

Long-term Analysis of Ocean Noise Floor in the Northeast Pacific Ocean

Felix Schwock, Shima Abadi

University of Washington – Dept. of Electrical and Computer Engineering

The 180th Meeting of the Acoustical Society of America



Research Effort

- **Goals:**

- ▶ characterize ocean noise floor at northeast Pacific continental margin
- ▶ correlate noise floor with wind speed, sound speed, and shipping activity

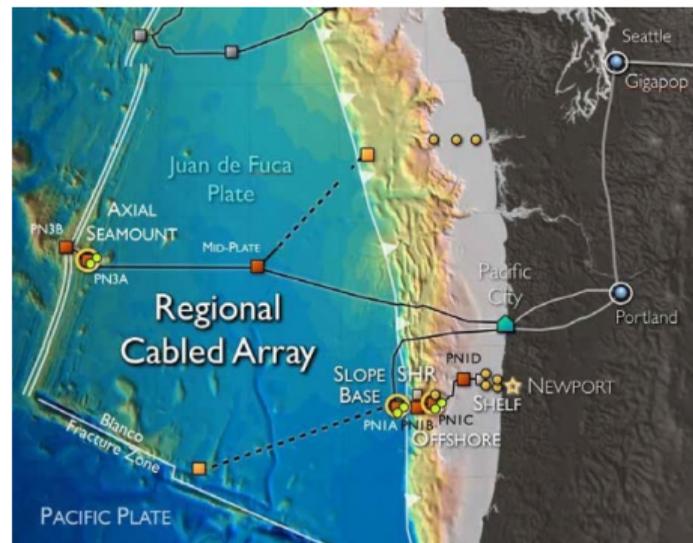


Figure from: Ocean Observatories Initiative (<https://oceanobservatories.org/image-gallery/>, Credit: University of Washington)

Research Effort

- **Goals:**

- ▶ characterize ocean noise floor at northeast Pacific continental margin
- ▶ correlate noise floor with wind speed, sound speed, and shipping activity

- **Data:**

- ▶ acoustic, meteorological, and CTD data from Ocean Observatories Initiative (OOI)

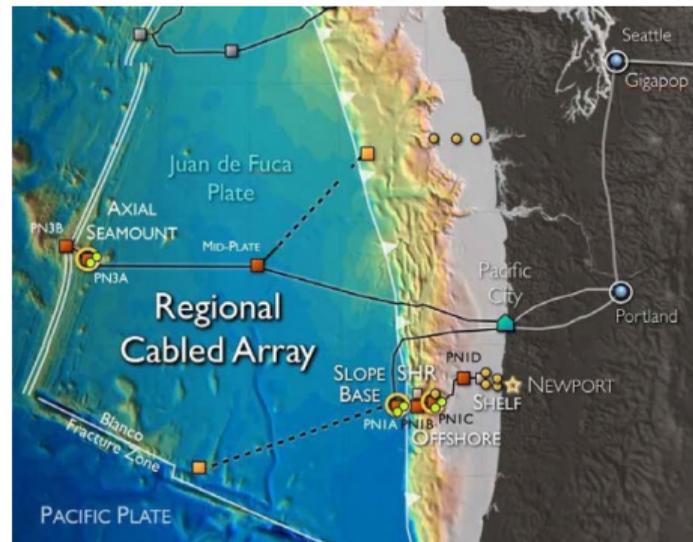


Figure from: Ocean Observatories Initiative (<https://oceanobservatories.org/image-gallery/>, Credit: University of Washington)

Research Effort

- **Goals:**

- ▶ characterize ocean noise floor at northeast Pacific continental margin
- ▶ correlate noise floor with wind speed, sound speed, and shipping activity

- **Data:**

- ▶ acoustic, meteorological, and CTD data from Ocean Observatories Initiative (OOI)
- ▶ ship position data from AIS

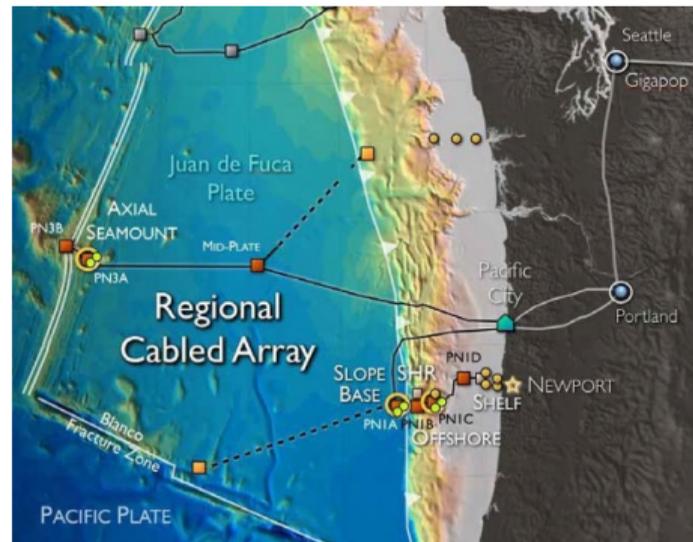


Figure from: Ocean Observatories Initiative (<https://oceanobservatories.org/image-gallery/>, Credit: University of Washington)

Research Effort

- **Goals:**

- ▶ characterize ocean noise floor at northeast Pacific continental margin
- ▶ correlate noise floor with wind speed, sound speed, and shipping activity

- **Data:**

- ▶ acoustic, meteorological, and CTD data from Ocean Observatories Initiative (OOI)
- ▶ ship position data from AIS
- ▶ Python toolbox OOIPY for OOI data processing

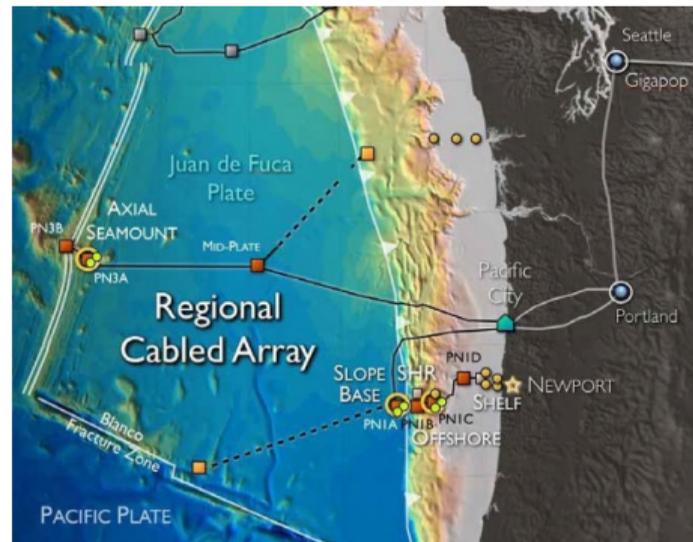


Figure from: Ocean Observatories Initiative (<https://oceanobservatories.org/image-gallery/>, Credit: University of Washington)

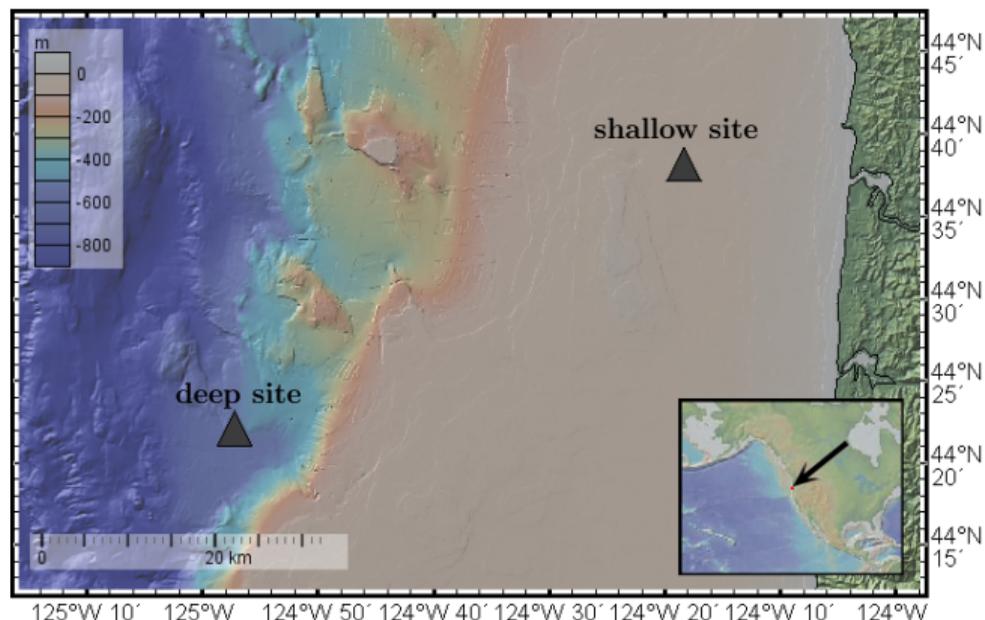
Measurement Setup – Acoustic Data

- **Acoustic Data:**

- ▶ two broadband icListen HF hydrophones, $f_s = 64$ kHz
- ▶ shallow site: 81 m depth
- ▶ deep site: 581 m depth

- **Measurement Time:**

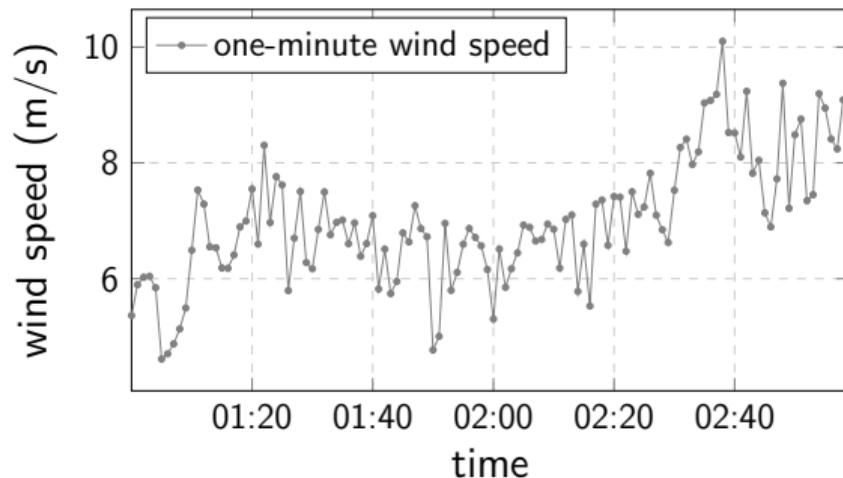
- ▶ September 2015 - June 2019



Measurement Setup – Wind and Sound Speed Data

- **Wind Data:**

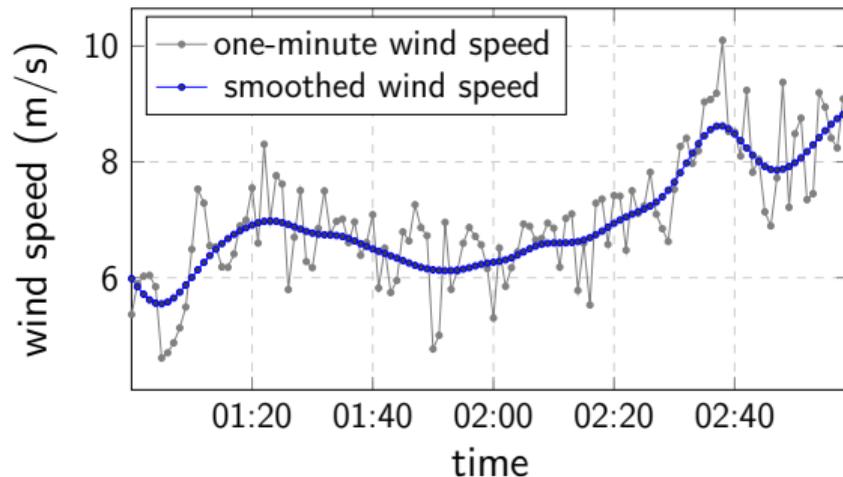
- ▶ measured by surface buoys every minute



Measurement Setup – Wind and Sound Speed Data

- **Wind Data:**

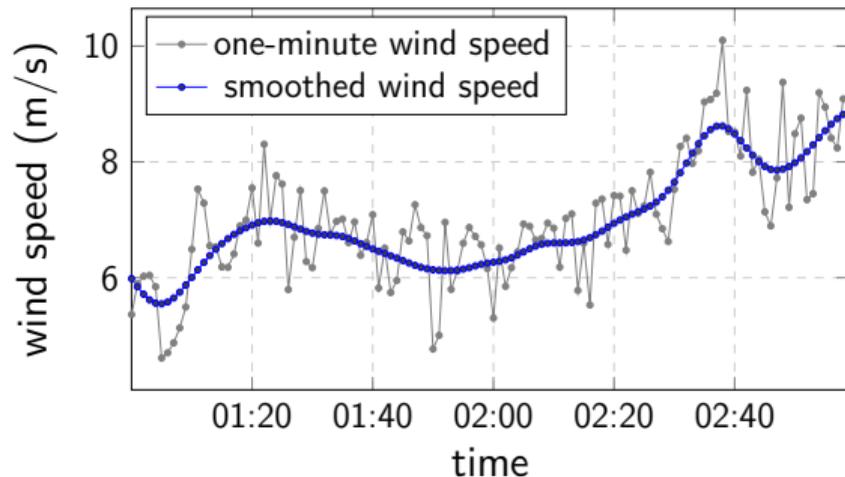
- ▶ measured by surface buoys every minute
- ▶ smoothen with 21-point Hann moving average filter



Measurement Setup – Wind and Sound Speed Data

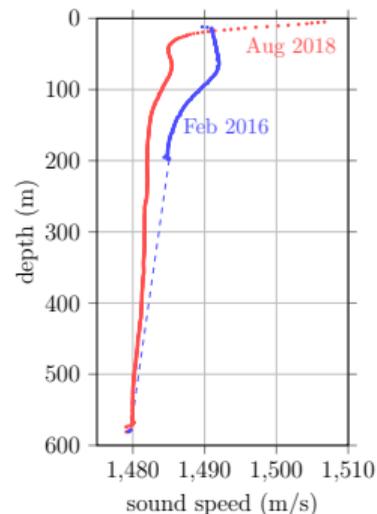
● Wind Data:

- ▶ measured by surface buoys every minute
- ▶ smoothen with 21-point Hann moving average filter



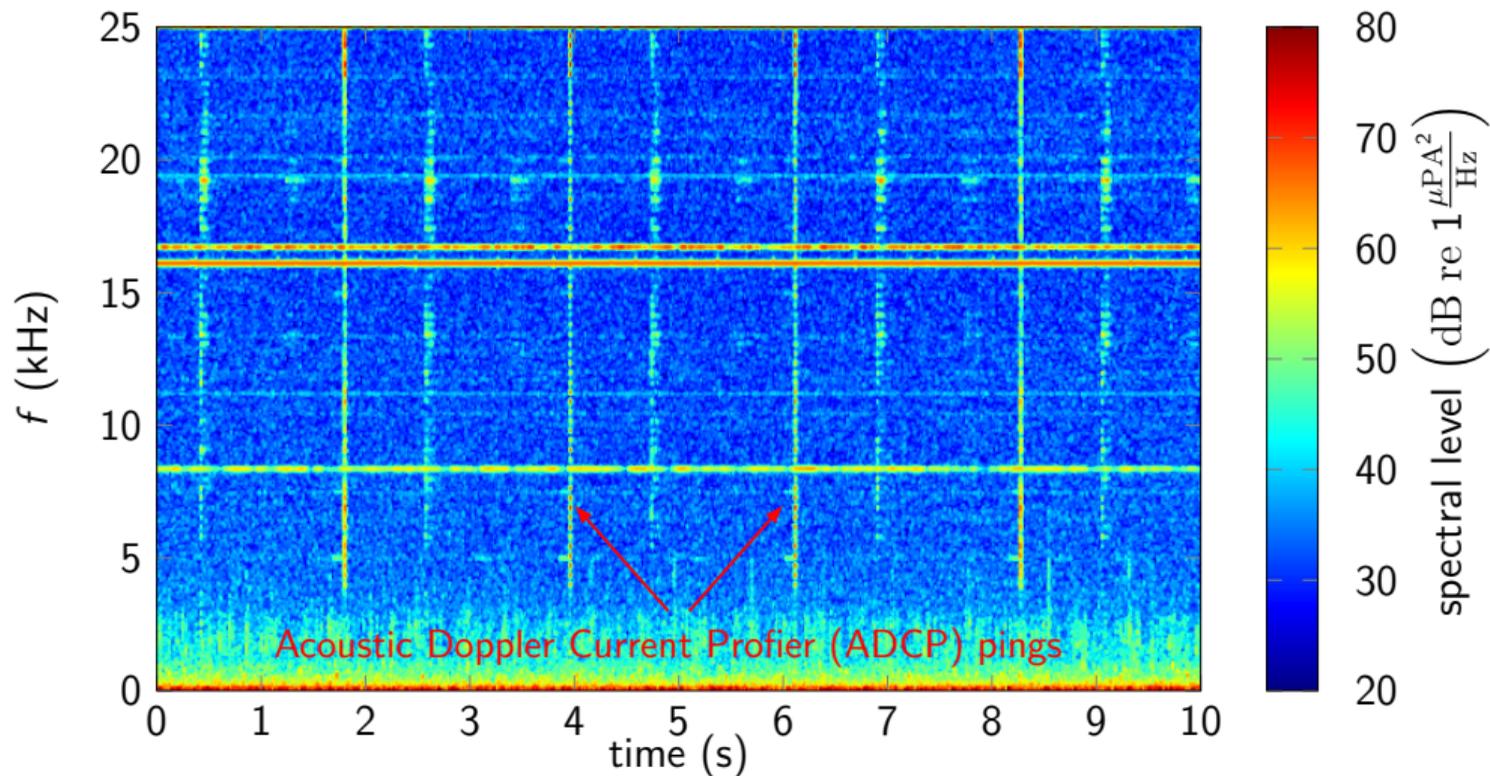
● Sound Speed Data:

- ▶ Average sound speed profile computed from the CTD data for each month



Example of Acoustic Data

10 s during June 3, 2019 (deep location)

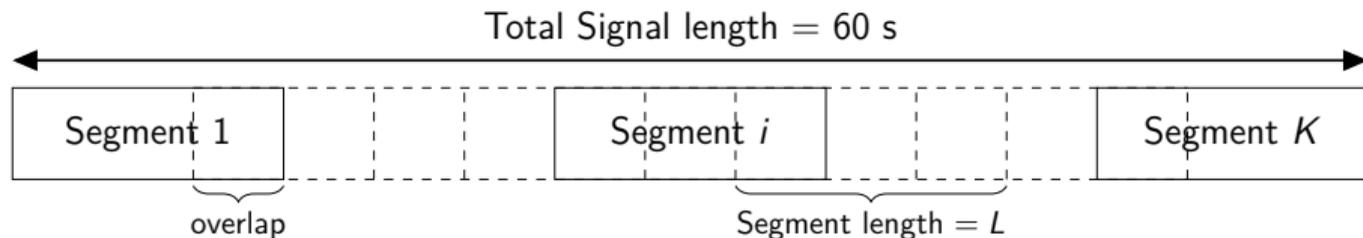


Processing of Acoustic Data to Obtain Power Spectra

- **Challenge:** find computationally efficient algorithm that is robust against outliers

Processing of Acoustic Data to Obtain Power Spectra

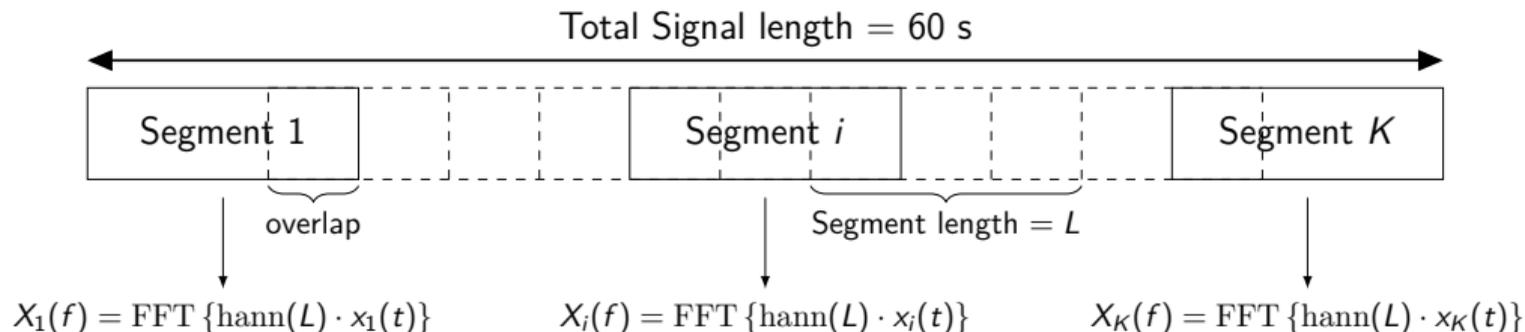
- **Challenge:** find computationally efficient algorithm that is robust against outliers
- **Approach:** modified Welch method¹



¹Schwock & Abadi, "Statistical Properties of a Modified Welch Method That Uses Sample Percentiles" IEEE ICASSP 2021, accepted.

Processing of Acoustic Data to Obtain Power Spectra

- **Challenge:** find computationally efficient algorithm that is robust against outliers
- **Approach:** modified Welch method¹

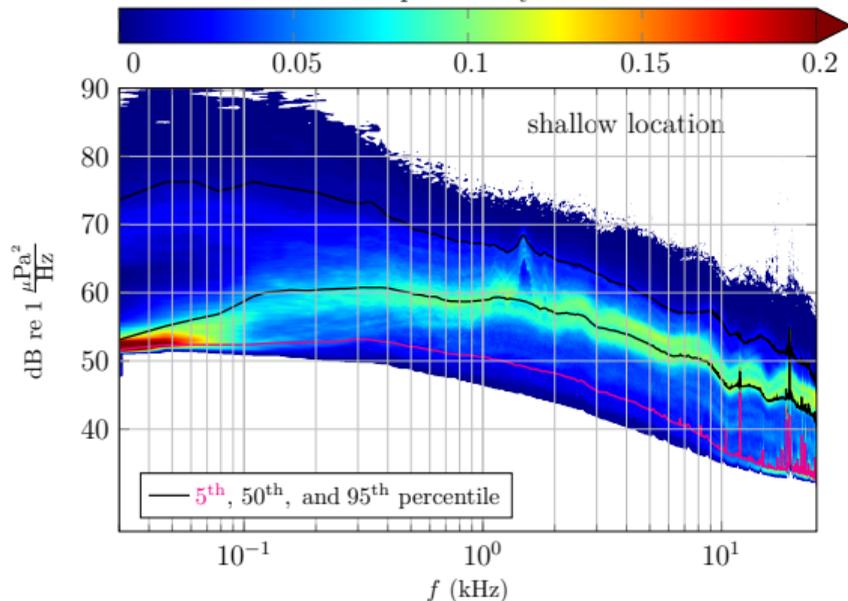


¹Schwock & Abadi, "Statistical Properties of a Modified Welch Method That Uses Sample Percentiles" IEEE ICASSP 2021, accepted.

Spectral Probability Density for July 2016

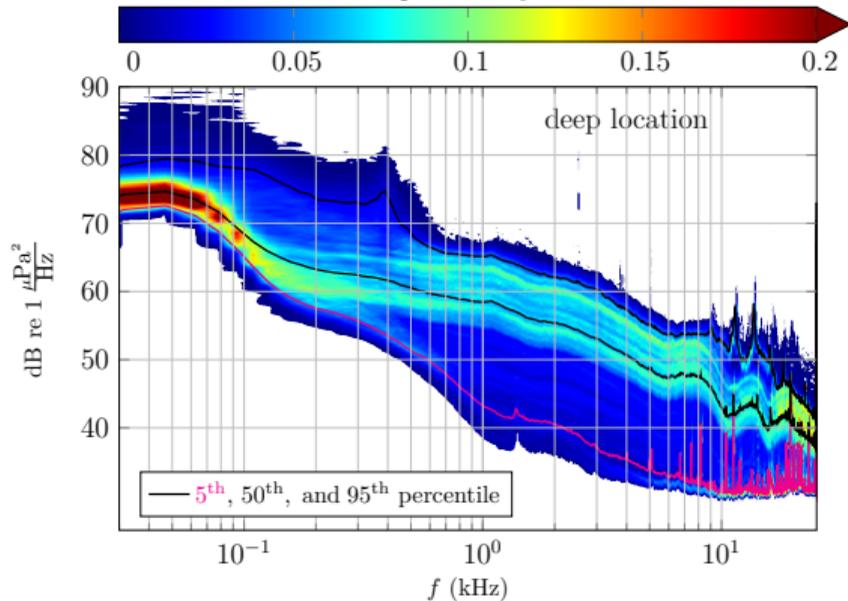
shallow location

probability



deep location

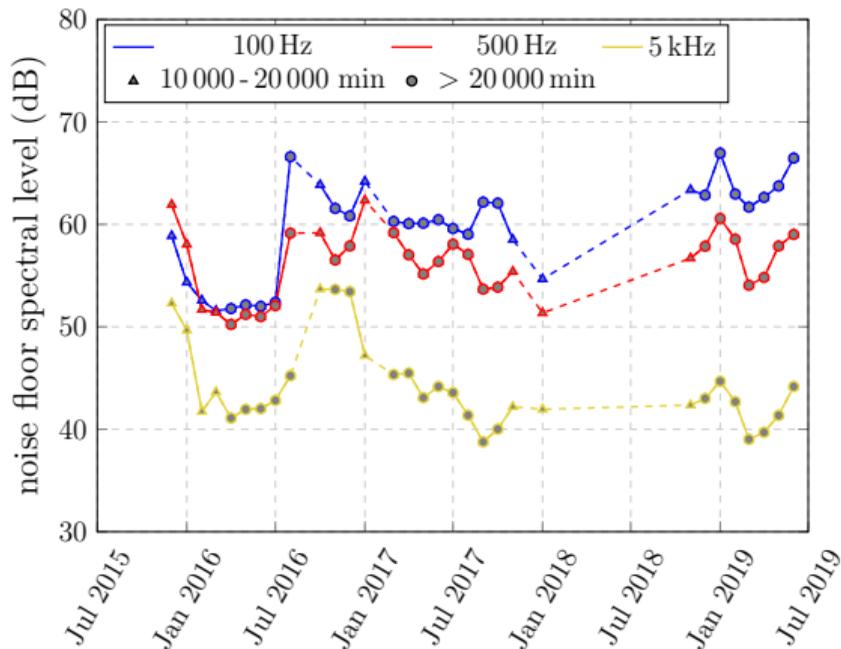
probability



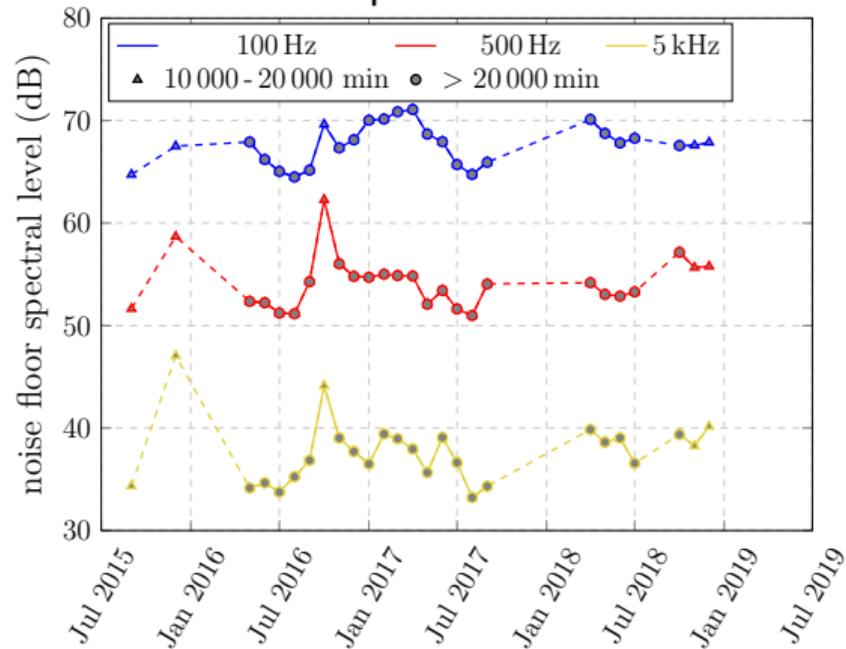
Noise Floor: 5th percentile of spectral probability density

Noise Floor Time Series

shallow location



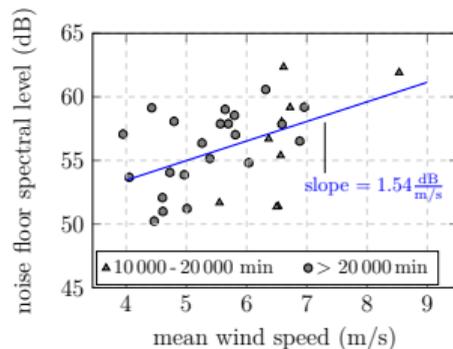
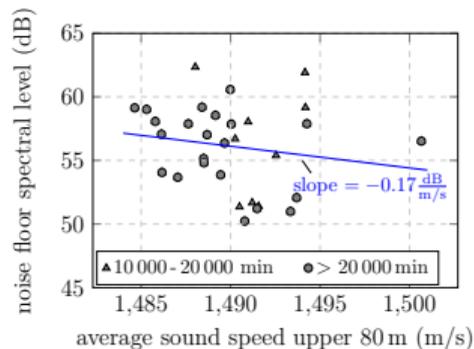
deep location



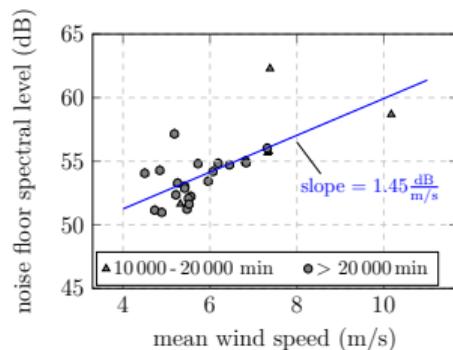
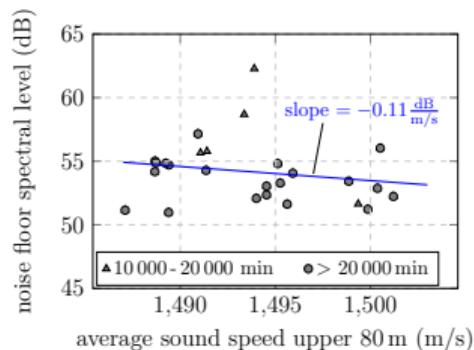
Only months with $\geq 10\,000$ min of available data are included

Dependence of Noise Floor Spectral Level at 500 Hz on Wind Speed, Sound Speed, and Ship Intensity

shallow location

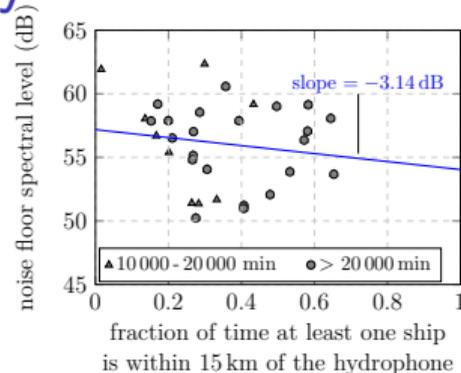
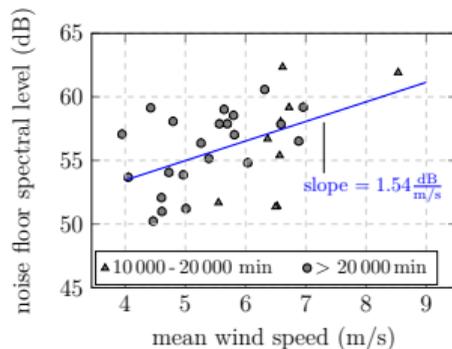
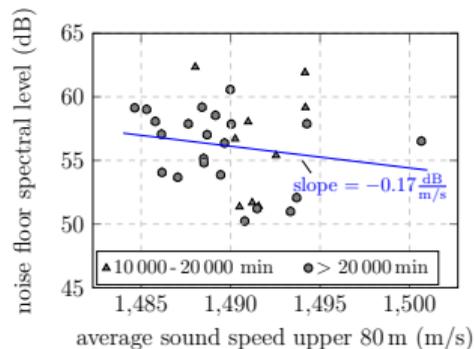


deep location

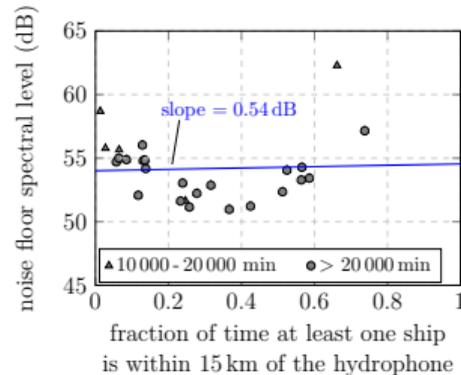
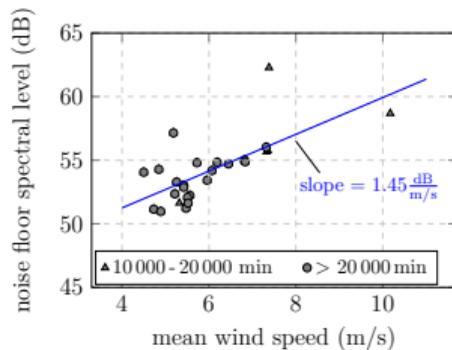
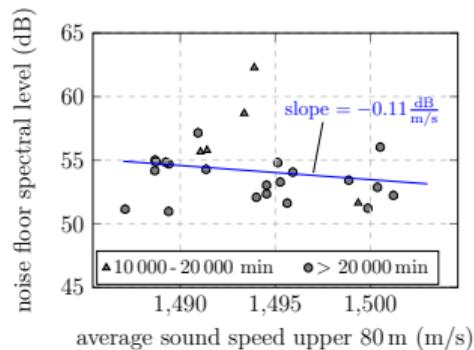


Dependence of Noise Floor Spectral Level at 500 Hz on Wind Speed, Sound Speed, and Ship Intensity

shallow location



deep location



Shallow Location - Linear Regression

$$\text{spectral level} = s_{\text{sound}} \cdot \underbrace{c_{\text{sound}}}_{\text{avg sound speed (m/s)}}$$

Shallow Location - Linear Regression

$$\text{spectral level} = s_{\text{sound}} \cdot \underbrace{c_{\text{sound}}}_{\text{avg sound speed (m/s)}} + s_{\text{wind}} \cdot \underbrace{c_{\text{wind}}}_{\text{avg wind speed (m/s)}}$$

Shallow Location - Linear Regression

$$\text{spectral level} = s_{\text{sound}} \cdot \underbrace{c_{\text{sound}}}_{\text{avg sound speed (m/s)}} + s_{\text{wind}} \cdot \underbrace{c_{\text{wind}}}_{\text{avg wind speed (m/s)}} + s_{\text{ship}} \cdot \underbrace{i_{\text{ship}}}_{\text{ship intensity}}$$

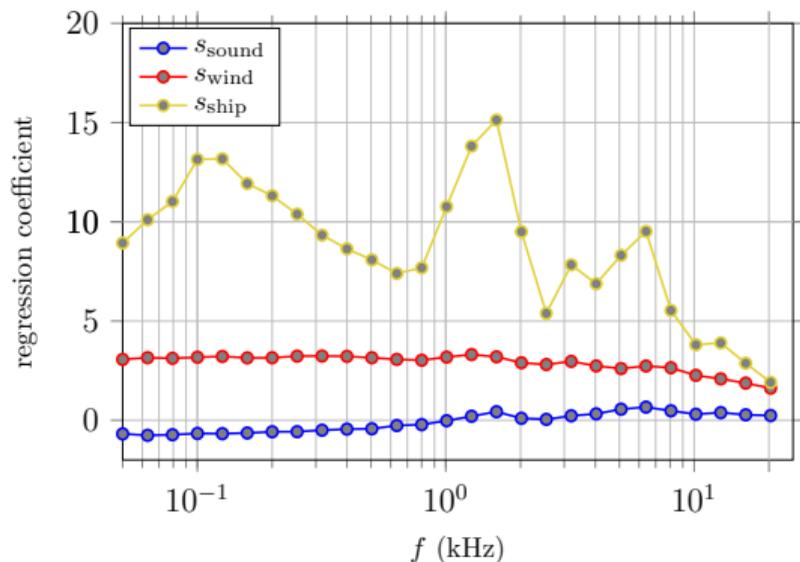
Shallow Location - Linear Regression

$$\text{spectral level} = s_{\text{sound}} \cdot \underbrace{c_{\text{sound}}}_{\text{avg sound speed (m/s)}} + s_{\text{wind}} \cdot \underbrace{c_{\text{wind}}}_{\text{avg wind speed (m/s)}} + s_{\text{ship}} \cdot \underbrace{i_{\text{ship}}}_{\text{ship intensity}} + b$$

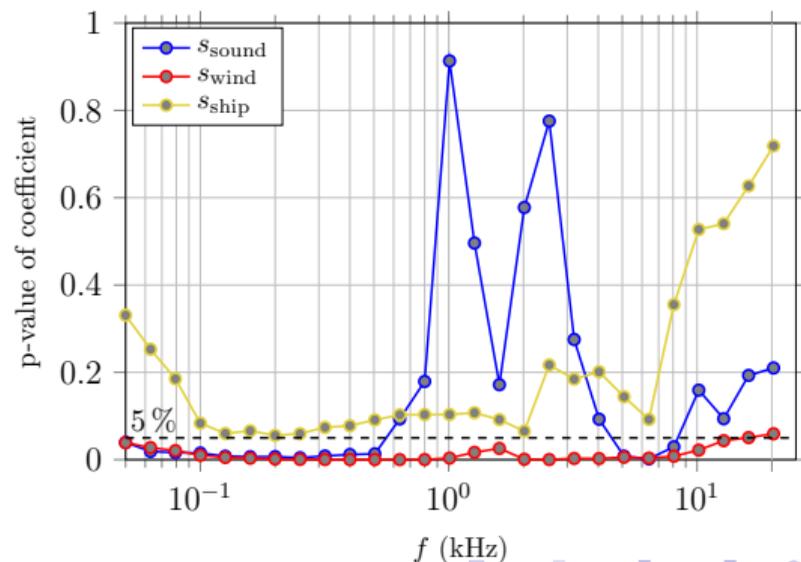
Shallow Location - Linear Regression

$$\text{spectral level} = s_{\text{sound}} \cdot \underbrace{c_{\text{sound}}}_{\text{avg sound speed (m/s)}} + s_{\text{wind}} \cdot \underbrace{c_{\text{wind}}}_{\text{avg wind speed (m/s)}} + s_{\text{ship}} \cdot \underbrace{i_{\text{ship}}}_{\text{ship intensity}} + b$$

regression coefficients



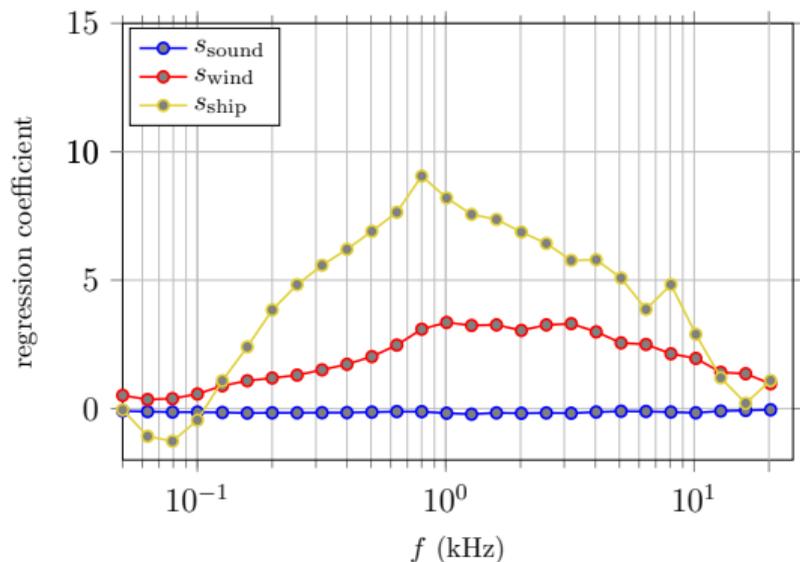
p-values



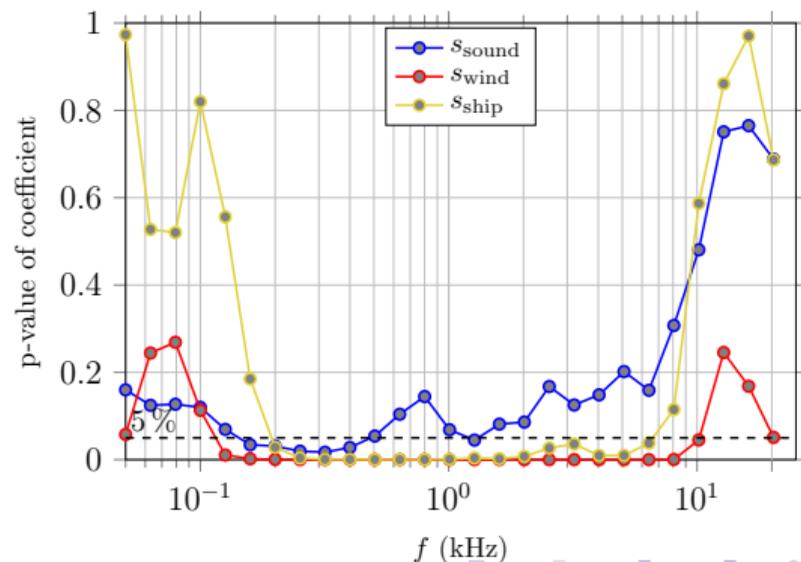
Deep Location - Linear Regression

$$\text{spectral level} = s_{\text{sound}} \cdot \underbrace{c_{\text{sound}}}_{\text{avg sound speed (m/s)}} + s_{\text{wind}} \cdot \underbrace{c_{\text{wind}}}_{\text{avg wind speed (m/s)}} + s_{\text{ship}} \cdot \underbrace{i_{\text{ship}}}_{\text{ship intensity}} + b$$

regression coefficients



p-values



Conclusions

- **Summary of Results:**

- ▶ Acoustic noise floor is defined as 5th percentile PSD estimate
- ▶ For various acoustic frequencies, time series of the noise floor spectral level were obtained
- ▶ Noise floor spectral levels were correlated to sound speed, wind speed, and shipping intensity
- ▶ Mean wind speed is the statistically most significant parameter to predict the noise floor

- **Future Work:**

- ▶ Analyze longer time periods to look for long-term trends and seasonal patterns