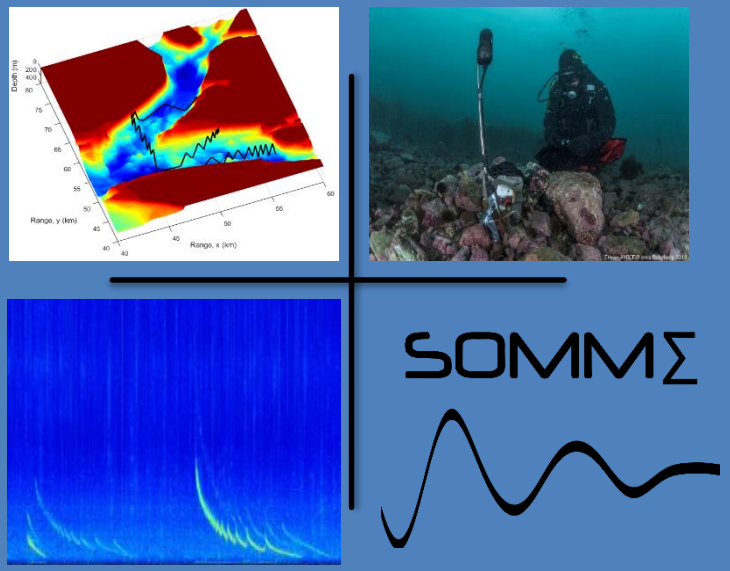
Prediction of acoustic pollution in Arctic fjords: the importance of 3-D acoustic propagation modeling.



Gaëtan Richard [1,2], Delphine Mathias [1], Jérémy Collin [2], Laurent Chauvaud [2] and Julien Bonnel [3]

[1] Société d'Observation Multi-Modale de l'Environnement (SOMME), 38 rue Jim Sevellec, 29200 Brest
[2] Institut Universitaire Européen de la Mer, CNRS (UMS3113), Technopôle Brest Iroise, 29280 Plouzané
[3] Woods Hole Oceanographic Institution, Applied Ocean Physics and Engineering department, 266 Woods Hole Rd, Woods Hole, MA 02543-1050, USA

Workshop SERENADE
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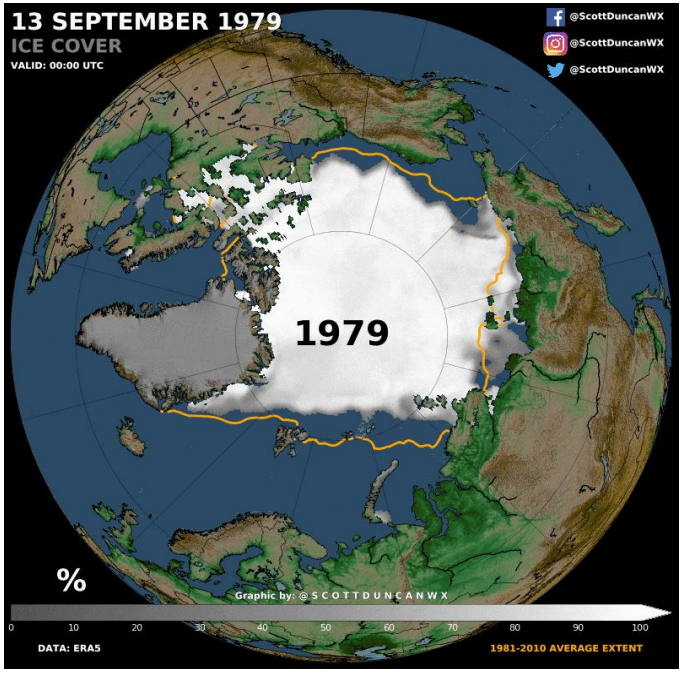
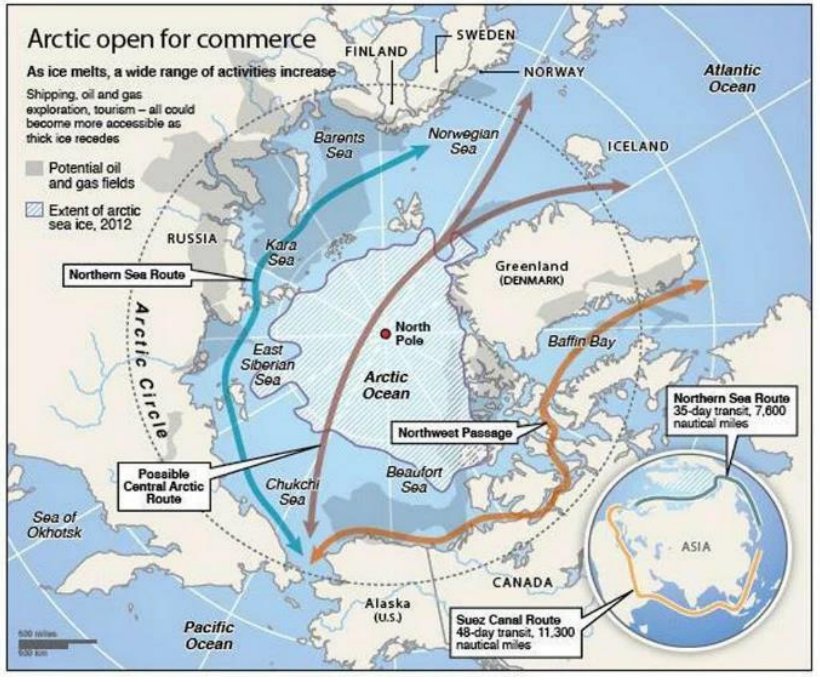
The Arctic is warming rapidly

Sea-ice covering declines drastically,
with a potential ice-free summer predicted by 2040:



Scott Duncan



Unprecedented access to the Arctic for anthropogenic activities :

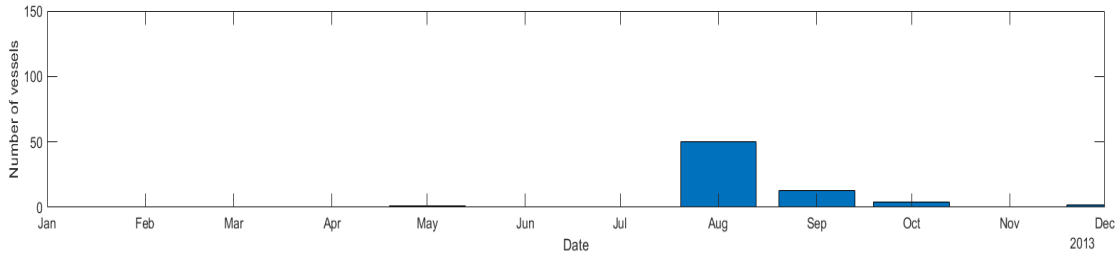
Increasing anthropogenic noise in a nearly pristine acoustic environment

Increasing noise pollution ?

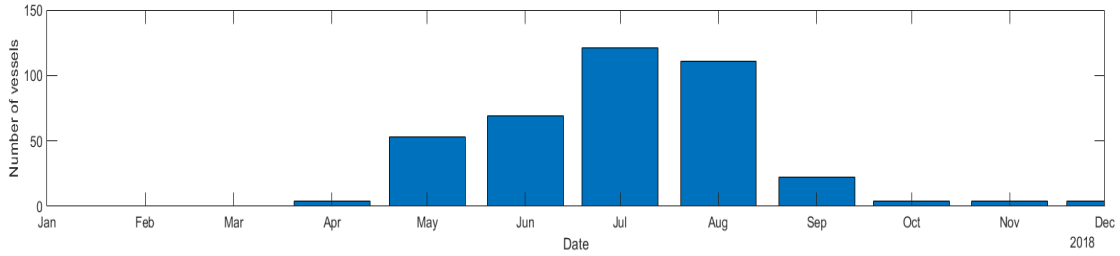
Underwater passive acoustic research in Ny Alesund :

- To describe soundscape (biophony, geophony, anthropophony);
- To monitor changes over time;
- To assess impacts of anthropogenic noise on marine fauna.

2013

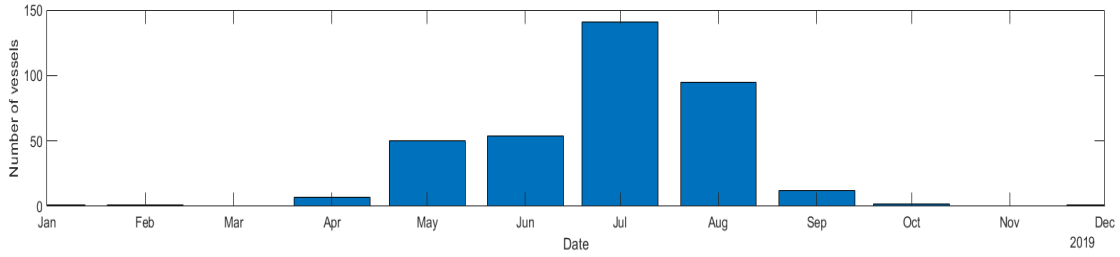


2018



x3

2019



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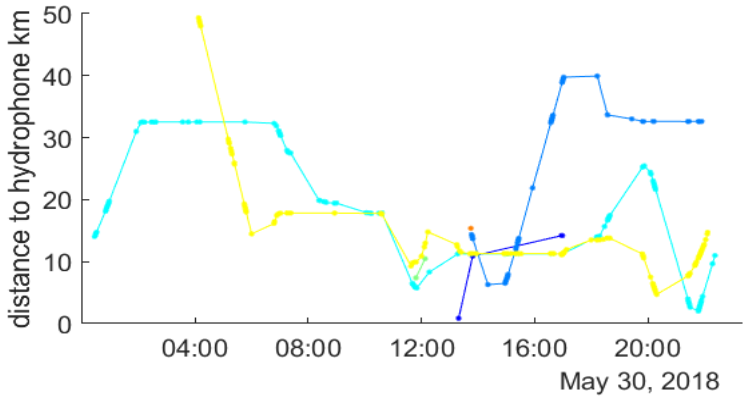
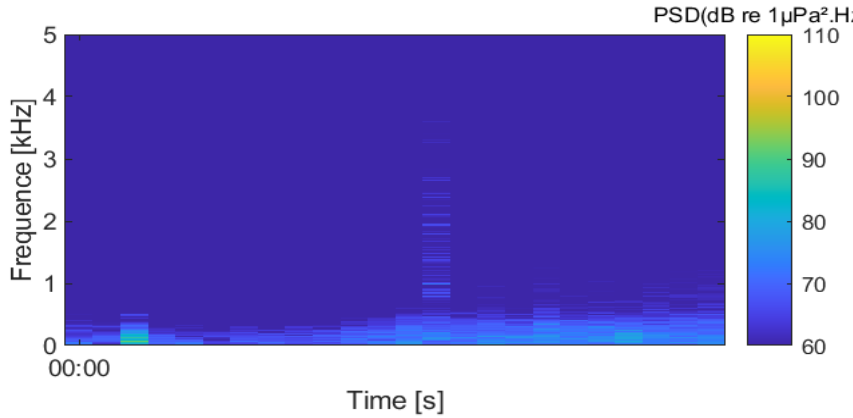
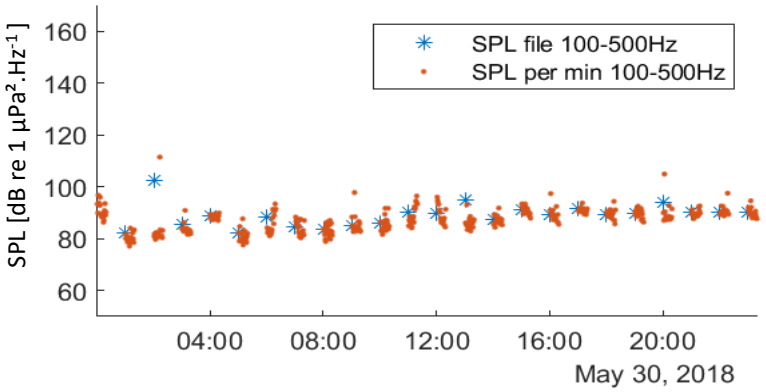
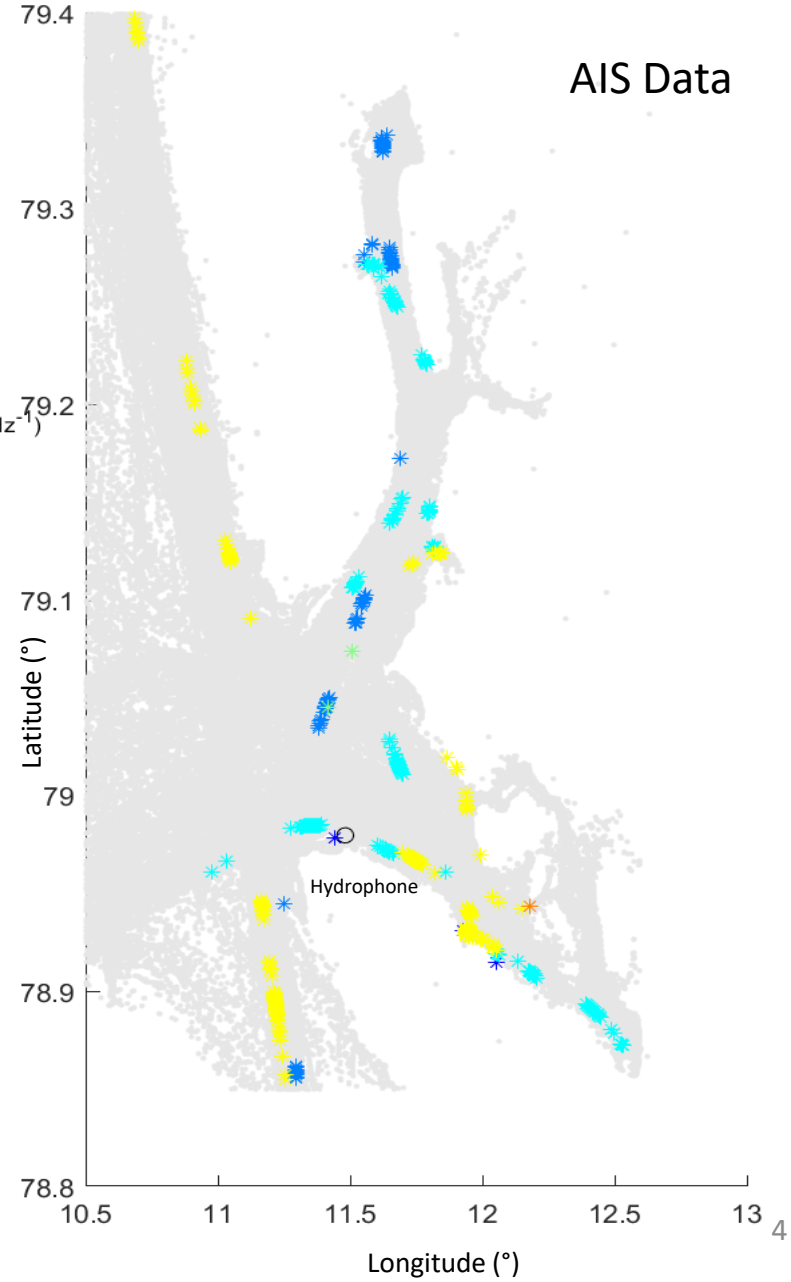
Increasing noise pollution ?

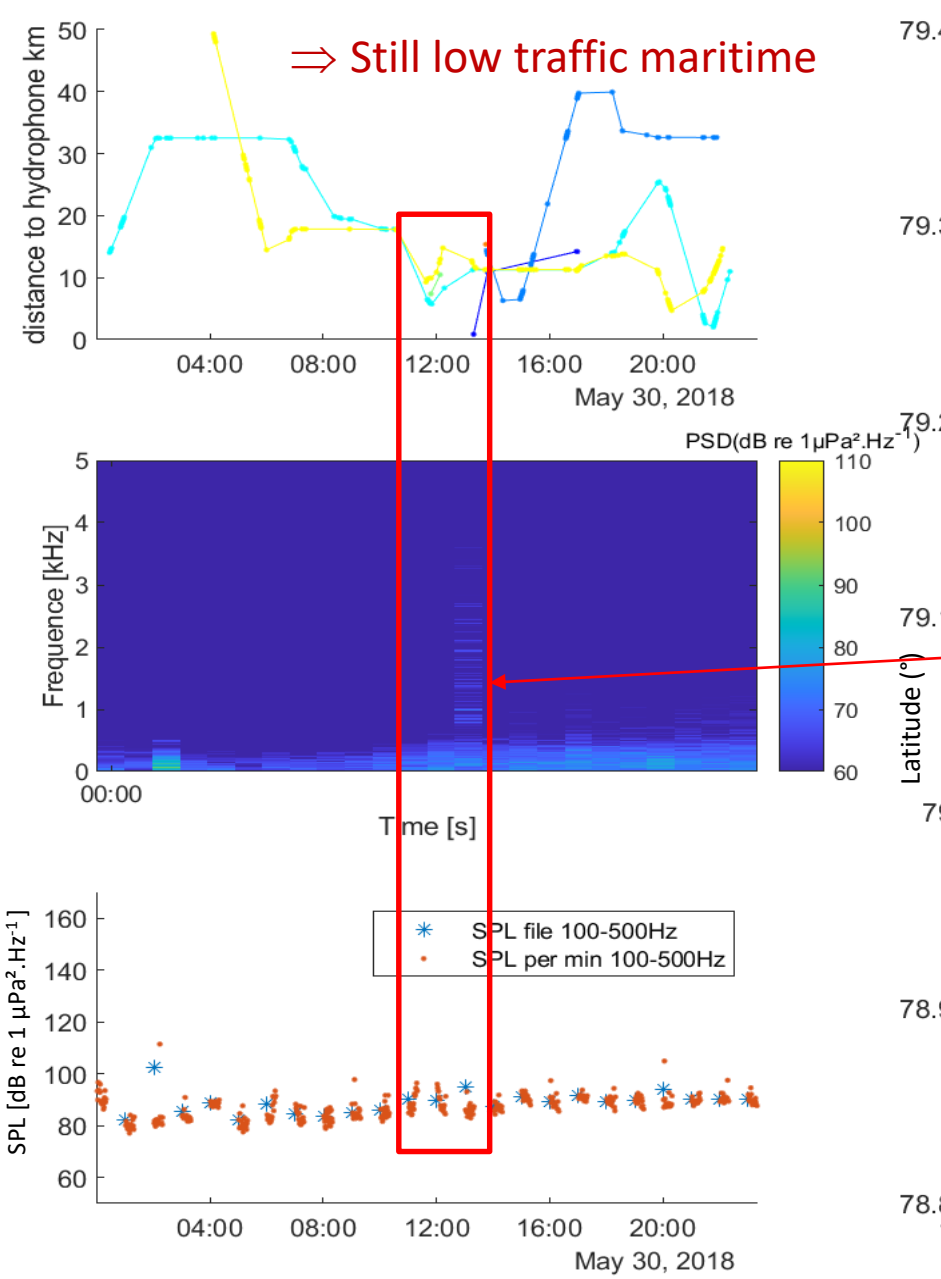


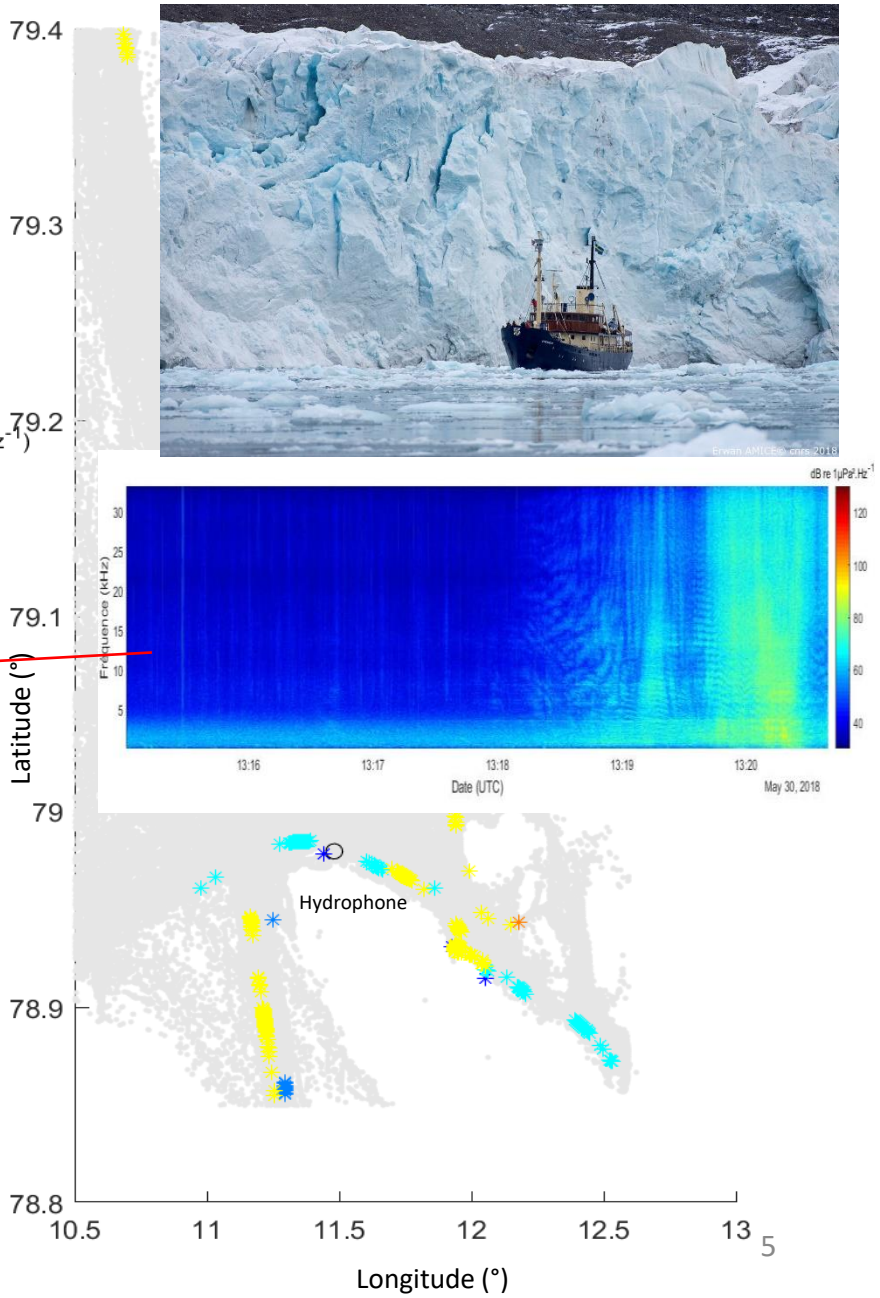




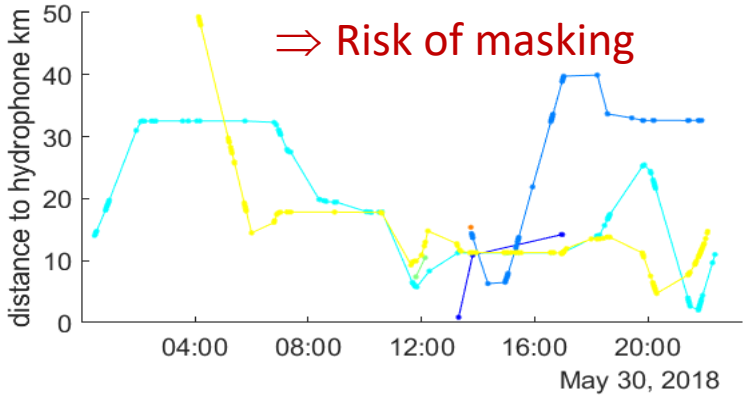


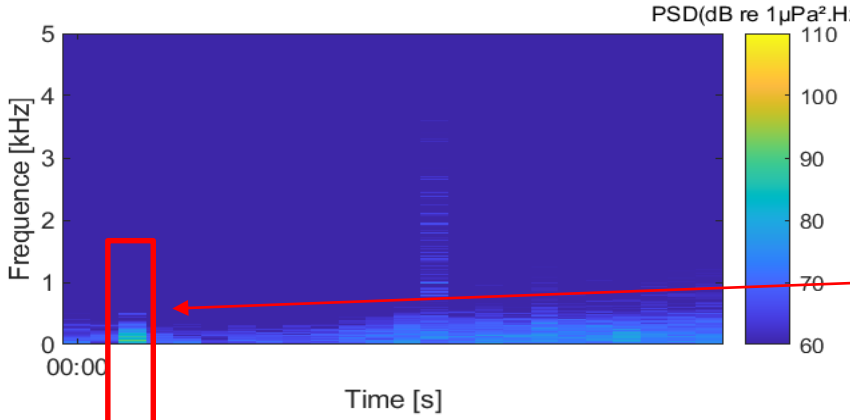
Increasing noise pollution ?

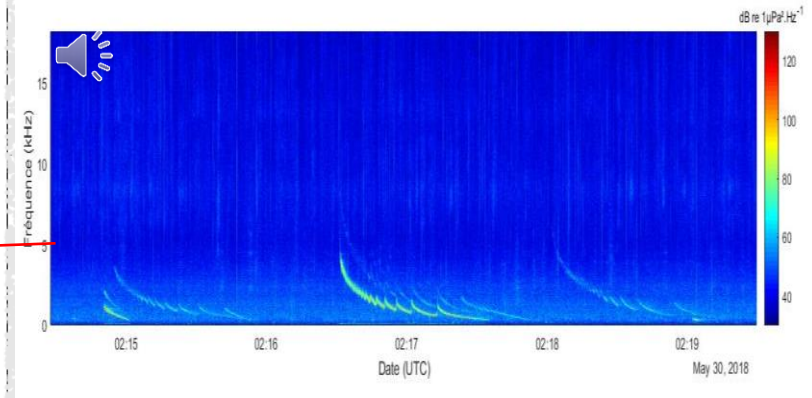


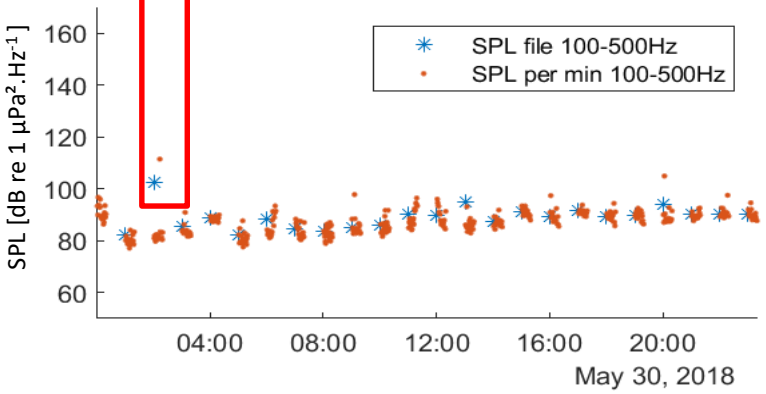


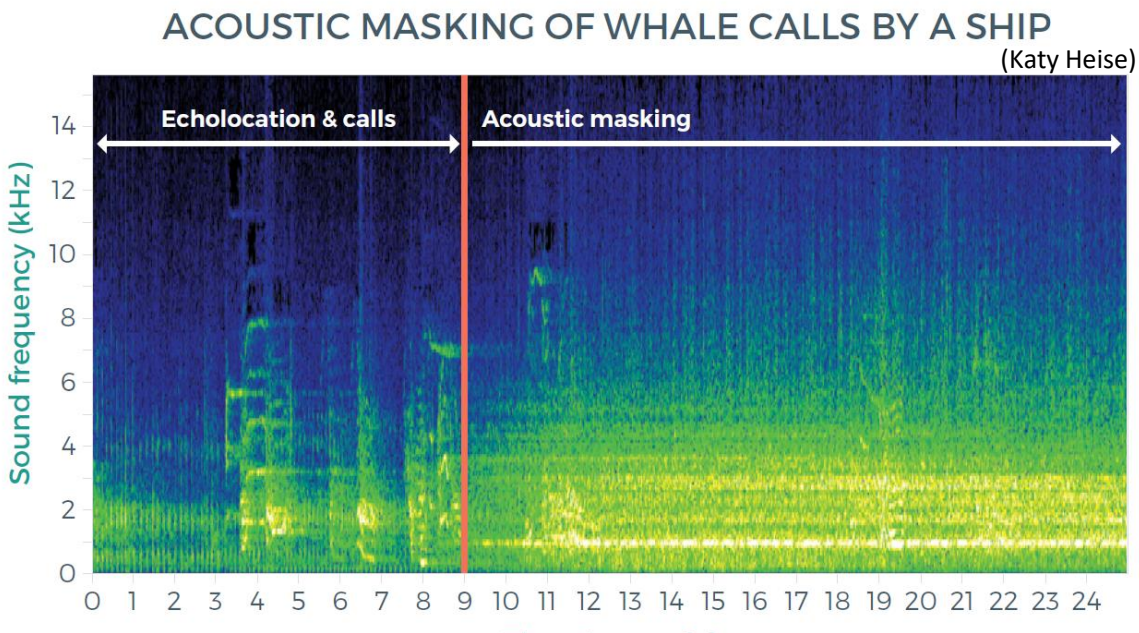
Increasing noise pollution ?

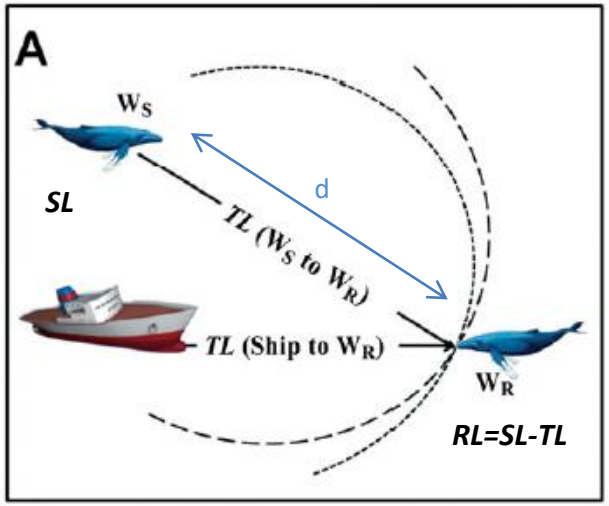




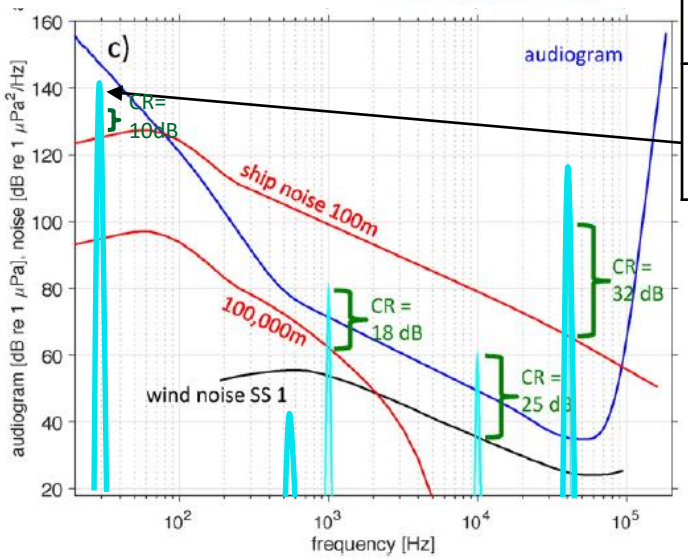






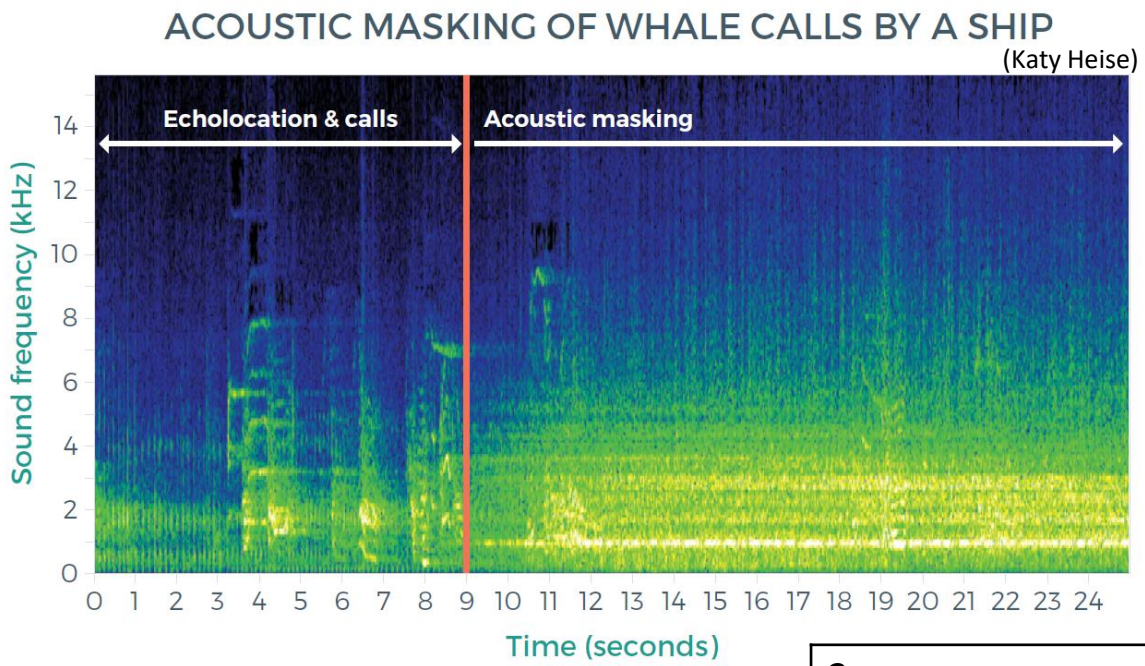


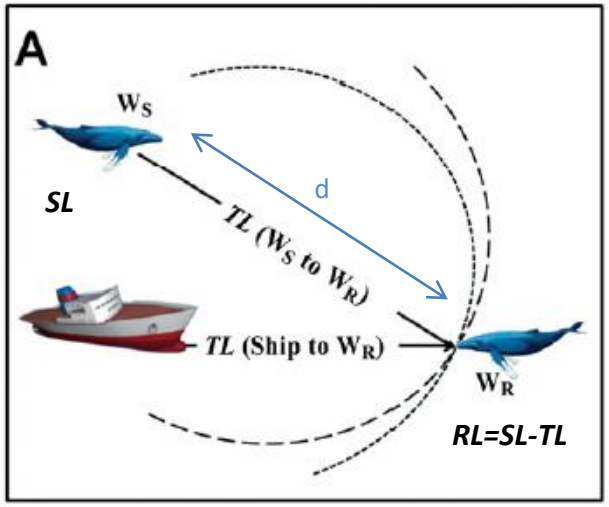
TL ~ 20log(d) , with d distance (source-receiver)



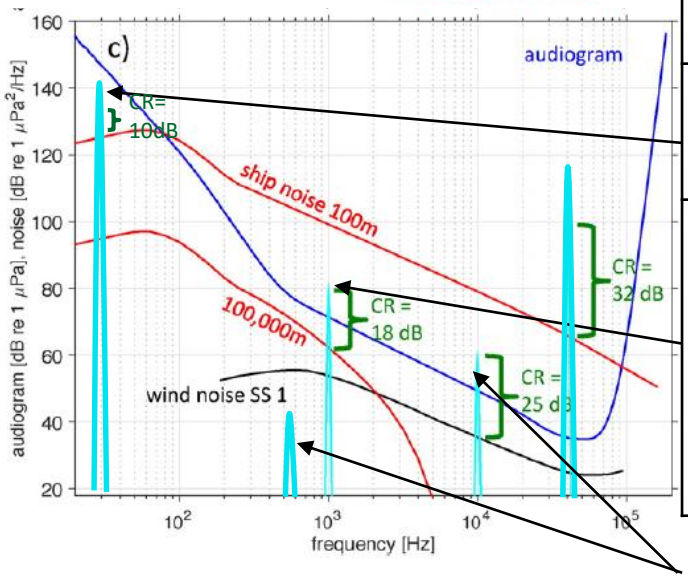
Cases	Tonal detection
Tone (dB) < Audiogram (dB)	No detection possible by animal

Clark et al. (2009), Erbe et al. (2016)





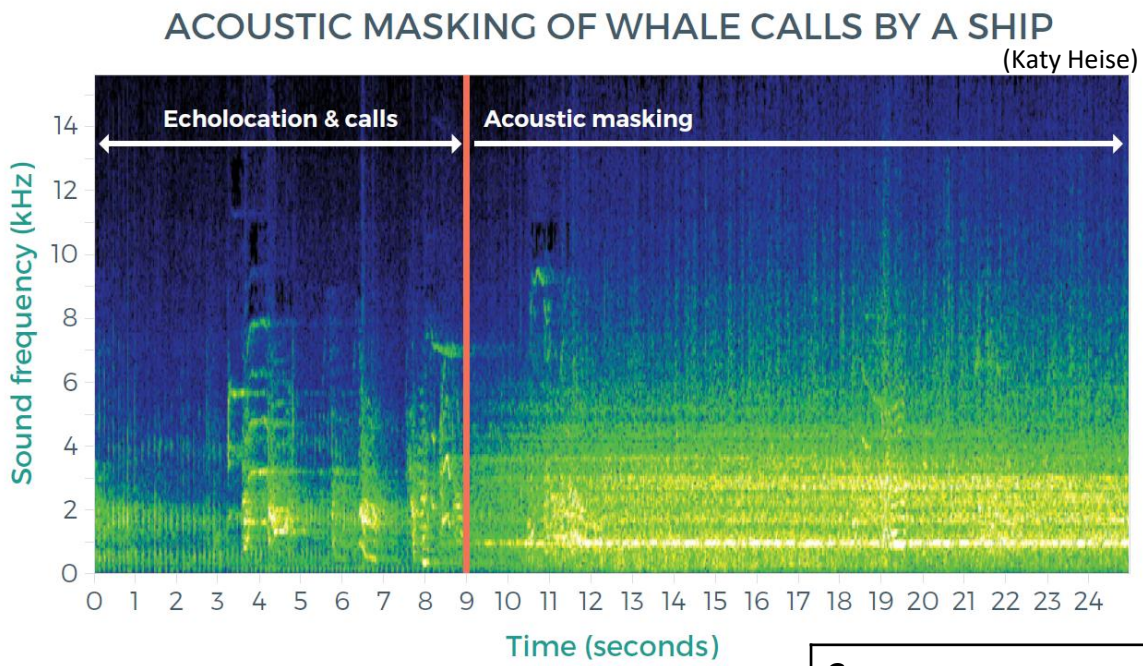
TL ~ 20log(d) , with d distance (source-receiver)
RL=SL-TL

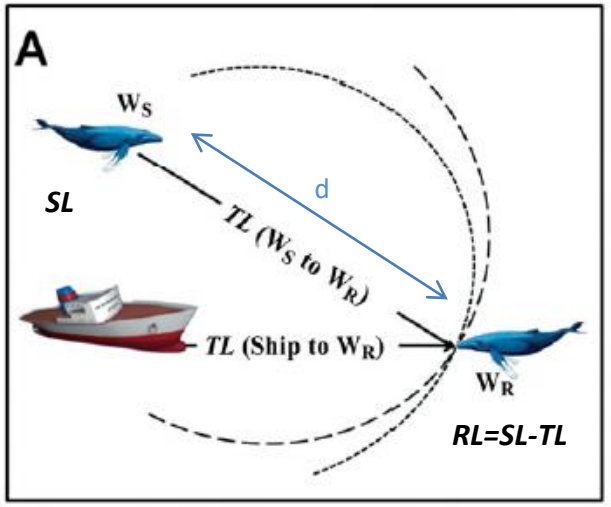


Cases	Tonal detection
Tone (dB) < Audiogram (dB)	No detection possible by animal
Tone (dB) > Audiogram (dB) • **& Tone < PSDship + CR**	Tonal detection possible: • Tonal masked by shipping noise

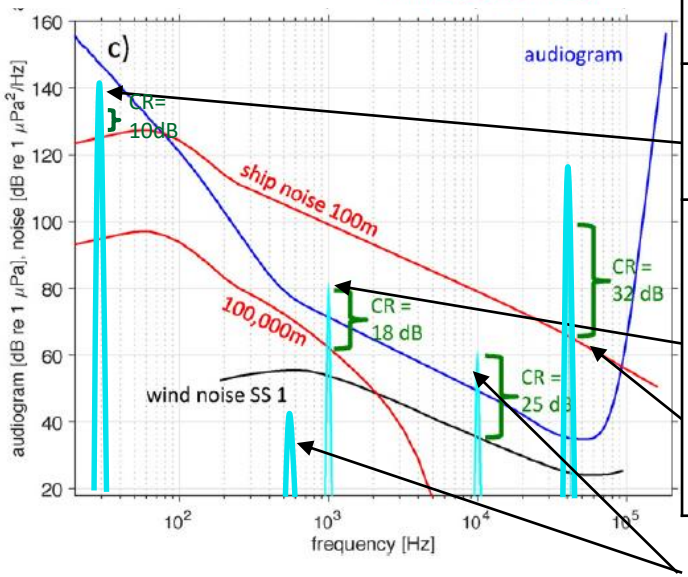
Tonal masked by wind

Clark et al. (2009), Erbe et al. (2016)





TL ~ 20log(d) , with d distance (source-receiver)
RL=SL-TL



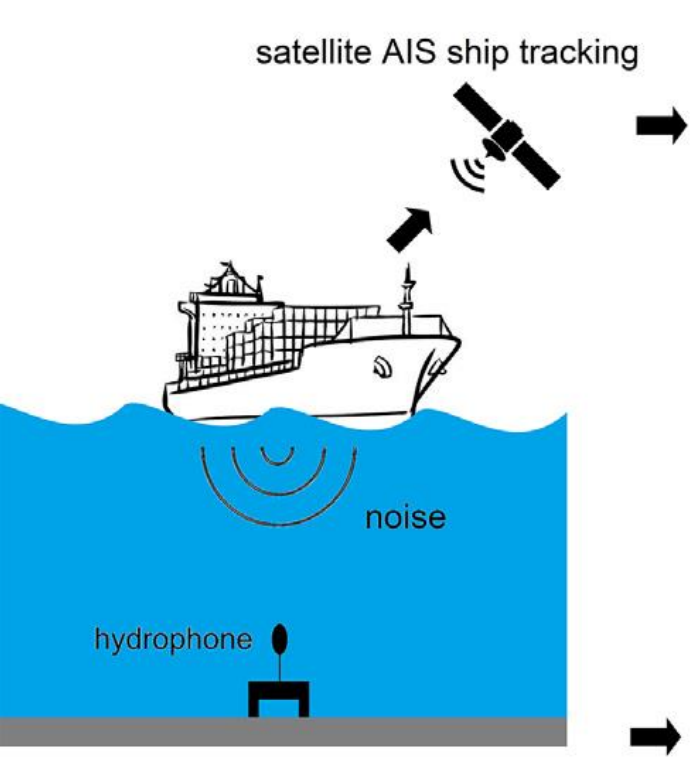
Cases	Tonal detection
Tone (dB) < Audiogram (dB)	No detection possible by animal
Tone (dB) > Audiogram (dB) • **& Tone < PSDship + CR** • **& Tone > PSDship + CR**	Tonal detection possible: • Tonal masked by shipping noise • Tonal audible

Tonal masked by wind

Clark et al. (2009), Erbe et al. (2016)

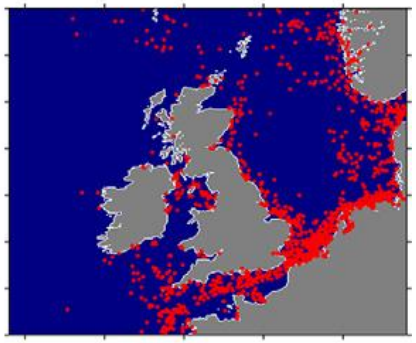
How to predict noise pollution level ?

Acoustic propagation modeling to predict noise pollution level

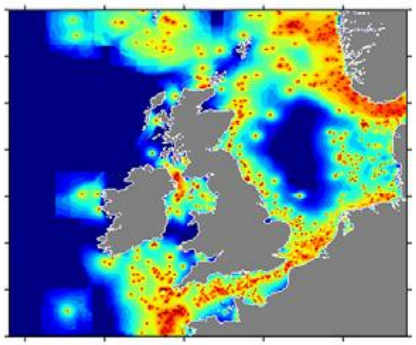


validation of modelled noise maps using hydrophone measurements

ship-tracking data



modelled ship noise map



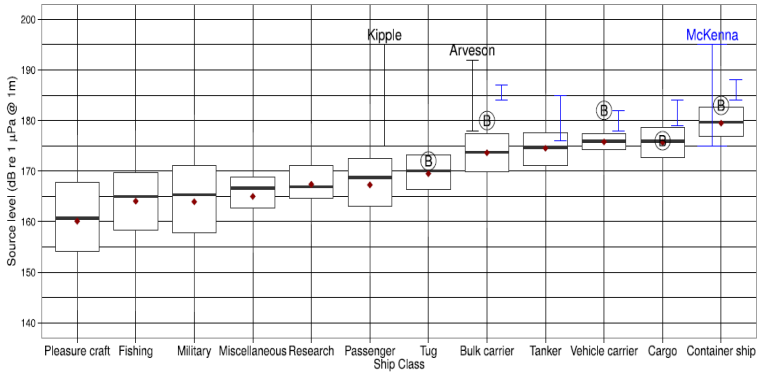
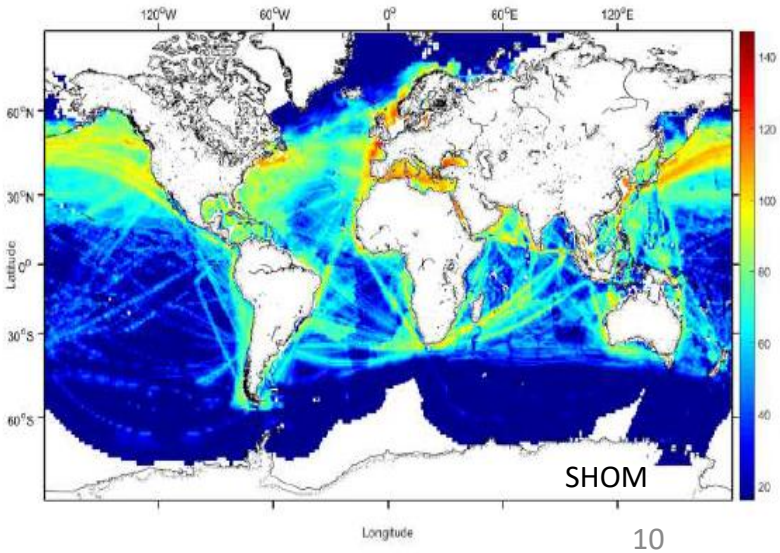


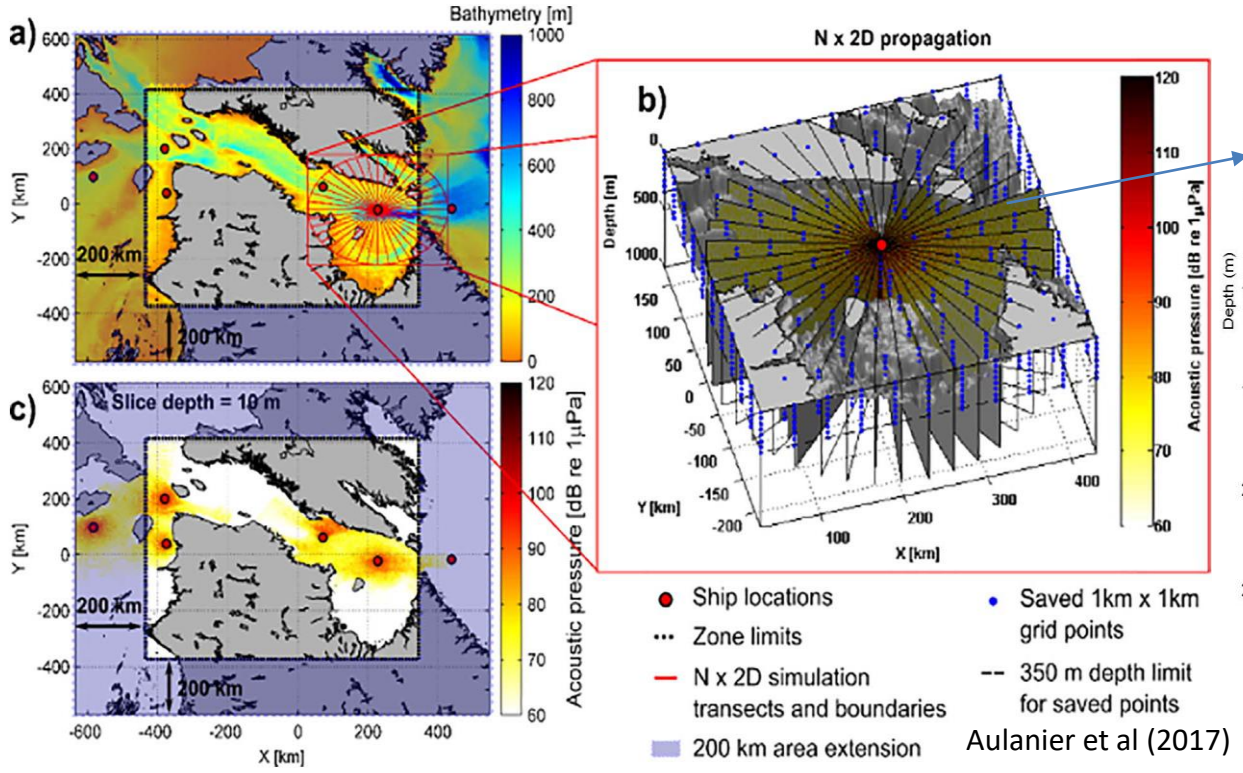
Figure 2 **Comparison of source levels from different studies for various classes of ships.** Broadband source level (*SL*) statistics for each ship class juxtaposed with results from recent studies of comparable classes. Bold horizontal lines are medians; gray box hinges are 25% and 75% quantiles; gray whiskers extend to the value that is most distant from the hinge but within 1.5 times the inter-quartile range (distance between the 25% and 75% quantiles); red dots are mean values from Table 2. Each encircled letter B represents a mean from *Bassett et al. (2012)*; blue vertical bars represent means from *McKenna et al. (2012)* with the container ship estimate of *McKenna, Wiggins & Hildebrand (2013)* labeled McKenna; black vertical bars represent estimates from *Kipple (2002)* and *Arveson & Vendittis (2000)*.



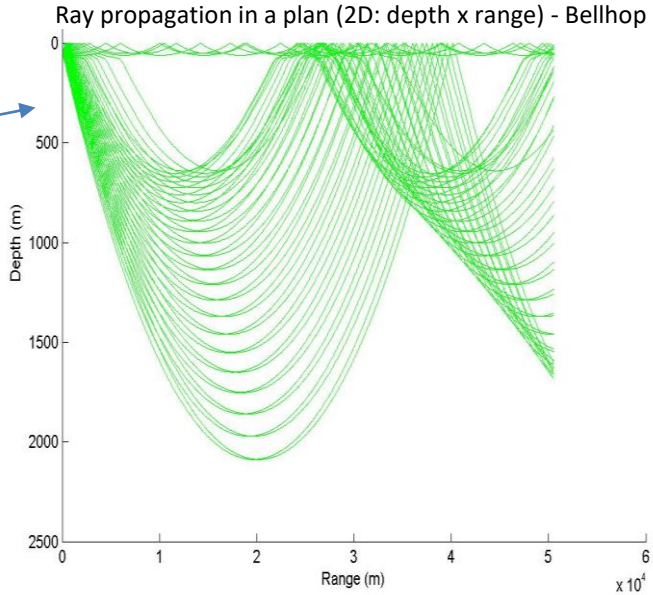
Le Courtois et al (2016), Veirs et al. (2016), Farcas et al (2020)

Acoustic propagation modeling to predict noise pollution level

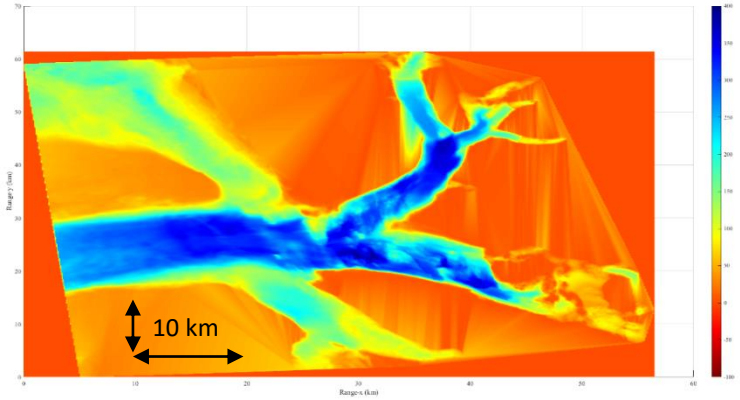
⇒ spatial acoustic propagation is often simplified in several (N) plans (2D)



Aulanier et al (2017)



Is a traditional N x 2D propagation model sufficient in Arctic fjords?



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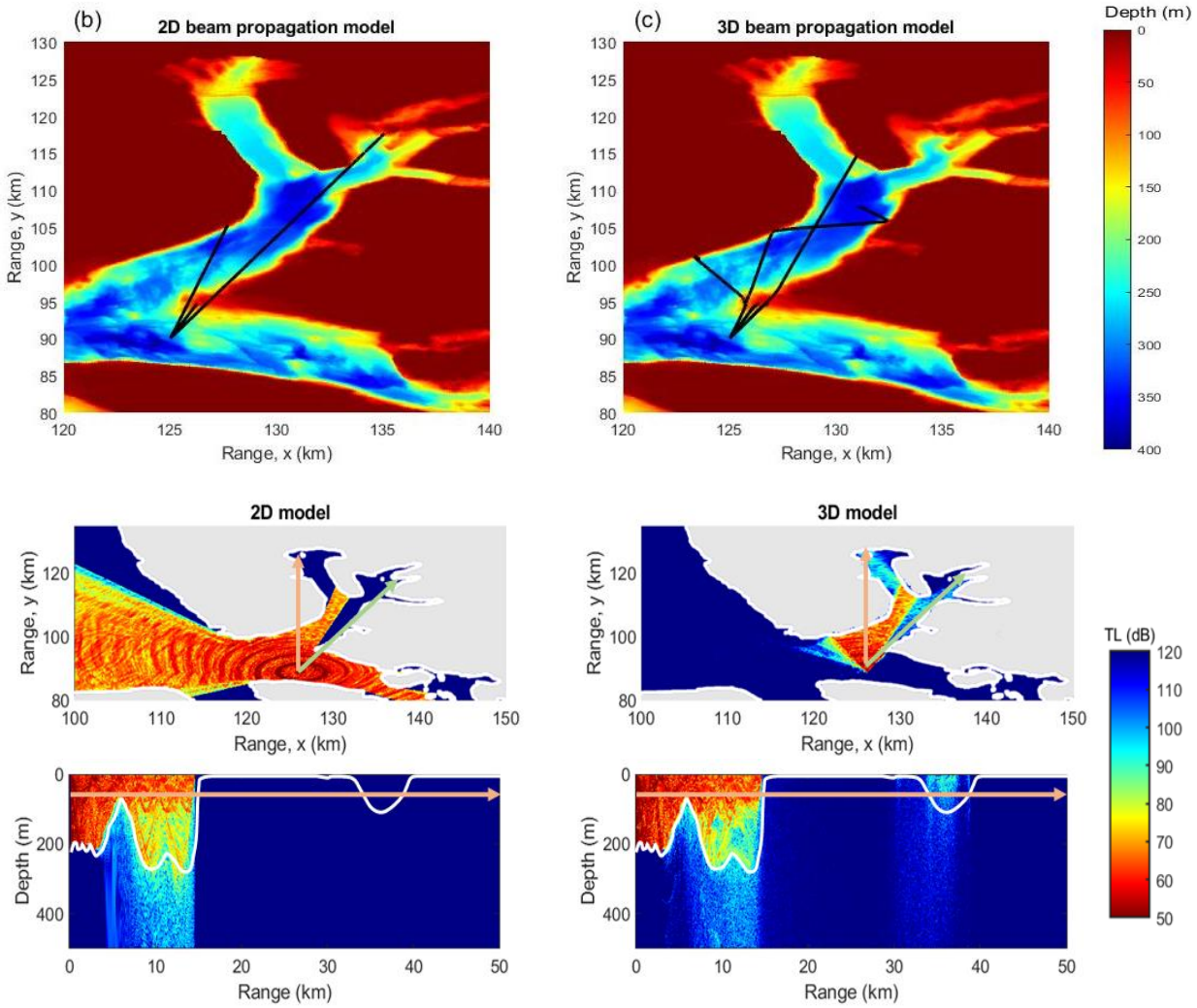
Propagation model considering the Fjord bathymetry and geography in 3D (Bellhop 3D)

- **Comparison propagation model nx2D vs 3D**



Footprint estimation via 3D propagation model

Propagation model considering the Fjord bathymethry and geography in 3D (Bellhop 3D)

- **Comparison propagation model 3D vs nx2D**

Signal Excess estimation:

SE =SL-TL-NL

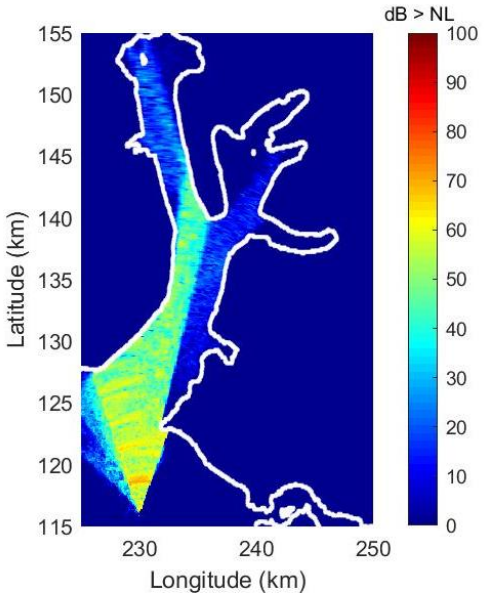
A ‘pessimist’ scenario:

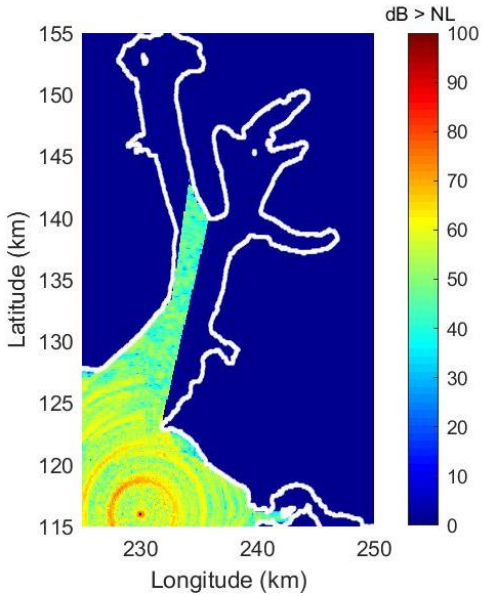
SL ~ value of nosiest vessel from literature

SL = 190 dB

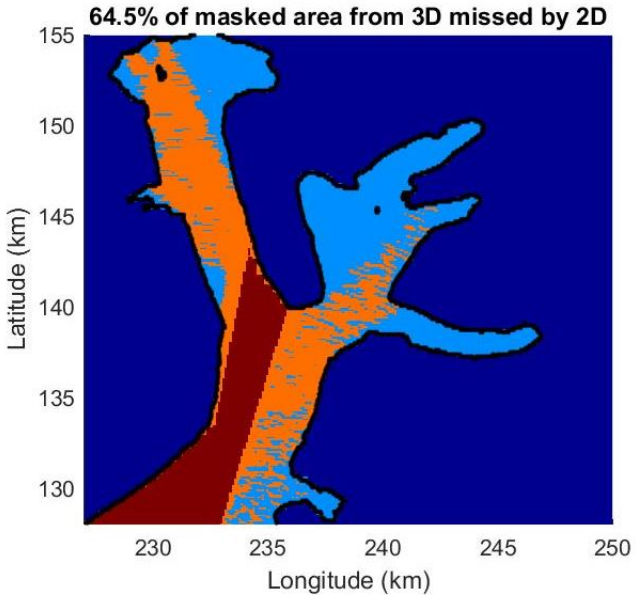
ex: Cargo (~100m)

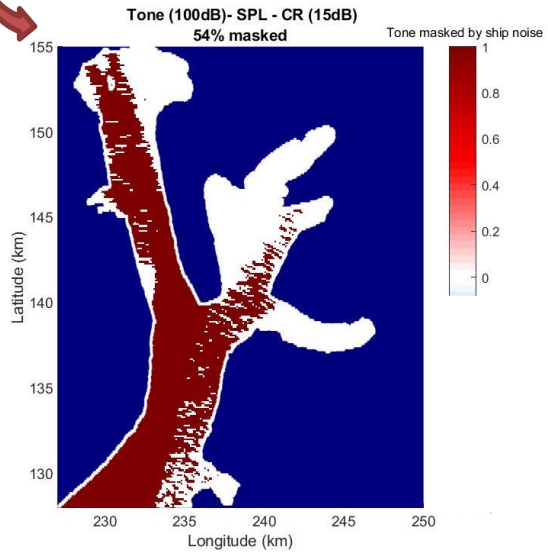
NL = 75 dB

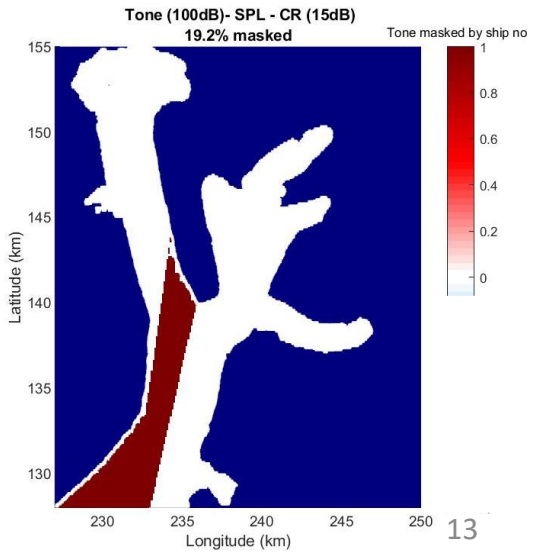




Zones having
a risk of masking





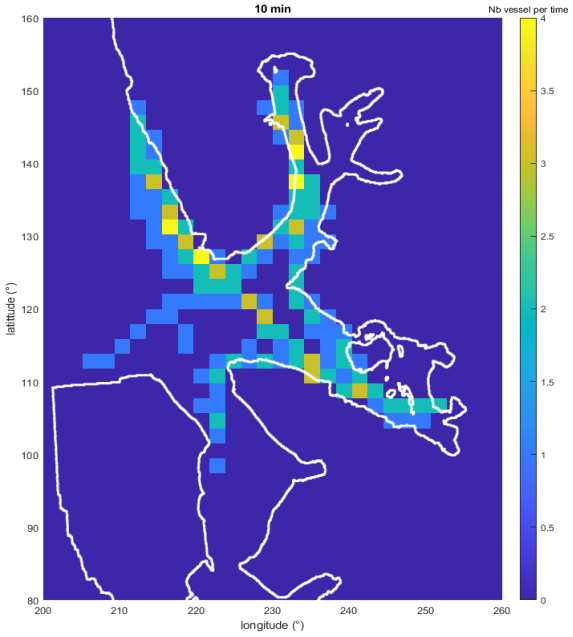


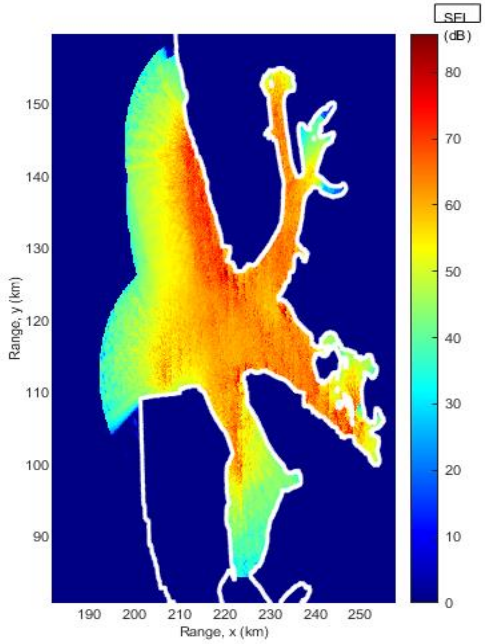
Toward a better qualification and quantification of anthropophony impacts for marine spatial planning through a 3D propagation model

- At a spatial scale: mapping acoustic footprint where 2D propagation models can't propagate sounds

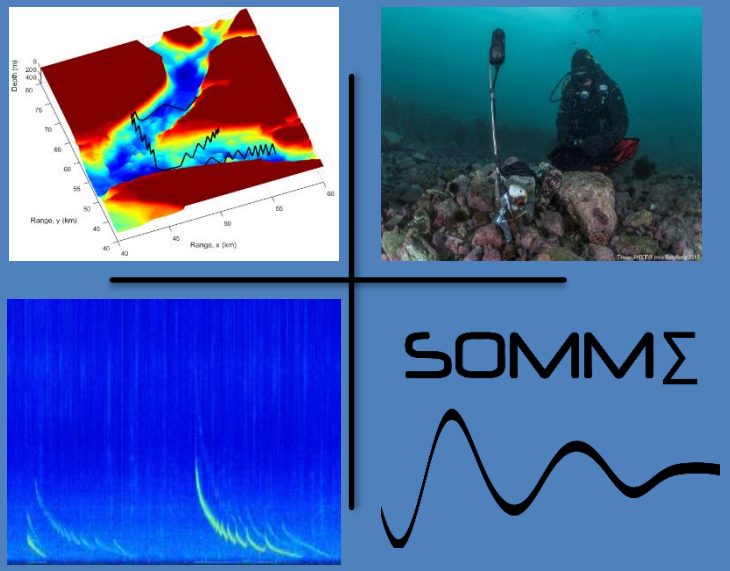
- Improvement of sound exposure level estimation : highlighting higher acoustic exposure to shipping noise to marine species than 2D propagation models

- Perspectives : predict acoustic footprint in the fjords.





Thank you for your attention
Any question ?



richard.somme@orange.fr

https://seaobs-somme.fr/

Workshop SERENADE

Juin 2022

Footprint estimation via 3D propagation model

Propagation model considering the Fjord bathymethry and geography in 3D (Bellhop 3D)

- **Comparison propagation model 3D vs nx2D**

Signal Excess estimation:

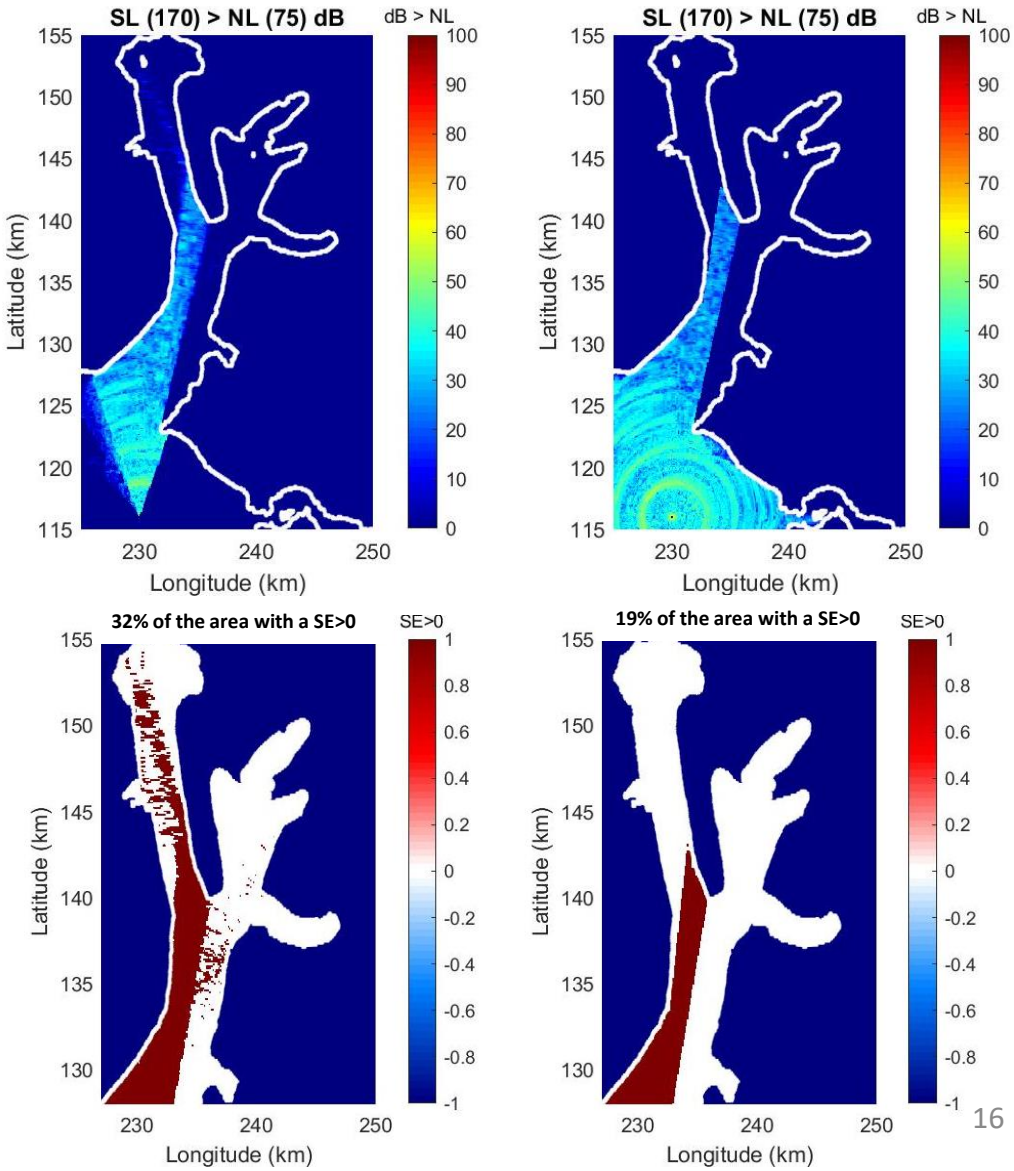
SE =SL-TL-NL

A ‘realistic’ scenario:

SL ~ median value from shipping literature

SL=170 dB

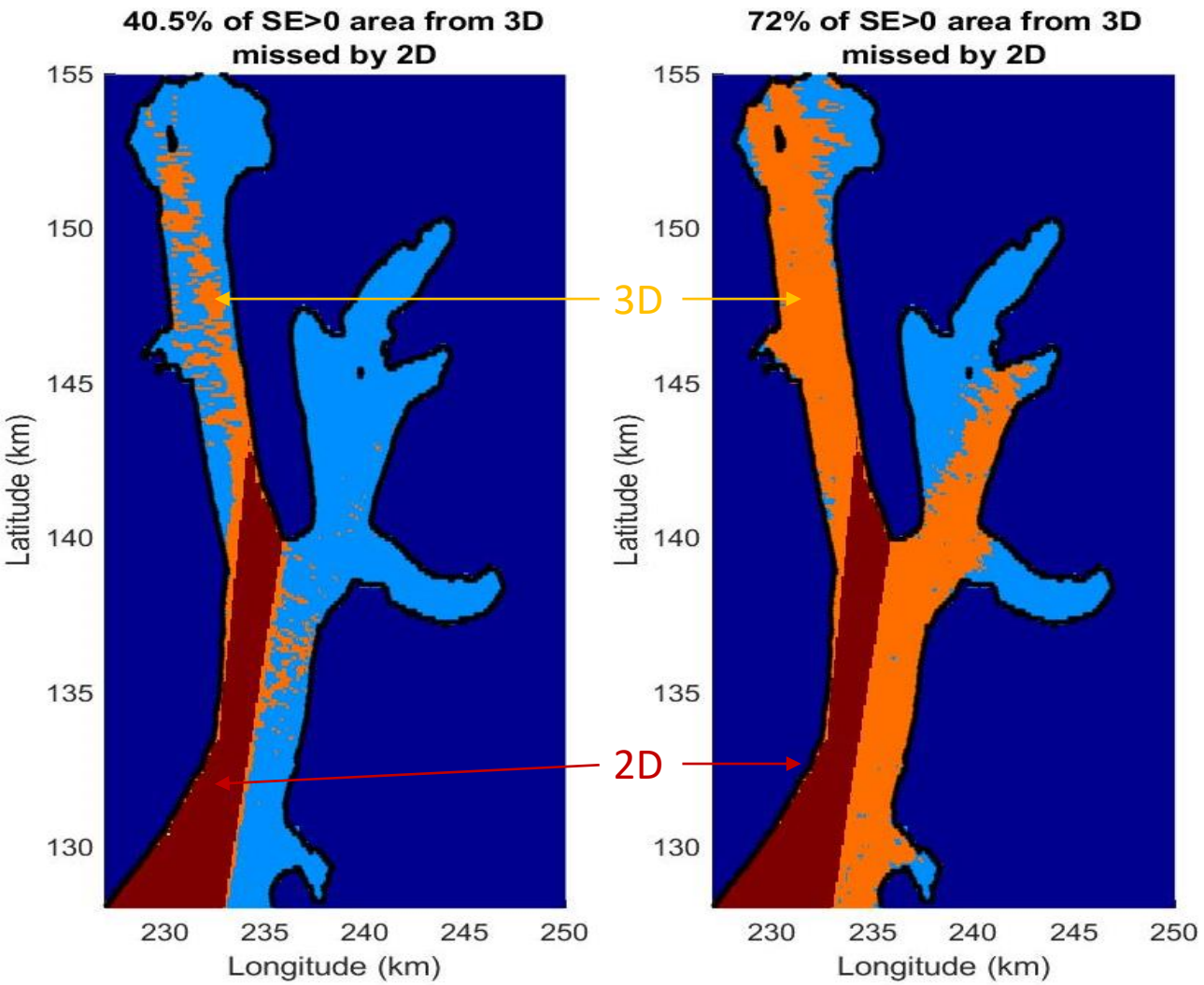
ex: Tourist vessels (~50-60 m)



Differences of Signal Excess (SE) between the full 3D model and the nx2D model

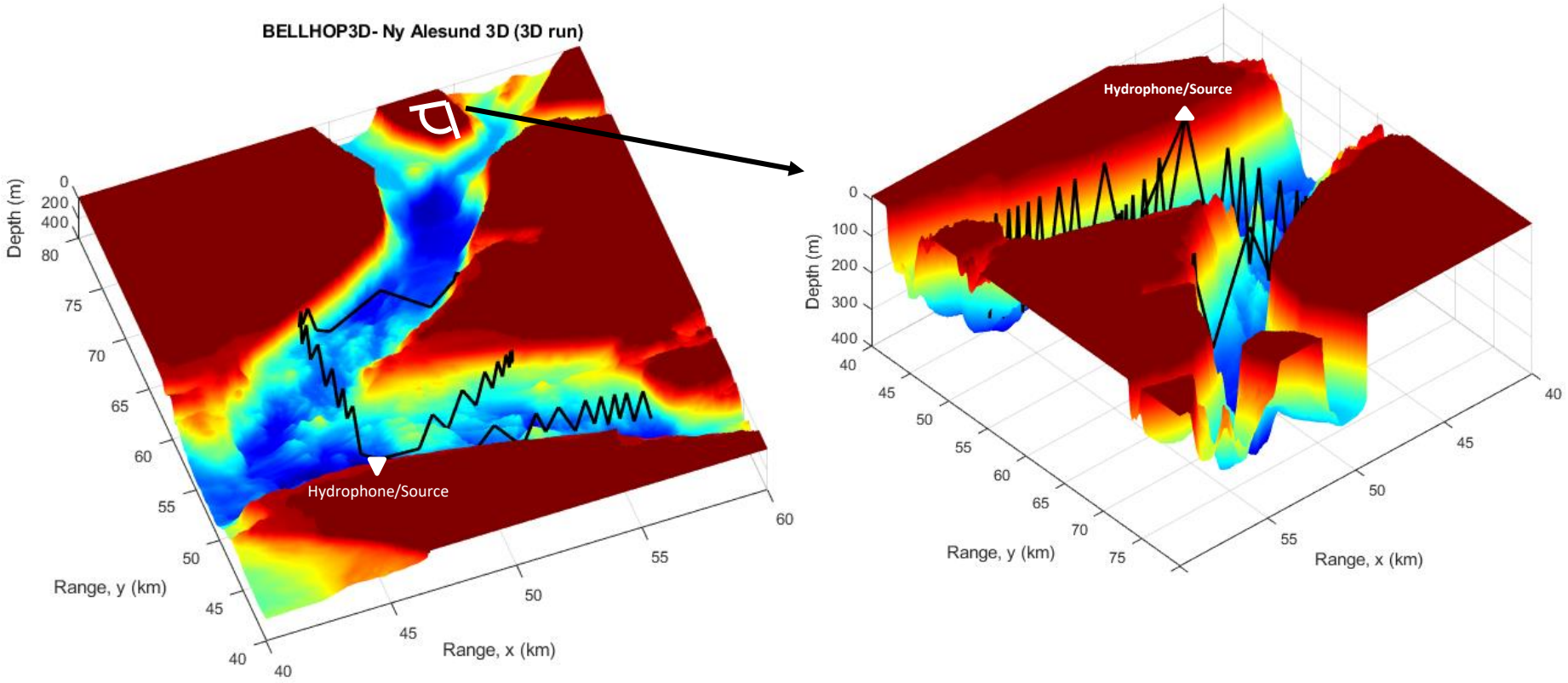
SL= 170dB

SL=190dB



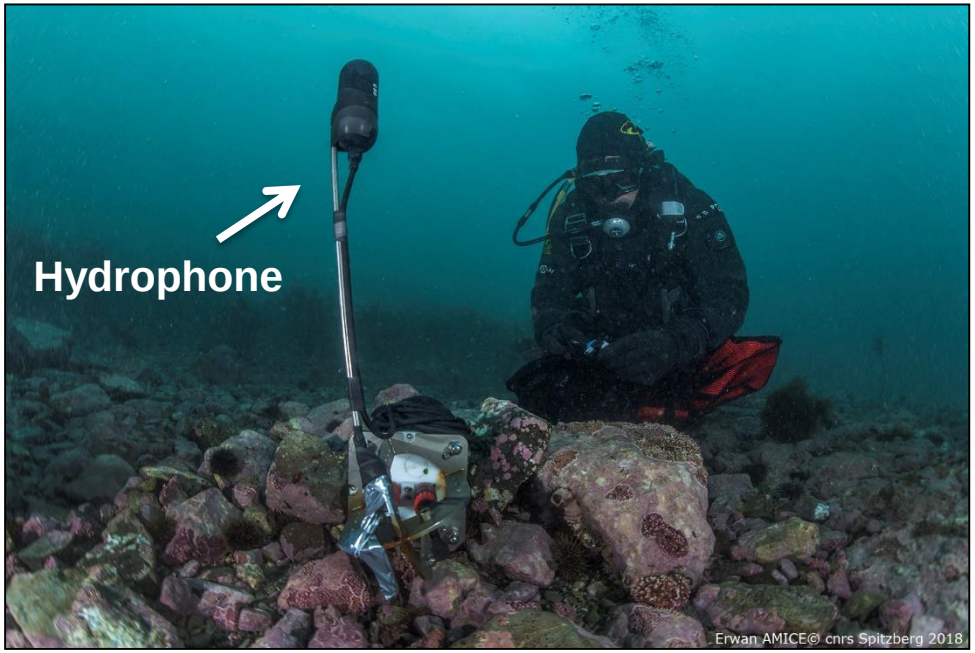
Propagation model considering the Fjord bathymetry and geography in 3D (Bellhop 3D)

- **Bellhop: Beam tracing propagation model**



How to monitor acoustic impact on biodiversity ?

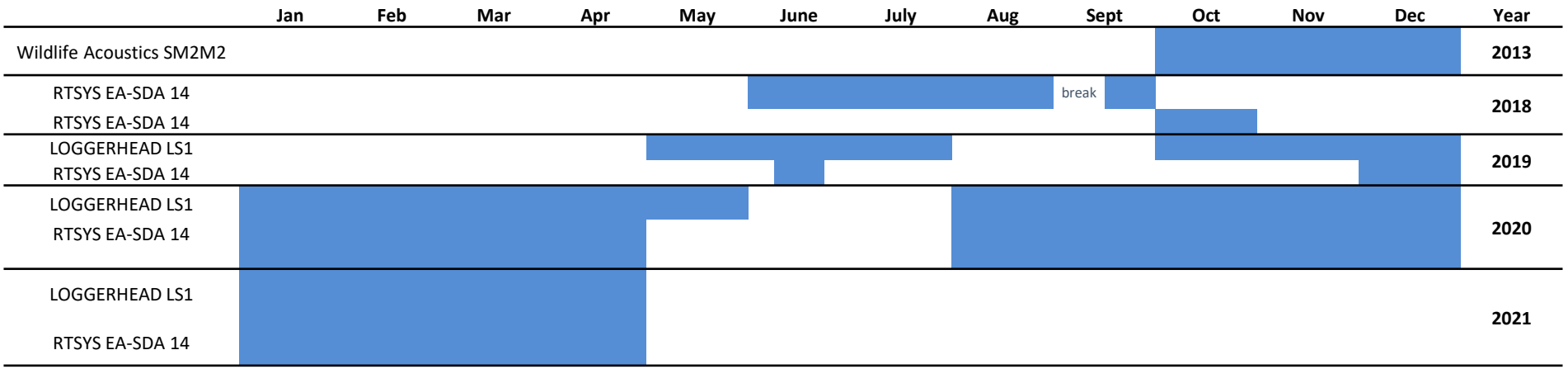
Long-term deployments at 10 m depth:



Battery pack for
long-term recording
(several months)

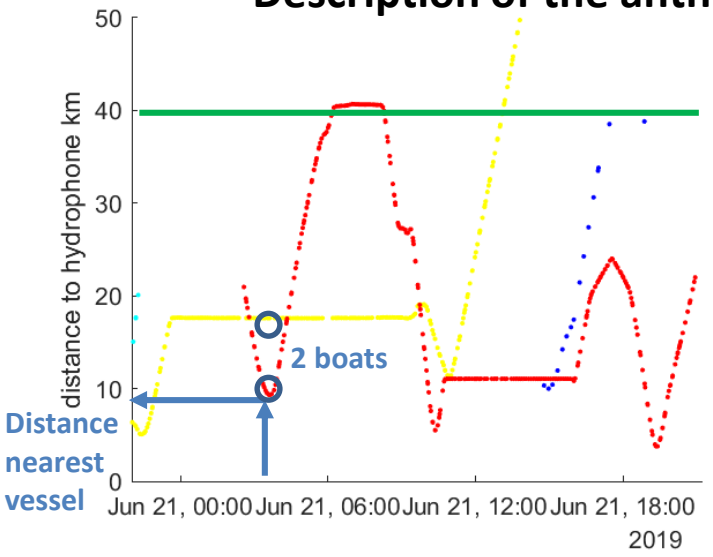
How to monitor acoustic impact on biodiversity ?

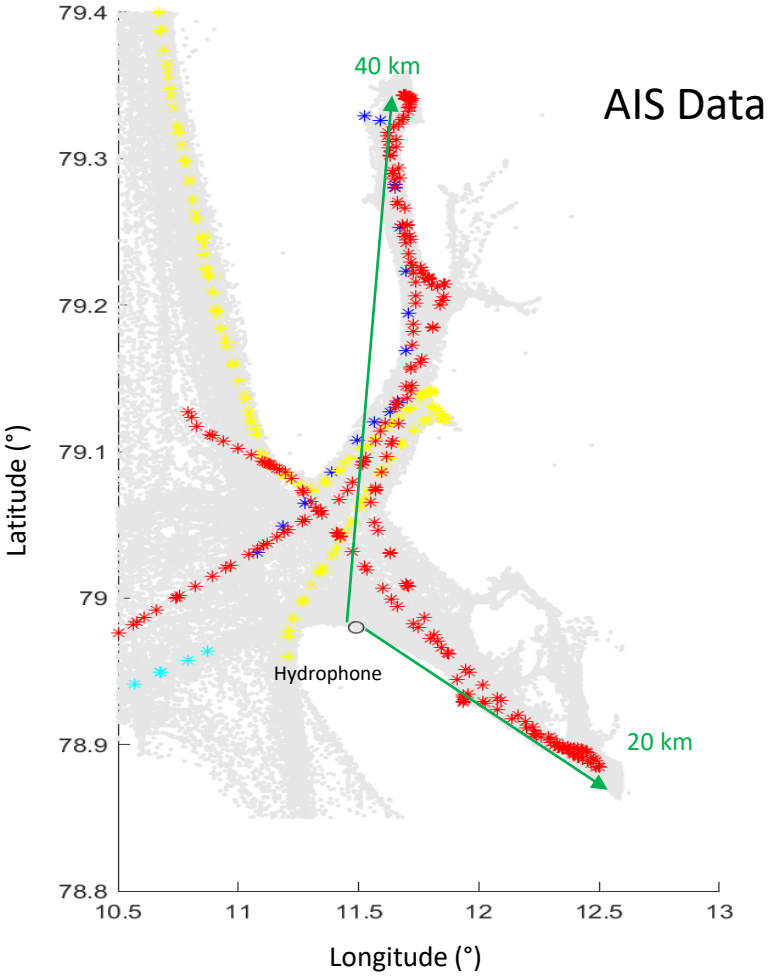
Long term monitoring : data

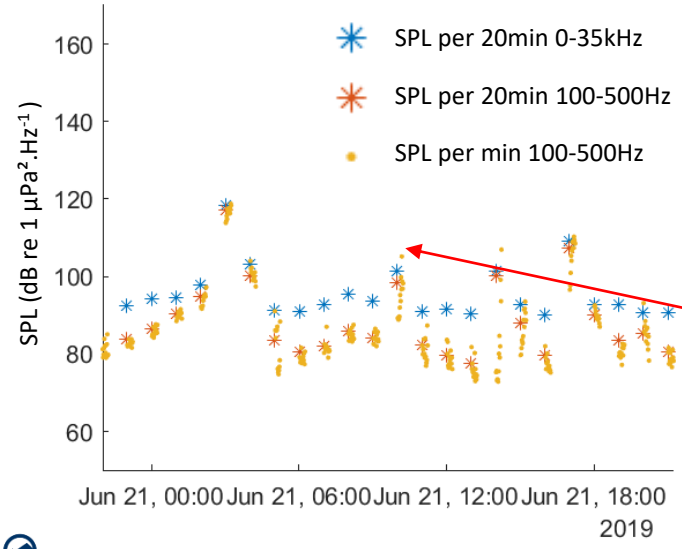


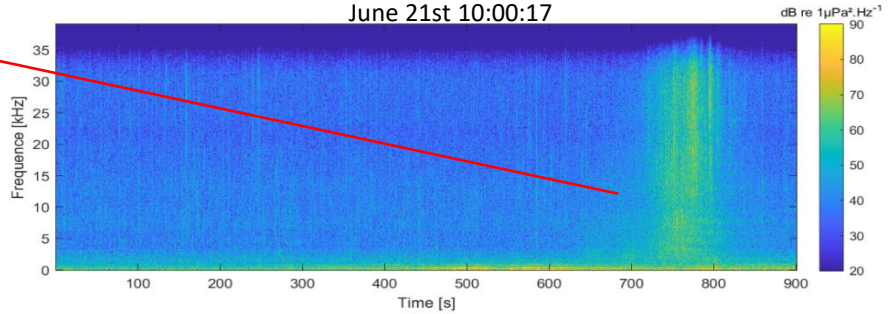
Estimation of vessel acoustic

Description of the anthropophony



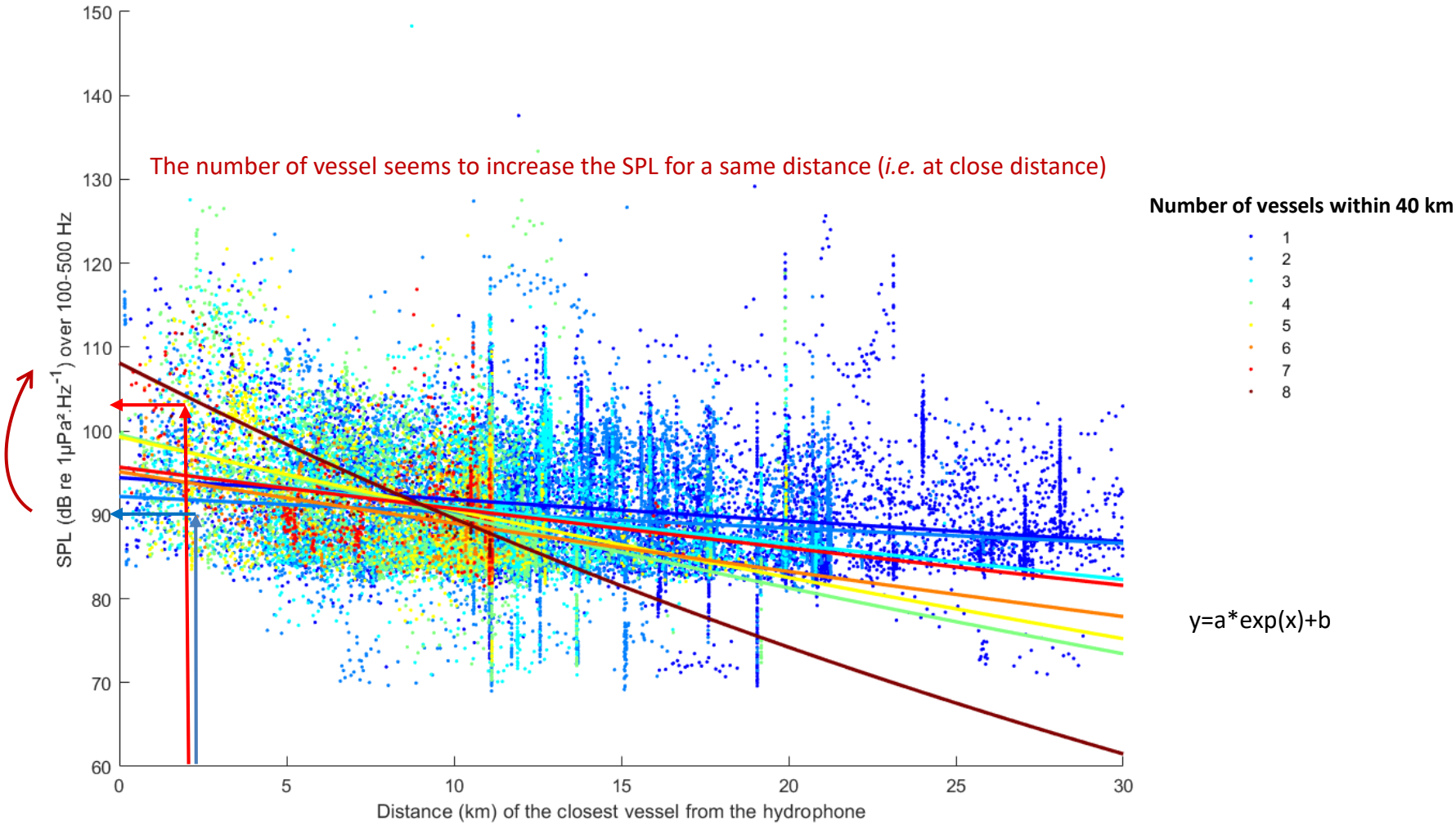






INTAROS

Effect of number of vessels and/or distance of the nearest vessel?



The comparison of slope may inform upon the transmission loss in this area, but this required firs a good understanding of the environment