Tracking water flow using continuous seismic tremor- A Pilot Study

Haleh Karbala Ali[1], Christopher J. Bean[1],
David Craig[1], Ka Lok Li[1], Gareth O'Brien[2], Caoimhe Hickey[3], Billy O'Keeffe[4]

1 Geophysics Section, School of Cosmic Physics, Dublin Institute for Advanced Studies, Dublin, Ireland

2 "New affiliation": Microsoft Azure Global, Dublin, Ireland

3 Geological Survey Ireland (GSI), Dublin Ireland

4 Transport Infrastructure Ireland (TII), Dublin Ireland

Summary

-The hydraulic process associated with surface and subterranean flow of water induces ground vibrations, to be called seismic tremor.

- We aim to develop methodologies for locating and tracking underground water-flow in Irish Karst.

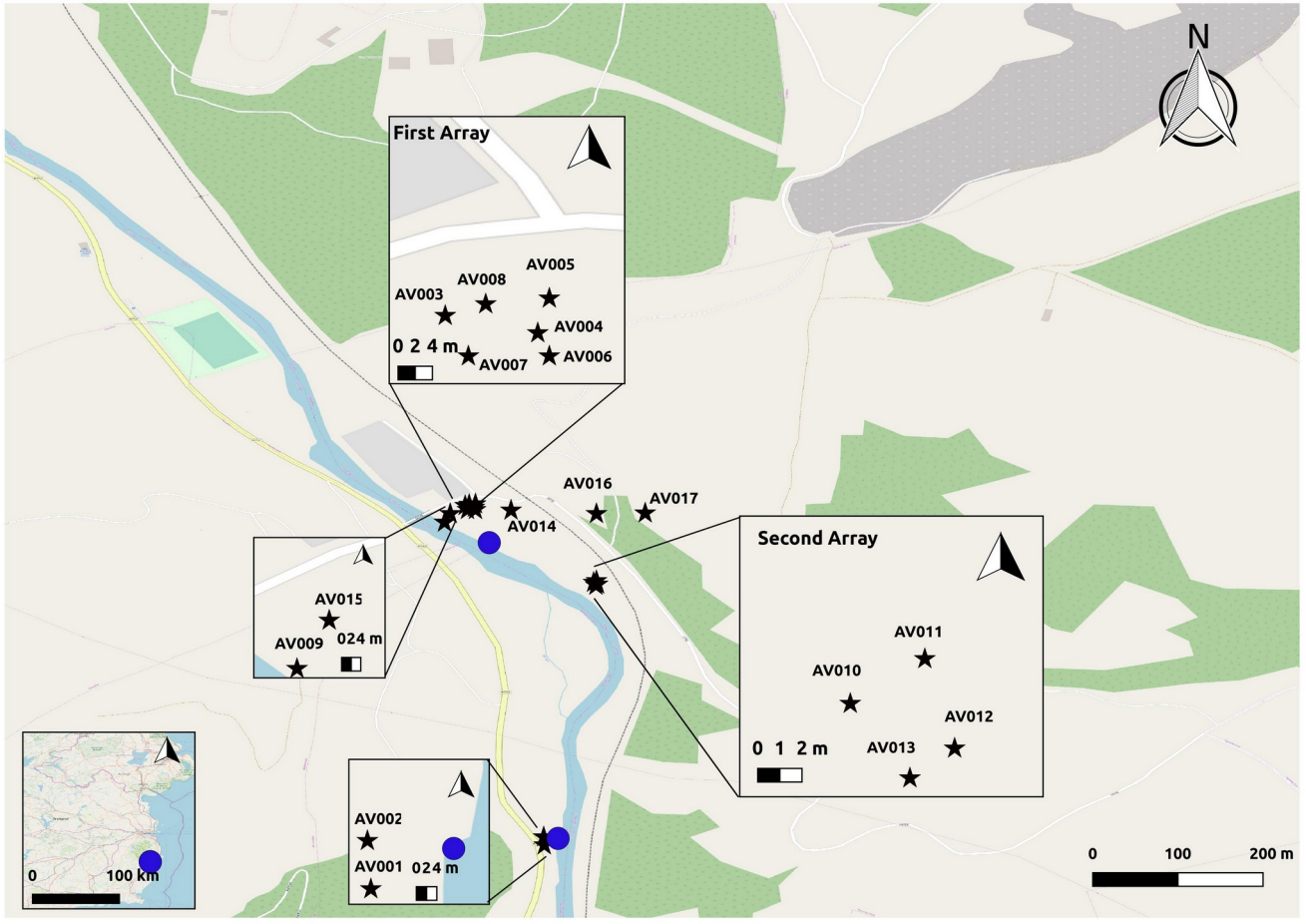
- As nearly all Karst landscapes locate in urban areas, it is vital to discriminate flow-induced signal from the cultural noise.

- We conducted a pilot experiment near a surface river to investigate the frequency content associated with the flow based on median filtered spectrograms and array-analysis.

- Prior to the lock-down, we conducted a quick noise test on two Karst sites with a few stations.

- In near future, we will conduct a larger-scale experiment including more seismic instruments on Irish Karst.

Location map of the Pilot study area: Avoca River, County Wicklow, Republic of Ireland



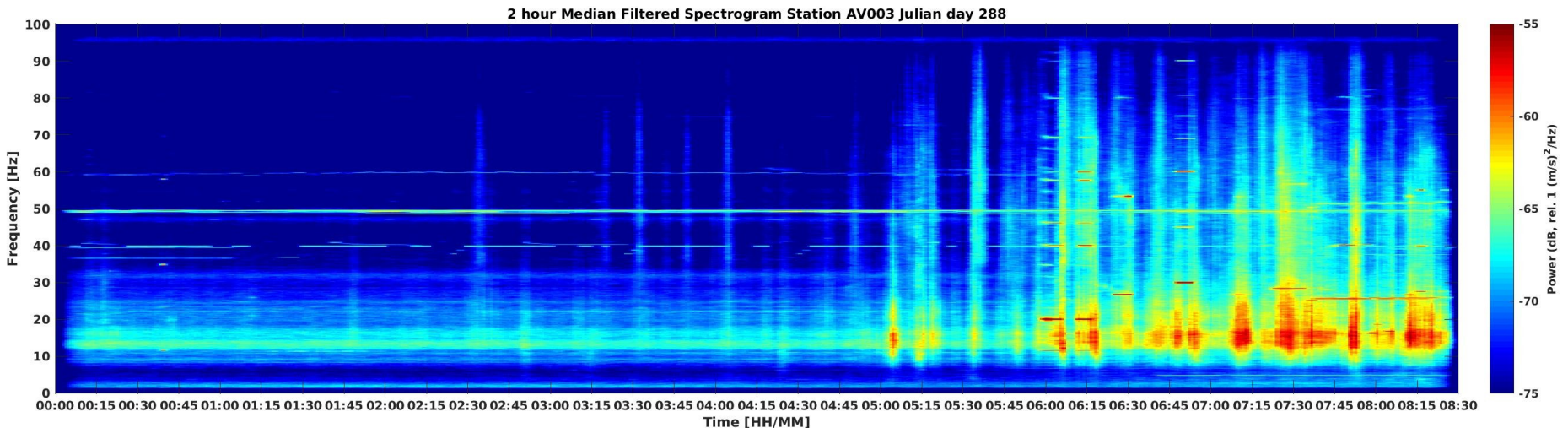
- stars are seismic stations and blue circles are EPA gauges.

-To get an idea of the frequency content of the flow-induced signal, differentiate it from interfering cultural noise and establish correlation between the seismic signal and the flow-rate we conducted this **pilot** experiment.

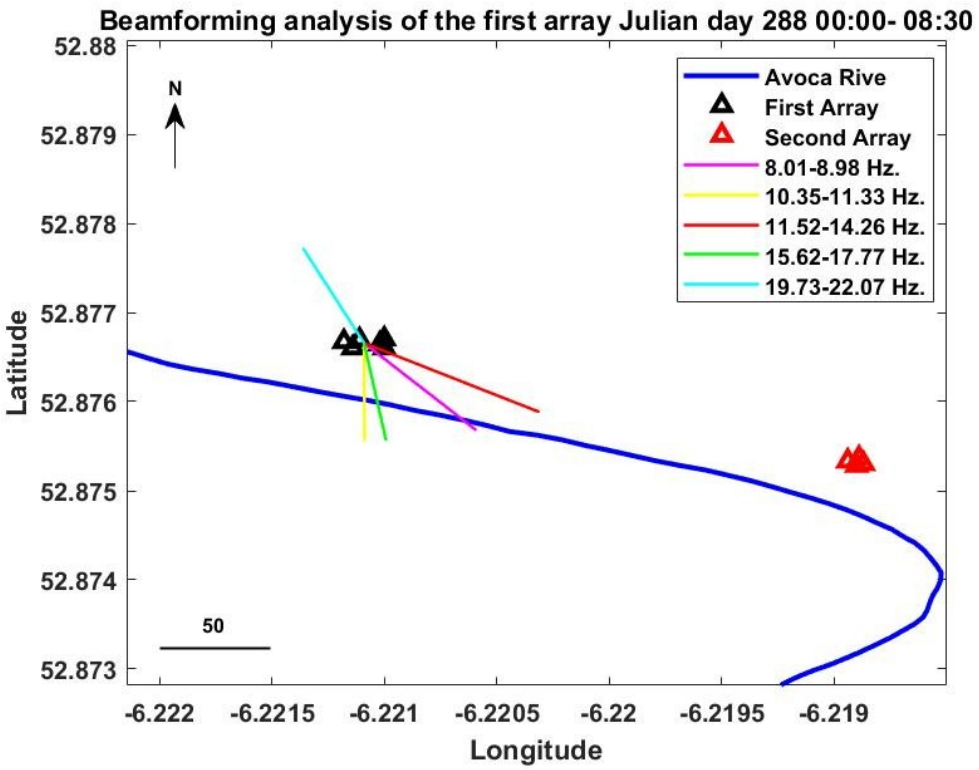
- We deployed 17 1 Hz. short-period seismometers with 200 Hz. Sampling rate during 10th-15th October 2019 and left two stations for monitoring and correlation with EPA water-level/flow-rate gauges until 17th December 2019.

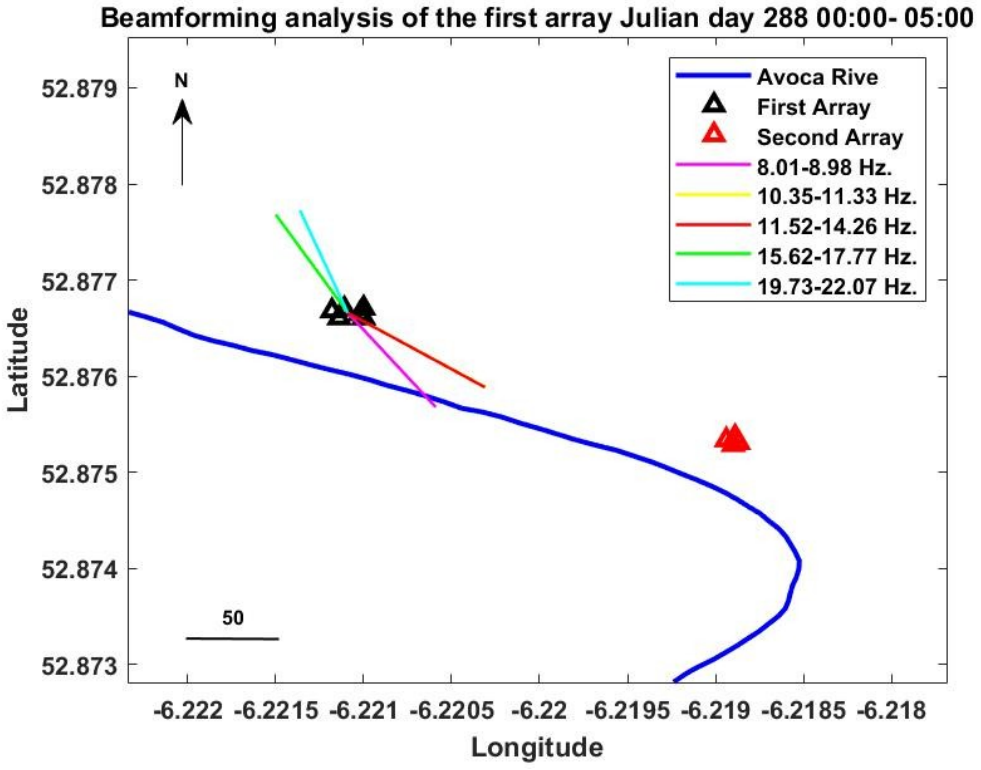
Dominant BAZ and slowness from the First Array, Julian day 288

Frequency [Hz]	Dominant BAZ [º]		Dominant Slowness [s/km]	
	00-08:30	00-05:00	00-08:30	00-05:00
8.01- 8.98	153.21	153	0.2236	0.2236
10.35- 11.33	179.84	134.61	0.2236	0.1414
11.52- 14.26	134.90	134.69	0.4472	0.4
15.62- 17.77	147.034	338.18	1.2042	0.5831
19.73- 22.07	345.75	345.54	1.5	1.5524



Beamforming Result: First Array- Julian day 288

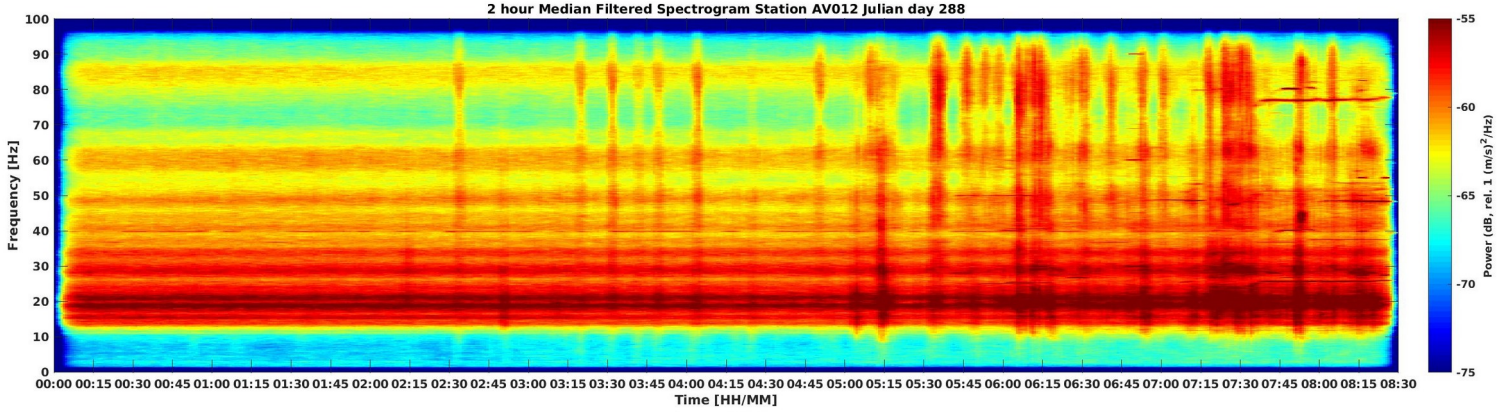




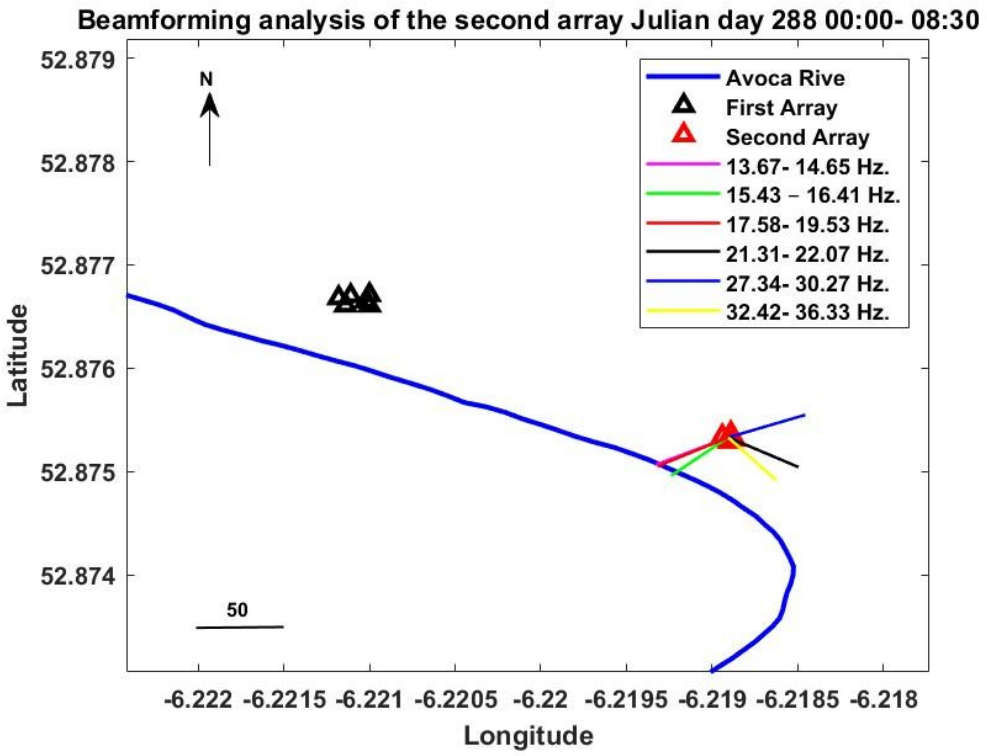
The frequency 10.35-11.33, 15.62- 17.77 and 19.73- 22.07 Hz. are **not** river-induced as they show different BAZ in different times.

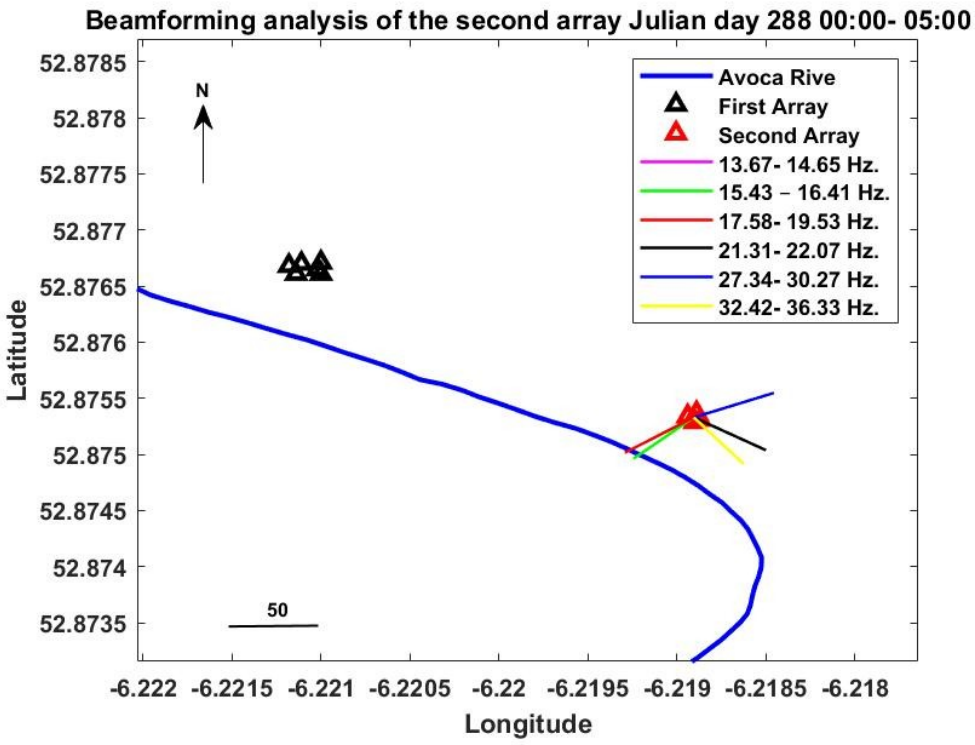
Dominant BAZ and slowness from the Second Array, Julian day 288

Frequency [Hz]	Dominant BAZ [º]		Dominant Slowness [s/km]	
	00-08:30	00-05:00	00-08:30	00-05:00
13.67- 14.65	238.81	231 239	0.6403	0.64031
15.43 – 16.41	222.73	225	1.9105	1.8439
17.58- 19.53	236.76	241.8	3.3121	3.3616
21.31- 22.07	125.80	123.55	5.4203	5.5218
27.34- 30.27	64.10	65.21	5.2801	5.2802
32.42- 36.33	146.01	146.49	3.8079	5.5218



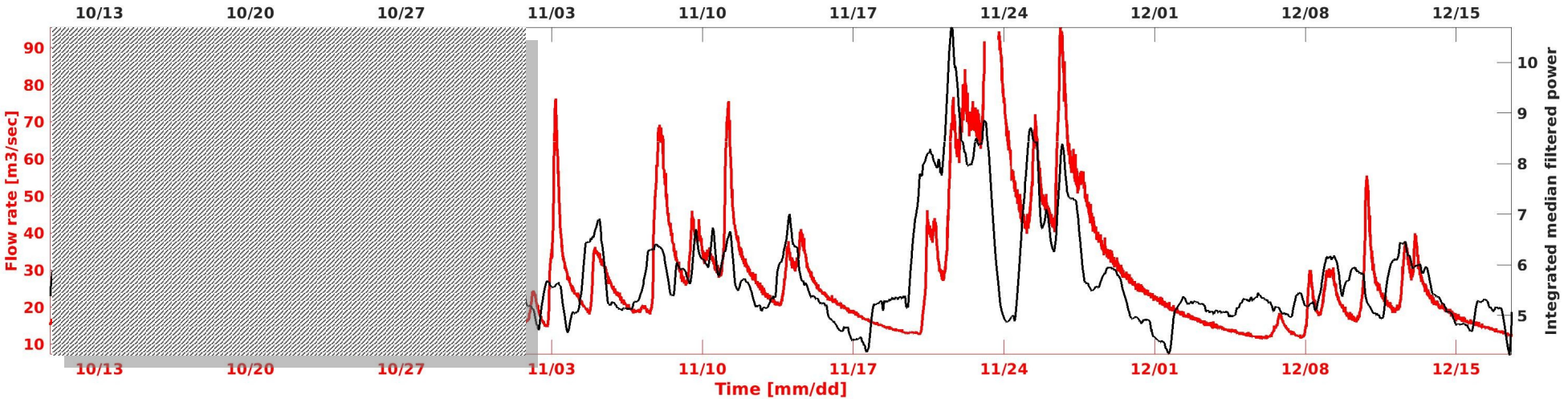
Beamforming Result: Second Array- Julian day 288





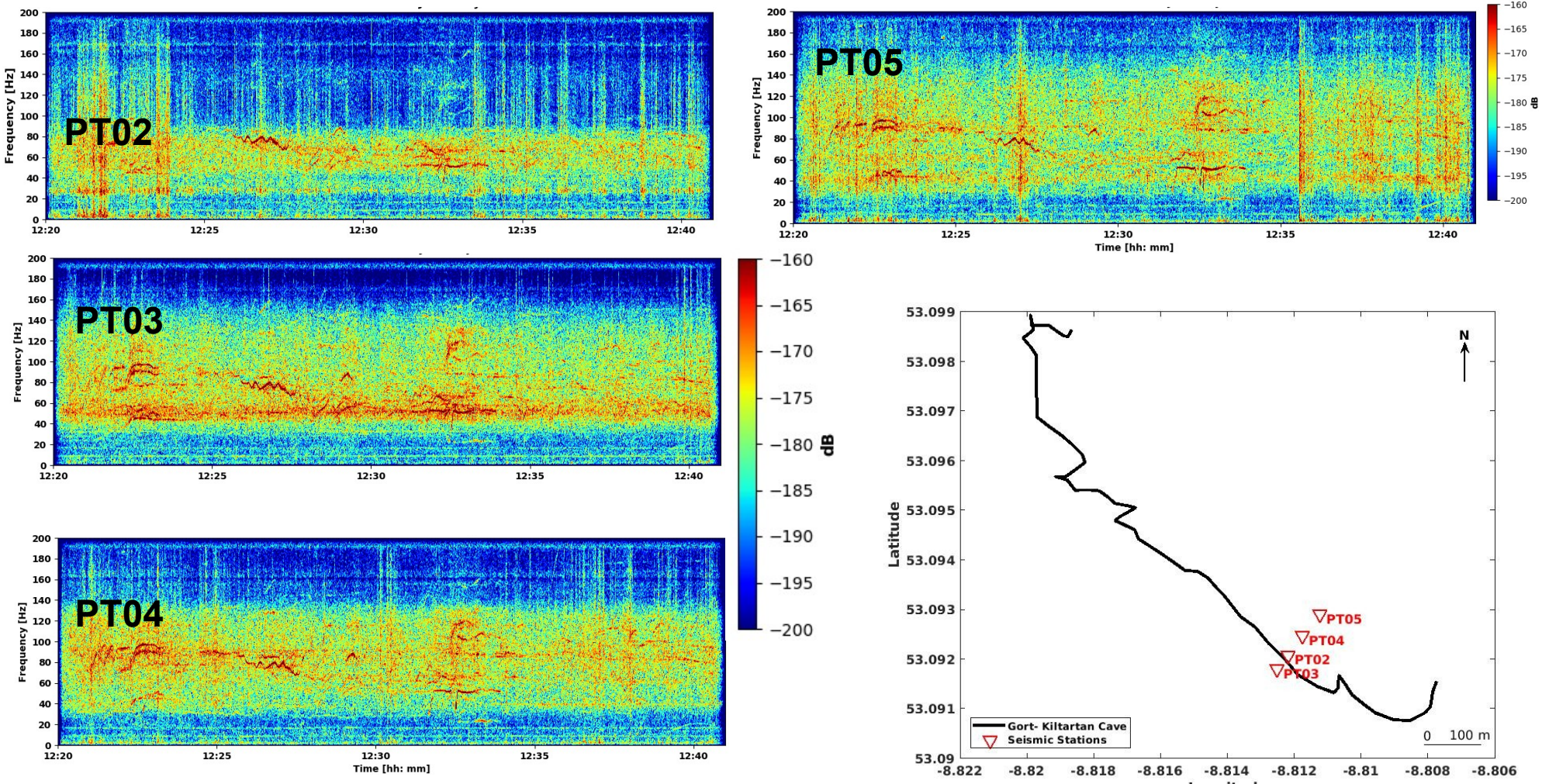
The frequency 21.31- 22.07, 27.34- 30.27 and 32.42- 36.33 Hz. are **not** river-induced as shown by BAZ.

Flow Rate vs. Seismic signal at WhiteBridge EPA monitoring gauge



Tremor amplitude is calculated as the integrated power in the frequency range 11.91-13.28 Hz. for Julian day 283- 351. The shaded area shows the time interval when the seismic data were highly contaminated by cultural noise due to a nearby construction site.

Noise Test on a Karst landscape- Gort- Kiltartan



Conclusions

- Surface and subterranean water-flow induces continuous ground vibrations.

- We determined frequency ranges associated with the water-flow based on the sustained frequency components on the median filtered spectrograms. In the next step, we excluded non-flow related signal using array-analysis based on beamforming.

- By deploying several seismic stations as dense arrays, it was possible to locate the source of the signal by performing beamforming through joint determination of the direction of back-azimuth (BAZ) and slowness.

- Tremor amplitude in the frequency range of interest is correlated with river water-level and flow-rate.

- The interpretation of the interesting features seen on the spectrograms of the Karst site needs a larger-scale deployment including more instruments and dense arrays.

- We look forward to having the main deployment on Irish Karst after the lock-down.