UNIVERSITÉ CÔTE D'AZUR

3iA Côte d'Azur
Interdisciplinary Institute for Artificial Intelligence

A self-supervised Deep Learning approach for blind denoising of Distributed Acoustic Sensing data

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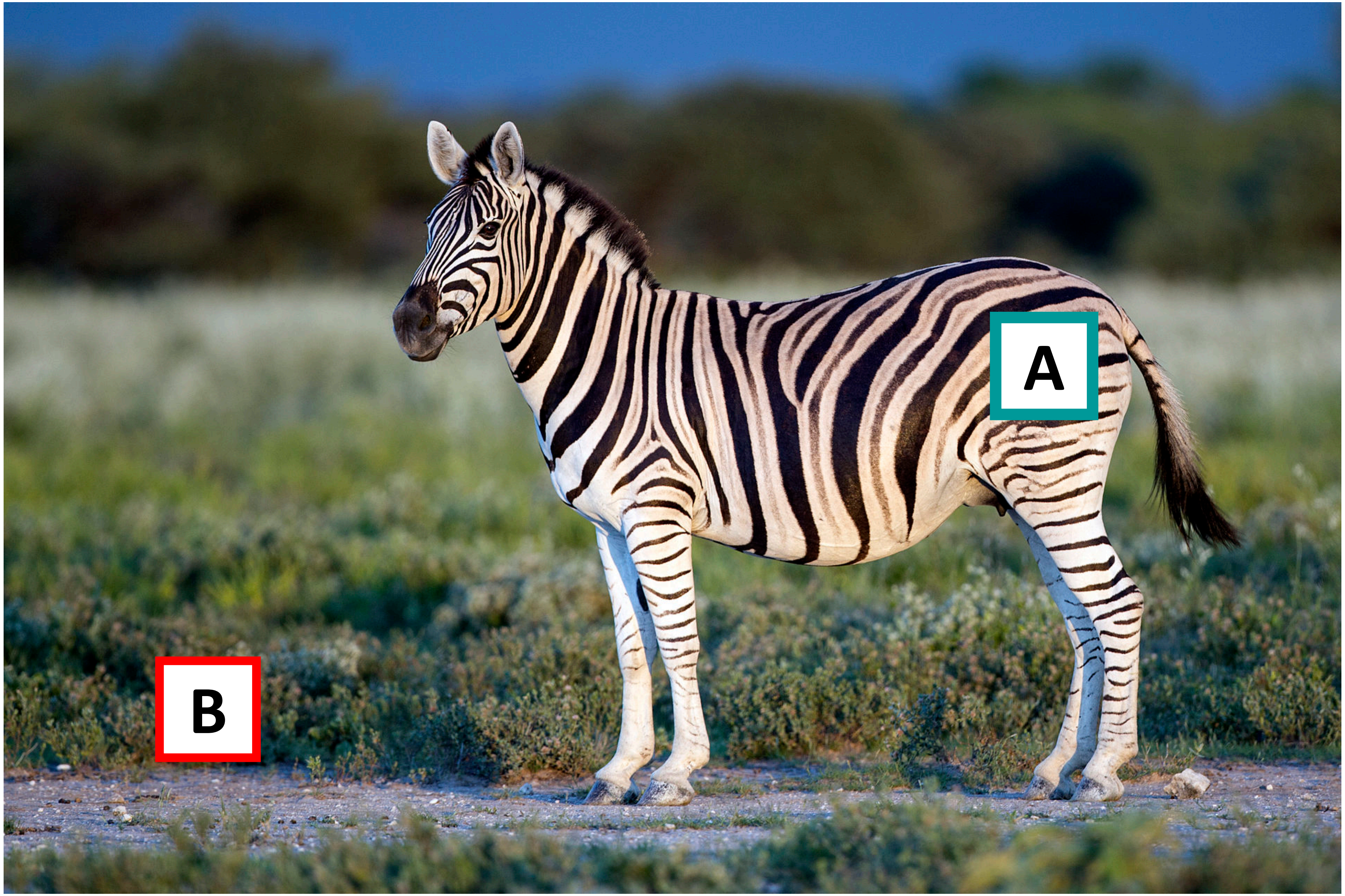
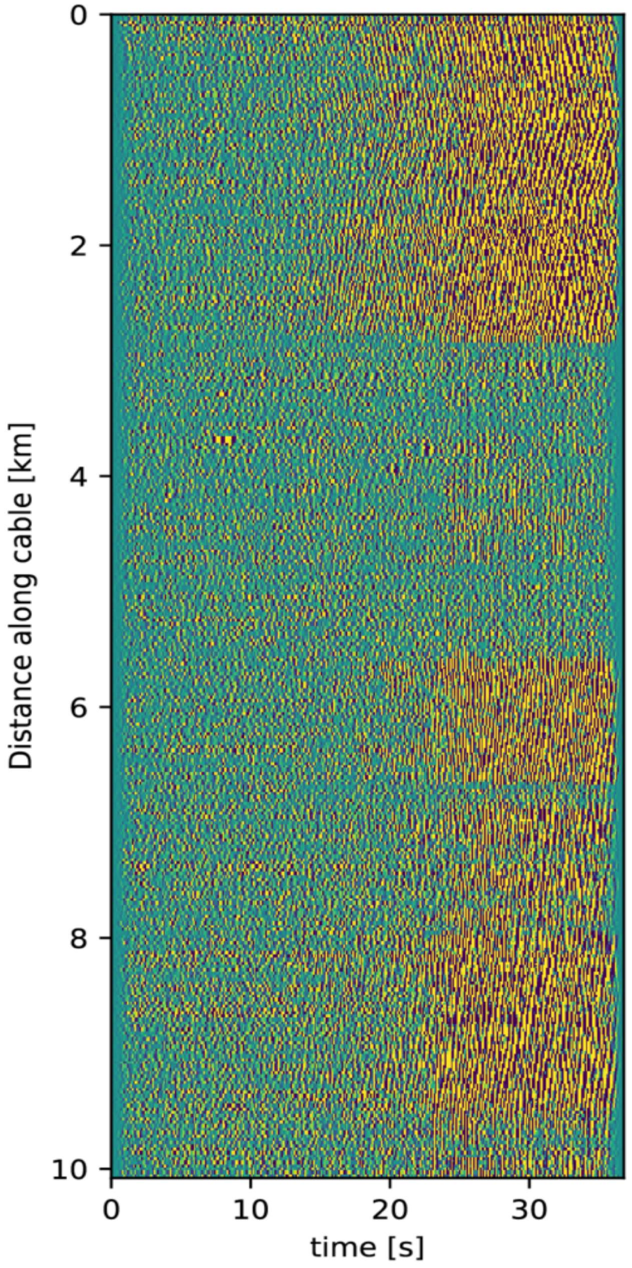

A
B

J-invariance (Batson & Royer, ICML '19)

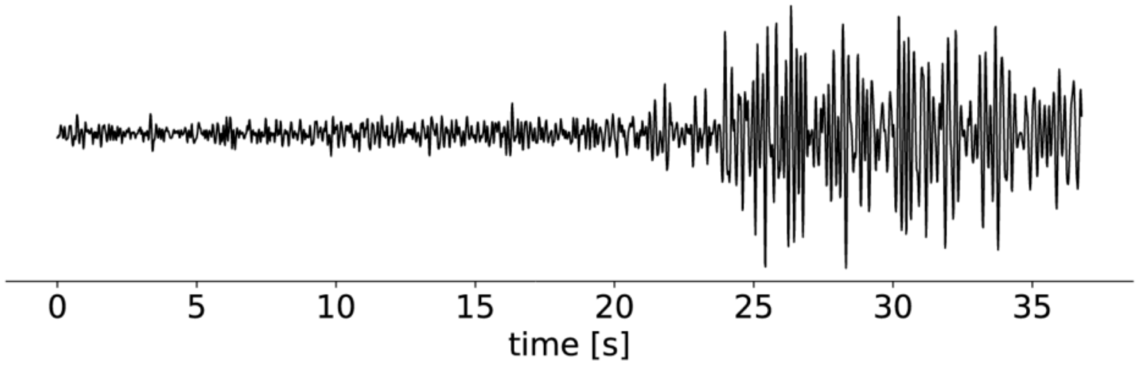
- Suppose we have an input z, for which we can define a partition J
- A J-invariant function $g(z)_J$ is one for which the output does not depend on z_J ("z *restricted to* J") for all z and partitions J
- Zebra example: input z is the picture of the zebra, J is a patch of pixels, and $g(z)_J$ is the prediction of the contents of J

Concept

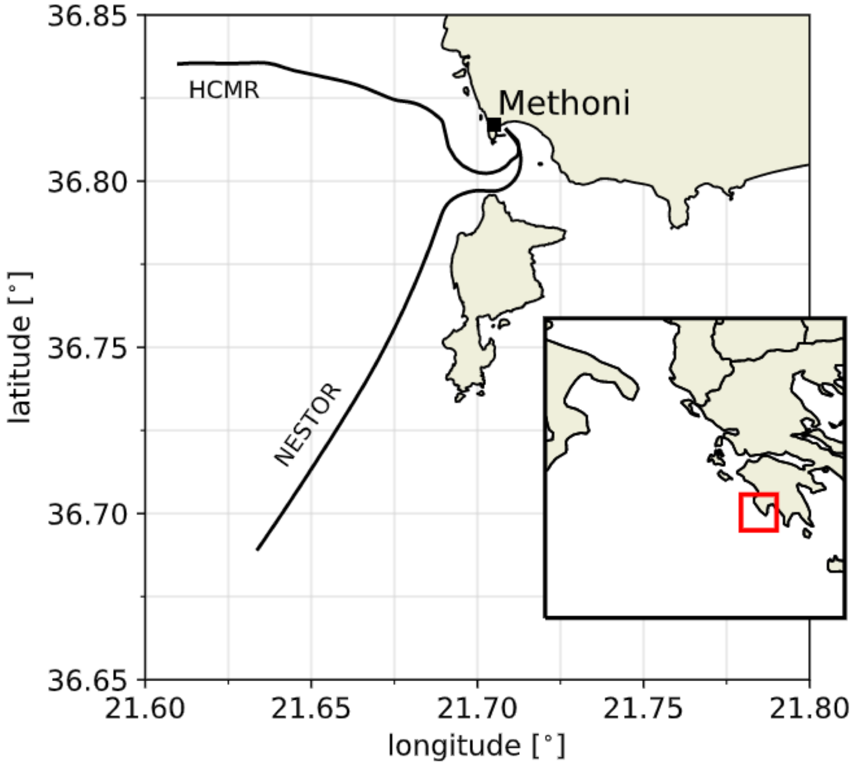
- Many interesting signals recorded with Distributed Acoustic Sensing are coherent in space and time (earthquakes, ocean waves)
- Incoherent noise (electronic, thermal) can obscure faint signals of interest, and may share a common frequency band
- Separate coherent signals from incoherent noise using J-invariance

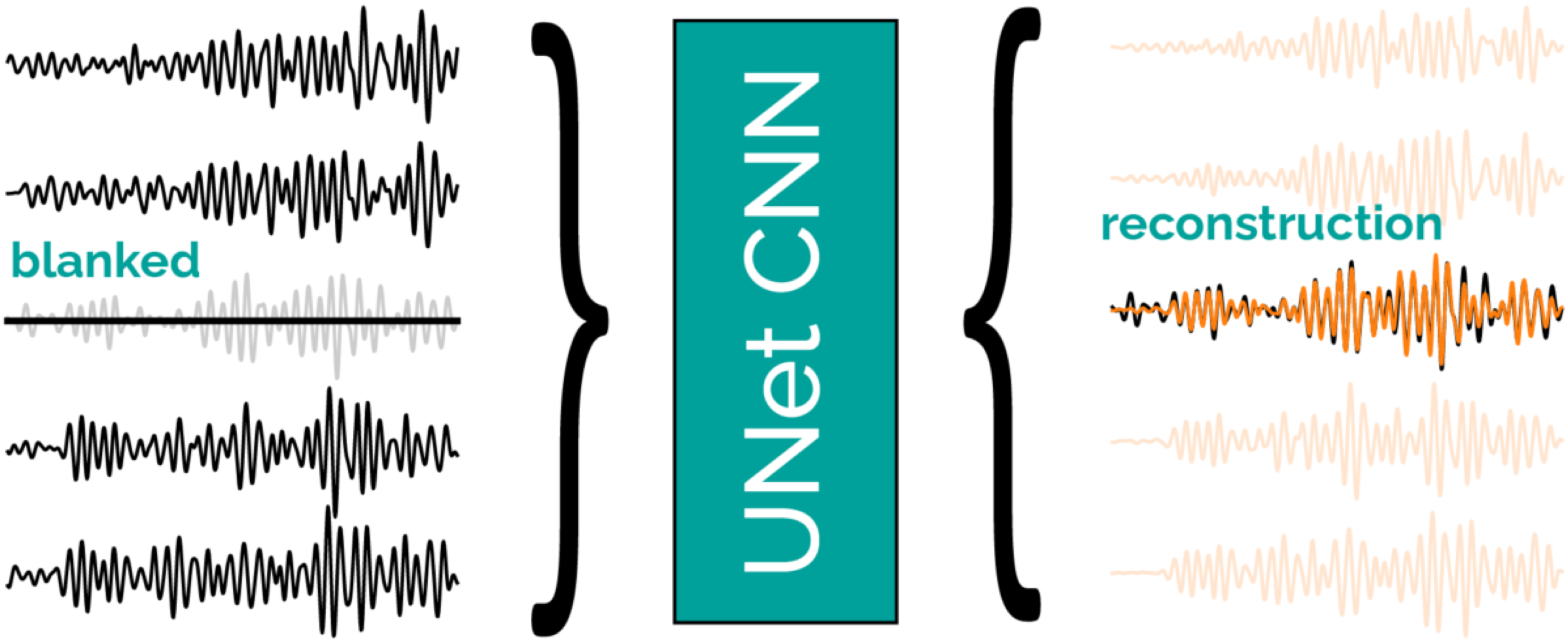


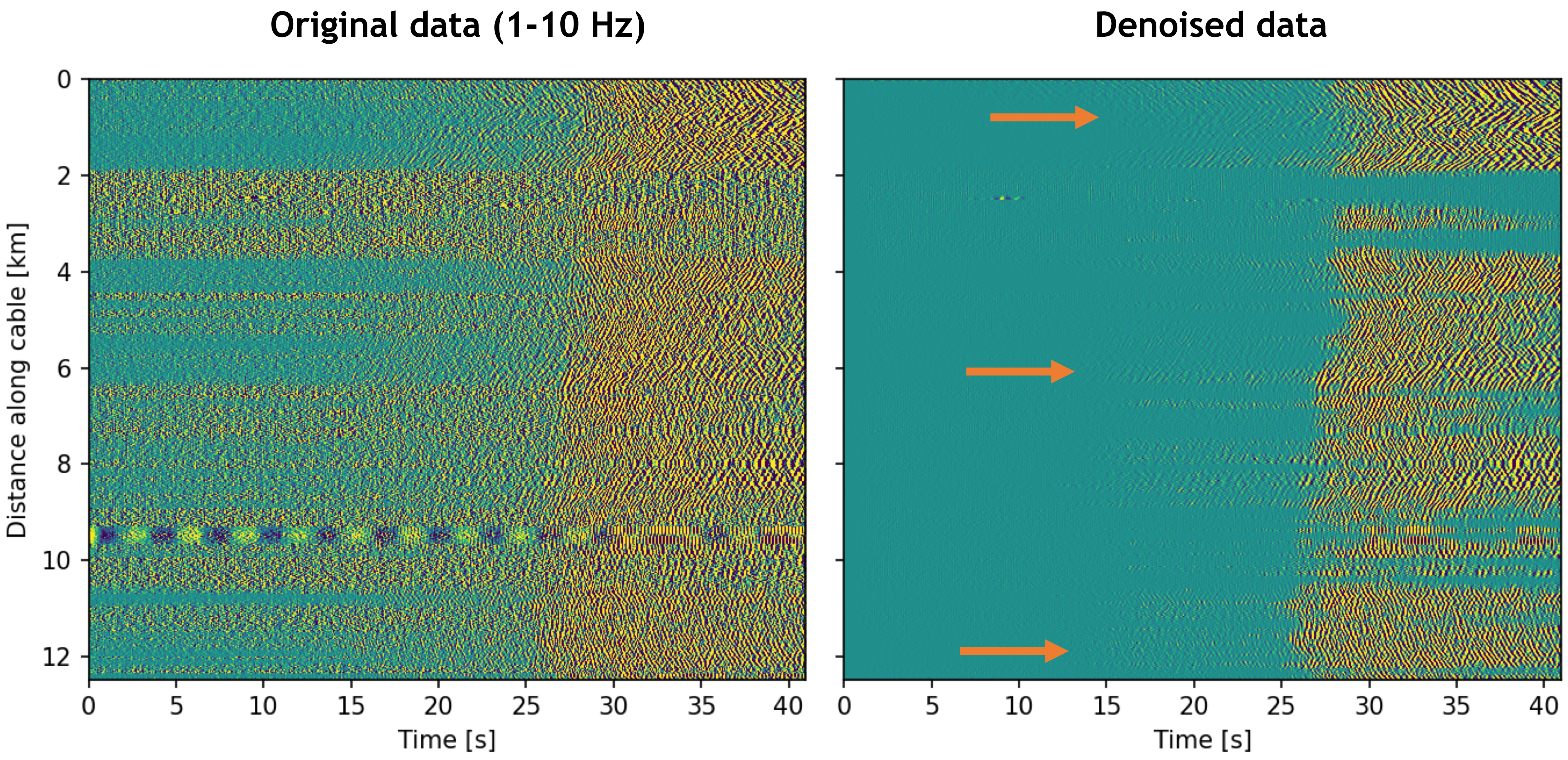
DAS data

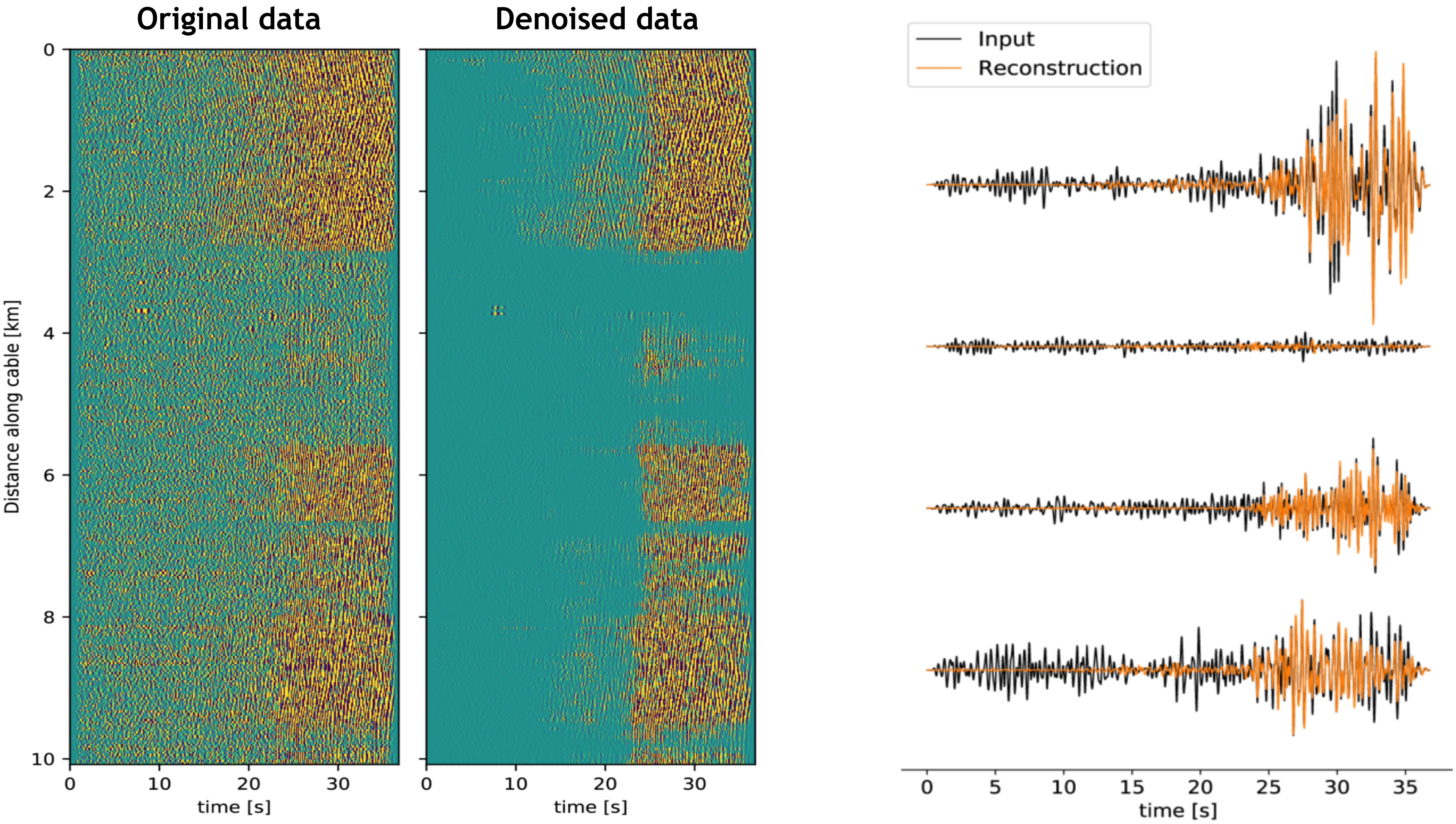


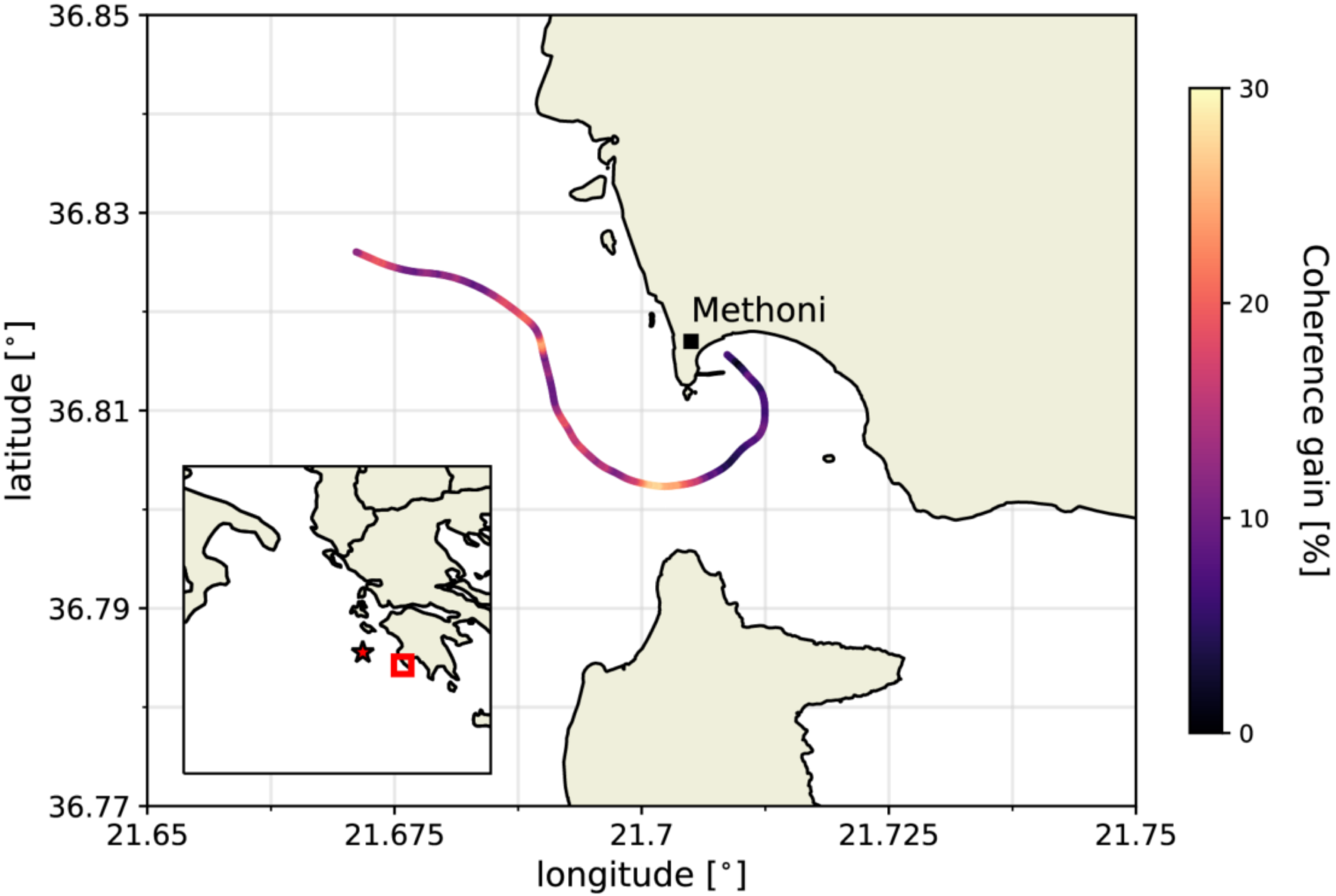
- Two DAS experiments (18-25 April 2019): HCMR and NESTOR
- During the experiment, several earthquakes were recorded
- Basic pre-processing:
  - Bandpass filtering between 1-10 Hz
  - Downsampling to 50 Hz
  - Cropping to 41-second windows

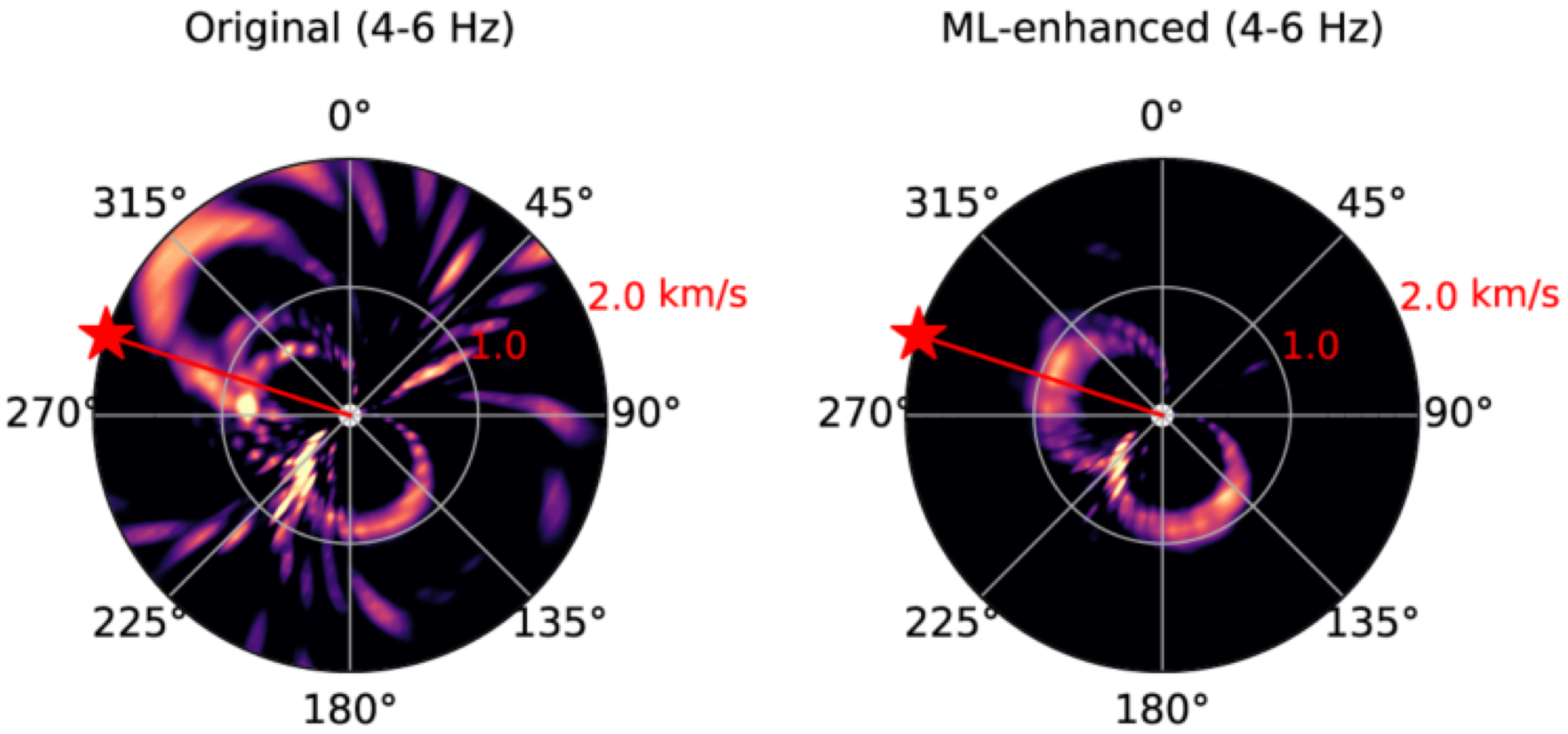



blanked
UNet CNN
reconstruction


Original data (1-10 Hz)
Denoised data
Distance along cable [km]
0
2
4
6
8
10
12
Time [s]
0
5
10
15
20
25
30
35
40
Time [s]
0
5
10
15
20
25
30
35
40


Original data
Denoised data
Distance along cable [km]
0
2
4
6
8
10
0
10
20
30
time [s]
0
10
20
30
time [s]
Input
Reconstruction
0
5
10
15
20
25
30
35
time [s]


36.85
36.83
36.81
36.79
36.77
latitude [°]
21.65
21.675
21.7
21.725
21.75
longitude [°]
Methoni
Coherence gain [%]
0
10
20
30


Original (4-6 Hz)
ML-enhanced (4-6 Hz)
0°
45°
90°
135°
180°
225°
270°
315°
2.0 km/s
1.0

Conclusions

- Our approach is entirely self-supervised, no “clean” ground truth needed (not available for DAS)
- The Deep Learning model is fast to train and requires little data
- The method separates signals from incoherent noise that share the same frequency band based on spatio-temporal coherence
- Signal coherence improves, which facilitates coherence-based seismological techniques, such as beamforming and template matching

Try it yourself!

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Jupyter notebooks (Python) are available at:

doi.org/10.6084/m9.figshare.14152277

A preprint describing the method is available at:

doi.org/10.31223/X55K63