Characterizing a laboratory water tank for ocean acoustics modeling

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Introduction

Sound propagation in an ocean environment is extremely complex. Not only does sound travel faster in water than in air, but many variables can lead to many interesting interference patterns, which include temperature variation with depth, bottom and surface reflections, and bubbles. There has been a significant amount of research in underwater acoustics, ranging from sound ecology to using SONAR for submarine navigation. This project used temperature data from four temperature sensors in a laboratory water tank to test the sound speed range possible for future sound measurements. The purpose of the project is to assess how a hydroacoustic lab tank with anechoic paneling on the sides is a good model for machine learning algorithms used in underwater acoustics analysis.

Ocean Acoustics

Sound is a compression wave and can only propagate through a medium.

Sound Speeds

Salt water = 1,500 m/s Air = 340 m/s

Complexities of modeling sound in the ocean

Temperature Depth Salinity
Reflections Bubbles

Applications of ocean acoustics:

Photo credit: https://ocean.si.edu/ocean-life/marine-mammals/whales

Photo credit: https://www.navytimes.com/news/your-navy/2021/09/10/a-persistent-proximate-threat-why-the-navy-is-preparing-for-a-fight-under-the-sea/

- Underwater navigation
- Locating marine animals
- Ocean depth measurements
- Military defense
- Tracking global climate change
- Weather
- Measurement of ocean currents

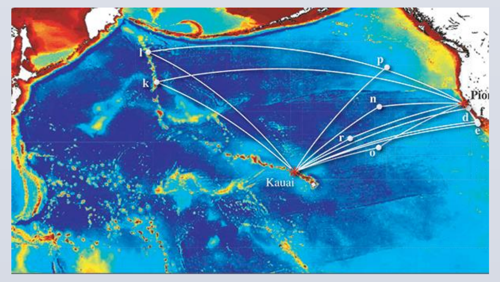

Photo credit: https://dosits.org/people-and-sound/research-ocean-physics/how-is-sound-used-to-measure-global-climate-change/

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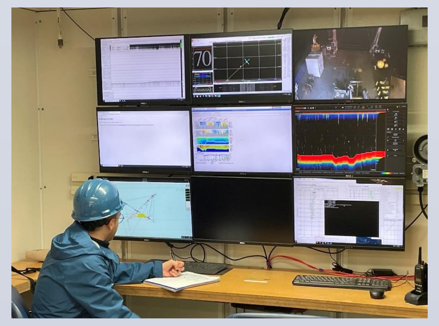
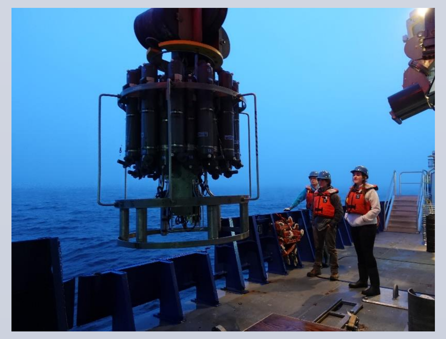
CTD Sensors

Conductivity-Temperature-Depth (CTD) sensors collect data useful for calculating sound speed from the surface to the bottom of the ocean.

The image of the CTD on the right was taken aboard the RV Neil Armstrong in the New England Mud Patch for an acoustics research project in May of 2022.



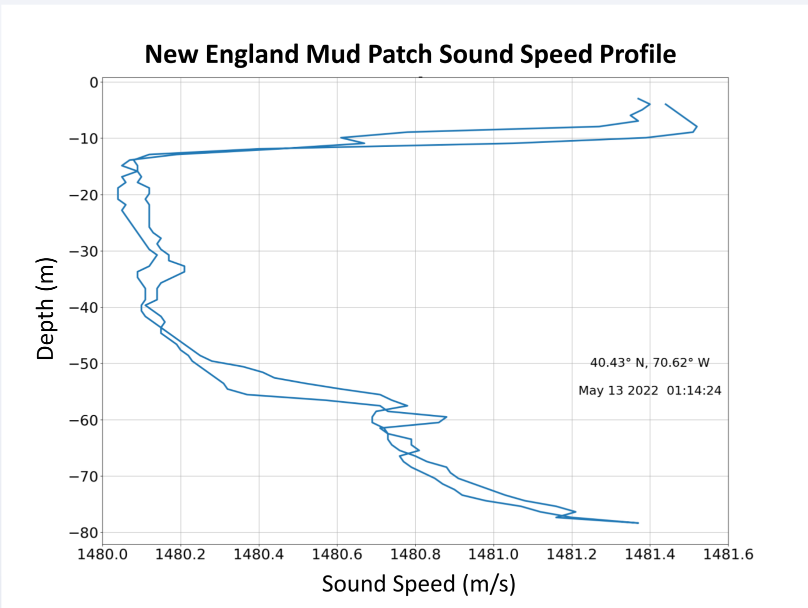


Sound Speed Profile

A sound speed profile shows the sound speed in the ocean as a function of depth.

The path the sound waves travels changes depending on the profile.

The profile on the right shows sound speed in the shallow ocean. Data was taken from the CTD sensors aboard the RV Neil Armstrong.



SOFAR Channel

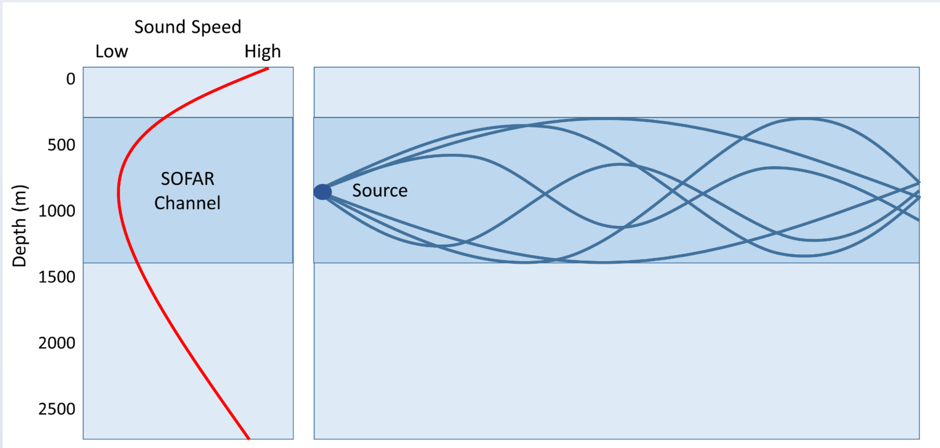


Photo credit: https://rwu.pressbooks.pub/webboceanography/chapter/6-4-sound/

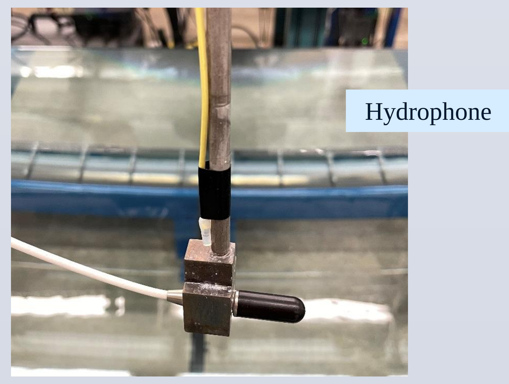
In the deep ocean there is a greater variation of sound speed due to greater temperature and depth variation.

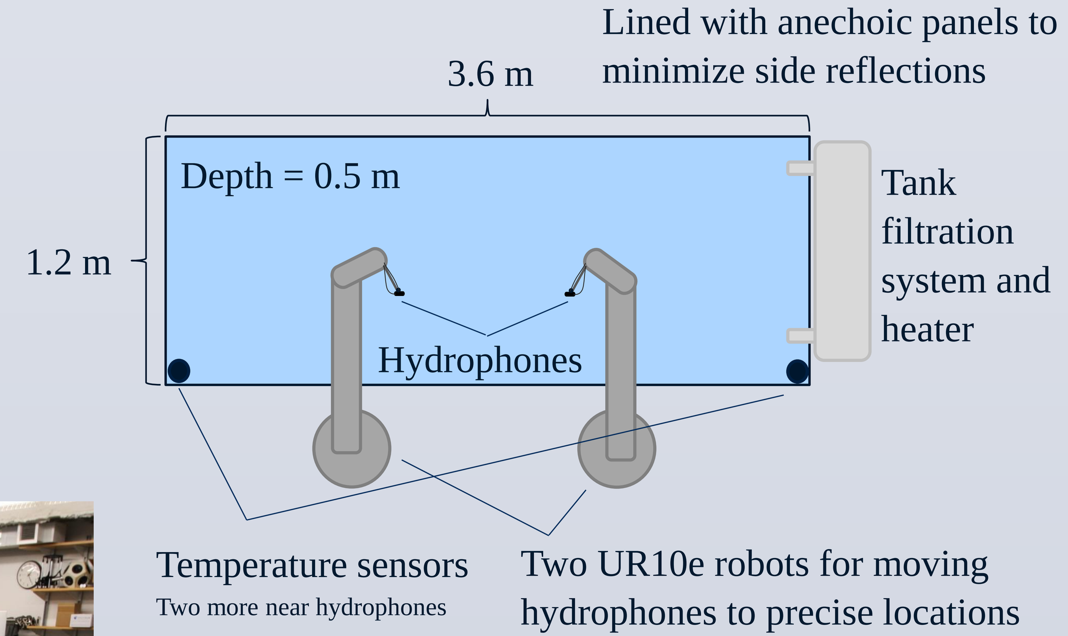
There is a special channel centered on the axis of lowest sound speed where low frequency sounds bend to remain within the channel. As a result, the waves can travel farther due to minimal energy loss.

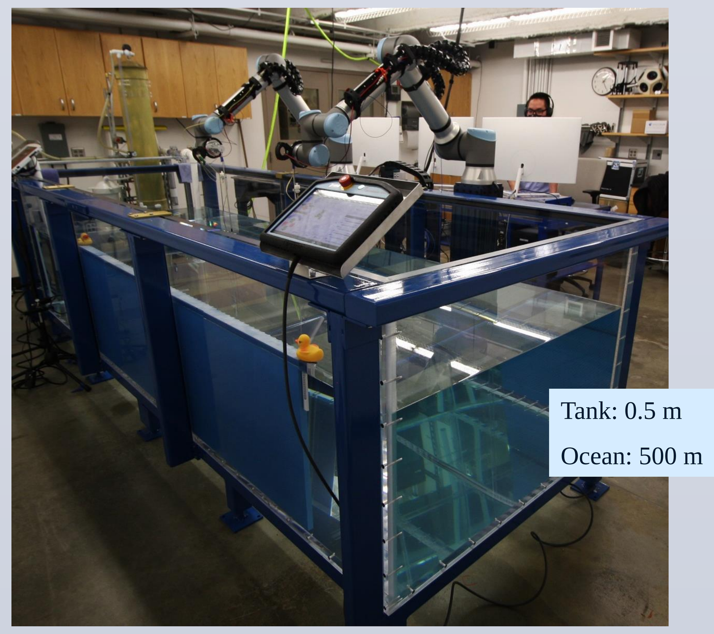
Fun Fact: Whales are aware of this sound speed channel and dive to this depth to send long-range messages.

Laboratory water tank

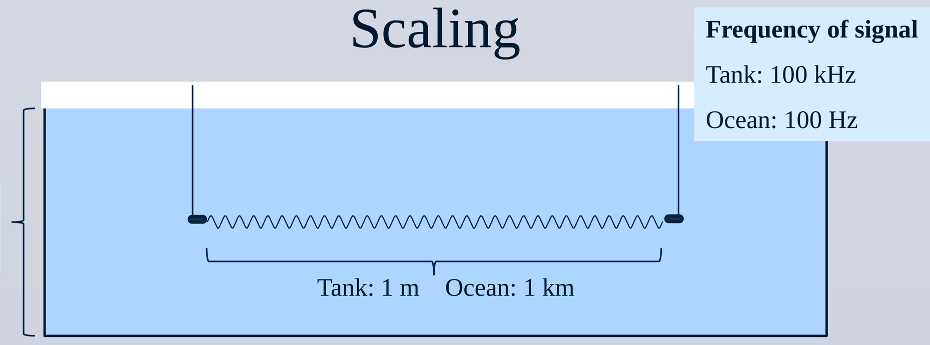
The purpose of this experiment is to test the variability in sound speed we can get with a laboratory water tank for a controlled ocean modeling experiment.







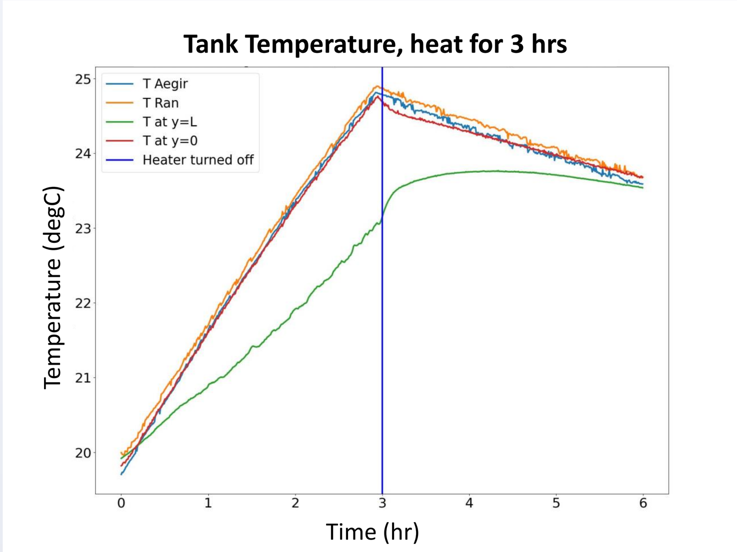
Scaling

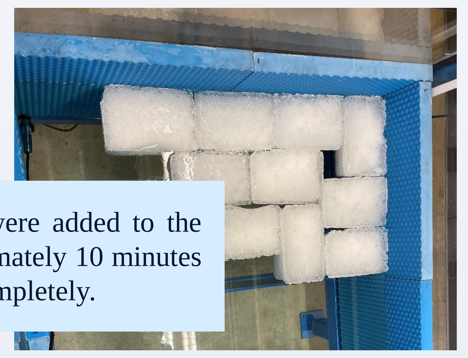


In a laboratory tank, we use a 1:1000 scale to better model wave propagation in the ocean. This gives the same number of wavelengths for a shorter distance.

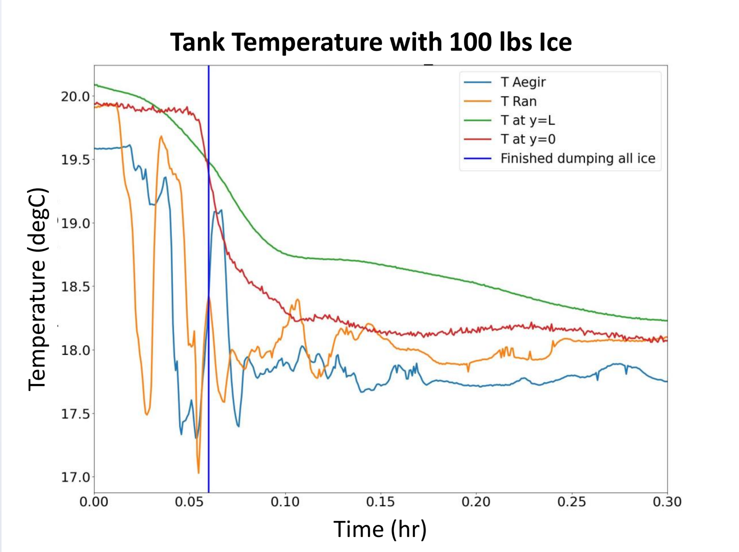
Temperature variability

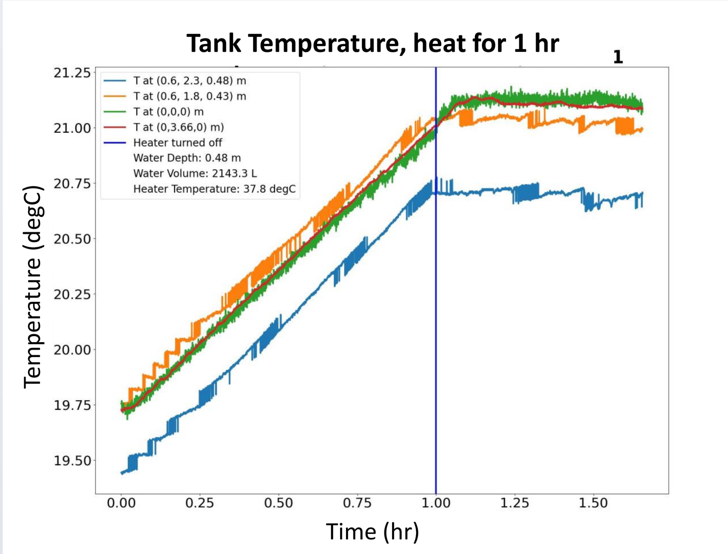
Used four temperature sensors at various depths.

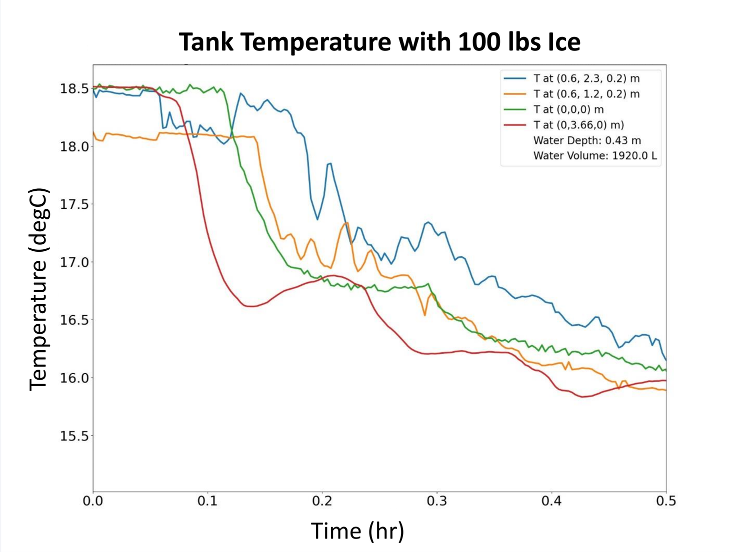




100 pounds of ice were added to the tank. It took approximately 10 minutes for the ice to melt completely.





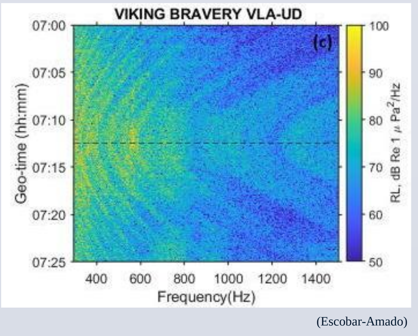


Results

Water temperature spatially uniform
Temperature range: 9.4 degrees Celsius
Sound speed range: 1465 m/s – 1485 m/s

Future research

Use the temperature variability possible in the tank to take acoustic measurements and make spectrograms of the data and compare to current machine learning algorithms.



(Escobar-Amado)

Conclusion

With heating the tank and adding ice to the water, a temperature change of 9.4 degrees Celsius was attained and this corresponds to a sound speed change of 20 m/s. As the temperature changes over time, it remains spatially uniform, so we were not able to generate a depth dependent sound speed profile. Despite not having a vertical temperature gradient, knowing the amount of temperature variation that can be created will allow further sound measurements to be taken at different sound speeds, which will modify the sound propagation. This variability will be helpful in training our machine learning training models in our ocean environment model.

References

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Acknowledgements

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