Improving Marine Mammal Monitoring Survey on *Langseth* using Streamer Data

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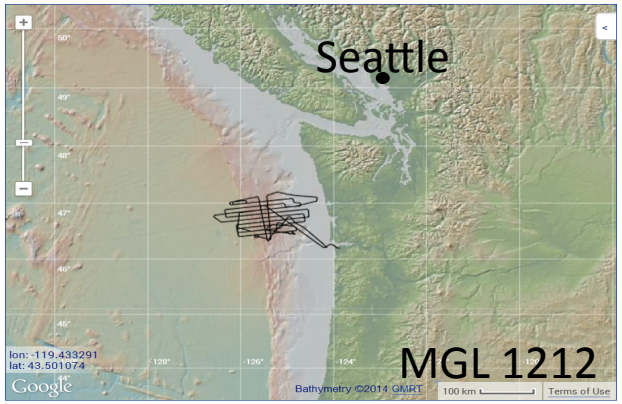
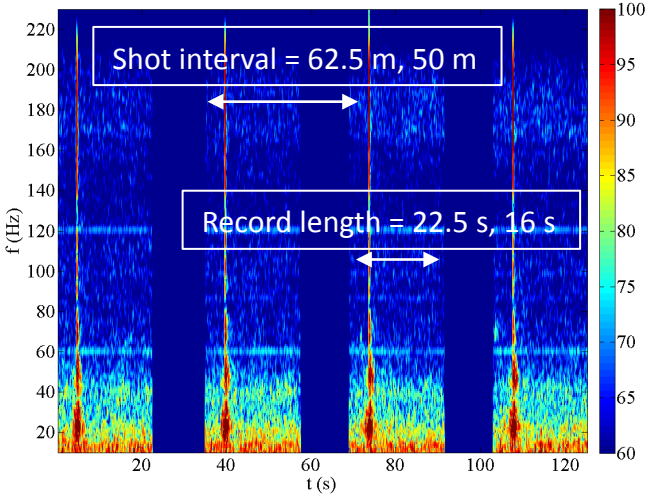
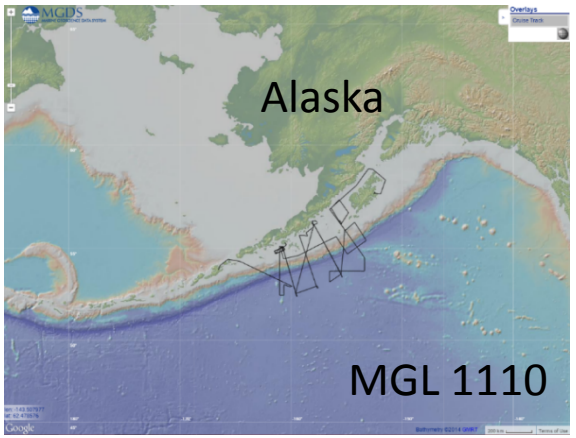
Marcus Langseth Science Oversight Committee, December 2014

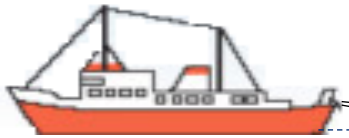
ALEUT: **A**laska **L**angseth **E**xperiment to **U**nderstand the mega**T**hrust, July 2011

COAST: **C**ascadia **O**pen-**A**ccess **S**eismic **T**ransects, July 2012

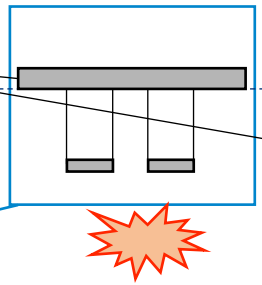




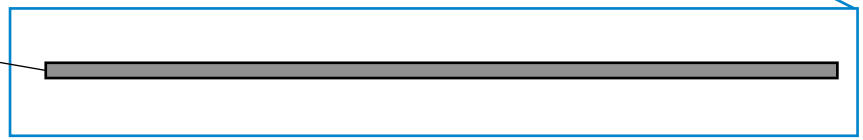




R/V Langseth



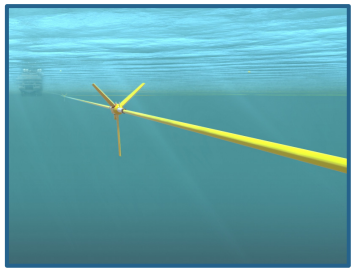
Receiver Array (Streamer)



Airgun Array

Full array: 36 Airgun (6,600 in^3)

Mitigation: Single Airgun (40 in^3)



- 8 km streamer
- 636 Hydrophones
- Fs = 500 Hz

Marine Mammals Monitoring

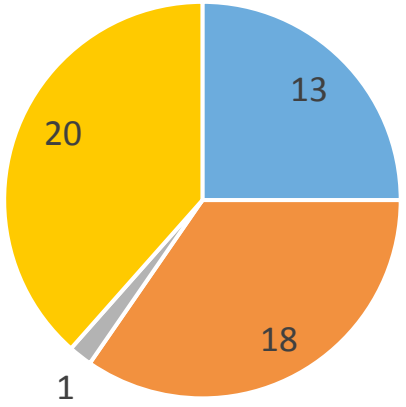
- **Visual Monitoring Survey**
  - 2-5 Observers
  - 18.9 m above the water surface

- **Acoustic Monitoring Survey (PAM)**
  - 3 hydrophones (2-200 kHz)
  - 1 hydrophone (75 Hz-30 kHz)
  - 24 hrs (during periods of darkness or low visibility)

- **Acoustic Monitoring Survey (Streamer)**
  - 636 Hydrophones
  - Recording for imaging and monitoring at the same time

Baleen Whale Detection (MGL 1110)

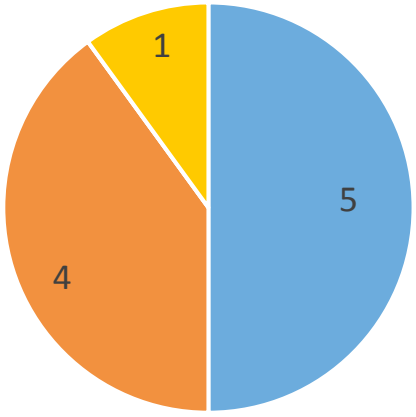
- **Visual Monitoring Survey**



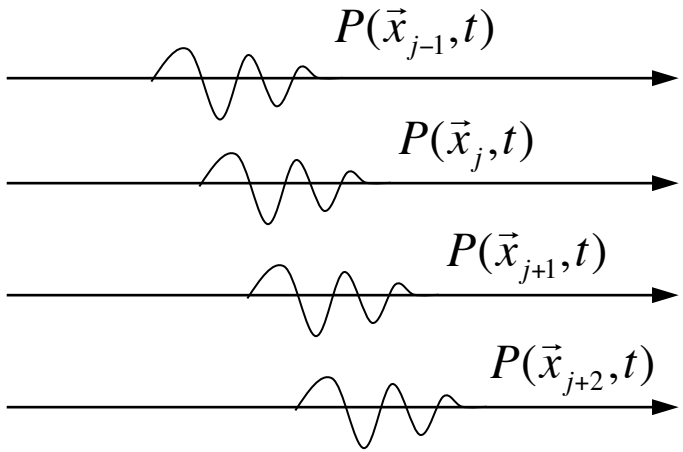
- **Acoustic Monitoring Survey (PAM)**
  - Ship noise interference
  - PAM cable entanglement with seismic equipment
  - Shallow water depth
  - Low frequency calls

NO DETECTION

- **Acoustic Monitoring Survey (Streamer)**
  - Silent animals
  - Animals were very far => full Airgun array was used
  - High frequency calls

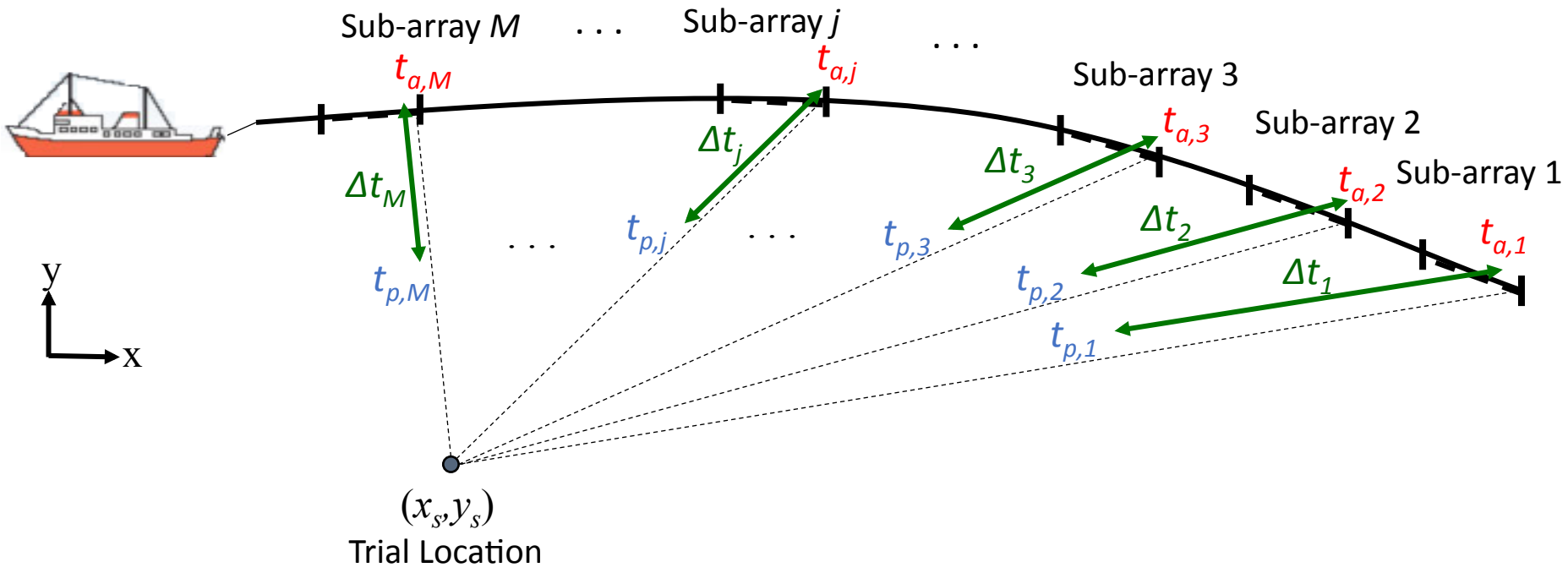


Fin Whale Humpback Whale North Pacific Right Whale Unidentified Baleen Whale



Localization Technique & Result

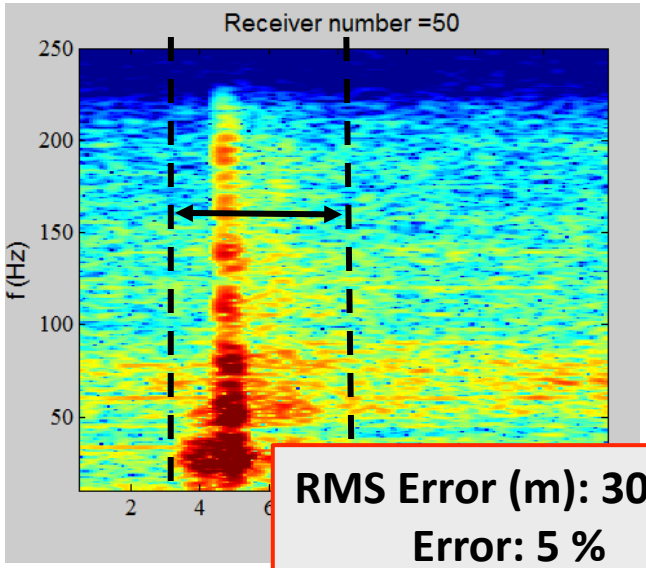
Localization



travel time residual $$\sigma_t(x_s, y_s) = \sqrt{\frac{1}{M}\sum_{j=1}^{M}(\Delta t_j - \mu_t)^2}$$

* Abadi, Wilcock, Tolstoy, Crone, Carbotte: "Sound source localization using data recorded by hydrophone streamers during seismic surveys", J. Acoust. Soc. Am., submitted.

Airgun Localization

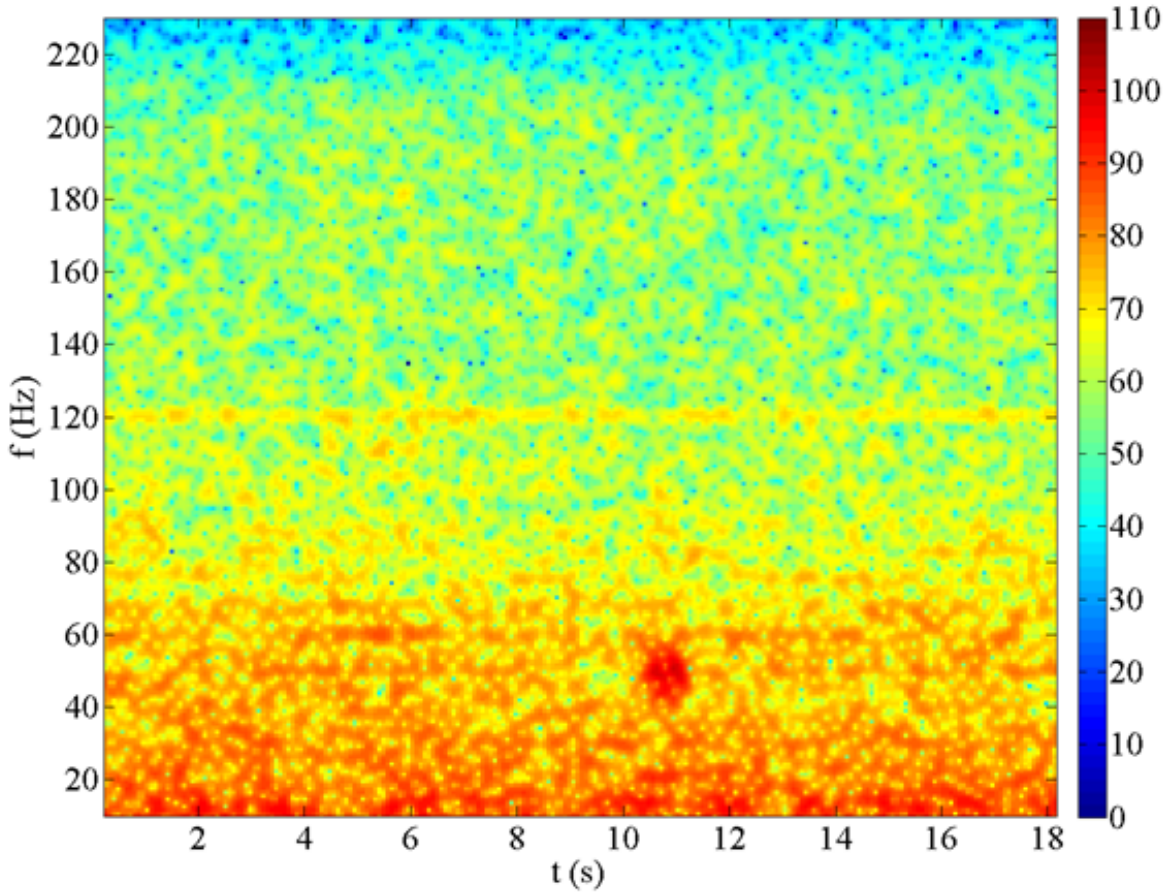


RMS Error (m): 300 m
Error: 5 %

Recorded time July 16, 2012	Shot #	Water Depth (m)	Estimated Location (m)	Actual Location (m)
17:59:47	12395	126	(-100±1000, 100±400)	(-33, 238)
18:05:54	12410	129	(-270±820, 280±580)	(-24, 241)
18:11:56	12425	120	(-320±550, 210±580)	(-31, 243)
18:16:01	12435	117	(150±1000, -100±950)	(-29, 240)
18:20:05	12445	124	(-150±700, 550±850)	(-31, 242)

Humpback Whale

Species	# of Visual Detection	Date	Time
Humpback	6	July 31	18:35:40-19:18:26



* Thompson, Cummings, Ha (1986), "Sounds, source levels, and associated behavior of humpback whales, Southeast Alaska", JASA 80(3)

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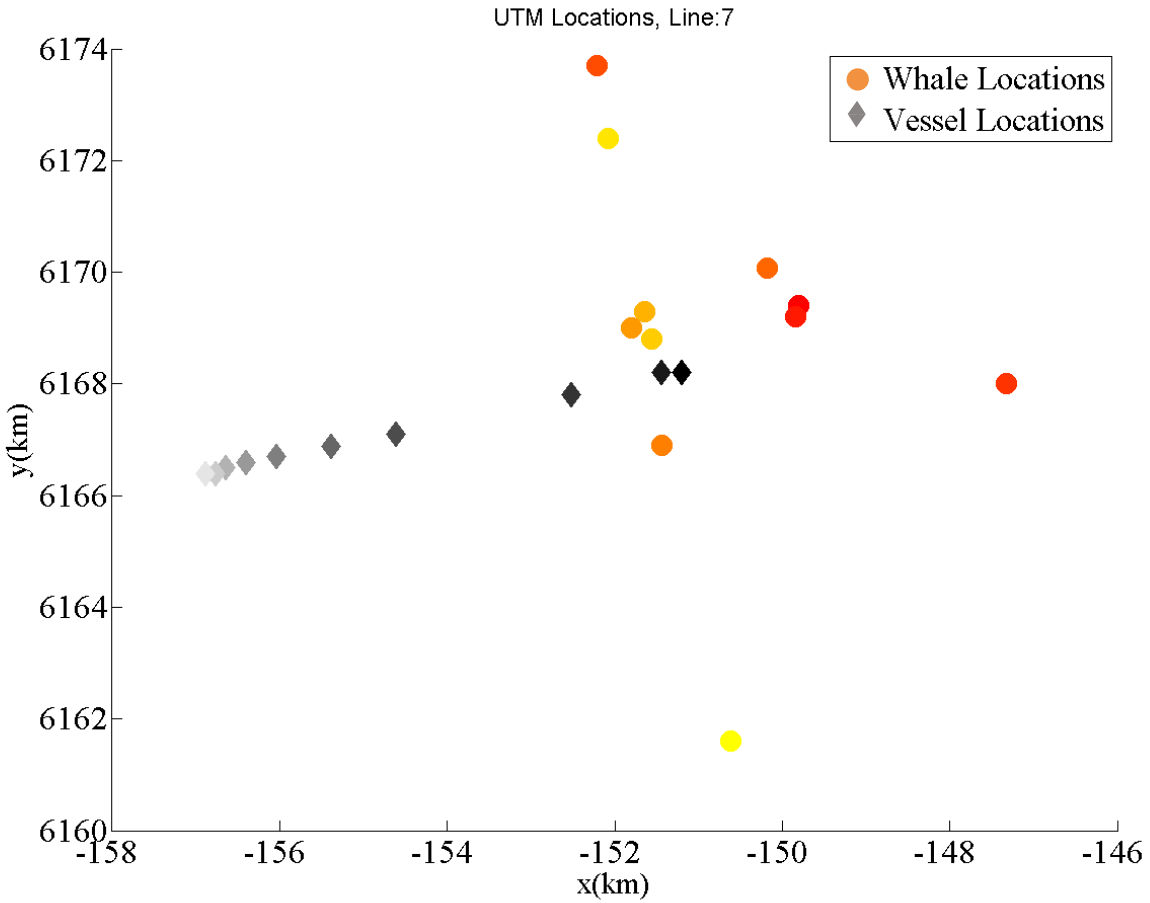
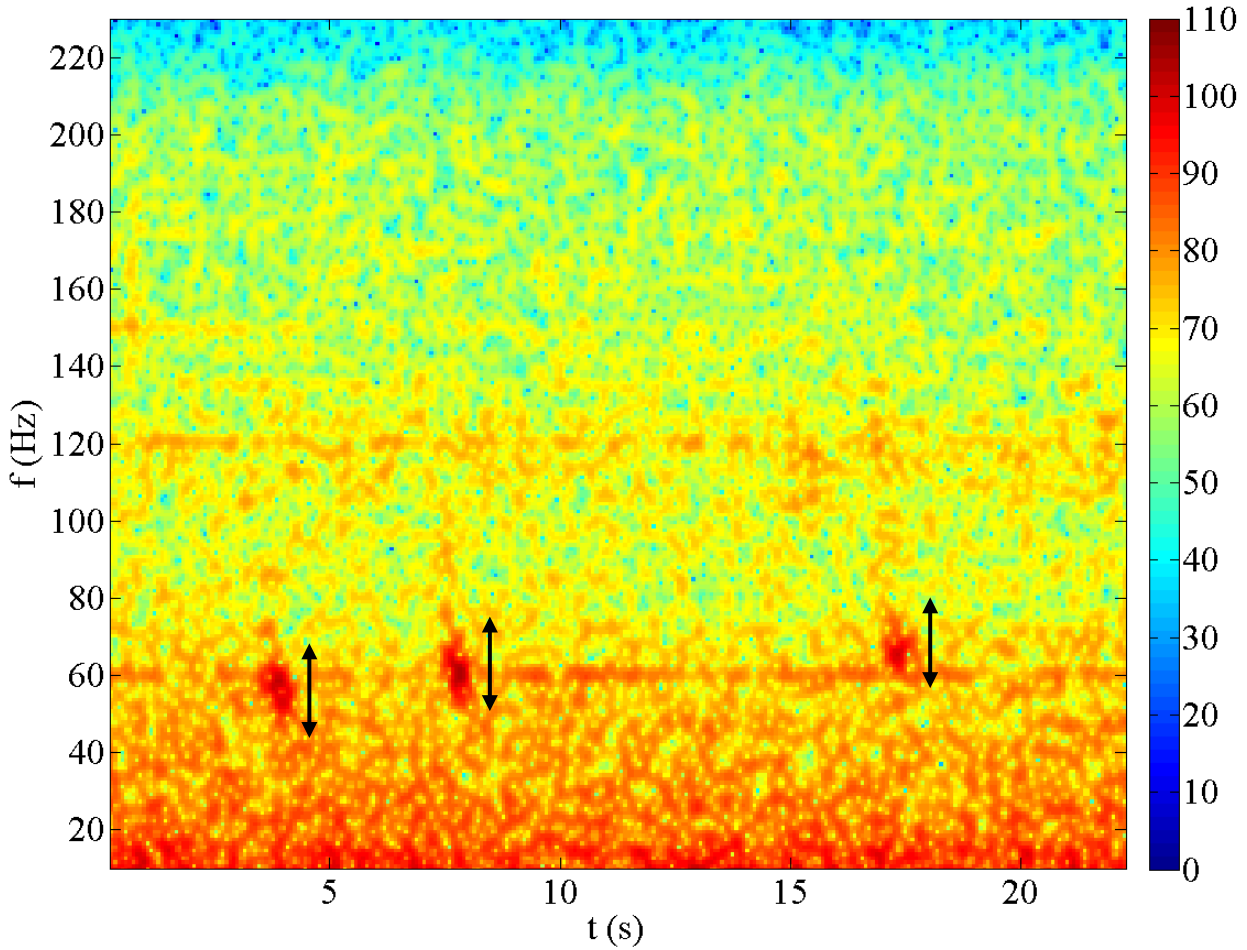


Unidentified Whale

Species	# of Visual Detection	Date	Time
Unidentified	6	July 27	15:50:25-16:15:38



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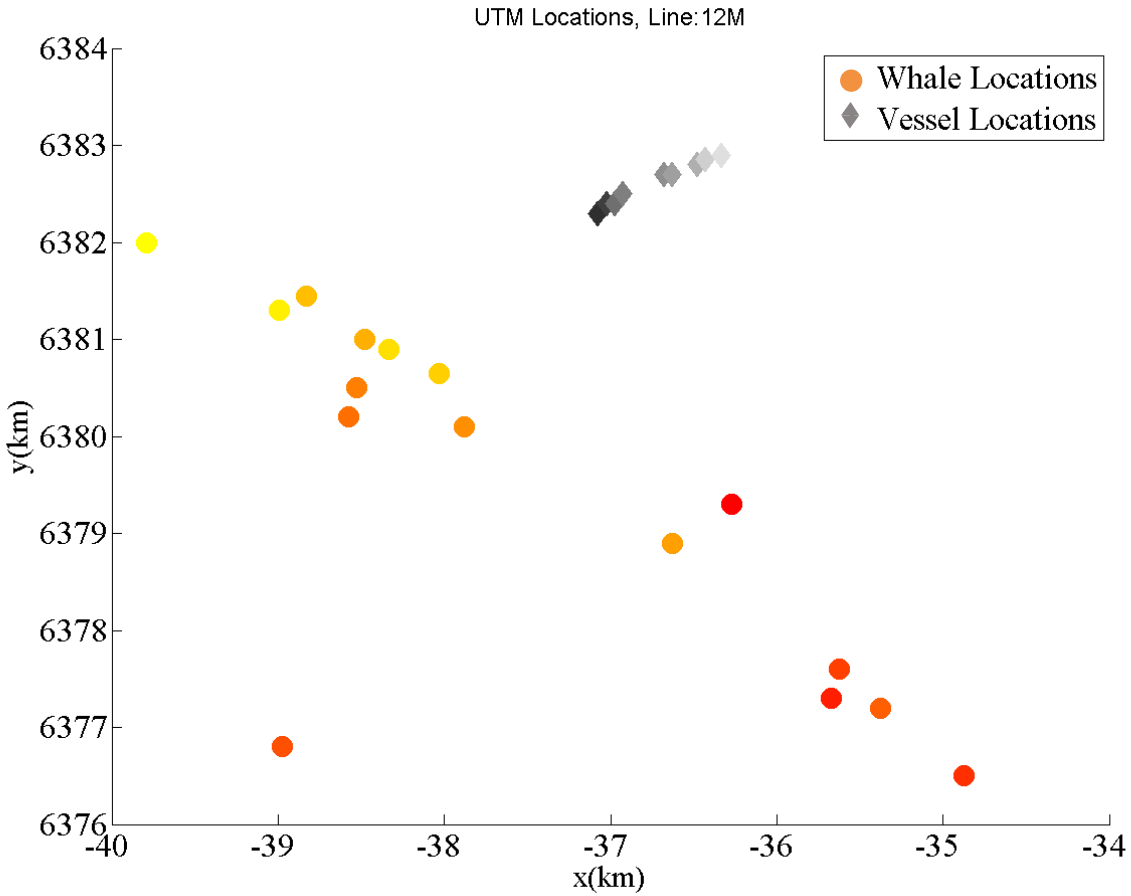
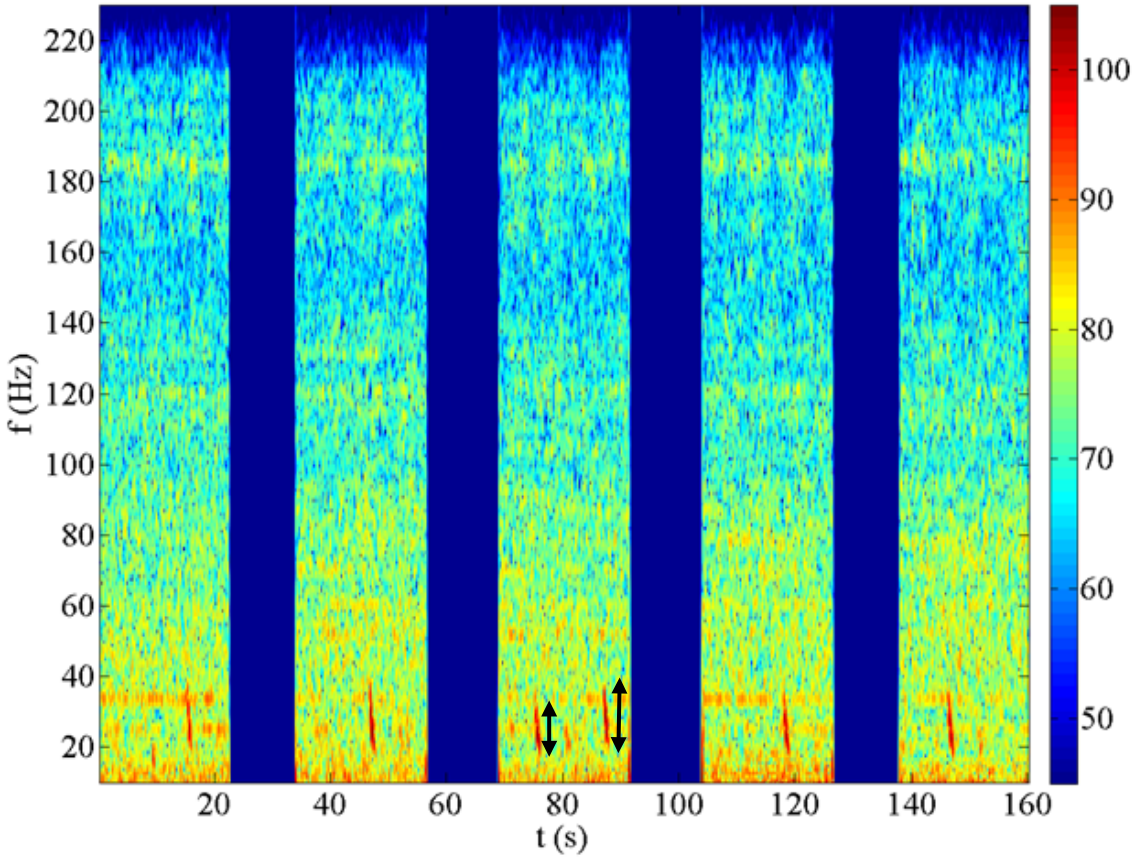


Fin Whale

Species	# of Visual Detection	Date	Time
Fin	2	July 23	15:43:00-17:24:00
NPRW	1	July 23	17:24:00-18:44:00

Winter calls ("20-Hz" calls) ?

Recorded Time: 18:17:49-18:47:19



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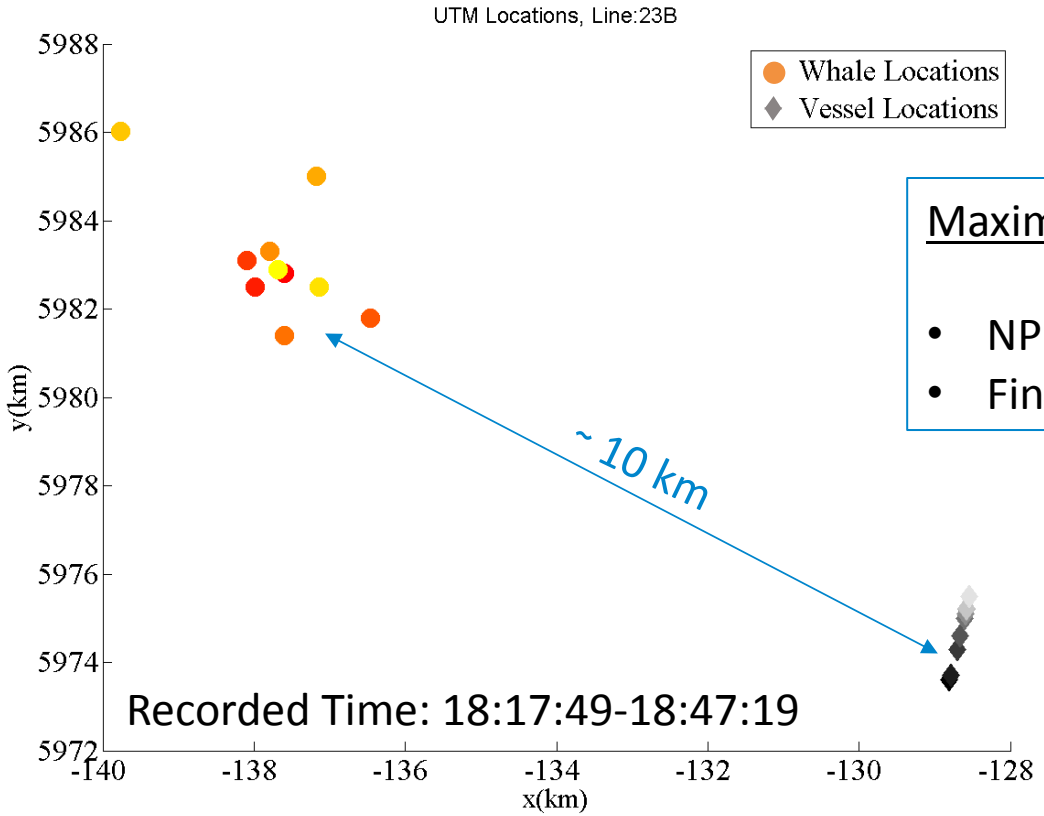


Maximum Speed

- NPRW: 9.3 km/h
- Fin: 37-41 km/h

Conclusions

- The streamer data can verify the accuracy of visual detections.
- This technique helps address environmental concerns about visual detection limitations.
- This offers a significant improvement on PAM capabilities at lower cost.

Future Work

Short Term:

- Improve the localization technique (reviewers' comments and suggestions)
- One more publication on whale localization (effectiveness of the mitigation process)

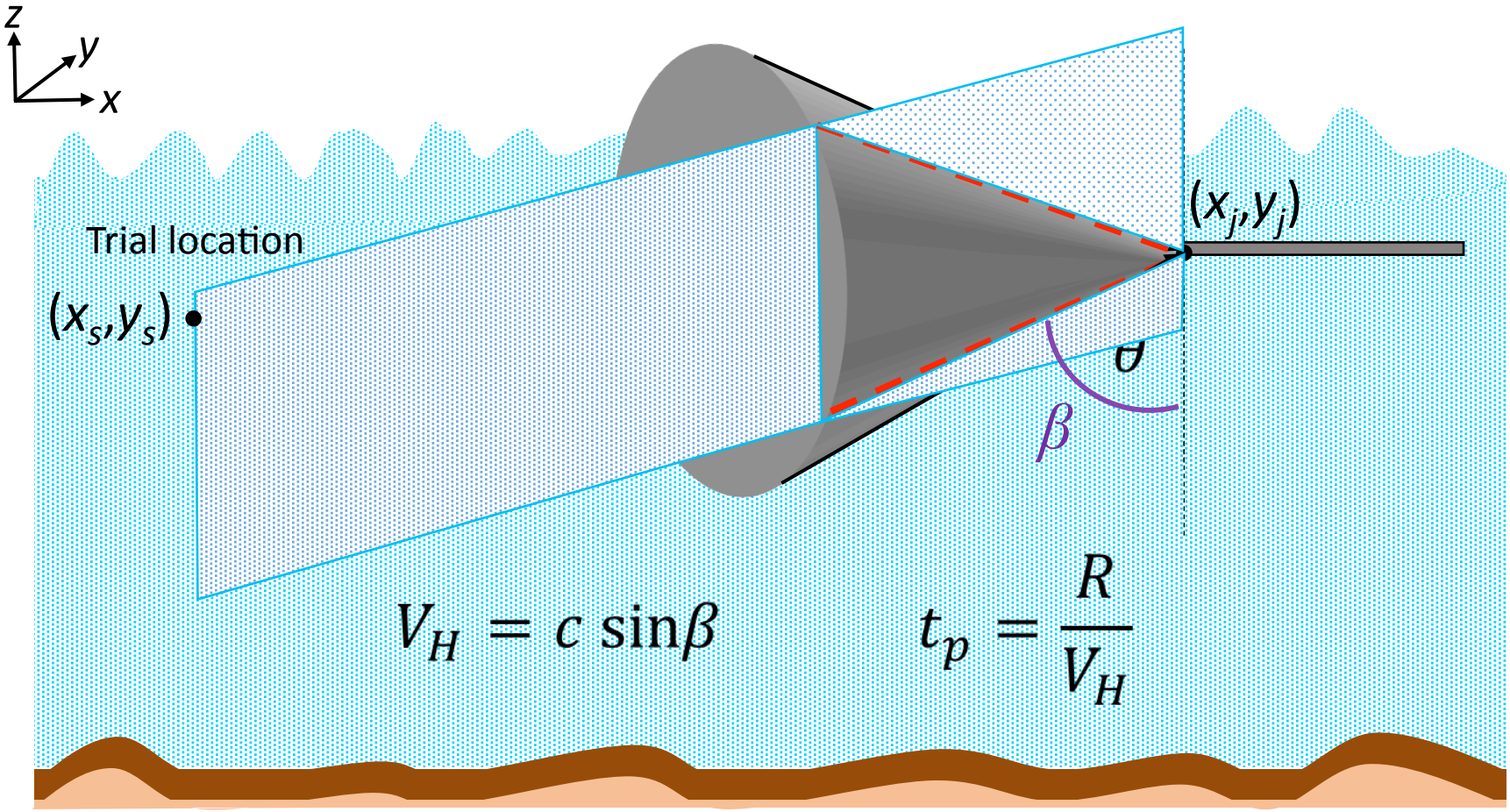
Long Term:

- Parameter study (SNR, straight streamer, deep water, …)
- Explore the possibility of using this technique on *Langseth* in near real time

Thank you

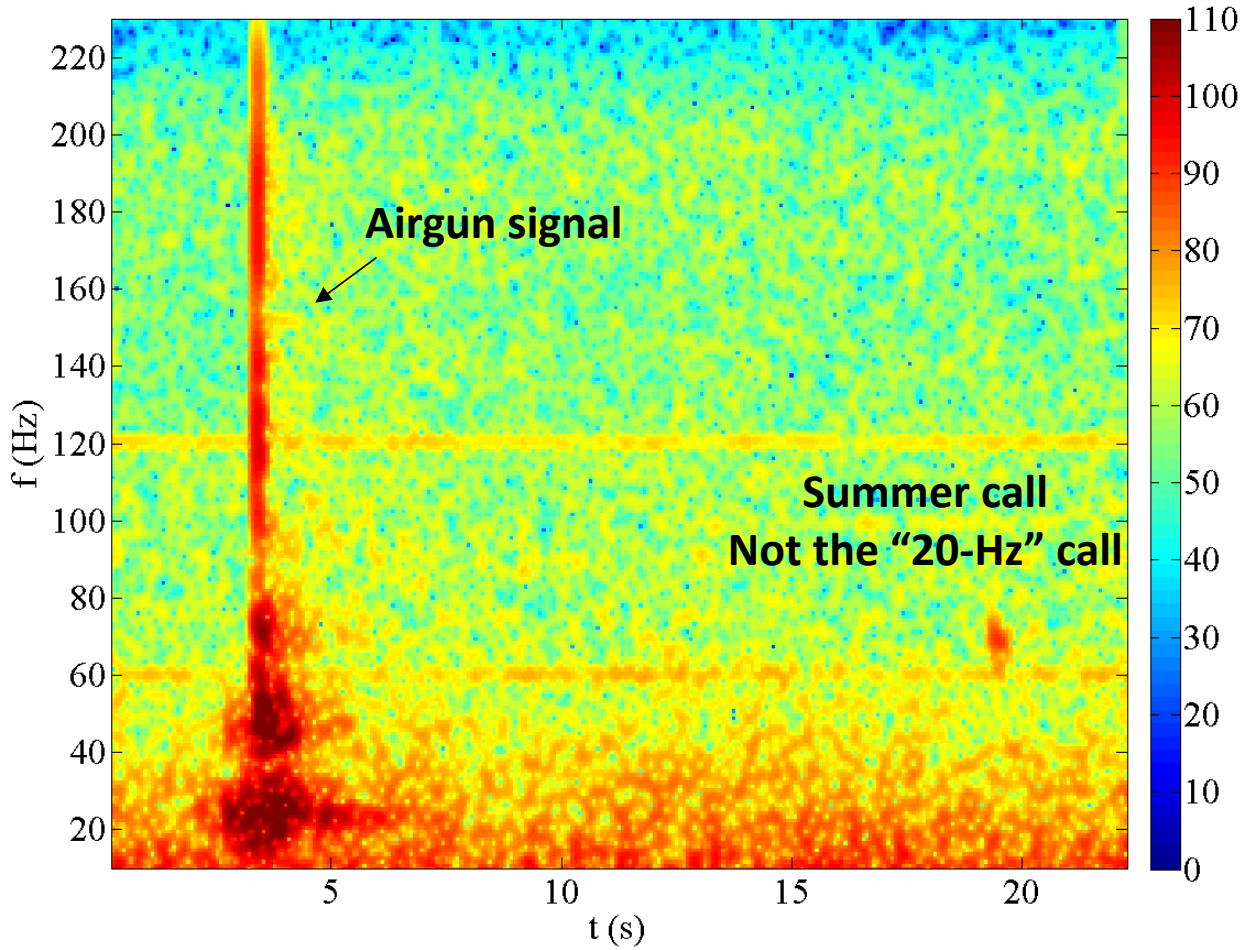
Questions?

Localization



Fin Whale

Species	# of Visual Detection	Date	Time
Fin	10	July 27	03:15:37-03:21:12



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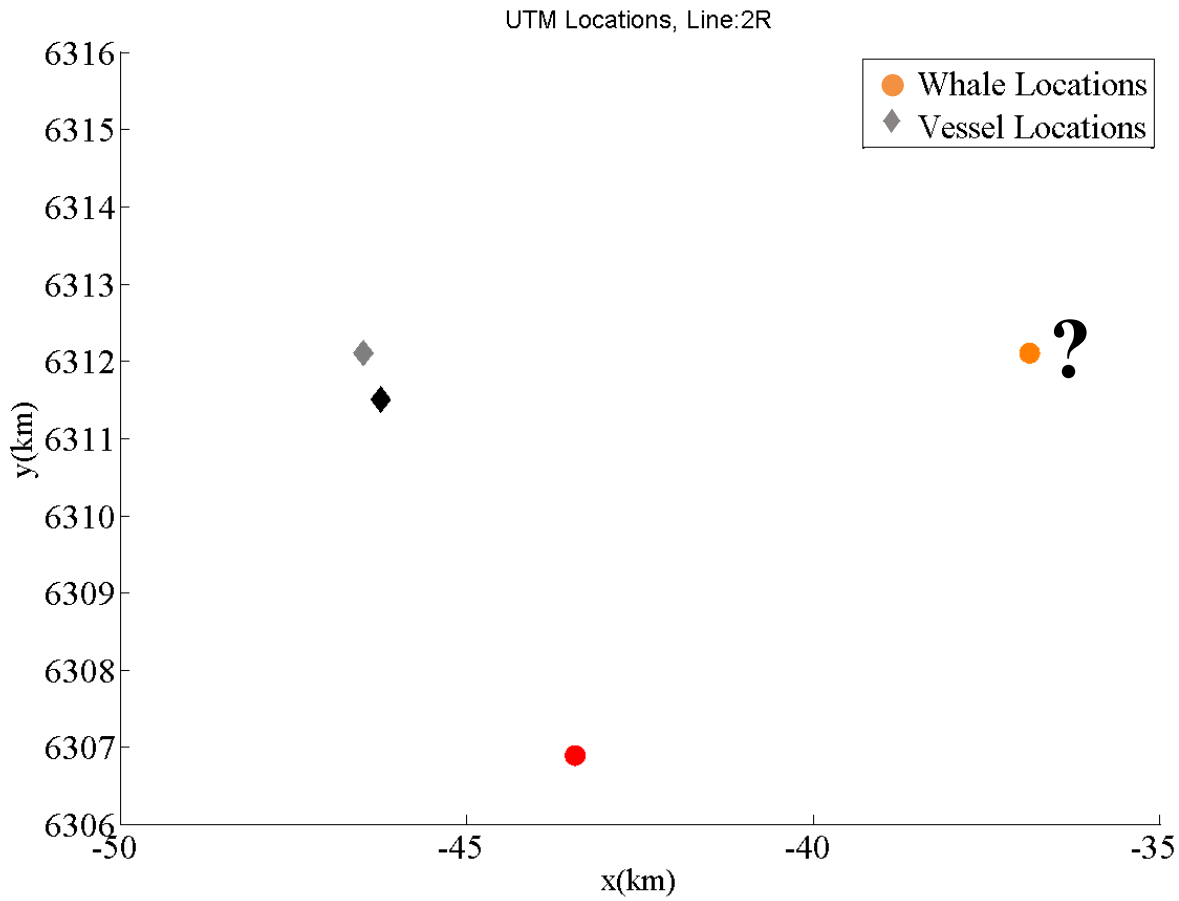
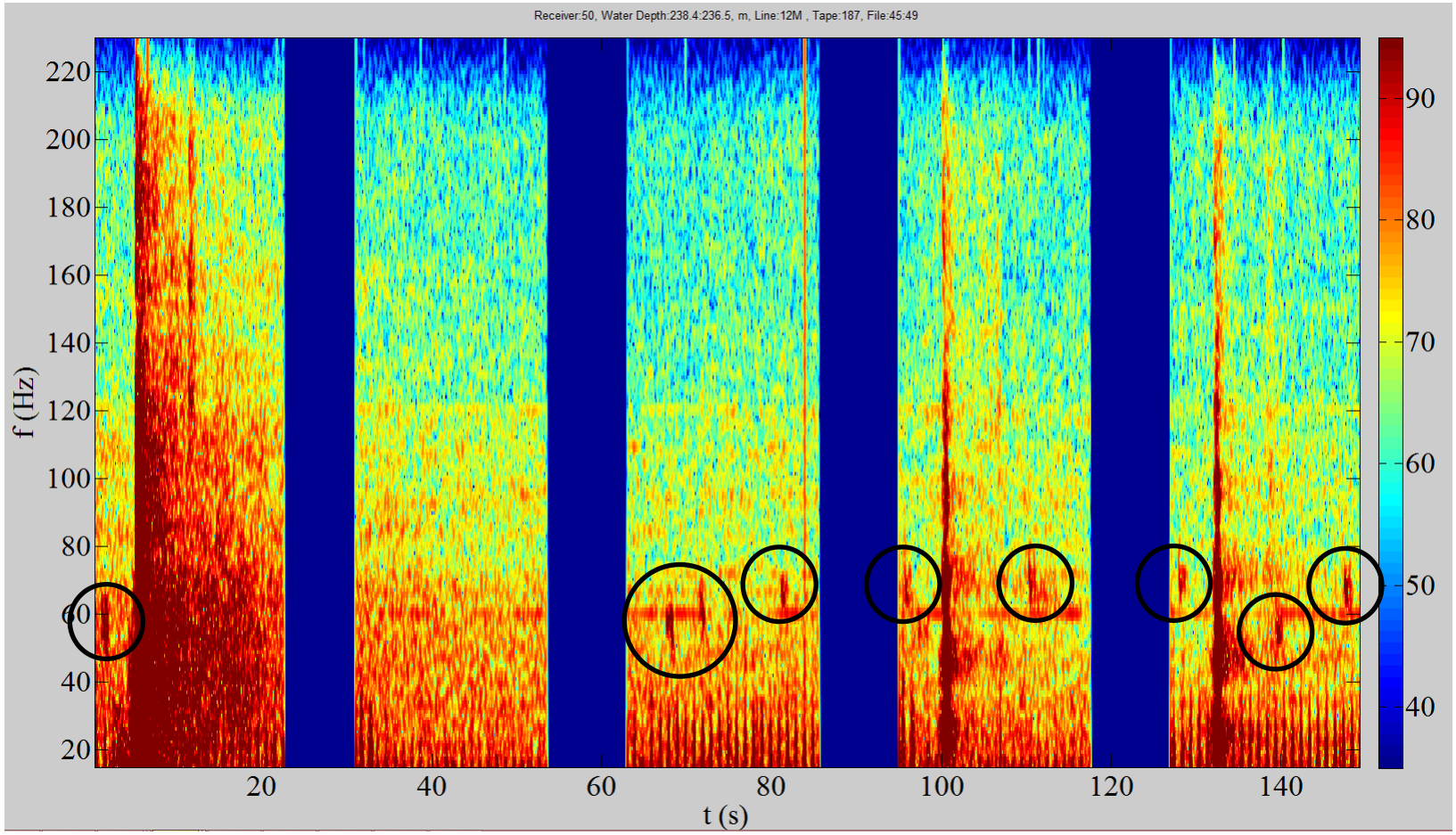


Species	# of Visual Detection	Date	Time
Unidentified	6	July 27	15:50:25-16:15:38



Localization Uncertainty

It is used for earthquake studies

$$R^2_{t,1-\alpha}(x_s, y_s) = \min[R^2_t(x_s, y_s)] + \frac{p-1}{M} s^2 F(p-1, Q, 1-\alpha)$$

F: value of *F*-distribution

p: number of free parameters (here *p=3*: origin time and two horizontal coordinates)

Q: $Q = \sum_{i=1}^{E} M_i - p$

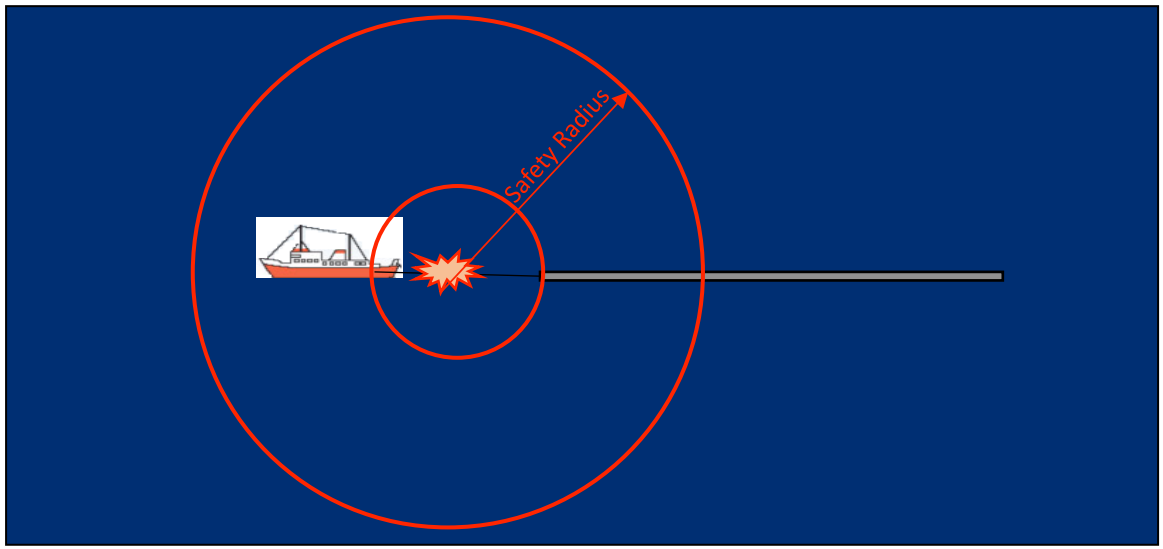
(*E*: number of events, m_i : number of sub-arrays used in the i^{th} source localization event)

1-α: confidence level

s: arrival time uncertainty $s^2 = \dfrac{\sum_{i=1}^{E} \dfrac{M_i^2}{M_i - p} \min[R^2_{t,i}(x_s, y_s)]}{Q}$

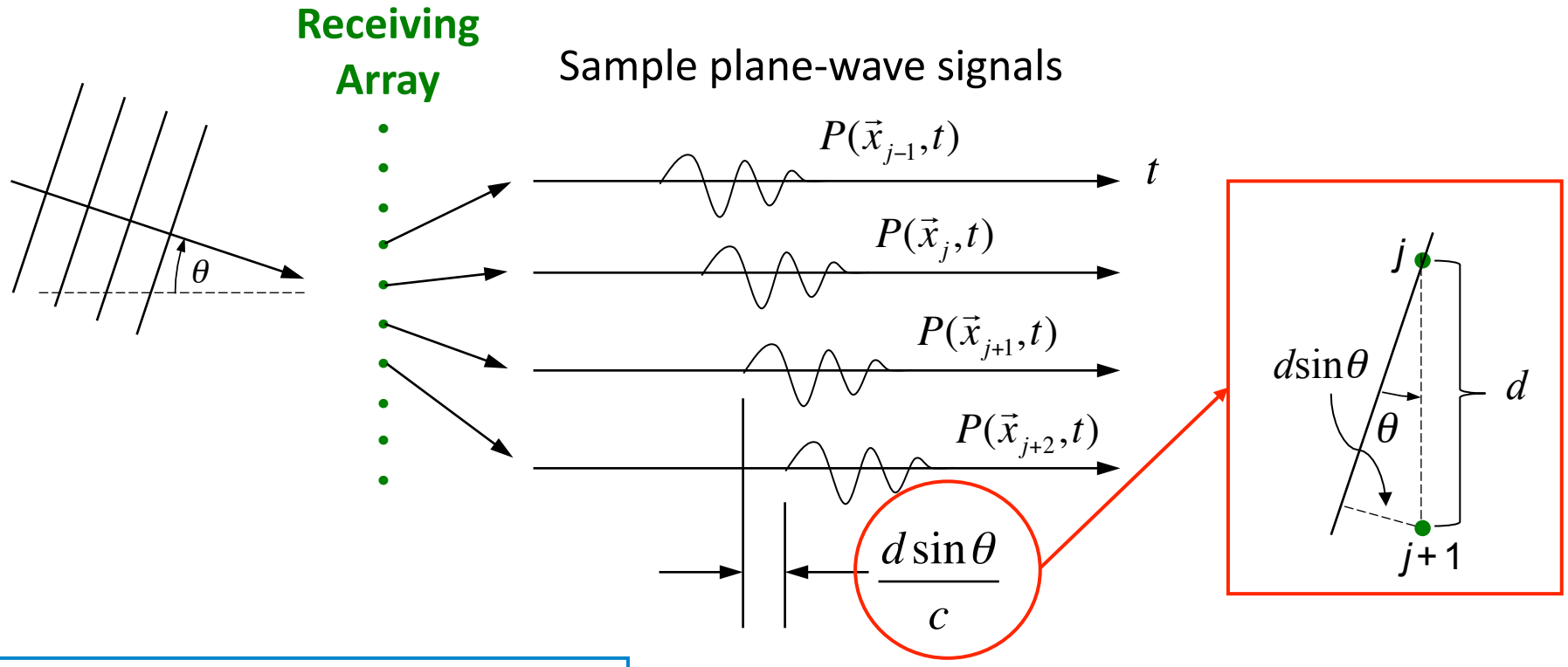
($R_{t,i}(x_s, y_s)$: residual of sub-arrays for the i^{th} source localization event)

Source & Volume	Water Depth (m)	Predicted RMS Distances (m)		
		190 dB (Pinnipeds)	180 dB (Cetaceans)	160 dB (Level-B Harassment Radius)
Single Airgun ($40\ in^3$)	>1000	12	40	385
	100-1000	18	60	578
	<100	150	296	1050
4 Strings 36 Airgun Source ($6{,}600\ in^3$)	>1000	460	1100	4400
	100-1000	615	1810	13395
	<100	770	2520	23470



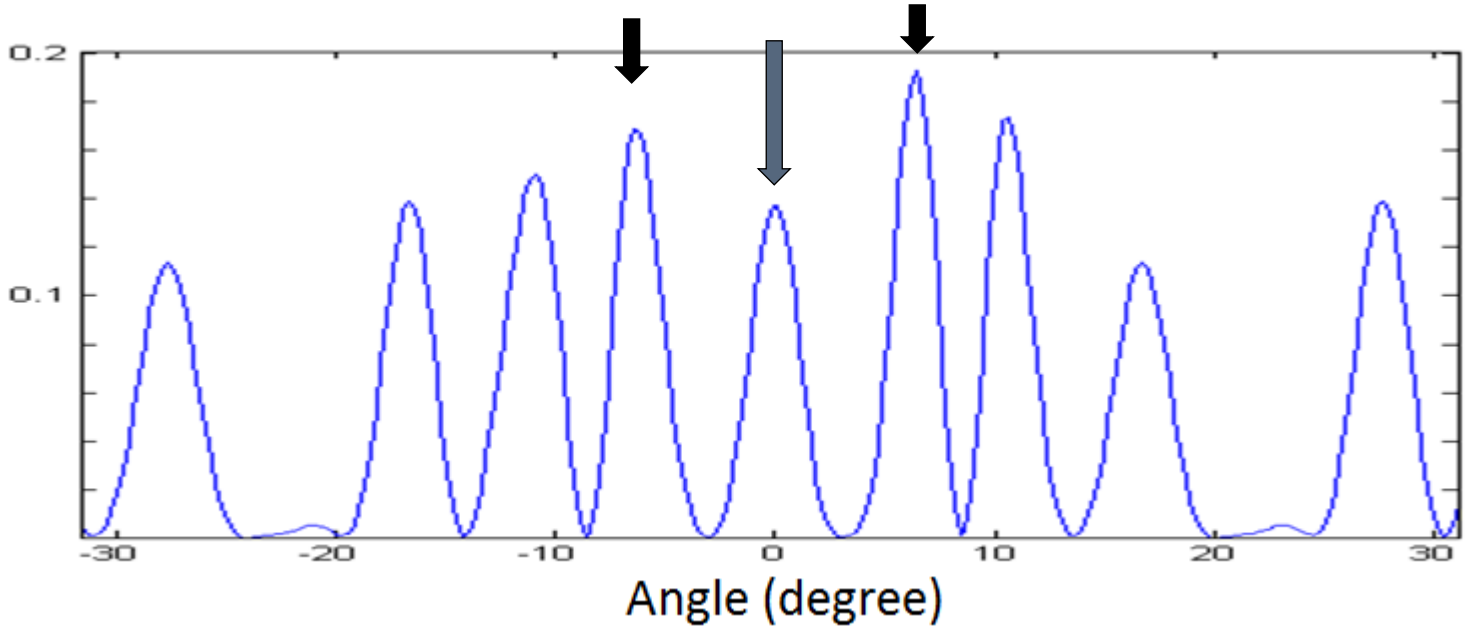
* Tolstoy, Diebold, Webb, Bohnenstiehl, Chapp, Holmes, Rawson (2004), "Broadband calibration of R//V Ewing seismic sources", Geophys. Res. Lett. , Vol. 31, L14310

Beamforming-1



Steering or Search angle = θ
Spacing between elements = d
Speed of Sound = c

Beamforming-2



$$\theta_1 = 0^\circ$$

$$\theta_2 = \tan^{-1}\left(\frac{50}{500}\right) = 5.71^\circ$$

$$\theta_3 = \tan^{-1}\left(\frac{-50}{500}\right) = -5.71^\circ$$