Studying the Correlation between Wind Noise Levels and Topography for Wind Noise Mapping and Site Selection

Céu Jesus[1,2], Roger Waxler[1], Claus Hetzer[1], Lance Yarbrough[2], Carrick Talmadge[1], Hank Buchanan[1], Naveen Thirunilath[1]

[1] National Center for Physical Acoustics, The University of Mississippi

[2] Department of Geology & Geological Engineering, The University of Mississippi

11 September 2025

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Wind Noise & Local Topography

Turbulent pressure fluctuations around infrasound sensors, known as **wind noise**, are the primary factor masking infrasound detections of interest, such as signals generated by natural hazards.

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Identifying deployment sites with **sufficiently low wind noise levels** is crucial for achieving good signal-to-noise ratios.

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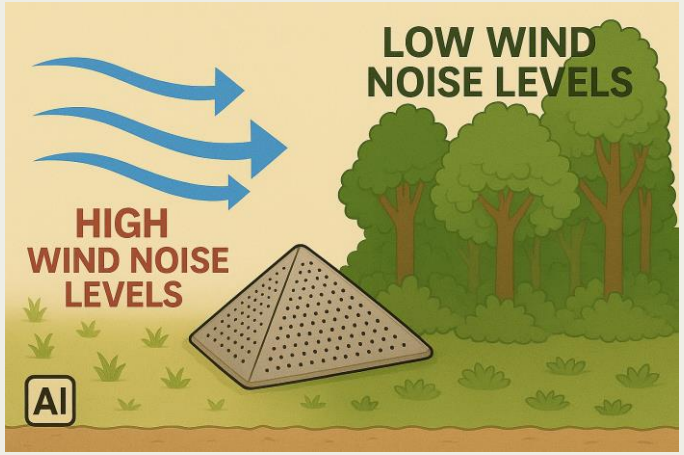
Noise levels are expected to correlate with local topography, which influences wind flow patterns and turbulence.



LONG TERM GOAL

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Establish a framework for understanding wind noise behavior across varying topographic conditions, supporting the **development of effective methodologies for wind noise mapping and site selection**.

THRESHOLD REFERENCE LEVEL:

- **WLB array** as the **standard** to equal or beat

(Waxler, R., Frazier, W. G., Talmadge, C. L., Liang, B., Hetzer, C., Buchanan, H., & Audette, W. E. (2024). **Analysis of infrasound array data from tornadic storms in the southeastern United States**. *The Journal of the Acoustical Society of America*, 156(3), 1903–1919. https://doi.org/10.1121/10.0028815)

↓

HOW QUIET THE SITE NEEDS TO BE?

- **≤ 60 dB** about **80%** of the time

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Methodology

DATA COLLECTION

Wind noise **data collected** from multiple deployment sites in Central Mississippi, analyzed for the periods August 15–31 and October 15–31, 2024.

DATA PROCESSING

RMS pressure levels calculated for **two frequency bands**: 0.1–1 Hz and 1–10 Hz.

STATISTICAL ANALYSIS

Epanechnikov Kernel Density Estimation (KDE) applied to estimate Probability Density Functions (**PDFs**).

Cumulative Distribution Functions (**CDFs**) processed based on the PDFs, to determine the probability of noise levels falling below 60 dB.

QUALITATIVE ASSUMPTIONS

Qualitative Observation between the CDF values and the Aerial Imagery.

FUTURE STEPS

Deploy more sensors to collect wind noise data near different topographic features.

Collect local topographic data in *situ* using LiDAR and Multispectral sensors onboard of sUAS.

Analyze in *situ* and satellite imagery data to obtain topographic parameters, such as ground elevation, canopy height and vegetation density.

Integrate the topographic parameters with the wind noise levels recorded from sensors.

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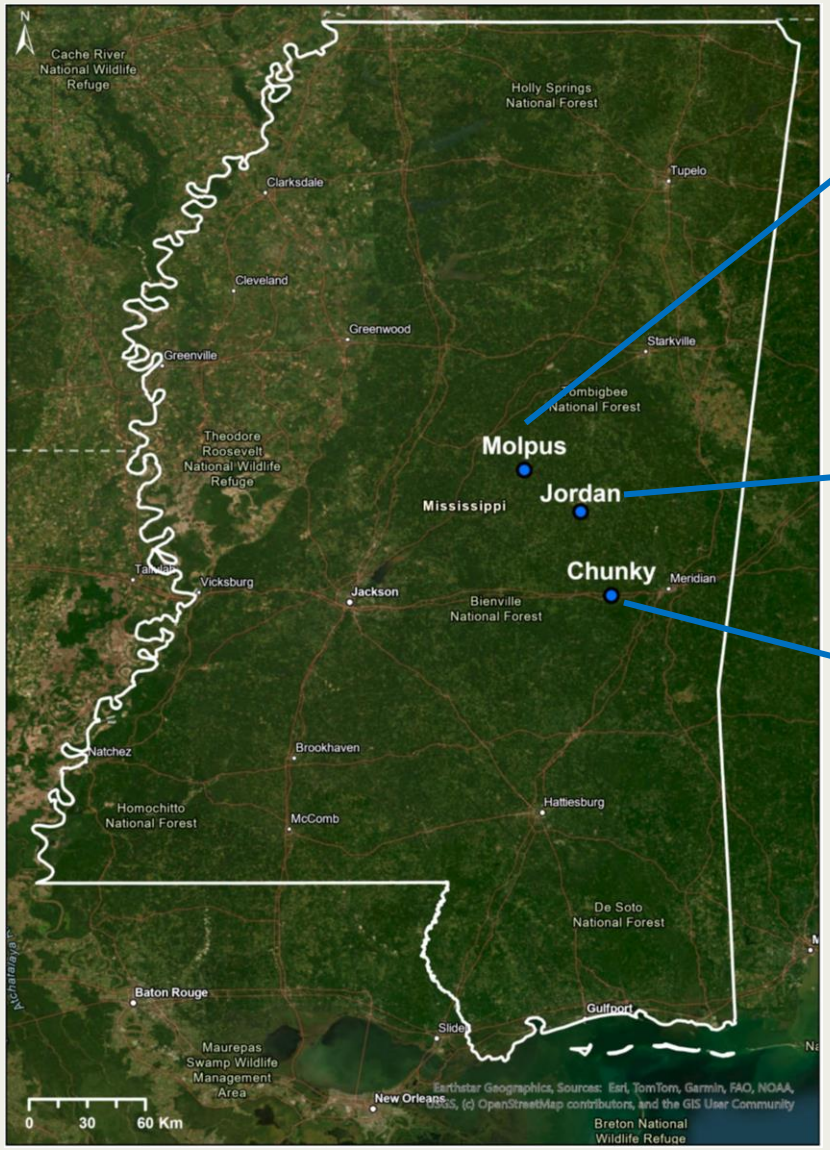
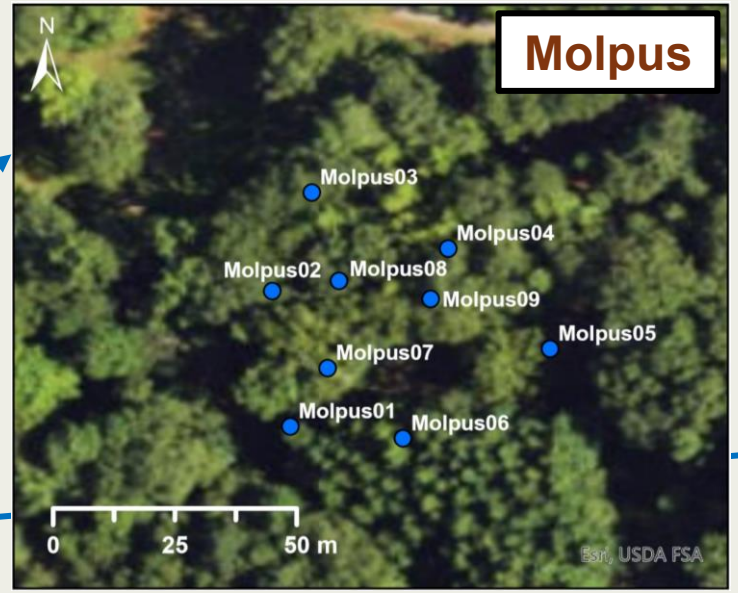
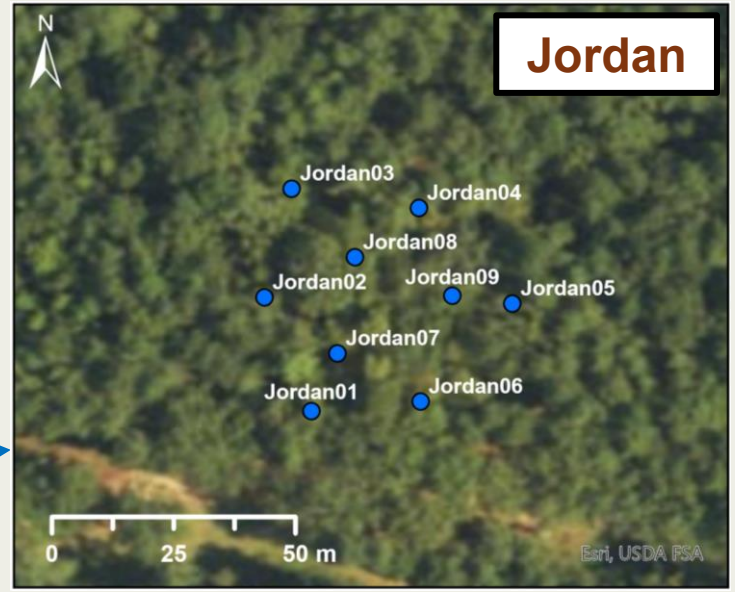
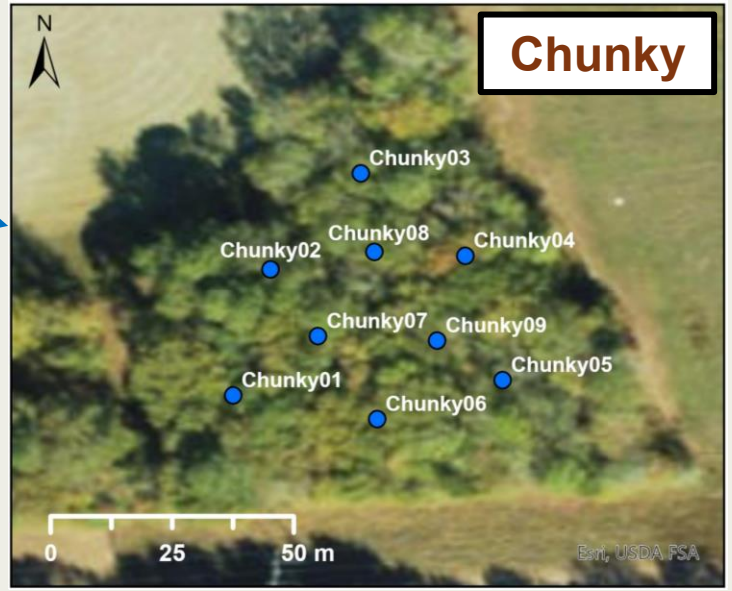
Deployment Sites in Mississippi









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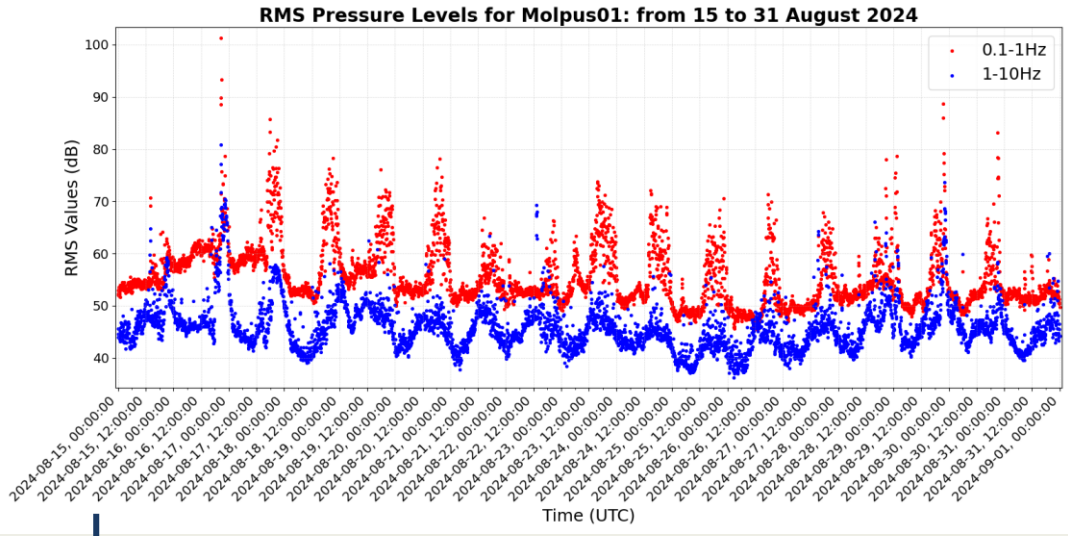
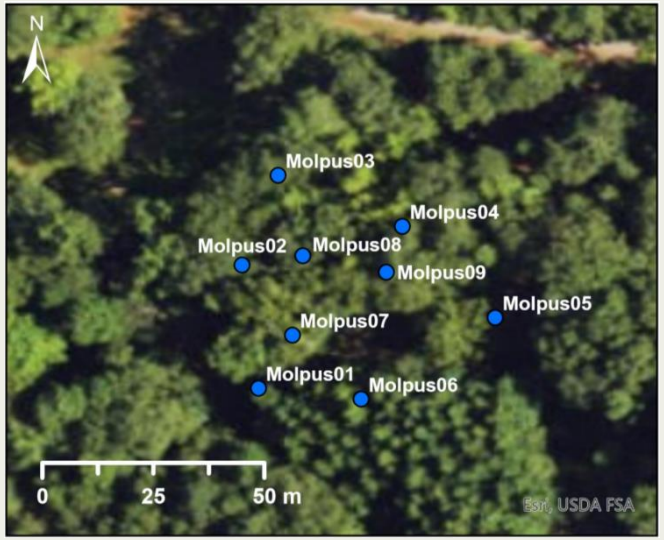
RMS Pressure & Statistics: Molpus Array



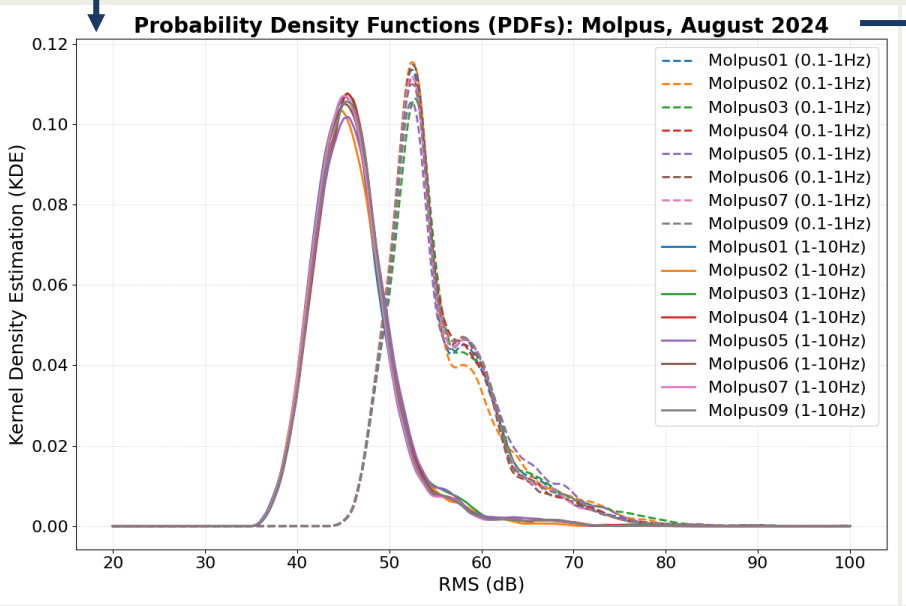


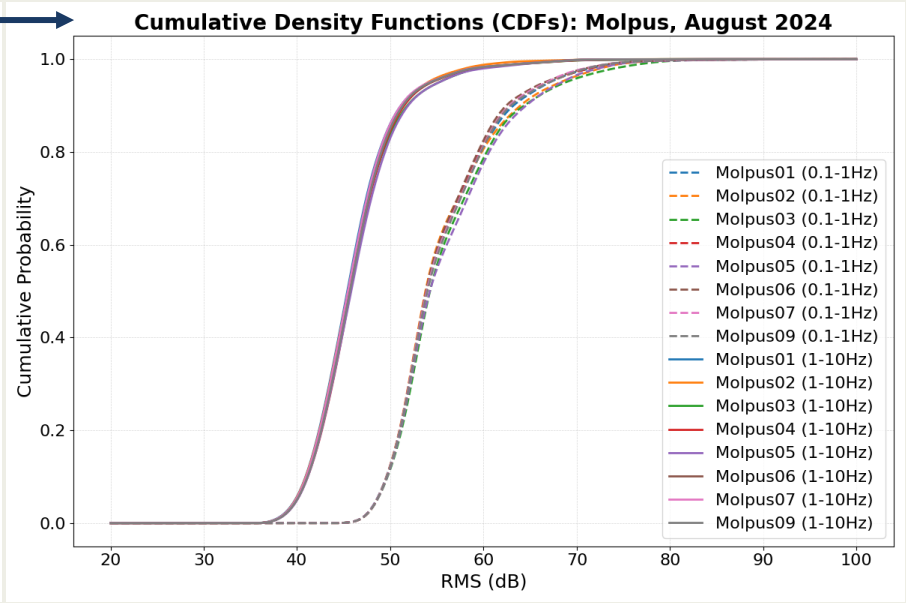
% of the Time at ≤ 60 dB

Lower Noise ↓

Higher Noise ↓

1-10 Hz	0.1-1 Hz
Molpus02: 99%	Molpus06: 83%
Molpus09: 98%	Molpus04: 82%
Molpus07: 98%	Molpus07: 81%
Molpus01: 98%	Molpus09: 81%
Molpus06: 98%	Molpus01: 81%
Molpus04: 98%	Molpus02: 81%
Molpus03: 98%	Molpus03: 79%
Molpus05: 98%	Molpus05: 78%





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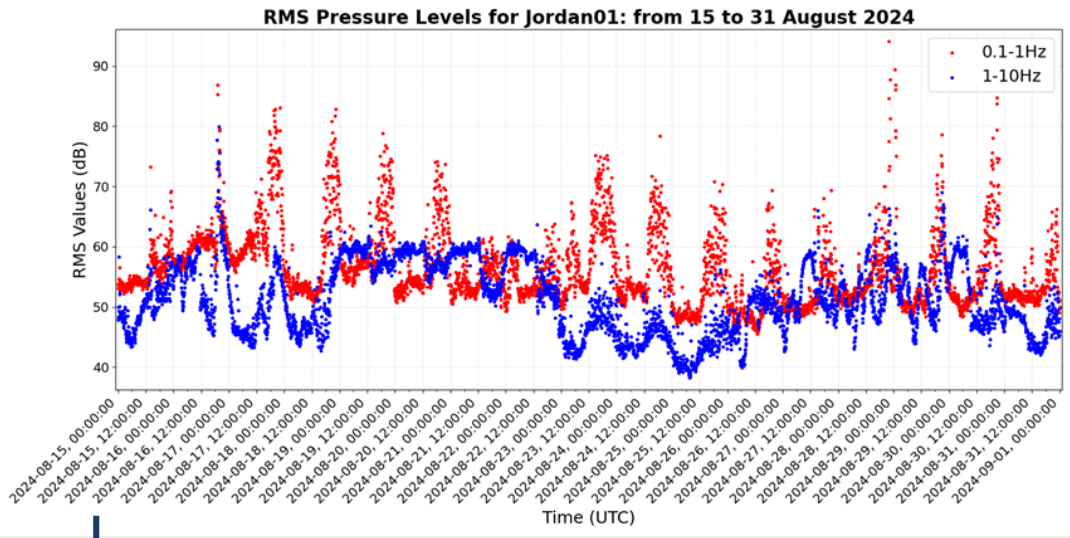
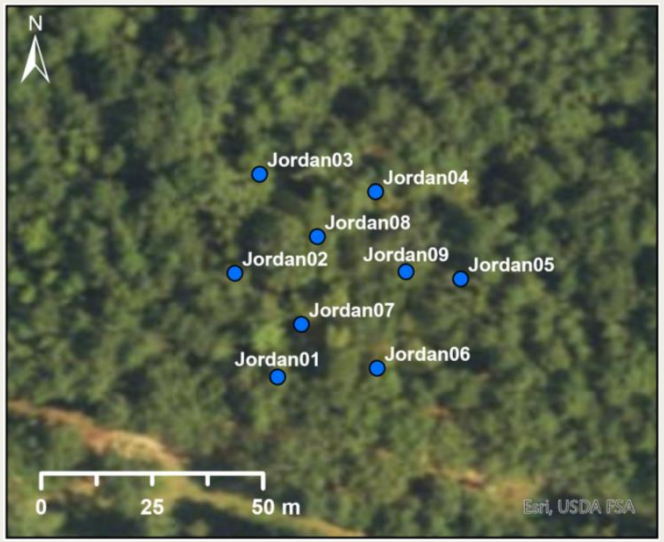
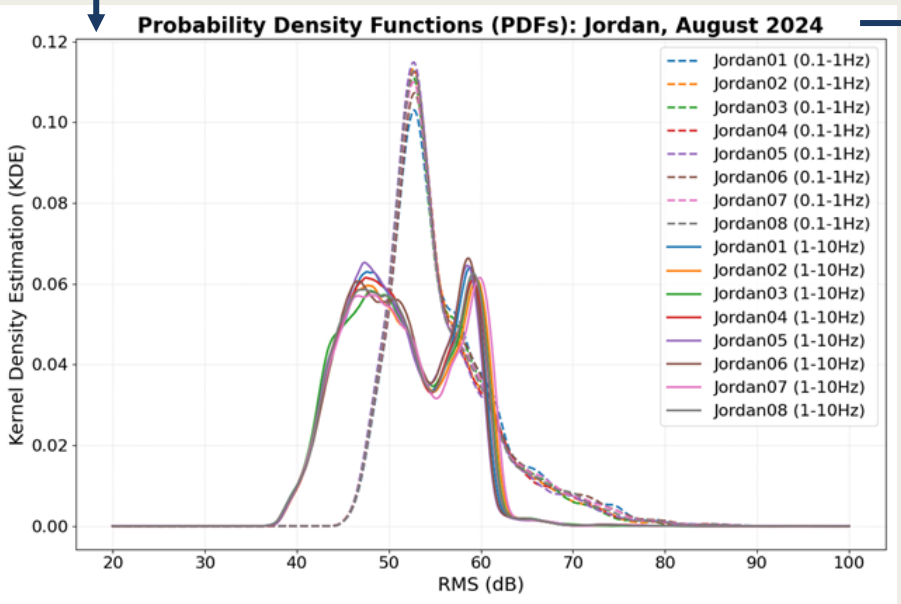
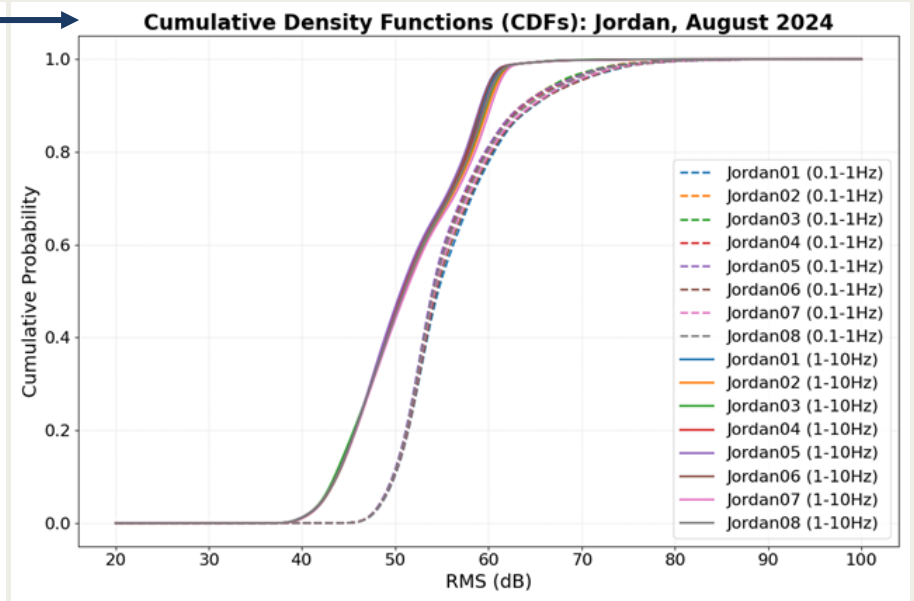
RMS Pressure & Statistics: Jordan Array









% of the Time at ≤ 60 dB

Lower Noise ↓

Higher Noise ↓

1-10 Hz	0.1-1 Hz
Jordan05: 95%	Jordan05: 81%
Jordan06: 94%	Jordan02: 81%
Jordan01: 93%	Jordan04: 81%
Jordan04: 92%	Jordan03: 81%
Jordan08: 91%	Jordan08: 80%
Jordan03: 91%	Jordan07: 80%
Jordan02: 90%	Jordan06: 79%
Jordan07: 88%	Jordan01: 78%

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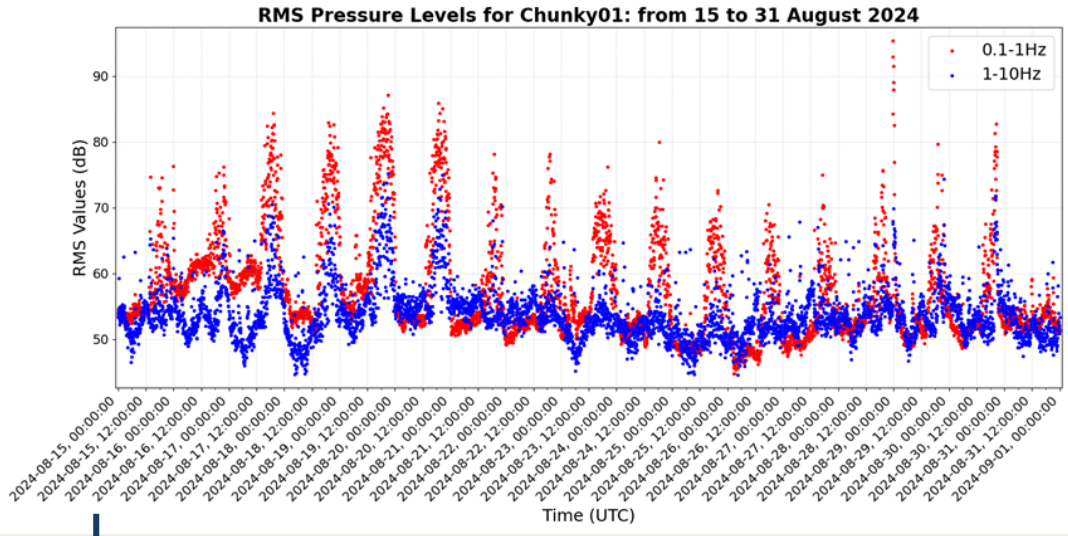
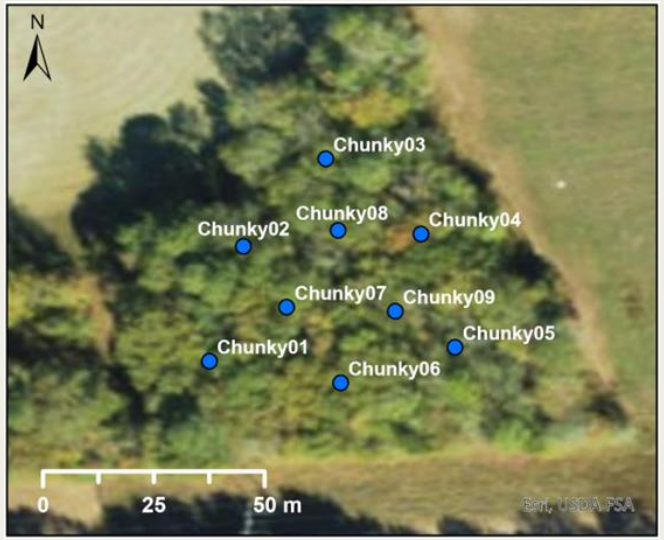
RMS Pressure & Statistics: Chunky Array



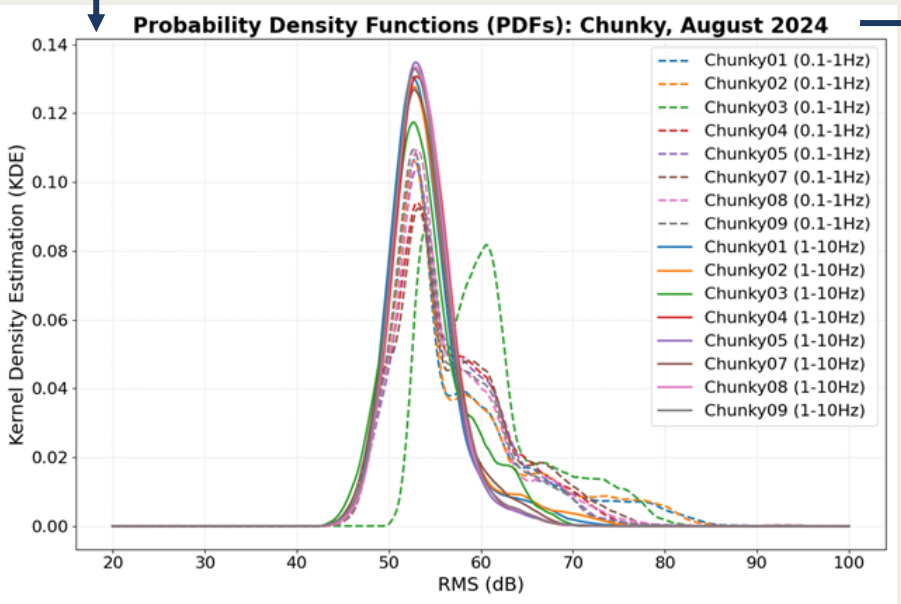


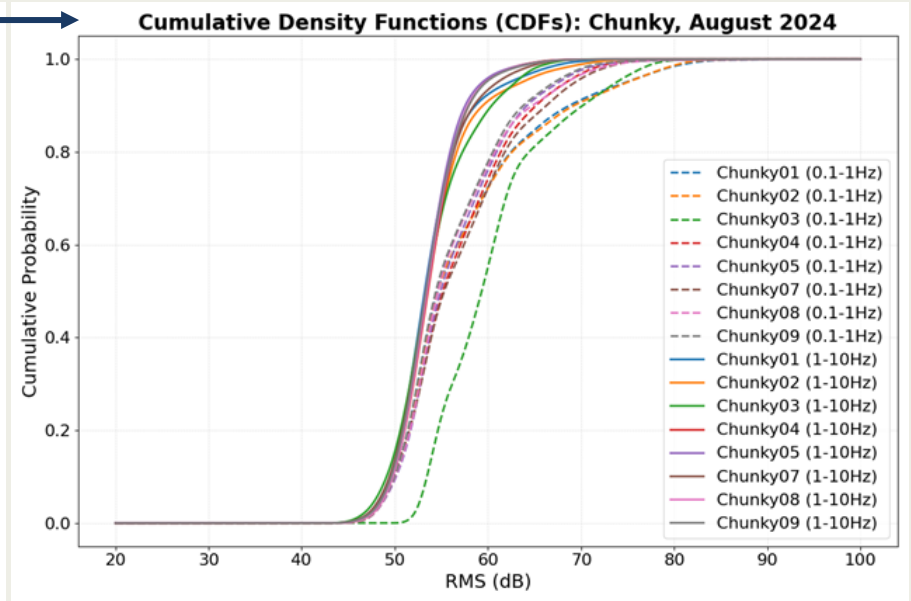
% of the Time at ≤ 60 dB

Lower Noise ↓

Higher Noise

1-10 Hz	0.1-1 Hz
Chunky05: 96%	Chunky09: 78%
Chunky04: 96%	Chunky08: 77%
Chunky08: 95%	Chunky05: 76%
Chunky09: 95%	Chunky04: 74%
Chunky07: 93%	Chunky01: 73%
Chunky01: 92%	Chunky07: 72%
Chunky02: 91%	Chunky02: 72%
Chunky03: 89%	Chunky03: 55%





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Chunky Array *vs* Chunky Noise Test Sensors

HOW MUCH BETTER ARE THE NOISE LEVELS INSIDE THE FOREST?

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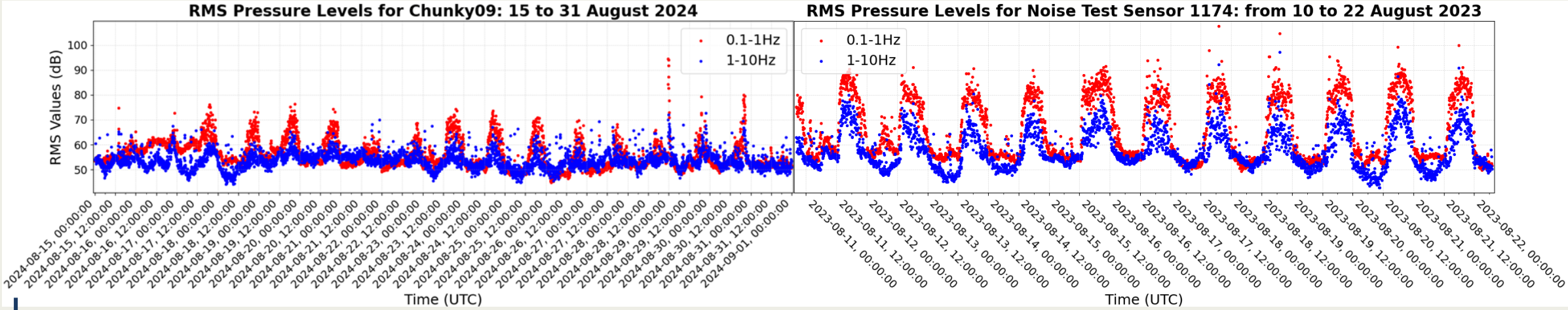
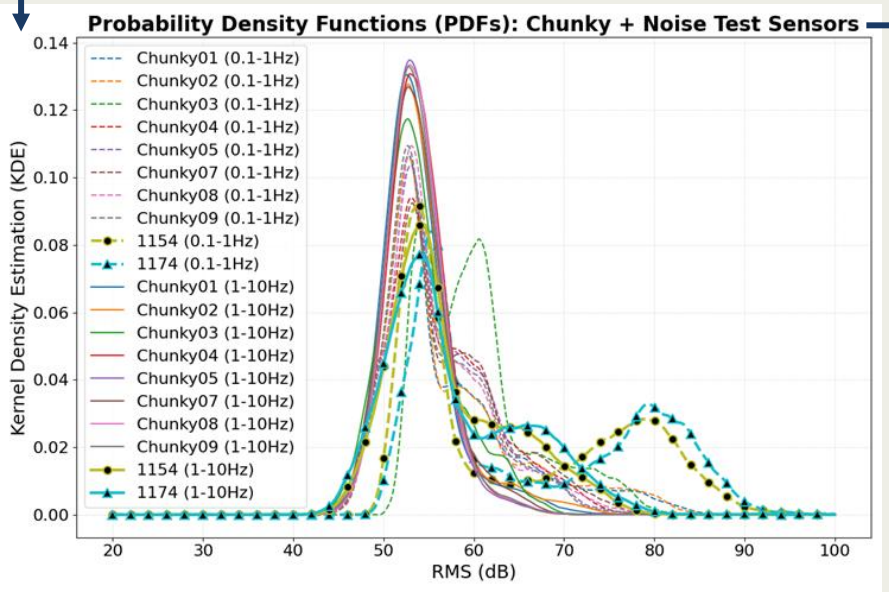
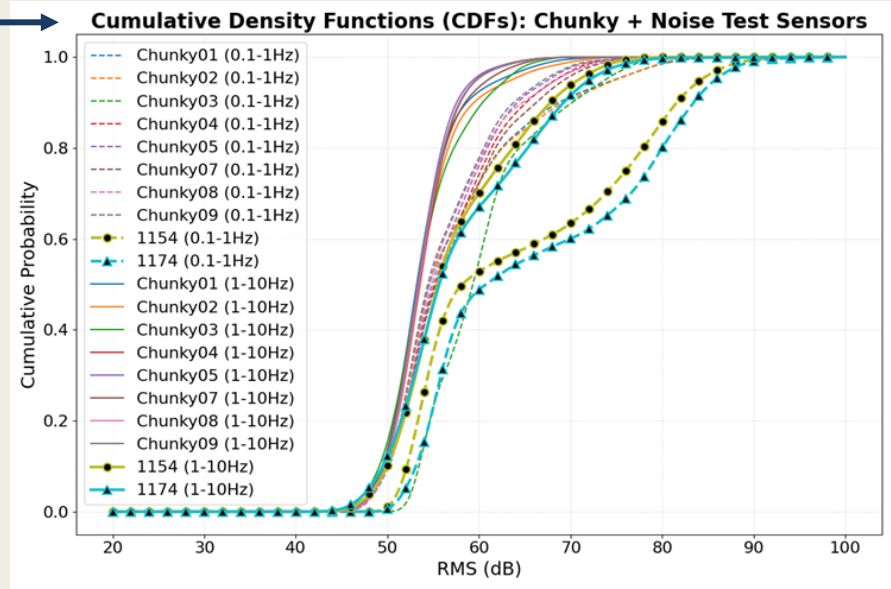
RMS Pressure & Statistics: Chunky Array *vs* Chunky Noise Test Sensors







% of the Time at ≤ 60 dB

Lower Noise ↓

Higher Noise ↓

1-10 Hz	0.1-1 Hz
Chunky09: 95%	Chunky09: 78%
1154: 70%	1154: 53%
1174: 67%	1174: 49%

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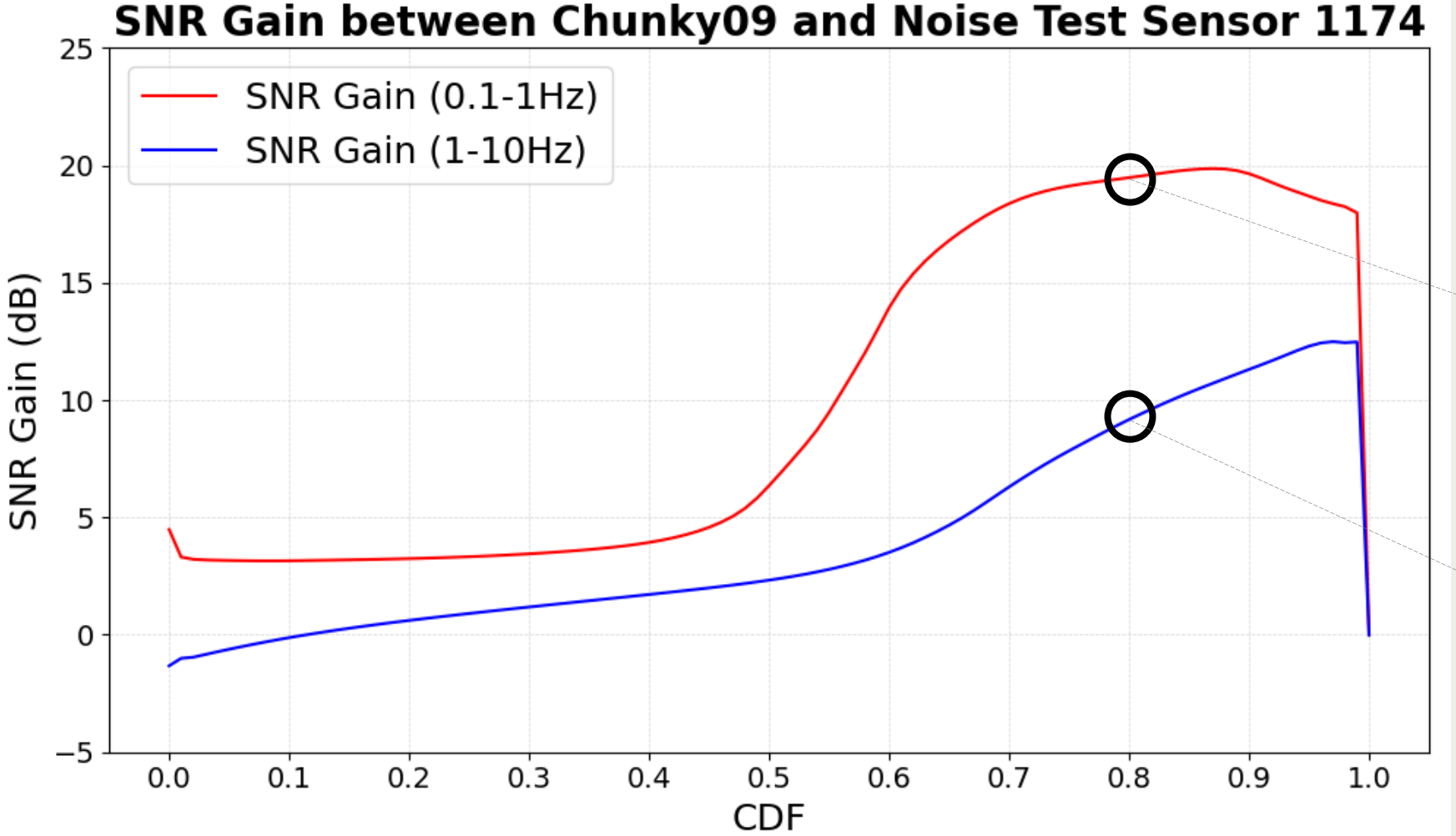
Difference in dB: Chunky09 (Forest) *vs* Noise Test Sensor 1174 (Open Field)



At 80% of the Time

0.1-1 Hz
Chunky09: <≈ 61 dB
1174: <≈ 80 dB
→ 19 dB Lower in the Forest!

1-10 Hz
Chunky09: <≈ 56 dB
1174: <≈ 65 dB
→ 9 dB Lower in the Forest!

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Preliminary Results and Next Steps

DATA

- Wind Noise data (CDFs ≤ 60 dB).
- Online Open Access LiDAR data.
- Sentinel-2 MSI.

METHOD

Linear Regression to correlate:

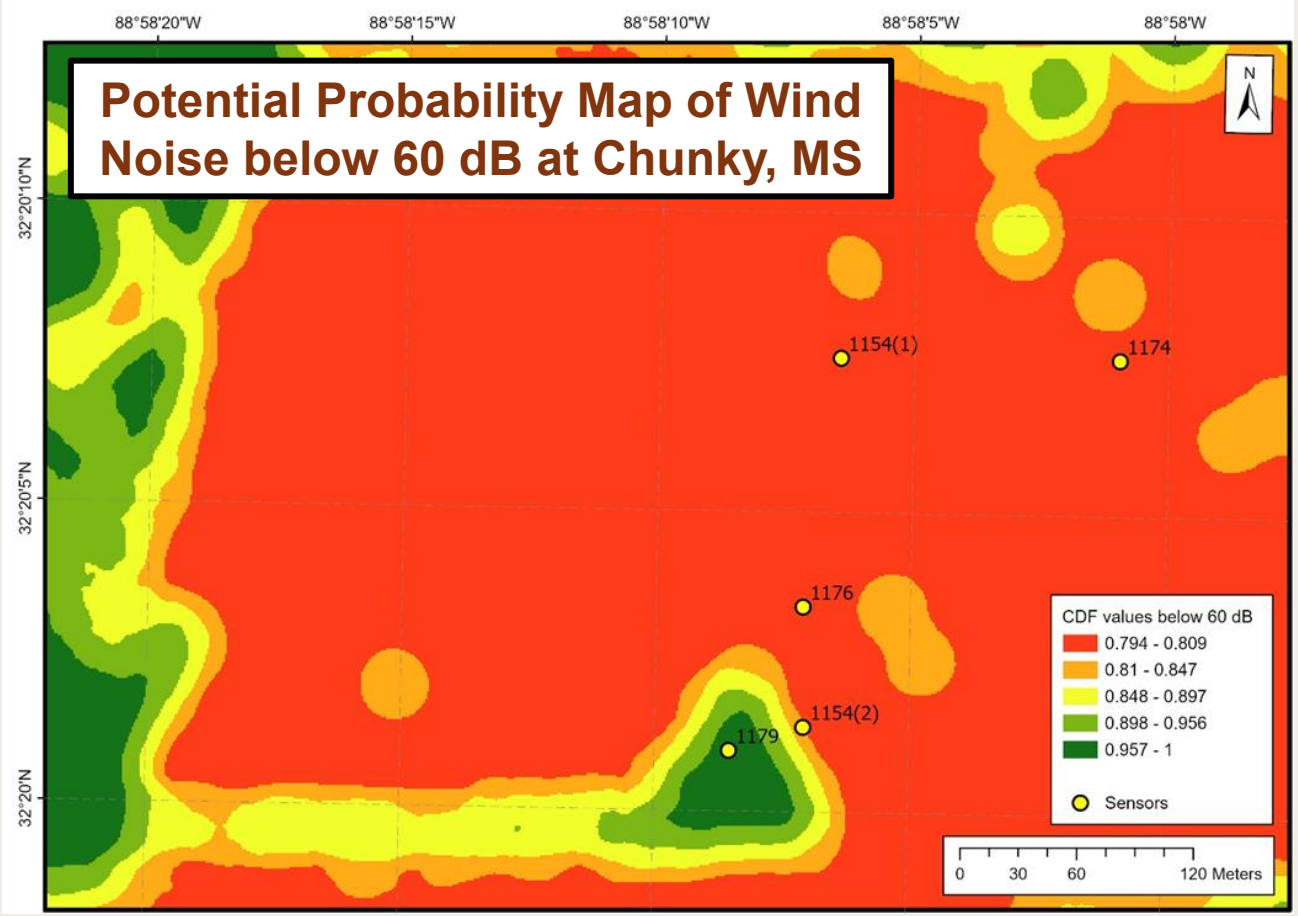
- CDFs ≤ 60 dB.
- Vegetation density of canopy height ≥ 5 m within a 20 m buffer around each sensor.

RESULTS

- Influence of canopy density on the probability of noise levels to be below 60 dB across the study area.
- **Green areas:** higher CDF, lower noise levels.
- **Red areas:** Lower CDF, higher noise levels.
- Quieter *vs* Noisier zones.

PhD

Develop a trained algorithm to correlate wind noise levels, collected near different topographic features, with several topographic parameters, such as ground elevation, canopy height, vegetation …



GIS Course, Semester Project, Fall 24

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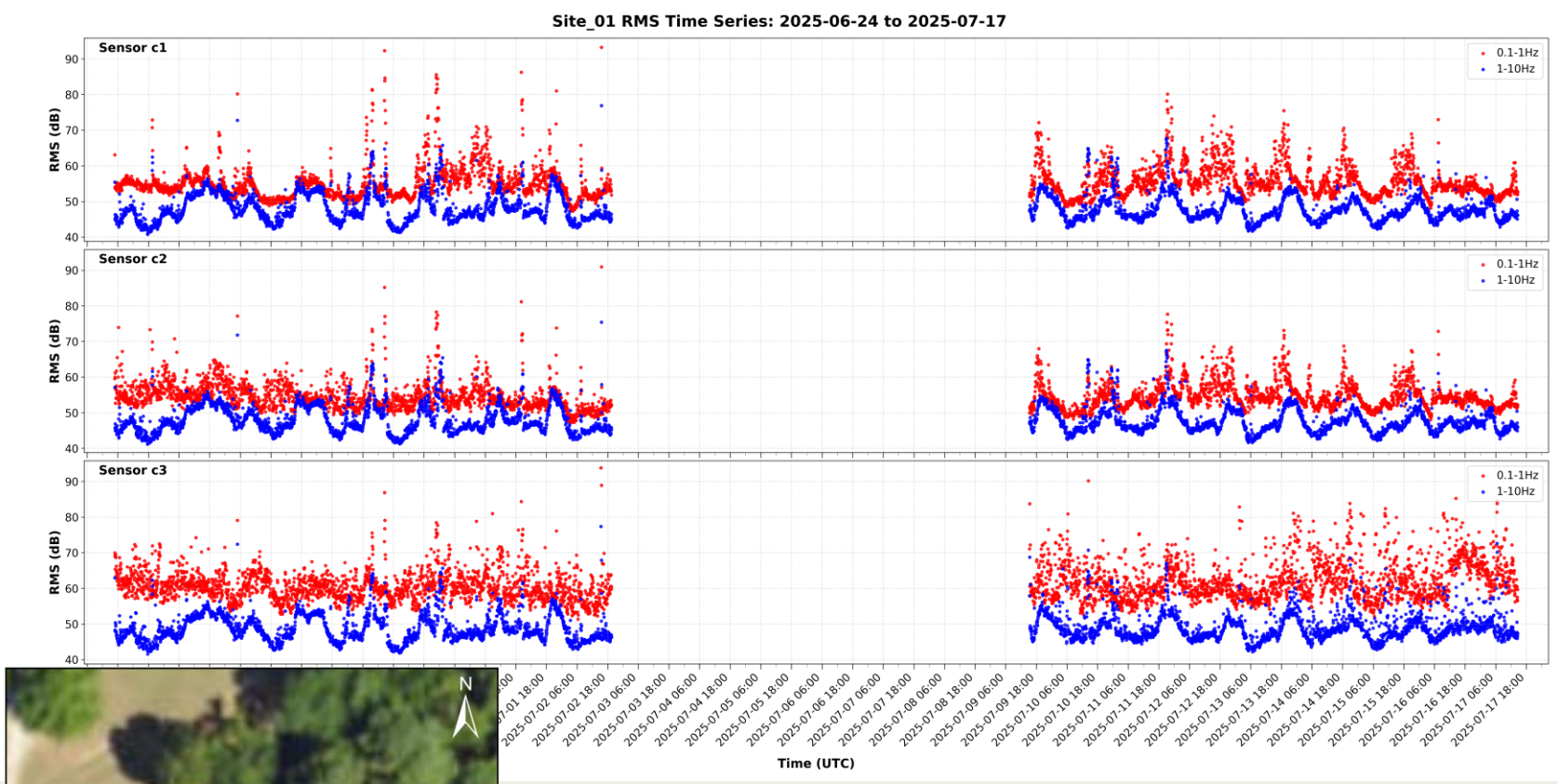
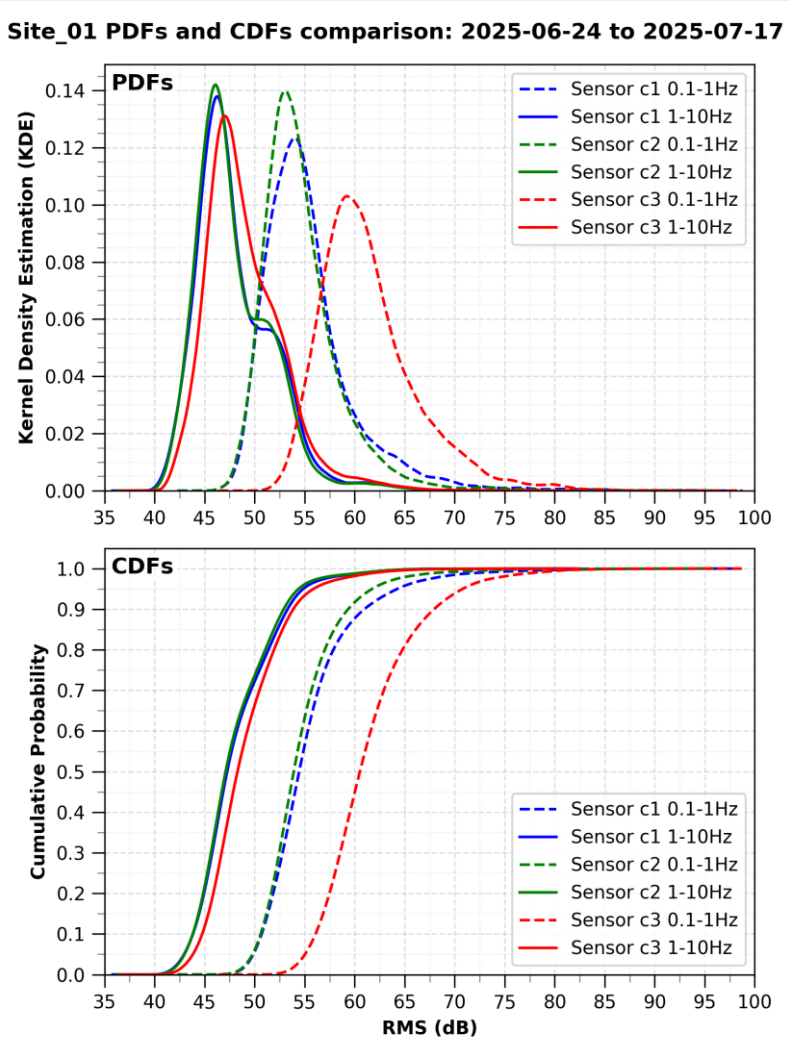
Wind Noise Test at the UM Biological Field Station





% of the Time at ≤ 60 dB

1-10 Hz	0.1-1 Hz
Sensor c2: 99%	Sensor c2: 92%
Sensor c1: 99%	Sensor c1: 86%
Sensor c3: 98%	Sensor c3: 45%

Lower Noise

Higher Noise

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Concluding Remarks

- Generally, the RMS pressure levels are noisier for the frequency band 0.1 – 1 Hz.
- The presupposition that the sensors at the edge of the forest are noisier that the ones in the middle of the forest is still inconclusive. More data needs to be collected and analyzed.
- Wind direction and speed is yet to be considered as well as the seasonal variations.
- It's very clear the influence of a forest in filtering part of the wind noise is around 10 dB for the frequency band 1–10 Hz and around 20 dB for 0.1-1 Hz, in the case presented.
- Data is being collected at the University of Mississippi's Biological Field Station, and potentially other locations, where there is variable topography to sample from.
- LiDAR and Multispectral sensors onboard of sUAS will be used for topographical data collection.
- The goal is to develop a trained algorithm to correlate wind noise levels with local topography.
- Apply the future model to IMS data and noise site characterization.

Thank you!