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Modelling the underwater noise of wind farms in the south-east of Gran Canaria

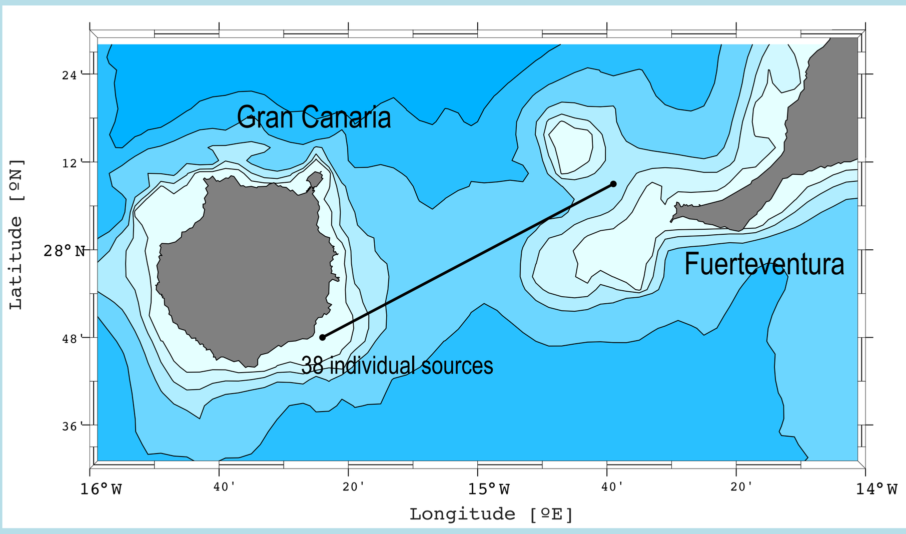
Melania Cubas Armas[1]*, Alonso Hernández-Guerra[1], Eric Delory[2], David Dellong[3], José Antonio Díaz[2]

*melania.cubas@ulpgc.es, 1: ULPGC, Spain; 2:PLOCAN, Spain; 3: SHOM, France;

INTRODUCTION

- Underwater noise is known to interfere with communication amongst groups of animals and drive them away from feeding grounds and migration routes. Moreover, they can also suffer from temporary hearing damage and permanent physical injury. Floating wind turbines are known to reduce the installation and decommissioning noise in contrast to fixed-bottom turbines. Nevertheless, the noise produced by the operation of the turbines and the anchoring systems have been scarcely studied, and it is still unknown whether added noise could significantly affect behaviour or even hearing capacity in the long term.
- In the framework of the JONAS project, we considered a regional case southeast of Gran Canaria, where several commercial offshore wind farms are under consideration. The aim of this study is to determine how noise would propagate in the region and potentially impact (or not) local fauna, focusing on mammal groups. We use the RAM model (Range-dependent acoustic model) to simulate the propagation of sound in the ocean and estimate transmission loss depending on the depth and distance to the source.

MODEL INPUTS



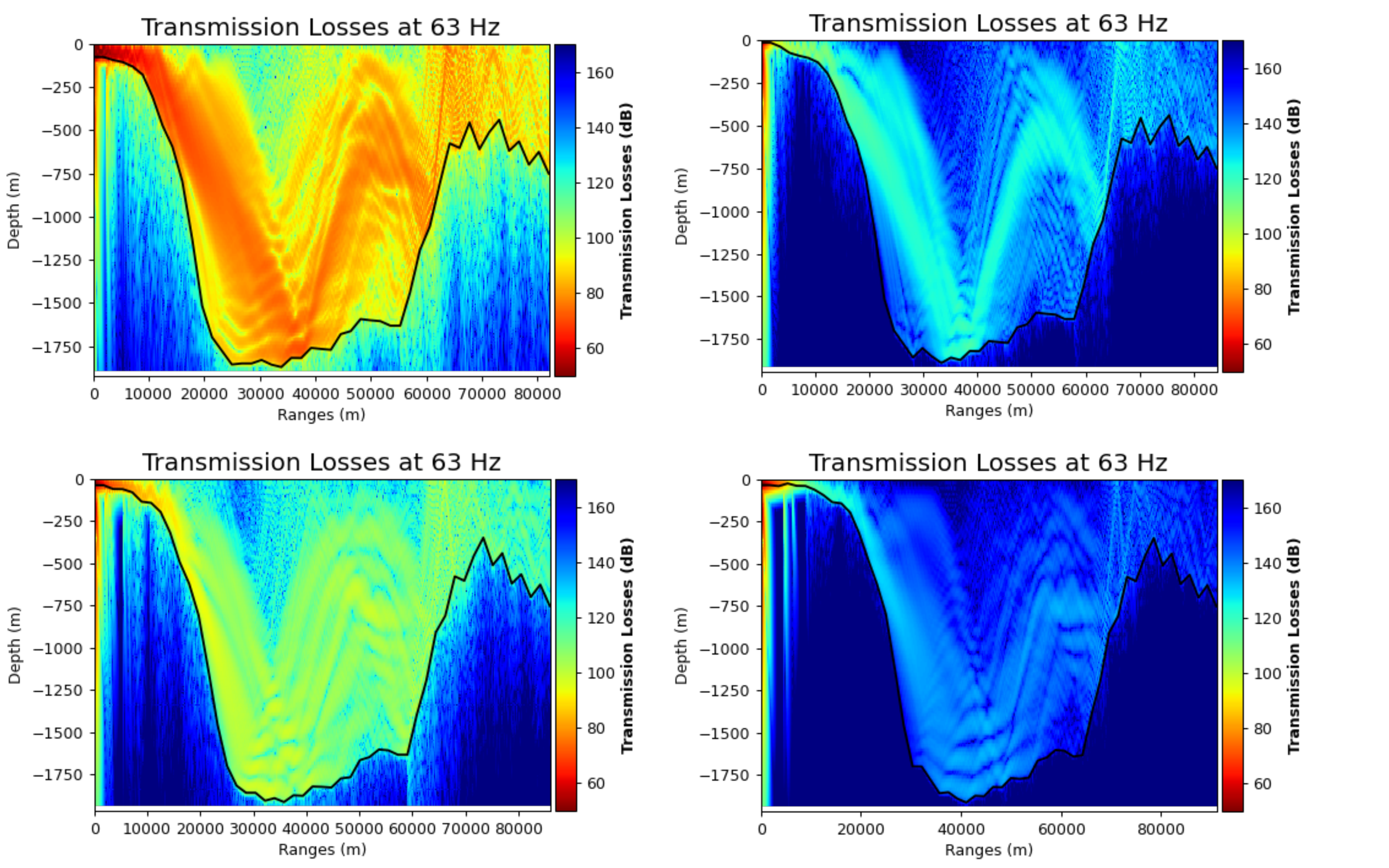
- The transect selected is shown in the Figure on the left. Source is located at the black point near the coast of Gran Canaria and receiver is close to Fuerteventura, in an area where different groups of cetaceans have been observed.
- We defined 38 individual sources and run the RAM code for each one of them. We considered all sources being equal and with narrow band source levels (SL) of 166 dB re 1µPa (following Equinor report).
- The temperature and salinity profiles are from Mercator for day 02/09/2019. The sound velocity profile is estimated from these data. Other parameters of the simulation are summarised in the table below.

Parameter	c_{bot} (m/s)	ρ (Kg/m)	Att.	dr (m)	dz (m)	z_{src} (m)	z_{rec} (m)	Frequencies (Hz)
Values	1650	1,9	0,88	10	10	45	100	63, 125, 500, 1000

RESULTS

Variations due to the position of the source

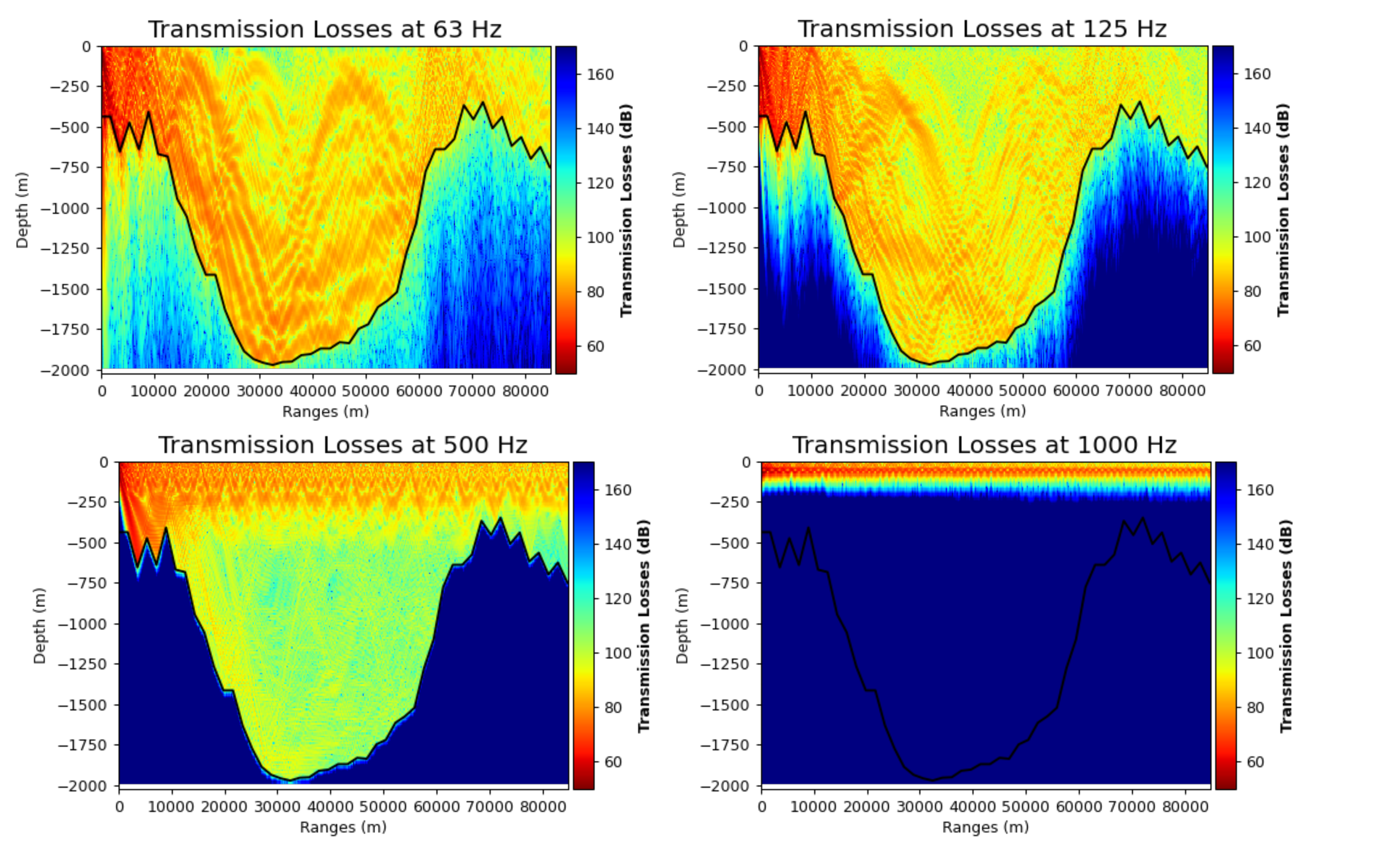
In the following panels we show the transmission loss (TL) maps simulated for the transect studied for 4 of the 38 sources considered at 63 Hz.



Above figure puts in evidence the high variability of sound intensities that will reach the receiver depending on source position. In this case, as we assume that the bottom is a constant sand layer, the only parameters that affect the result are bathymetry and the distance to the coast. When the source (wind turbine) is located in very shallow waters (closer to the shore), there are more reflections with the bottom and the surface, and the sound can barely travel more than 20 km. However, if the wind turbine is located in deeper waters, a significant part of the energy remains up to 80km.

Variations due to the frequency

In the following panels we show the TL maps simulated for one of the sources considered and for the four frequencies.



Frequency is a very important parameter for simulating transmission loss. In the above figure the source is located in deeper waters than the previous case.

- For the 63 Hz and 125 Hz maps there is noise almost everywhere, and the transmission loss value at the receiver is around 90 dB.
- However, as we move to higher frequencies there is greater attenuation in the water column and sound, according to the model, seems to better propagate close to the surface, here within the first 250 m depth. In deeper waters, for 1000 Hz, sound is attenuated nearly entirely. For this and higher frequencies, the result should however be contrasted with a ray tracing model (future work), better adapted to higher frequencies than RAM.

Threshold values for temporary and permanent hearing damage for different groups of cetaceans

From the TL values obtained at the receiver depth and location, we calculated the sound pressure levels (SPL) for each of the frequencies studied (see Eqs (1) and (2)). Sound exposure level (SEL) was also obtained (see Eq. (3)) in order to compare it with threshold values for temporary and permanent shifts (TTS, PTS respectively) from NOAA's report (2018).

$$\mathrm{SPL} = \mathrm{SL} - \mathrm{TL} \quad (1)$$

$$\mathrm{SPL_{total}} = 10\log_{10}\left[10^{\left(\frac{\mathrm{SPL_1}}{10}\right)} + 10^{\left(\frac{\mathrm{SPL_2}}{10}\right)} + 10^{\left(\frac{\mathrm{SPL_3}}{10}\right)} + \cdots\right] \quad (2)$$

$$\mathrm{SEL} = \mathrm{SPL} + 10\log\left(\frac{\mathrm{T}}{\mathrm{T_0}}\right) [\mathrm{dB\ re\ 1\mu Pa^2 s}] \quad (3)$$

- SPL and SEL values for each frequency are shown in Table 2. The highest value obtained is for 1000 Hz with a SEL = 53,56 dB re 1µPa²s.
- This value is lower than the 178 dB that is considered in NOAA's report as causing temporary hearing damage for Mid-frequency cetaceans

Frequency (Hz)	63	125	500	1000
SPL (dB re 1 µPa)	83,40	80,74	87,85	89,12
SEL (dB re 1 µPa²s)	47,84	45,18	52,29	53,56

TTS onset thresholds for non-impulsive sounds.

Hearing Group	K (dB)	C (dB)	Weighted TTS onset acoustic threshold (SEL_{cum})
Low-frequency (LF) cetaceans	179	0.13	179 dB
Mid-frequency (MF) cetaceans	177	1.20	178 dB
High-frequency (HF) cetaceans	152	1.36	153 dB
Phocid pinnipeds (underwater)	180	0.75	181 dB
Otariid pinnipeds (underwater)	198	0.64	199 dB

Taken from NOAA's report (2018)

CONCLUSIONS

- From this work, we can firstly conclude that the position of the source is very important, not only considering the seabed is made of and their geo-acoustic properties, but also water depth or the proximity to the coast. Further, the frequency under consideration is a crucial parameter when simulating the transmission loss values.
- Moreover, the higher SEL value obtained in this study for a wind farm of 38 wind turbines is 53,56 dB re 1µPa²s, which is much lower than the 178 dB expected to cause temporary hearing damage to the most common group of cetaceans in Canarian waters. Thus, we can conclude that at a distance of more than 80 km the effect of the wind farm simulated is negligible. However, it is crucial to study the area close to the wind farm.

REFERENCES

1. NOAA Technical Memorandum NMFS-OPR-59 April 2018.
2. Noise impact assessment Hywind tampen (Equinor, 2019).
3. Shouthall et al. (2017)
4. http://staff.washington.edu/dushaw/AcousticsCode/RamMatlabCode.html