Infrasound array analysis of debris-flows: an application to Illgraben, Switzerland

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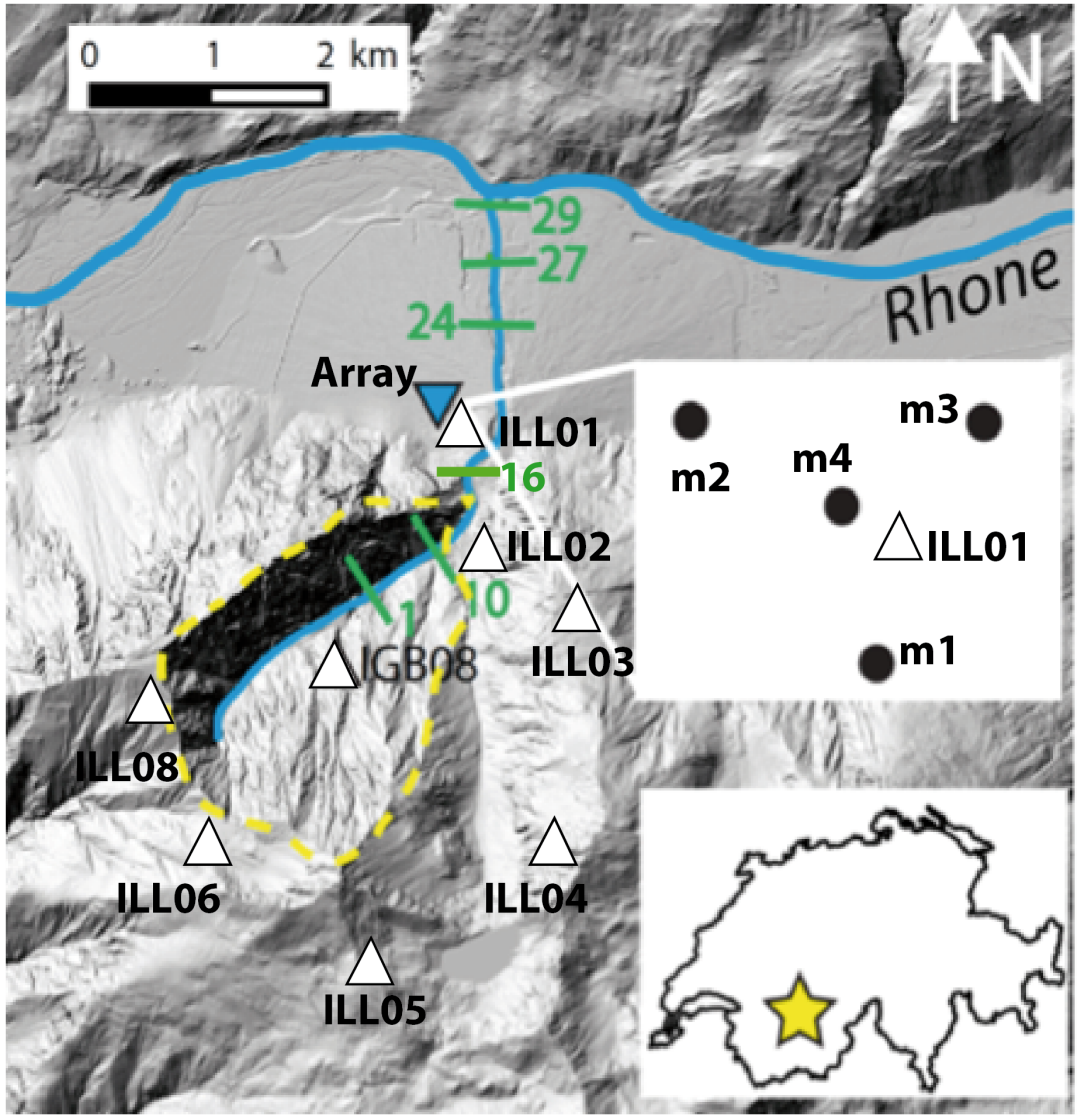
debris flow 29 May 2017, Illgraben, Switzerland

www.agu.org

Debris flows are mobilized water/sediment mixtures in steep mountain with max velocity of several meters per seconds.

Illgraben has typically several debris flows/year, with maximum volumes of ~10^5 m^3.

Experimental setup



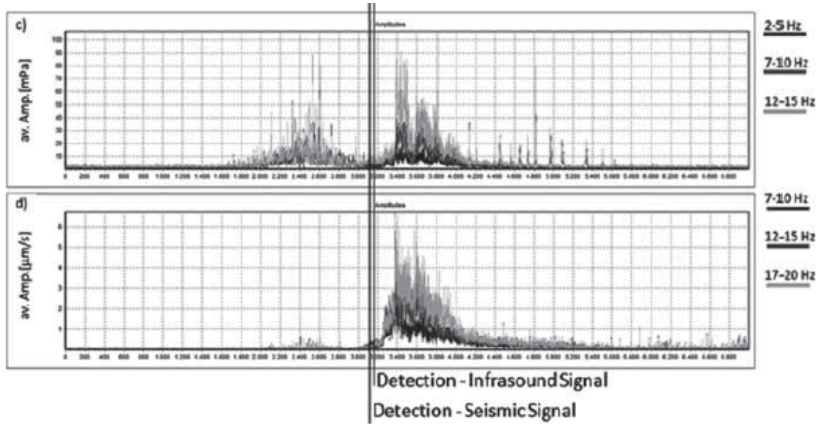
In spring 2017 we installed a network of 8 seismic stations and a 4 element infrasound array.

We use here data infrasound data and a co-located seismic station, deployed outside the graben and compare with an Early-Warning system by WSL.

Seismic network Wenner et al, EGU 2018 (poster)

Motivation

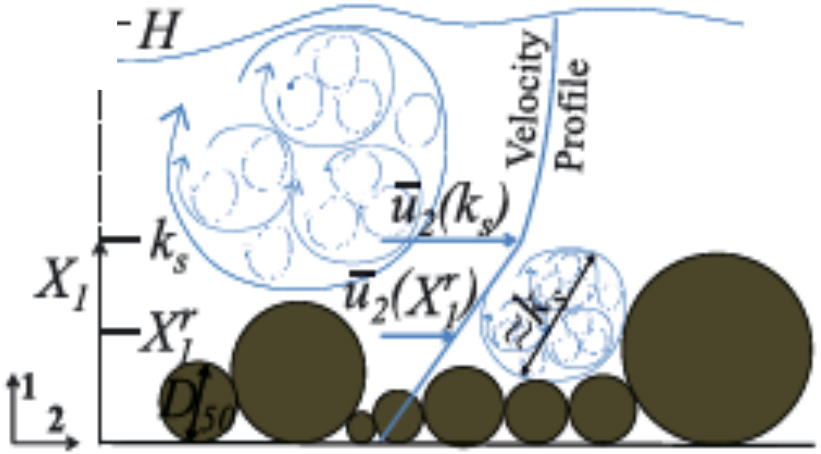
Seismo-acoustic data are used to detect automatically debris flow events: (e.g. Huebl et al., 2013; Kogelnig et al., 2014; Schimmel et al., 2013)



Huebl et al., JSSE, 2013

Seismic noise produced by:

1) *Turbulence*
2) *Bedload transport*



Gimbert et al., JGR, 2014

The infrasound source process is not really investigated…..

We want to:

- ***Further investigate the mechanism of infrasound radiation from debris flow and signal characteristics.***
- ***Evaluate the potential of infrasound array monitoring as an early warning system***

"Infrasound is a wave phenomenon sharing the physical nature of sound but with a range of frequencies below that of human hearing"

Pressure Perturbations with frequency < 20 Hz

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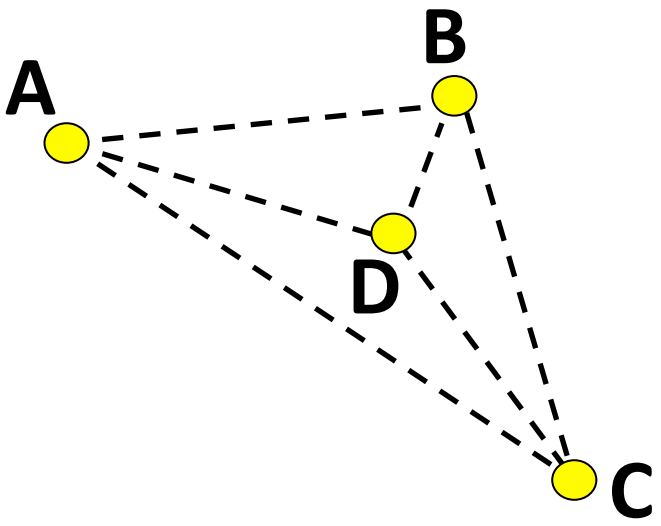
Pressure Perturbations with frequency < 20 Hz



multiple sensors used as an antenna to discriminate signal from noise

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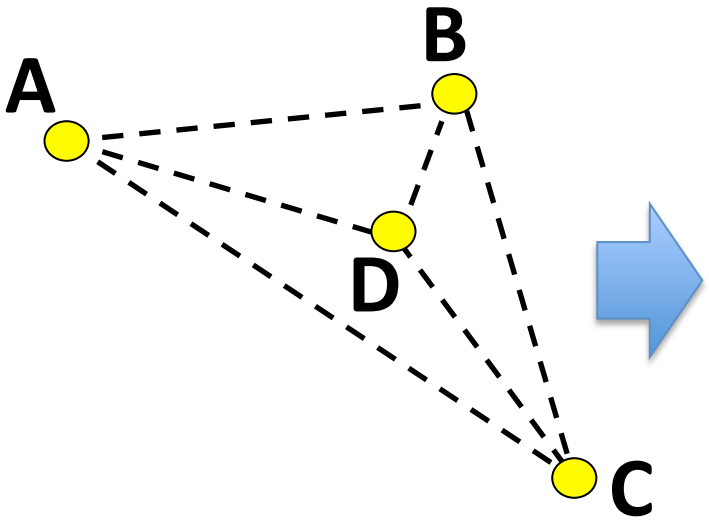

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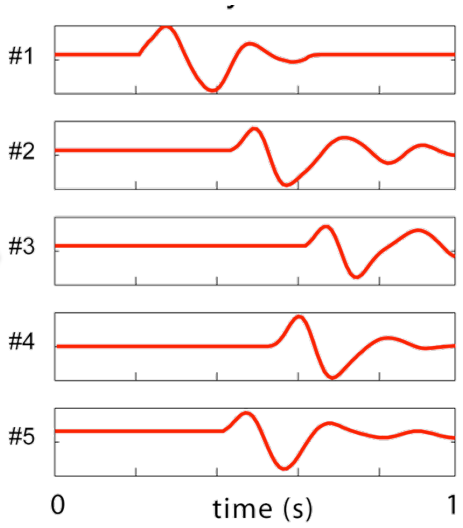
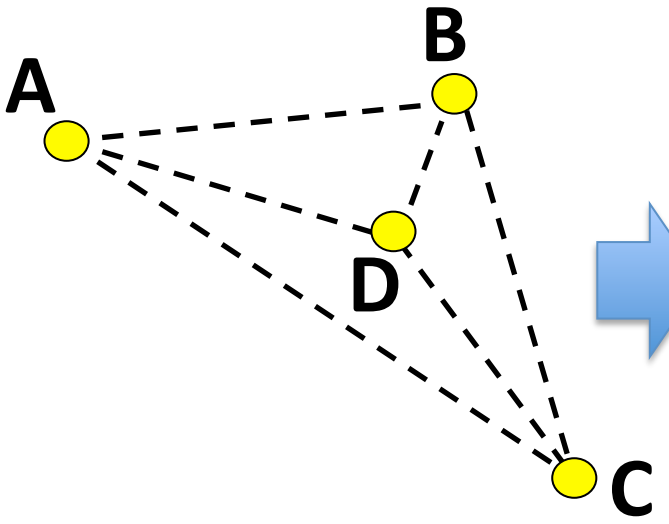


arrival time depends on infrasounic ray

"Infrasound is a wave phenomenon sharing the physical nature of sound but with a range of frequencies below that of human hearing"

Pressure Perturbations with frequency < 20 Hz



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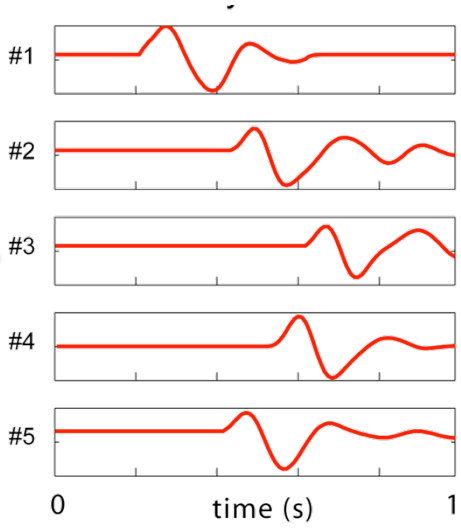

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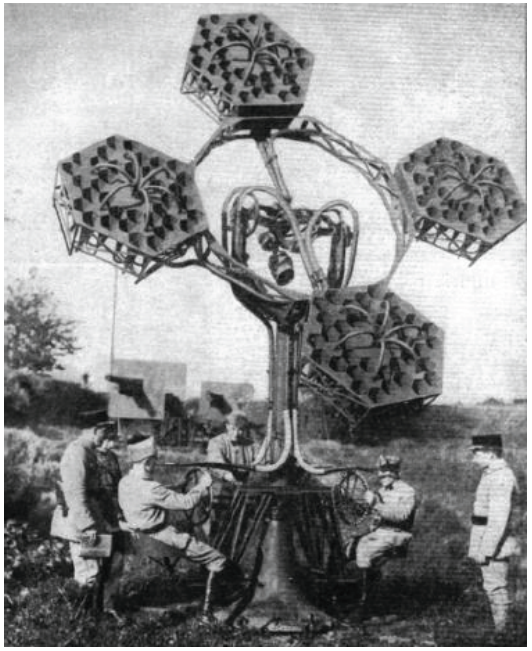
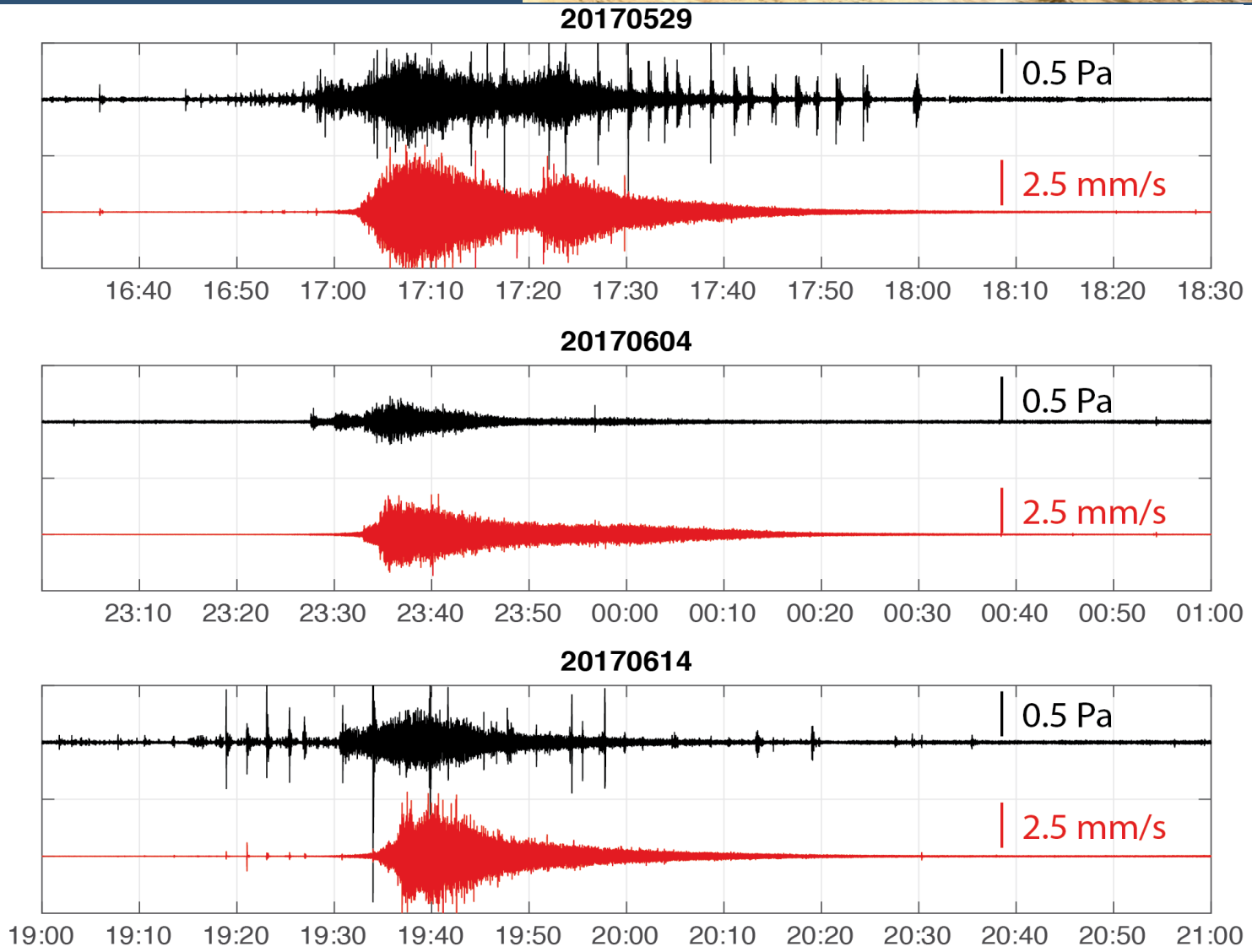
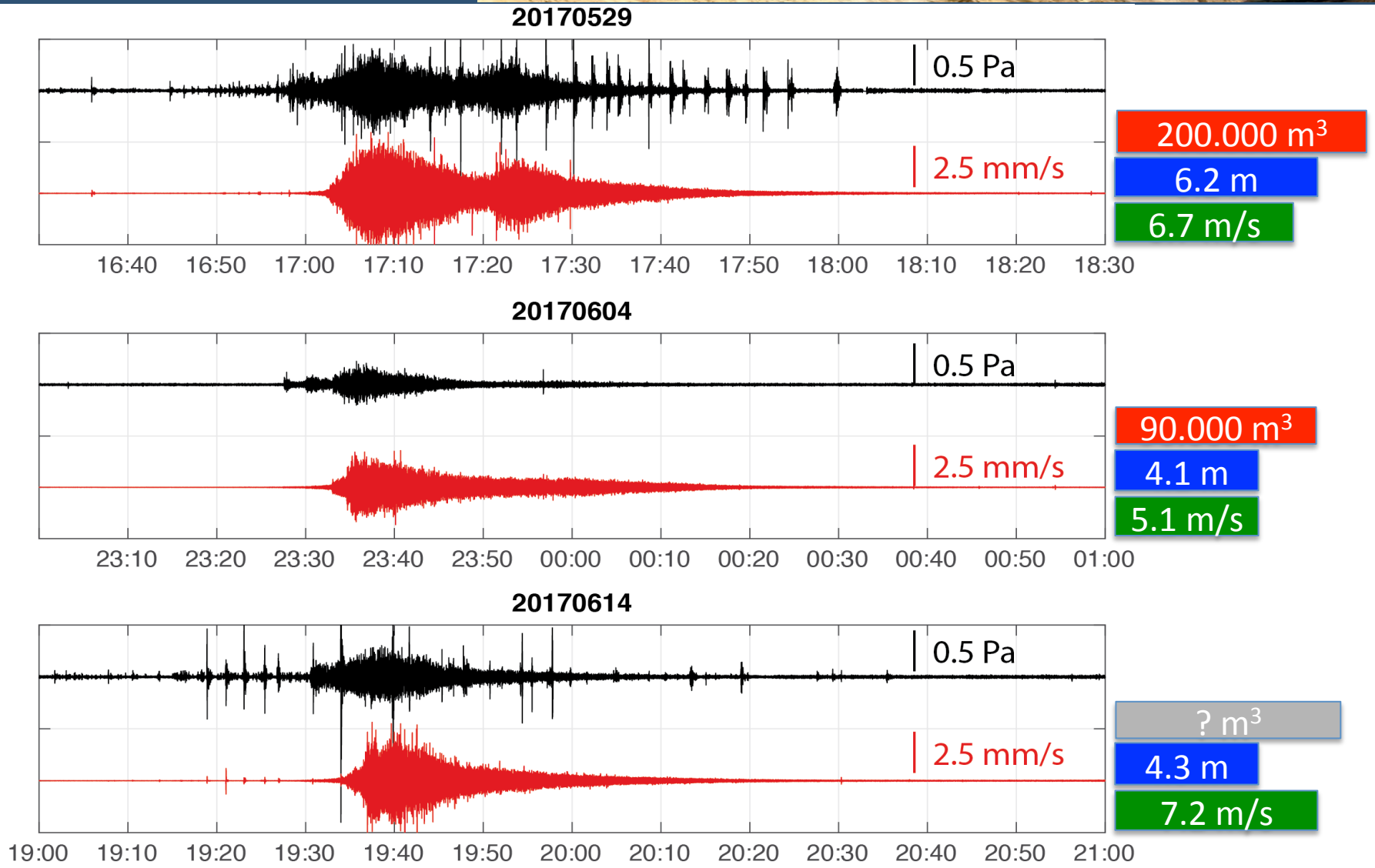


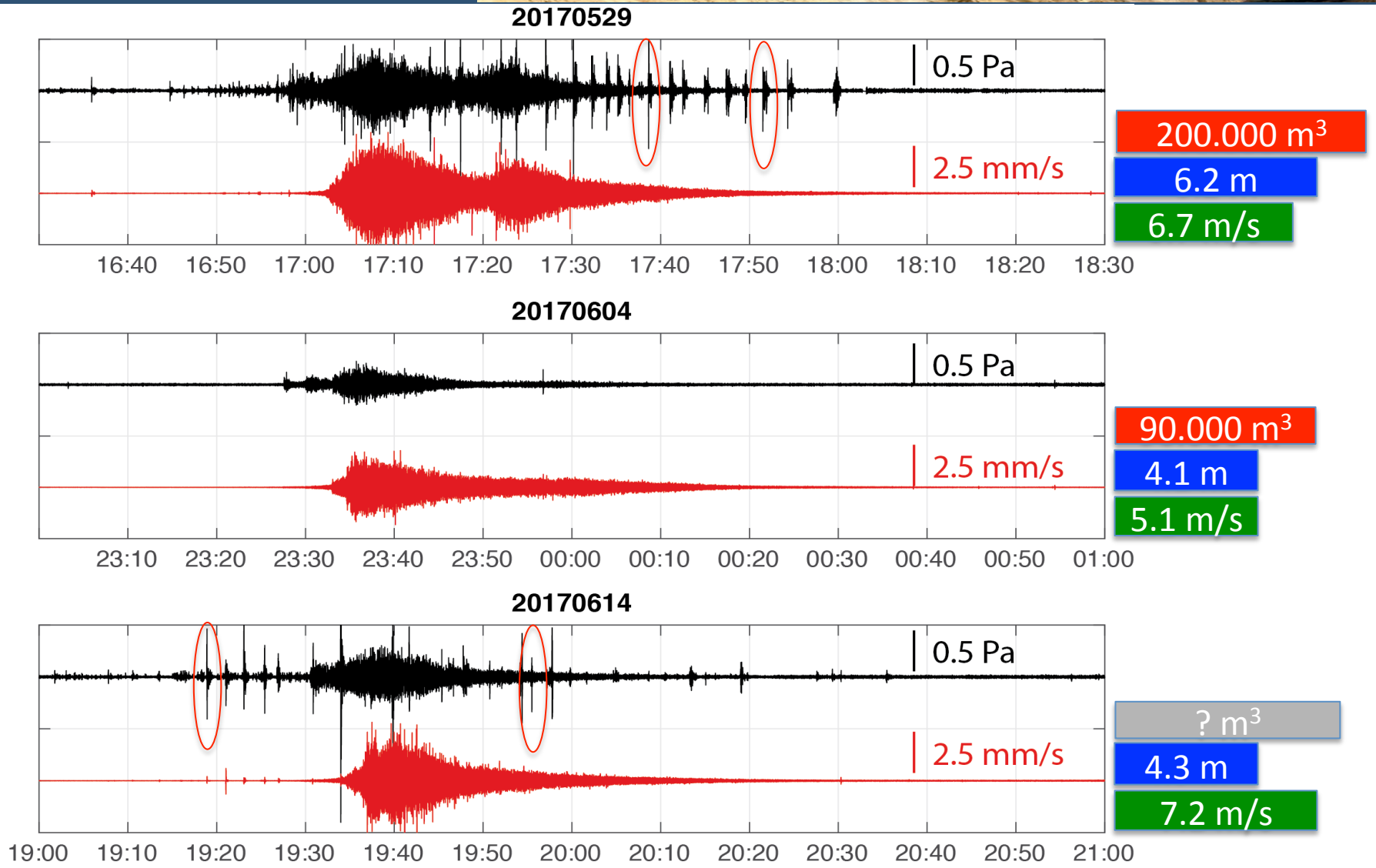
signal identified in terms of back-azimuth and apparent velocity



2-hour-long sample of debris flows recorded with the array and co-located seismometer



2-hour-long sample of debris flows recorded with the array and co-located seismometer



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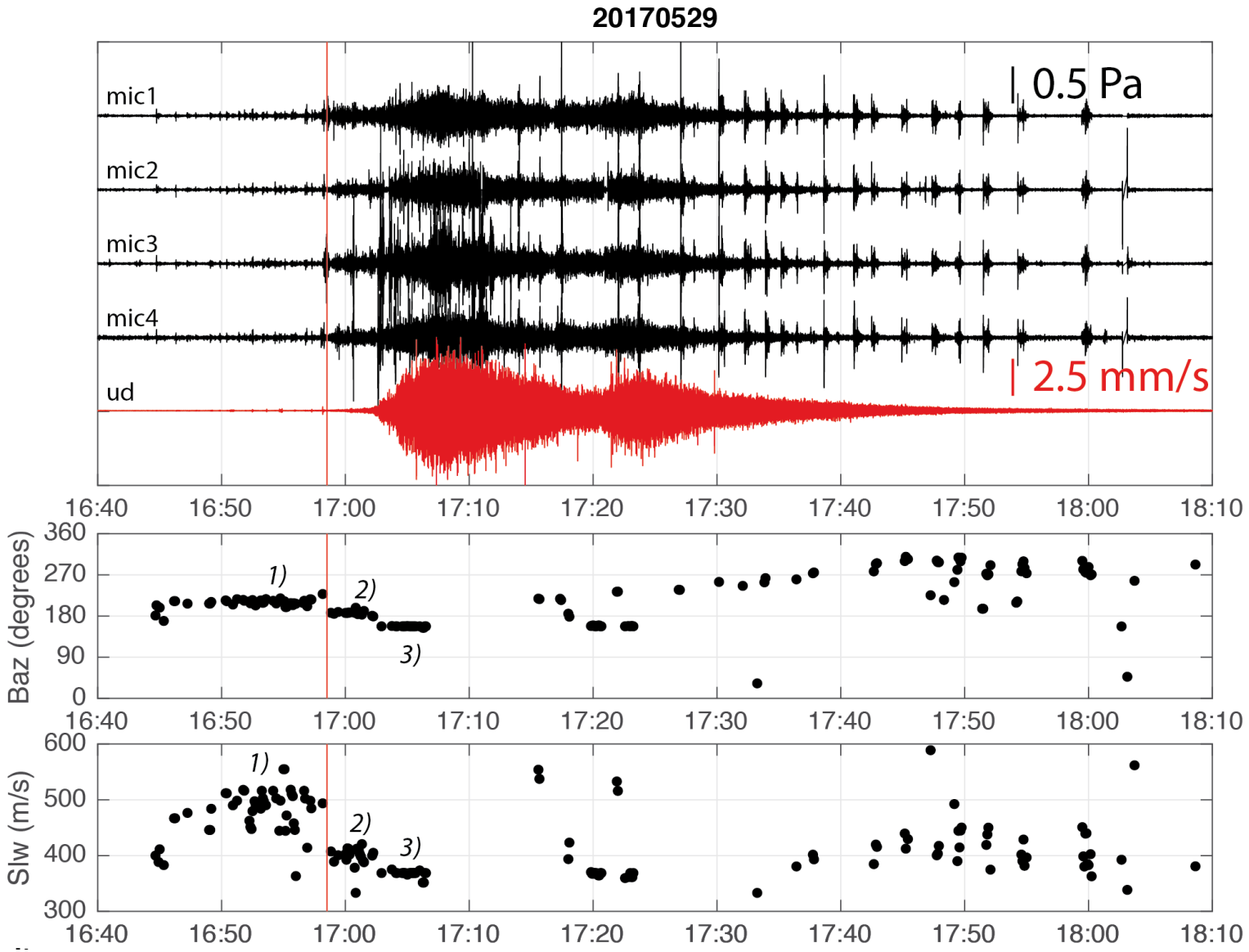
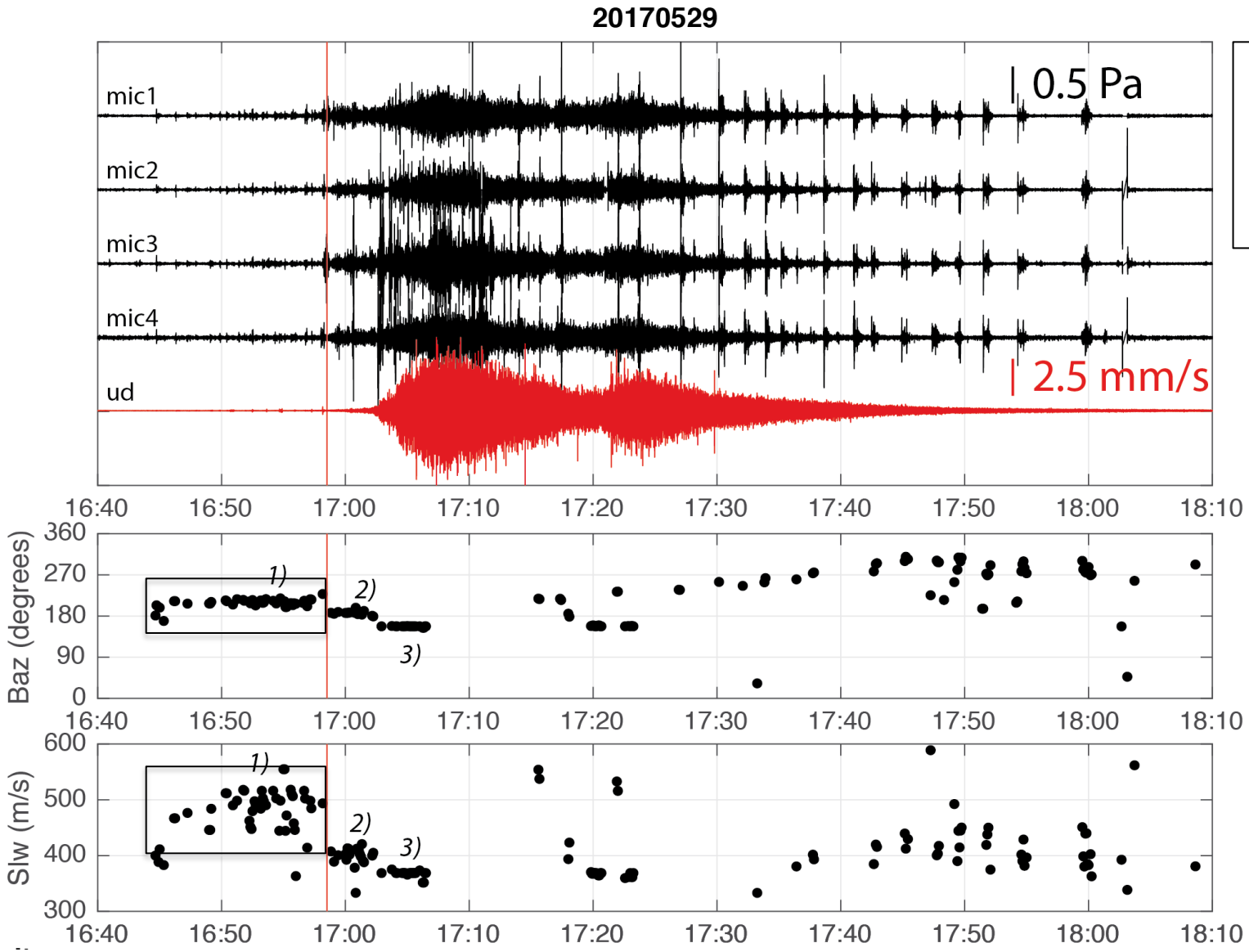
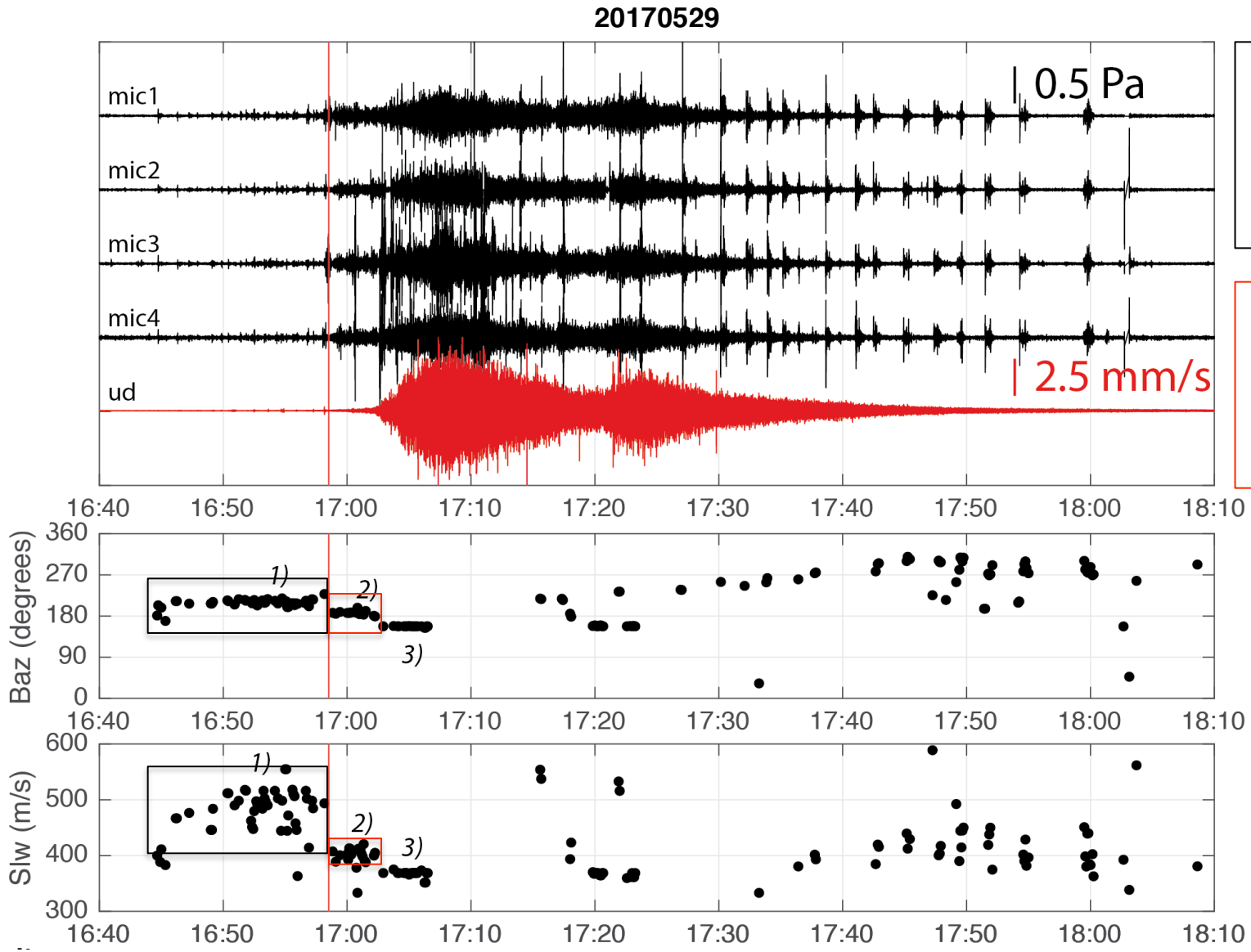

20170529
mic1
mic2
mic3
mic4
ud
| 0.5 Pa
| 2.5 mm/s
16:40
16:50
17:00
17:10
17:20
17:30
17:40
17:50
18:00
18:10
Baz (degrees)
360
270
180
90
0
1)
2)
3)
Slw (m/s)
600
500
400
300
Time UTC

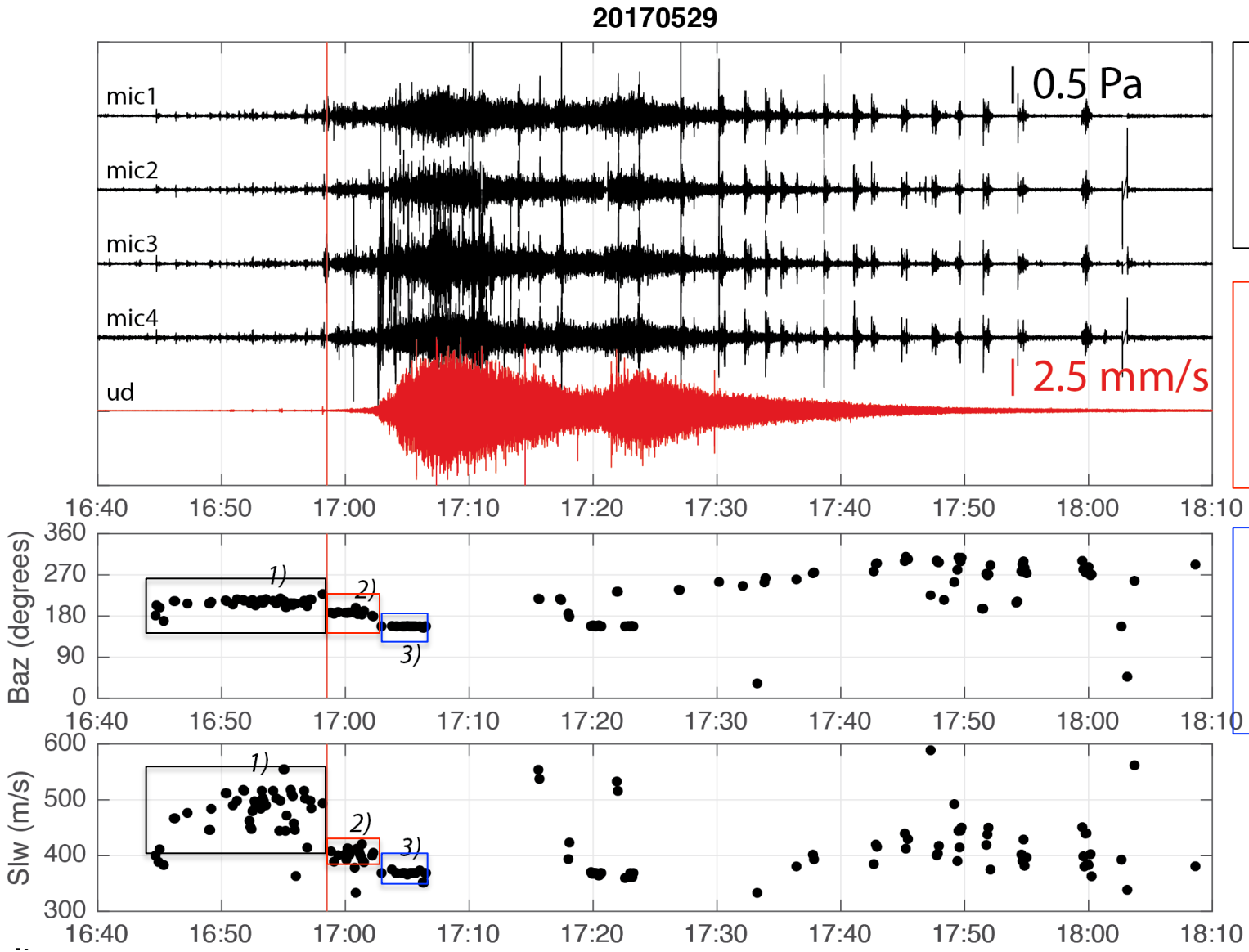


Phase (1)
~ 480 m/s
200-220 °N
15 minutes



Phase (1)
~ 480 m/s
200-220 °N
15 minutes

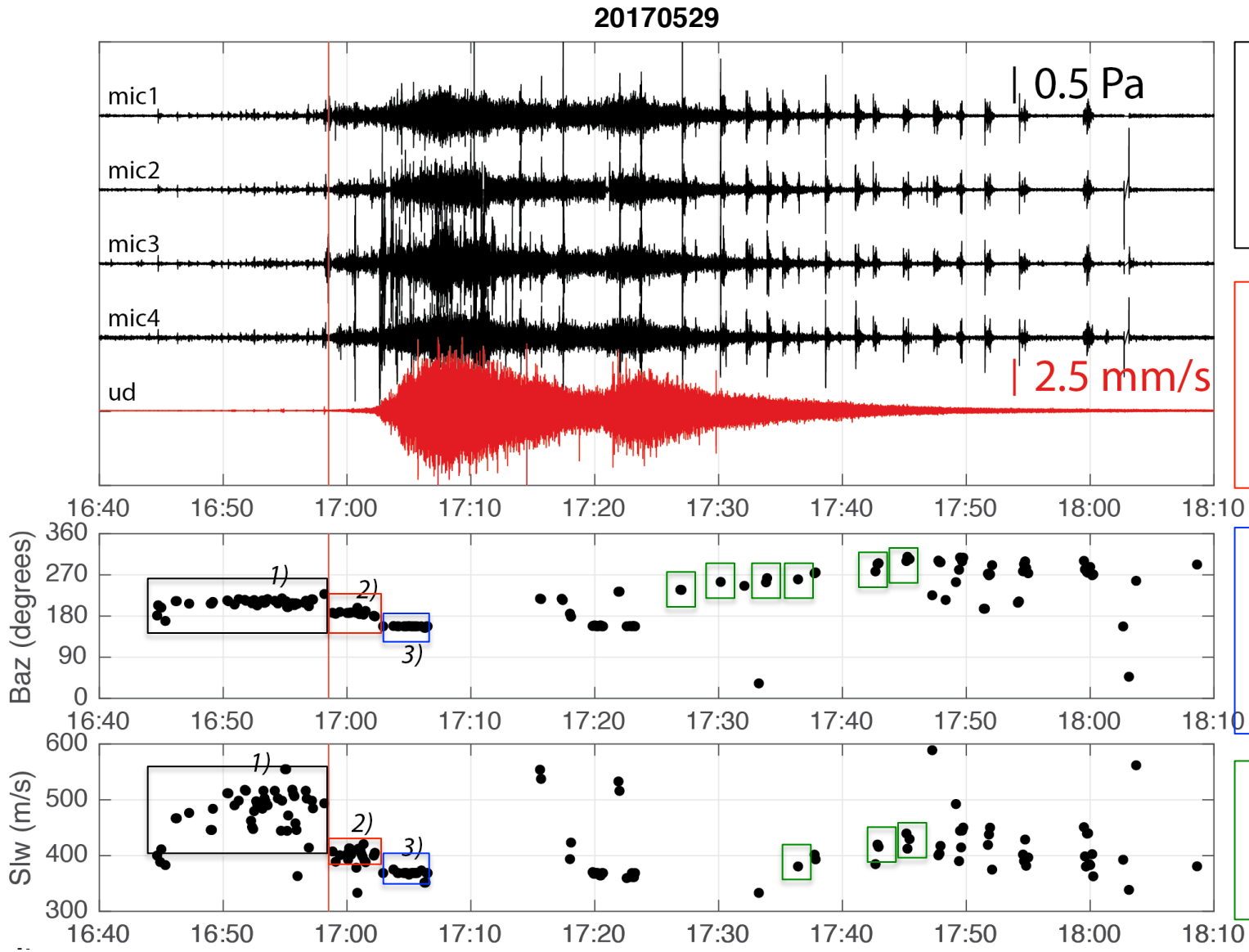
Phase (2)
~ 400 m/s
190 °N
3 minutes



Phase (1)
~ 480 m/s
200-220 °N
15 minutes

Phase (2)
~ 400 m/s
190 °N
3 minutes

Phase (3)
~ 330 m/s
159 °N
3 minutes

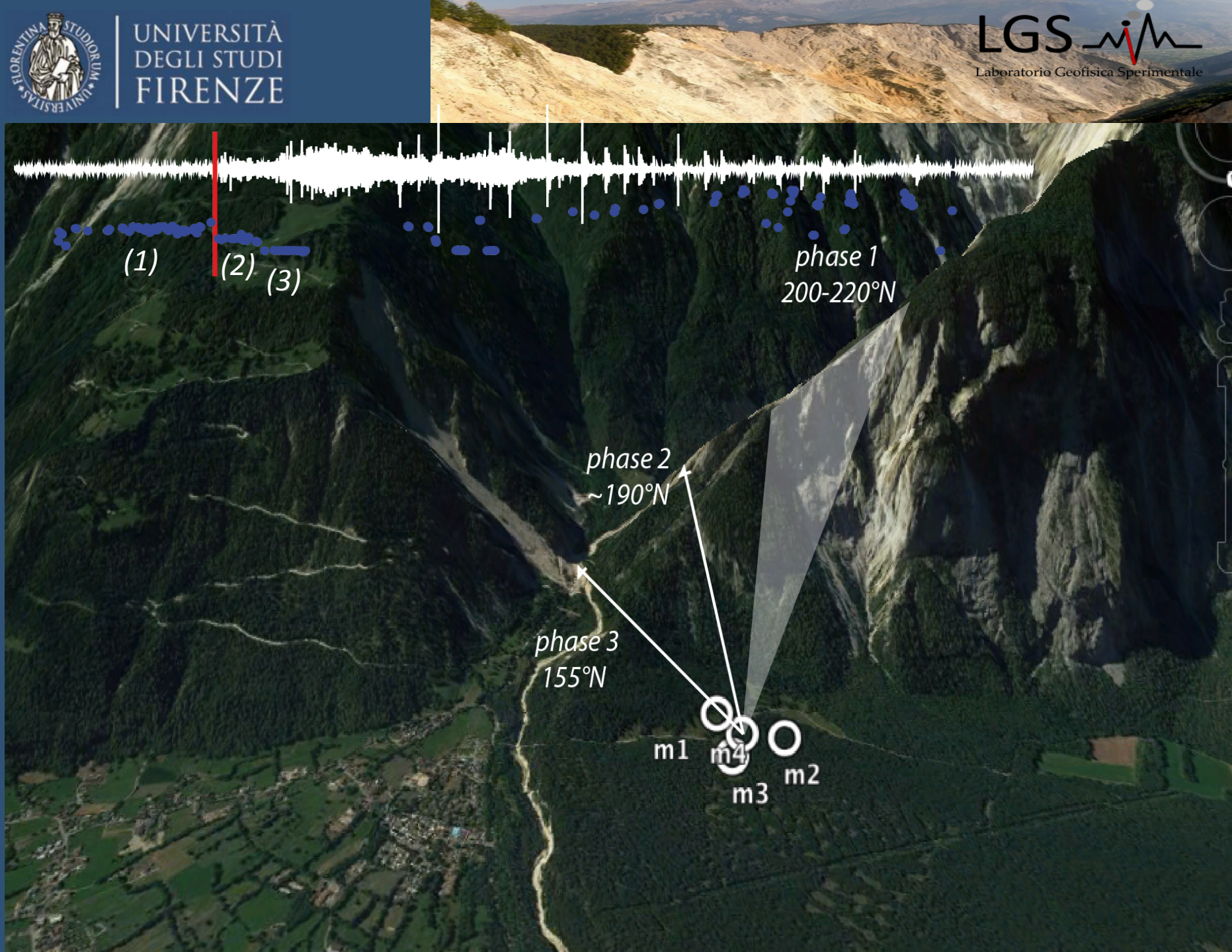


Phase (1)
~ 480 m/s
200-220 °N
15 minutes

Phase (2)
~ 400 m/s
190 °N
3 minutes

Phase (3)
~ 330 m/s
159 °N
3 minutes

Lightnings
>400 m/s
220-300 °N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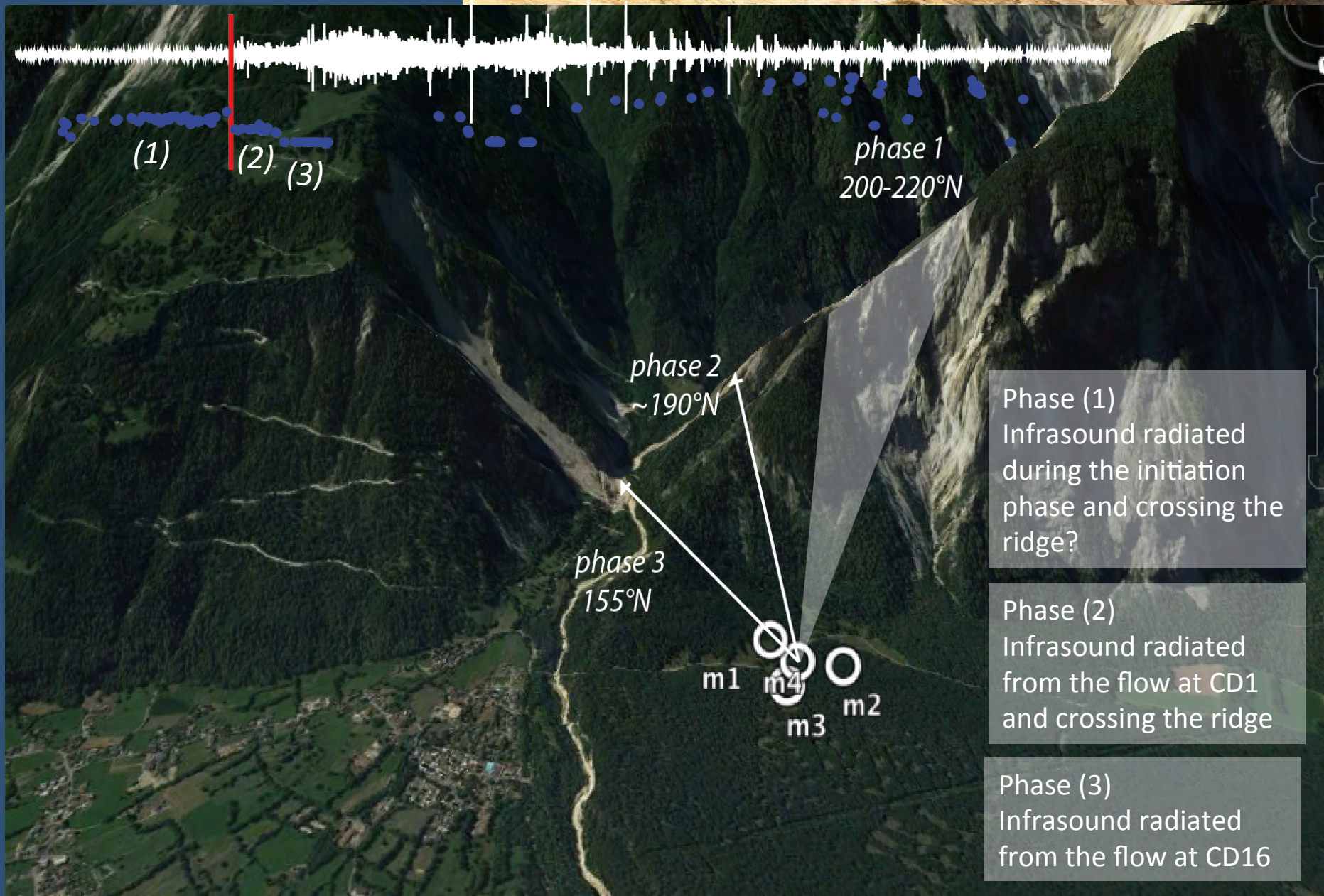
DEGLI STUDI
FIRENZE
LGS
Laboratorio Geofisica Sperimentale
(1)
(2)
(3)
phase 1
200-220°N
phase 2
~190°N
phase 3
155°N
m1
m4
m2
m3



UNIVERSITÀ DEGLI STUDI FIRENZE

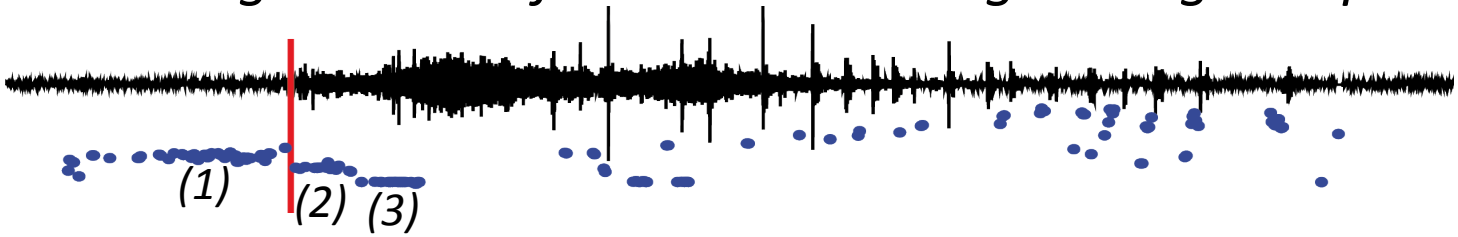
LGS Laboratorio Geofisica Sperimentale

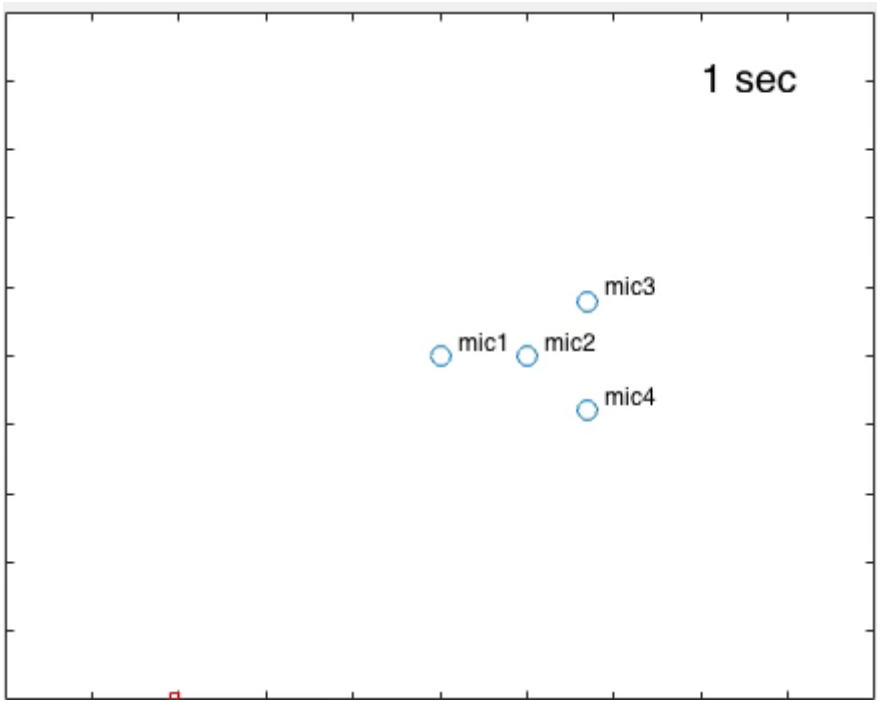
Phase (1)
Infrasound radiated during the initiation phase and crossing the ridge?

Phase (2)
Infrasound radiated from the flow at CD1 and crossing the ridge

Phase (3)
Infrasound radiated from the flow at CD16

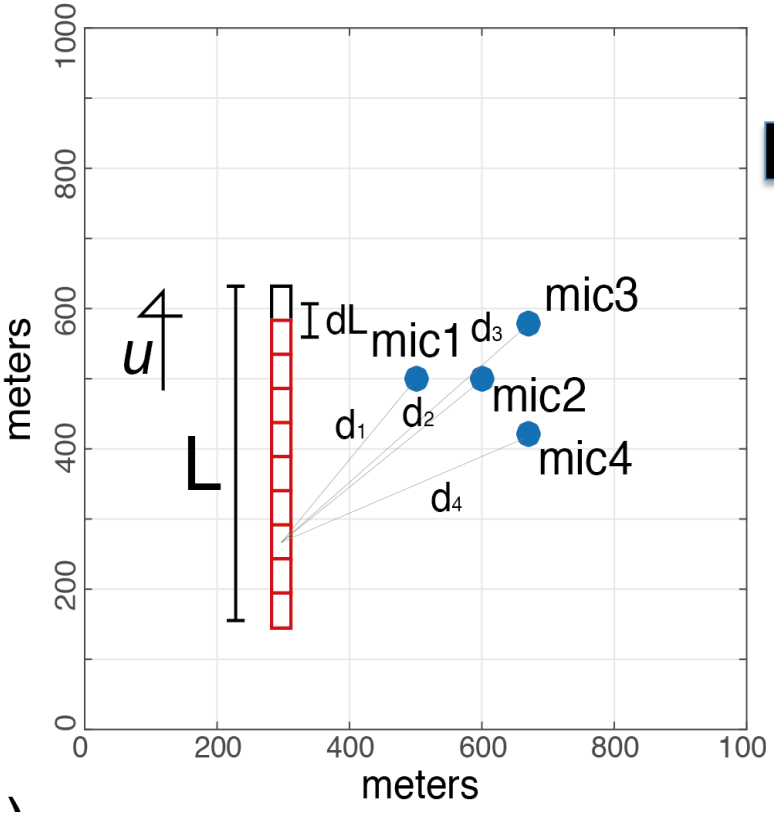
Modeling the lack of coherence during the high amplitude phase

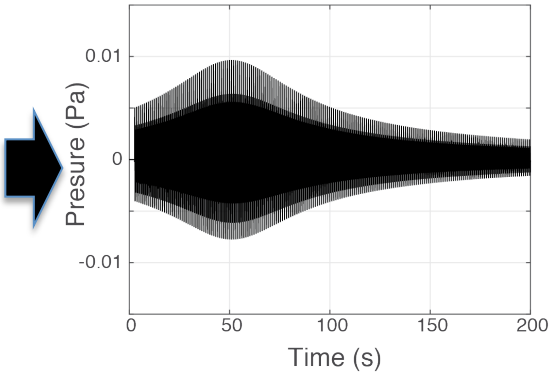


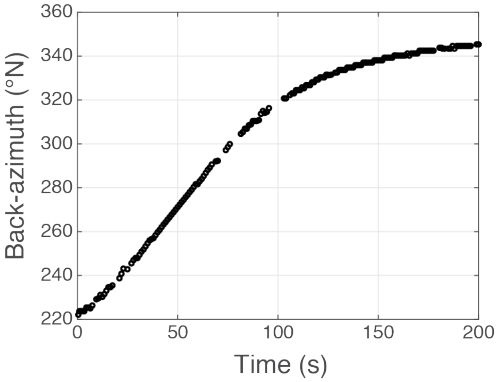


Moving extended source composed of 50 point sources with variable phase

Modeling the lack of coherence during the high amplitude phase







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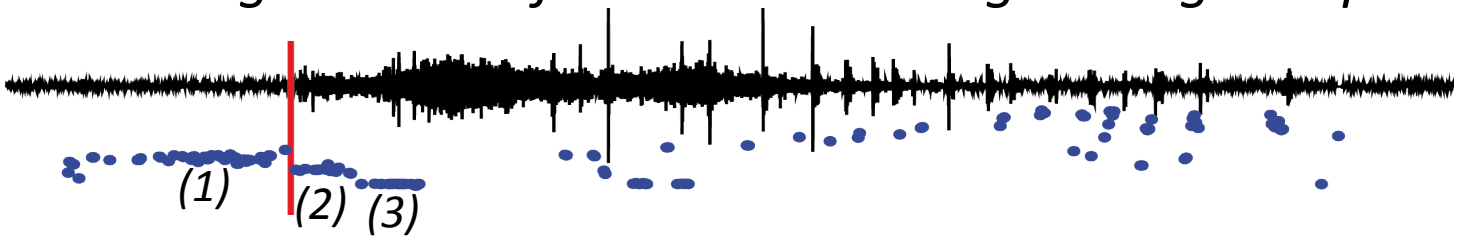
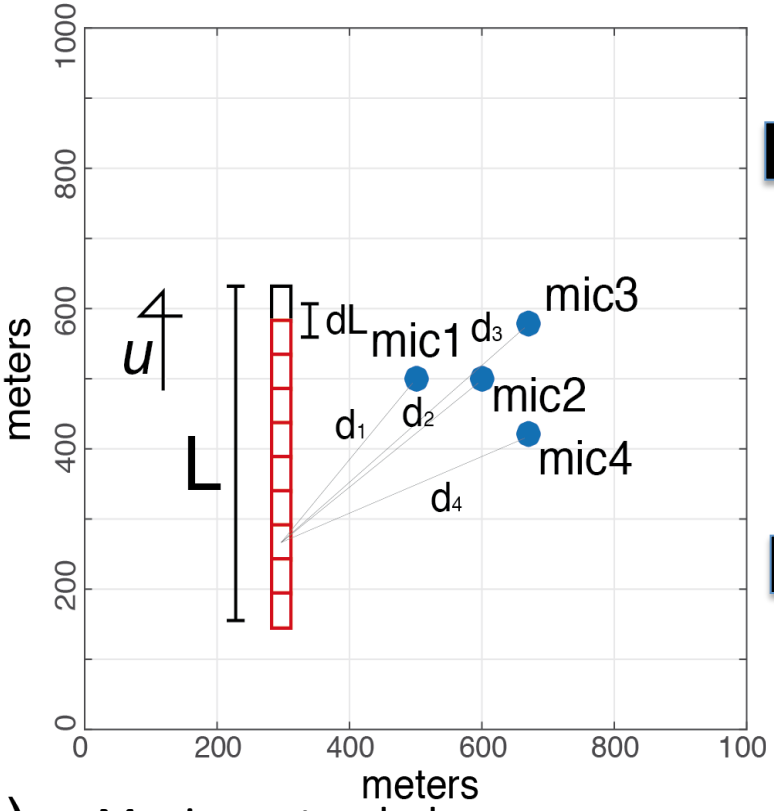
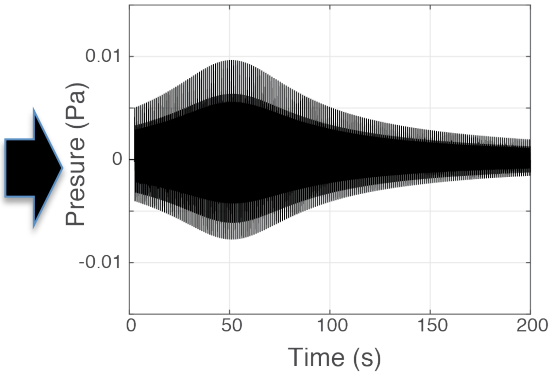
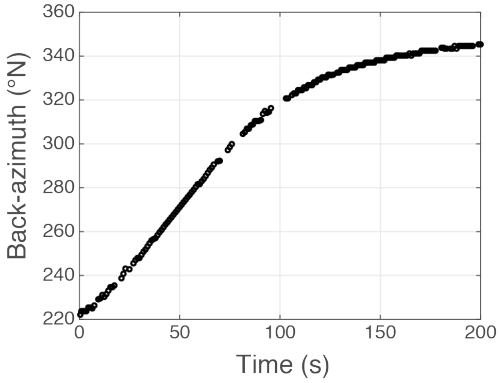
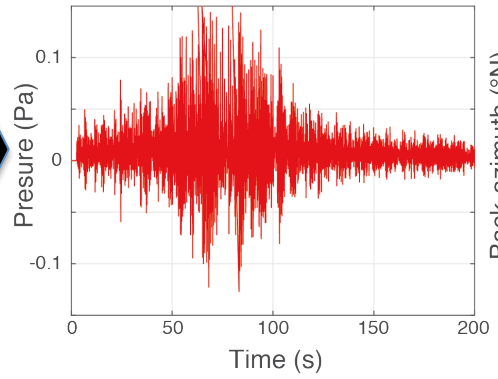
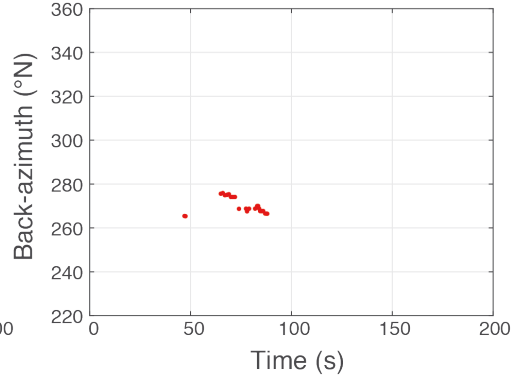






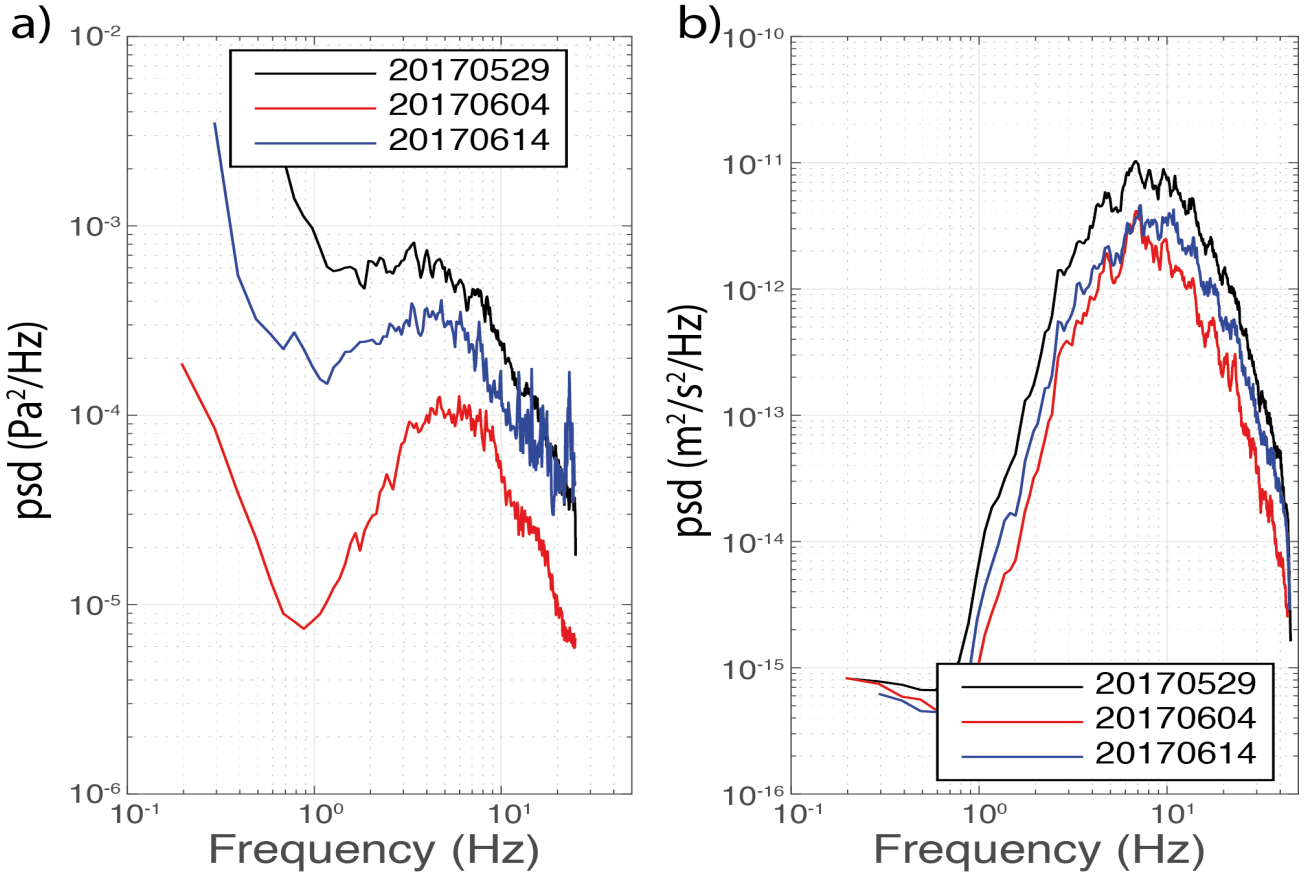






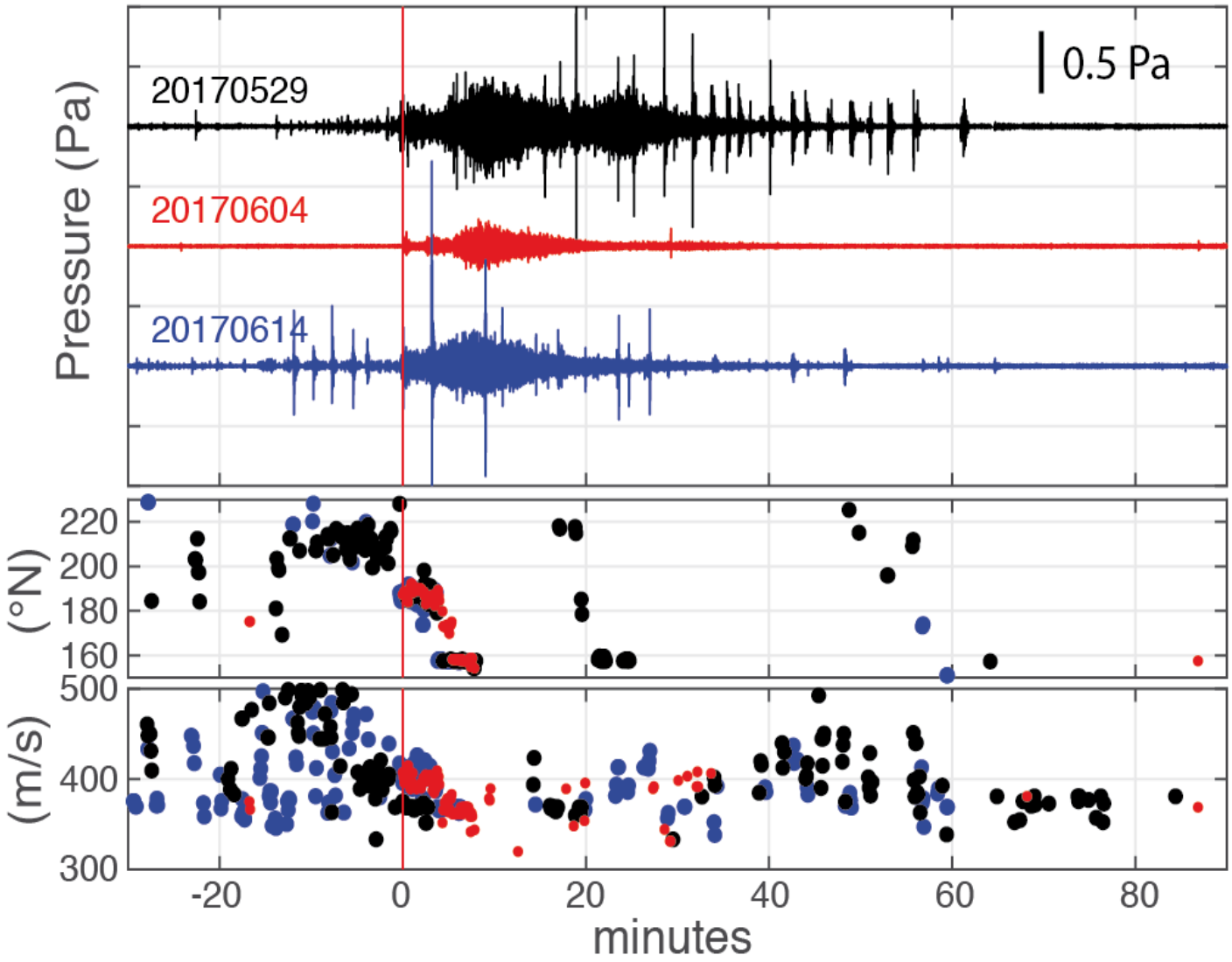
Moving extended source composed of 50 point sources with constant frequency and variable phase ➡ TURBULENCE

Seismo-acoustic coupling



Amplitude of PSD appears to scale with flow volume but frequency content is stable and differ between seismic (~8 Hz) and infrasound (~ 5 Hz). We interpret the spectral difference as resulting from two different processes, possibly bed-load and turbulence a the flow free surface

Using the infrasound array as an Early-Warning system



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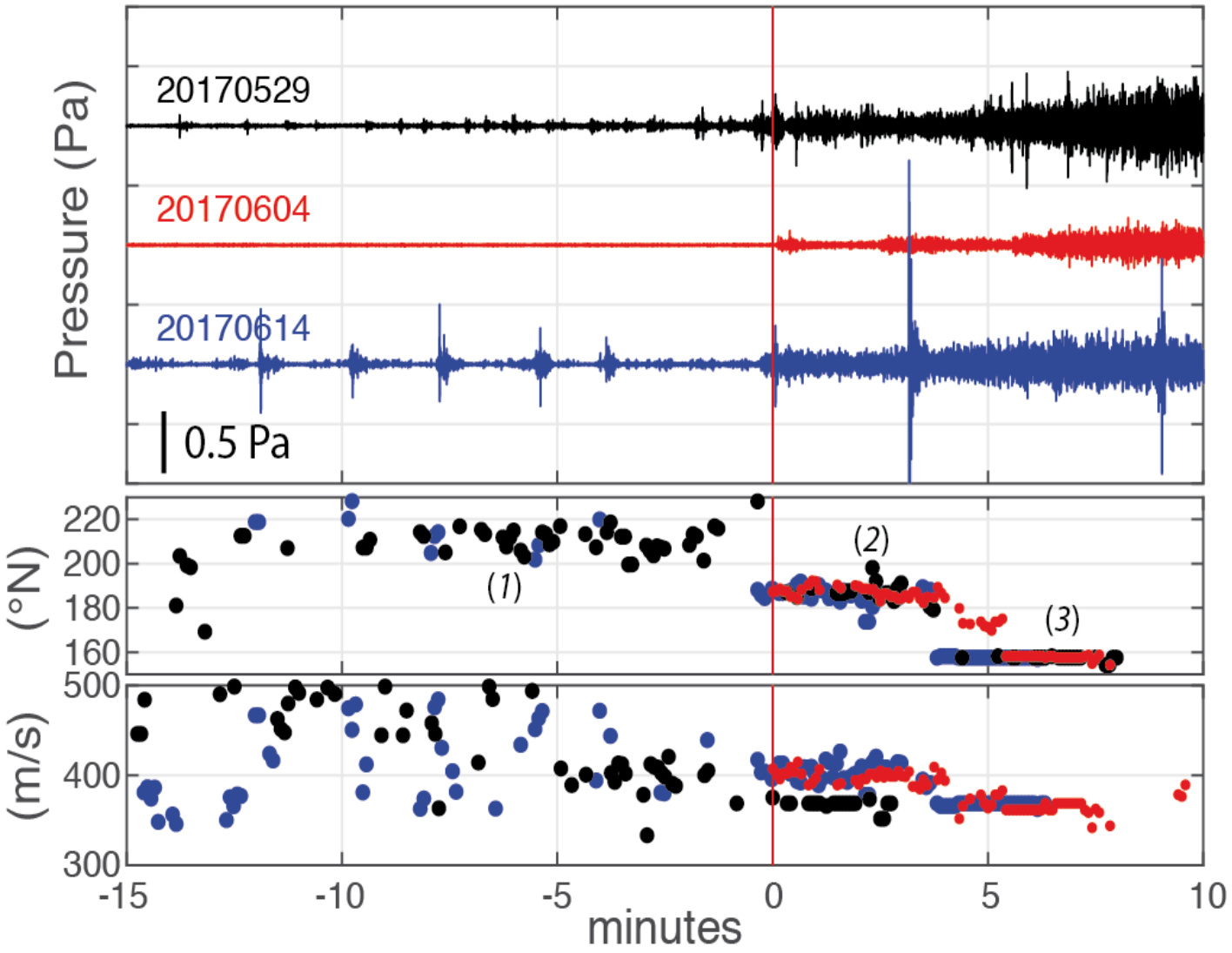

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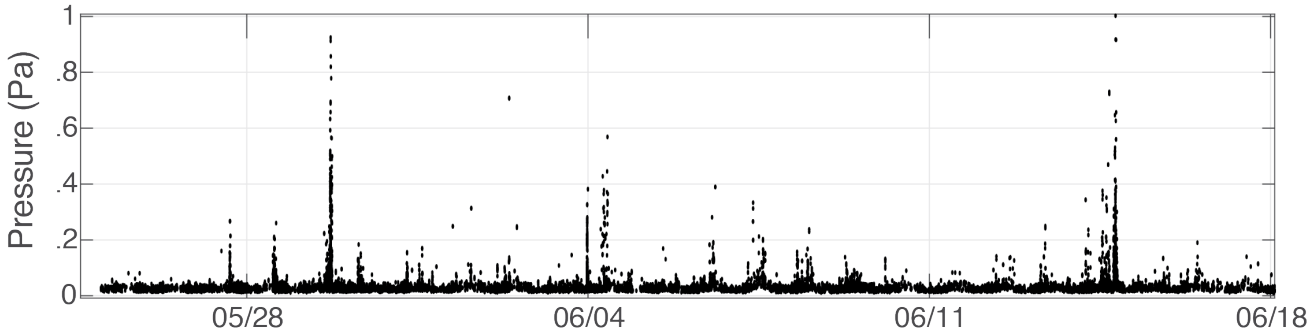
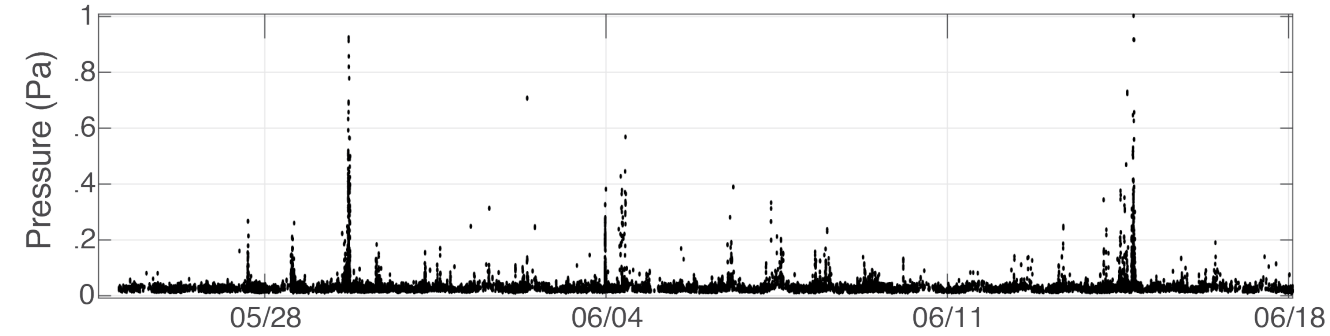
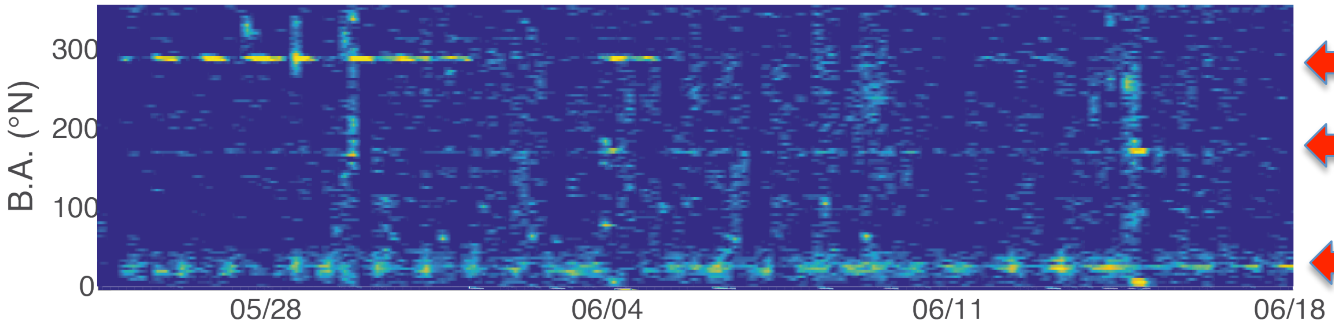


> 20000 detections

Using the infrasound array as an Early-Warning system



> 20000 detections

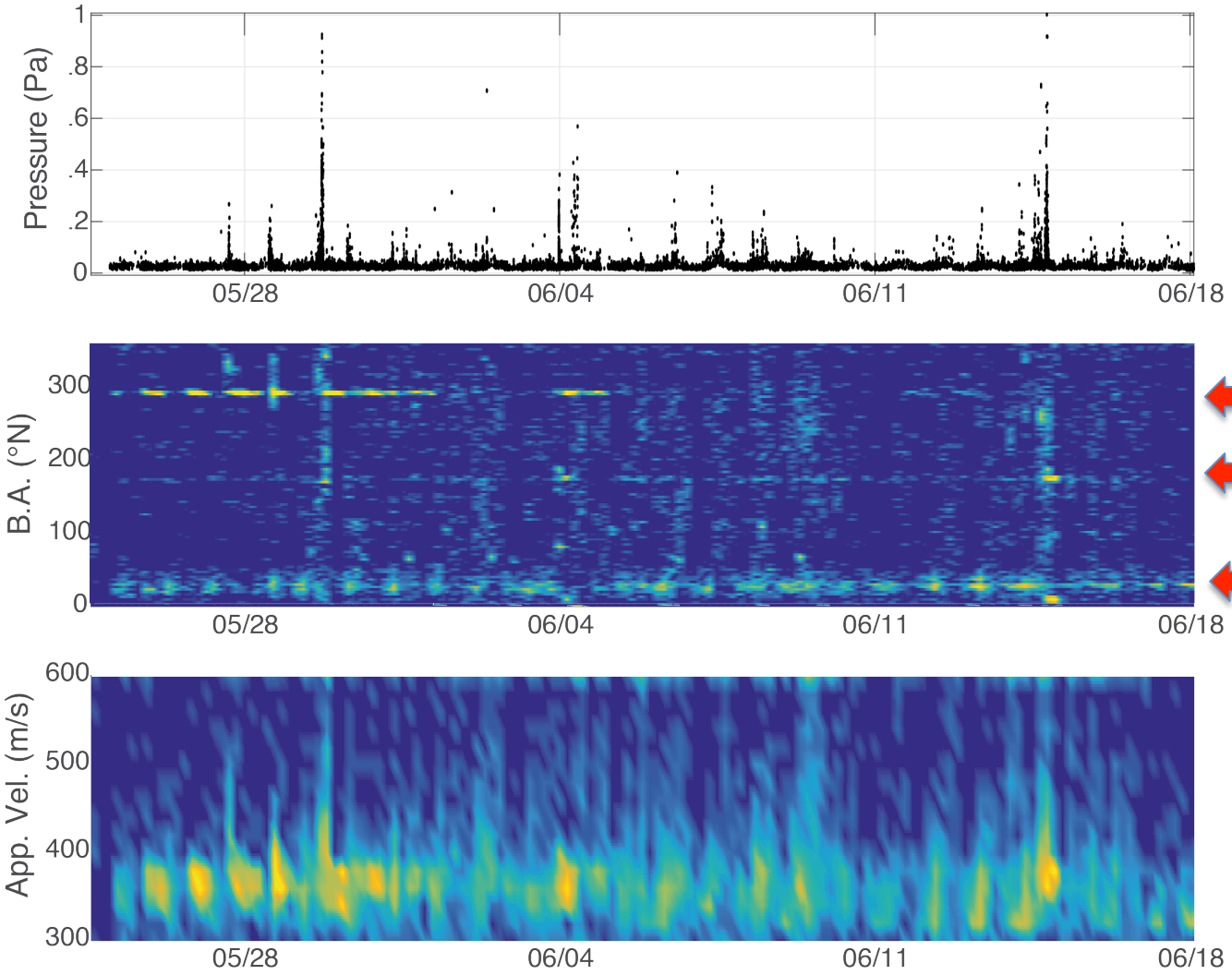


292°N

180°N

25°N

Using the infrasound array as an Early-Warning system



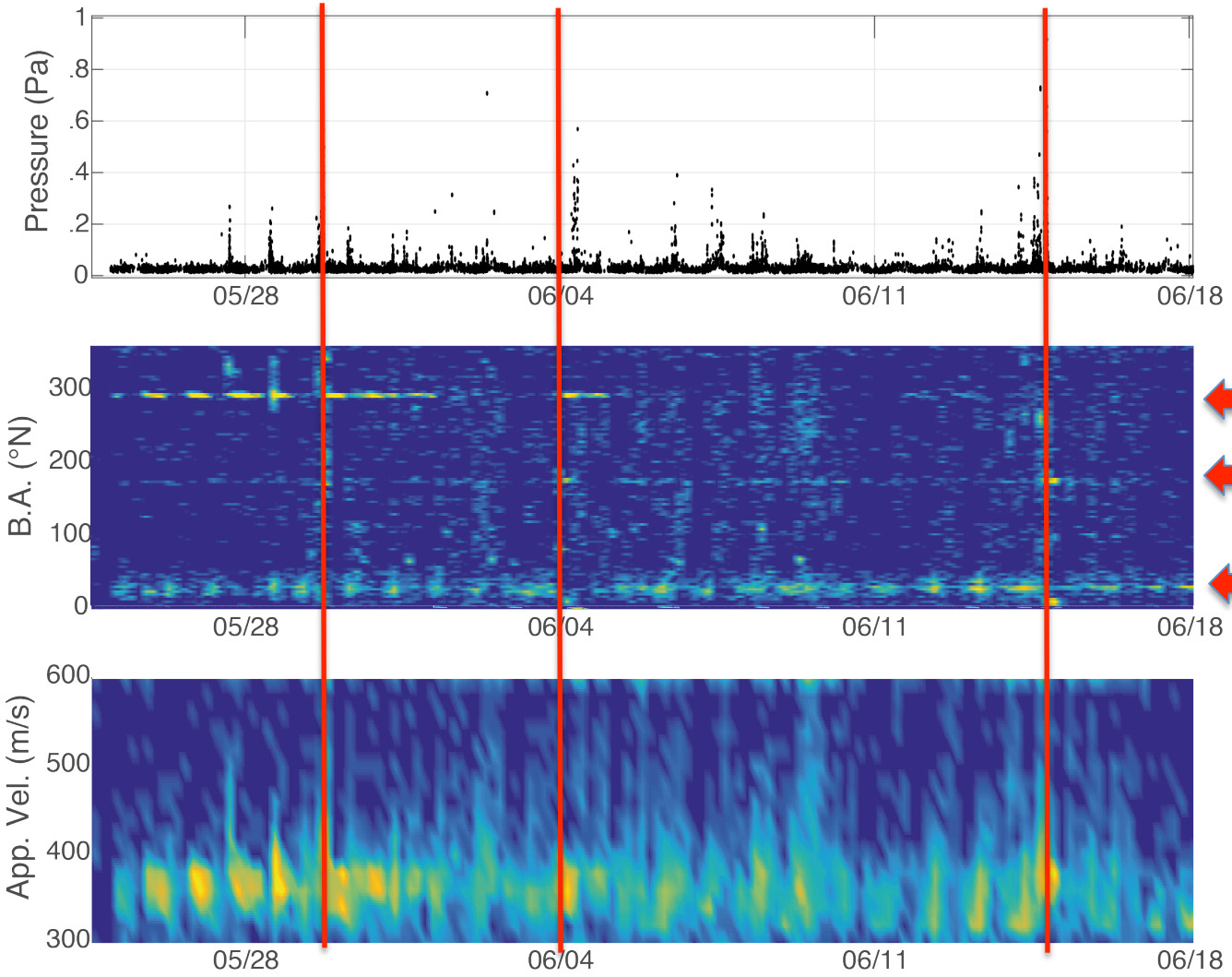
> 20000 detections

292°N

180°N

25°N

Using the infrasound array as an Early-Warning system



> 20000 detections

292°N

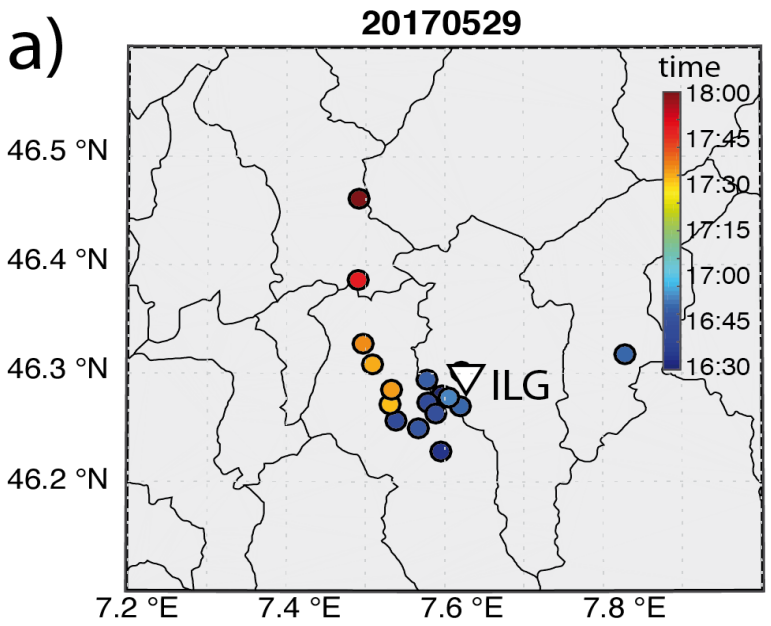
180°N

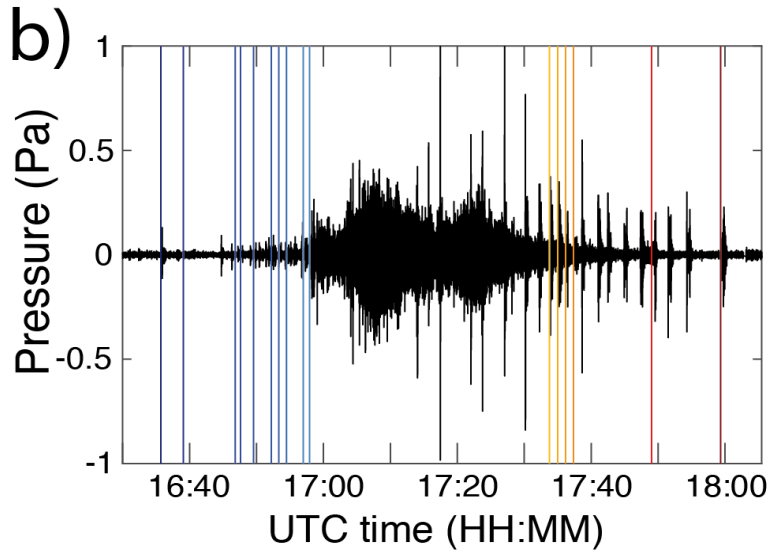
25°N

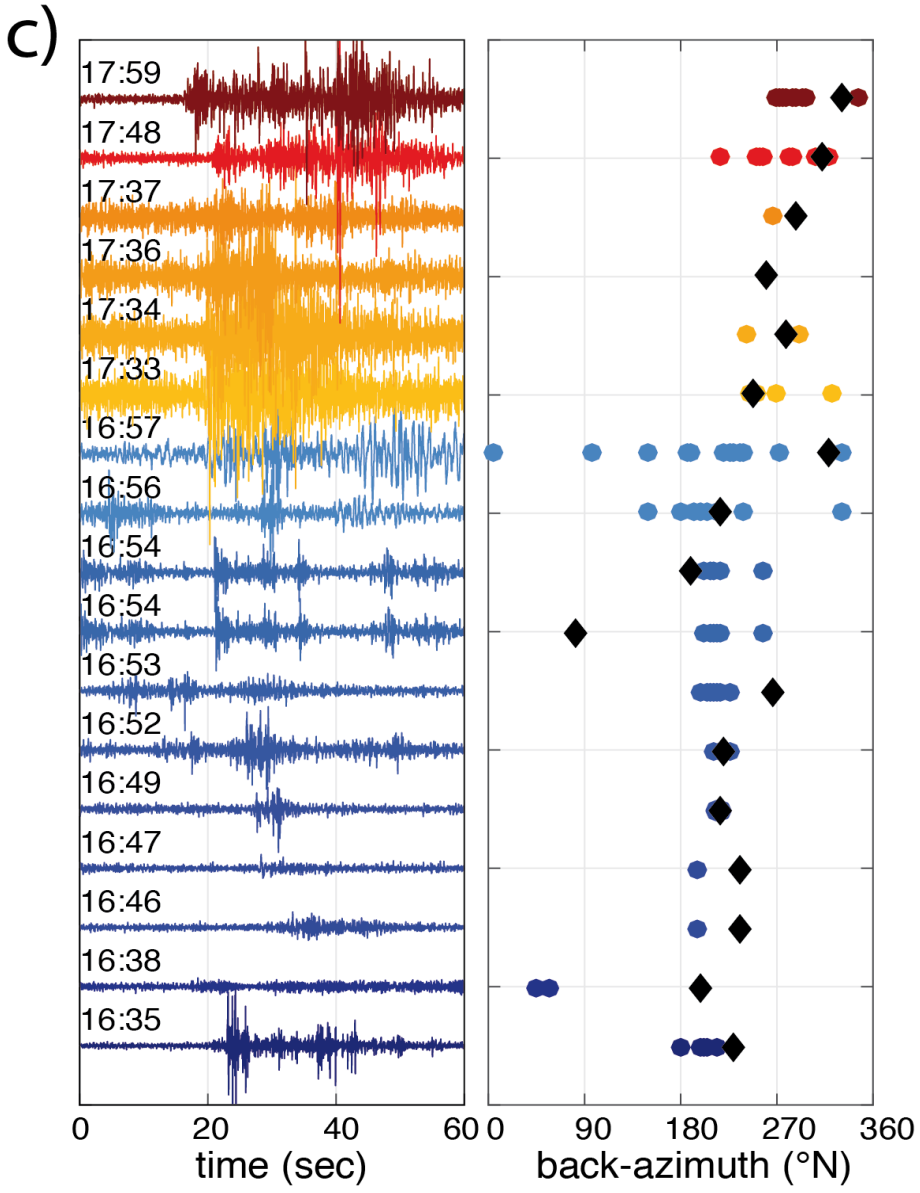
Only 3 automatic detections, same timing as CD1, and no false alerts

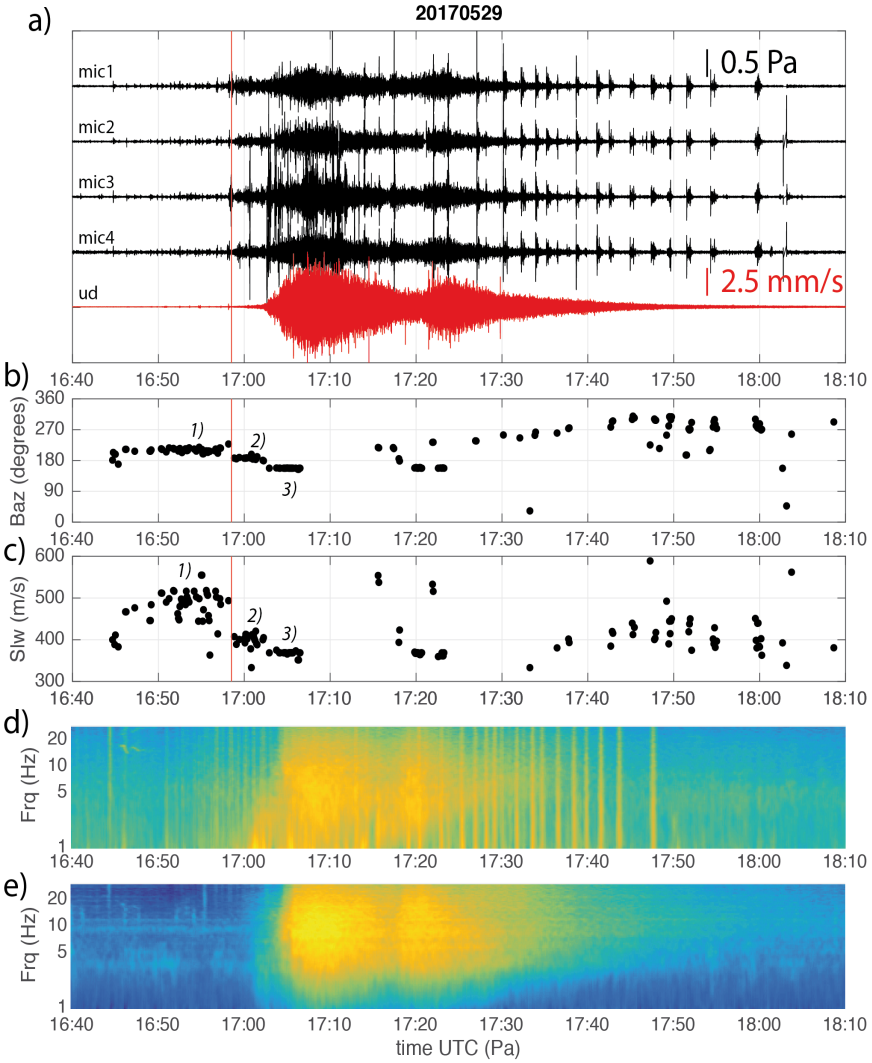
Conclusions

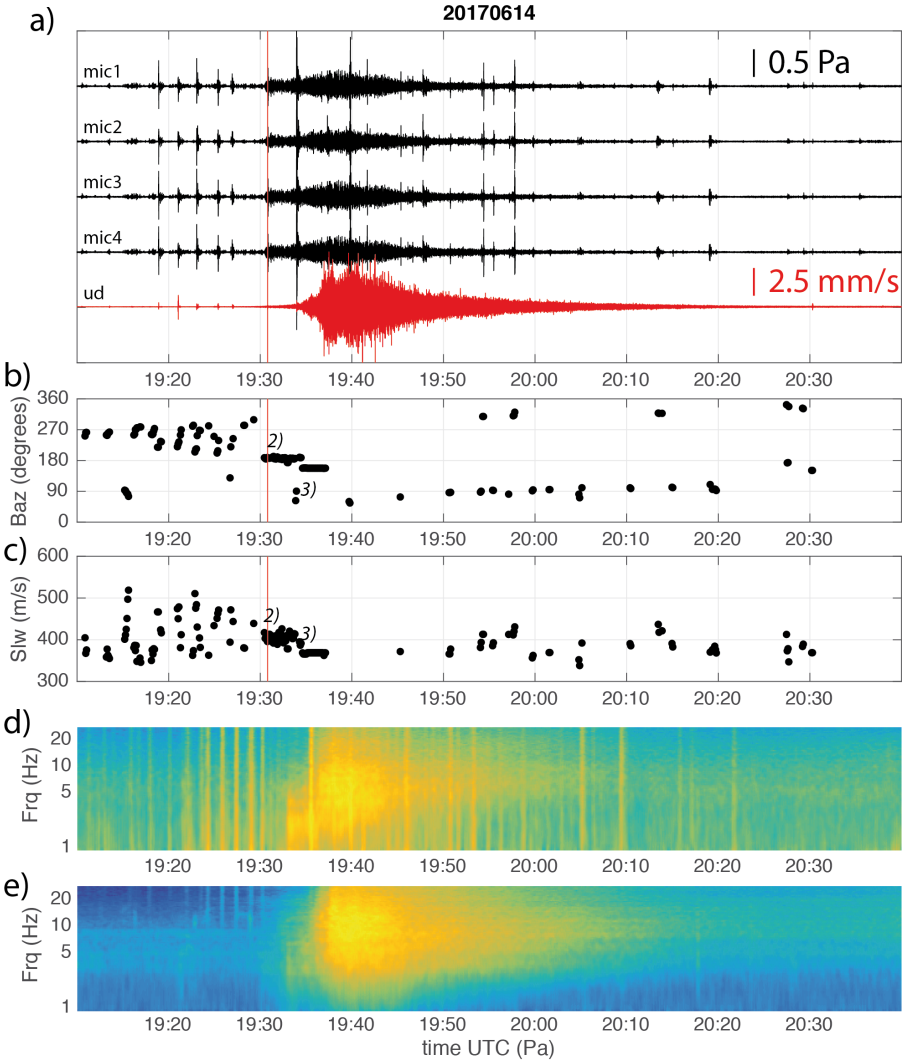
- **Infrasound from debris flow is produced by an extended source (i.e. the turbulence at the flow free surface). This results into a lack of coherence.**
- **Stable infrasound detections are obtained at obstacles, like dams or sharp discontinuities of the topography.**
- **Infrasound and seismic spectra at Illgraben appear to be decoupled, with seismic possibly driven by bed-load transport and infrasound by the waves at the flow free surface.**
- **Infrasound array can be used as an efficient warning system if stable sources of infrasound are expected along the flow path. In the specific case of Illgraben the same timing of CD1 is provided from the remote location**


a)
20170529
time
18:00
17:45
17:30
17:15
17:00
16:45
16:30
ILG
46.5 °N
46.4 °N
46.3 °N
46.2 °N
7.2 °E
7.4 °E
7.6 °E
7.8 °E


b)
Pressure (Pa)
1
0.5
0
-0.5
-1
16:40
17:00
17:20
17:40
18:00
UTC time (HH:MM)


c)
17:59
17:48
17:37
17:36
17:34
17:33
16:57
16:56
16:54
16:54
16:53
16:52
16:49
16:47
16:46
16:38
16:35
0
20
40
60
time (sec)
0
90
180
270
360
back-azimuth (°N)


a)
20170529
mic1
mic2
mic3
mic4
ud
0.5 Pa
2.5 mm/s
b)
Baz (degrees)
c)
Slw (m/s)
d)
Frq (Hz)
e)
Frq (Hz)
1)
2)
3)
16:40 16:50 17:00 17:10 17:20 17:30 17:40 17:50 18:00 18:10
time UTC (Pa)


a)
20170614
mic1
mic2
mic3
mic4
ud
0.5 Pa
2.5 mm/s
b)
Baz (degrees)
c)
Slw (m/s)
d)
Frq (Hz)
e)
Frq (Hz)
2)
3)
19:20 19:30 19:40 19:50 20:00 20:10 20:20 20:30
time UTC (Pa)