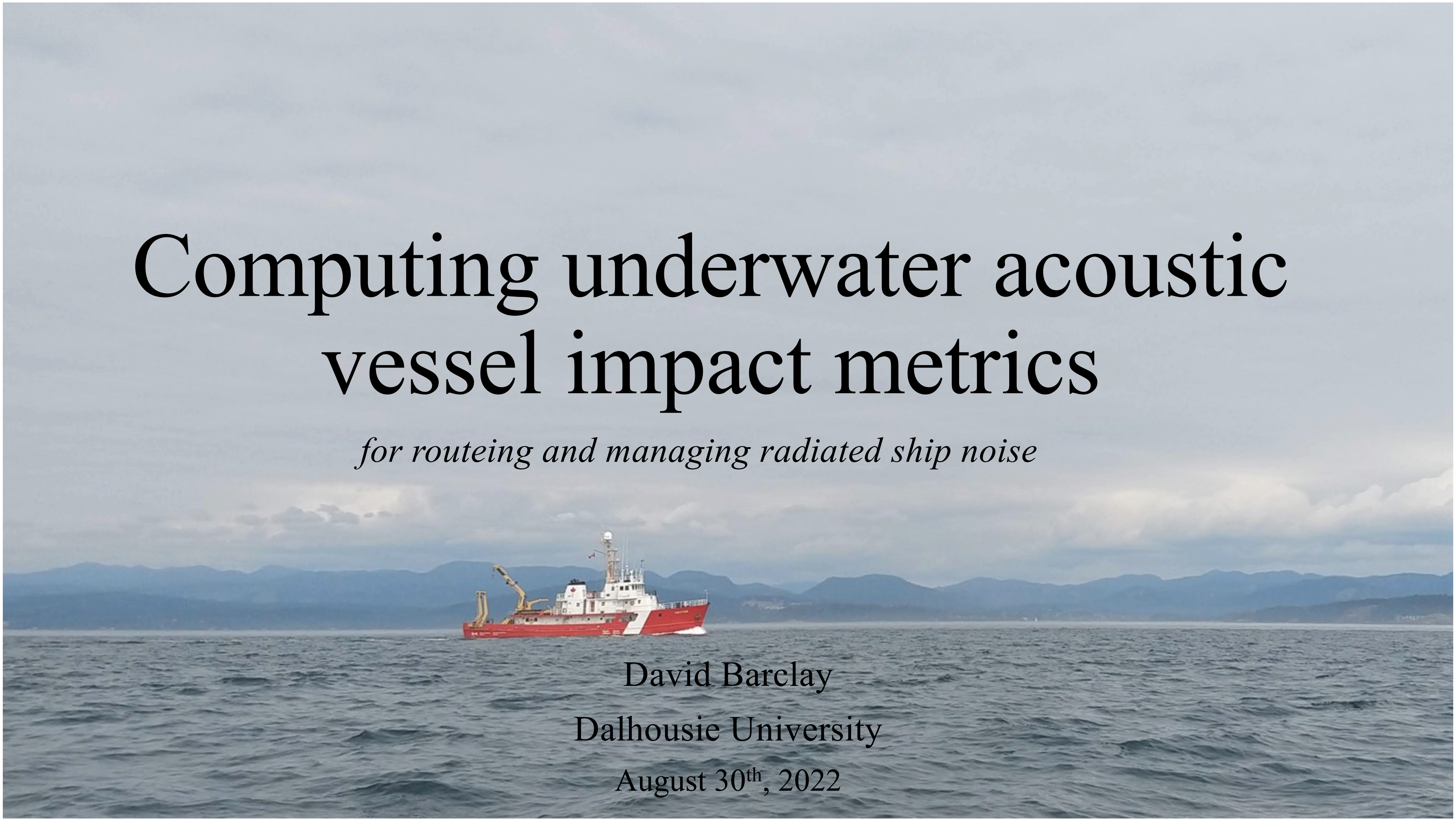
Computing underwater acoustic vessel impact metrics

for routeing and managing radiated ship noise



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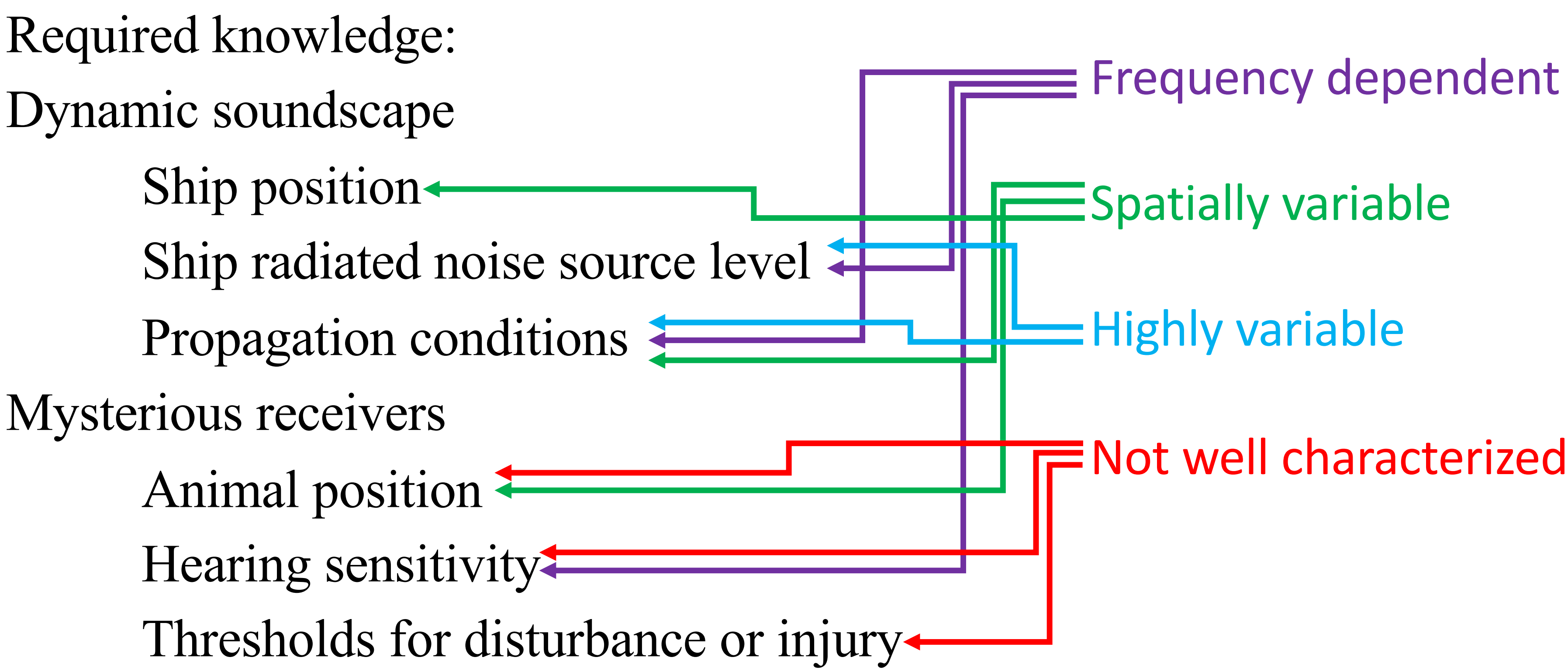
August 30th, 2022

Predicting animal sound exposure



Mapping soundscape

- Turn best input data into a minute-by-minute noise map.
- Compute sound exposure with a model of animal motion.
- Computationally expensive as space (3D) and time are so vast…
- Verifiable by measurement

A. Farcas et al. / Science of the Total Environment 735 (2020) 139509 3

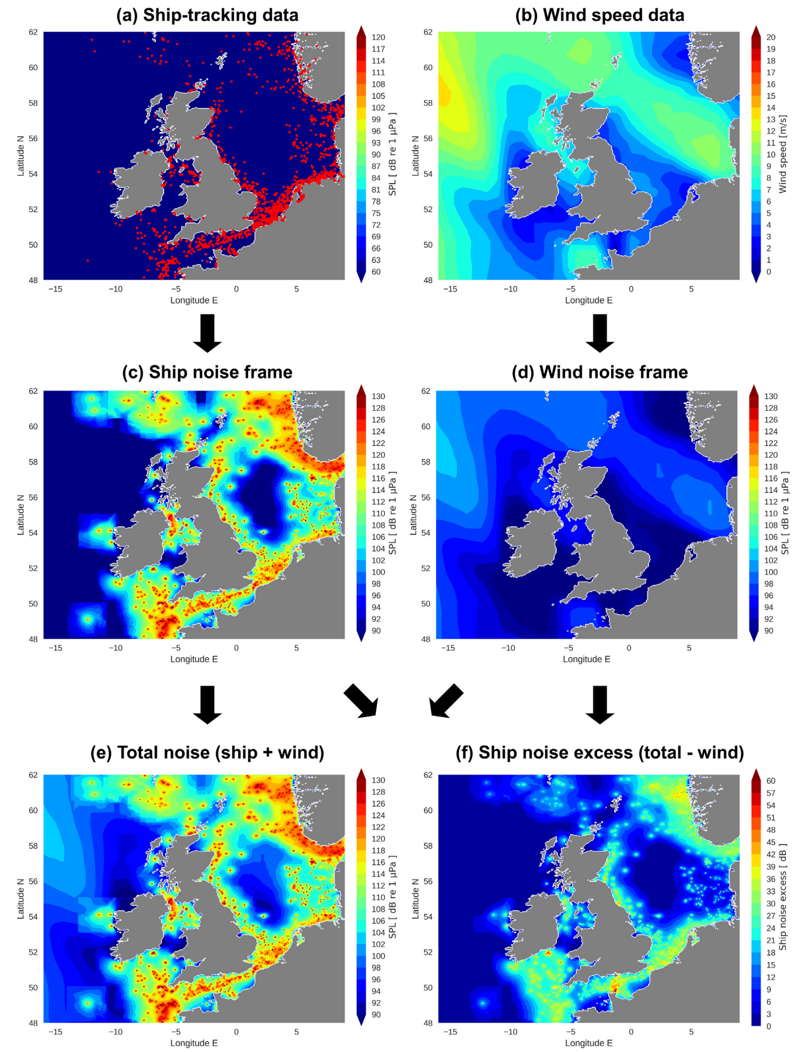


Fig. 1. Construction of total noise and ship noise excess maps. (a) sAIS ship-tracking data frame; (b) Wind speed data frame; (c) Ship noise frame corresponding to (a); (d) Wind noise frame corresponding to (b); (e) Total noise frame, sum of (c) and (d); (f) Excess level of ship noise above wind, (e) minus (d). Such frames were computed at 10-min intervals for calendar year 2017.

Farcas et al. (2020)

Mapping sound exposure

Turn best input data into:

a probabilistic noise map

and

animal map.

Use to compute exposure risk.

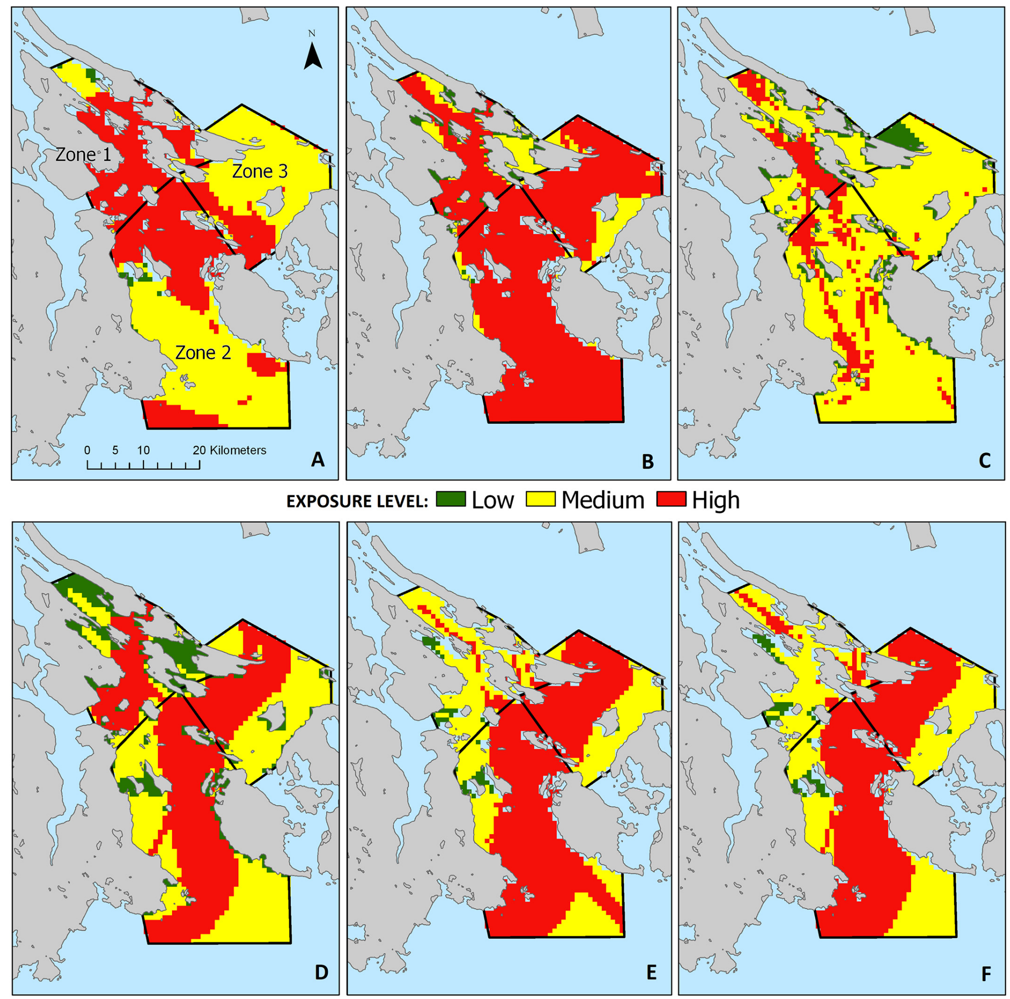


Fig. 16. Maps showing exposure levels for ferries (A), tugboats (B), recreational vessel (C), vehicle carriers (D), containers (E) and bulkers (F). Low exposure levels (green) correspond to $L_{eq} \le 60$ dB re 1 μPa, medium exposure levels (yellow) correspond to $60 < L_{eq} \le 90$ dB re 1 μPa while high exposure levels (red) correspond to $L_{eq} > 90$ dB re 1 μPa. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Cominellie et al. (2018)

Case study: Tugs in transit in the Salish Sea

How can we translate a reduction in radiated noise level into a Southern Resident Killer Whale (SRKW) habitat relevant metric?

1. *Compute a reference 'acoustic footprint'*

2. Translate into 'detection', call masking, echo location masking, sound exposure level.

(3. Compare individual tugs against the reference)

A Monte-Carlo approach

Choosing randomly (from best available data)

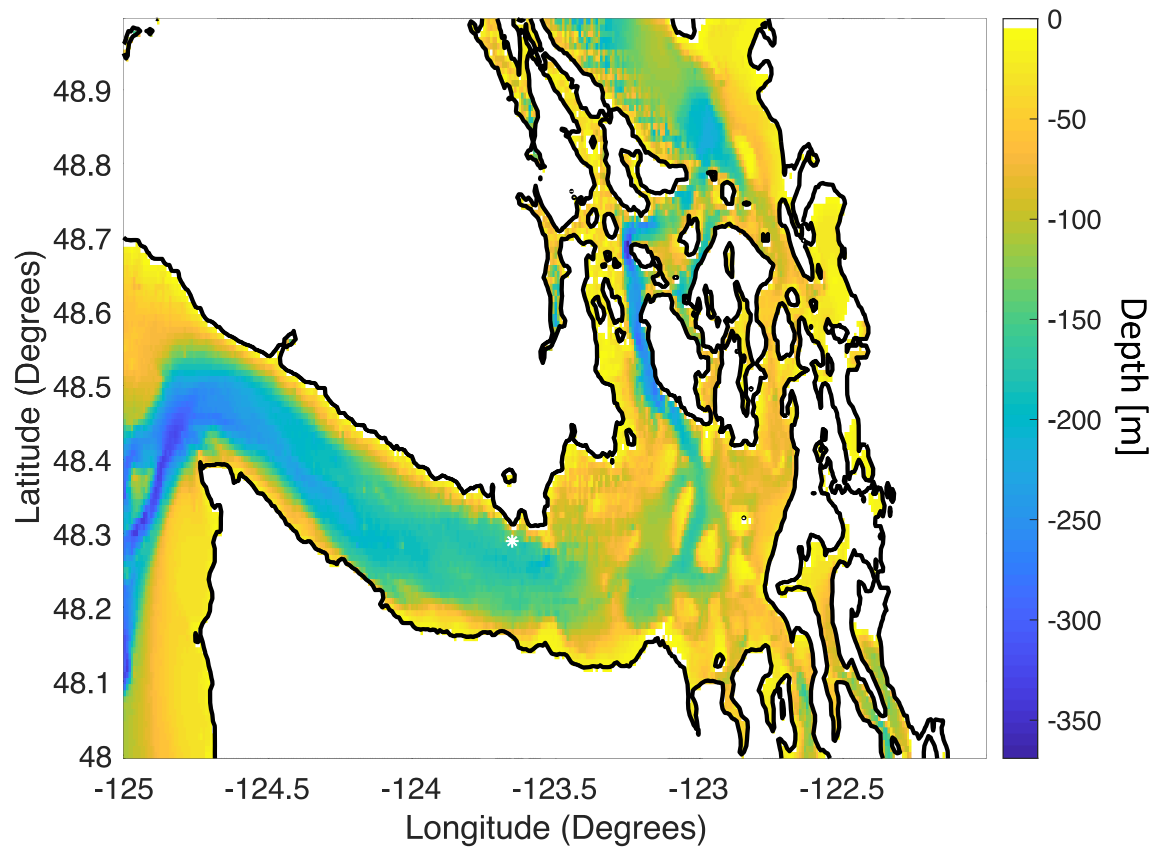
Ship position
Ship radiated noise source level
    Speed
Propagation conditions
Animal position
    (lat, lon)
    depth

For a large number of runs, these interrelated factors will converge to a 'canonical environment'

and repeating many many times.

The canonical environment in the Salish Sea

- Isovelocity SSP
- Depth
  250 m
- Seabed
  1700 kg/m3
  1640 m/s
- Whale depth
  $F_X(z) = e^{\beta z/250}$
  β fit from data
- Ship source level
  - from data



Acoustic footprint algorithm

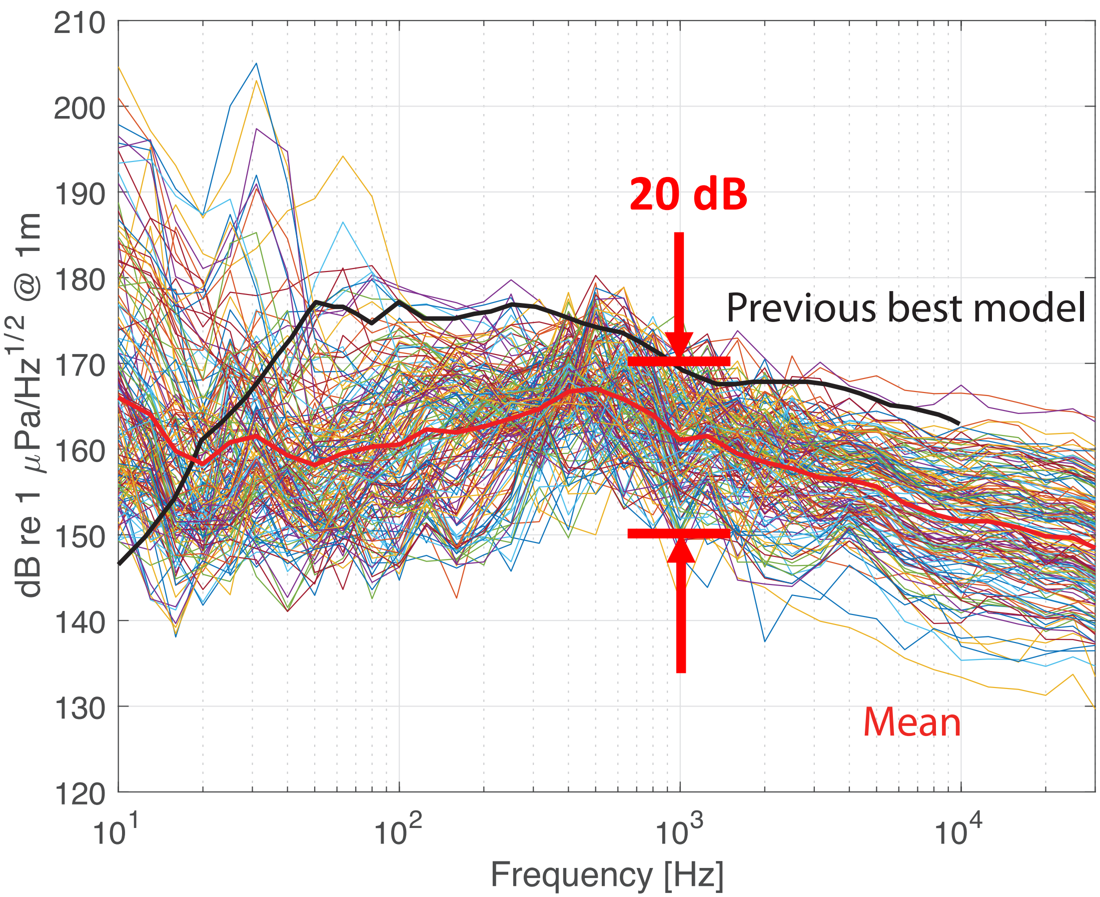
For a single realization

1. Choose source level from library and probabilistic source characteristics (speed)
2. Choose receiver depth according to parameterized whale depth cumulative distribution function (CDF)
3. Compute field at receiver at 100, 500, 1000, 10,000 and 30,000 Hz

From the ensemble

- Compute PDFs of received level (detection range), communication and echolocation space reduction.

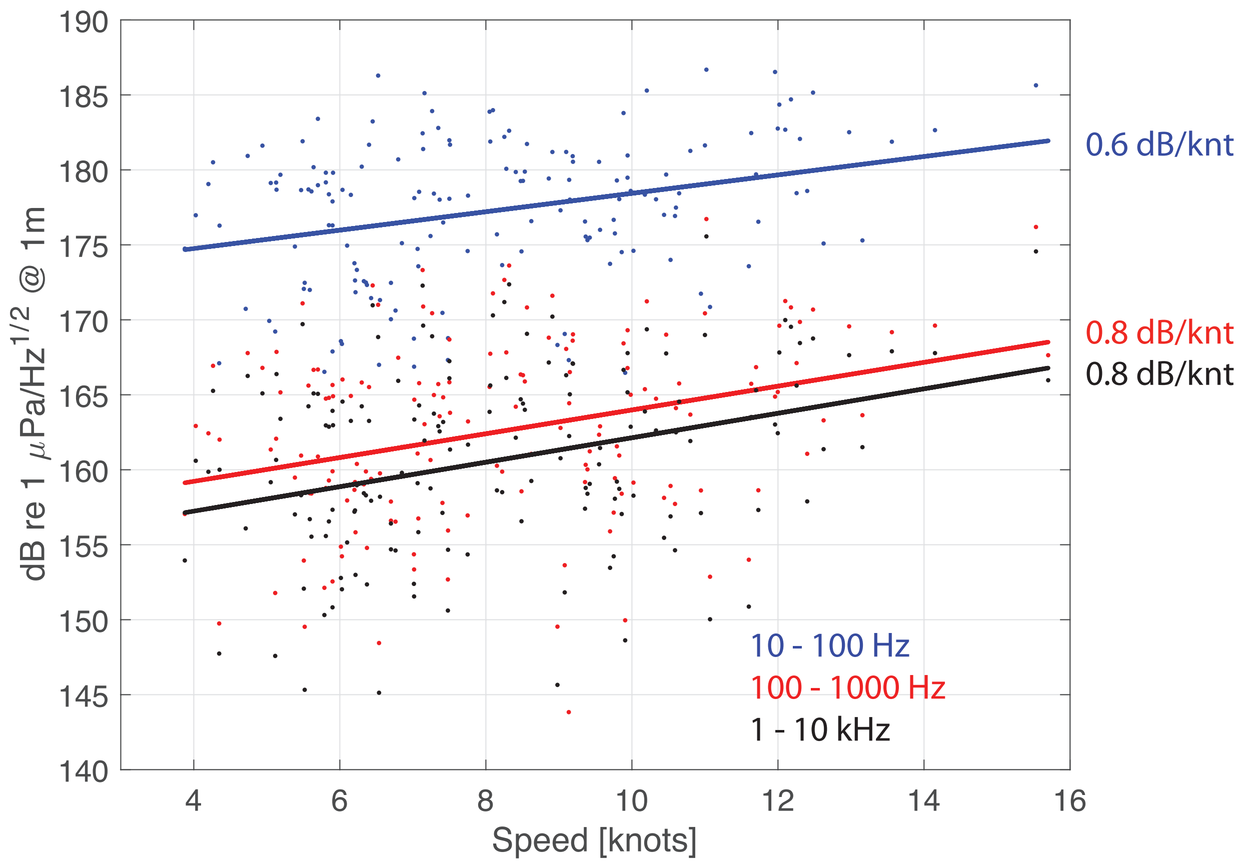
Tug source levels measured by ECHO



Vessel speed dependence

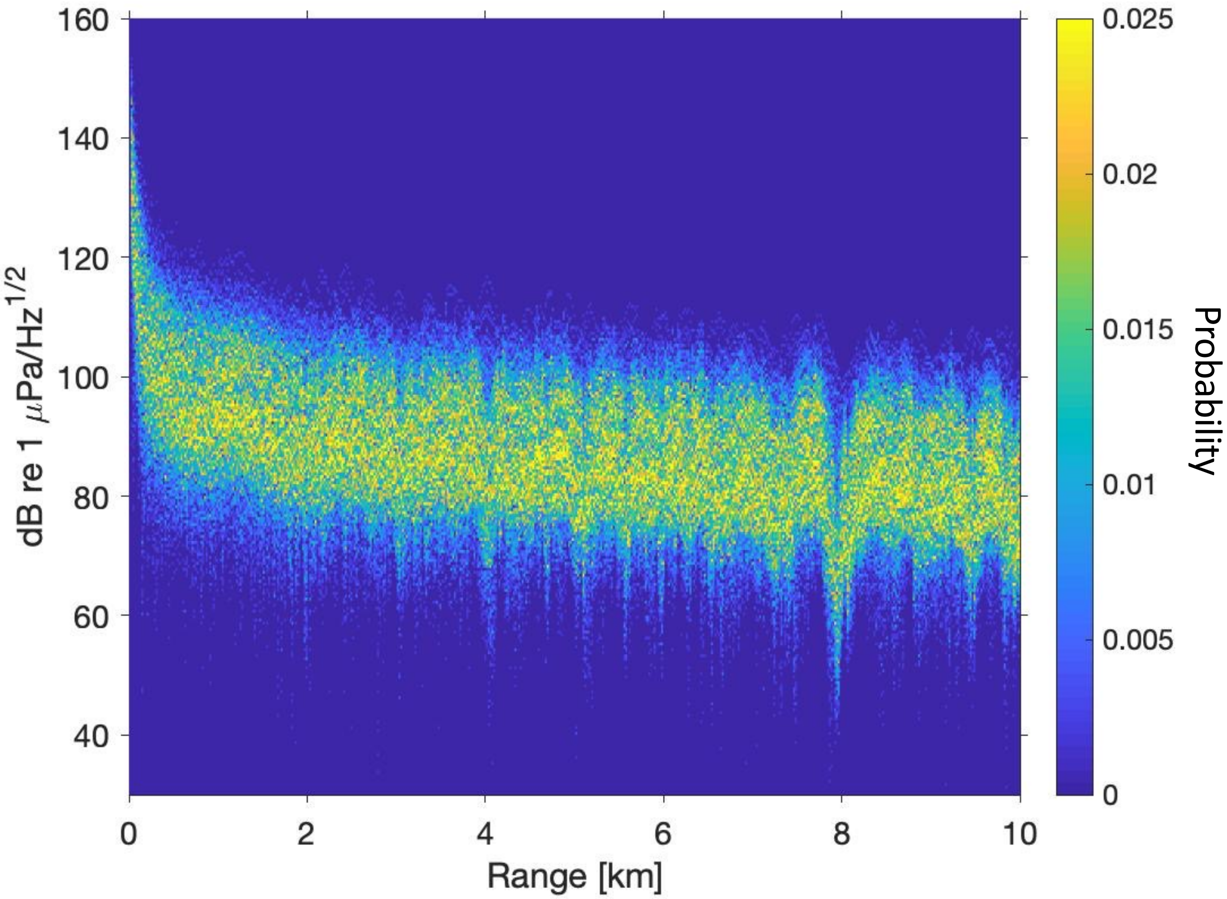
Random speed chosen from speed PDF

SSpeed dependence added to randomly chosen source sound level using empirical relationship.



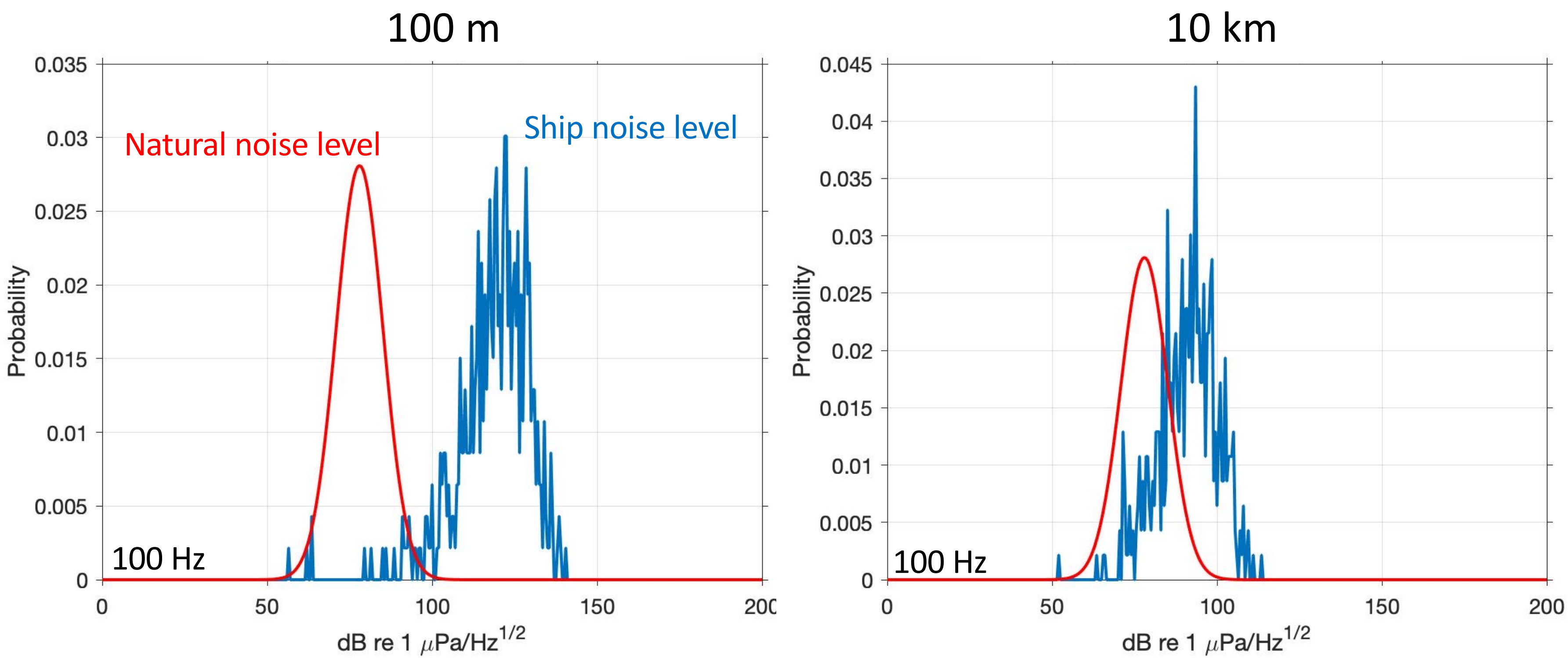
SRKW receive level probability at 100 Hz

500 realizations, 160 source spectra



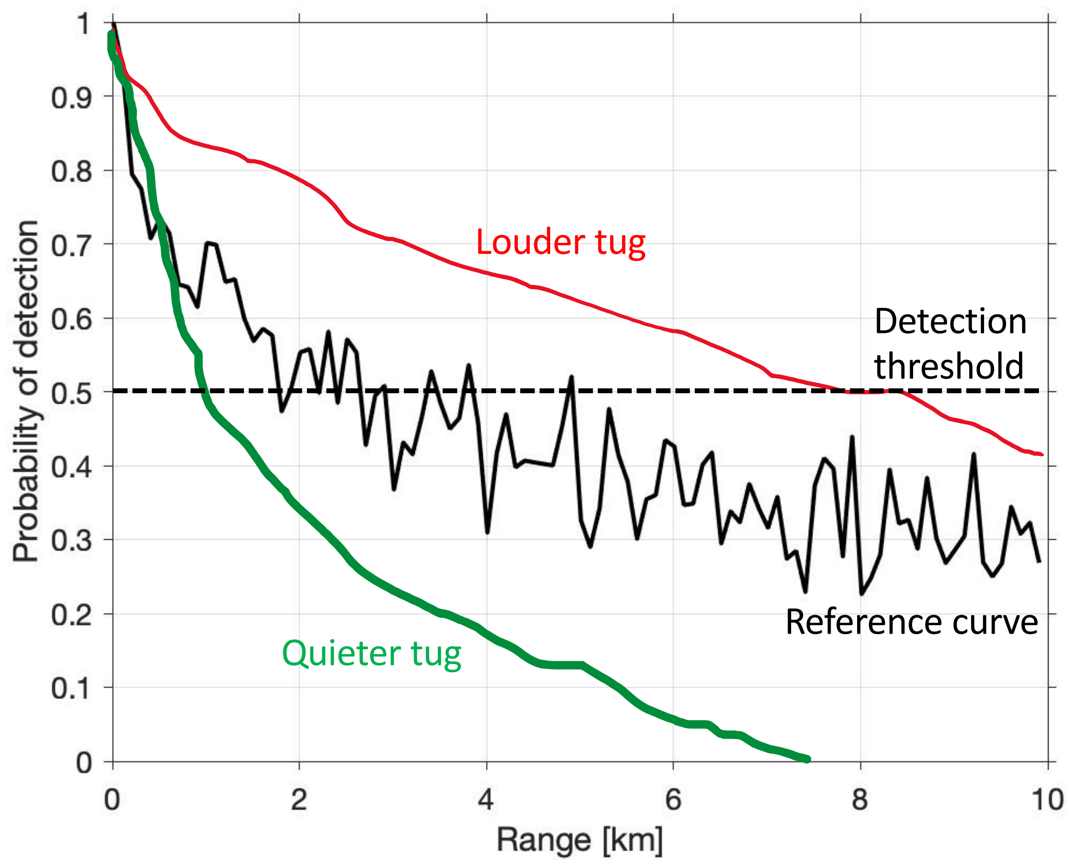
Compute probability of tug detection vs range

Can the whale hear a tug?



Noise level derived from ONC 'COVID-19 anthropause' data with a Gaussian fit at each frequency

Detection probability as a comparison metric



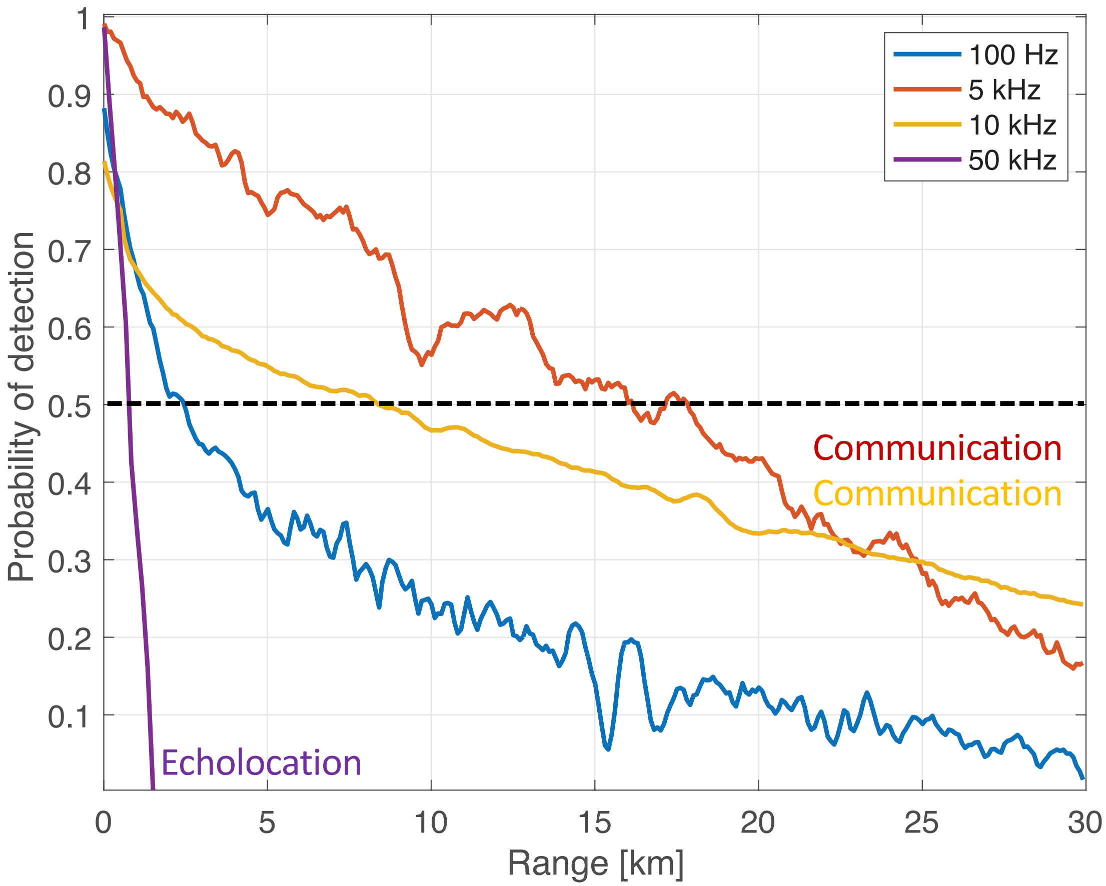
A direct comparison of the 'acoustic footprint' as an area in a Salish Sea type environment

Further reduce dimensionality of result by applying a detection threshold.

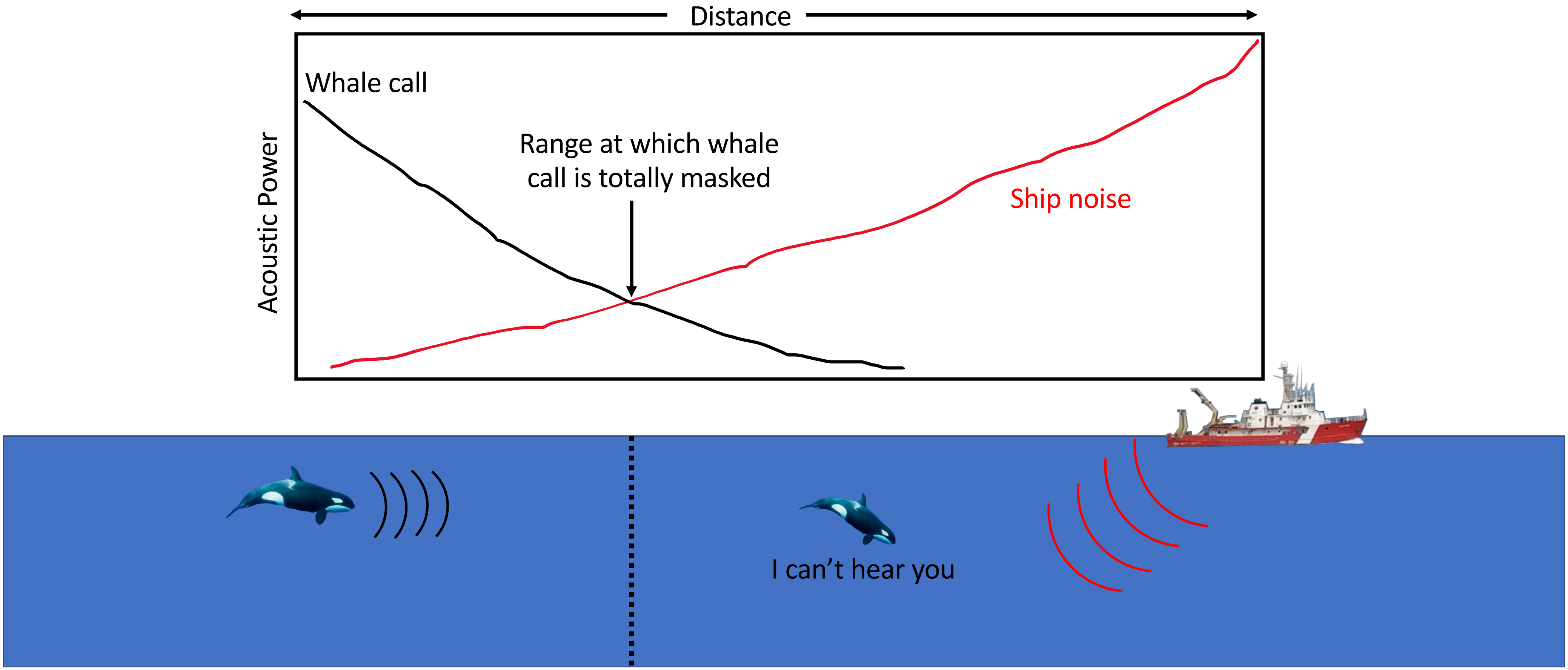
e.g. "The louder tug pollutes to a 4x greater range than normal"

"The quieter tug pollutes ½ as much as a normal one"

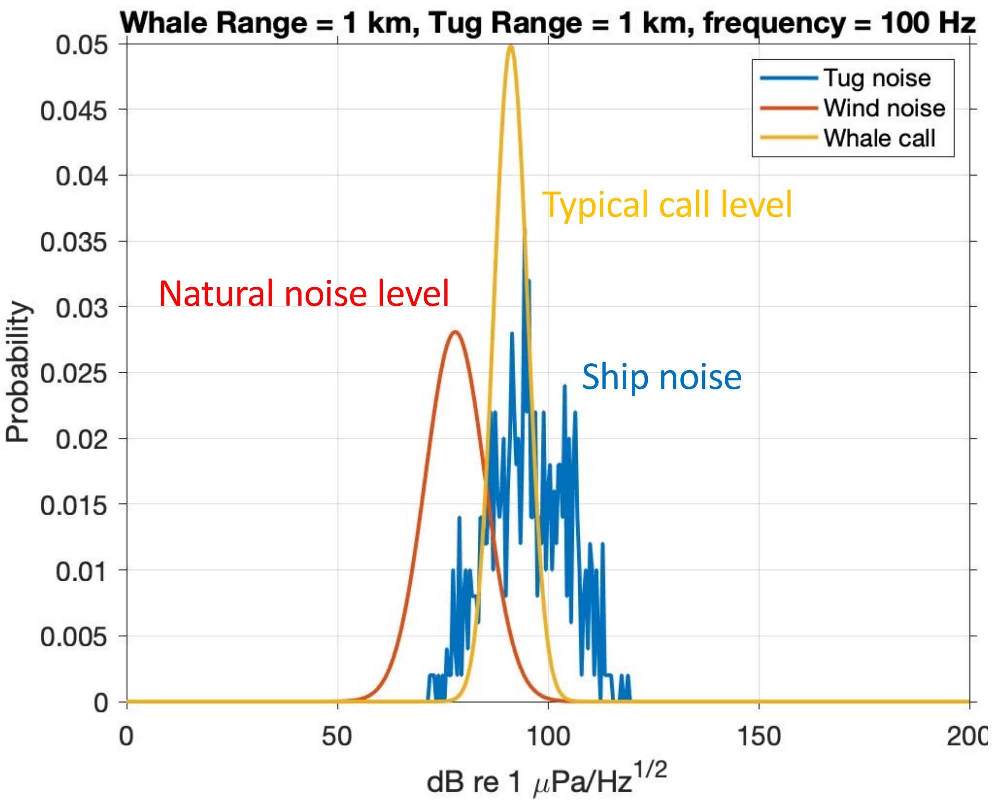
Reference detection ranges over frequency

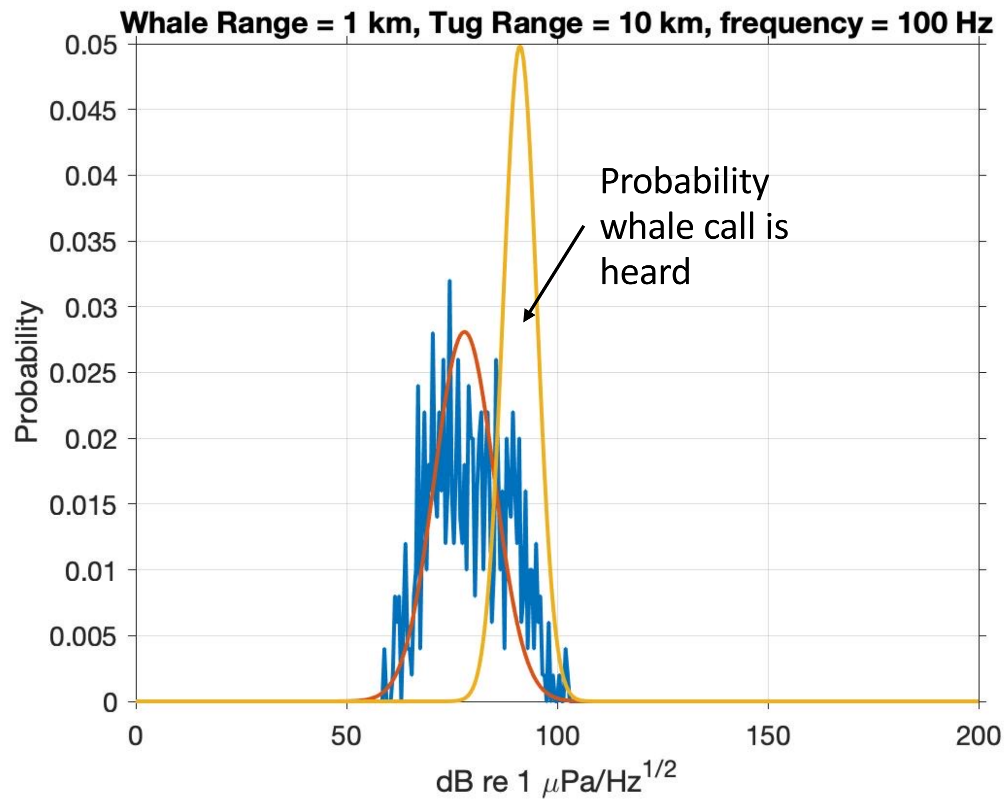


Comparison of received levels: masking

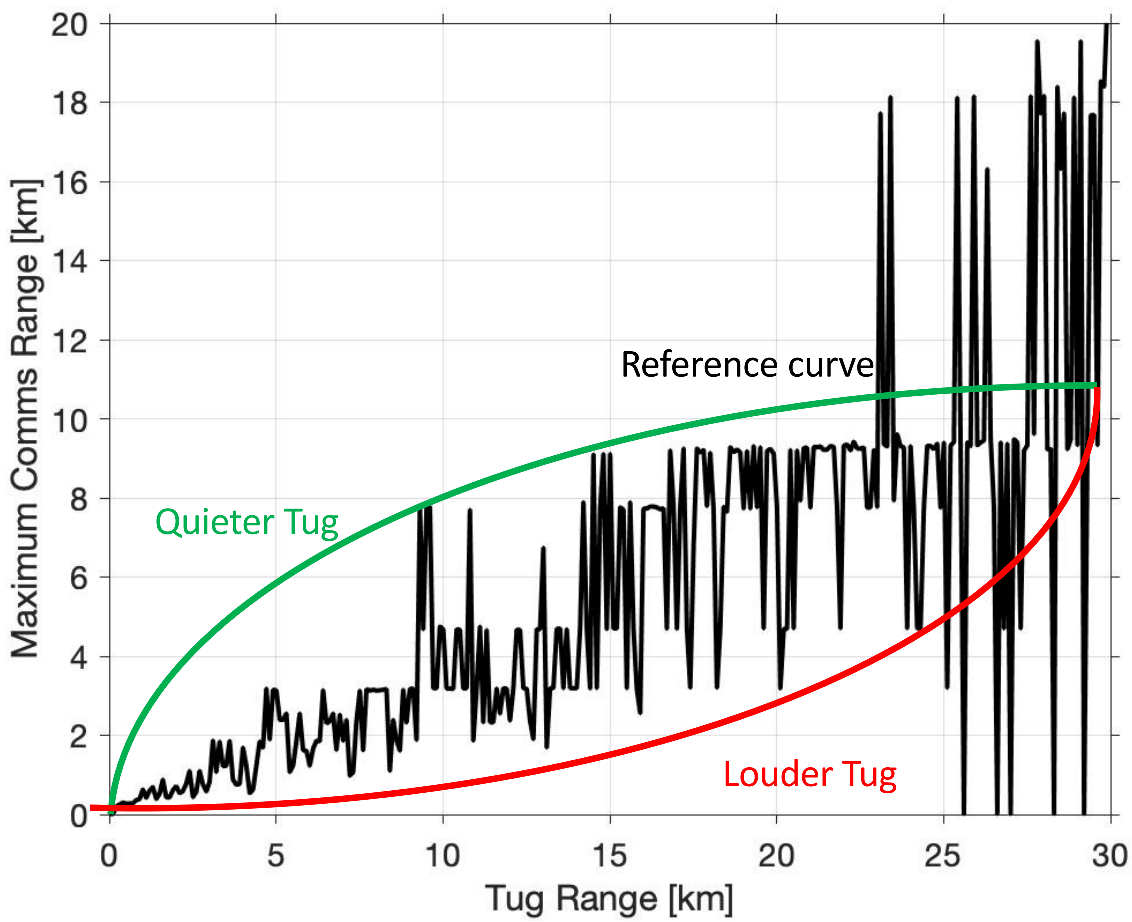


Communication masking



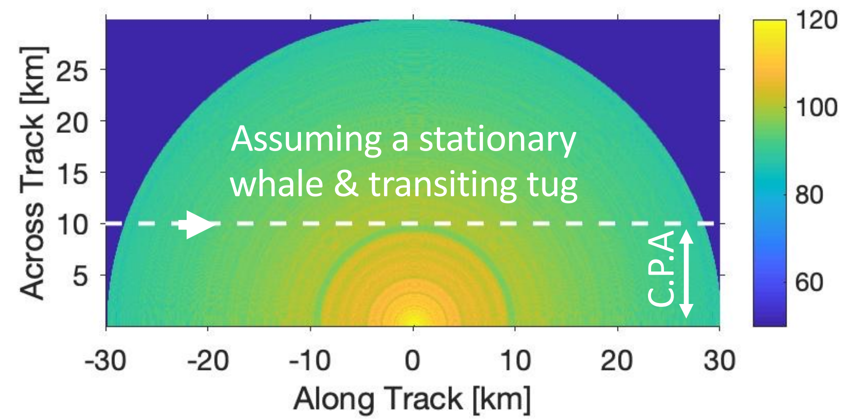


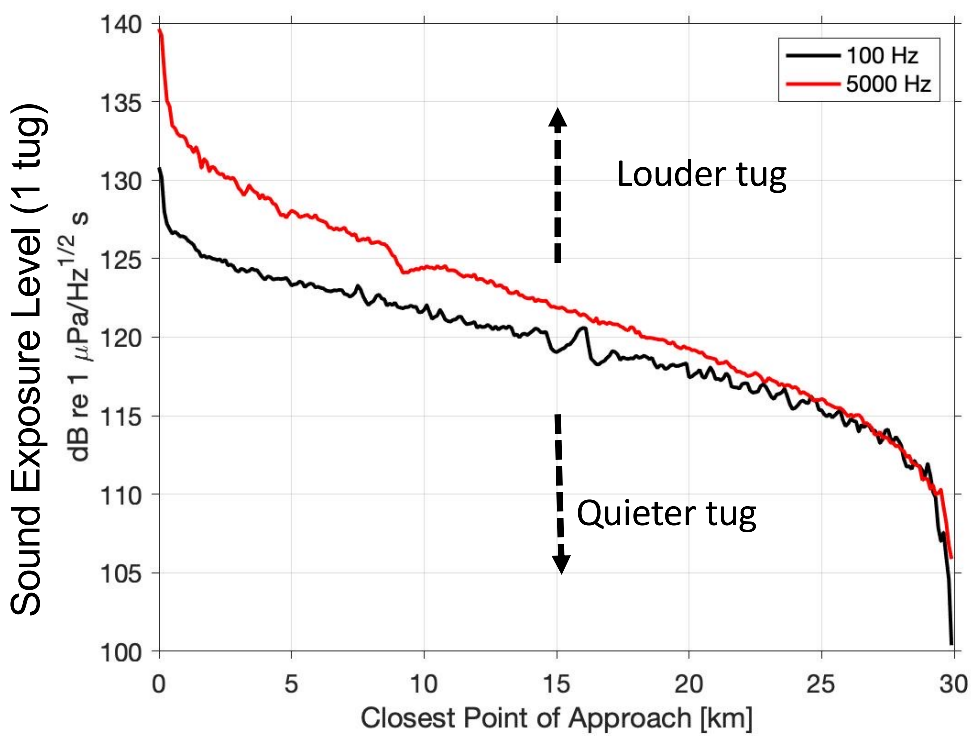
Reference: Maximum SKRW communication range



Sound exposure level

from a single 'normal' tug pass





24-hour SEL thresholds for hearing loss:
178 dB re 1 μPa s (temporary)
198 dB re 1 μPa s (permanent)

Constant tugs passing for 24 hours would not reach these thresholds.

Useful as a comparison metric

Conclusions

Predicting absolute acoustic impacts is computationally expensive with many accumulating uncertainties

Monte-Carlo acoustic footprints to compute **reference** metrics:

Detection range

Maximum communication (masking) range

Single vessel pass sound exposure levels

Echolocation masking ranges were very small (10’s m)