Xi Engineering Consultants

SAMS Scottish Association for Marine Science

COMSOL Certified Consultant

Using Artificial Intelligence to Identify Mooring Line Shock Load Events at Floating Offshore Wind Farms

Keith Cobry[1], Brett Marmo[1], Guy Favill[1], Denise Risch[2]

All-Energy Exhibition and Conference
SEC Glasgow
10.05.2023

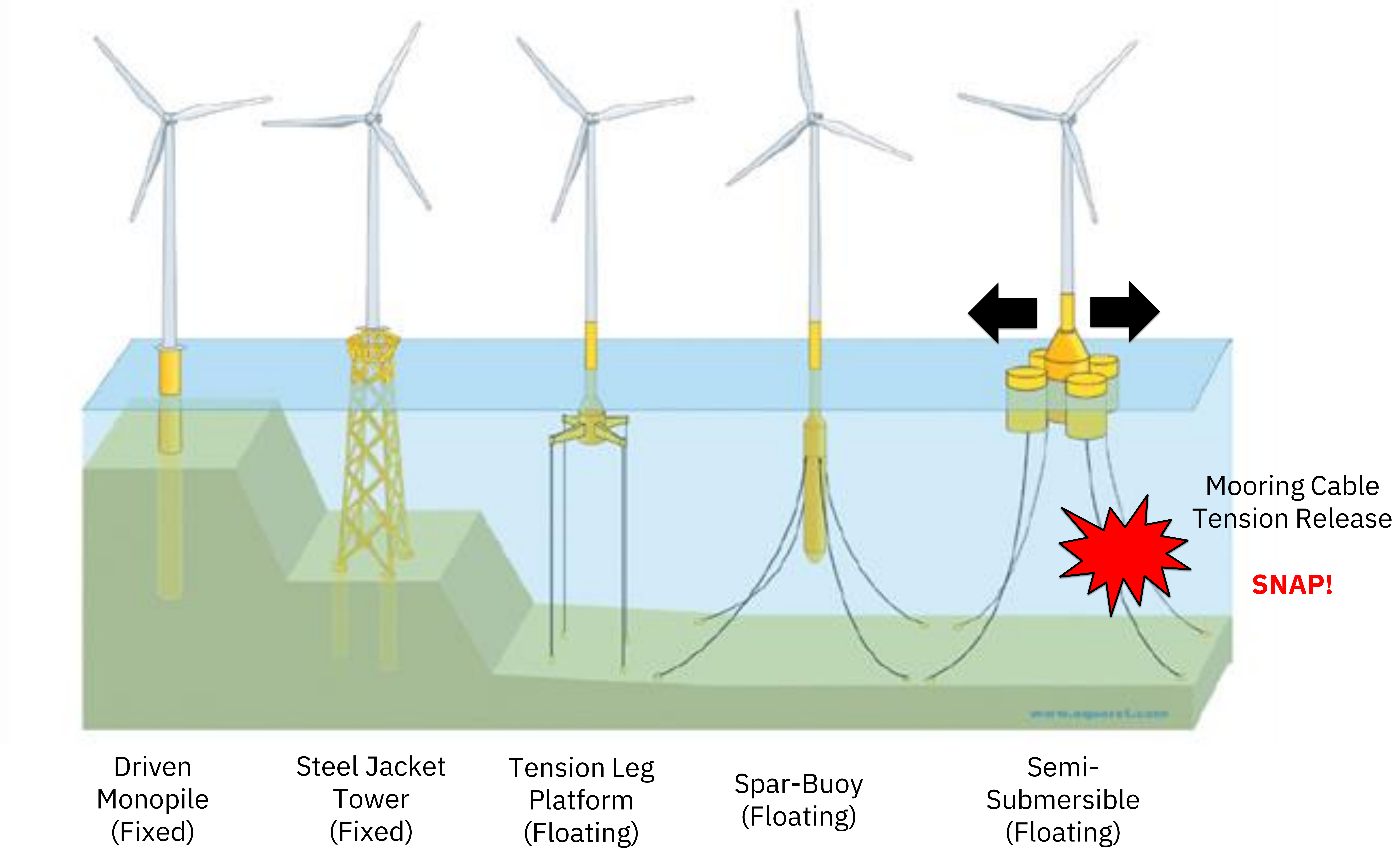
1: Xi Engineering Consultants Ltd., Edinburgh, UK
2: Scottish Association for Marine Science, Oban, UK

Introduction

- Global capacity for floating offshore wind generation is expected to be as high as 4.3 GW by 2030[1].
- A large fraction of global floating offshore wind capacity is installed in the UK, especially in Scottish waters[1].
- As FOW development expands with deployment of larger turbines and arrays placed in deeper waters, long-term impacts of operational noise on marine life is a growing concern.
- Operational underwater noise is expected to be similar between fixed and floating offshore platforms: tower, nacelle, turbines, rotors (< 1 kHz)[2]
- FOW mooring lines can release tension in irregular broadband “snaps” (i.e. 160 dB re. 1 μPa at 150 m)[3;] should be considered in environmental impact reviews.
- Study of non-trivial acoustic profiles of these noise events can benefit from a machine learning approach.

1: Hannon et al. 2019
2: Madsen et al. 2006
3: Xodus Ltd. 2015

Introduction

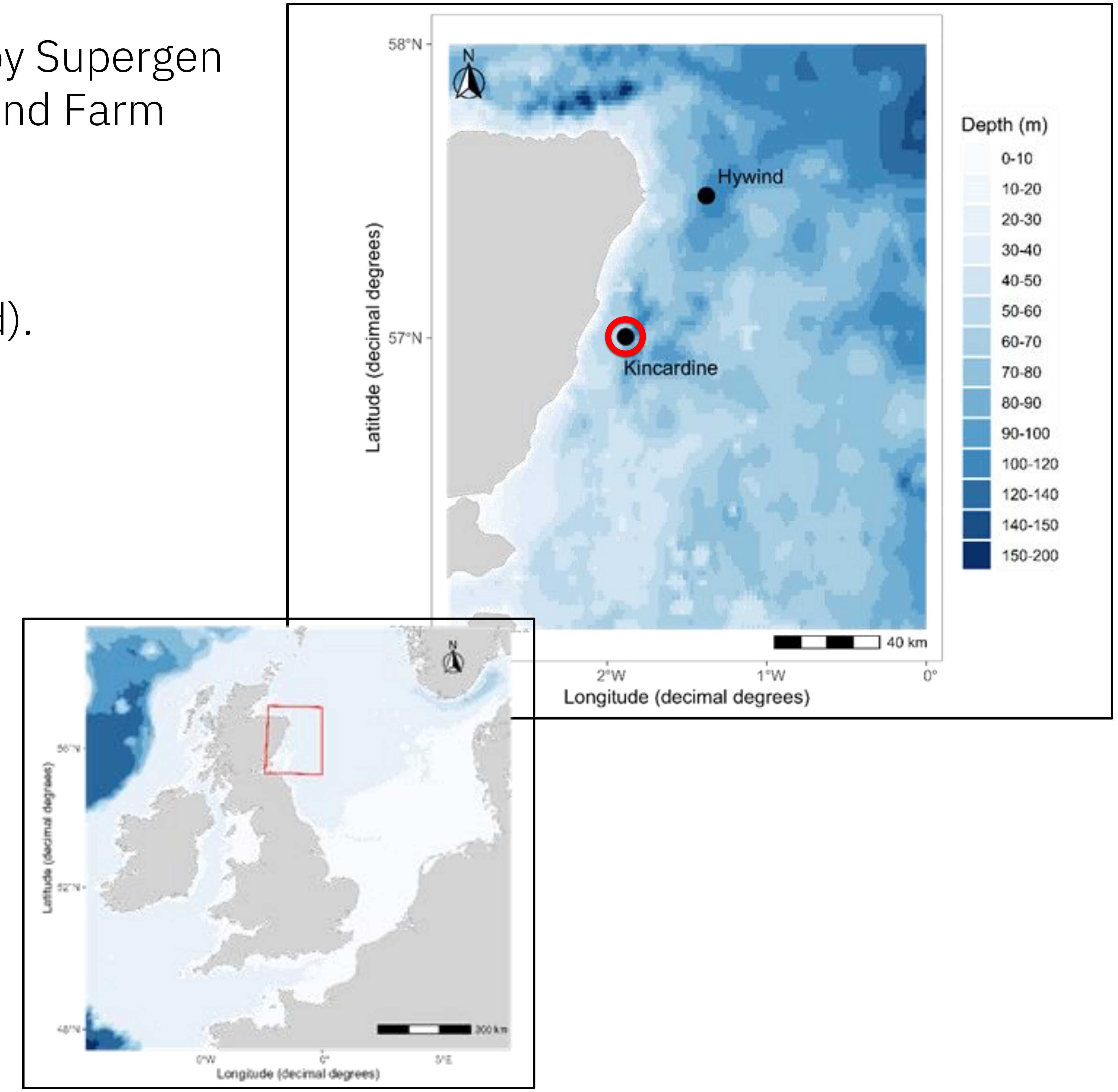


Data Collection

- Underwater acoustic data collected by SAMS, funded by Supergen ORE Hub 2018 Pilot projects at Kincardine Offshore Wind Farm (Principle Power) and Hywind Scotland (Equinor).
- 47.5 MW (Kincardine) and 30 MW (Hywind) capacities.
- Semi-submersible (Kincardine) and spar-buoy (Hywind).
- Five turbines currently installed at each farm.
- Analysis of data from Kincardine discussed here.

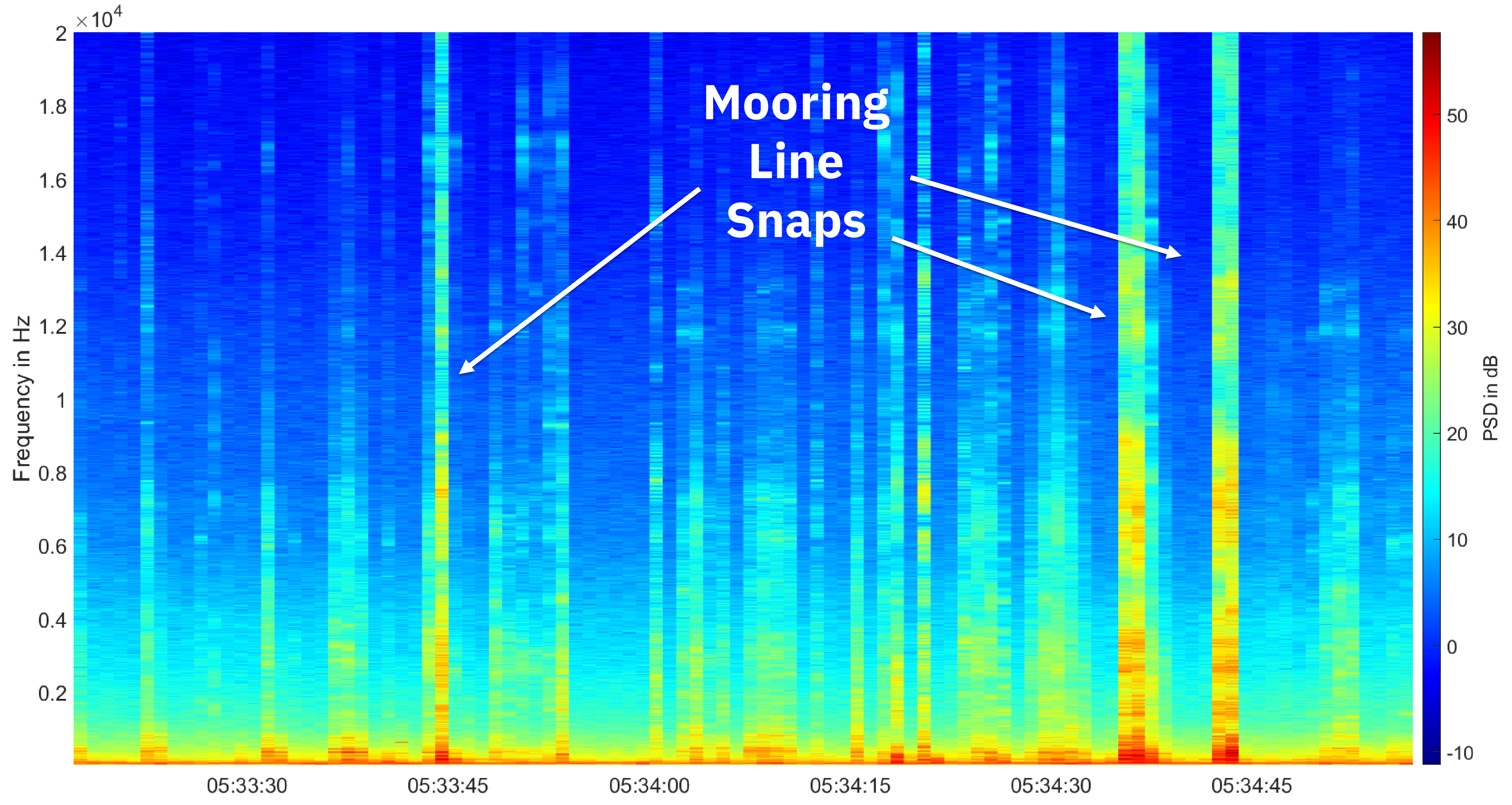
Kincardine

Hywind



Data Collection

- The acoustic signals are recorded by hydrophones and typically represented as spectrograms of sound pressure level (re. 1 μPa) to visualize the frequency response vs. time.
- Each column in the spectrogram is a spectrum representing a 1 s recording.
- Operational noise appears as low frequency horizontal band (up to ~200 Hz).
- Snaps appear as short broadband streaks (impulses).



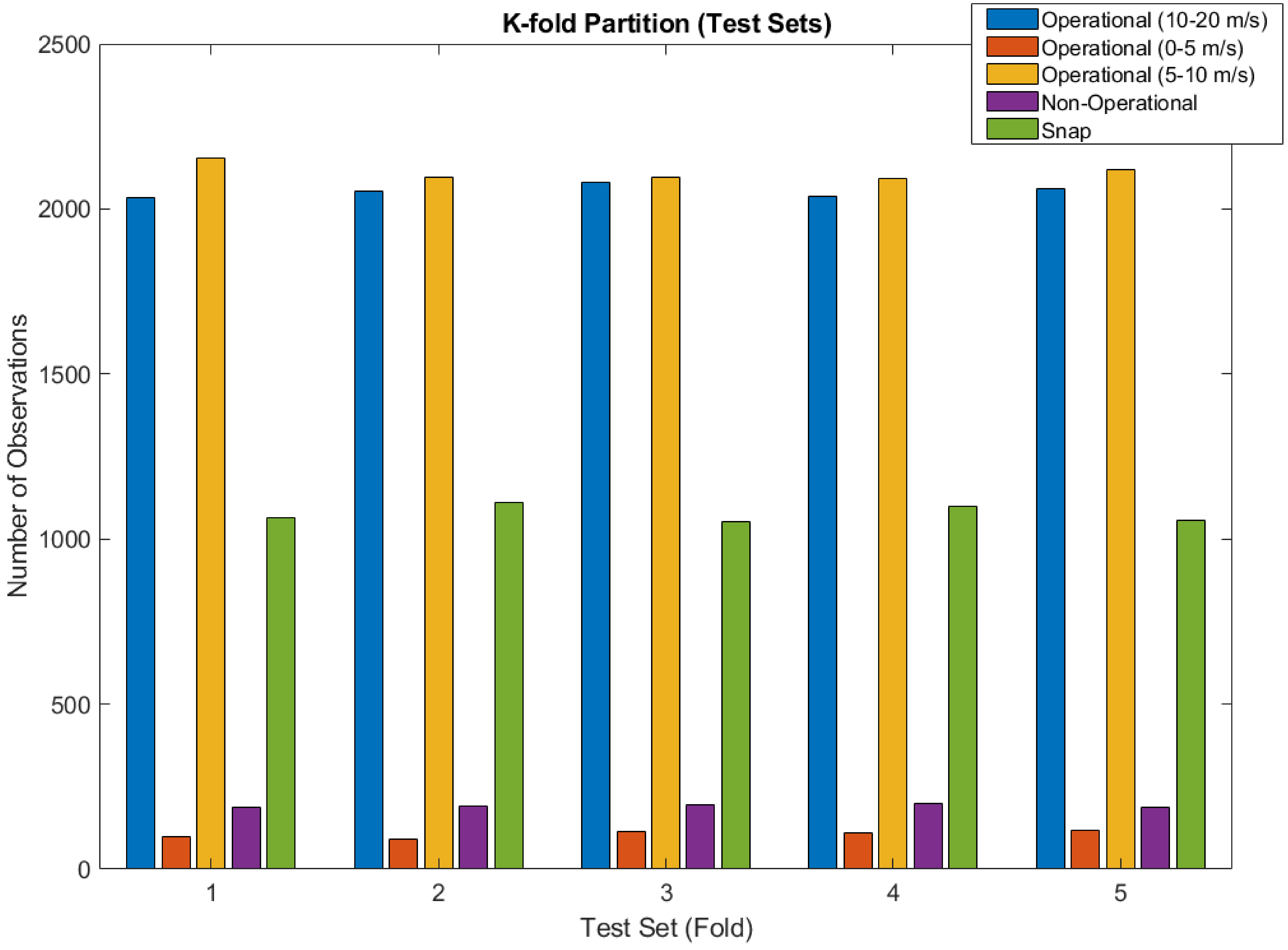
Soundtrap 4300STD Hydrophone

Machine Learning Analysis of Signals

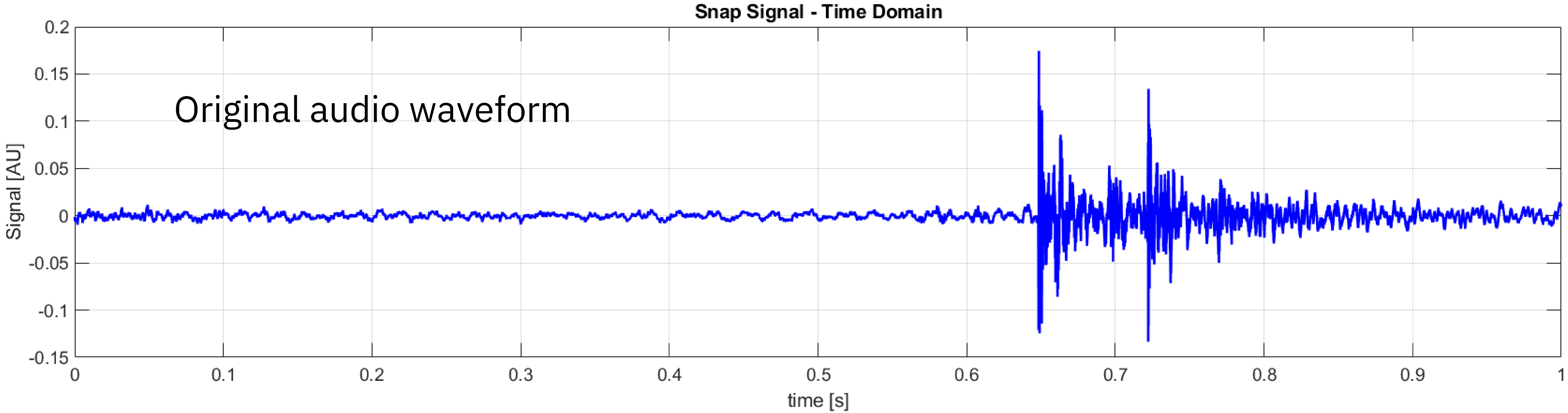
Classes (windspeeds from SCADA data)

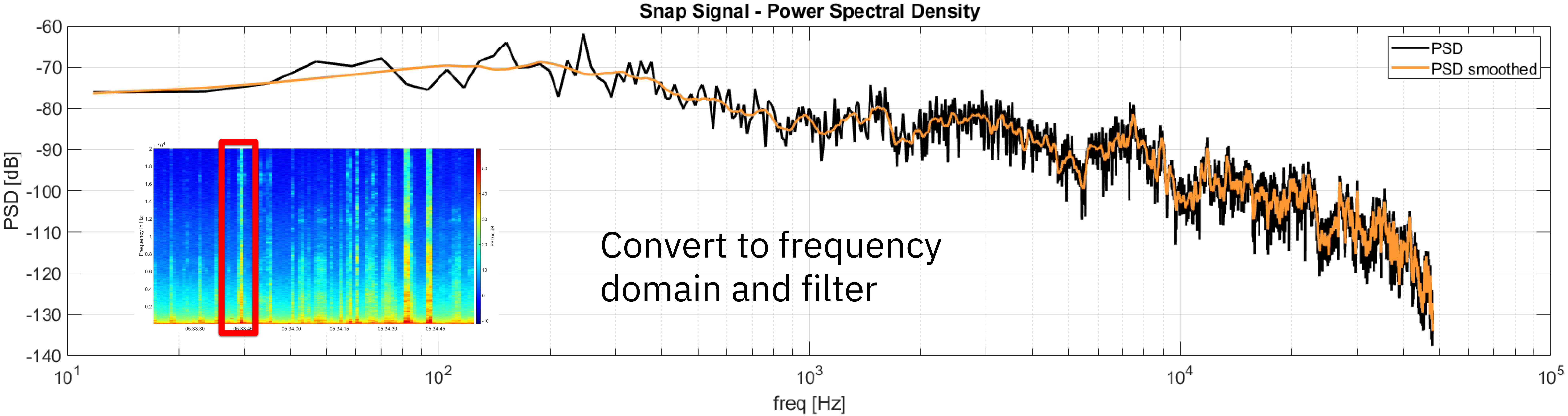
- Operational (10-20 m/s windspeed)
- Operational (0-5 m/s windspeed)
- Operational (5-10 m/s windspeed)
- Non-operational
- Snap

- Classification with a 1D Convolutional Neural Network in Keras (Tensorflow framework)
- 27,700 total signals
- 4:1 training: test signals
- Training/testing signals selected for 5-fold cross-validation.

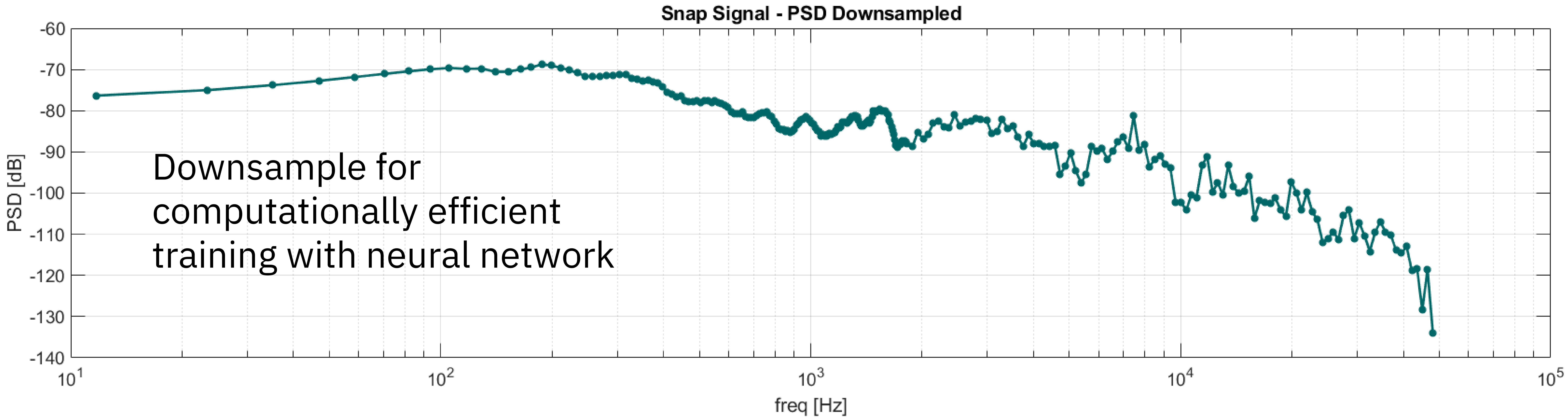


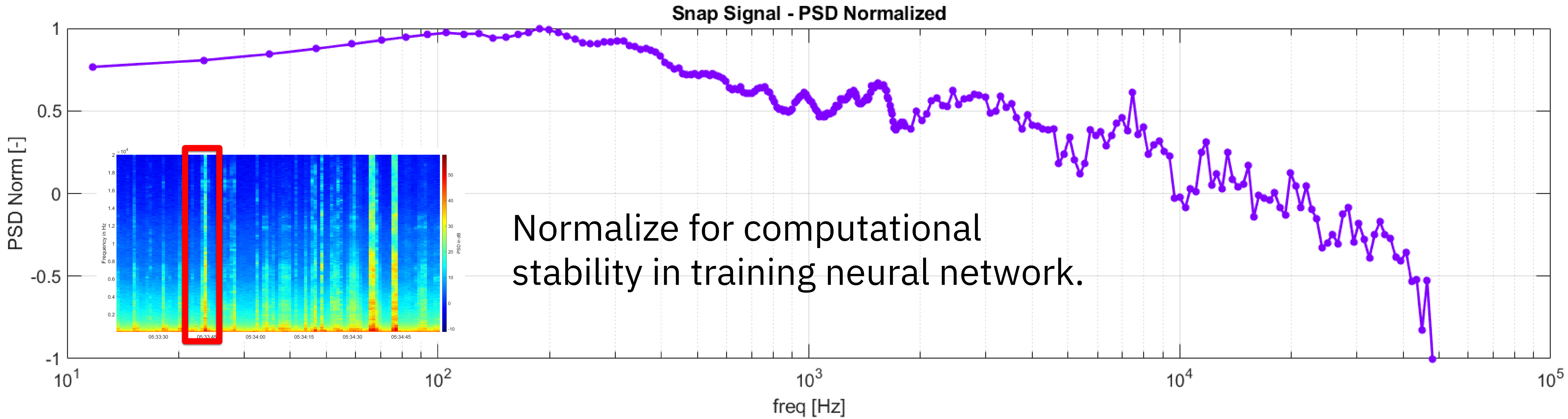
Data Pre-Processing for Analysis



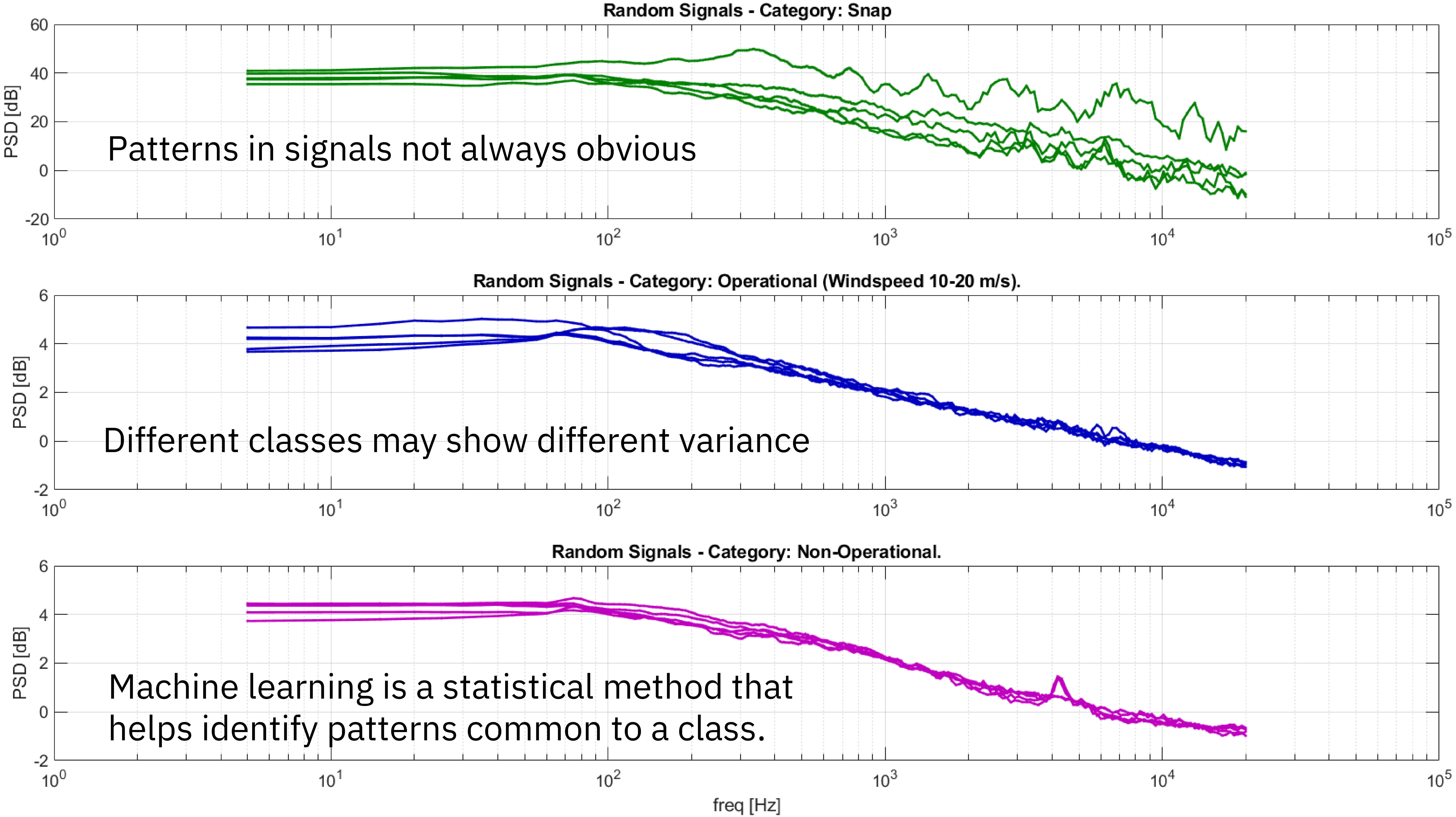


Data Pre-Processing for Analysis





Data Pre-Processing for Analysis



Patterns in signals not always obvious

Different classes may show different variance

Machine learning is a statistical method that helps identify patterns common to a class.

Machine Learning Analysis of Signals

- High accuracy achieved with a 1D Convolutional Neural Network. Relatively fast computation.
- Test signals used for classification not used in the training process – avoids model bias.
- Lowest accuracy for operational conditions at low windspeed (0-5 m/s)
  - Windspeed value provided from SCADA is averaged over a 10-minute interval. Unknown if parts of intervals had no wind present.
  - Individual acoustic signal represents a 1 s interval.
  - Larger variance in gearbox acoustic profile i.e. 1 m/s vs 4 m/s compared w/ 16 m/s vs 18 m/s
- Method as an analytical tool in studies on wildlife impact.
- Machine Learning approaches can also be used more generally for monitoring gearbox acoustic output – i.e. preventative maintenance.

True Class \ Predicted Class	1: Non-Op.	2: Op. (0-5 m/s)	3: Op. (5-10 m/s)	4: Op. (10-20 m/s)	5: Snap
1: Non-Op.	97.8%	1.2%	0.0%	0.0%	0.0%
2: Op. (0-5 m/s)	0.3%	90.2%	0.6%		
3: Op. (5-10 m/s)	0.5%	6.5%	97.9%	1.3%	1.9%
4: Op. (10-20 m/s)	0.3%		0.8%	97.7%	3.9%
5: Snap	1.0%	2.2%	0.6%	1.0%	94.2%
	97.8%	90.2%	97.9%	97.7%	94.2%
	2.2%	9.8%	2.1%	2.3%	5.8%

COMSOL Certified Consultant

Contact Us

Xi Engineering Consultants
Codebase, 3 Lady Lawson Street
Edinburgh
EH3 9DR
Tel: +44 (0) 131 290 2250
E-mail: hello@xiengineering.com