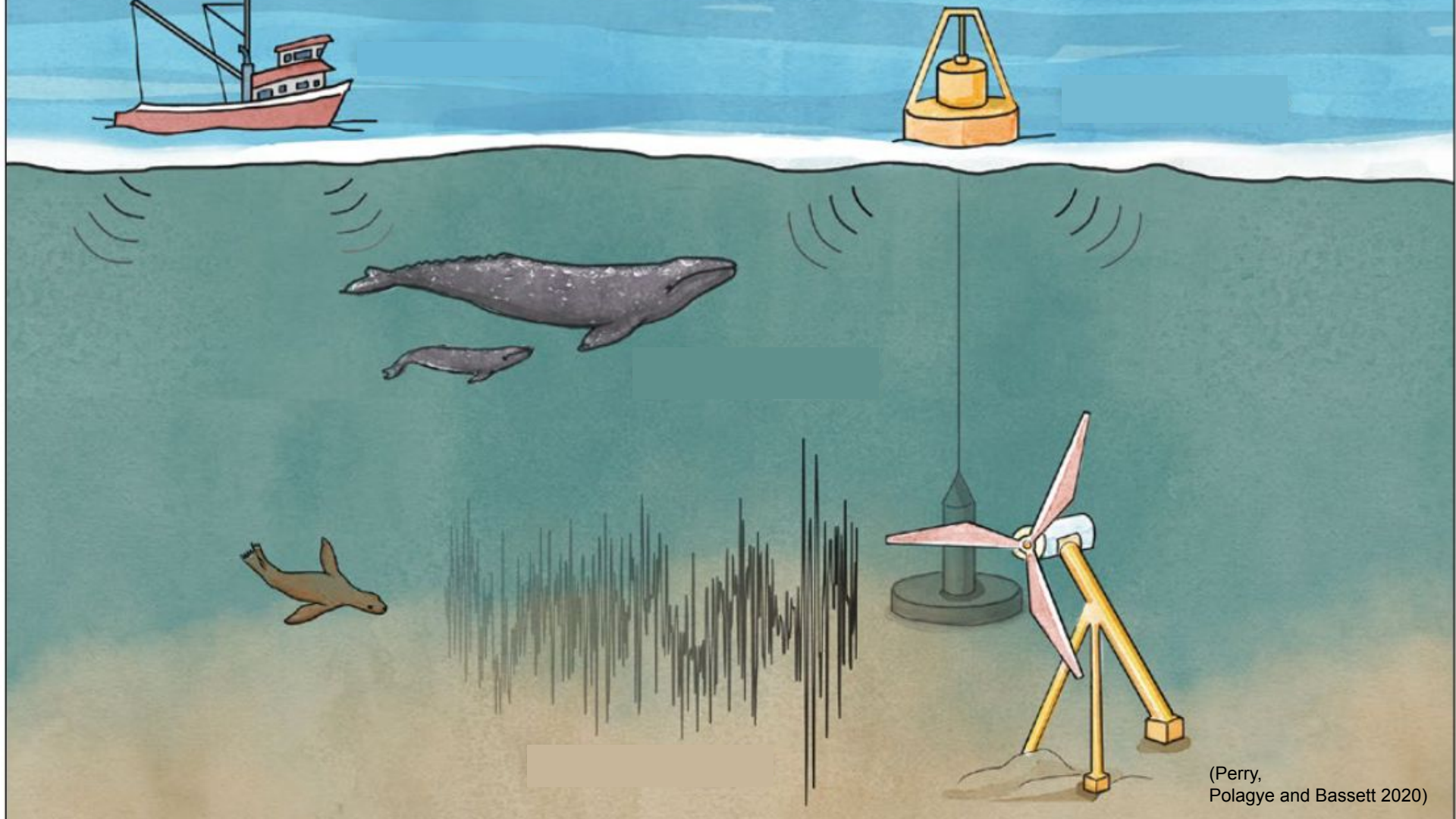


# **Influence of powertrain components on noise from a pair of cross-flow turbines**

**Lindsey Jones**, Corey Crisp, Gemma Calandra, Kathryn Sellers Reynolds, Chris Bassett, and Brian Polagye





# Presentation Structure

- How we conducted our study
- What sounds we observed and how we attributed them
- Which choices affect sound levels and their spatial distributions



# Site: Millinocket Stream

Millinocket

MAINE

Modular RivGen  
Turbines



100 m

100 m

20 m

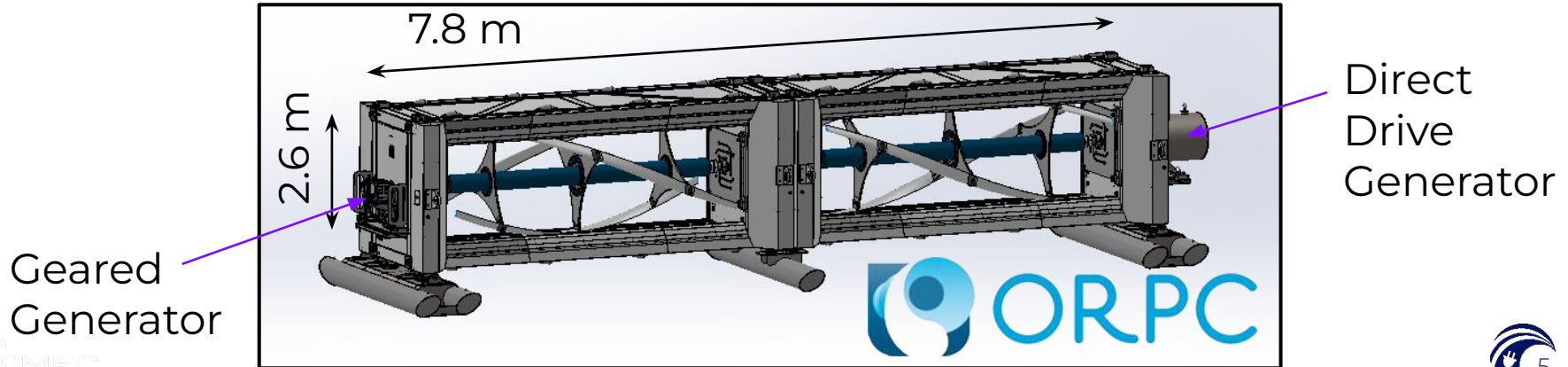
50 ft

# Turbine Overview

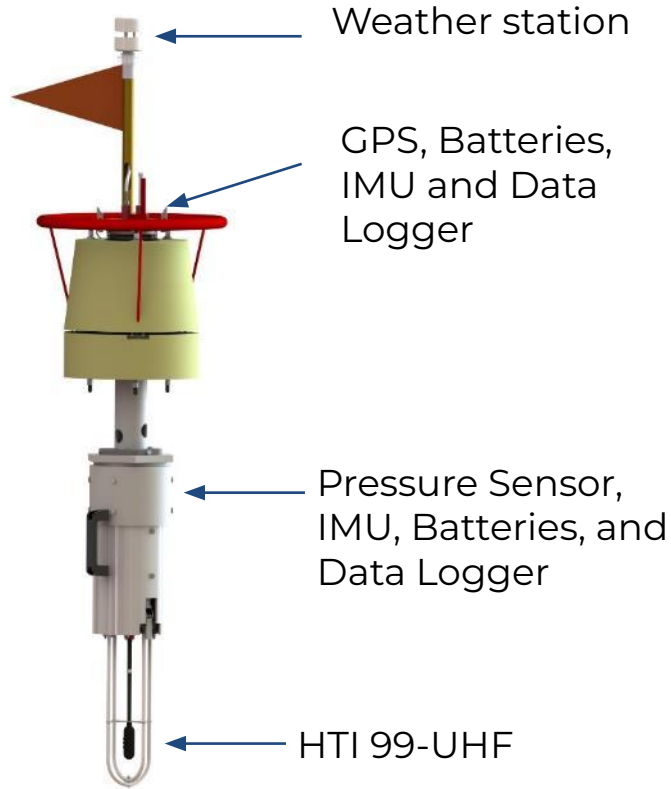


Credit: ORPC

- Ocean Renewable Power Company prototype turbines (“Modular RivGen”)
- Cross-flow (“vertical-axis”) turbine with three foils
- Variable Frequency Drive (VFD) on shore controls torque



# “Shallow” DAISY



*Credit: Corey Crisp*



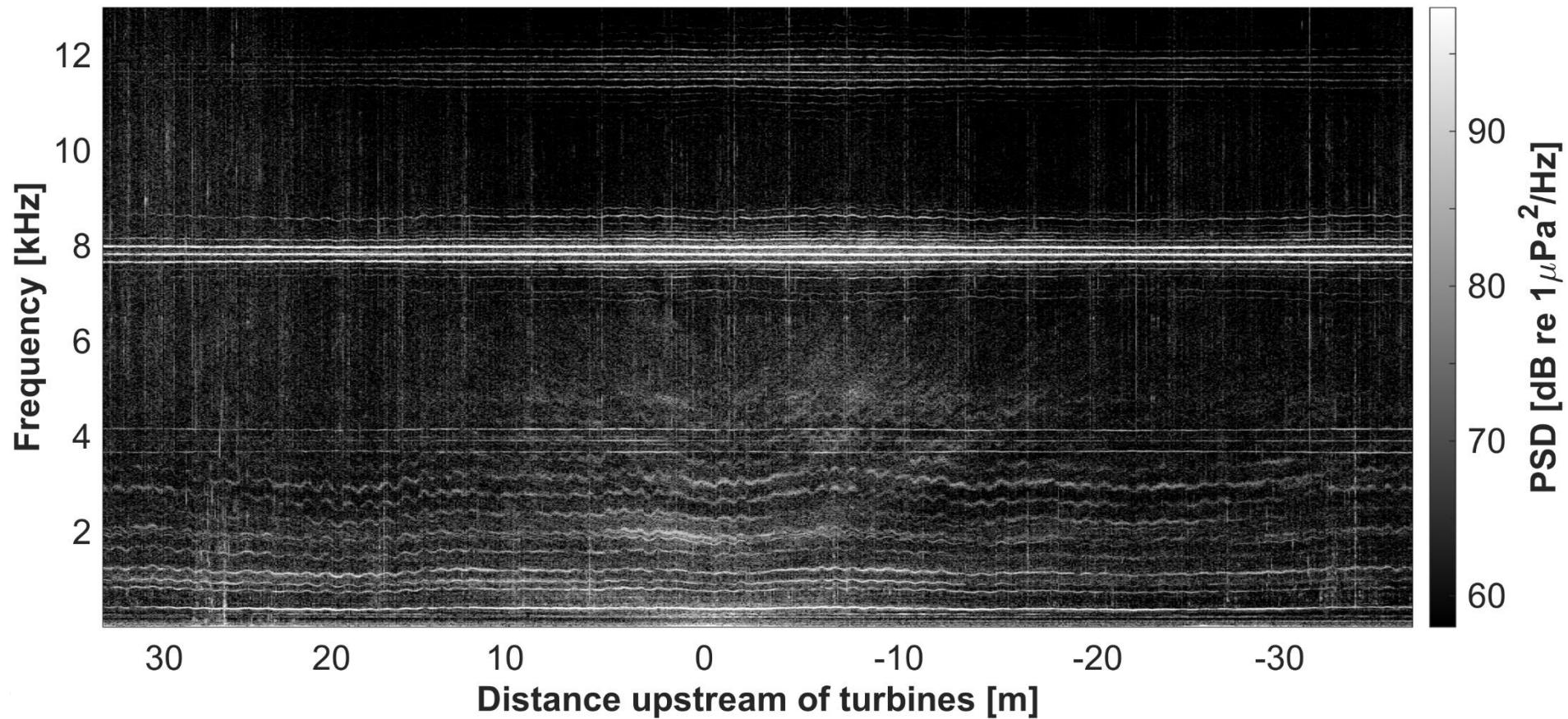


# DAISY Deployments

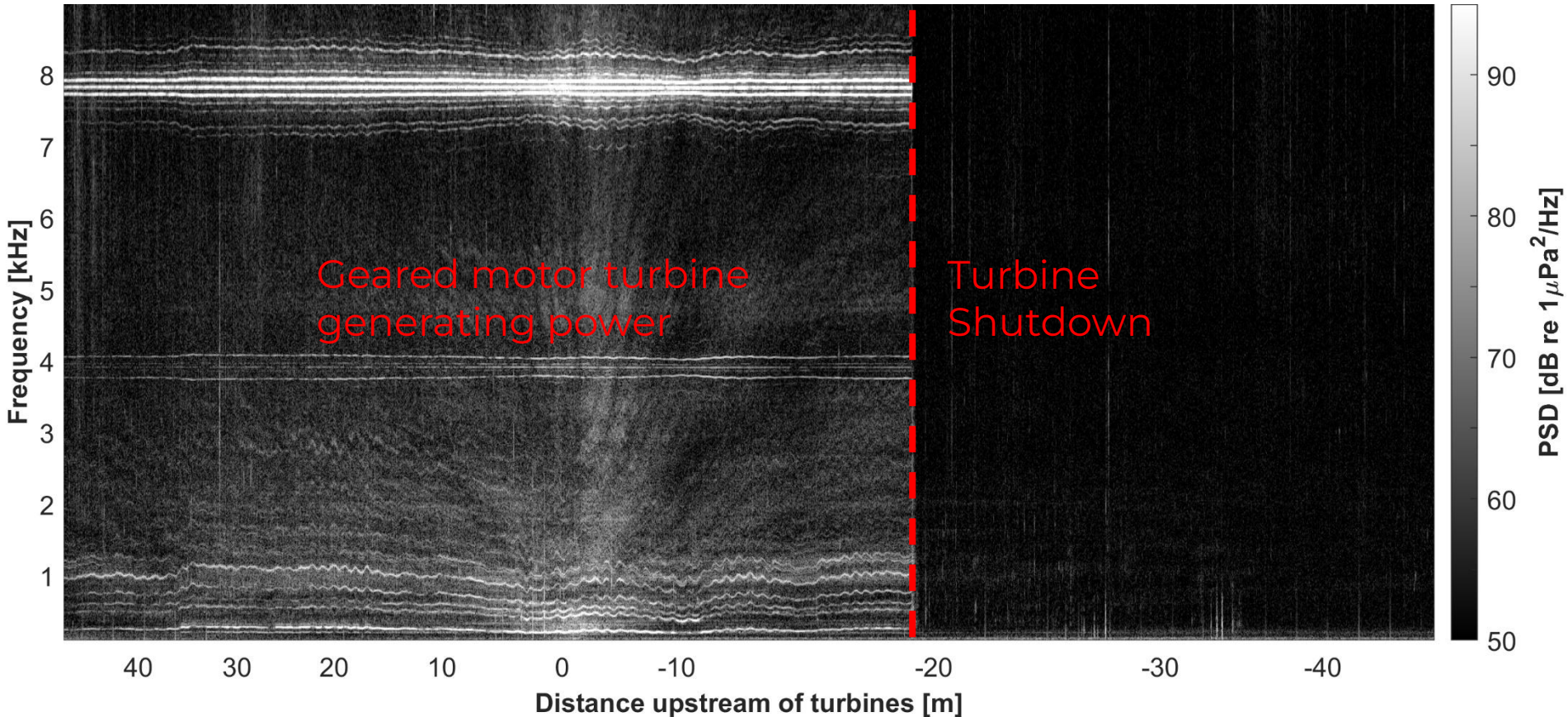




# Radiated Noise Drivers



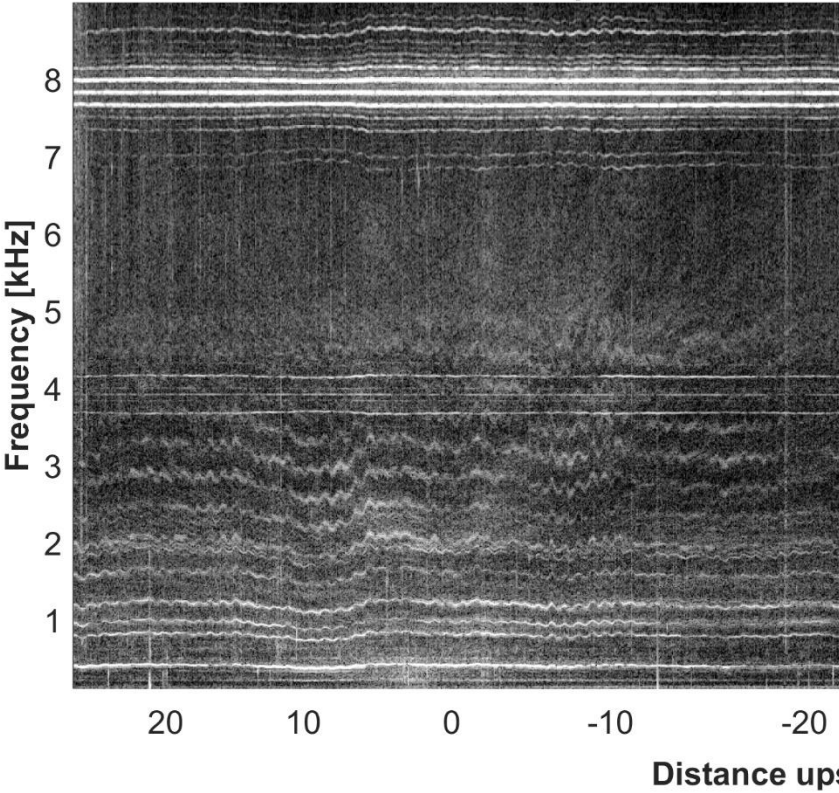
# Turbine Remote Control/Variation



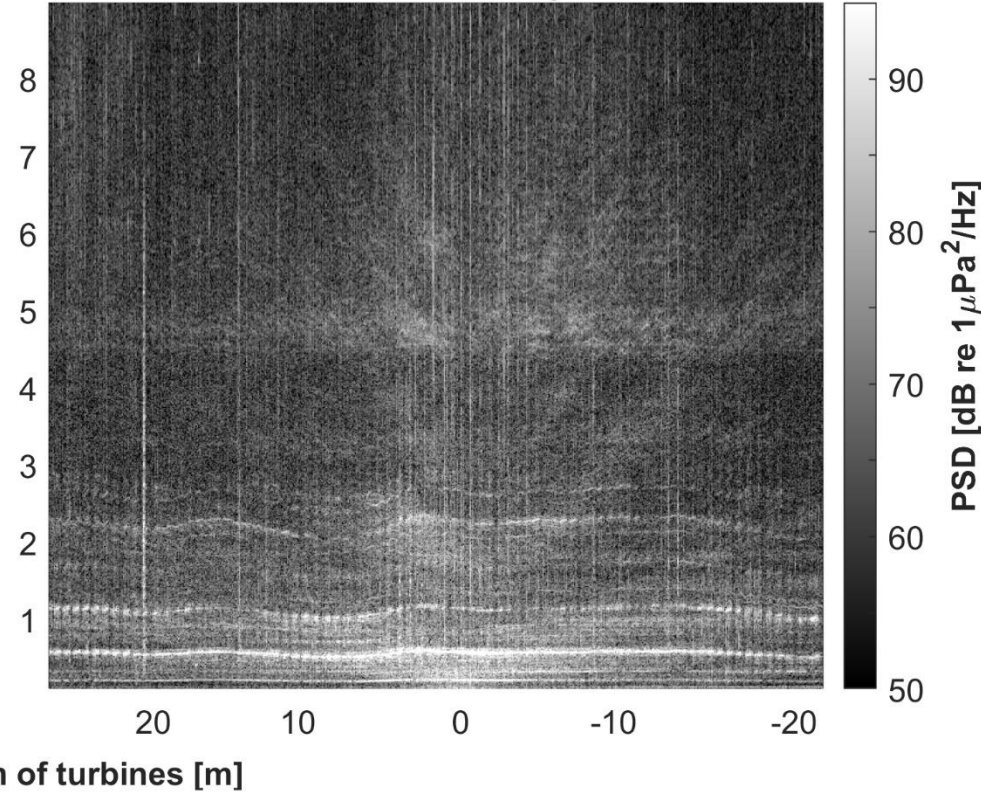


# Geared Motor Comparison

**100% Power**  
**Motor:  $1576 \pm 46$  rpm**



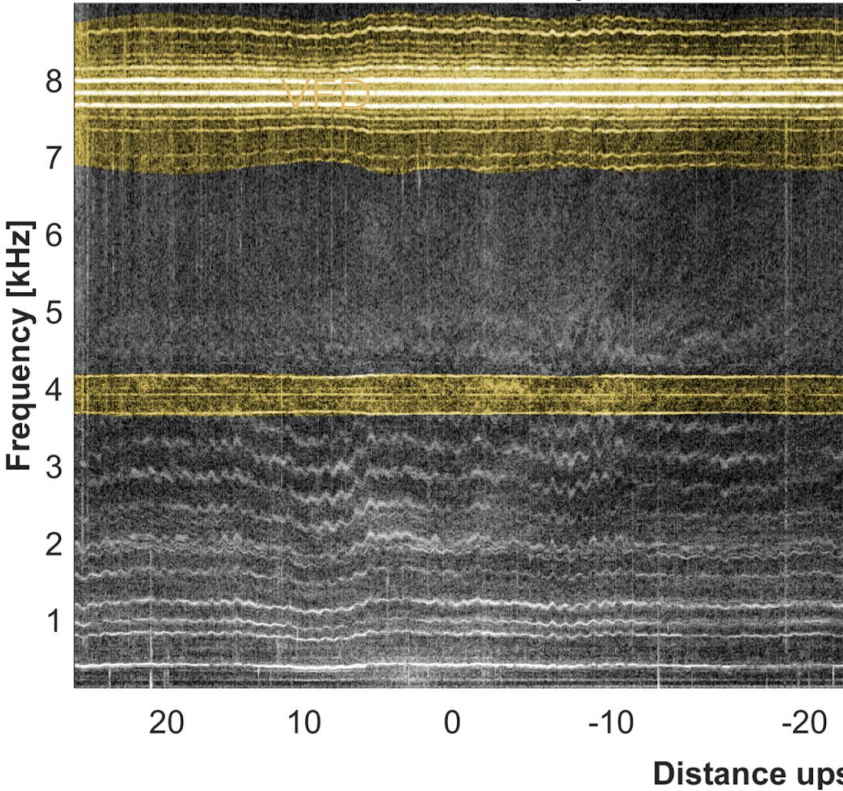
**Freewheeling**  
**Motor:  $2297 \pm 98$  rpm**



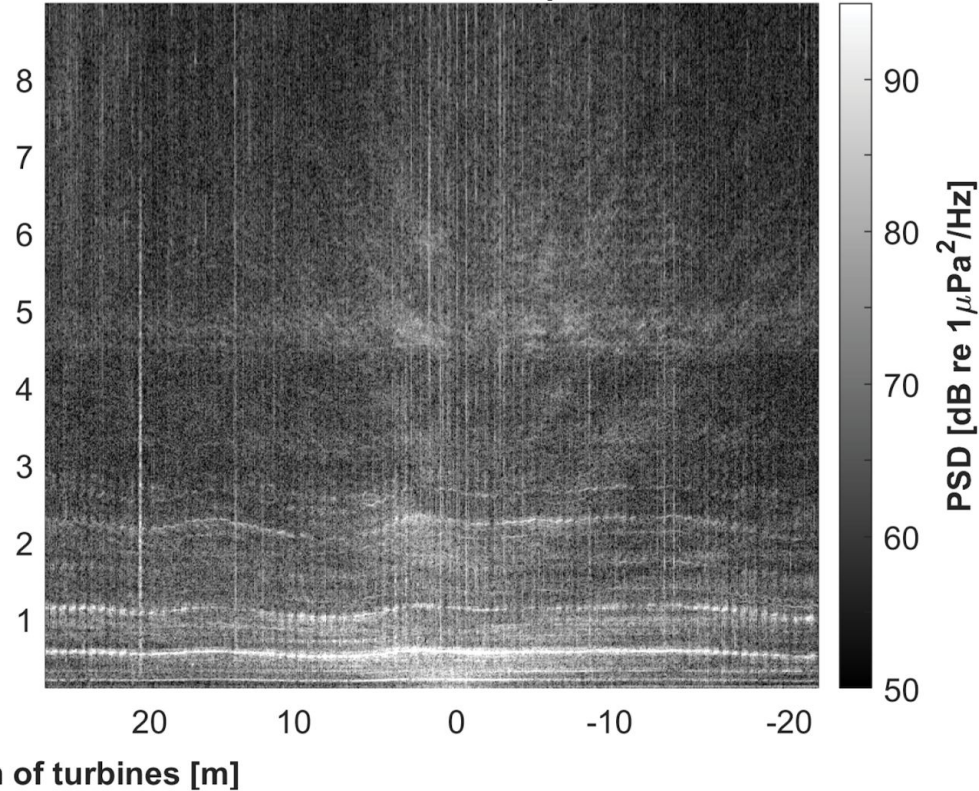


# Geared Motor Comparison

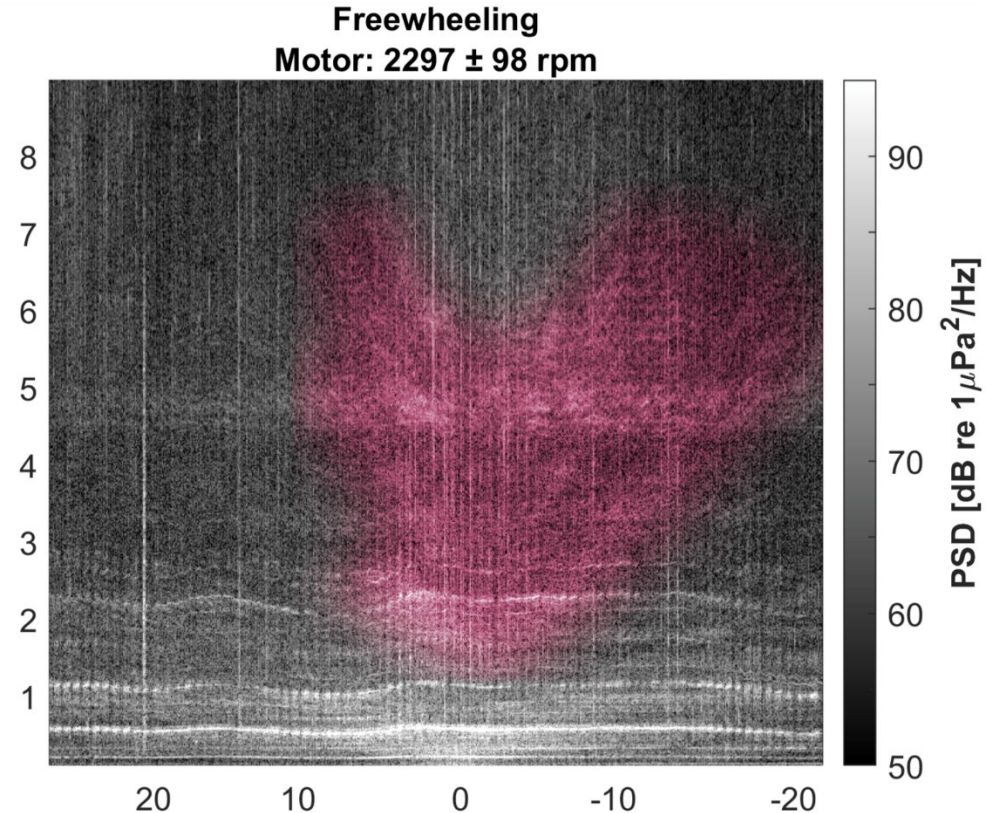
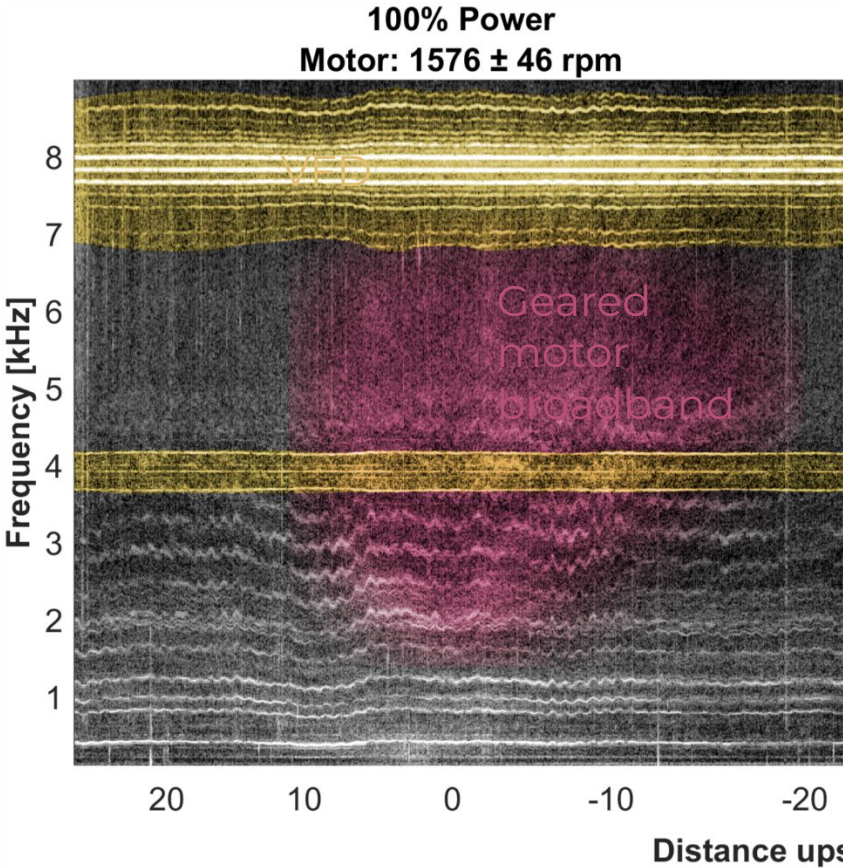
**100% Power**  
**Motor:  $1576 \pm 46$  rpm**



**Freewheeling**  
**Motor:  $2297 \pm 98$  rpm**

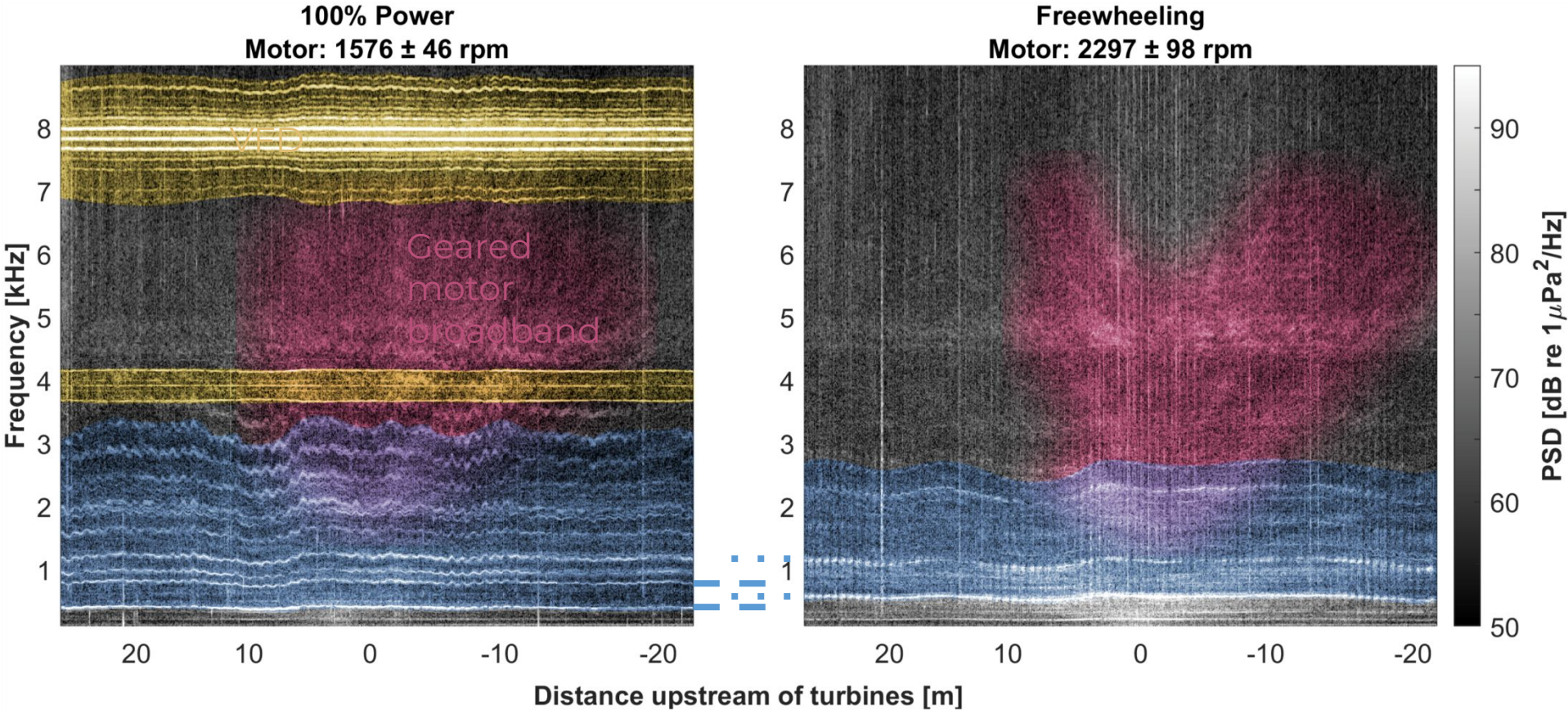


# Geared Motor Comparison



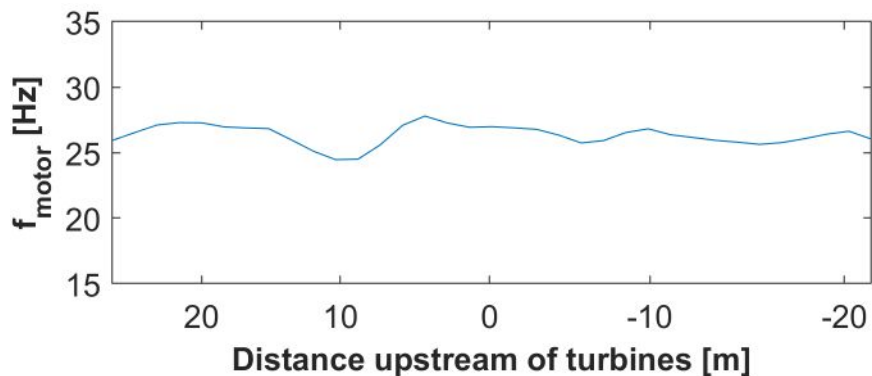
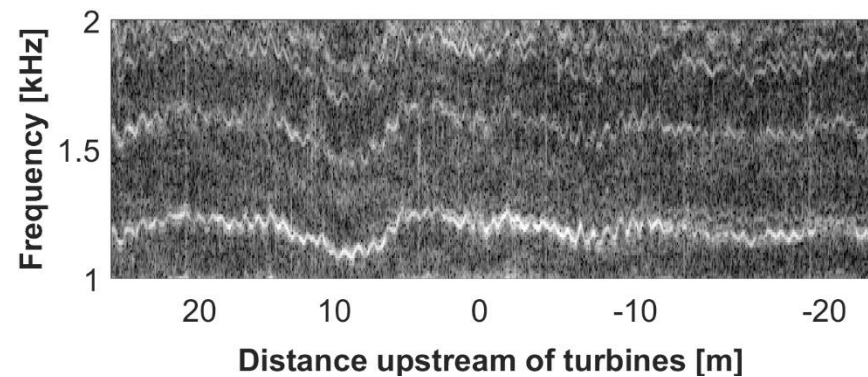


# Geared Motor Comparison

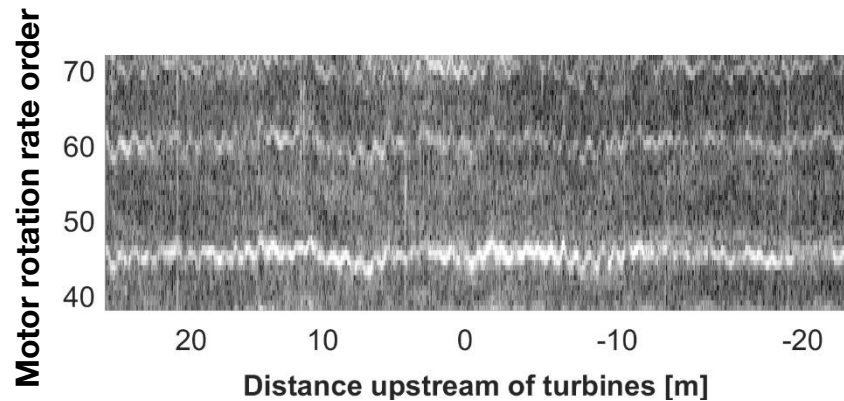




# Order Analysis

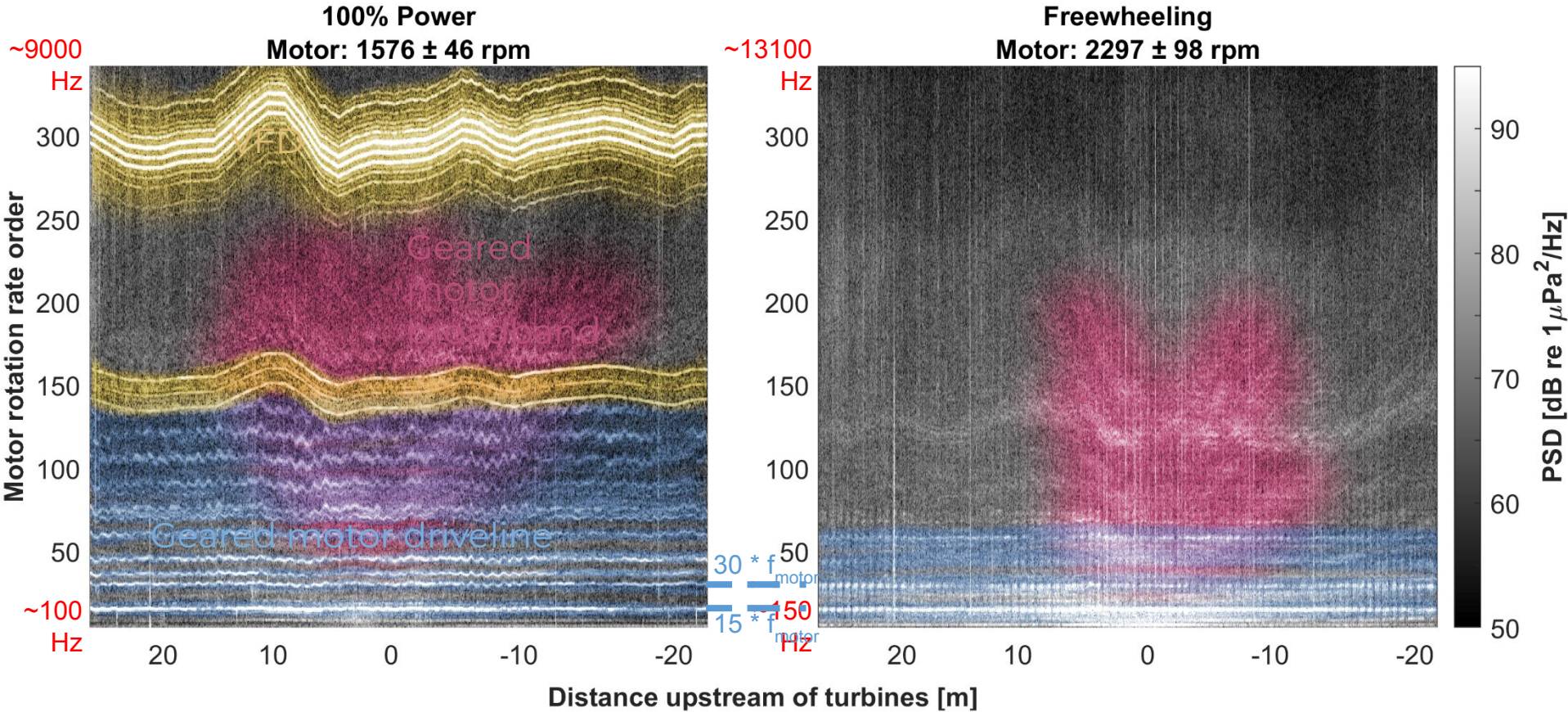


=



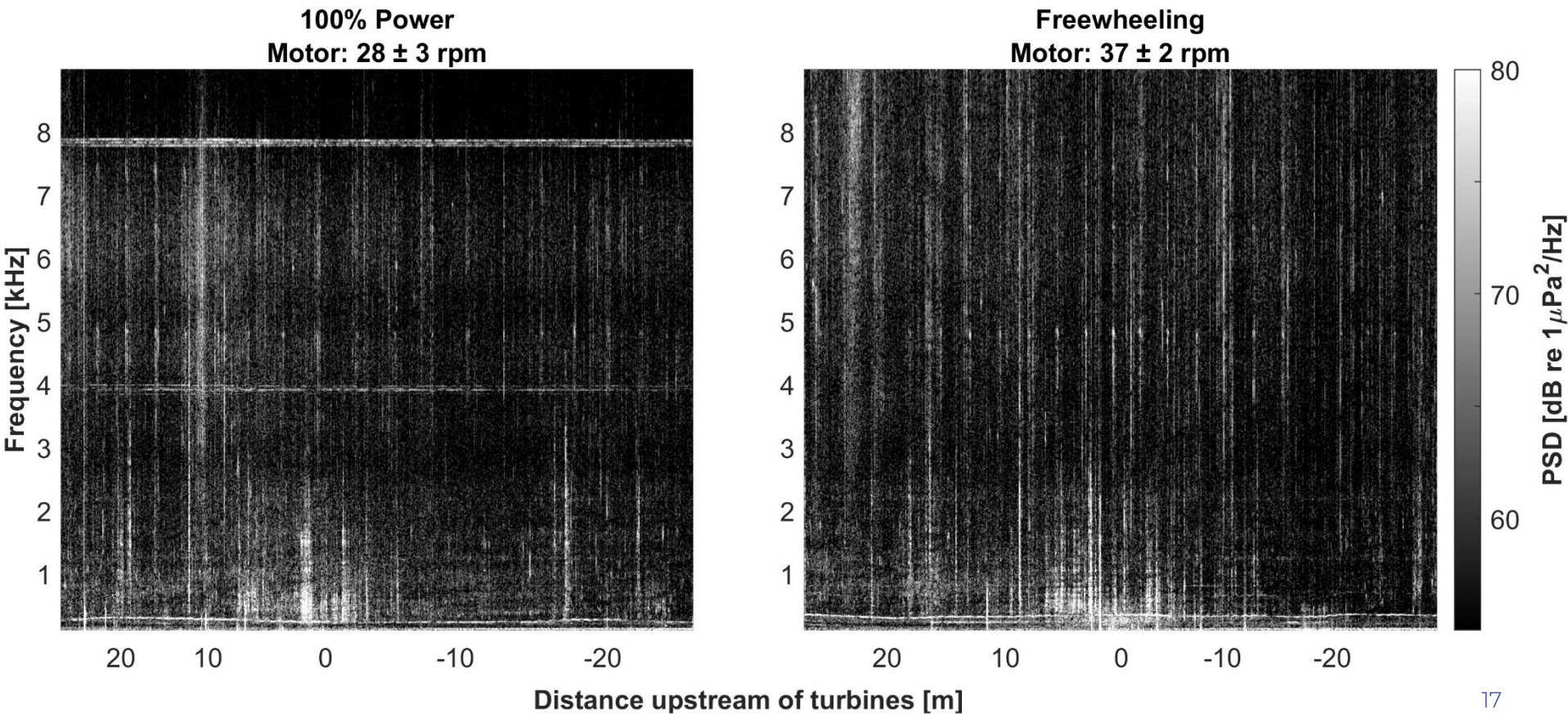
# Geared Motor Order Analysis

$$order = \frac{f}{f_{motor}}$$



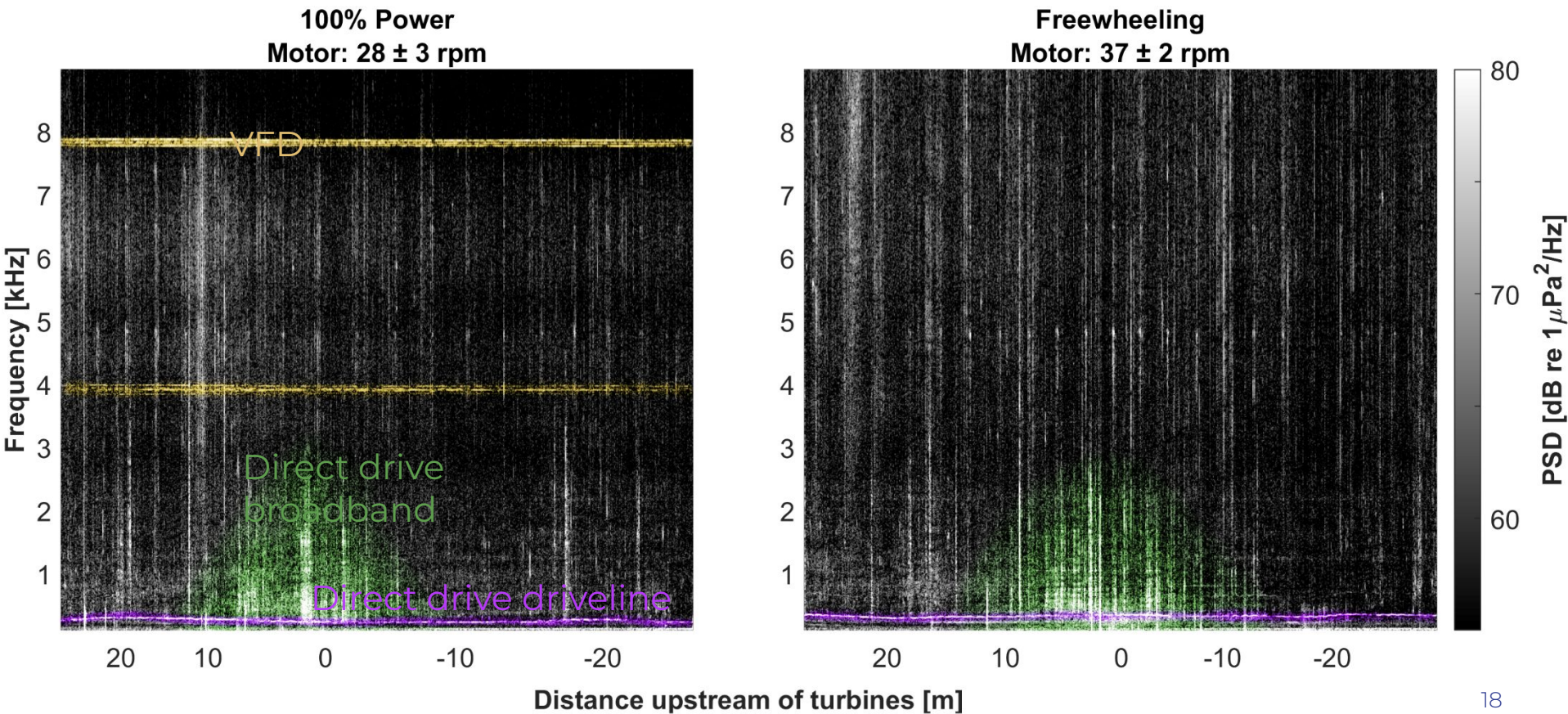


# Direct Drive Comparison





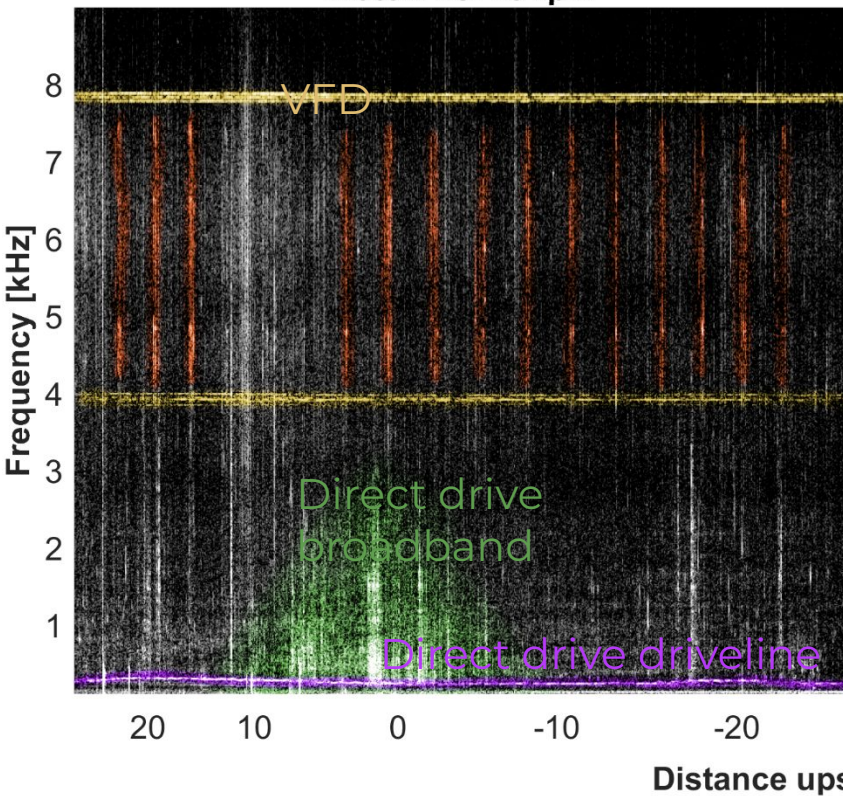
# Direct Drive Comparison



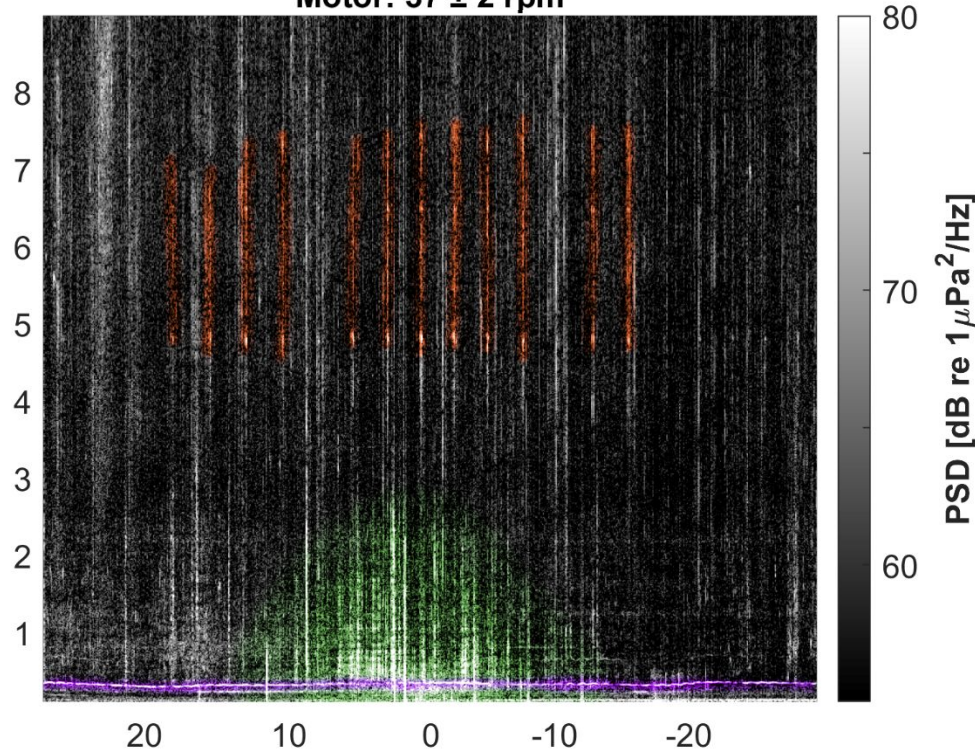


# Direct Drive Comparison

100% Power  
Motor:  $28 \pm 3$  rpm

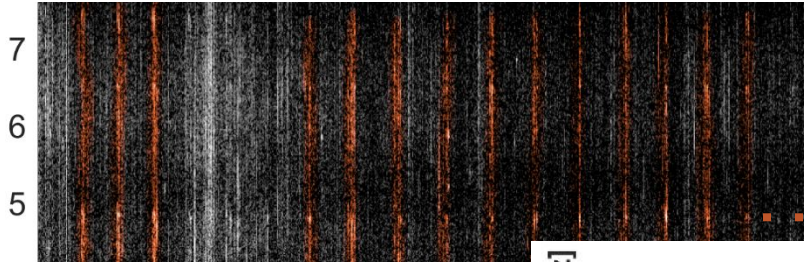


Freewheeling  
Motor:  $37 \pm 2$  rpm

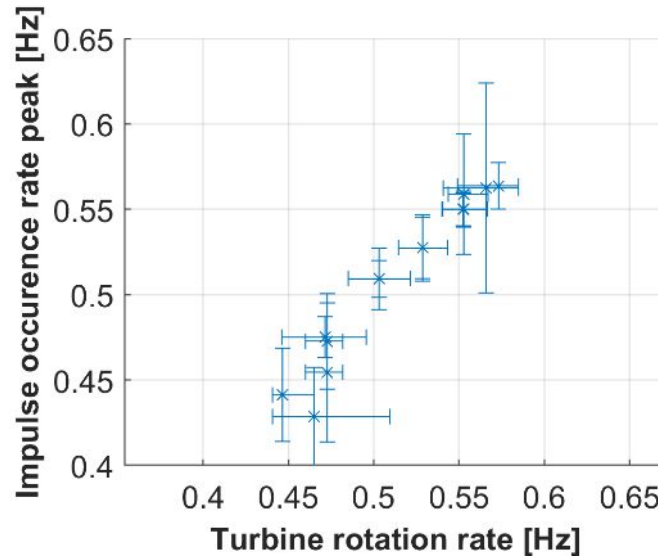
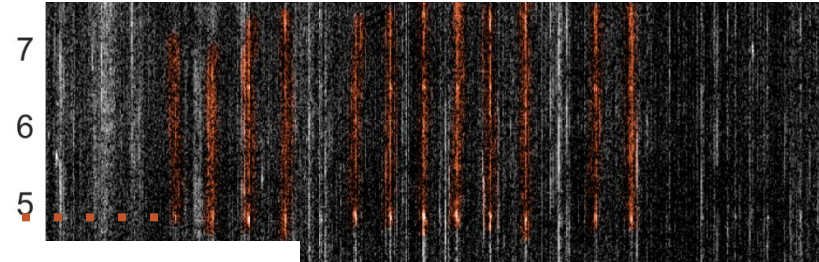


# Direct Drive Impulses

**100% Power**  
**Motor:  $28 \pm 3$  rpm**



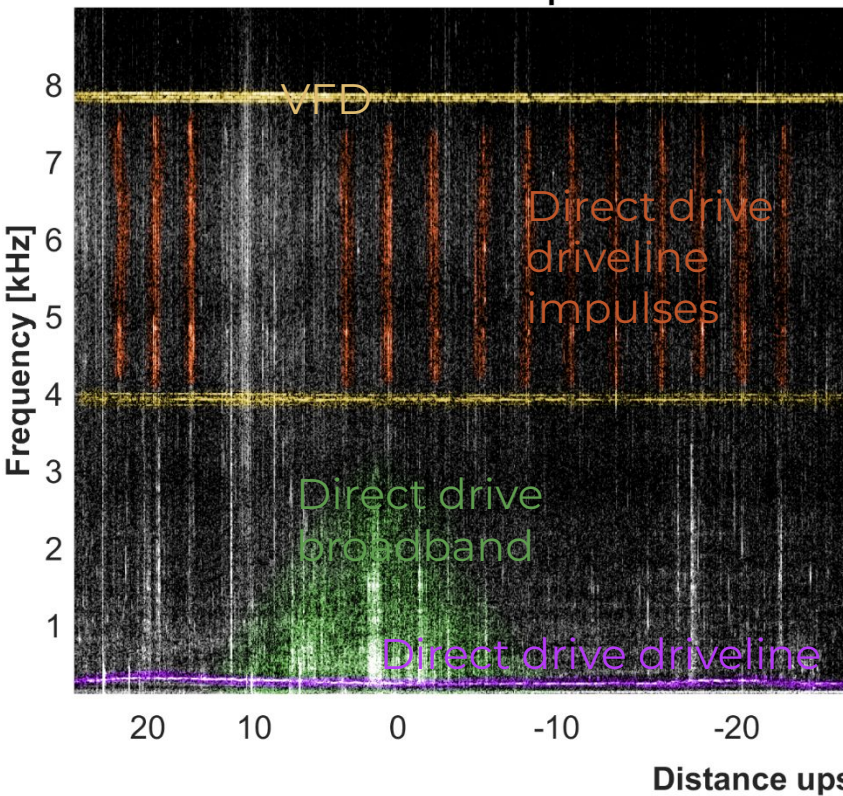
**Freewheeling**  
**Motor:  $37 \pm 2$  rpm**



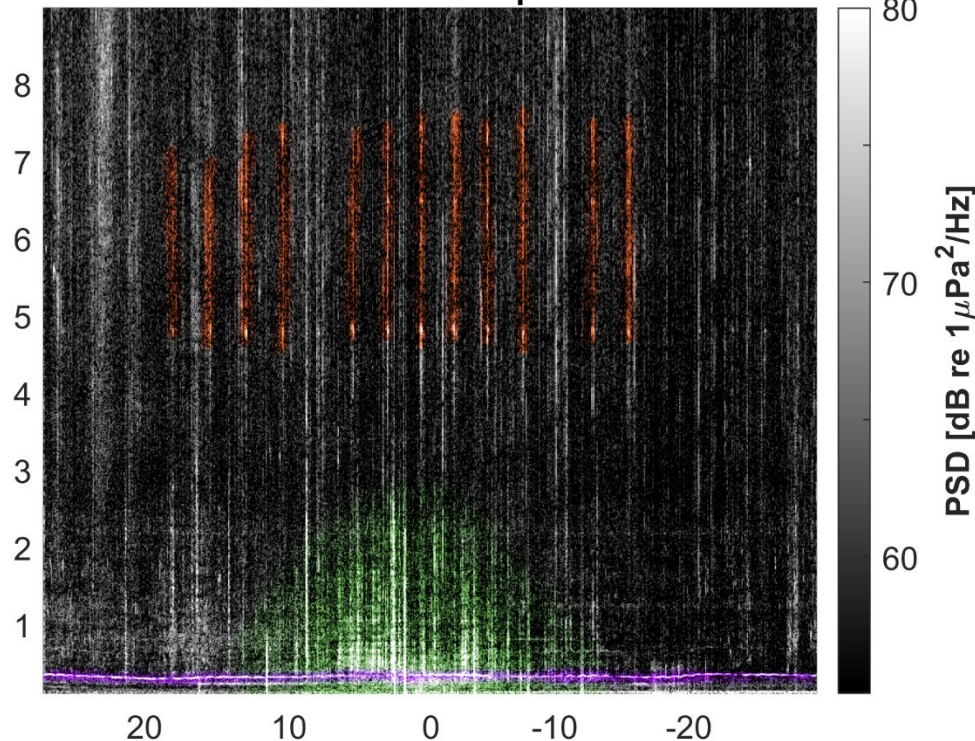


# Direct Drive Comparison

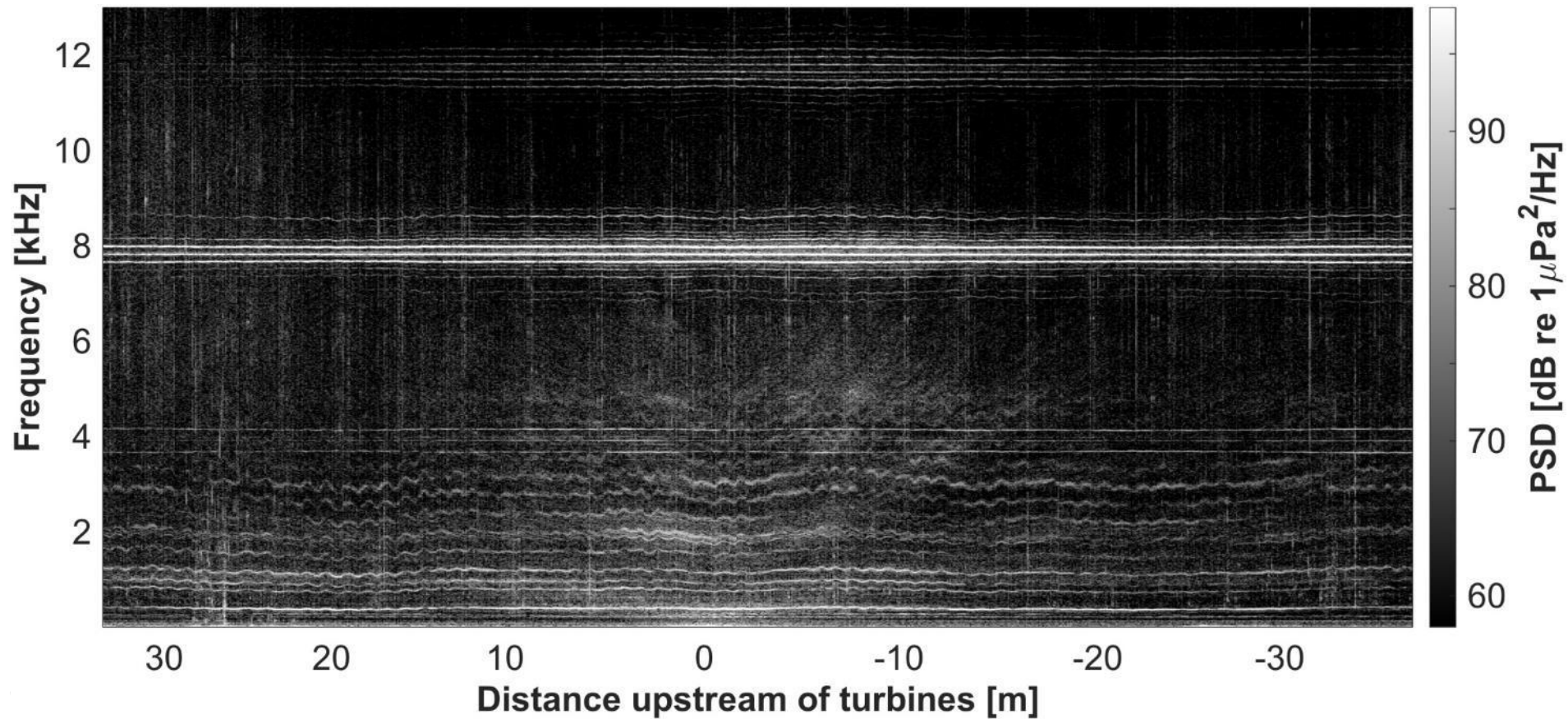
100% Power  
Motor:  $28 \pm 3$  rpm



Freewheeling  
Motor:  $37 \pm 2$  rpm

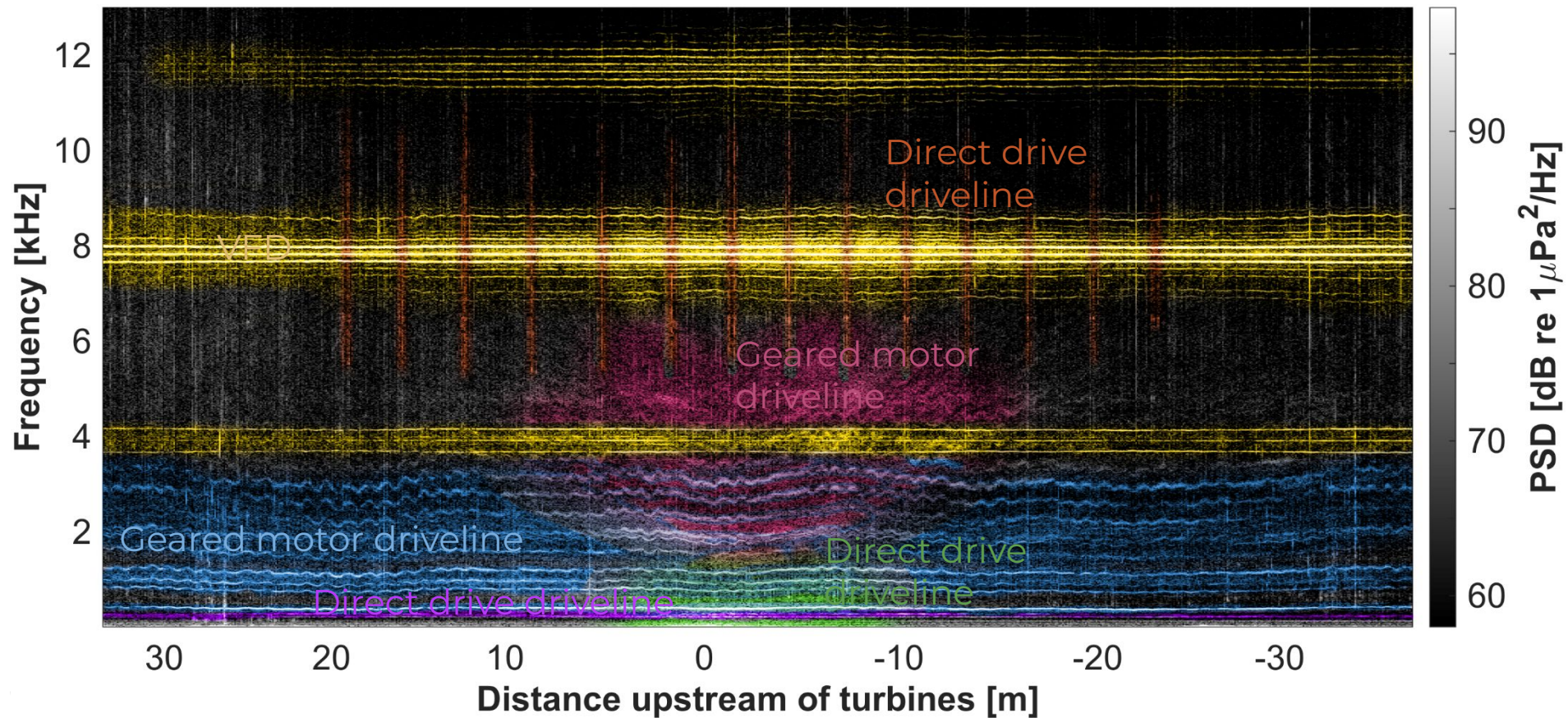


# Radiated Noise Drivers





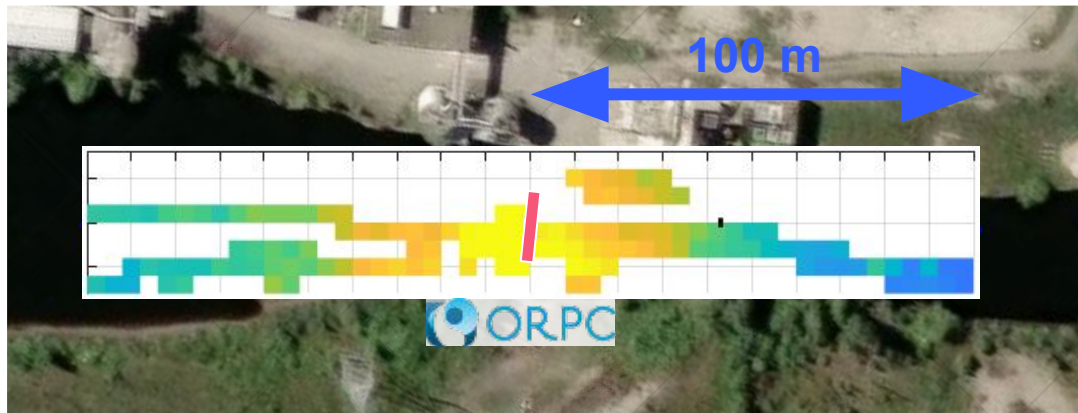
# Radiated Noise Drivers





# Acoustic spatial distributions

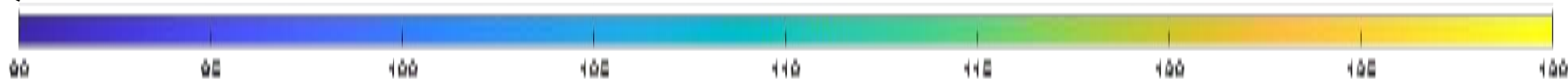
SW



NE

Quieter

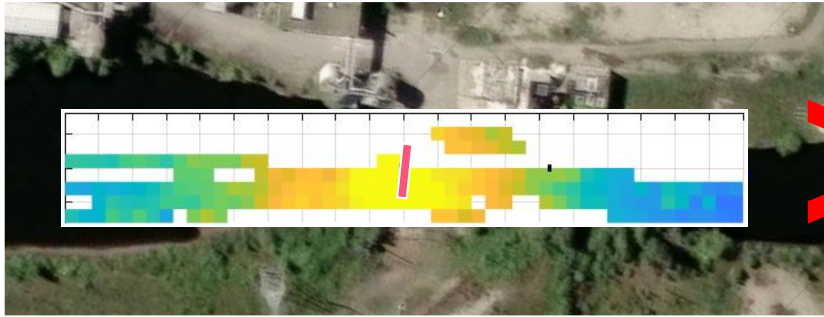
Louder



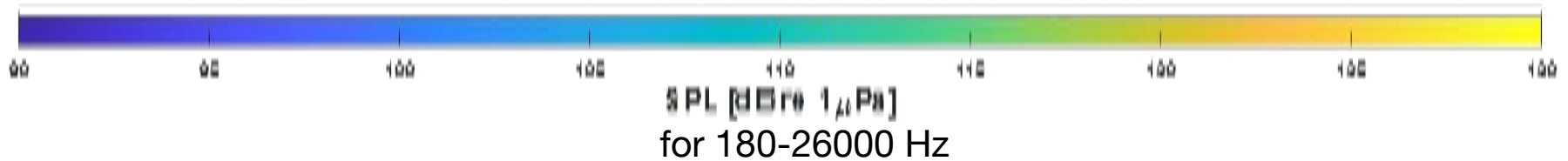
SPL [dB re 1  $\mu$ Pa]  
for 180-26000 Hz

# Does driveline affect noise levels?

Geared motor turbine



Direct drive turbine





# Does rotation speed affect noise levels?

**Geared motor: 30-40 shaft RPM**



**Direct drive: 20-30 shaft RPM**



**Geared motor: 40-50 shaft RPM**



**Direct drive: 30-40 shaft RPM**



# Conclusions

- **Unique opportunity for close-range measurements around prototype turbines**
  - Individual signals could be attributed to driveline vs VFD
- **Value of order analysis**
- **Powertrain choice strongly impacts radiated noise**
  - Opportunities to significantly alter radiated noise through powertrain design



# Acknowledgements

This study was funded by the U.S. Department of Energy through the Testing Expertise & Access for Marine Energy Research (TEAMER) program



Thank you to Nicholas Harris and Kaelin Chancey of ORPC for their field support.



Corey  
Crisp



Gemma  
Calandra



Kathryn Sellers  
Reynolds  
(ORPC)



Dr. Chris  
Bassett



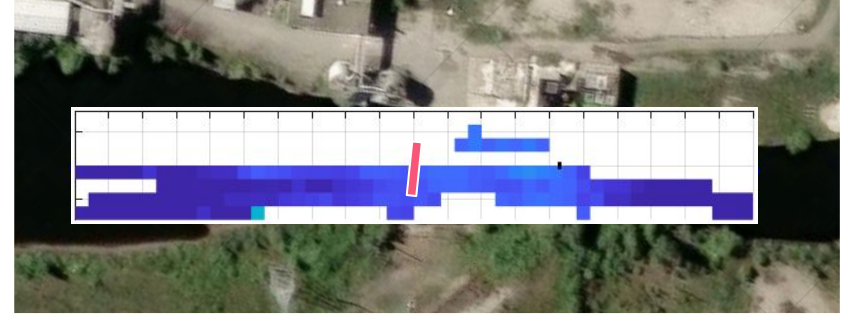
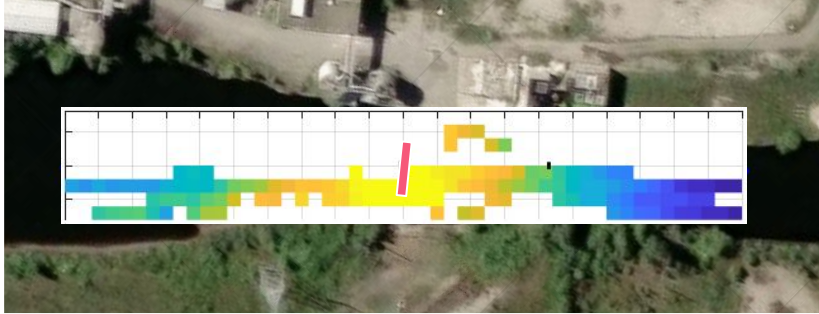
Dr. Brian  
Polagye

# Considering different frequency ranges

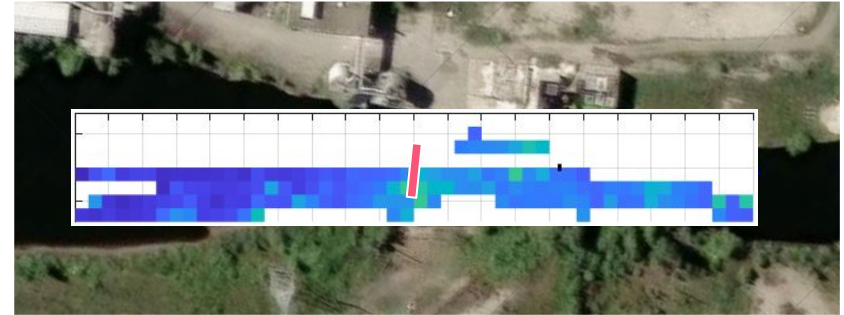
Geared motor turbine

Direct drive turbine

7000  
-9000  
Hz



180  
-3500  
Hz





# Direct Drive Order Analysis

