22nd Annual Gulf of Mexico

Deepwater Technical Symposium

Localization of bubble sources in a water tank for oil spill detection

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AADE American Association of Drilling Engineers

SPE International Delta Section

New Orleans Geological Society, Founded 1941

Outline

- Introduction
- Experimental setup
- Bubble sounds
- Localization
- Characterization
- Conclusions
- Future works

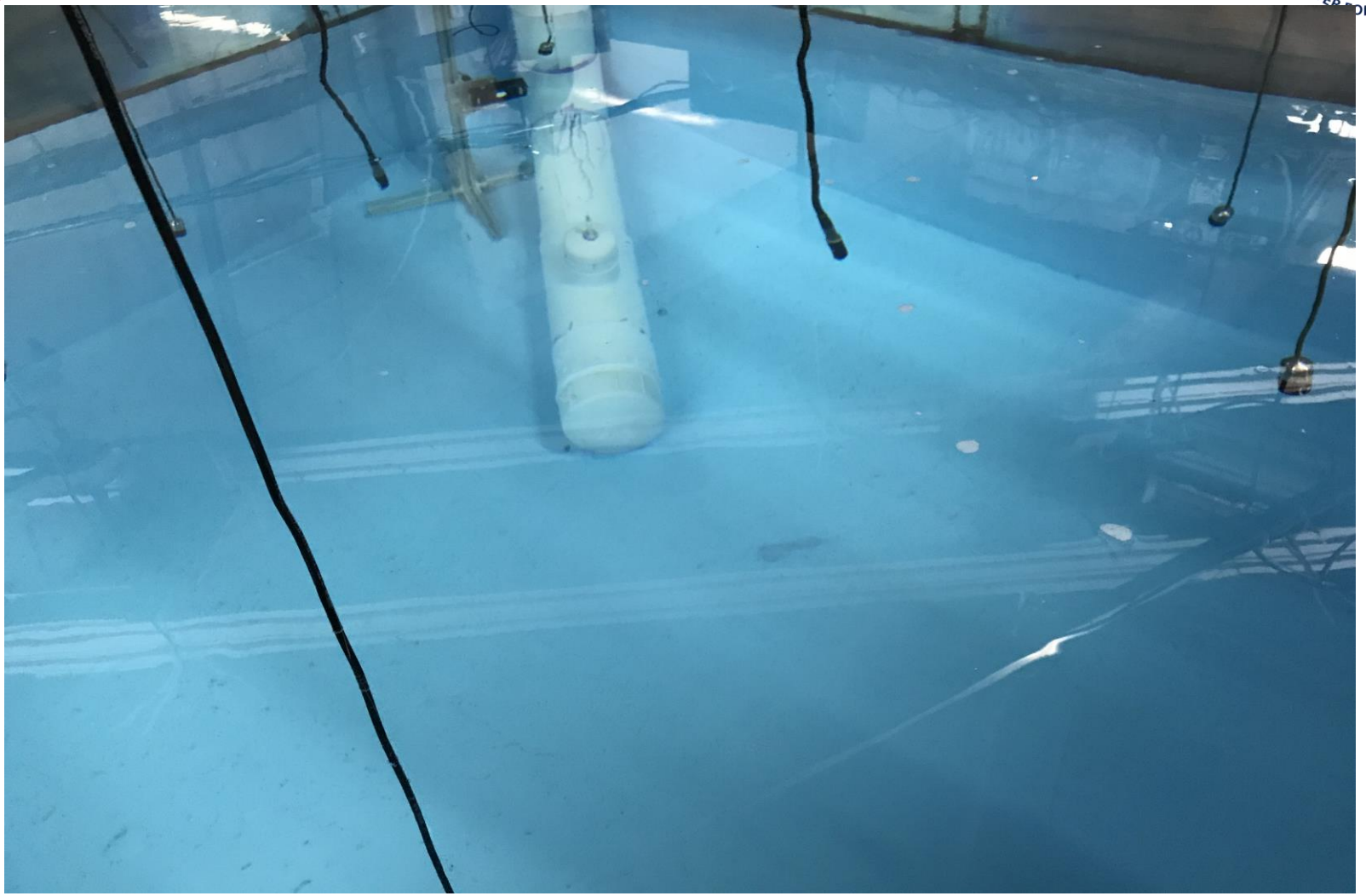
Introduction

- Detection, localization, and characterization of oil leakages
- Oil leakages create underwater sounds through bubble oscillations
- Active sonar vs passive sonar
- Passive real-time monitoring system

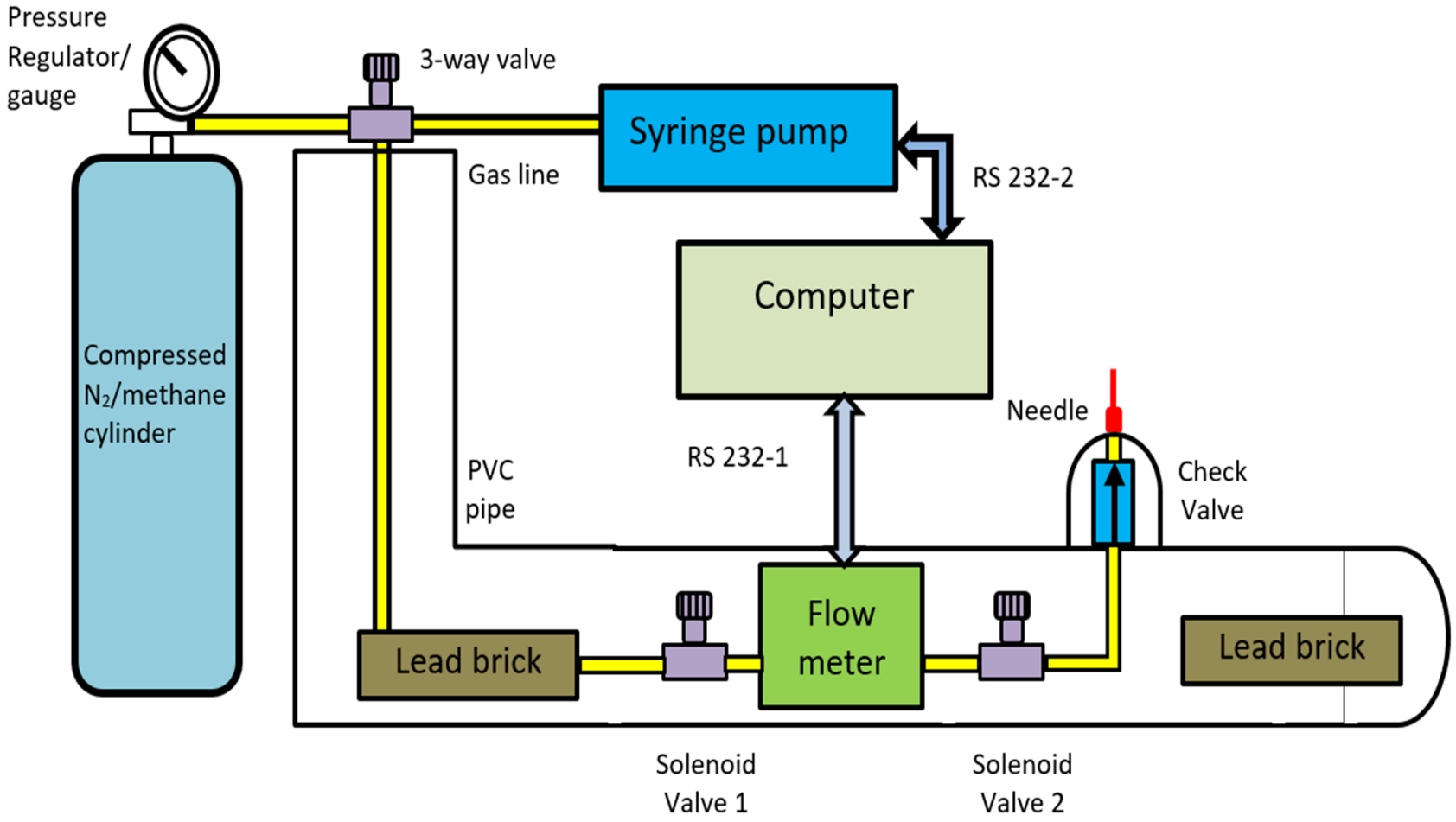
Tasks in this water tank study

- Study oil leakages under controlled conditions
- Develop and test localization algorithms
- Study bubble dynamics and its acoustic characteristics
- Conduct two types of oil leakage studies (a constant flow and a few bubbles)

Experimental setup

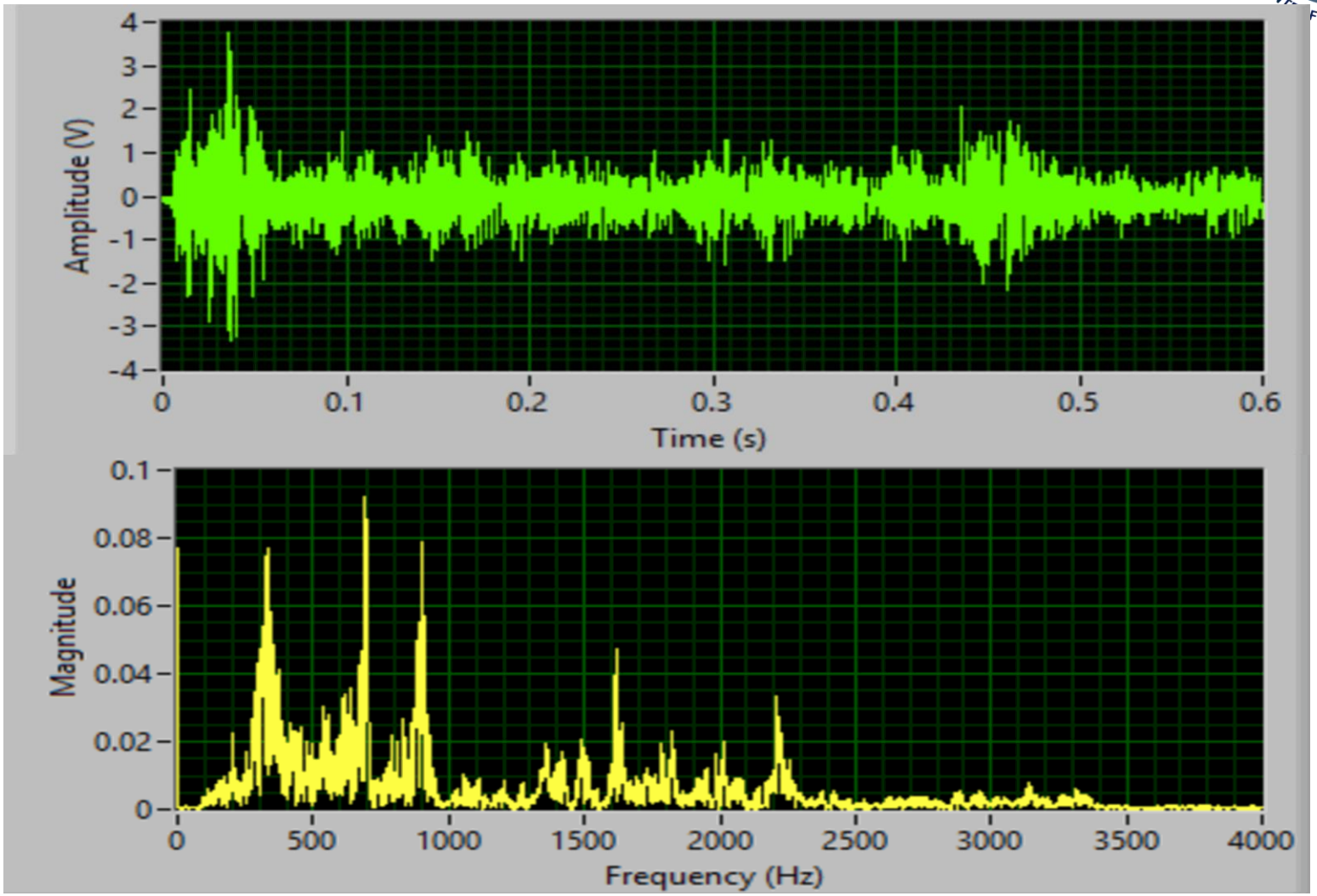


Bubble generation

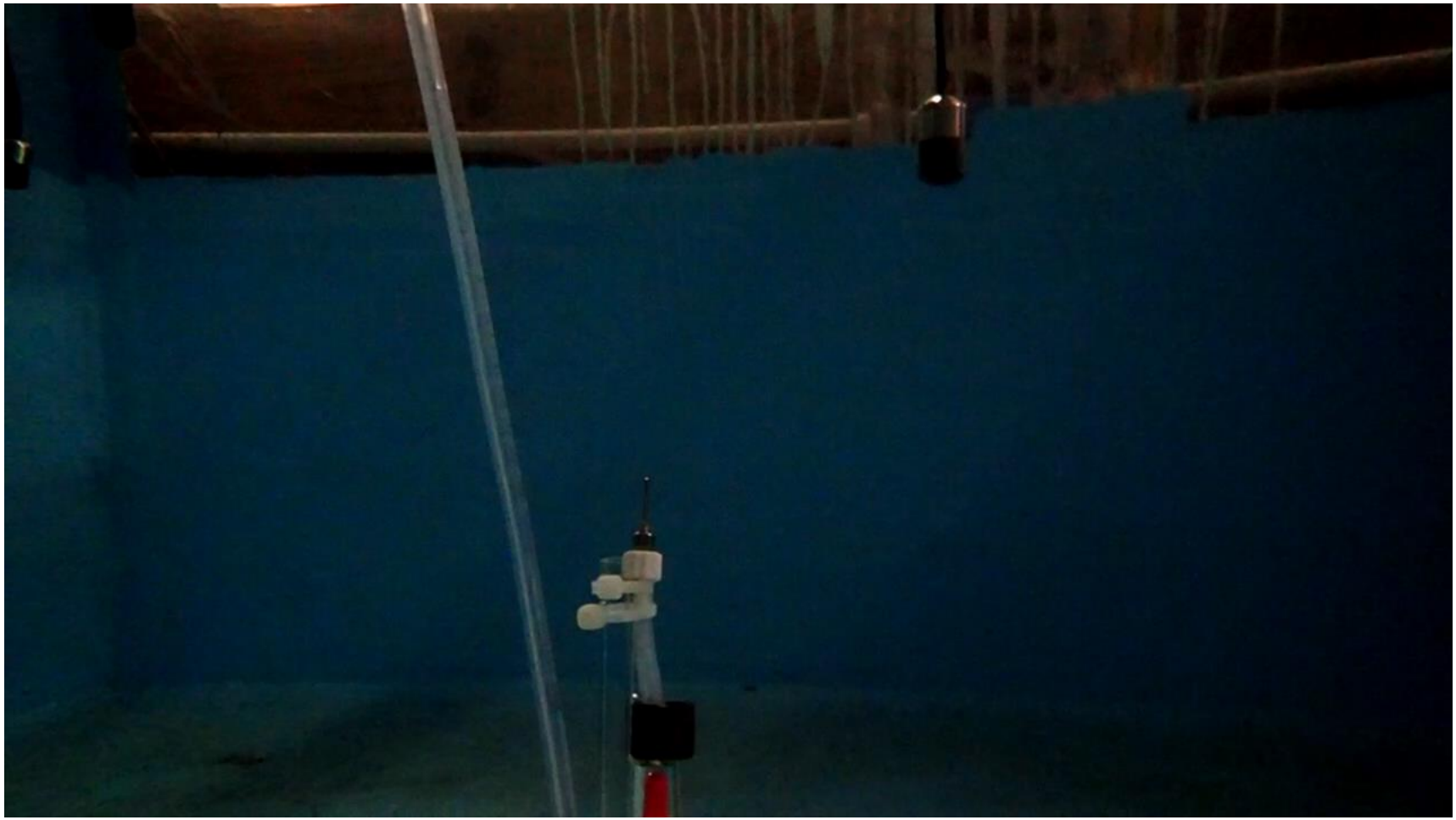


Movie of constant flow

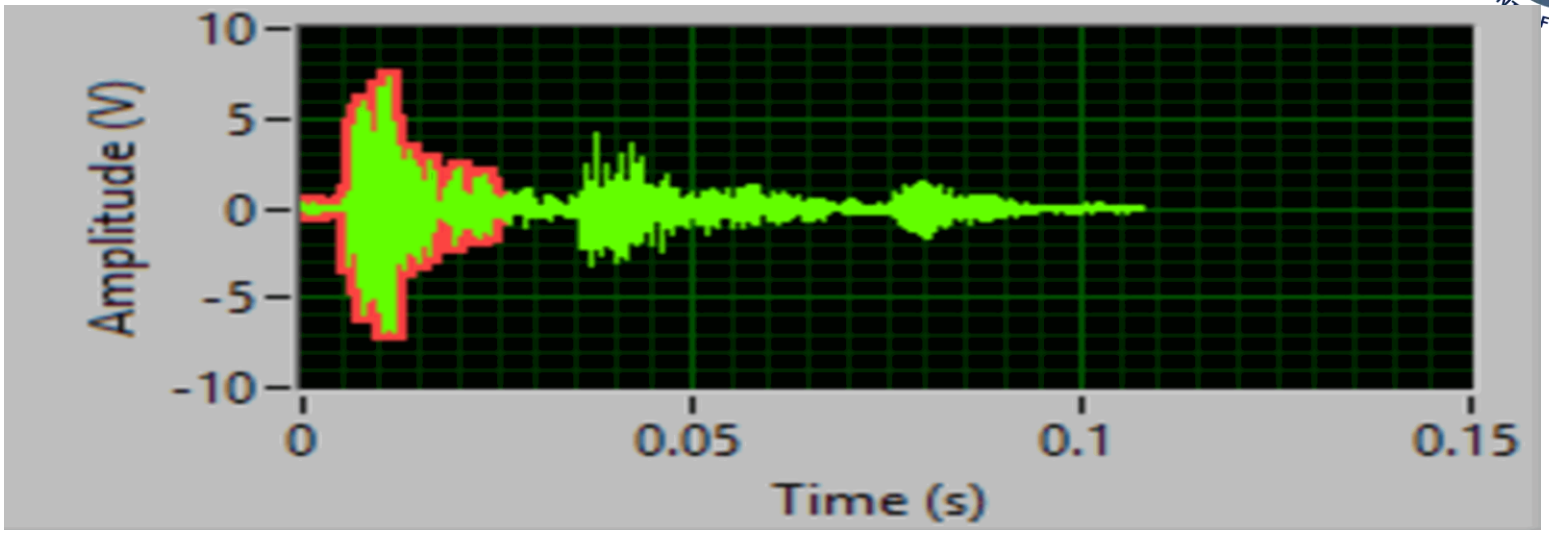
Sound of constant flow

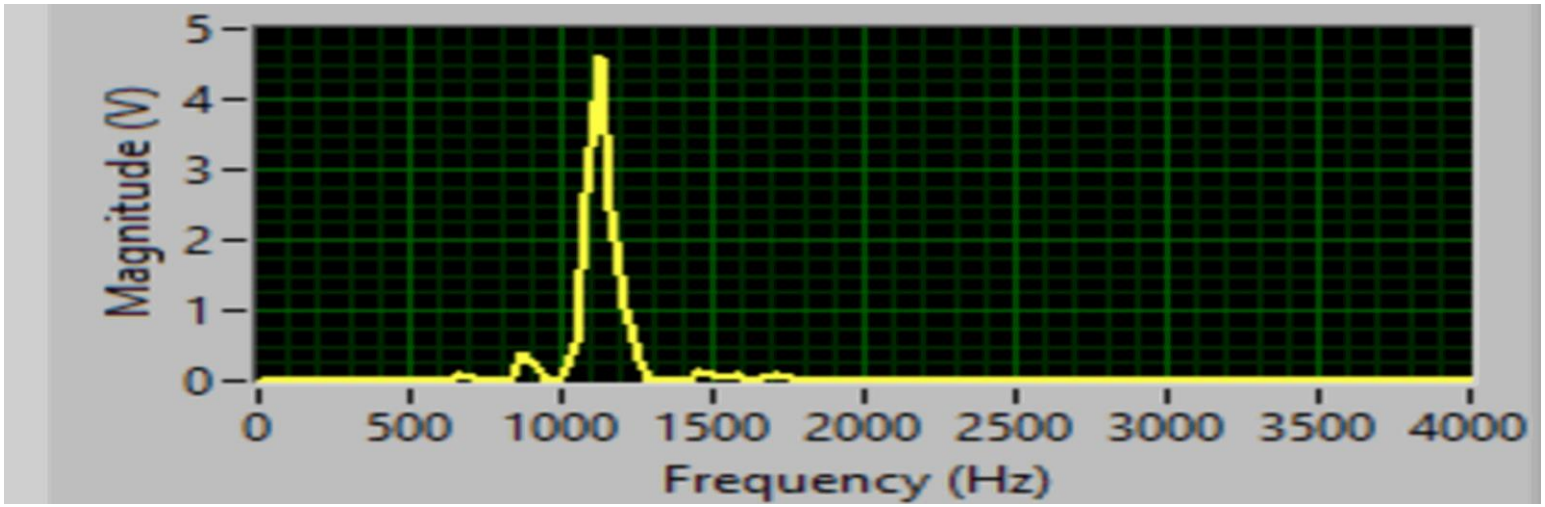


Movie of a few bubbles

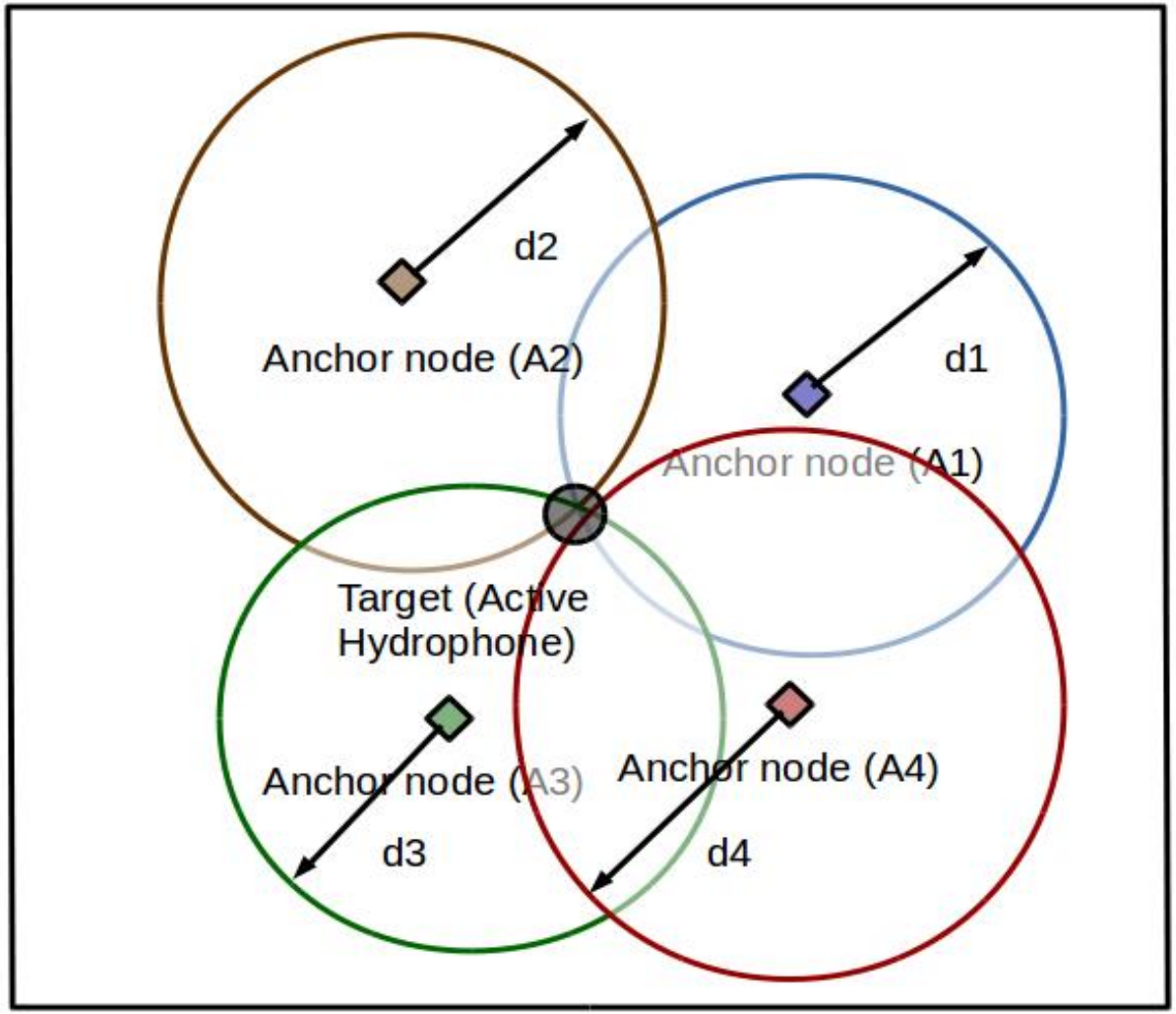


Sound of a few bubbles





Localization concept



Distance equations

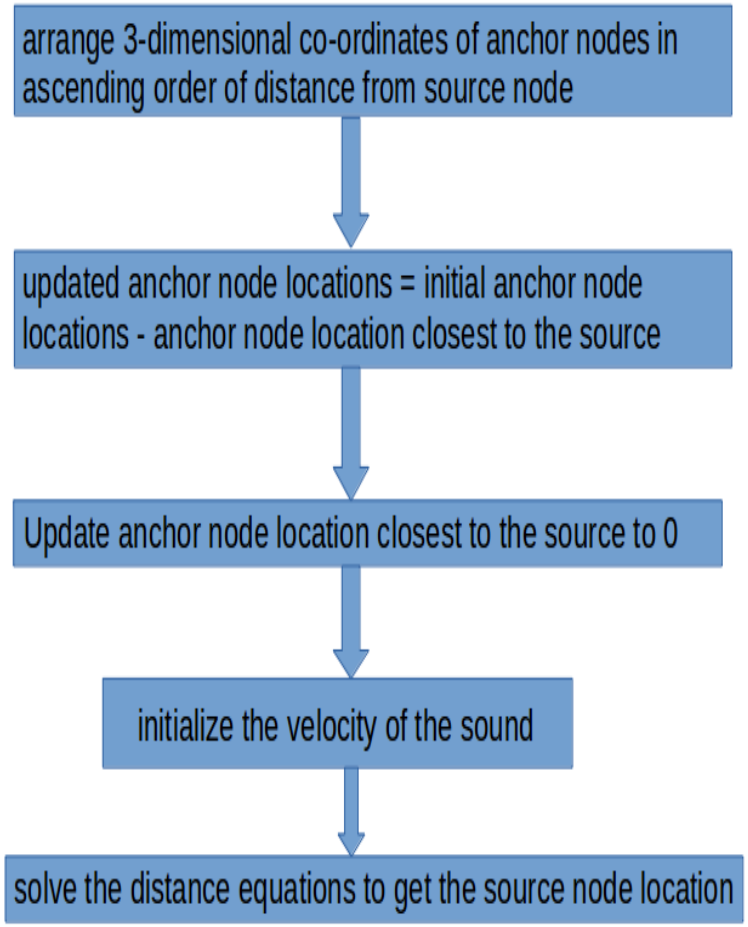
$$\left[(x_s - x_1)^2 + (y_s - y_1)^2 + (z_s - z_1)^2\right]^{1/2} = c \cdot \Delta t_1$$

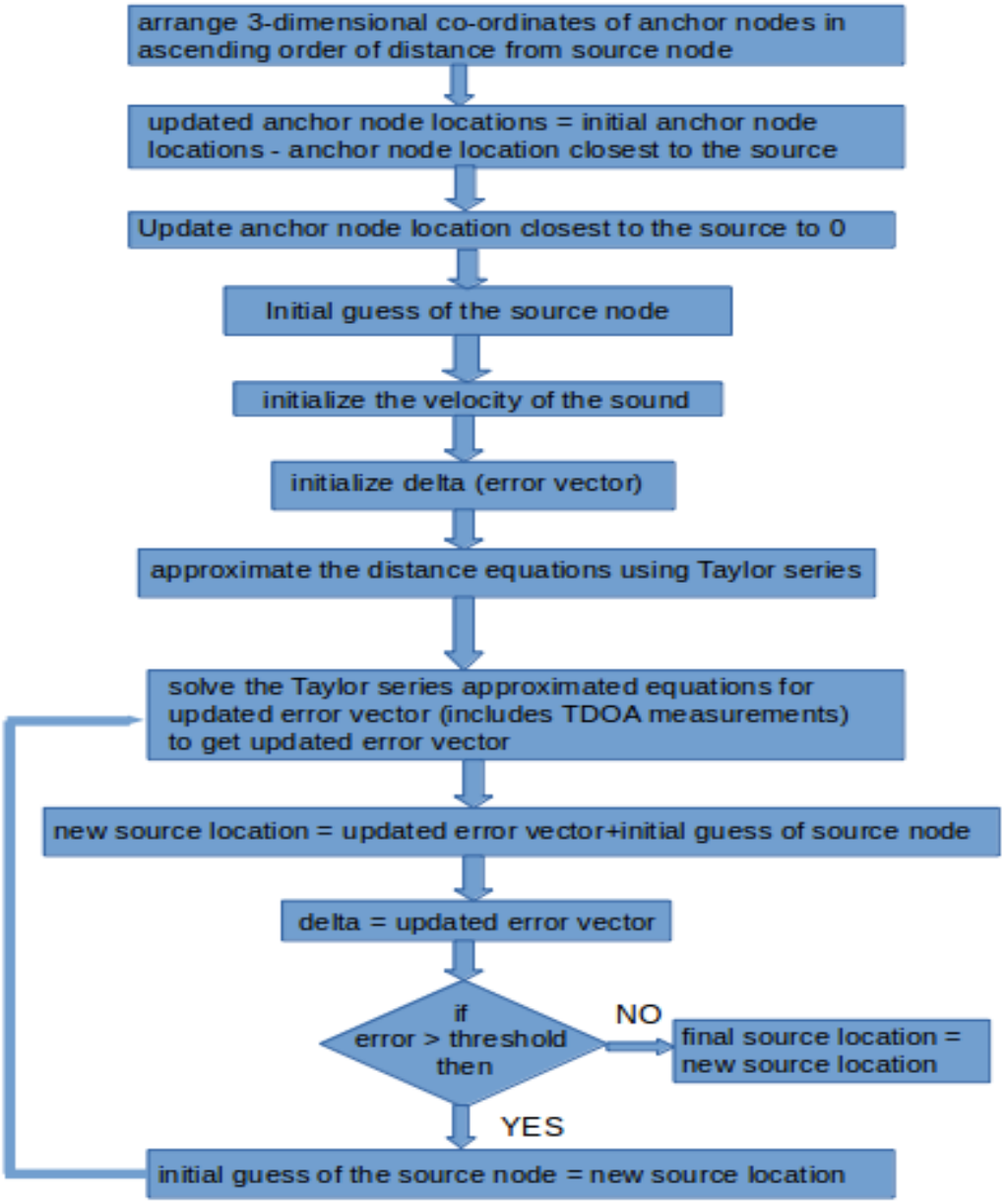
$$\left[(x_s - x_2)^2 + (y_s - y_2)^2 + (z_s - z_2)^2\right]^{1/2} = c \cdot \Delta t_2$$

$$\vdots$$

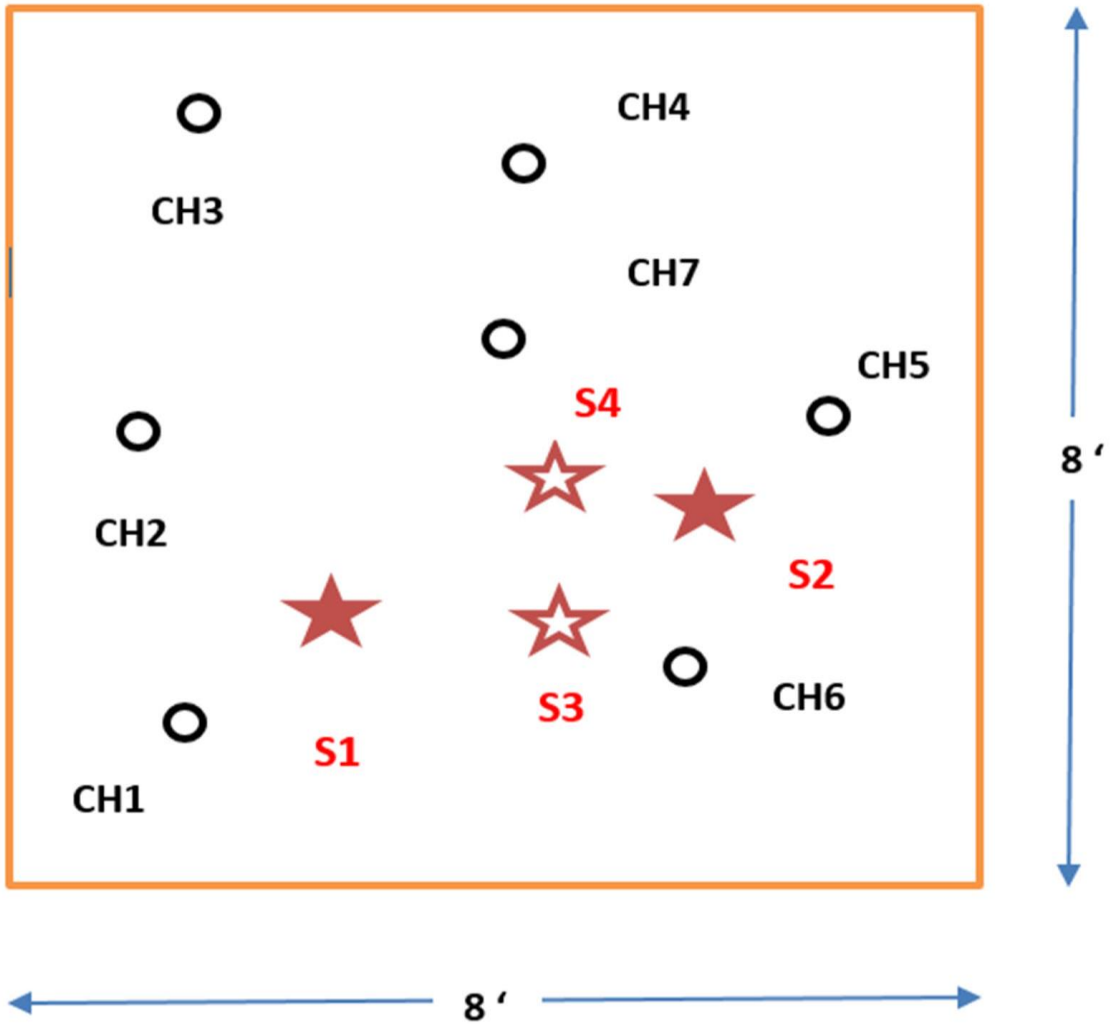
$$\left[(x_s - x_N)^2 + (y_s - y_N)^2 + (z_s - z_N)^2\right]^{1/2} = c \cdot \Delta t_N$$

LSE and TSE algorithms

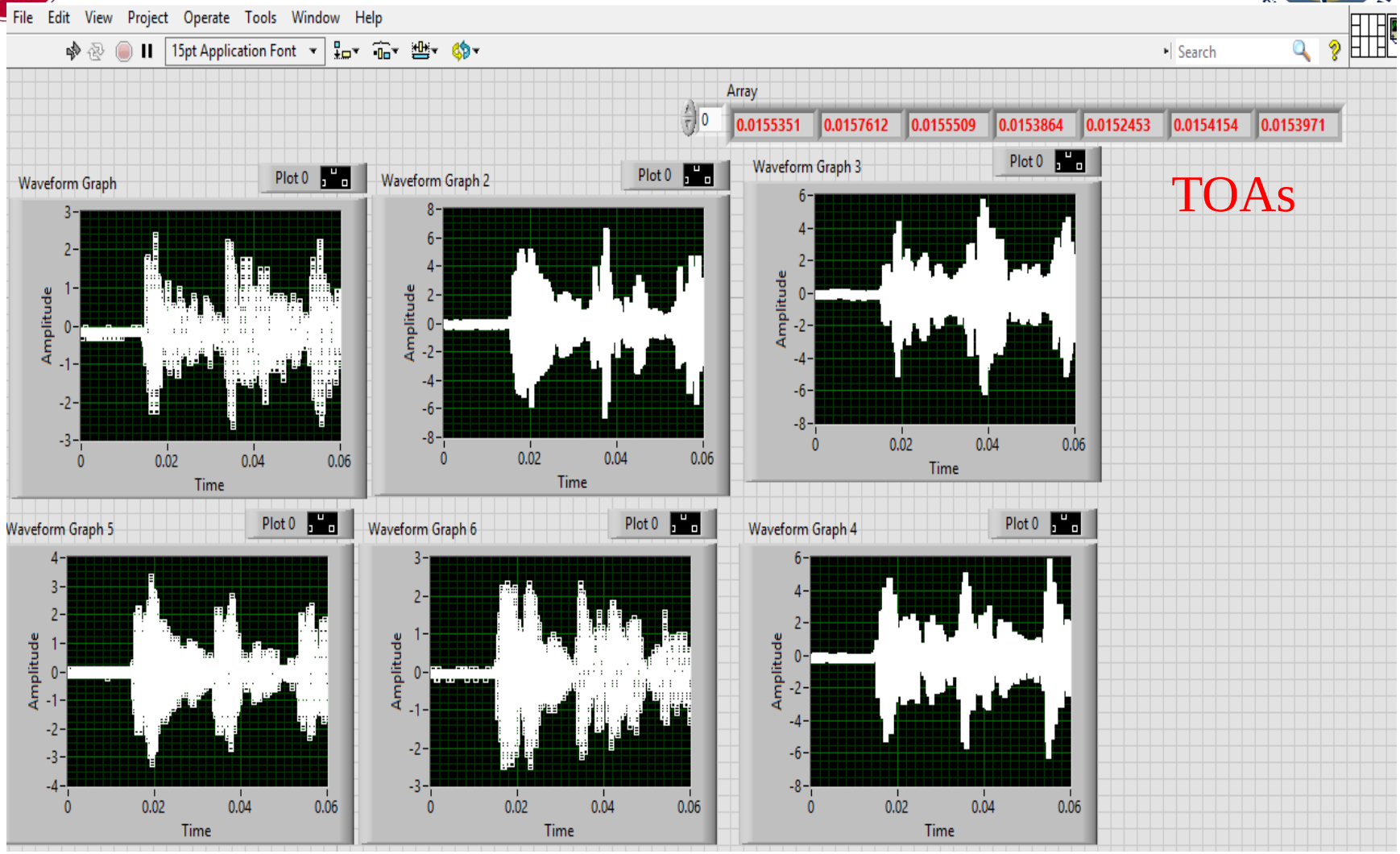




Top view of the setup



6 signals from passive hydrophones



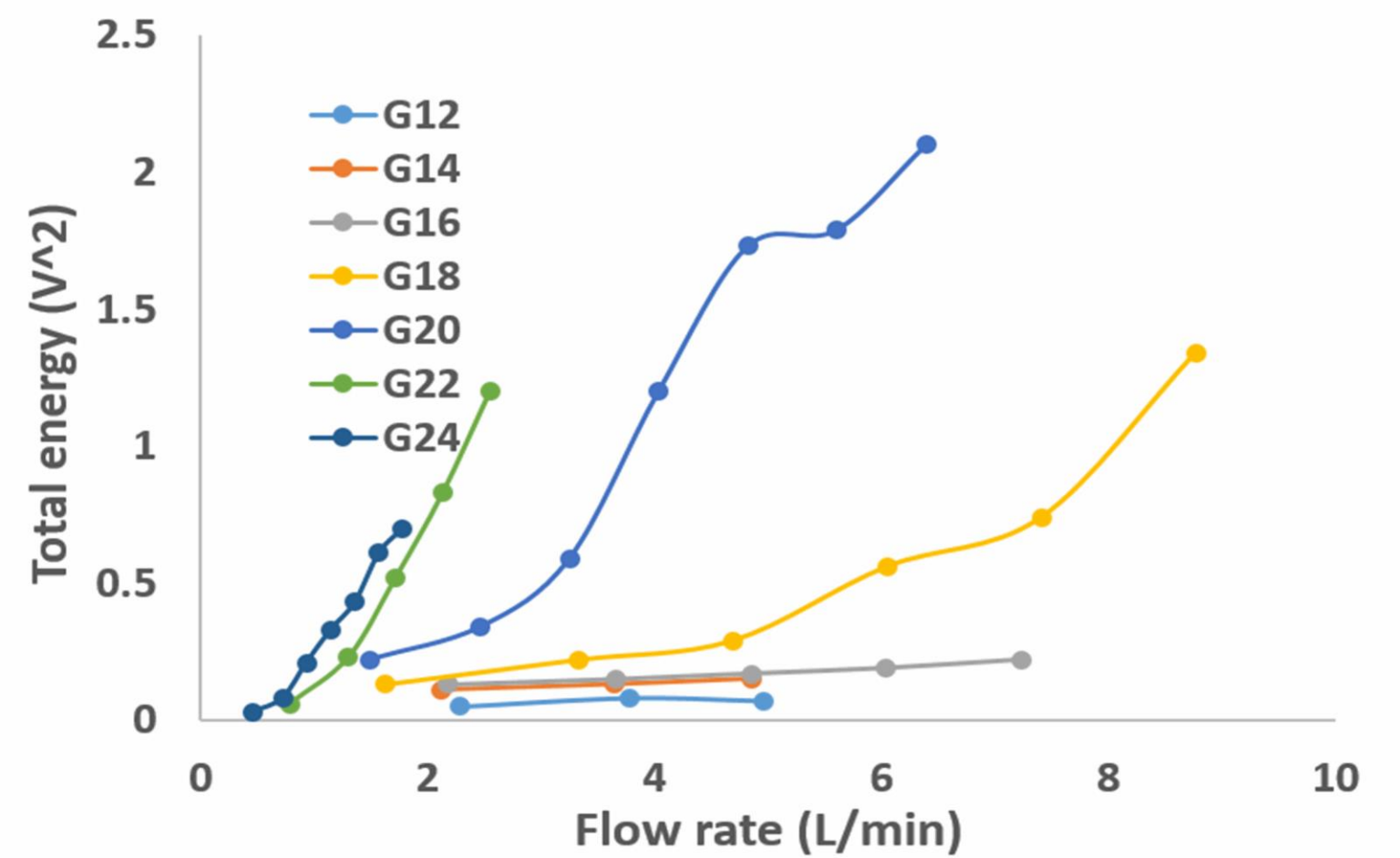
Results of four sources

Sources	True Location (cm)	Estimated Location (cm)		MSE) (cm)	
		LSE	TSE	LSE	TSE
S1	(174.0, 73.0, 136.0)	(180.6, 75. 8, 134. 8)	(179.6, 76.7, 135.6)	4.2	3.9
S2	(90.0, 64.0, 115.0)	(90.6, 65.1, 105.5)	(90.3, 65.3, 107.0)	5.5	4.7
S3	(139.5, 52.5, 145.0)	(138.4, 52.4, 151.1)	(136.9, 53.1, 144.0)	3.6	1.7
S4	(136.0, 112.5, 140.0)	(133.4, 115.5, 146.2)	(136.3, 115.6, 145.6)	4.3	3.7

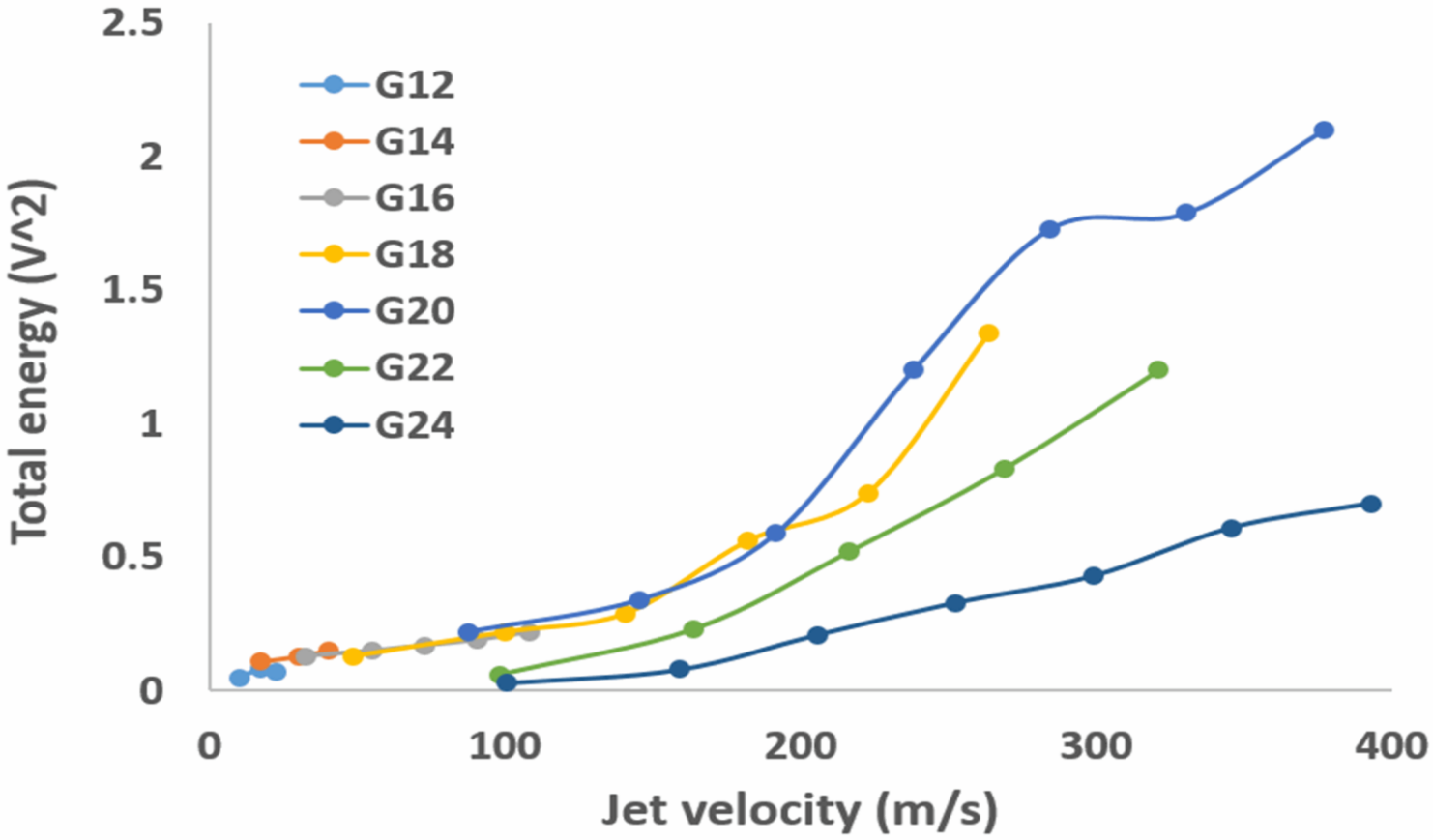
Bubble sound characterization

- Needle diameter
- Flow rate
- Jet velocity
- Total energy
- Resonant frequency

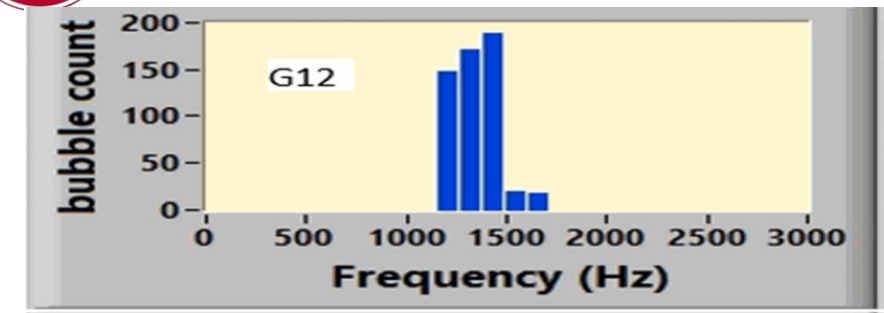
Total energy vs flow rate (for constant flow)

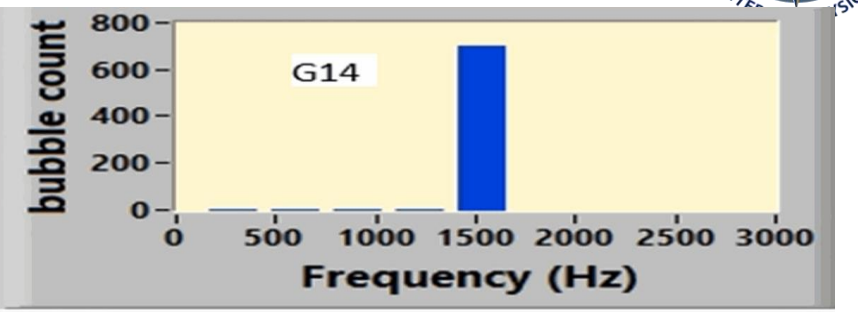


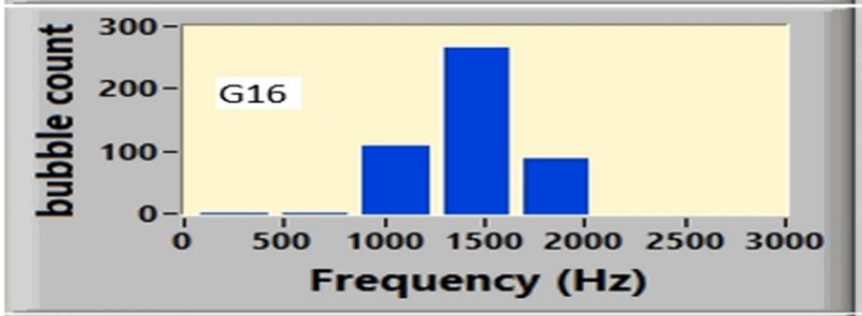
Total energy vs jet velocity (for constant flow)

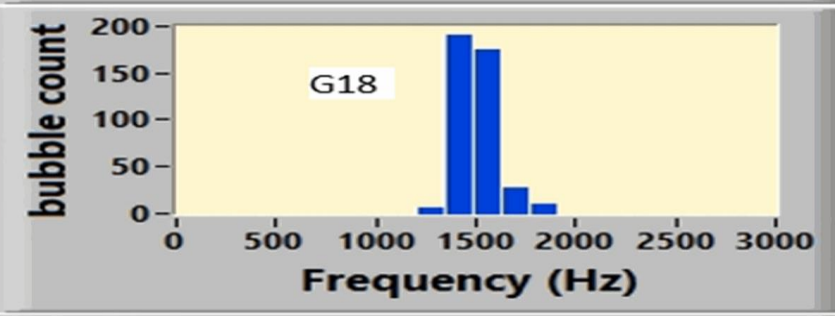


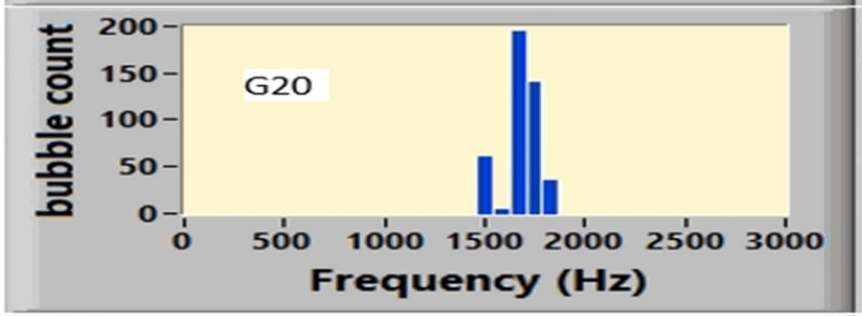
Resonant frequency vs needle size

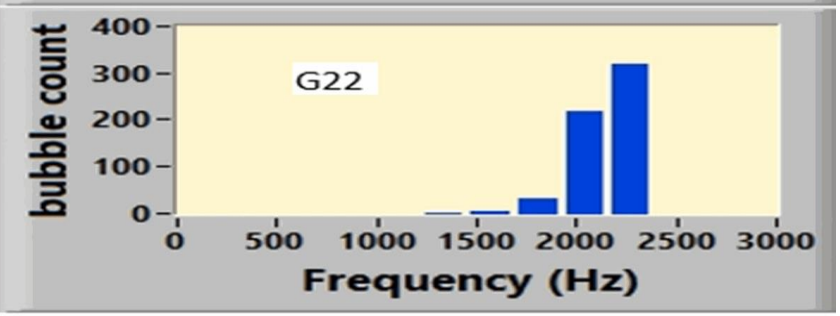


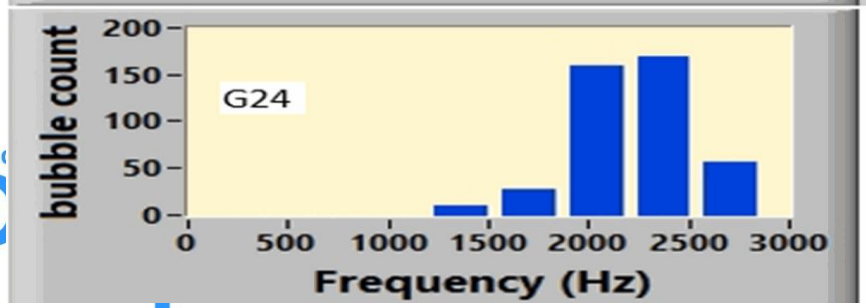












Minnaert resonance frequency

$$\omega_M = \frac{1}{R_0}\sqrt{\frac{3\gamma\rho_0}{\rho}}$$

Conclusions

- Localization algorithms were able to determine the locations of bubble sources
- Acoustic signatures in terms of total energy and resonate frequency can be used to estimate the intensity and crack size of oil leakages.

Future works

- Repeat the tests on methane
- Study the bubble sound mechanisms
- Build a hydrophone array to measure the direction of arrivals (DOAs)
- Develop algorithms using the DOAs for localization.

Acknowledgment

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QUESTIONS

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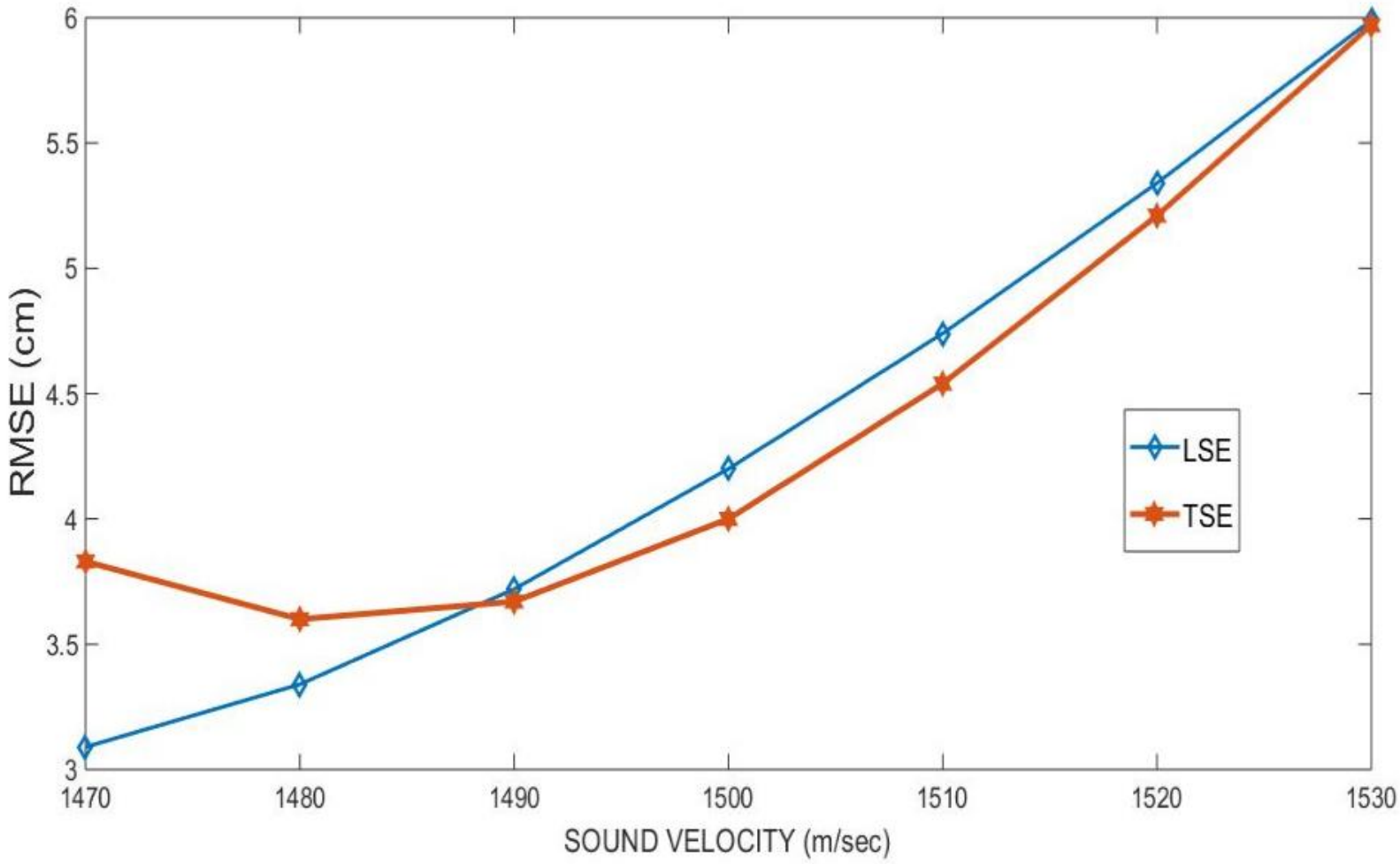
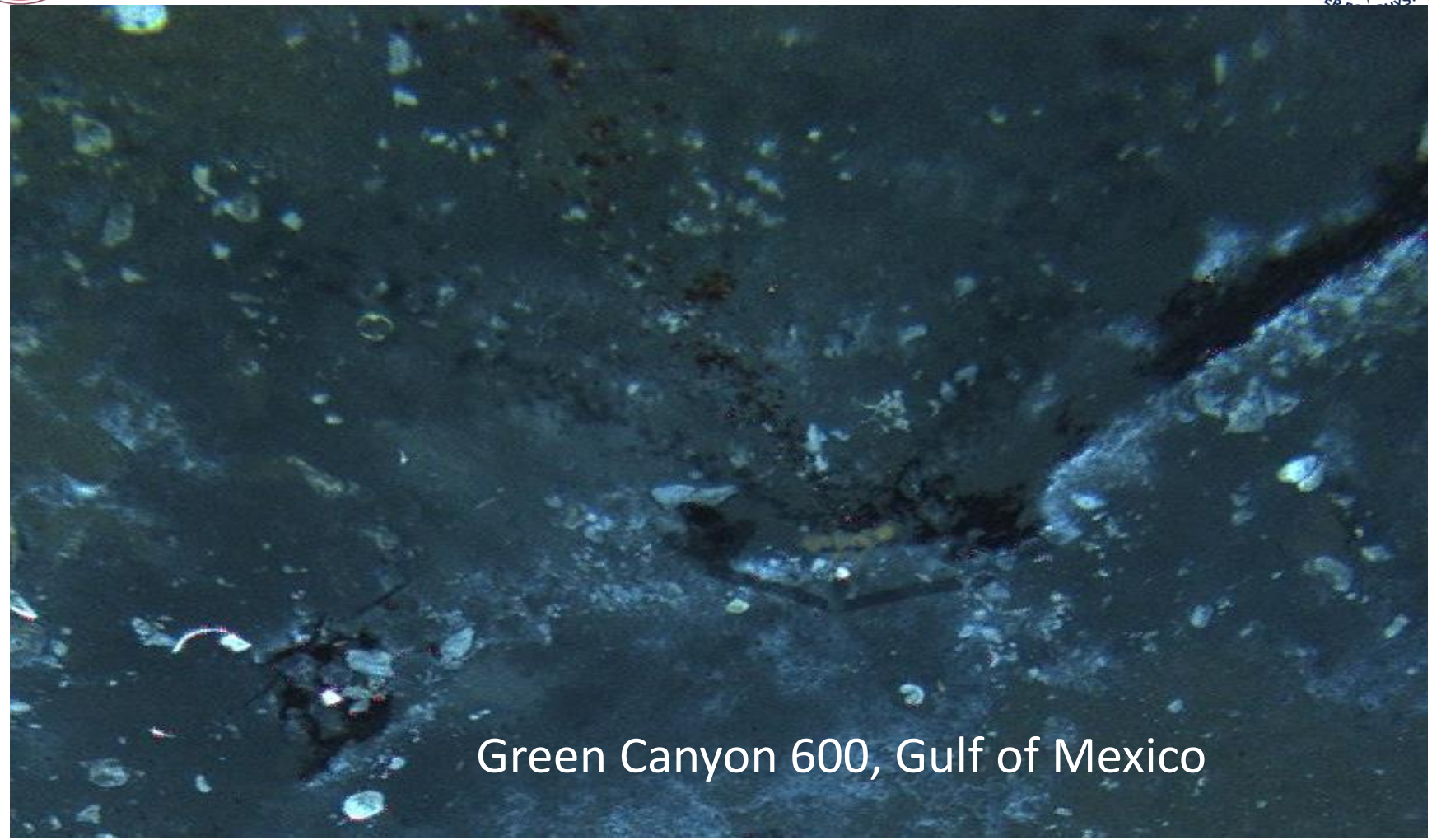
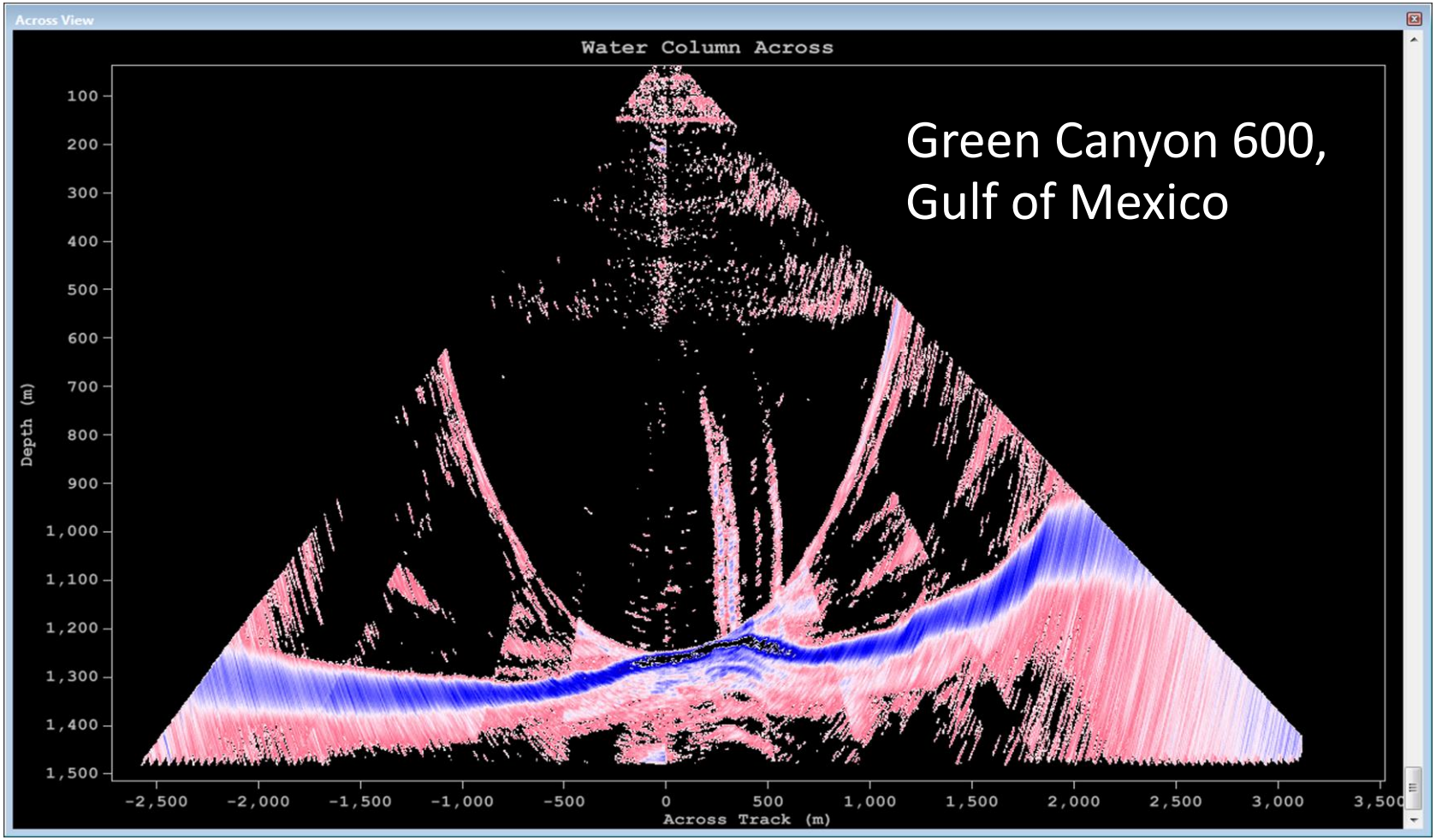
Calibration of sound speed with an active hydrophone



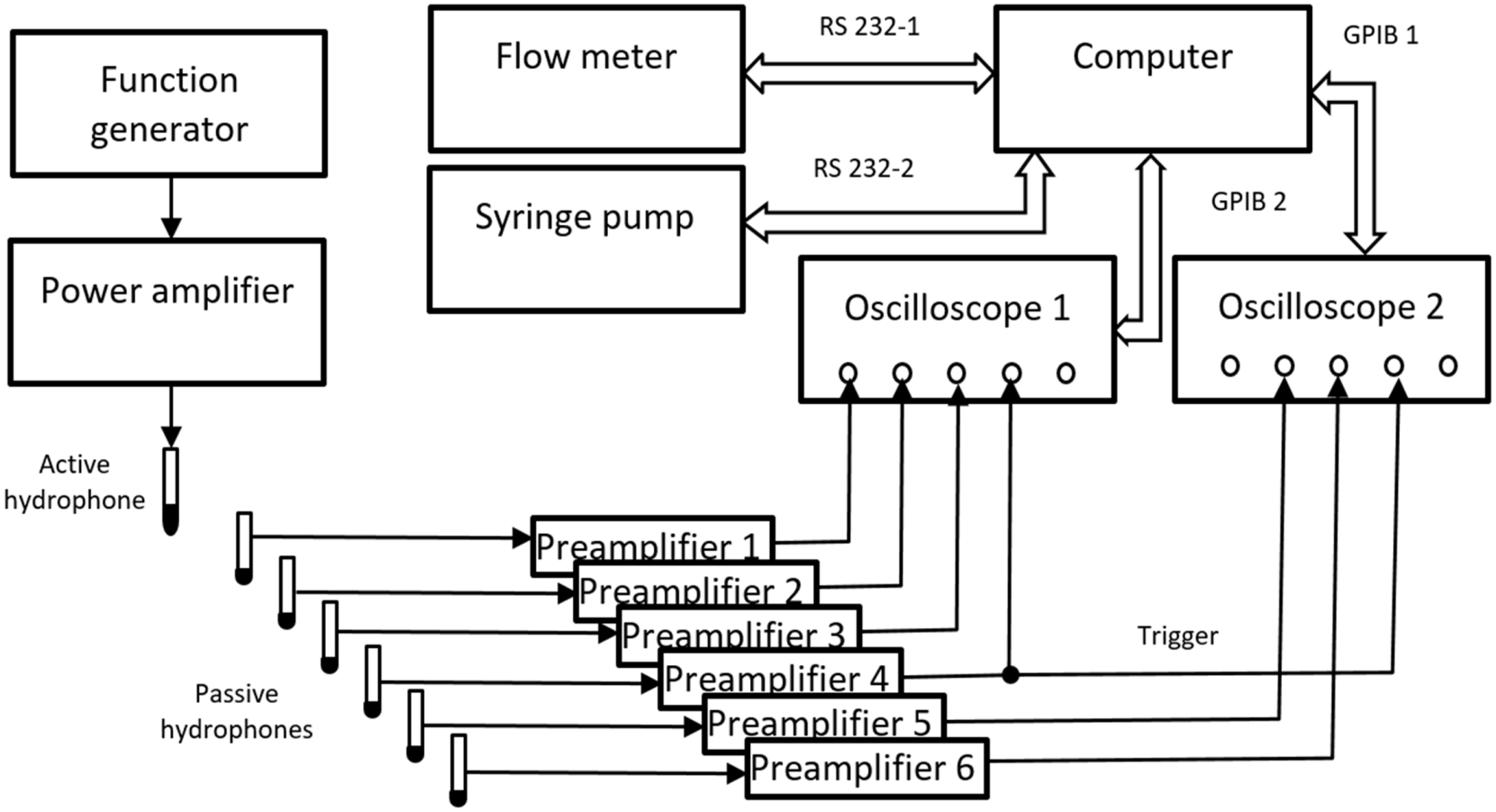
Sea floor seepage



Multi-beam sonar image of sea floor seepage



Data Acquisition



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Session: "Integrated Engineering & Geoscience Research in the Gulf of Mexico".
Presentation: 8:30 AM – 9:00 AM, Aug 29, 2018

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