POLITECNICO DI TORINO

Department of Environment, Land and Infrastructure Engineering (DIATI)

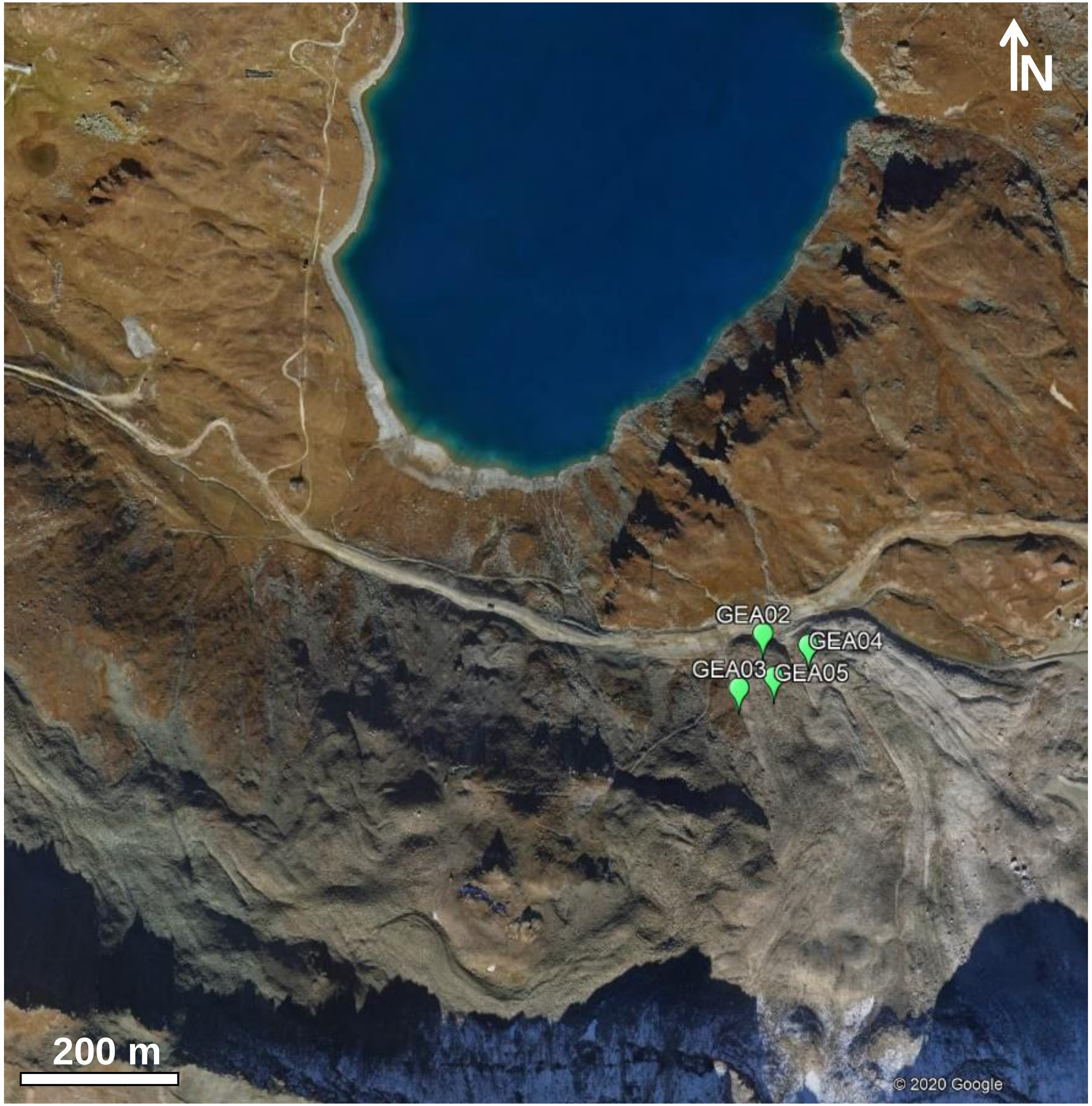
Chiara Colombero – chiara.colombero@polito.it
Alberto Godio – alberto.godio@polito.it
Diego Franco – diego.franco@polito.it

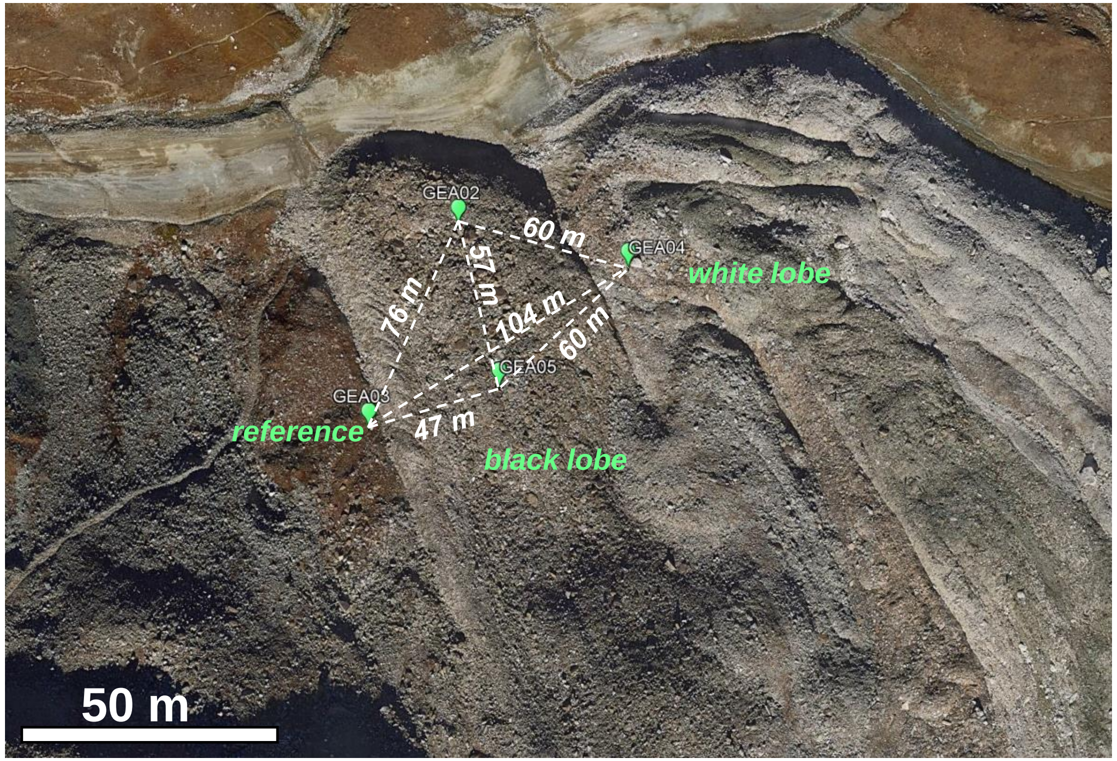
Passive seismic monitoring network Gran Sometta rock glaciers (Cervinia, VdA)

Network installation: 20-21/07/2020

Analyzed data: 21/07/2020 – 01/04/2021

REPORT 02 – 05/05/2021



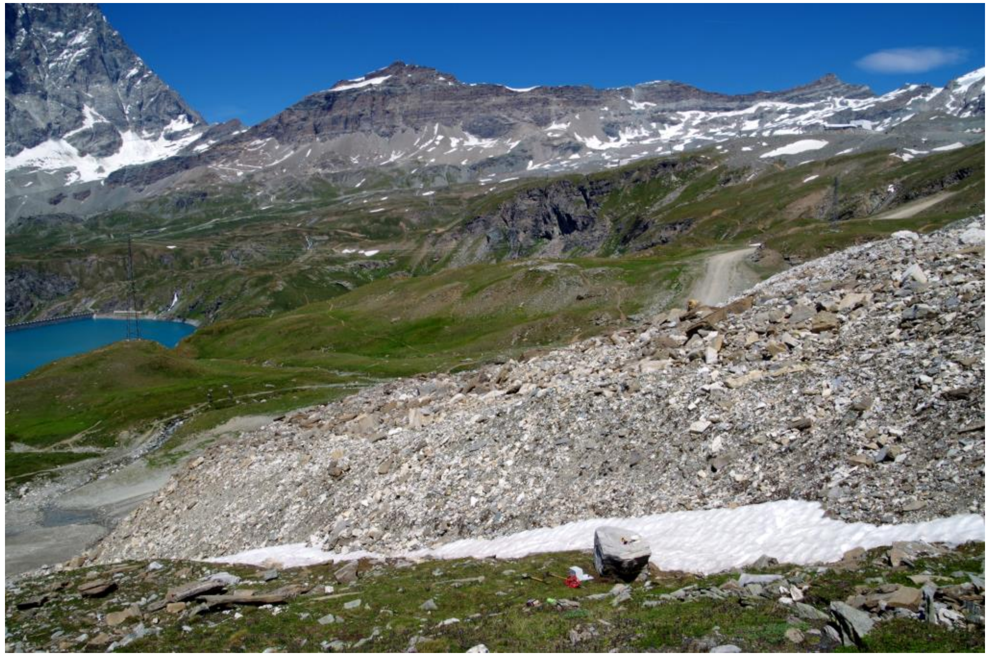


Station	X WGS84 UTM32N [m]	Y WGS84 UTM32N [m]	Z GPS [m]
GEA02	396704	5086284	2654
GEA03	396672	5086215	2661
GEA04	396762	5086268	2660
GEA05	396717	5086228	2667

Instrumentation:
4 triaxial geophones (2 Hz)
GEA-GPS (PASI) acquisition
System (*wireless self-standing stations*)

Continuous acquistion
1-h files, fs=250 Hz

GEA03 (stable-reference): *outside the lobes*



Instrumentation:
4 triaxial geophones (2 Hz)
GEA-GPS (PASI) acquisition System (*wireless self-standing stations*)

Continuous acquistion
1-h files, fs=250 Hz

GEA02: *black lobe, close to the front*

GEA05: *black lobe*

Instrumentation:
4 triaxial geophones (2 Hz)
GEA-GPS (PASI) acquisition
System (*wireless self-standing stations*)

Continuous acquistion
1-h files, fs=250 Hz

Instrumentation:
4 triaxial geophones (2 Hz)
GEA-GPS (PASI) acquisition System (*wireless self-standing stations*)

Continuous acquistion
1-h files, fs=250 Hz

GEA04: *white lobe*

Ambient seismic noise – spectral analysis

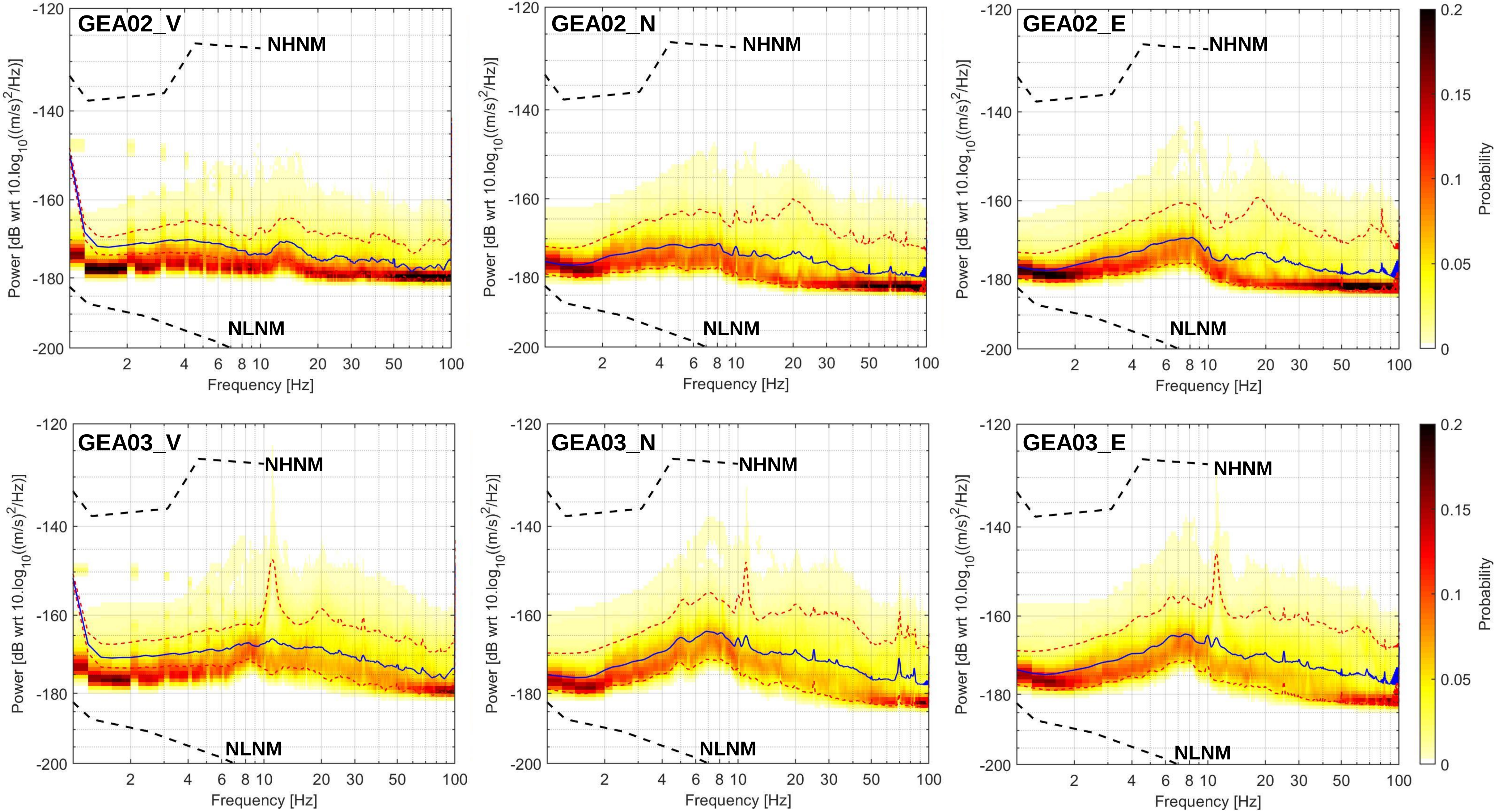
- Power Spectral Density (PSD) is computed on the 3 components of each station to check the recording quality (with respect to the NHNM and NLNM of Peterson, 1993) and to search for potential peaks indicating resonance phenomena.

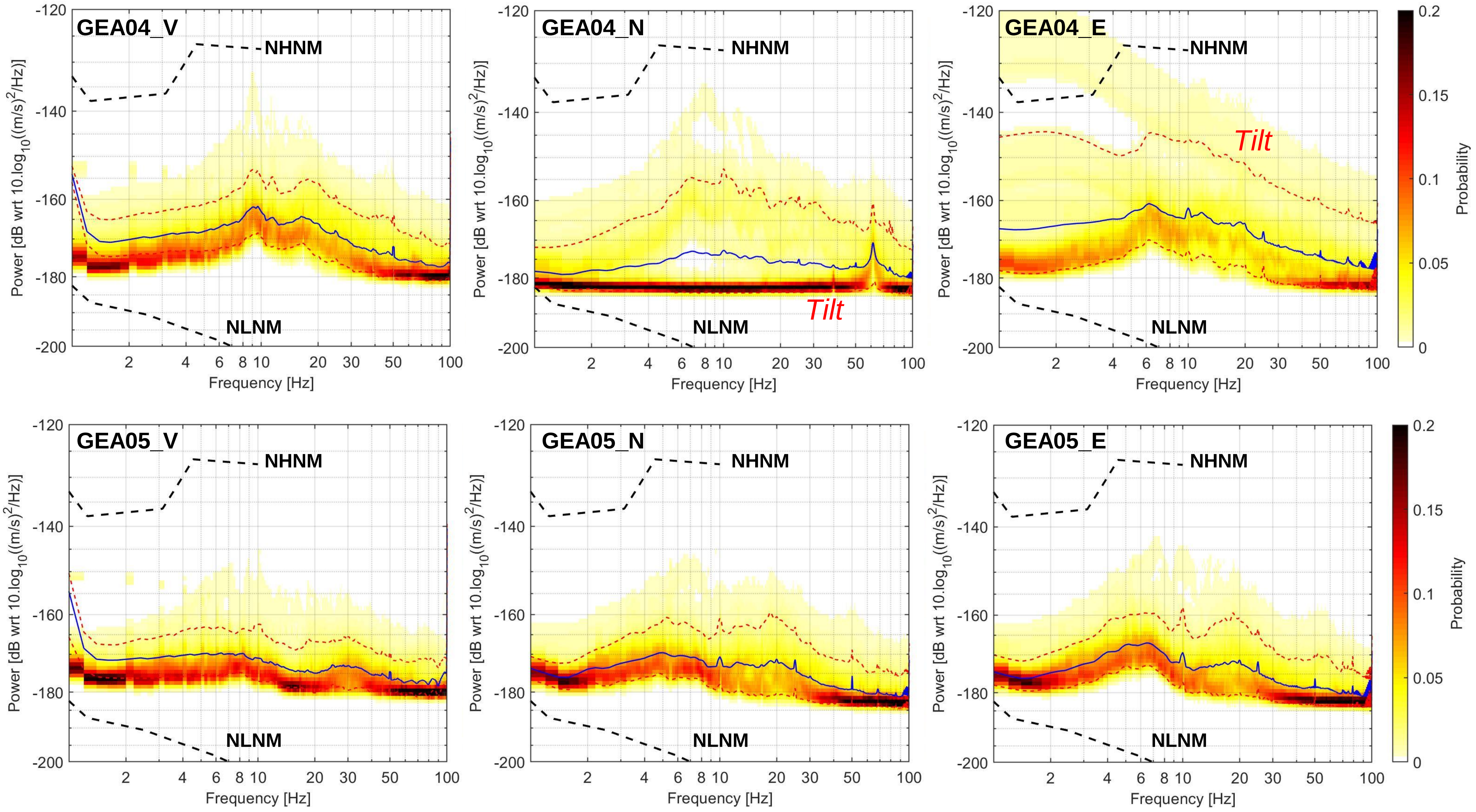
- Single-station or site-reference spectral ratios are computed to enhance the presence of these peaks in the recordings.

- The resonance frequencies can be linked to the presence of subsurface interfaces with significant contrast in mechanical properties (e.g. RG – bedrock, active layer, unfrozen-frozen materials…).

- Their evolution with time can be related to variations in the subsurface conditions and changes in the depth of these interfaces, driven by external modifications in air temperature and precipitation amounts.

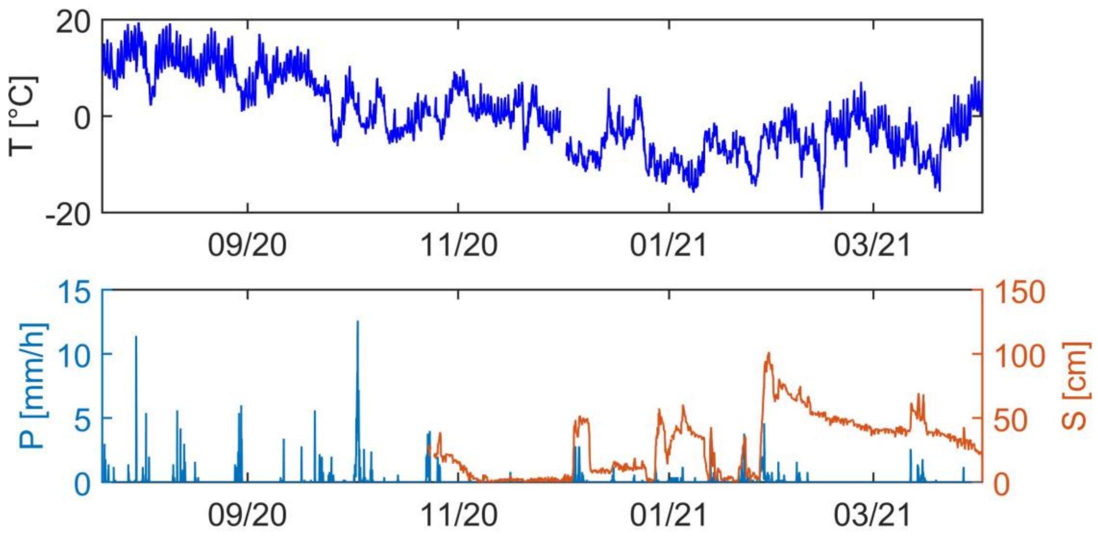
Probability Density Functions of Power Spectral Densities



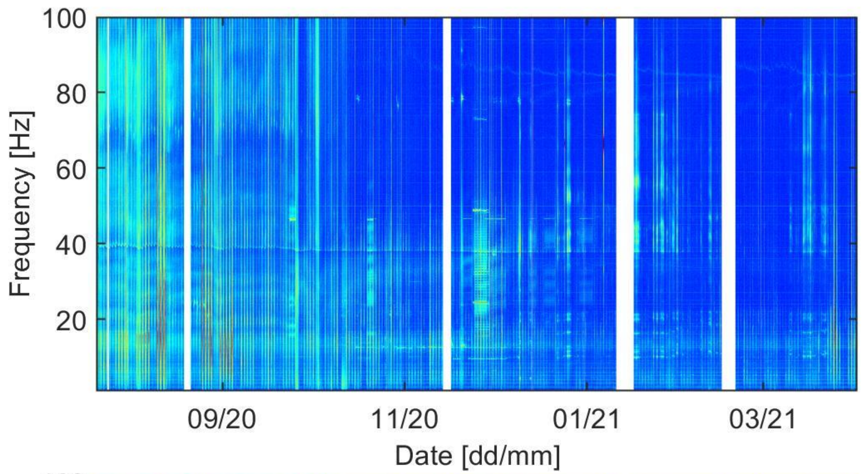


The recording quality is good on all stations, with the exception of GEA04 that tilted at the beginning of the freezing period (see next slides).

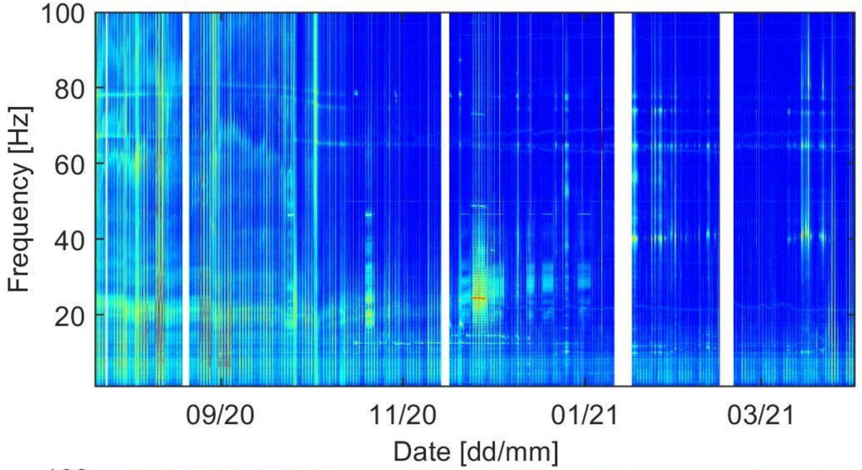
Periodograms (PSD time evolution)



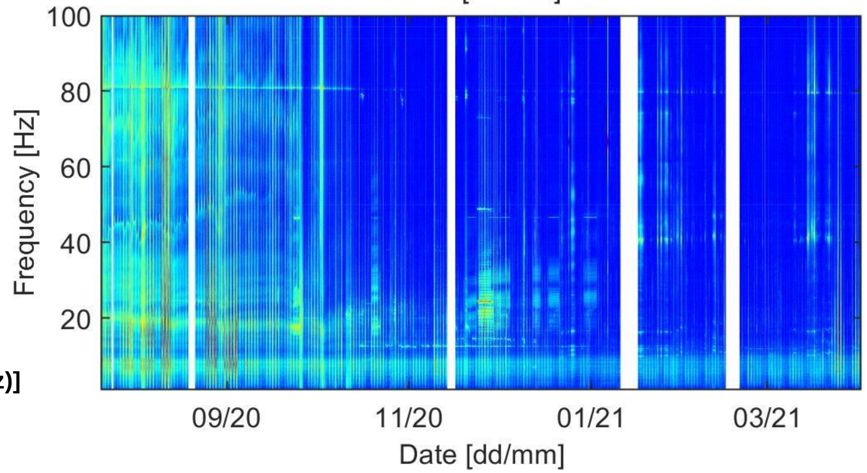
GEA02_V



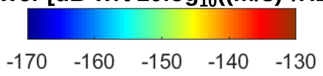
GEA02_N



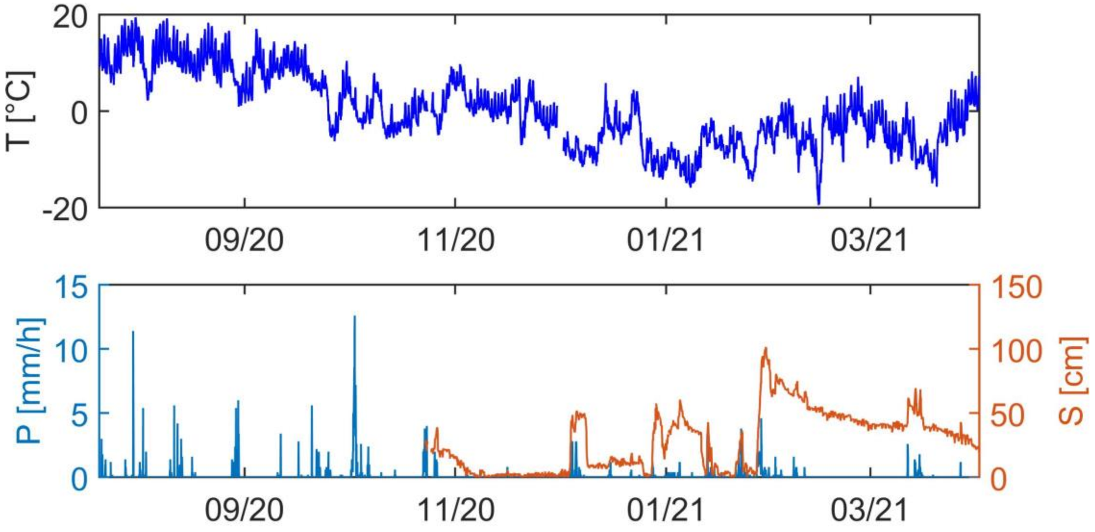
GEA02_E



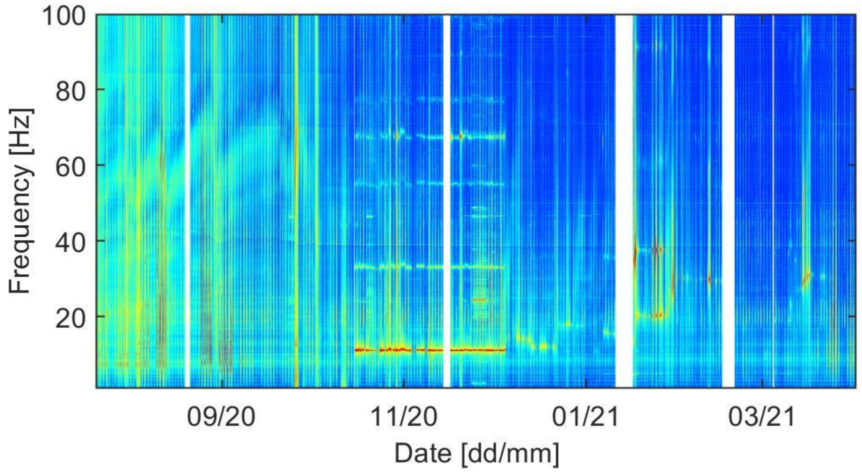
Power [dB wrt $10\log_{10}((m/s)^2/Hz)$]



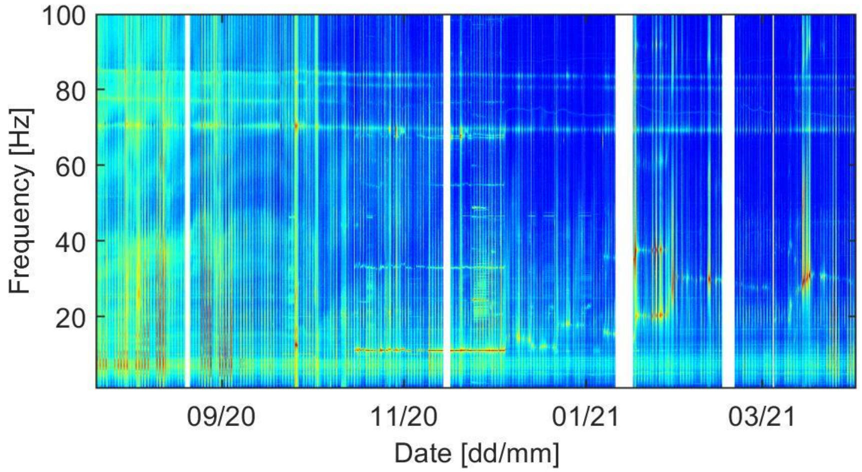
Periodograms (PSD time evolution)



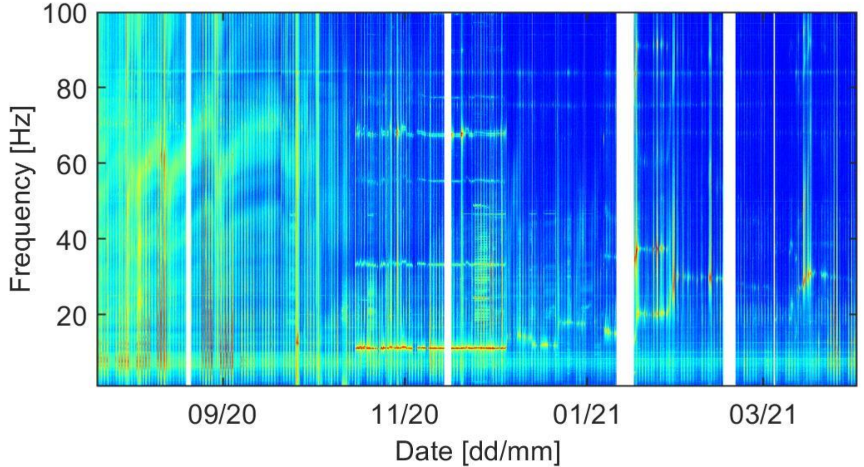
GEA03_V



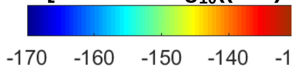
GEA03_N



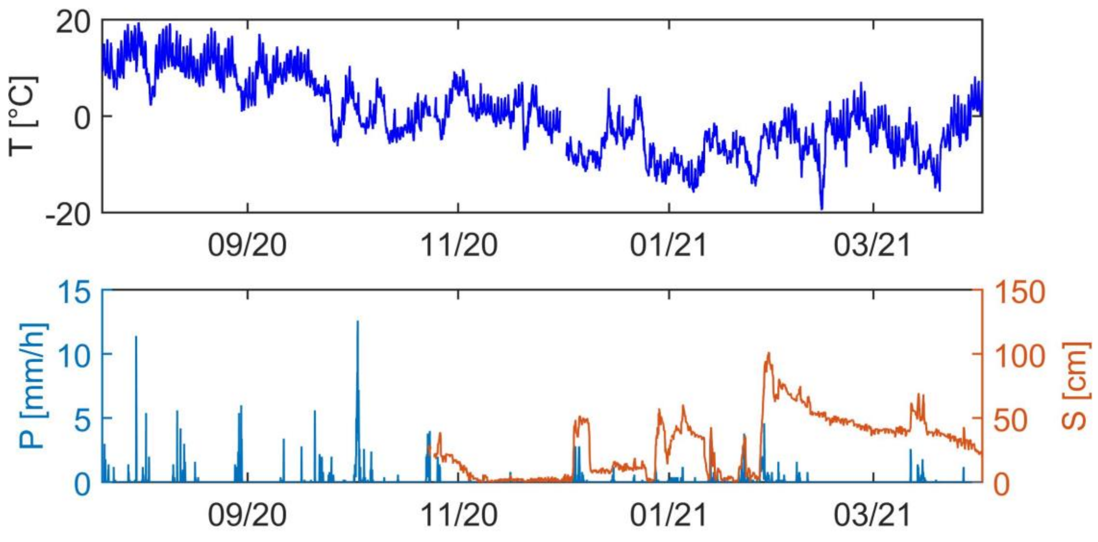
GEA03_E



Power [dB wrt $10log_{10}((m/s)^2$



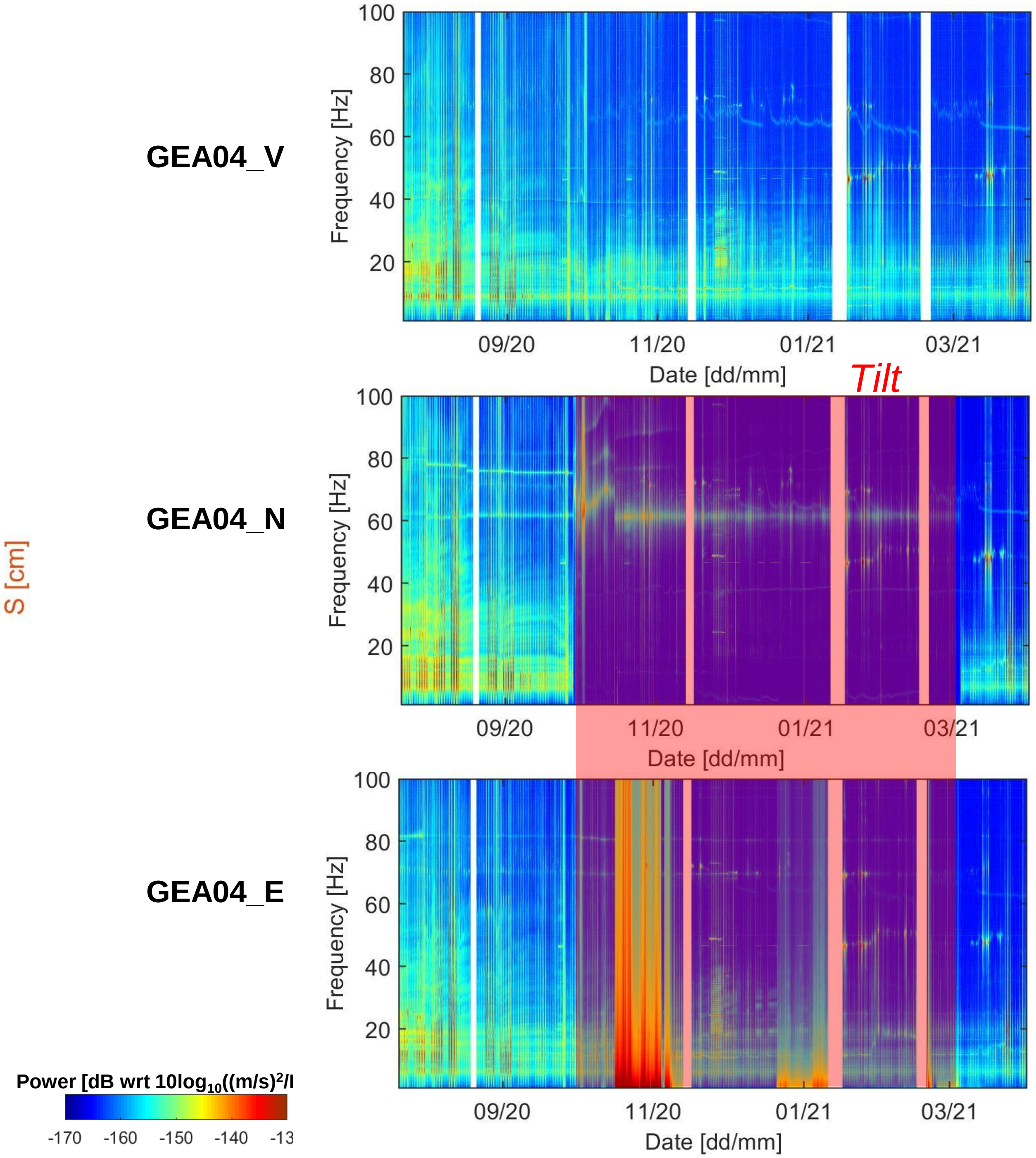
Periodograms (PSD time evolution)



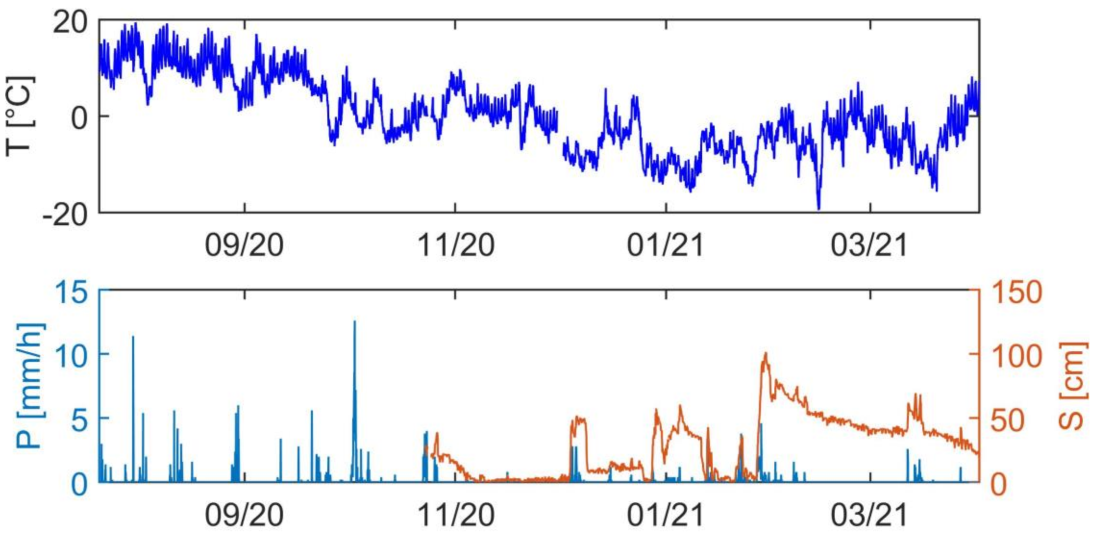
GEA04_V

GEA04_N

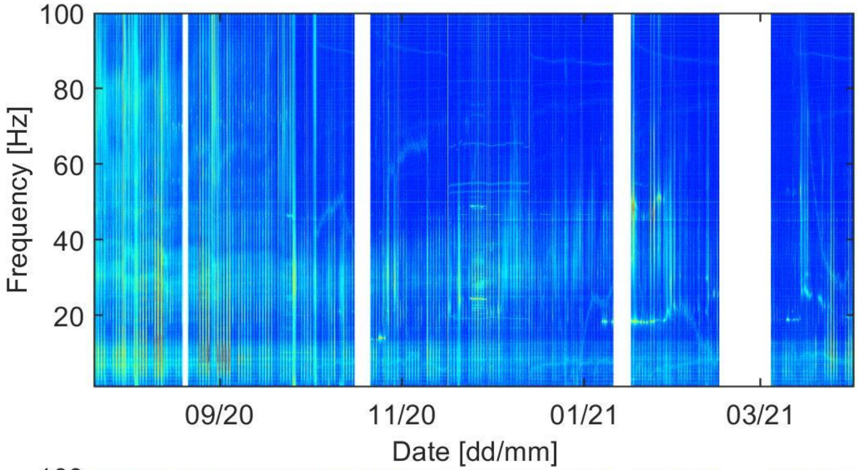
GEA04_E



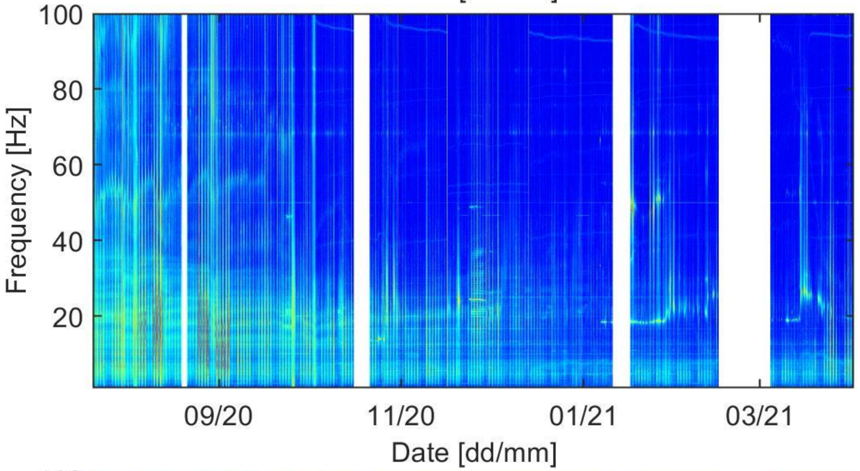
Periodograms (PSD time evolution)



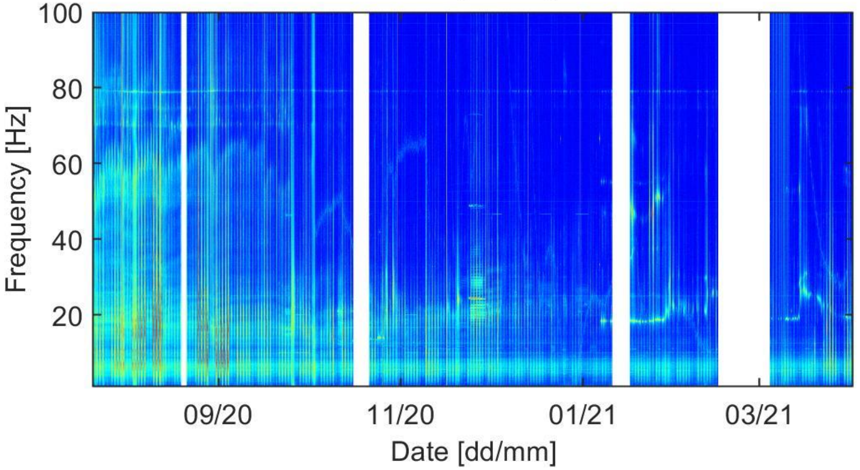
GEA05_V



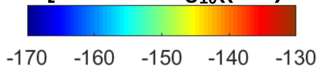
GEA05_N



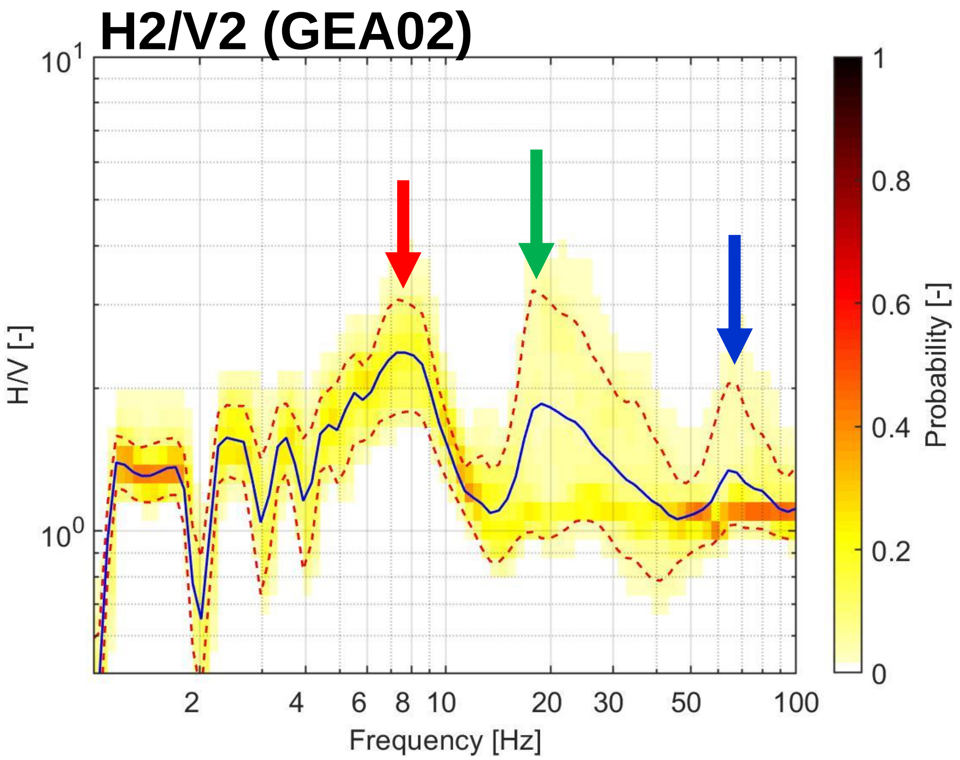
GEA05_E

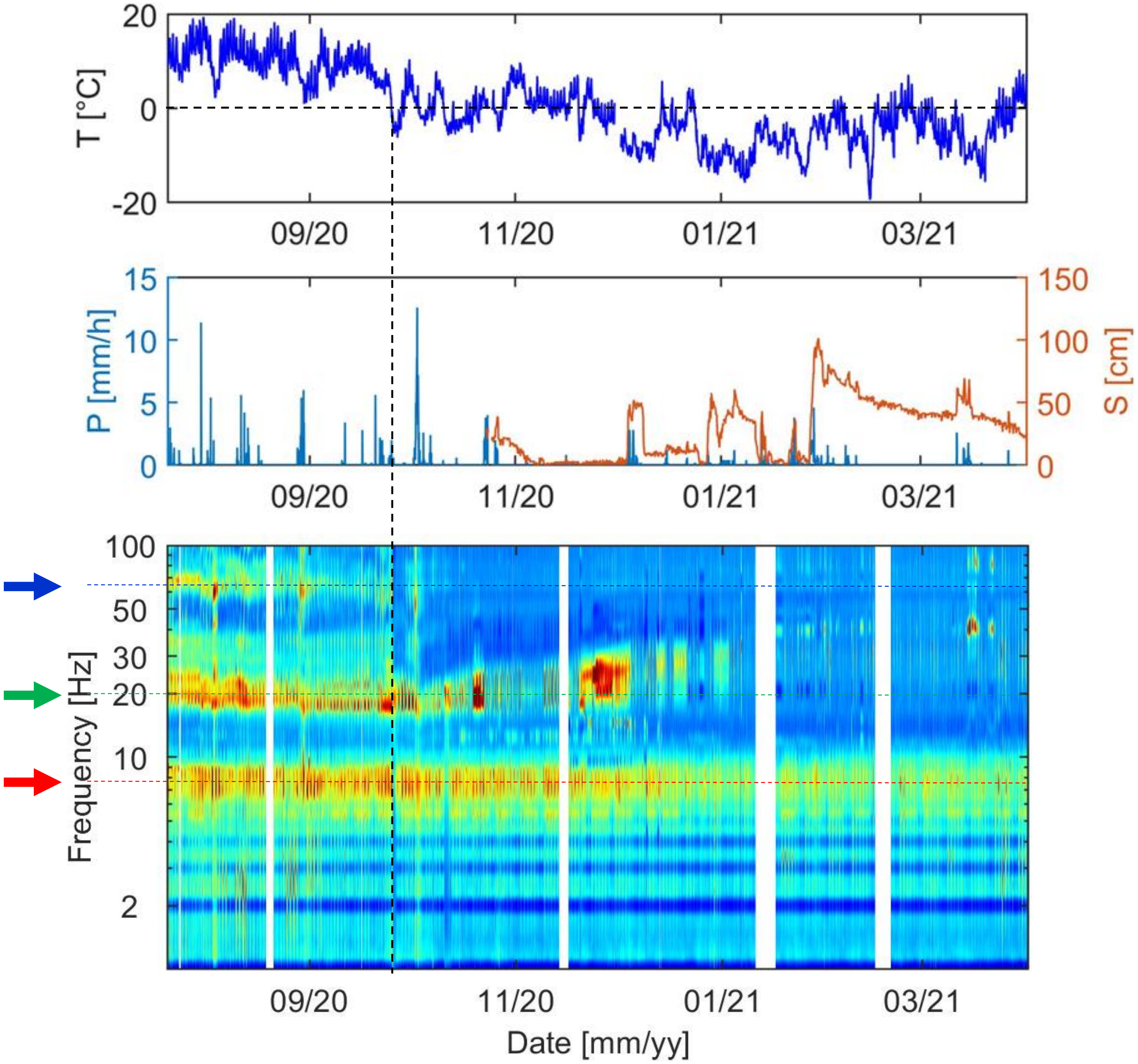


Power [dB wrt $10\log_{10}((m/s)^2/Hz)$]



Spectral ratios





f1 — *Constant with time, bedrock interface?*

f2 — *T>0°C – negative correlation with T*
T<=°C – negative correlation with T

f3 — *Positive correlation for T>0°C*
disappears (or > 100 Hz) when T<0°C

~ 7.5 Hz @vs=1500 m/s $z_{bedrock}$= 50 m

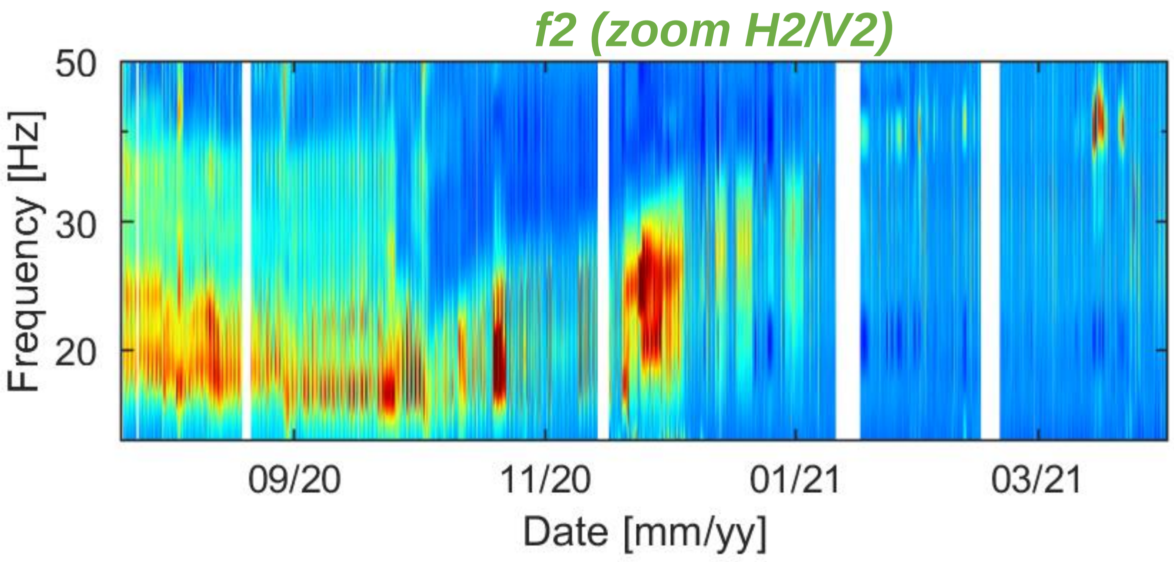
@vs=2000 m/s $z_{bedrock}$=67 m

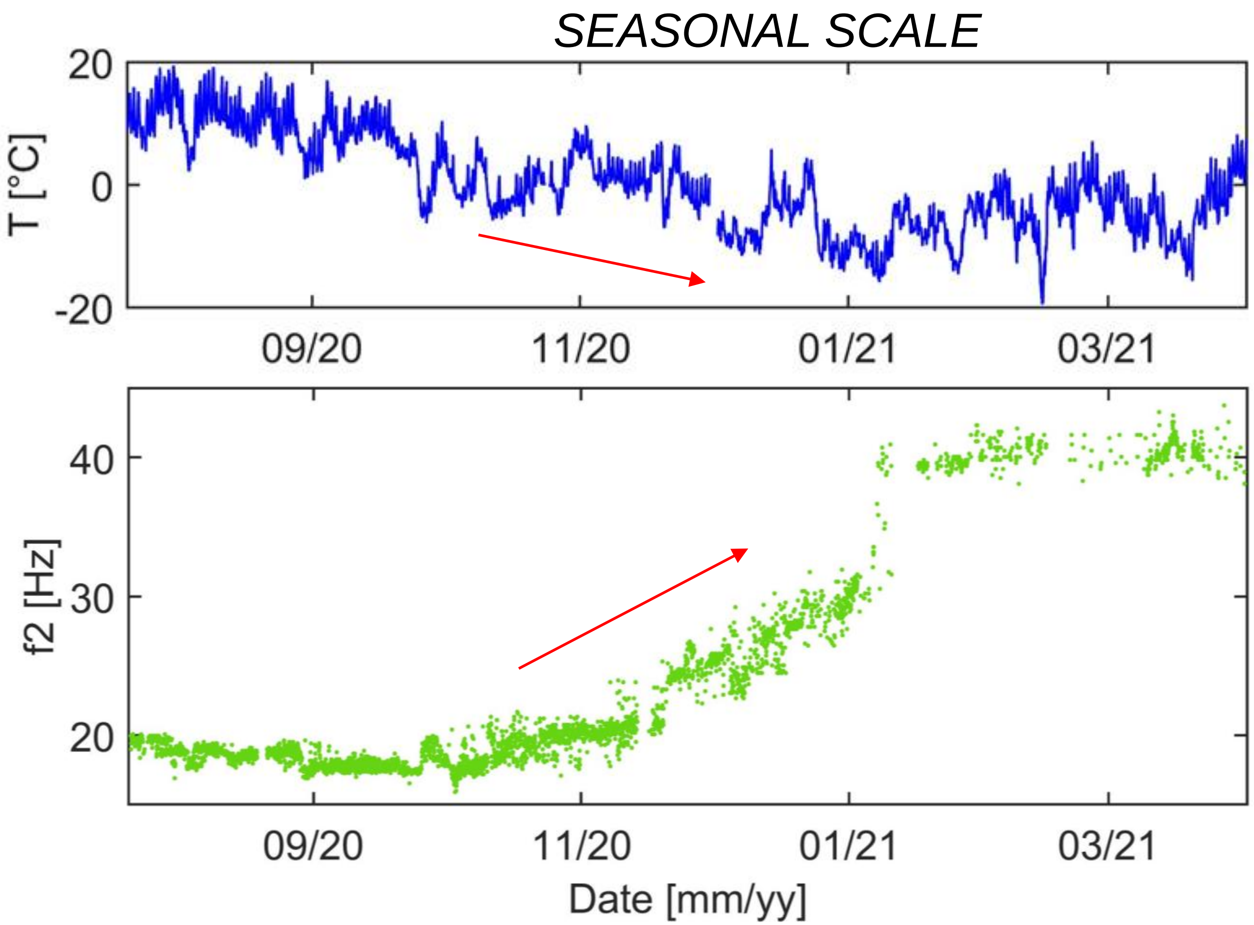
Is it consistent with active seismic / ERT surveys?

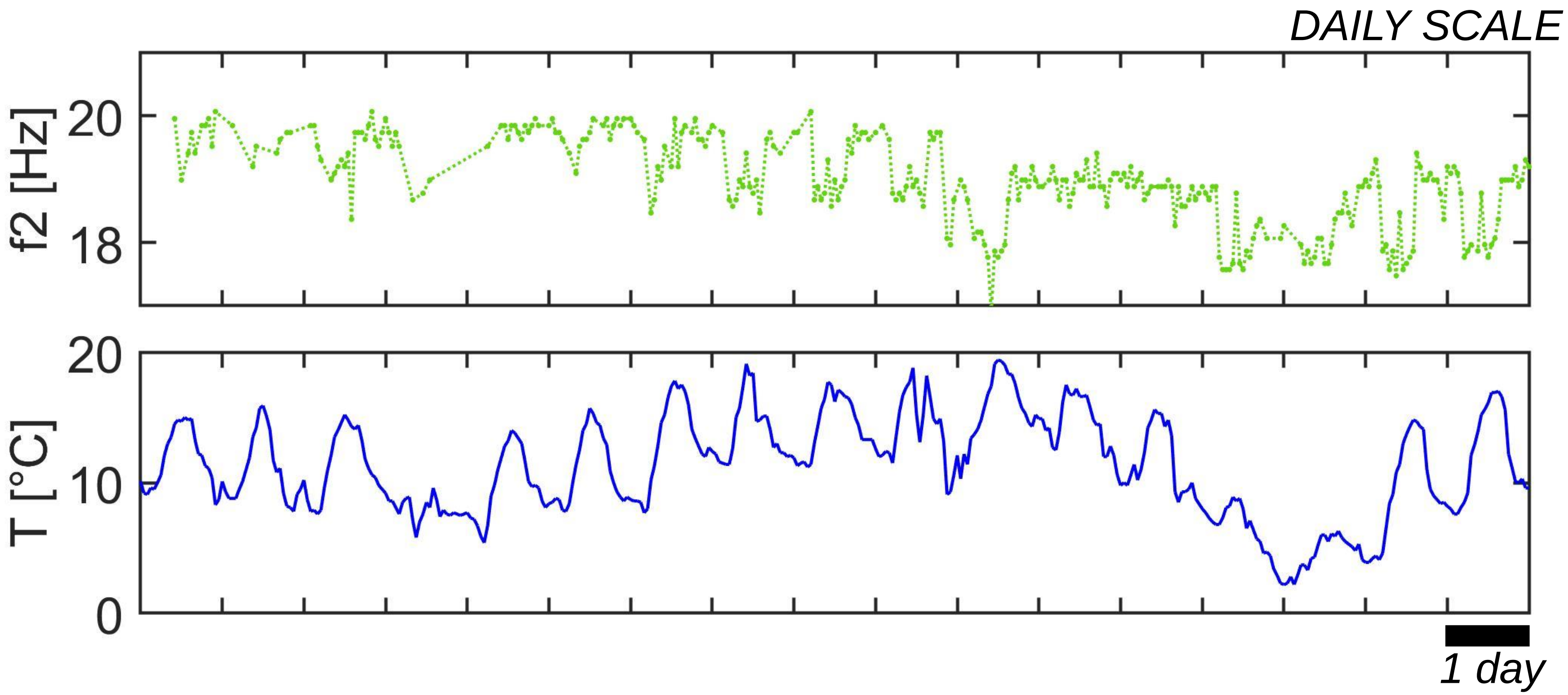
V constraints from active seismic surveys?

~ 20 Hz DAILY SCALE: f2-T negative correlation, SEASONAL SCALE: f2-T negative correlation = when T decreases f2 increases → shallower depth? It may track a shallow interface between unfrozen-frozen material (active layer?)

~ 70 Hz higher mode?

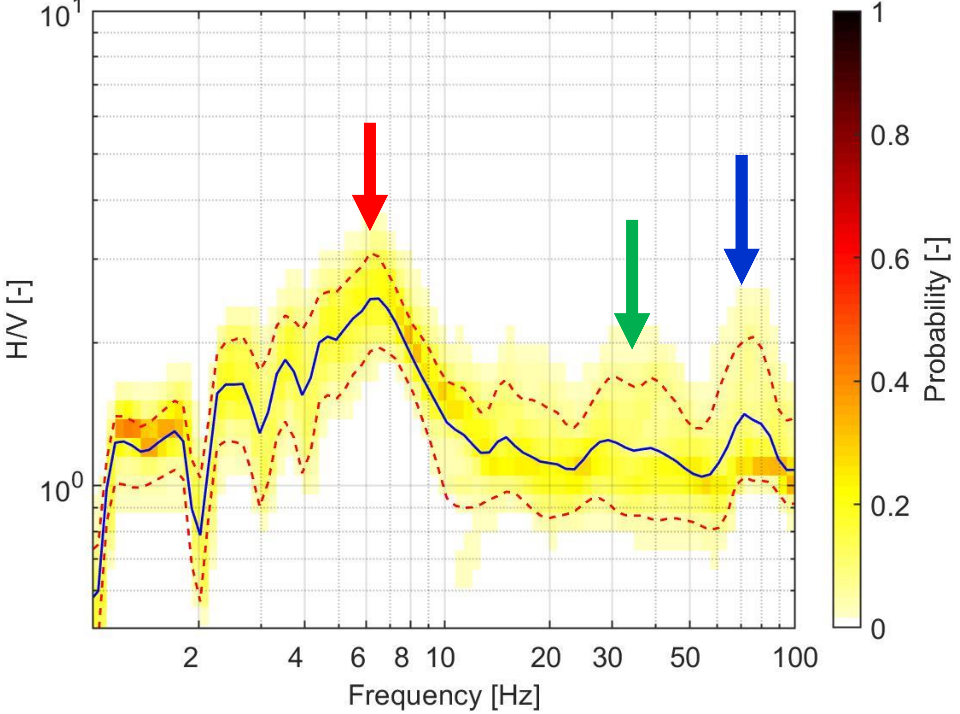


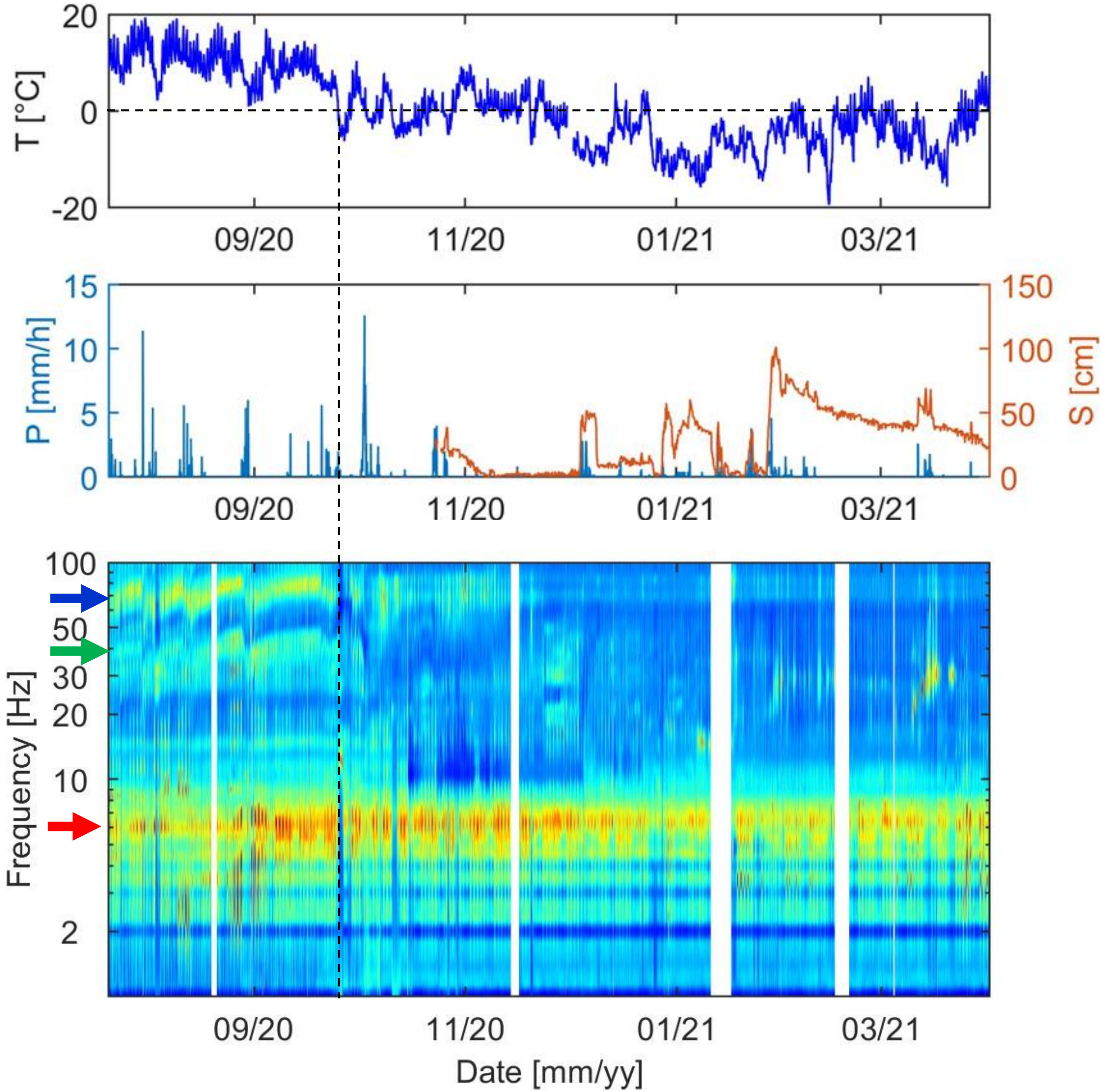




DAILY SCALE
f2 [Hz]
20
18
T [°C]
20
10
0
1 day

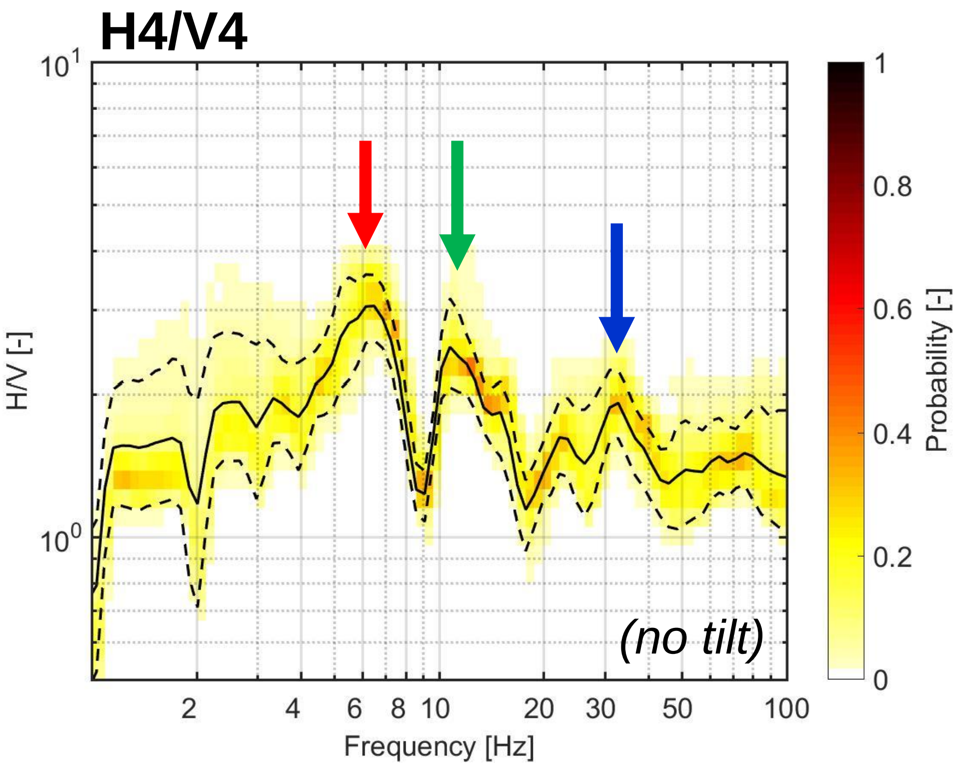
H3/V3

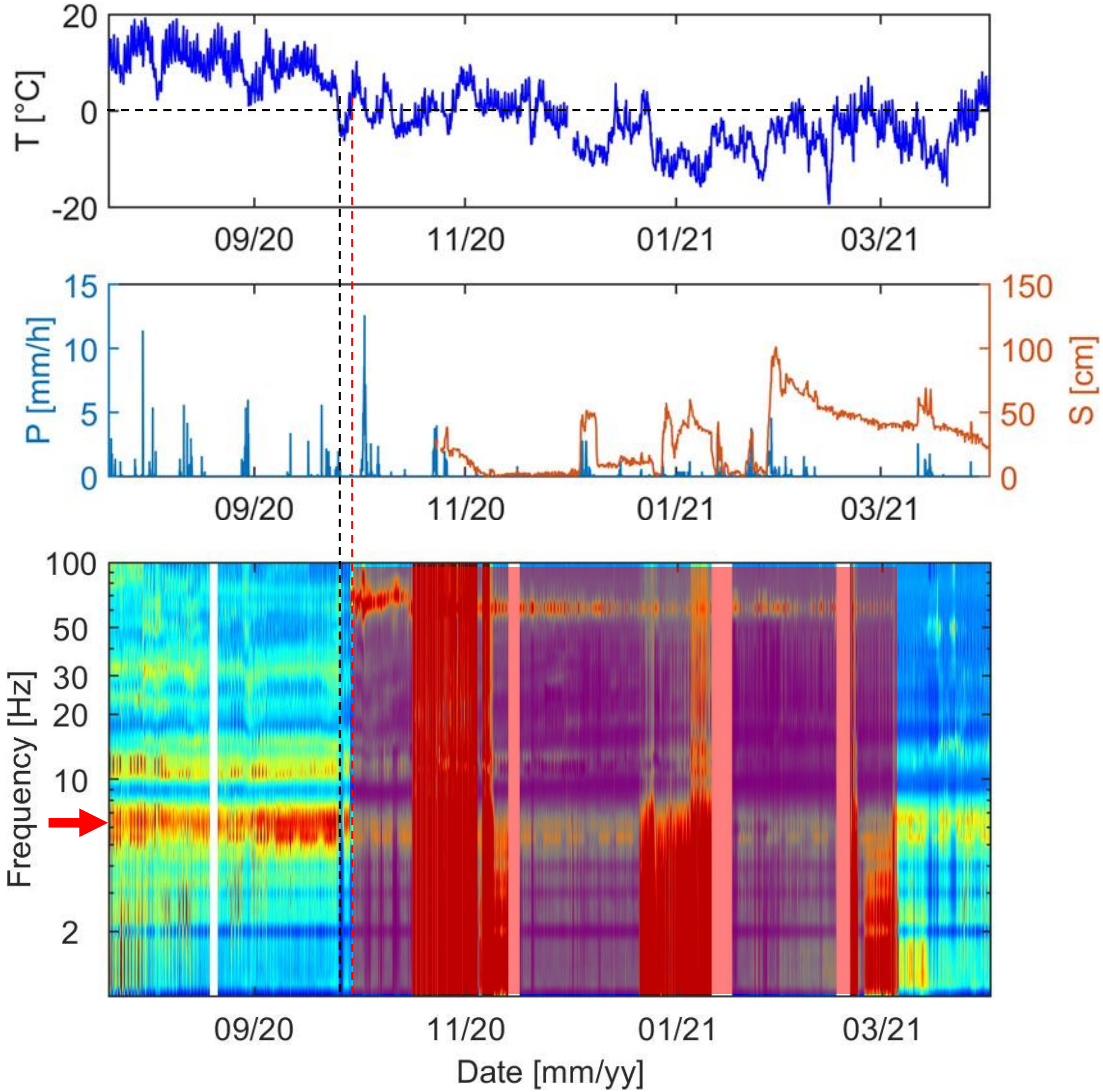




Constant with time, bedrock interface?

The high frequencies disappear when
T<0°C also at the reference station.
Positive correlation with T?



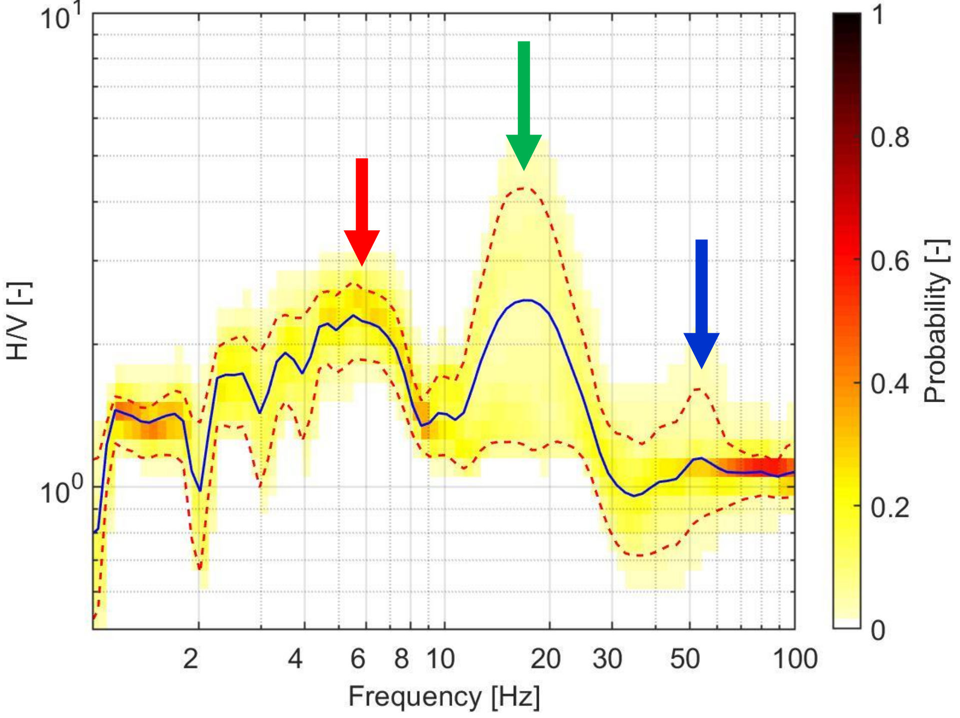


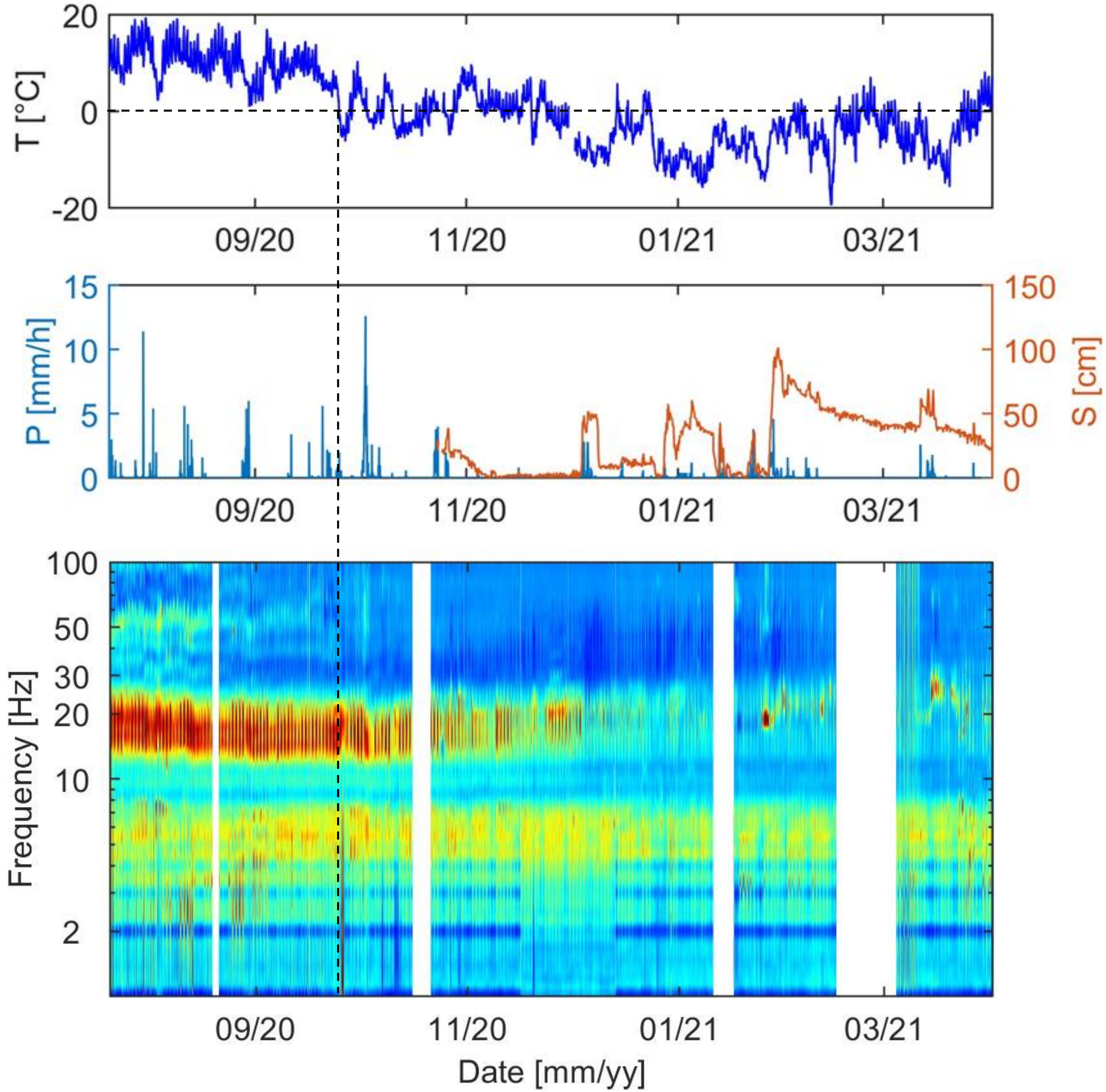
Tilted when T rises above 0°C
Restored at the beginning of March 2021

Deeper bedrock? Lower Vs?

Lower T effect?

H5/V5





Similar to GEA02, T effect on f2 is less pronounced.

Ambient seismic noise – cross-correlation

- Cross-correlation of the noise simultaneously recorded at two stations give access to the impulsive response between the two stations, as one was an active source and the other one a receiver.

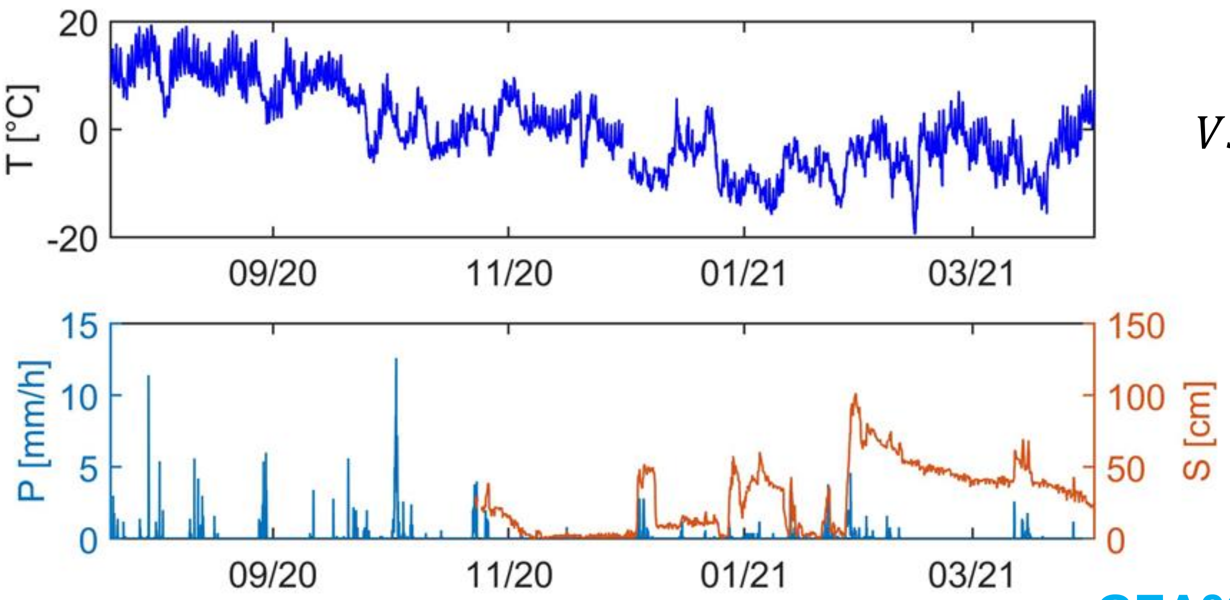
- A modification in the mechanical properties in the materials between the two stations is expected to cause a seismic velocity change (maily shear-wave velocity Vs).

- The seismic velocity change over time (%) can thus be estimated from the cross-correlograms (e.g. stretching technique).

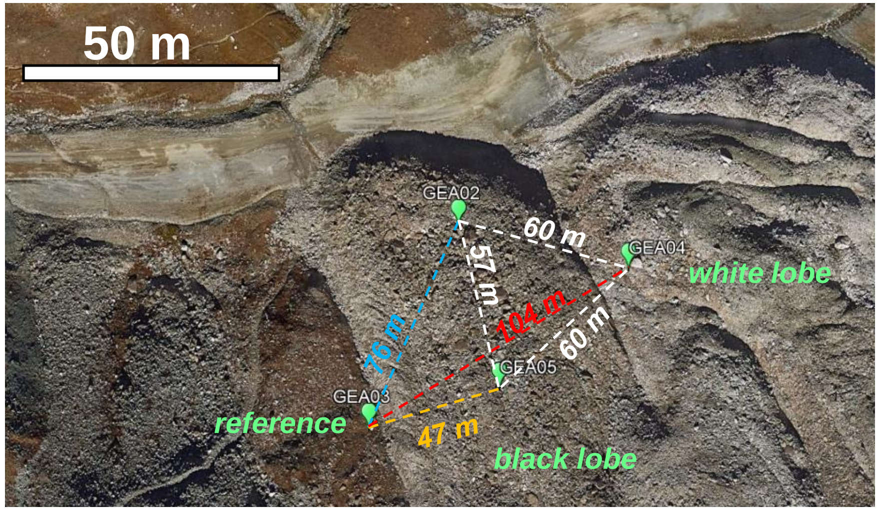
- A degradation in the mechanical properties inside the RG is expected while it is prone to flow downwards → negative velocity changes within the RG (obtained from cross-correlation) may highlight accelerations in the RG movement.

$$Vs = \sqrt{\frac{G}{\rho}}$$

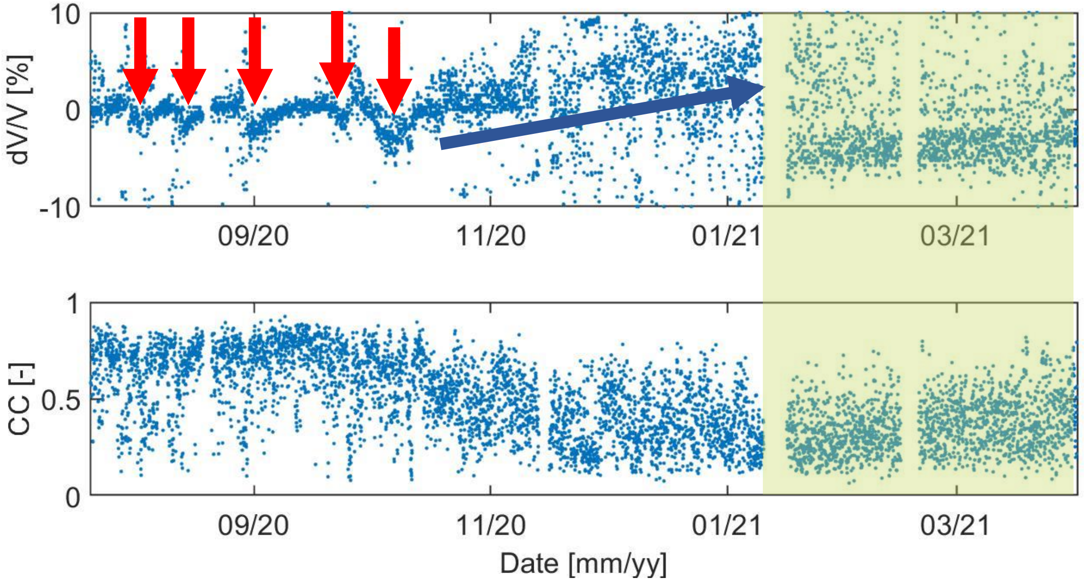
Ambient Sesmic Noise cross-correlation



$$Vs = \sqrt{\frac{G}{\rho}}$$



GEA02-GEA03 – V – [14 16] Hz



Velocity changes [%] within the rock glacier with respect to the average cross-correlogram

Correlation coefficient

While T>0°C, seismic velocity drops after P (=RG movement)

While T<0°C, seismic velocity increases (stable phase)

Correlation is lost at the beginning of January 2021 (processing problem, f2 exceeds the f band?)

Microseismicity

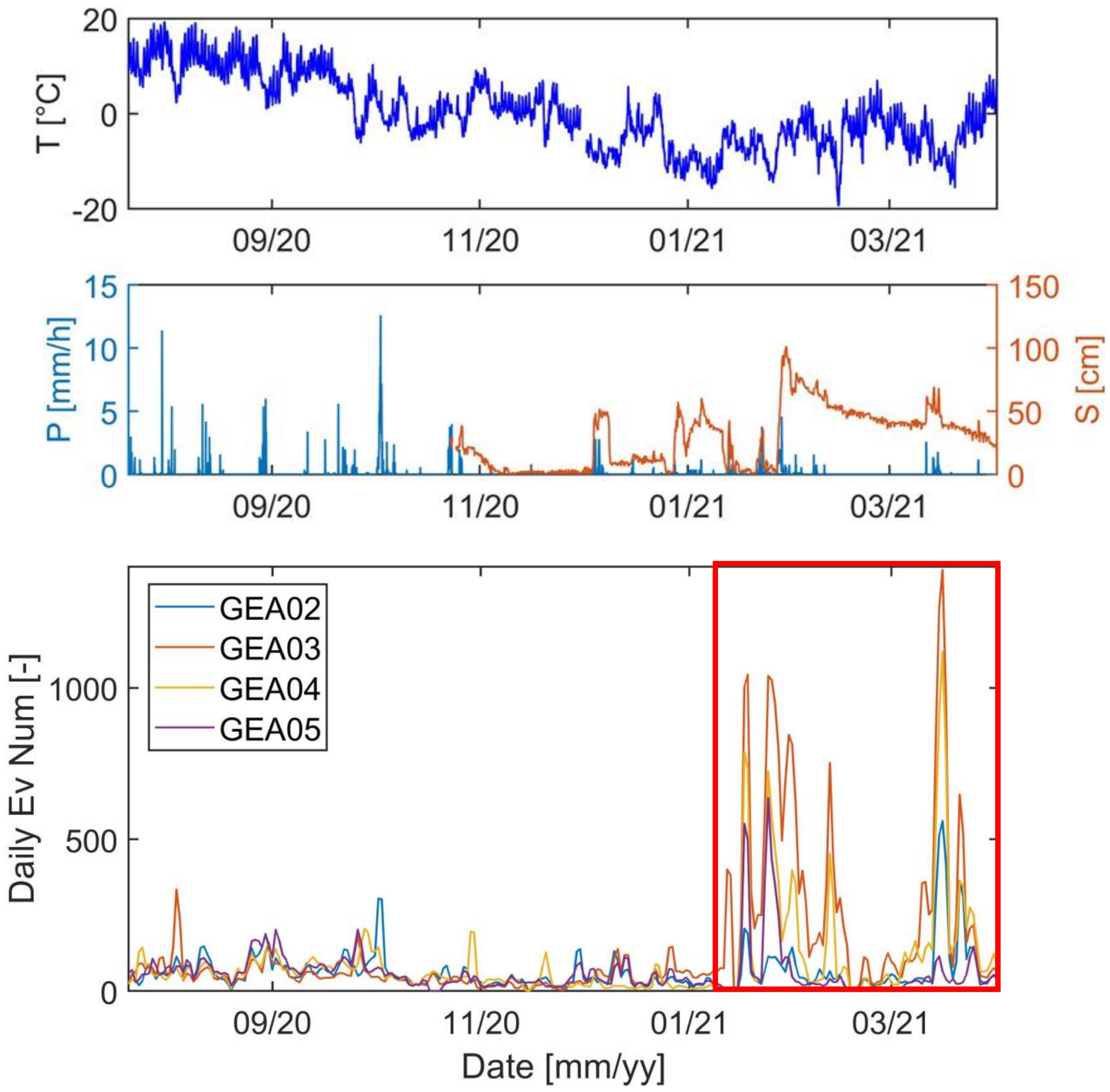
- Seismic events can be extracted from the continuous ambient seismic noise recordings by detection algorithms.

- The seismic events need to be classified (on the basis of salient features in time and frequency domain) to understand their source (e.g. natural/anthropic?).

- Natural events (interesting for the study of RG evolution) include: microseismic events related to rock micro-fracturing/micro-cracking, icequakes, rock falls, slip on pre-existing surfaces.

- The source location and temporal trend of these events can track RG activity as a function of the external modifications in temperature and precipitation.

EVENT DETECTION AND CLASSIFICATION



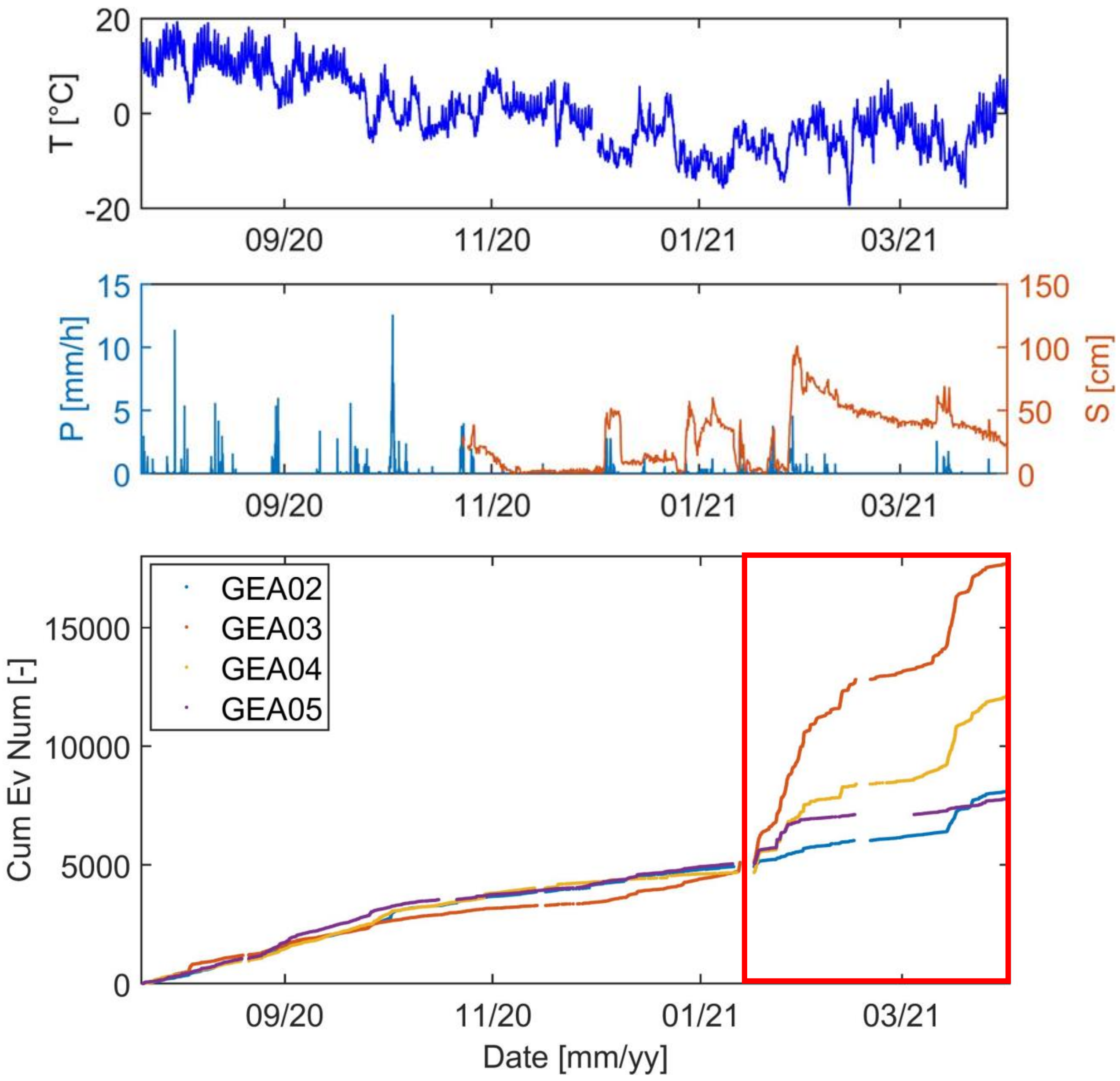
STA/LTA algorithm to extract events from 1-h noise recordings of the station:
STA=0.5 s LTA=20 s STA/LTA=6

07/20 – 10/20: MS event peaks after P → cross-correlation results are confirmed

From the end of October 2020, reduced microseismic activity (T<°C). Minor peaks (150 events/day) when T rises above 0°C in winter months.

From mid January 2021, intense anthropic disturbances → trucks? Anthropic works?

EVENT DETECTION AND CLASSIFICATION



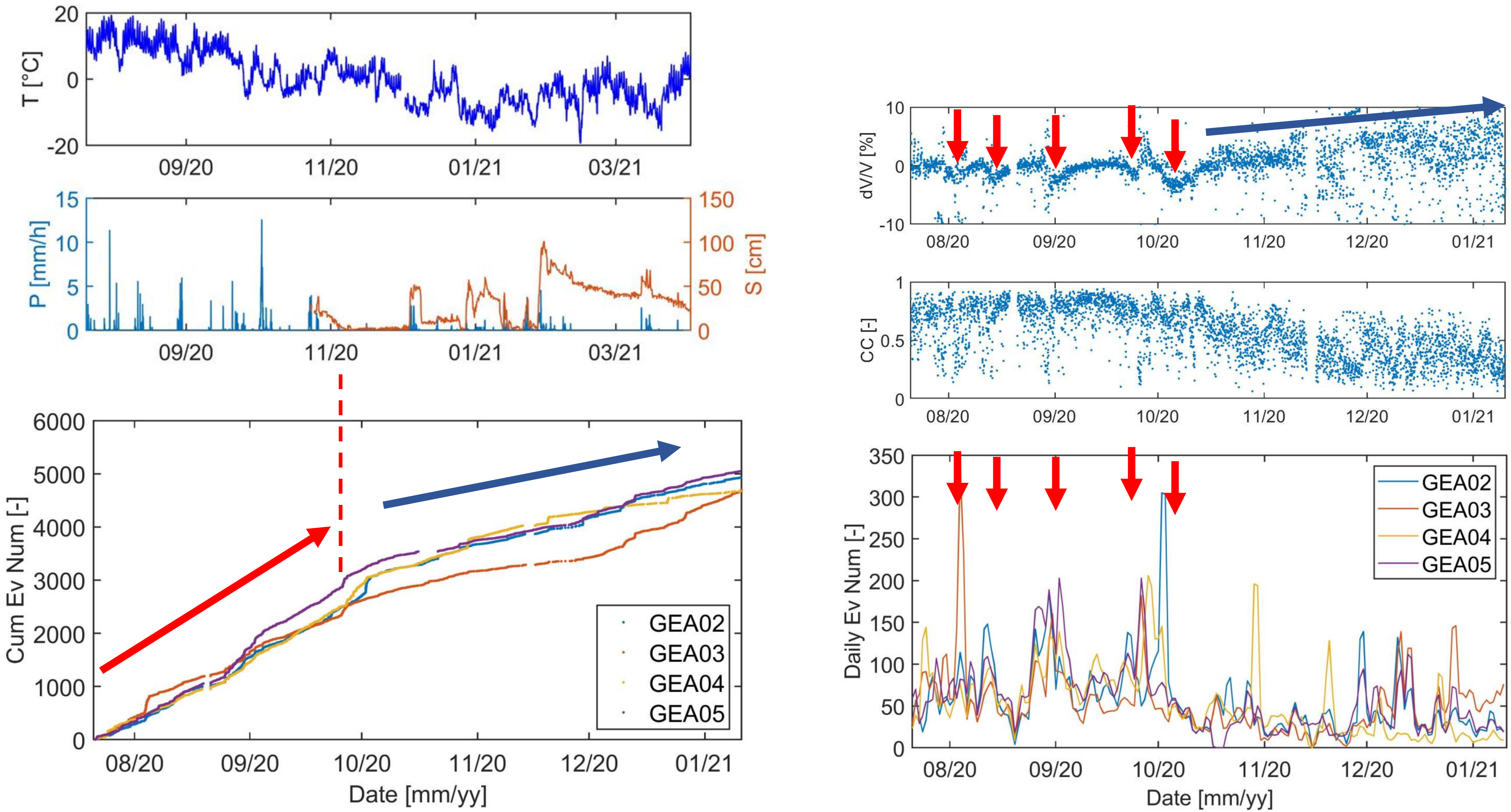
STA/LTA algorithm to extract events from 1-h noise recordings of the station:
STA=0.5 s LTA=20 s STA/LTA=6

07/20 – 10/20: MS event peaks after P → cross-correlation results are confirmed

From the end of October 2020, reduced microseismic activity (T<°C). Minor peaks (150 events/day) when T rises above 0°C in winter months.

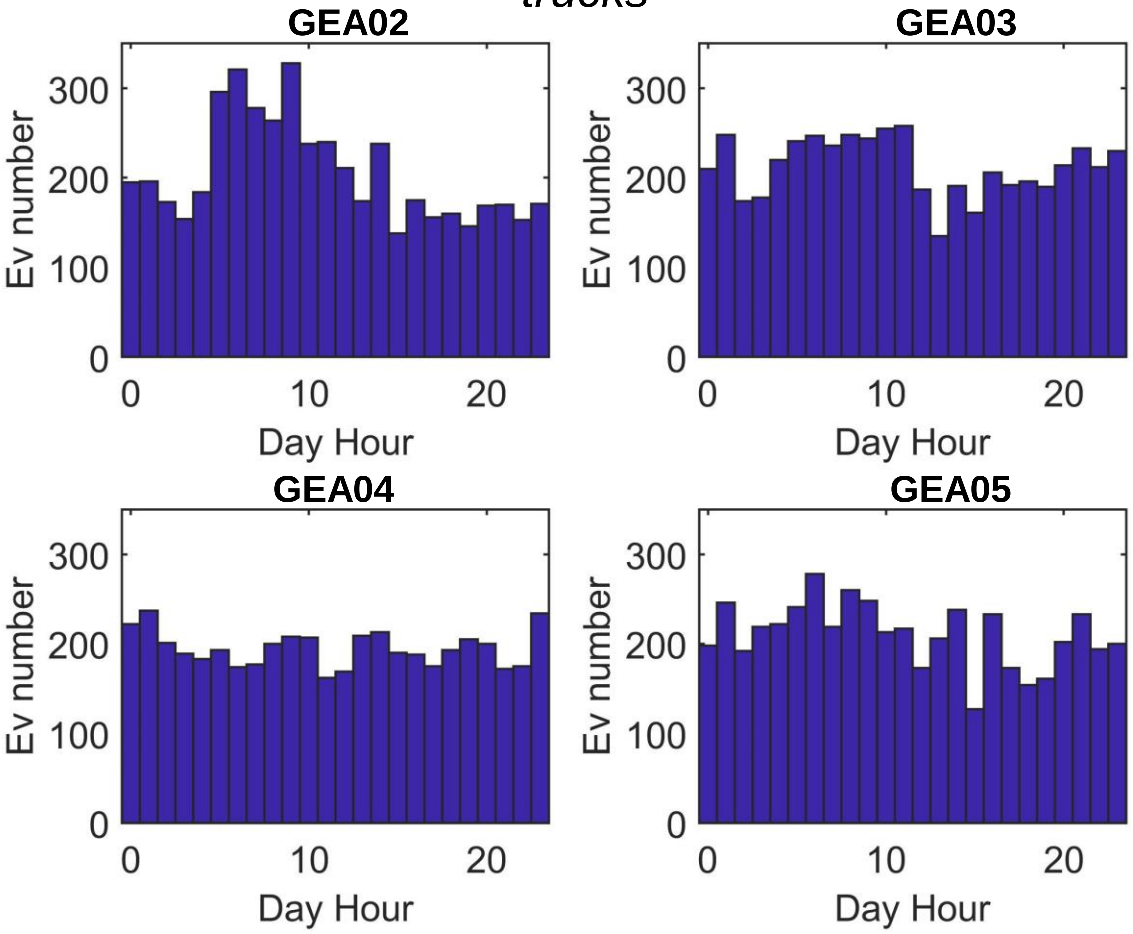
From mid January 2021, intense anthropic disturbances → trucks? Anthropic works?

EVENT DETECTION AND CLASSIFICATION

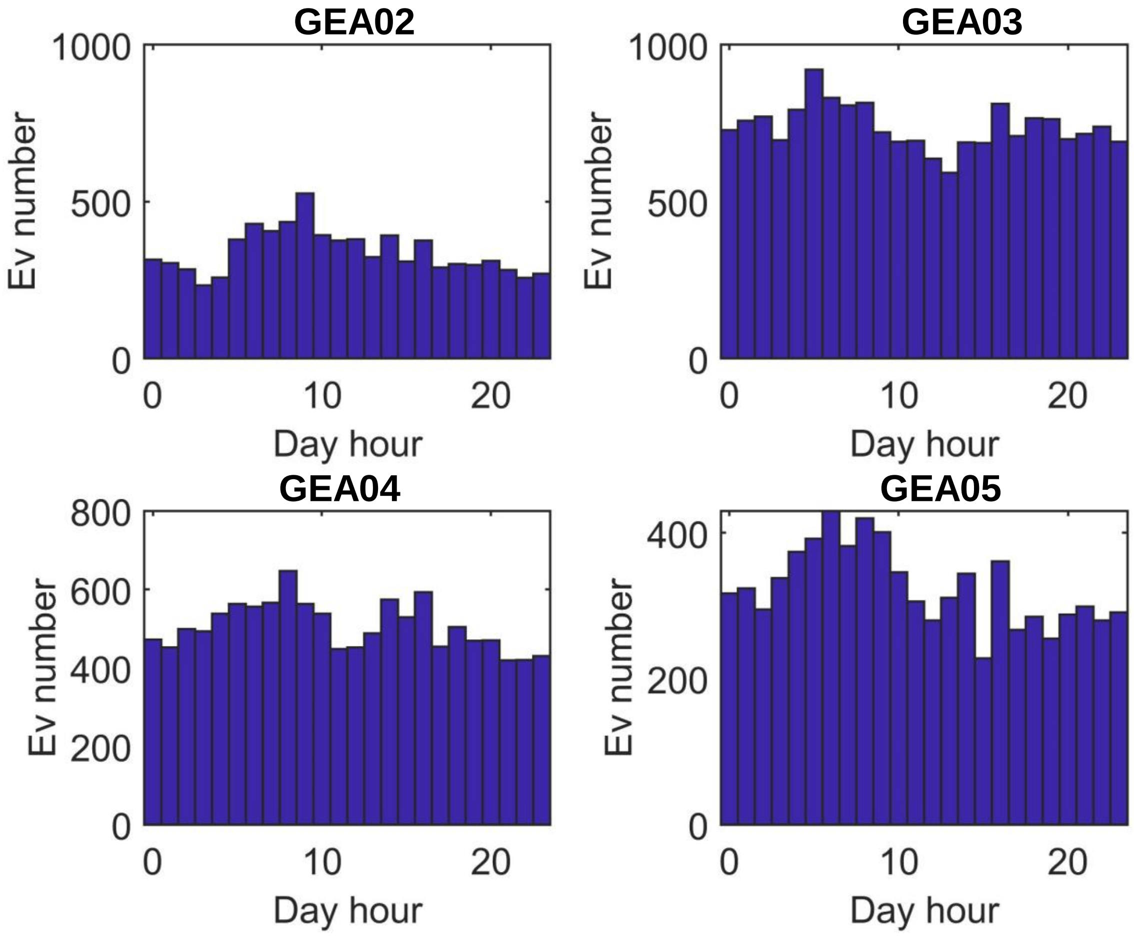


EVENT DETECTION AND CLASSIFICATION

Before trucks

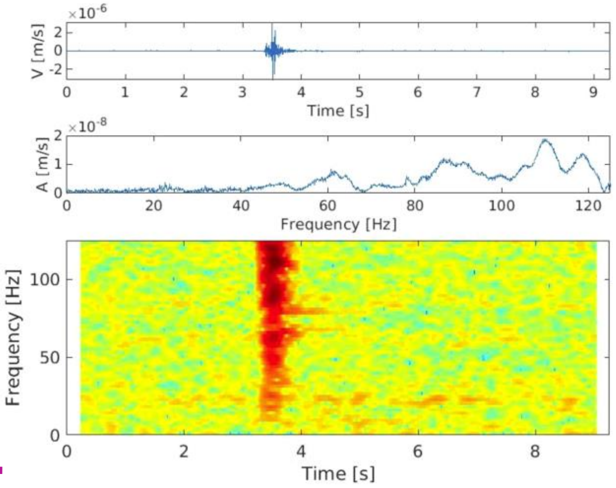


After trucks

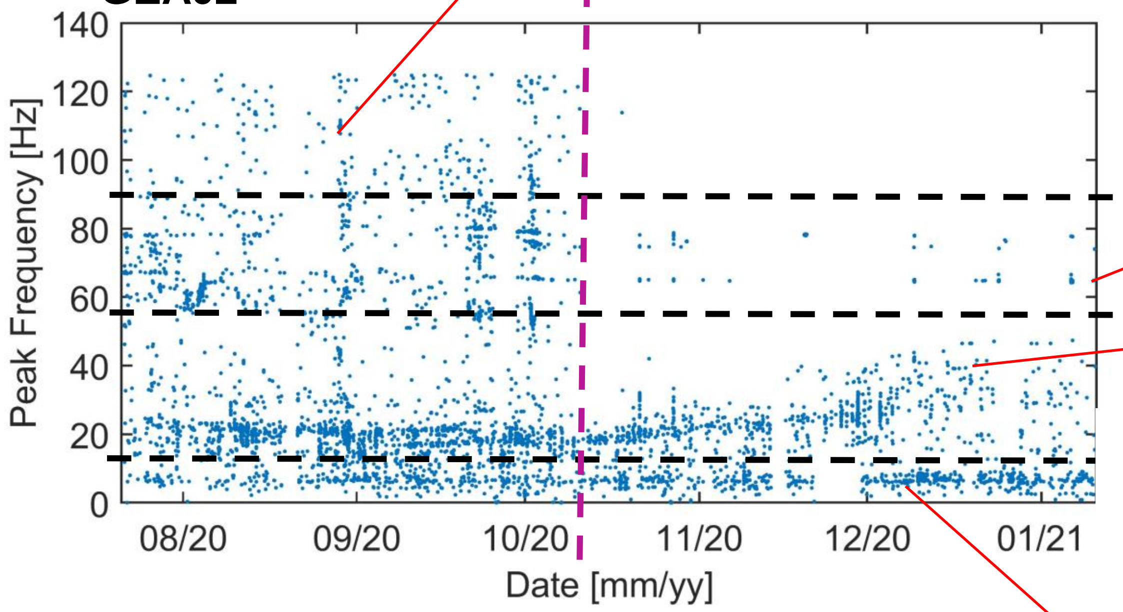


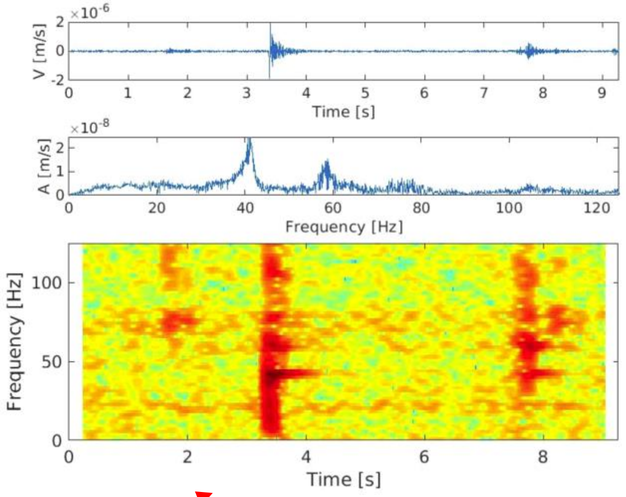
EVENT CLASSIFICATION

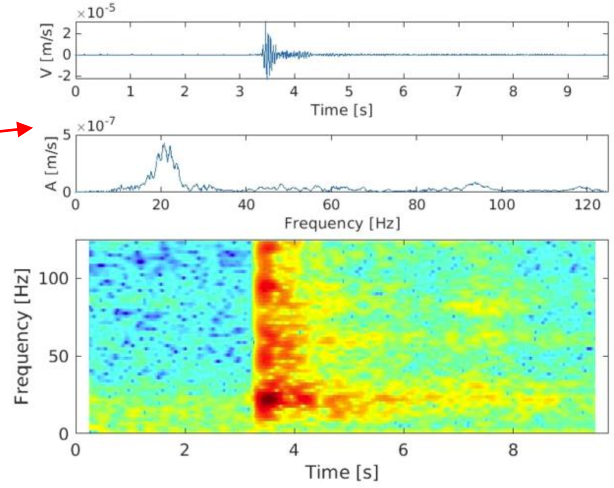
Classification based on the peak frequency of the events (before trucks)

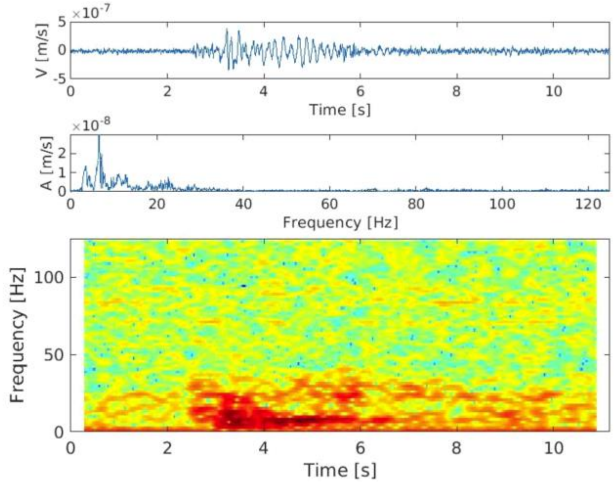


GEA02









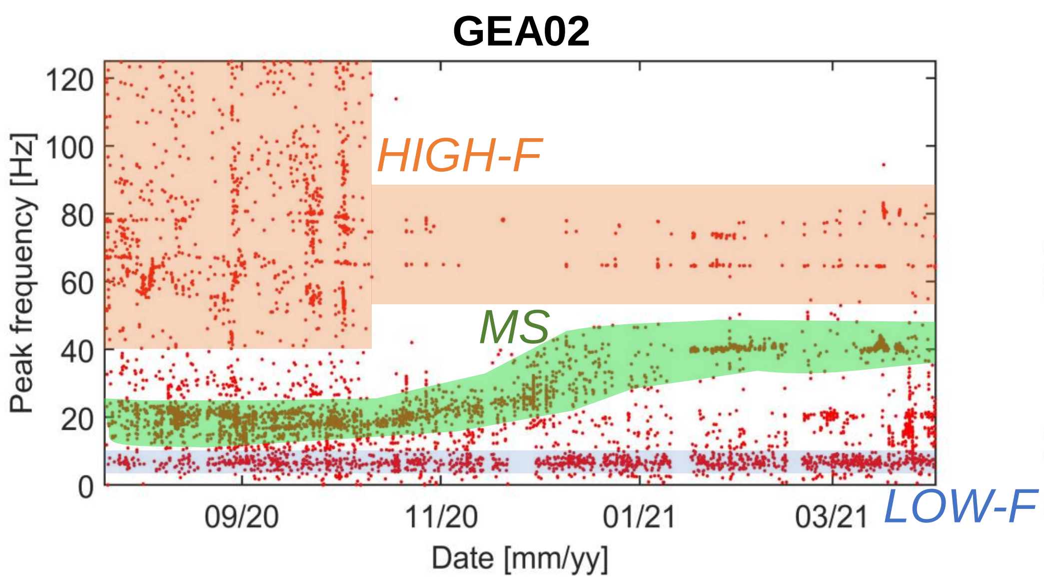
<u>Peak frequency > 10 Hz</u>

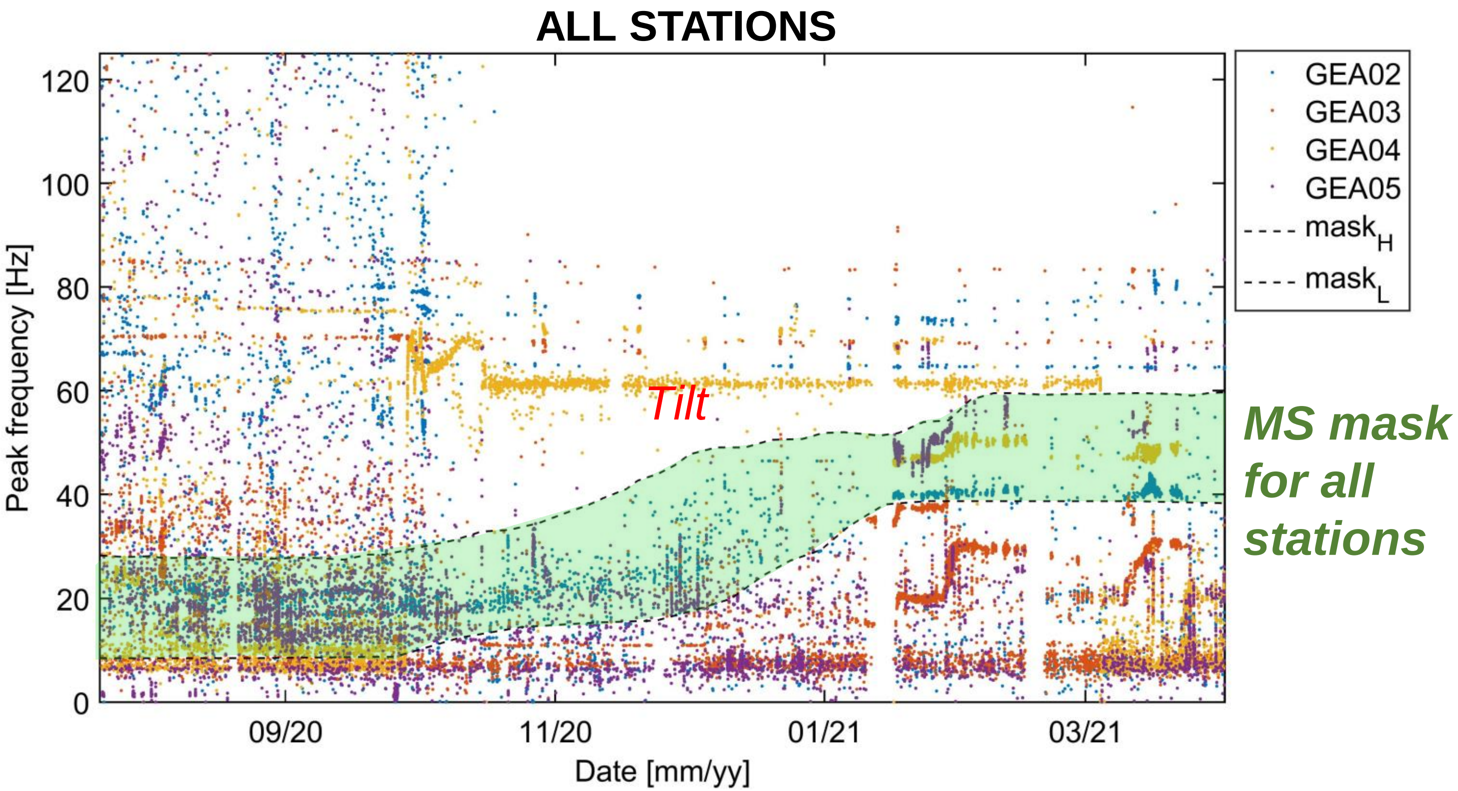
→ microcracking/fracturing/icequakes → different peak frequency due to different distance/size of the source, the 20-Hz peak frequency shows a clear T effect. High-frequency events disappear in October 2020.

Peak frequency < 10 Hz

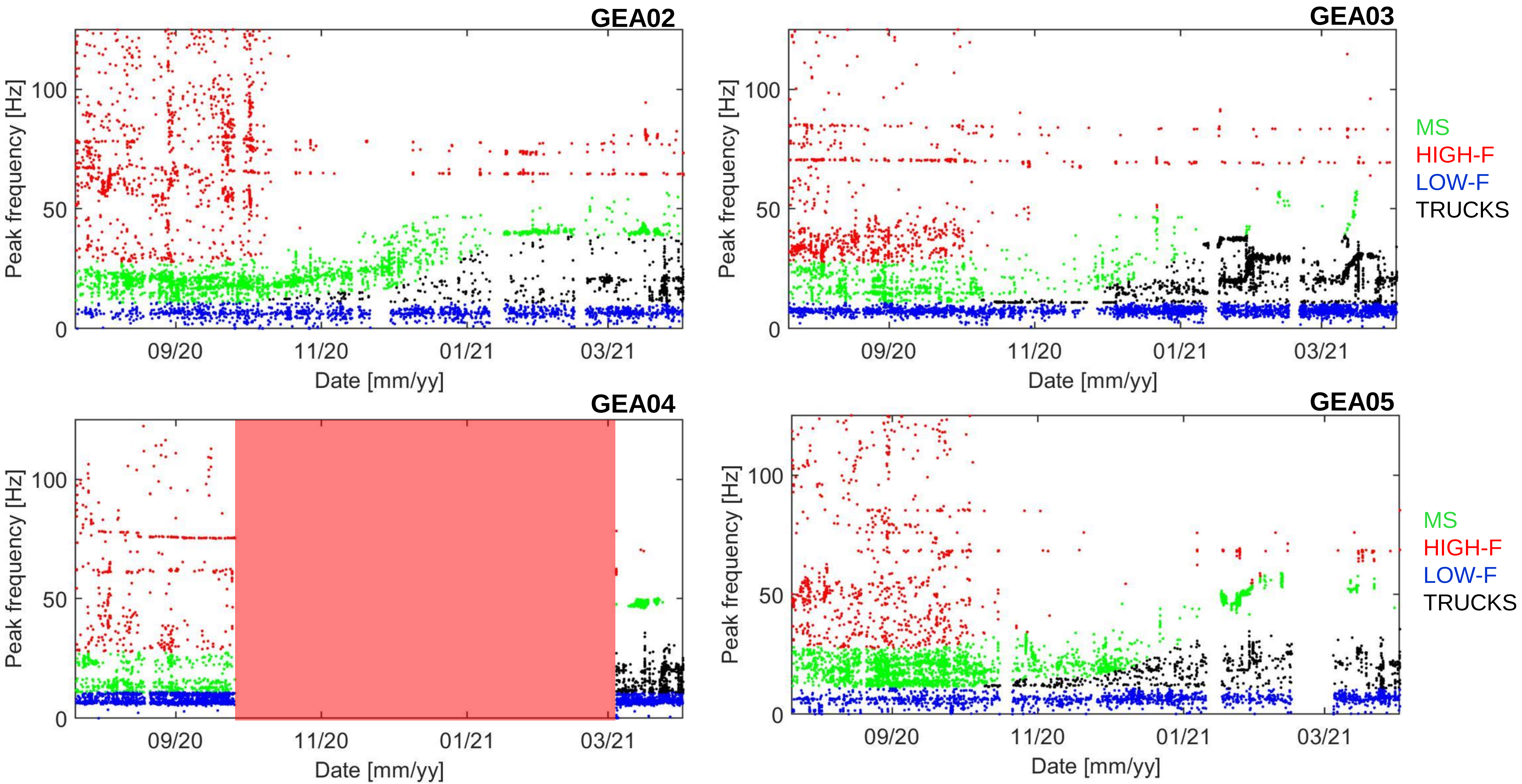
→ long-duration events, slip along preexisting weak surfaces, boulder movements?

EVENT DETECTION AND CLASSIFICATION

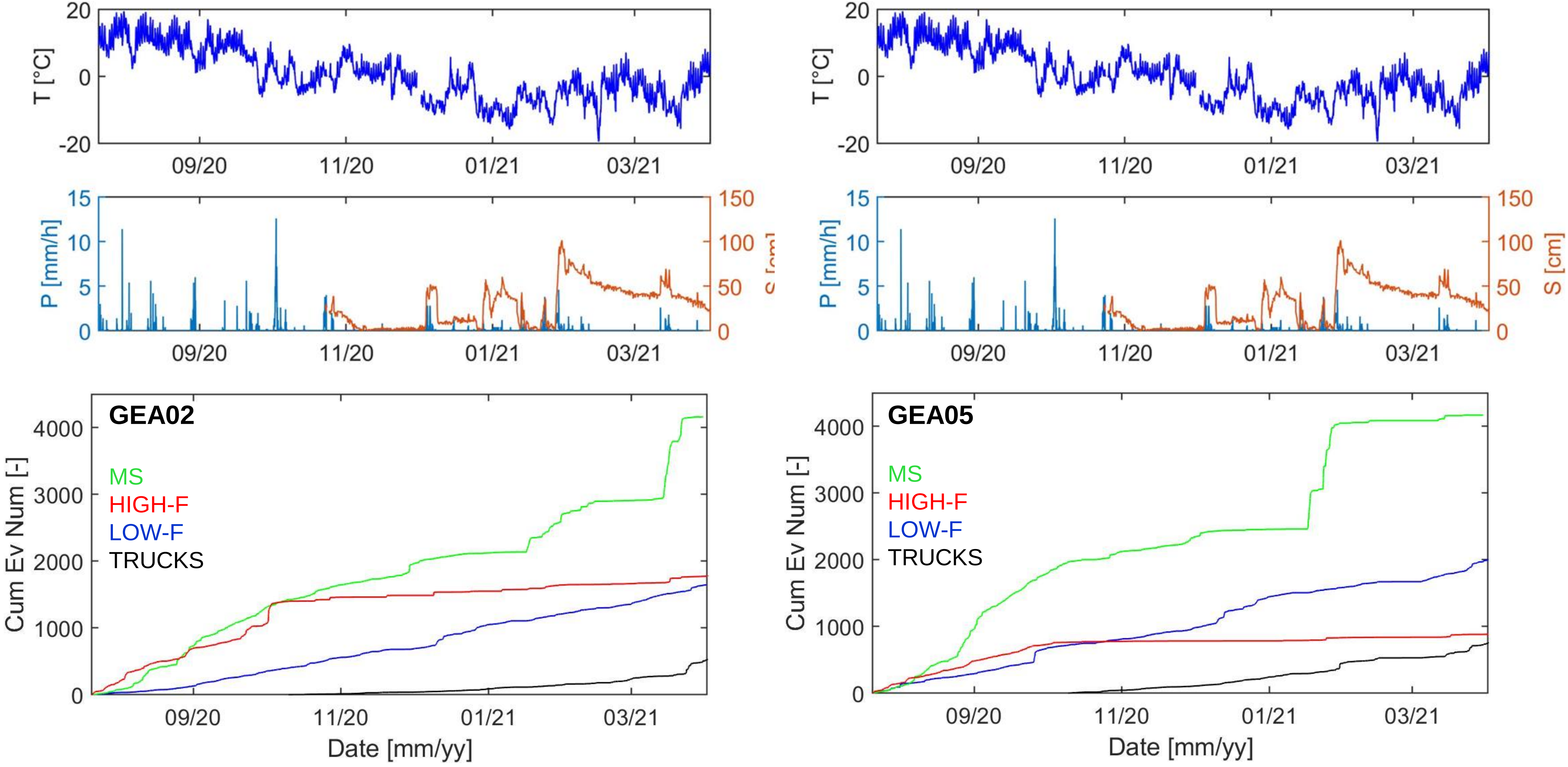




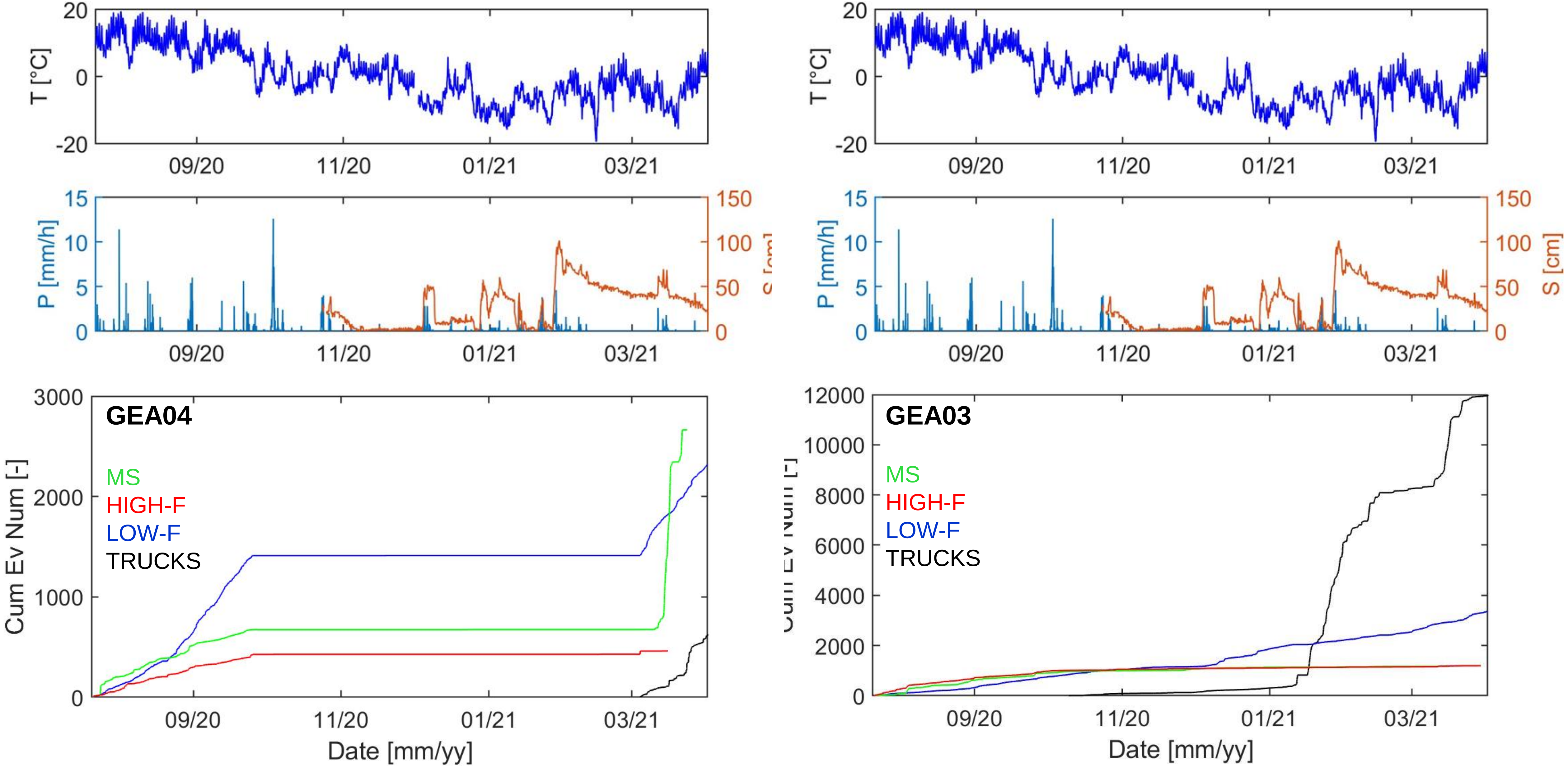
EVENT DETECTION AND CLASSIFICATION

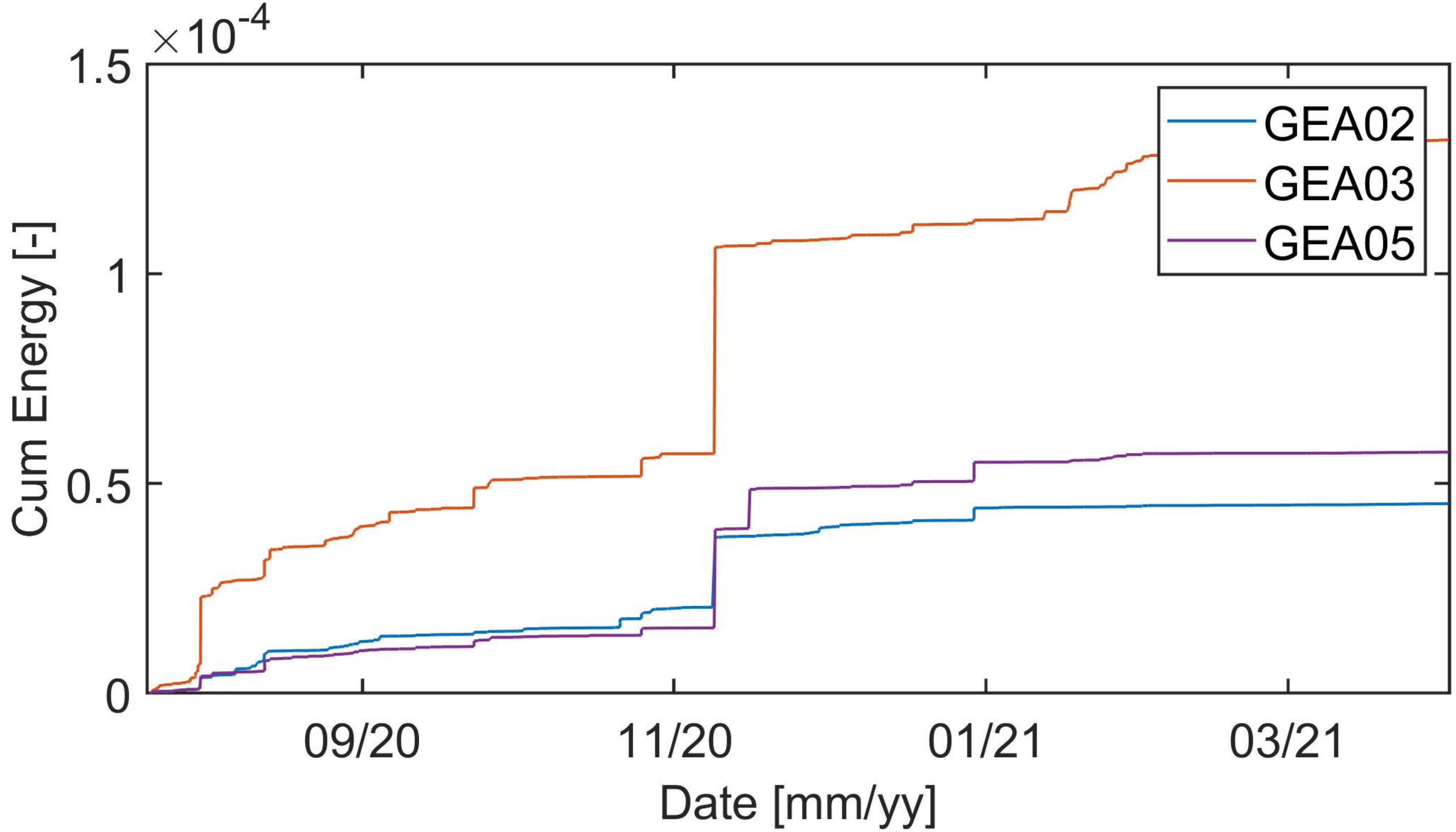


EVENT DETECTION AND CLASSIFICATION



EVENT DETECTION AND CLASSIFICATION





×10^-4
1.5
1
0.5
0
Cum Energy [-]
09/20
11/20
01/21
03/21
Date [mm/yy]
GEA02
GEA03
GEA05

Concluding remarks

- Both ambient seismic noise and microseismicity analyses seem suitable to study the RG activity.

- Outside the freezing period, the RG responds mainly to precipitations (microseismicity/cross-correlation results). Winter months are associated with low microseismicity and a general increase in the RG mechanical properties due to freezing. An inverse correlation between temperature and the frequency peaks of ambient seismic noise is highlighted, probably tracking the active layer thickness.

- From mid January 2021 the site is affected by intense anthropic noise in the surroundings → an improvement in event classification is under investigation to remove the anthropic disturbances from the microseismic data set (simple example given in previous slides). Cross-correlation results are unfortunately also affected by this noise (overlapping frequency band).