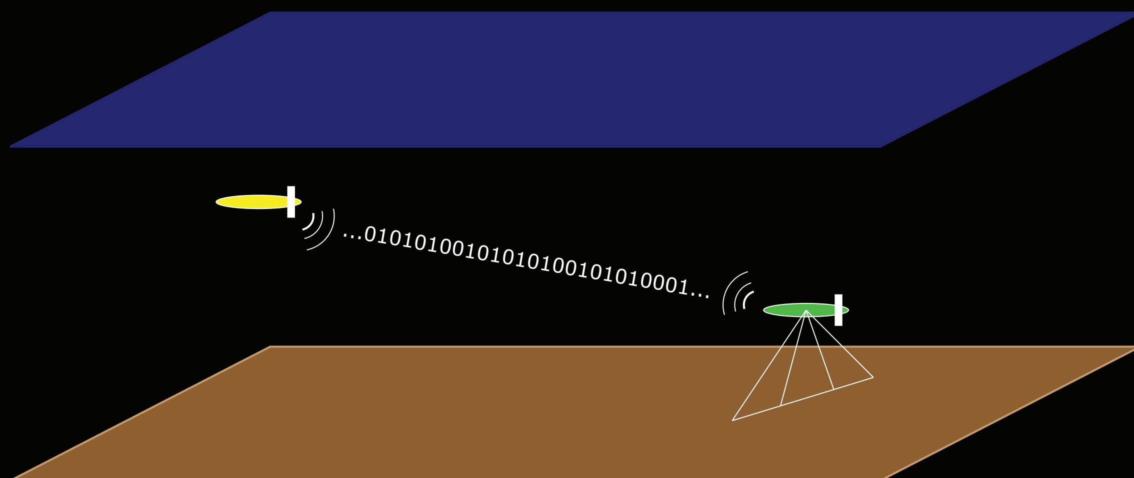
Approaches to Improving Acoustic Communications on Autonomous Mobile Marine Platforms



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Overview

1. Autonomous underwater vehicles (AUVs) *need* wireless data transfer:

- Collaborative missions
- Collected data
- Commands

2. Current state-of-the-art information throughput is unacceptable

3. However, AUVs have:

- Mobility
- "Intelligence" - modeling, state awareness

Overview

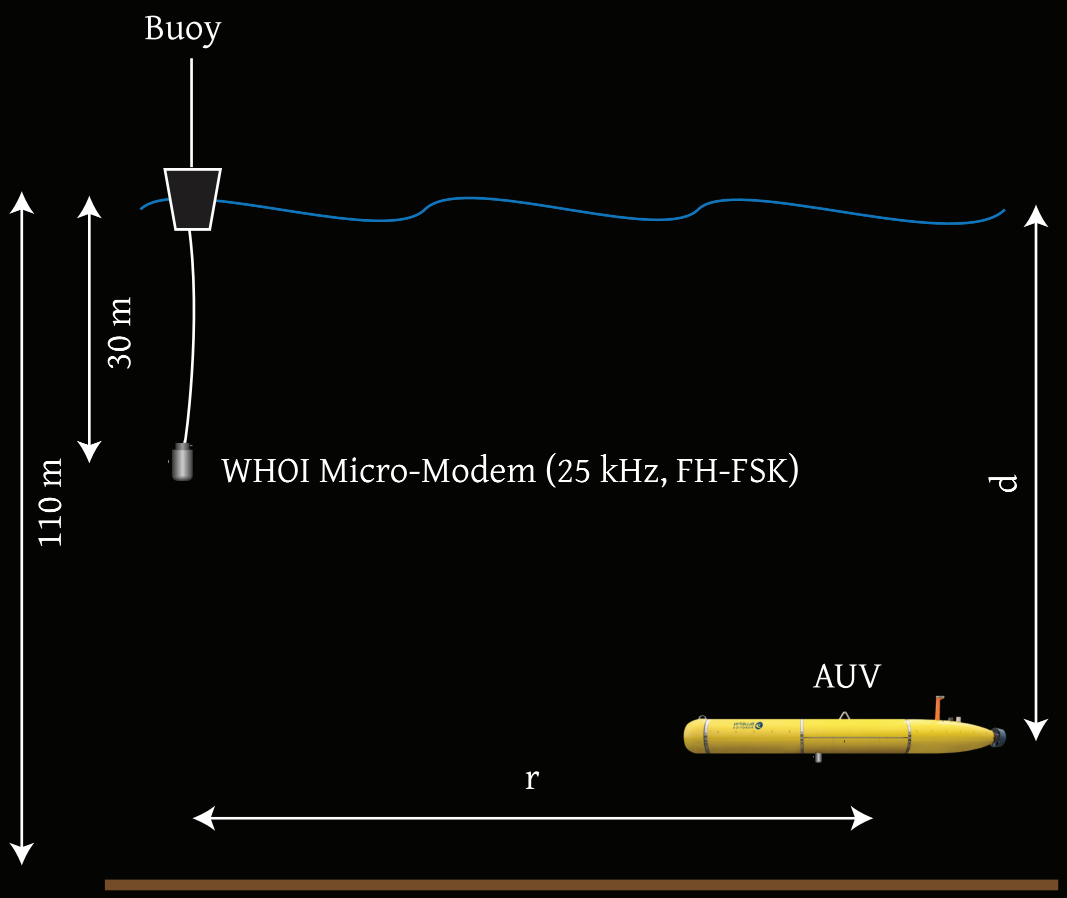
Can we use the AUV's "intelligence" to increase acoustic comms throughput (useful information / unit energy)?

Two (complementary) approaches:

- Disruptive (affects vehicle course)
  - stop to transmit or receive (reduce Doppler or self-noise)
  - move to expected beneficial position (SNR maximum)
- Non-disruptive (transparent to mission)
  - frequency band or transmit power selection
  - mission-based source coding

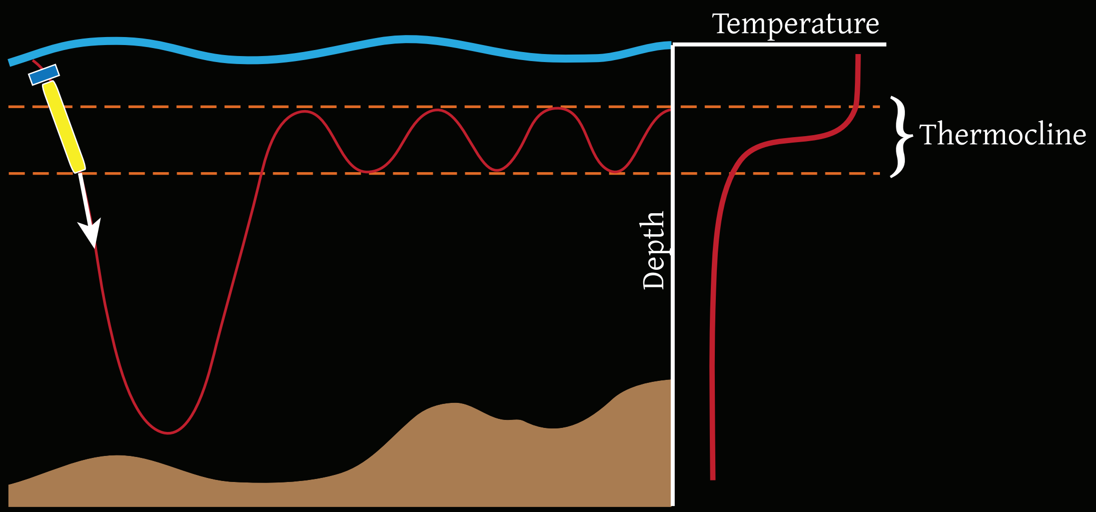
GLINT10

Use measured environment to generate acoustic model to drive adaptation in depth (assume range is out of our control). Goal: improve SNR from buoy to AUV

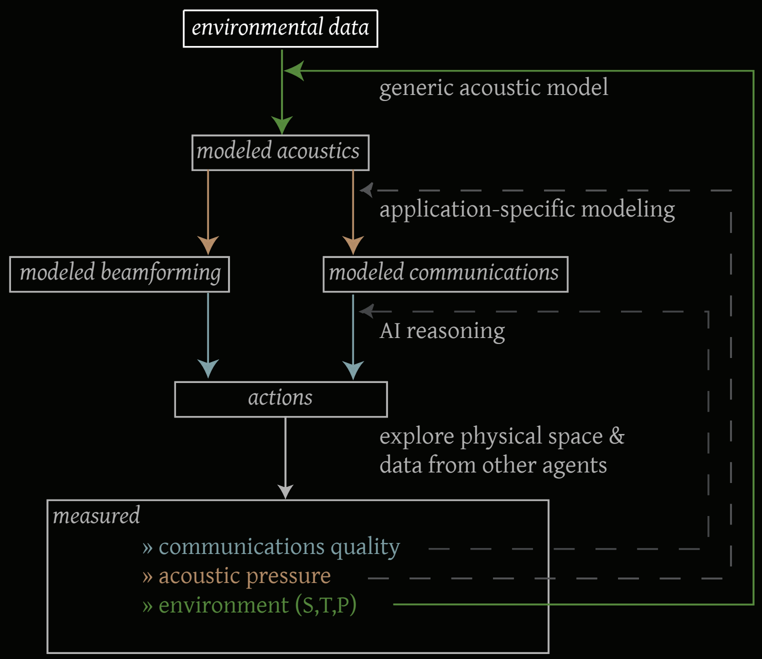


1. Measure Environment

- AUV meaures SSP using CTD via "yoyo" depth excursions.
- Thermocline-adaptive sampling (Petillo 2010) used.

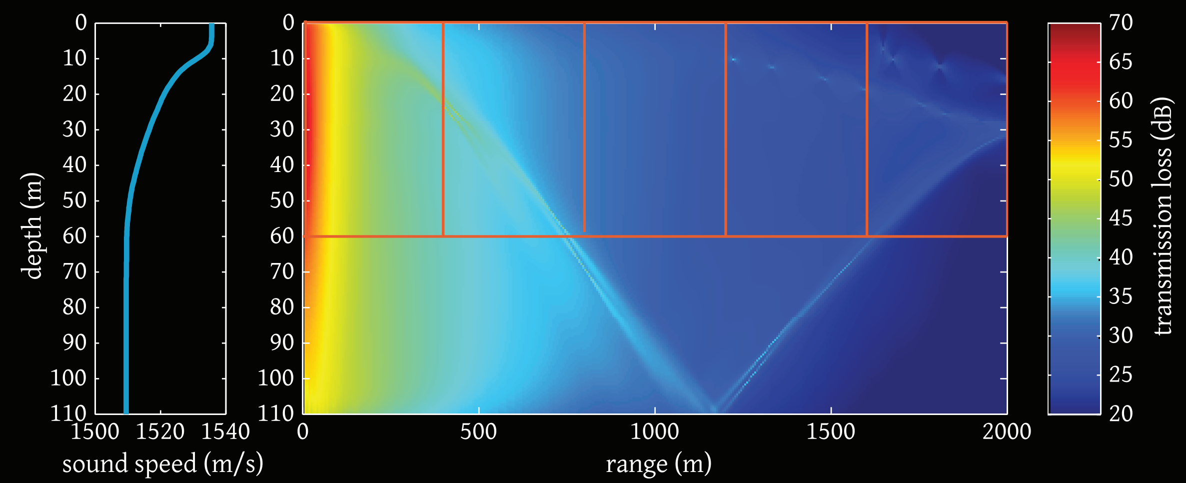


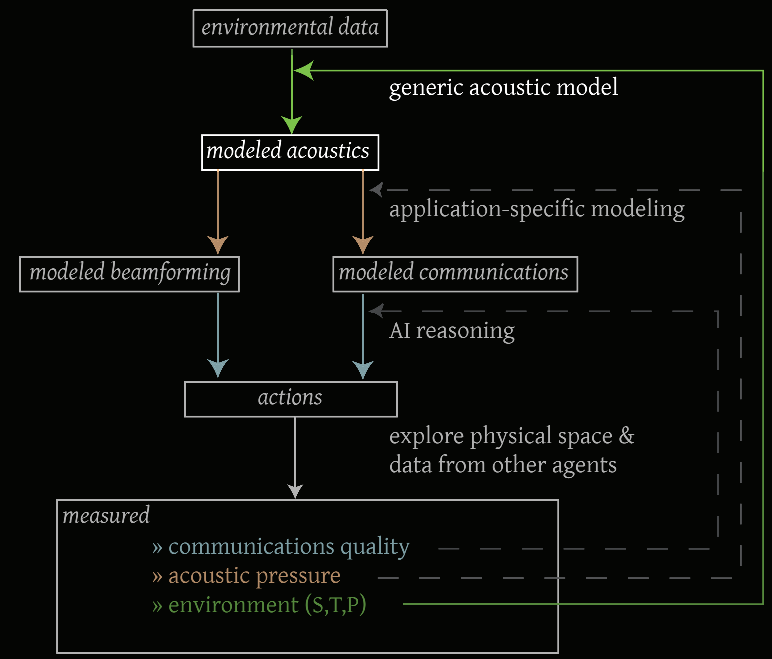
S. Petillo: Adapted with permission



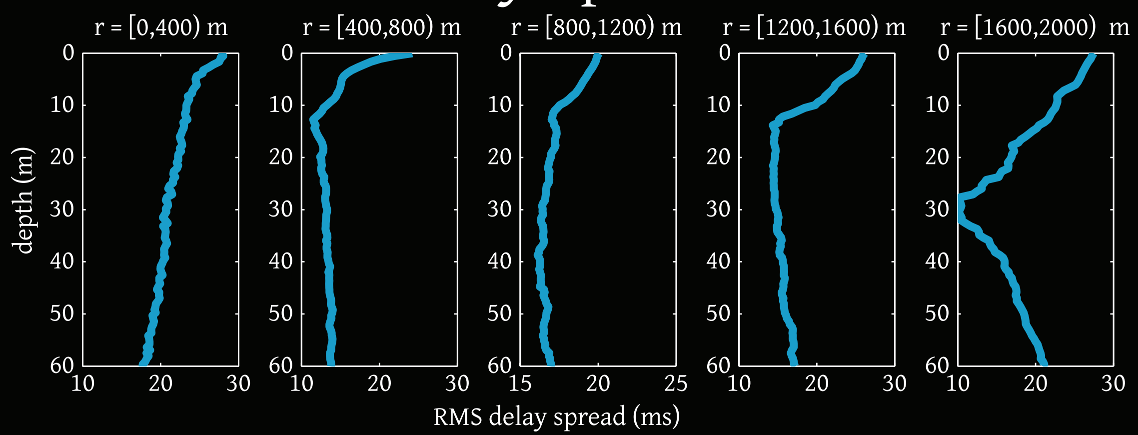
2. Model Acoustics (GRAM + BELLHOP)

SSP TL





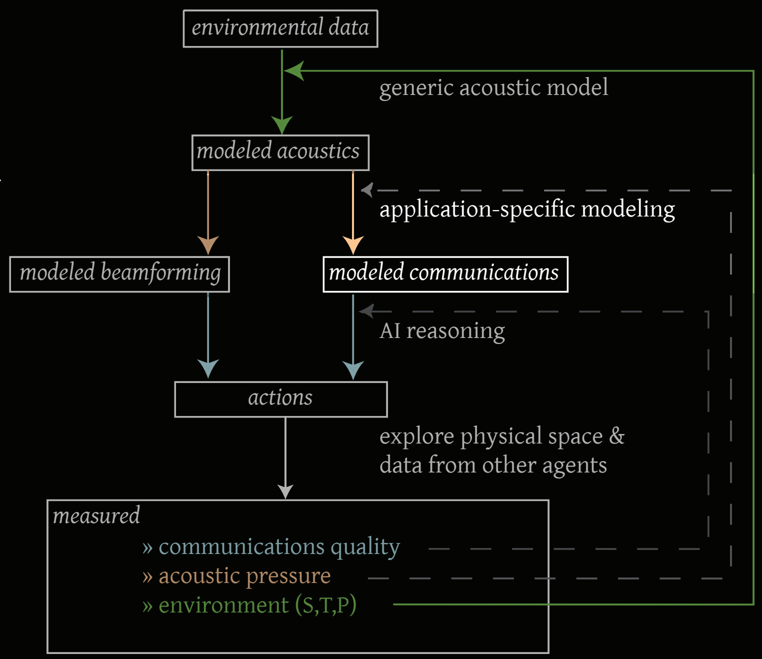
Delay Spread

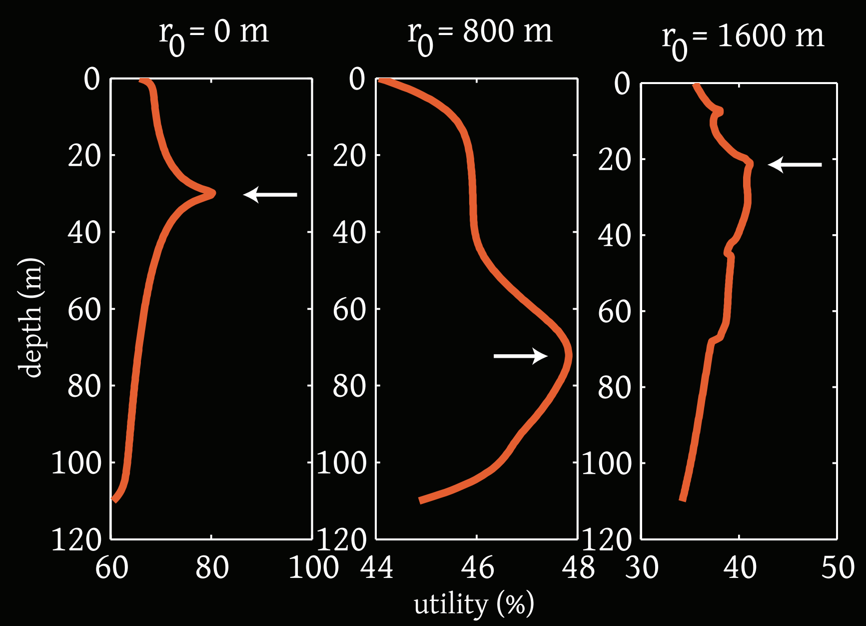


3. BHV_AcommsDepth Utility Function

Averaged modeled acoustic intensity in range for future horizon:

- based on AUV's instantaneous speed heading
- scaled by local extrema or overall utility metric from past data



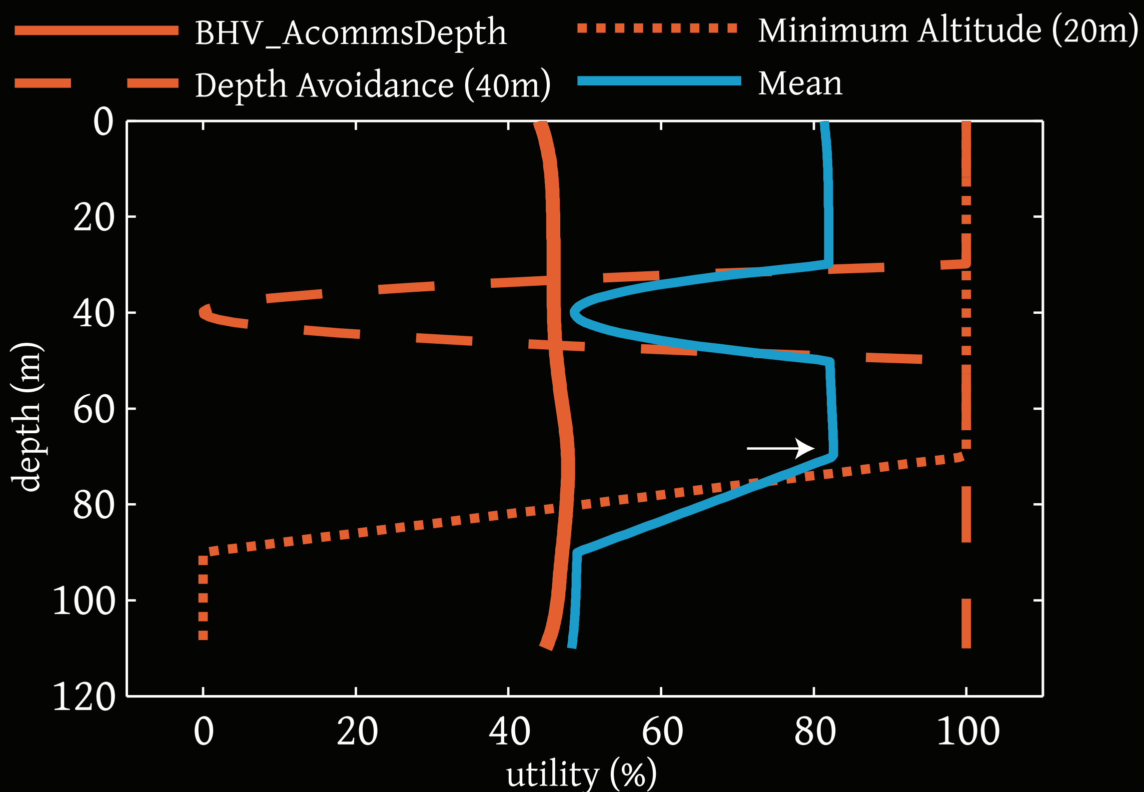


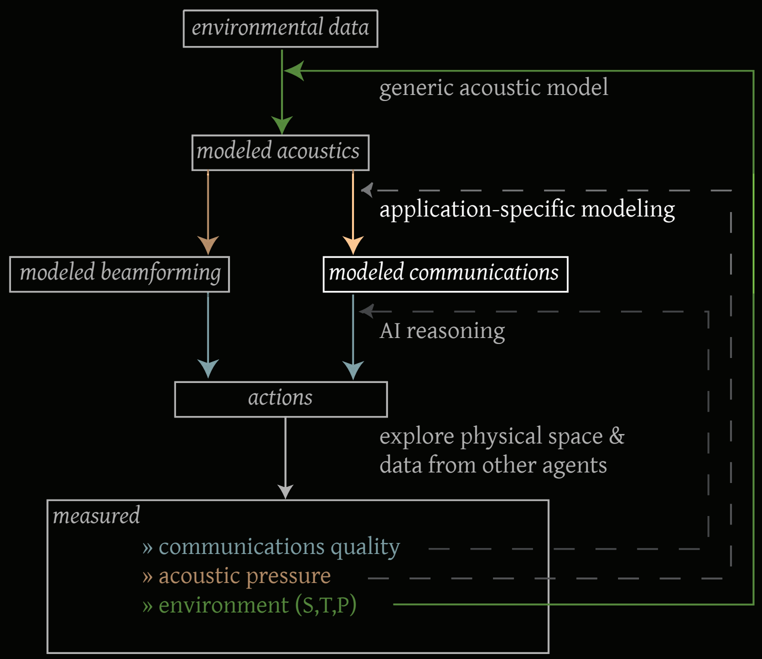
0% utility: TL = 108 dB (<1% messages received)

100% utility: TL = 0 dB

3. BHV_AcommsDepth Utility Function

Interaction with other behaviors:





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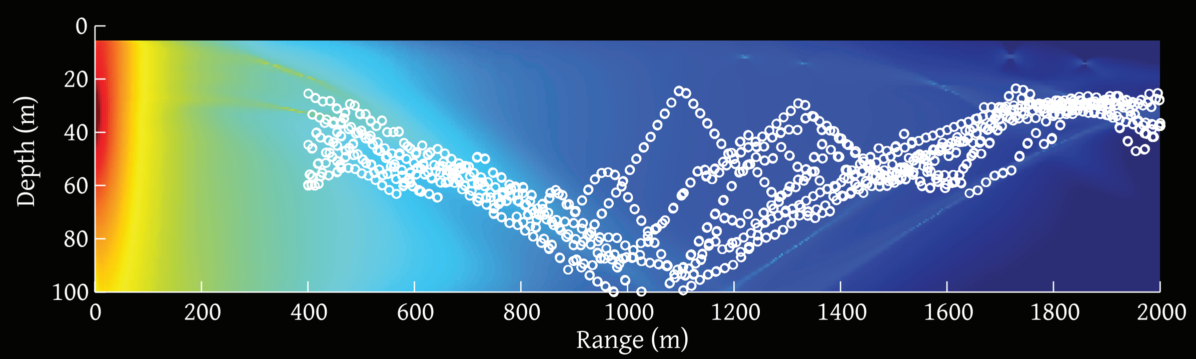
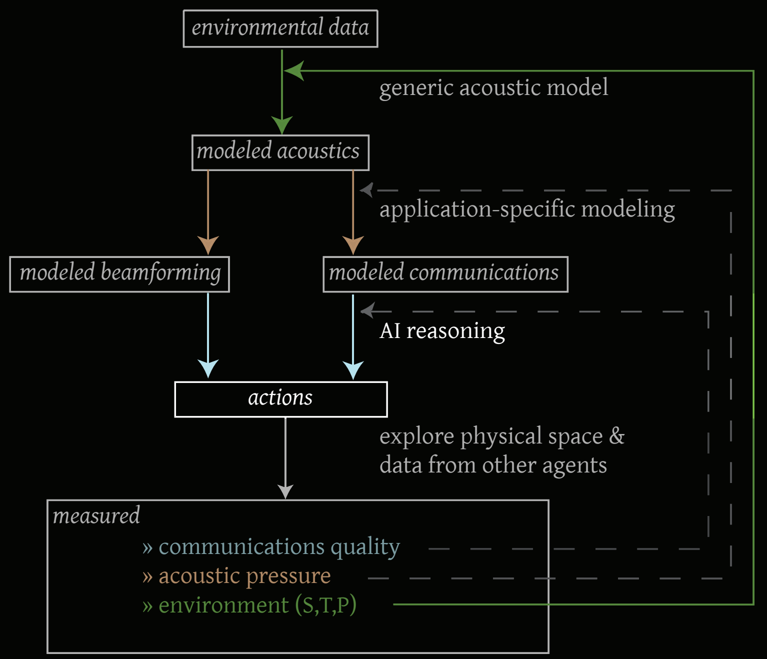
4. Transit

2010-08-08 runs:

- white dots: AUV position
- Buoy: range = 0 m, depth = 30m
- Underlay: TL model from representative SSP.



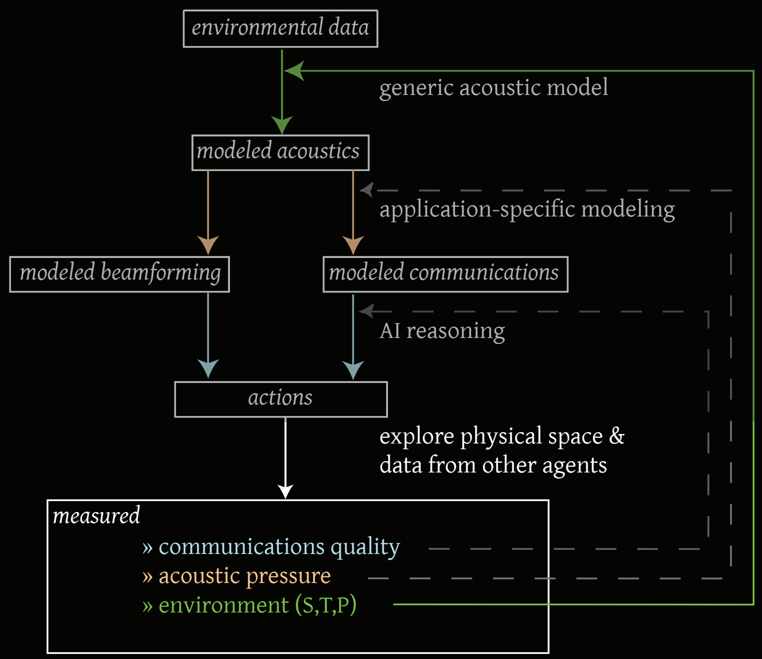


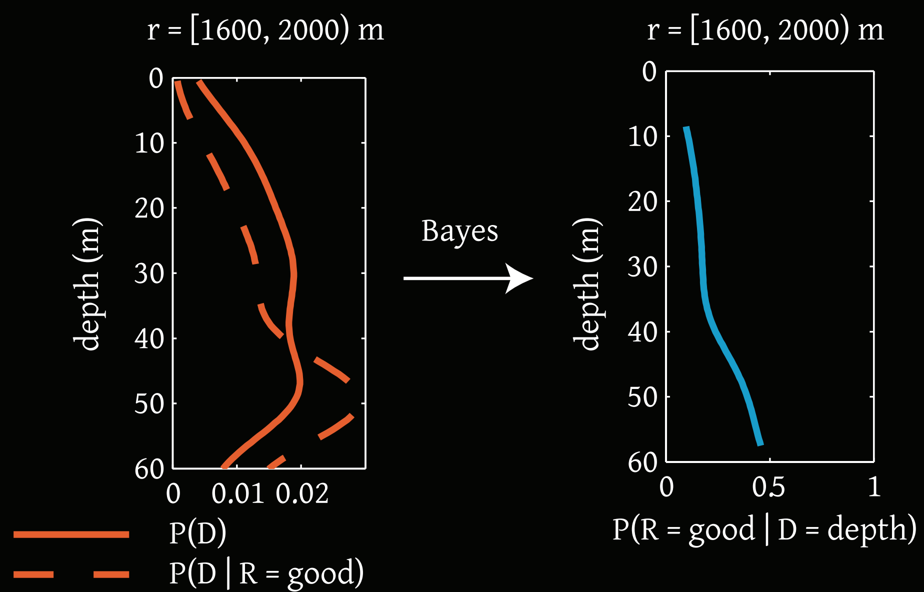
5. Measure data and feedback

Measured data:

1. Vehicle depth:
   - random variable D

2. Received 32 byte messages (good = passed CRC without errors):
   - Bernoulli random variable R (good / bad)





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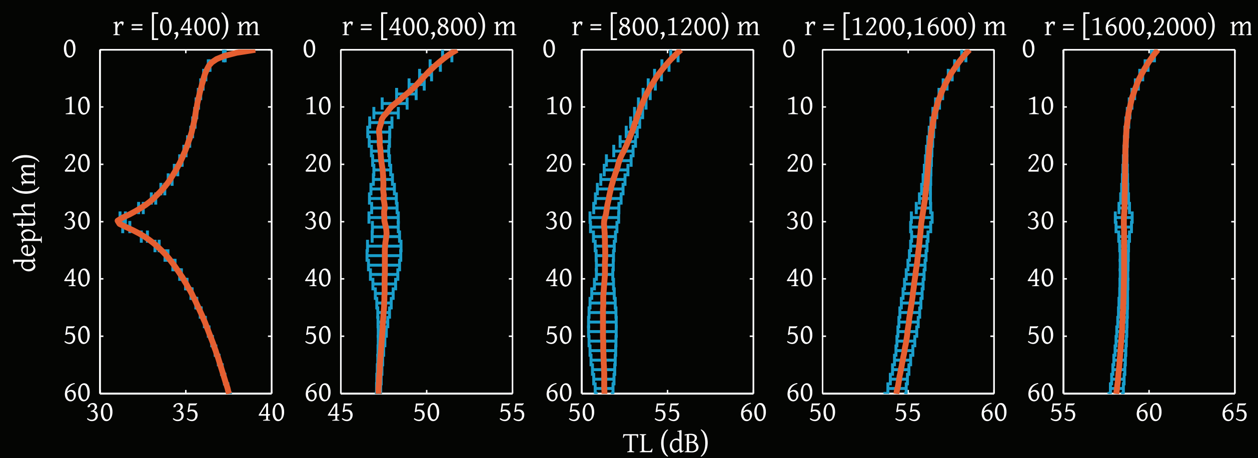
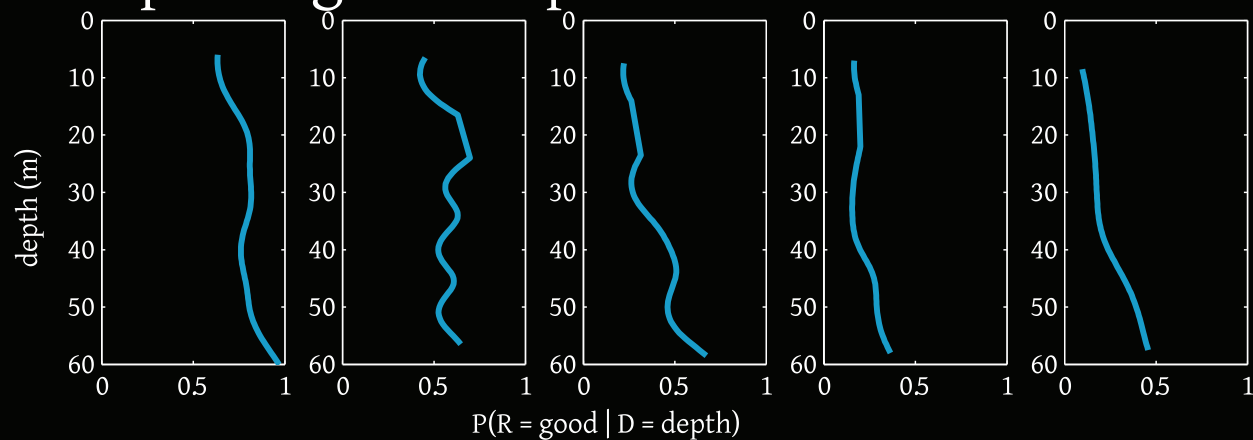
Schneider & Schmidt: Improving Acomms on AUVs
UComms 2012 - Sestri Levante, Italy

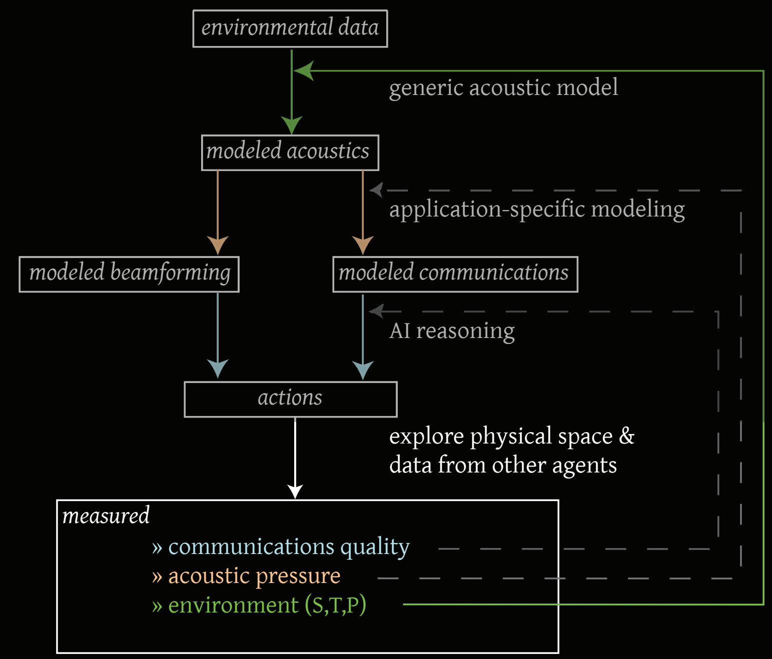
5. Measure data and feedback

μ, σ for modeled TL for 111 measured SSPs



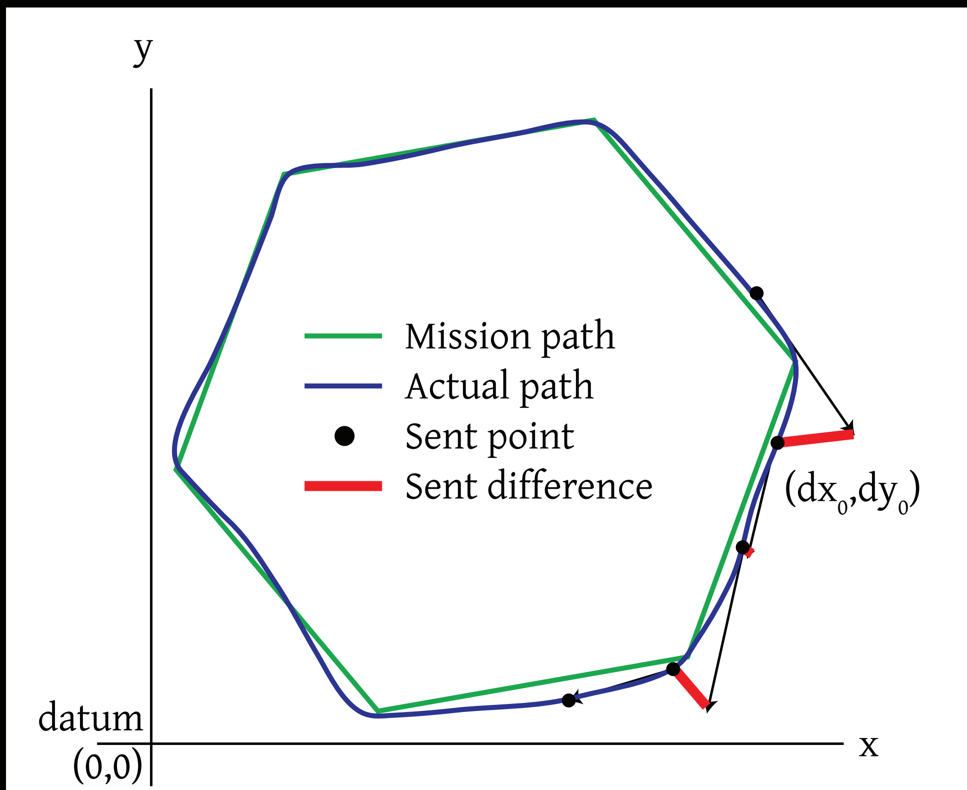
Measured Bayesian probability of message receipt for given depth

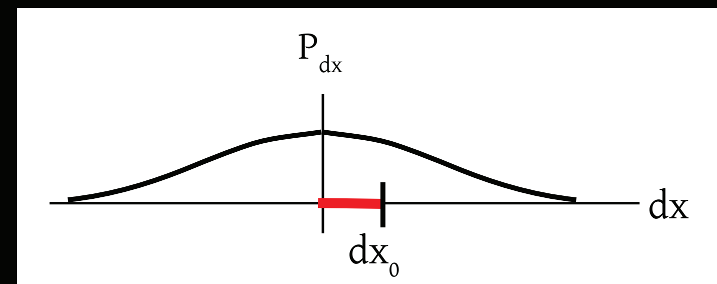


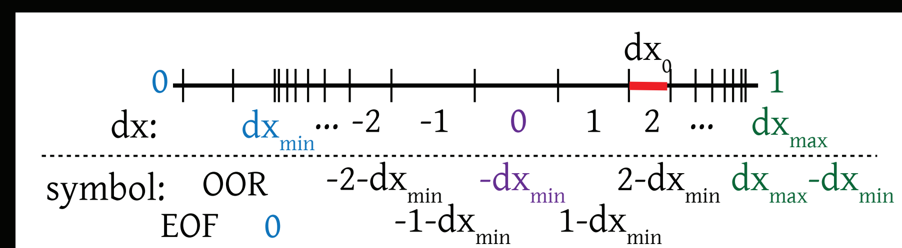


Non-disruptive: source coding

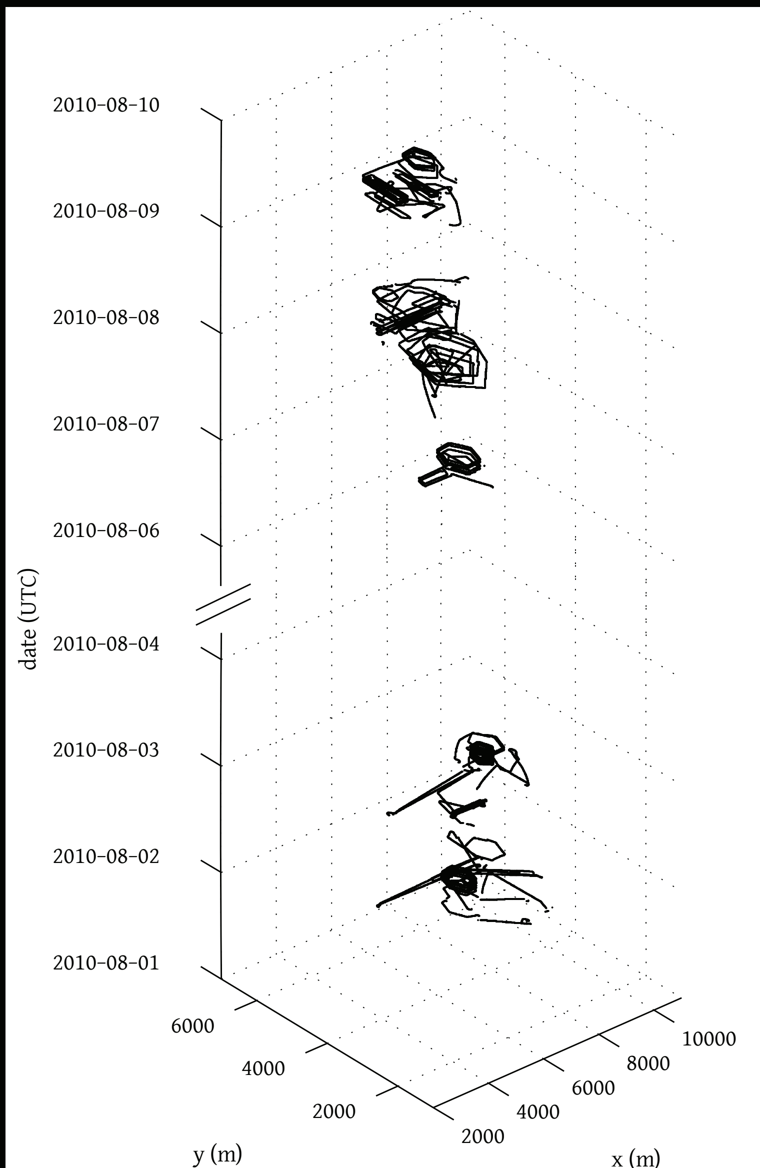
Use mission knowledge and models to greatly improve compression of vehicle data, e.g. position in space (x,y,z).



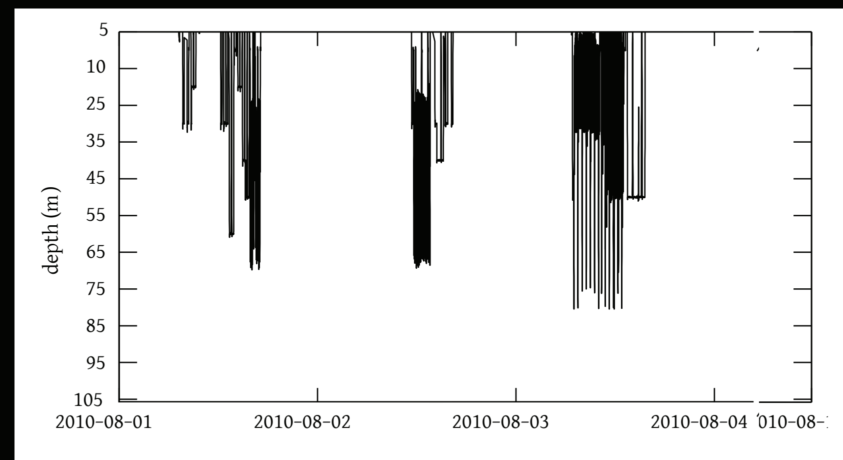


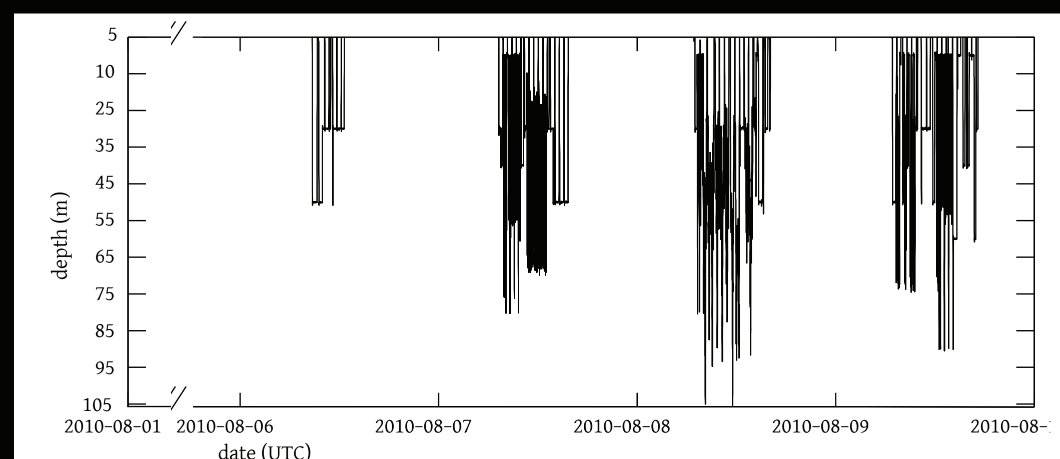


Source coding: GLINT10 data



Position of single AUV doing many different missions over 60+ hours dive time:

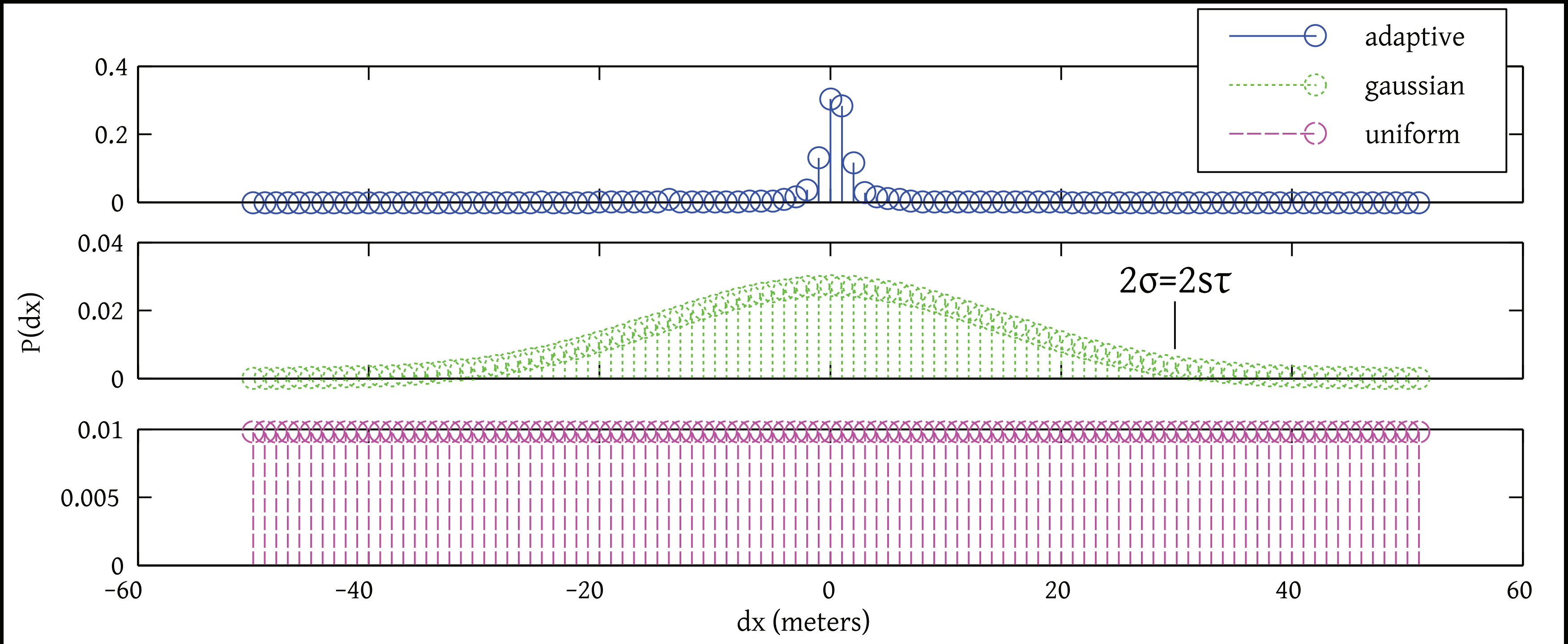




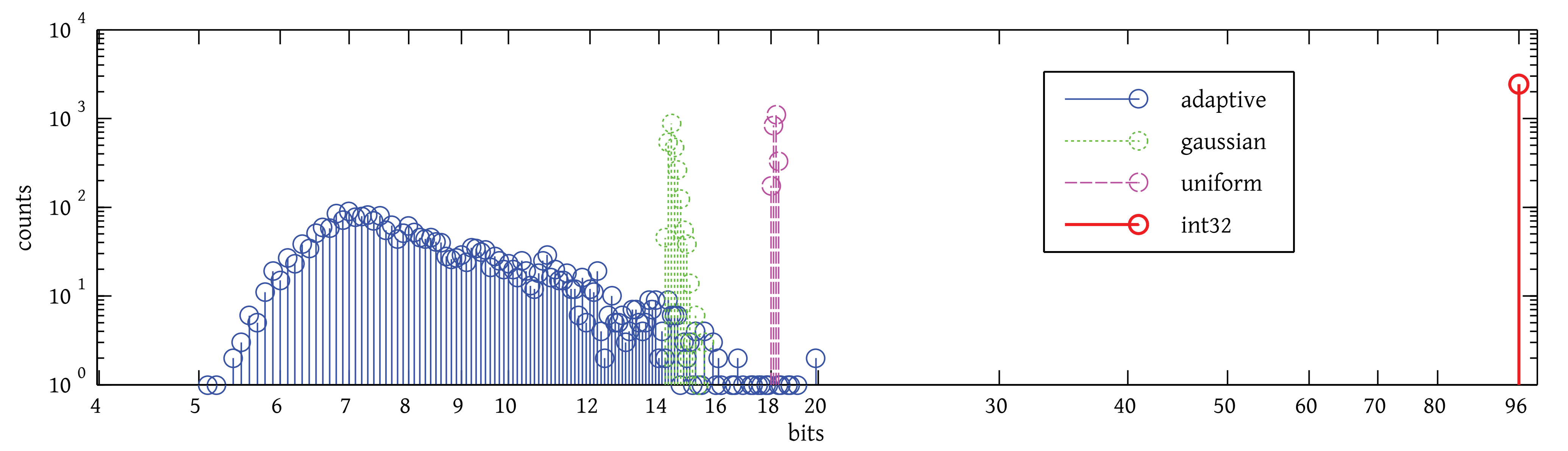
Source coding: models

Three models (s = AUV speed, τ = time between updates):

1. Adaptive: generated from cumulative frequencies
2. Gaussian (σ = sτ)
3. Uniform over [-5sτ, 5sτ)



Source coding: results



Encoded bits/message:

1. Adaptive: μ = 8.66, σ = 2.2
2. Gaussian: μ = 14.46, σ = 0.16
3. Uniform: μ = 18.16 , σ = 0.080
4. REMUS CCL: μ = 61, σ = 0
5. int32 (uncompressed): μ = 96, σ = 0

Summary

Two complementary techniques, which are in turn complementary to signal processing advances:

- Disruptive (changes vehicle motion)
- Non-disruptive (does not change mission)

As acomms become standardized, we want to see:

- quantification of various physical effects on performance. How much does multipath, SNR, Doppler matter?
- flexibility in choosing bit-rates, bandwidth, etc. to suite vehicle mission needs & knowledge.

Acknowledgments

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