Neural Implicit Representation Compress Distributed Acoustic Sensing Data

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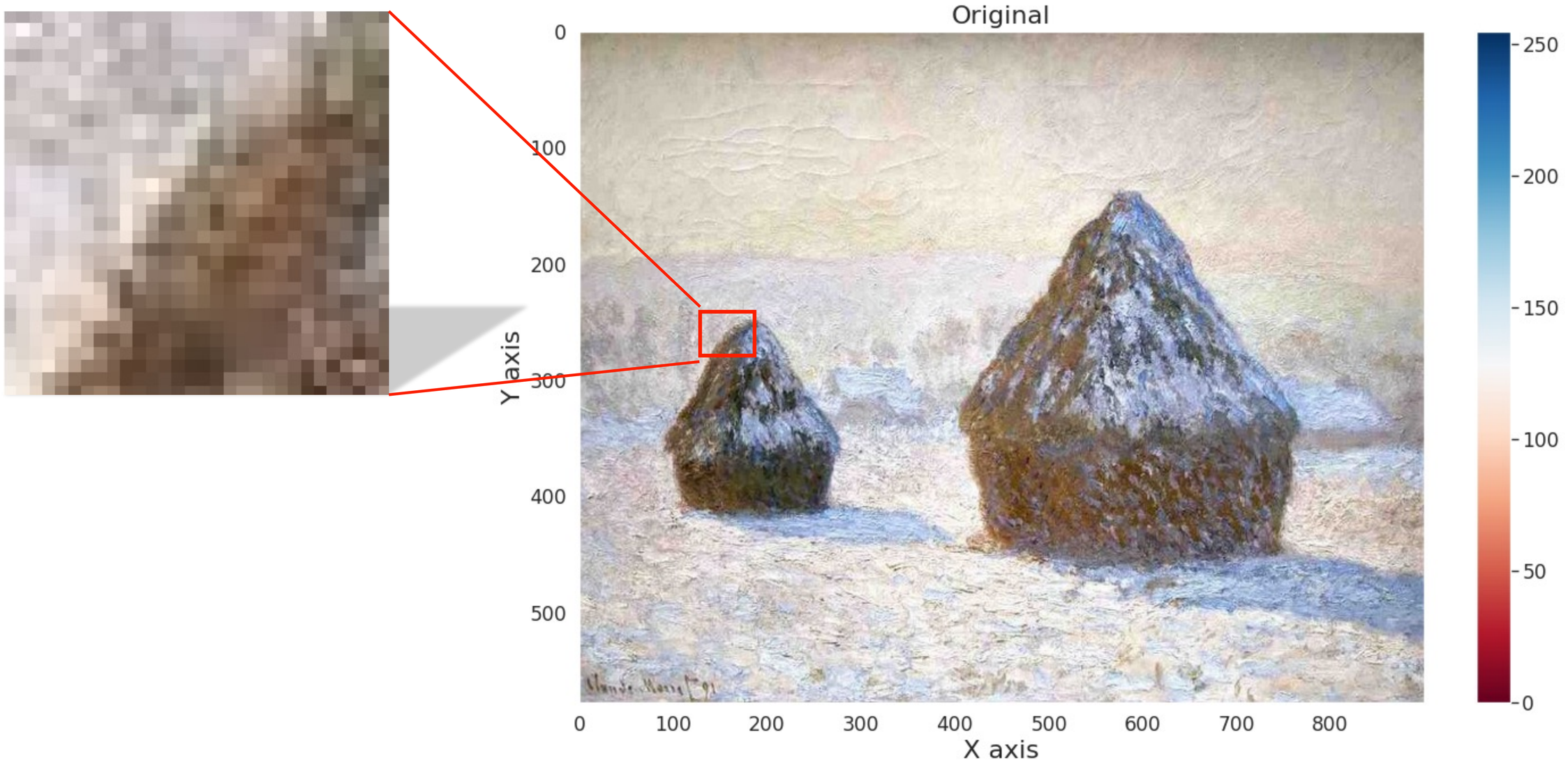
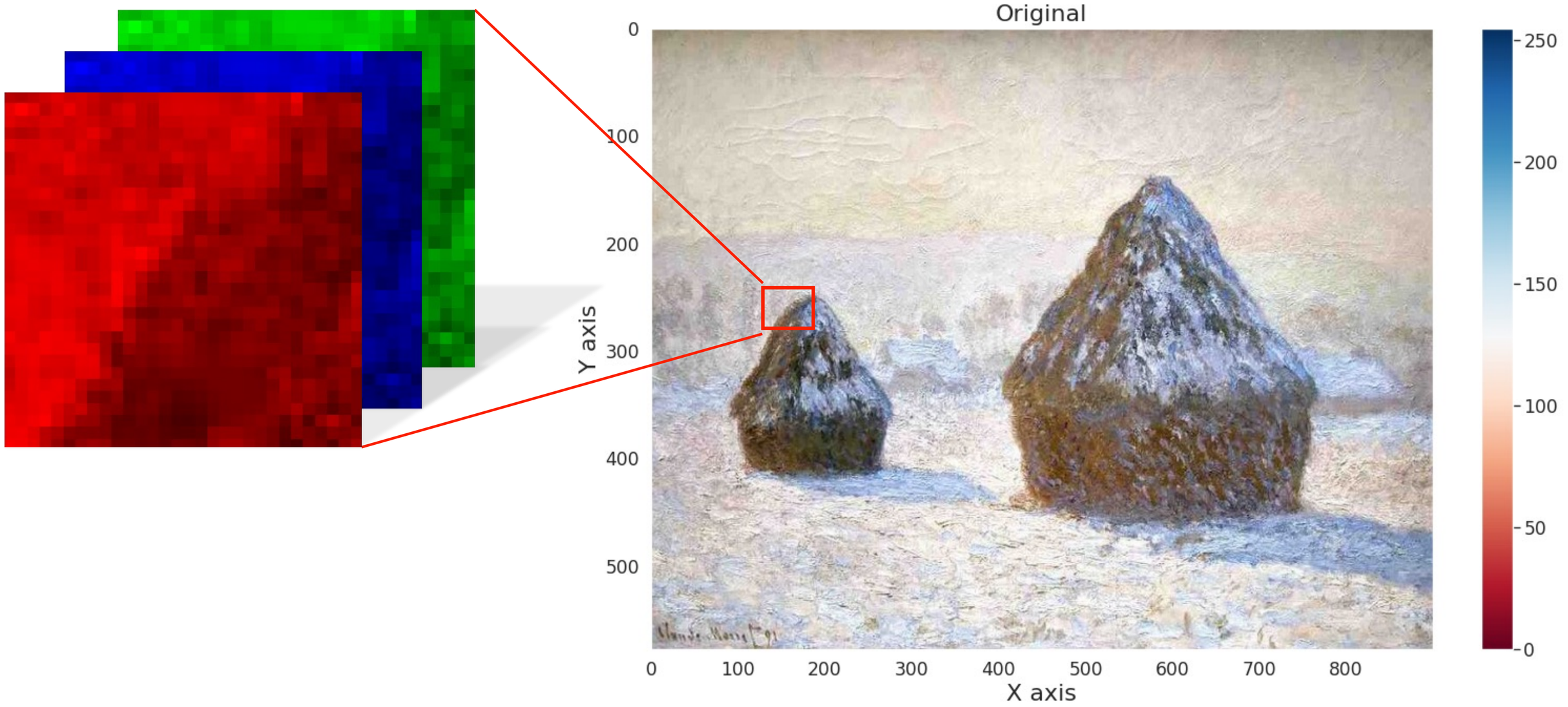
ESS 590C Final Project

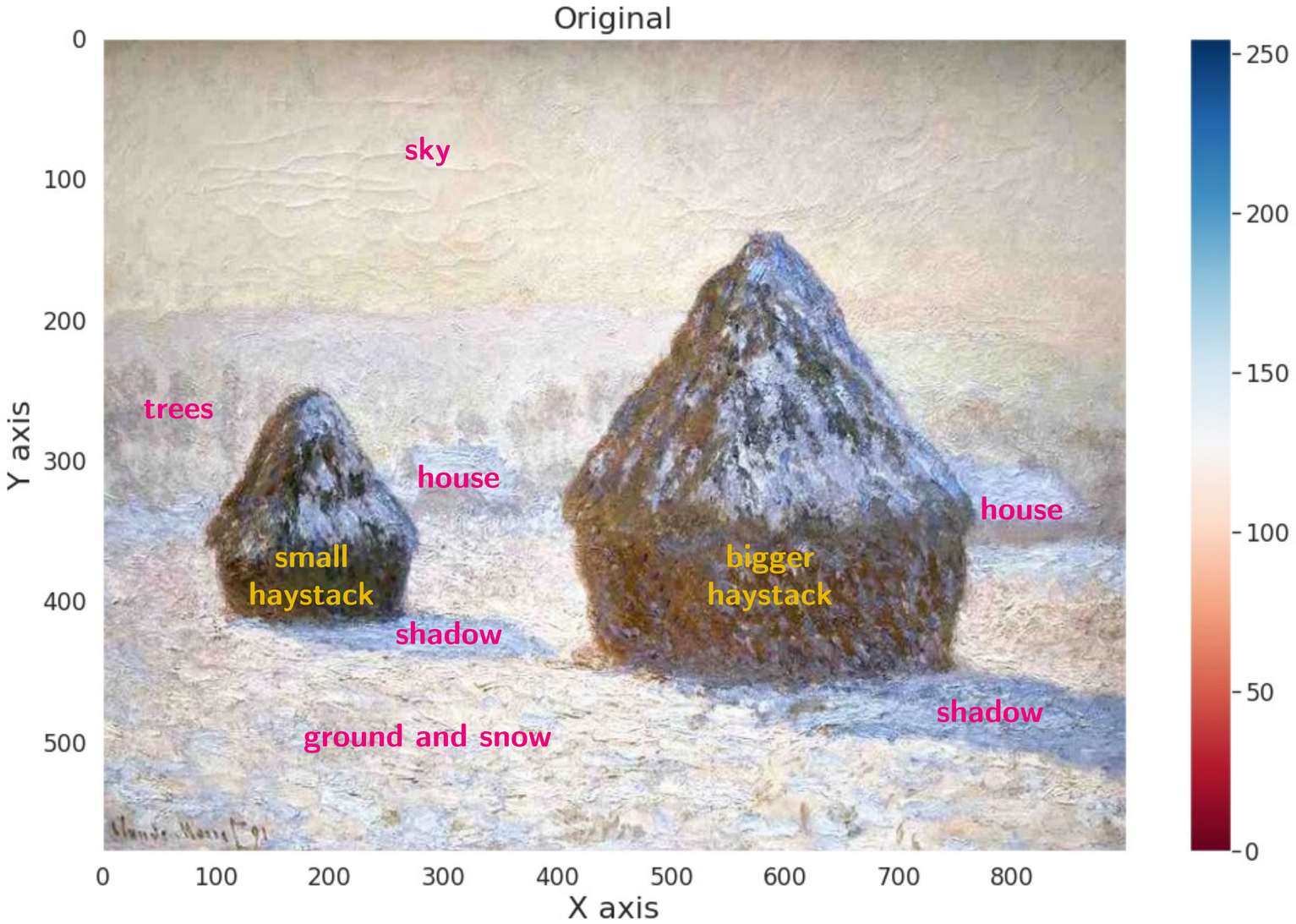
Stack of Wheat



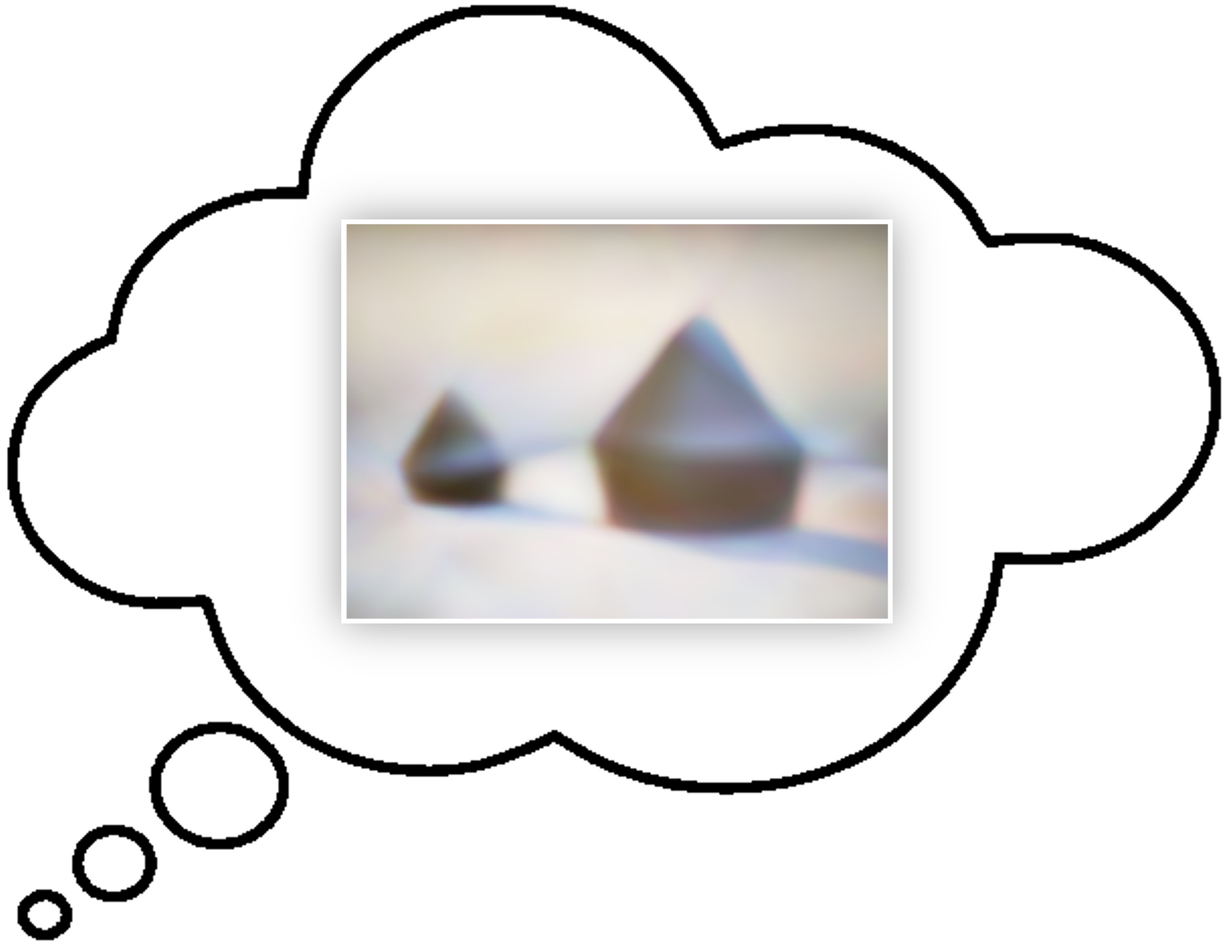
Stack of Wheat



Stack of Wheat



Stack of Wheat



Remembering…

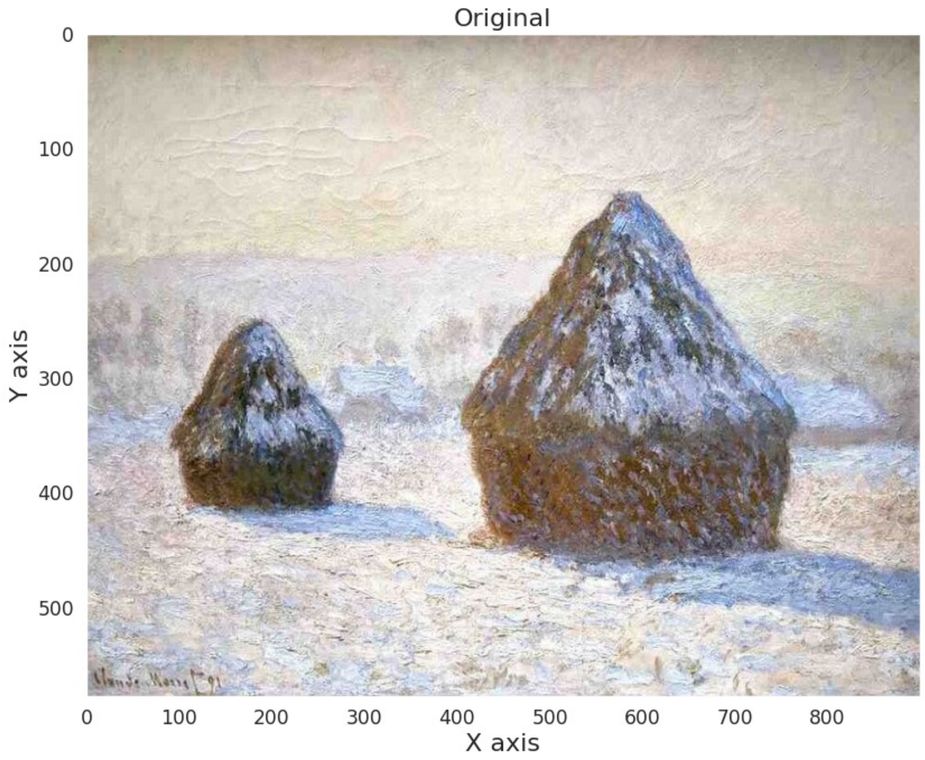
Stack of Wheat

Remembering...
More learning...

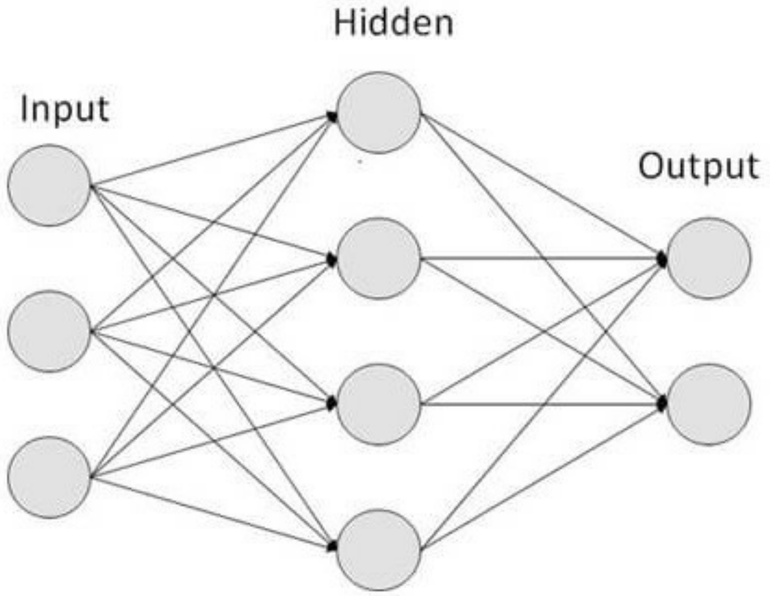
Stack of Wheat

Remembering...
More learning...
And more...

Stack of Wheat



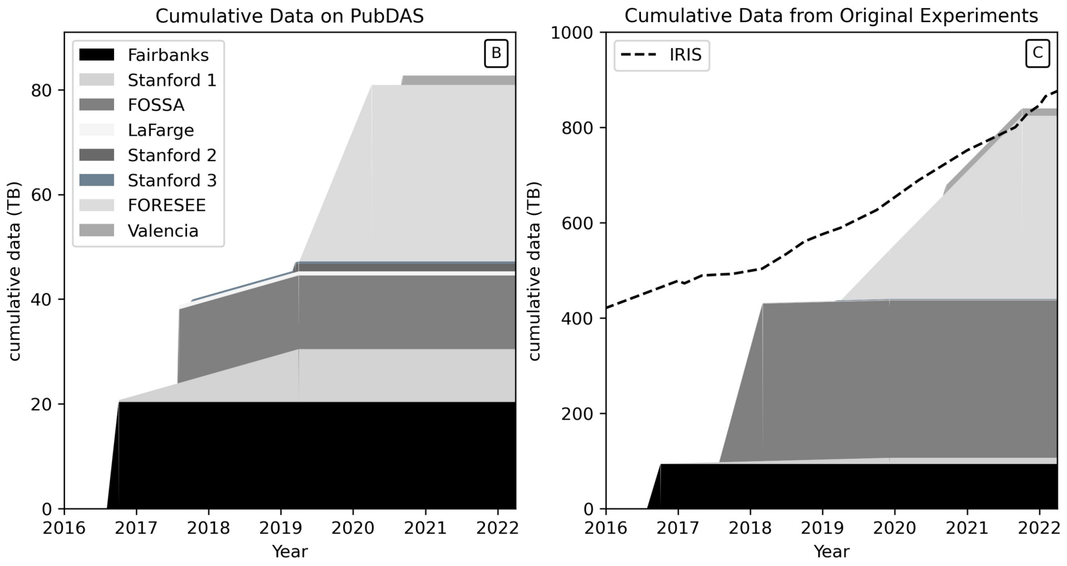
$f_\theta(x, y)$

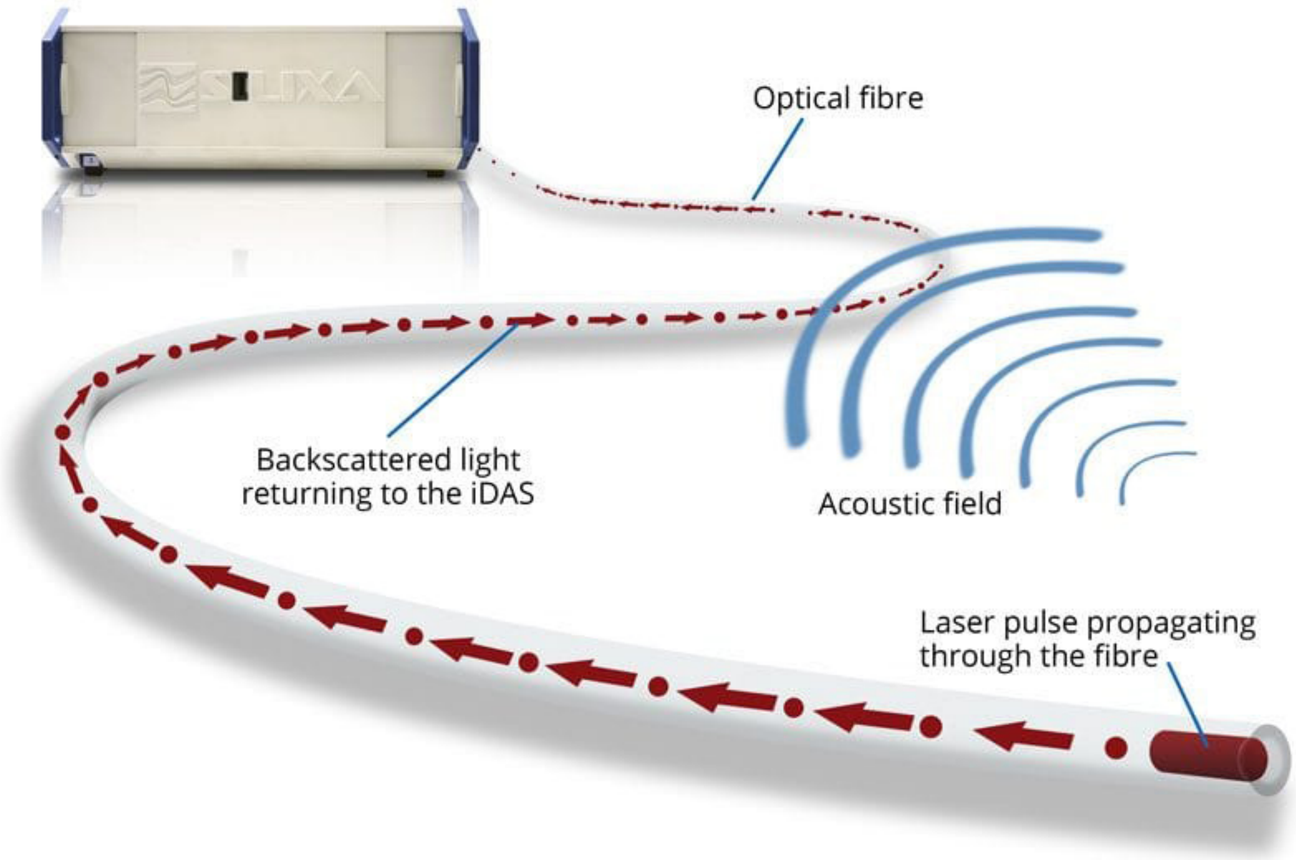


Neural Implicit Representation (NIR)
simulate this learning and
remembering process.

Distributed Acoustic Sensing

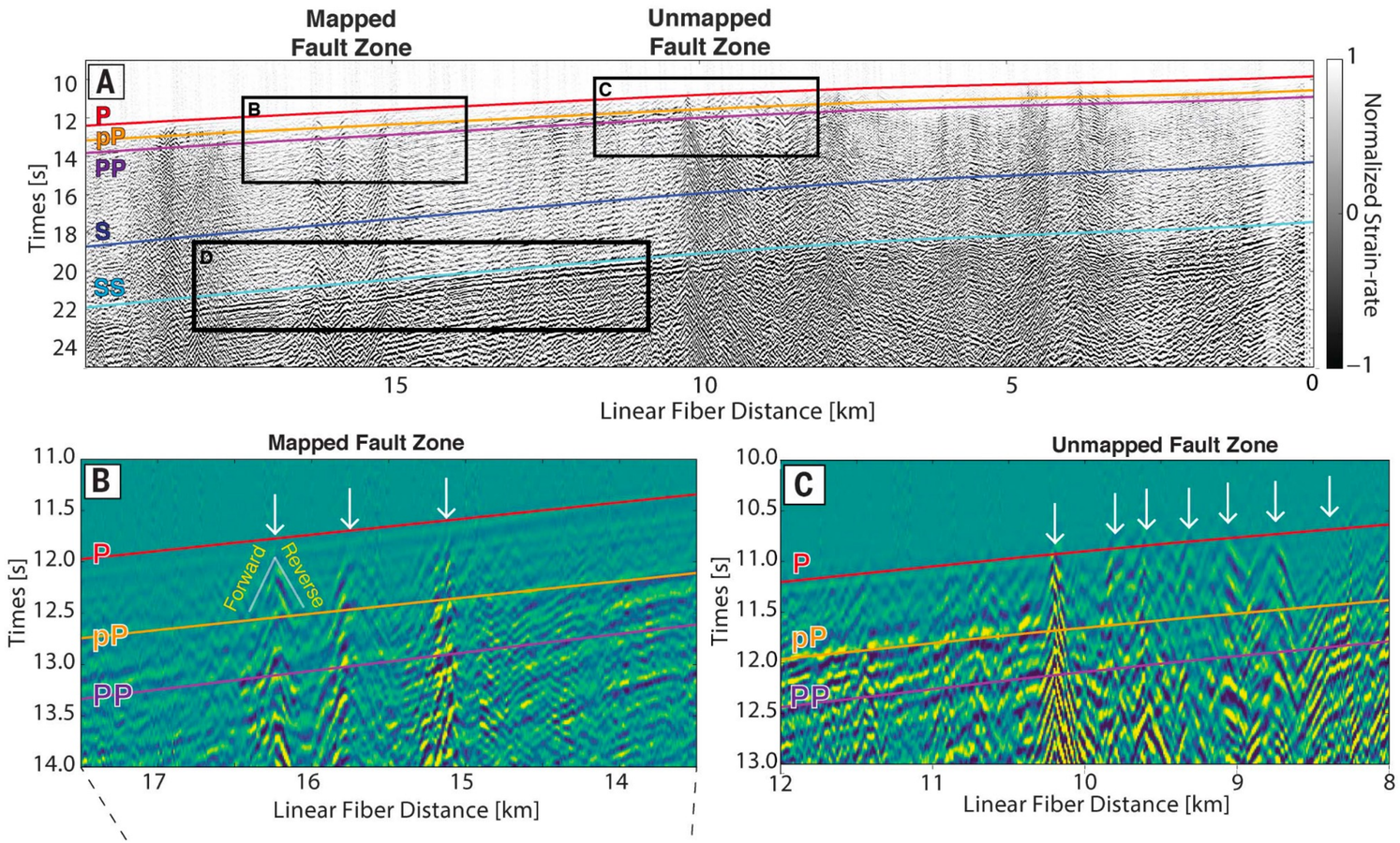
- Strain (rate) measurement along an existing dark fiber using repeated laser pulse.
- Dense sample in time (100~2000 Hz) and space (~2 meter).
- Large data generating rate.

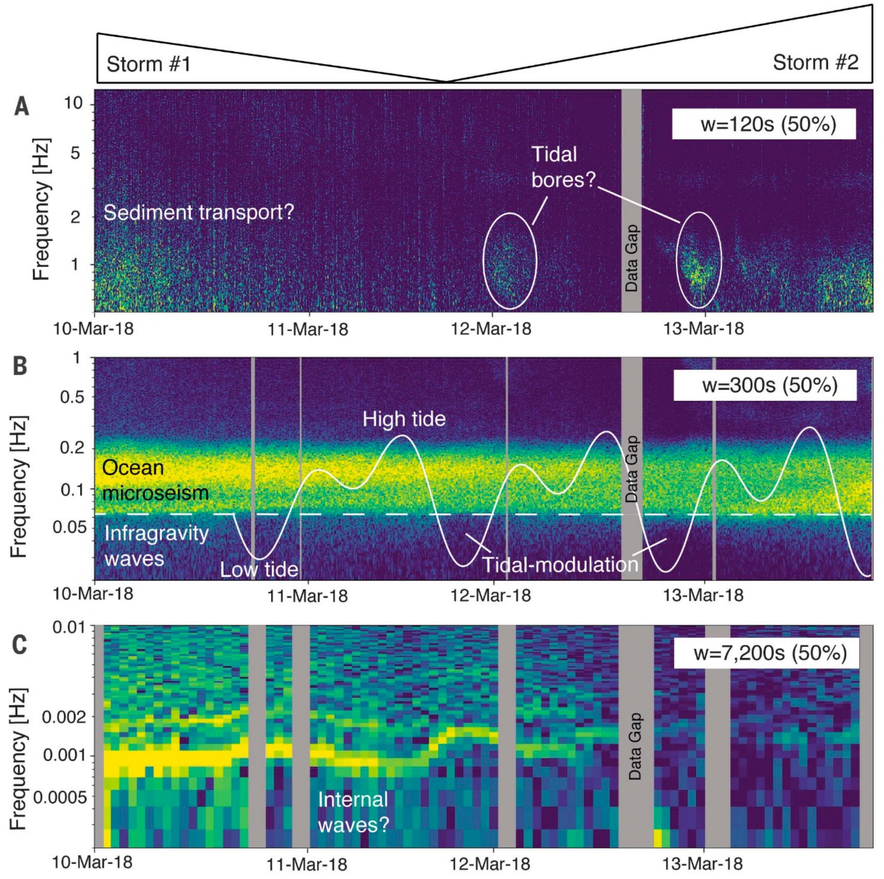




Spica et al., 2022

Distributed Acoustic Sensing

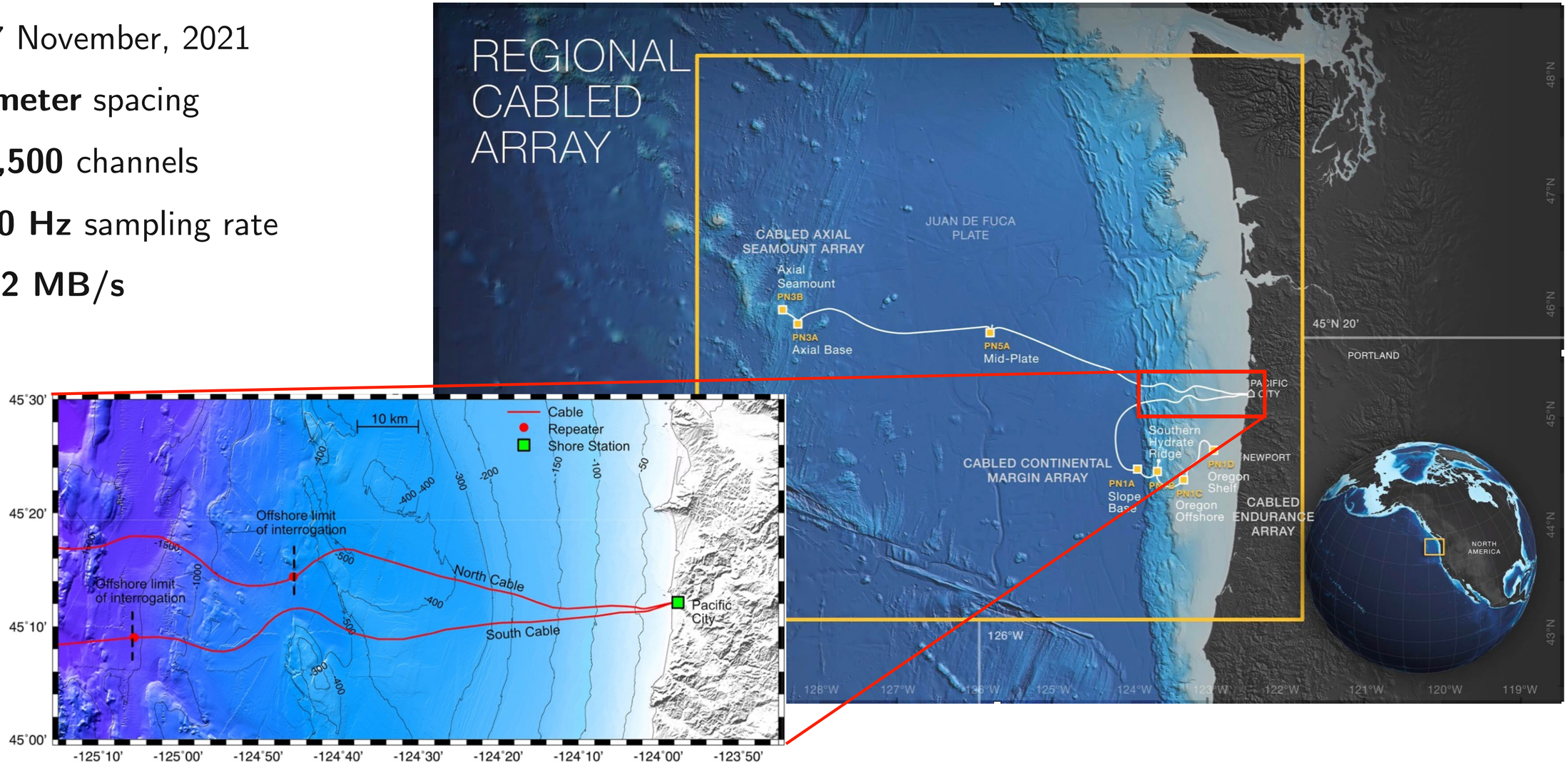




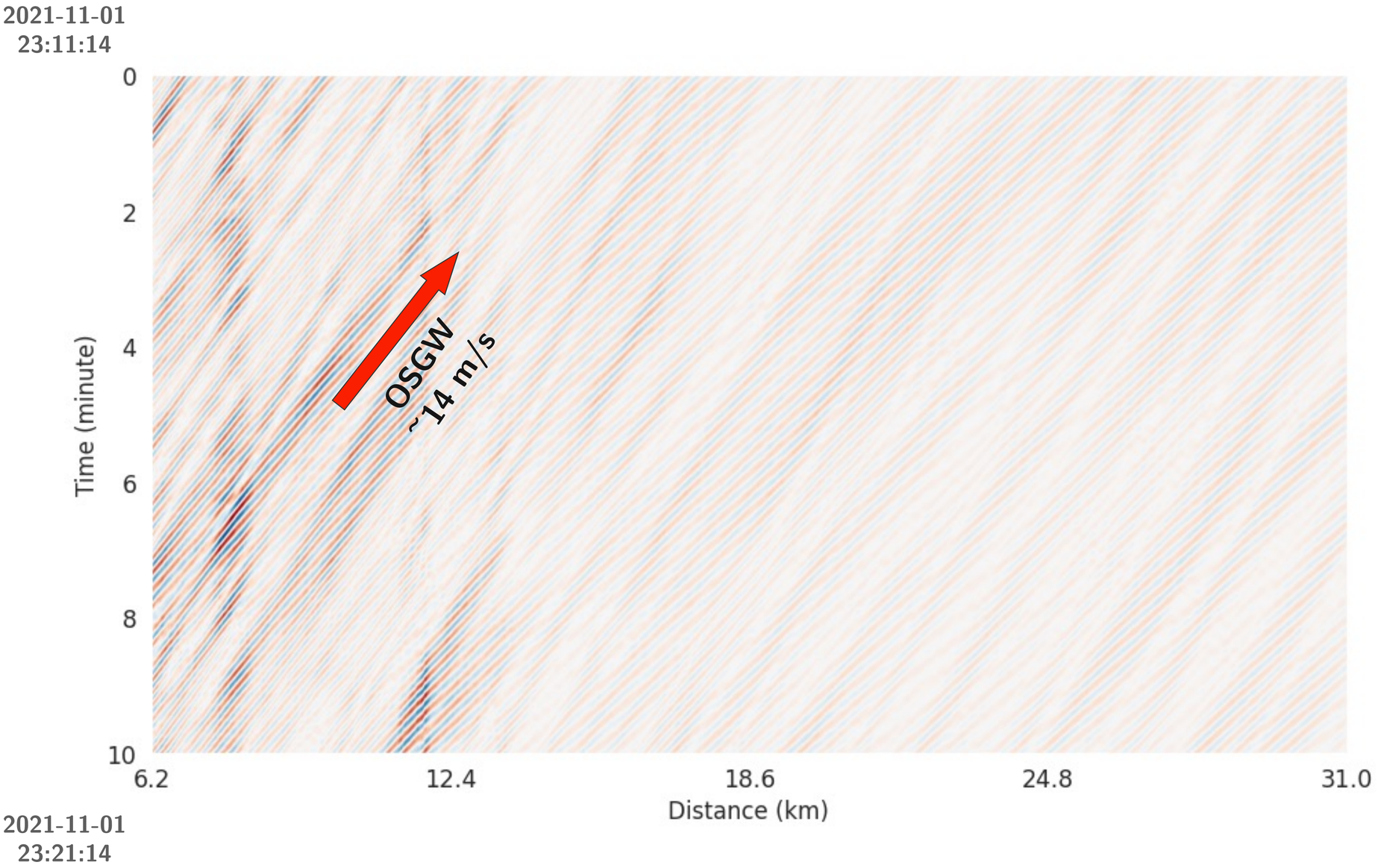
Lindsey et al., 2019

OOI DAS

- 1-7 November, 2021
- **2-meter** spacing
- **47,500** channels
- **200 Hz** sampling rate
- **~72 MB/s**



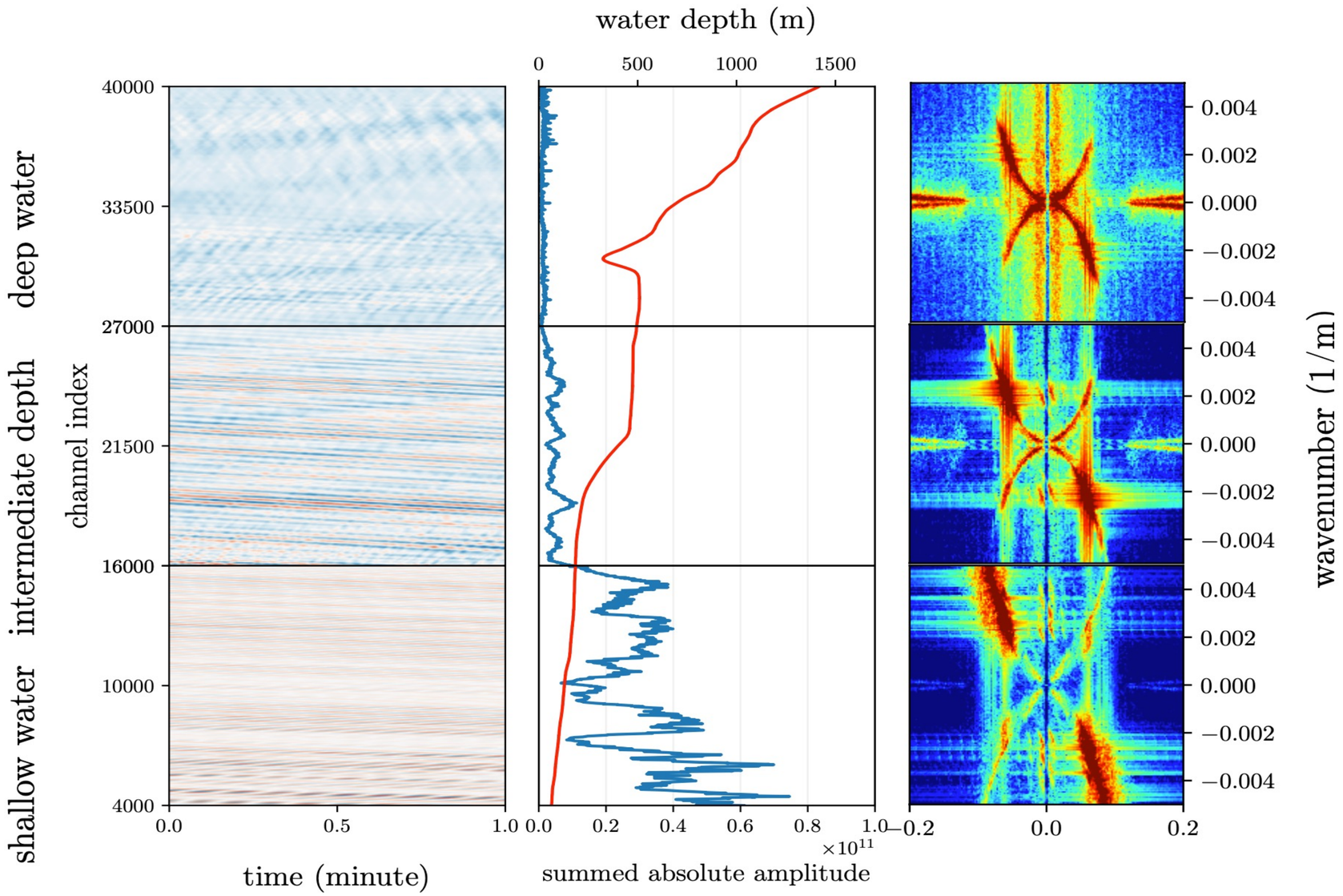
OOI DAS



$$\in \mathbb{R}^{1250\times1500}$$

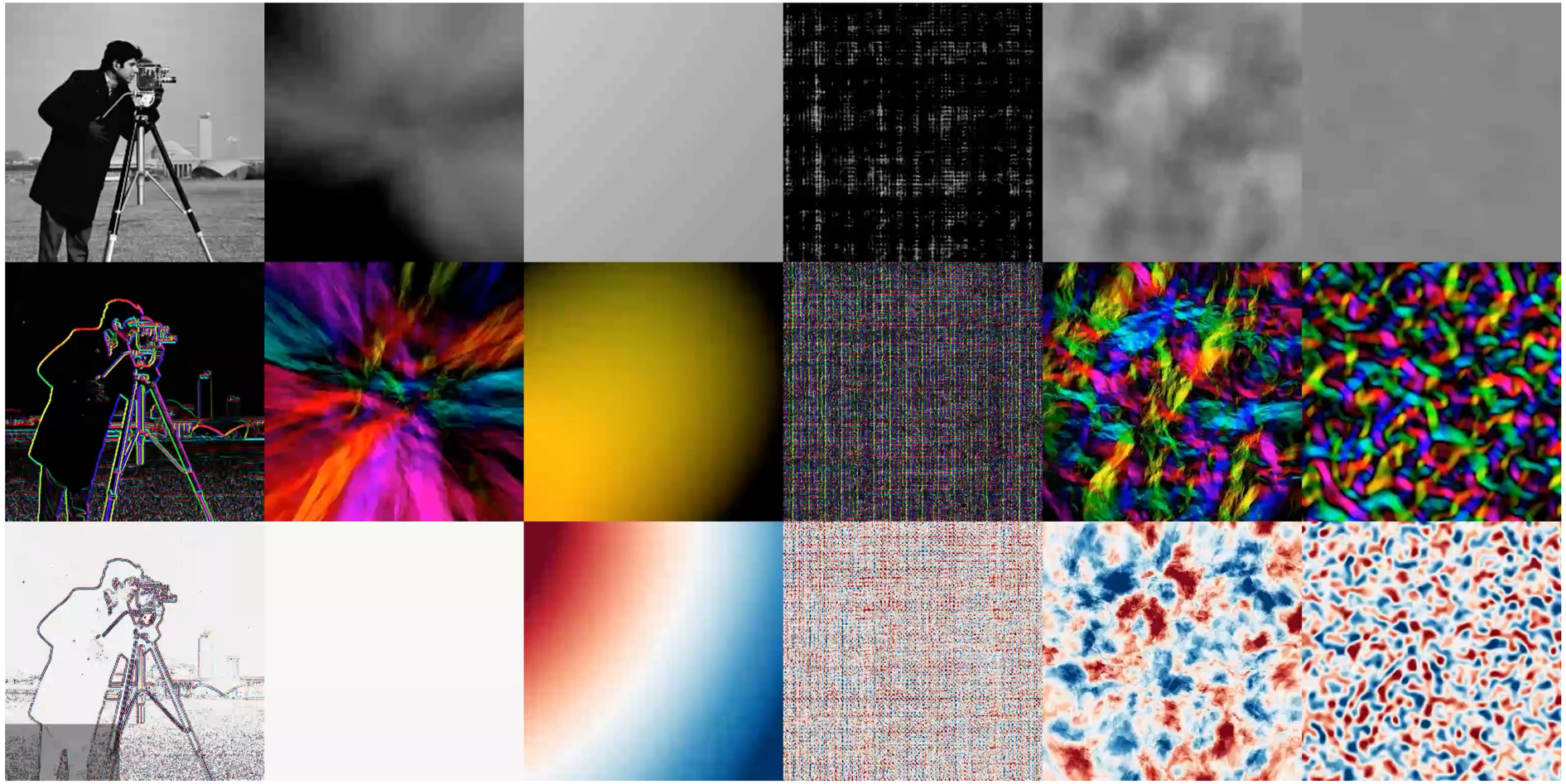
- Down-sample in special and temporal domain.
- Demean by channel.
- Concatenate 10-minute data.

OOI DAS


water depth (m)
0
500
1000
1500
shallow water
intermediate depth
deep water
channel index
40000
33500
27000
21500
16000
10000
4000
0.0
0.5
1.0
time (minute)
0.0
0.2
0.4
0.6
0.8
1.0
×10^11
summed absolute amplitude
0.004
0.002
0.000
−0.002
−0.004
−0.2
0.0
0.2
wavenumber (1/m)

Methods

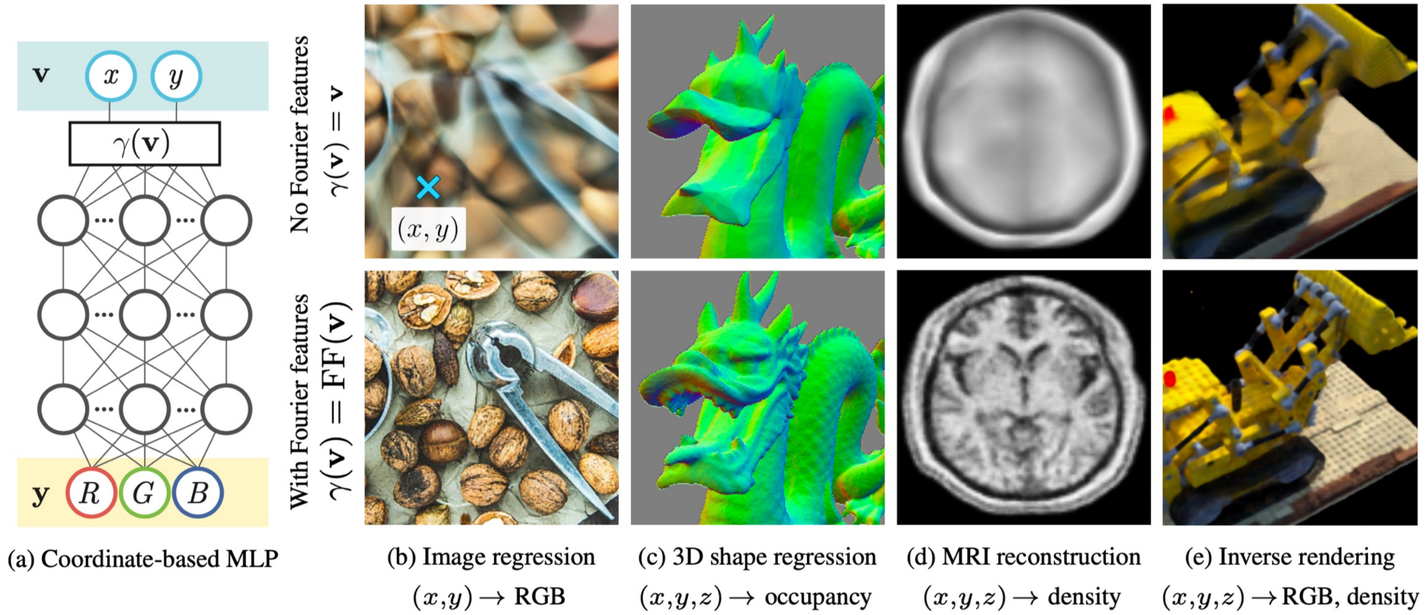
SIREN



Sitzmann et al., 2020

Methods

RFFN



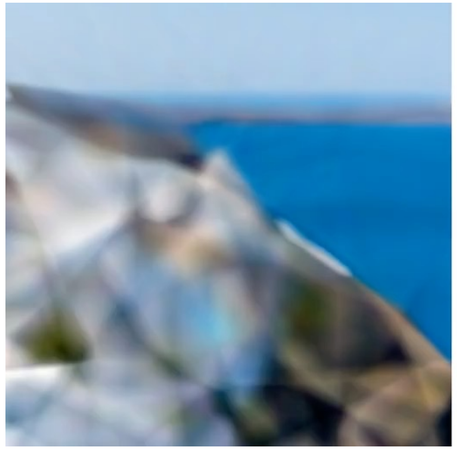
(a) Coordinate-based MLP

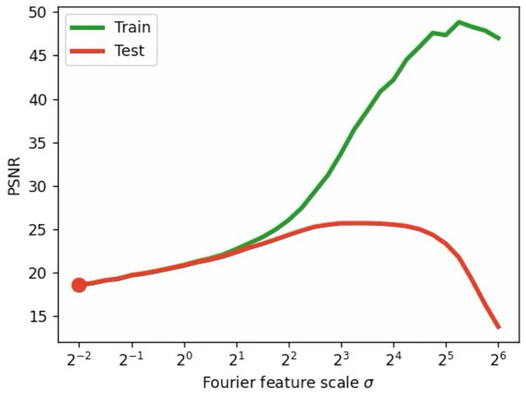
(b) Image regression
$(x,y) \rightarrow$ RGB

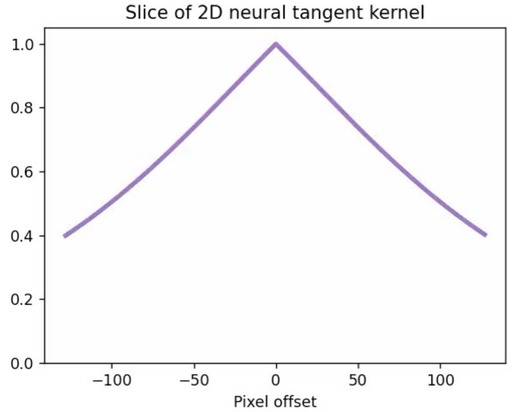
(c) 3D shape regression
$(x,y,z) \rightarrow$ occupancy

(d) MRI reconstruction
$(x,y,z) \rightarrow$ density

(e) Inverse rendering
$(x,y,z) \rightarrow$ RGB, density



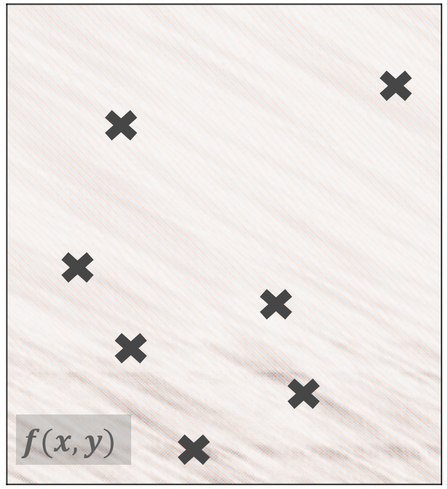




Tancik et al., 2020

Methods

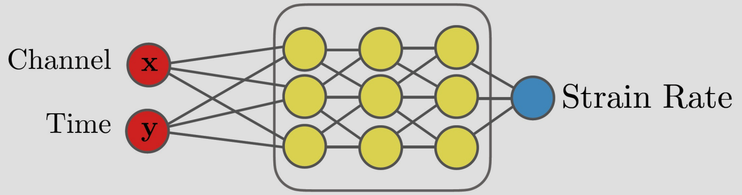
Original Data



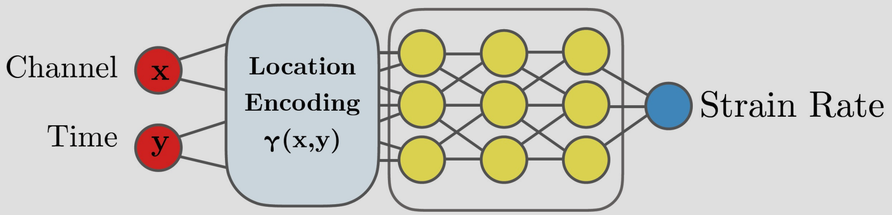
86 MB

ML training

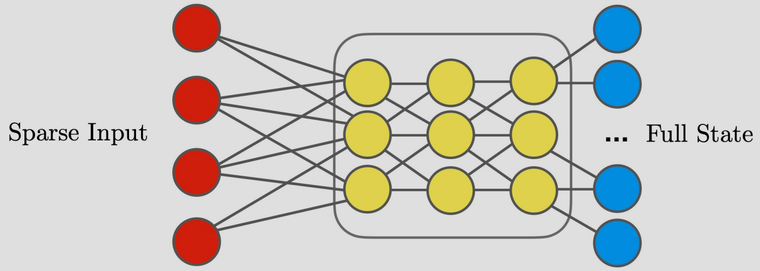
SIREN



Random Fourier Feature Network



Shallow Decoder Network



Reconstruction

Training

- 1x A100 GPU (80 GB)
- PyTorch v1.13.0
- MSE loss function
- Stop training when loss < 1e-4

- **RFFN**
  1. Adam optimizer
  2. 5e-4 learning rate
  3. 4096 batch size
  4. 193k weights
  5. 0.75 MB, 0.8%

~120 seconds
9 GB VRAM
50 GB RAM

- **SIREN**
  1. Adam optimizer
  2. 1e-4 learning rate
  3. 16384 batch size
  4. 330k weights
  5. 1.3 MB, 1.5%

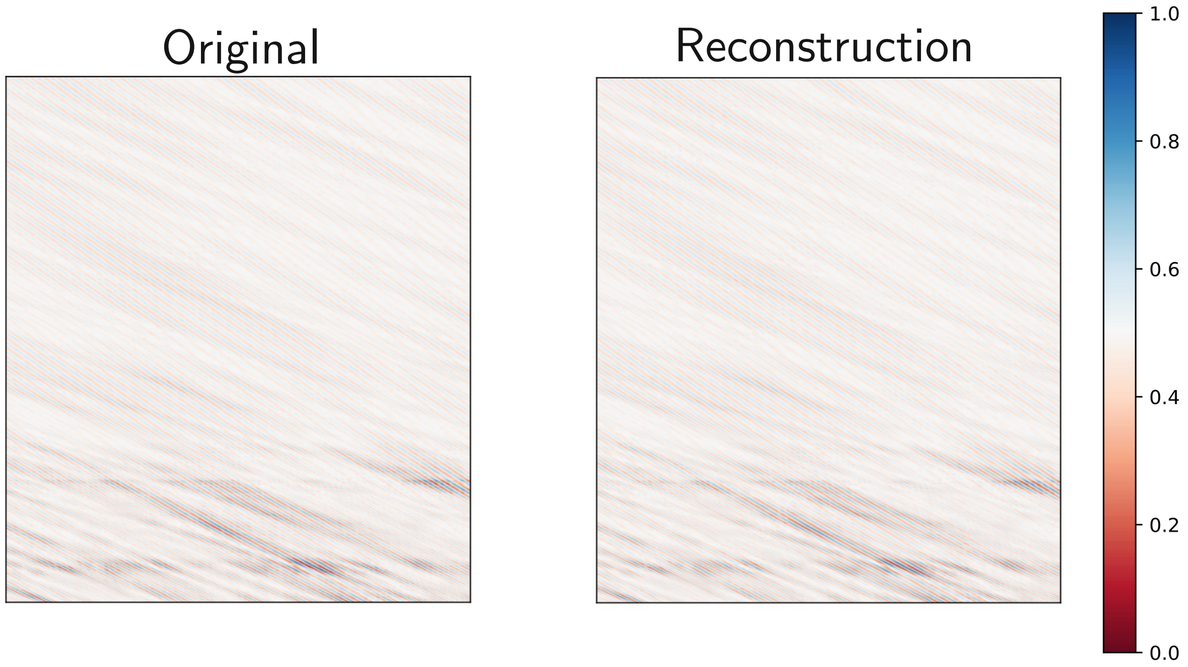
350-500 seconds
1 GB VRAM
3 GB RAM

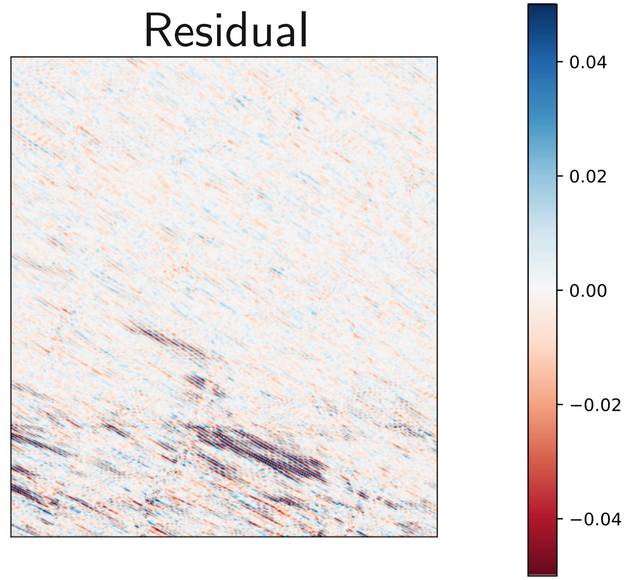
- **SDN**
  1. Adam optimizer
  2. 5e-4 learning rate
  3. 32 batch size

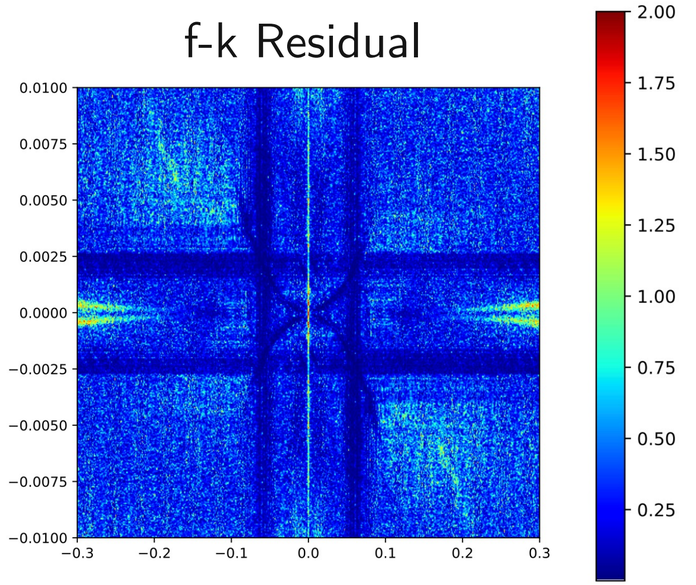
no satisfactory results yet

Results

SIREN

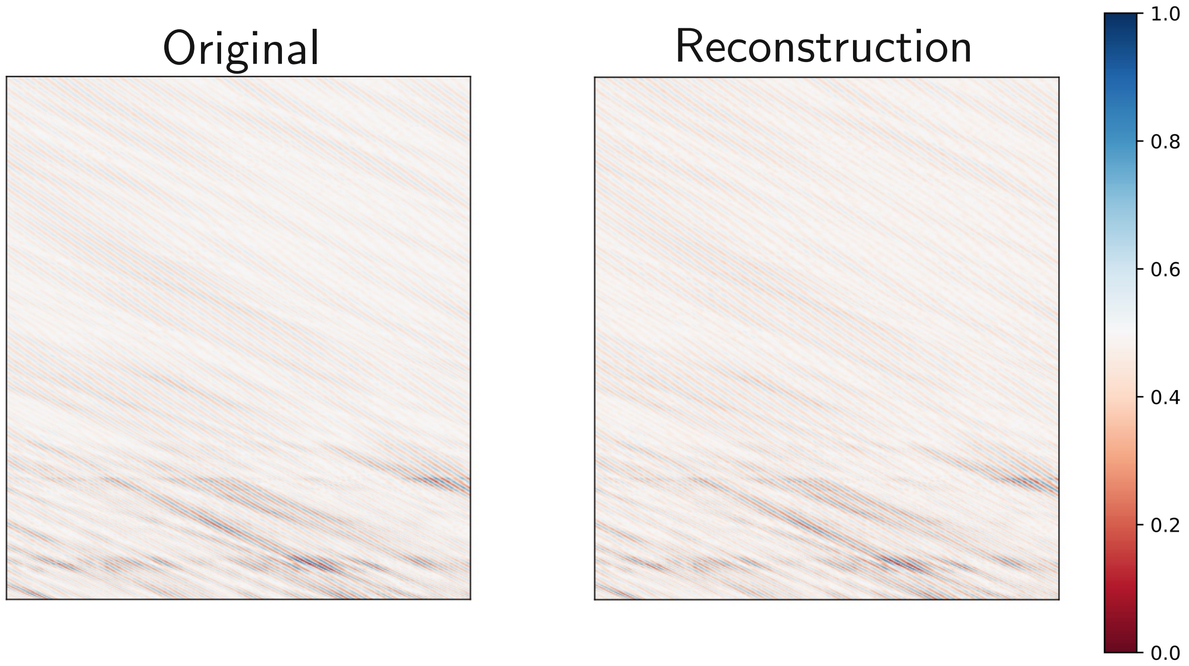


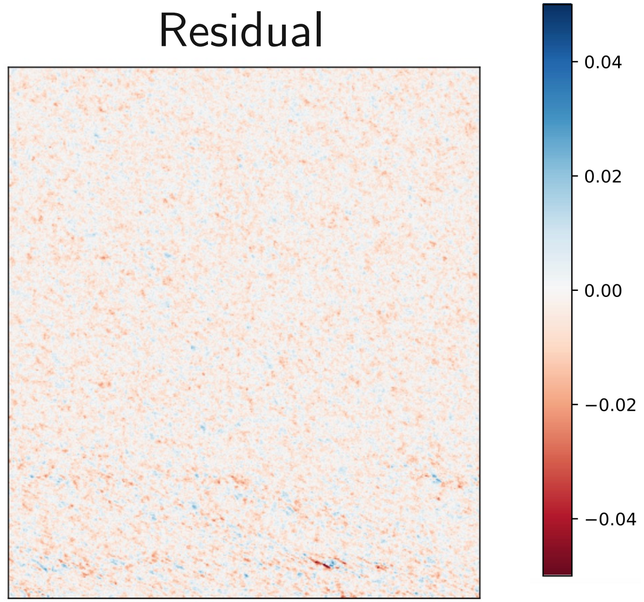


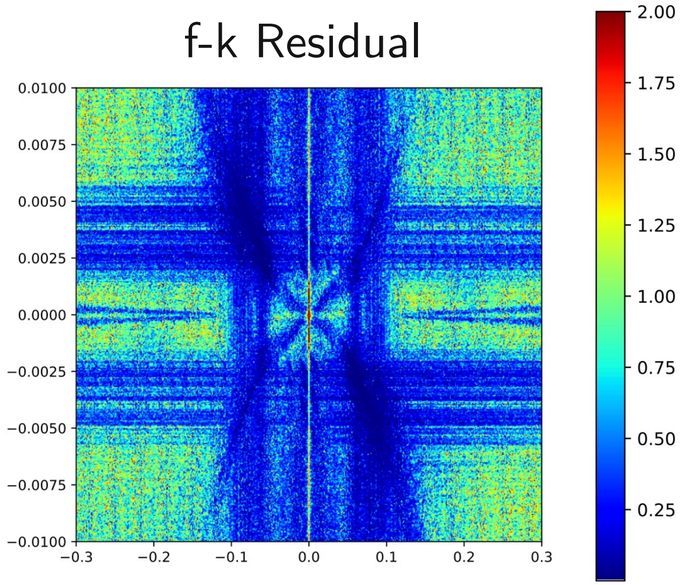


Results

RFFN







Conclusion

- The Distributed Acoustic Sensing technique provides a very dense seismic observation by sending repeating laser pulse into a dark fiber.
- Neural network could be effectively used as a DAS data compression method. Strong Ocean Surface Gravity Wave (<0.1 Hz) could be well reconstructed.
- Limitation exists that constrain further generalization of the methods. There should be more discussion about the strategy for real-time compression for further permanent DAS experiment.