# DAS+ML:
# *a seismic 'listening' revolution for geoscience*

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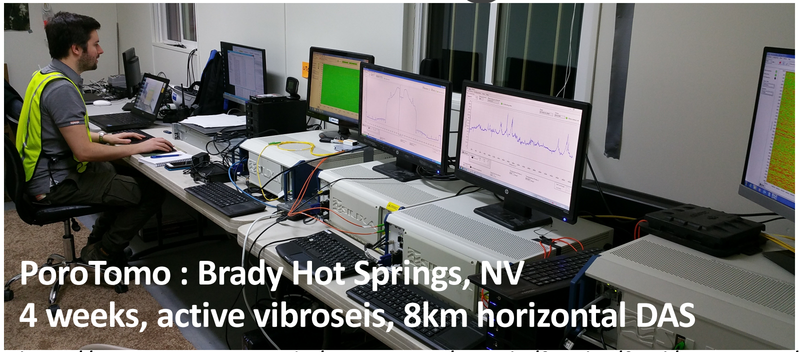
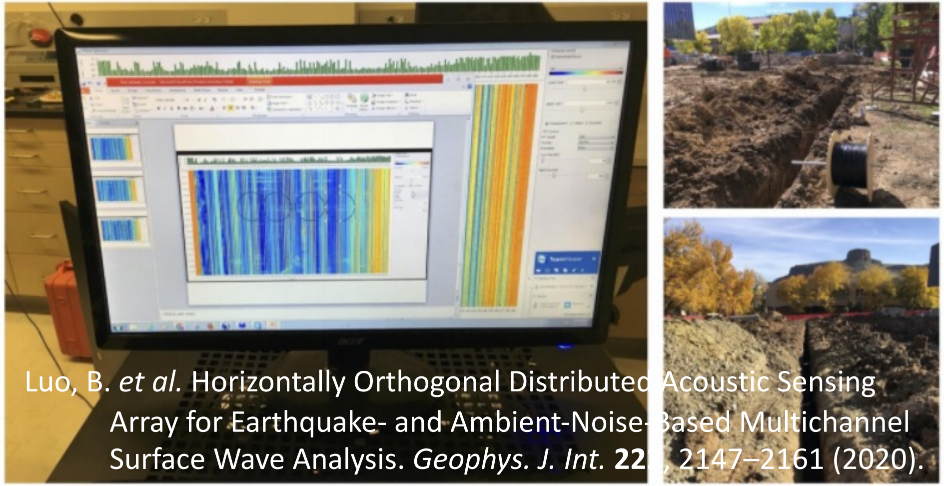
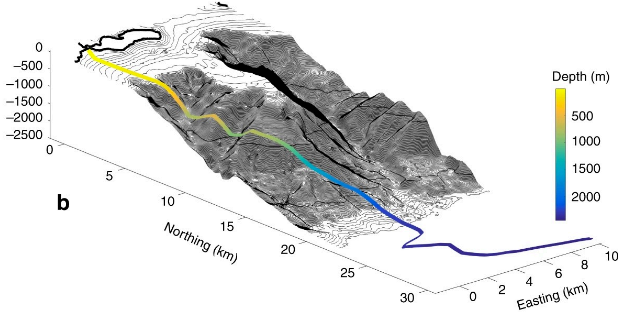
# DAS: a deluge of data



**PoroTomo : Brady Hot Springs, NV**
**4 weeks, active vibroseis, 8km horizontal DAS**
http://geoscience.wisc.edu/geoscience/people/faculty/feigl/porotomo/



Luo, B. *et al.* Horizontally Orthogonal Distributed Acoustic Sensing Array for Earthquake- and Ambient-Noise-Based Multichannel Surface Wave Analysis. *Geophys. J. Int.* **22**, 2147–2161 (2020).

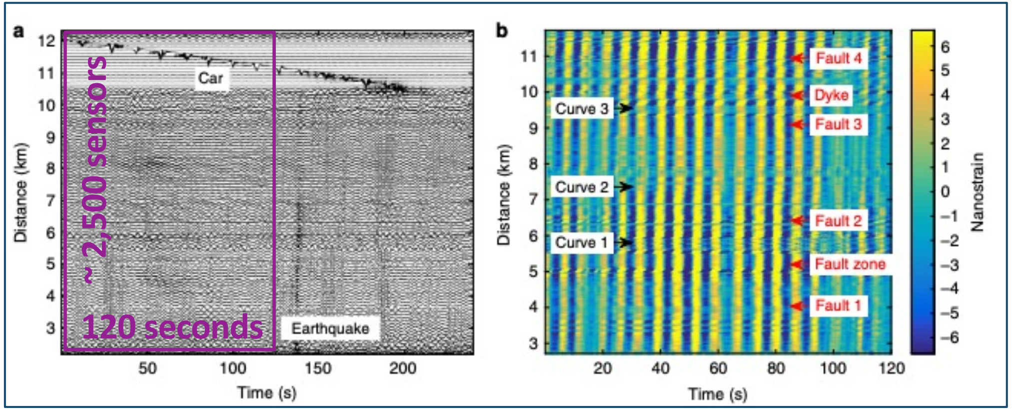



Sladen et al. (2019). Distributed sensing of earthquakes and ocean-solid Earth interactions on seafloor telecom cables, Nature Communications, 10(5777).


*Views of (A) before, (b) during and (c) after the construction of SR-1, located at the Richmond Field Station*

http://geomechanics.berkeley.edu/people/hubbard/

# Why DAS+ML?




15-km-long fiber Reykjanes Peninsula, SW-Iceland

Jousset, P. *et al.* Dynamic strain determination using fibre-optic cables allows imaging of seismological and structural features. *Nat. Commun.* **9**, 2509 (2018)

*Time to Manually Interpret long/large DAS*

One week of recording = 604,800 seconds

Interpretation : ~30 seconds for each 120 second "chunks":

*30 seconds (interpretation) * 5,040 chunks*

*= 302,400 seconds (interpretation time)*

OR

*= 42 hours of interpretation time*

1 week of recording ~ 1 work week of interpreting

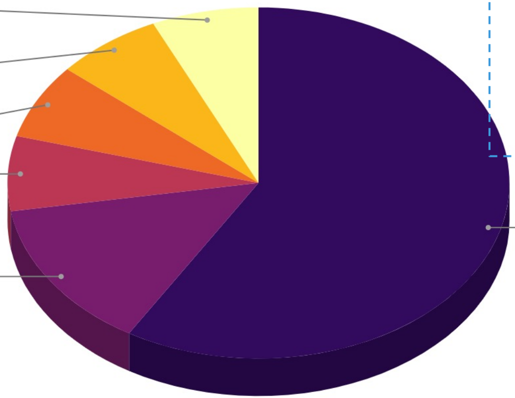
*What about city-scale fiber?*

# Timeline of key distributed vibration/acoustic sensing

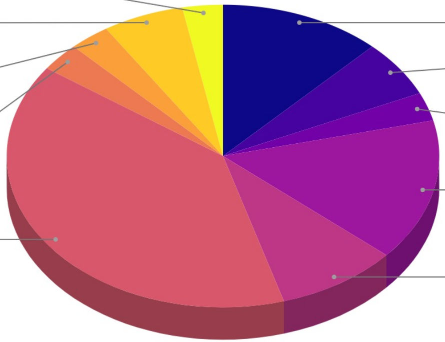
| Year | Milestone | Reference | DOI | Description |
|---|---|---|---|---|
| 1976 | Introduction to OTDR technology | **Barnoski & Jensen** | *10.1364/ AO.15.002112* | |
| 1982 | Introduction to multipoint sensing | ***Harmer*** | 10.1177/ 002029408201500403 | |
| 2002 | **First ML application to fiber-optic data** | ***Lyons & Lewis*** | 10.1177/ 014233120002200504 | NEURAL NETWORKS FOR IDENTIFYING POLLUTANT SIGNATURES IN WATER |
| 2013 | Early subsurface uses of DAS | ***Daley et al.*** | 10.1190/ tle32060699.1 | FEASIBILITY OF DAS DOWNHOLE FOR IDENTIFYING CO2 SIGNATURES |
| 2015 | **First ML application to DAS data** | ***Cao et al.*** | 10.1364/ ACPC.2015.ASu2A.145 | PERIMETER MONITORING OF DAS WITH SUPPORT VECTOR MACHINE |
| 2017 | **First CNN applied to DAS data** | ***Aktas et al.*** | 10.1117/ 12.2262108 | CNN TREATS DAS DATA AS 2D TO DISCRIMINATE BETWEEN WALKING, DIGGING, WIND ETC. |
| 2018 | **First GAN applied to DAS data** | ***Shiloh et al.*** | 10.1364/ OFS.2018.ThE22 | GAN'S TO GENERATE LABELED TRAINING SETS |

# Applications & Algorithms

33 Papers with DAS+ML since 2015




~20% subsurface
versus
~80% above ground
applications




SVM: Support Vector Machine
RVM: Relevance Vector Machine
RBF: Radial Basis Function
MLP: Multilayer Perceptron
GMM: Gaussian Mixture Model
CNN: Convolutional Neural Network
GAN: Generative Adversarial Network
DPN: Dual path network

*Useful Review Papers:*

Tejedor, J. *et al.* Machine learning methods for pipeline surveillance systems based on distributed acoustic sensing: A review. *Appl. Sci.* **7**, 1–26 (2017).

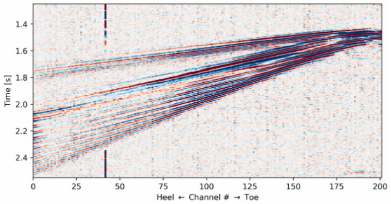
Shao, L. Y. *et al.* Data-Driven Distributed Optical Vibration Sensors: A Review. *IEEE Sens. J.* **20**, 6224–6239 (2020).

# Challenges for subsurface DAS applications

## Labeling Challenges

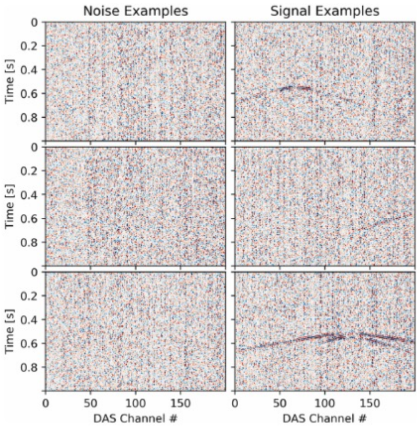
We can’t directly see the earthquake tremors or fractures opening!

confirmed microseismic event




Real DAS noise

synthetic microseismic + real noise




Binder & Tura (2020), CNN for automated microseismic detection in downhole distributed acoustic sensing data and comparison to a surface geophone array. Geophysical Prospecting, 68: 2770-2782.

## Computing Power & Data Accessibility

Tend to have longer fibers - > higher volume

Data collection (field) may be far from physical data storage locations

Concurrent Developments in:

- High Performance Computing
- CUDA
- GPU and TPU

Need and Potential for

- Data lakes : avoid downloading
- Edge computing: processing alongside the sensor, extracting only the useful information from massive data streams

# The Exciting Future of DAS+ML

**GOAL: Improve DAS interpretability**

fast and accurate labeling

domain-specific feature engineering

- prepping & choosing characteristics of the DAS data

physics-based new pattern discovery

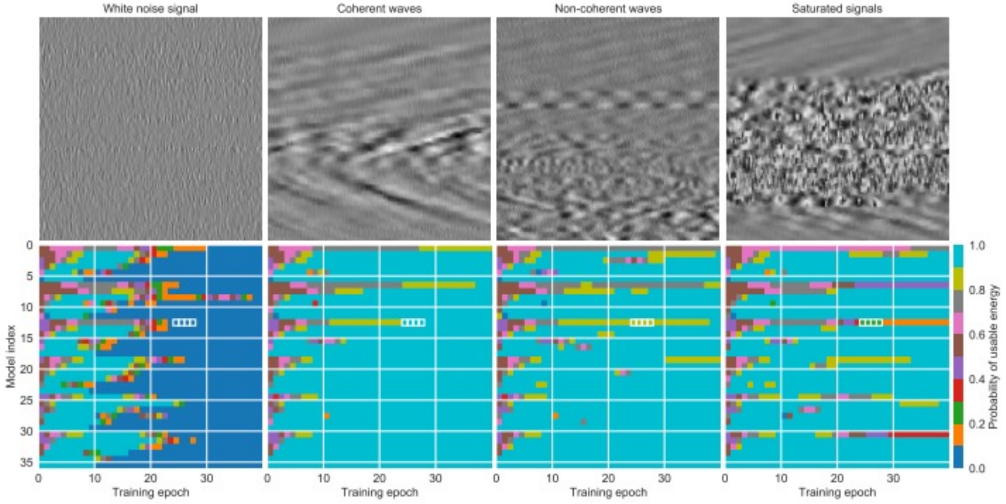
initial data quality control

improved efficient seismic processing

automated interpretation of events & subsurface properties (e.g. geology)

integration with other sensors

Evolution of probability of usable energy for 4 reference signal types across 36 different models




Dumont, V., Tribaldos, V. R., Ajo-Franklin, J. & Wu, K. Deep Learning on Real Geophysical Data: A Case Study for Distributed Acoustic Sensing Research. (2020).

# Please join us!
# 4th Thursday of every month

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