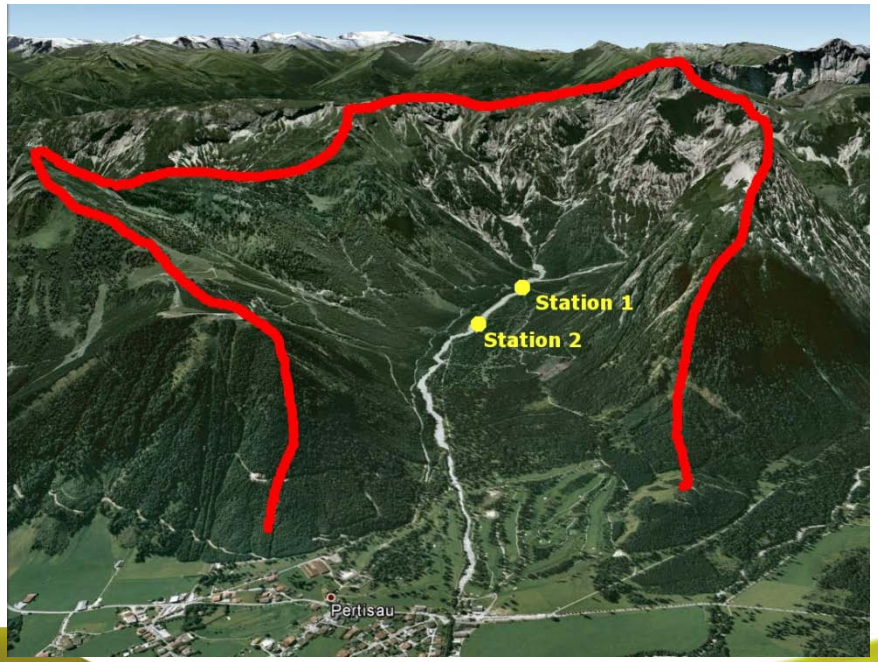
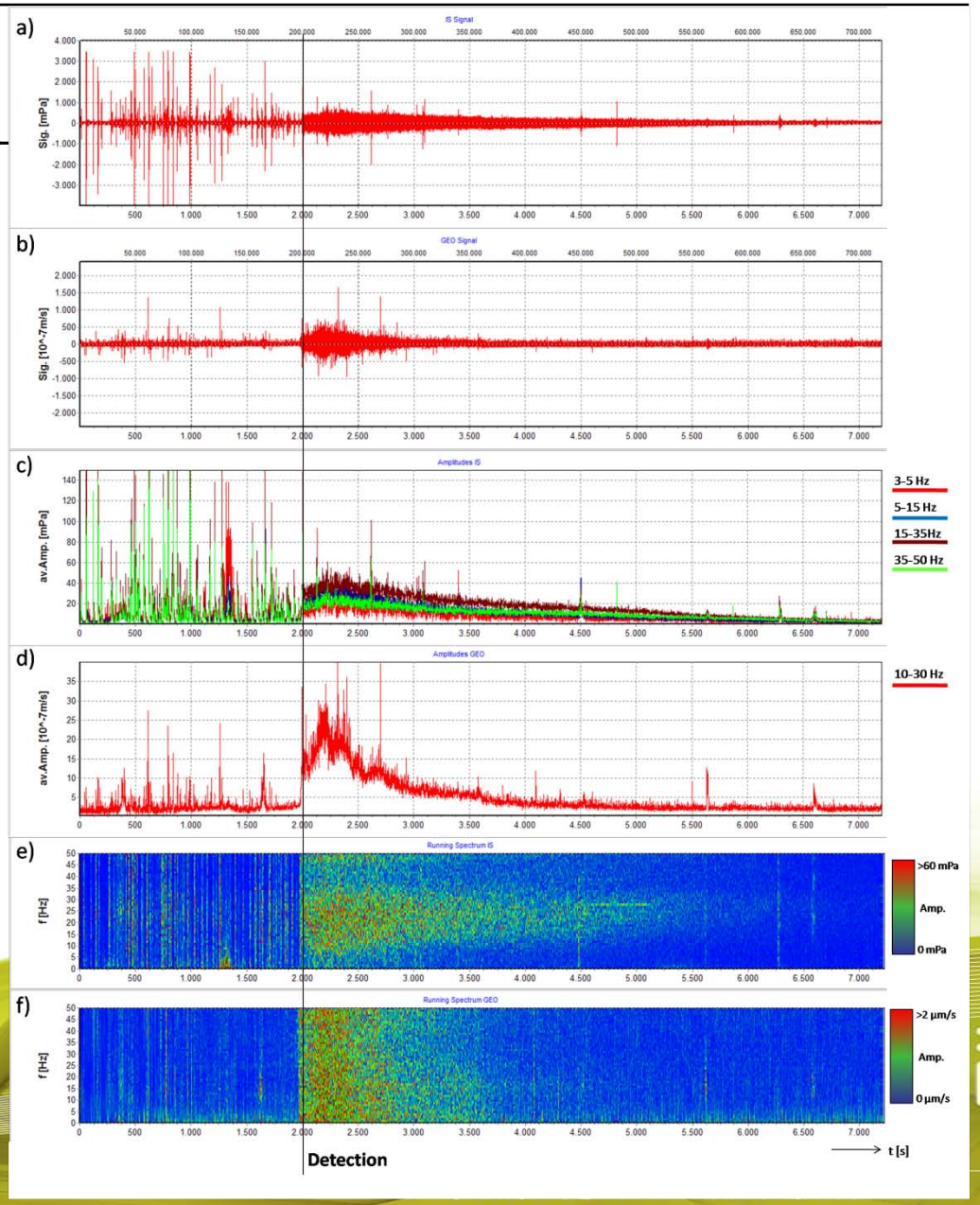
Example for detection

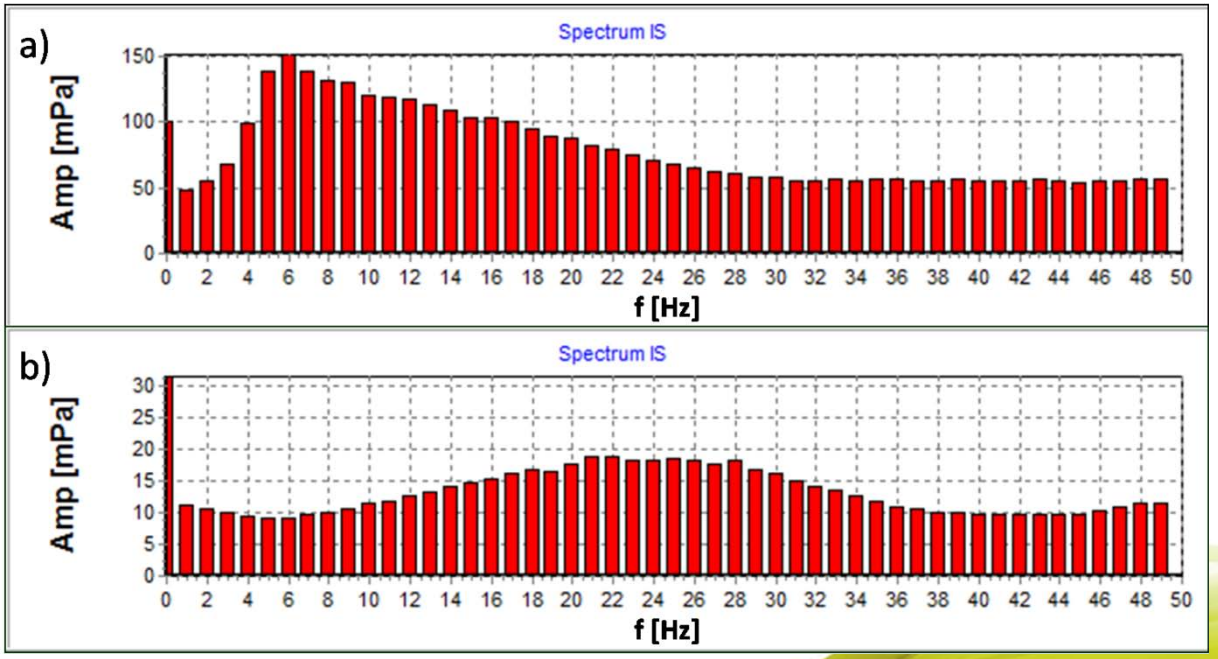
Debris flood on 9.7.2013
Dristenau (Tyrol)
Early detection: -4 s





Example for detection

Comparison infrasound spectrum
Debris flow Lattenbach – Debris flood Dristenau



Debris flow Lattenbach (a)

Debris flood Dristenau (b)

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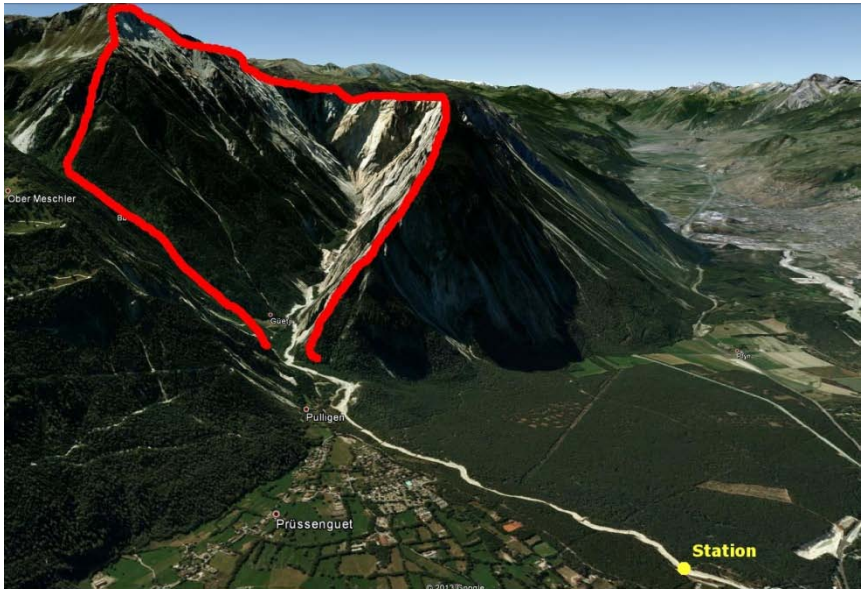
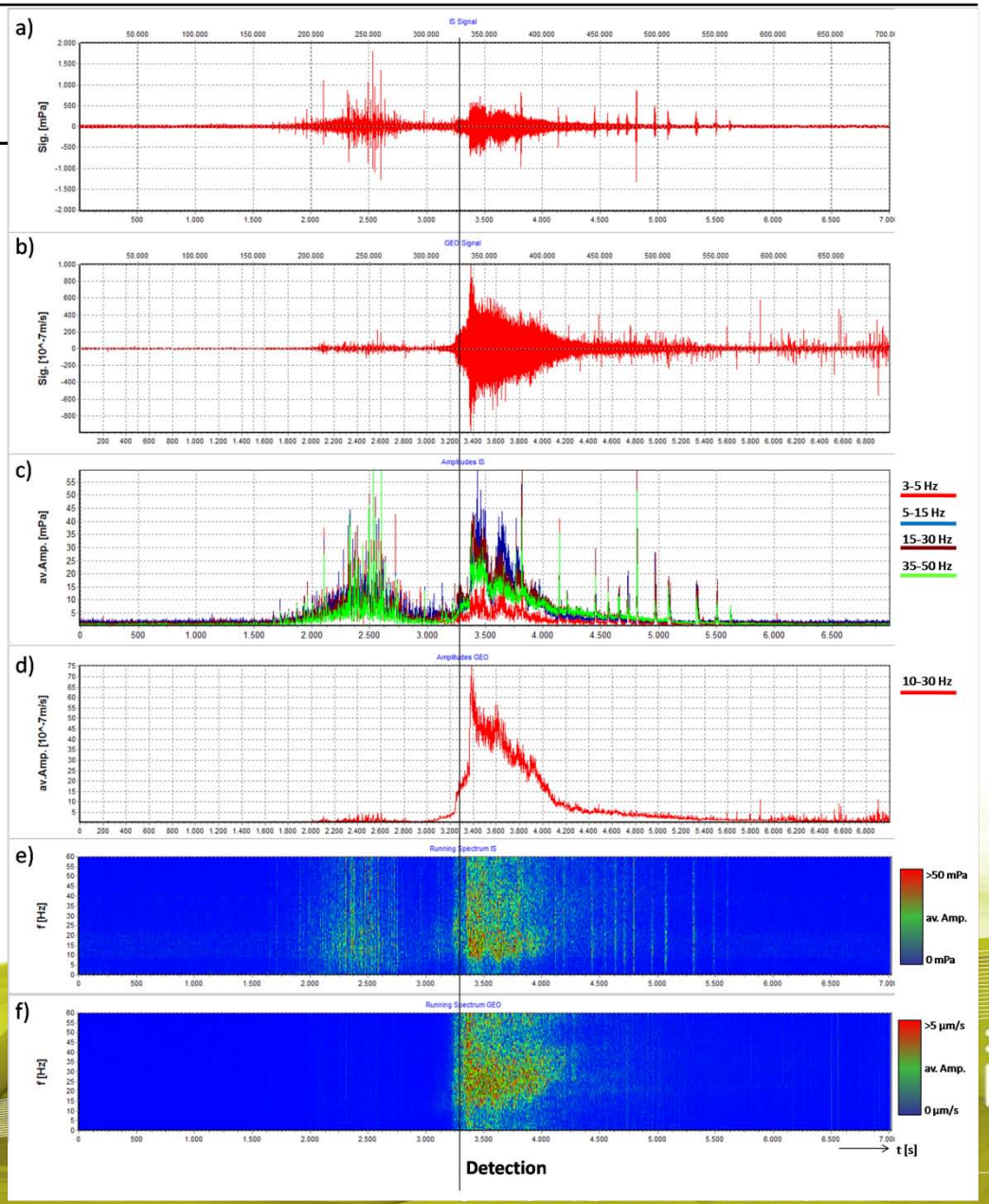
Example for detection

Debris flood on 28.7.2009
Illgraben (Wallis, Switzerland)
Early detection: 89 s





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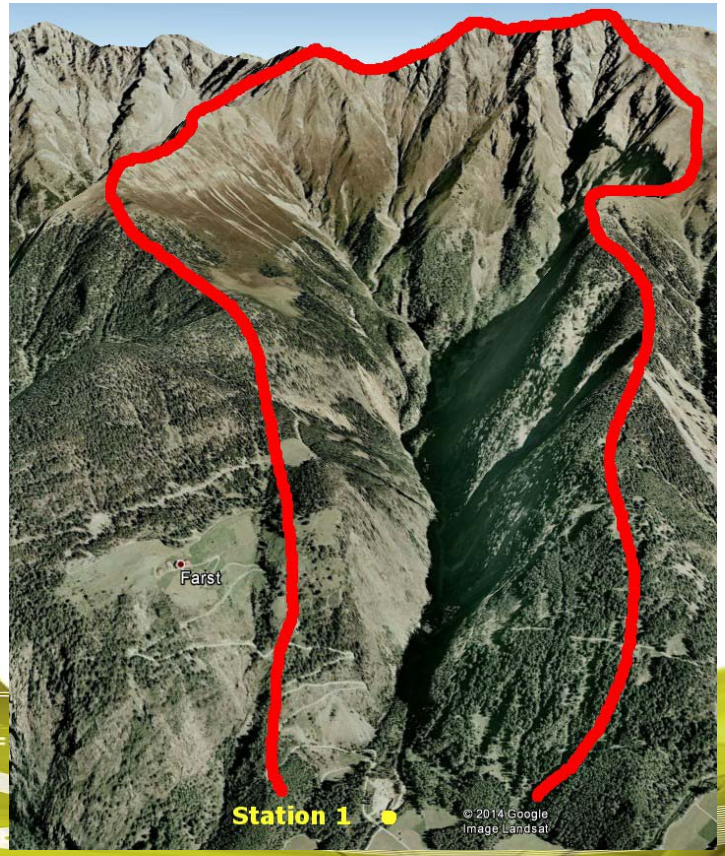
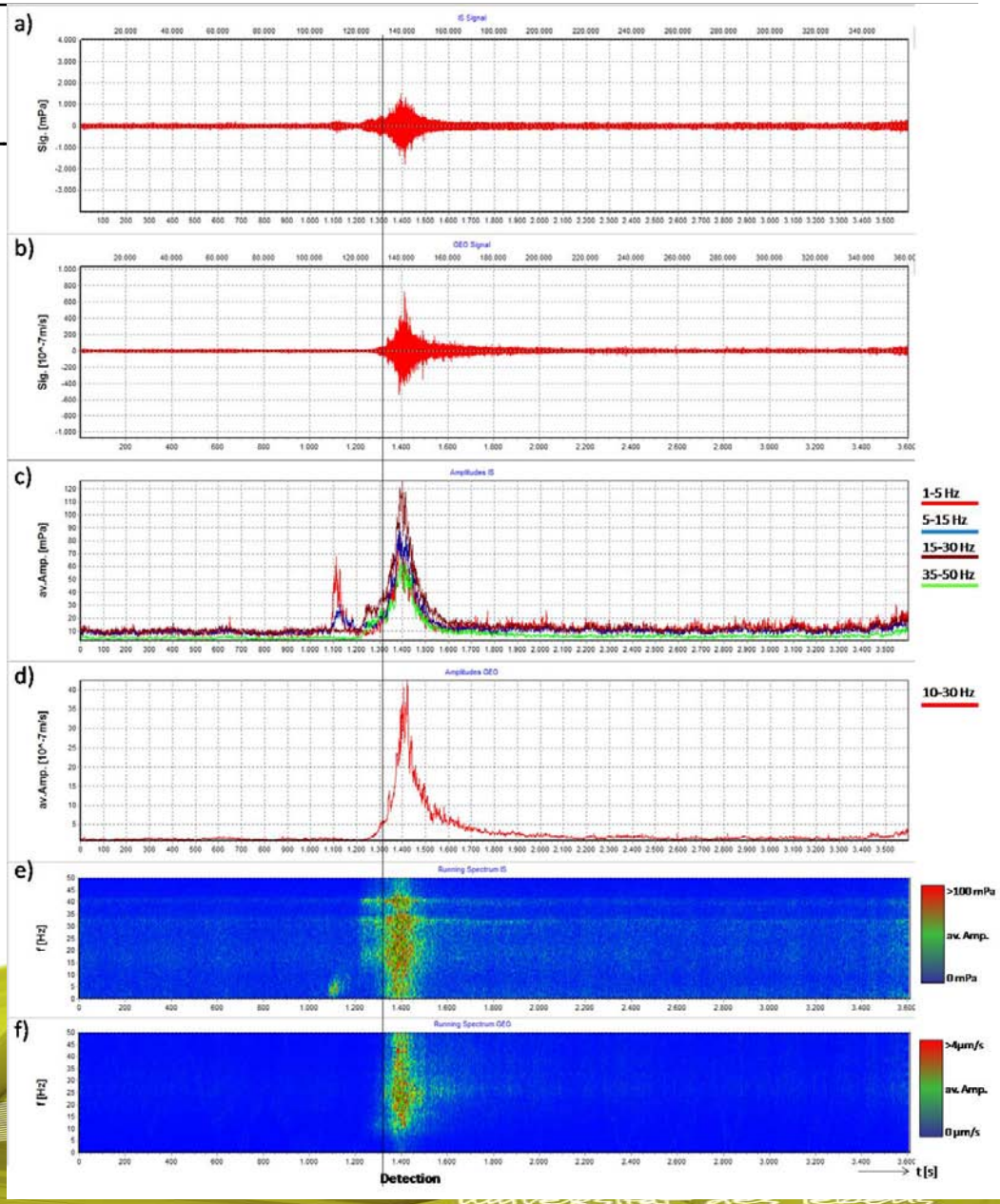
Example for detection

Debris flood on 31.7.2014
Farstrinne (Tyrol)
Early detection: 99s





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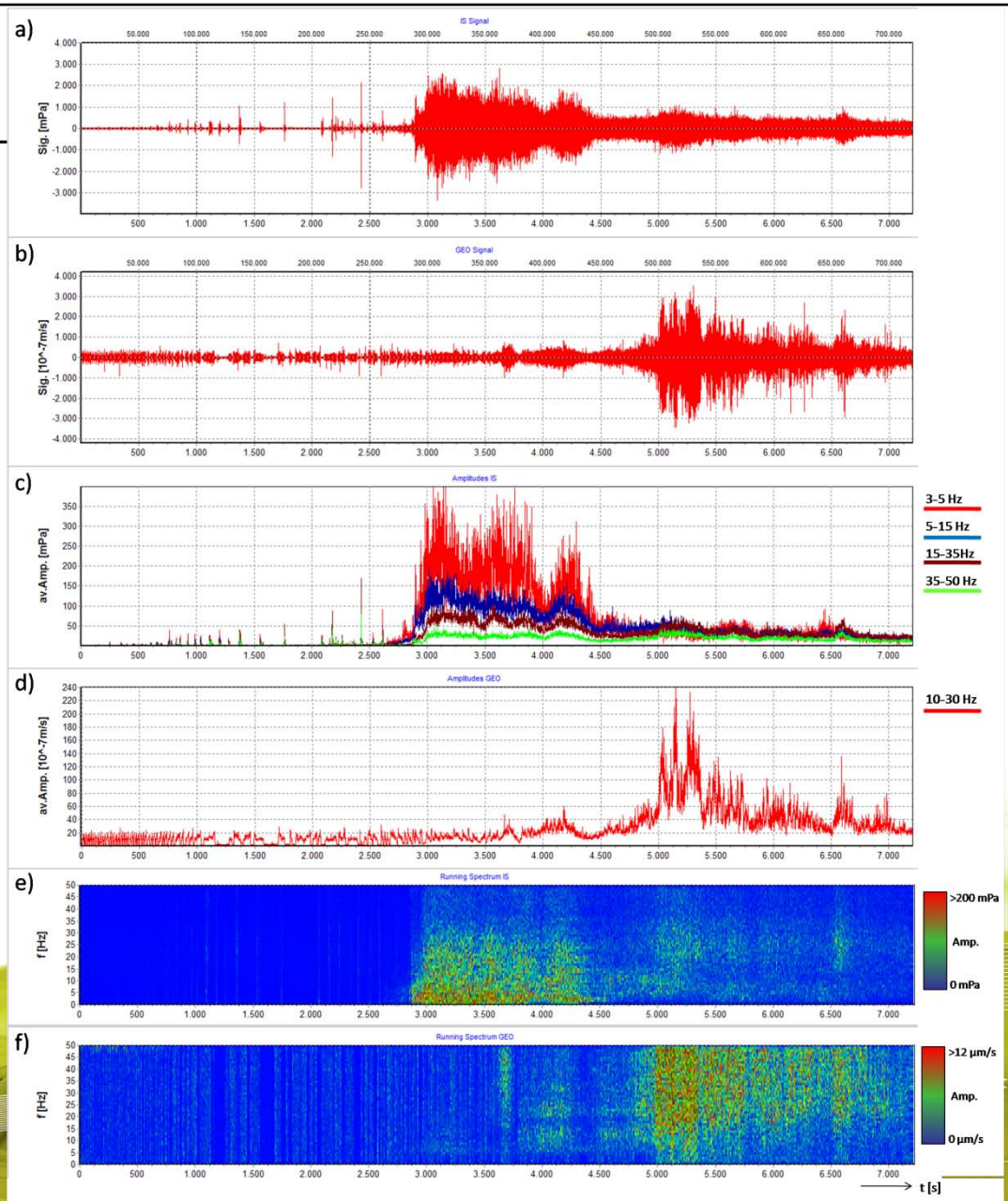
Example for detection

Debris flood on 9.8.2015
Marderello (Italy)



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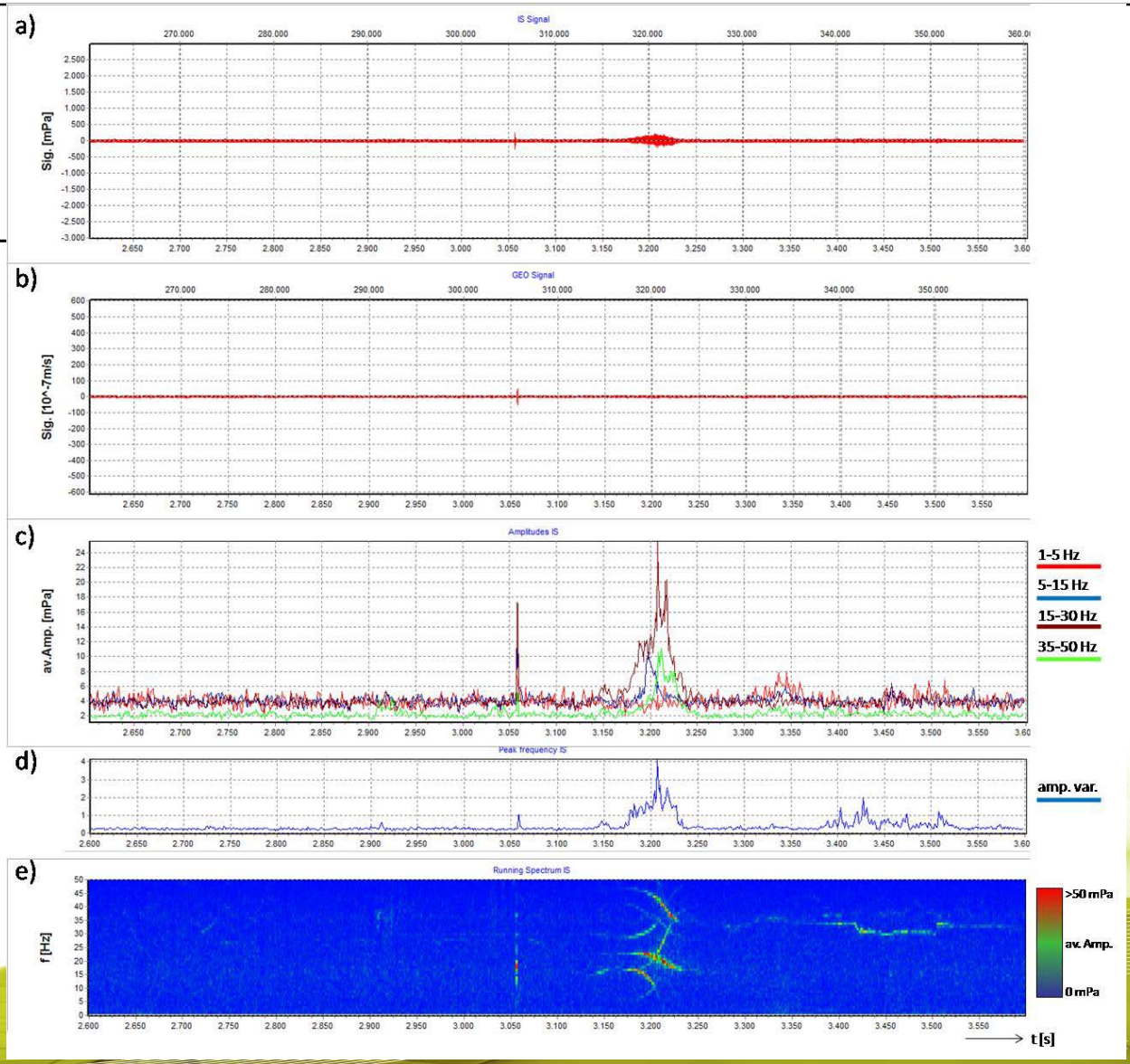
Example for artificial interfering noise

30.6.2014
Farstrinne (Tyrol)

Aeroplane



Results - Test sites

Debris flow / debris floods, season 2013 – Number events / detections

Test Site	Number events			Detections			False alarms
Size:	very small <100 mPa	small >100 mPa <400 mPa	medium >400 mPa	very small <100 mPa	small >100 mPa <400 mPa	medium >400 mPa	
Lattenbach	0	0	0	0	0	0	4
Warschenbach	8	3	1	2	2	1	0
Farstrinne	0	0	0	0	0	0	0
Dristenau	18	4	4	12	3	4	2
Schüsserbach	2	3	1	0	2	1	0
Overall:				**50 %**	**70 %**	**100 %**	**6**

Results - Test sites

Debris flow / debris floods, season 2014 – Number events / detections

Test Site	Number events			Detections			False alarms
Size:	very small <100 mPa	small >100 mPa <400 mPa	medium >400 mPa	very small <100 mPa	small >100 mPa <400 mPa	medium >400 mPa	
Lattenbach	3	0	0	2	0	0	0
Farstrinne	0	0	2	0	0	2	0
Dristenau	10	1	1	4	1	1	1
Schüsserbach	0	0	0	0	0	0	0
Overall:				**45 %**	**100 %**	**100 %**	**1**

Further points of research

- Estimation of event size (magnitude, deposit) *
- Determination of process-type (viscosity) *
- Determination of the duration of the event
- Localization of the event (sensor array)

*) ÖAW ESS-Project:
„Identification of sediment-related disaster based on seismic and acoustic signals”

Debris flow - Test sites