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Field Validation of Octave Band Sound Modeling for Wind Turbines

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Sugar Creek Wind Project

The Sugar Creek Wind Project is a 57-turbine wind farm across 12,120 acres of private land in Logan County, Illinois, with a capacity of up to 202 megawatts.

PROJECT SUMMARY

- 2019: Preconstruction sound modeling completed
- 2020: Project construction completed
- 2021: Postconstruction sound monitoring

Conditional Use Permit (CUP)

Requirements

- Daytime and nighttime octave band sound pressure level limits
- Tonality

- Original: Attended postconstruction sound monitoring at "all primary structures…"
  - ➢ 174 sites met this criteria

- Revised: Attended monitoring at all "primary structures" within 5 dB of modeled nighttime sound limits at any frequency whose land-owners had given written permission to access their property.
  - ➢ 38 sites met this criteria

Overview

Requirements

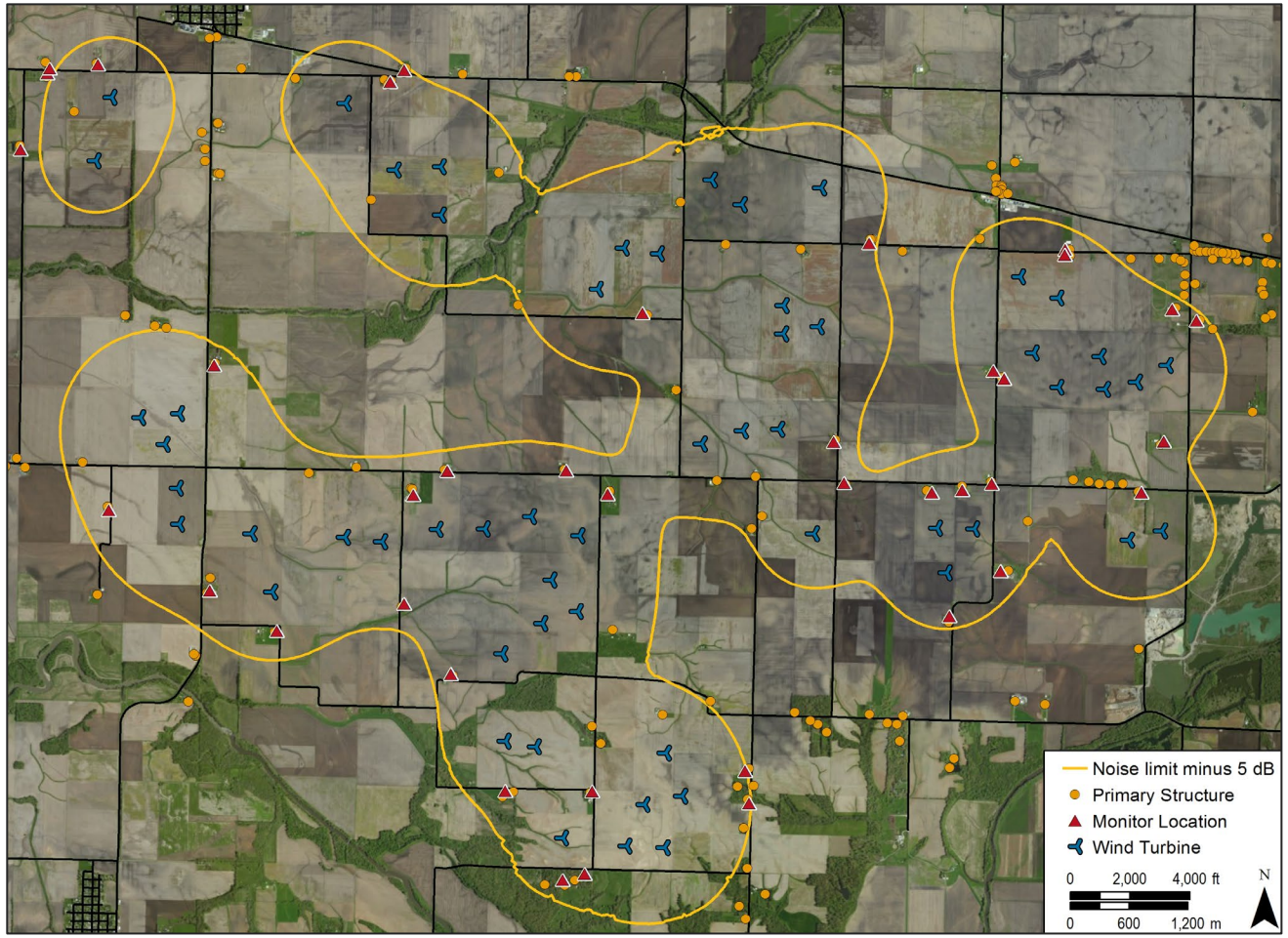
✓ Daytime and nighttime octave band sound pressure level limits – Not discussed

✓ Tonality – Not discussed

Outline

- Comparison between modeled and measured levels
- Challenges
  - ➢ Sites
  - ➢ Attended monitoring
  - ➢ Octave band limits

Sound Monitoring Sites



- 38 sites
- Attended monitoring
- Signal-to-noise ratio not a factor in requirements
- Nighttime measurements: reduced background sound levels, improved wind shear

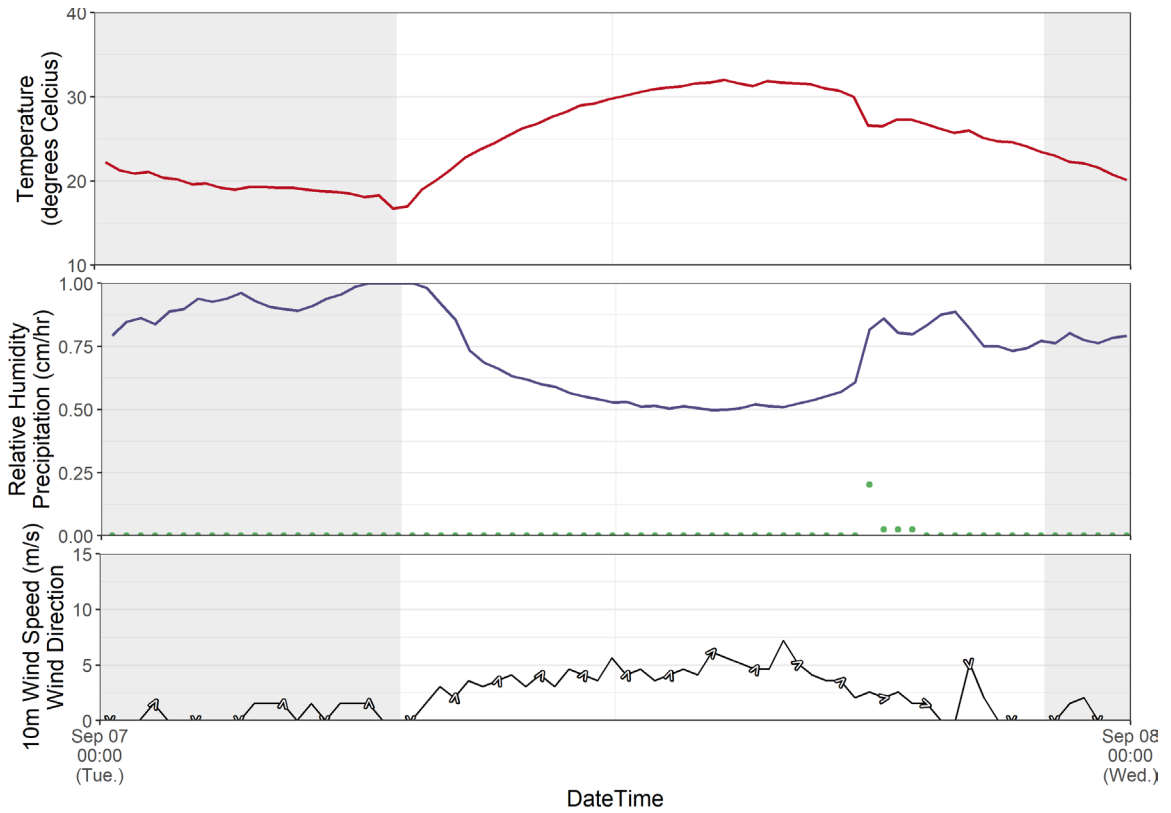
Attended Monitoring

TURBINE CONSIDERATIONS

- Within +/- 1 dB of maximum sound power level
  - 75% of full power or greater
  - 8-10 m/s at the turbine hub height

WEATHER CONSIDERATIONS

- Wind speeds < 5 m/s
- No rain or thunder
- Less than 90% humidity



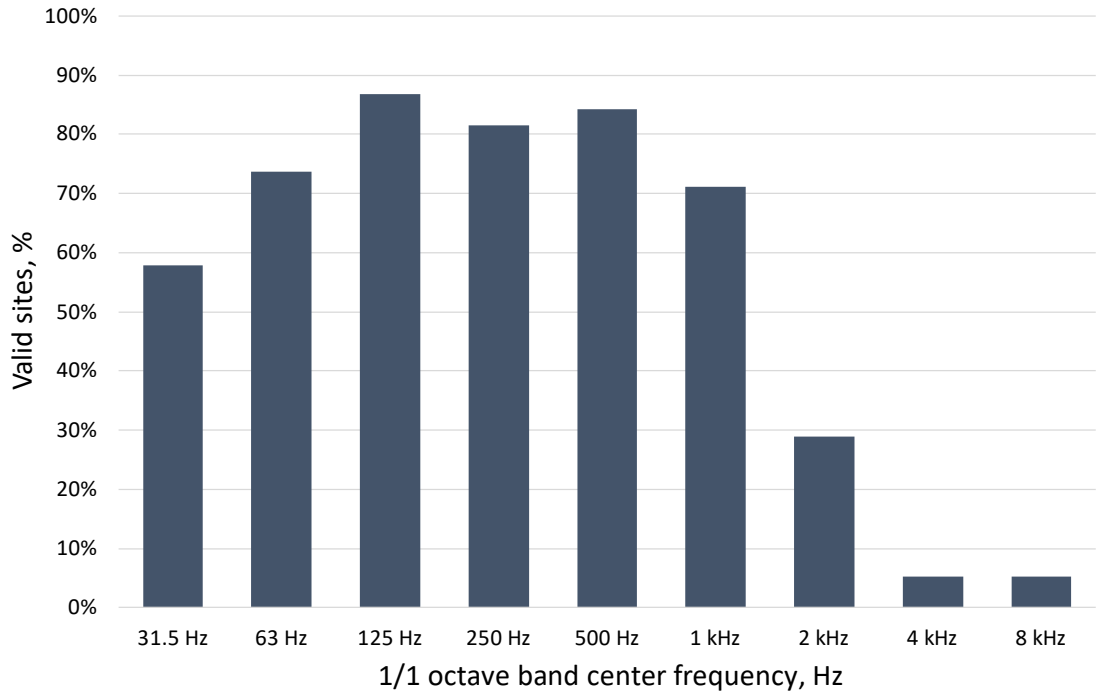
Automated Surface Observation Station (“ASOS”) data compiled after the monitoring period for additional relative humidity and temperature information

Modeling and Measurement Methodology

METHODOLOGY DETAILS

- Modeling: ISO 9613-2 in CadnaA
  - G=0.5, 4 m receptor height, +2 dB uncertainty factor
- Measurements:
  - Acoustical data: 1-sec from 6.5 Hz to 20 kHz, recordings
  - Meteorological data: temp., wind speed, humidity
  - SCADA data (provided by APCo): turbine hub height wind speed and turbine power output
- Data exclusions (turbine operations, weather, anomalies)
- Background subtraction method

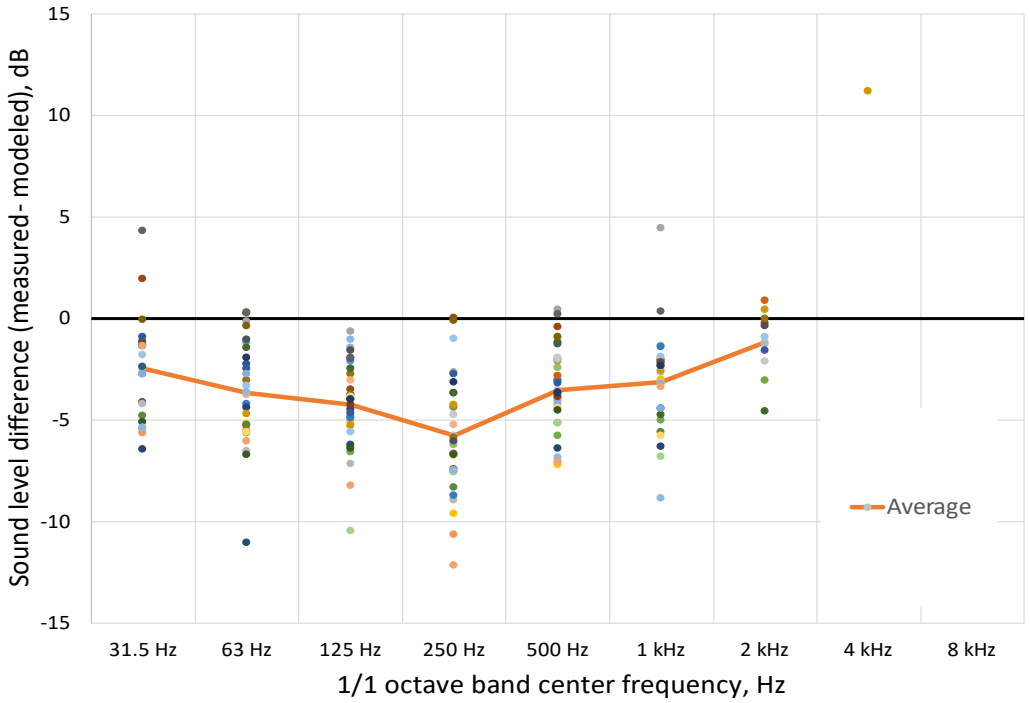
Results



TURBINE-ONLY DATA

- Data @ 4 & 8 kHz determinable at only 2 of 38 sites (5%)
- Data @ 2 kHz determinable at only 11 of 38 sites (29%)

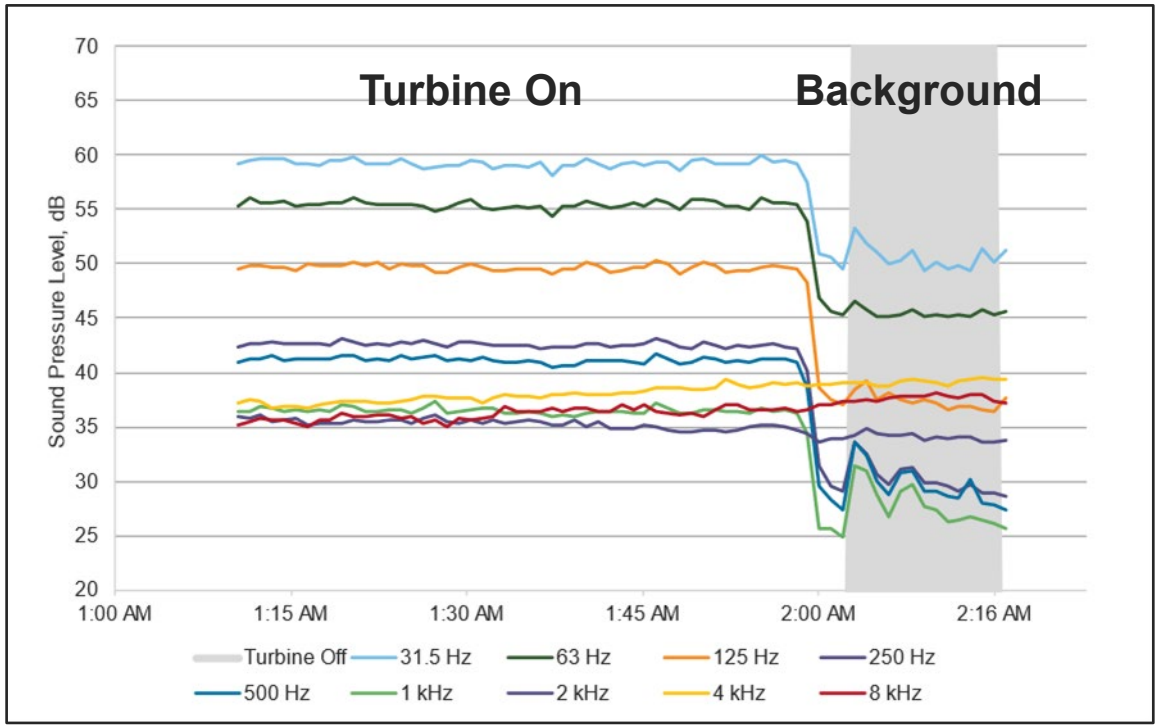
Results



COMPARISON OF MEASURED AND MODELED LEVELS

- Measured levels below modeled levels at all frequencies for almost all sites
- Measured levels on average 1 to 6 dB below modeled from 31.5 Hz to 2 kHz
- Where measured sound levels exceeded modeled by more than 0.5 dB — attributable to background

Results

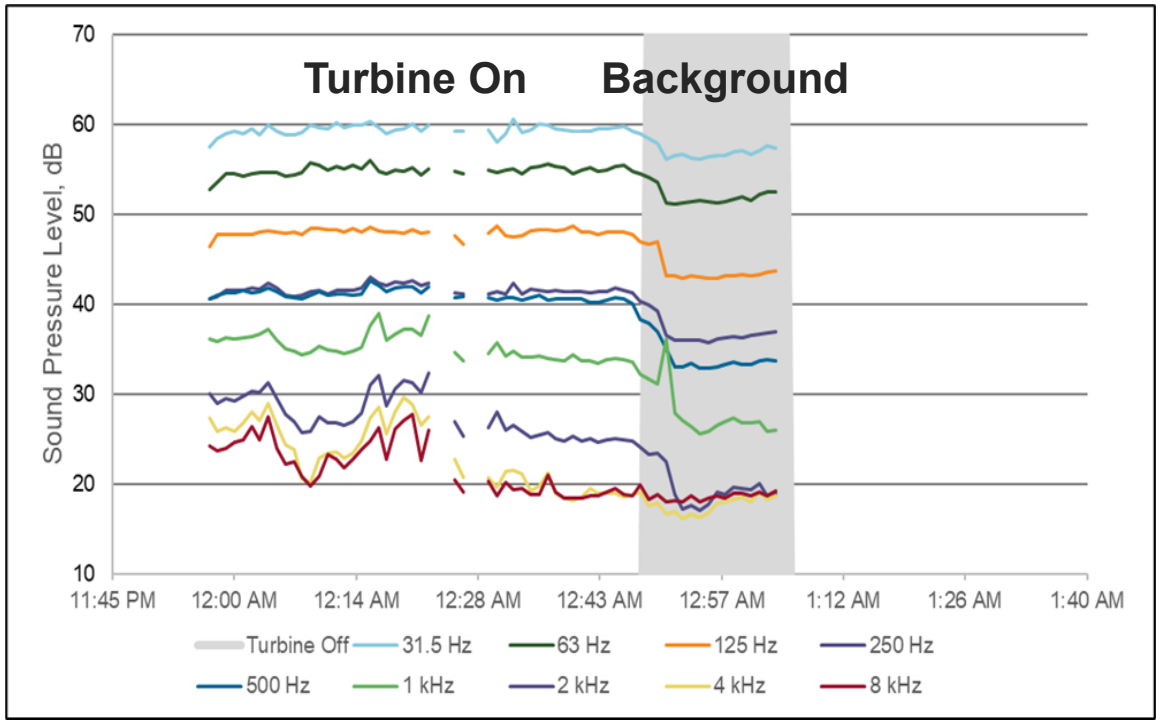


Gaps indicate data excluded from averaging due to anomalous sounds or high wind gusts at the monitoring location. Grayed areas are turbine-off periods.

EXAMPLE SITE 1: GOOD SIGNAL-TO-NOISE RATIO

- Clear difference between turbine-on and turbine-off periods at frequencies of 31.5 Hz to 1 kHz
- 2, 4 & 8 kHz data dominated by biogenic sound

Results

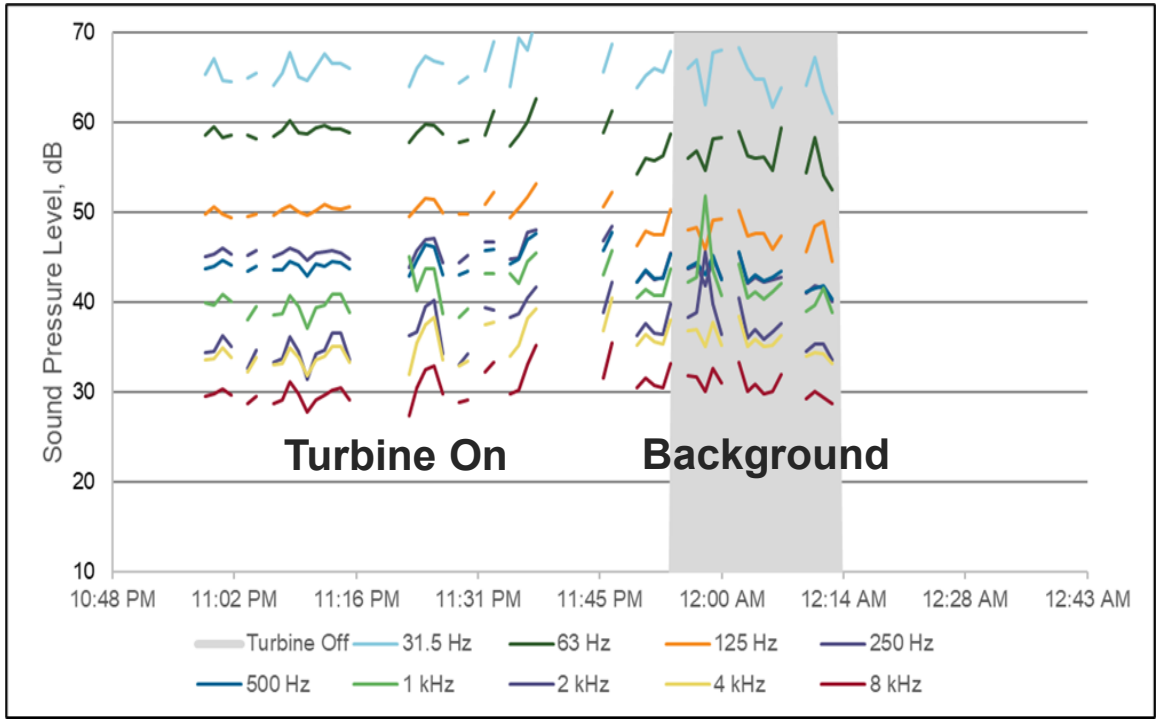


Gaps indicate data excluded from averaging due to anomalous sounds or high wind gusts at the monitoring location. Grayed areas are turbine-off periods.

EXAMPLE SITE 2: VARIED HIGH FREQUENCY DATA

- Varying high-frequency sound levels
- Little to no change when turbines shut down
- High-frequency sounds not discernable in audio, maybe due to Nyquist freq.
- Likely background biogenic sounds

Results



Gaps indicate data excluded from averaging due to anomalous sounds or high wind gusts at the monitoring location. Grayed areas are turbine-off periods.

EXAMPLE SITE 3: BACKGROUND DOMINATES

- Background sound levels not considered in site selection process

Discussion

SITE SELECTION

- Sites for this study based on landowner permissions (county requirement)
- Many sites had turbine sounds levels that were not discernable from background

Recommendation: Select/prioritize sites where a higher signal-to-noise ratio can be achieved for a cost-effective monitoring program.

Discussion

ATTENDED VS. UNATTENDED MONITORING

	Pros	Cons
Attended Monitoring	• Observer to identify anomalous sounds • More sites can be measured	• Difficult to capture favorable weather conditions • Only a short time period is measured • Safety concerns for nighttime monitoring
Unattended Monitoring	• Collects data over wide range of weather conditions	• Time-consuming to identify anomalies • Fewer sites can be measured • Large amount of data

Recommendation: Collect more data at fewer representative sites using unattended monitoring.

Discussion

OCTAVE BAND NOISE STANDARDS

- Sound modeling of octave bands is feasible and conservative using the typical modeling parameters cited in noise standards such as ANSI/ACP 111-1-2022
- High-frequency data (> 2kHZ) not generally valid; atmospheric attenuation reduces sounds below background
- Low-frequency data easily contaminated by wind-induced sound and pseudonoise
- Octave band sound modeling is not supported in ISO 9613-2
- Octave band sound power levels are often not guaranteed/warranted by the wind turbine manufacturer
- Mitigation measures not specific to individual frequencies

Recommendation: Shy away from measured octave band standards and focus on A-weighted broadband equivalent continuous sound levels.

Discussion Topics – Questions for Audience

- Better methods of forecasting wind shear?
- Results show that octave bands can be conservatively predicted using typical modeling parameters – but should they be?

Acknowledgments

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