Baleen whale localization using a dual-line towed hydrophone array during seismic reflection surveys

Shima H. Abadi[*], Maya Tolstoy[*], William S. D. Wilcock[+]

[*] Lamont–Doherty Earth Observatory, Columbia University, Palisades, NY
[+] School of Oceanography, University of Washington, Seattle, WA

LAMONT-DOHERTY EARTH OBSERVATORY
THE EARTH INSTITUTE AT COLUMBIA UNIVERSITY

School of Oceanography
University of Washington

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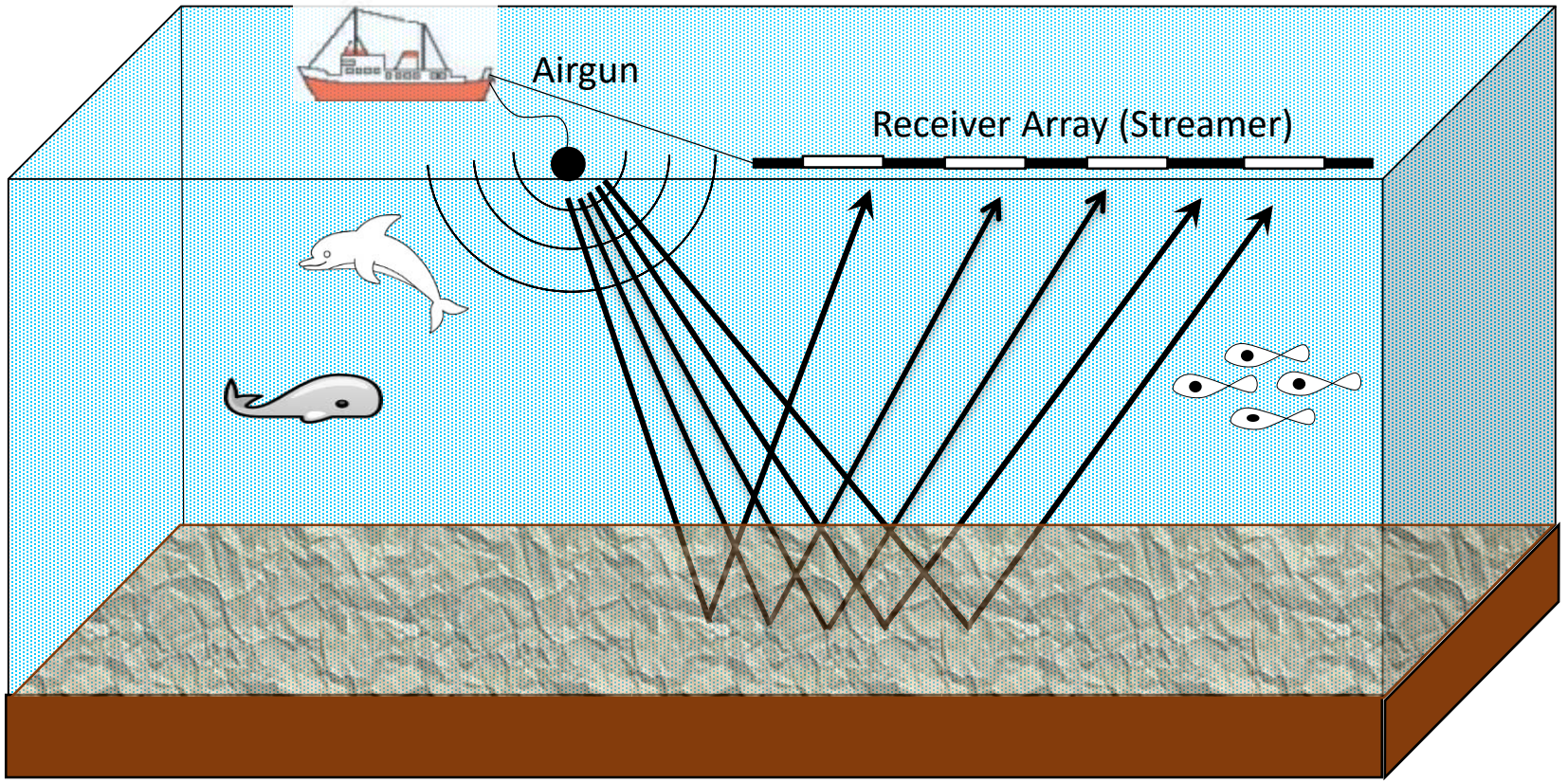
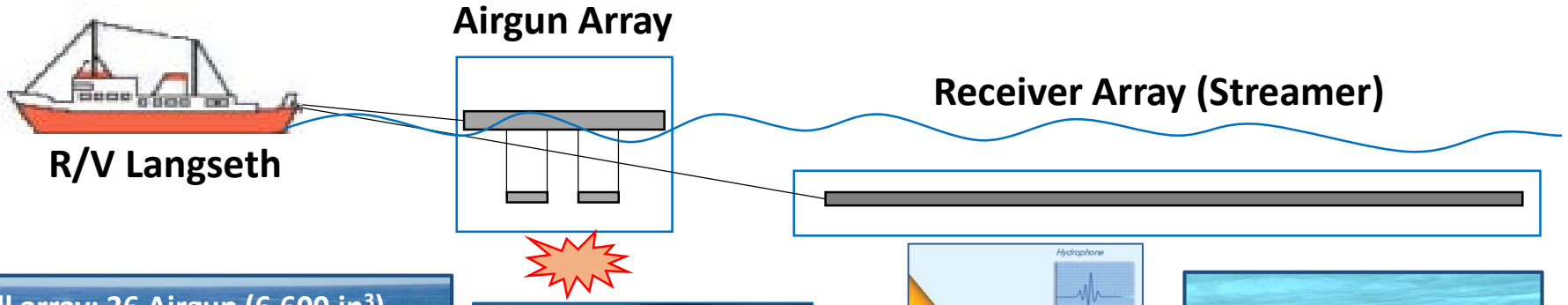
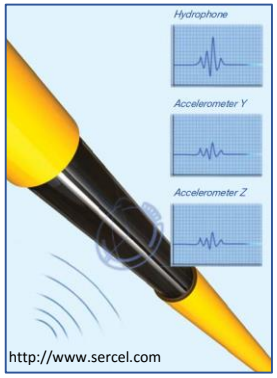
Motivation

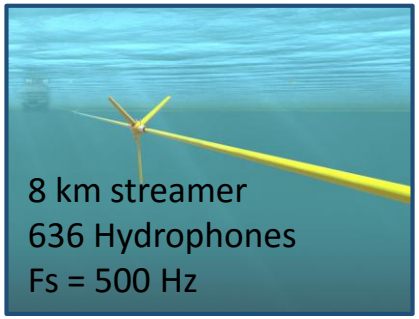
Seismic Reflection Survey: To study and map ocean bottom



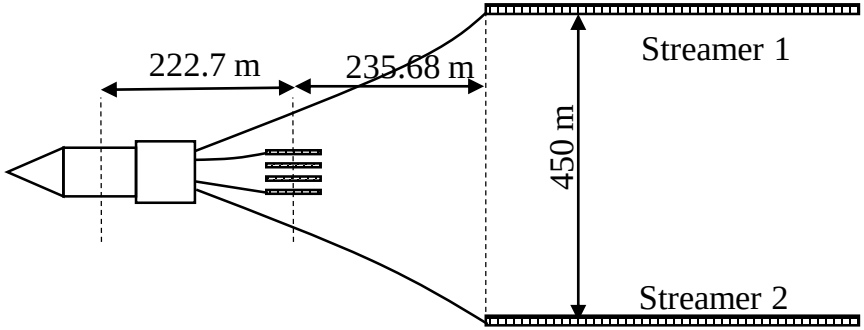
R/V Marcus G. Langseth







Source & Volume	Water Depth (m)	Predicted RMS Distances (m)		
		190 dB (Pinnipeds)	180 dB (Cetaceans)	160 dB (Level-B Harassment Radius)
Single Airgun (40 in³)	>1000	12	40	385
	100-1000	18	60	578
	<100	150	296	1050
4 Strings 36 Airgun Source (6,600 in³)	>1000	460	1100	4400
	100-1000	615	1810	13395
	<100	770	2520	23470

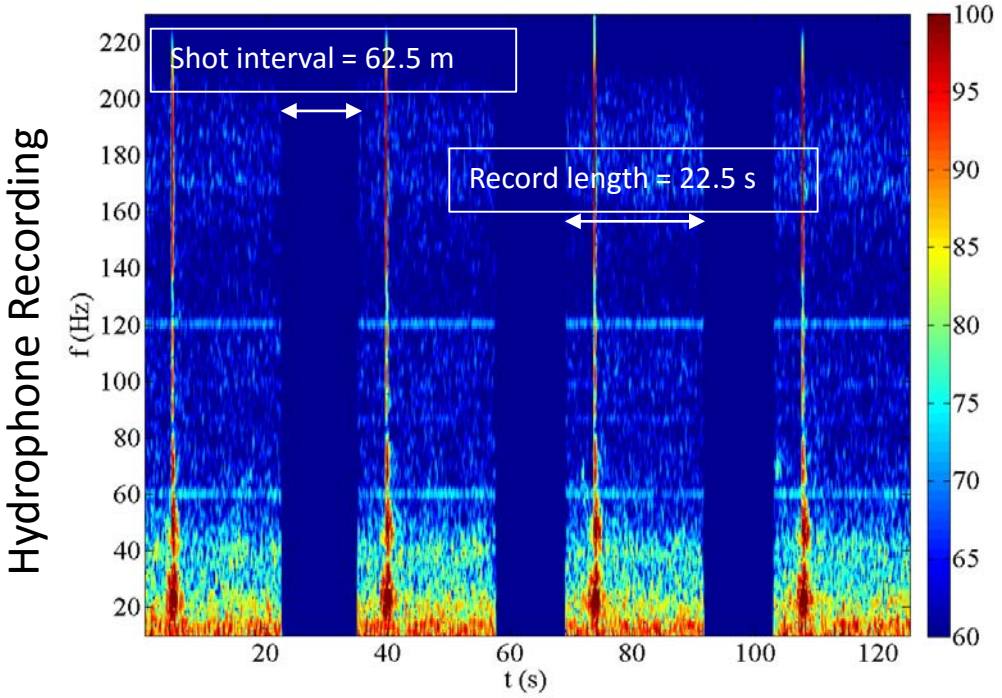


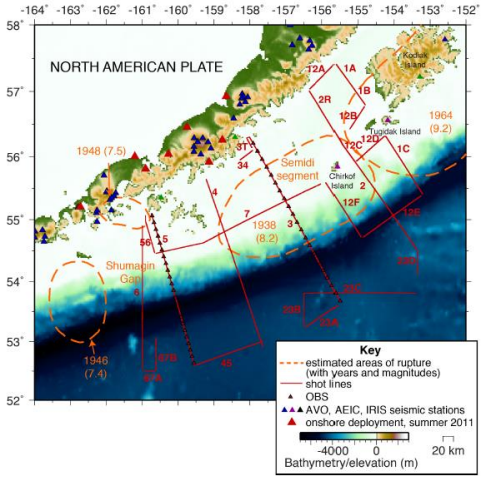
Marine Mammals Monitoring

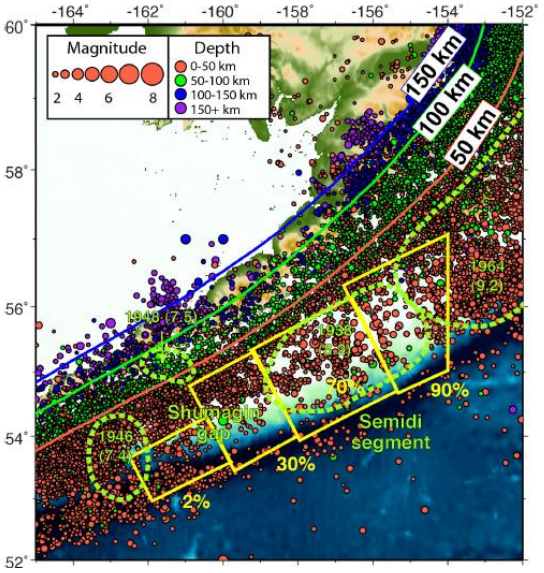
- **Visual Monitoring Survey**
  - 2 Observers
  - 18.9 m above the water surface
- **Acoustic Monitoring Survey (PAM)**
  - 3 hydrophones (2-200 kHz)
  - 1 hydrophone (0.075-30 kHz)
  - 24 hrs (during periods of darkness or low visibility)
- **Acoustic Monitoring Survey (Streamer)**
  - 636 Hydrophones
  - Recording for imaging and monitoring at the same time

Alaska Langseth Experiment, July 2011

- Alaska/Aleutian subduction zone: coupling between the Pacific and North America plates.
- The largest and most destructive earthquakes occur on subduction zone megathrusts.

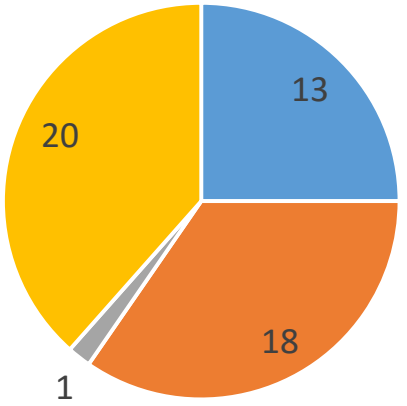






Baleen Whale Sightings

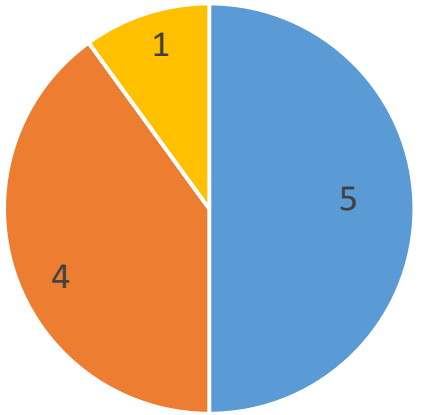
- **Visual Monitoring Survey**



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

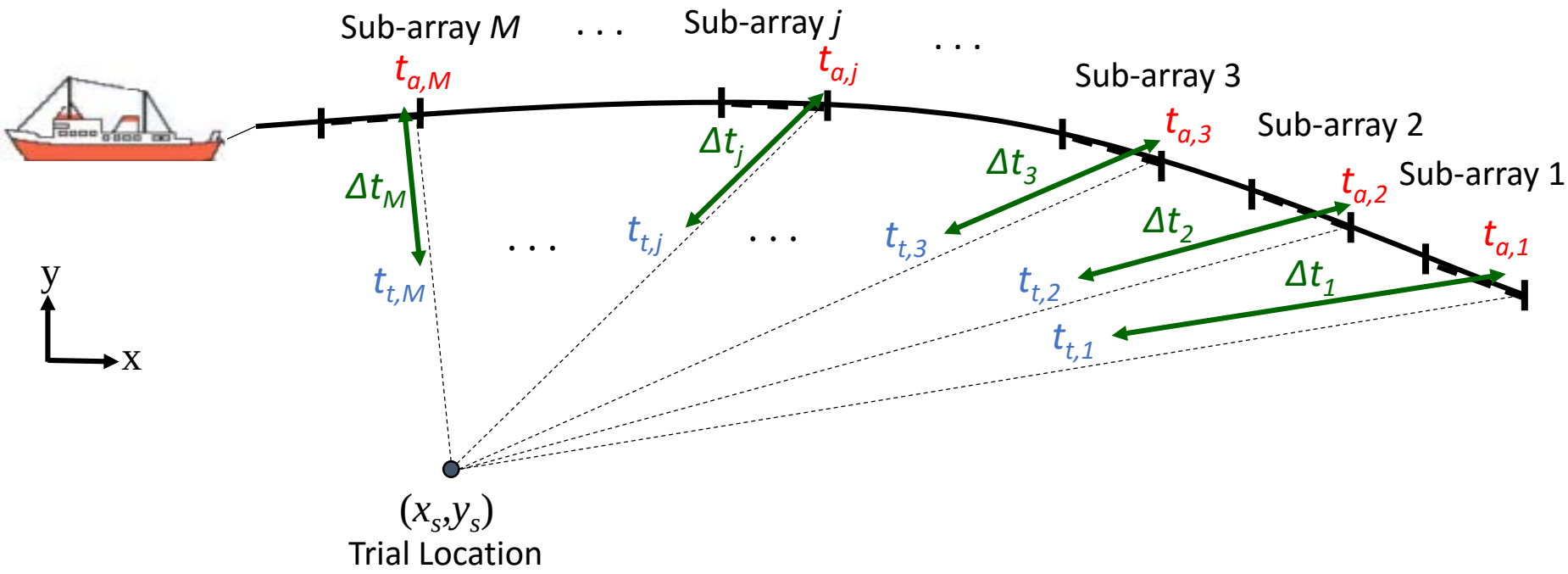
NO DETECTION

- **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 ■

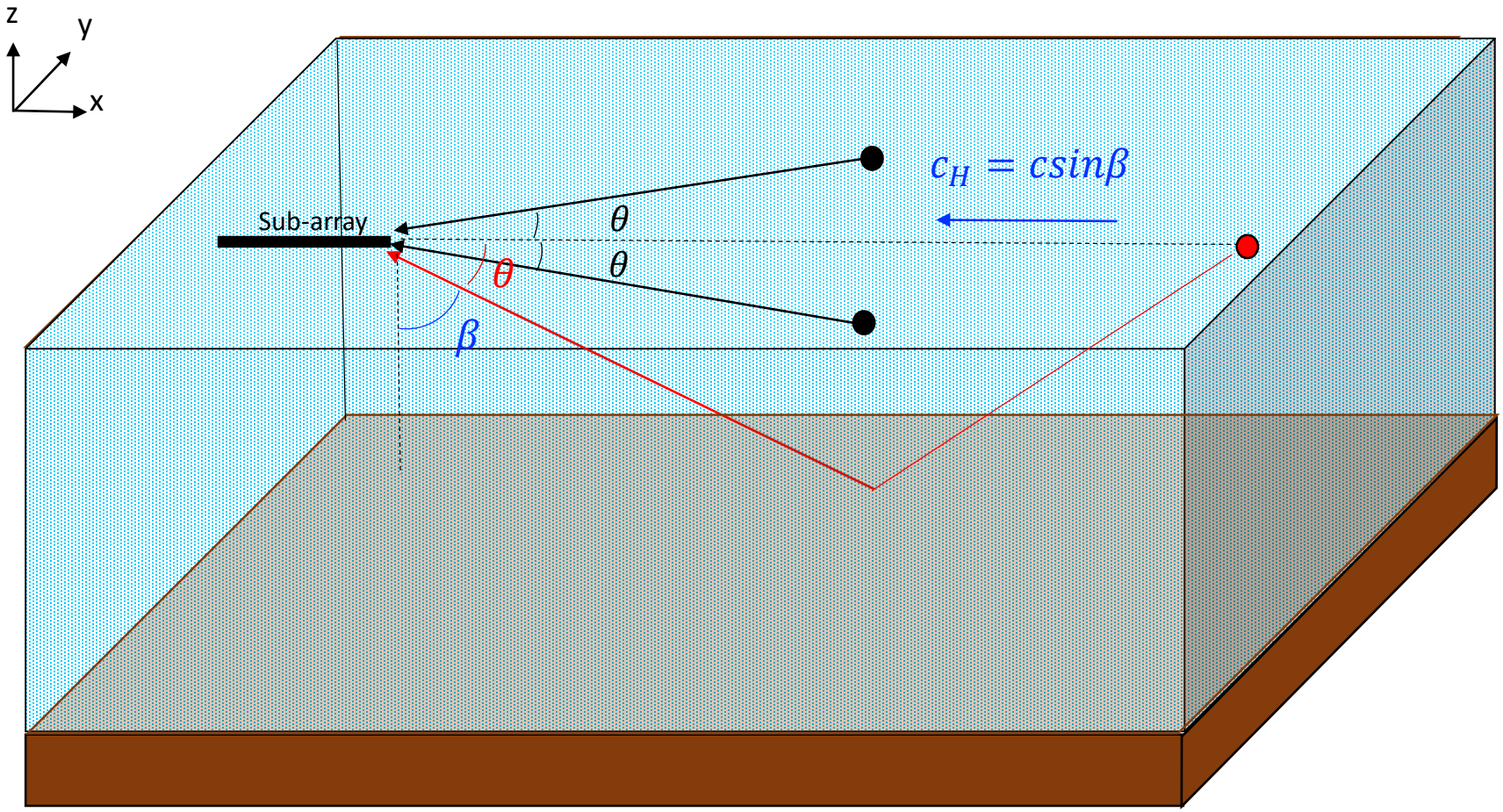
Localization



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

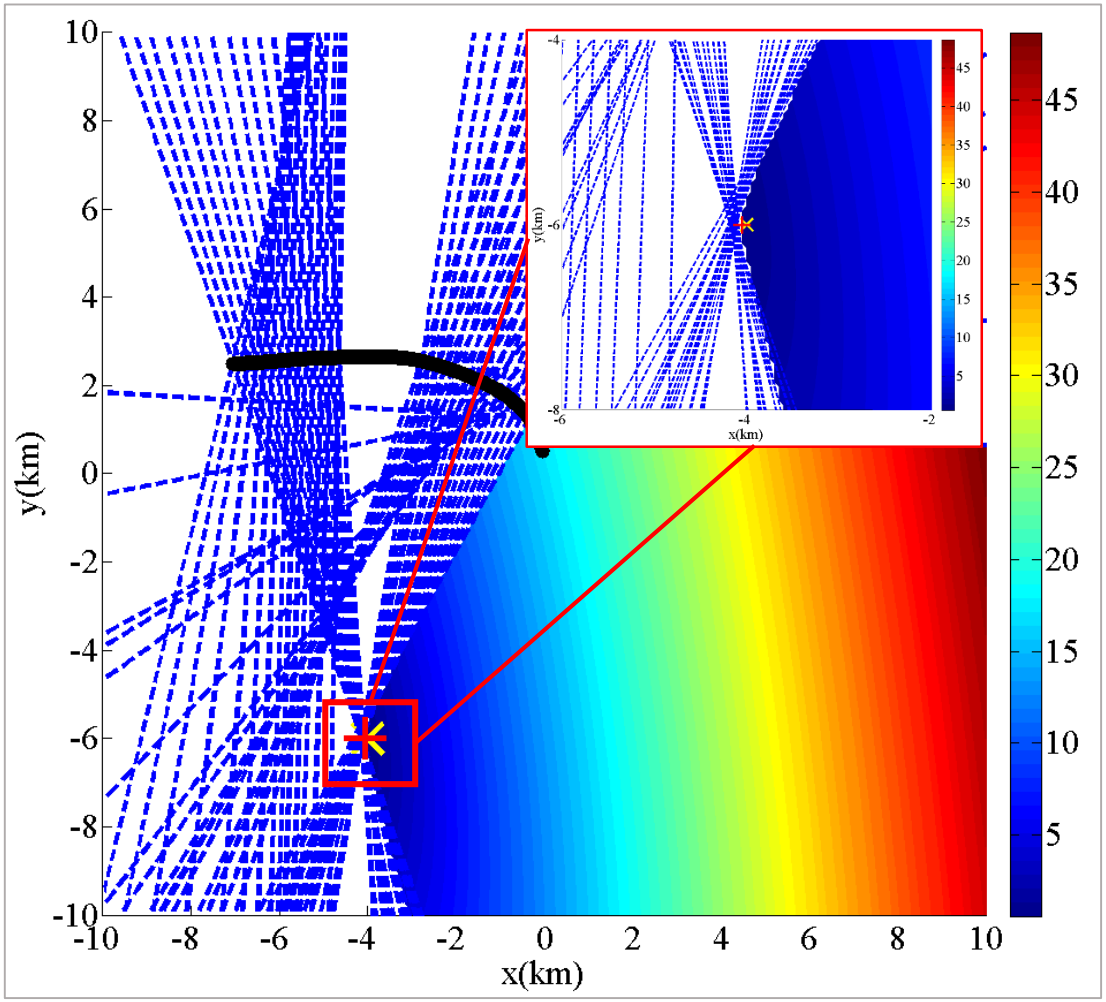
* Abadi, Wilcock, Tolstoy, Crone, Carbotte: "Sound source localization using data recorded by hydrophone streamers during seismic surveys", J. Acoust. Soc. Am., in review.

Travel Time Calculation



Previous Work

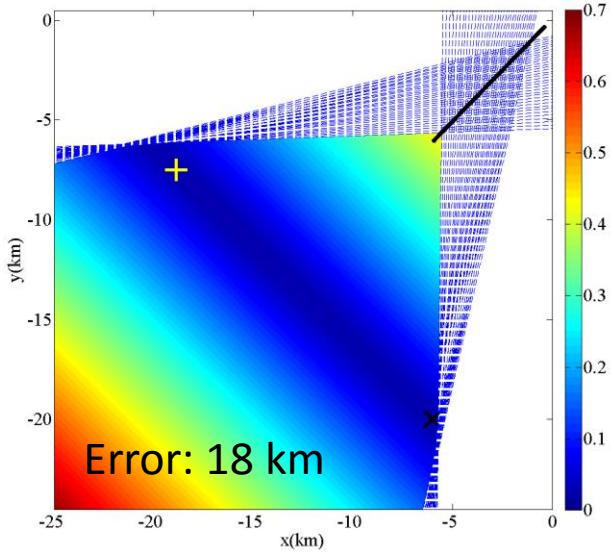
- Single streamer
- During turns between track lines



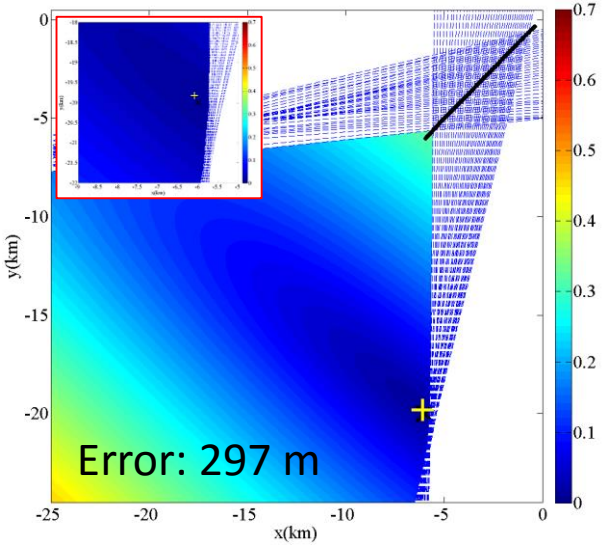
Straight Streamer-Simulation

- KRAKEN
- 800 ms chirp, 10-40 Hz
- 90 m water depth

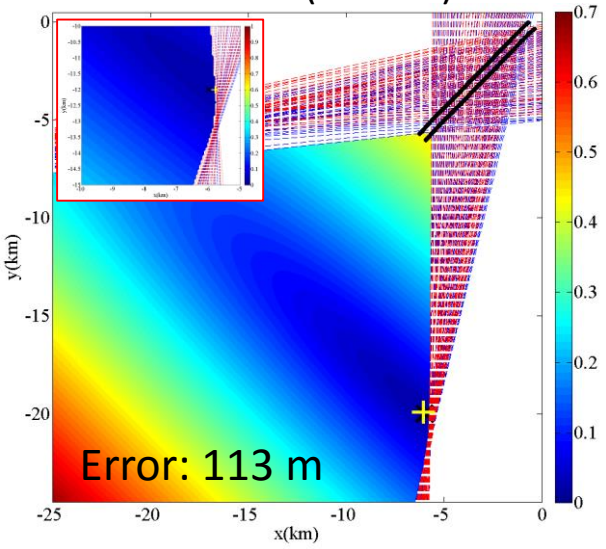
Perfect Straight Line



Actual Straight Streamer (Single)



Actual Straight Streamer (Double)



- Straight streamer has more localization error compared to turned streamer
- Second streamer improves localization results

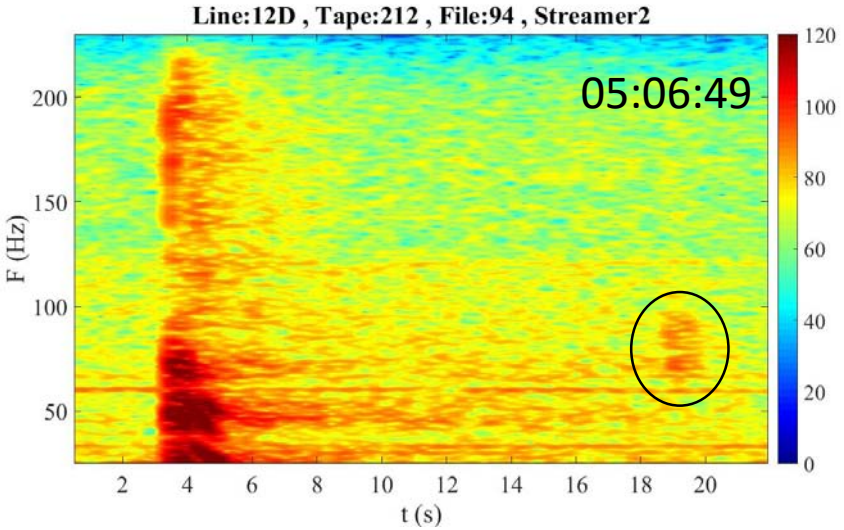
Humpback Whale

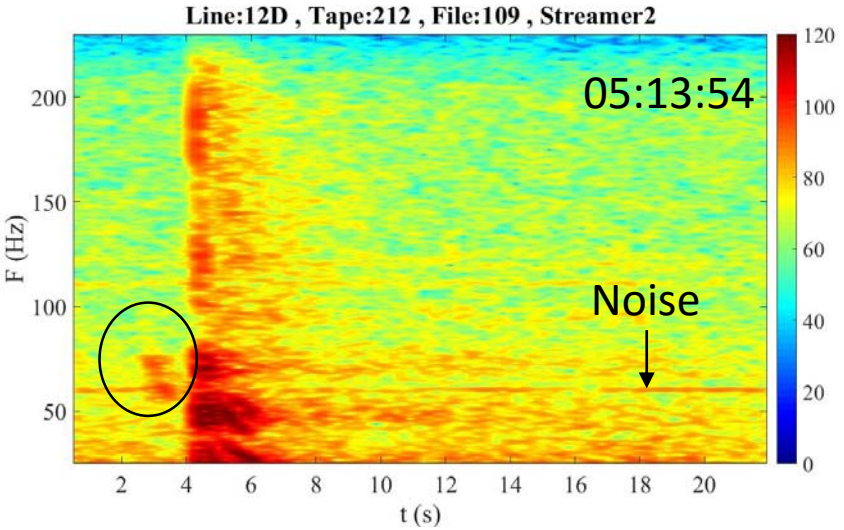
Species	# of Visual Detection	Date	Water Depth (m)	Time of Observation	Movement	Airgun Action	Time of Acoustic Recording
Humpback	2	July 29	93	02:43:00	PV SD One off the bow and one off the stern	Delayed Ramp Up	02:49:44
Humpback	4	July 29	90	05:05:00	PV OD	Full Power To Mitigation Gun	05:06:49-05:35:28

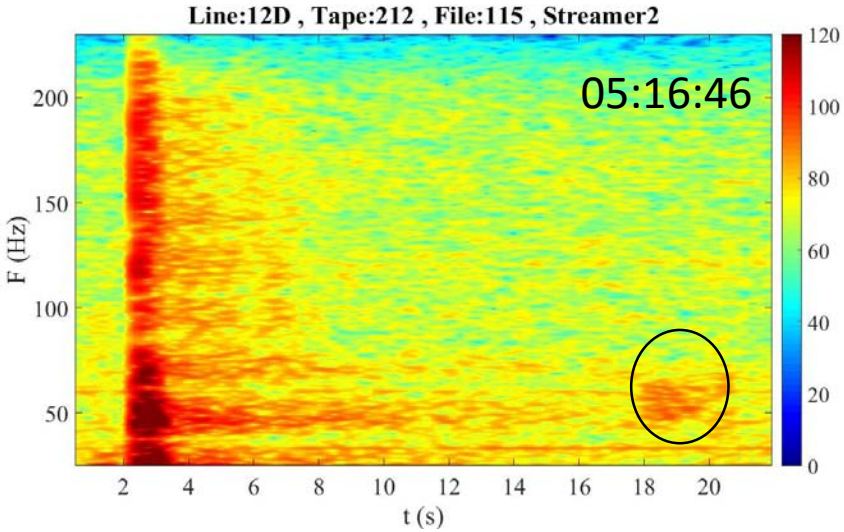
Unknown for this cruise:

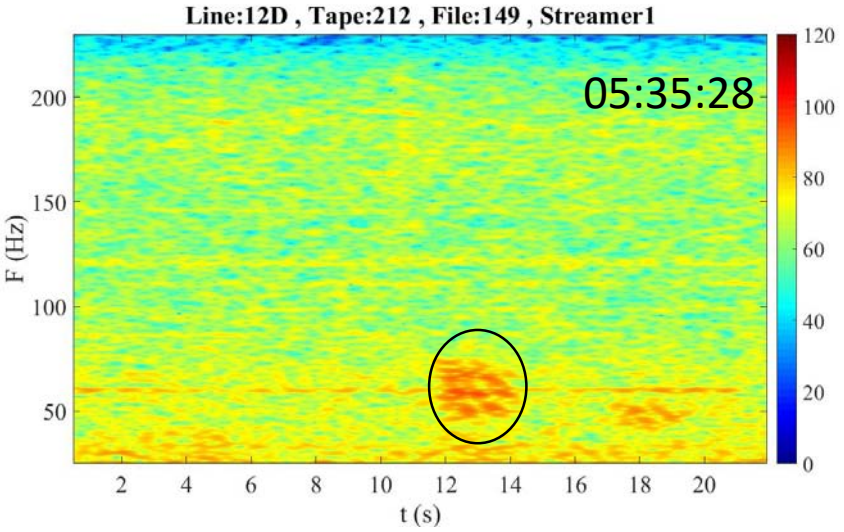
- Whale location at the time of first observation
- Whale location at the time of last observation
- More details about their movements

Spectrograms

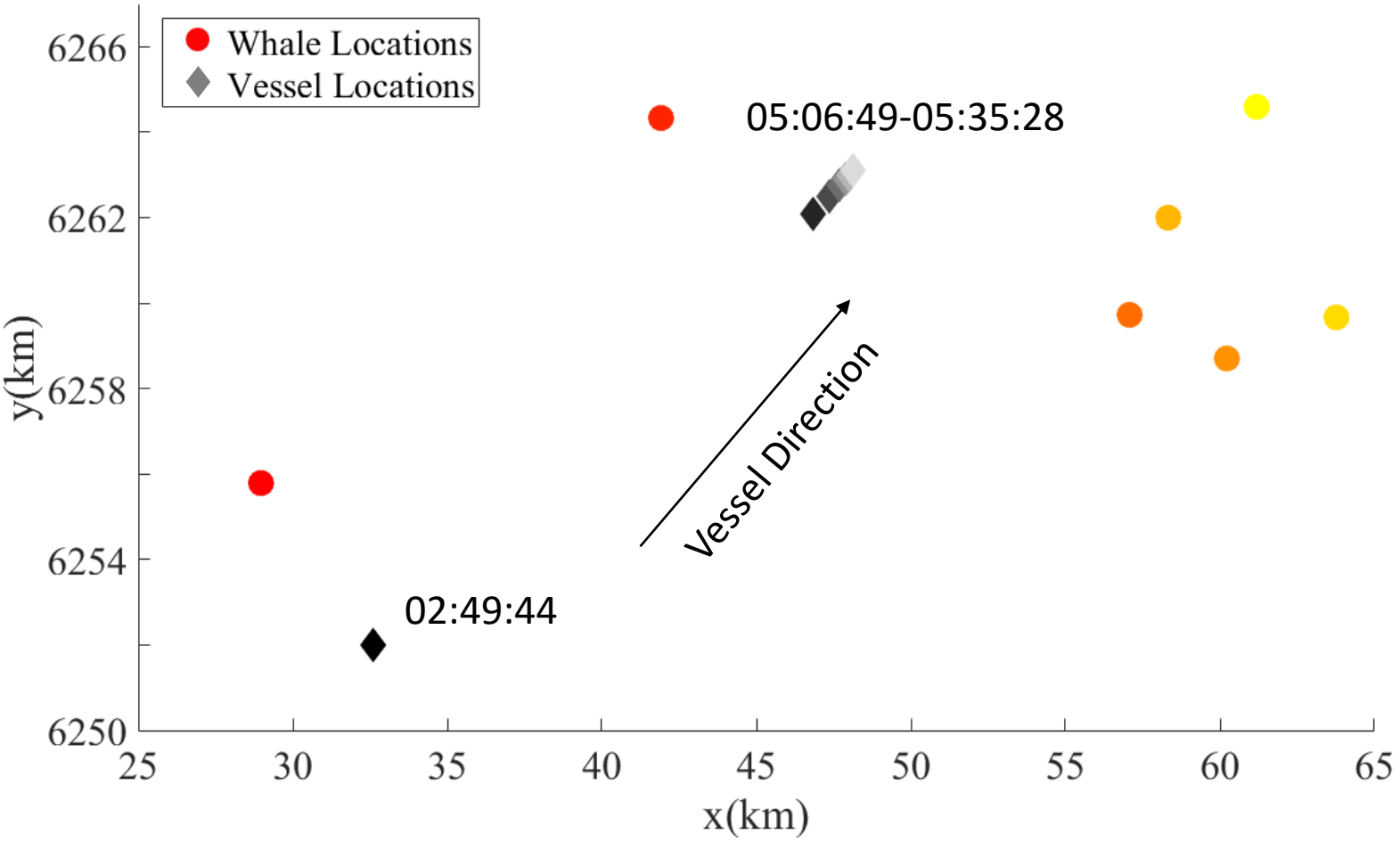








Localization Result



Conclusions

- The streamer data verifies the accuracy of visual detections.
- The streamer data can be used for detecting and locating the *Baleen* whales during the survey.

Future Work

- Study the effectiveness of mitigation process.
- Expand this method for deep water measurements

Acknowledgement

- captain, crew, and technical and science party of cruise MGL1110

Thank you

Questions?