Probabilistic Methods for Improved Self-consistency of Doppler Velocity Log Range-Based Bathymetry

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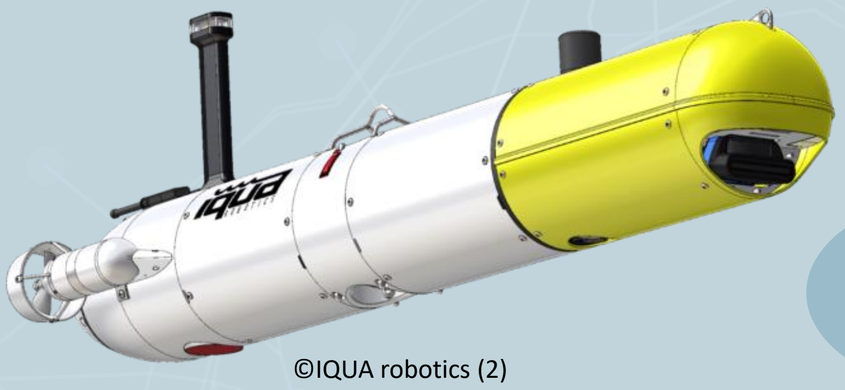
1 Motivation - Underwater Navigation

Position error accumulation is a problem for underwater robot navigation. **SLAM** is employed to bound this error – but requires extra sensors. DVLs are already present on most vehicles, so could be used to gather low-resolution bathymetry information for **loop closure**. The challenge is that **DVL** measurements experience **terrain bias**.



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Doppler Velocity Log (DVL)

DVLs use acoustic signals to track vehicle velocity over the seafloor. **BUT** they also provide low resolution bathymetry information

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Terrain Bias

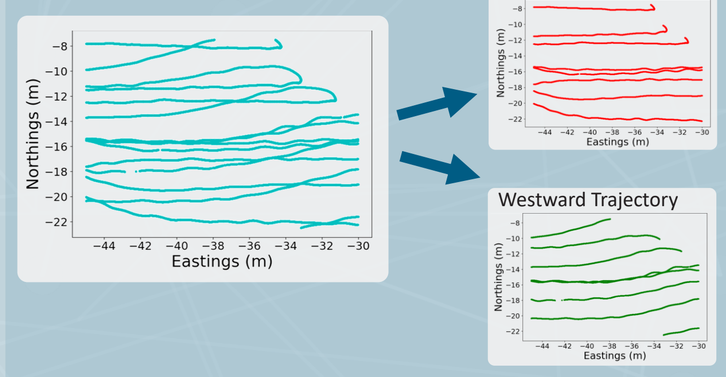
Error between the expected and measured acoustic reflection due to the incident angle of the beam interacting with the seafloor.

2 Aims and Objectives

- Develop acoustic model of DVL terrain-slope bias
- Demonstrate that this improves mapping **self-consistency**

Mapping Process & Self-consistency Comparison

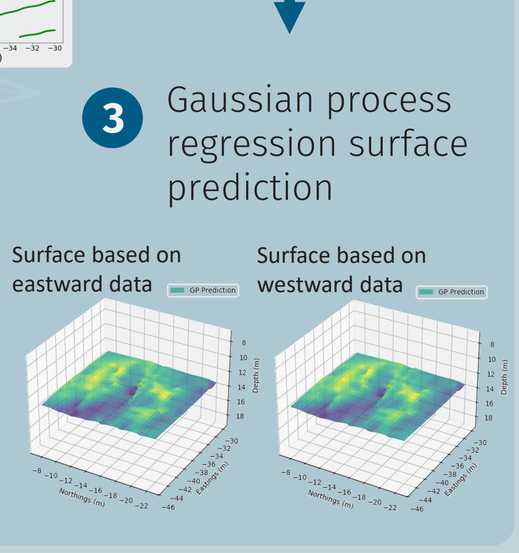
1 Split data into east/west transects



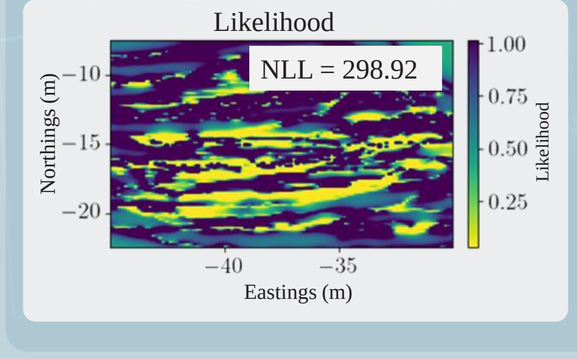
2 Measurement uncertainty (with or without **acoustic model uncertainty**)

σ

3 Gaussian process regression surface prediction



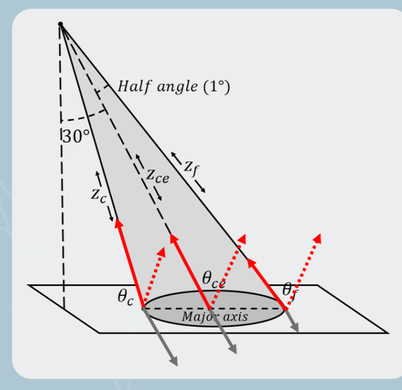
4 Calculate Negative Log Likelihood of resulting maps



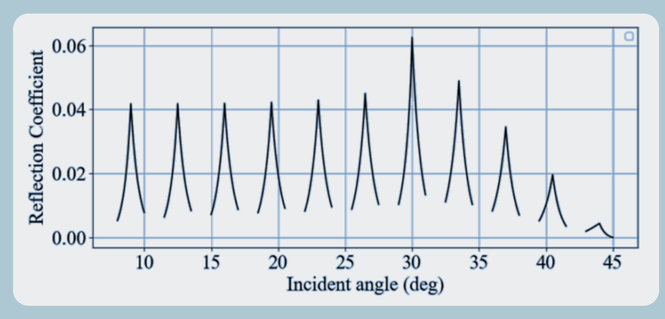
3 Method

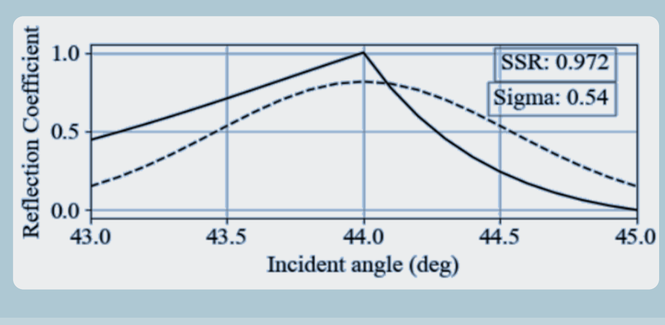
Compare the self-consistency of maps built using the acoustic model vs. without.

Acoustic model



- The acoustic signals can be treated as a cone. Different parts of the signal have different intensities and reflection behaviour
- Use acoustic theory to predict the spread of the reflected acoustic signal at different incident angles.
- This informs the measurement uncertainty





4 Results

Maps built using the uncertainty from the acoustic model showed **lower NLL** metric, meaning **greater self-consistency**.

	Without acoustic model	With acoustic model
NLL	404.02	298.92

5 Conclusion and Future Work

Applying an acoustic model to DVL range data **improves the self-consistency** of resulting maps. This work lays the foundation for using **DVL range data for loop closure in bathymetry-based SLAM**.

1. Sonardyne, "Homepage," [Online]. Available: https://www.sonardyne.com. [Accessed: Jan. 9, 2025]
2. IQUA Robotics, "Sparus II AUV," [Online]. Available: https://iquarobotics.com/sparus-ii-auv. [Accessed: Jan. 9, 2025]

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