Underwater Noise Level Study during Impact Pile Driving

FDOT Project No. BDV34 985-03, Katasha Cornwell, Office of Environmental Management, Project Manager

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Motivation

- Pile driving may make enough noise to kill/injure fish and other marine animals

- Florida does not have reliable local guidelines to predict anthropogenic noise during pile driving and it has been using CalTrans' "Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish" (Buehler et al. 2015)

Specific Variables of Interest

- Sound Attenuation Coefficient
  - $TL = F \times \log_{10}\frac{R}{R_0}$
  - R = Range from sound source
  - R_0 = Reference range
  - F = Transmission loss coefficient
  - TL = Transmission loss (in dB)
- Sound Statistics
  - LZ_{peak} = Peak sound measured at 1-Hz
  - RMS_{90} = 90^{th} sound percentile
  - Peak data = Peak data from each drive event from LZ_{peak} data
  - $Peak_{90}$ = Peak data from RMS_{90}
  - SEL_{90} = Sound exposure level from RMS_{90}
  - SEL_{CUM} = Cumulative sound exposure level

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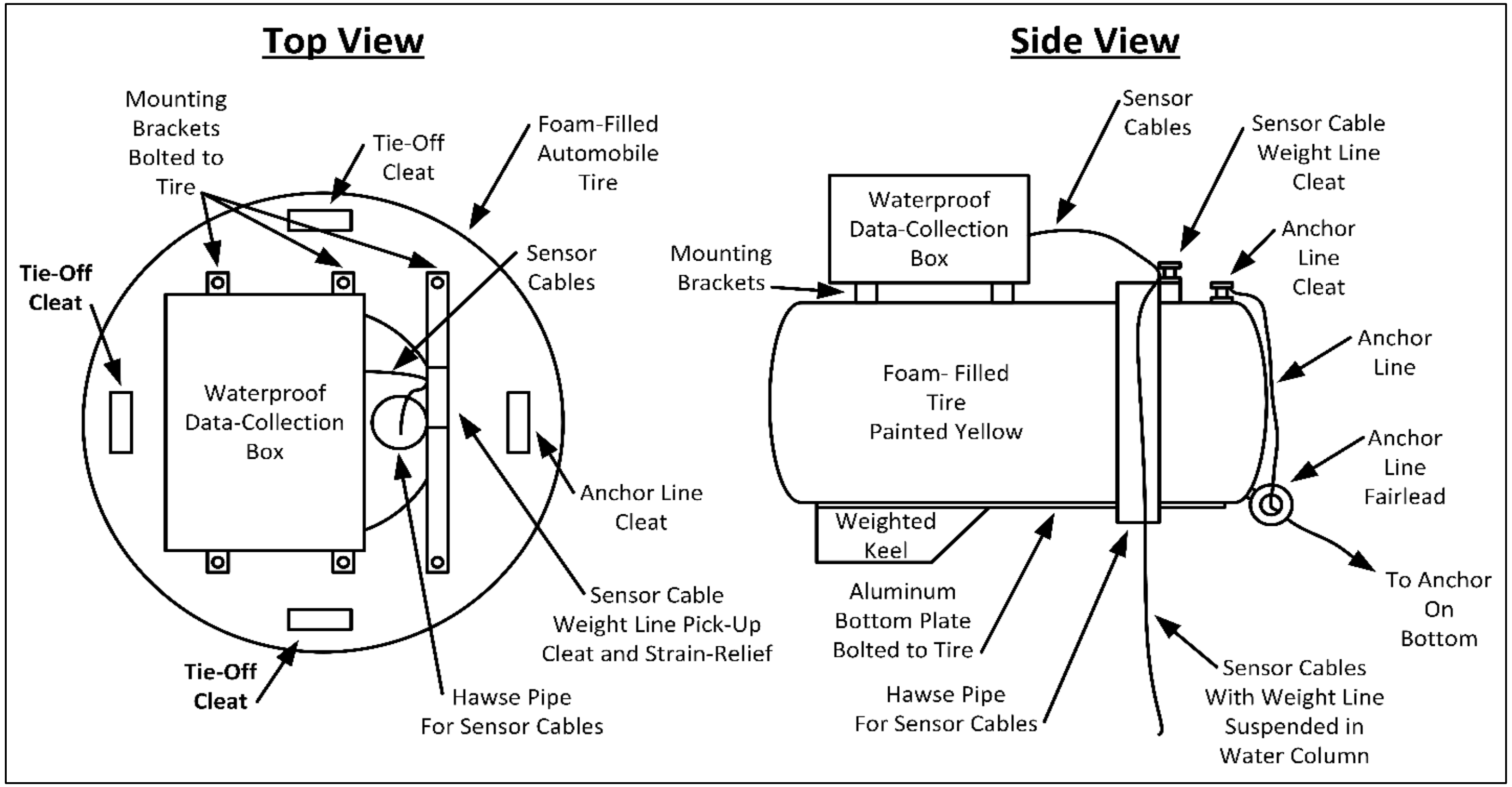
Project Objectives

- Main Objective – Characterize underwater noise levels during impact pile driving throughout the State of Florida
  - Sample noise data at several bridges throughout the state and use data to develop correlations between noise and other variables
  - Determine transmission loss coefficients and use to data to develop statistics between noise and other variables
  - Develop technical guidance in collaboration with NMFS and USFWS

Field Data Collection – Data Collection System Development

- Field data collection system must be
  - Robust
  - Easily deployable/movable
  - Capable of sending real-time data to users
  - Capable of capturing accurate data
- Solution – buoy-mounted hydrophone array with onboard WiFi transmission (5 buoys)

Field Data Collection – Buoy Development



Field data collection original buoy schematic

- Issues with original design:
  - Too heavy (over 50 lbs per buoy)
  - Too large/bulky – would not be easy to deploy from watercraft

Field Data Collection – Buoy Development

New buoy design idea

- Pontoon-based system with aluminum frame
  - Lightweight (approximately 30 lbs. per buoy)
  - Easy to deploy
  - Stackable/can fit several in watercraft
- Issues to solve
  - How to get instruments into/out of box?
  - Strain Relief?
  - How to give WiFi appropriate range?
  - Where to coil cables?
  - How to anchor?
  - Buoy drift

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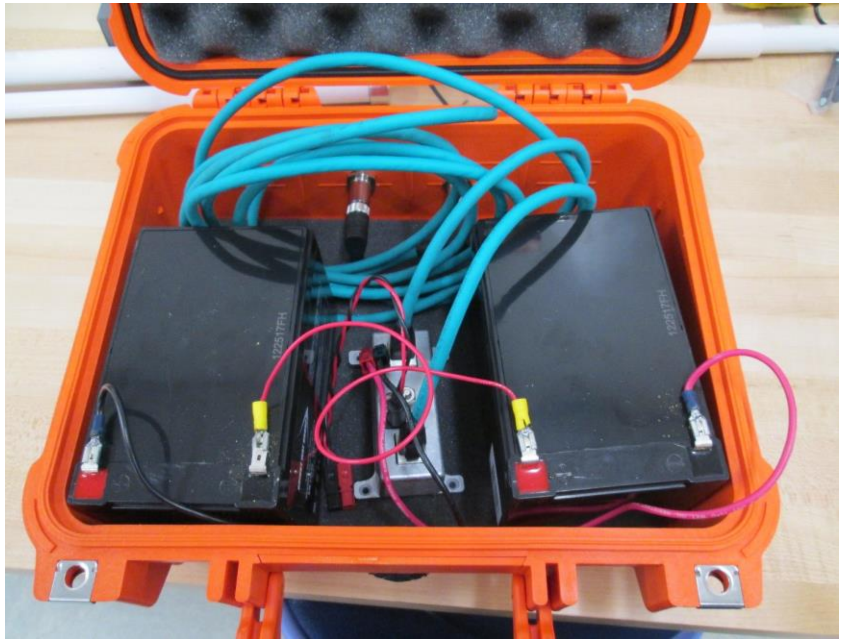
Buoy Electronics

WiFi Antenna and Bullet

Data loggers, batteries, power converters, etc.



Receiver box

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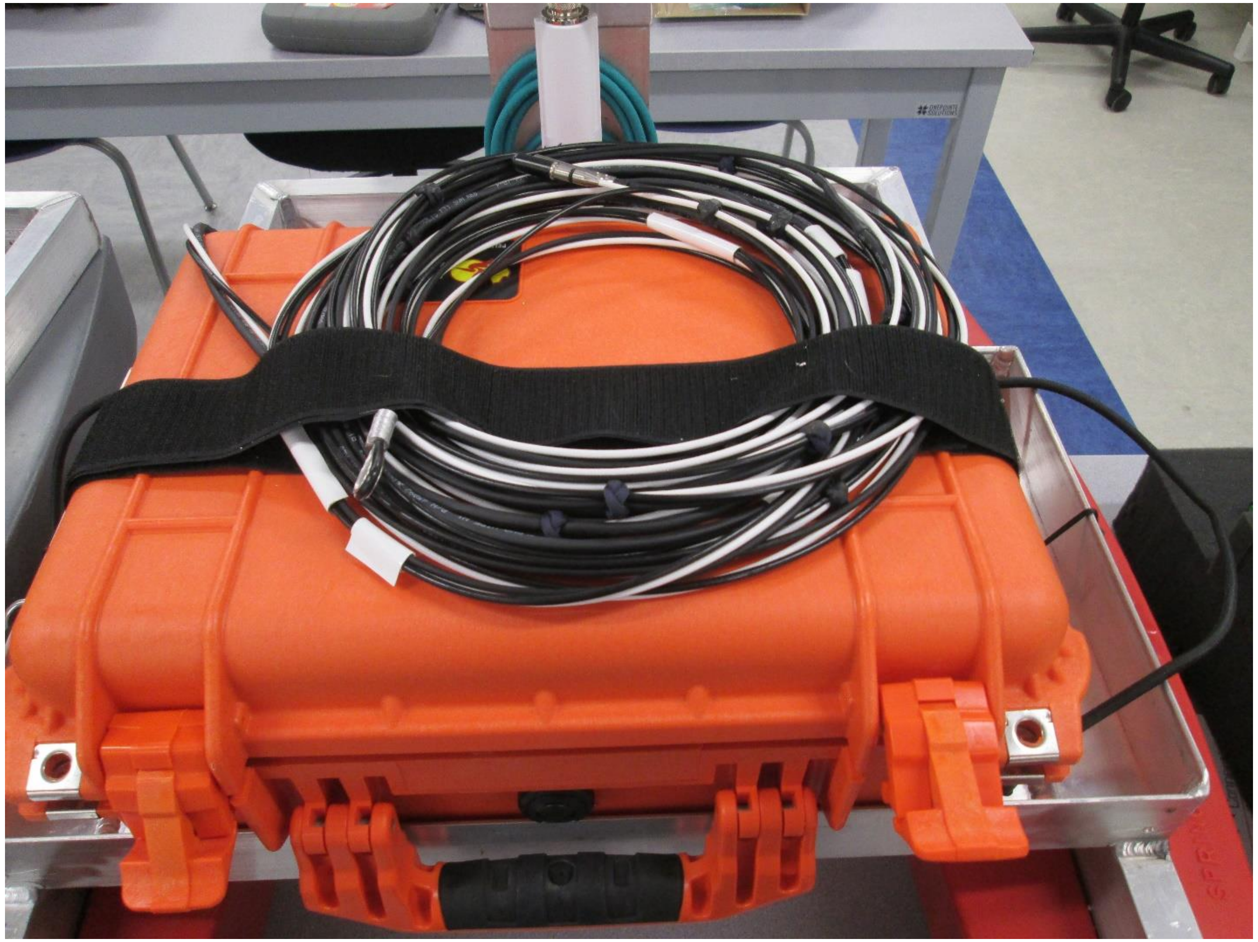
How to Keep Instruments Dry, Provide Strain Relief, Coil Cables ?

Bulkhead connections through box and strain relief



Hydrophone/cable/thermocouple coil attached to box

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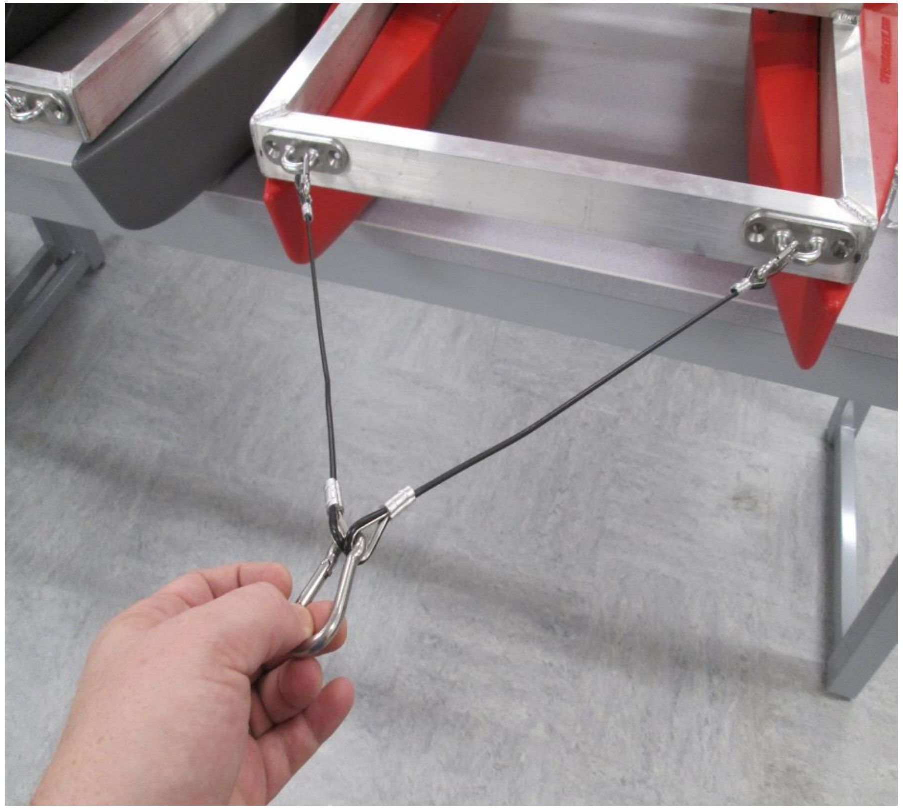
Anchoring/Deployment



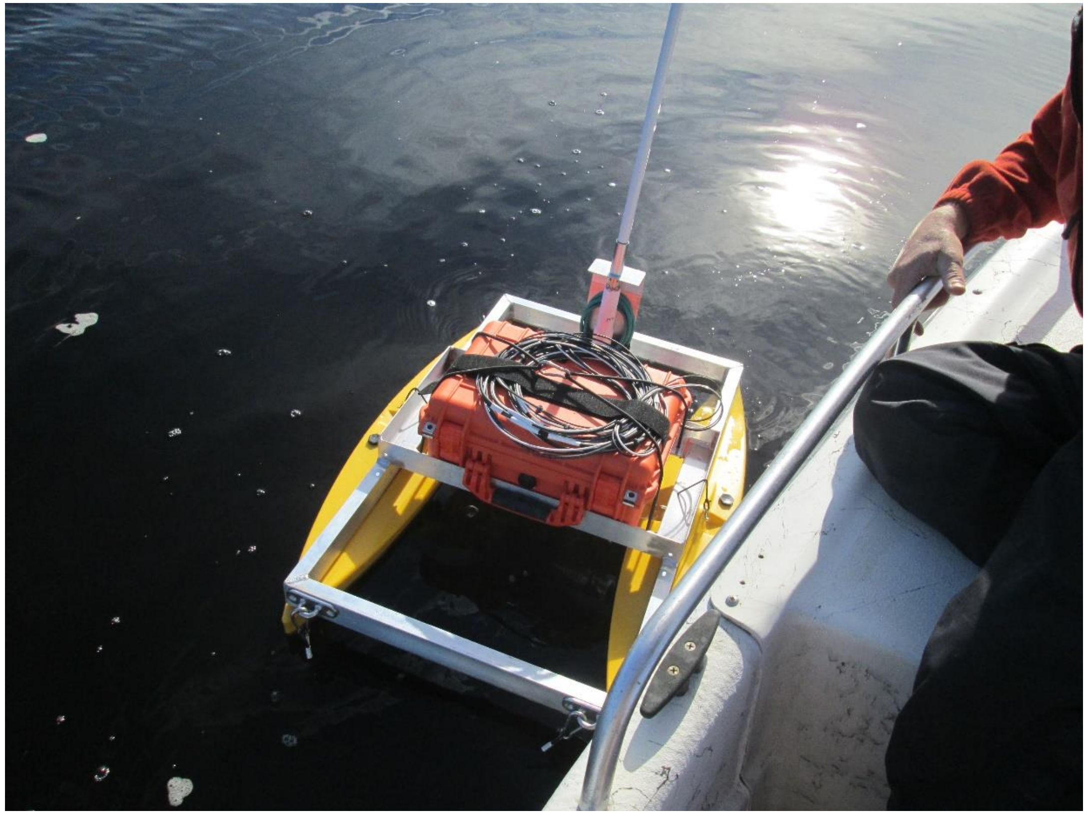
Bridle connection

Secondary buoys/ropes/daisy chains

River anchors

Field Data Collection – Buoy Development

Buoy fleet ready for deployment



First buoy launch (it floats!)

Field Data Collection – Buoy Development

Stacked Buoys

Pulling away from first buoy

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Field Data Collection – Successful Buoy Deployment

Successful buoy deployment in ICWW

Grad students with buoys in watercraft

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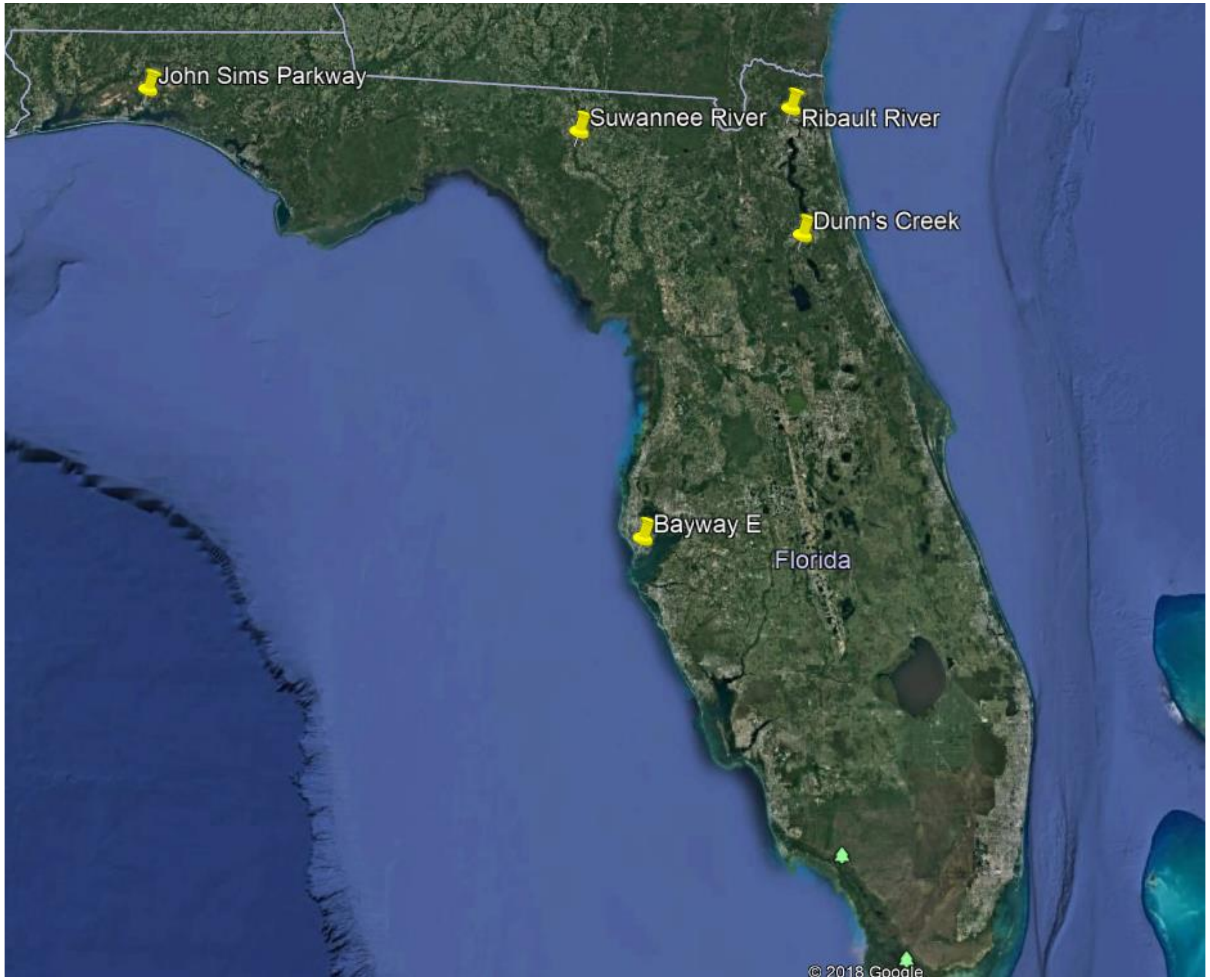
Data Collection



Data Collection Location Map

Site Name	Latitude (N)	Longitude (W)	Date(s) of Visit	Number of Piles	Drive Type
Bayway E	27°41'41.06”	82°43'0.84"	6/3/19 6/4/19	1 steel pile	Steel trestle vibrating
Dunn’s Creek	29°34'38.95"	81°37'34.73"	3/14/19 3/15/19	2 sheet pile pairs	Sheet pile vibrating
John Sims Pkwy	30°30'9.73"	86°29'38.51"	6/24/19 6/26/19	1 concrete pile	Concrete production piles percussion hammer
Ribault River	30°23'43.99"	81°42'52.21"	5/7/19 6/10/19	1 concrete test pile and 3 production piles	Percussion hammer
Suwannee River	30°14'40.86"	83°15'0.34"W	4/18/19	3 concrete piles	Percussion hammer

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Data Analysis

- $SEL = 10\log_{10}\int_0^T P^2(t)dt$
- $P = P_{ref}10^{\frac{LZ_{peak}}{20}}$
- $SEL = 10\log_{10}\frac{\int Pdt}{P_{ref}^2}$
- $SEL \approx \overline{(LZ_{peak})} + 10\log_{10}T$

- SEL = Sound Exposure Level
- P = Sound Pressure
- P_{ref} = Reference Sound Pressure
- LZ_{peak} = Peak Sound @ 1-Hz Sampling Rate
- T = Time of Sound Event

- $TL = F\log_{10}\left(\frac{R}{R_0}\right)$
- $P_s - P_b = F\log_{10}\left(\frac{R}{R_0}\right)$
- $P_B = P_s - F\log_{10}\left(\frac{R}{R_0}\right)$
- $P_B = a\log_{10}\left(\frac{R}{R_0}\right) + b$

- TL = Transmission Loss
- R = Range from Sound Source
- R_0 = Reference Range (usually 1 m)
- P_B = Sound at the Buoy
- P_S = Sound at the Source
- F = Transmission Loss Coefficient
- a,b = Best-Fit Regression Coefficients

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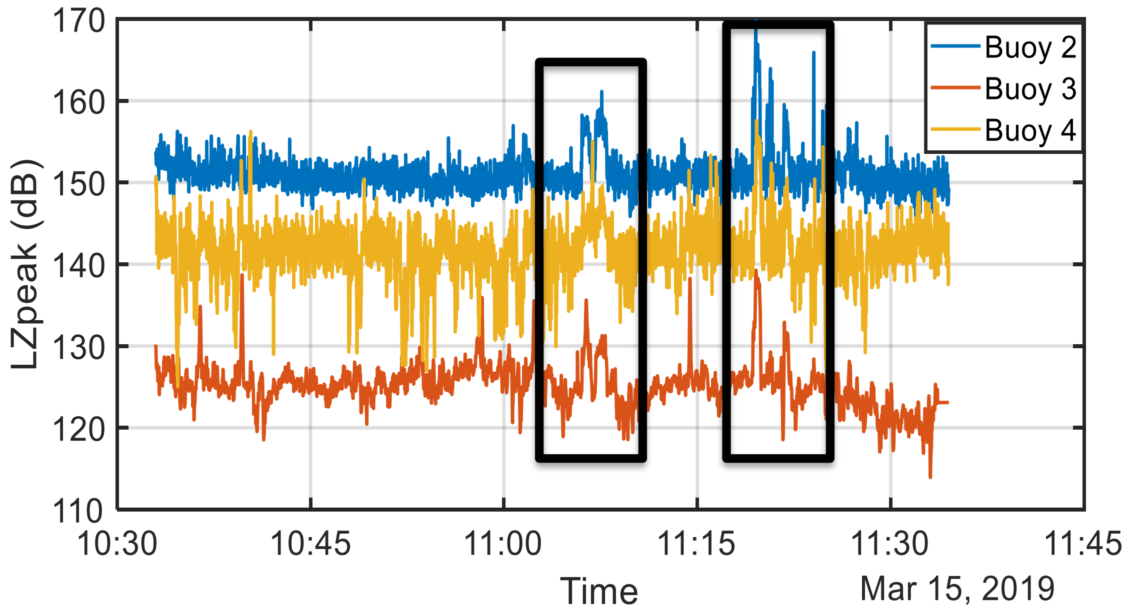
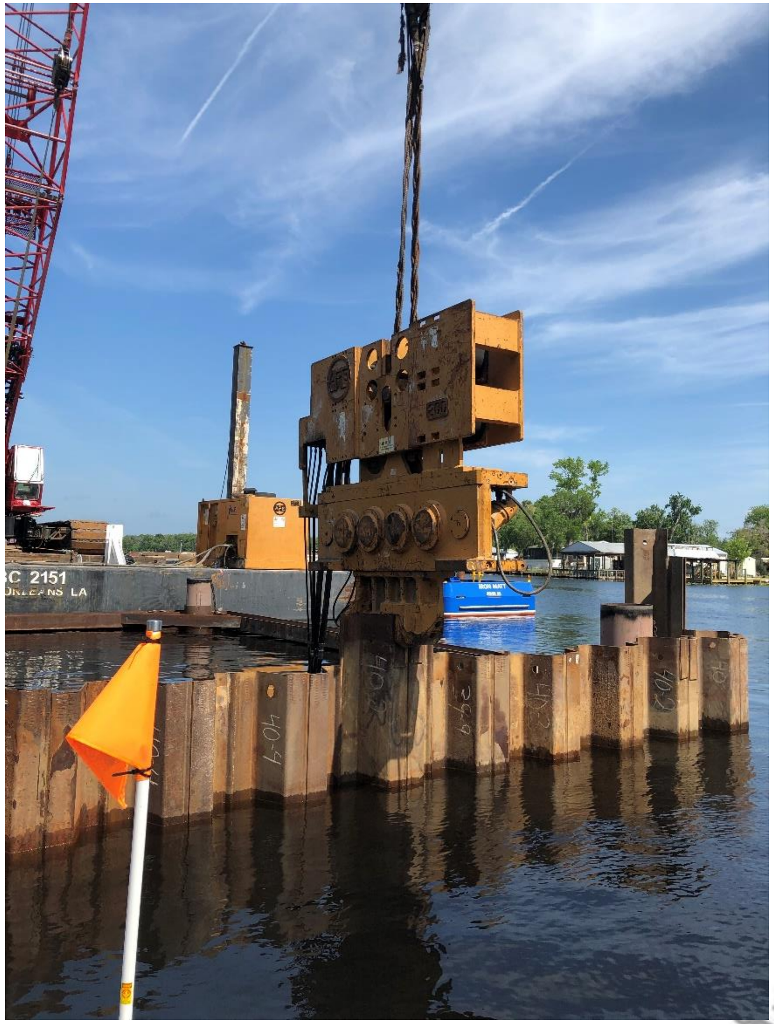
Dunn’s Creek – Sound Collection



Raw Data from Dunn’s Creek

Buoy Number	Buoy Distance (m)	Water Depth (m)	Hydrophone Depth (m)
1	59.5	7.62	3.96
4	202.0	6.10	2.74
3	396.0	6.71	3.09

Dunn’s Creek Buoy Distance



Dunn’s Creek Sheet Piles

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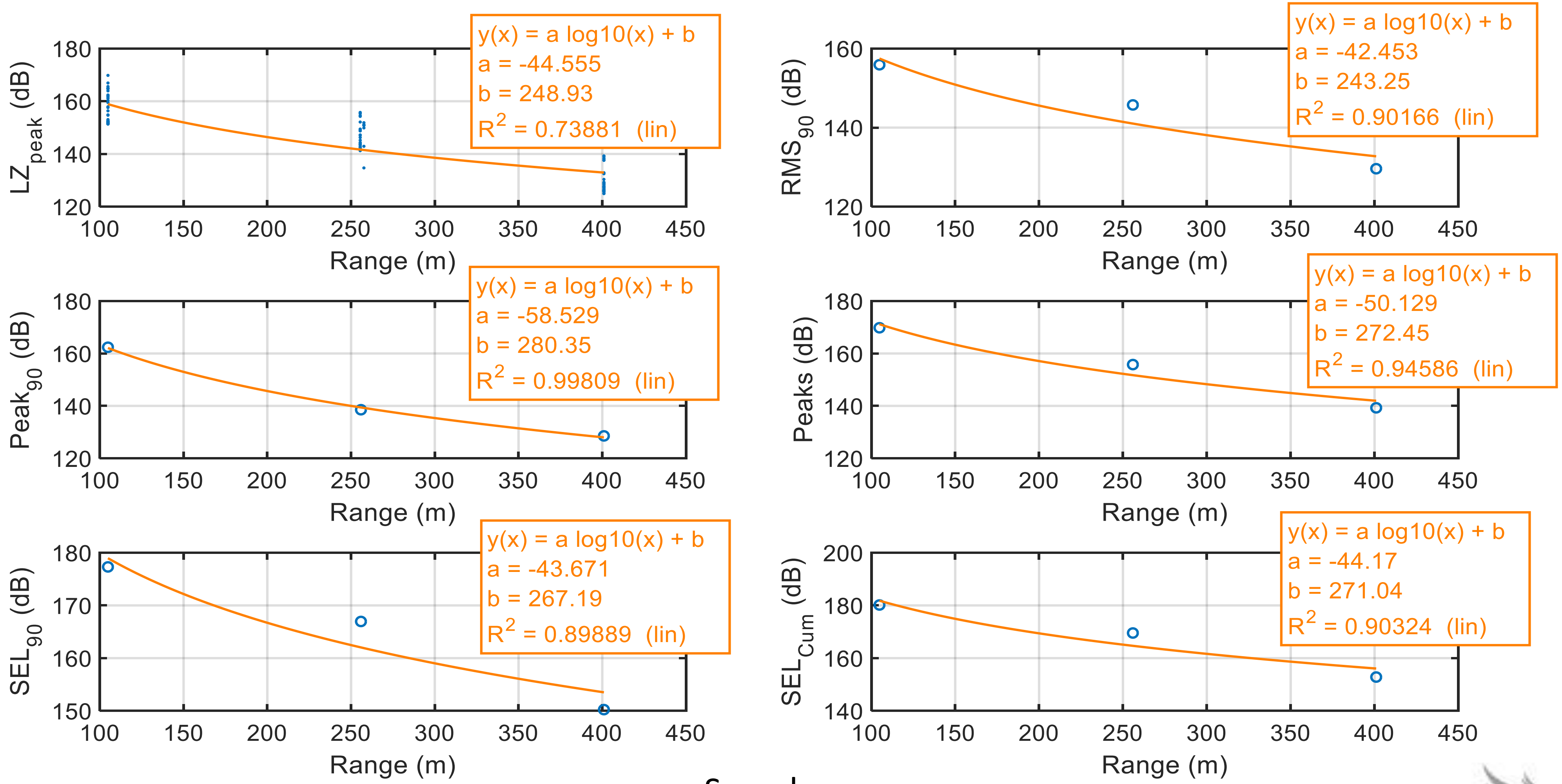
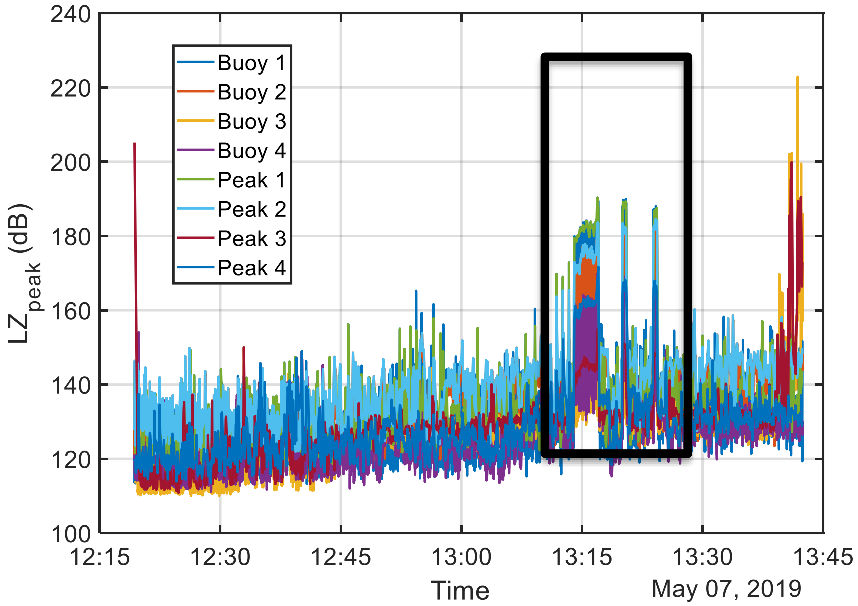
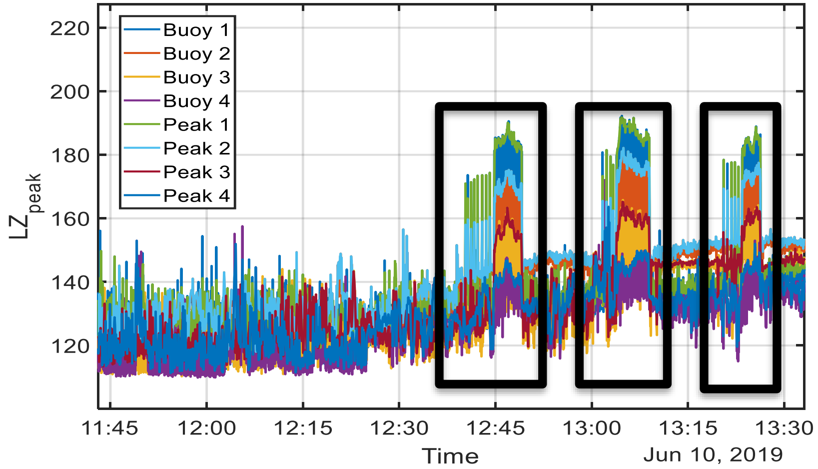
Dunn's Creek – Data Analysis Sample



Sample o

Ribault River Test and Production Piles – Data Collection





Buoy Number	Buoy Distance (m)	Water Depth (m)	Hydrophone Depth (m)
1	25	2.35	1.22
2	49	2.19	1.22
3	195	2.10	1.22
4	70	2.26	1.22

Top-Left – Test Pile Data
Bottom-Left – Production Pile Data
Middle – Test Pile Driving

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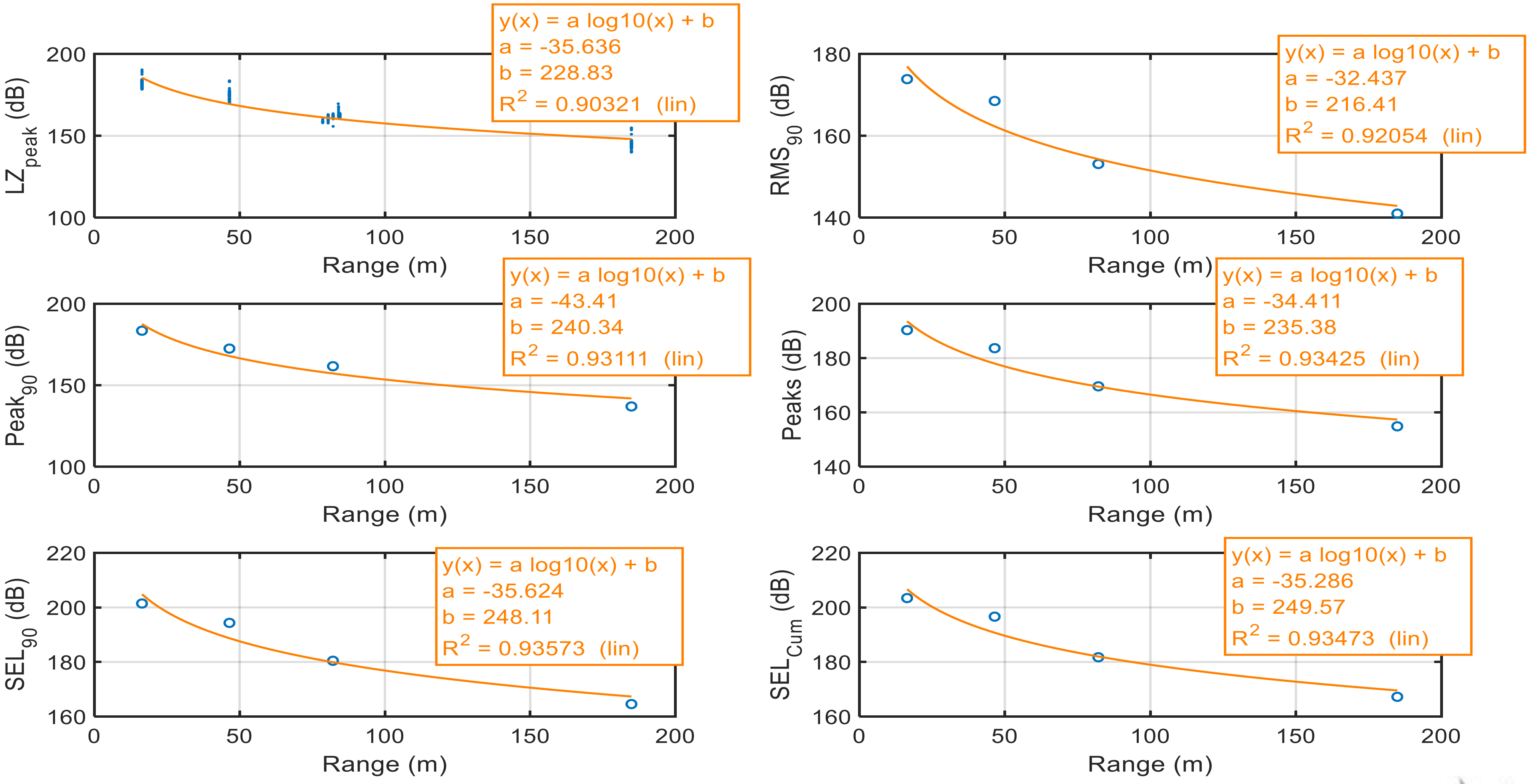
Ribault River – Data Analysis Sample Results



Ribault River Sample Data Analysis (Test Pile Shown)

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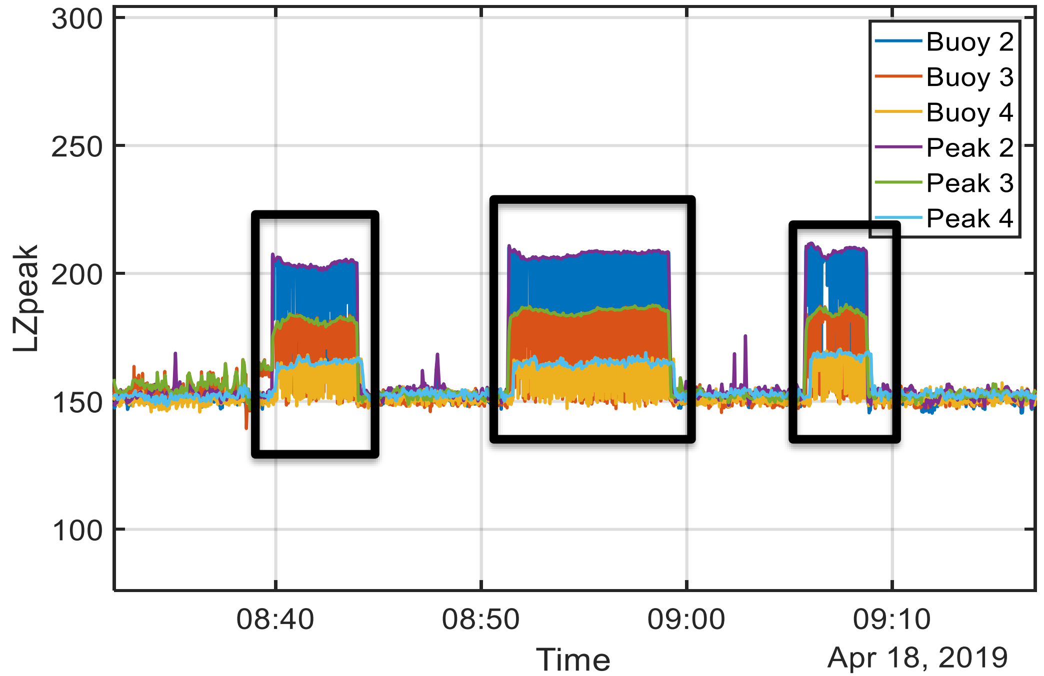
Suwannee River – Data Collection



Suwannee River Raw Data

Buoy Number	Buoy Distance (m)	Water Depth (m)	Hydrophone Depth (m)
2	15	4.88	2.44
3	65	3.96	2.44
4	502	2.74	1.52

Suwannee River Buoy Distances

Suwannee River Construction Trestle

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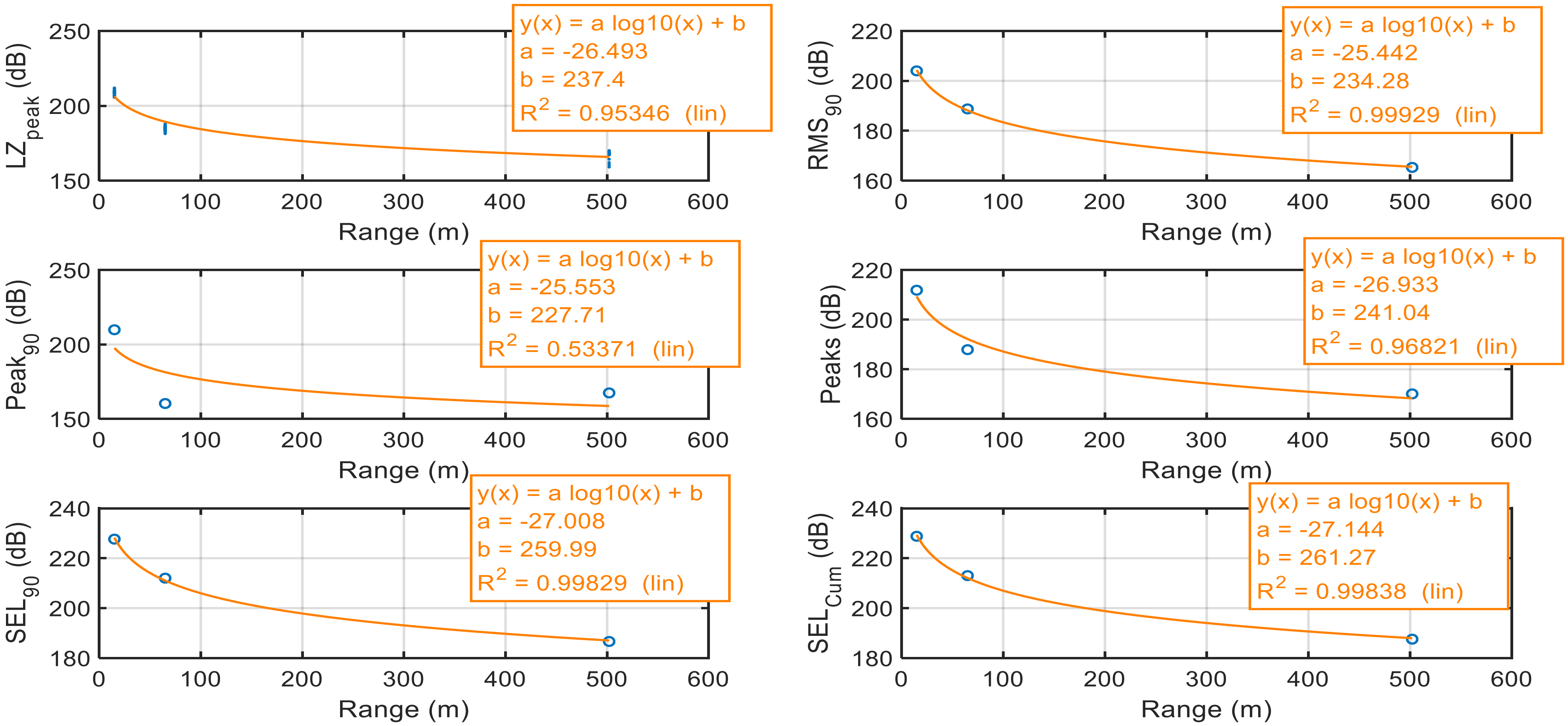
Suwannee River – Data Analysis and Sample Results



Suwannee River Sample Data Analysis (Pile 3 Shown)

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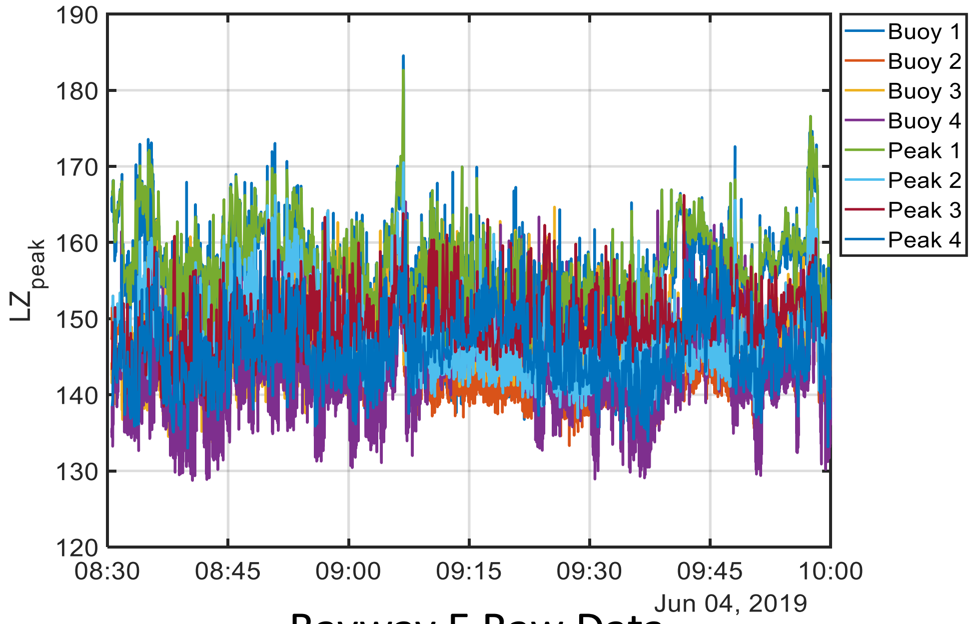
Bayway E – Data Collection



Bayway E Raw Data

Buoy Number	Buoy Distance (m)	Water Depth (m)	Hydrophone Depth (m)
1	16-25 distance to pile 1 and to pile 4	3.05	1.52
2	73	3.96	1.83
3	177	3.66	1.83
4	370	2.96	1.83

Bayway E Buoy Distances

Bayway E Pile Rig

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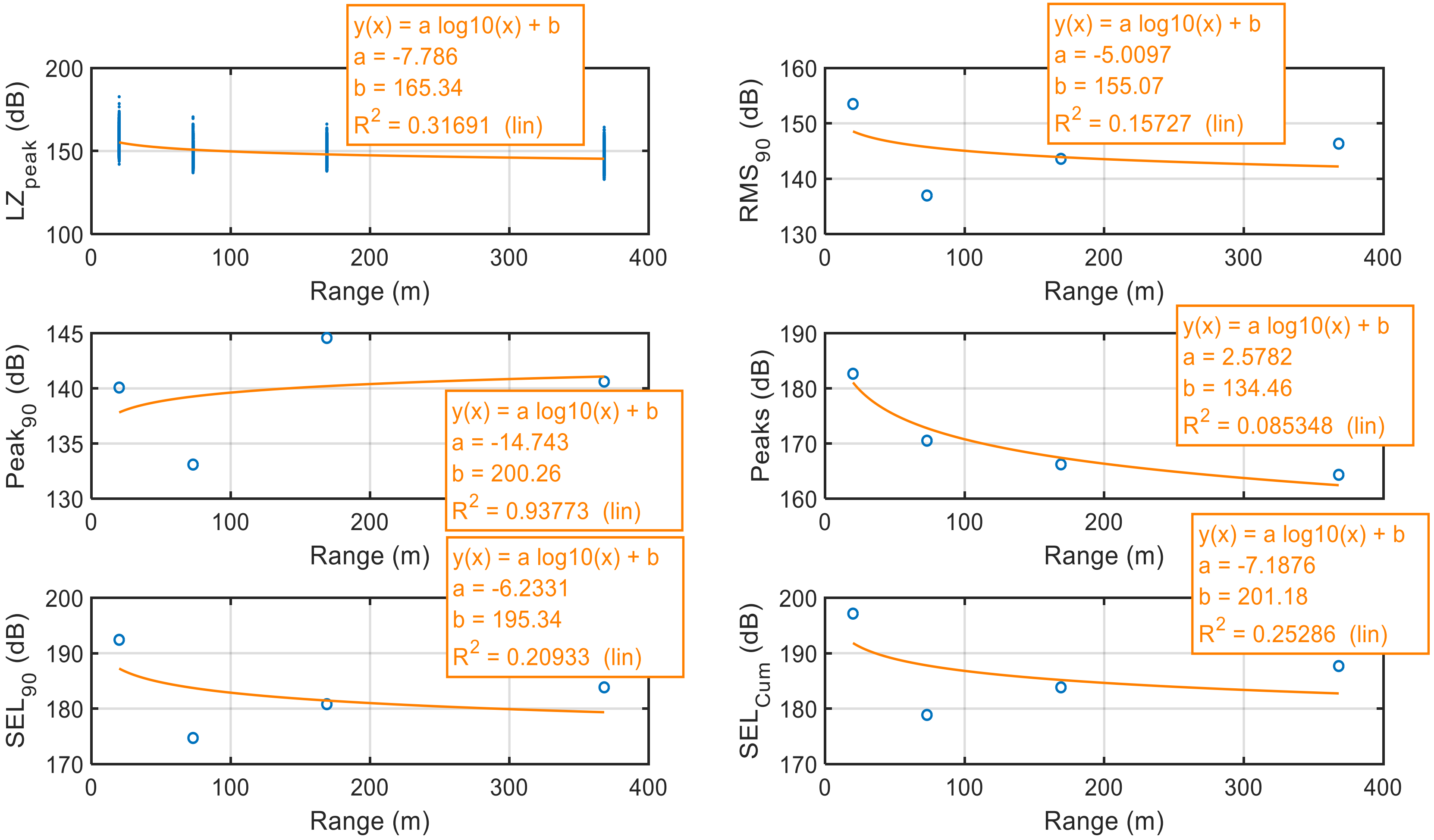
Bayway E – Data Analysis and Results



Bayway E Data Analysis

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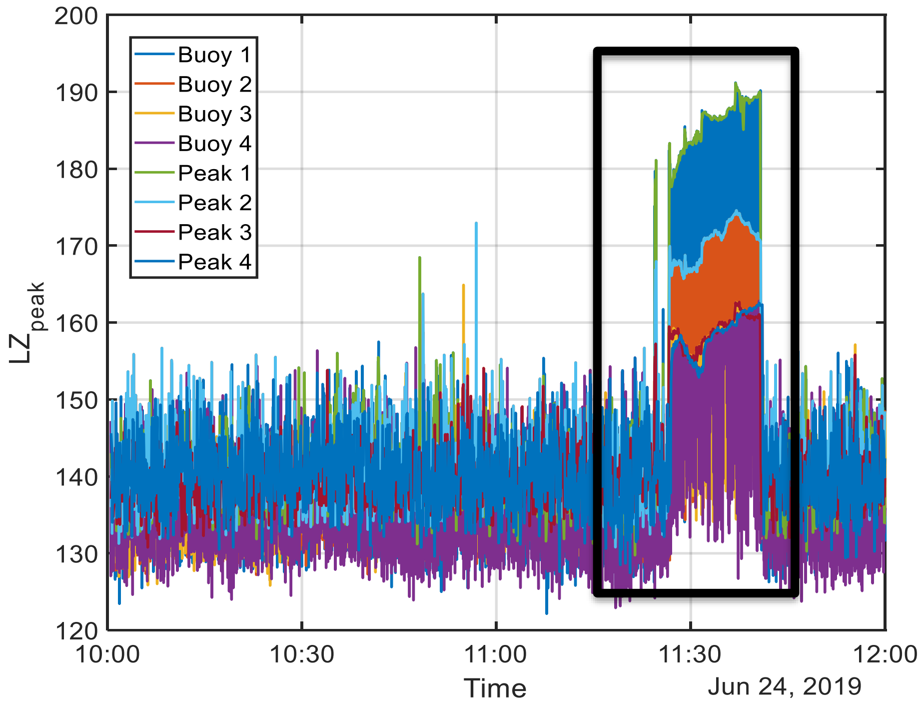
John Sims Parkway – Data Collection



Buoy Number	Buoy Distance (m)	Water Depth (m)	Hydrophone Depth (m)
1	25	3	1.5
2	85	3	1.5
3	190	3	1.5
4	375	3	1.5

Top-Left – Raw Signal
Bottom-Left – Buoy Distances
Above – Driving the Pile

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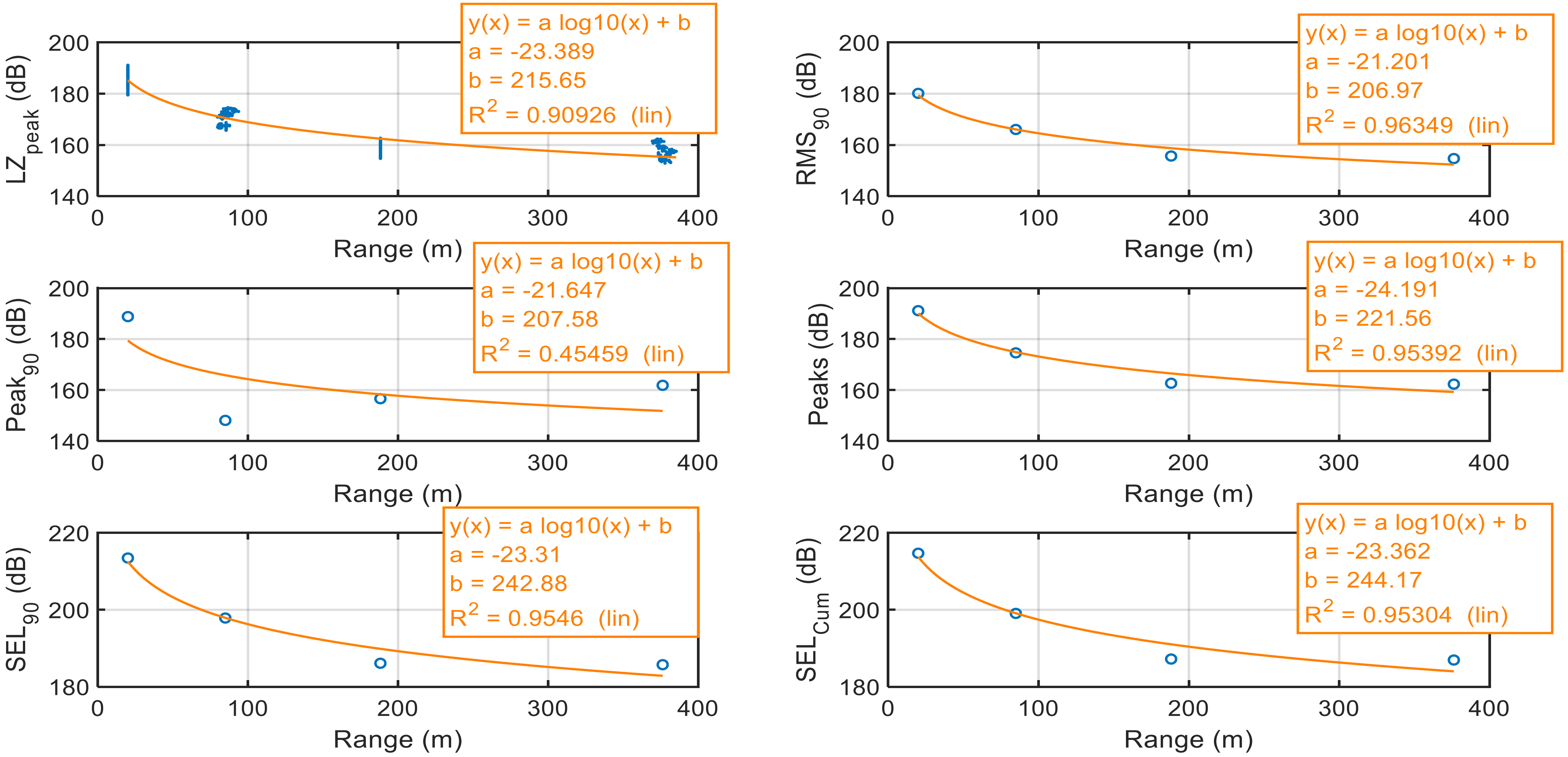
John Sims Parkway – Data Analysis and Results



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Data Collection Summary

Site Name	Mean F-value	Mean Worst-Case SEL_{cum}
Dunn's Creek	43.81	257.75
Ribault River Test Pile	35.64	249.57
Ribault River Production Piles	42.06	270.26
Suwannee River	26.26	262.24
Bayway E*	7.79*	201.18*
John Sims Parkway	23.39	244.17

- Except for Bayway E, *F* has consistently been greater than the recommended value, *F*=15
- Worst-case *SEL* may be <u>very</u> high, but appears to dissipate quickly as a function of distance

Issues with Testing/Areas for Improvement

- Hydrophone reliability needs to be improved
- GPS reliability needs to be improved
- WiFi reliability needs to be improved

Upcoming Work

- Short-term (fall 2019)
  - Back to Bayway E (St. Pete, D4)
  - Choctawhatchee Bay Bridge Fender Replacement? (Destin, D3)

- Longer-term (2020)
  - C Street Cedar Key (Cedar Key, D2)
  - Manatee River Bridge (Bradenton, D1)
  - Howard Frankland Bridge (Tampa, D7)
  - New River Bridge (West of Starke, North of Gainesville, D2)
  - Simpson River Bridge (Amelia Island, D2)
  - Myrtle Creek bridge (Amelia Island, D2)
  - Simpson Creek Bridge (Pensacola, D3)

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Thank you!