Mapping Underwater Noise Footprints for Ship Traffic in the Canadian Arctic

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WCS CANADA

Underwater Noise from Shipping

Photo: The Shipyard

Sources:

- **propeller cavitation**
- engines
- other operations on board
- ice breaking

- Shipping noise can be very loud
  - Averaging around 175-180 dB re 1 uPa
  - Reaching levels of 200 dB re 1 uPa or more for ice breaking
- How loud a ship is varies greatly depending on the size of ship, speed it’s traveling, among many other factors.

Underwater Noise from Shipping

NOTE: Sound in water is measured using a different reference pressure level than sound in air, and cannot be directly compared: **re 1 uPa in water** and **re 20 uPa in air**.

For example, a rock concert may be 120 dB re 20 uPa in air, which is equivalent to 180 dB re 1 uPa in water. An average container ship is 180-190 dB re 1 uPa in water.

Underwater Noise and Marine Life

Underwater noise causes a variety of issues in marine life:

- Acoustic masking – blocking important acoustic cues from being heard
- Behavioural disturbance
- Hearing damage (temporary or permanent)
- Death:
    - Barotrauma
    - behavioural disturbance leading to a rapid change in depth (the bends/decompression sickness)

Our Goal:

- Build a shipping noise footprint map for the Canadian Arctic/Northwest Passage
  - Complete: Lancaster Sound
  - In progress: Western Arctic (Kitikmeot and Inuvialuit Regions AND the Alaska North Slope)
- Overlay these noise footprints with important areas for marine mammals to estimate noise exposure/risk

- Study Area: the new Tallurutiup Imanga (Lancaster Sound) National Marine Conservation Area in Nunavut, Canada

Noise Metrics

Depends on the question being asked:

- What are the average underwater noise levels in a region?
- What are the maximum underwater noise levels in a region
- Will underwater noise in this region cause:
  - hearing damage?
  - behavioural disturbance?

Noise Metrics

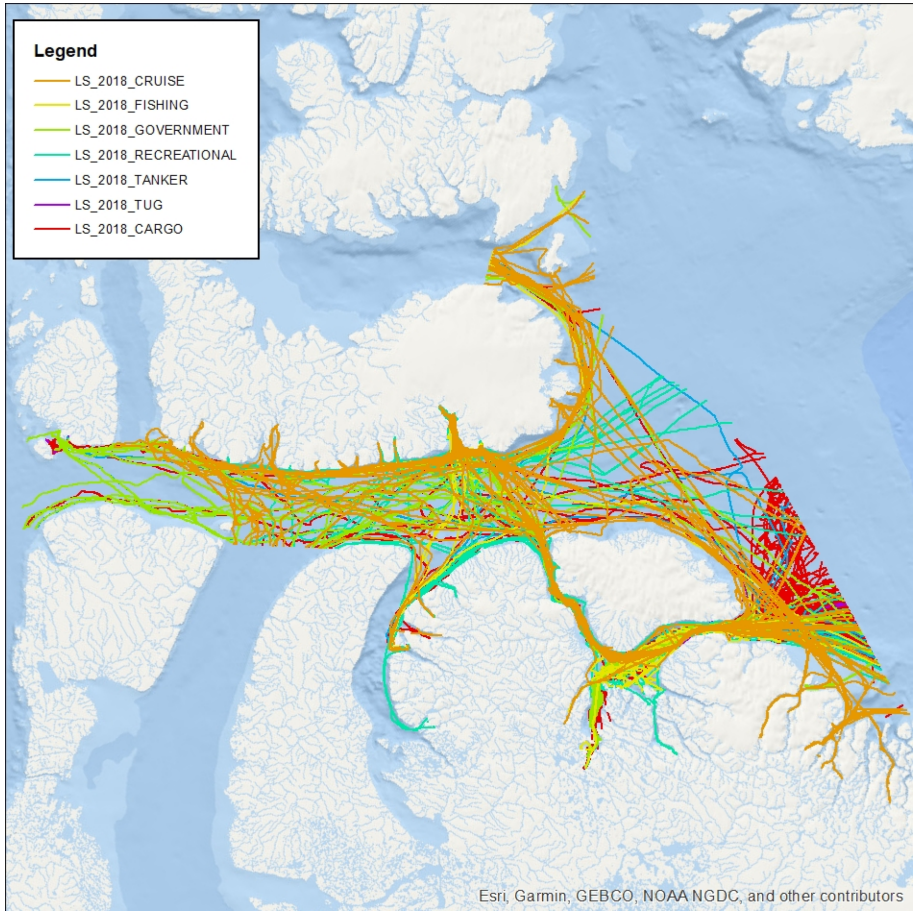
Question	Duration: Short	Duration: Long
Average Noise	RMS Sound Pressure Level	Continuous Equivalent Sound Level
Maximum Noise	Peak-to-Peak Sound Pressure Level	Sound Exposure Level
Behavioural Disturbance	RMS Sound Pressure Level	How often threshold is surpassed, or Continuous Equivalent Sound Level
Hearing Damage	Instantaneous Maximum Noise	How often threshold is surpassed

Temporal and spatial resolution are important.

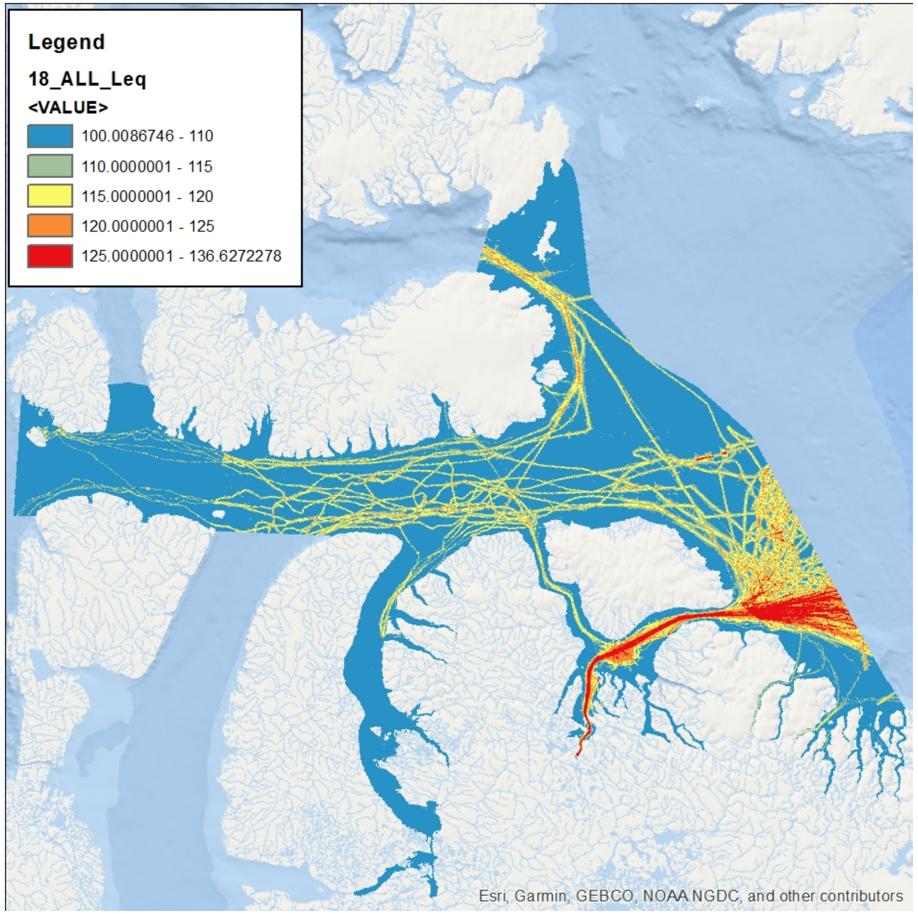
- Every individual ship passage has the potential to cause behavioural disturbance and possibly hearing damage if it is close enough to the marine animal
- Over large spatial extents, the spatial resolution might be reduced; however, this will reduce the importance of highest noise levels right beside the ship
- Similarly, large temporal scales will have to average across ship passages

Methods Overview:

How to get from ships tracks to a ship noise footprint



2018 AIS Ship Tracks



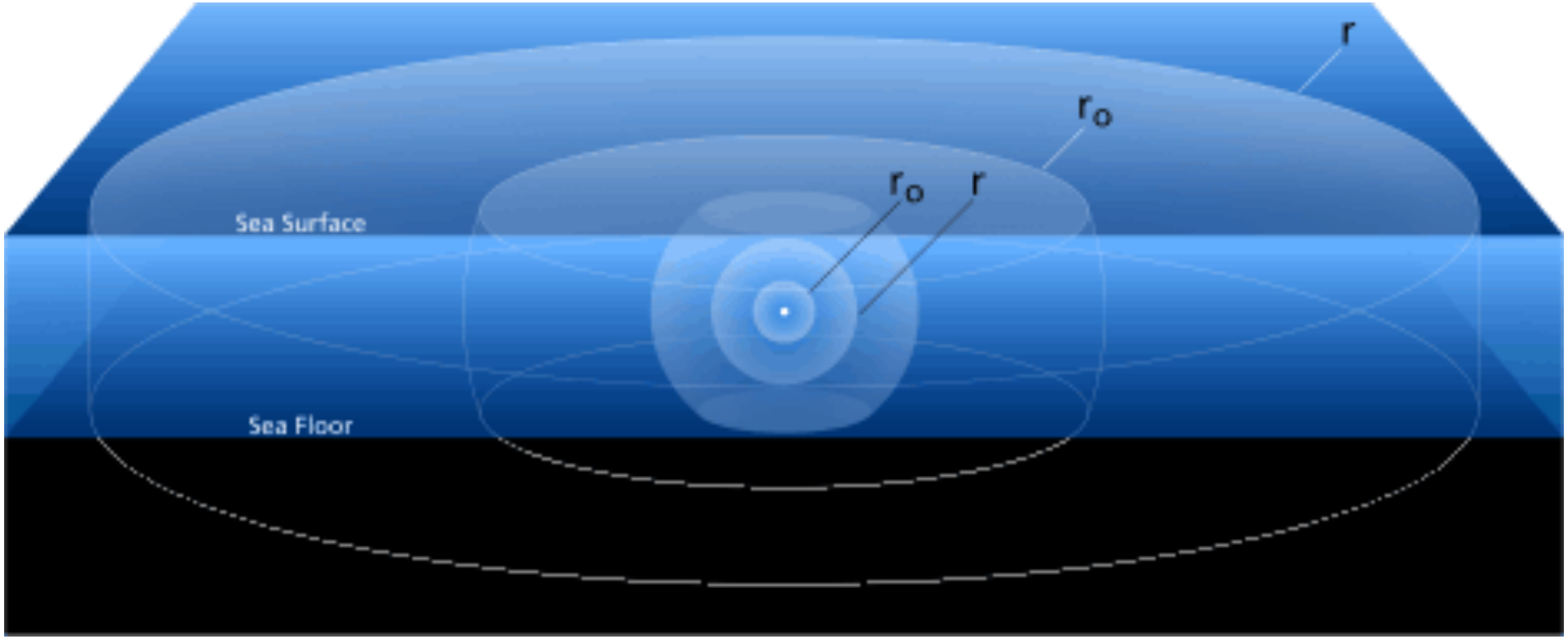
2018 Noise Footprint

Methods Overview:

- Acoustic propagation modeling: assess transmission loss throughout area of interest
- Ship tracking data (AIS): calculate ship density and distance to nearest ship
- Apply transmission loss to ship distance and density data, account for different source levels of ships
- Calculate different metrics of noise footprints, such as by ship class, monthly, or yearly levels, at different spatial resolutions, or based on different hearing bandwidths.

Acoustic Propagation Modeling

- Transmission Loss = 10 log R or 20 log R? Not really…



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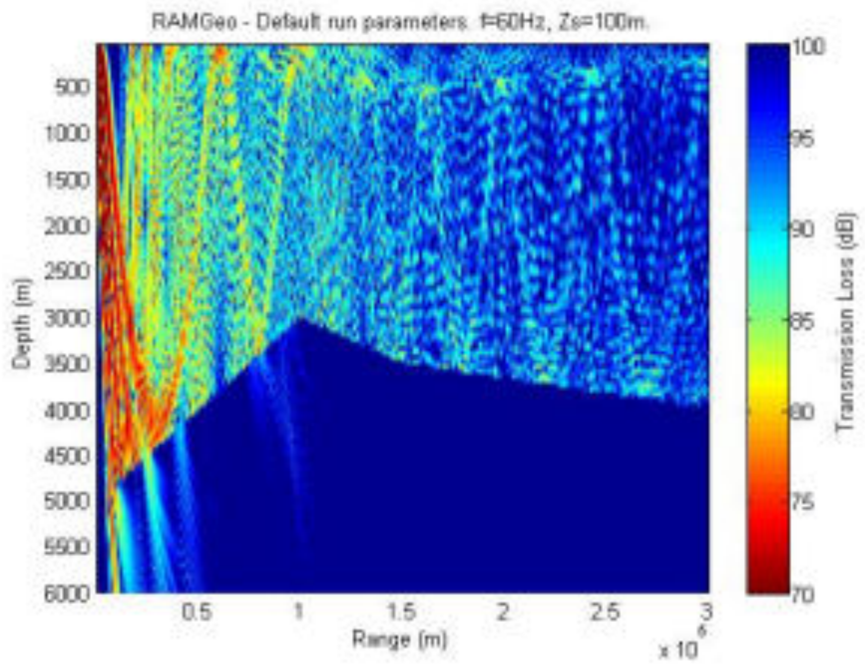
Acoustic Propagation Modeling

Acoustic signals travel like a wave – ray tracing

Water chemistry, bathymetry, and bottom sediment are important factors.



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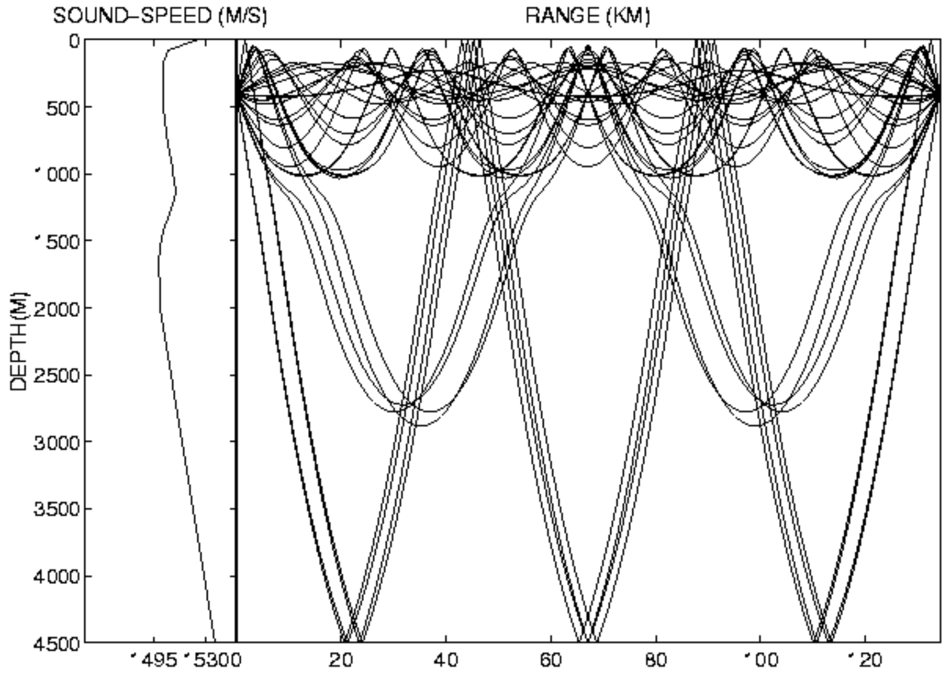

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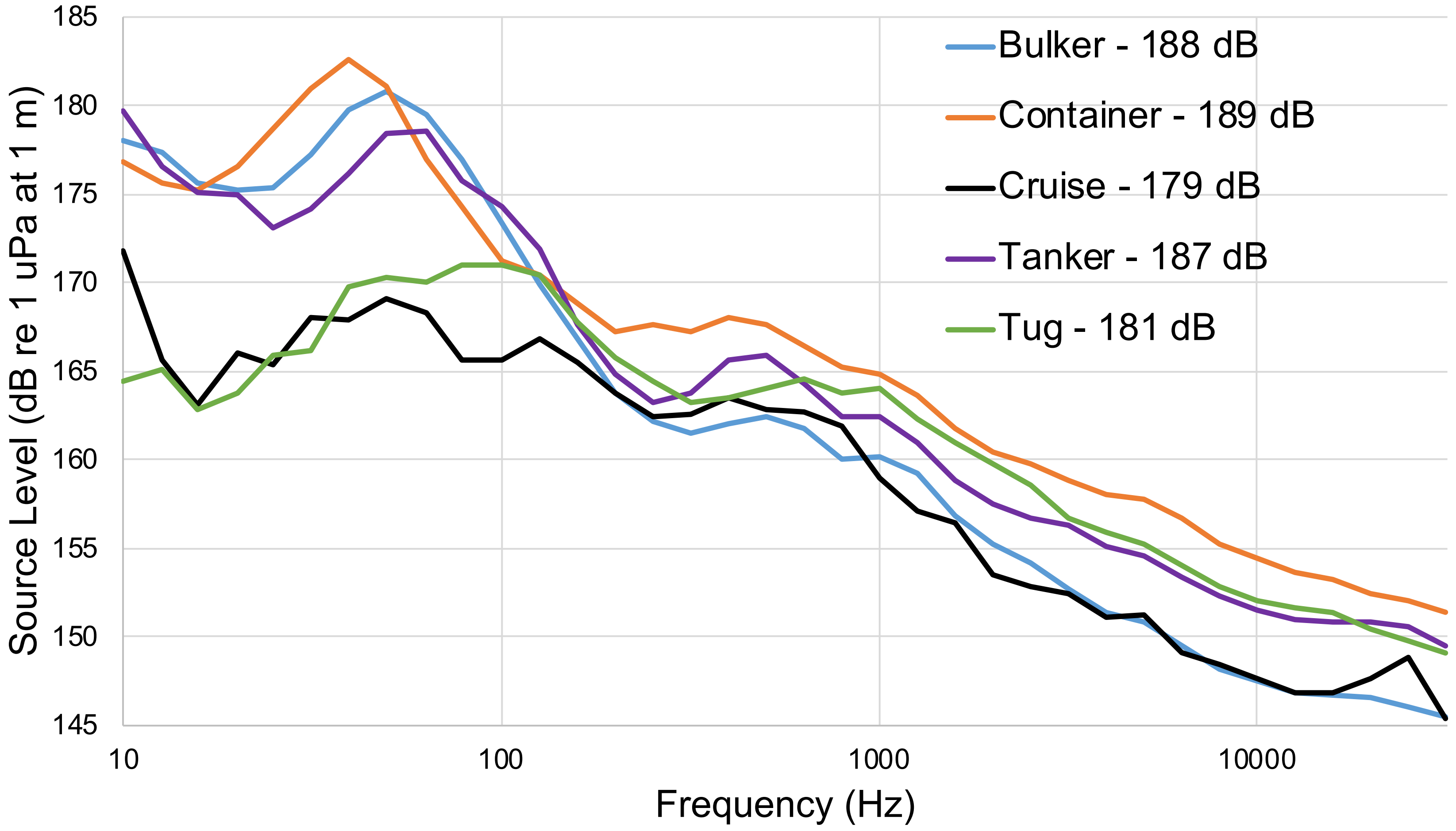
Acoustic Propagation Modeling

- Sound travels different distances and at different rates depending on:
  - Bottom characteristics (bathymetry and sediment) of the area
  - Water characteristics: temperature, pressure, and salinity = speed of sound
  - Frequency of the sound source
- Model this variability throughout the area of interest to try to capture these differences in modeling output.

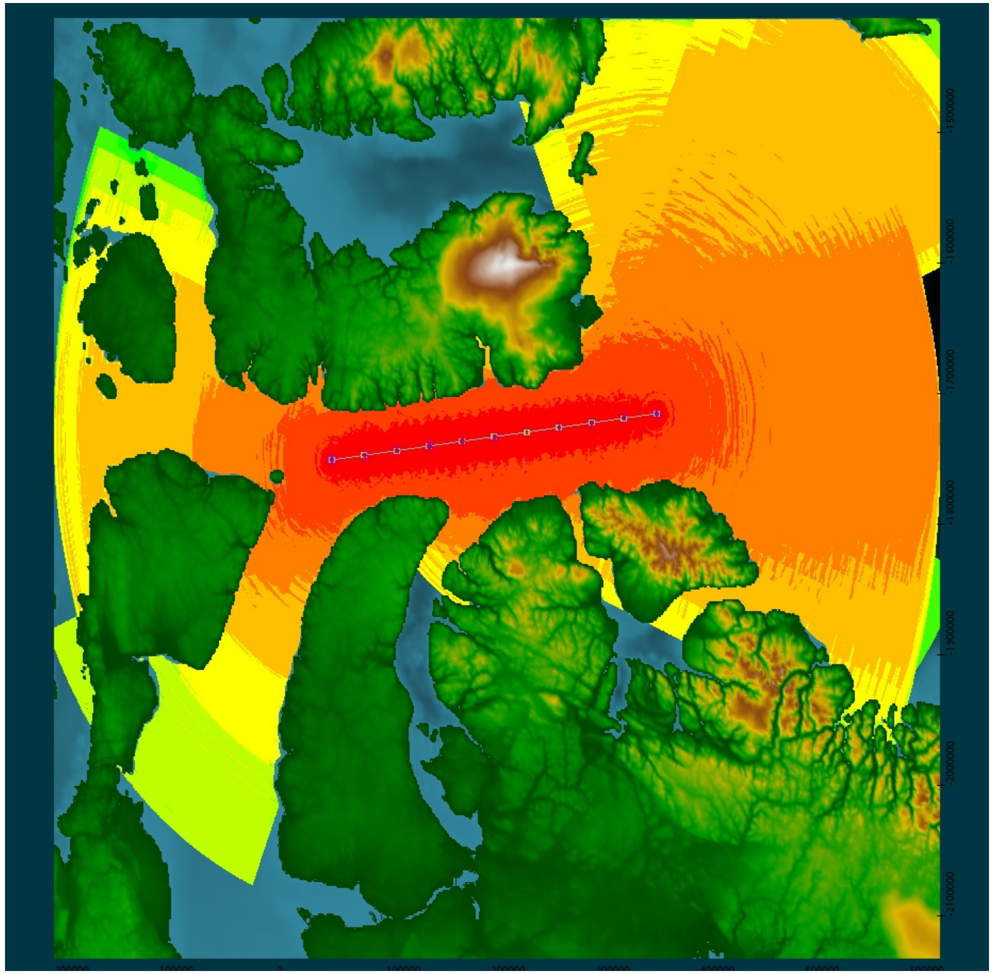
Acoustic Propagation Modeling

- Used the software dBSea 2.0 with the following parameters:
  - 500 m resolution (based on bathymetry layer)
  - Bathymetry layer from International Bathymetric Chart of the Arctic Ocean
  - Very coarse bottom sediment data – a single value for the whole region
  - Conductivity, temperature, and depth (CTD) data from ArcticNet’s cruises aboard the CCGS Amundsen, averaged to create a sound speed profile for the region
  - Average source levels for different vessel classes, measured at the Port of Vancouver’s ECHO program listening station; source levels in 1/3 octave bands from 10 Hz to 32 kHz.

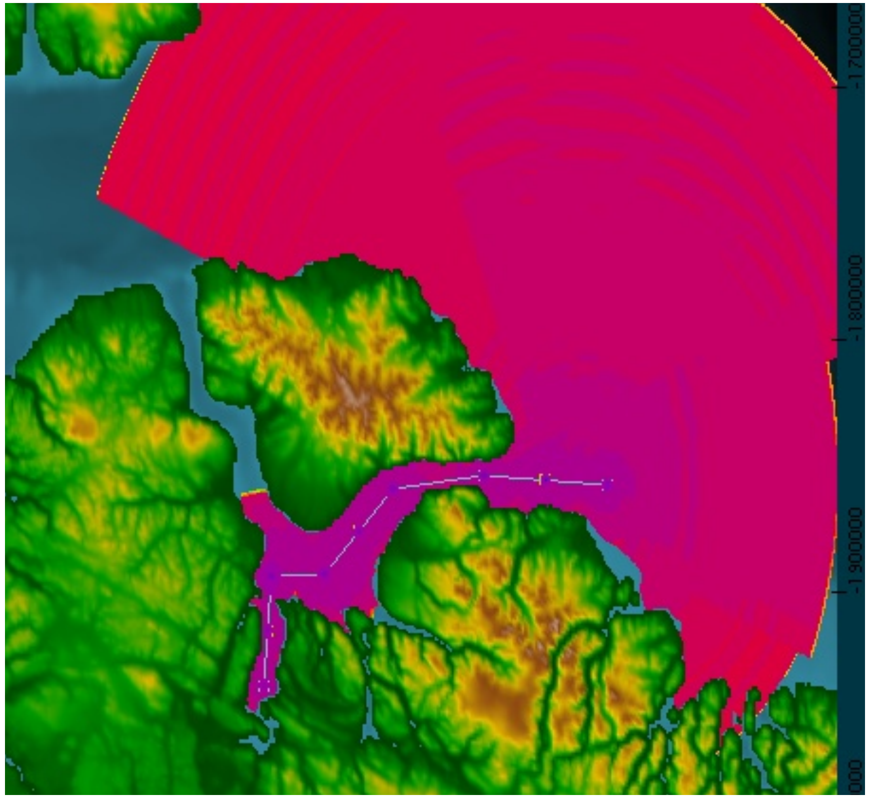
Vessel Source Levels



Acoustic Propagation Modeling
Lancaster Sound, Nunavut, Canada



Parry Passage: Deep, straight channel; relatively low variability

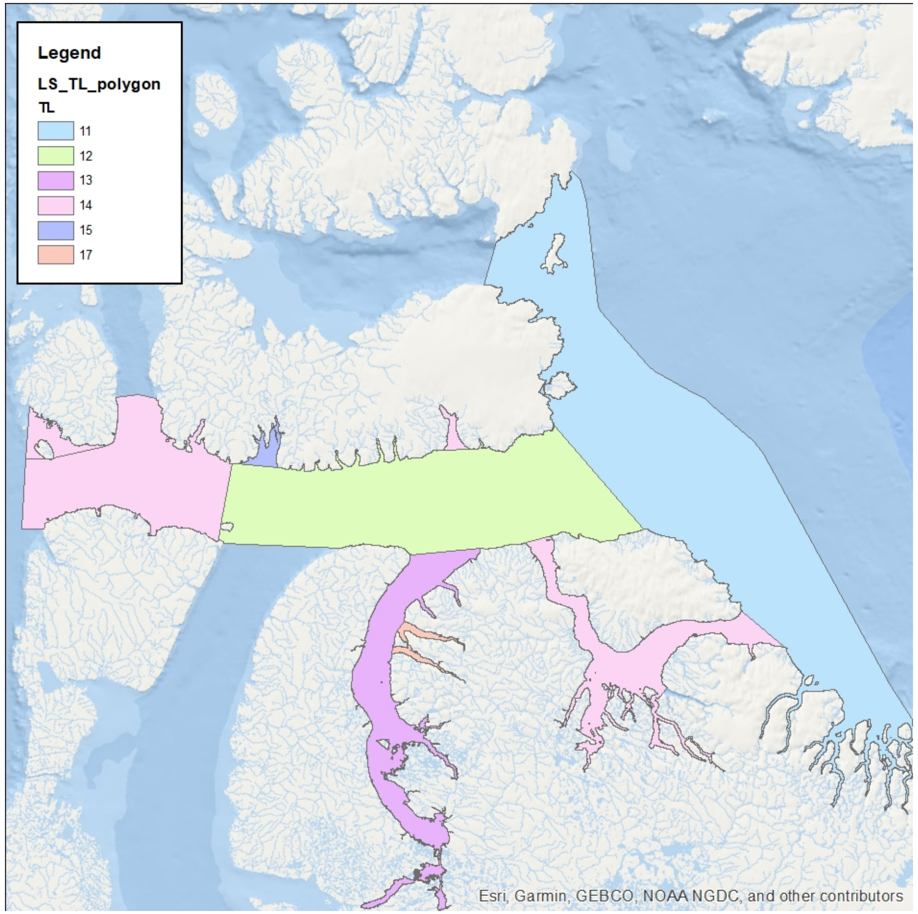


Eclipse Sound: Narrow channel and wide inlet, varying depth; high variability

Acoustic Propagation Modeling Lancaster Sound, Nunavut, Canada

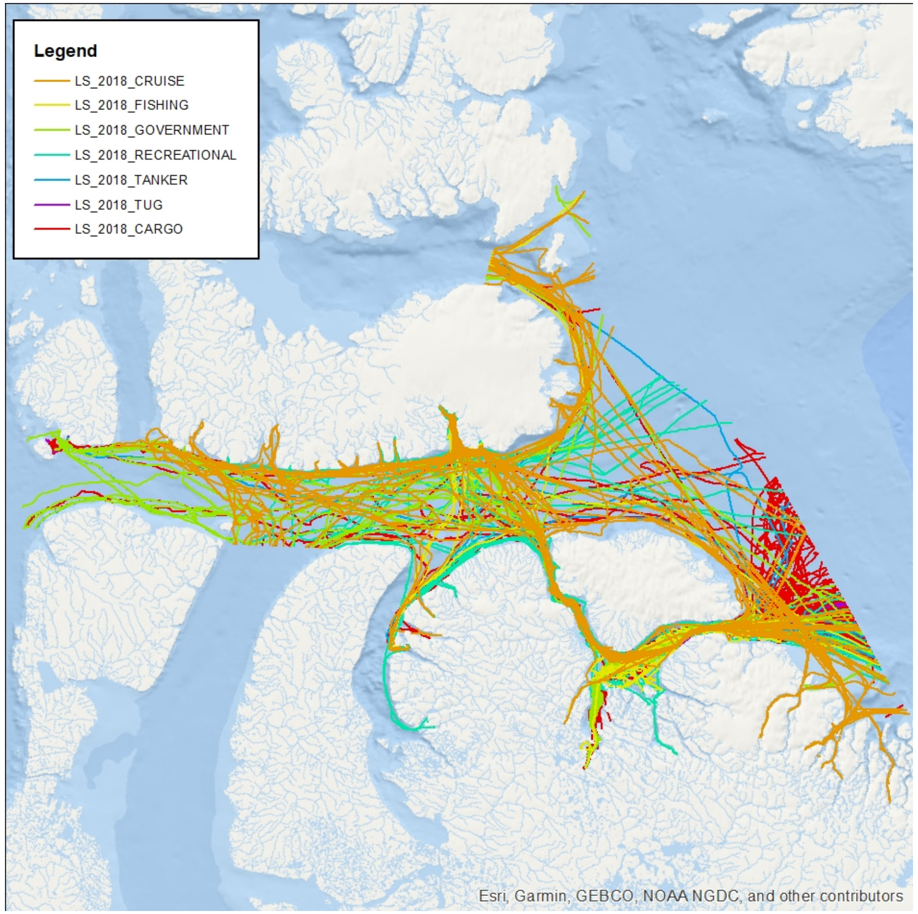
- Different zones of transmission loss in Lancaster Sound

Area	Transmission Loss (X Log R)
Baffin Bay (very deep and wide)	11
Parry Passage	12
Admiralty Inlet	13
Barrow Strait, Eclipse Sound, Resolute, Various Narrow Inlets	14
Maxwell Bay (narrow, shallow inlet)	15
Nanisivik, Arctic Bay	17



Ship Tracking Data

- Satellite AIS (automatic identification system) data from exactEarth
- Straight lines fitted between points, with least distance going around land (i.e. islands)
- For each vessel class in each year between 2015 and 2018:
  - Calculated a density grid in ArcGIS with 500 m resolution
  - Calculated the distance to the nearest ship for each grid cell



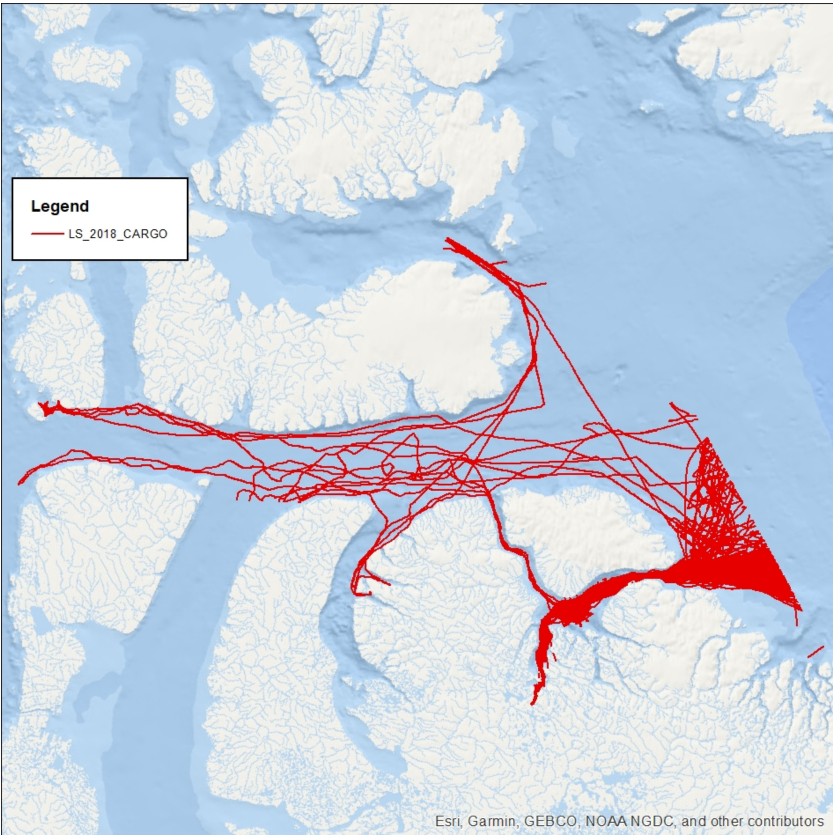
Noise Footprint

- For each vessel class in a year, applied the broadband vessel source level and transmission loss equations to the distance grid, and multiplied by the density grid

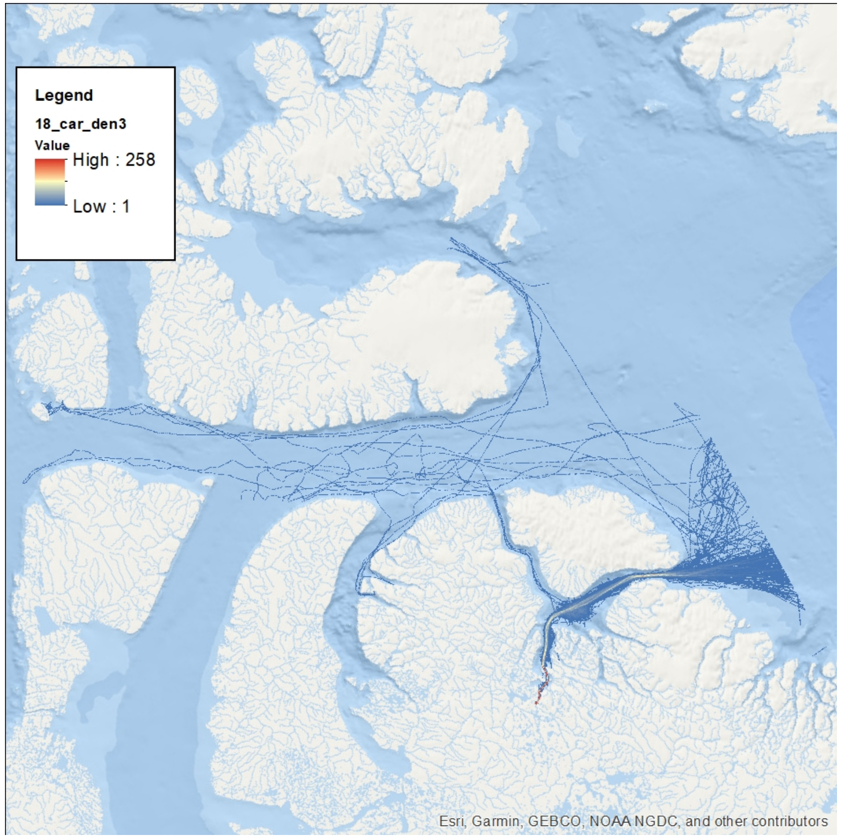
Class	Source	Source Level (dB re 1 uPa at 1 m)
Bulker	ECHO	188.3
Tanker	ECHO	187.4
Cruise	ECHO	179.5
Tug	ECHO	180.8
Government	Veirs et al 2016	167
Military	Veirs et al 2016	161
Recreational	Veirs et al 2016	159
Fishing	Veirs et al 2016	164

- Calculated Sound Exposure Level (SEL) and Equivalent Continuous Sound Level (Leq) based on an 84 day shipping season.

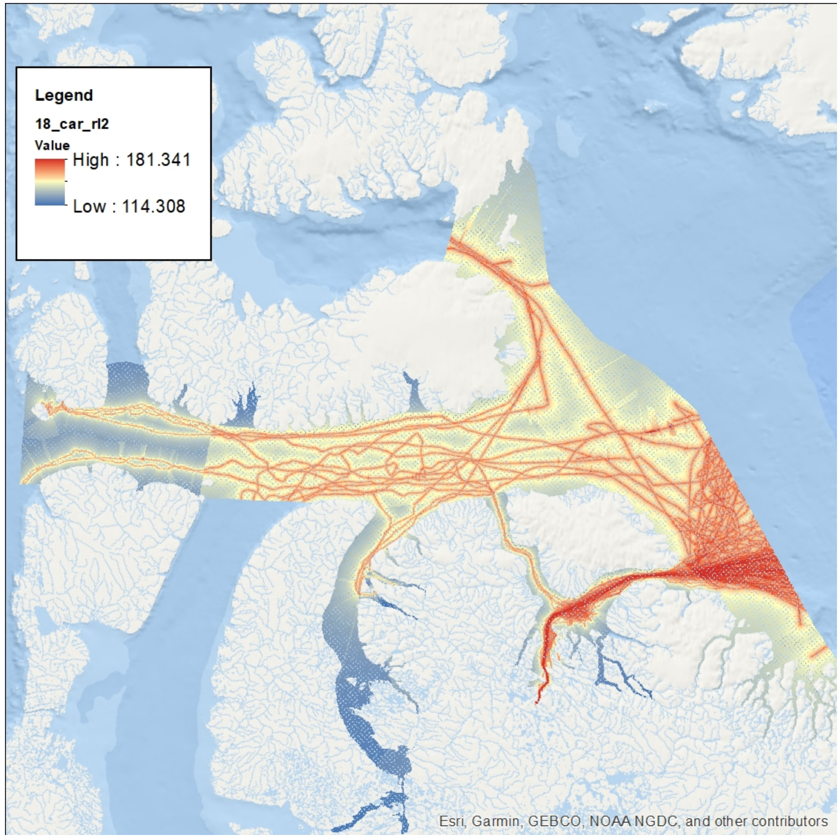
Noise Footprint – Cargo Ships in 2018



2018 AIS Cargo Ship Tracks



2018 Cargo Ship Density, 500 m res

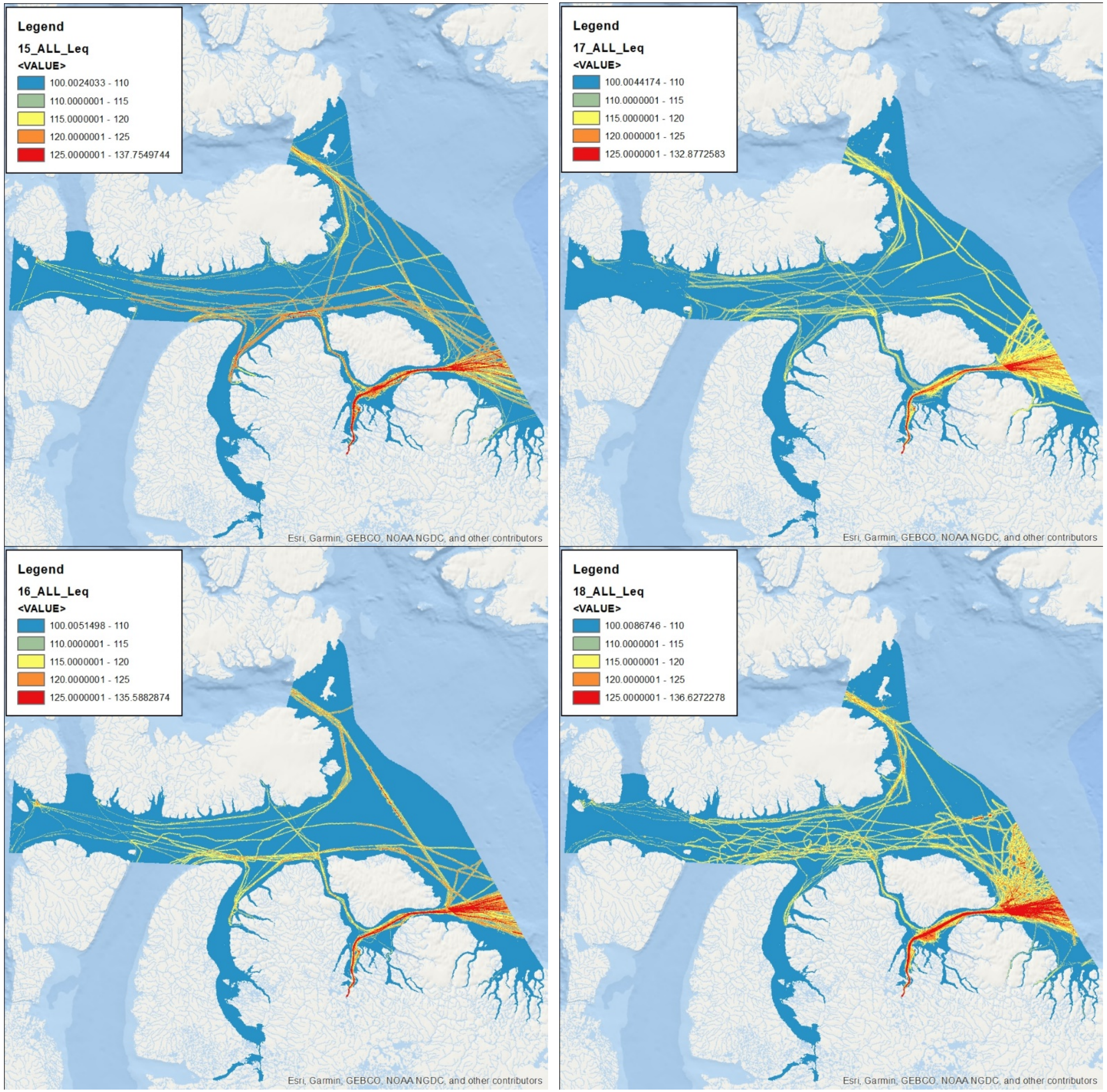


2018 Cargo Ship Received Level (dB)

Leq: Continuous Equivalent Sound Level: 2015-2018

Legend:
Blue = not above ambient sound level
Orange and red = above the NOAA 120 dB threshold for disturbance to marine mammals.

Summary:
- Consistently high Leq in Eclipse Sound due to ships from Baffinland Iron Ore Mine (1 or more ships per day).
- High variability between years
- Smaller boats (fishing, recreation) and military ships have almost no impact on this metric



Items to Consider

For this case study:

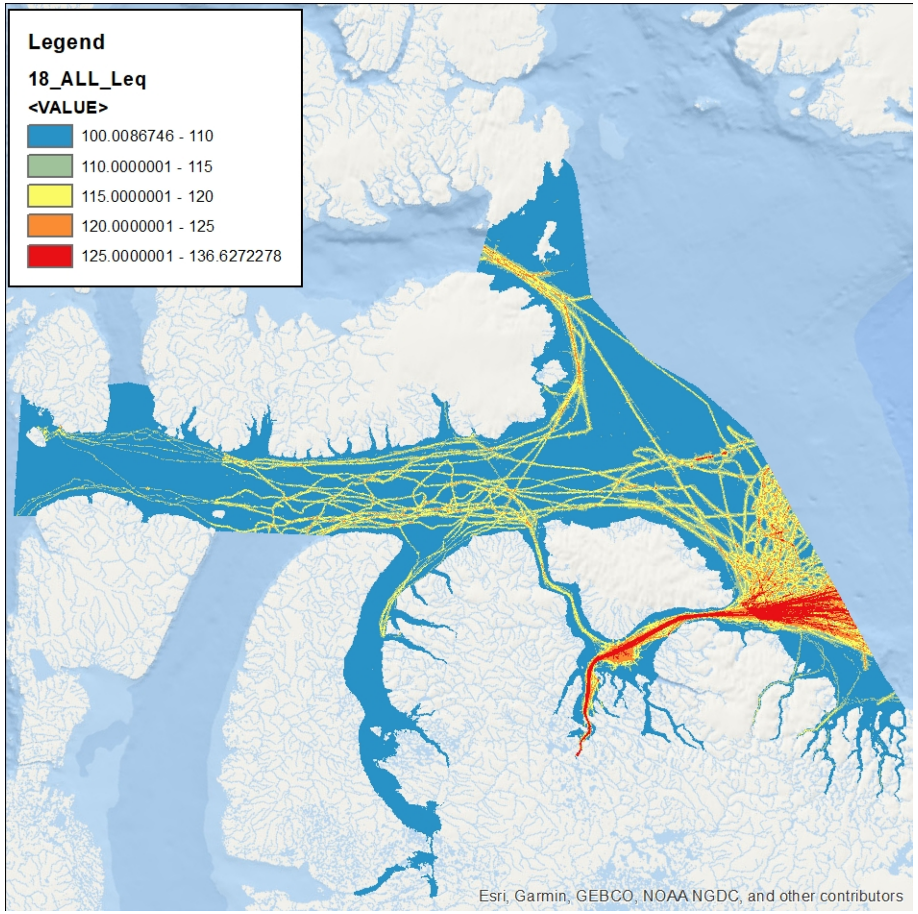
- Time for work: 6 weeks of work (2 for modeling, 2 for ship tracks, 2 for noise footprint)
- Acoustic Propagation Modeling: About 100 point estimates throughout region based on locations where ships travel
- Spatial extent: relatively small region (108,000 km^2), compared to the size of Canada's Arctic or the global Arctic
- Spatial resolution: lowest possible given bathymetry layer (500 m)
- Temporal resolution: one value for entire shipping season, mid July to early October

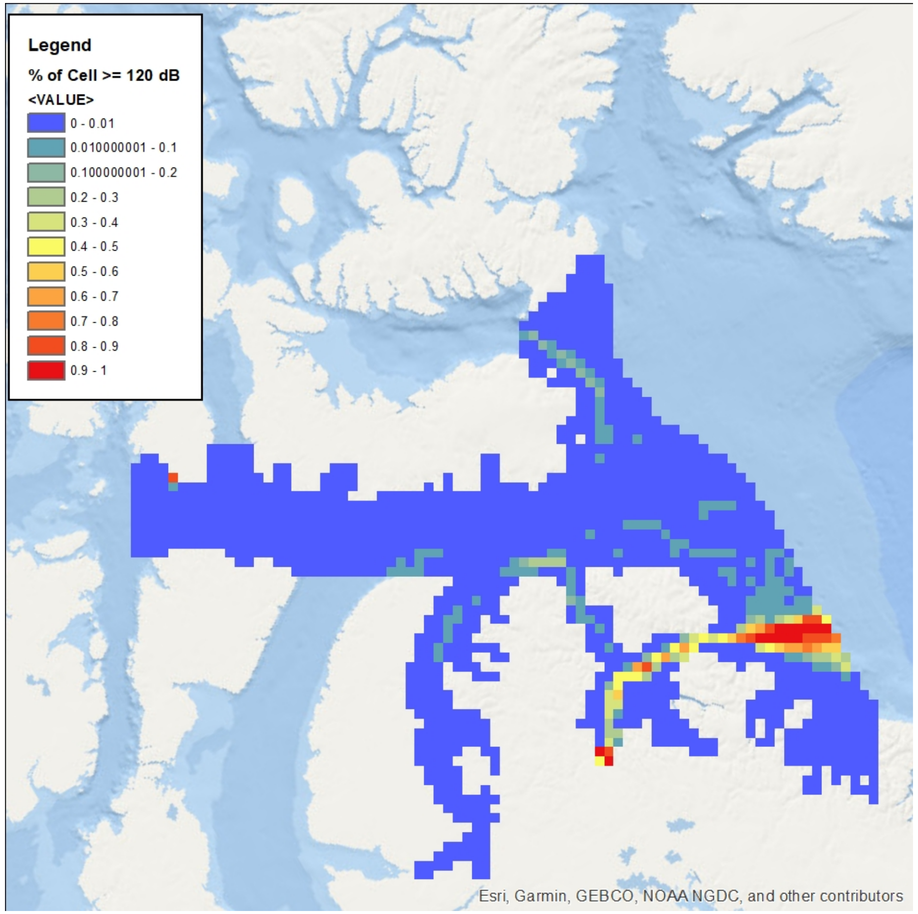
Items to Consider

Future Studies:

- Greater area means more time required
- 500 m spatial resolution may not be feasible at large spatial scales due to computational power limitations
- High detailed acoustic propagation modeling requires more computational power and much more time
- Specific source levels for vessels impractical, but important to have a consistent source of high quality source levels, at least within a given vessel class

Spatial Resolution: 500 m vs 10 km.





Thanks!

- Ship source level data provided by the Port of Vancouver, Transport Canada, Jasco Applied Sciences Ltd, and Oceans Network Canada
- Satellite AIS data provided by exactEarth through the MEOPAR network in Canada, then processed by Zuzanna Kochanowicz in Jackie Dawson’s lab at the University of Ottawa
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