Monitoring Results from Block Island Wind Farm

Offshore Wind Best Management Practices Workshop

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& a dozen years of collective wisdom from the JASCO Tribe

Presented by David Zeddies

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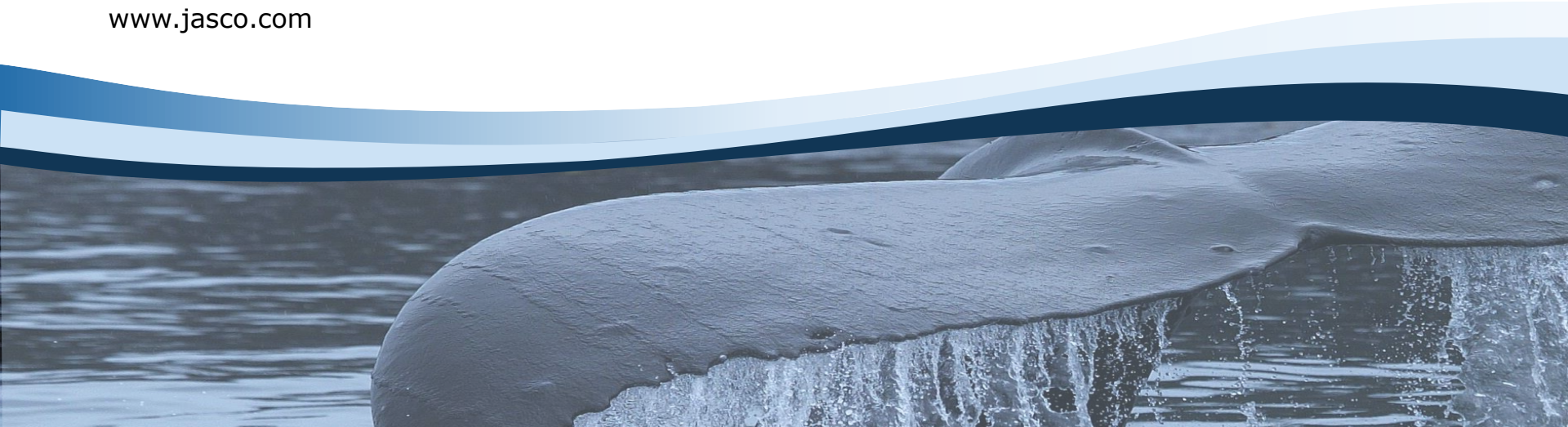
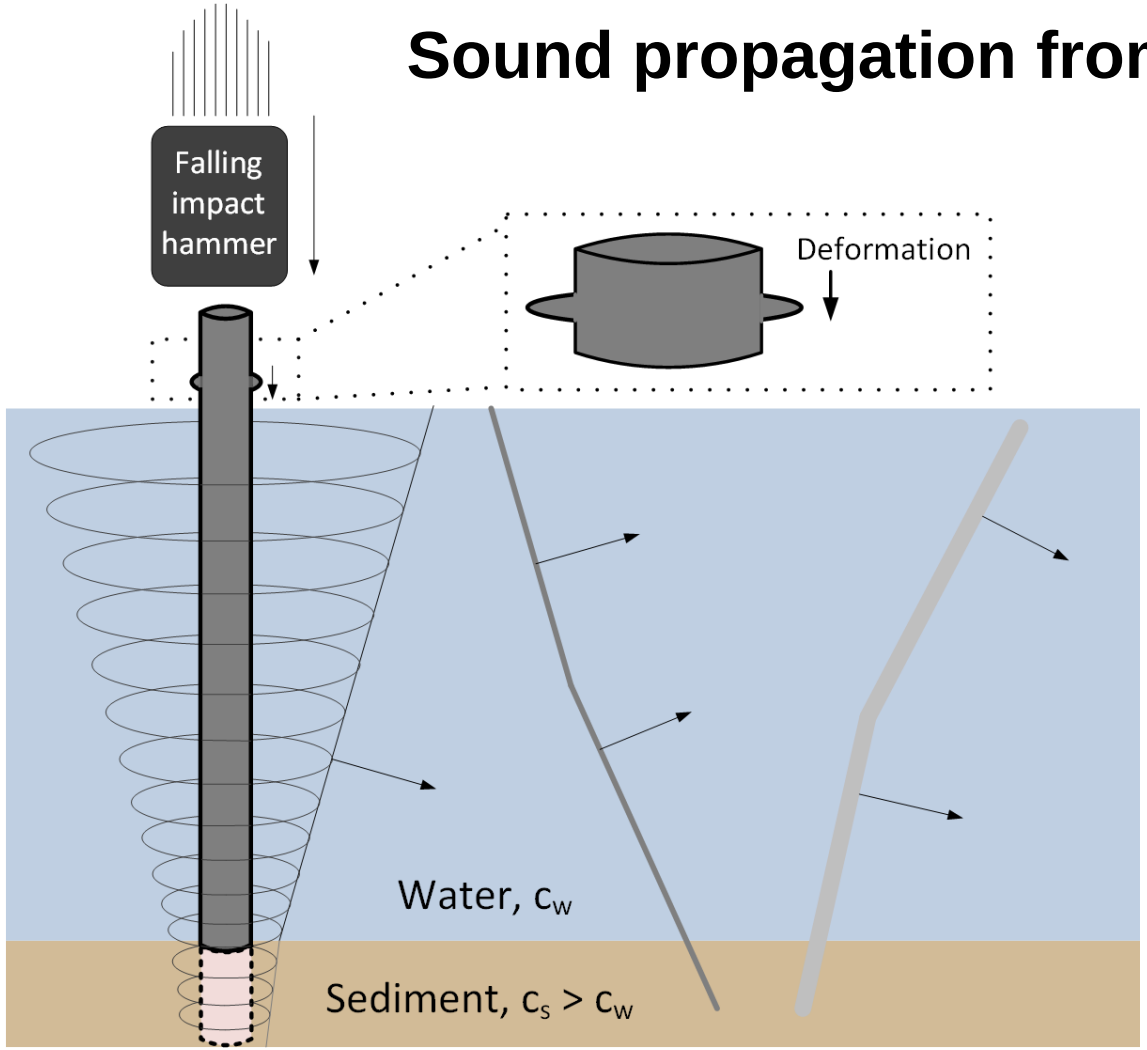
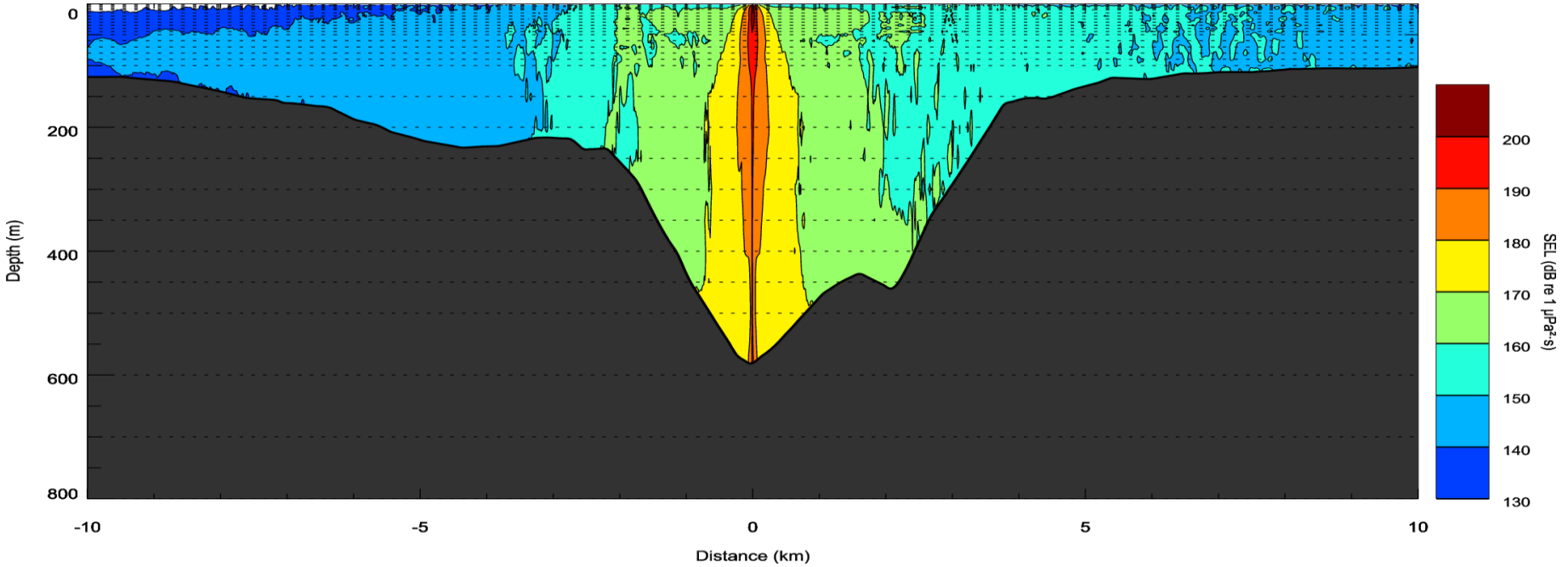


Sound propagation from a pile

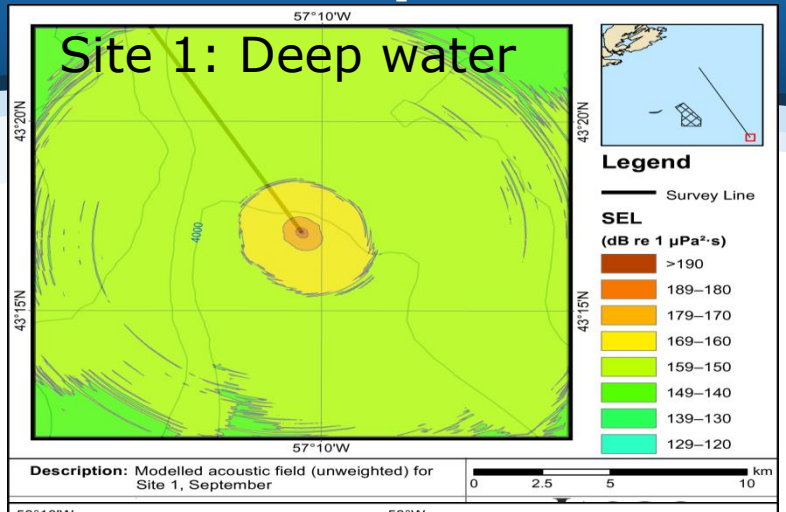


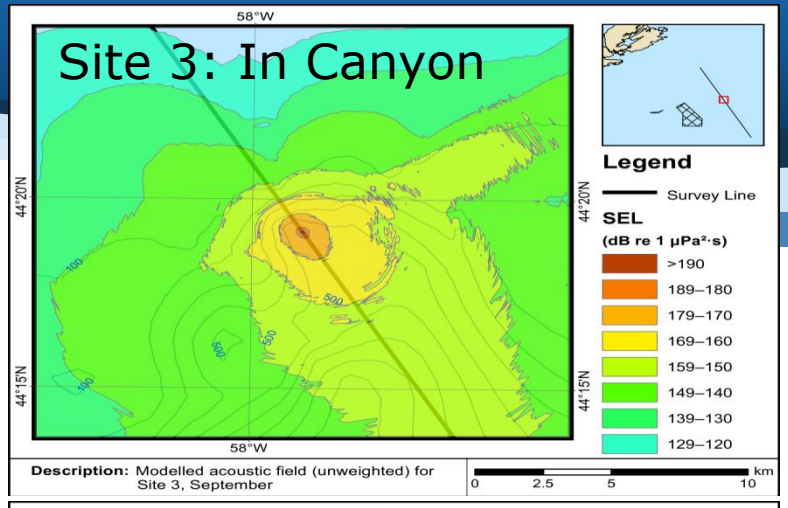
after Reinhall and Dahl, 2011; Dahl, 2015

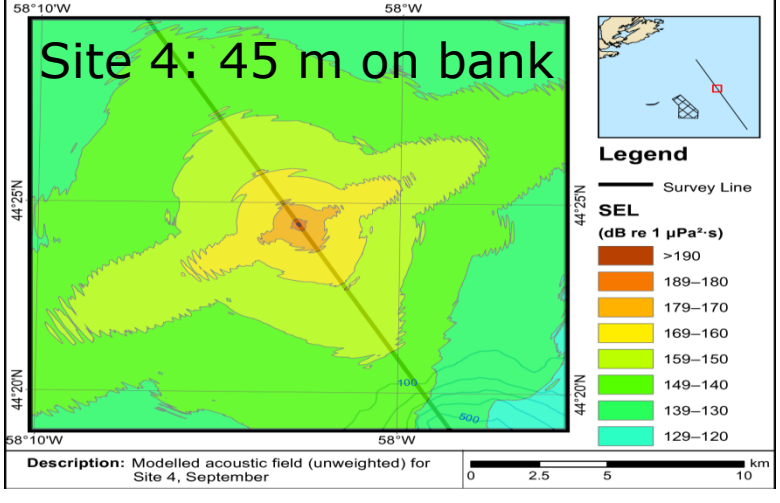
Example sound propagation radial

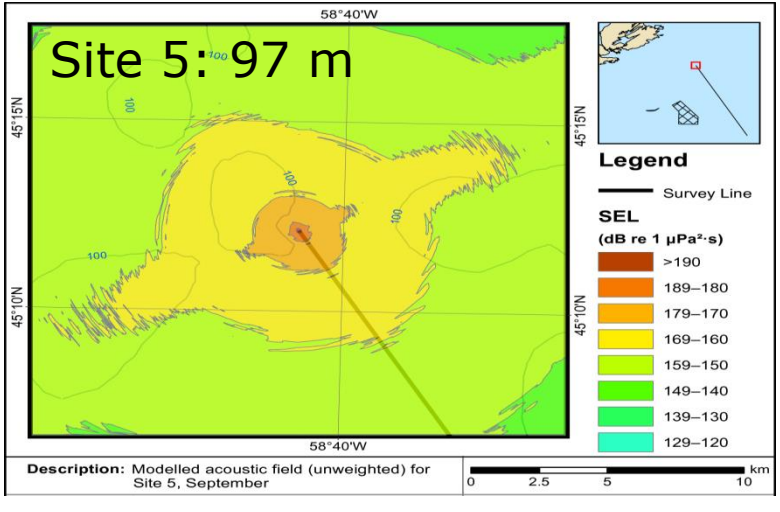


Max-over-depth Differences









Permitting of Marine Operations

- Predict isopleths (ranges) for sound levels that could harm marine life
  - Estimating take
  - Establishing exclusion zones
- Verify and/or monitor isopleths
  - Analysis done in a timely manner

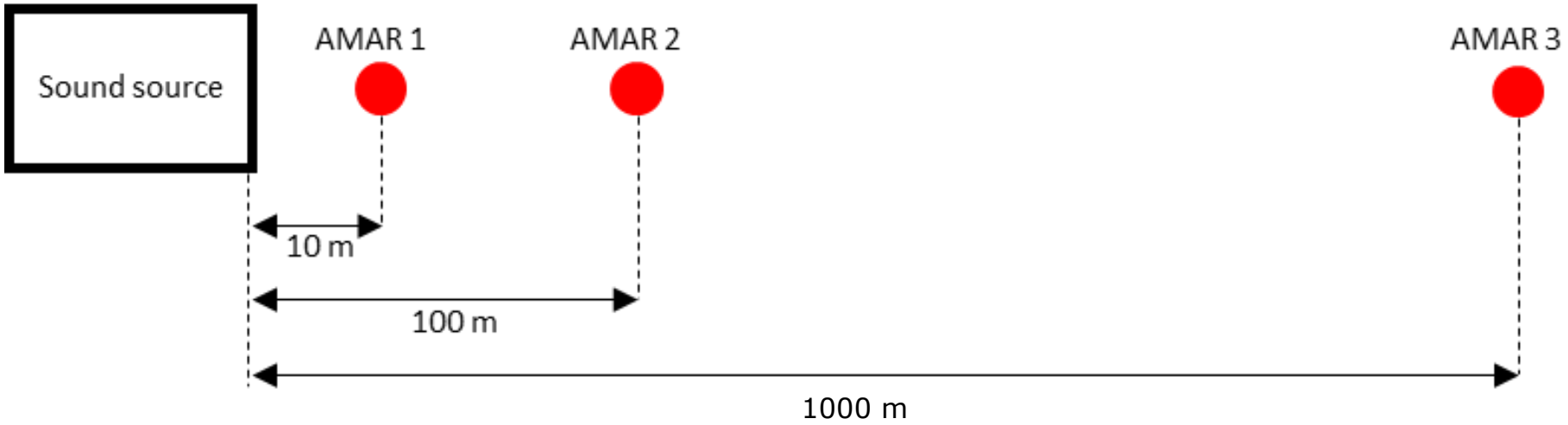
How to make in situ measurements

- Goal: Determine the behaviour of sound as a function of range and use that information to find the isopleths
- Need to get answers quickly:
  - Often before resumption of pile driving the next day
  - 72 – 120 hours typical for seismic operations
- Data fitting exercise
- Needs to be easy enough to do in the field
- But, also has to be:
  - Robust
  - Accurate
  - Conservative … but not too conservative

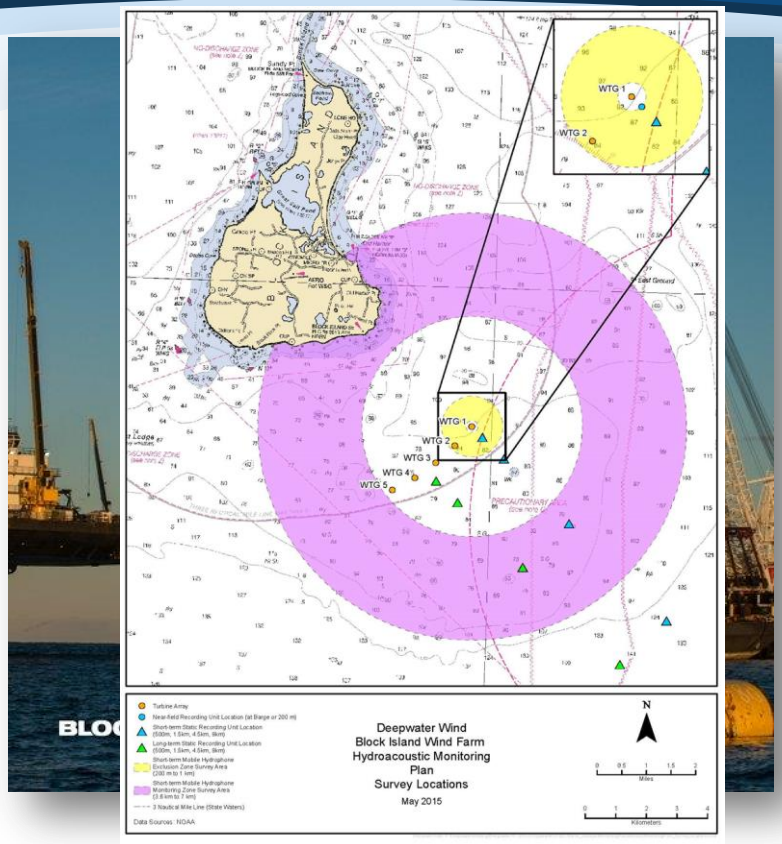
Models for the ‘data fitting exercise’

- Geometric - Practical Spreading Model (PSM):
  - Measure sound at one location (R) in far-field (20x water depth from the source in shallow water)
  - $R_{threshold} = R * 10^{(dB_R - dB_{threshold})/15}$
- Empirical - Regression of in situ measurements:
  - Make measurements at multiple ranges from the source and fit results to get an estimate of the spreading coefficient
  - $RL = ESL - Alog_{10}R - \alpha R$
- First Principles – e.g., Parabolic Equation (PE) Model:
  - Measure at multiple ranges, then perform an ‘inversion’ of the results by ensemble selection of environmental parameters and then forward model using wave equation solution to get isopleths

Basic Sound Source Characterization Set Up

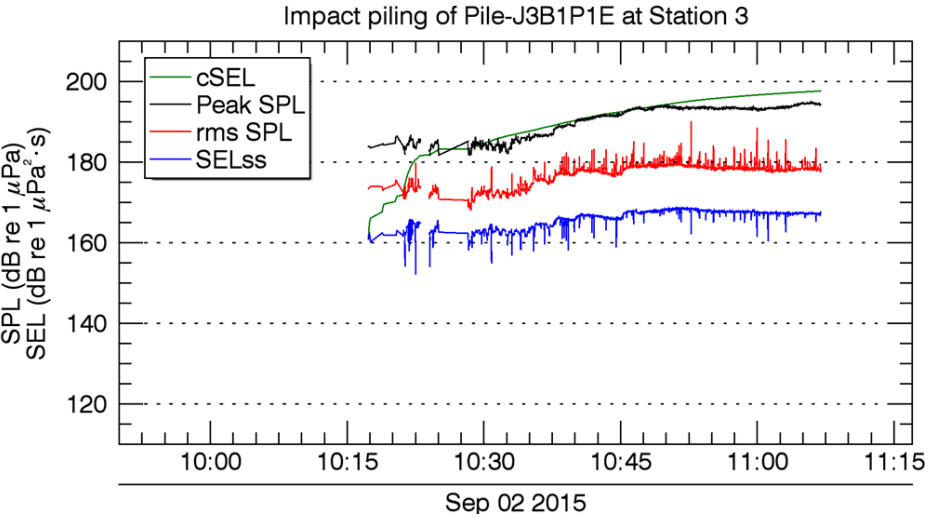


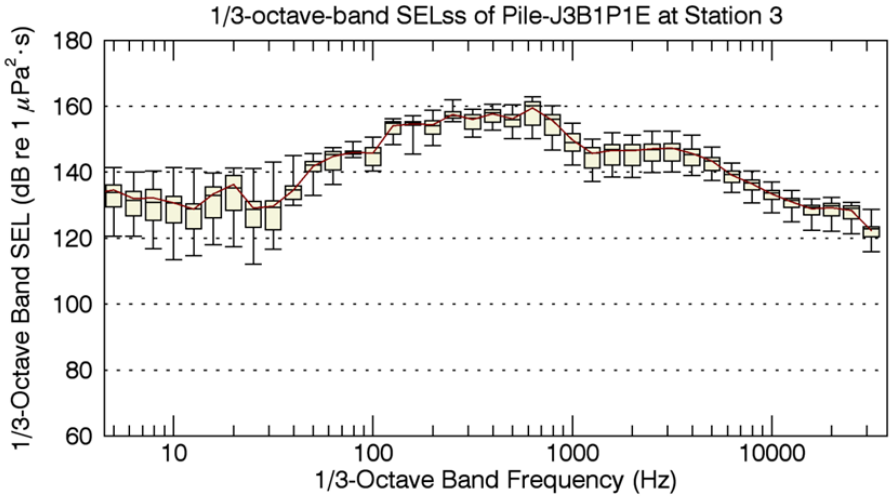
Case Study – Block Island Wind Farm 2015



- Impact piling of 60” piles in 25 m of water, sloping to 45 m in south east. No noise abatement systems
- Isopleths:
  - Mammals: 180 & 160 dB SPL re 1 µPa
  - Sea Turtles: 207 & 166 dB SPL re 1 µPa
  - Sturgeon: 206 dB re 1 µPa peak SPL, 187 dB re 1 $\mu Pa^2 \cdot s$ 24-hour SEL
- Joint TetraTech / JASCO project; two phases – short and long term.
- Recorder distances: ~100 m, 500, 1500, 4500 & 9000 m.

Measurements at 500 m from WTG 1





Practical Spreading Model (PSM)

NMFS BO Sound Level Isopleth	Maximum Radius per BO (m)	PSM Isopleths using 500 m (m)
180 dB re 1 µPa rms SPL	600	346
166 dB re 1 µPa rms SPL	3,414	2968
160 dB re 1 µPa rms SPL	7,000	7454
187 dB re 1 µPa²·s daily SEL	116,591	2500
150 dB re 1 µPa rms SPL	39,810	34600

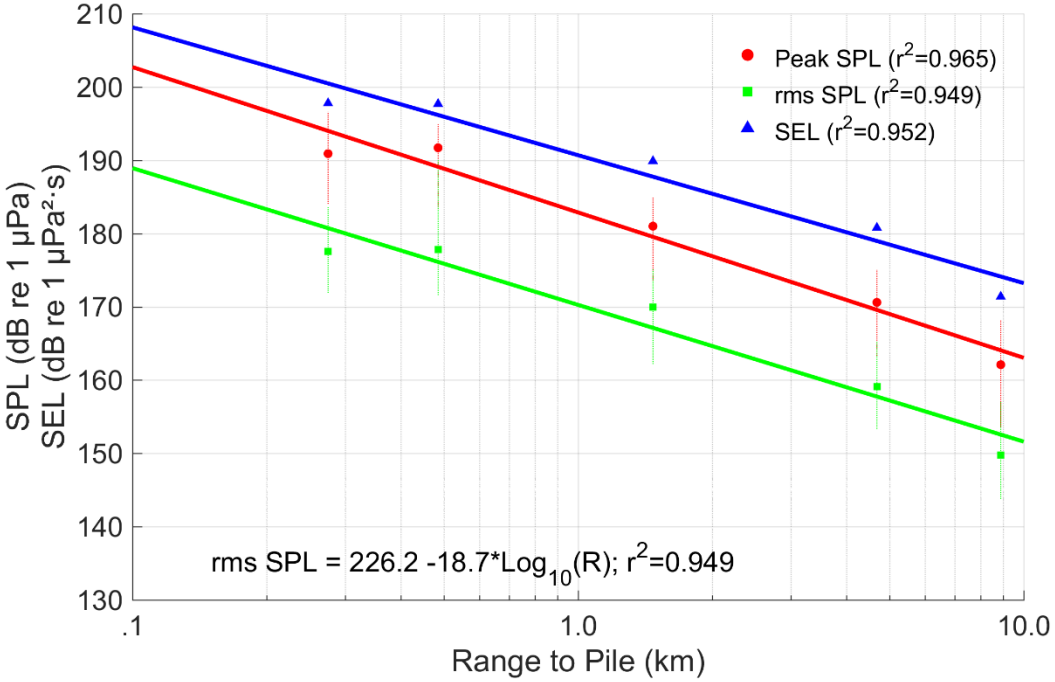
Practical Spreading Model (PSM)

NMFS BO Sound Level Isopleth	Maximum Radius per BO (m)	PSM Isopleths using 500 m (m)	PSM Isopleths using 275 m (m)
180 dB re 1 µPa rms SPL	600	346	190
166 dB re 1 µPa rms SPL	3,414	2968	1630
160 dB re 1 µPa rms SPL	7,000	7454	4094
187 dB re 1 µPa²·s daily SEL	116,591	2500	1438
150 dB re 1 µPa rms SPL	39,810	34600	19005

Practical Spreading Model (PSM)

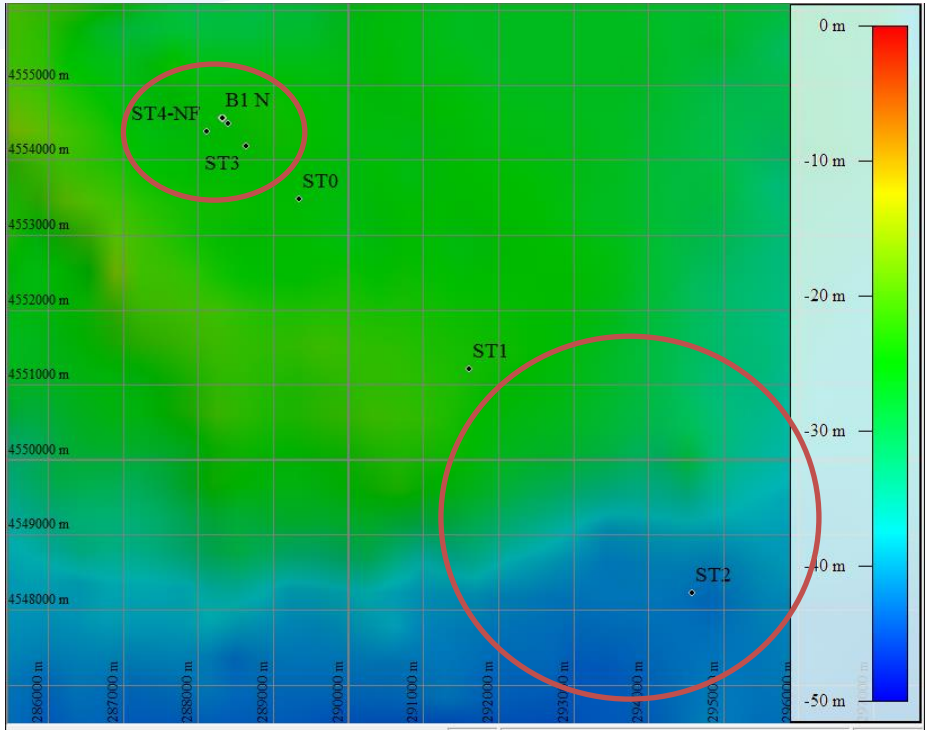
NMFS BO Sound Level Isopleth	Maximum Radius per BO (m)	PSM Isopleths using 500 m (m)	PSM Isopleths using 275 m (m)	PSM Isopleths using 1500 m (m)
180 dB re 1 µPa rms SPL	600	346	190	317
166 dB re 1 µPa rms SPL	3,414	2968	1630	2720
160 dB re 1 µPa rms SPL	7,000	7454	4094	6832
187 dB re 1 µPa²·s daily SEL	116,591	2500	1438	2292
150 dB re 1 µPa rms SPL	39,810	34600	19005	31713

Linear Regression



NMFS BO Sound Level Isopleth	Maximum Radius per BO (m)	Regression Isopleths(m)
180 dB re 1 µPa rms SPL	600	301
166 dB re 1 µPa rms SPL	3,414	1692
160 dB re 1 µPa rms SPL	7,000	3547
187 dB re 1 µPa²·s daily SEL	116,591	1626
150 dB re 1 µPa rms SPL	39,810	12182

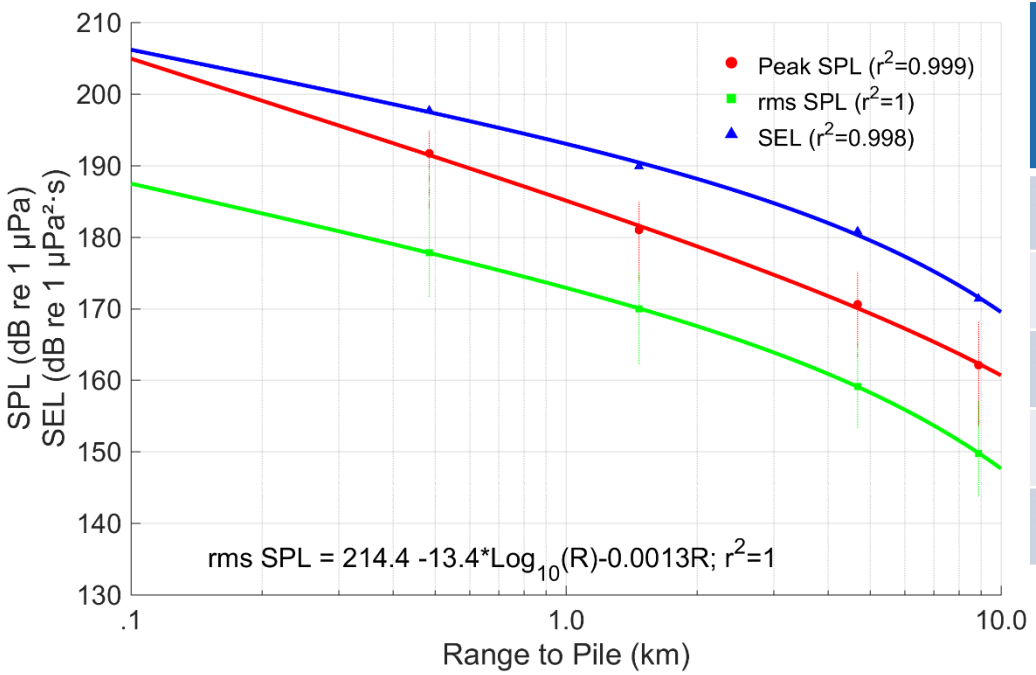
Are the linear regression method assumptions respected?



→ Water depth drops off from 25 m to 42 m – that will change the attenuation rate

→ ST4-NF (275 m) is not along the same line as the other recorders. If the source is directional, this will affect the source level and the regression

Include αR term …

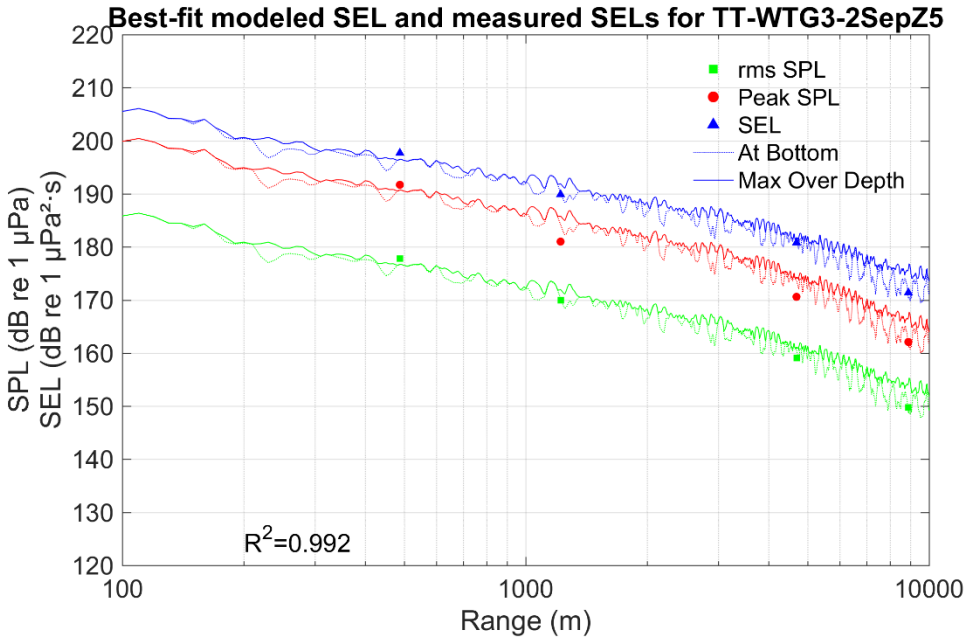


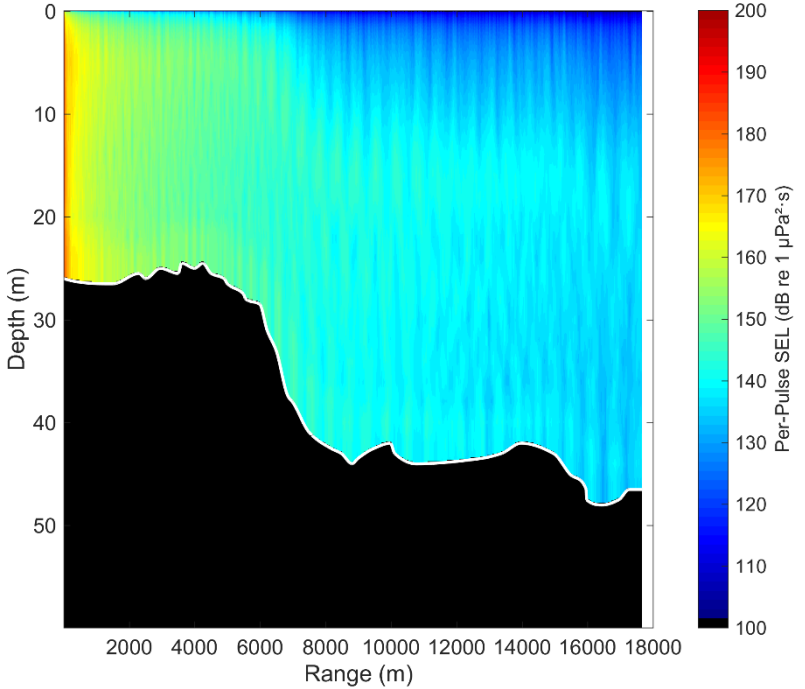
NMFS BO Sound Level Isopleth	Maximum Radius per BO (meters)	Isopleth with 4 recorders	Isopleth with 4 recorders & α term
180 dB re 1 µPa rms SPL	600	438	342
166 dB re 1 µPa rms SPL	3,414	1925	2391
160 dB re 1 µPa rms SPL	7,000	3629	4326
187 dB re 1 µPa²·s daily SEL	116,591	1843	2310
150 dB re 1 µPa rms SPL	39,810	10446	8785

First Principles Model

- First principles propagation model with parameters selected to best fit the measured data
- Model:
  - Omnidirectional sources at depths of 5, 10, 20 m
  - Sediments: grain size (φ=3, 4, 5, 6, 7) and depth (D = 100, 200, 300)
  - Measured sound speed profile
- What is involved?
  - Setup - ~1 hour to enter co-ordinates, configuration files, check SSP, etc.
  - Run time: ~2 hours (PE on i7 laptop)
  - Modeling can be done in background while processing the acoustic data.
- So yes it can be used for fast turn around measurements

Model – Data Assimilation Results





And the radii …

NMFS BO Sound Level Isopleth	Maximum Radius per BO (m)	Assim. Isopleths (m)	Regression Isopleths (m)	Isopleths with 4 recorders & a term	PSM Isopleths @ 500 m (m)	PSM Isopleths @ 275 m (m)
180 dB re 1 µPa rms SPL	600	246	301	342	346	190
166 dB re 1 µPa rms SPL	3,414	2526	1692	2391	2968	1630
160 dB re 1 µPa rms SPL	7,000	5036	3547	4326	7454	4094
187 dB re 1 µPa²·s daily SEL	116,591	2317	1626	2310	2500	1438
150 dB re 1 µPa rms SPL	39,810	11896	12182	8785	34600	19005

Summary

- Permits often require verification of predicted isopleths
  - Monitoring to ensure that EA assumptions remain valid
  - Guide for PSOs
- Looked at three models for determining isopleths:
  - Geometric - Practical Spreading Model (PSM)
    - Easiest, but low confidence
  - Empirical - Linear regressions of measurements
    - Better, but likely to overestimate near field and does account for environmental interactions
    - Site-specific improvement with additional fitting term
  - First principles – e.g., Parabolic Equation (PE) with selected parameters
    - Highest confidence, greater information, but most computationally intensive

Questions?

JASCO APPLIED SCIENCES

- Thanks to:
  - Deepwater Wind for allowing the presentation of the BIWF data;
  - Shell Global Solutions for the deep water seismic data
  - JASCO's field team Rob Mills, David Zeddies and Jeff MacDonnell
  - TetraTech's Field Team of Kristjan Varnik & Erik Kalapinski
  - Master and Crew of the F/V Heather Lynn