EUROPAM, MITI, ADSIL & CIAN Workshop

29th January 2024 - University Toulon - France

anr
biodiversa+ European Biodiversity Partnership
Funded by the European Union
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MUR Ministero dell'Università e della Ricerca
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Parc national de Port-Cros
VALHALLAB
LONGITUDE 181 La Voix de l'Océan
INNOVATION DÉFENSE LAB
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LIS LABORATOIRE D'INFORMATIQUE & SYSTÈMES UMR 7020
cnrs MITI MISSION INTERDISCIPLINAIRE POUR LES INITIATIVES TRANSVERSES ET INTERDISCIPLINAIRES
LIVE TOGETHER Association Monégasque
UNIVERSITÀ DI PAVIA
UNIVERSITÉ DE TOULON

Schedule

10:00 : Presentation of all participants, present or in visio
10:15 : Summary of EUROPAM work packages
10:30 : EUROPAM / PELAGOS missions we did in Med Sea in 2023
- Historic results from Bombyx1 and Bombyx2 : J. Girardet et al (10’)
- Current runnings of Bombyx2 near Monaco : H.Glotin et al (10’)
- Results from WhaleWay Longitude 181 missions : S. Chavin et al (10’)
- Results from LT missions : Biosonar analyzes : N. Deloustal et al (10’)
- Summary WW : F. Sarano (10’)

11:30 : ACORES : preparation of the mooring / BX3 to be sent (15’+ discussion)
11:45 : ITALY : preparation of the moorings : IMPERIA / GENOVA ? (15’+ discussion)
12:00 : FRANCE : Placement in Corsica, Marseille, Golf du Lion (Eolian) (15’+ discussion)
Discussion

12:30 : lunch in the room “plateau repas”, 19 present.

13:45 : EUROPAM / ADAPREDAT in Norway : a little Movie for introduction :
https://pod.univ-tln.fr/video/6463-projet-adapredat-fjord3d-luniversite-de-toulon-a-lecoute-des-cetaces-des-fjords-arctiques-norvegiens/

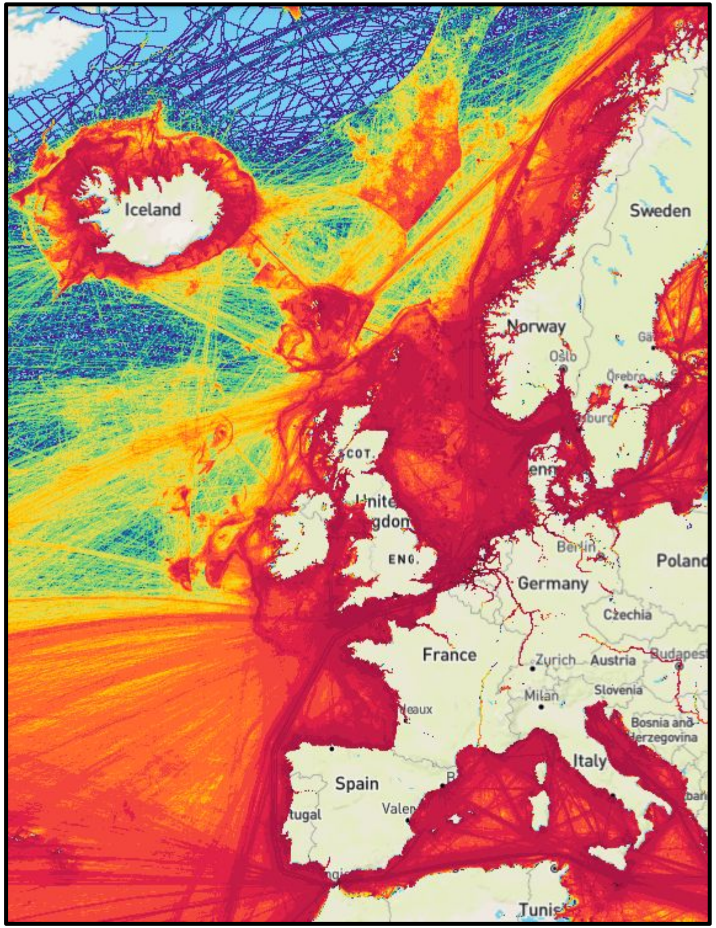
- Summary of EUROPAM and MITI missions 2023+2022 & first results H. Glotin et al (10’)
- First correlations interspecific interactions : J. Girardet et al. (10’)
- Historics and current data of CTD in the fjord : Katie, M. Chami & Akvaplan coll. (20’)
- Propagation and serious Gaming : S. Paris et al. (10’)

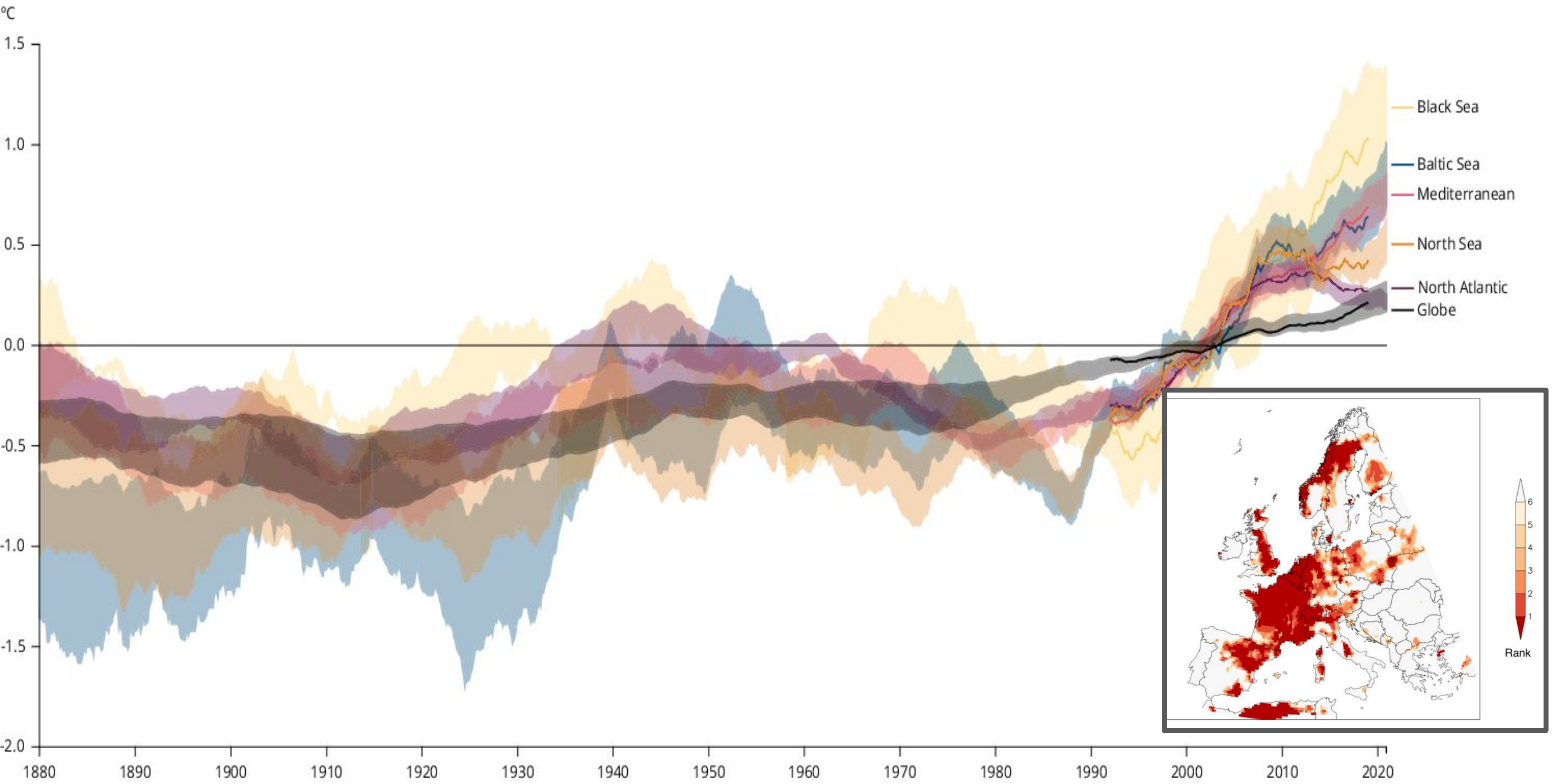
14:45 : NORWAY : the second Bombyx in Norway in 2024 (15’+ discussion)
15:00 : EUROPAM missions in 2024 in Norway (15’+ discussion)

15:15 : Next Events EUROPAM Communications : DCLDE Rotterdam 3-7th june 2024, 10-13th june SERENA in Toulon, AI Bioac schools 14-15th june 2024
15:45 : Administration (30’, possible extension ?)
16:15 : Discussions
17:00 : End

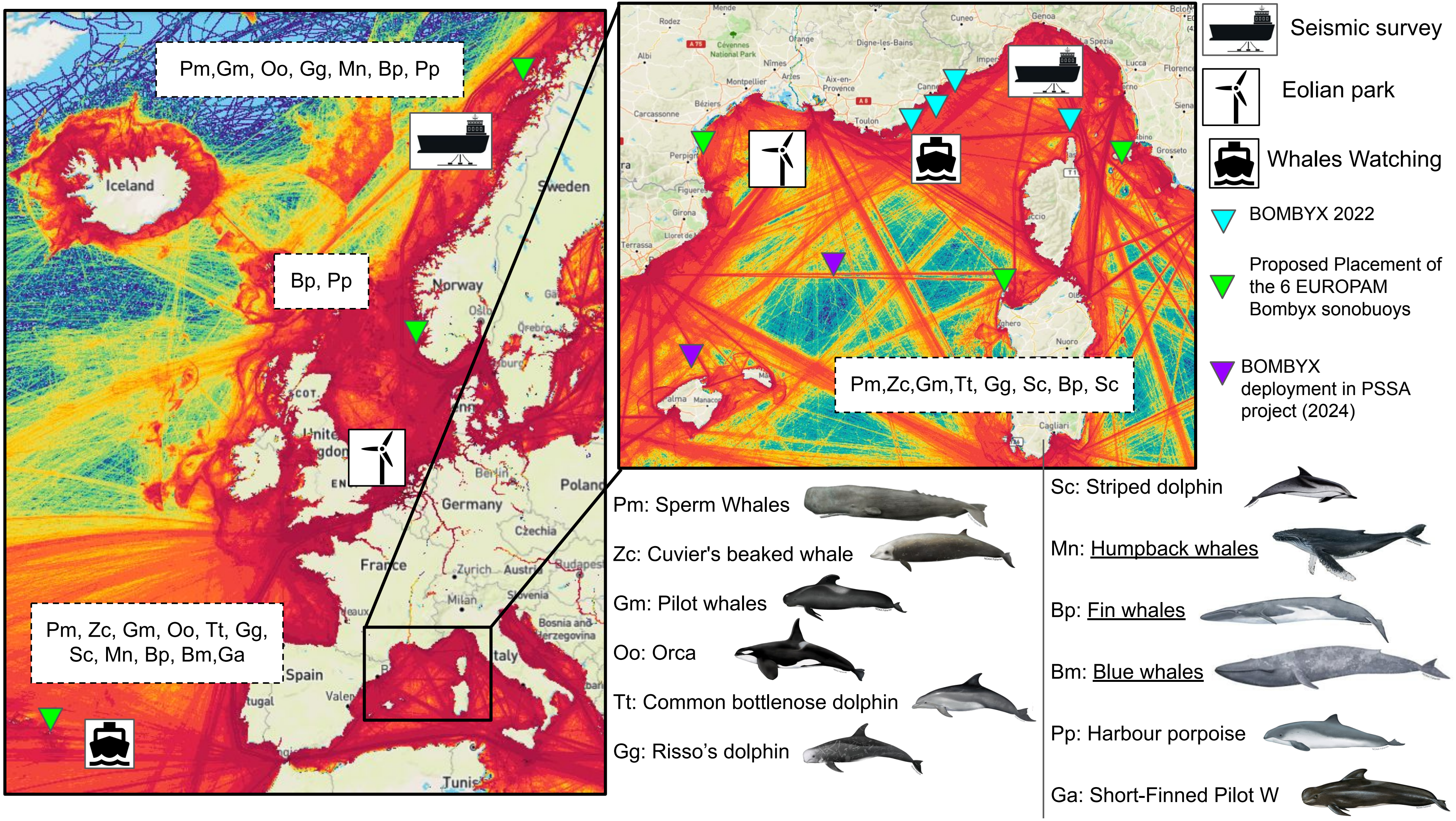
Summary of Europam work packages

Adaptations of super-predators to Climate Change In the Ocean : comparative study in the European Arctic versus Mediterranean Seas

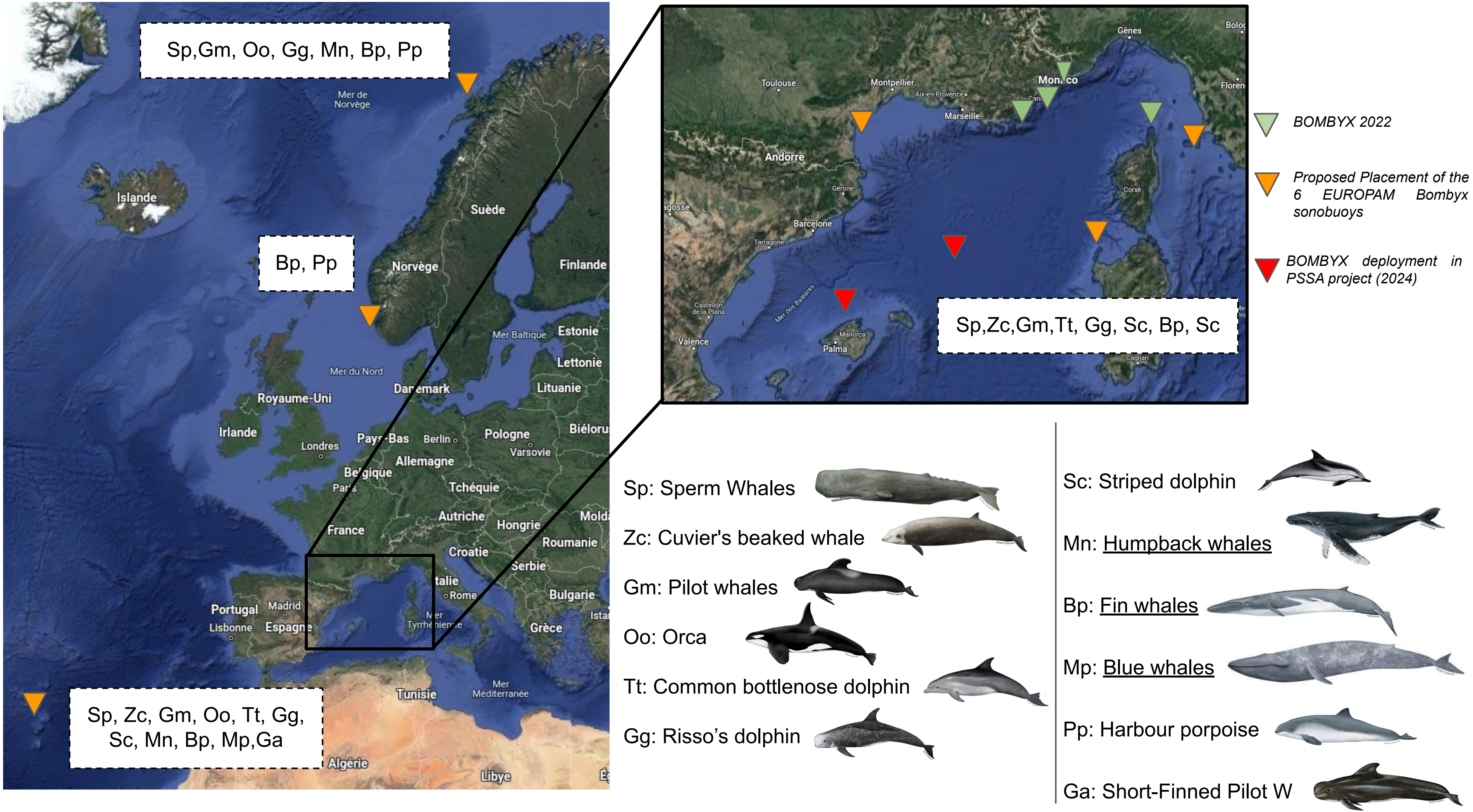




Decadal average sea surface temperature anomaly in different European seas (1870 to 2020), (European Environment Agency) and Heatwaves in Europe (2019, https://www.worldweatherattribution.org)



Pm,Gm, Oo, Gg, Mn, Bp, Pp
Bp, Pp
Pm, Zc, Gm, Oo, Tt, Gg, Sc, Mn, Bp, Bm,Ga
Pm,Zc,Gm,Tt, Gg, Sc, Bp, Sc
Iceland
Norway
Sweden
Germany
France
Spain
Seismic survey
Eolian park
Whales Watching
BOMBYX 2022
Proposed Placement of the 6 EUROPAM Bombyx sonobuoys
BOMBYX deployment in PSSA project (2024)
Pm: Sperm Whales
Zc: Cuvier's beaked whale
Gm: Pilot whales
Oo: Orca
Tt: Common bottlenose dolphin
Gg: Risso's dolphin
Sc: Striped dolphin
Mn: Humpback whales
Bp: Fin whales
Bm: Blue whales
Pp: Harbour porpoise
Ga: Short-Finned Pilot W


Sp,Gm, Oo, Gg, Mn, Bp, Pp
Bp, Pp
Sp, Zc, Gm, Oo, Tt, Gg,
Sc, Mn, Bp, Mp,Ga
Sp,Zc,Gm,Tt, Gg, Sc, Bp, Sc
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Mer de Norvège
Islande
Suède
Norvège
Finlande
Estonie
Lettonie
Lituanie
Mer Baltique
Mer du Nord
Danemark
Royaume-Uni
Irlande
Londres
Pays-Bas
Berlin
Pologne
Varsovie
Allemagne
Belgique
Paris
Tchéquie
Autriche
Hongrie
France
Croatie
Roumanie
Serbie
Italie
Rome
Bulgarie
Portugal
Madrid
Espagne
Lisbonne
Mer Tyrrhénienne
Grèce
Tunisie
Mer Méditerranée
Algérie
Libye
Toulouse
Montpellier
Aix-en-Provence
Marseille
Monaco
Gênes
Andorre
Gérone
Barcelone
Tarragone
Corse
Castellón de la Plana
Mer des Baléares
Valence
Mallorca
Palma
Cagliari

BIODIVERSA “EUROPAM”

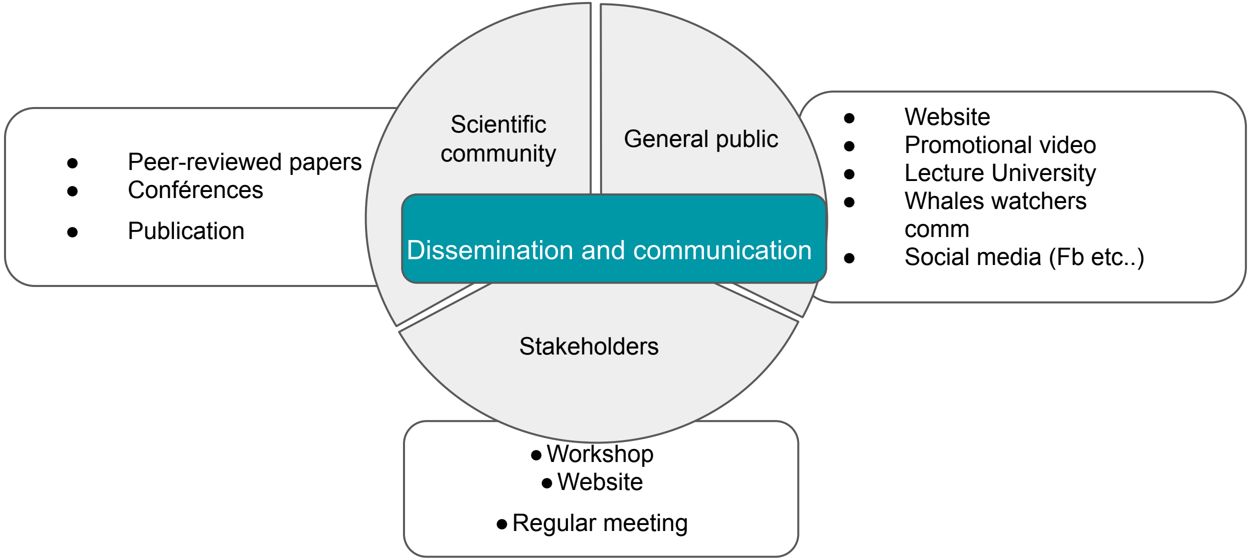
CALL = https://www.biodiversa.org/1932/download
P26 : preproposal

Objectives : Assess and build a common framework at European Scale, Arctic, Atlantic and Med Sea for comparative study of the resiliency of megafauna

Methods : Bombyx sonobuoys already deployed in GIAS in MedSea, AI methods

Expected impacts : provide knowledge based conservation tools for important ecological areas and community networks in Mediterranean sea, Atlantic Ocean and Norwegian sea.

UN, PELAGOS, ASCOBAMS, OSPAR, Migratory species and Marine strategy framework directive (monitor soundscape 63Hz + 125Hz) IPCC report climate change and endurance of this species in warming waters. **Species could be resilient, prey may be not resilient**

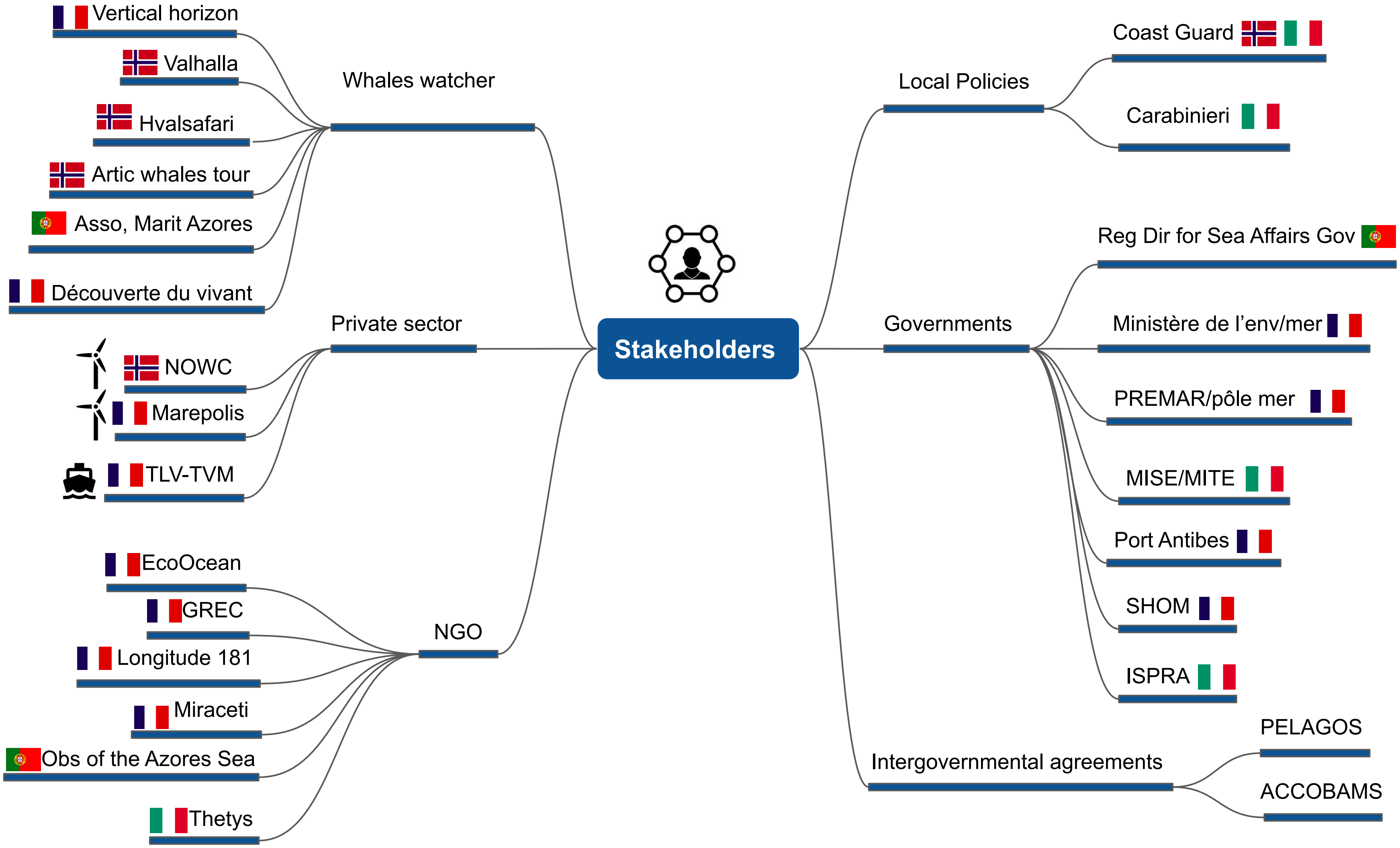


LIS Toulon, H. Gotin (France) / PI : AI for bioacoustical & instrumentations, http://bioacoustics.lis-lab.fr

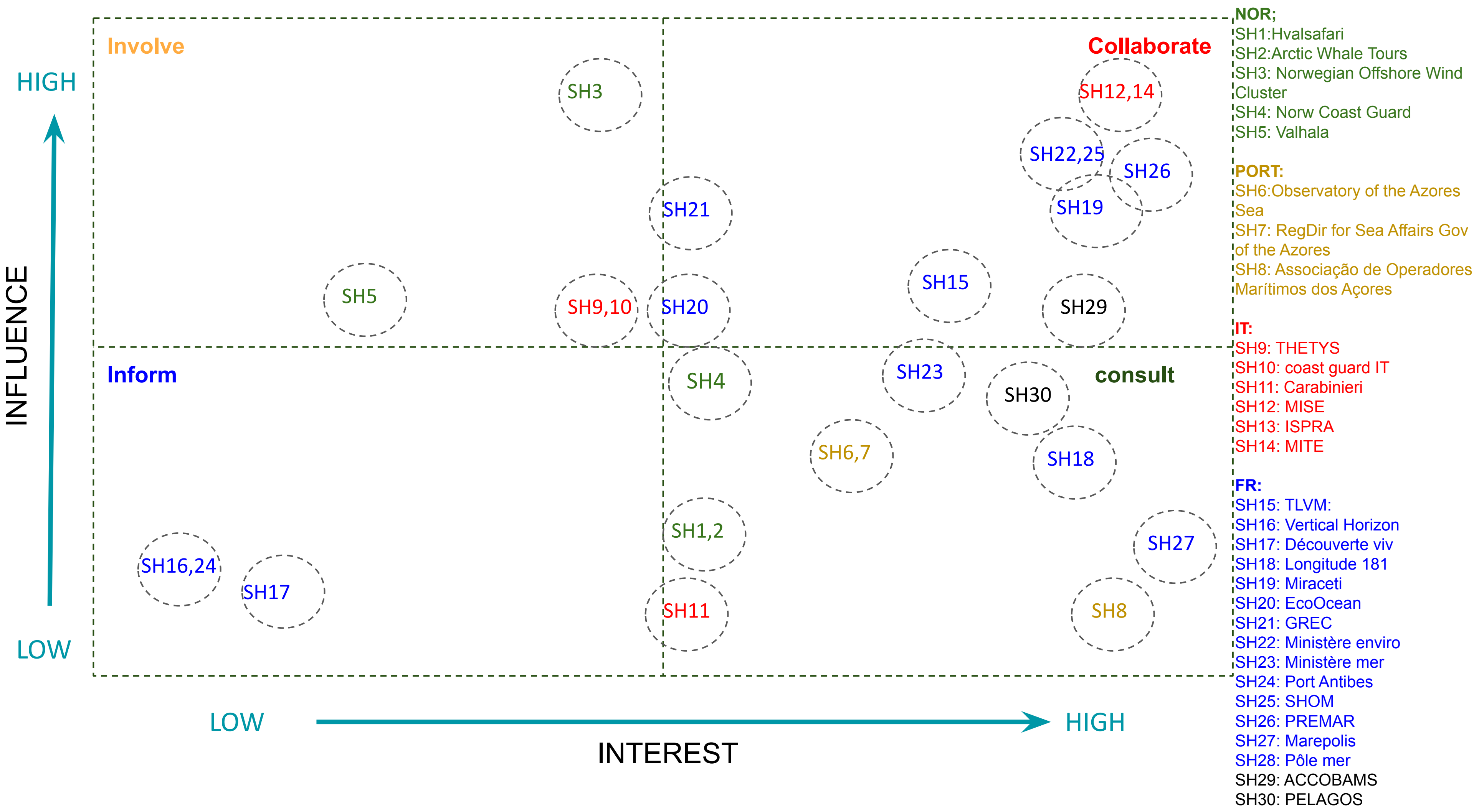
AKVAPLAN, L. Tassara (Norway) : PAM, biodiversity survey

University Acores, (Portugal) : PAM

CIBRA G. Pavan (Italy) : Bioacoustics, ecoacoustics



Stakeholders
Whales watcher
Vertical horizon
Valhalla
Hvalsafari
Artic whales tour
Asso, Marit Azores
Découverte du vivant
Private sector
NOWC
Marepolis
TLV-TVM
NGO
EcoOcean
GREC
Longitude 181
Miraceti
Obs of the Azores Sea
Thetys
Local Policies
Coast Guard
Carabinieri
Governments
Reg Dir for Sea Affairs Gov
Ministère de l'env/mer
PREMAR/pôle mer
MISE/MITE
Port Antibes
SHOM
ISPRA
Intergovernmental agreements
PELAGOS
ACCOBAMS


Involve
Collaborate
Inform
consult
HIGH
LOW
INFLUENCE
LOW
HIGH
INTEREST
SH3
SH12,14
SH22,25
SH26
SH21
SH19
SH5
SH9,10
SH20
SH15
SH29
SH4
SH23
SH30
SH6,7
SH18
SH1,2
SH27
SH16,24
SH17
SH11
SH8
NOR;
SH1:Hvalsafari
SH2:Arctic Whale Tours
SH3: Norwegian Offshore Wind Cluster
SH4: Norw Coast Guard
SH5: Valhala
PORT:
SH6:Observatory of the Azores Sea
SH7: RegDir for Sea Affairs Gov of the Azores
SH8: Associação de Operadores Marítimos dos Açores
IT:
SH9: THETYS
SH10: coast guard IT
SH11: Carabinieri
SH12: MISE
SH13: ISPRA
SH14: MITE
FR:
SH15: TLVM:
SH16: Vertical Horizon
SH17: Découverte viv
SH18: Longitude 181
SH19: Miraceti
SH20: EcoOcean
SH21: GREC
SH22: Ministère enviro
SH23: Ministère mer
SH24: Port Antibes
SH25: SHOM
SH26: PREMAR
SH27: Marepolis
SH28: Pôle mer
SH29: ACCOBAMS
SH30: PELAGOS

3 years : Mai 2024 to Mai 2027

Main goal: spatial-temporal noise management

Targeted species : Pm, Pp, Oo, Mn, Bp, Gm, Bm

WP1: Deployment of Bombyx instrumentation : Fjords (stratified water col.), Svalbard (ice), Trondheim (eolian), Acores (seismic), Italy (Thyr or Genova Golf), Med Sea (Golf du Lion & Pelagos)

WP2: Biophony

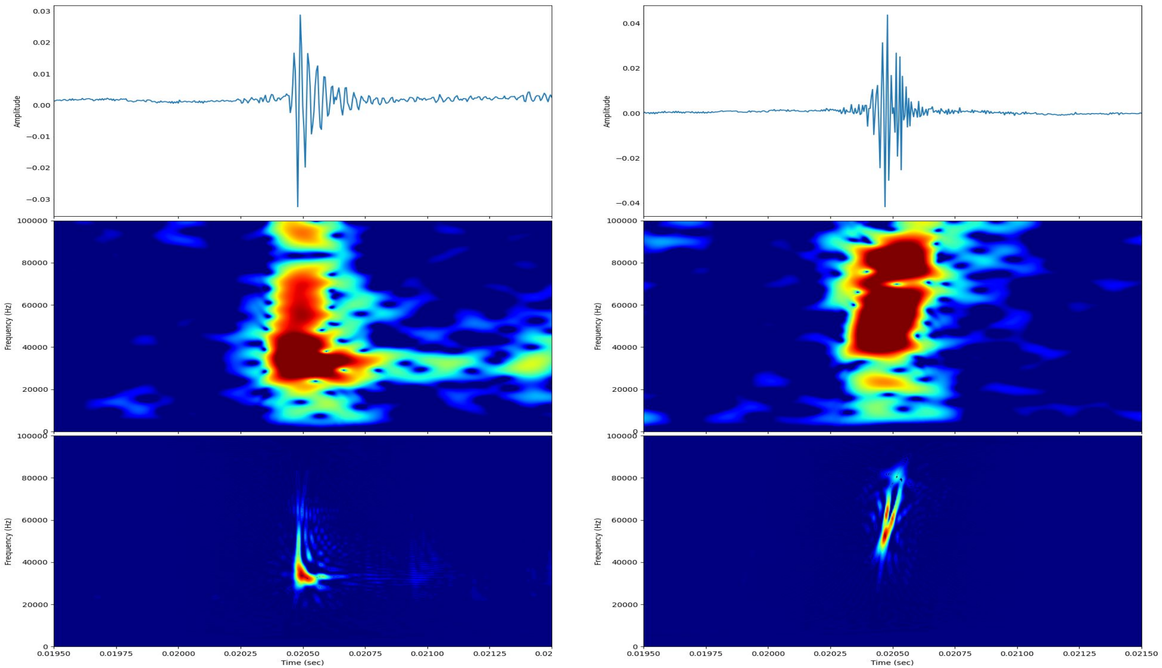
WP3: Geophony (seismic activities and different weather conditions, dB level) and Anthrophony

WP4: spatial-temporal biodiversity and noise management

Tasks :
1) identify area and periods of high species diversity
2) compare noisy with quiet areas
3) measure noise and level changes during and after windfarm construction
4) Arctic as quickly changing environment
5) exponential increase marine traffic
6) observation of species displacement (predators)
7) Acoustic Biopopulation (dialects between Med Sea, Acores and Norway)

WP5: Management and communication to stakeholders

Example of methodology : precise analyses at different SNR anthropophony of the waveform, Fourrier vs Wigner Ville :

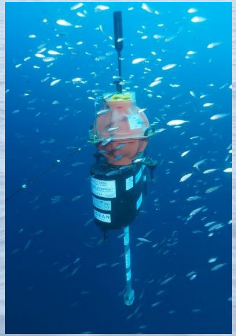


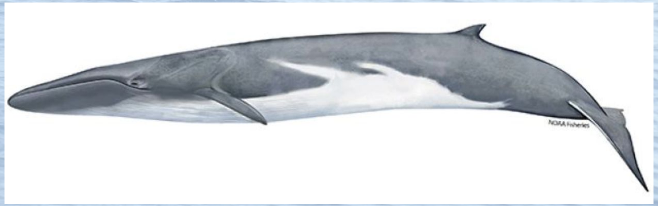
We'll analyse Ambiguity function of biosonar
of pilot whales, Orcas, Physeters,
at **different anthropic pressures**
in order to compare varieties of adaptive foraging strategies

EUROPAM, MITI, ADSIL & CIAN Workshop -
January 29, 2024

Historic result from Bombyx-1 and updates from Bombyx-2 in Northwestern Mediterranean Sea

Justine Girardet, V. Sarano, H. Glotin et al.





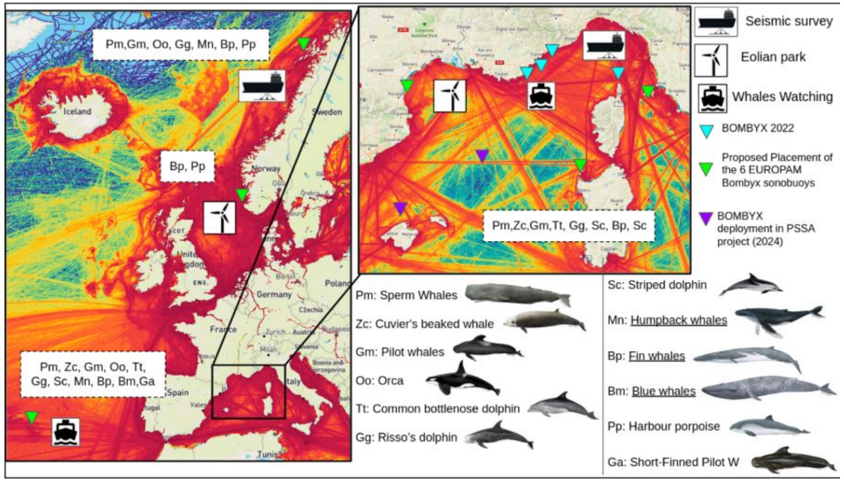
CONTEXT

Bombyx as part of the Europam project

- Passive acoustic monitoring of ecosystems and cetaceans

- Mediterranean Sea, Norway and Acores

- Evaluate impact of anthropogenic activities



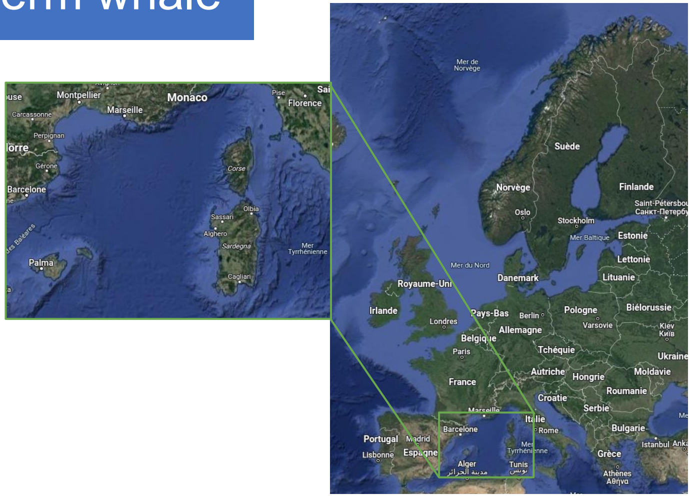
OBJECTIVES

Let’s focus on the Mediterranean Sea

Passive acoustic recordings

Assess acoustic presence of fin whale and sperm whale

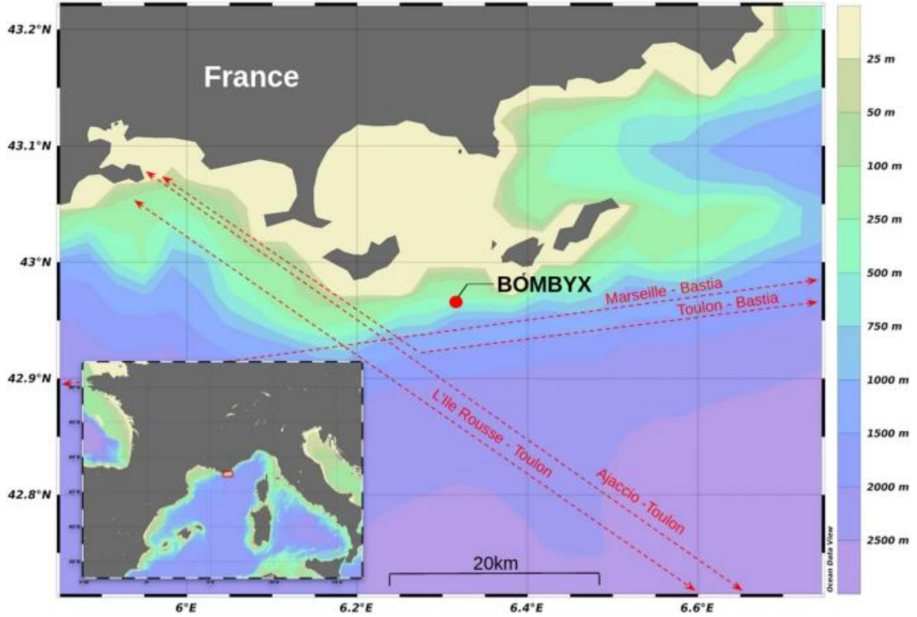
Evaluate impact of anthropophony

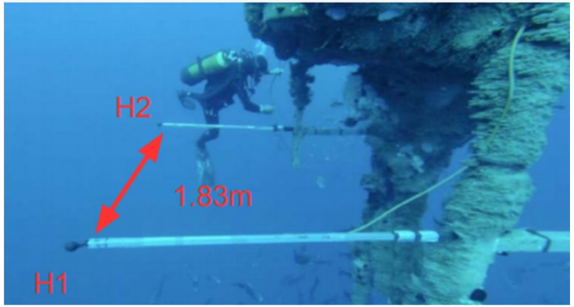


METHODS : Data collection

The Bombyx-1 sonobuoy

- May 2015 - December 2018
- 25 m of depth
- two hydrophones, 50 kHz
- recording of 5 min every 20 min

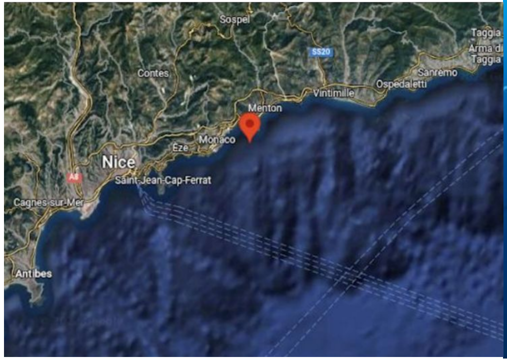


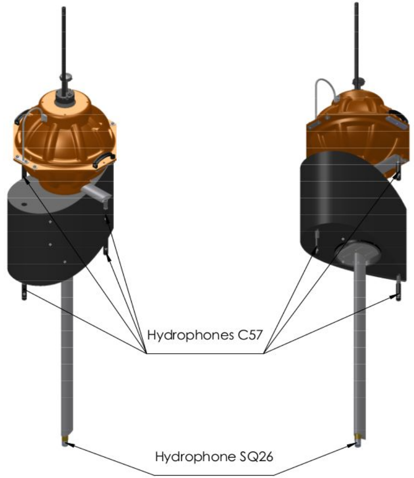


METHODS : Data collection

The Bombyx-2 sonobuoy

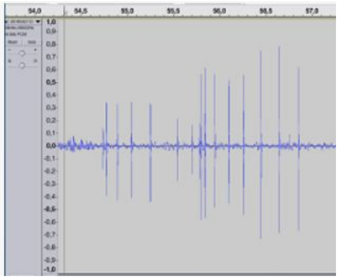
- July 2022 - September 2023
- 25 m of depth
- 5 hydrophones
- surface wireless data transmission
- Embedded AI
- recording of 5 min every hour



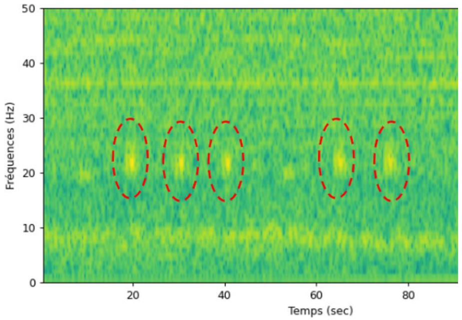


METHODS : Data analysis

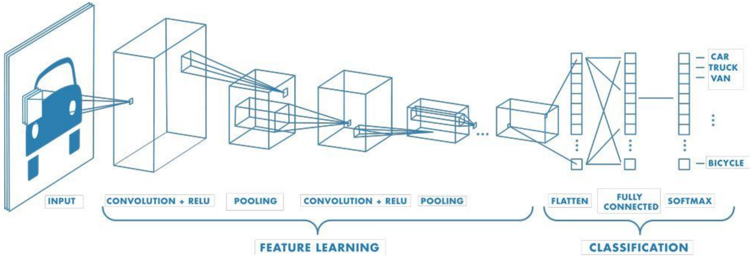
clic 0.2-25kHz



pulse 20-130Hz



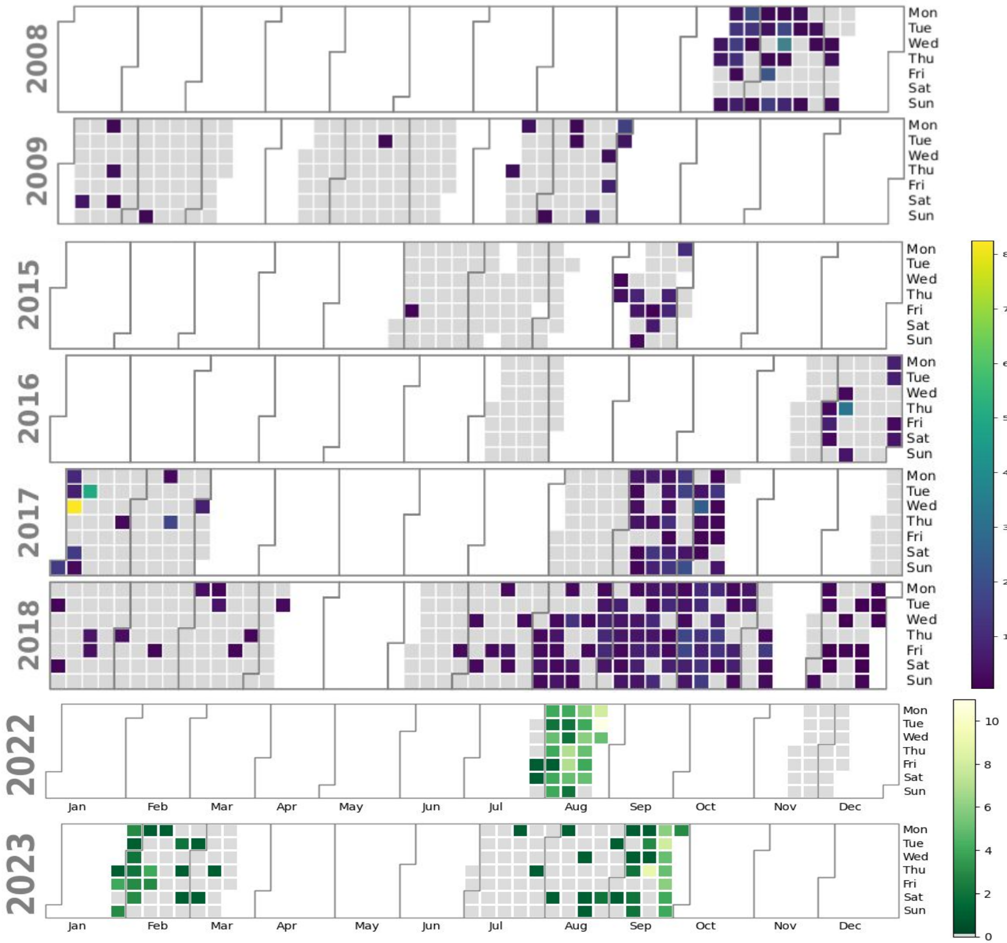
Convolutional neural network for cetaceans detections



PSD calculations for ambient noise estimations

RESULTS : fin whale acoustic presence

- High singing activity in fall from KM3, BX1
- Sporadic presence during the rest of the year
- Less detections in June-July

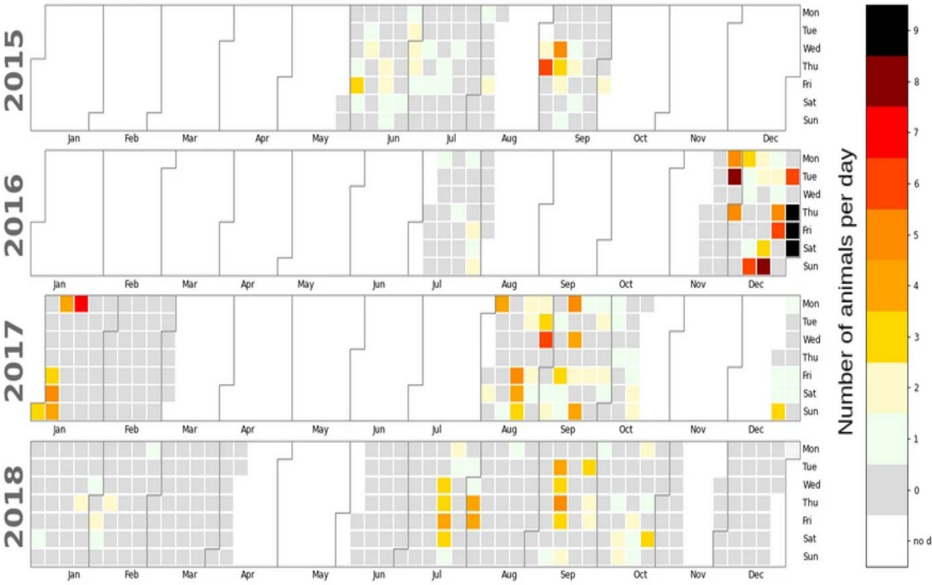


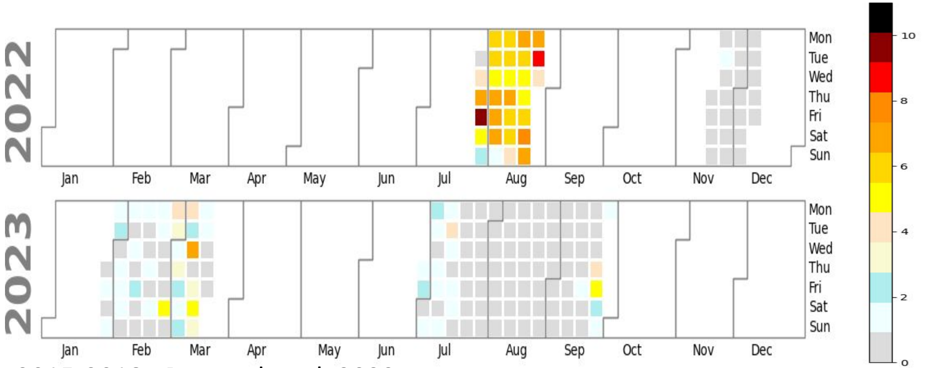
2015-2018 : Best et al. 2022

Positive detection threshold : 0.75 for 2022, 0.45 for 2023

RESULTS: sperm whale acoustic presence

- 226 sperm whale passages in BX1
- no particular seasonal cycle
- some periods with more acoustic activity





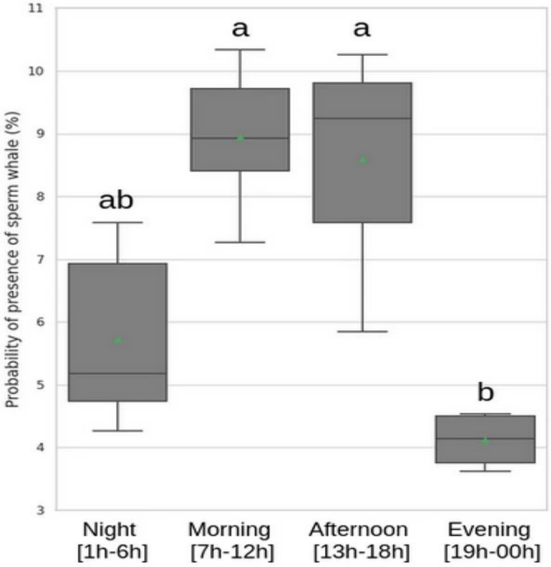
2015-2018 : Poupard et al. 2022

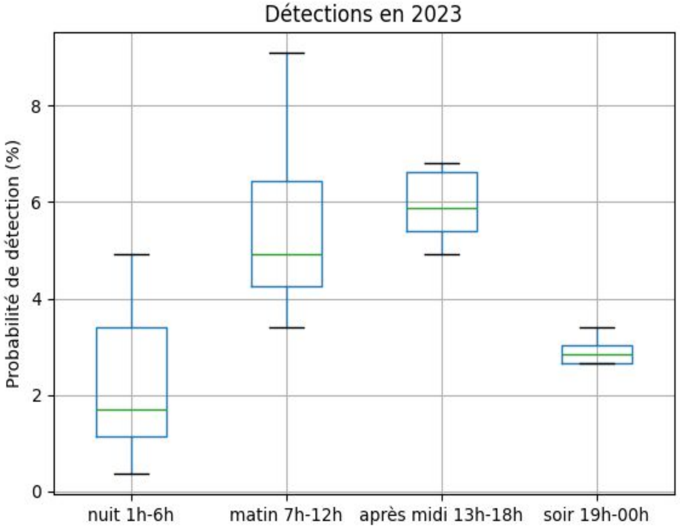
A positive recording = a recording with least 3 positives detections above a 0.5 threshold (0.9 for 2022)

RESULTS : sperm whale acoustic presence

- more detection during day than night

- same daily pattern between Porquerolle and Monaco





Mean probability of presence for each period of the day for BX1 (left, from Poupard et al. 2022) and BX2 (right)

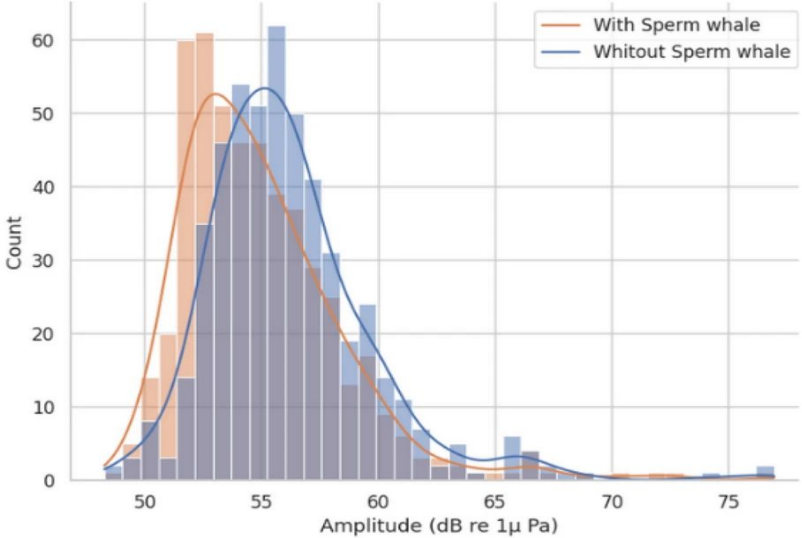
RESULTS : sperm whale and background noise

- energy peaking around 4 AM and 9 PM

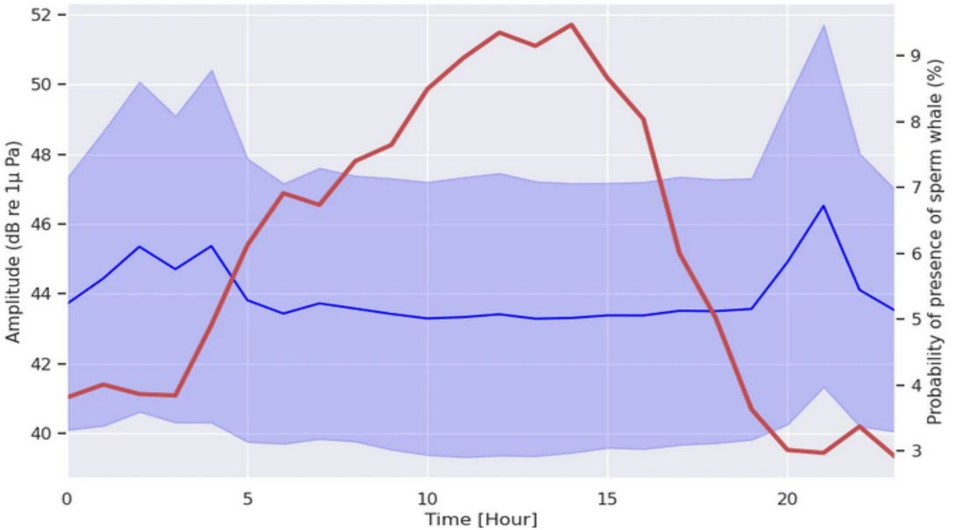
- sperm whales are statistically less present/active in noisier environments

- What about BX2 ?

From Poupard et al. 2022

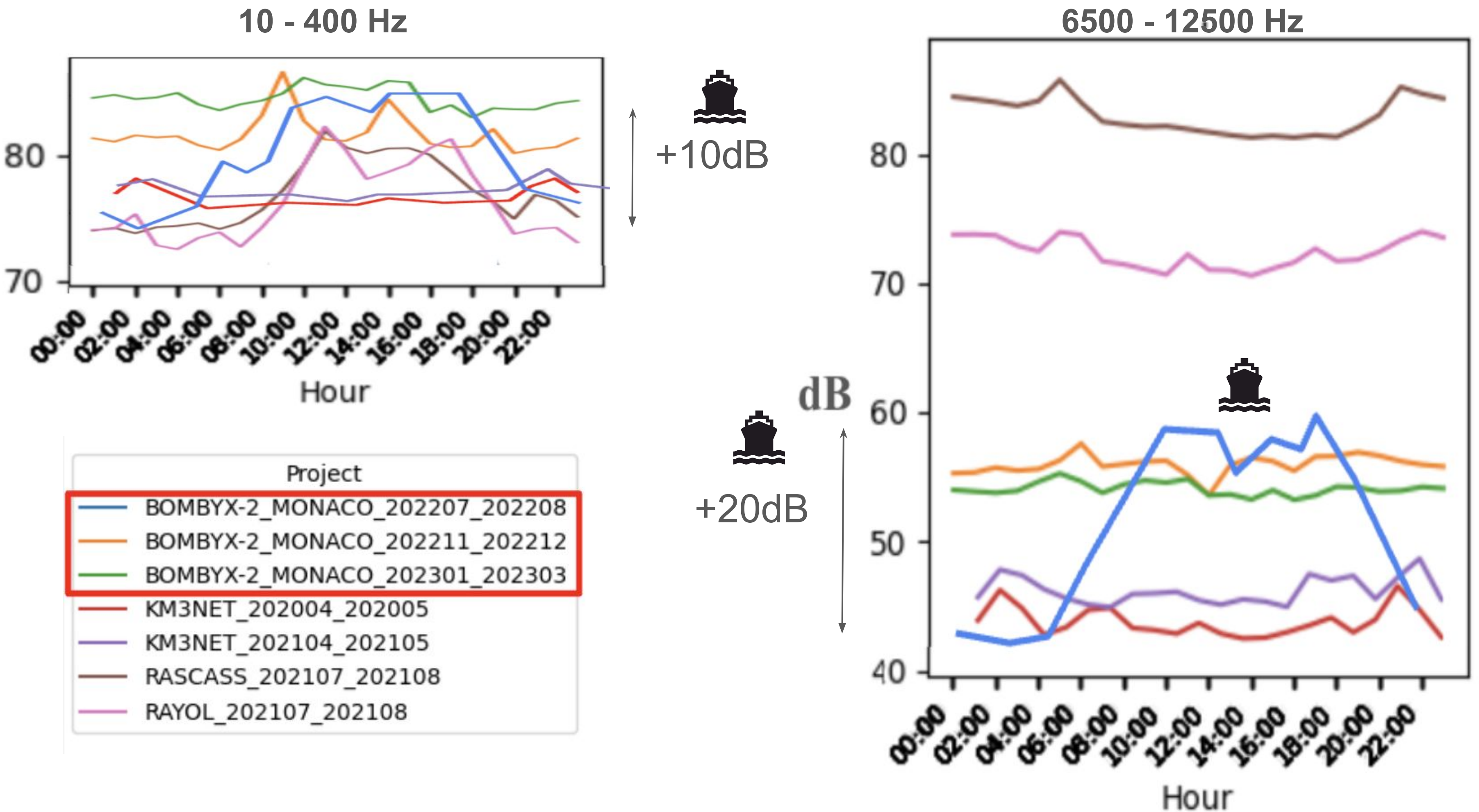


Distribution of the amplitude for the octave 12,800 Hz according to presence/absence of sperm whales.



Superposition of dial pattern of amplitudes for the octave 12,800 Hz and probability of presence of sperm whales

Median dB levels per hour over several months



PERSPECTIVES/ONGOING

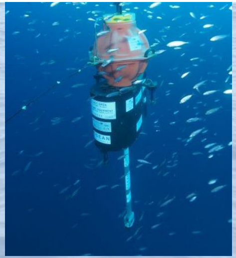
- Link ambient noise to sperm whale presence
- Determine the impact of anthropophony on fin whale presence
- Estimate the number individual sperm whale

Thank for listenning

Bibliography

Poupard M., Ferrari M., Best P., Glotin H. Passive acoustic monitoring of sperm whales and anthropogenic noise using stereophonic recordings in the Mediterranean Sea, North West Pelagos sanctuary. 2022. Scientific report

Best P., Marxer R., Paris S., Glotin H. Temporal evolution of the Mediterranean fin whale song. 2022. Scientific report.



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CHAVIN Stéphane, Ourmières Y., Giraudet P., Glotin H., with Girardet J., F. V. Sarano
LIS MIO, CIAN, UTLN

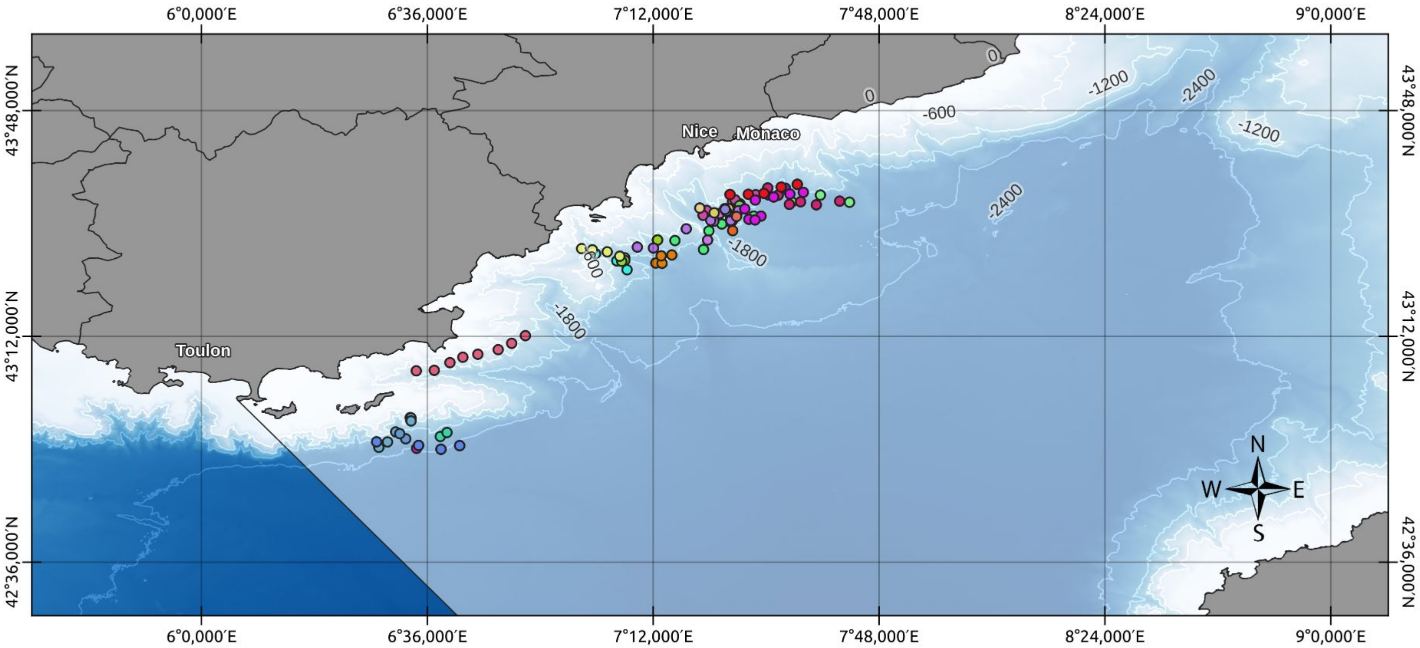
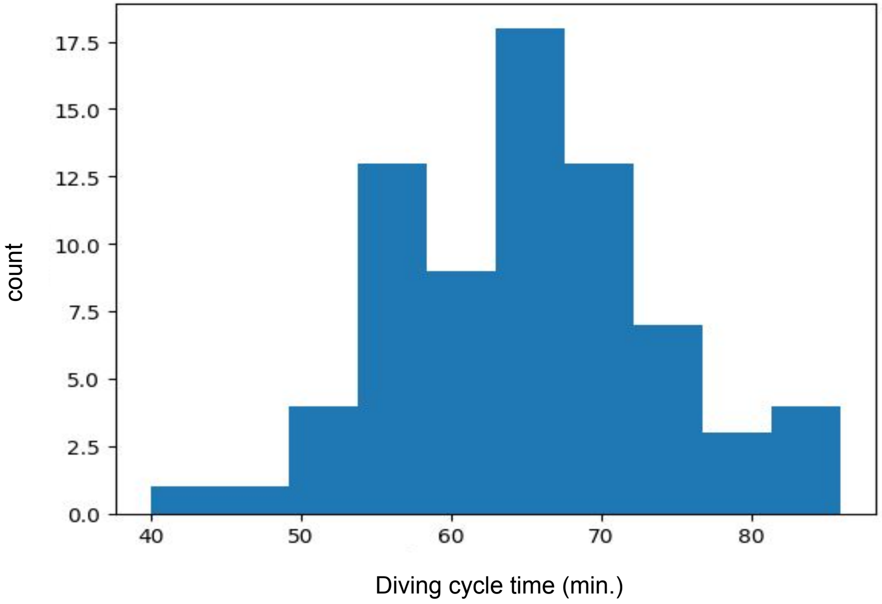


Figure 1 : *WhaleWay4 map with sperm whale position*



approx. 40 breath during surface
12 sec. between each breath
surface time ~10 minutes

Figure 2 : *Duration of all diving cycles (minutes) from WW4 (63 samples)*

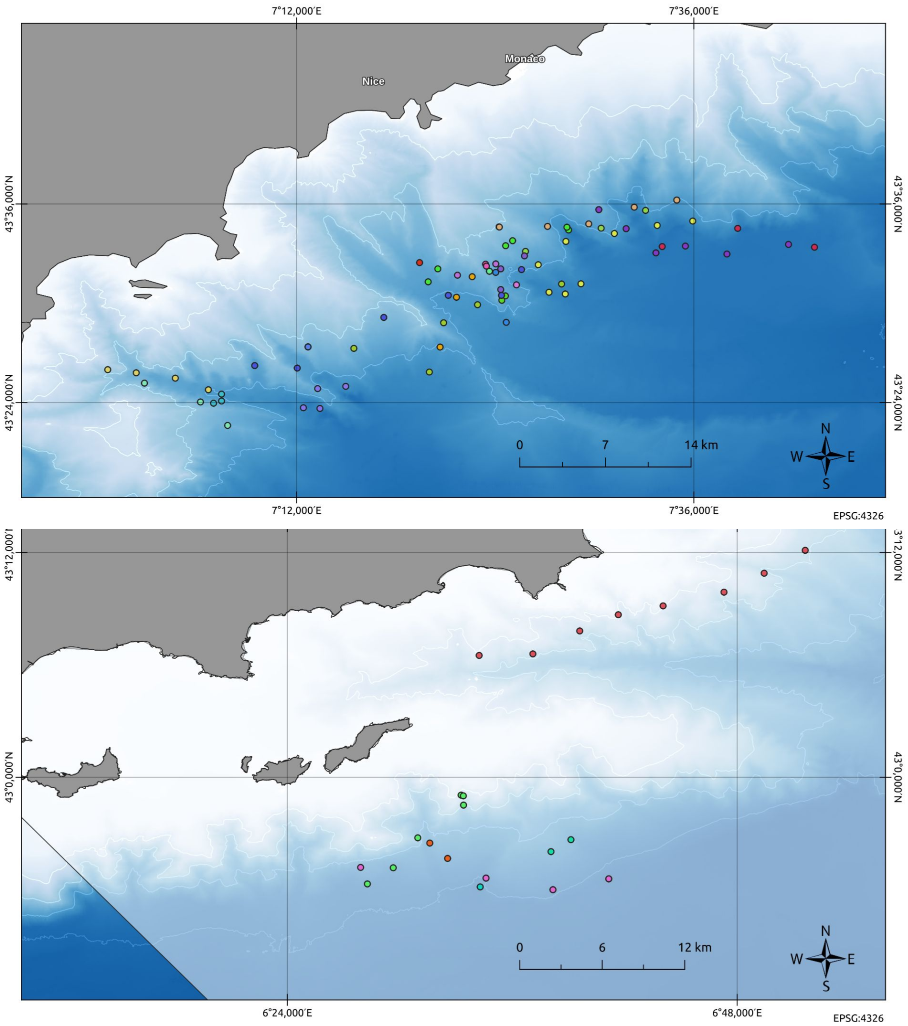
Table 1 : *WW4 sperm whale identification*

First Observation	Name	IPI (ms)	Mission	Estimated Size (m) *
24/09/2023	*Cyclone*	**5.35**	WW4	12.21
25/09/2023	*Survivor*	**5.22**	WW4	12.03
26/09/2023	*Jupiter*	**5.44**	WW4	12.34
26/09/2023	*Patte_dours*	**5.26**	WW4	12.09
27/09/2023	*ZZTop*	**5.67**	WW4	12.67
28/09/2023	*Farouche*	**5.14**	WW4	11.92
28/09/2023	*Plune*	**5.0**	WW4	11.72
01/10/2023	*Nada*	**5.05**	WW4	11.79
02/10/2023	*Casnada*	**4.26**	WW4	10.67
02/10/2023	*Inattendu*	**5.33**	WW4	12.18
04/10/2023	*WW41*	**2.1**	WW4	7.61
04/10/2023	*WW42*	**2.24**	WW4	7.81
04/10/2023	*WW43*	**2.58**	WW4	8.29
04/10/2023	*Fleche*	**2.69**	WW4	8.44
04/10/2023	*WW46*	**3.06**	WW4	8.97
05/10/2023	*WW45*	**2.85**	WW4	8.67
05/10/2023	*WW47*	**2.4**	WW4	8.03
06/10/2023	*Bicorne*	**4.58**	WW4	11.12

* Pierantonio et al., 2016

$$L = 1.417 * IPI + 4.632$$

with IPI in milliseconds and L in meters



18 differents individual in 2 weeks

1200 and 1800m depth

Figure 3 : *Close-up on observations between Cannes and Monaco (a.) and near Port-Cros National Park (b.)*

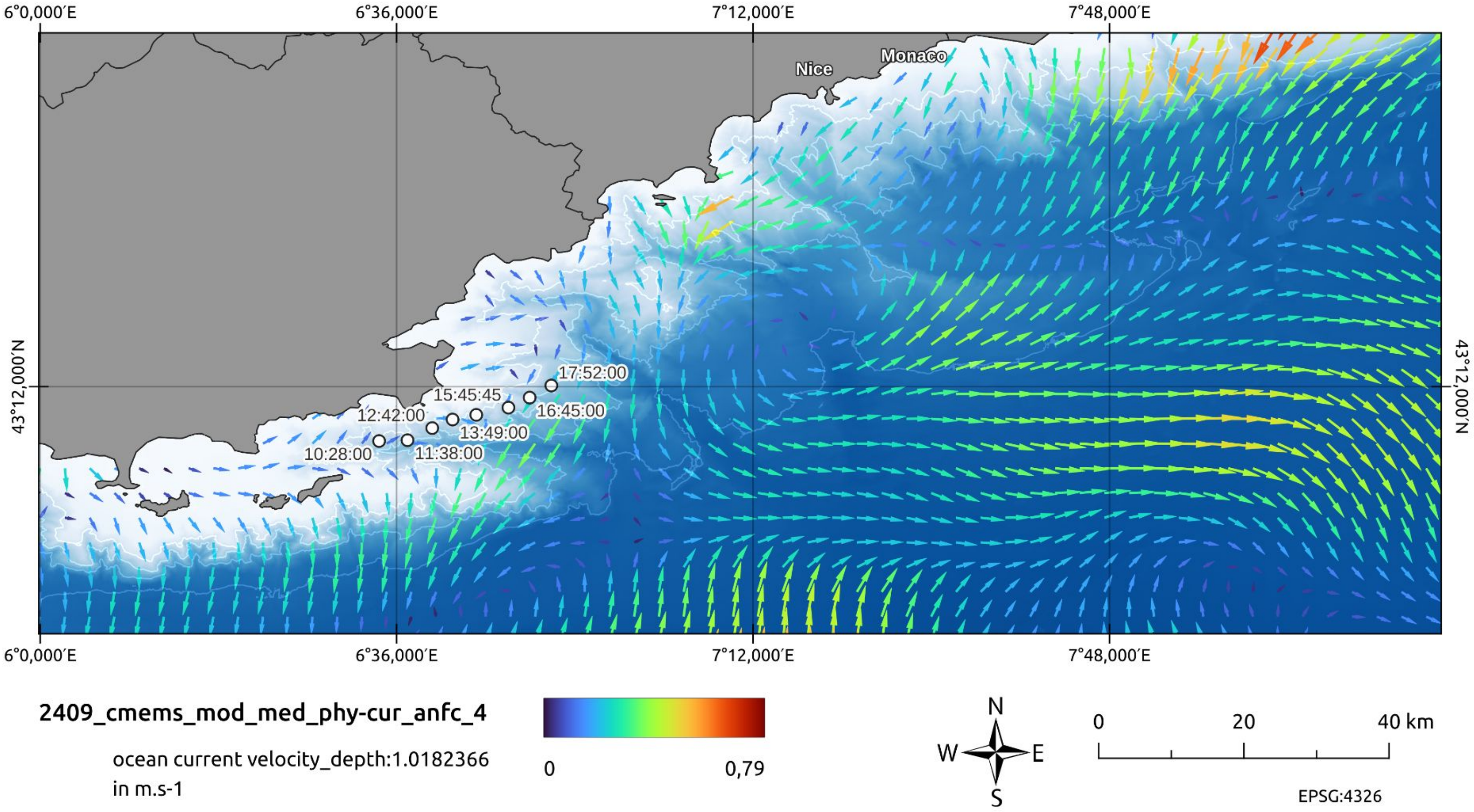


Figure 4 : *Cyclone surface positions and surface water velocity on september 23, 2023*

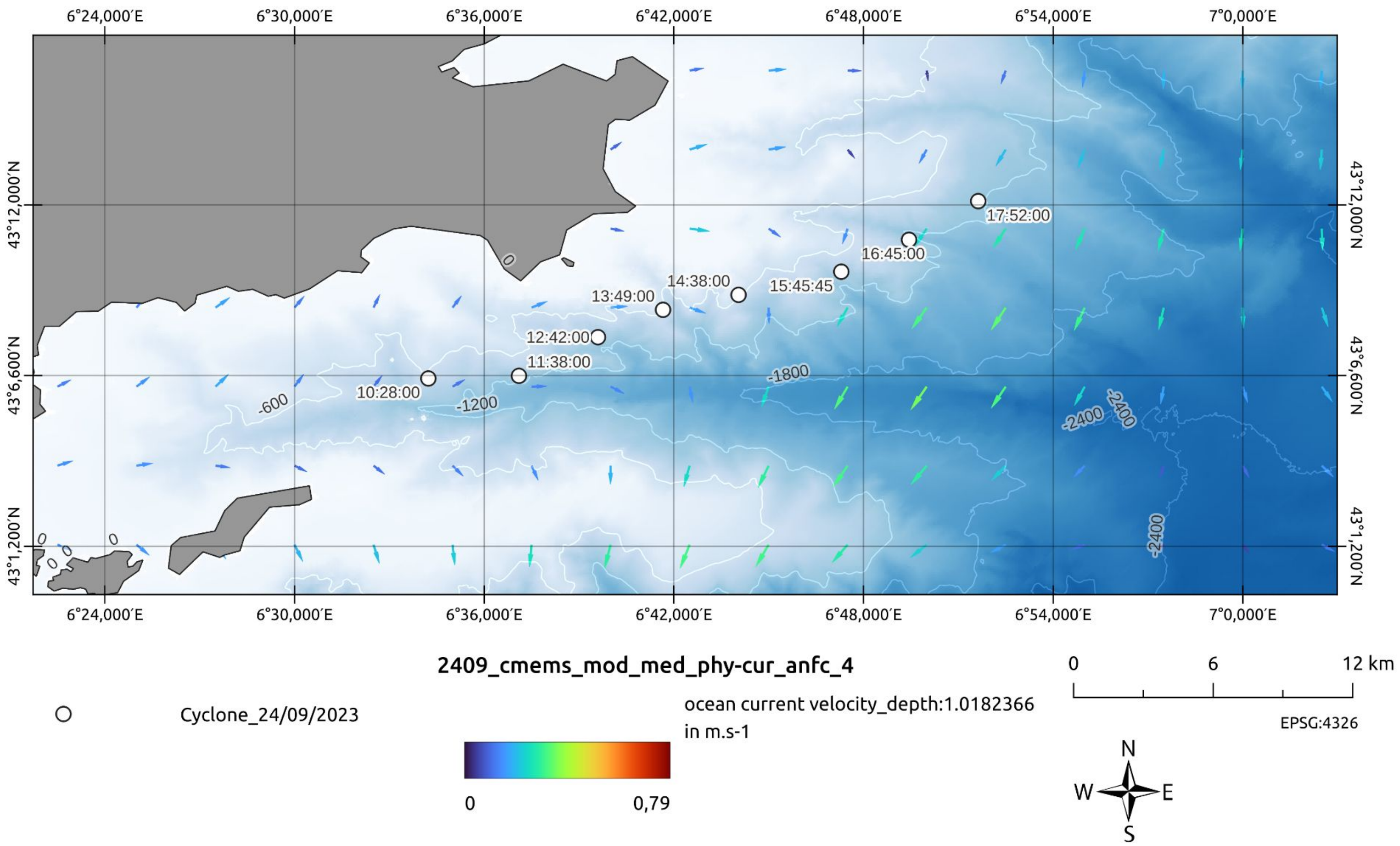


Figure 4 : *Cyclone surface positions and surface water velocity on september 23, 2023*

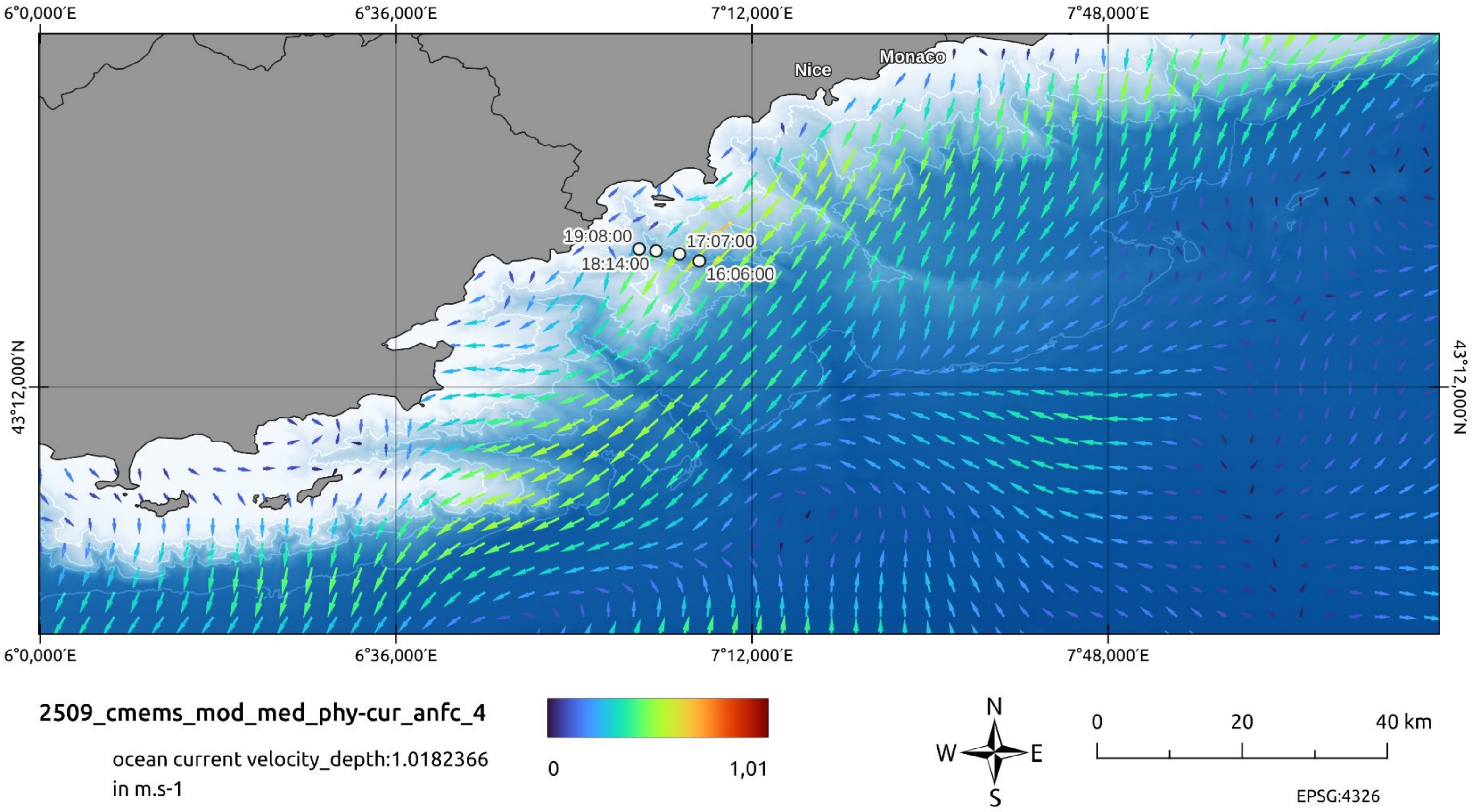


Figure 5 : *Survivor surface positions and surface water velocity on september 25, 2023*

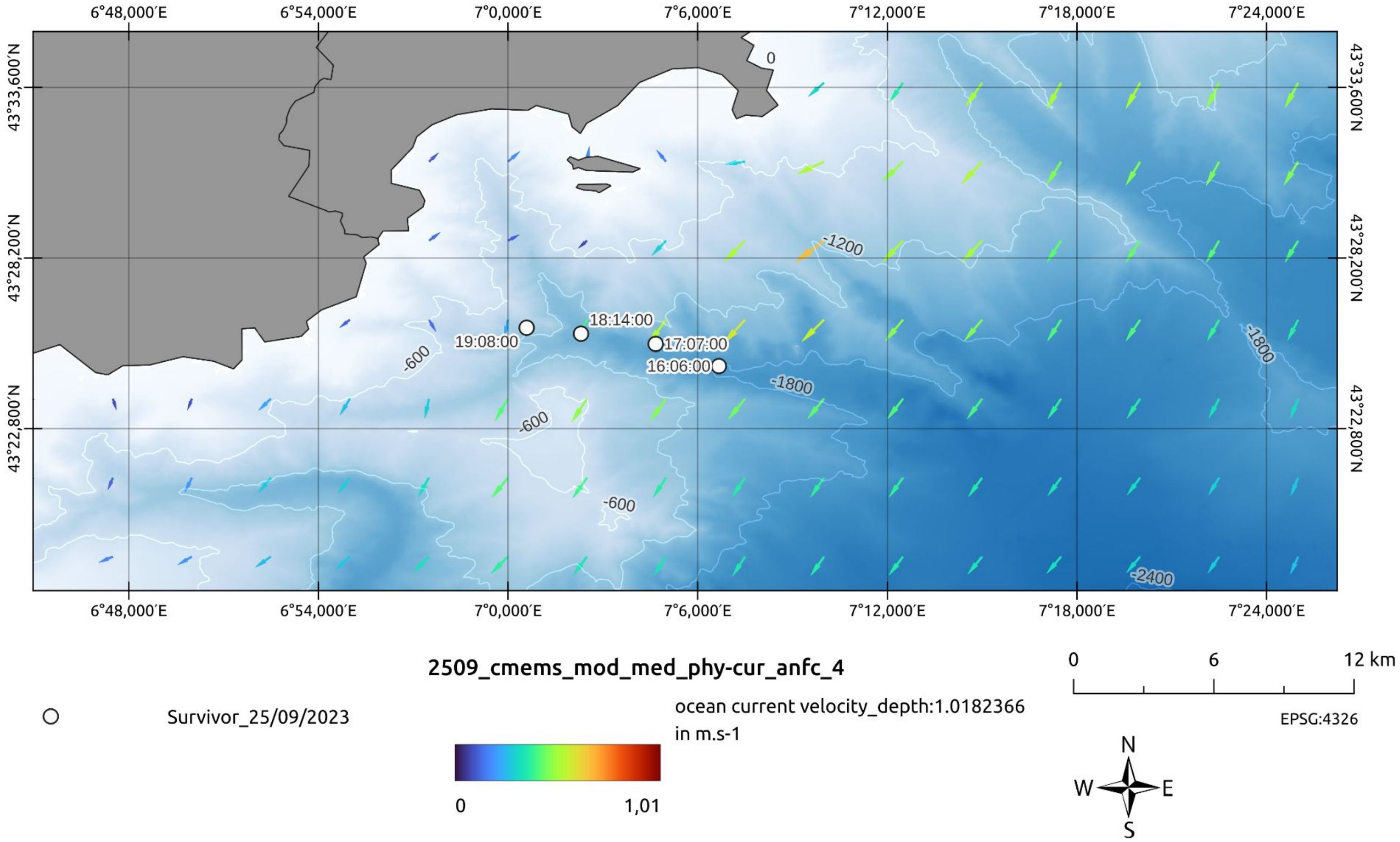


***Figure 5 :** Survivor surface positions and surface water velocity on september 25, 2023*

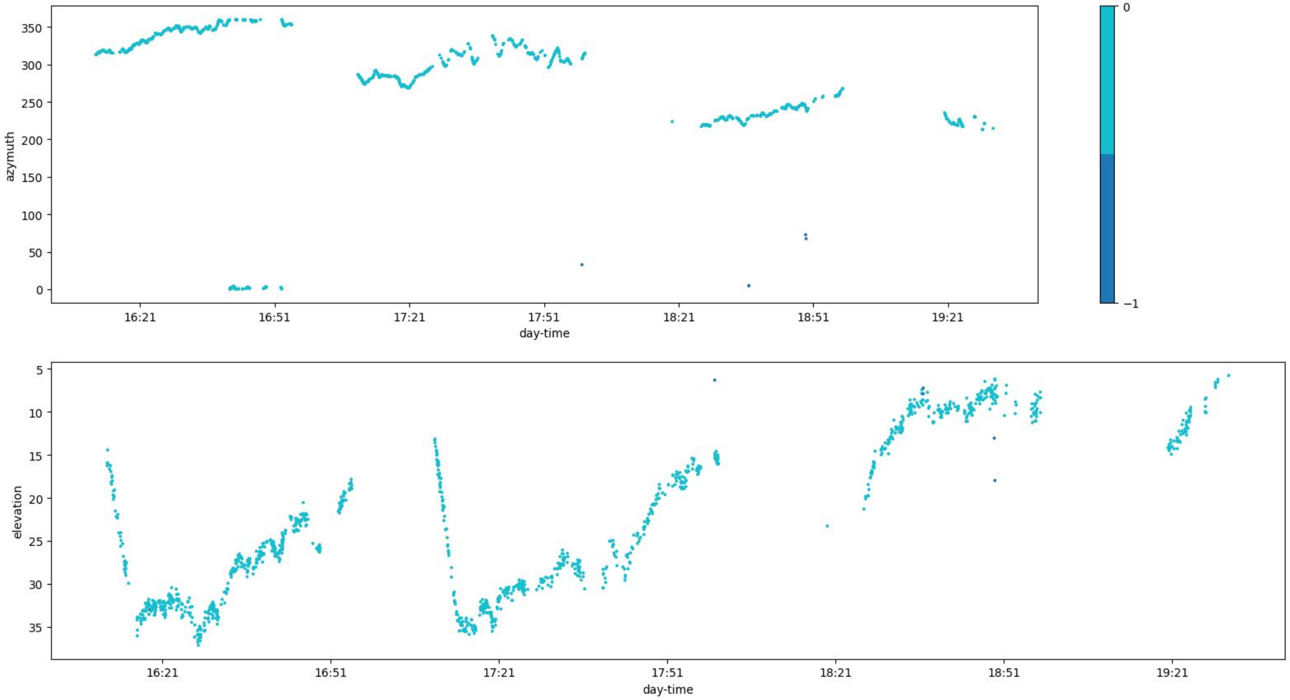


Figure 6 : *Azimuth/Elevation angle for each clicks of Survivor giving an idea on its position*

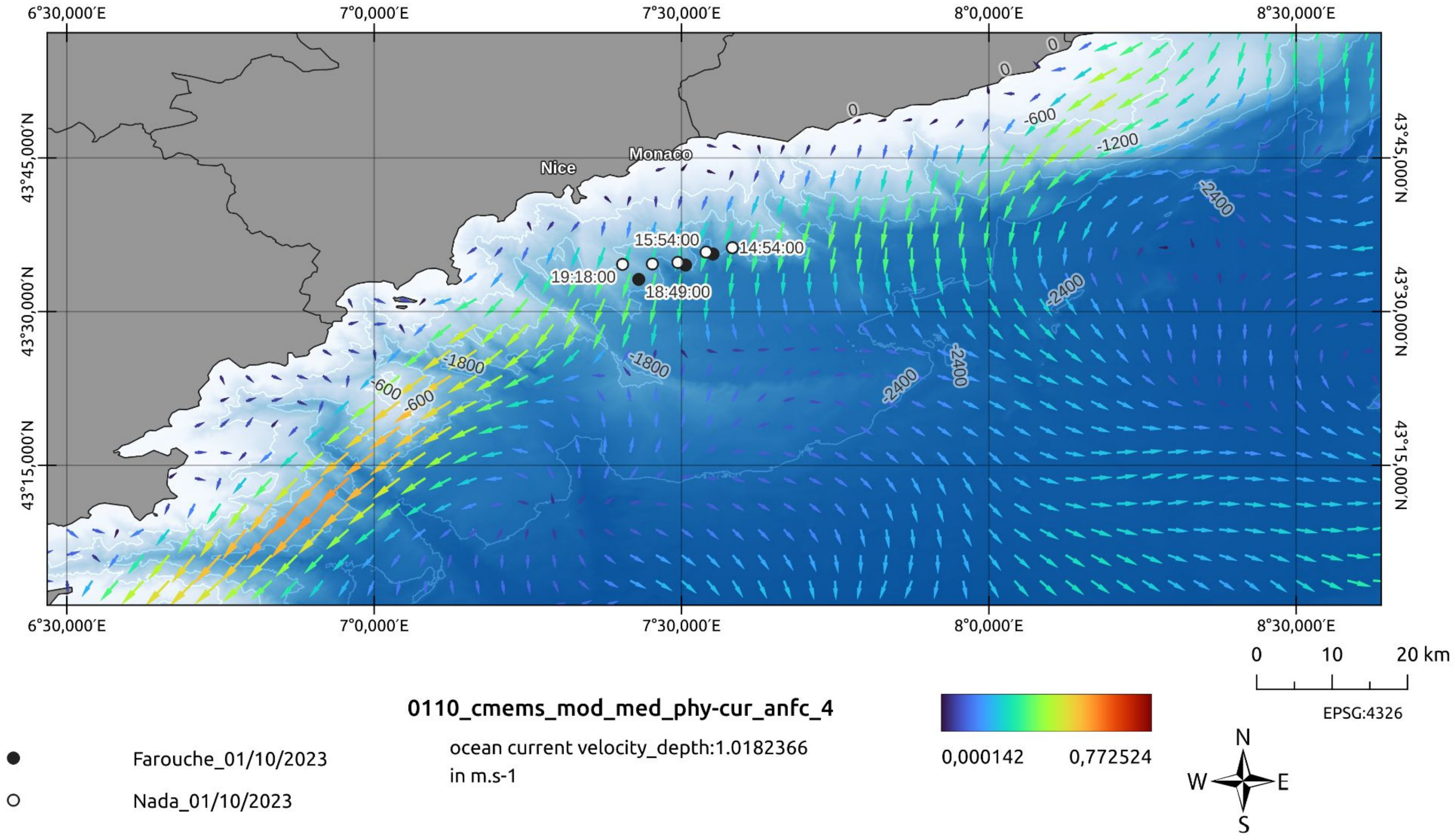


Figure 7 : *Nada and Farouche surface positions and surface water velocity on october 01, 2023*

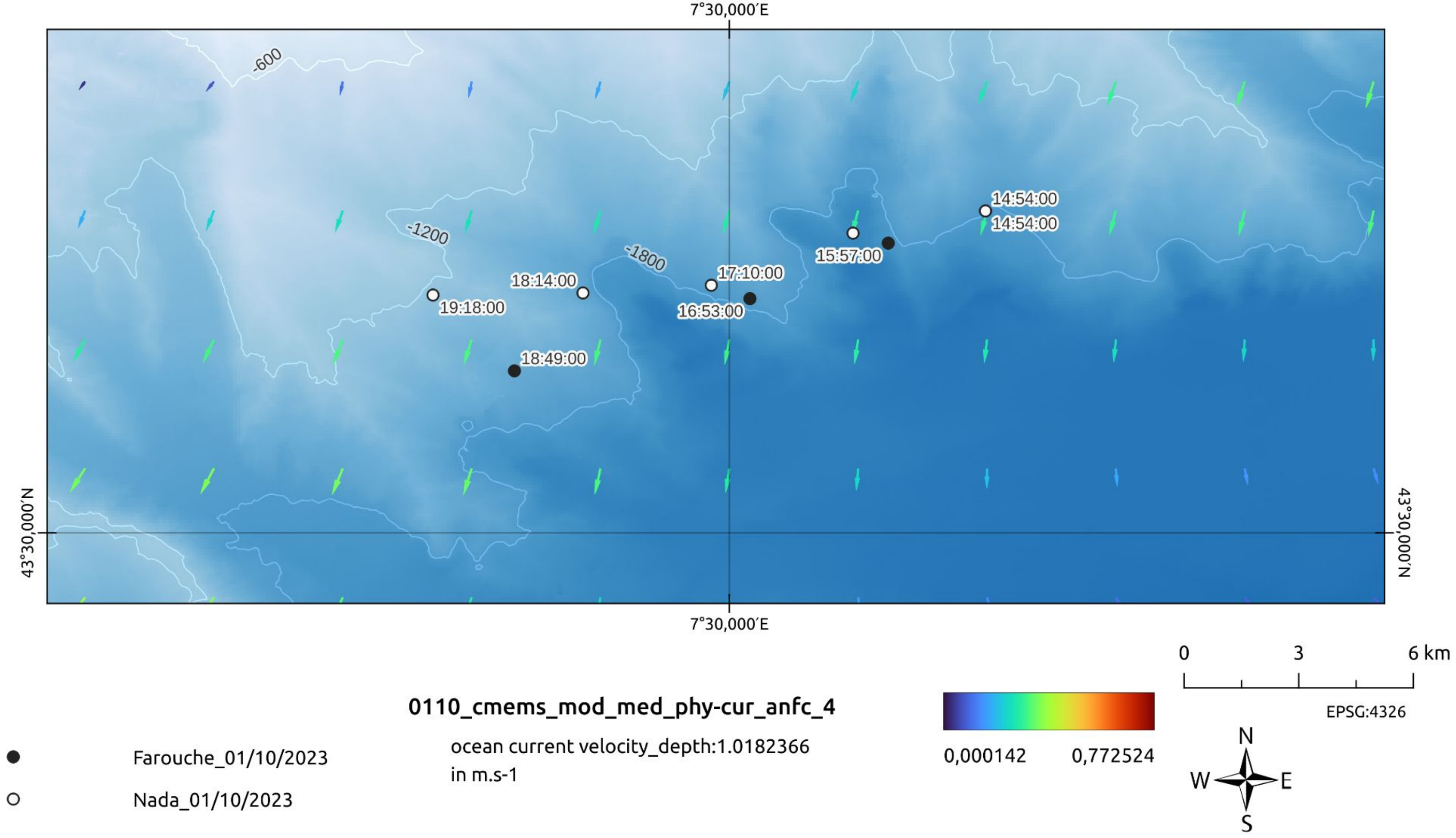


Figure 7 : *Nada and Farouche surface positions and surface water velocity on october 01, 2023*

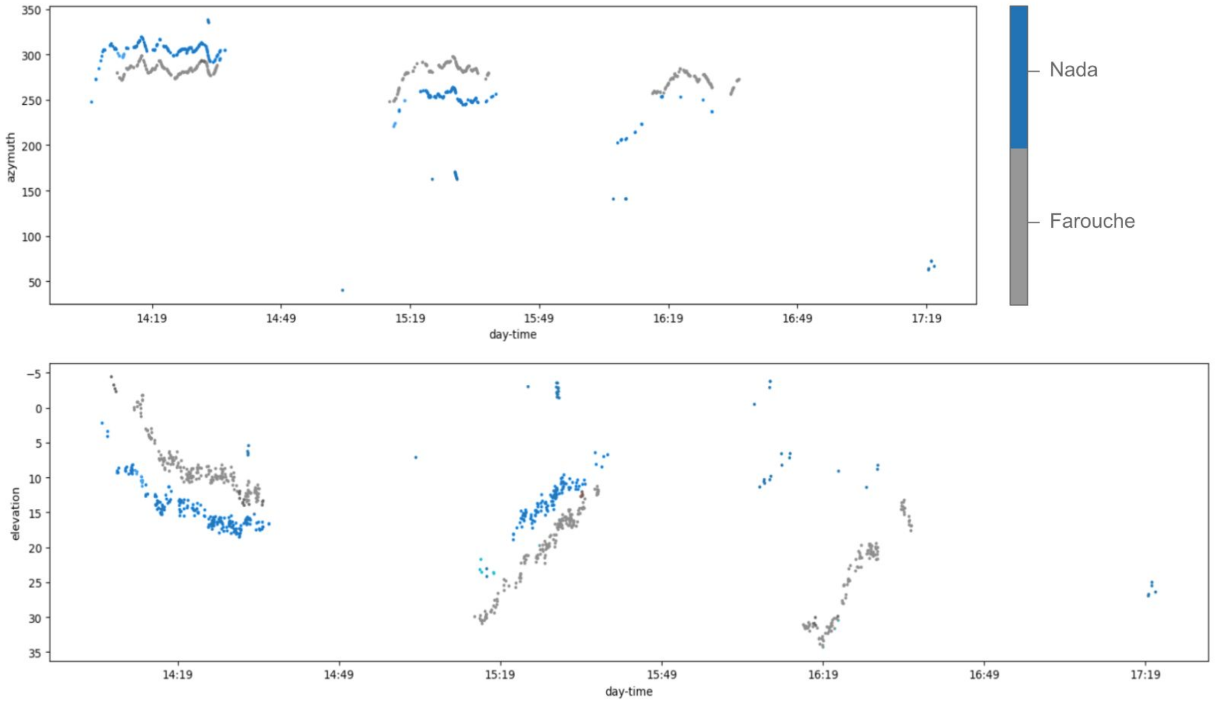


Figure 8 : *Azimuth/Elevation angle for each clicks of Farouche and Nada giving an idea on there position*

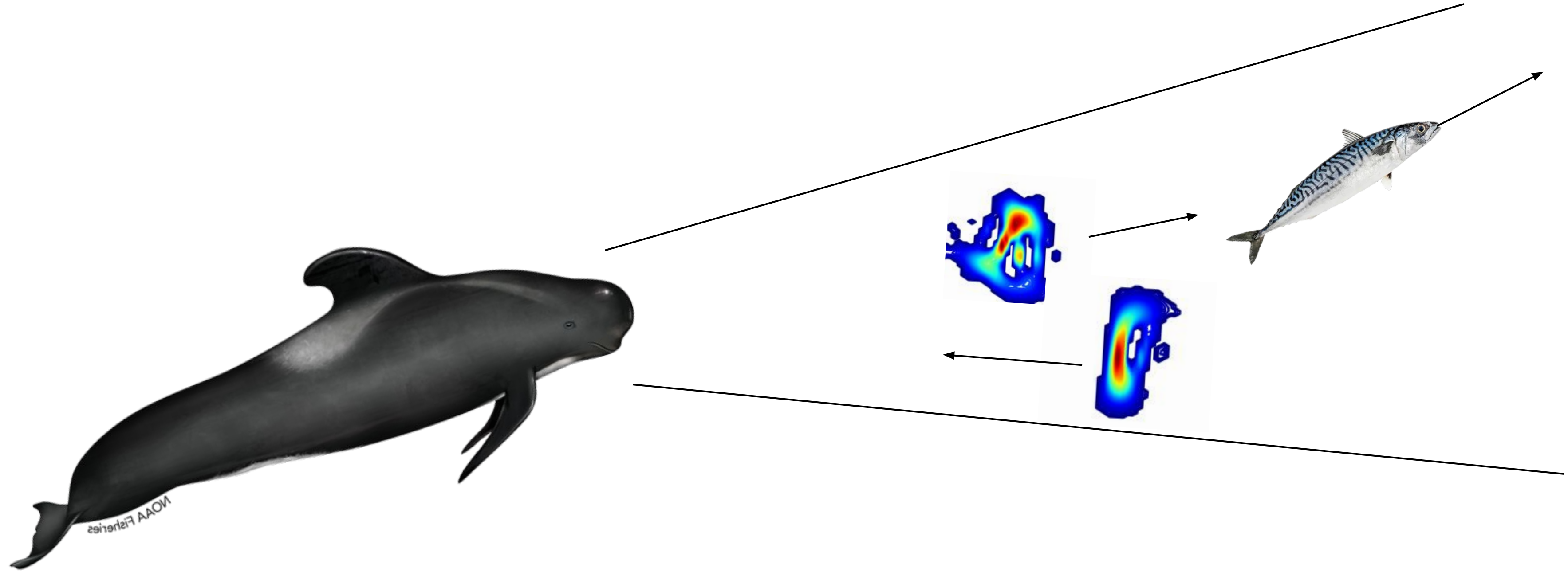
More tracks are in process,
and other missions are
planed in 2024…

We aim to link behaviours of megafauna in various
noise, streams and bathymetry conditions,
in order to better mitigate cetacean marine traffic collision.

More to read :
Pelagos Report 2024, Megafauna in anthropized NW Pelagos using Bombyx and other antennas,
Glotin et al. 138 pages, to appear in http://bioacoustics.lis-lab.fr/

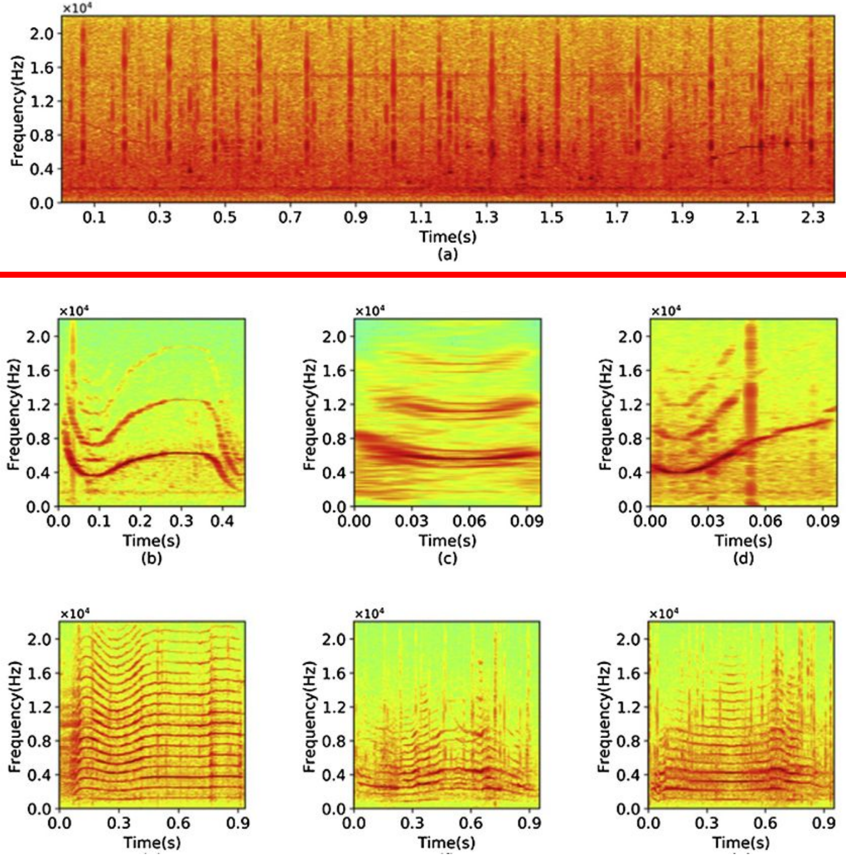
Analysis of pilot whales biosonars using time-frequency decomposition

N. Deloustal, S. Paris, A. Paiement, H. Glotin



Introduction

The pilot whale acoustic emission :



Clicks

Echolocation

Whistles

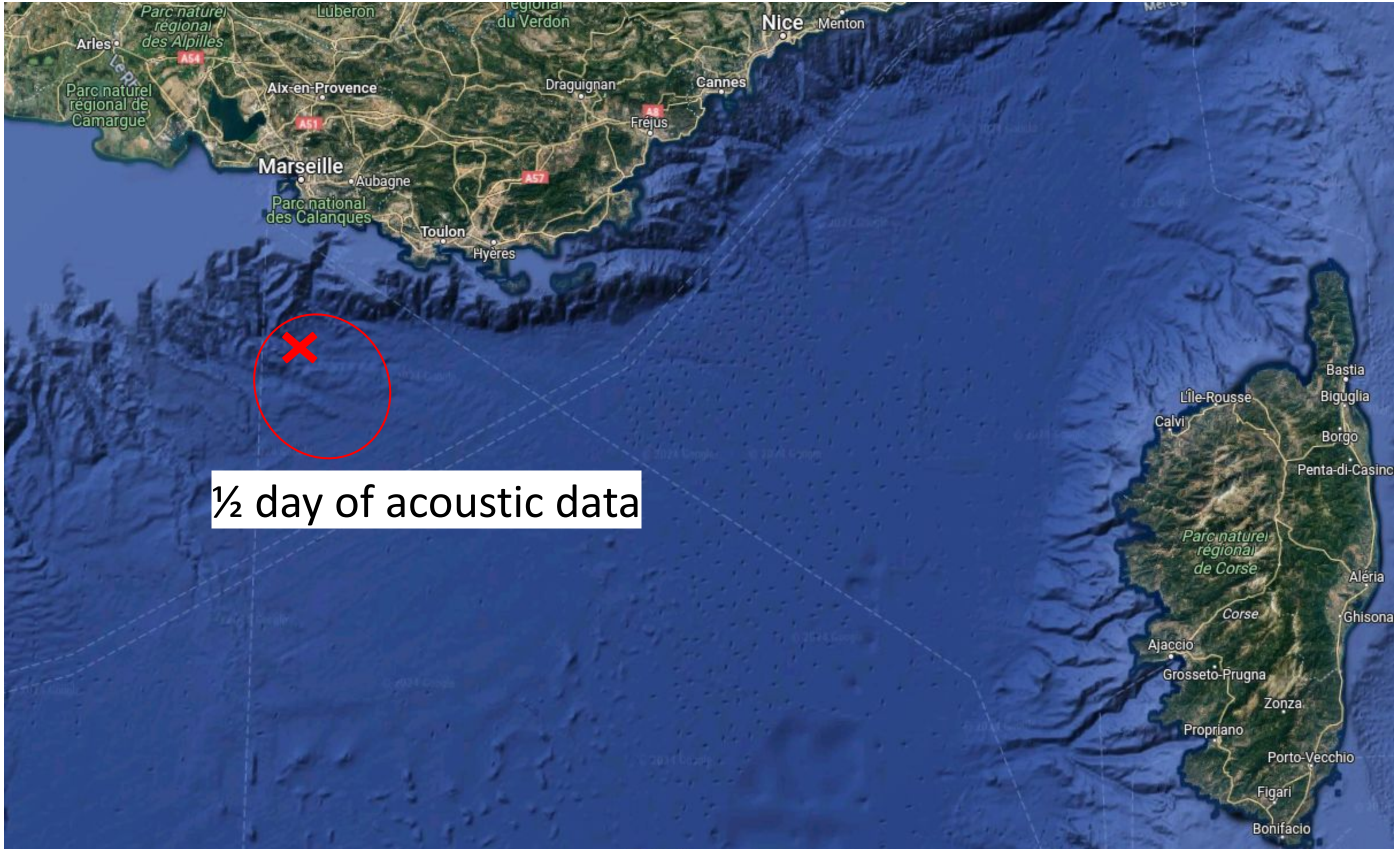
Pulsed calls

Socialisation &

Communication

Spectrograms (frequency-time diagrams) showing examples of the three types of pilot whale sound. [Jiang et al., 2019]

Materials & Methods



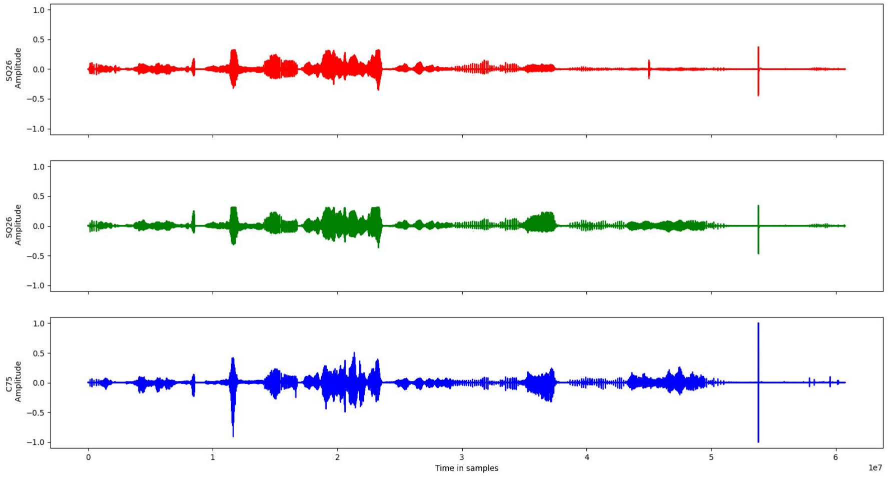
Acoustic sampling site

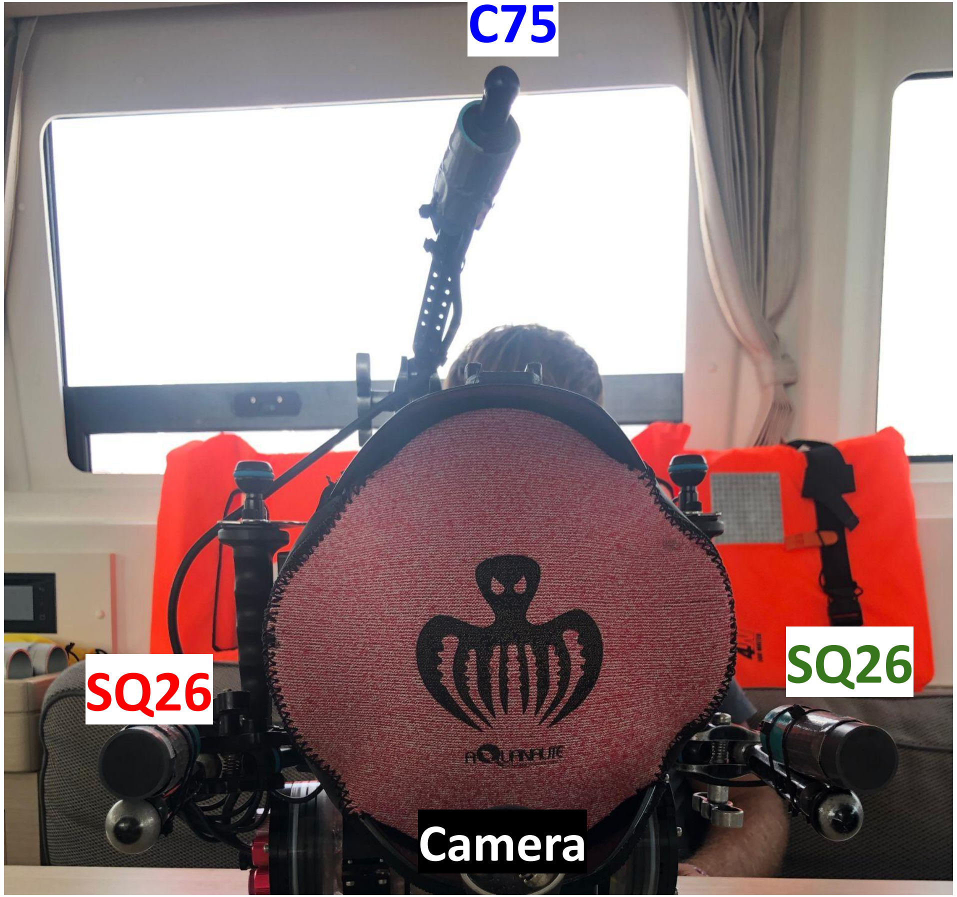
Materials & Methods

Data acquisition

Sampling rate :

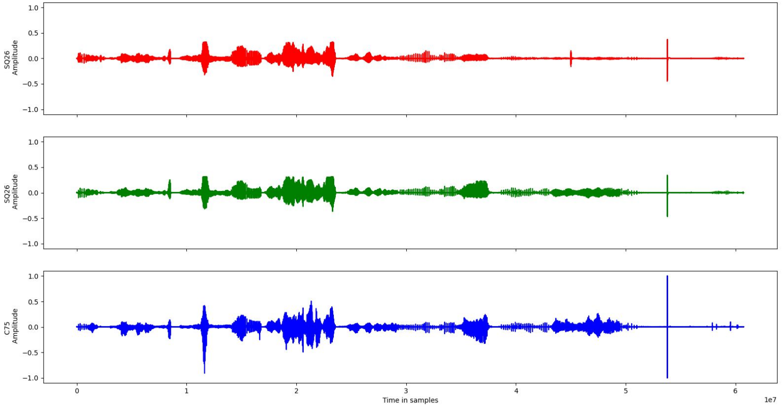
3 x 512 KHz fe 16 bits



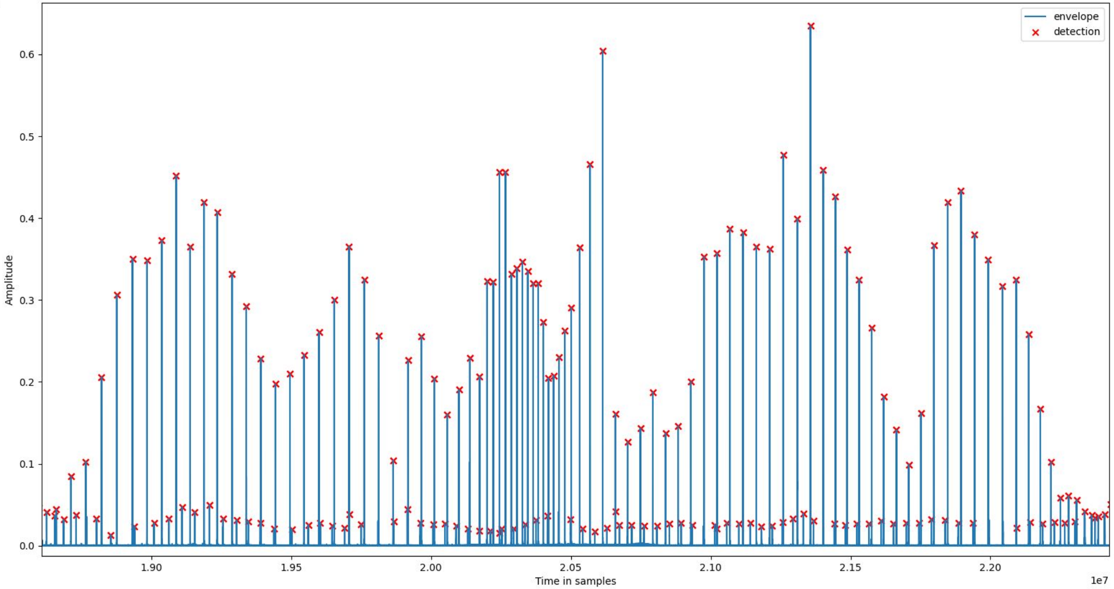


Hand-crafted antenna

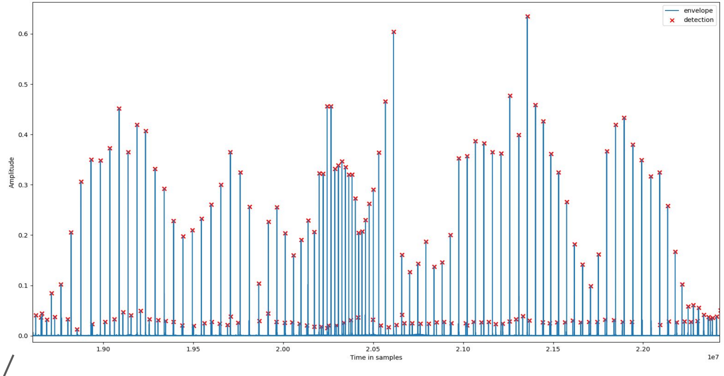
Materials & Methods

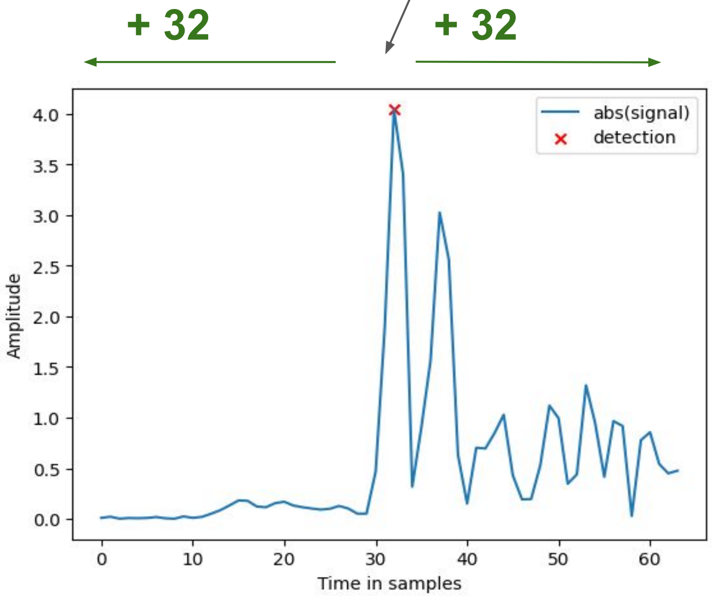


- High pass (10 kHz)
- Quadratic detector on c75, step 10 ms



Materials & Methods





- 1 ms window per click
- convolution with a Tukey window (alpha = 0.6)

- Centering max amplitude, 32 bins left and right.

- Z norm Click per Click :
- $(X - \mu) / \sigma$

- Hilbert transform

Materials & Methods

- Pseudo Wigner Ville Transform :

$$PWVD_z(t,f) = \int_{-\infty}^{+\infty} h^2\left(\frac{\tau}{2}\right) z\left(t+\frac{\tau}{2}\right) z^*\left(t-\frac{\tau}{2}\right) e^{-i2\pi f\tau} d\tau.$$

z : signal
h : window
t : time
f : frequency
τ : delay

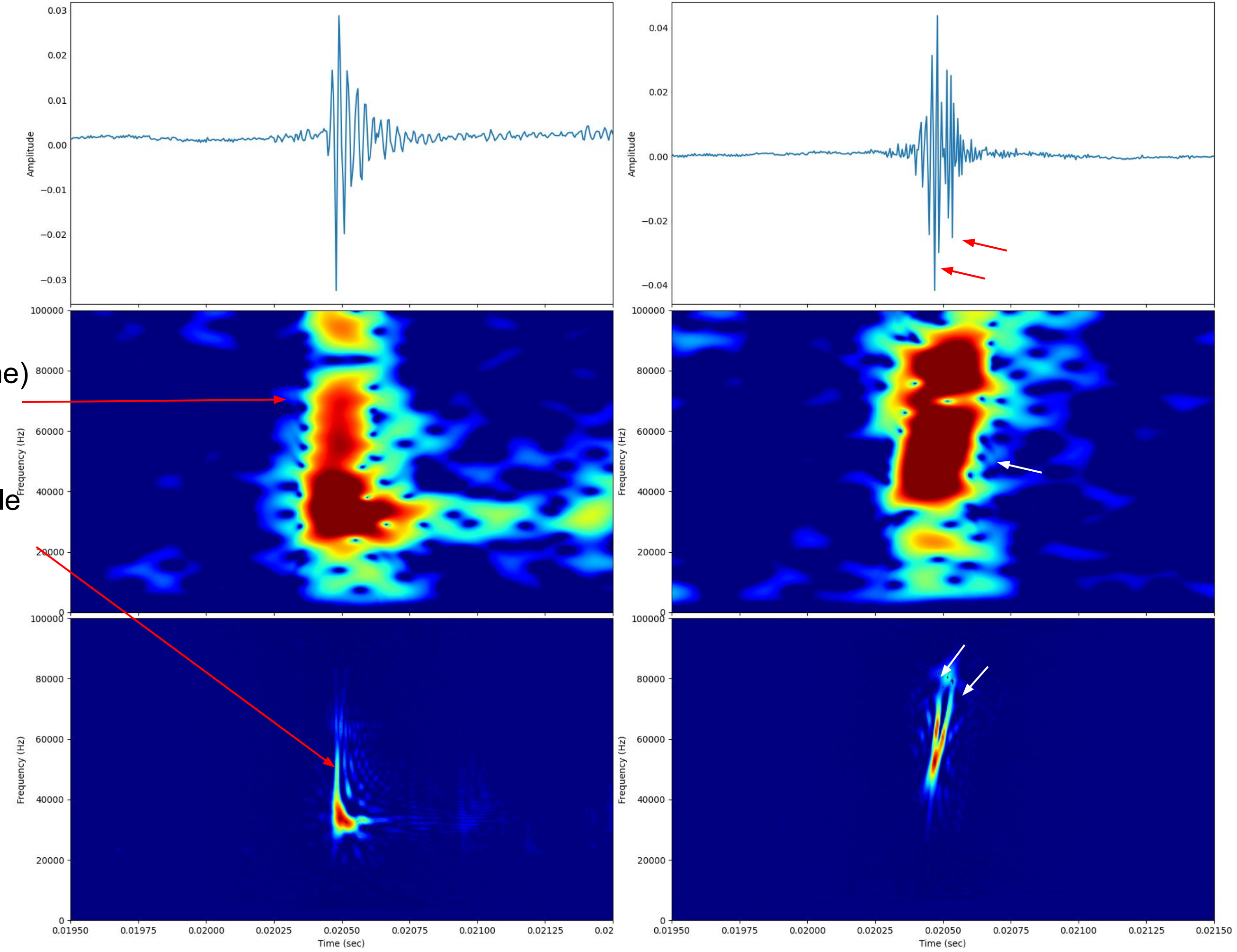
- We get a 64 freq channel x 64 temporal bins pattern,
- This (64 x 64) is flatten in **4096 dimensions**,
- Keep percentil 85 % (aspect ratio),
- Then it is reduced by UMAP into only **2 dimensions**.

Example

Signal

STFT (spectrograme)

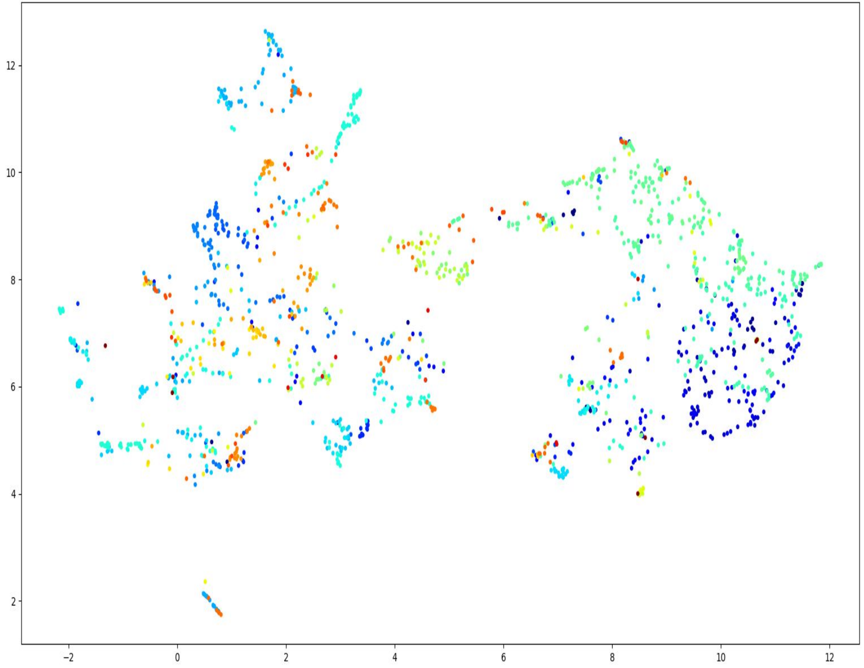
Pseudo Wigner Ville



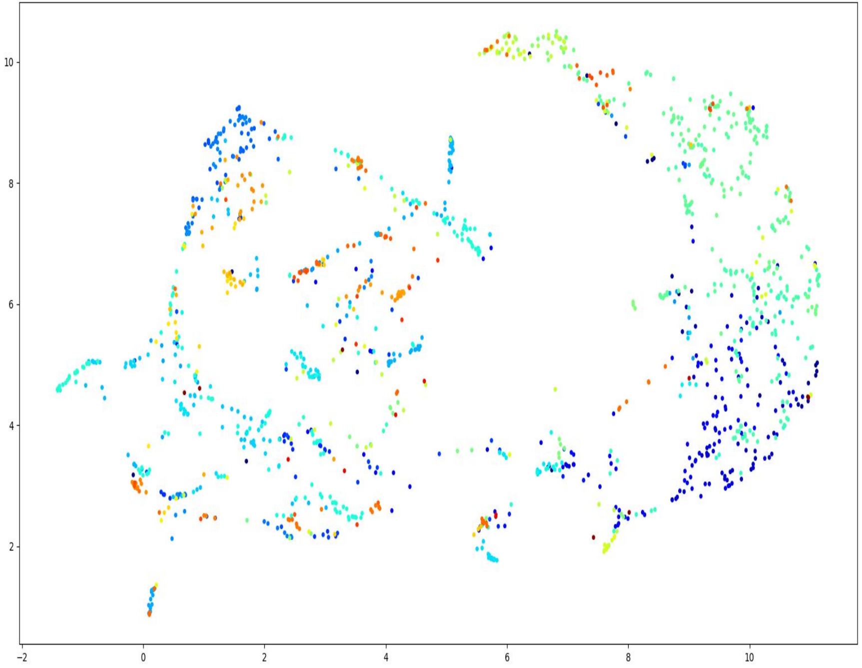
2ms

First Results : Reduced clicks to 2 dimensions by UMAP

PWVD



STFT



each dot = click

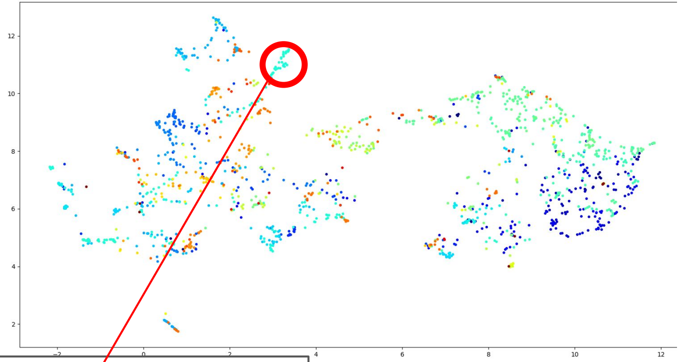
color = time position

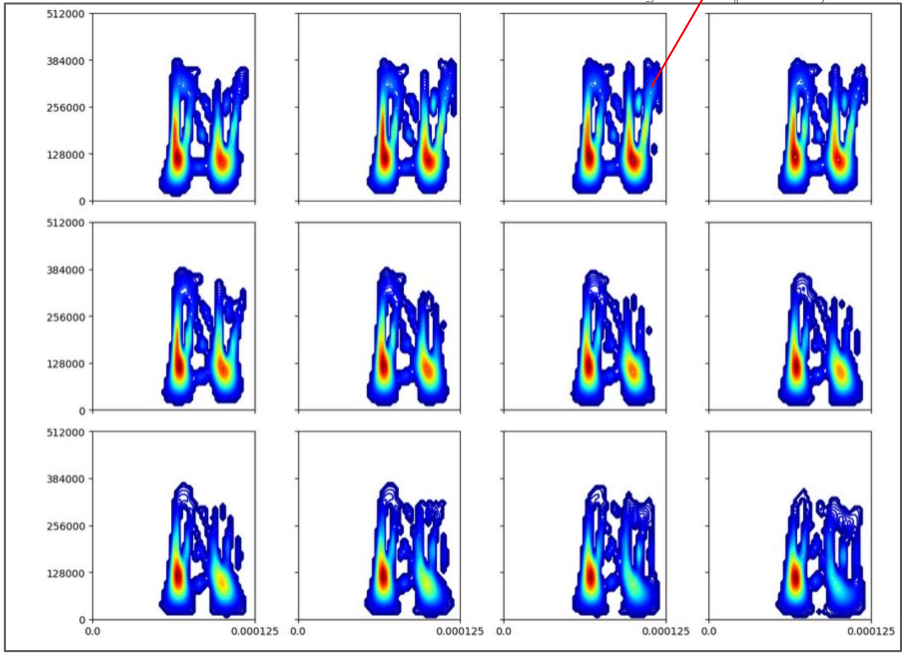
→ Clicks close in time have a similar shape

First Results & Discussion

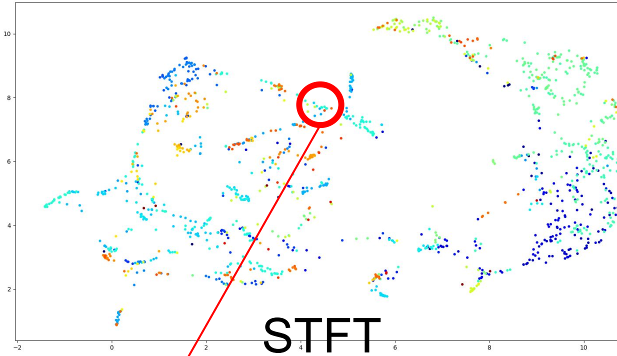
Comparison over 2 min recordings
consistant patterns
color = position

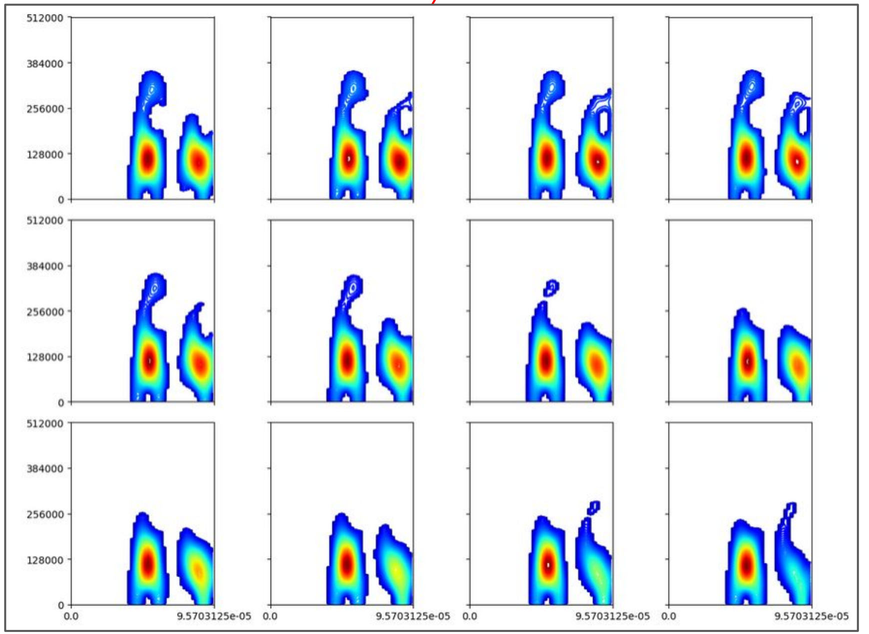
PWVD 483+12





STFT

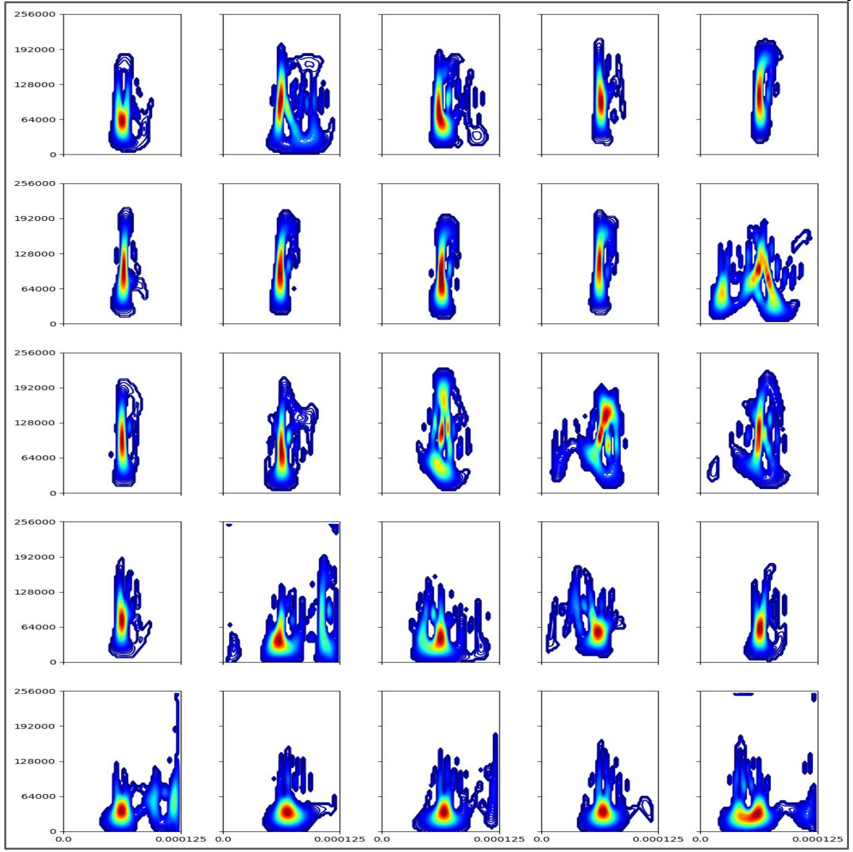


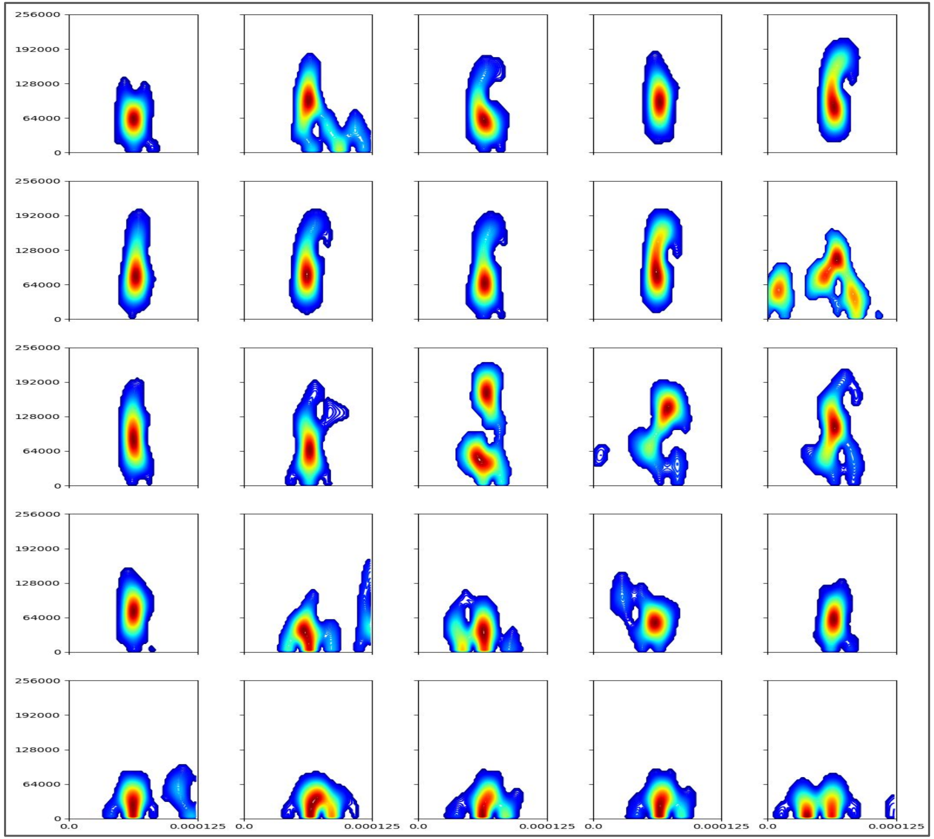


First Results & Discussion

Which representation gives more information ?

PWVD vs (same click) STFT

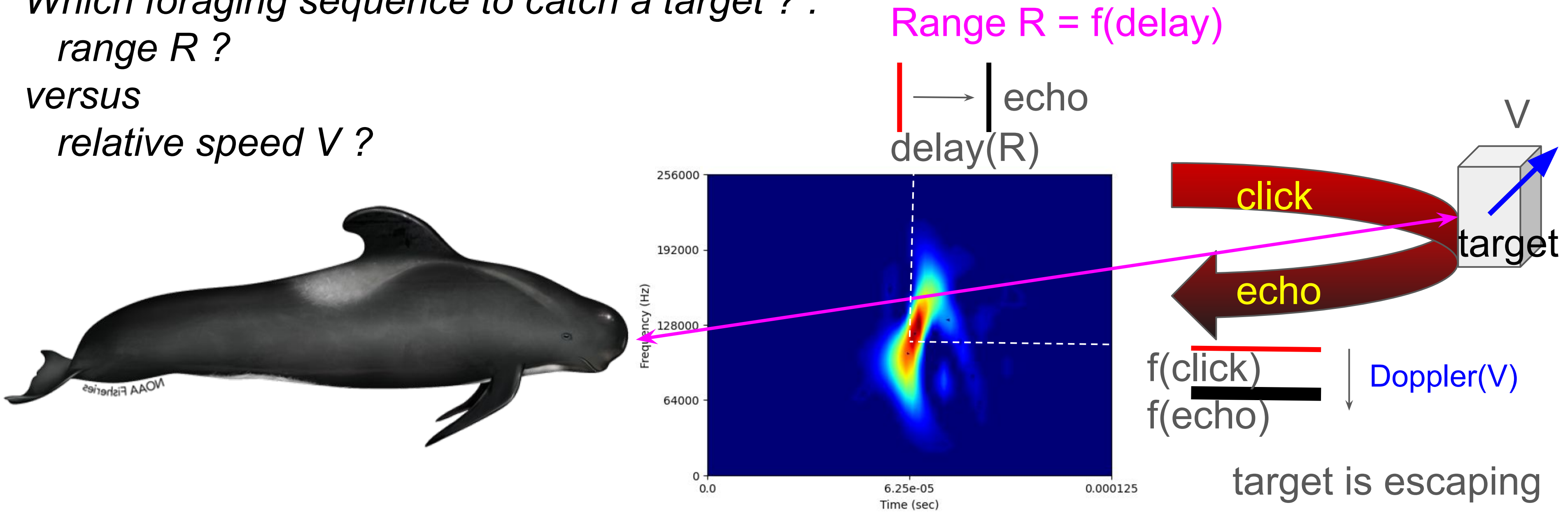




Perspectives : Towards more precision on the effect of the time-frequency echo

Optimal shape of the waveform of the click for detection is not the optimal shape for ranging, nor for doppler observation
Is it an active / adaptive process ?

Which foraging sequence to catch a target ? :
range R ?
versus
relative speed V ?



RVRV … or RRRVVV …?

Perspectives : The Wideband Ambiguity Function

AF is the convolution of the emission by its echo

It allows to analyse the **biosonar** perception process :
The acoustic wave **reaches** the target and then is **reflected back** to the cetacean with which information, **delay** or **frequency shift** ?

$$\chi(\tau,\eta)=\sqrt{\eta}\int_{-\infty}^{+\infty} s(t)s^{*}(\eta t-\tau)\mathrm{d}t$$

s(t) : sound of the pilot whale,
s(ηt-τ) : echo reflected by targets,
τ : time delay,
η : Doppler shift.

In this case :

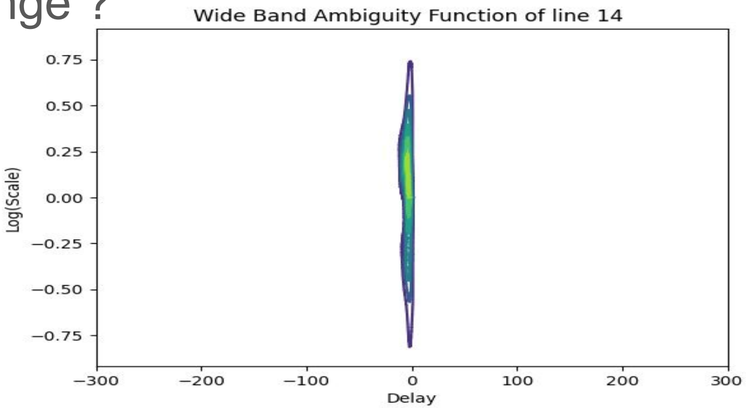
$$\tau = 2\frac{d}{c},\quad \eta=\frac{c+v}{c-v}$$

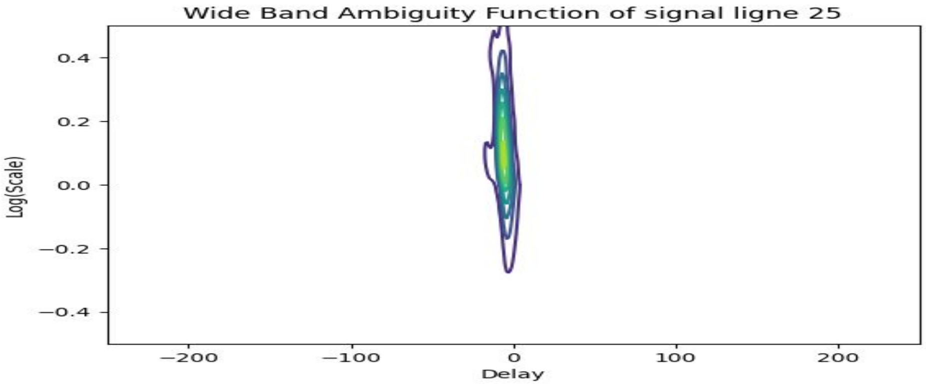
d : distance between the pilot whale and its target (partners or prey),
v : relative speed between the pilot whale and its target,
c : propagation speed of sound.

Biosonar = high or low doppler tolerance (condition-dependent) → Transient optimal shape → **Classification Behaviour ?**

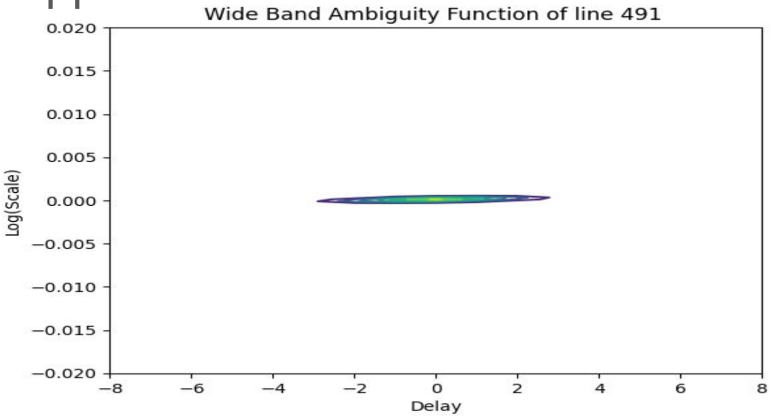
Some FA sample from Docc10’s clicks

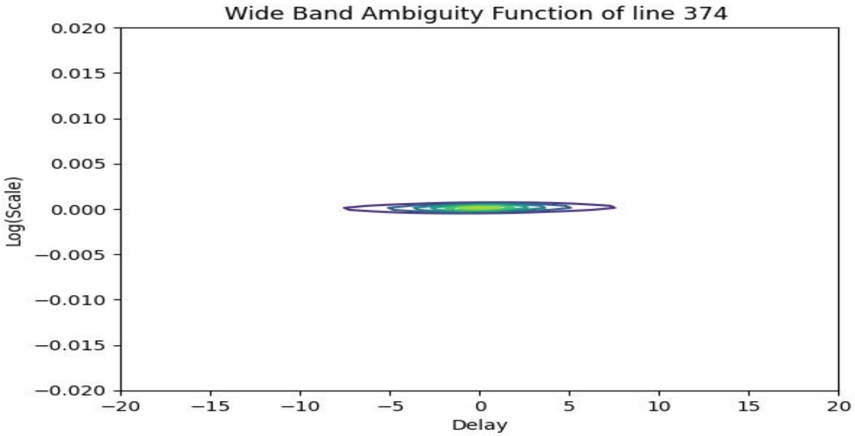
Range ?





Doppler ?



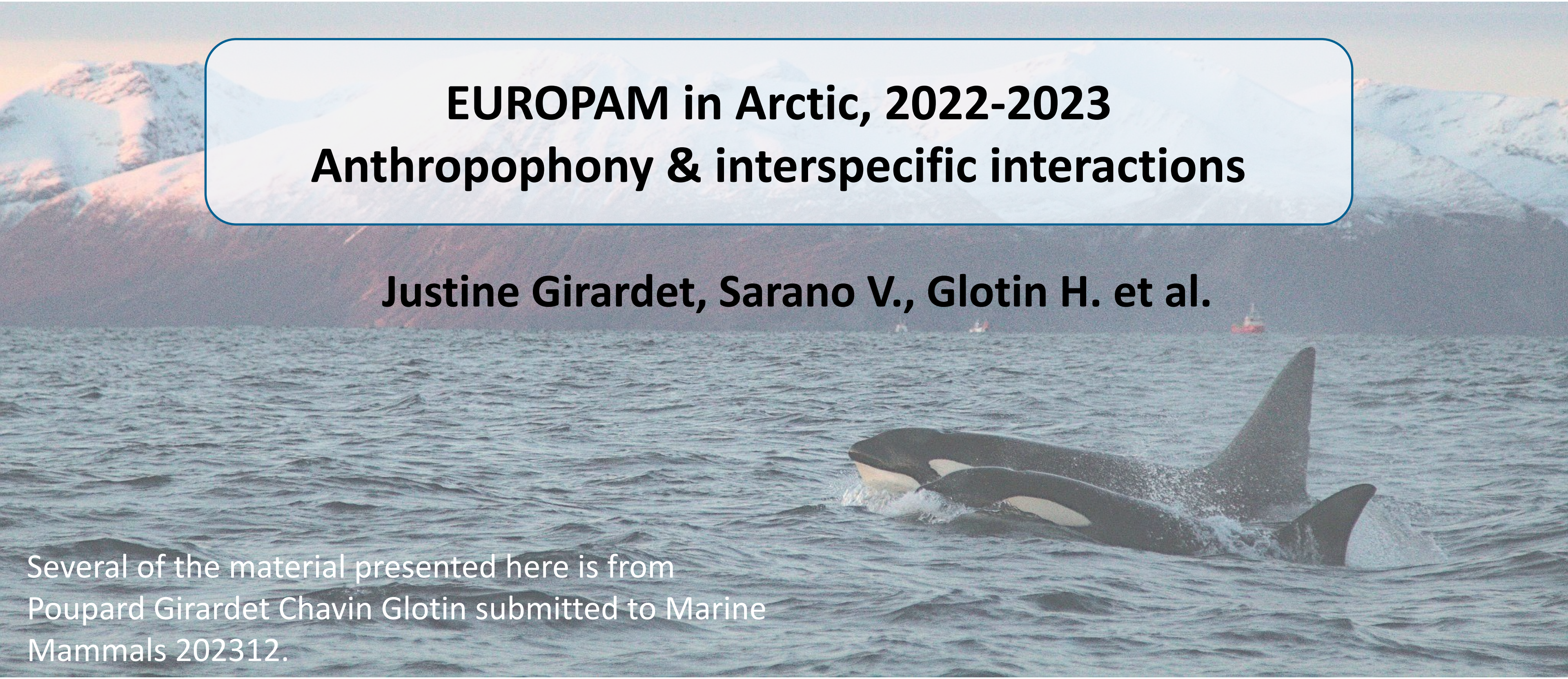


We’ll analyse AF of pilot whales, Orcas, Physeter’s Biosonar, at different anthropic pressures in order to compare varieties of foraging strategies

Bibliography

Flandrin, P., Cros, P., & Mange, G. (1986). Sensitivity of Doppler tolerance to the structure of bat-like sonar signals. *Acta Acustica*, *62*(1), 40-47.

Jiang, J., Wang, X., Duan, F., Liu, W., Bu, L., Li, F., ... & Deng, C. (2019). Study of the relationship between pilot whale (Globicephala melas) behaviour and the ambiguity function of its sounds. *Applied Acoustics*, *146*, 31-37.

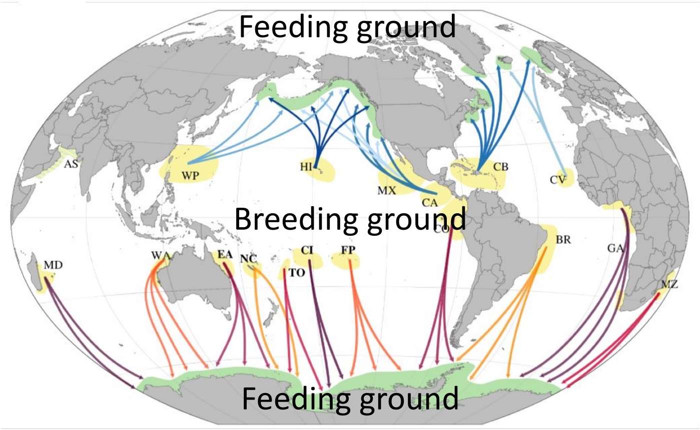


EUROPAM in Arctic, 2022-2023
Anthropophony & interspecific interactions

Justine Girardet, Sarano V., Glotin H. et al.

Several of the material presented here is from Poupard Girardet Chavin Glotin submitted to Marine Mammals 202312.

CONTEXT

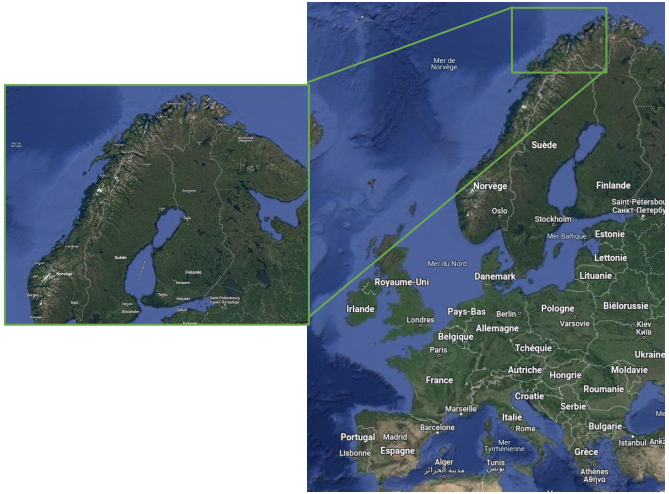


Migration routes of humpback whales. From Zandberg et al.

Multi-species interactions © Granier et Granzotto

Anthropogenic activities © Sarano F.

OBJECTIVES

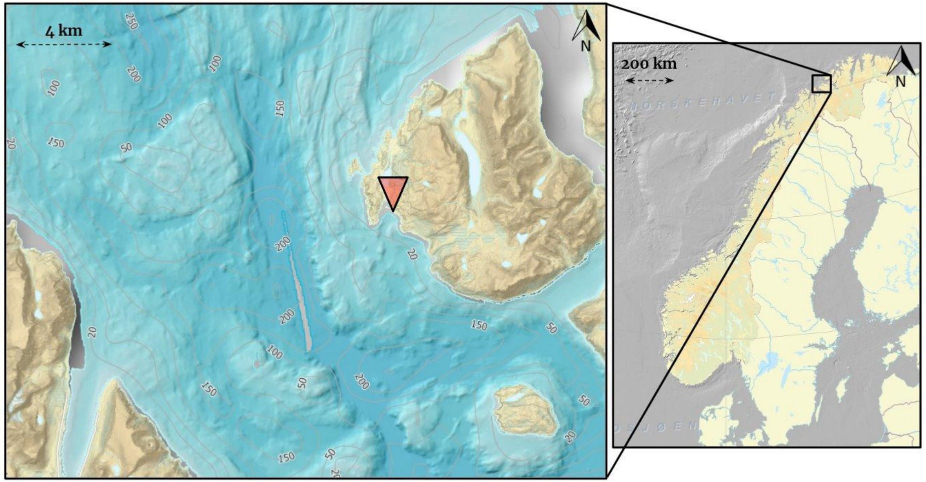


- Passive acoustic recordings
- Assess acoustic presence
- Evaluate interspecific interactions
- Study evolution of interspecific interactions

METHODS : Data collection

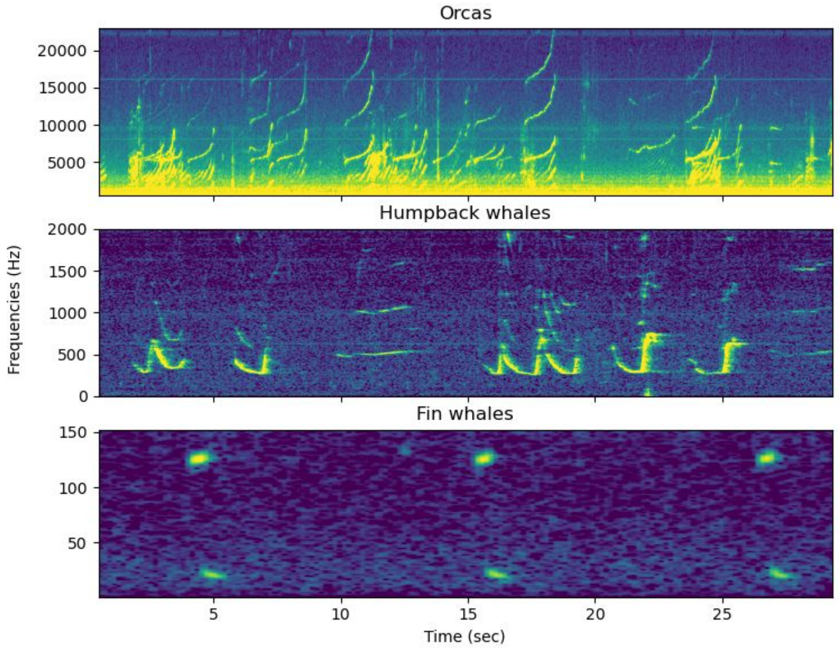
- continuous recording
- November 12, 2022 to January 31, 2023

Stereo acoustic array, which was placed on the seabed © H. Glotin



Map of the Kvaenangen Fjord and the position of the antenna (red triangle). © Norwegian Mapping Authority, Hydrographic Service

METHODS : Data analysis



Below 12kHz

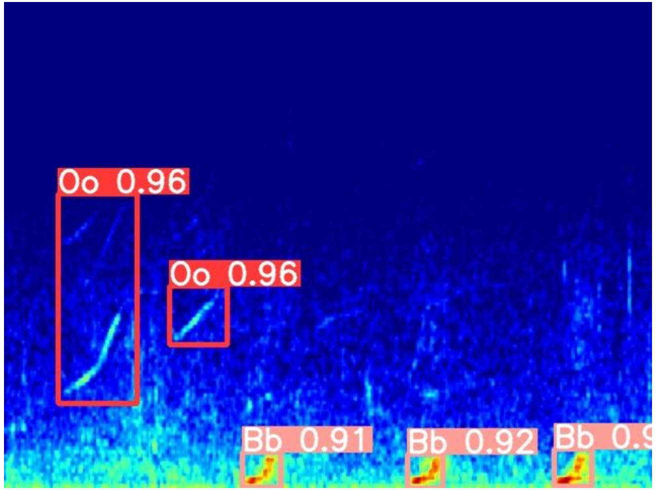
0.1 to 6kHz

20 to 130Hz

Exemple of spectograms. Pouaprd et al.

- Neural network (Yolo v5) for automatic detection

Example of detections from YOLO1 (Oo=orca; Bb=humpback whale). From Poupard et al.

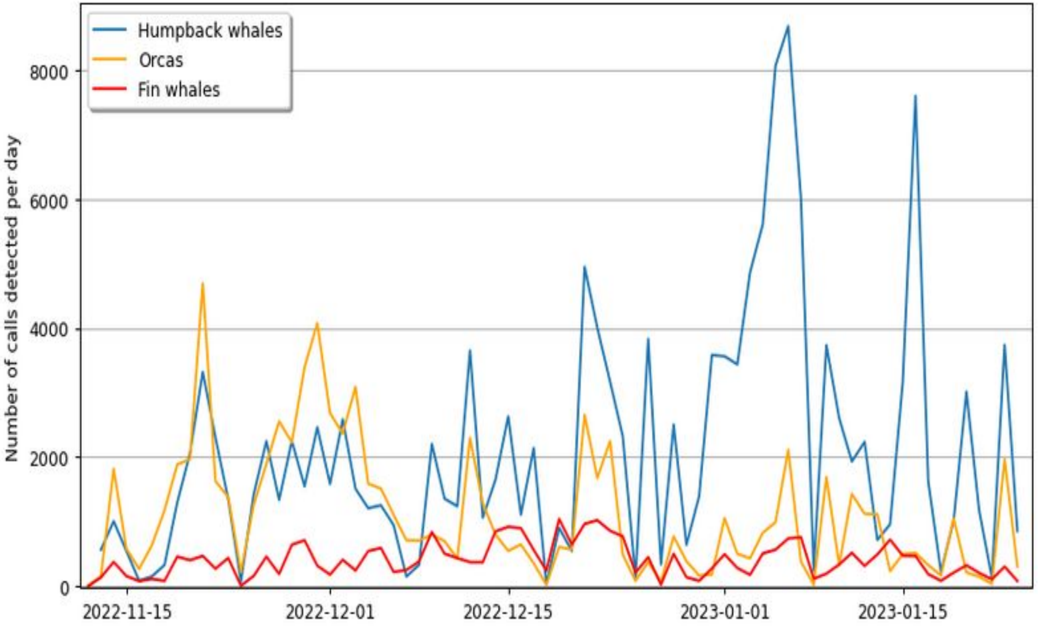


RESULTS : cetaceans detections

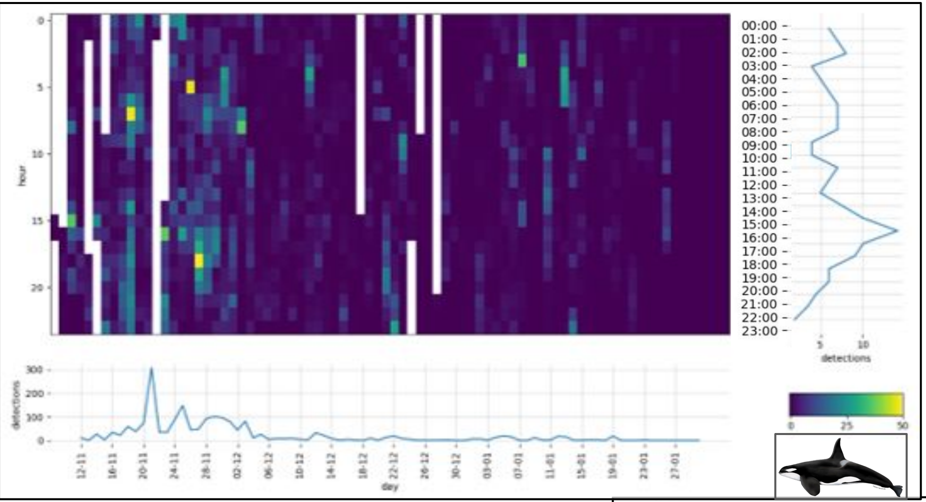
80 days of recordings and automatic AI detections :

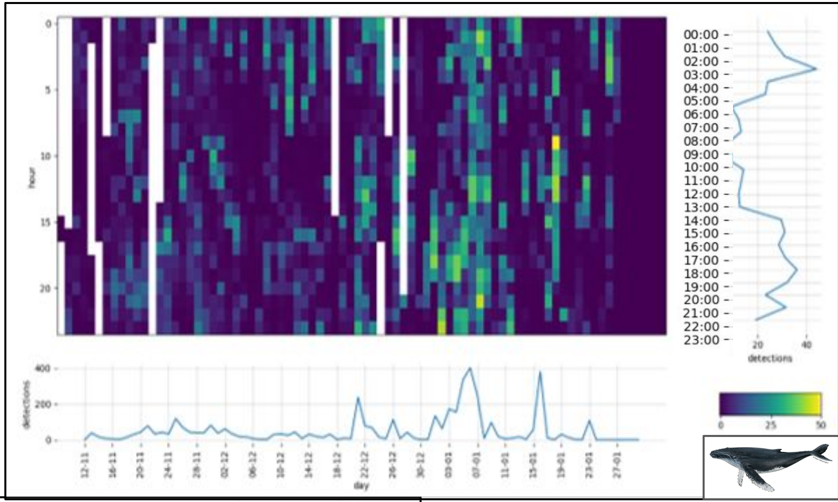
- 155 000 humpback whale vocalizations (58%)
- 80 000 orca vocalizations (31%)
- 30 000 fin whale vocalizations (11%)

Evolution of the number of vocalizations and pulses detected per day (From Poupard et al.)

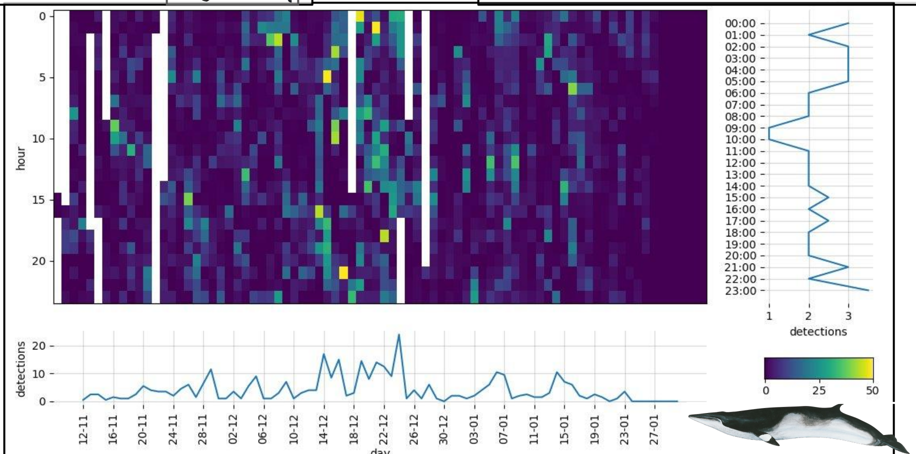


RESULTS : compared cetaceans presence

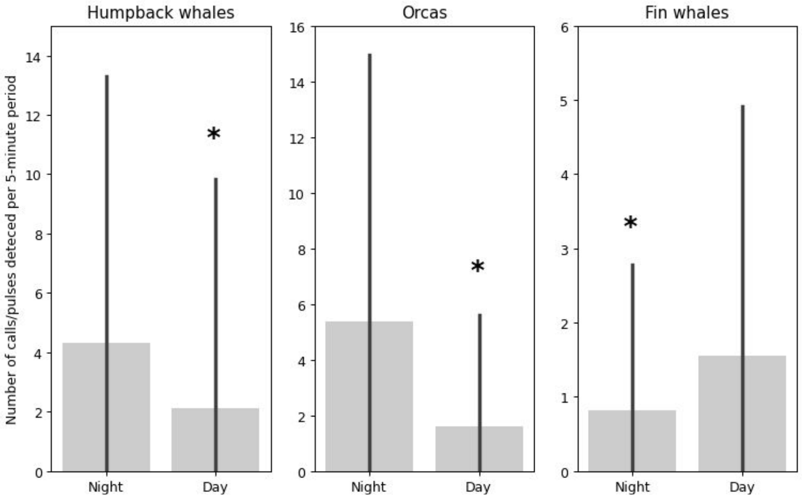




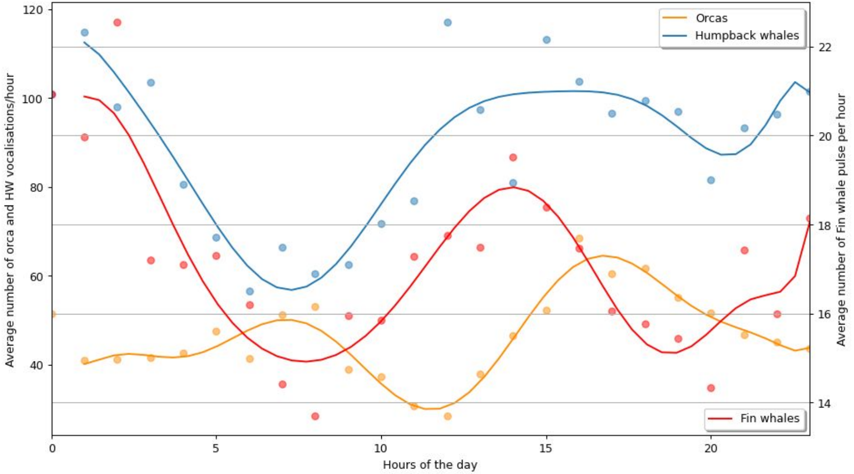
No overlap in maximum activity



RESULTS : daily acoustic activity



Mean number of vocalisations detected per 5-minutes period per species for night vs day. (From Poupard 2023 sub.)



Average number of vocalisations for each species. (From Poupard 2023 sub.)

No correlation between orcas and humpback whale
Positive correlation between fin and humpback whale
Fin whale more silent when feeding → concurrent feeding between orcas and fin whales ?

PERSPECTIVES

- Assess cetaceans acoustic behaviour in relation to anthropophony
- Examine sperm whale presence in 2023 recordings
- Monitor evolution of interspecific interactions
- Evaluate influence of environmental parameters on cetaceans presence

Thanks for listening

Bibliography

Poupard M., Girardet J., Chavin S., Guiderdoni J., Tanneau R., Glotin H. Passive acoustic monitoring and interspecific interactions of orcas, fin whales and humpback whales in arctic Kvaenangen Fjord, Norway. Submitted to Marine Mammals 2023-12.

Poupard, M., Symonds, H., Spong, P., Glotin, H., 2021. Intra-group orca call rate modulation estimation using compact four hydrophones array. Front. Mar. Sci. 8, 681036.

Aulich, M.G., Miller, B.S., Samaran, F., McCauley, R.D., Saunders, B.J., Erbe, C., 2023. Diel patterns of fin whale 20Hz acoustic presence in Eastern Antarctic waters. R. Soc. Open Sci. 10, 220499.

Jourdain, E., Vongraven, D., 2017. Humpback whale (*Megaptera novaeangliae*) and killer whale (*Orcinus orca*) feeding aggregations for foraging on herring (*Clupea harengus*) in Northern Norway. Mamm. Biol. 86, 27–32.

SeGaMaS

a Serious Game for Marine (mammals) Survey

S. PARIS, H. Glotin and All / LIS-DYNI

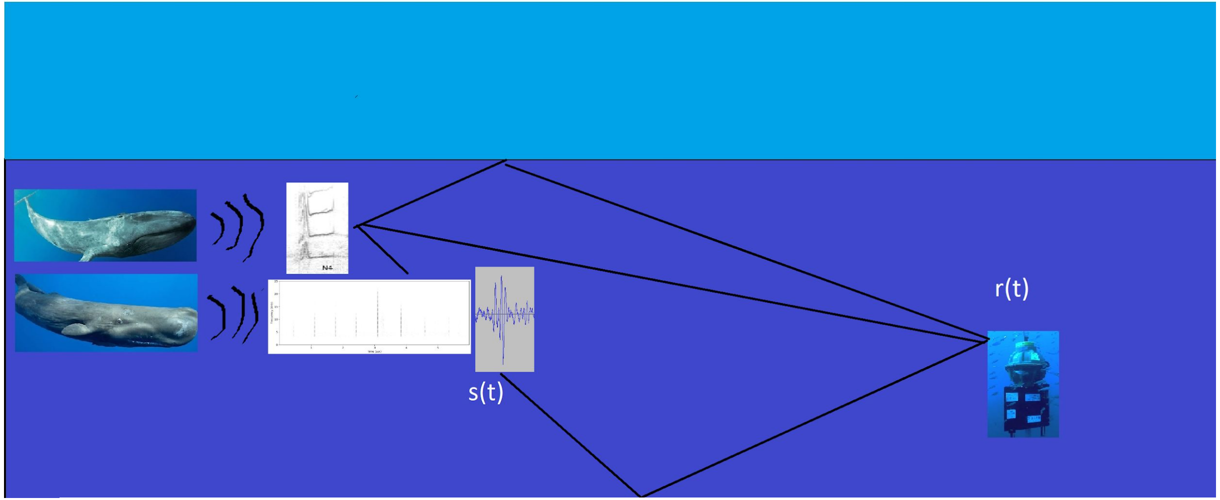
Main motivations from our bioacoustic researches (from 2000...)

Given some collected underwater acoustic data (mostly unsupervised), we are working on these 5 different tasks:

1 - **Detection** : Is there at least one animal surrounding the sonobuoy ? (and when it’s detected)
2 - **Classification**: What type of species have been detected ? (among a finite catalog)
3 - **Sequence modeling** : What mammals are trying to say ? (communication understanding)
4 - **Tracking** : Where mammals are ?
5 - **Optimal control/Reinforcement Learning**: Where to deploy our sonobuoy ?
(to maximize the last four tasks performances)

A common denominator for all these tasks: we went from signal processing/statistical modeling to some (full) machine learning (ML)/artificial intelligence (AI) solutions….

Acoustic data acquisition model

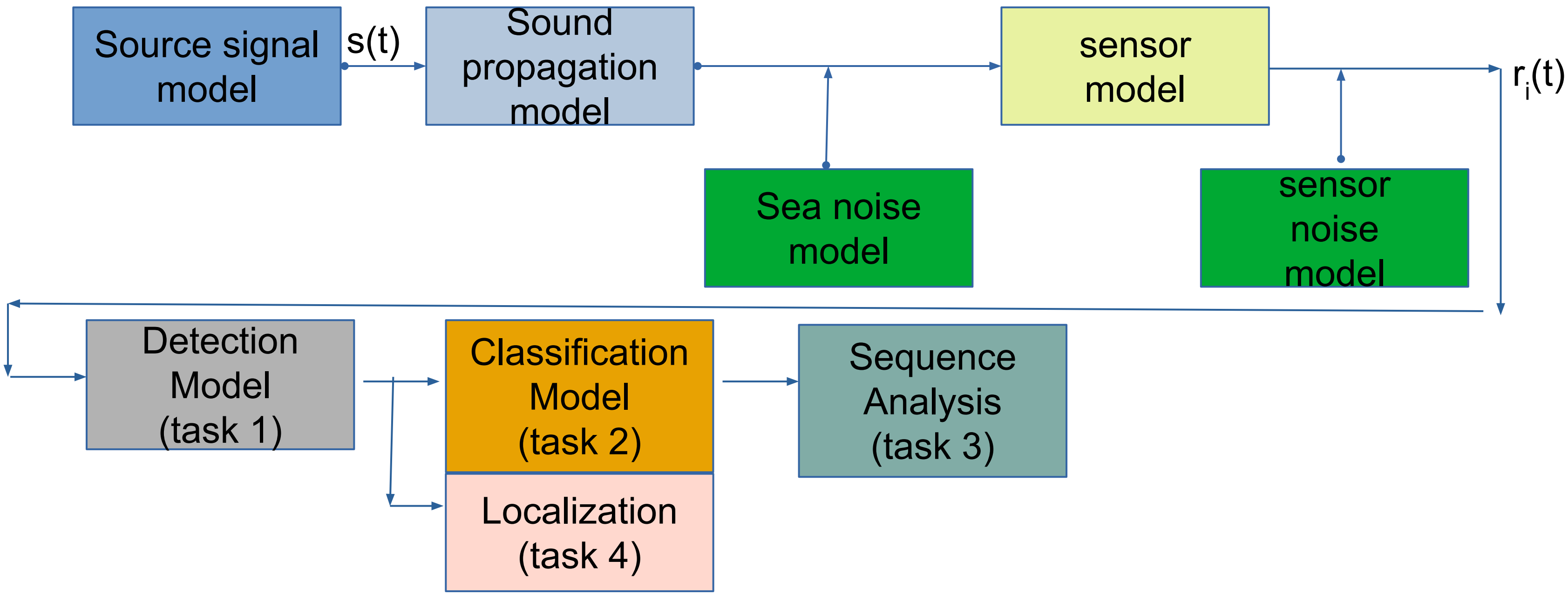


$$r_i(t)=(g(s(t)*h_i(t))+n(t))*a_i(t)+b(t)$$

$s(t)$: source signal (calls, clicks, ...)
$h_i(t)$: propagation/scattering equivalent transfer function
$g(t)$: transmission loss
$n(t)$: ambient sea noise
$a_i(t)$: hydrophone transfer function
$b(t)$: receiver noise
$r_i(t)$: observed signal on hydrophone i

Very complex and noisy signal

Received signal + first processing pipelines attempted



For **tasks 1-2-3**, many signal processing have been used from: *quadratic detector, wavelet transform*, *MFCC*, TF representations (*STFT, Scalogram*, *etc..*) up to *GMM, HMM*

For **task 4**, from *TDOA* estimators (*cross-corr, GCC-PHAT*, etc..), mammal's positioning is conducted by gradient descent technics. Reliable only for one animal with few TDOA clutter and a good initialization. But the main problem is : **no reliable ground truth to check performances**

From signal processing to statistical learning

At least for **tasks 1-2**, from 2006-2007, since more datasets starts to be available(with partial labeling), we started to work on (mostly unsupervised) ML technics to produce more reliable latent representations (invariant to more complex transformations and embedded data living into a lower rank manifold)

$$\mathbf{z} = f_{\theta}\big(l(\mathbf{r};\beta)\big)$$

where *l* can be typically a TF representation (*STFT, scalogram*, etc..) with fixed β hyper-parameter and f_{θ} is trained representation (*clustering,GMM, sparse coding*...)

Can be considered of a first trained hybrid learned representation, Improved a lot performances for tasks 1-2

For **task 4**, unsupervised learning (like clustering) helped to **filter out clutter** in TDOA but we still using simple localization methods (instead to perform a real (multi) target tracking). Aside, a first attempt to learn (*via* regression) a relation between latent vectors (*sparse coding*) and distance directly was successfully done. It helped to input a *particle filter* to conduct a real tracking. Whatever, w**e still missing some good ground truth mammal's trajectories to upscale the procedure**

Task 5 is not yet considered

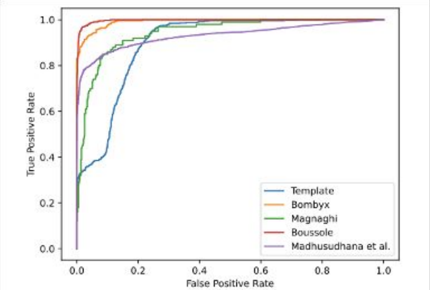
From 2013 ...

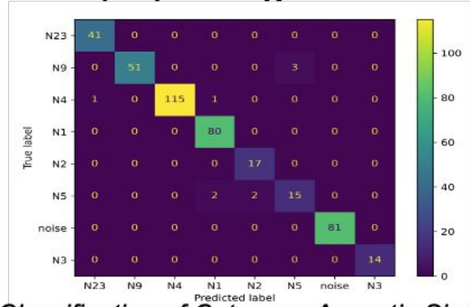
The IA's tsunami started from this date. Better latent representations (invariant to more complex non-linear transforms) are obtained thanks to modern *NN* architectures (*CNN, RNN, Transfomer, etc…*). Key points were :

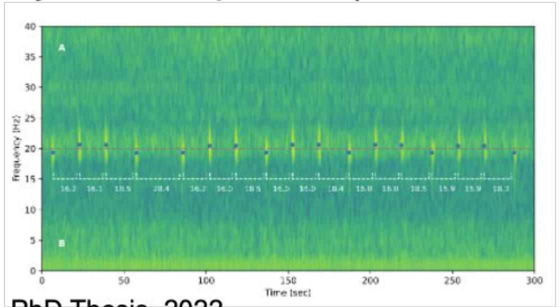
- Huge effort in labeling (partially) databases
- Better optimization gradient based solutions (*Adam, autodiff, etc...*),
- Transfer learning, self-supervised learning, active learning
- Regularization by data augmentation (noise, transform, etc..), dedicated layers
- Coupling unsupervised learning with supervised to increase labeled data

$$\mathbf{z} = f_{\theta_1} \circ f_{\theta_2} \circ \cdots \circ f_{\theta_L}\big(l(\mathbf{r};\beta)\big)$$

$\longrightarrow$ **Performances for tasks 1-2 are now quiet good.** More sequences are **automatically extracted** (improving statistical analysis of sequences)



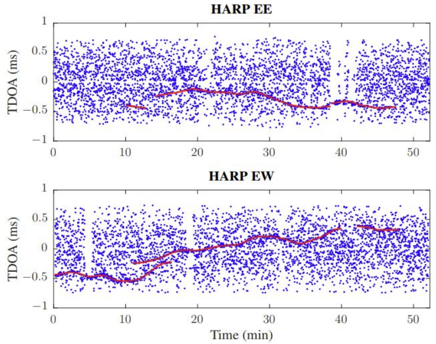


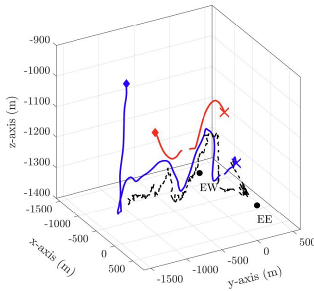


[1] Paul Best, *Automated Detection and Classification of Cetacean Acoustic Signals*, PhD Thesis, 2022
[2] Paul Best and all, *Temporal evolution of the Mediterranean fin whale song,* Scientific Report, 2022

Why AI also for tasks 4-5 ?

For **task 4**, we increased number of hydrophones on our new sonobuoy (now up to 5): more robust TDOA estimators are achieved to perform better localization… but we know (thanks to the CRB) we can **obtain only poor range estimators** from TDOA (more or less ok for bearings/angles). With TDOA (+doppler), we have to perform a real *multi-target tracking* (MTT)=> *(P)MHT, JPDAF, Bayesian filter*[3], *ect*..





The main difficulty in MTT is the (combinatorial) **assignment problem between measures and targets**

One way to overcome/make more easy the *MTT challenge* would be to train directly from detected sound events some more robust *TDOA/DOA/*direct positioning estimators **with builtin source separation**[4]

→ To train such *Deep NN* we need much more ground truth data with animal's trajectories. But since we don't want to tag mammals directly ...

[3] J Jang, *Bayesian Detection and Tracking of Odontocetes in 3-D from Their Echolocation Clicks*, arXiv preprint arXiv:2210.12318

[4] T. Nguyen, *Spatial Cue-Augmented Log-Spectrogram Features for Polyphonic Sound Event Localization and Detection, IEEE Trans ASLP*

SeGaMas - generator -

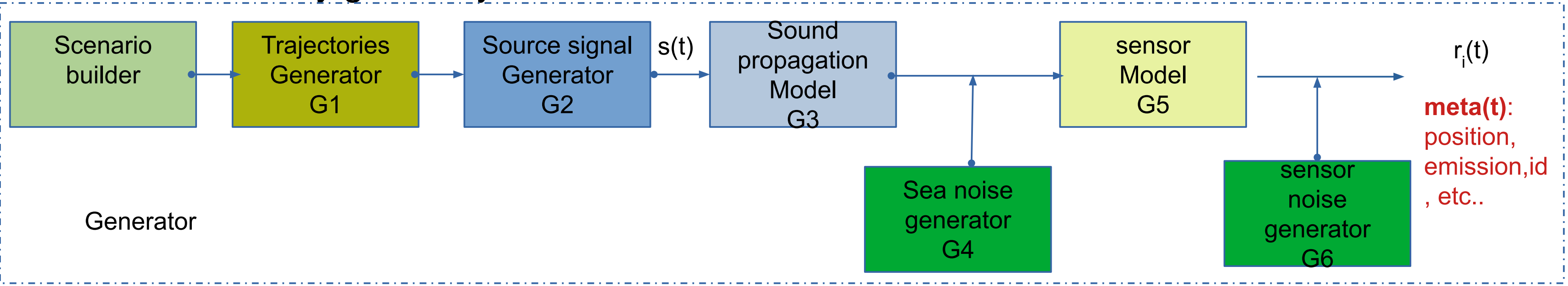
To overcome the non tagging possibility/wish, we started to build a complete **serious game** divided in two parts **: generator & analyzer** The generator have to:

– generate realistic mammals trajectories (cinematic, behavior, ROI, weather, food, multiples, etc...)

– generate realistic source emissions

– model sound propagation and sea noise characteristics

– model sonobuoy geometry and sensor characteristics

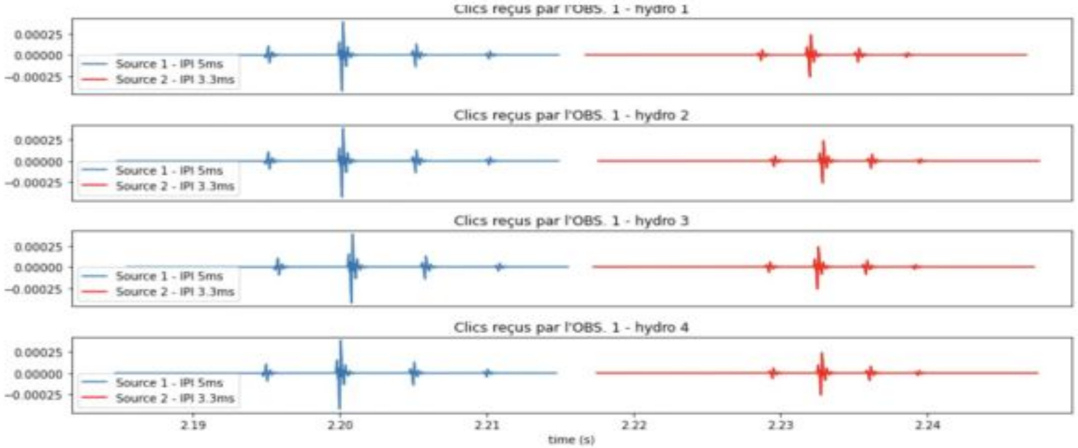


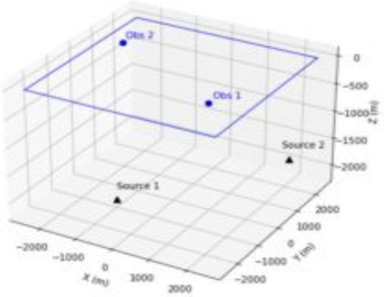
In the generative part of SeGaMas, the goal is not only to generate realistic acoustic signals at antenna but **also all important associated meta-data** used as label for tasks 3-4-5

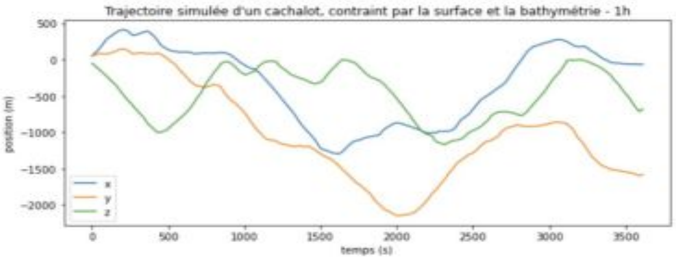
Our plan is to **compare classic signal processing methods with new AI generative approaches** (*VAE, GAN, NF, Diffusion Models, etc…*) for most of the block G's.

Example of generated trajectories & acoustic sounds

First results for the generator: parameters defined in the scenario builder : kinematics constraints, head angle, behavior, number of mammals, bathymetry, antenna’s geometry, number of antenna, etc…. (to be completed)



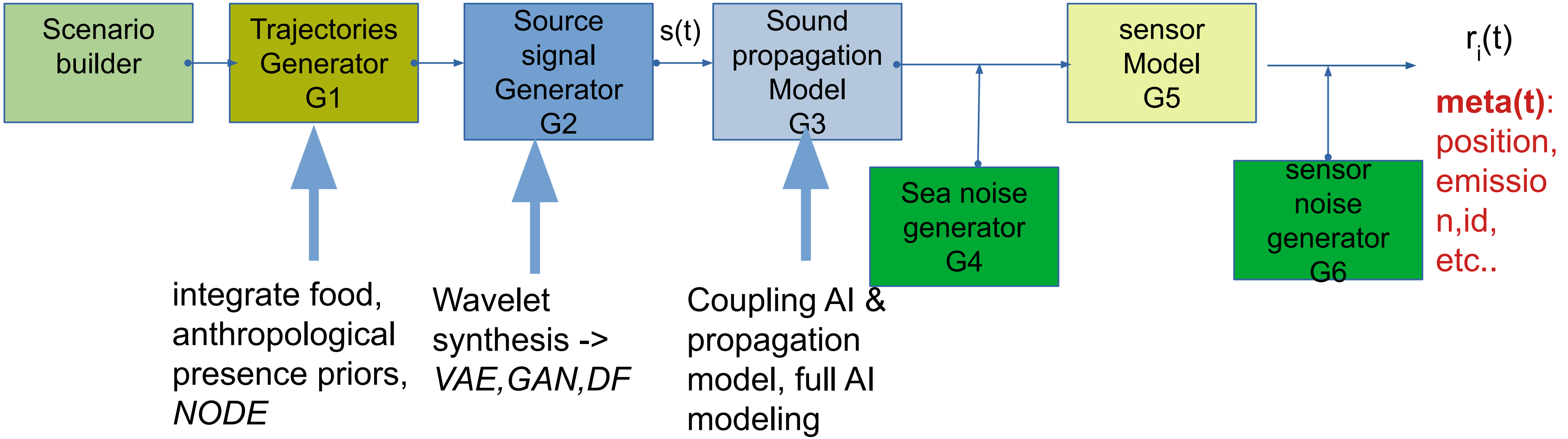




For block G1, no AI solutions tested (yet) since we got only very few real ground truth paths, so hard to train efficiently a generative model

[5] N. Thellier, internal lab report

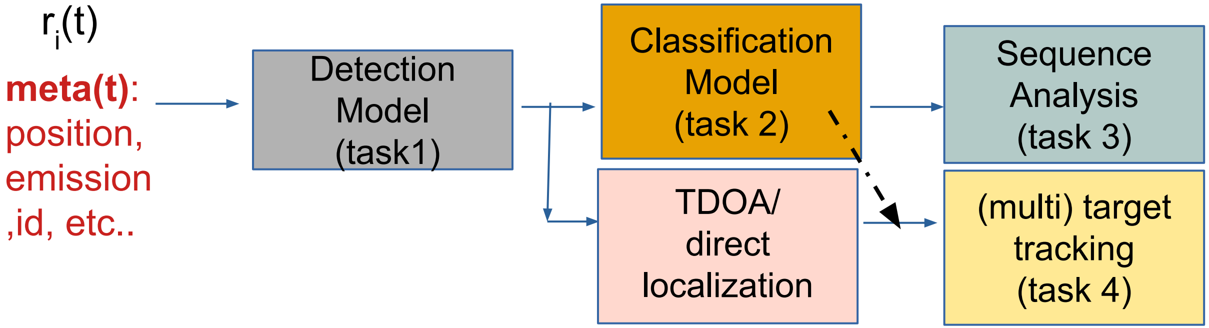
Current work & future development For SeGaMas



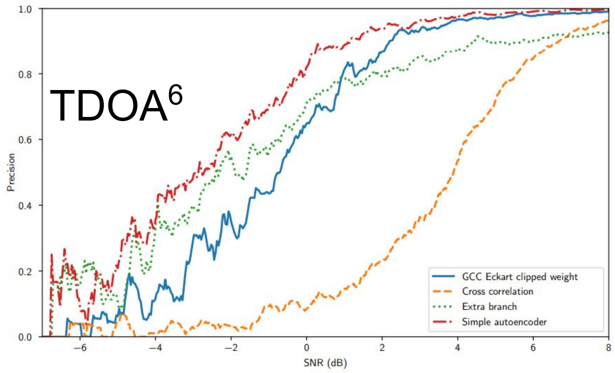
→ Most of generated (intermediate) data coming from full AI samplers

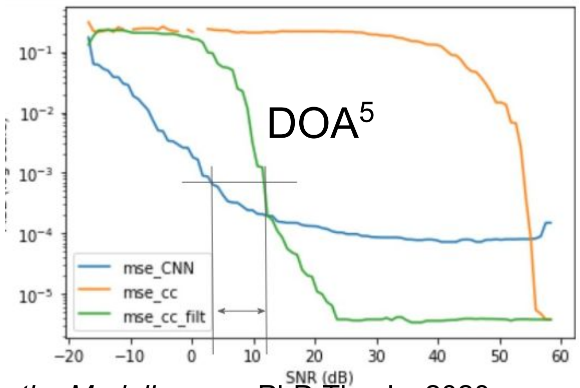
SeGaMas - analyzer 2/

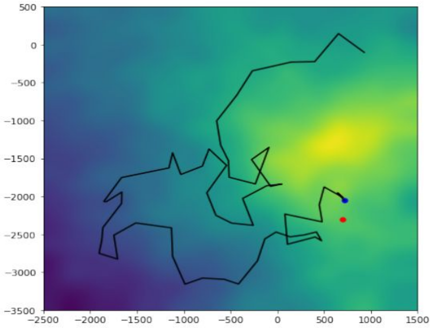
Analyzer



Ex : - Generated signal & associated meta can be used as data augmentation for tasks 1-2
- NN can be trained to obtained more robust *TDOA/DOA/doppler* estimators or thanks to meta-data directly raw position/(range,angles) estimators (feeding MTT for task 4)
- Reinforcement Learning (RL) used as tracker & can be compared with sota MTT algorithms







RL tracking[7]

[6] Maxence Ferrari, *Study of a Biosonar Based on the Modeling .....*, PhD Thesis, 2020
[7] A-K Shamba and all, ,*Reinforcement Learning - A WHALE GYM, MIR Ms Thesis, dir Glotin*

SeGaMas - generator+analyzer full control loop

For **task 5** , thanks to all generated trajectories and associated sound events & meta labels, we can imagine find the best sensor's location minimizing such loss

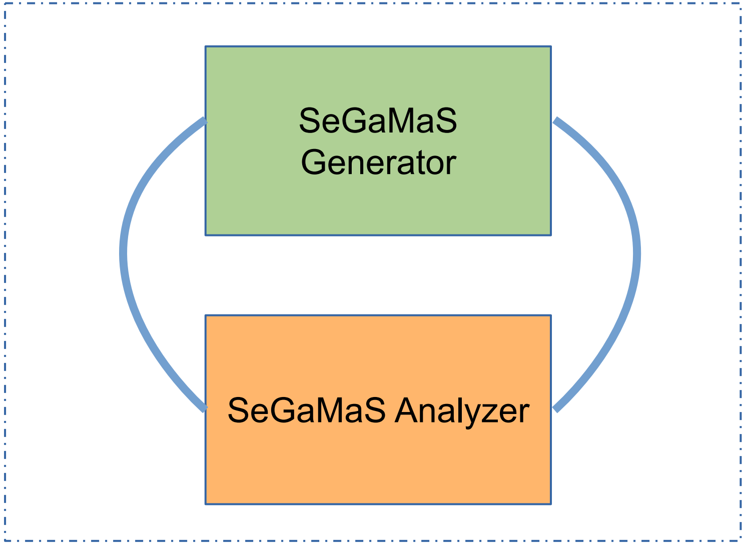
$$L(\boldsymbol{U})=\min_{\boldsymbol{U}}\{E_{\boldsymbol{T}}[\sum_{k} det(cov(\boldsymbol{x}_k|\boldsymbol{Z}_{1:k}(\boldsymbol{U})))]\}$$

Sensor's location

Trajectories from G1

MTT (task 4) or PCRB

Find best sensor's location minimizing the sum of ellipse's incertitude volume given a set of trajectories sampled from G1



L(**U**) can be optimized by stochastic optimization technics or via RL (agent = sonobuoy)
Would be interesting to compare both way to solve the corresponding problem

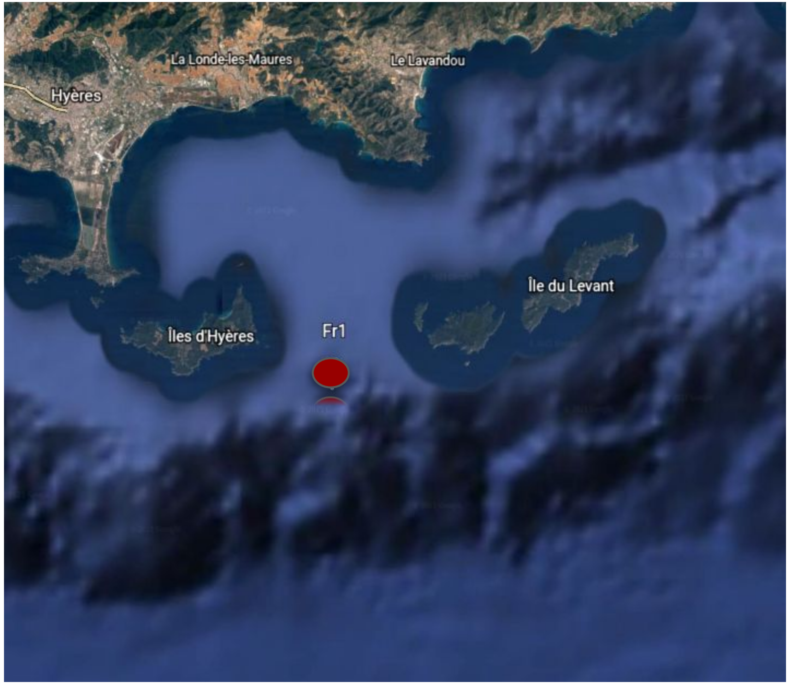
To resume SeGaMaS

- A serious game generating realistic trajectories and mammals acoustics events mostly via modern IA samplers
- Allow to compare traditional signal processings technics with AI approaches
- A way to solve 5 (sensor deployment)
- Can be extended to any maneuvering sources

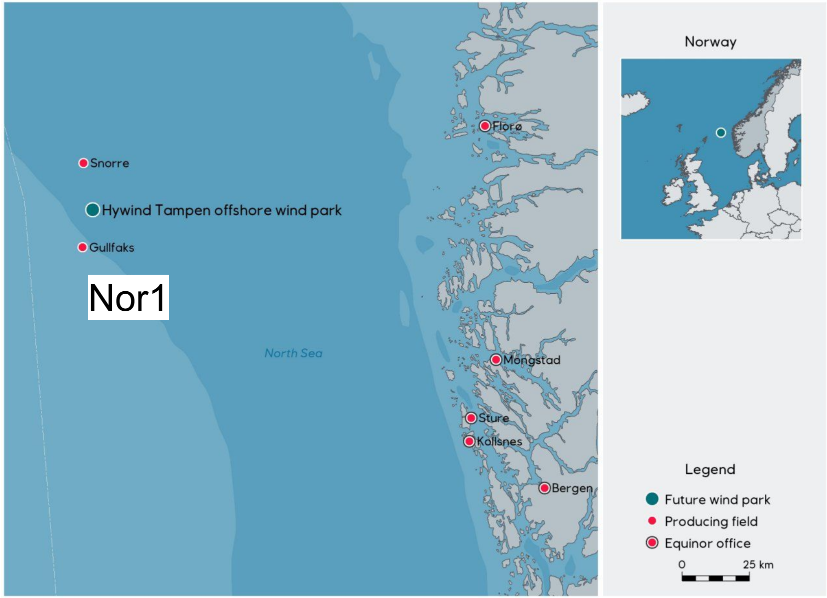
Thanks for your attention !!
Questions ?

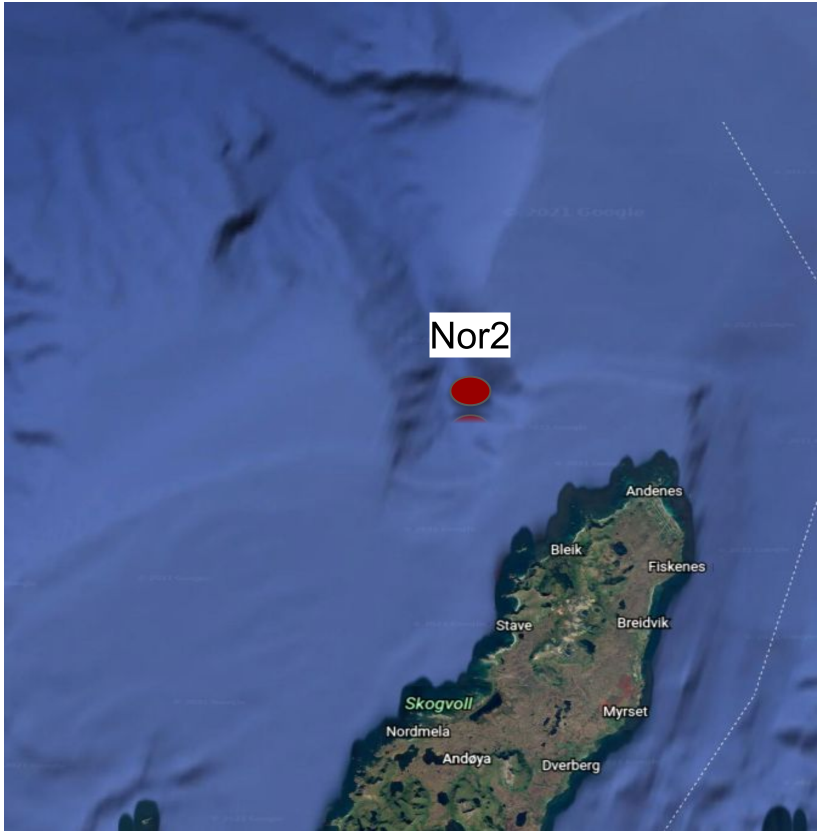
Placements of other Bombyx

Instrumentation in France (Fr1 and Fr2)

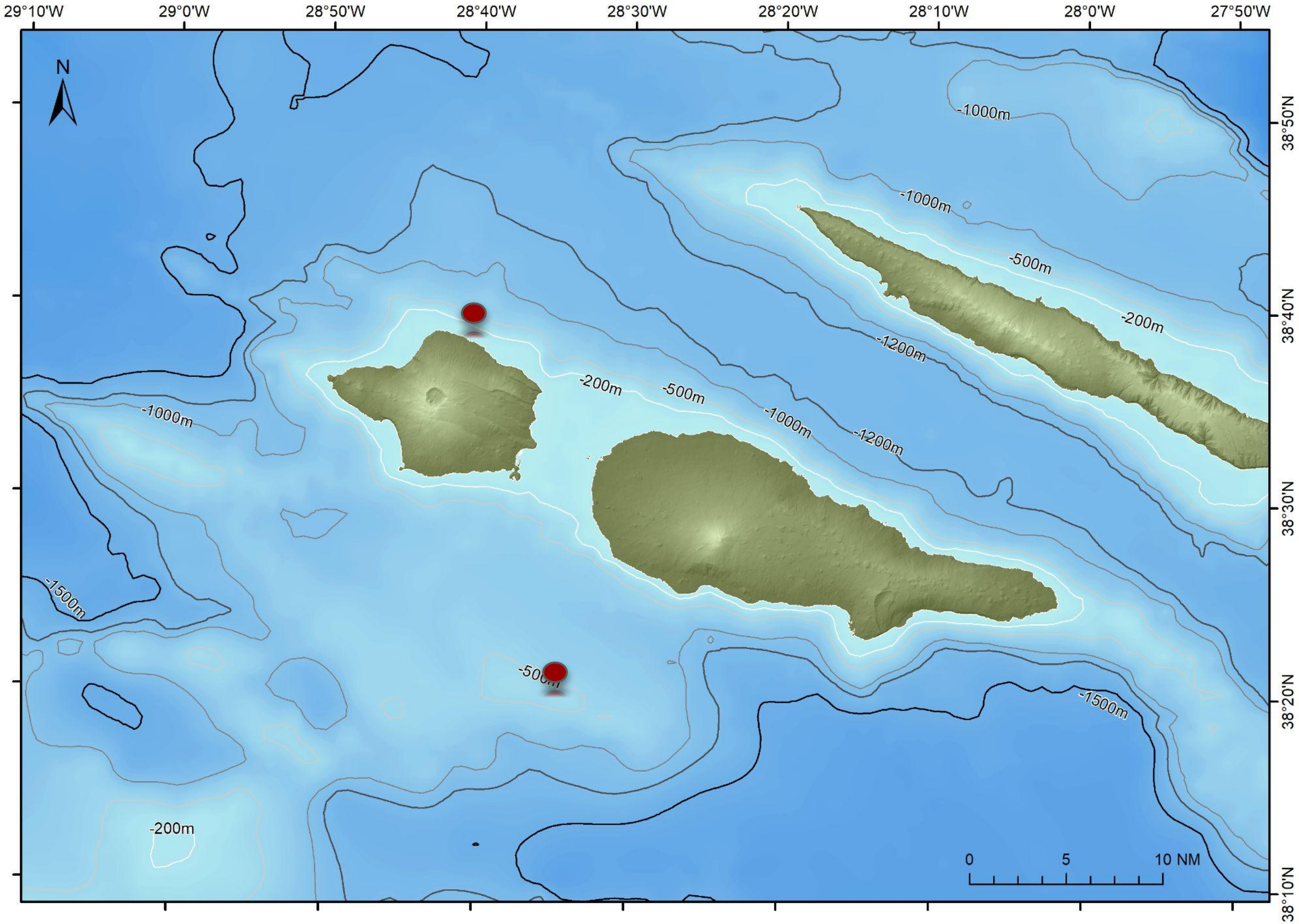


Instrumentation in Norway





Instrumentation in Azores



Total of instrumentations and species

Country	Localisation (GPS)	Depth	Target species	Target anthropic
France (Fr1)			Gm, Bp, Pm	
France (Fr2)			Gm, Bp, Pm	
France (Fr3) (Lion)			Bp, Gm	Eol
Norway (Nor1)	Tampen		Pp,Bp	Eol
Norway (Nor2)	Bleik canyon		Pp,Pm,Oo,Gm,Mn	
Italy (Ita1)			Gm, Bp, Pm	Eol
Italy (Ita1)				
Azores	S. Mateus seamount	500 m	Pm,Oo,Gm,Bm	Vessel traffic (fishing boats, sometimes whale watching)
Azores	North Faial	500 m	Pm,Oo,Gm,Bm	Vessel traffic (fishing boats, sometimes whale watching)