Variations in the Sound Field during Pile-driving

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22 May 2019

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Outline

- Question: At what range from a pile-driving source does a signal transition from impulsive to non-impulsive?
  - Time spread of a signal with range from the source
  - Metric of kurtosis
- Question: How does sound propagate away from pile-driving
  - Sound spreading measurements
  - Directional spreading from raked (angled) piles

Background

- Sound sources are divided into impulsive and non-impulsive (National Marine Fisheries Service [NMFS] Acoustic Guidance, 2018, NOAA Technical Memorandum NMFS-OPR-59; Southall et al., 2019)
  - Impulsive: sounds are typically transient, brief (less than 1 second), broadband, and consist of high peak sound pressure with rapid rise and decay times
  - Non-impulsive: sounds can be broadband, narrowband or tonal; brief or prolonged; continuous or intermittent; and typically do not have a high peak sound pressure with rapid rise/decay time (ANSI 1995; NIOSH 1998; ANSI 2005)
- Exposure to impulsive sounds more often leads to mechanical damage of the inner ear, as well as more complex patterns of hearing recovery

Background

- Sound sources are divided into impulsive and non-impulsive
- Exposure to impulsive sounds has the potential for greater impacts
- Question: At what range from a pile-driving source does a signal transition from impulsive to non-impulsive?
  - Time spread of a signal with range from the source
  - Metric of kurtosis
- Question: How does sound propagate away from pile-driving
  - Sound spreading measurements
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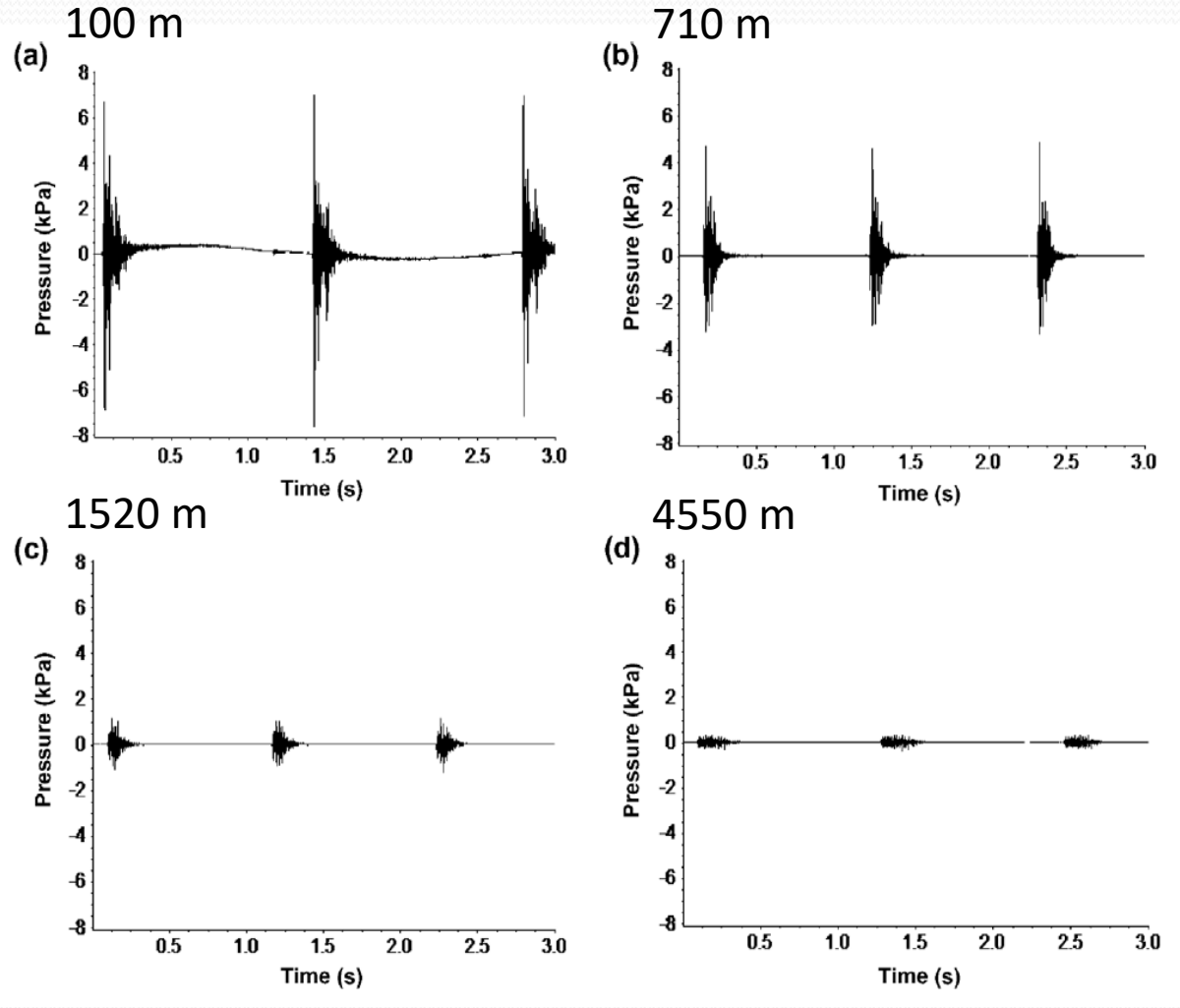
Time Spread of Signal

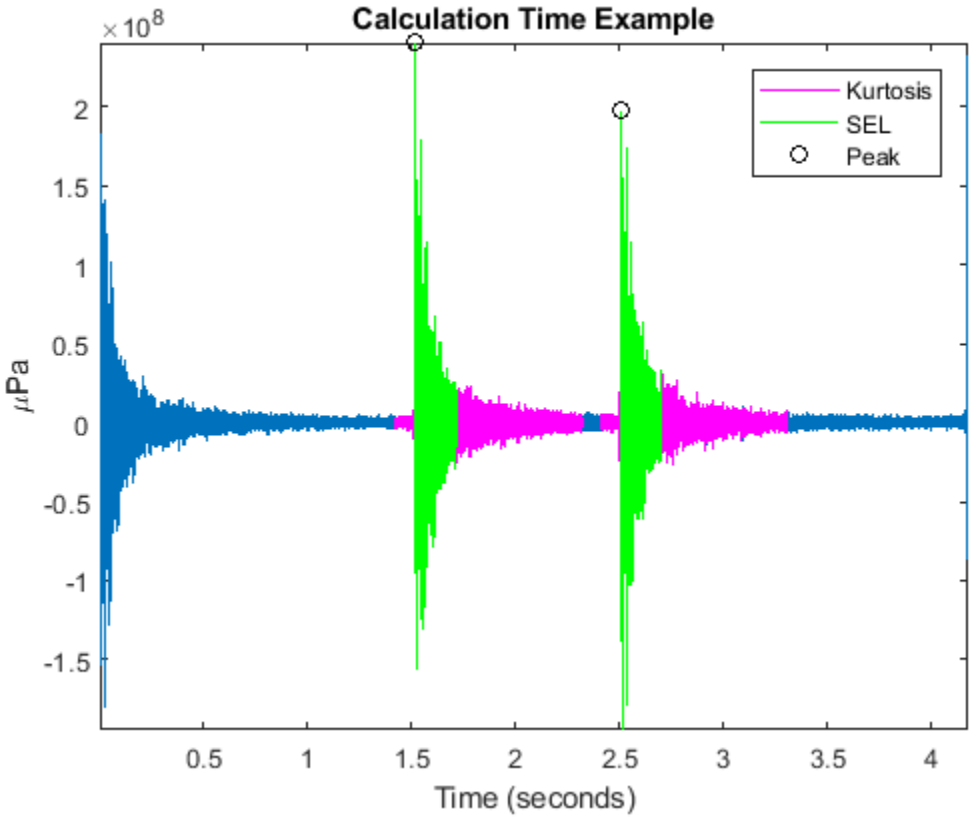
- At close ranges (within 1 km of pile-driving), peak lasted about 10 ms, with total signal duration of 200 ms.
- At 40 km, the peak had increased to 200 ms, with the total signal increasing to 600 ms.

Bailey et al., 2010



Time Spread of Signal

Block Island Wind Farm



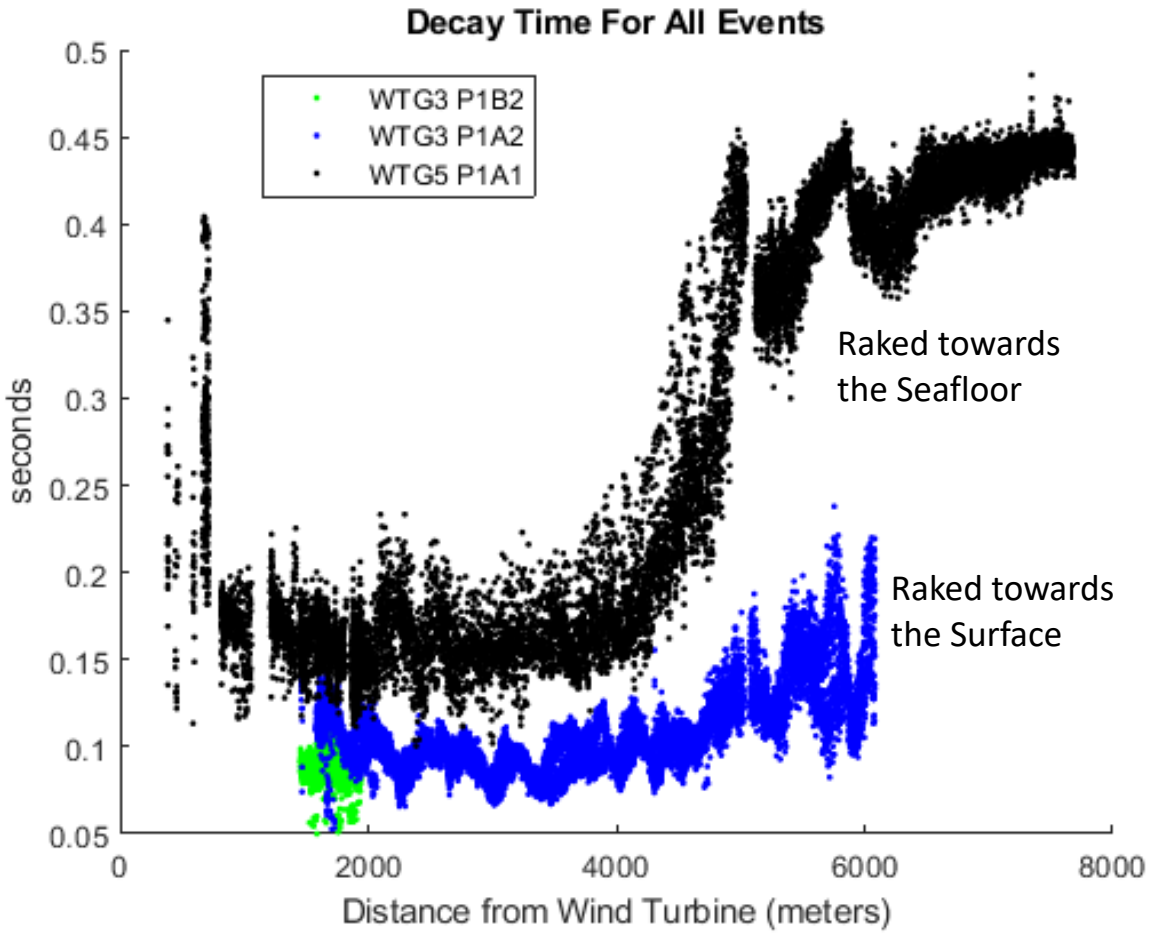
- Decay time = the time at which 95% of the energy is present (T95) minus the peak time.
- Kurtosis = A time window of 0.1 seconds before and 0.8 seconds after the peak

Study concept, oversight, and funding were provided by the U.S. Department of the Interior, Bureau of Ocean Energy Management, Environmental Studies Program, Washington, D.C. under Contract Number M16PD00025.

Time Spread of Signal

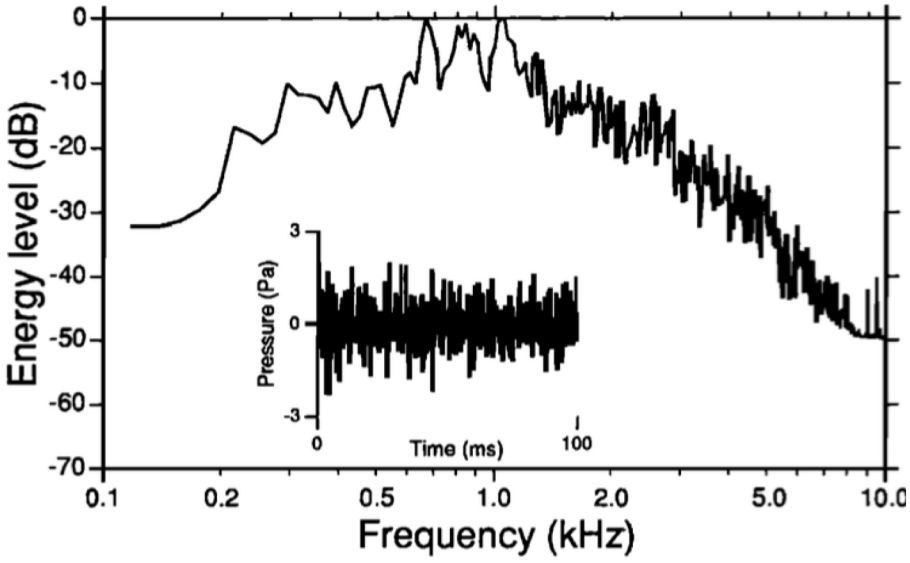
Block Island Wind Farm

- Decay time = the time at which 95% of the energy is present (T95) minus the peak time.
- Decay time increased at ranges greater than 4.5 km, meaning the energy of the signal is spread over a longer time

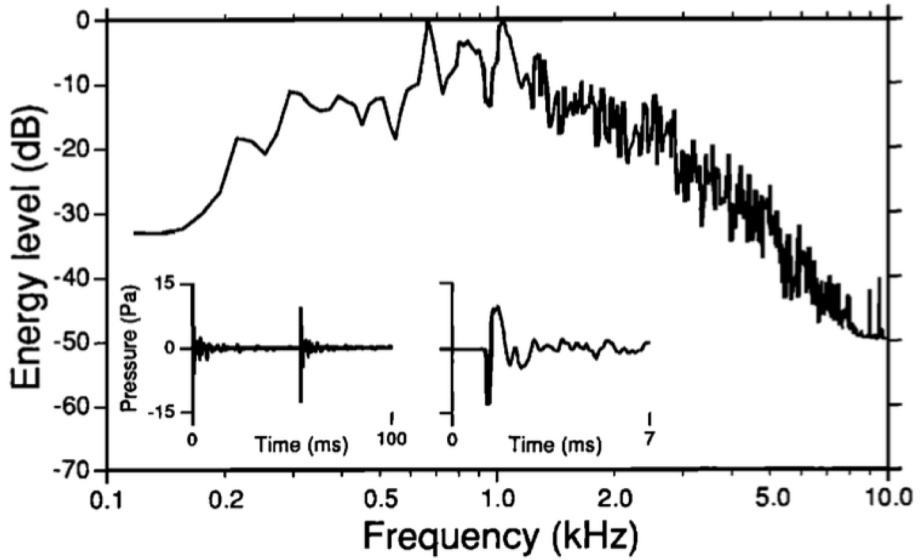


Kurtosis

Higher kurtosis means more of the variance of a signal is the result of infrequent extreme deviations, as opposed to frequent, modestly sized deviations



Kurtosis = 3

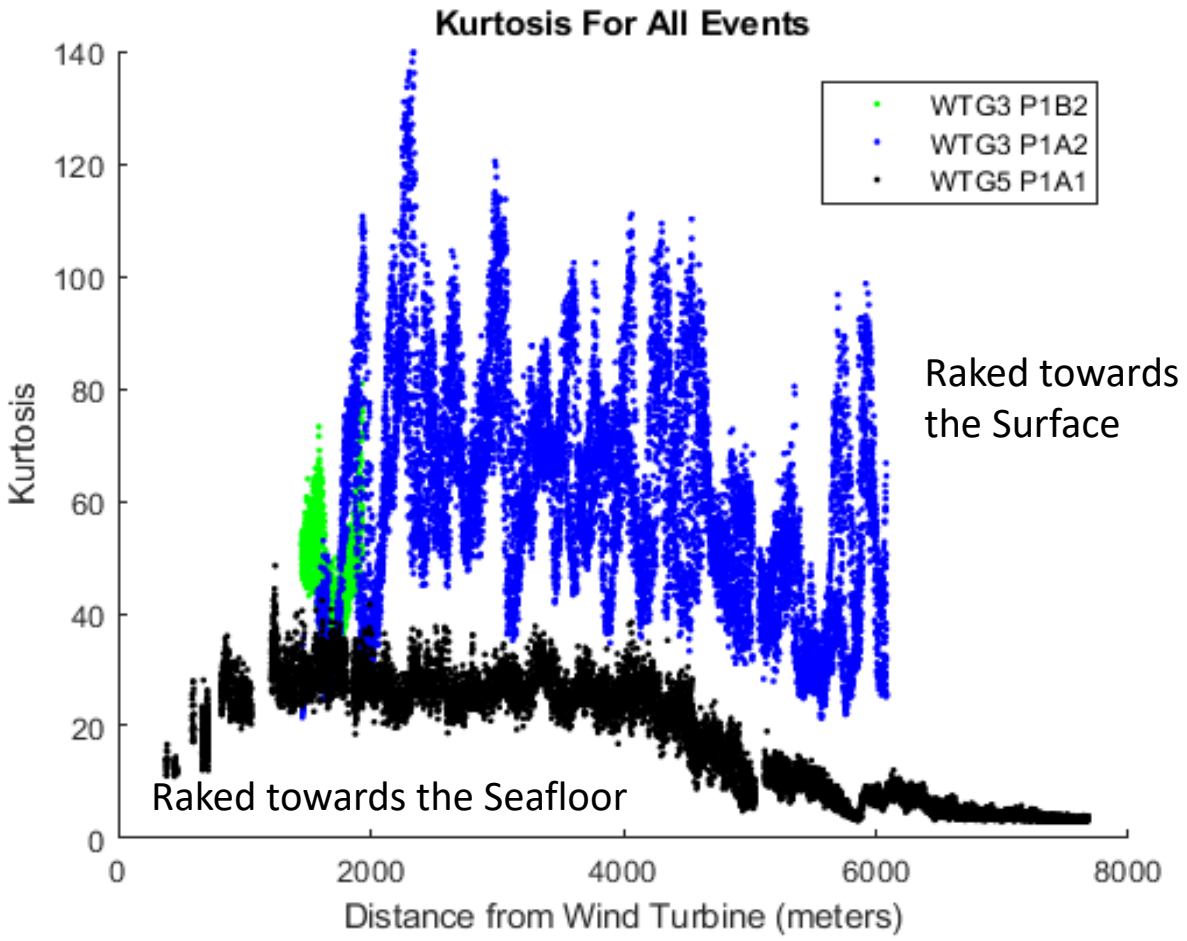


Kurtosis = 189

Kurtosis

Block Island Wind Farm

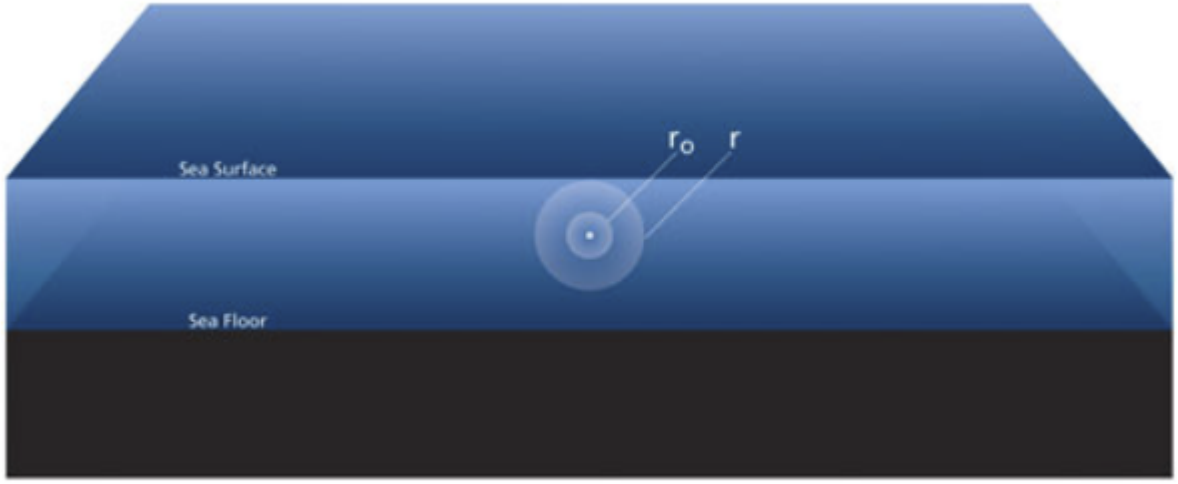
- Kurtosis = A time window of 0.1 seconds before and 0.8 seconds after the peak
- Kurtosis decreases with range, meaning the energy of the signal is spread over a longer time

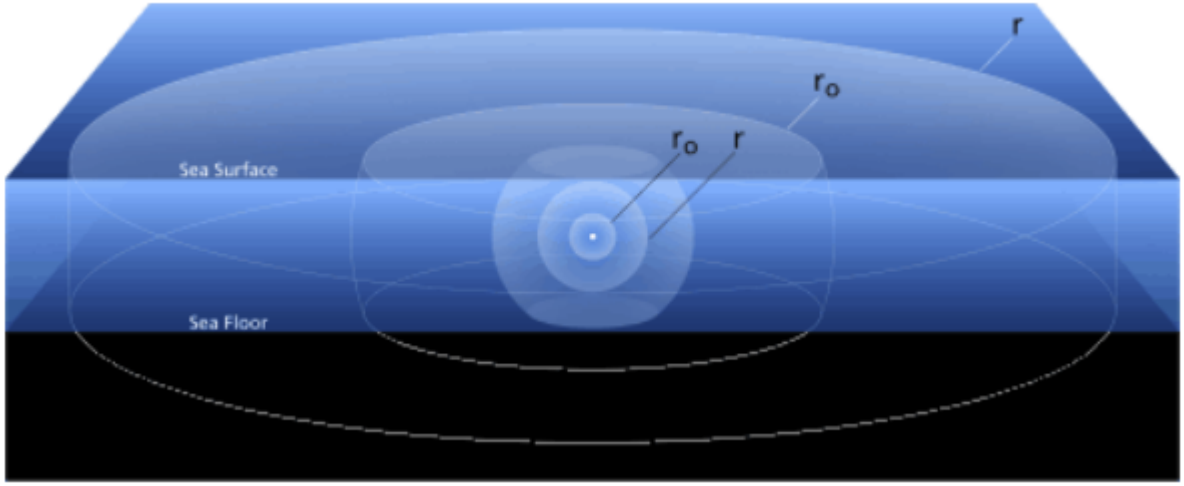


Sound Spreading

https://dosits.org/science/advanced-topics/cylindrical-vs-spherical-spreading/

- How sound level decreases as a sound wave propagates away from a source
- Spherical spreading: sound radiates equally in all directions
- Cylindrical spreading: sound is trapped by the seafloor and surface and can only radiate horizontally away from the source (like a cylinder)

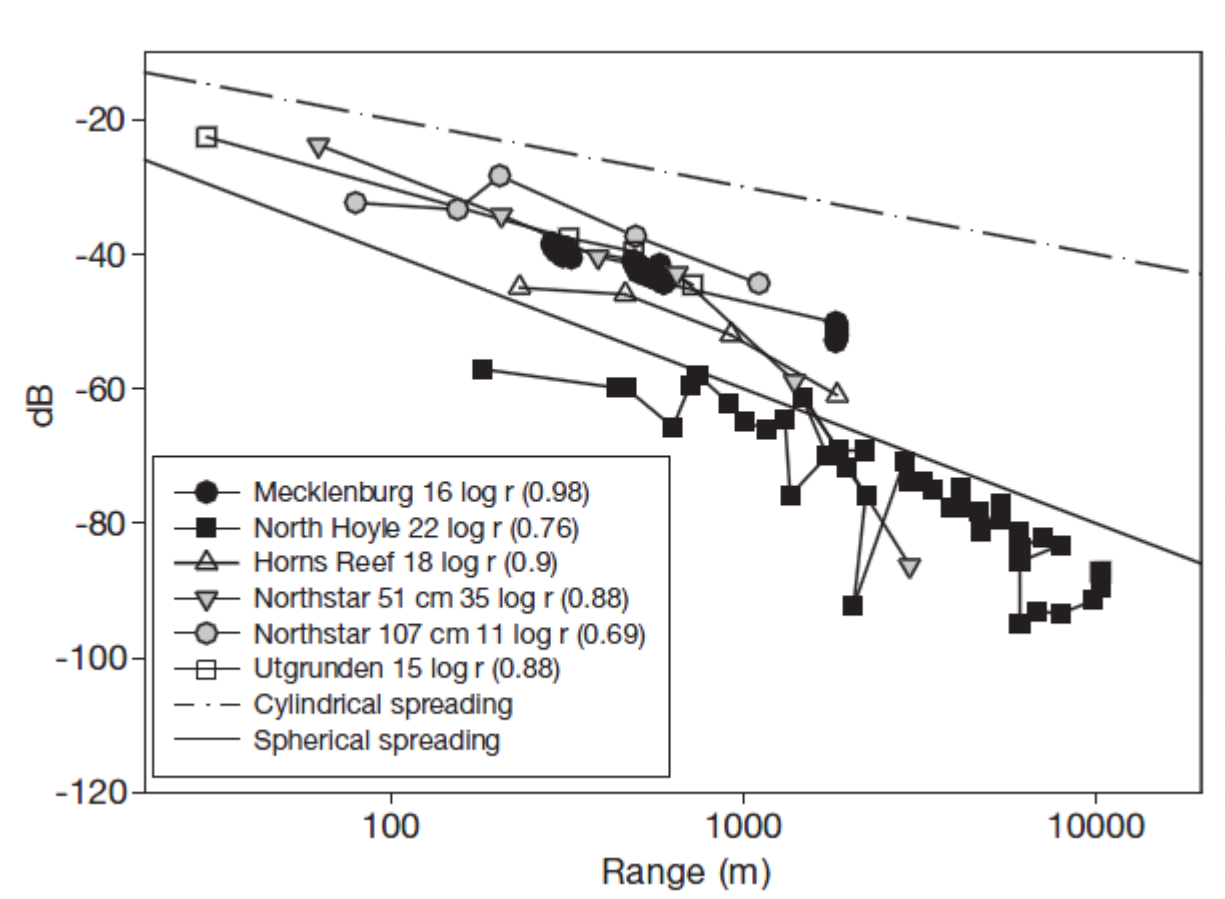




Sound Spreading

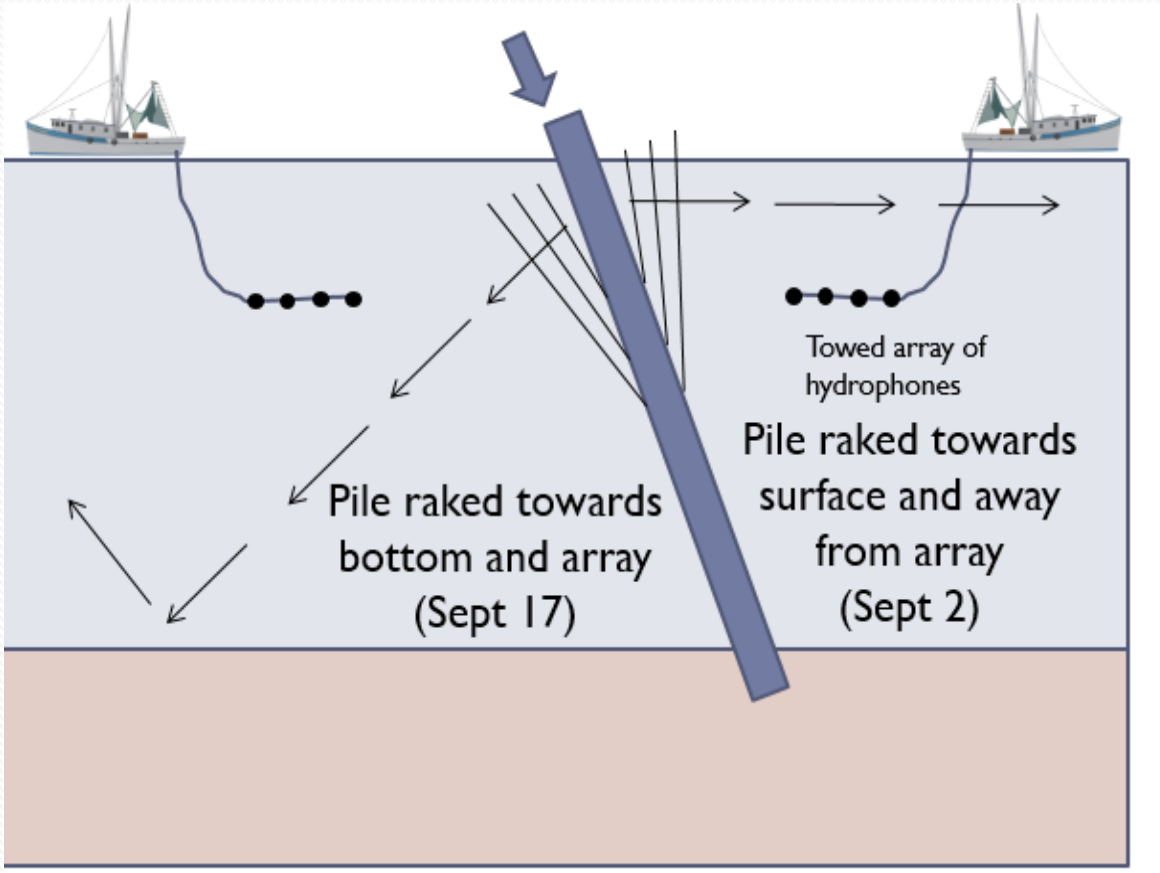
Sound spreading at five locations ranged from cylindrical to spherical spreading

Madsen et al., 2006



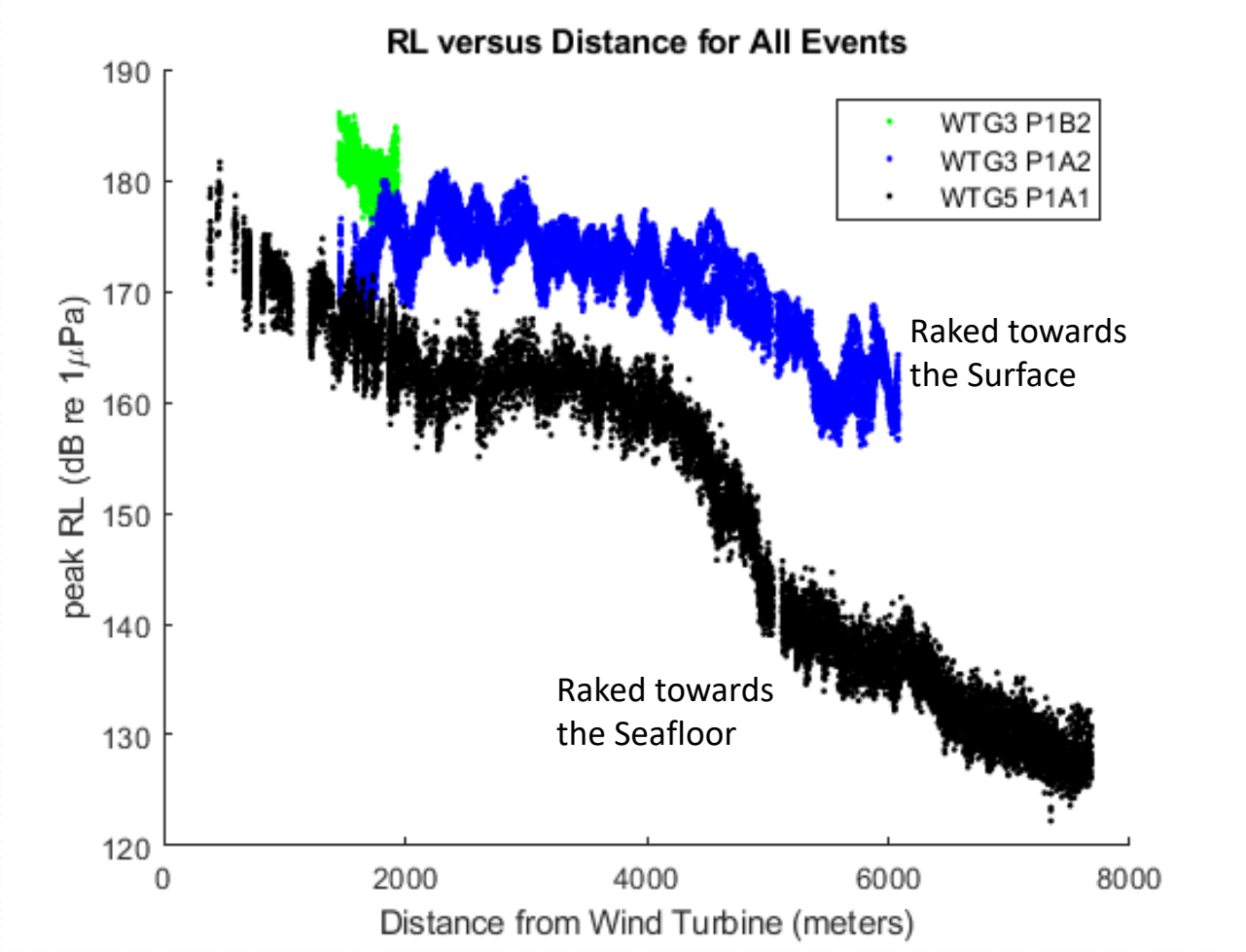
Sound Spreading

Sound spreading at the Block Island Wind Farm with raked piles



Sound Spreading

Sound spreading at the Block Island Wind Farm with raked piles



Conclusions

- Question: At what range from a pile-driving source does a signal transition from impulsive to non-impulsive?
  - Need more studies to generalize a transition range
  - Depends on location and source
- Question: How does sound propagate away from pile-driving
  - Within the range of cylindrical to spherical spreading within 1 km of pile-driving
  - Propagation at farther distances depends on location and source

References

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