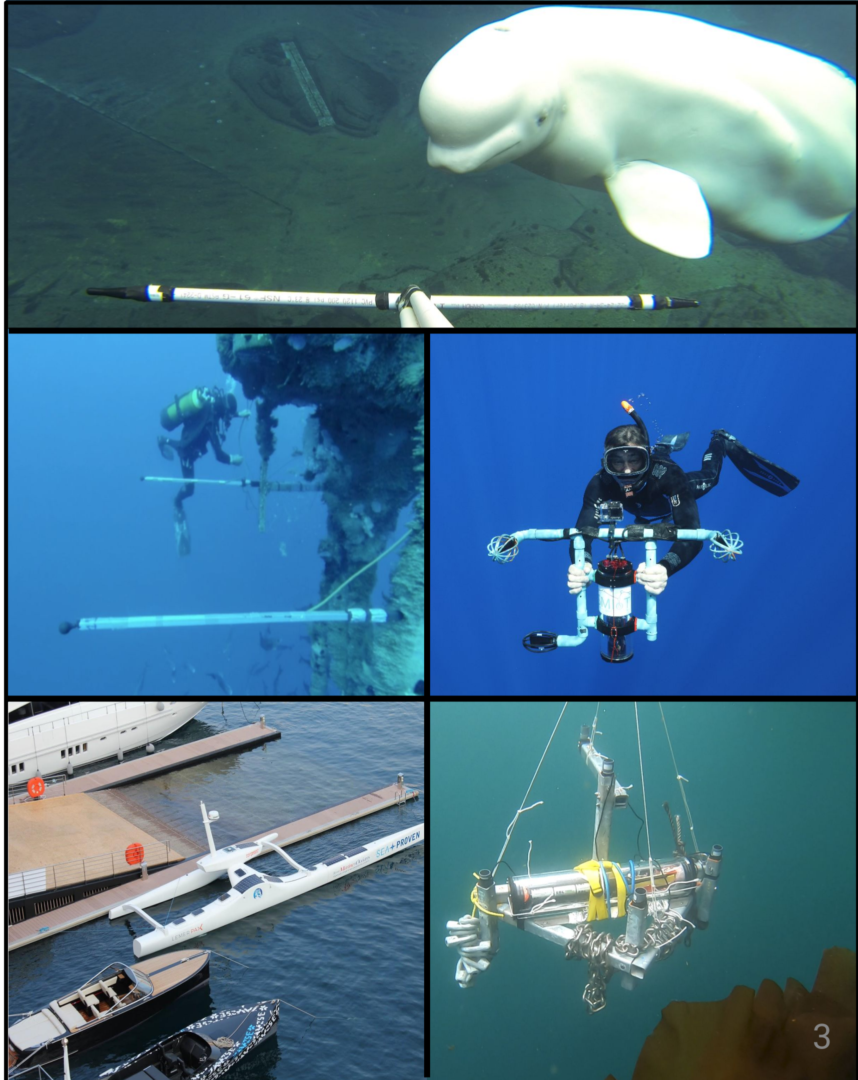
CARIBBEAN MARINE MAMMAL'S PASSIVE ACOUSTIC OBSERVATORY

Maxence Ferrari, Marion Poupard, Hervé glotin
CNRS LIS DYNI, SMIoT, Univ Toulon, SABIOD MADICS

Contents

The team DYNI

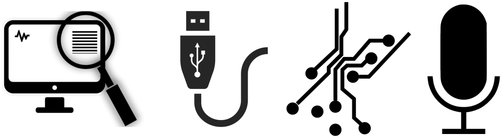
We are research group of the Laboratoire d’Informatique et Systemes (LIS) - UMR 7020 CNRS hosted at the Université de Toulon (UTLN), France. Our aim is develop and innovate in methods of machine learning, signal processing and data analysis in order to improve our knowledge and understanding in physical, natural and human sciences.

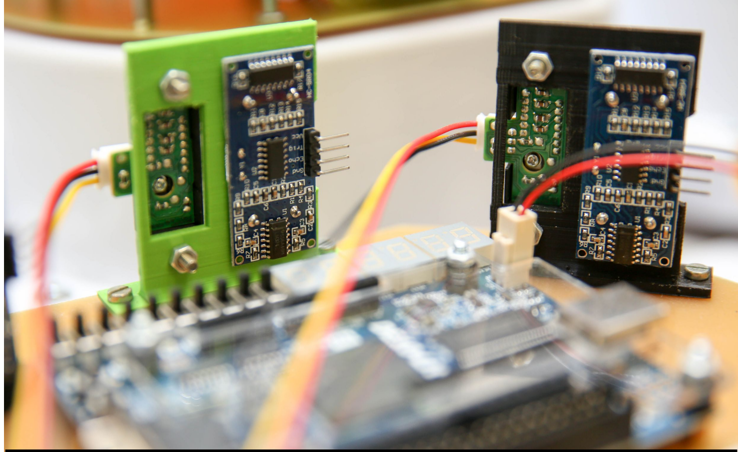


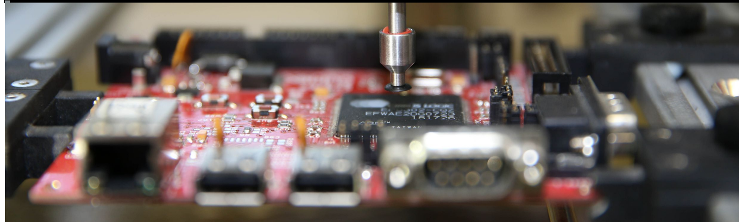
SMIoT: Scientific Microsystems for the Internet of Things

Design of electronic hardware (conception et routage des PCB), front-end, RF.
Assembly and testing of electronic prototypes
Industrialization of connected objects

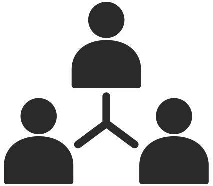
Design, Test and Construction of the
HIGH BLUE MONO system







Speakers



Hervé Glotin

Prof. Univ Toulon, DYNI LIS team, France in Computer Sciences AI and Bioacoustics

Marion Poupard

Doctoral student
DYNI LIS Toulon,
3rd year in bioacoustics and Ethoacoustics, on marine mammals and birds.
Master in Marine Sciences

Maxence Ferrari

Doctoral student at Dyni LIS Toulon,
3rd year in bioacoustics (transient analysis and model)
Centrale Lille in physics and applied math

Map of the DYNI collaboration

Schedule: first day

Thursday, 31st oct 2019

8h00 : Participants welcoming

8h15 : Opening

- *Welcoming - Director of the sanctuaire Agoa (Laurie Hec)*
- *CARI'MAM project presentation - Head of the project (Gérald Mannaerts)*
- *Training objectives - Scientific coordinator (Jeffrey Bernus)*

9h00 : Organization & presentation of the team *(Hervé Glotin)*

9h30 : What is a sound ? Definition and introduction to sound processing *(Maxence Ferrari)*

10h00 : Introduction to bioacoustics & ethoacoustics *(Marion Poupard)*

- Study case A: Detection, monitoring and localization of orcas

Please ask questions !!

10h45 - Coffee break

11h20 : Study case B : Ethoacoustic of pantropical spotted dolphin in Martinique

11H40 : Study case C : Sphyrna and Beam pattern of odontocetes, Clan Id

12h00 : How can bioacoustics help in conservation ? Various possibilities with different numbers of hydros
Comparison with other monitoring methods

12h20 : Listen to various cetacean recordings: orcas, sperm whales, dolphins..

12h40 : Data analysis : Various possibilities, how does it work ?

13h00 - Lunch

14h00 : Study case D : long term stereo sonobuoy Bombyx

14h40 : Automatic classification, first results of the CARI'MAM preliminary study. Semi-sup and active learning :
the importance of the joint and homogeneous long term observations

15h20 : *The CHAMP Project (Genevieve Davis)*

15h40 - Coffee break

16h10 : *The Dominican sperm whale project (Shane Gero)*

16h30 : *PAM at the BMMRO (Charlotte Dunn)*

16h50 : Explanation of the material, mooring & experiment
Groups organization for the practical trainings

Schedule: 2nd Day

8h00 - Welcoming

4 parallel groups of a dozen of people each, will turn over these 4 workshops during 4 hours :

Workshop 1: Preparation of highEAR, program, batteries, storage, closing tube
Workshop 2: Deployment under water **(bring your swim suit)**
Workshop 3: Recovery of the highEAR + save the data + emergency procedure
Workshop 4: Training on the software Audacity for a fast look, and sending data

10h30 : Coffee Break

11h00 - Press conference start

12h00 - Closing of the training by the head of the project (Gérald Mannaerts)
12h15 - Signature of the loan agreement and delivery of the 3 first hydrophones

12h45 - Press interviews

13h00 - lunch

The afternoon workshop will be limited to the participants that will deploy one of the 20 hydrophones.

14h00 - Workshop : Hydrophones logistics

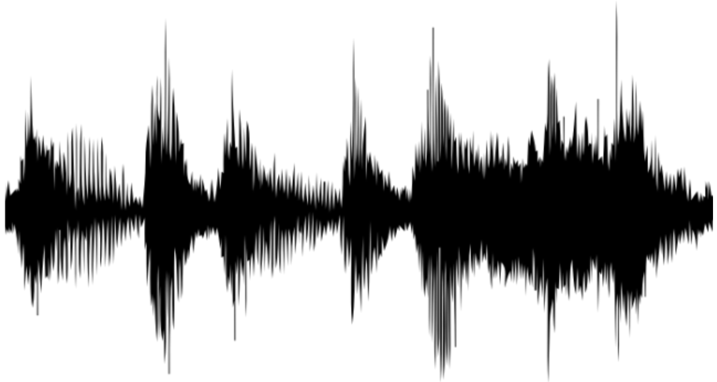
Definition for each island :

- Location
- Periods of deployment, retrieval and data transfers
- Authorization required
- Identification of needs

15h30 - Coffee break

16h00 - Workshop : Hydrophones logistics 2

19h30 - Dinner

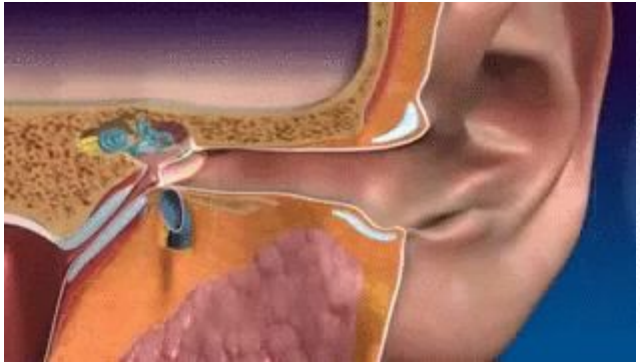


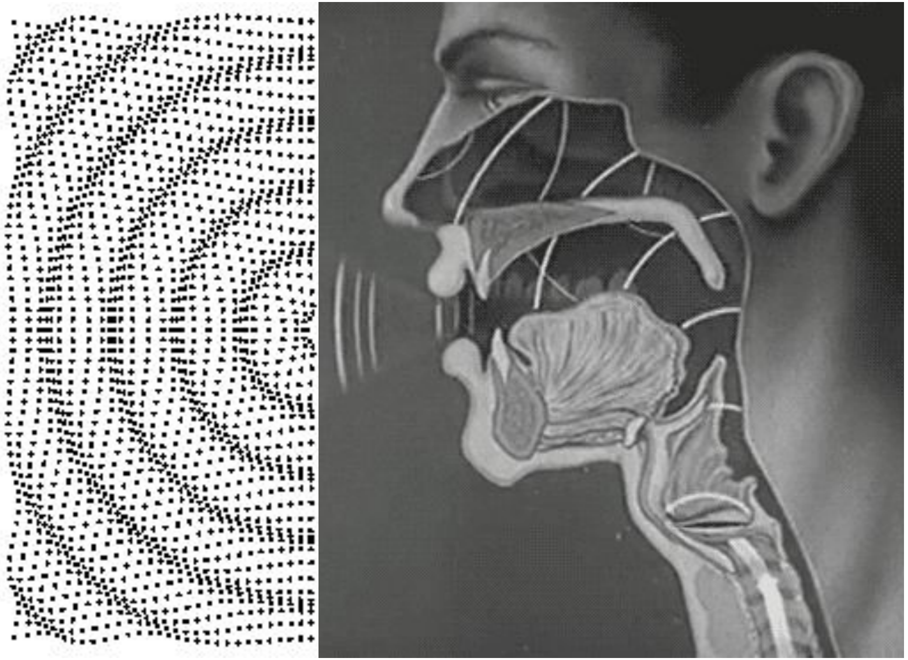
1. What is sound ? Definition and introduction to sound processing

Maxence Ferrari

Definition and introduction to sound processing

Basic notion

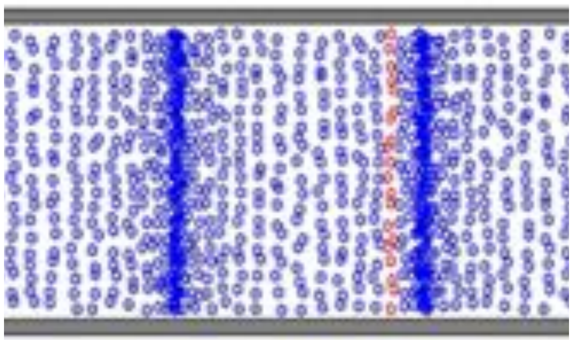




Definition and introduction to sound processing

Sound velocity

Speed at which the sound wave (information) propagate

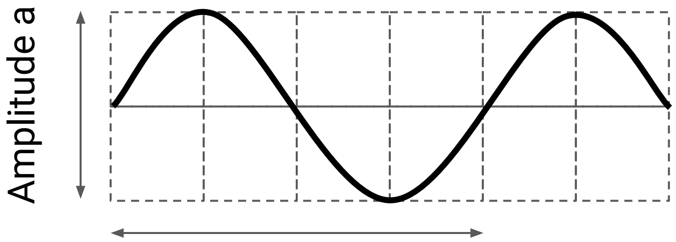


Particle velocity

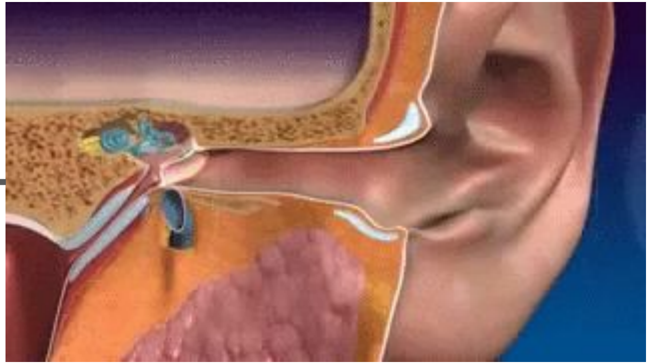
Speed at which the particles oscillate

Definition and introduction to sound processing

Sine wave



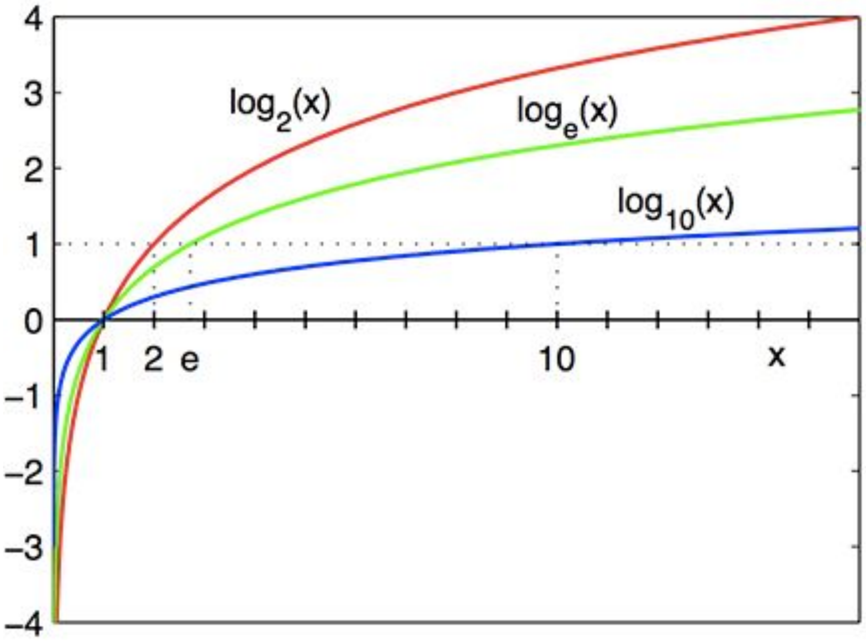
Period T
Frequency f = 1/T in Hz or rad/s
1 rad/s = 2π Hz

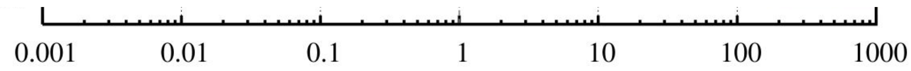


Definition and introduction to sound processing

Log scale

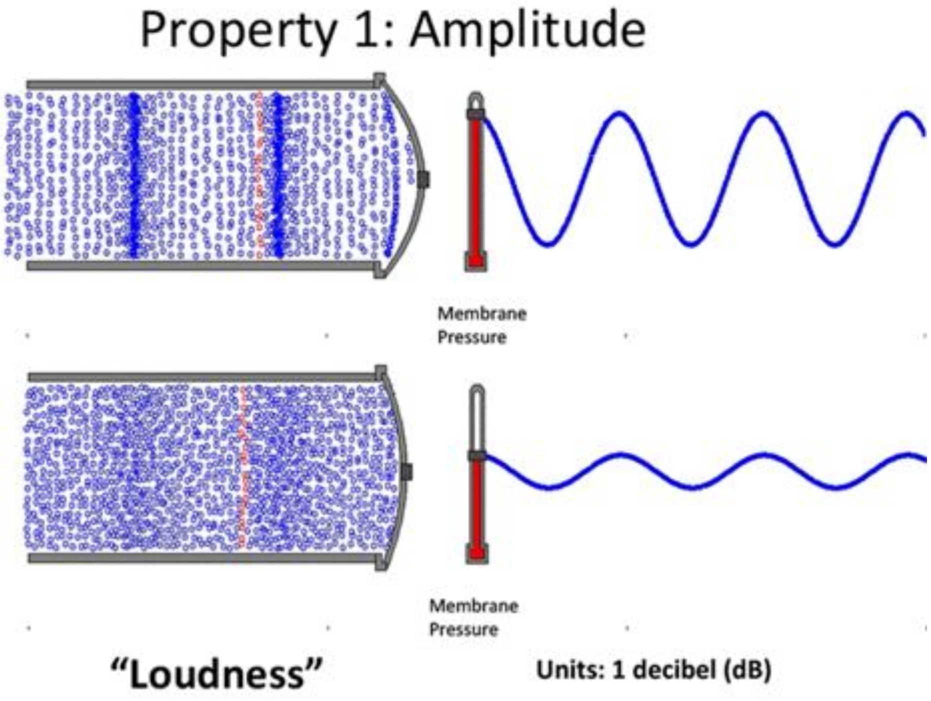
A log scale is useful way to study ratio between two values





Definition and introduction to sound processing

Decibel

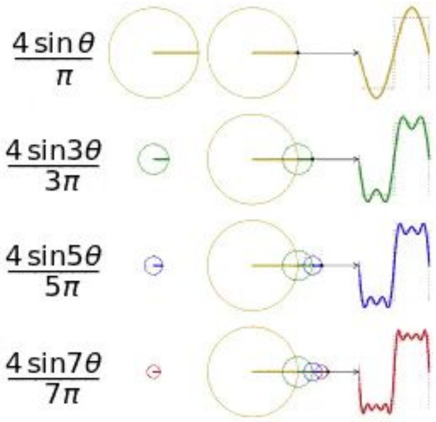


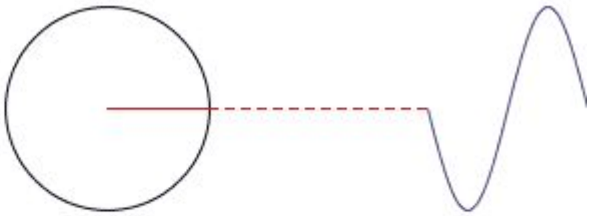
The amplitude in dB is computed from $20 \log_{10}(a / A_{ref})$, with a the scalar amplitude, and A_{ref} a reference Amplitude

An increase of 6dB means that the sound is 2 times louder

Definition and introduction to sound processing

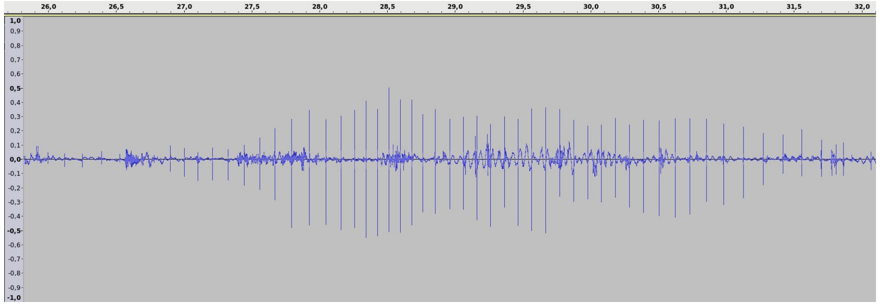
Decomposition

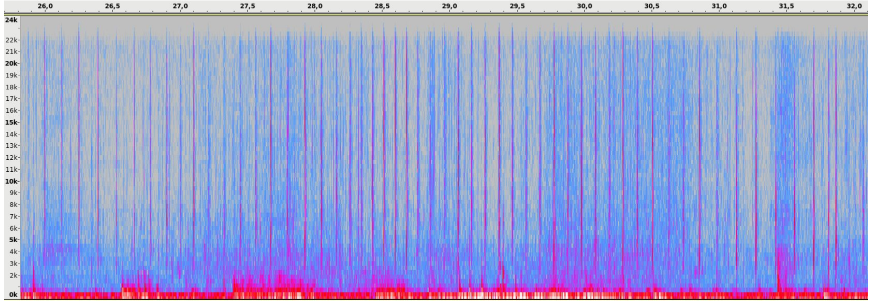




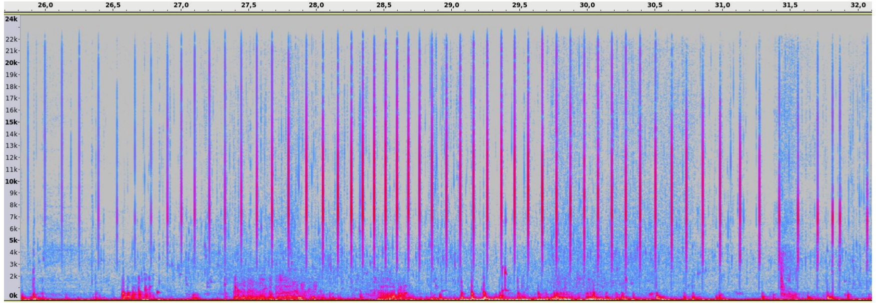
Definition and introduction to sound processing

Spectrogram

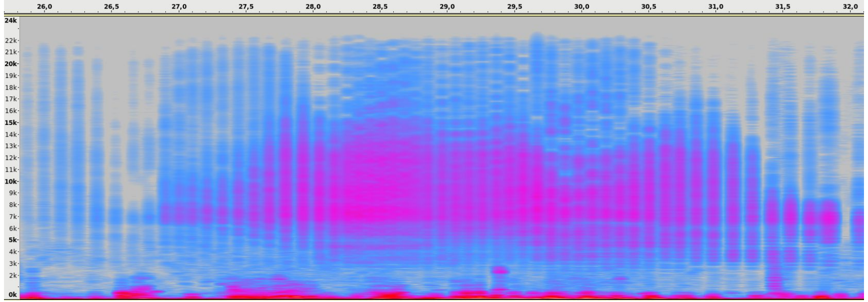




Window size : 128 samples



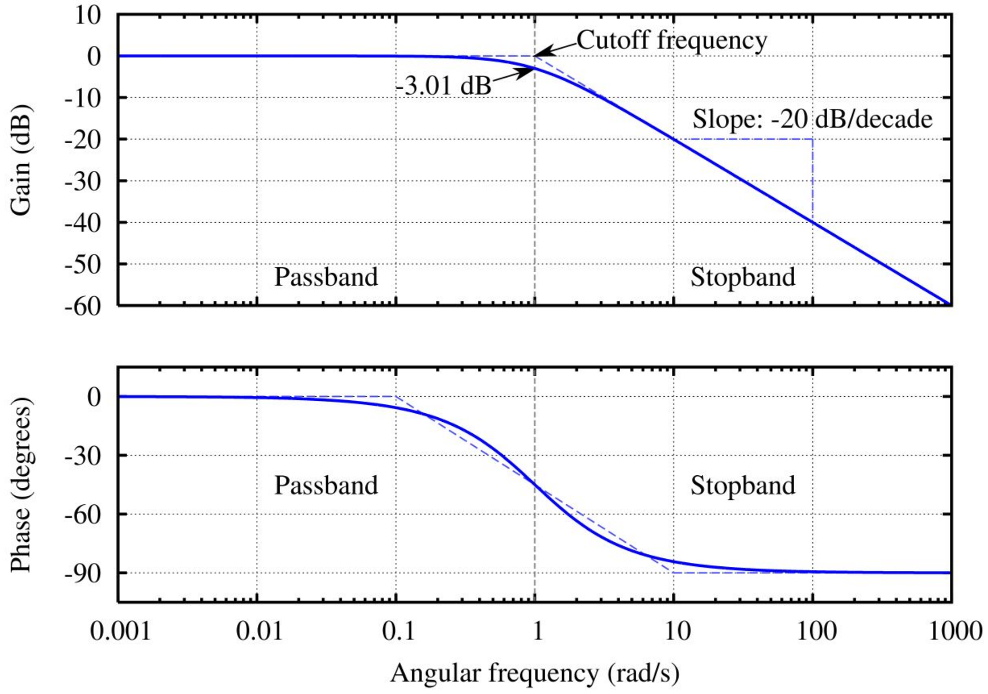
Window size : 1024 samples



Window size : 8192 samples

Definition and introduction to sound processing

Filter



Cutoff frequency : anything pass it will be below 3dB

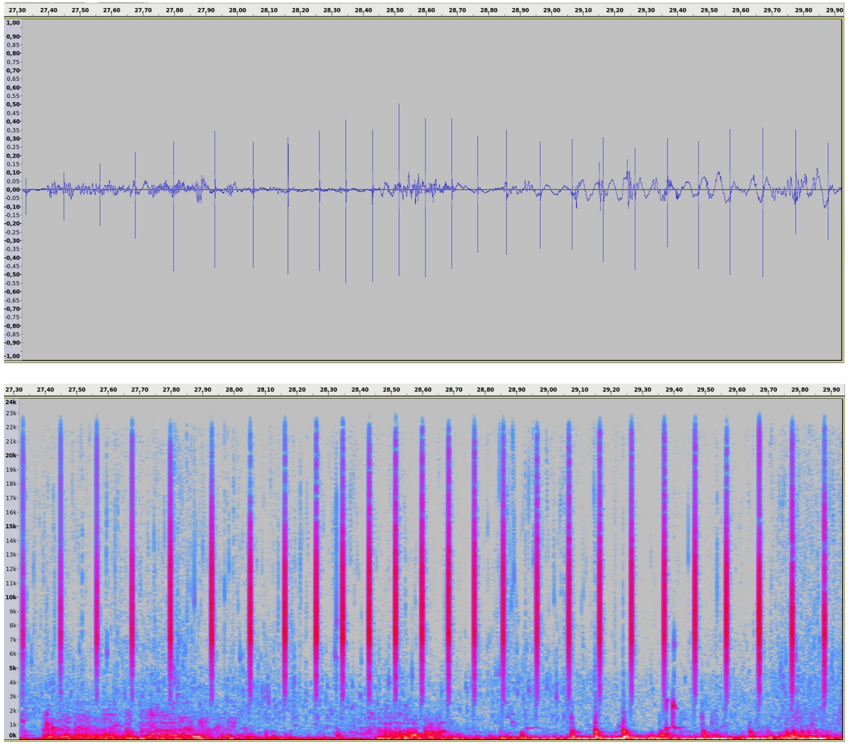
-3dB is equivalent to divide the amplitude by √2 or the power by 2

Order : each order will increase the slope by -20 dB/decade or -6dB/octave

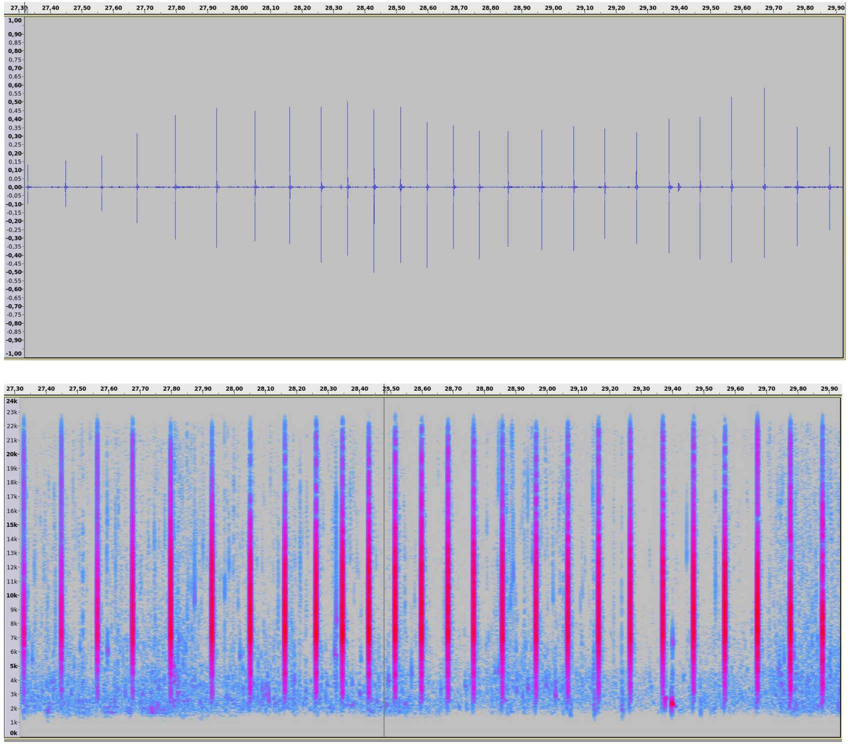
lowpass : only low frequencies stays
bandpass : only middle frequencies stays
bandstop : filter out middle frequencies
highpass : only high frequencies stays

Definition and introduction to sound processing

Filter

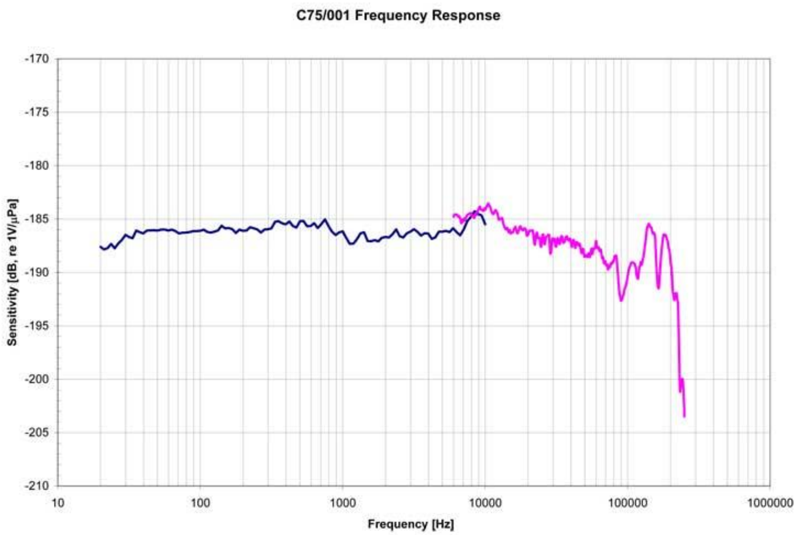


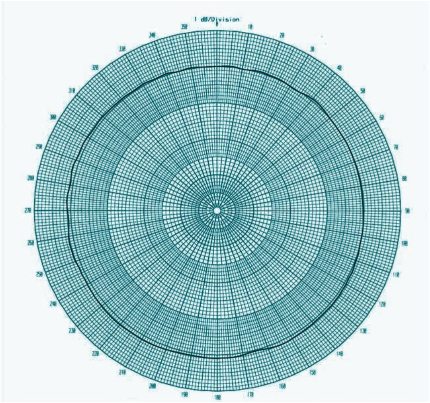
Order 8 highpass filter at 2 kHz

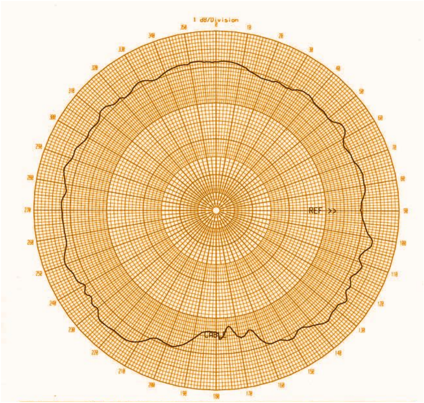


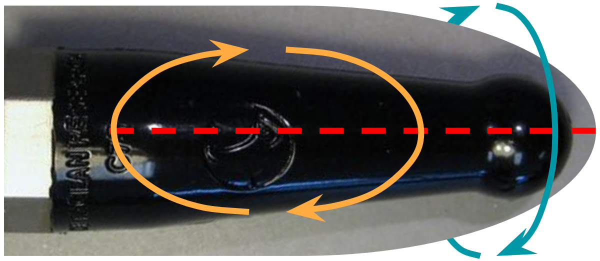
Definition and introduction to sound processing

Directivity and frequency response



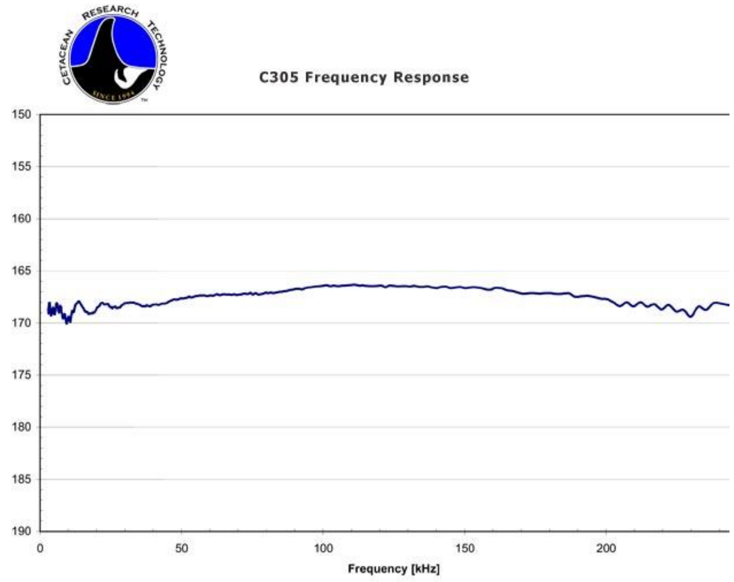


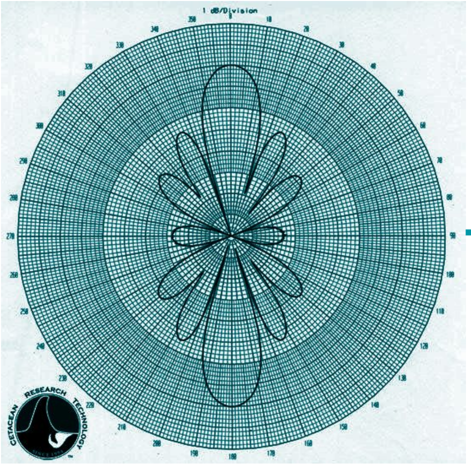




Definition and introduction to sound processing

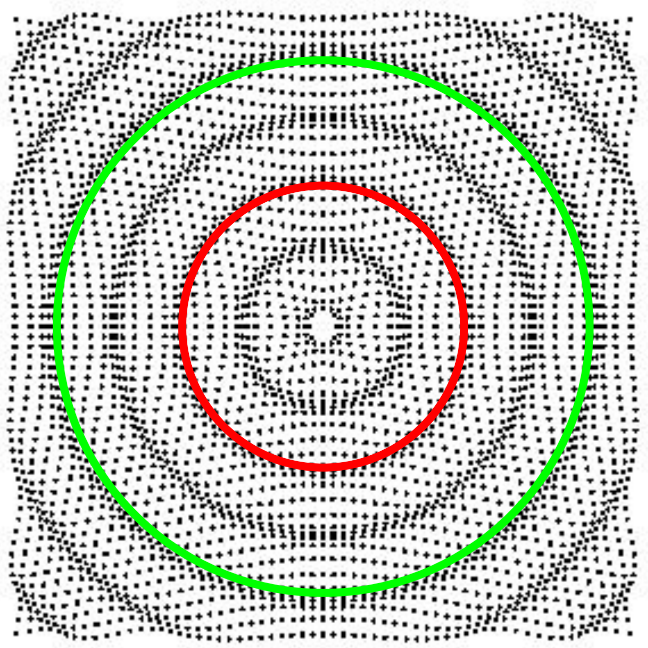
Directivity and frequency response



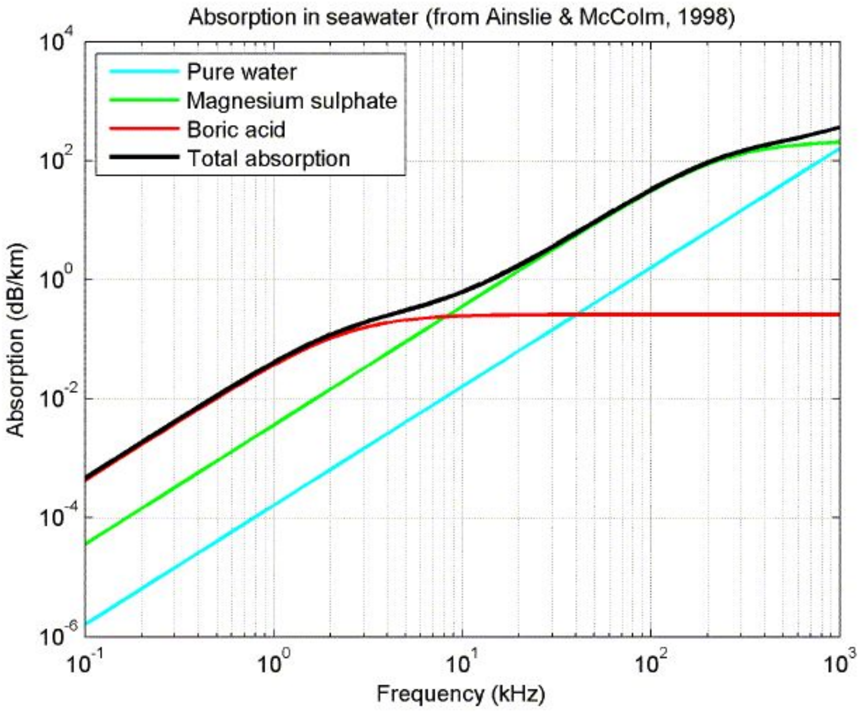


Definition and introduction to sound processing

Loss

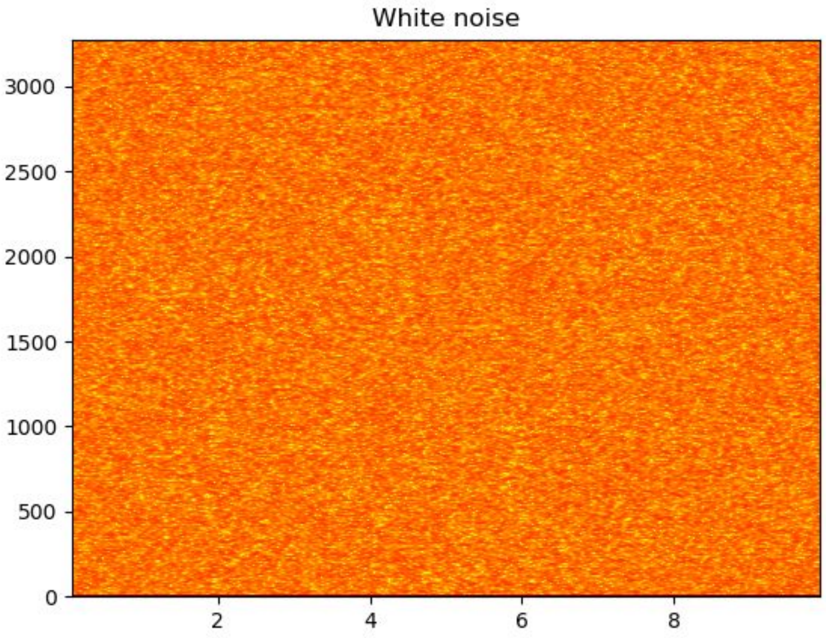


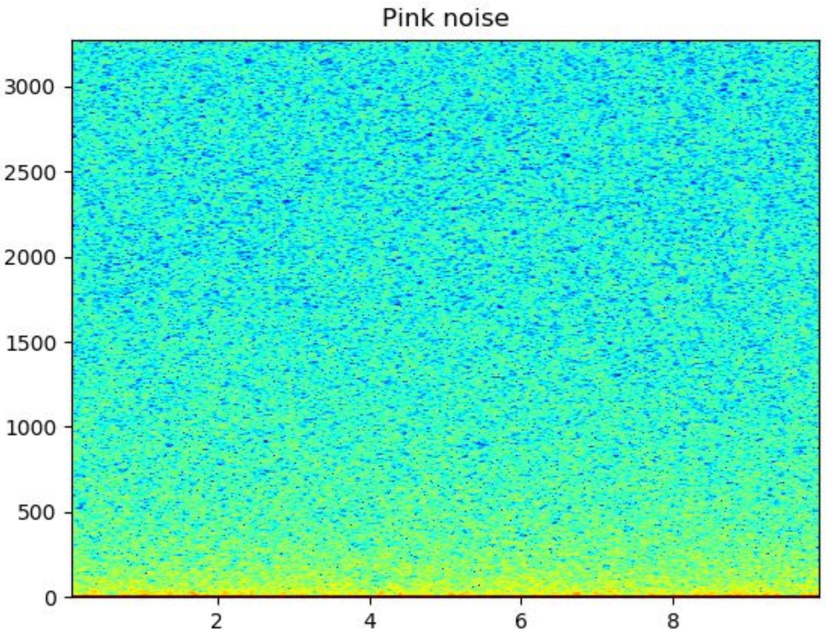
Spreading loss



Definition and introduction to sound processing

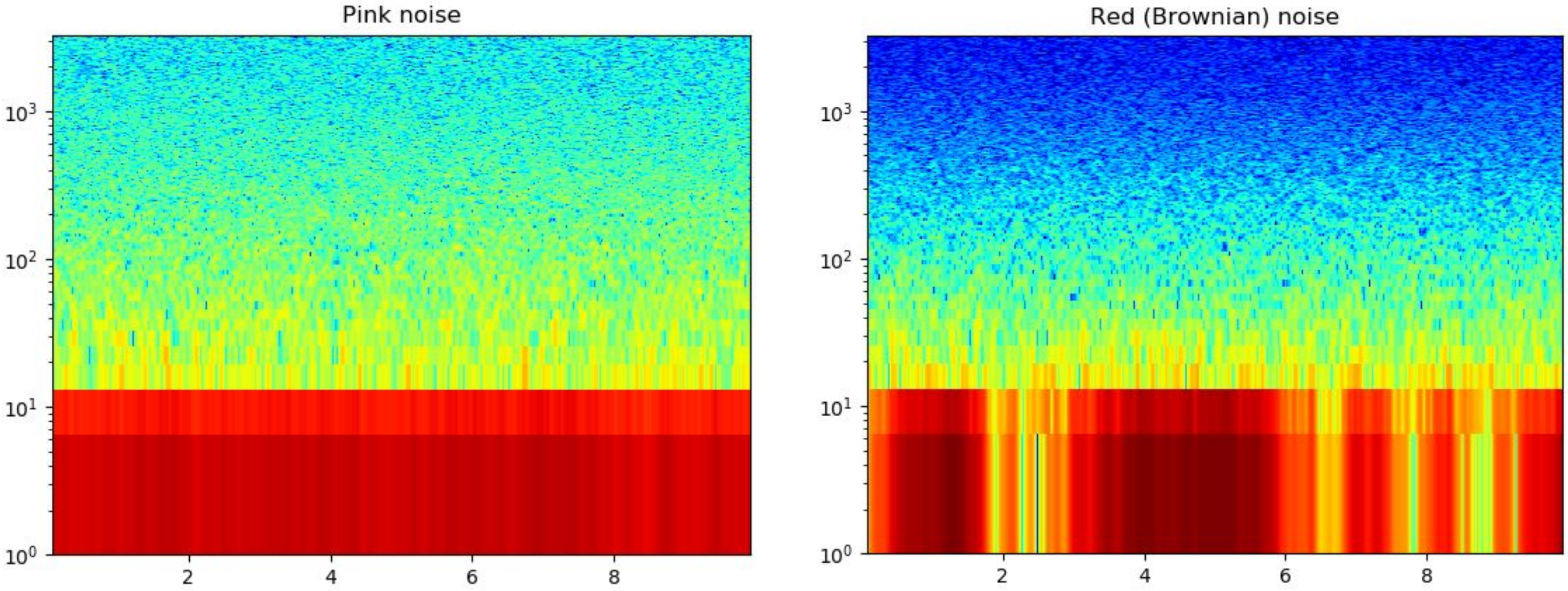
Types of noise





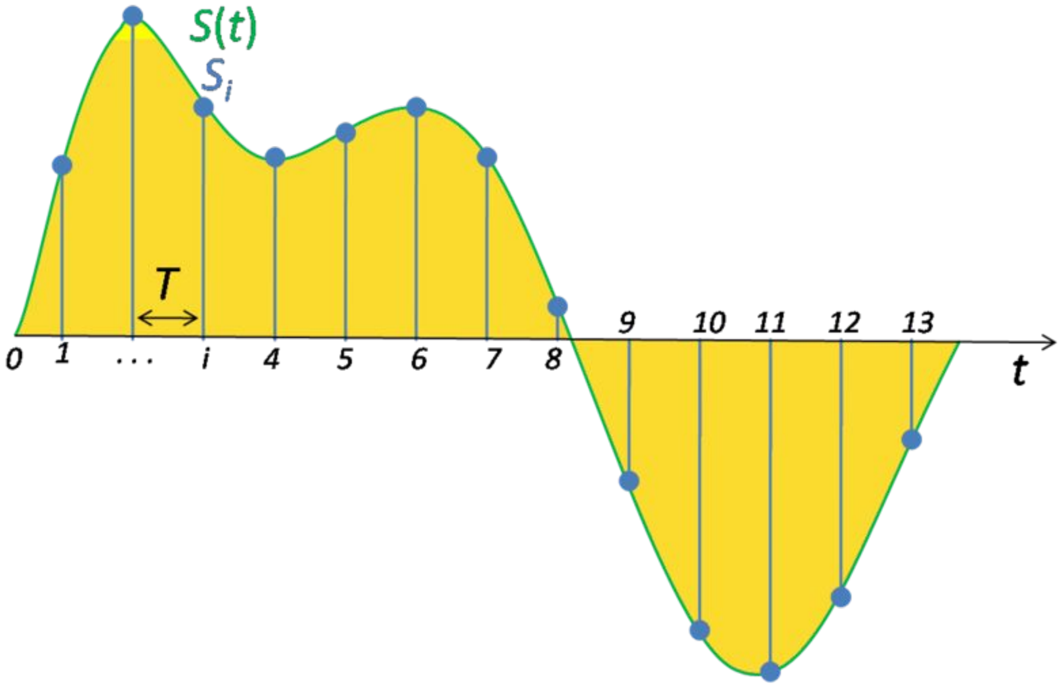
Definition and introduction to sound processing

Types of noise



Definition and introduction to sound processing

Sampling



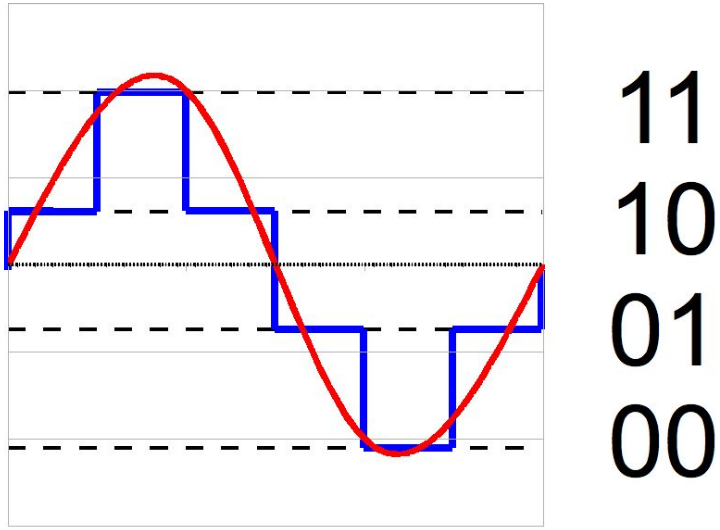
Sampling frequency : 1/T

Every period of T the value of the signal is sampled

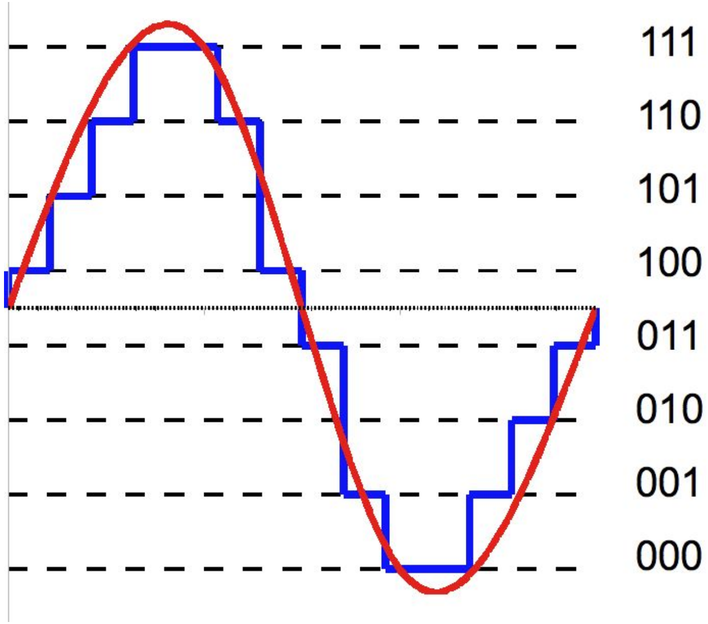
Higher sampling rate also mean larger file (in Mb) and higher energy consumption.

Definition and introduction to sound processing

Quantization



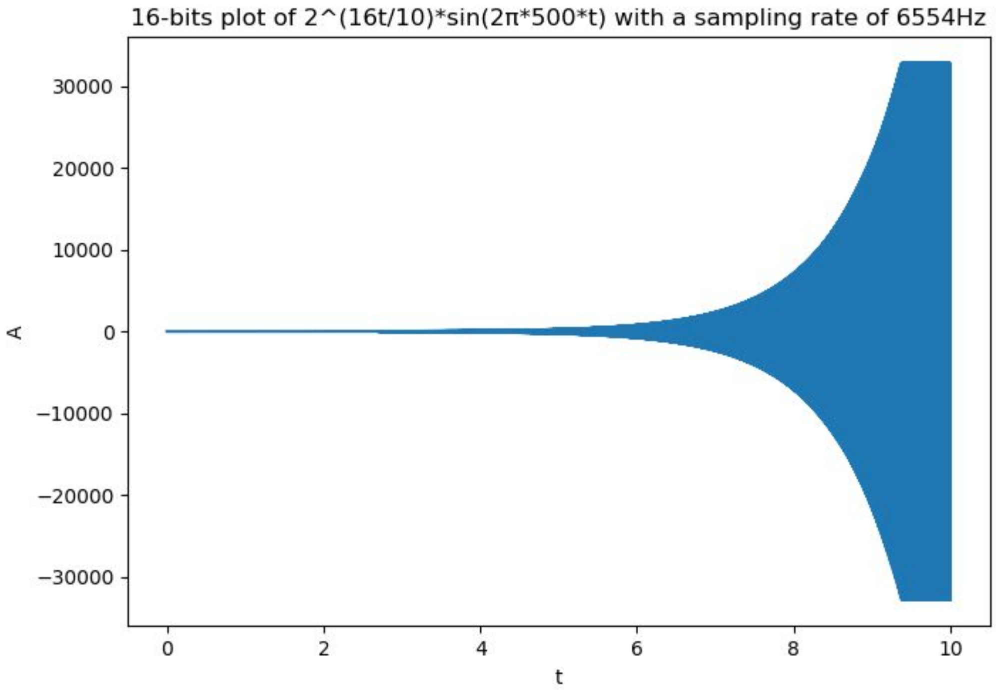
2 bits quantization



3 bits quantization

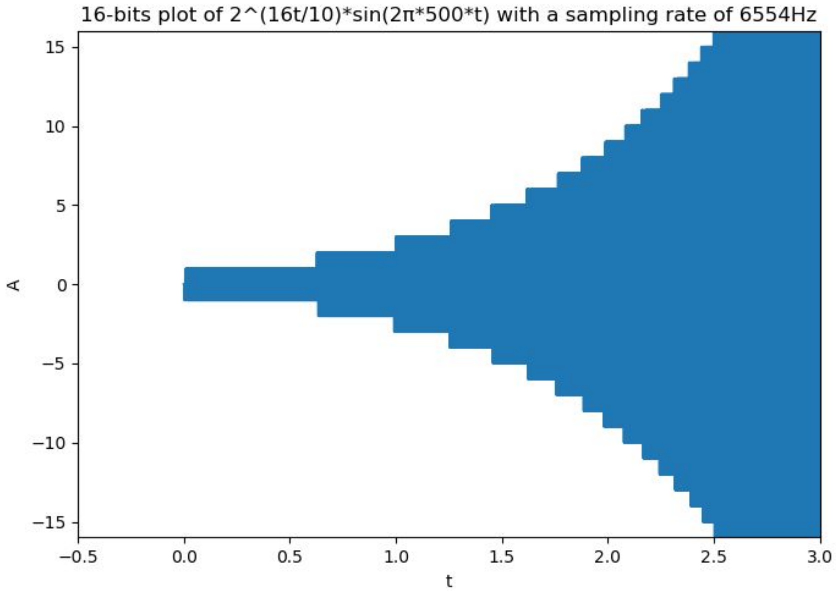
Definition and introduction to sound processing

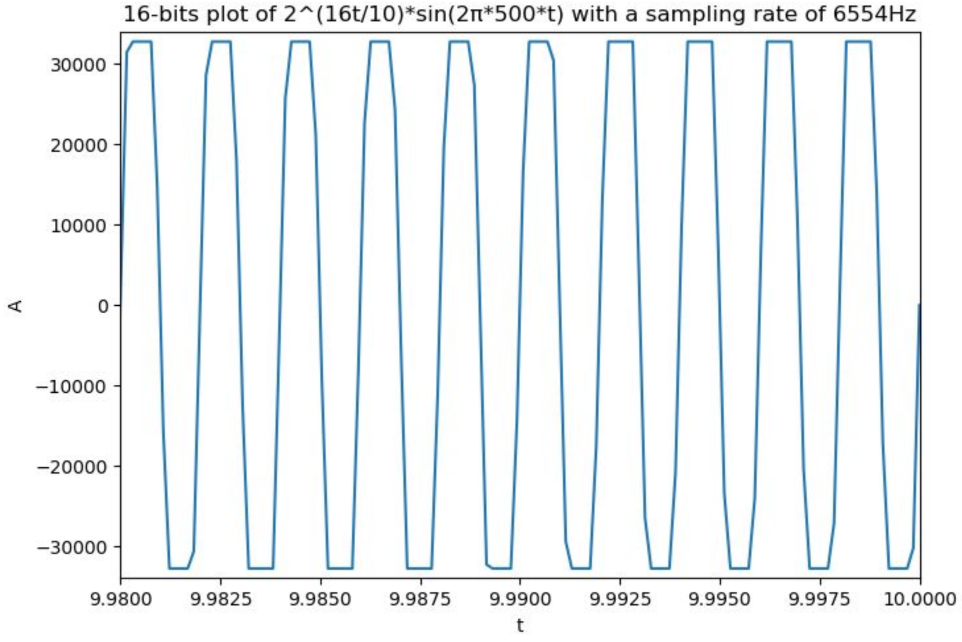
Quantization and clipping



Definition and introduction to sound processing

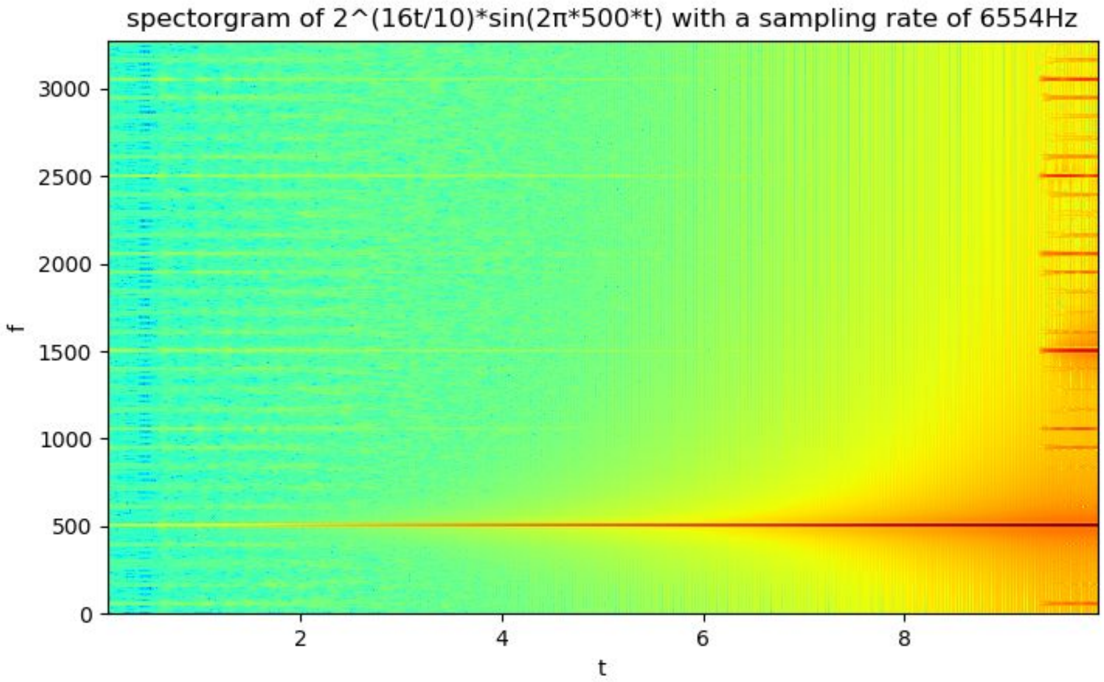
Quantization and clipping





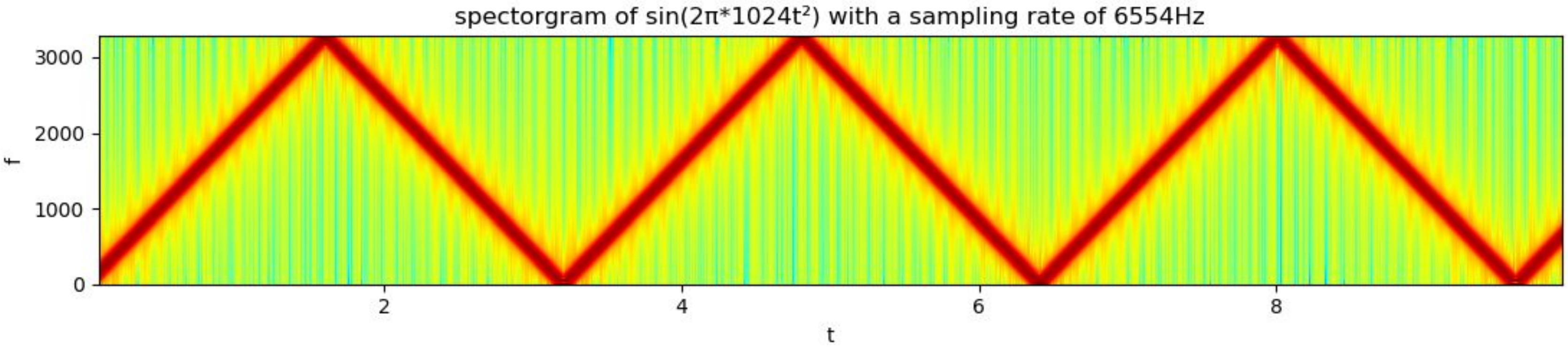
Definition and introduction to sound processing

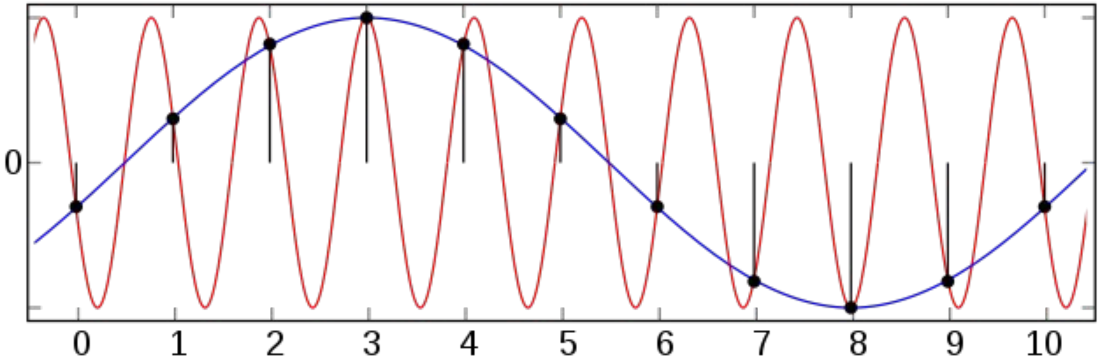
Quantization and clipping



Definition and introduction to sound processing

Aliasing



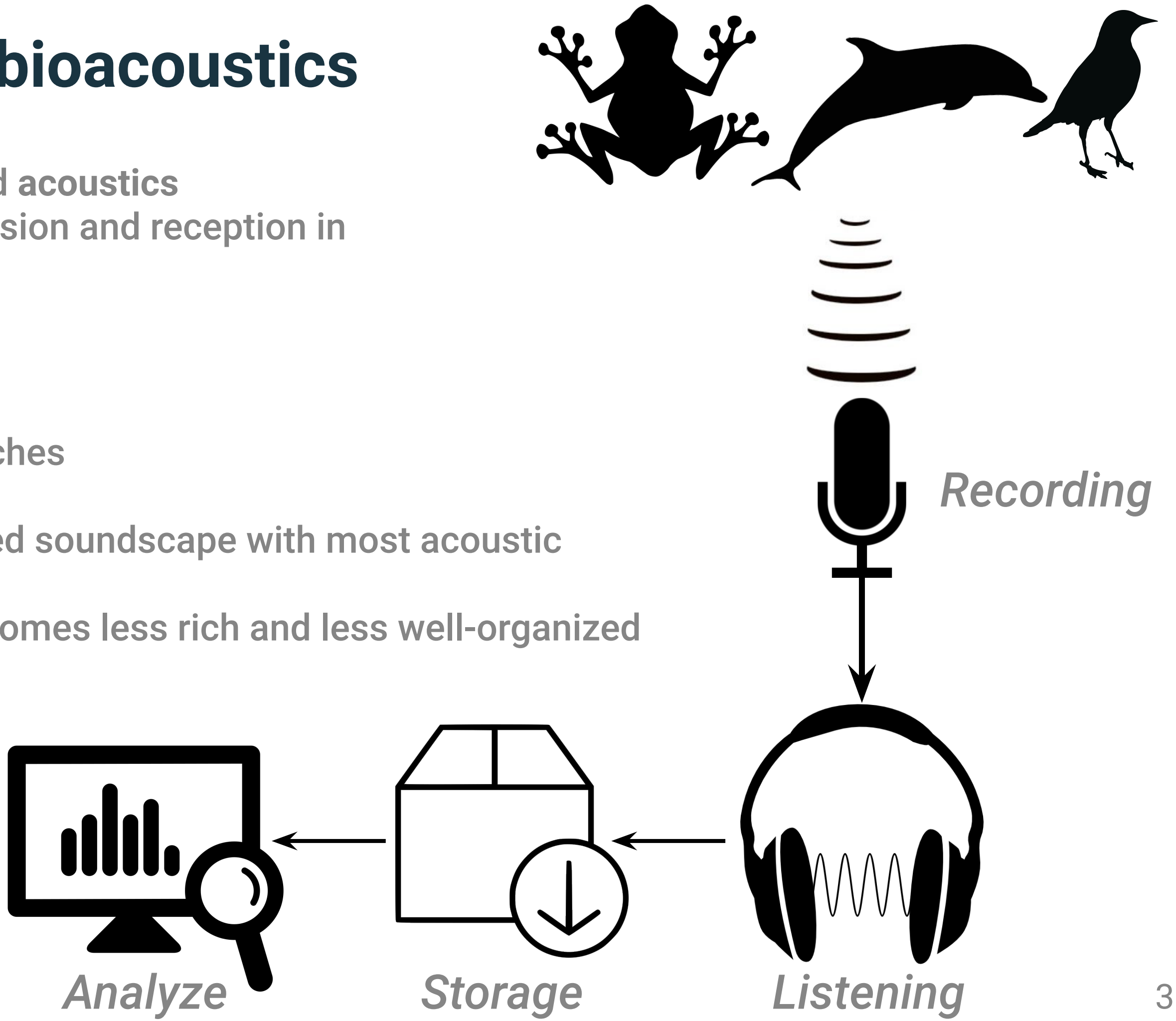


2. Introduction to bioacoustics and ethoacoustics

Marion Poupard

2. Introduction to bioacoustics

Cross-disciplinary science: **biology** and **acoustics**
Study the sound production, the dispersion and reception in animals (including human)
Different steps of bioacoustics :



The sound: present in all ecological niches
The acoustic niche hypothesis
Intact habitat: complex and well-defined soundscape with most acoustic frequencies occupied
Degraded habitat: the soundscape becomes less rich and less well-organized

Example of Papua

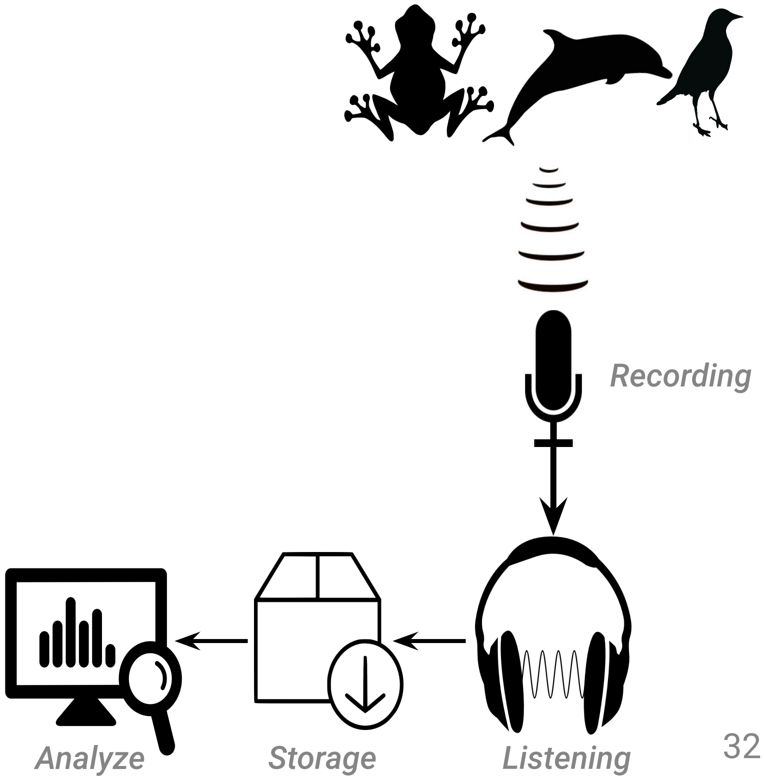
Rossing, T. (Ed.). (2007). Snaddon, J., Petrokofsky, G., Jepson, P., & Willis, K. J. (2013)

Introduction to bioacoustics

The sounds of any ecosystem are inherently unique and can reveal important information about the health of that ecosystem

<u>Passive acoustic monitoring</u>

More and more accessible with new material: hydrophones and microphones
Improvement of processing power and digital recordings technology
Availability of open-source software, audio processing tools



Sueur, J., & Farina, A. (2015)

Introduction to bioacoustics

Advantage to bioacoustic

Cost effective

Less invasive

Repeatable

Archivable

Big temporal and spatial scale !

Objectives of bioacoustic

Rare species detection

Population trend estimation

Influence of human on population

Sueur, J., Pavoine, S., Hamerlynck, O., & Duvail, S. (2008).

Introduction to bioacoustics

Bioacoustics to Ethoacoustics

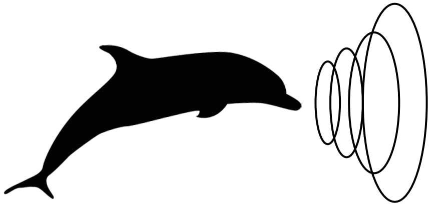
- **Bioacoustics** : the branch of acoustics concerned with sounds produced by or affecting living organisms, especially as relating to communication.

Some bioacoustic programs give greater consideration to animal behavior.
Particularly for cetaceans that pass 90% of their time under the surface.

- **Ecoacoustics**: method of large-scale quantification of ecological communities and their habitats (Acoustic Complexity Index)
- **Ethoacoustics** : Describing behavior of animal that we do not see but listen at. Spatiotemporal pattern of acoustic and animal behavior in wild animals: soundscape ethology

Describe behavior for a better conservation
Example: Behavioral responses to anthropogenic impacts

Introduction to bioacoustics

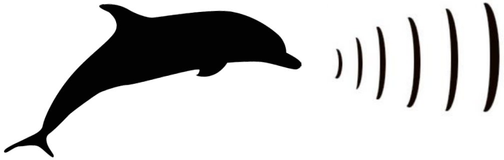


Marine bioacoustics :

- Understand the marine mammals behaviour and their relationships with the marine environment
- Marine mammals : 90% of their time under the surface
- Count or estimate the number of individuals living in a given area
- For some species, bioacoustics may be the only feasible approach with which to acquire behavioral data
- Propagation: 1500 m/sec, almost five times greater than in air
- Marine mammals use sound to navigate, avoid danger, locate prey and partner

Au, W. W., & Hastings, M. C. (2008)

Introduction to bioacoustics

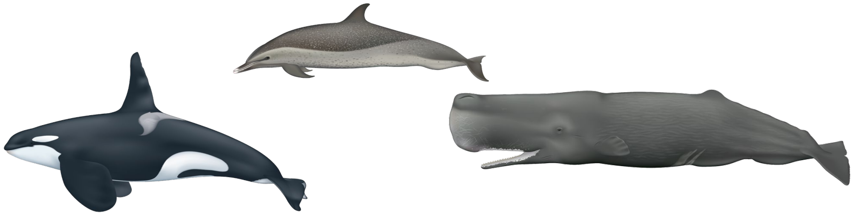


Marine bioacoustics

- Production of sound by many aquatic organisms: Invertebrates (crustaceans), fishes, marine mammals... to infrasounds until ultrasounds.
- Cetaceans : very active with the sound.

Odontocetes

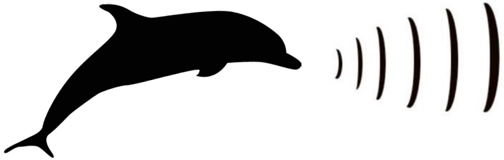
- 1.4 to 18 meters
- They feed on fish and squids: Echolocation
- Socialisation: tonal whistles for communication
- Buzz (low-power echolocation clicks at high speed



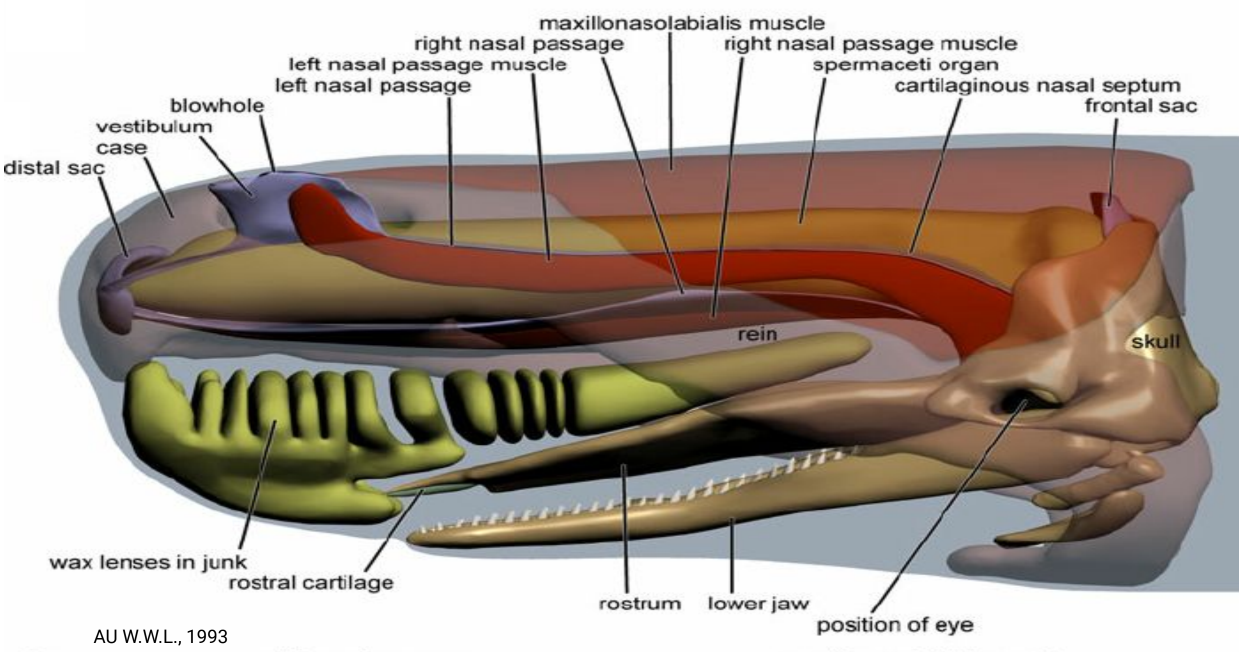
Mysticetes

- 8 to 28 meters
- Filter feeders feeding on plankton and small fish
- Low frequency tonals for inter-animal communication

Introduction to bioacoustics

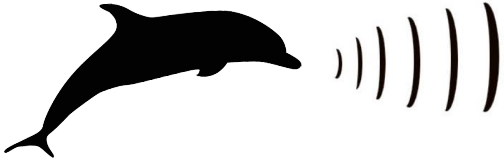


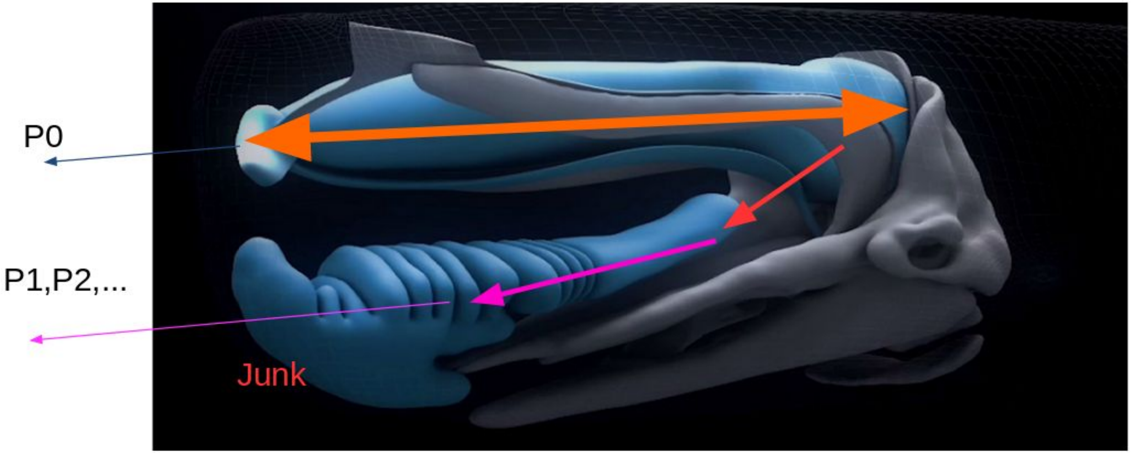
Different types of sounds:
- Clicks
- Whistles / Vocalizations



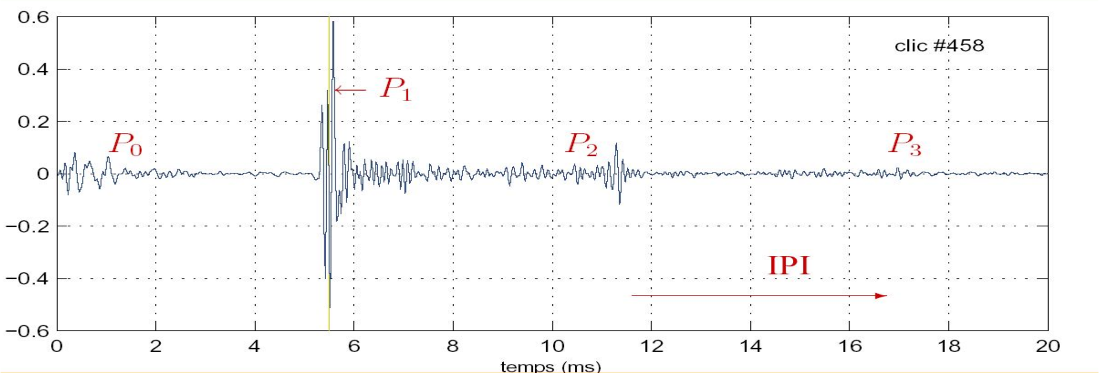
AU W.W.L., 1993

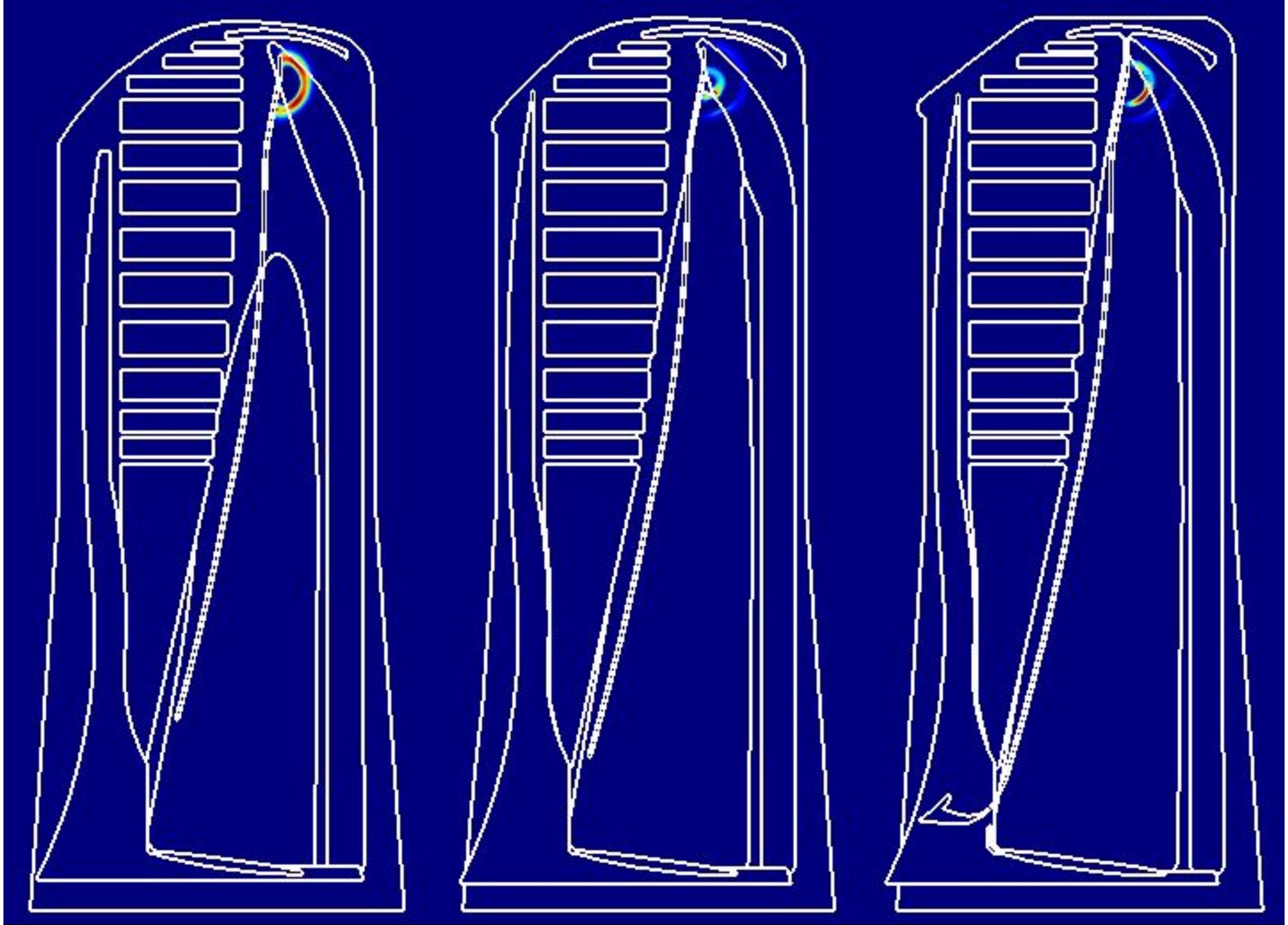
Introduction to bioacoustics



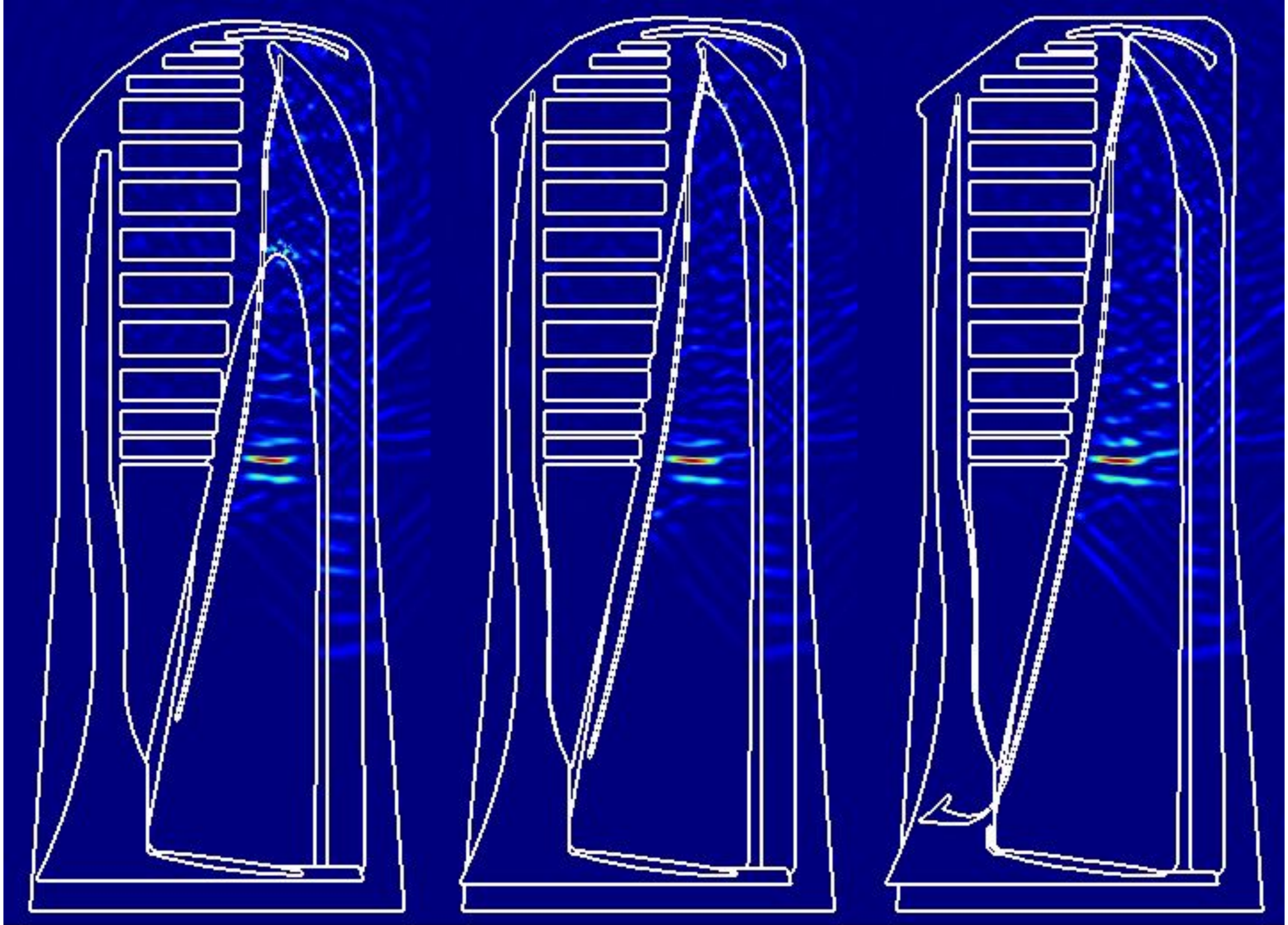


Intra click effect:
the inter pulse Interval

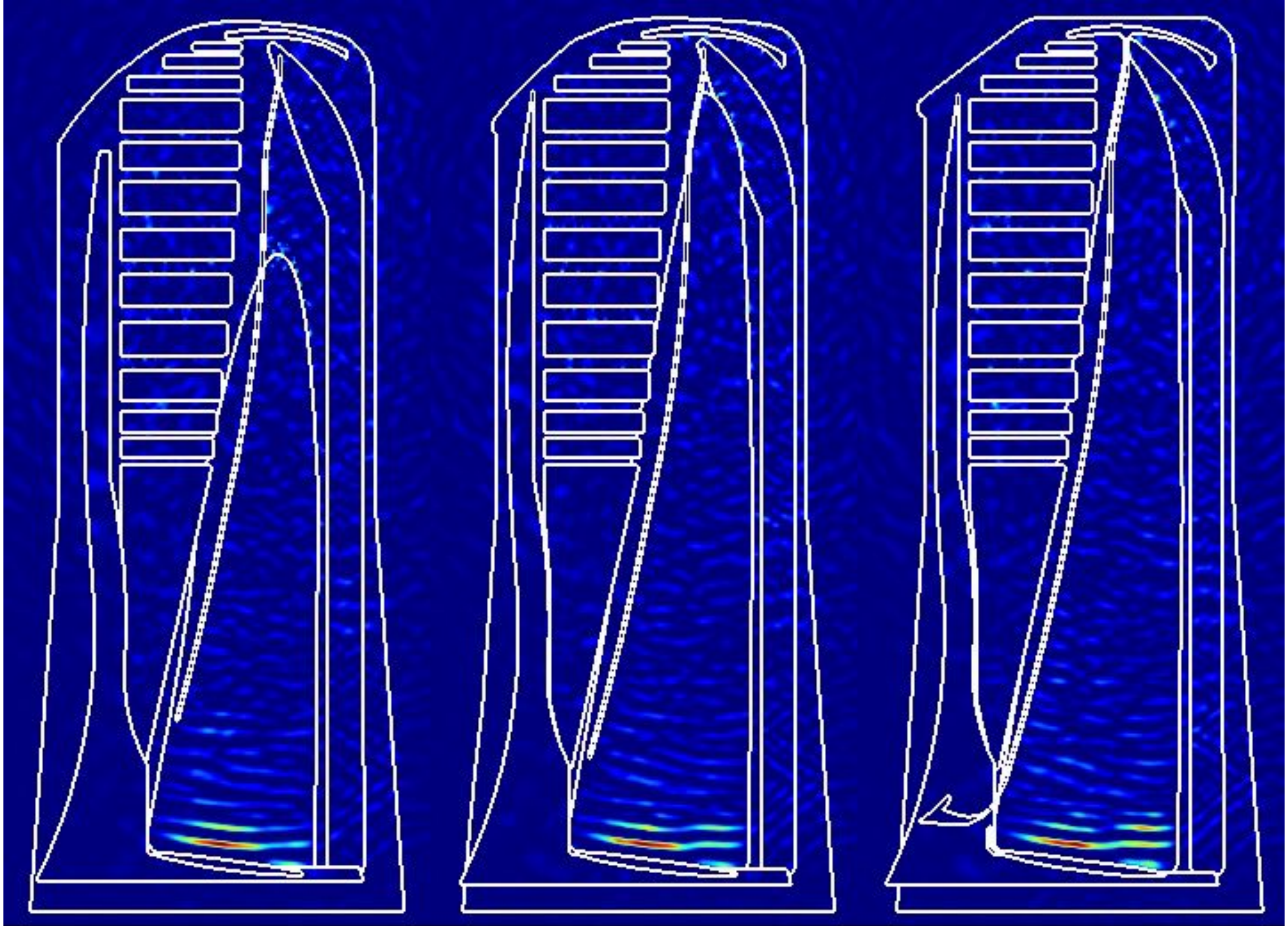




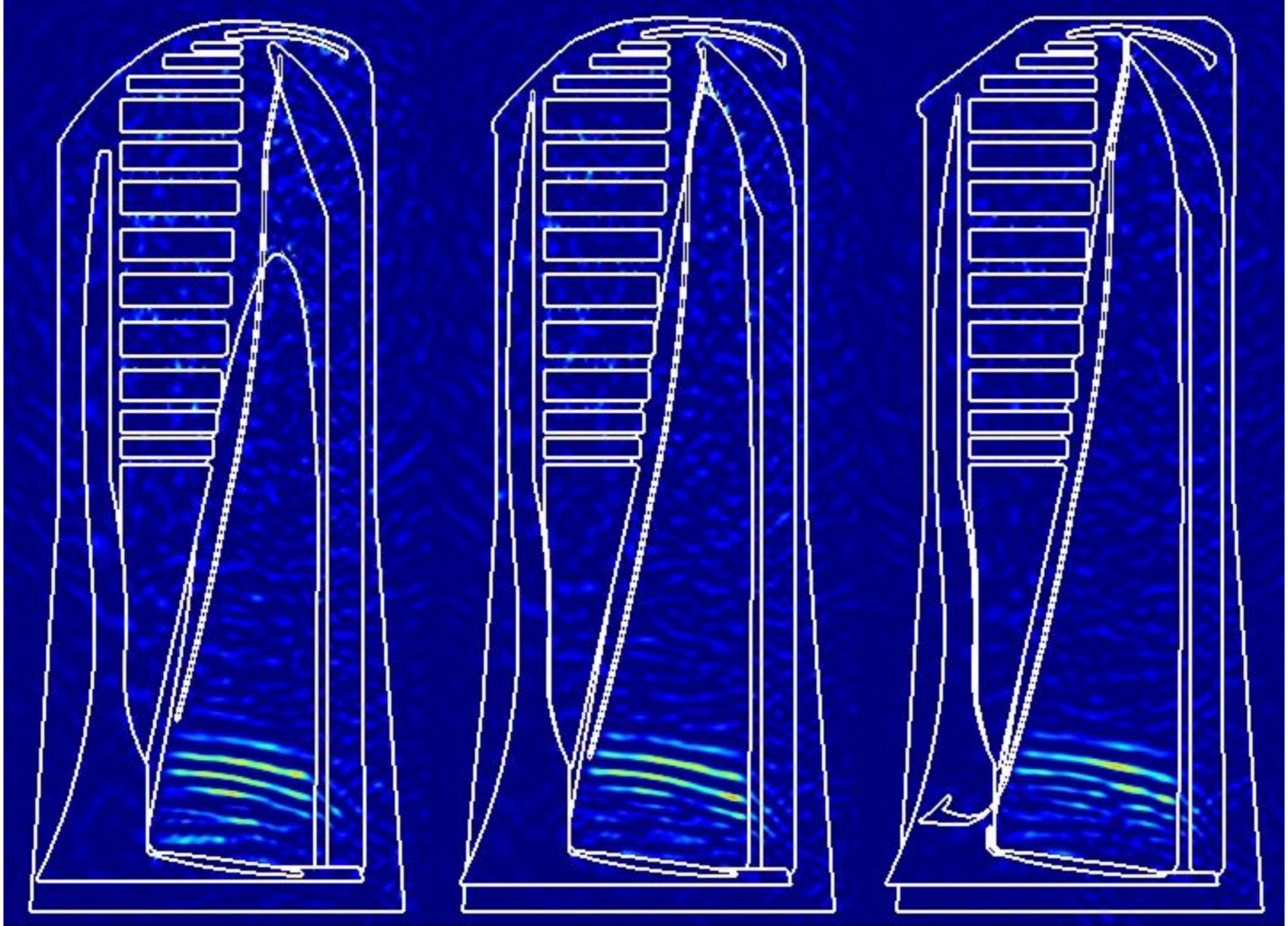
(Ferrari et al 2019 IEEE)



(Ferrari et al 2019 IEEE)



(Ferrari et al 2019 IEEE)



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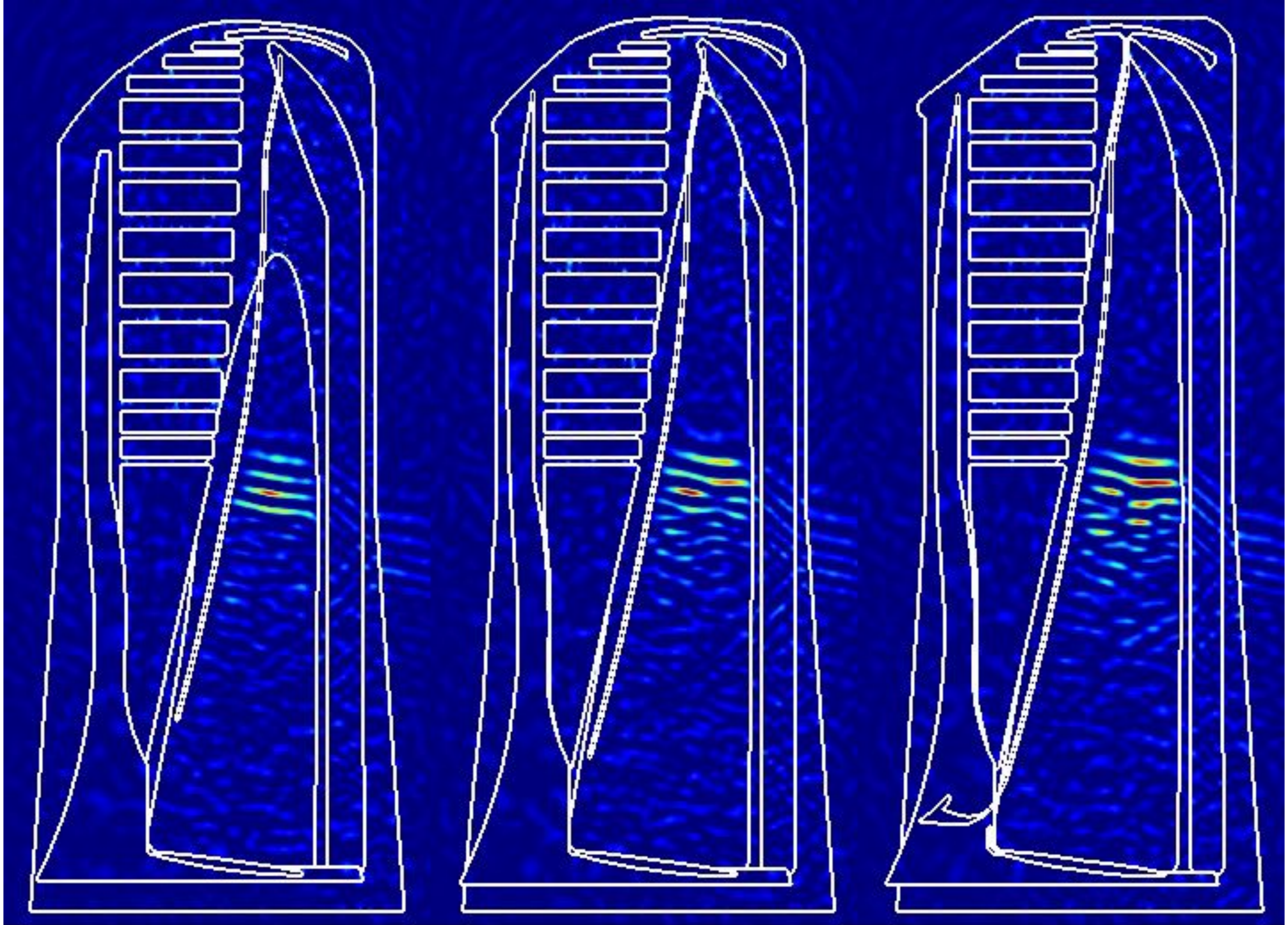
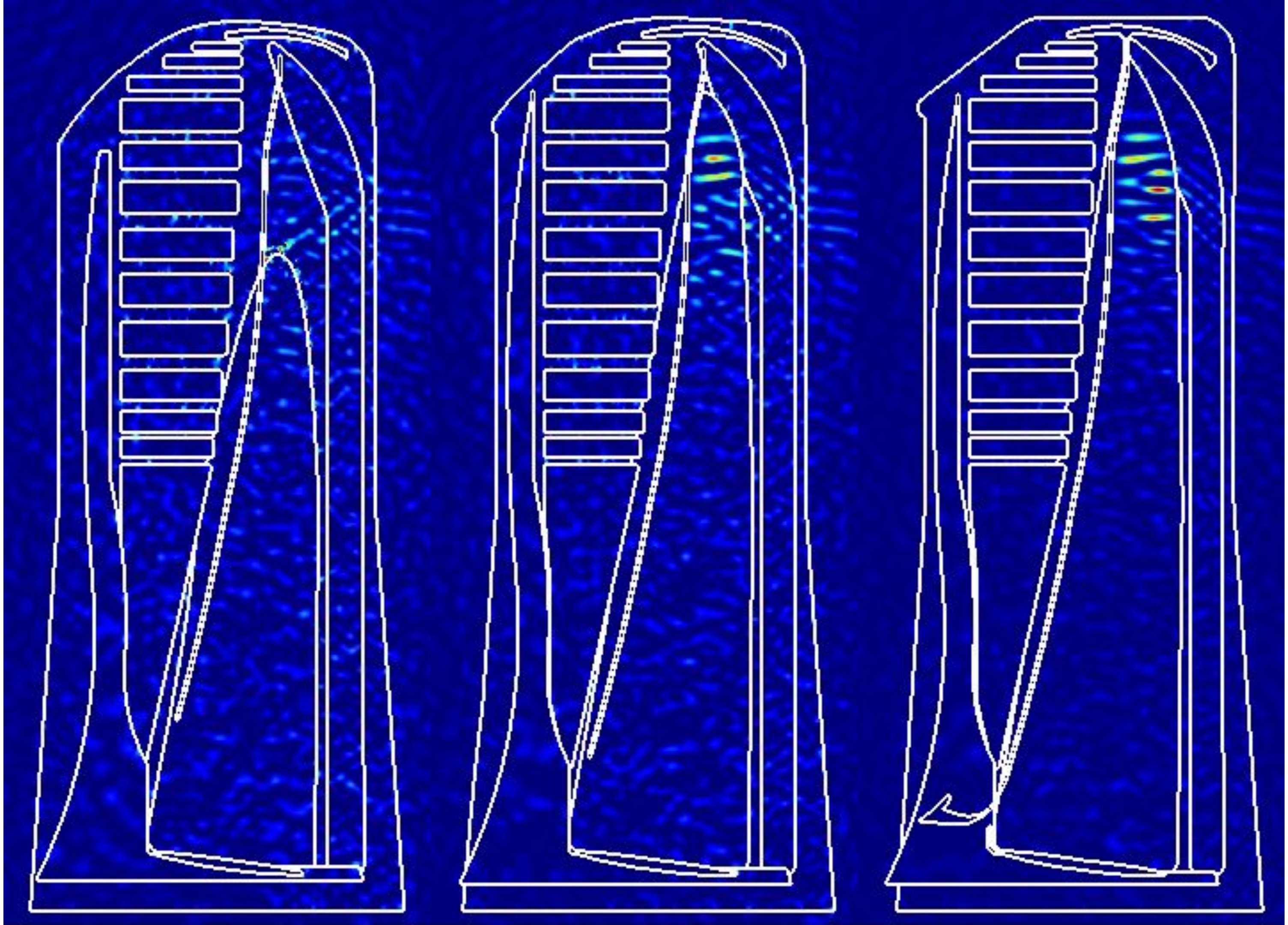


(Ferrari et al 2019 IEEE)



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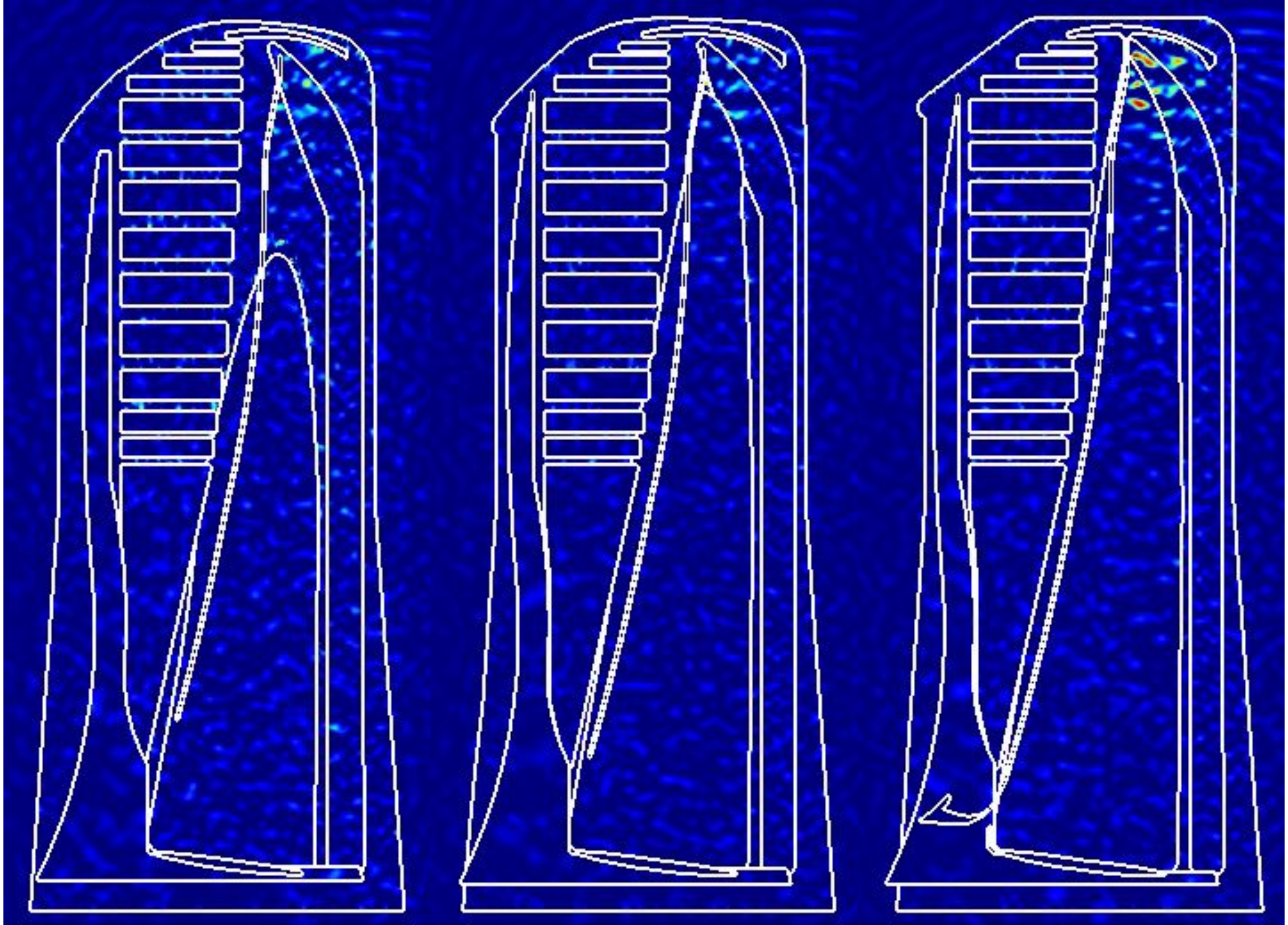
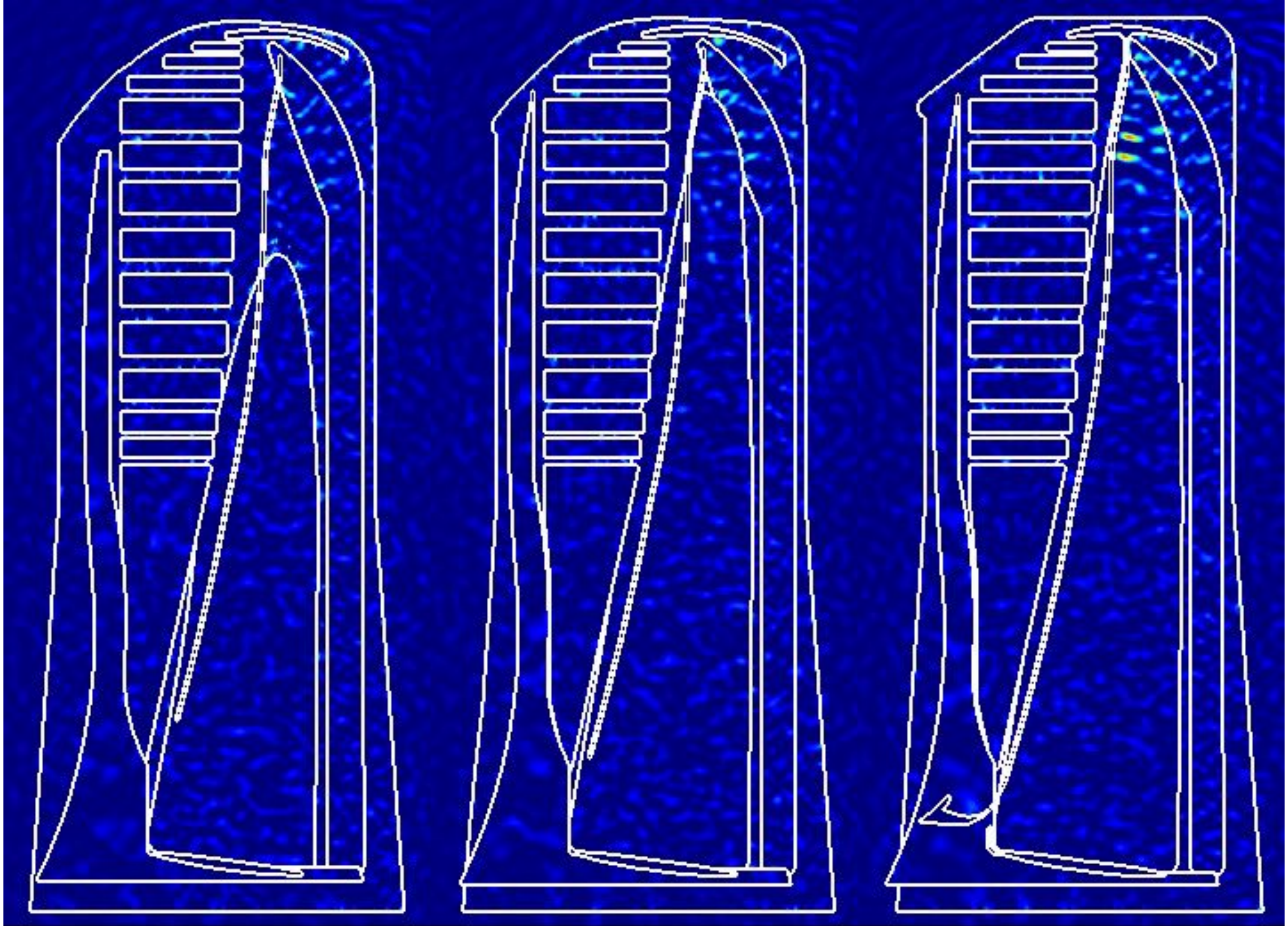


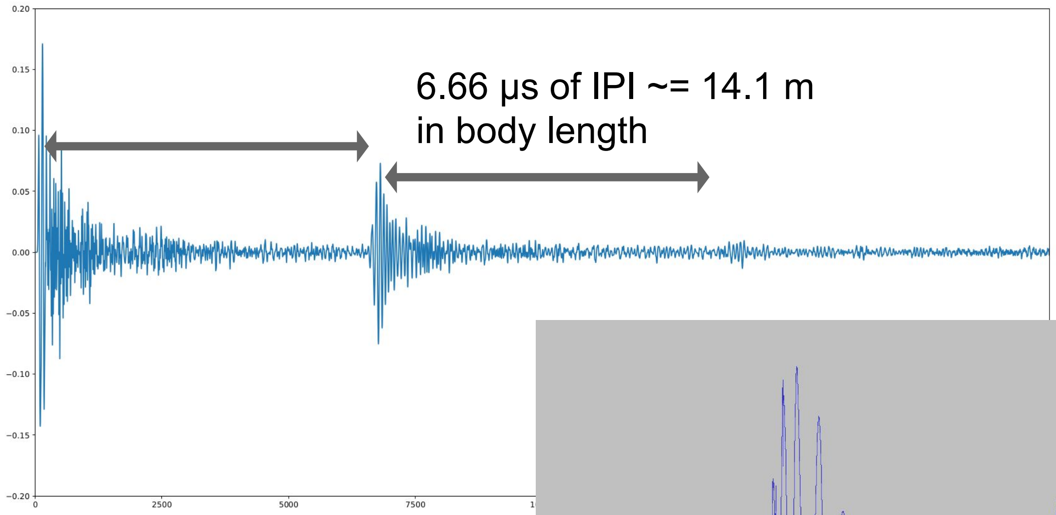
(Ferrari et al 2019 IEEE)

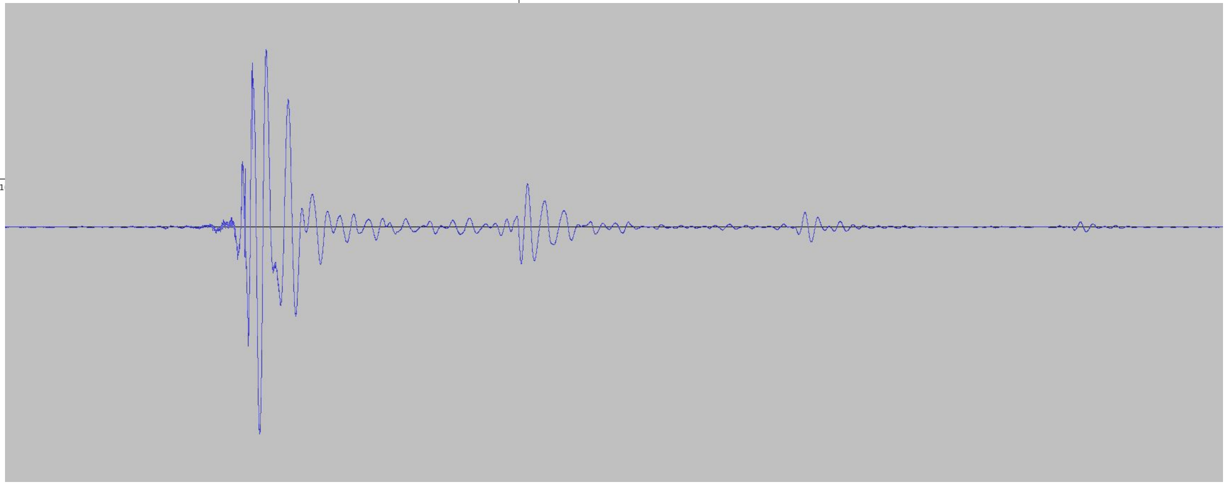


(Ferrari et al 2019 IEEE)

Simulated versus recorded Sperm Whale click (Ferrari et al 2018)

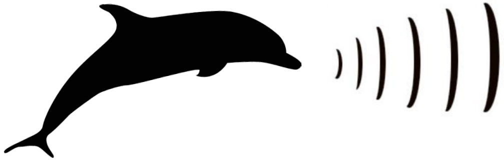
3D model based on a 14.2 m long sperm whale [1]

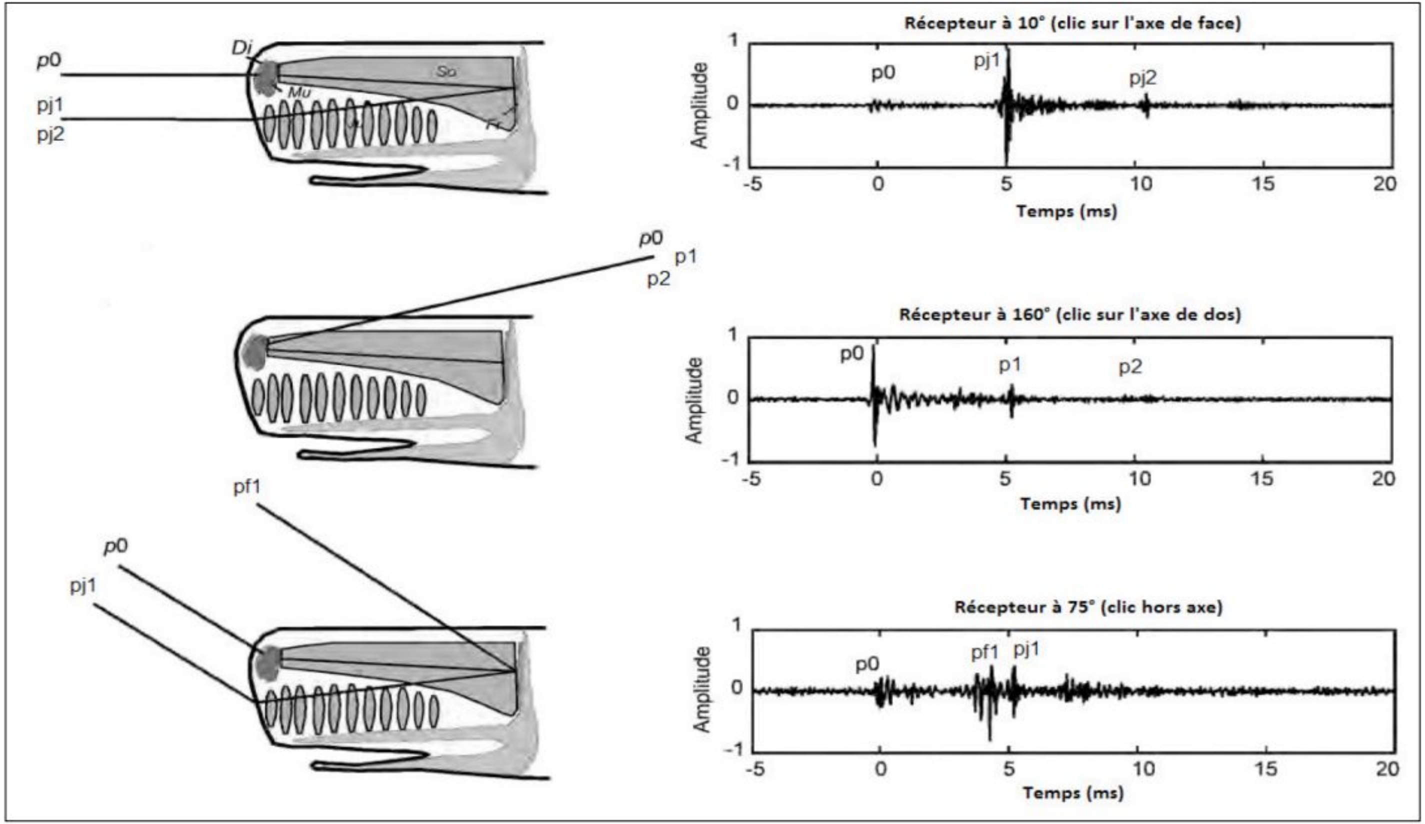




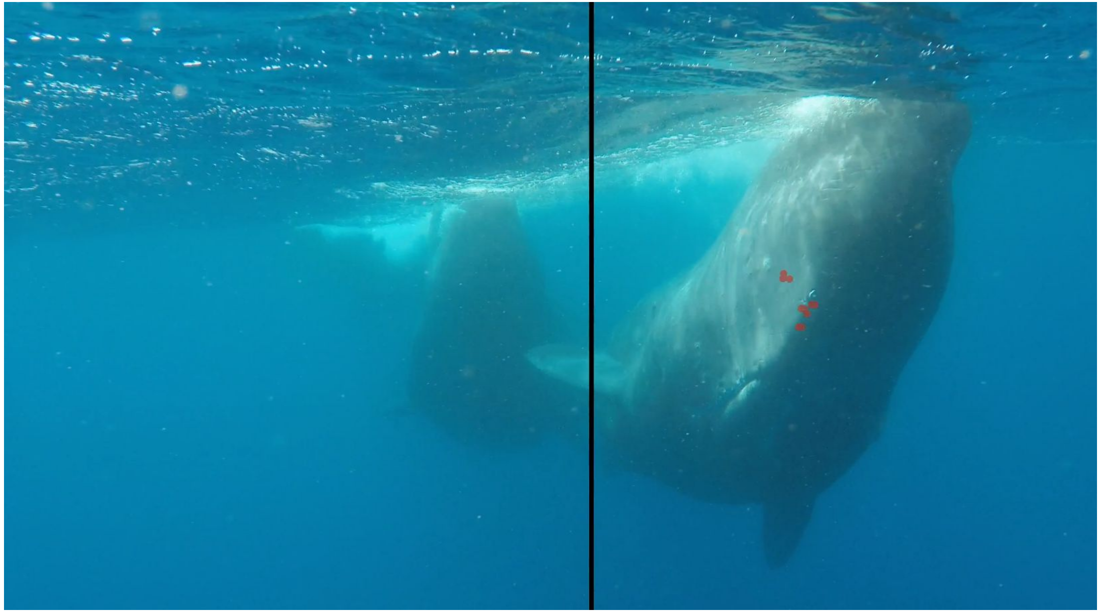
[1] Clarke, M. R. (1978). Structure and proportions of the spermaceti organ in the sperm whale. Journal of the Marine Biological Association of the United Kingdom

Introduction to bioacoustics



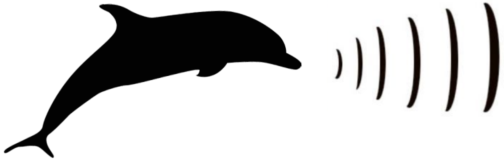


Introduction to bioacoustics



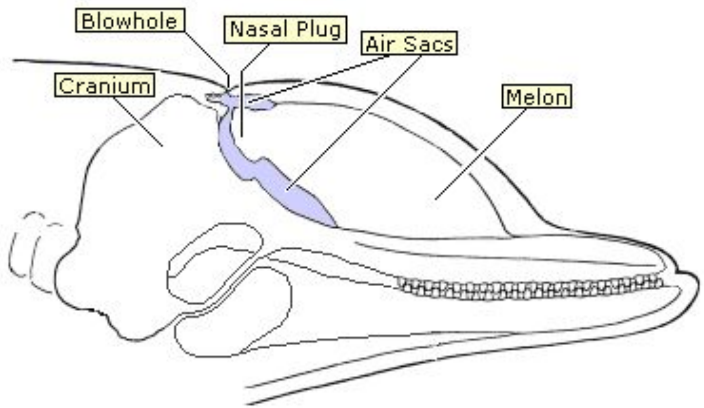
https://youtu.be/NnOkQBzBqms

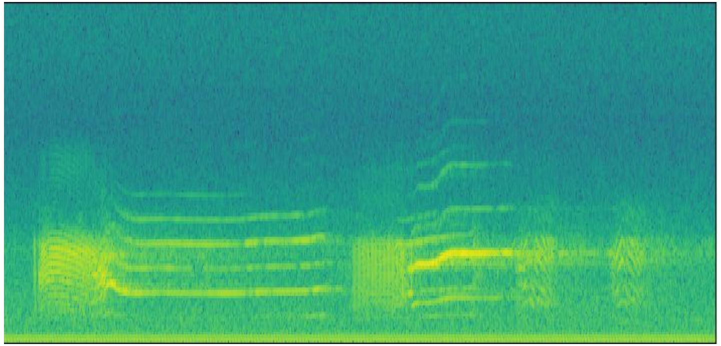
Introduction to bioacoustics



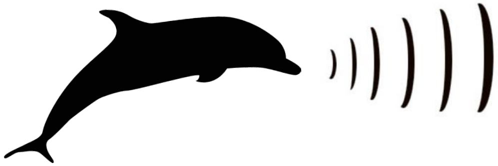
Different types of sounds:

- clicks
- Whistles / Vocalizations





Introduction to bioacoustics



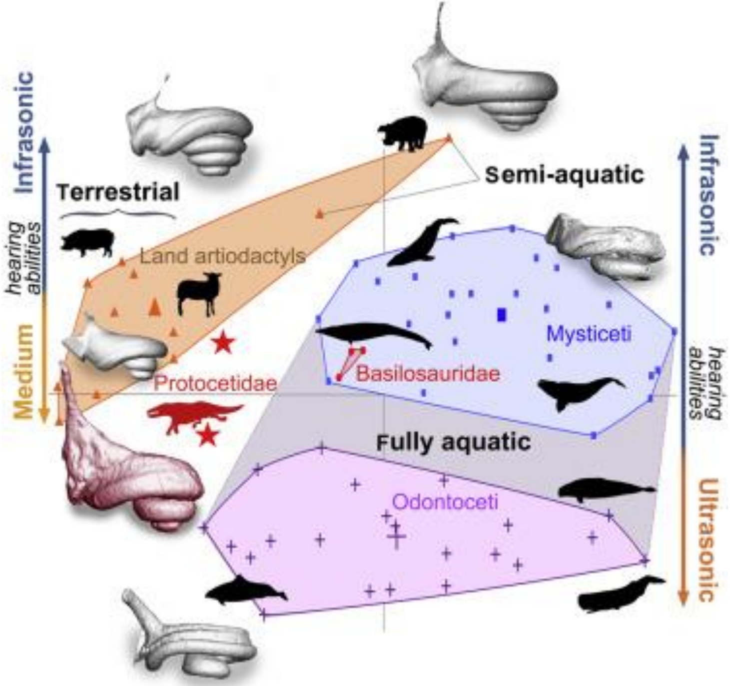
- Hearing in Cetaceans

No external pinnae. Nearly similar cochlea.
B
Vibration of the basilar membrane on cochlea

Odontoceti can hear underwater through the lower jaw bone which conducts sounds to the middle ear.

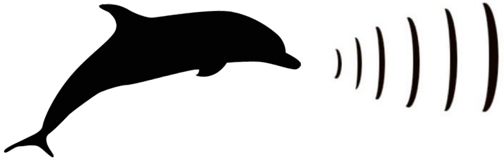
Large size of the auditory nerve indicate that cetaceans are very good at discriminating high frequency tones and sound waves and especially where they come from.

Human : audible range sound: 20 Hz to 20kHz
Odontoceti: 20 to 150 kHz (7 times more than human)



credit Science direct

Introduction to bioacoustics



Uses of hydrophones

- Fix station, sonobuoy
- Towed array during navigation
- Other kind of mobile array

Marine mammals are subjects to lot of treats:

Chimic pollution
noise pollution
Loss of biodiverisity
depletion of living ressource
Increase of human disturbance

Conservation of marine mammals is essential

Whales, Porpoises, and Dolphins

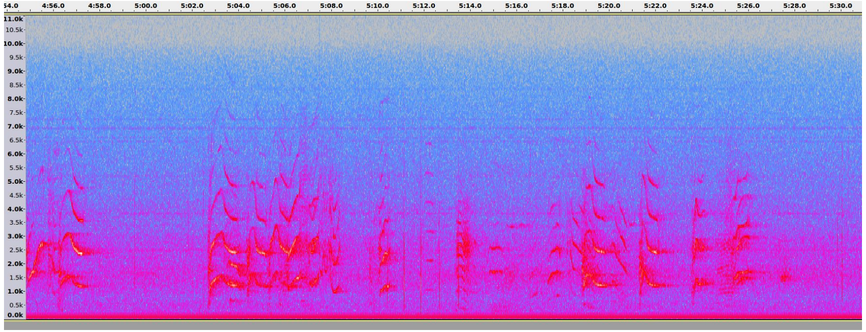
SPECIES/POPULATION	ESA LISTING	MMPA LISTING
Beluga, Cook Inlet population *Delphinapterus leucas*	Endangered	Depleted
Beluga, Sakhalin Bay-Nikolaya Bay-Amur River stock *Delphinapterus leucas*	Not Listed	Depleted
Blue whale *Balaenoptera musculus*	Endangered	Depleted
Bottlenose dolphin, U.S. mid-Atlantic coastal population *Tursiops truncatus*	Not Listed	Depleted
Bowhead whale *Balaena mysticetus*	Endangered	Depleted
Chinese river dolphin (baiji) *Lipotes vexillifer*	Endangered	Depleted
Coastal spotted dolphin *Stenella attenuata graffmani*	Not Listed	Depleted
Humpback whale, Mexico distinct population segment (DPS) *Megaptera novaeangliae*	Threatened	Depleted
Humpback whale, Western North Pacific distinct population segment (DPS) *Megaptera novaeangliae*	Endangered	Depleted
Indus river dolphin *Platanista gangetica minor*	Endangered	Depleted
Killer whale, AT1 population *Orcinus orca*	Not Listed	Depleted
Killer whale, southern resident population *Orcinus orca*	Endangered	Depleted
Northeastern offshore spotted dolphin *Stenella attenuata attenuata*	Not Listed	Depleted

Introduction to bioacoustics

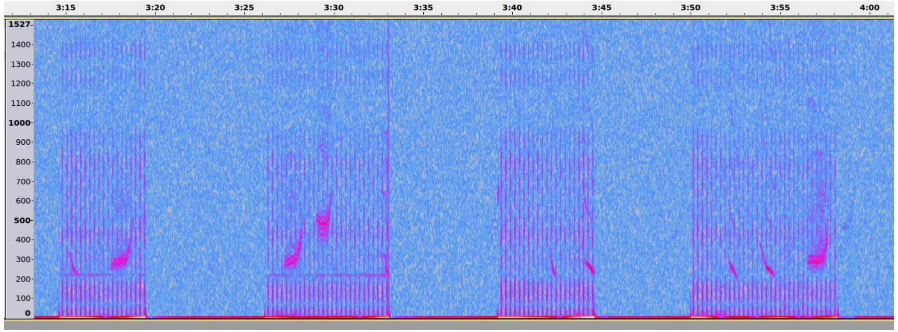
How to do a good recording ?

- Good sampling rate
- Signal-to-noise ratio (SNR): that compares the level of a desired signal (vocalization or clicks) to the level of background noise. SNR in decibels
- Band pass

Good example



Bad example

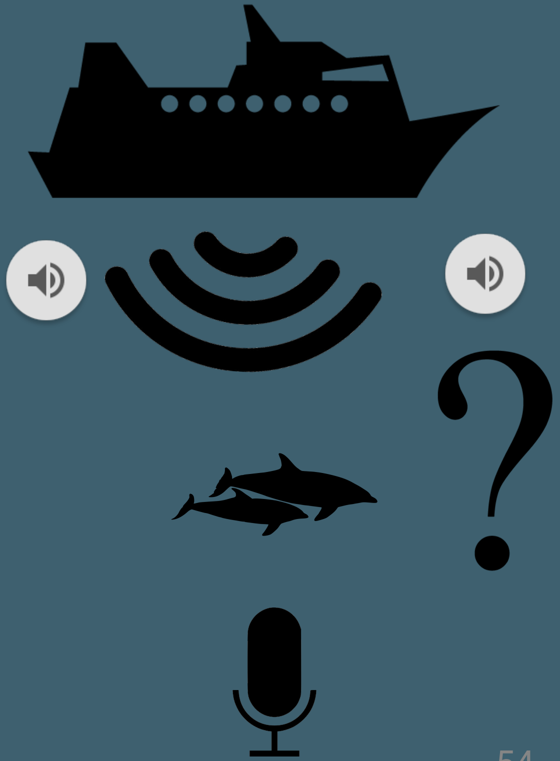


How can bioacoustic help in conservation

Studying bioacoustics at the soundscape level is emerging as a useful tool for conservationists to assess ecosystem health.

Animal vocal behavior can reveal important information about critical life history events: ethoacoustic

Influence of human on marine mammals : marine traffic



Laiolo, P. (2010). Richardson, W. J et al 2013

Ethoacoustic

Reproduction and recruitment

Sexual selection for call complexity

Presence of juveniles

Alarm and defense

Monitor presence via prey species' alarm calls

Specific calls for hunting

Sociality and vocal complexity

Vocal convergence within and between groups cultural transmission animals that live in complex societies exhibit complex vocal repertories

Monitoring programs should be designed to record appropriate vocal behaviors while maximizing efficiency

Teixeira, D., Maron, M., & van Rensburg, B. J. (2019)

How can bioacoustic help in conservation

Example of applications

Provide direct measure of reproductive events: birds
Acoustic allometry

Group behaviors and contexts, for example, foraging, fission–fusion, demographic composition

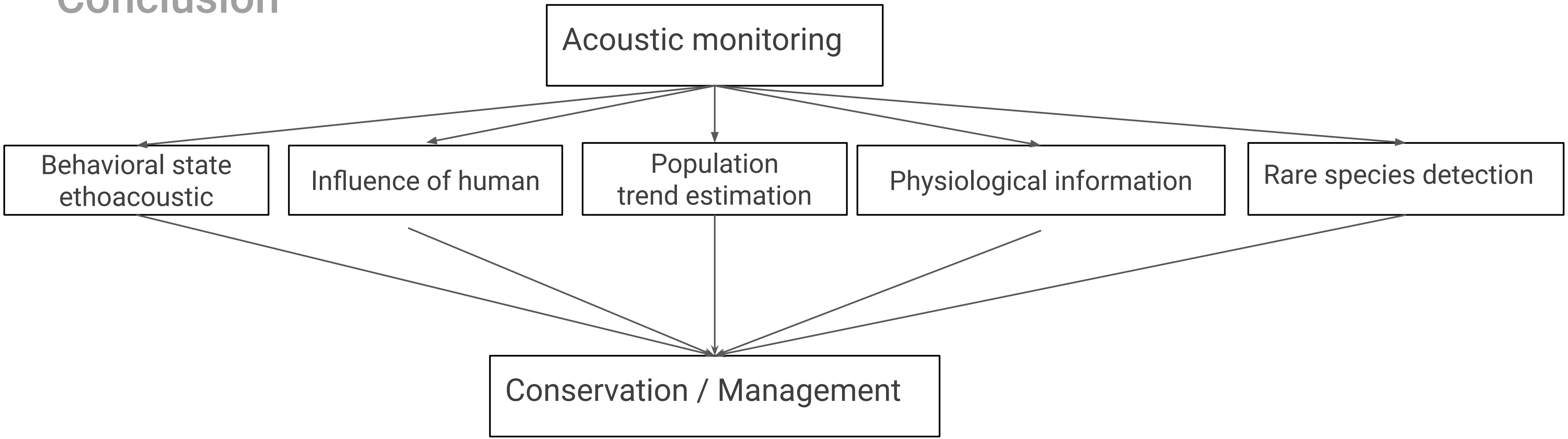
Social complexity hypothesis for vocal communication: animals that live in complex societies exhibit complex vocal repertoires

Monitor predator presence or abundance via prey species' alarm calls

Signal the presence of juveniles in groups

Introduction to bioacoustics

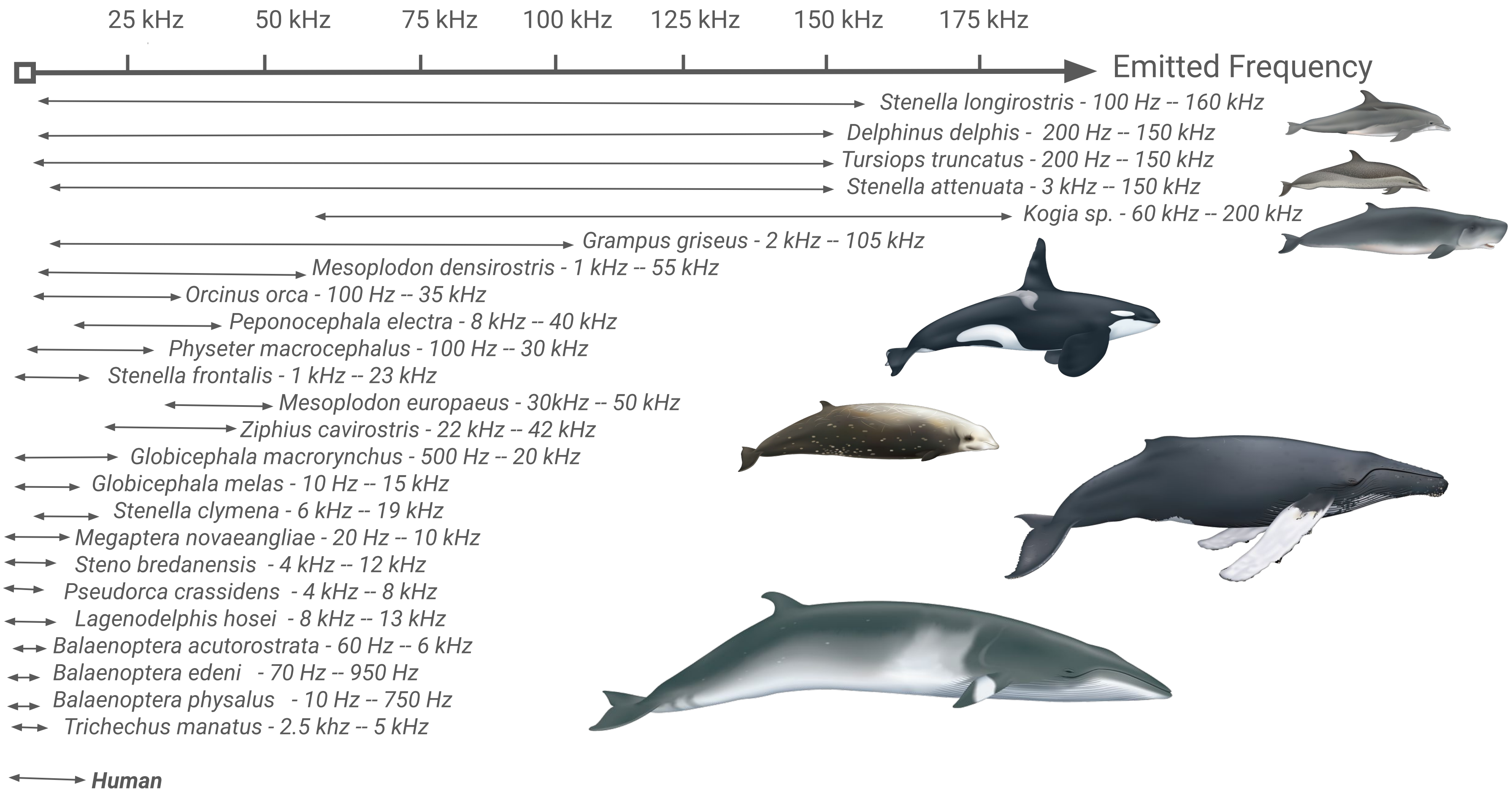
Conclusion



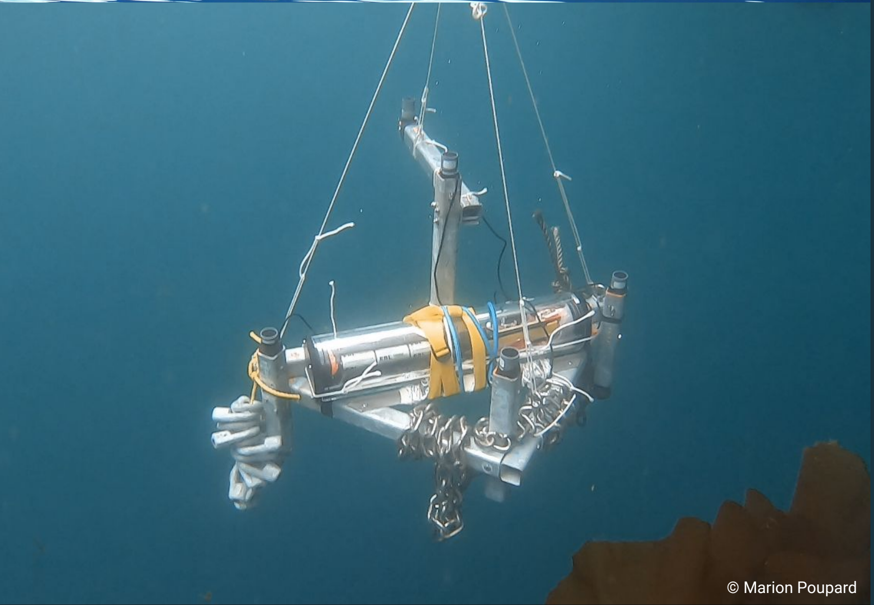
Important to choose the algorithm according to species and the problematic

Whitehead, H. (2010).

Targets in Carimam project




© Marion Poupard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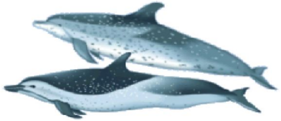
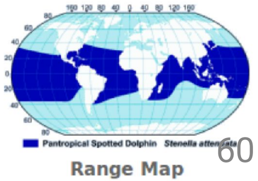
3. Examples of Study Cases

a. Pantropical spotted dolphin (*Stenella attenuata*)
b. Long term stereo sonobuoy
c. Orca (*Orcinus orca*)
d. Sperm whale from Autonomous Surface Vehicle

a. Ethoacoustic by bayesian non parametric and stochastic neighbor embedding to forecast anthropic pressure on dolphins

- Pantropical spotted dolphin, *Stenella attenuata*
- Analyse impact of whales watching on communication of Pantropical spotted dolphin : comparing whistles produced without boat with whistles in the presence of several boats
- Develop a method of analysis of treatment and interpretation of a bioacoustic dataset





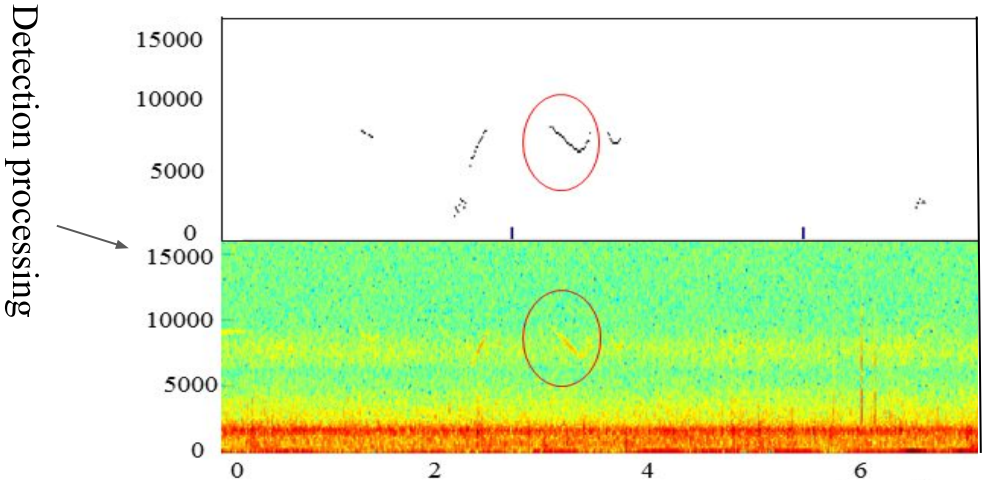
a. Ethoacoustic by bayesian non parametric and stochastic neighbor embedding to forecast anthropic pressure on dolphins

- A number observations were made
- Motor was off
- Hydrophone (H2a-XLR, Aquarian Audio Products)
- Continuous recordings were made during the times when dolphins were present.
- The environmental data :
- - Start and end of the observation, the date, Geographic coordinates
- - Number of animals, Behaviors, adults and juveniles
- - Number of boats in the area

Table I
BEHAVIORAL STATES CATEGORIES AND THEIR DESCRIPTIONS

Behaviors	Characteristics
Resting	Slow velocity, directed movement, closely grouped
Hunting	Fast swimming velocity, followed a heading
Socializing	Interactive behavioral event, breach,body contact, chases
Motion	Constant direction, splashing, Fast and medium velocity
Harassment	Avoidance behavior, different subgroups, dive intervals vary

a. Ethoacoustic by bayesian non parametric and stochastic neighbor embedding to forecast anthropic pressure on dolphins



Automatic detection

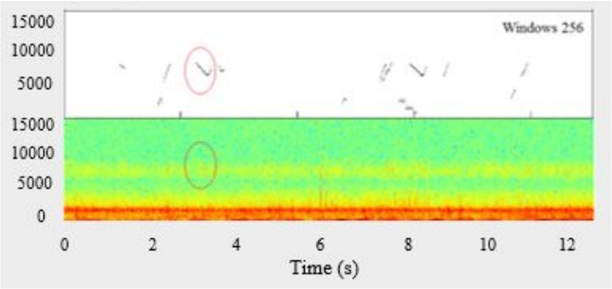
Signal on spectrogram

Binarization

Continuous trajectories ?

a. Ethoacoustic by bayesian non parametric and stochastic neighbor embedding to forecast anthropic pressure on dolphins

Automatic detection →



→ Extraction of features for each whistles

Matrix for each recording containing:
12 features (for each whistles) : maximal, minimal frequencies, duration, velocities of whistles...

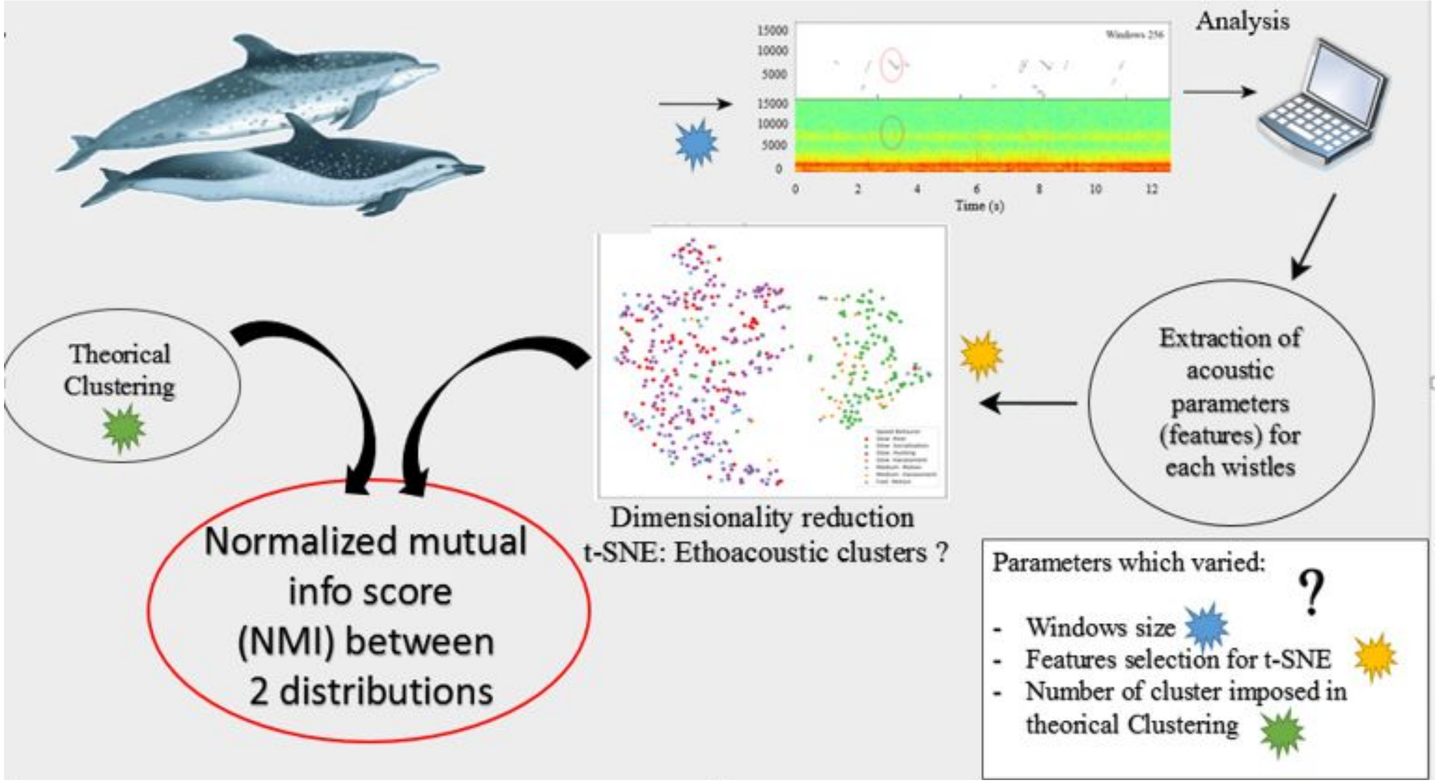
	Max freq	Min freq	duration	...	...	...	...
whi 1							
Whi 2							

Dimensionality reduction
t-SNE: Ethoacoustic clusters?

↓

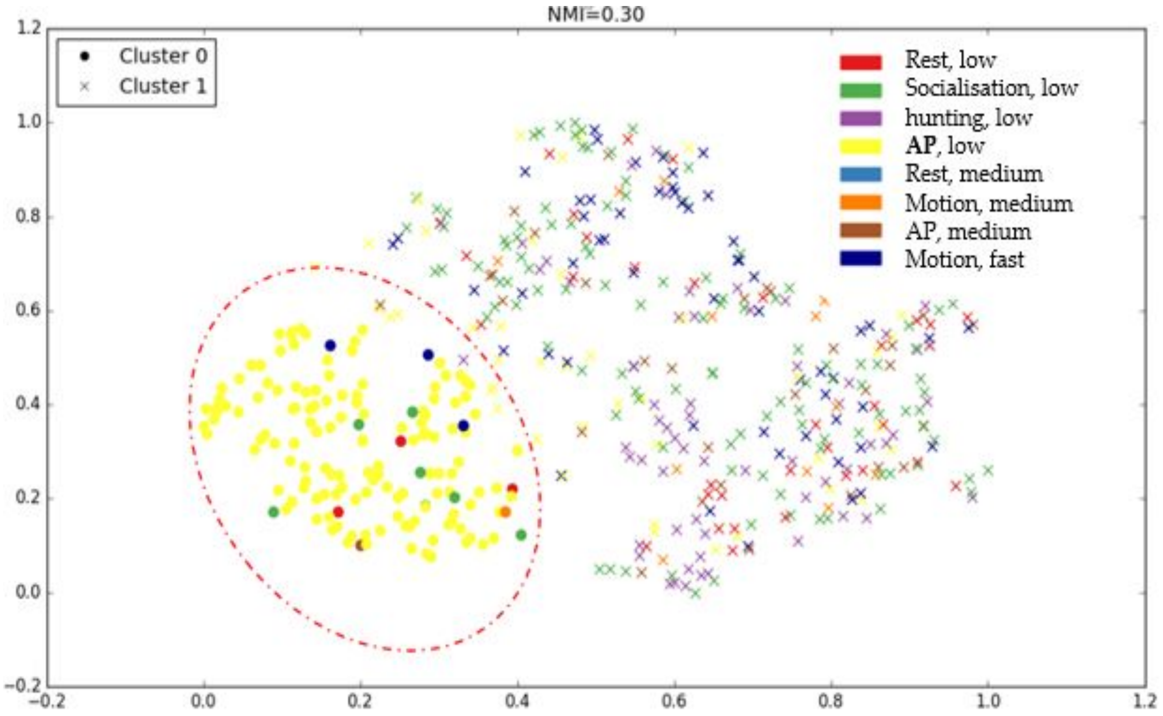
clustering and NMI

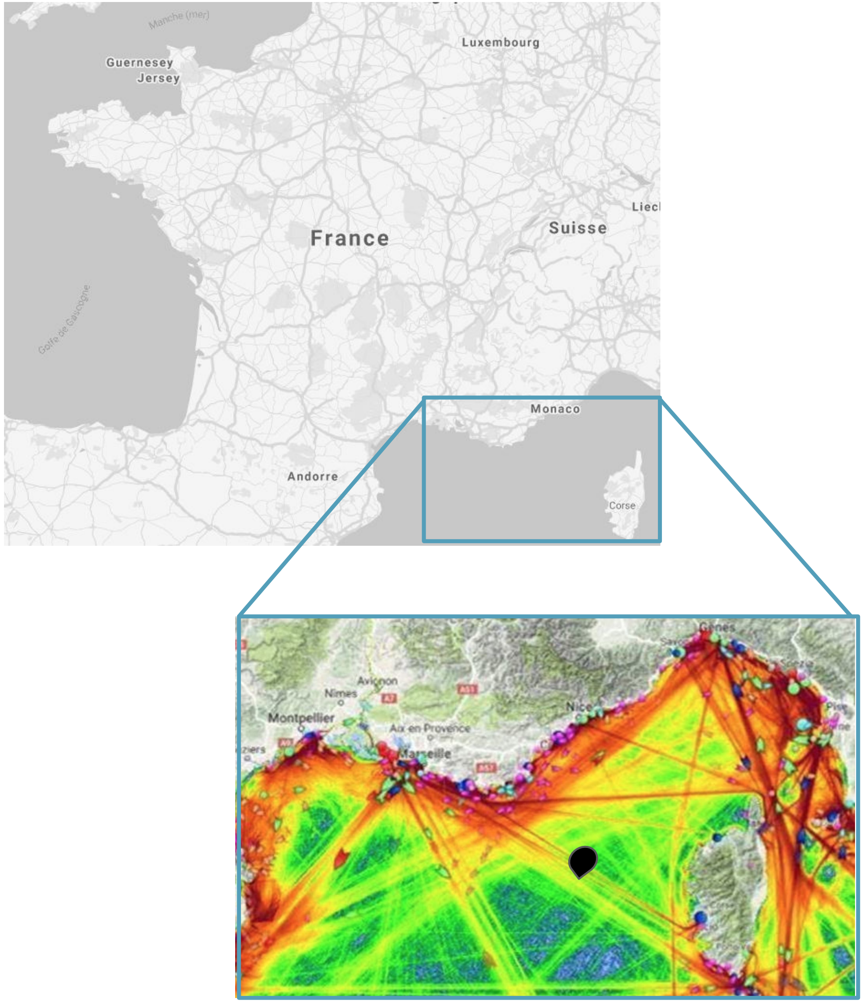
a. Ethoacoustic by bayesian non parametric and stochastic neighbor embedding to forecast anthropic pressure on dolphins



a. Ethoacoustic by bayesian non parametric and stochastic neighbor embedding to forecast anthropic pressure on dolphins

- Whistles depend on activity
- Acoustic emissions in anthropogenic pressure (AP) are different compared to other behaviours
- Modulations of frequencies
- Variations between species, areas and individually
- Extension of this method for other species





b. Long term stereo sonobuoy

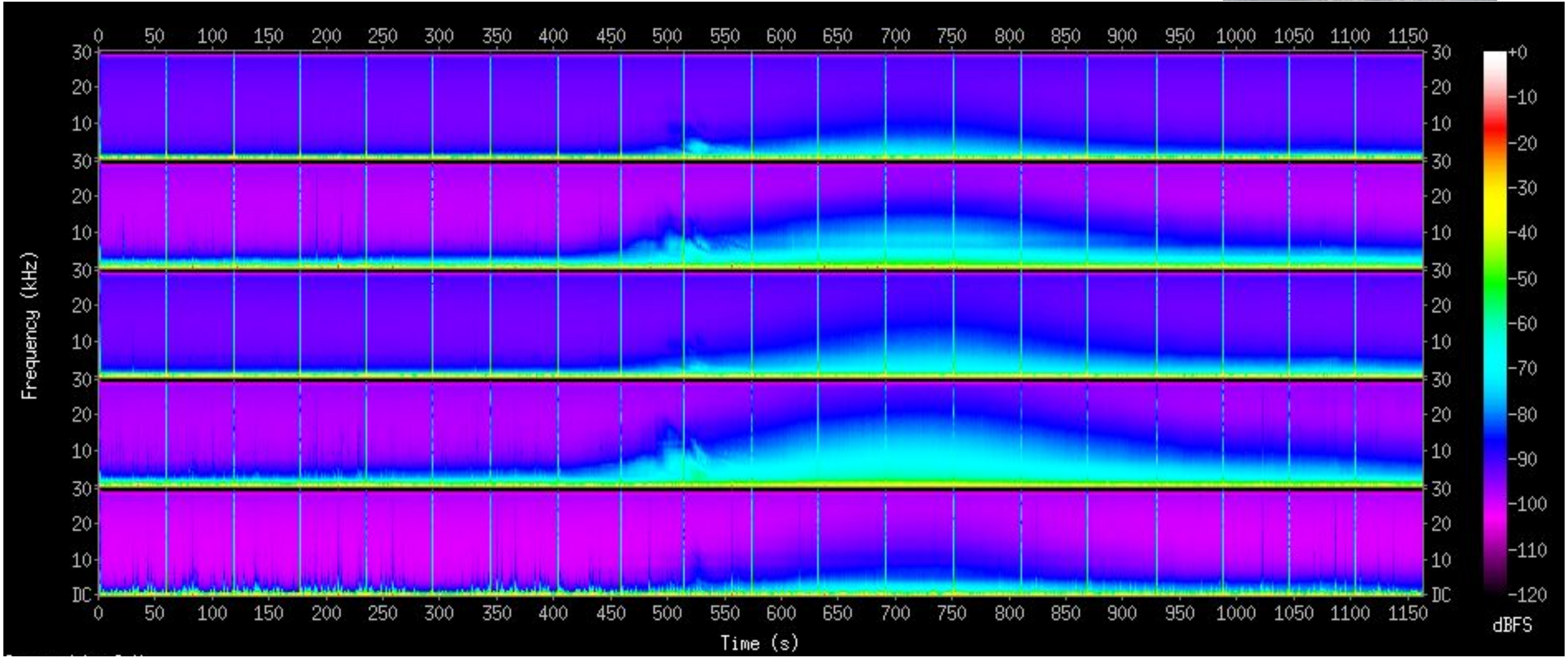
Hervé Glotin

Cumulation of maritime roads
during one summer : high risk
of collision of large cetacean

b. Long term stereo sonobuoy : soundscape monitoring

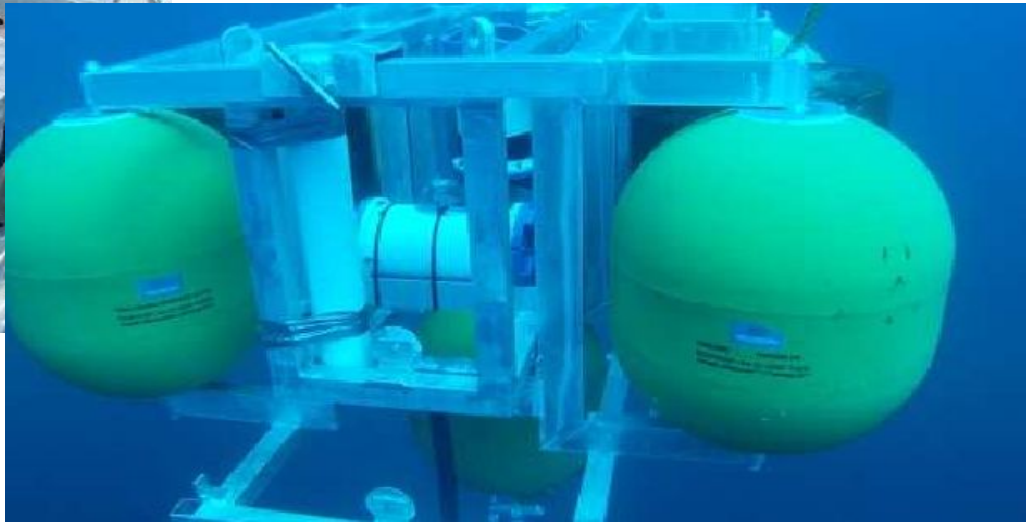
Jean Nicoli

Noise emitted by this Ferry with various hydrophones and directions but same place

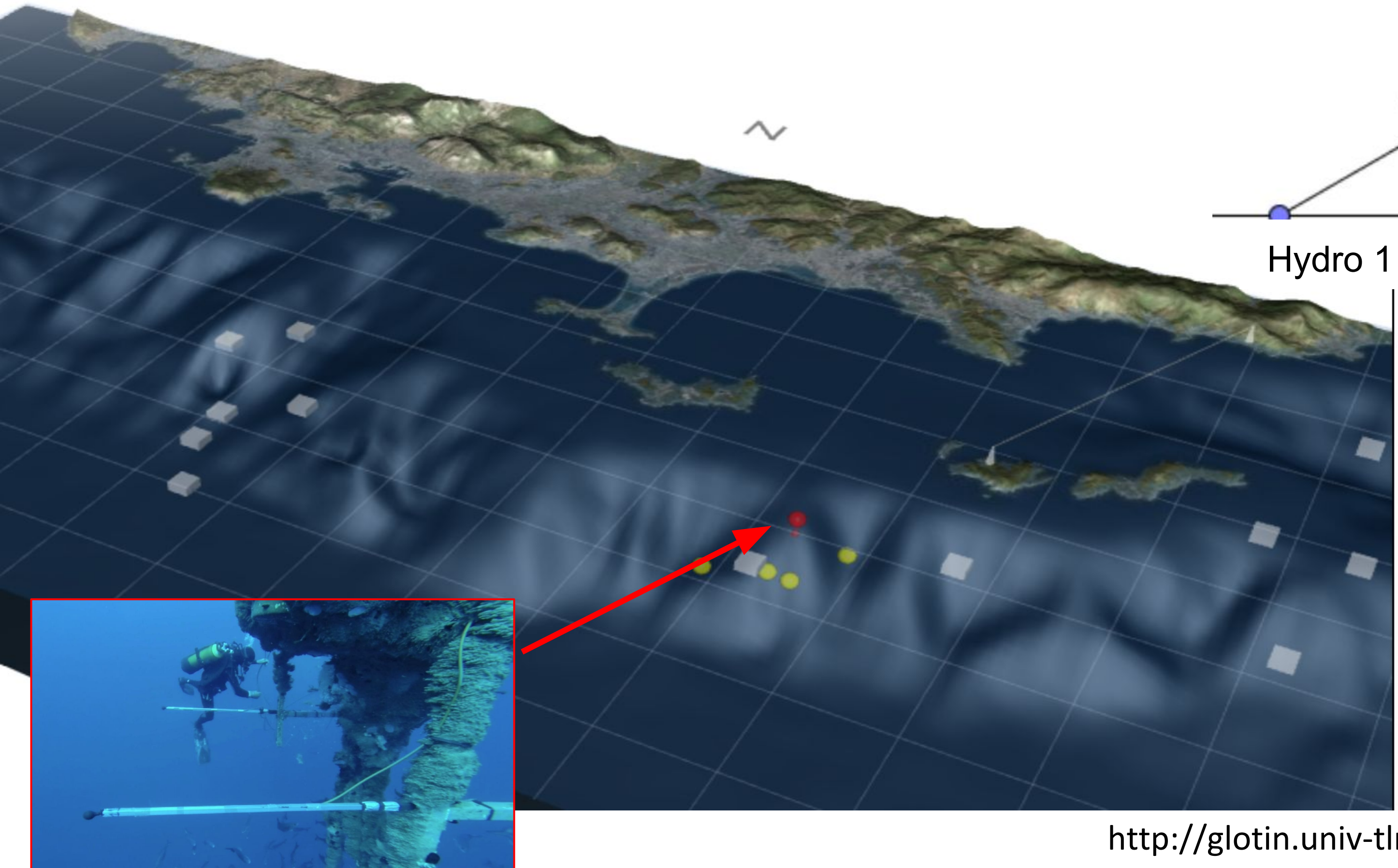


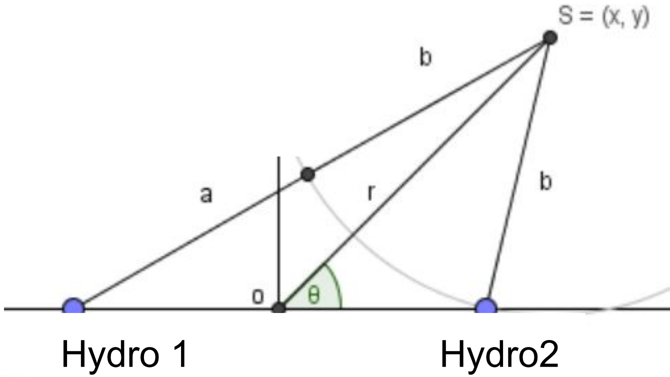
b. Long term stereo sonobuoy

SABIOD BOMBYX Observatory – near Port Cros National Park – 2014 – 2019...



b. Long term stereo sonobuoy



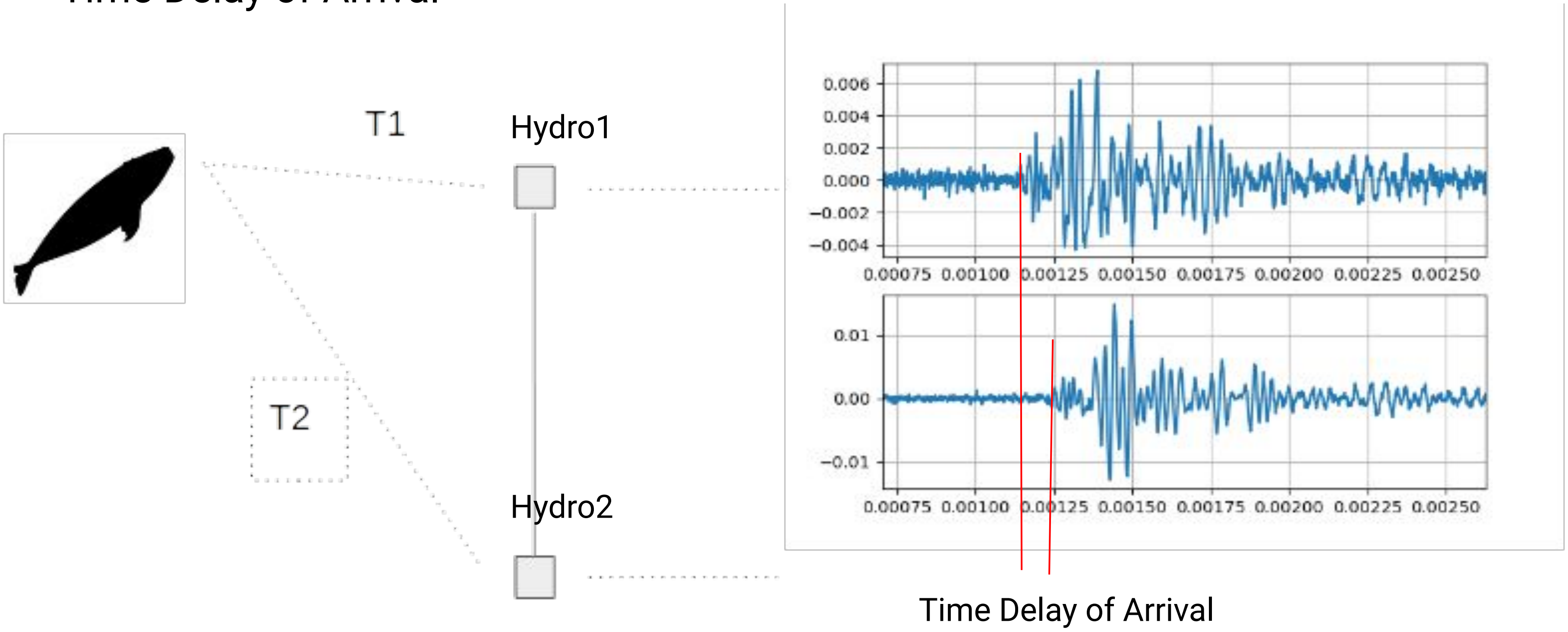


Stereo allows
azimuth estimations

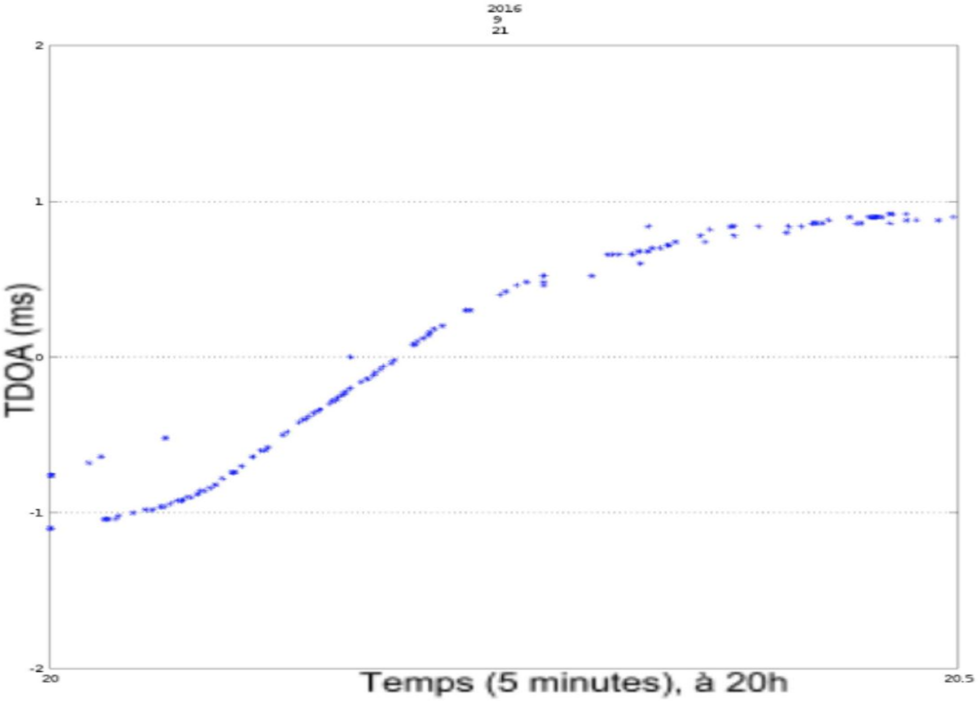
http://glotin.univ-tln.fr/BOMBYX

b. Long term stereo sonobuoy

Time Delay of Arrival

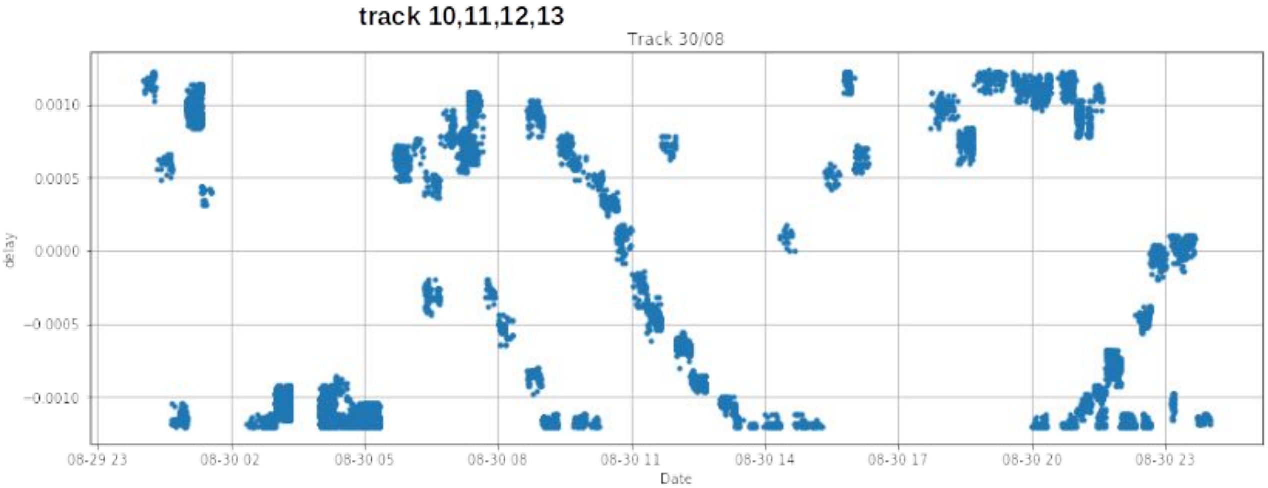


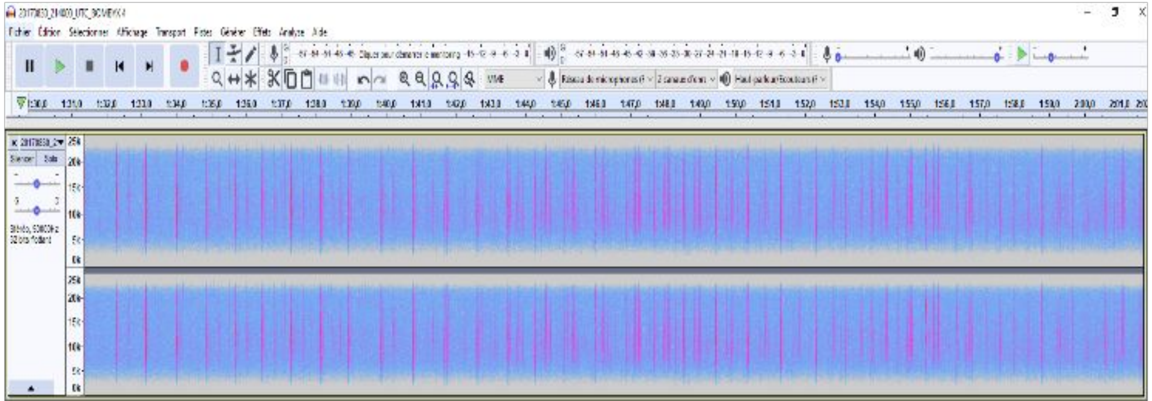
b. Long term stereo sonobuoy



Example of monitoring of Pm versus time from stereo Bombyx. Time Delay Of Arrival showing acoustic detections of Pm going from East to West in 5 mn nearby Bombyx the 21/09/2016.

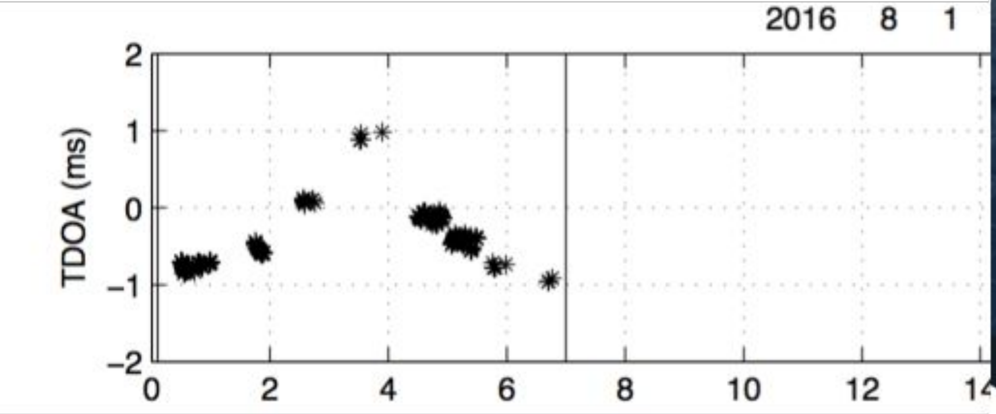
b. Long term stereo sonobuoy

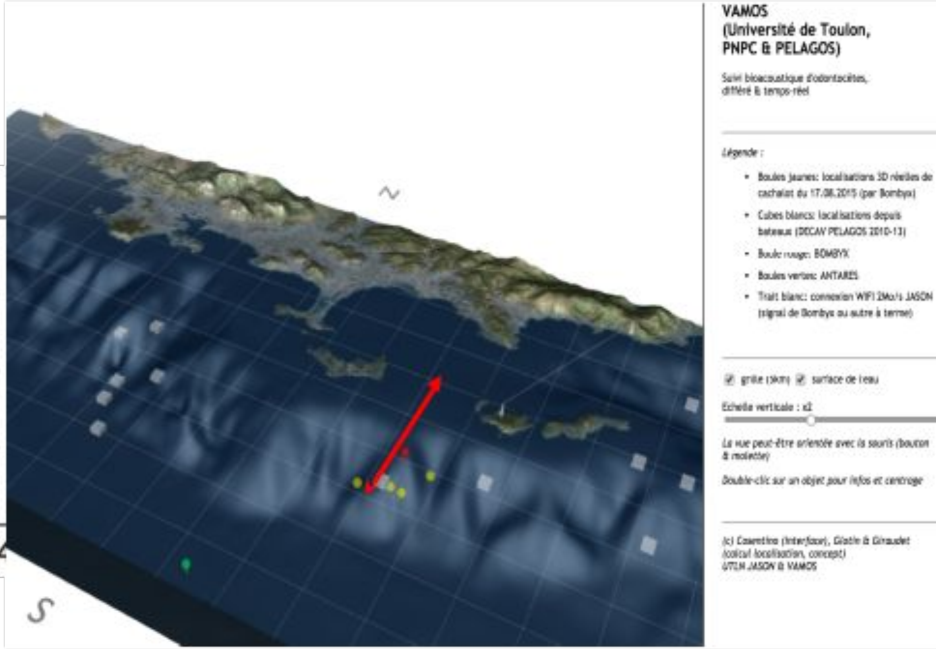




b. Long term stereo sonobuoy : Example of track

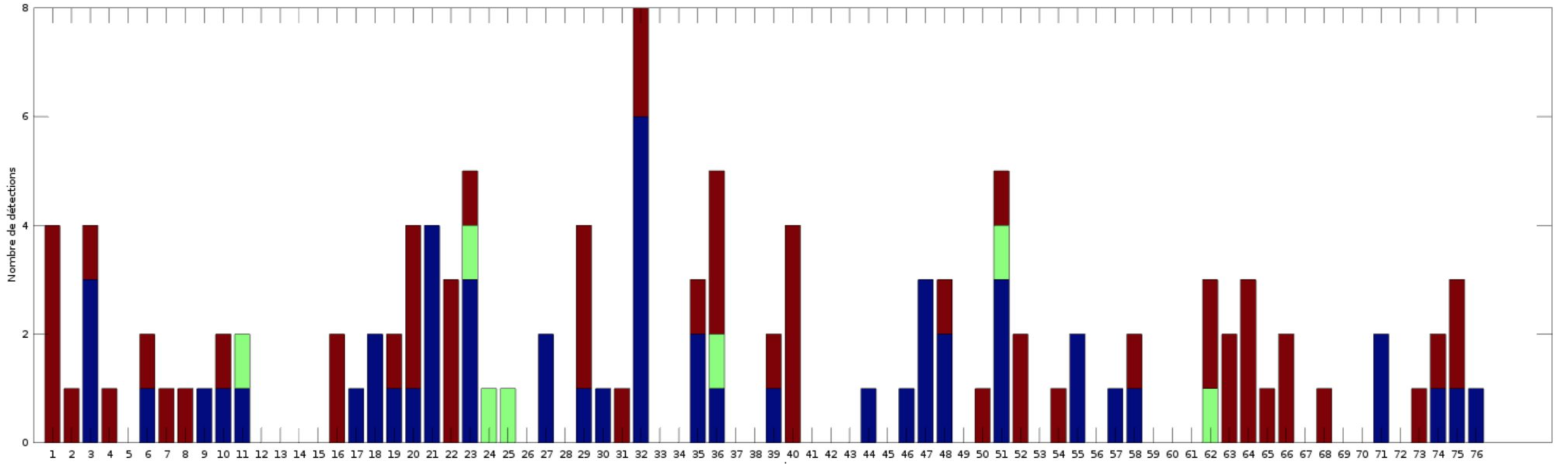
- Cliquez pour ajouter un texte





b. Long term stereo sonobuoy

Following Physeter's tracks



Example of monitoring of Pm versus time from stereo Bomby Total Pm countings and directions in the 0-15 km range of Bombyx, Red: from East to West, Blue inverse, Green: unknown, on 76 days of summer 2016 (Glotin et al., Vamos Pelagos 2016)

b. Long term N-hydrophone subsurface sonobuoy: GIAS 2019-22 biopopulation and anticollision system

- Extension of BOMBYX subsurface stereo sonobuoy to 3 to 5 Hydros for biopop. studies
- Online detection
- Low power subsurface buoy
- Analogic trigger
- Computation into the buoy of basic features
- TDOA
- Intensity difference
- Transmission of detection each 30 min to manager to help to avoid boat / whale collision

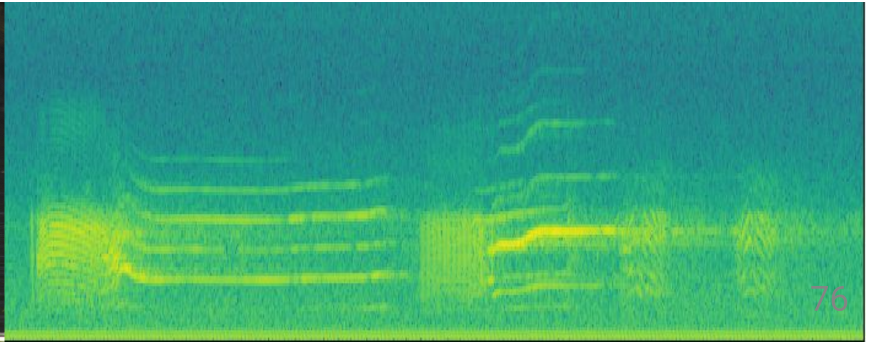
more details :

http://interreg-maritime.eu/fr/web/gias/-/gias-presentato-a-palazzo-san-giorgio

c. Can we identify Individual orca Calls within a Cocktail Party of Orcas ?

- Orca (Orcinus Orca) top predator of the marine food chain.
- The Northern resident killer whale community [1] pods dialect: repertoire of 7-17 discrete calls.
- But how could we more describe the orca communication ?
- Who When voices Which pattern nearby Whom ?
- Is there any acoustic individual Identity that would complete the acoustic pod Id ?

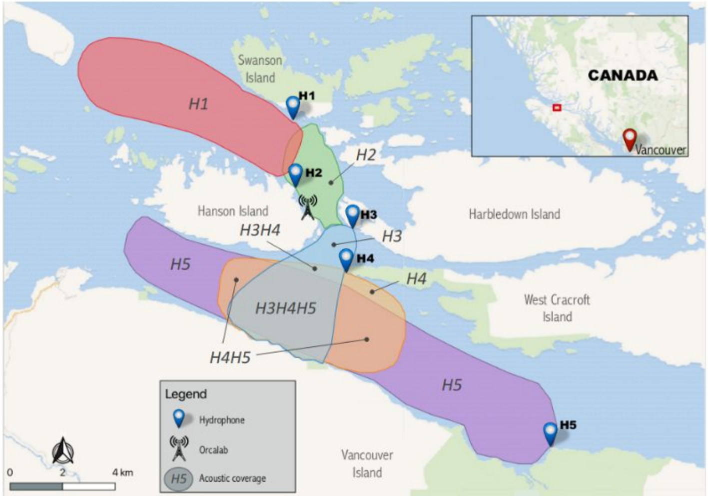
These question demands detailed timing and localisation of the vocalisations and pulses.

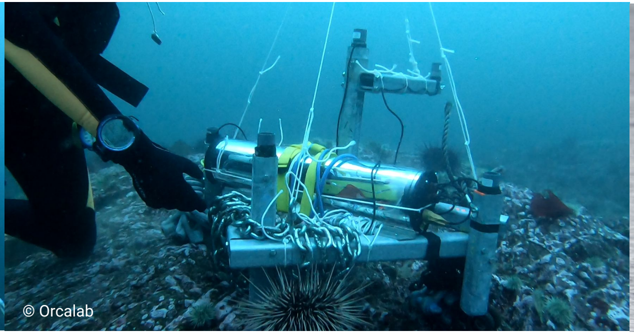


c. Can we identify Individual orca Calls within a Cocktail Party of Orcas ?

How describe the orca communication?

2 different protocols: analyze the actuals recordings and put another antenna

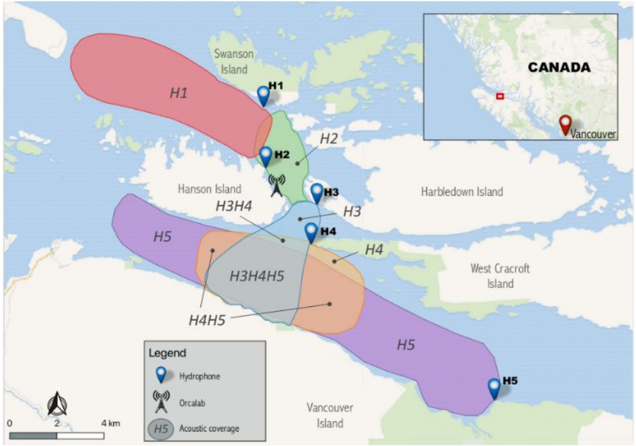


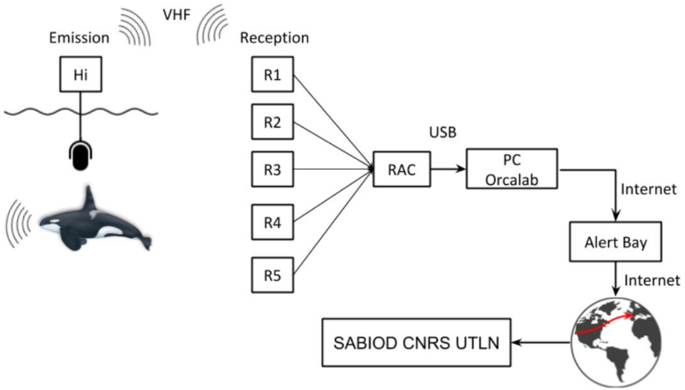


c. Can we identify Individual orca Calls within a Cocktail Party of Orcas ?

Material

The hydrophones record the soundscape continuously.
Transmission of recordings to the Orcalab station in real time via VHF.
Then digitized to a Presonus analog-to-digital converter (ADC) and sent to a PC in Orcalab.
The recordings are then compacted in segments of 2 minutes including all 5 channels (.flac, 22050 Hz)
Each segment is then sent to DYNI Toulon University big data NAS (Network Attached Storage) .
In total, from July 2015 to 2017, around 50 TB of sound (about 14,500 h) was stored on our server.





c. Can we identify Individual orca Calls within a Cocktail Party of Orcas ?

Material

Data set for training is composed of 872 orca vocalization samples and 6801 noise samples (boats, rain, void..).

Split randomly with 20% for the test set, 60 % for the training set; 20 % for the validation set.

Train a CNN originally designed for a bird detection task [3] to distinguish orca vocalizations

Computation of Orca predictions from 2015-2017.

An ROC threshold of 0.9 is applied to the output of the model.

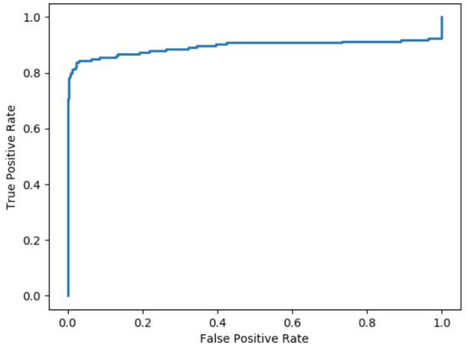


Table 1. TEST SET PERFORMANCE OF DEEP LEARNING MODEL FOR ORCA DETECTION

	Accuracy	Area Under Curve
Training	0.97	0.88
Validation	0.96	0.89
Test	0.97	0.89

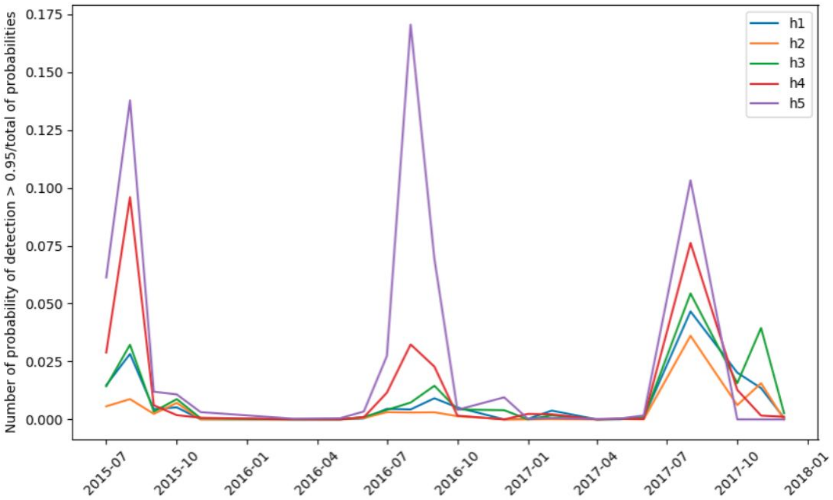
c. Can we identify Individual orca Calls within a Cocktail Party of Orcas ?

Material

2 days of computation required for 2015-2017 data.

Orcas are present (acoustically) mostly during summer (June, July, August and September)[4].

orcas are abundant in Johnstone Strait between July and October, when salmon migrate into it.
The second peak (October-December) may reflect the presence of Humpback whales [5].

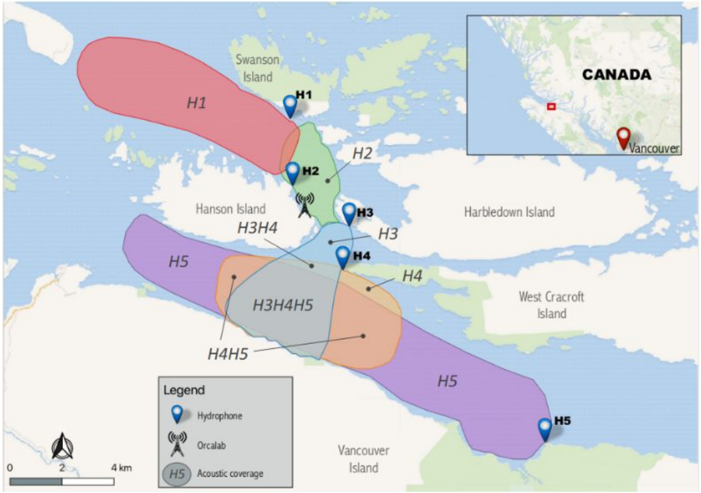


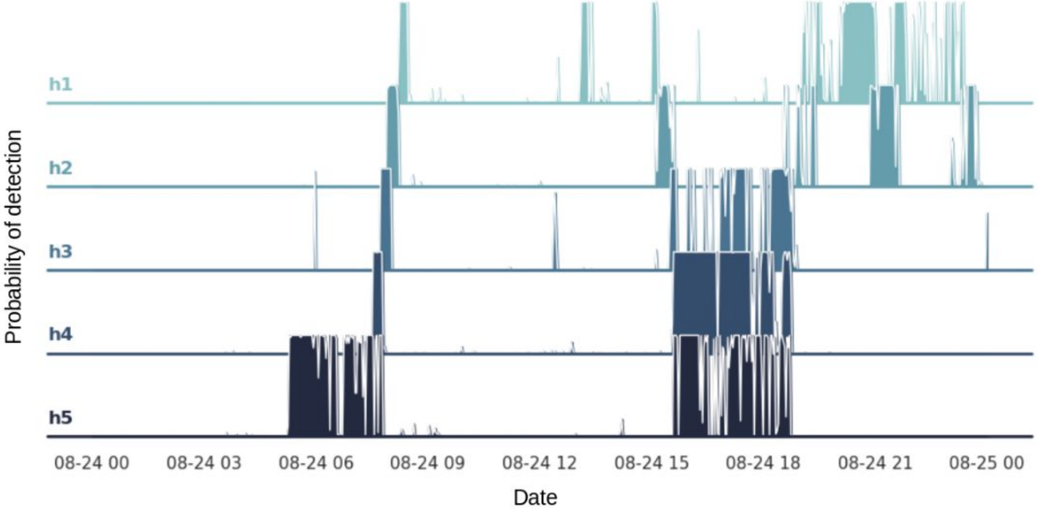
c. Can we identify Individual orca Calls within a Cocktail Party of Orcas ?

Results

Estimation of the acoustic activity of orcas in the range of each hydrophone over time.

Example for August 24, 2017.





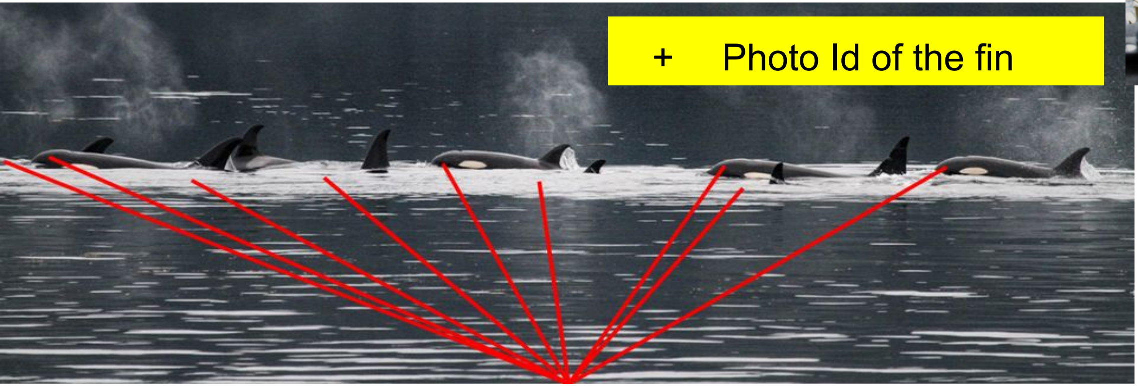
c. Can we identify Individual orca Calls within a Cocktail Party of Orcas ?

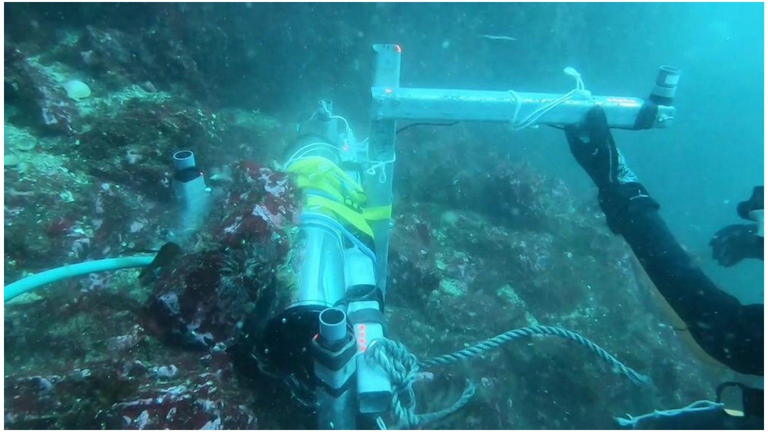
Protocole 2: installation of an antenna with 4 hydrophones

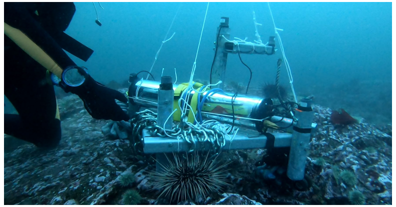
Calculation of the TDOA

Identification in real time of each individual

Pictures and videos







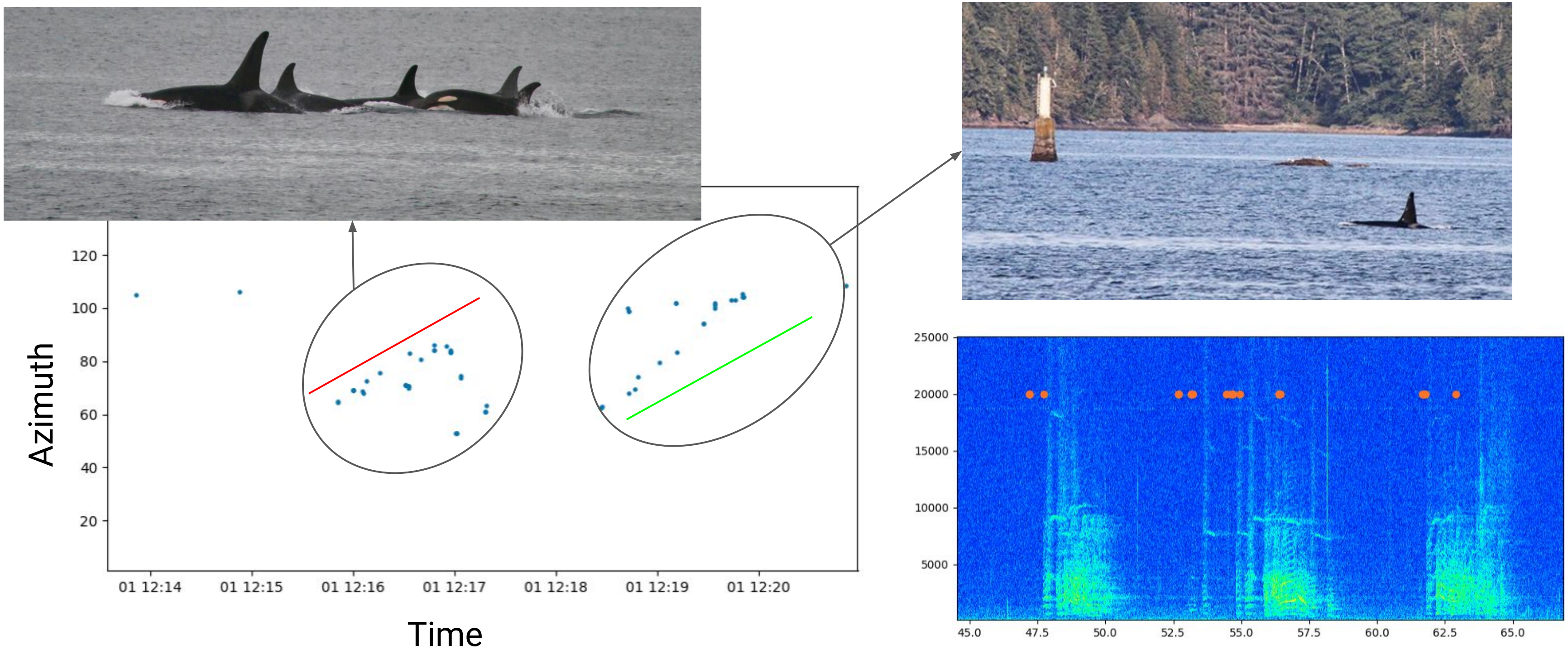
c. Can we identify Individual orca Calls within a Cocktail Party of Orcas ?

Identification in real time of each individual

Pictures and videos

Group 1: Big group made up of I16s, I65s and I27s

Group 2: one orca, A66



d. Mission Sphyrna Odyssey 2018/2019

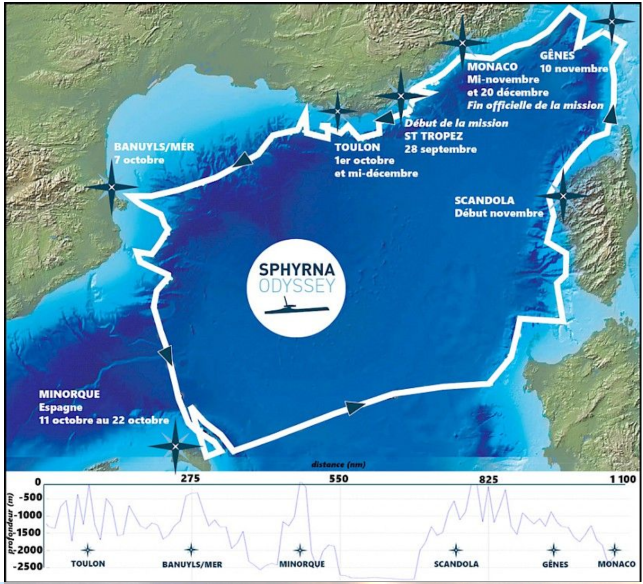
SPHYRNA ODYSSEY

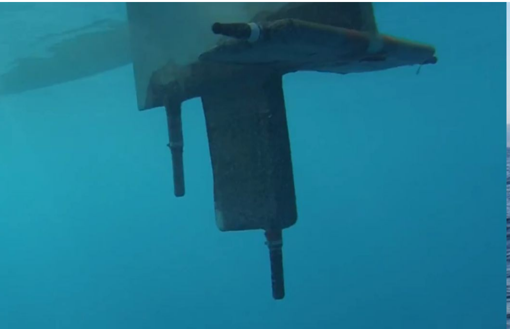
- Monitoring bioacoustic
- pollution measurement
- Mapping
- Trajectography

FONDATION PRINCE ALBERT II DE MONACO · ACCOBAMS · SEA PROVEN · Revue Marine & Océans · LIS · UNIVERSITÉ DE TOULON · SMIoT · LEMERPAX · esa · cnes · kinéis · ATMOSPHERE · cnrs · ITKA

d. Mission Sphyrna Odyssey 2018/2019

- 17m long and 4m large, made of carbon fibre
- Inspired by the shape of Polynesian canoe
- Two asymmetric hulls: decreasing pitch and roll
- Electric propulsion (solar energy)





d. Mission Sphyrna Odyssey 2018/2019

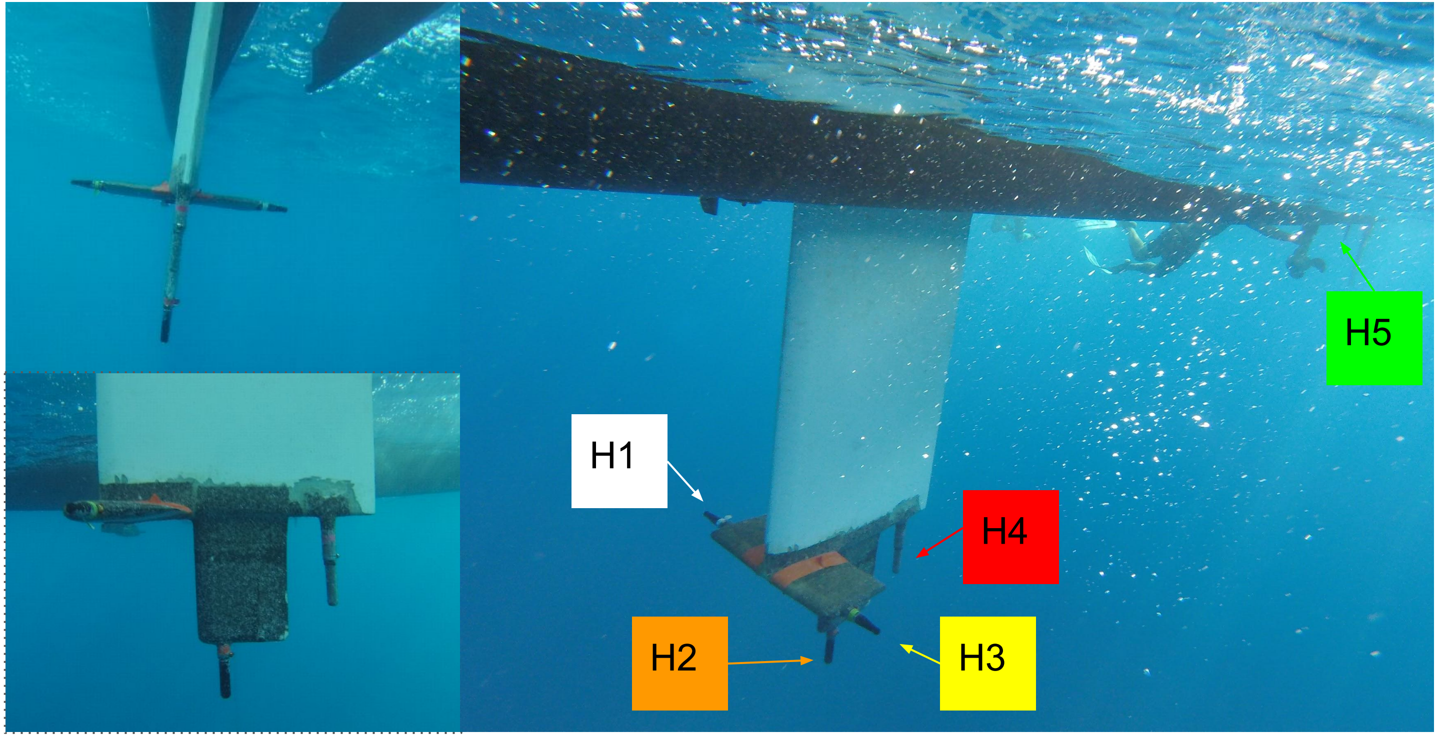
The drone Sphyrna

- 17m long and 4m large, made of carbon fibre
- Inspired by the shape of Polynesian canoe
- Two asymmetric hulls: decreasing pitch and roll
- Electric propulsion (solar energy)

d. Mission Sphyrna Odyssey 2018/2019

Antenna video :
http://sabiod.org/seeabyss

Design of the antenna



d. Mission Sphyrna Odyssey 2018/2019

Example of Clear dolphin clicks, TDOA measures, recorded on 5 channels

d. Mission Sphyrna Odyssey 2018/2019

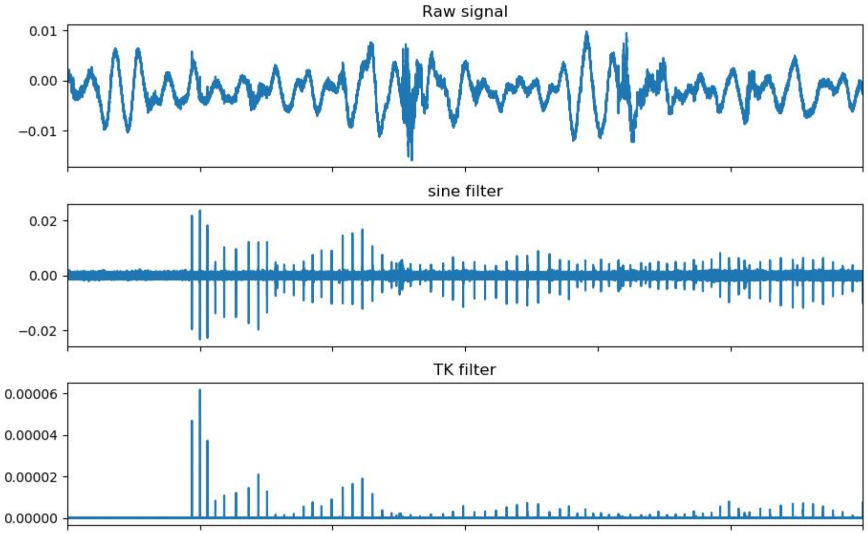
12th of august

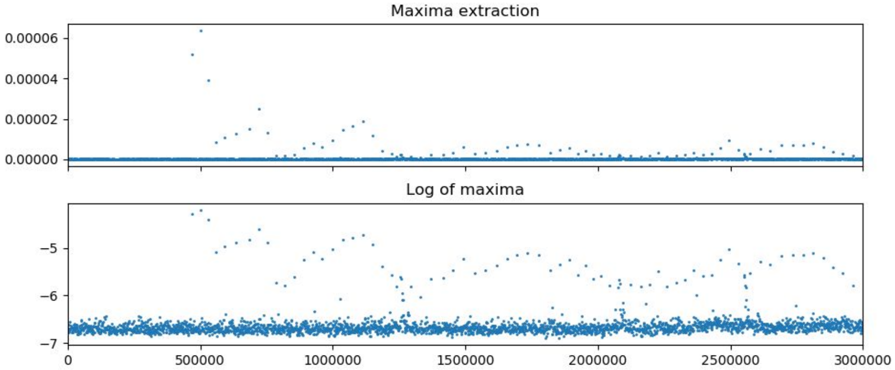
2 hours of recordings of a single sperm whales

South of Toulon

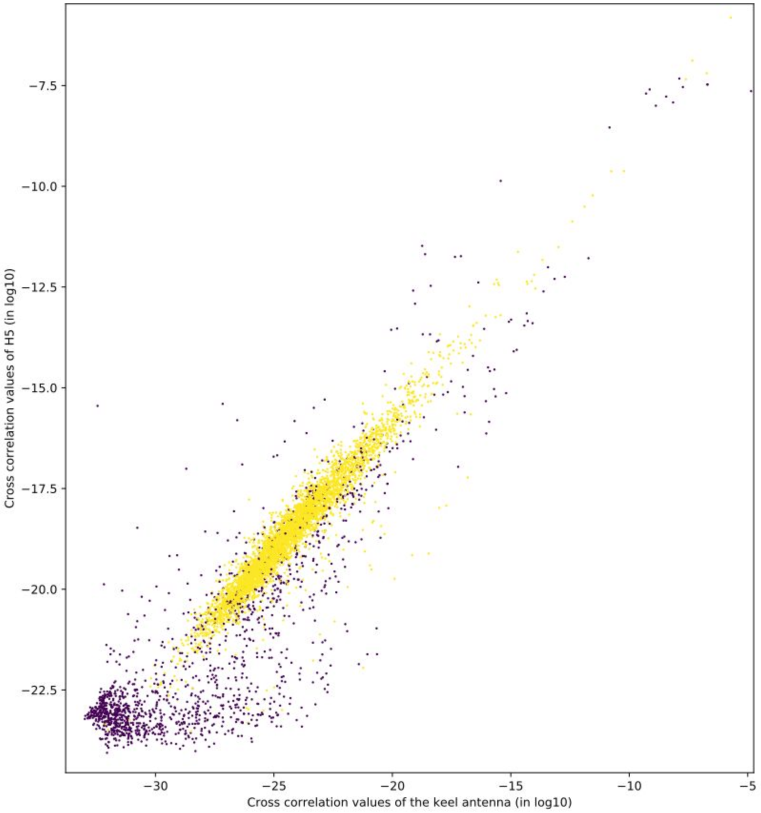
d. Mission Sphyrna Odyssey 2018/2019

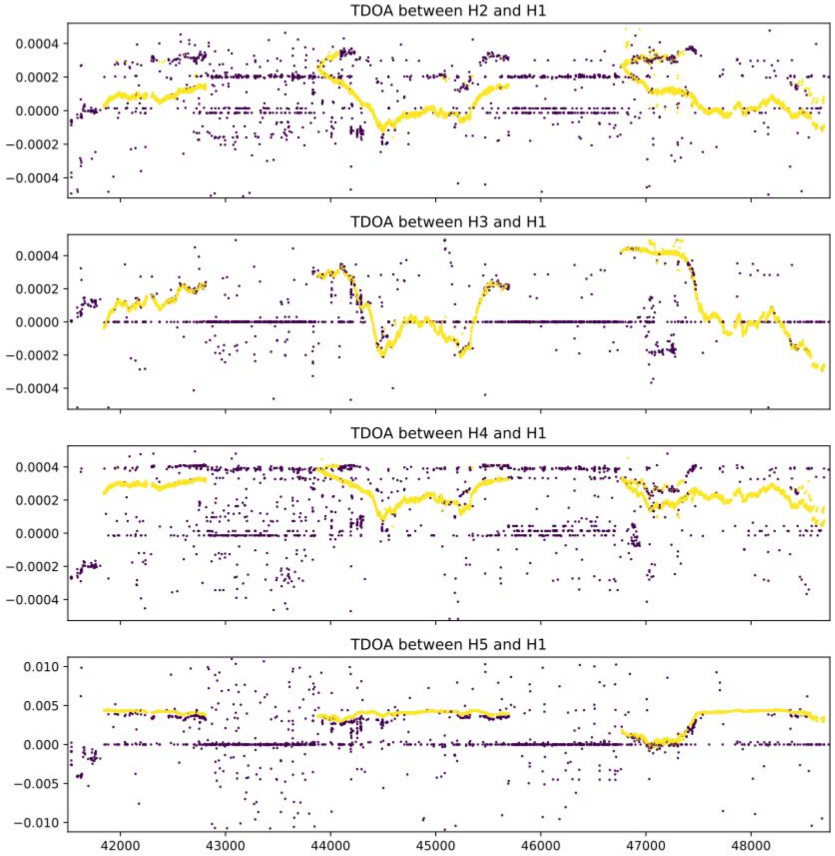
Data analysis





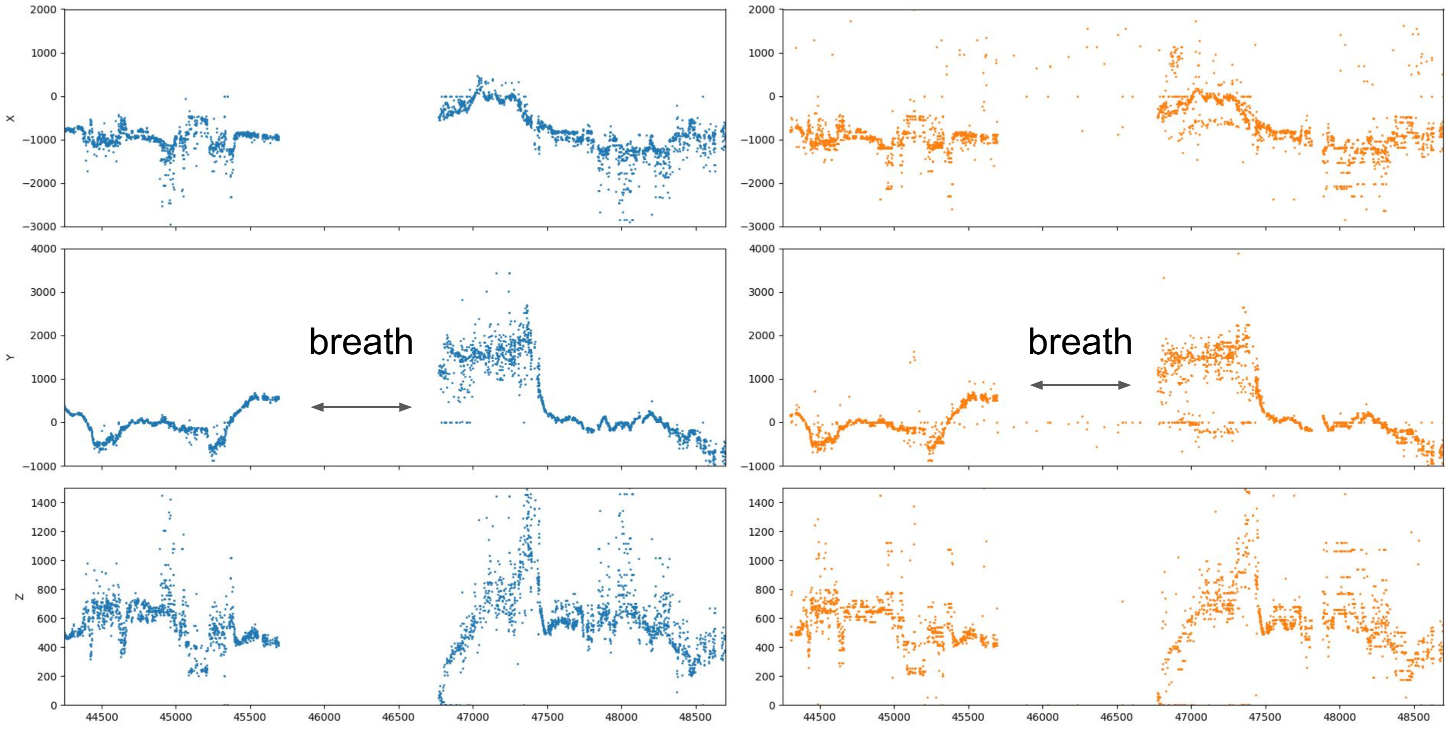
d. Mission Sphyrna Odyssey 2018/2019





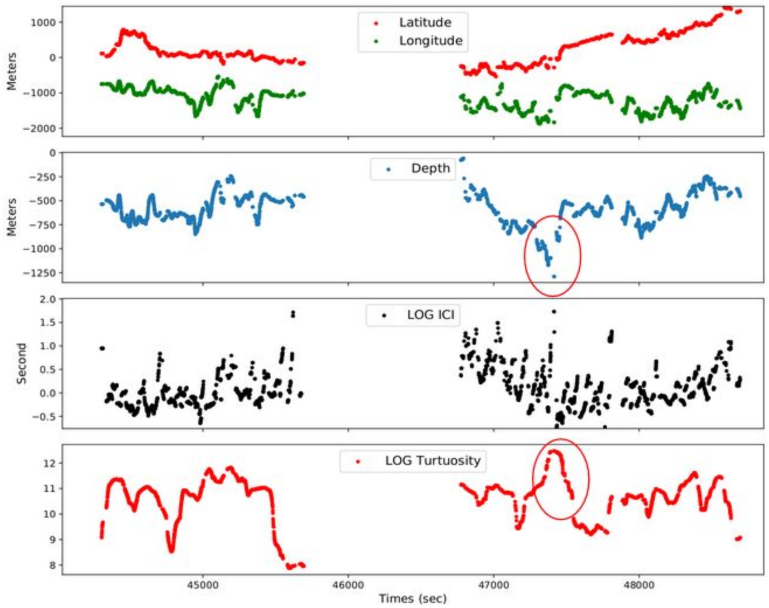
d. Mission Sphyrna Odyssey 2018/2019

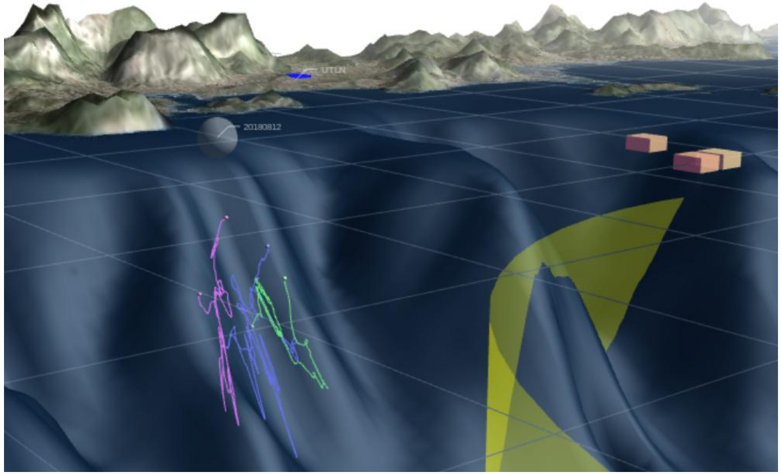
Raw position during 2 hours of recording of Physeter



d. Mission Sphyrna Odyssey 2018/2019

Calculations of TDOA
Calculation of positions
Tortuosity: index of the movement behavior



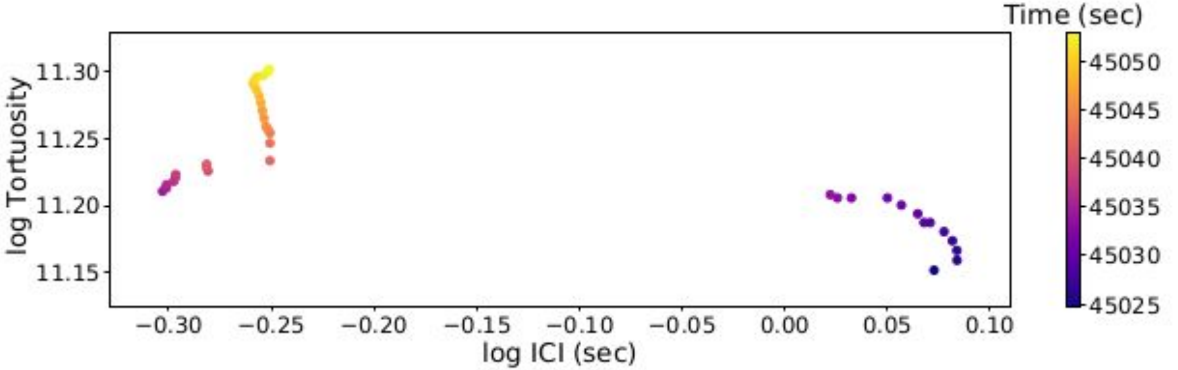


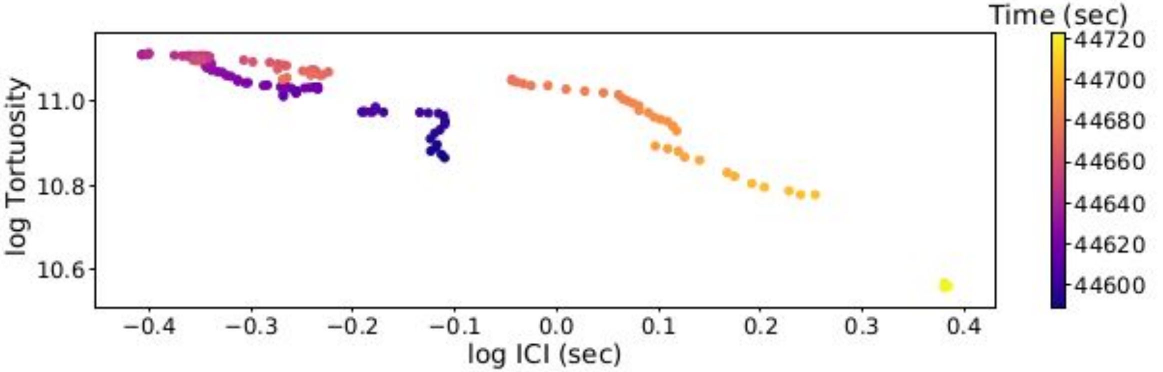
d. Mission Sphyrna Odyssey 2018/2019

The sequence of 25 sec (Top) shows that ICI and T are not dependant by construction.

The 2 min sequence (Bottom) shows a strong anticorrelation between ICI and T

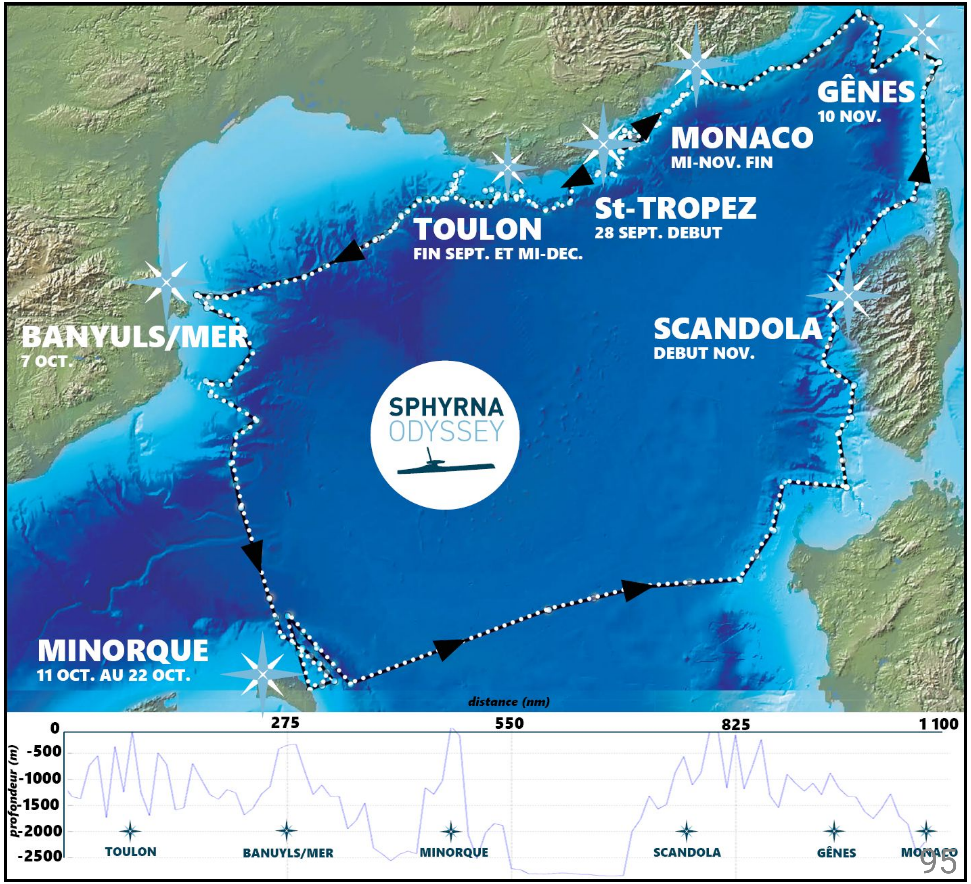
$$T = V(X_1, \ldots, X_n) + V(Y_1, \ldots, Y_n) + V(Z_1, \ldots, Z_n)$$





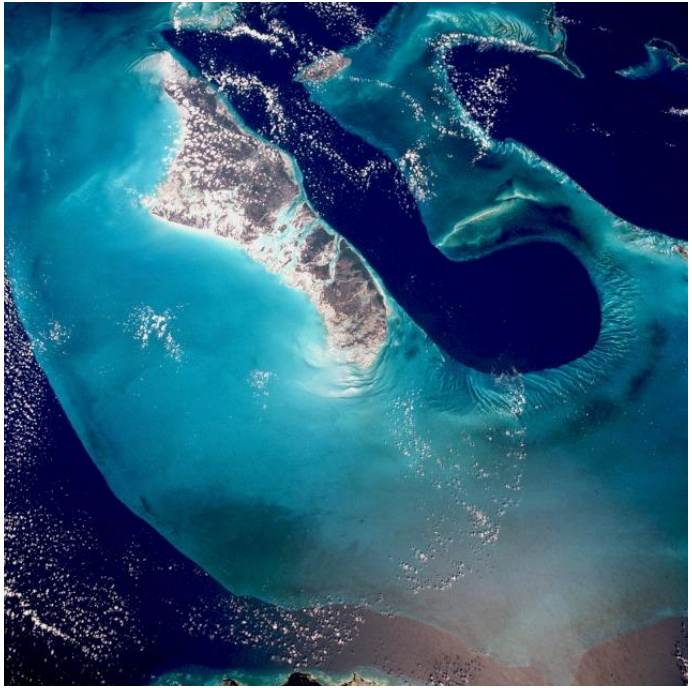
d. Mission Sphyrna Odyssey 2018/2019

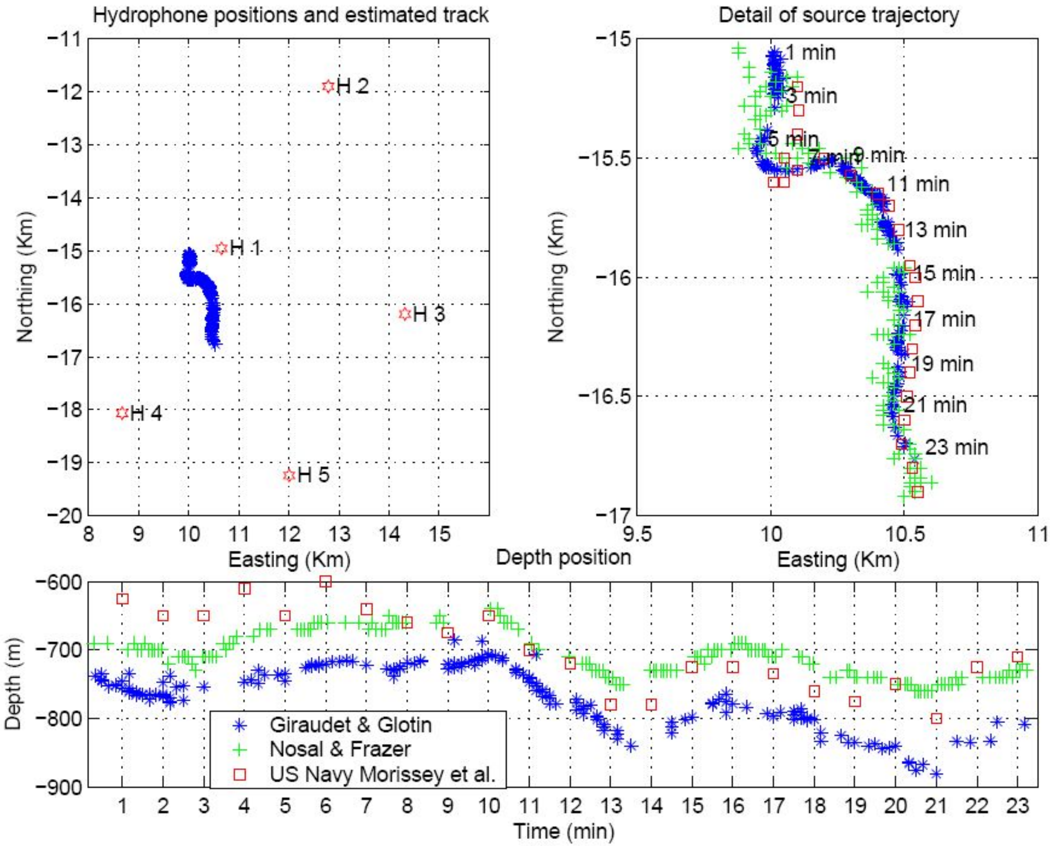
2019 Sphyrna Odyssey : 2 drones
=> long term drifted monitoring
=> comparison to towed array
Perspectives in monitoring biodiversity between sonobuoys



d. Other tracking : Large Fixed Antenna

Bahamas AUTEC





Demonstration on real data :

[Glotin et al. Multiple whale tracking USA patent 2013
Glotin et al. Whale Cocktail Party, Canac Acoustics, 2008
Bénard Glotin, Neutrino whale tracking, Applied Acoustics 2011]

Online demo at http://sabiod.org/tv

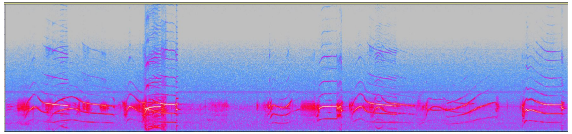
RANGE [500 to 5000 m] prec :15m

4.Recordings: Orcas, Sperm whales, Dolphins...

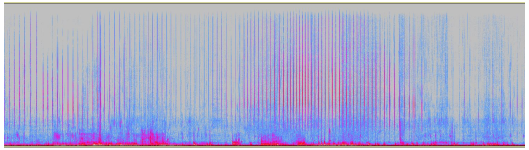
Marion Poupard

Some recordings...

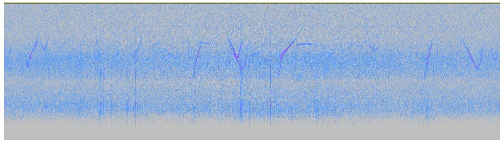
Orca (*Orcinus orca*)



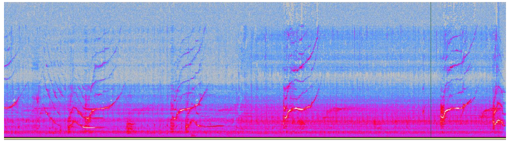
Sperm whales (*Physeter macrocephalus*)



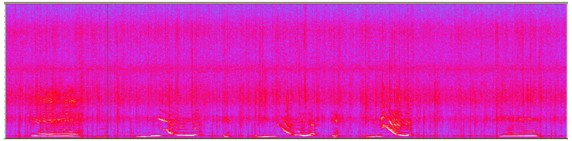
Pantropical spotted dolphin (*Stenella attenuata*)



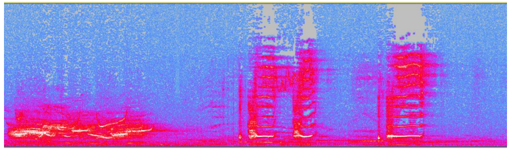
Long-finned pilot whale (*Globicephala melas*)

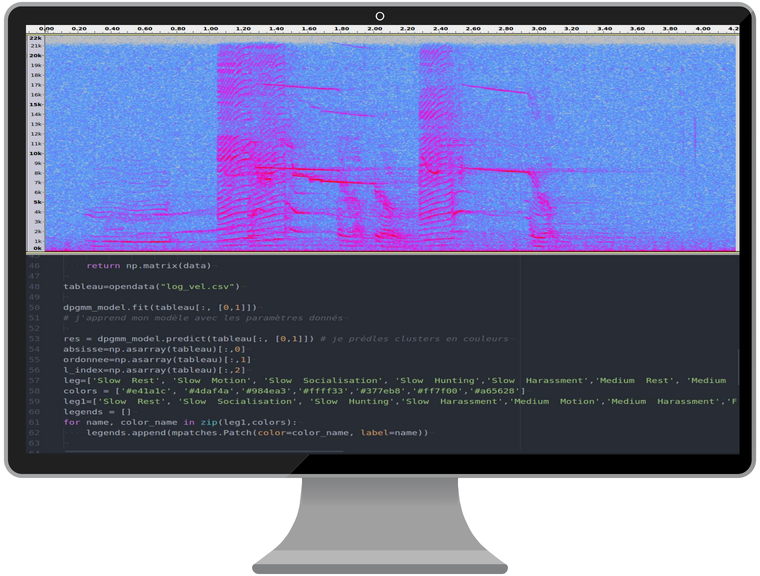


Humpback whales (*megaptera novaeangliae*)



Beluga whale (*Delphinapterus leucas*)

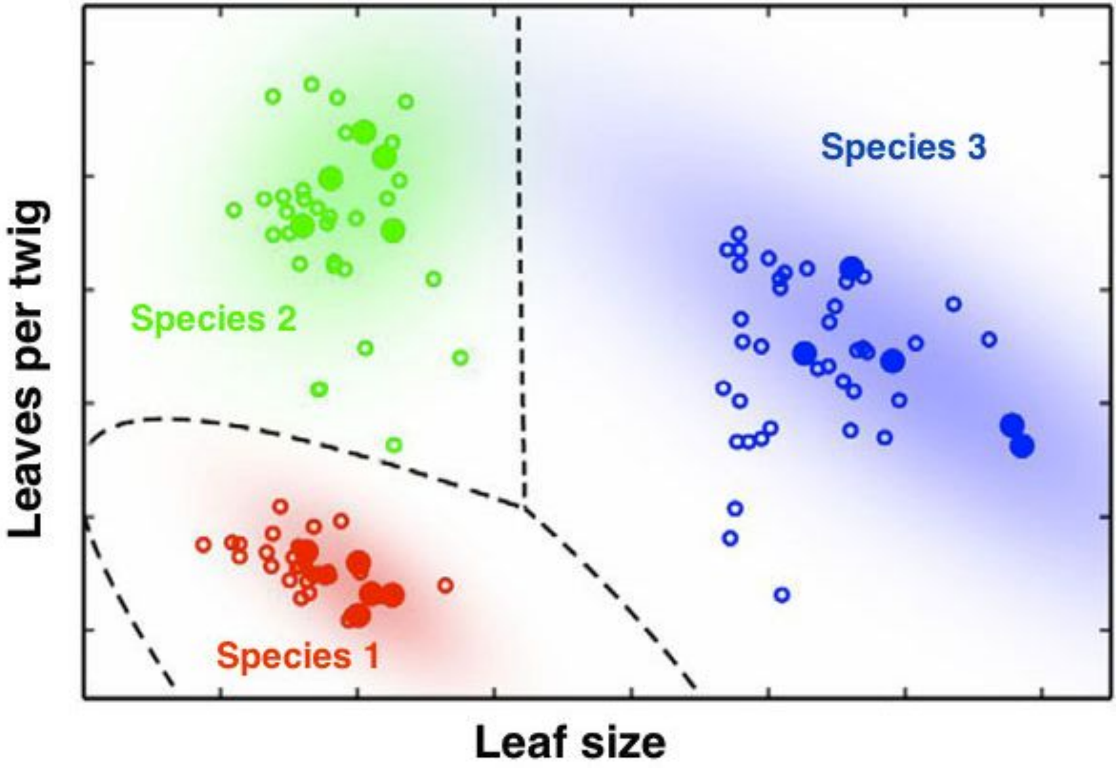




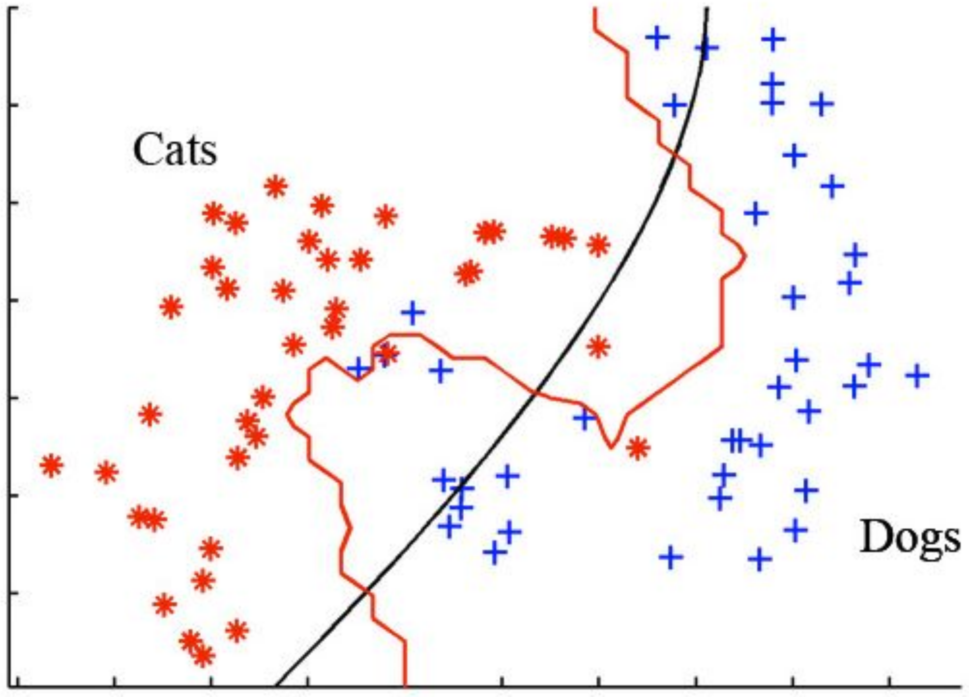
5. First results of the Cariman project

Maxence Ferrari

5. Classification, overview : (a) Machine learning



5. Classification, overview : (a) Machine learning



Learning = separate classes in optimal representation

5. Classification, overview : (a) time frequency dictionnary

Classification of mysticete sounds using machine learning techniques

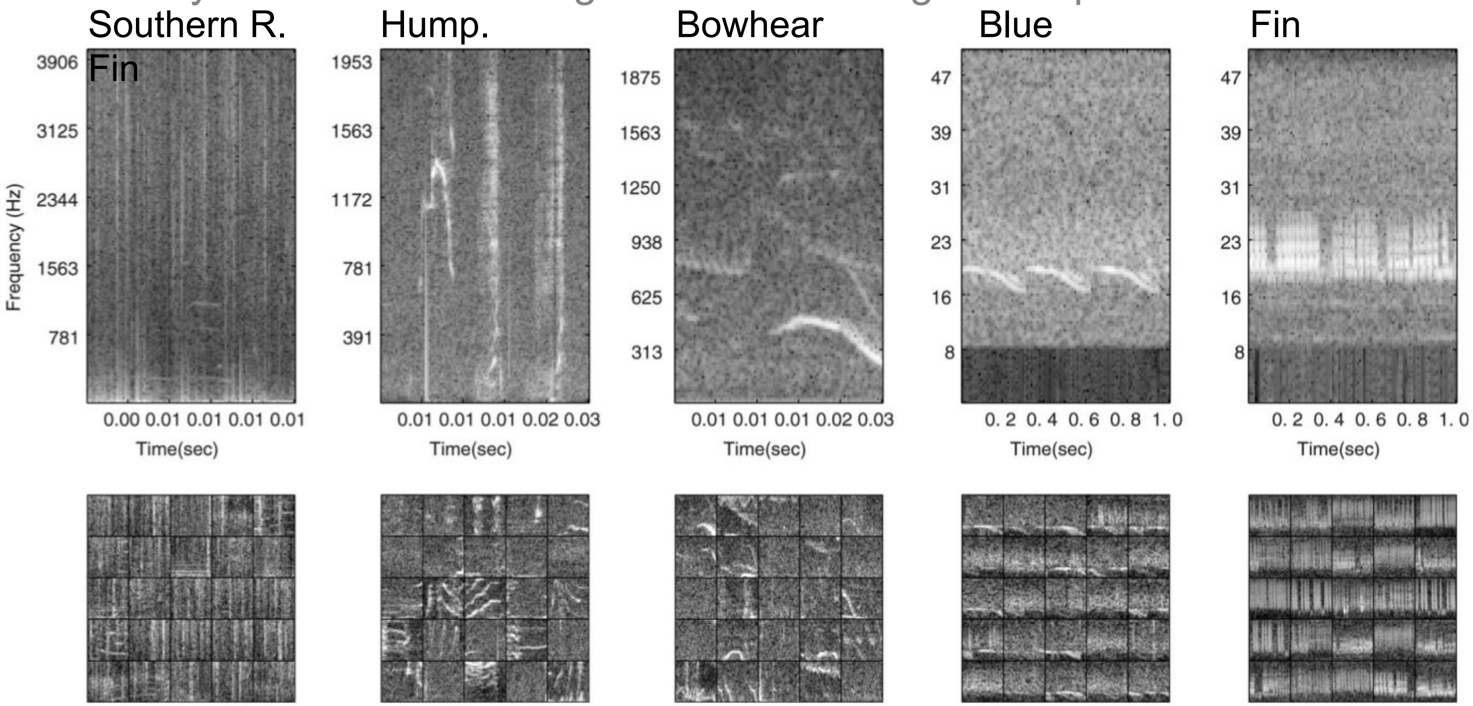
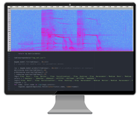


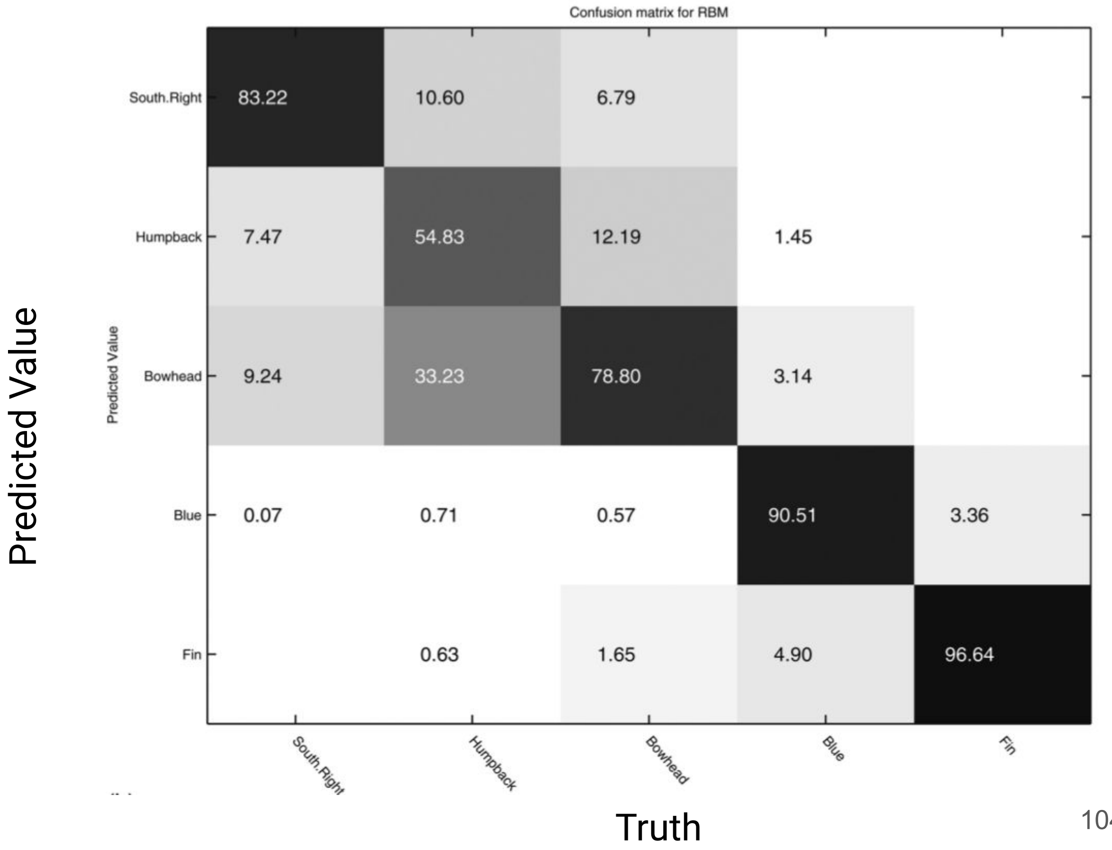
FIG. 2. Sample call spectrograms/ROIs [top row; *x*-axis: time (s), *y*-axis: frequency (Hz)] and 25 standardized and scaled patches per species (bottom row; *x*-axis, *y*-axis: bin number) used as an input for the different networks. Left to right: southern right, humpback, bowhead, blue, and fin.

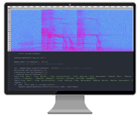


5. Classification

- Classification of Mysticetes

South righ w.
Humpback w.
Bowhead w.
Blue w.
Fin w.



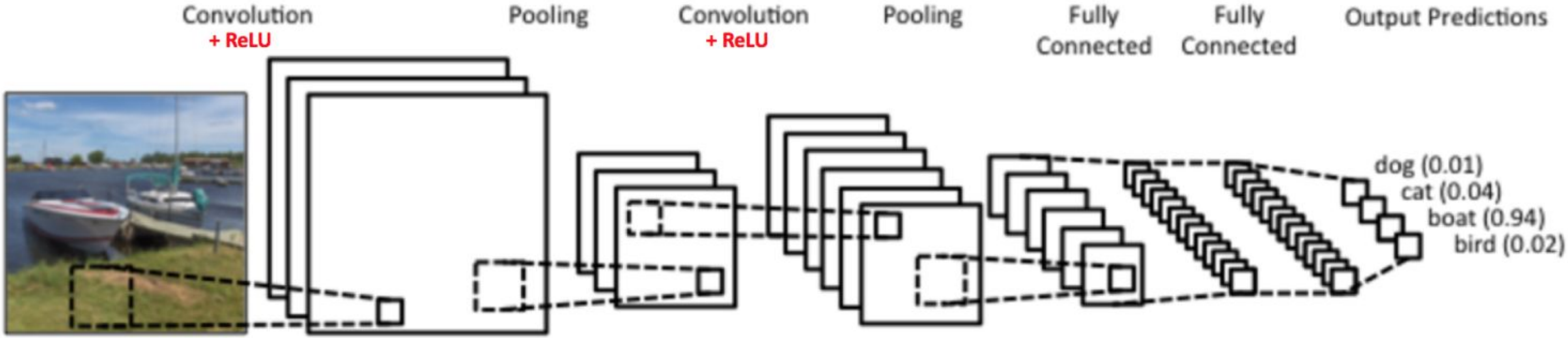


5. Classification : (b) Convolutionnal Deep Learning

Convolutional Neural Networks (ConvNets or CNNs) are a category of Neural net that have proven very effective in areas such as image recognition and classification. ConvNets have been successful in identifying faces, objects and traffic signs apart from powering vision in robots and self driving cars.

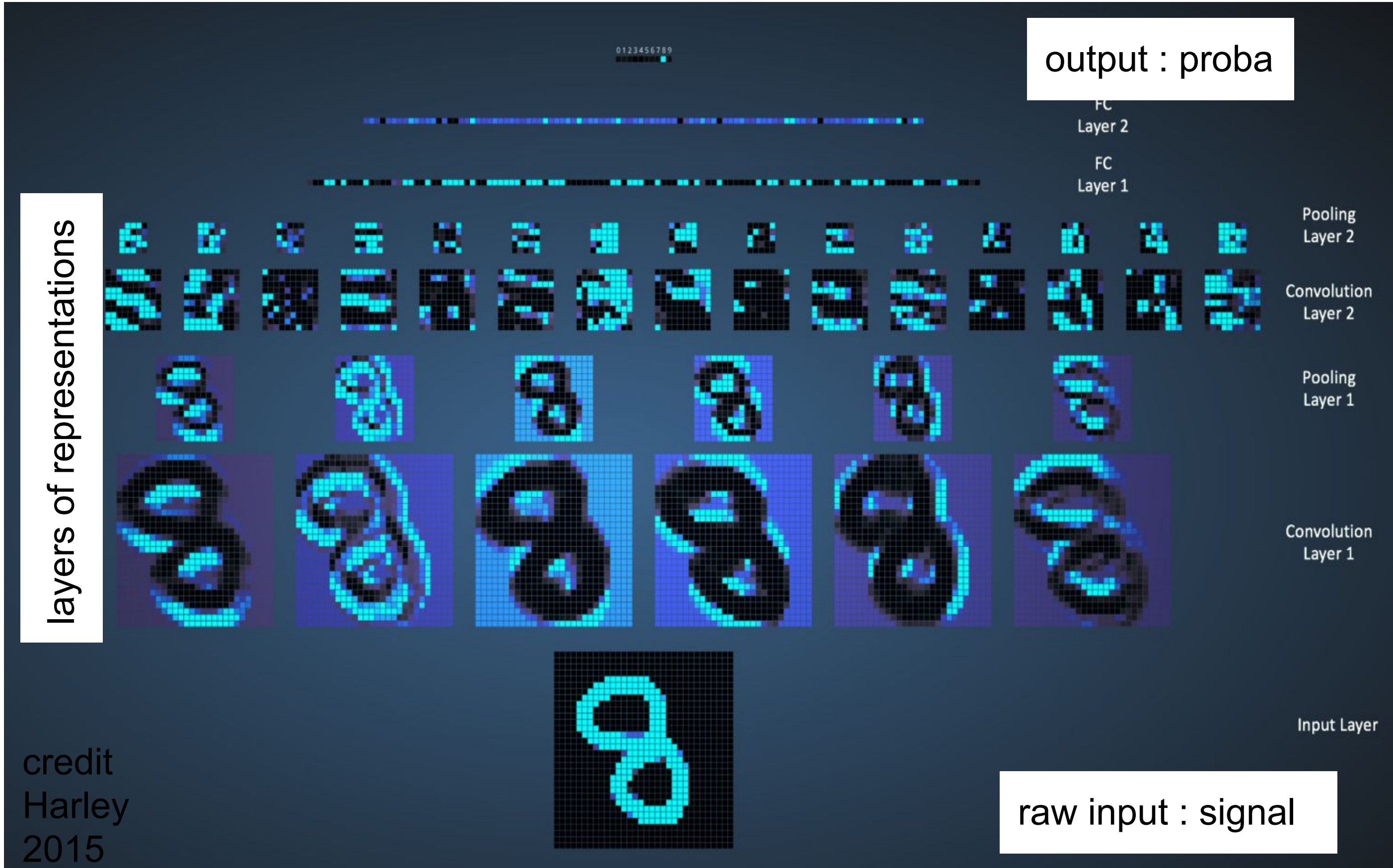
LeNet was one of the very first convolutional neural networks which helped propel the field of Deep Learning. This pioneering work by Yann LeCun was named LeNet5 and was used mainly for character recognition tasks such as reading zip codes, digits, etc. (1988).

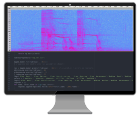
There have been several new architectures proposed in the recent years which are improvements over the LeNet, all mostly based on same cascade of (Conv, non lin, pool) and then classification.



5. Classification : (b) Convolutionnal Deep Learning

The Deep Neural Net **learns** from **lot of labeled** samples a **representation to classify** inputs.

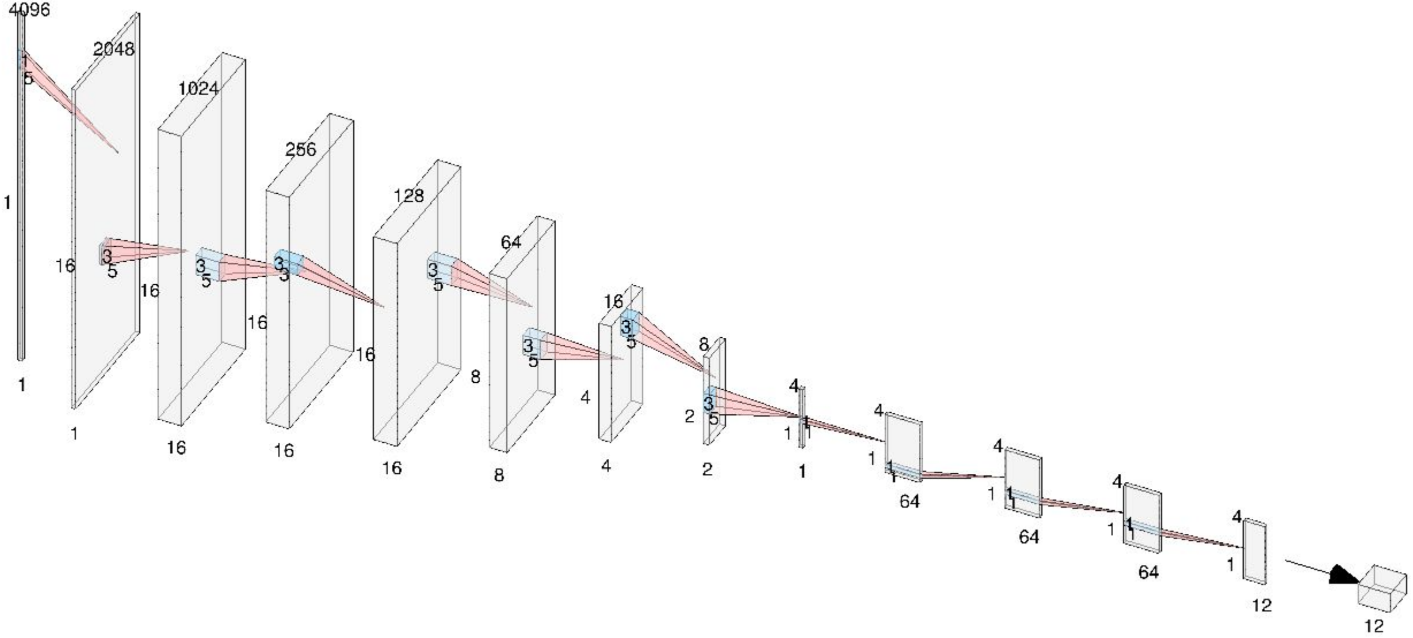




5. Classification : (b) Convolutionnal Deep Learning

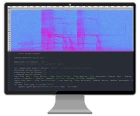
Neural network architecture of the DOCC10 model

RAW
WAV
Input
signal



Output
probabilities

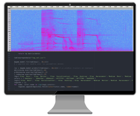
Me	0.03
Zc	0.9
Mb	0.03
La	0.001
Gg	0.01
Gma	0.01
Ssp	0.00
UDA	0.008
UDB	0.01
Pm	0.001



5. First results on Carimam

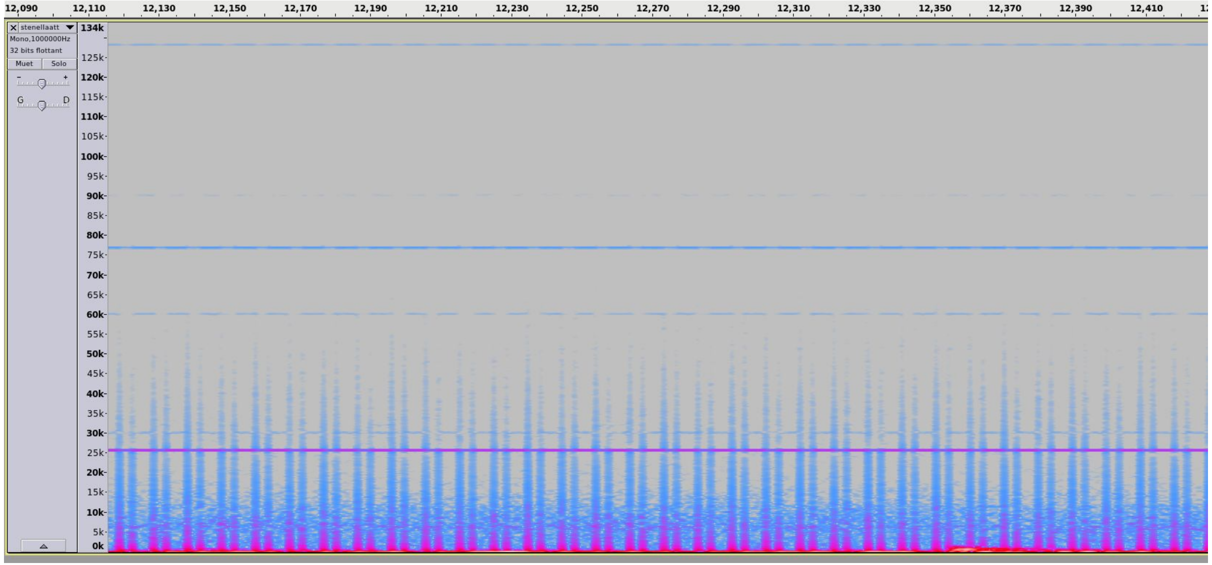
Training dataset made by CARI'MAM

Characteristics	Why is it not convenient yet ?
Sampling rate ranging from 128 Hz to 1 MHz	Resampling can generate learnable artifact
Each species has a specific recording device associated	The network could learn to discriminate using the background noise
Weak label	Unusable if the cue rate is too small
Unbalanced classes	Smaller classes will be overfitted

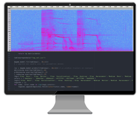


5. First results on Cariman

Training dataset made by CARI’MAM



stenellaattenuata_137105_mtq_aqs_20112016_17.wav showing various noises band at 25, 75 kHz and some impulsions.



5. First results on Carimam

DCLDE dataset

Characteristics

3 To

Sampling rate at 200 kHz

Multiple site location per species / site are not species specific

Weak label

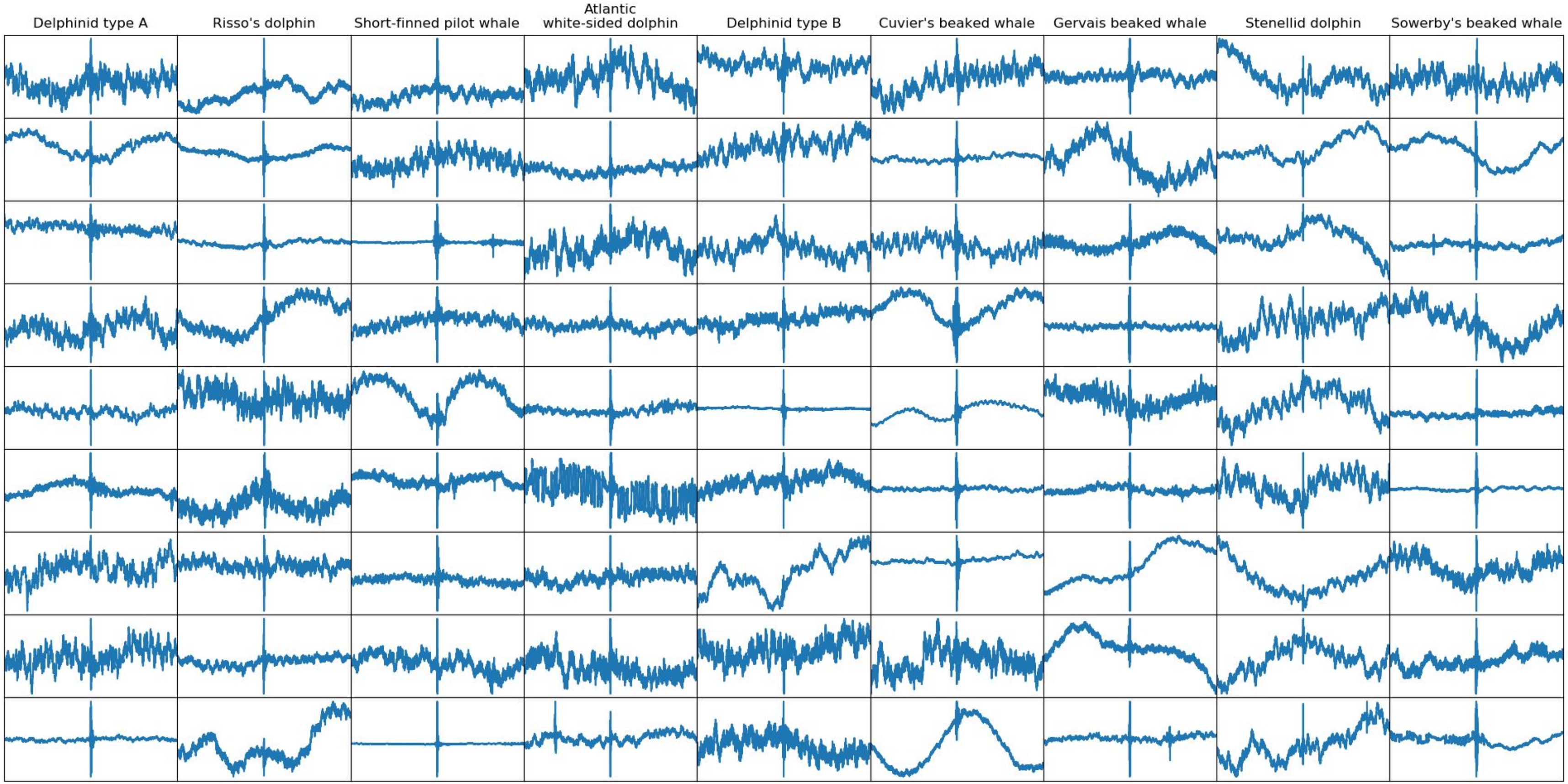
Almost balanced classes

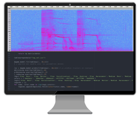
How to improve week label

1) Tk based detector
2) Discard samples with multiple labels
3) Filter on the centroid of the clicks

5. Automatic classification, first results on Cariman

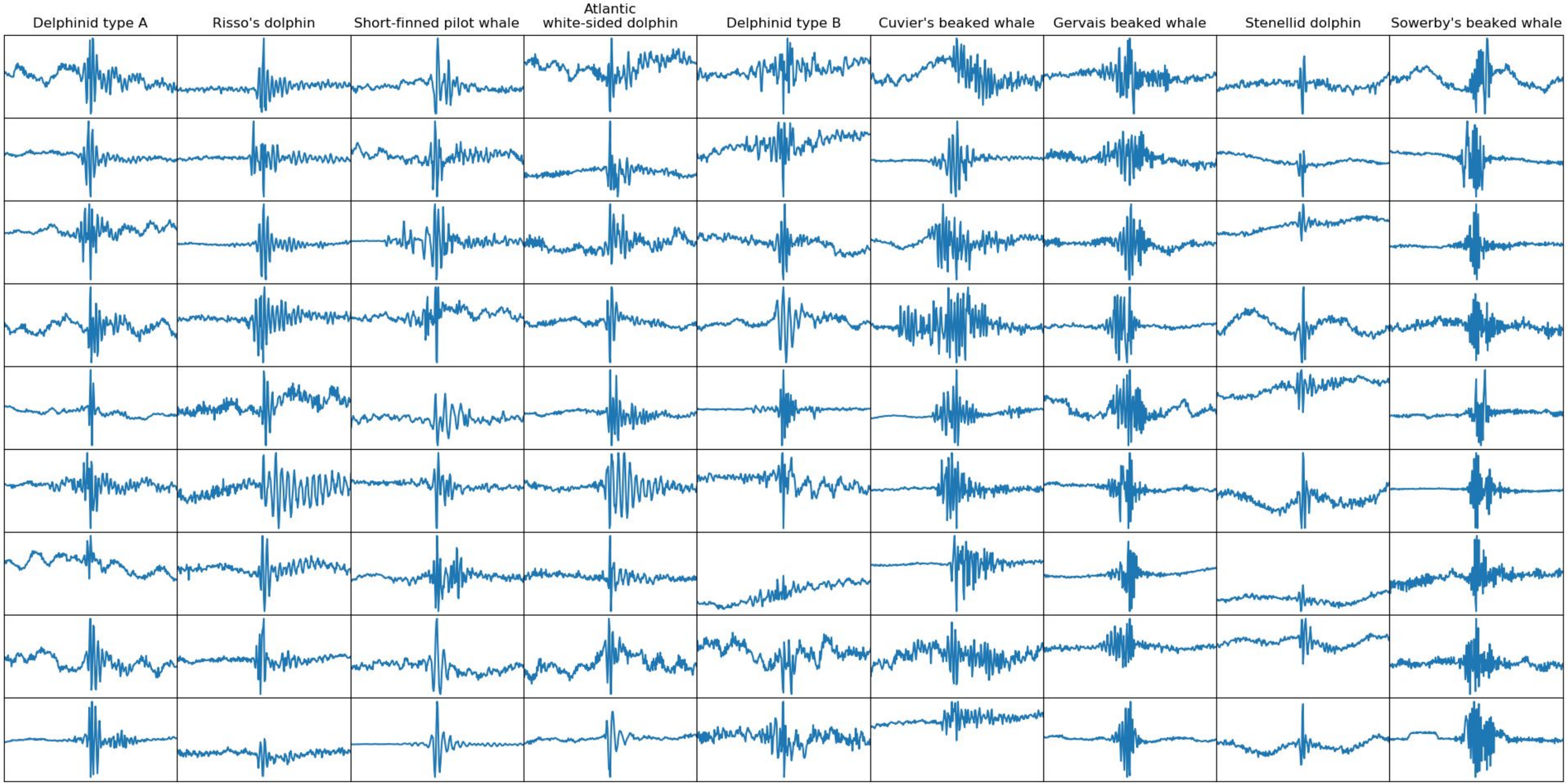
Examples of dclde test instances for each class (4096 samples long)





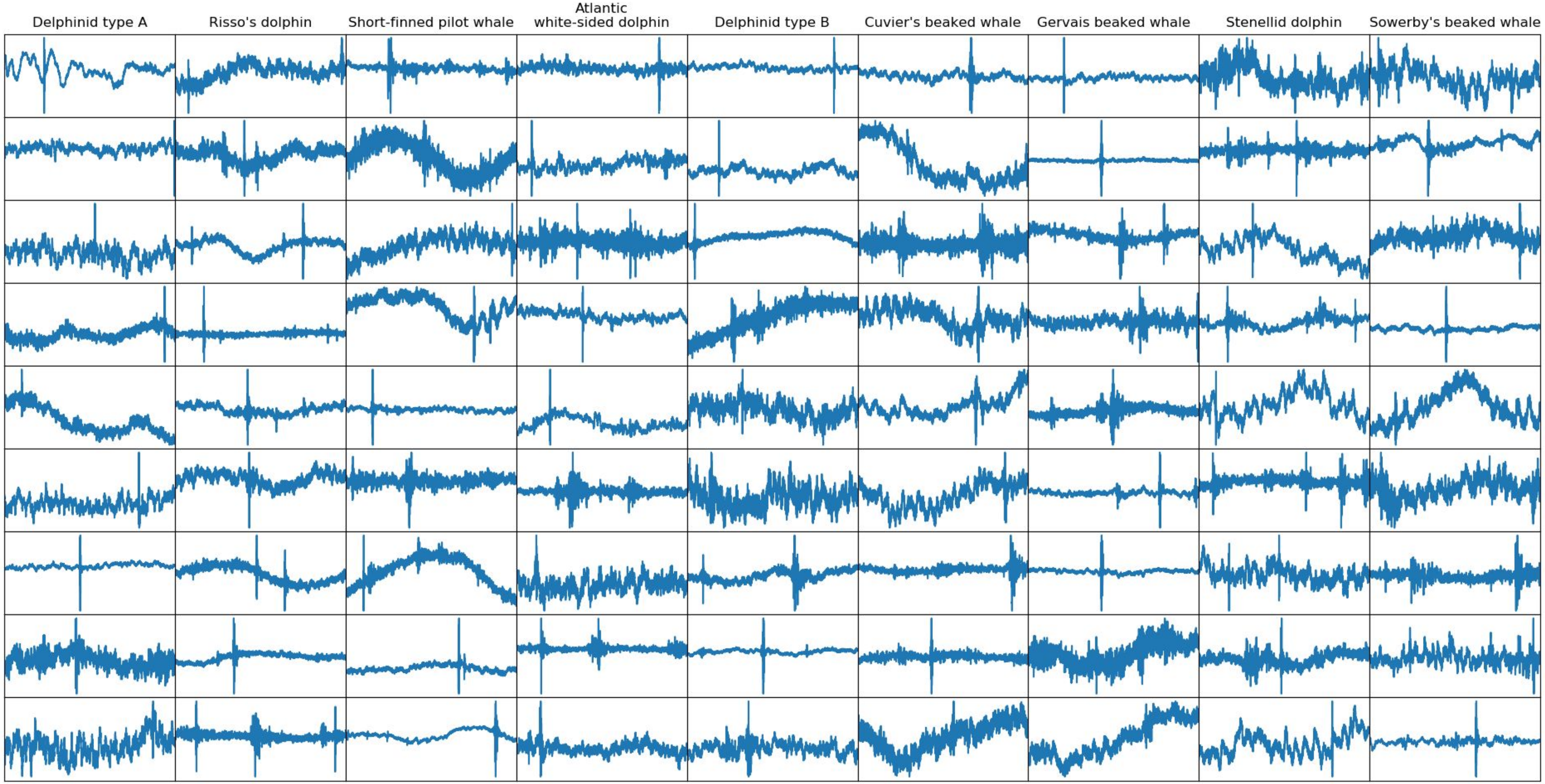
5. Automatic classification, first results on Cariman

Zoom on the 256 middle samples of the previous test instances



5. Automatic classification, first results on Cariman

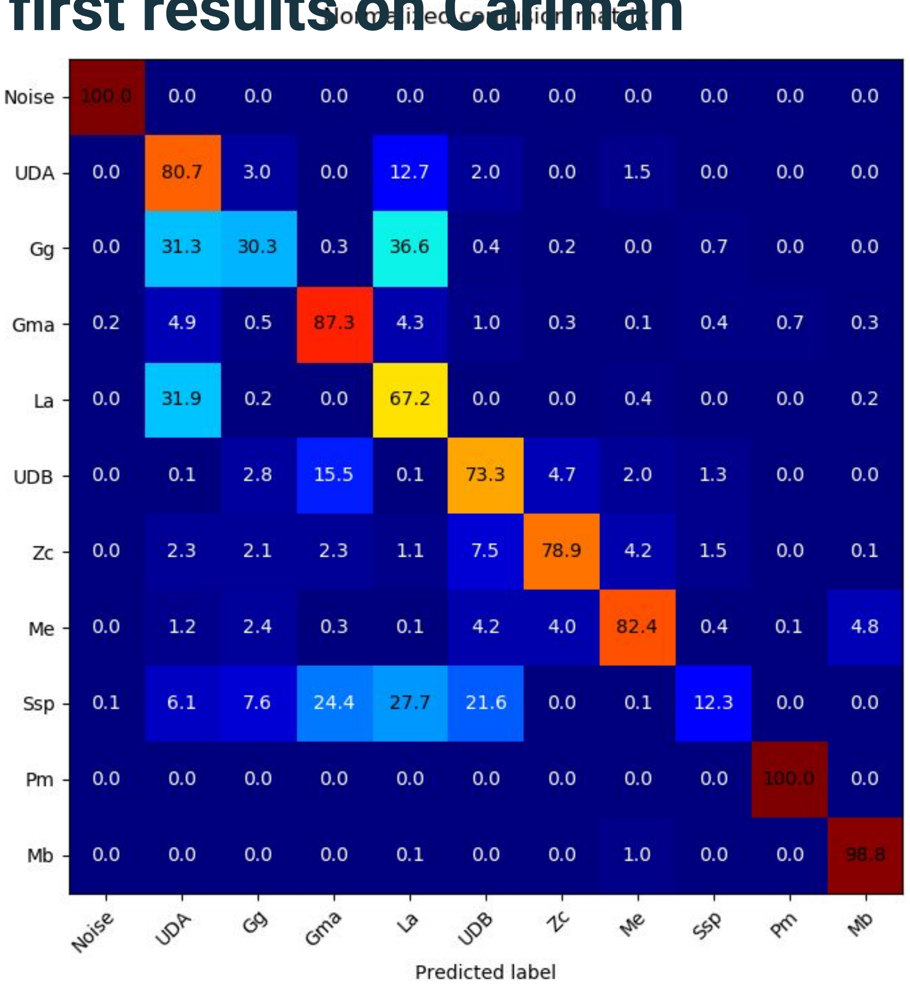
Examples of dclde training instances for each class (4096 samples long)



5. Automatic classification, first results on Cariman

First results - DCLDE test set (12Go)

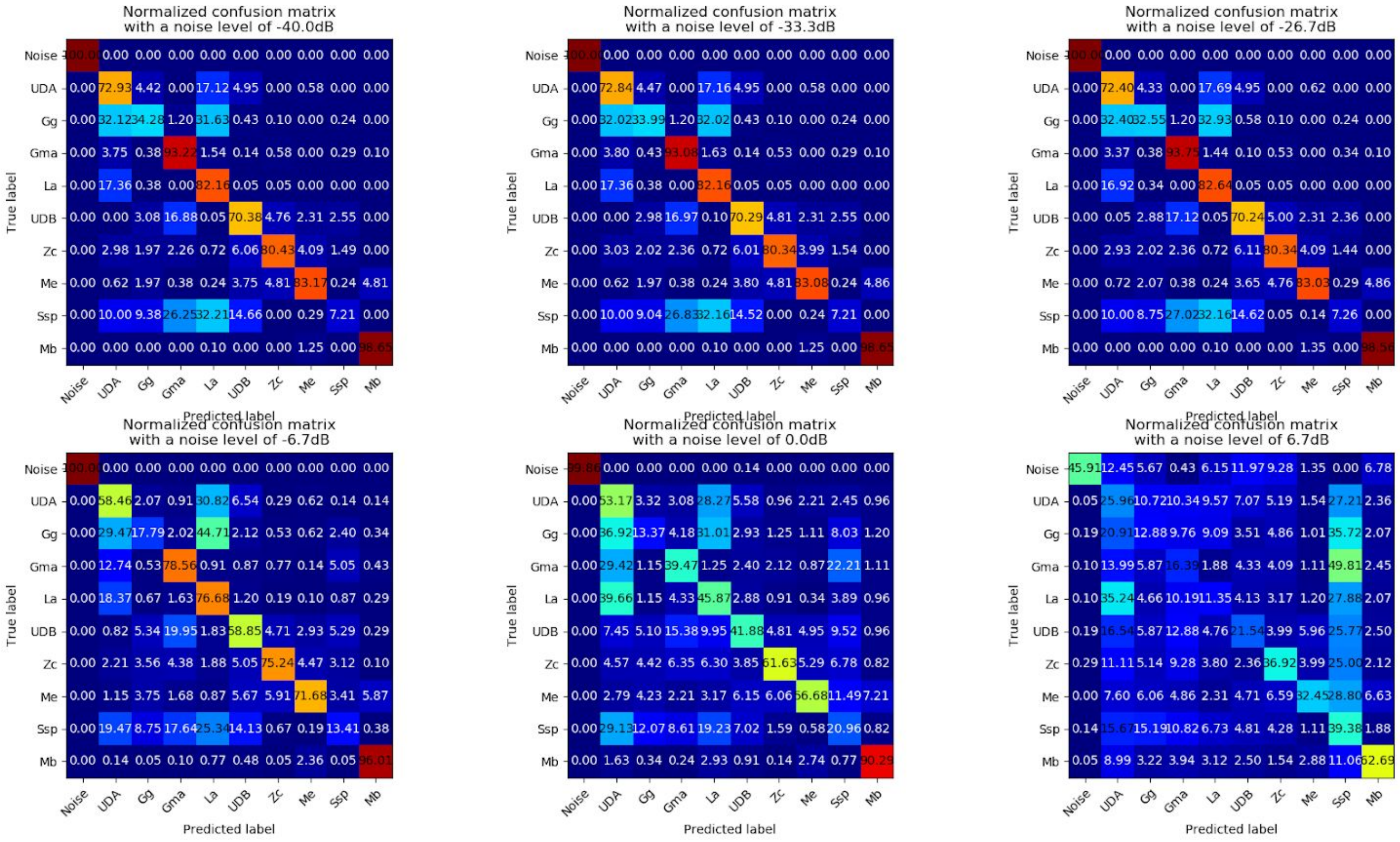
Abbreviation	Species
Me	*Mesoplodon europaeus*- Gervais beaked whale
Zc	*Ziphius cavirostris*- Cuvier's beaked whale
Mb	*Mesoplodon bidens*- Sowerby's beaked whale
La	*Lagenorhynchus acutus*- Atlantic white-sided dolphin
Gg	*Grampus griseus*- Risso's dolphin
Gma	*Globicephala macrorhynchus*- Short-finned pilot whale
Ssp	*Stenella sp.*Stenellid dolphin
UDA	Delphinid type A
UDB	Delphinid type B
Pm	*Physeter macrocephalus*- Sperm whale



5. Automatic classification, first results on Cariman

Effect of NOISE :

High to Low Signal to Noise Ratio

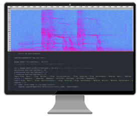


5. Automatic classification, first results on Cariman

Famille	Nom vernaculaire	Nom scientifique
Balaenopteridae	Rorqual à bosse	*Megaptera novaeangliae*
	Petit rorqual	*Balaenoptera acutorostrata*
	Rorqual tropical	*Balaenoptera edeni*
	Rorqual boréal	*Balaenoptera borealis*
	Rorqual commun	*Balaenoptera physalus*
Physeteridae	Grand cachalot	*Physeter macrocephalus*
Kogiidae	Cachalot nain	*Kogia sima*
	Cachalot pygmée	*Kogia breviceps*
Ziphiidae	Baleine à bec de Gervais	*Mesoplodon europaeus*
	Baleine à bec de Cuvier	*Ziphius cavirostris*
	Baleine à bec de Blainville	*Mesoplodon densirostris*
	Baleine à bec de True	*Mesoplodon mirus*
Delphininae	Grand dauphin	*Tursiops truncatus*
	Dauphin tacheté pantropical	*Stenella attenuata*
	Dauphin tacheté Atlantique	*Stenella frontalis*
	Sténo rostré	*Steno bredanensis*
	Dauphin de Fraser	*Lagenodelphis hosei*
	Dauphin à long bec de l'Atlantique	*Stenella longirostris*
	Dauphins bleu et blanc	*Stenella coeruleoalba*
	Dauphin de Clymene	*Stenella clymene*
	Dauphin commun	*Delphinus delphis*
Globicephalinae	Péponocéphale	*Peponocephala electra*
	Dauphin de Risso	*Grampus griseus*
	Globicéphale tropical	*Globicephala macrorhynchus*
	Globicéphale noir	*Globicephala melas*
Orcininae (Globicephalinae)	Orque épaulard	*Orcinus orca*
	Orque naine	*Feresa attenuata*
	Pseudorque	*Pseudorca crassidens*

Merging in groups : for simplicity of illustration
we merge the probabilities of species into these 7 groups

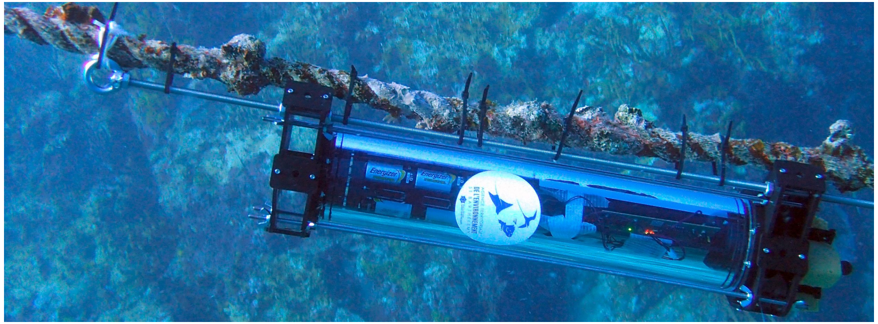
(except Kogiidae which is not yet represented)



5. First results on Cariman

HighBlue Mono recorder

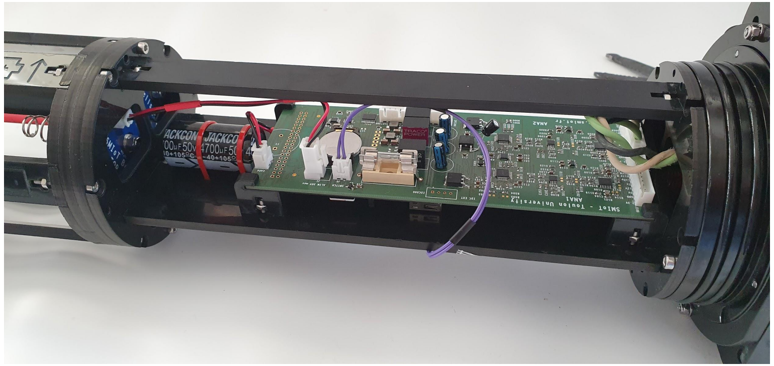
- 24 bits / 16 bits / 8bits mono channel
- Sampling frequency up to 512 ksps.
- Easy schedule of recording sessions
- SD storage : up to 512 GB
- 7 to 28 D -type (24Wh) batteries
- Up to 28 batteries in 56cm tube



5. First results on Cariman

The sound card

Qualilife sound: high performance
audio extension board
high performance anti-aliasing filter
Analog pre-filtering
Direct HDD USB recording



Hydrophone

C75
omnidirectional
high freq. answer
(200 kHz)

3 sets

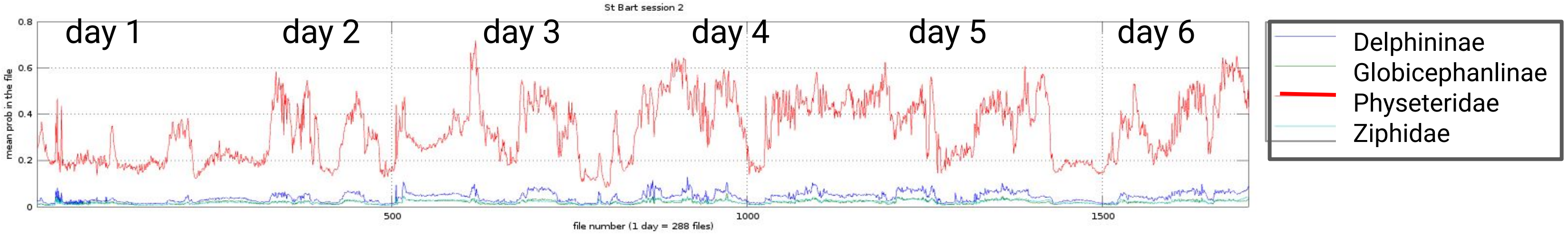
SABA 2nd to 12th of April 2019
St Barth 1 : 26th March to 3rd April 2019
St Barth 2 : June 2019

Result :
Presence of Humpback in SABA and St Barth 1

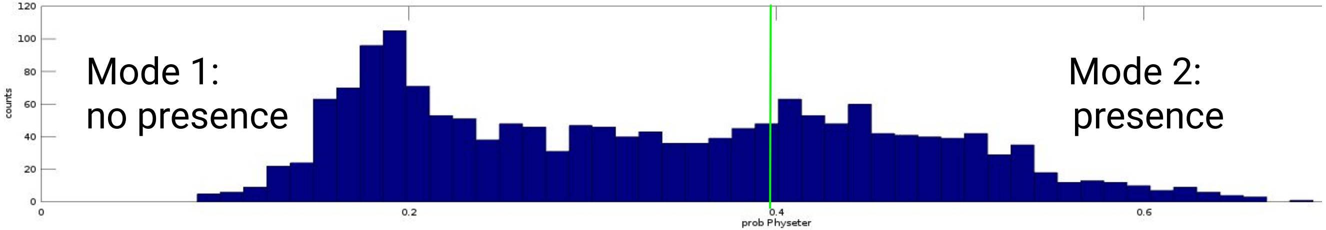
Presence of Physeteridae in St Barth 2 (days 4 & 5), nursery ?

5. Automatic classification, first results on St Barth 2

Probability of each classes but the noise class

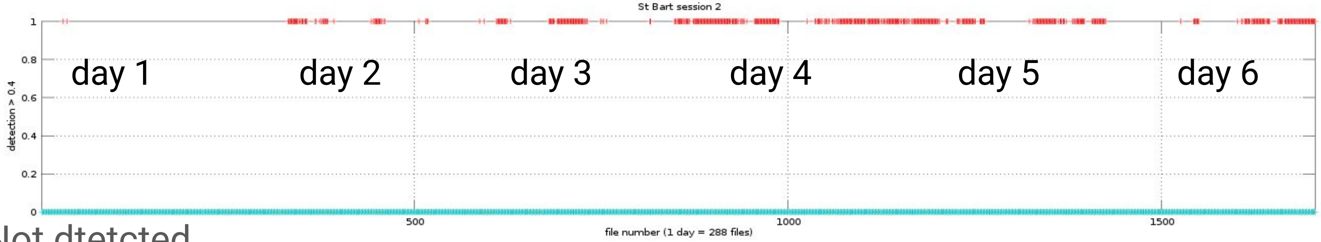


Distribution of the probability of the sperm whale class



Detected

Thresholding: Detection for each species

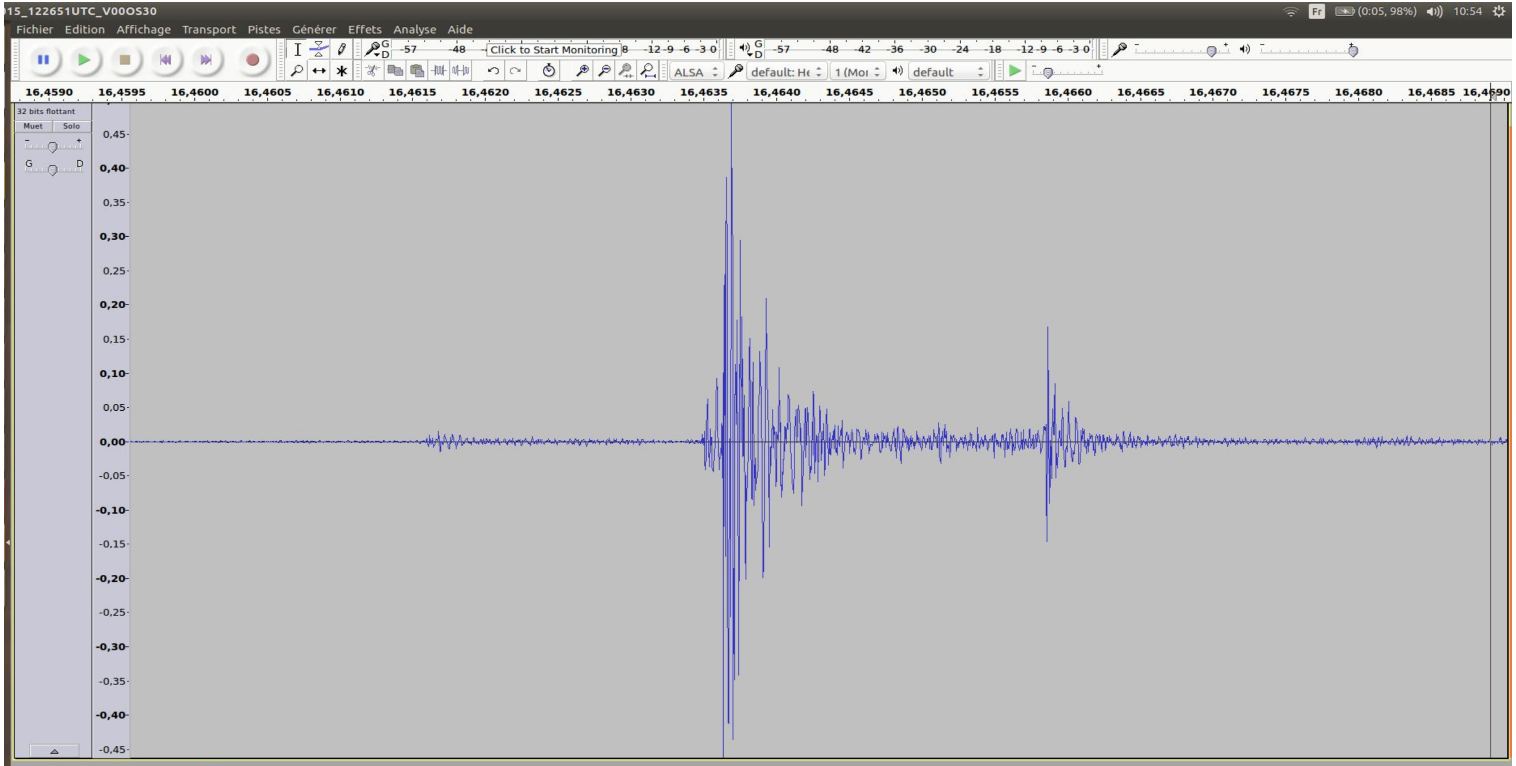


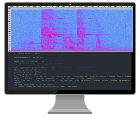
Not dtetcted

5. Automatic classification, first results on St Barth 2

St Barth. session 2 : Classification and detection of Physeter macrocephalus Validation in day 4 :

IPI
~
2ms

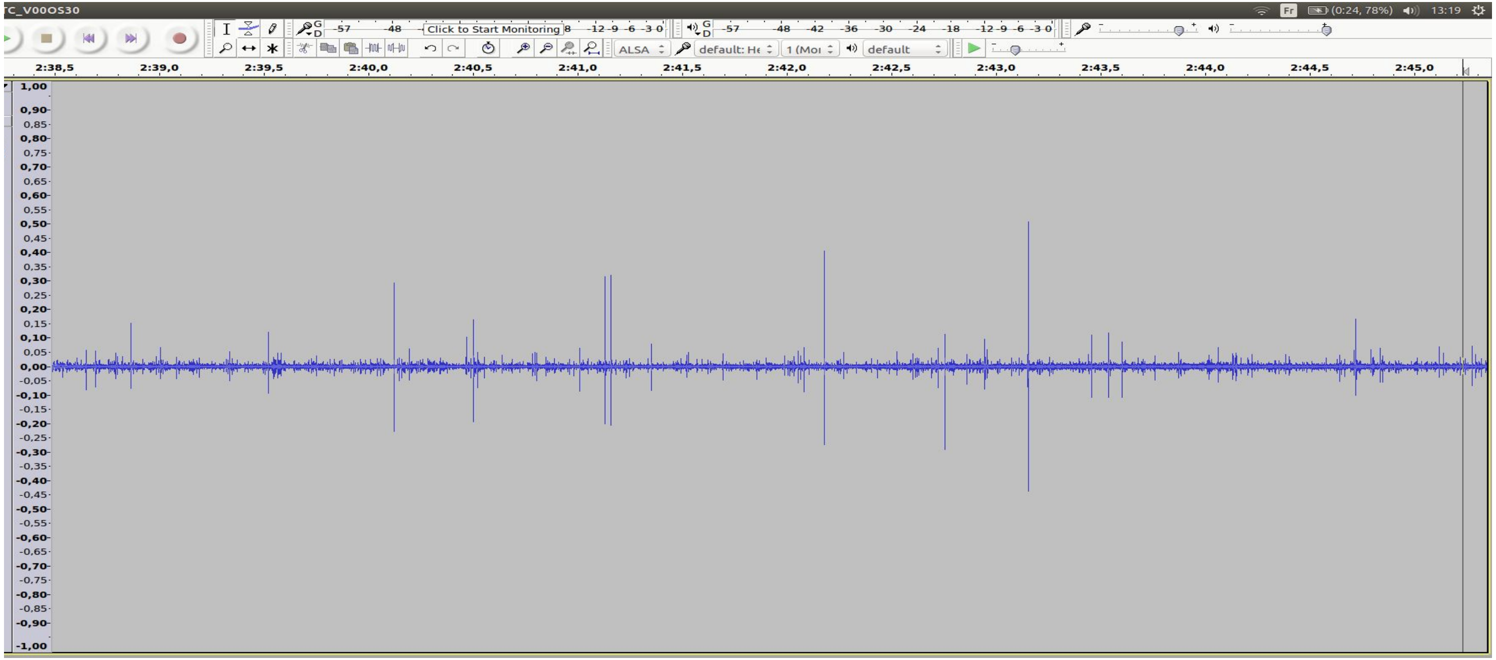


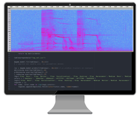


5. Automatic classification, first results on St Barth 2

Click train of Physter in St Barthelemy

Inter
Click
Interval
~
1 sec

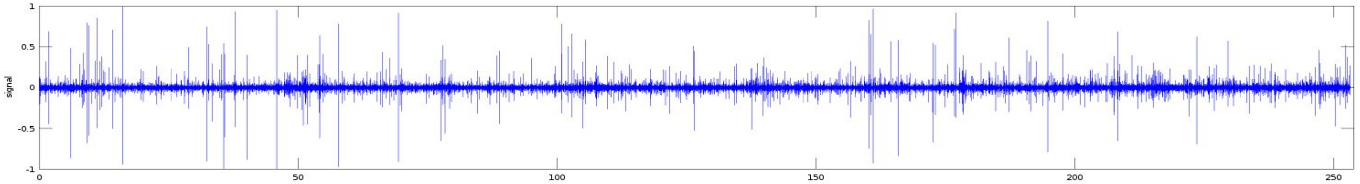




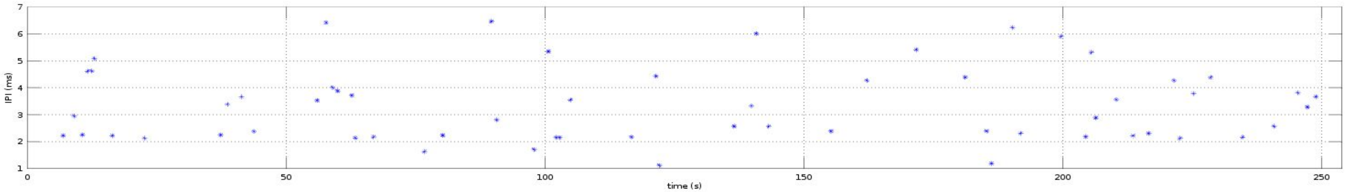
5. Automatic classification, first results on St Barth 2

Physeter IPI distribution on St Barthelemy : small individuals nursery ?

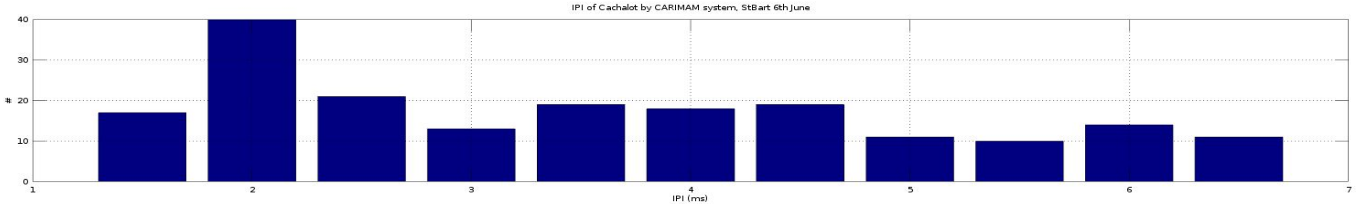
signal



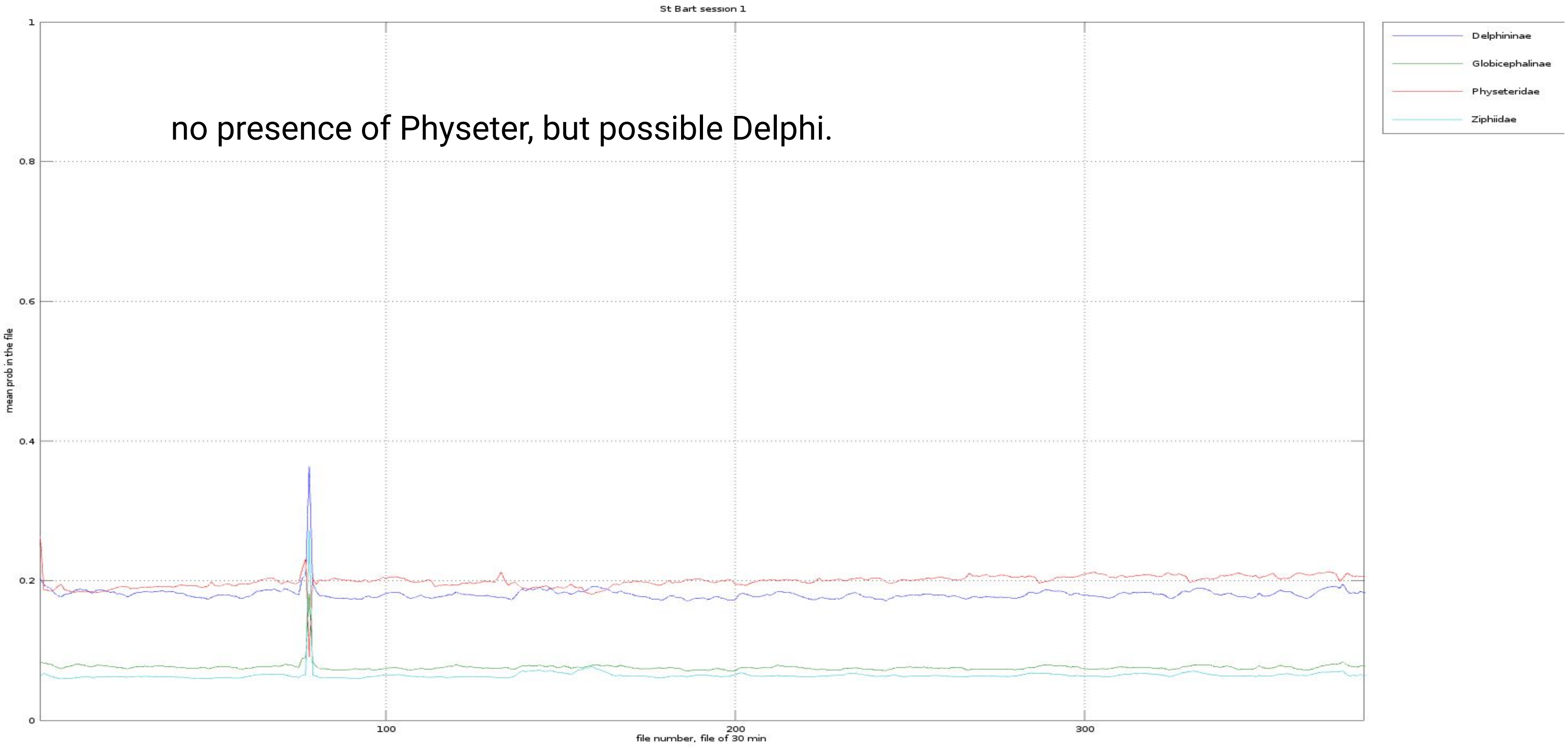
IPI
(from AC)

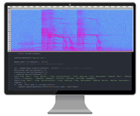


Distribution



5. Automatic classification, first results on St Barth session 1



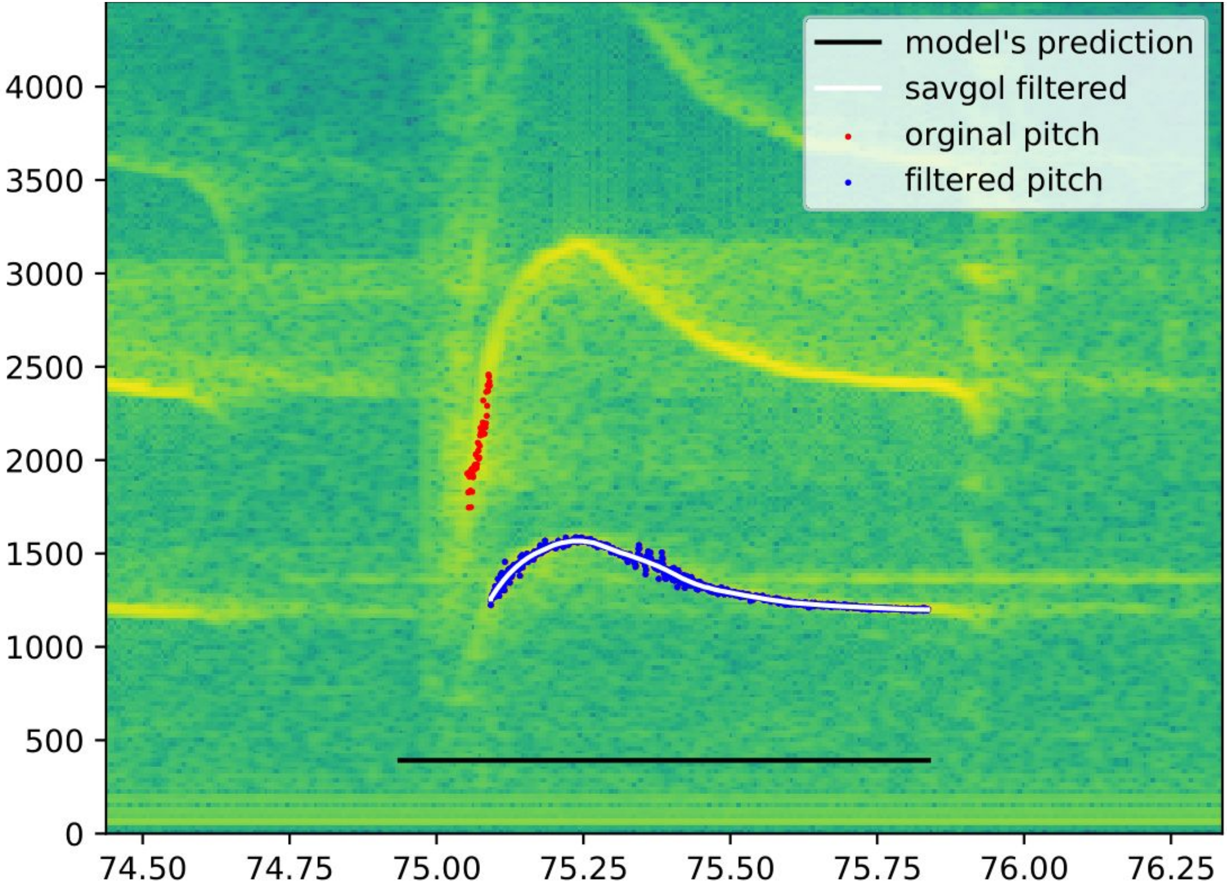


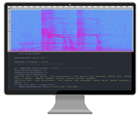
5. Automatic classification, time frequency tracking

Voicings can be automatically extracted to classify the different species.

Blue whale : [10 , 50] Hz
Fin whale : [30 , 80] Hz
Megaptera n. : [400 , 8000] Hz
Orca : [2000, 20000] Hz (here :)

We have developed such tools for CARIMAM.



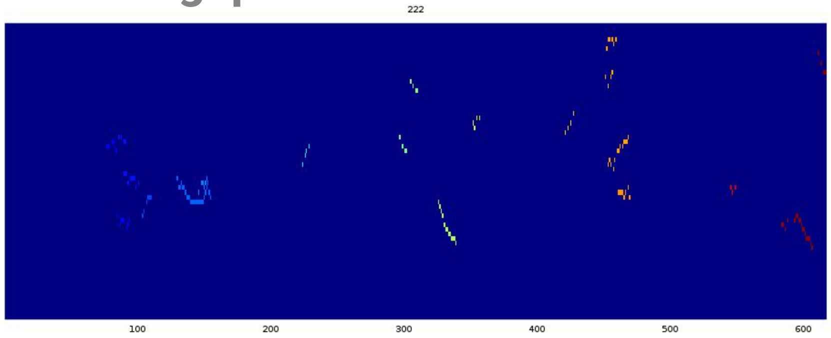


5. Automatic classification, first results on SABA

St Bart session 1 & SABA : Classification of Megaptera n.

Voicings are automatically extracted also at low SNR with local TF tracking.

Filtering

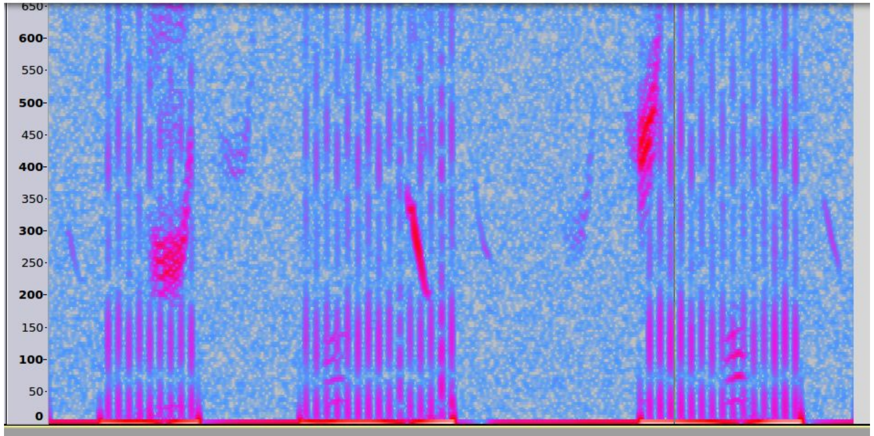


CARIMAM SABA

file 222

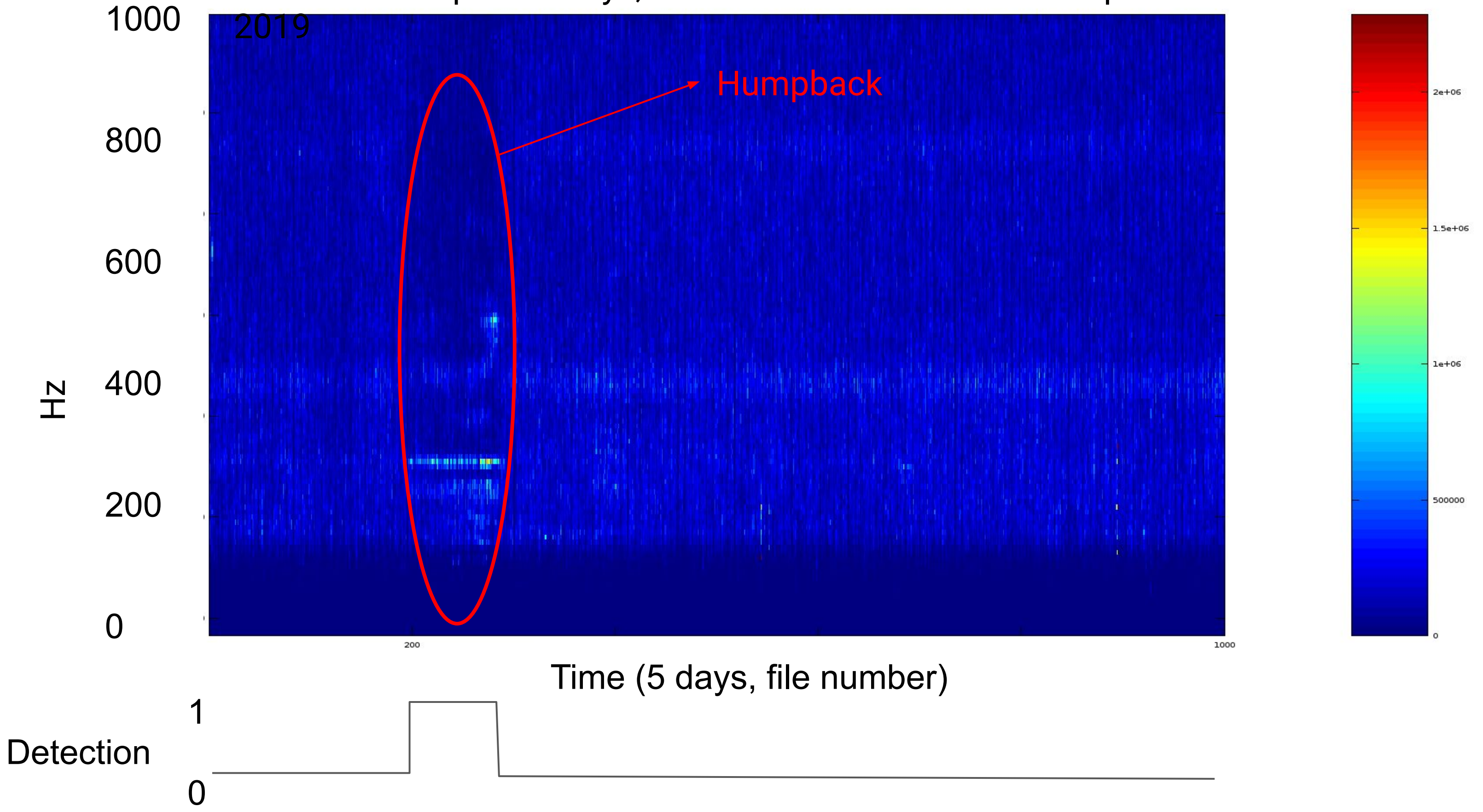
Then we follow by a neighbour search in time frequency domain voicing.

Results are given here with classification of Megaptera on St Barth session 1 :



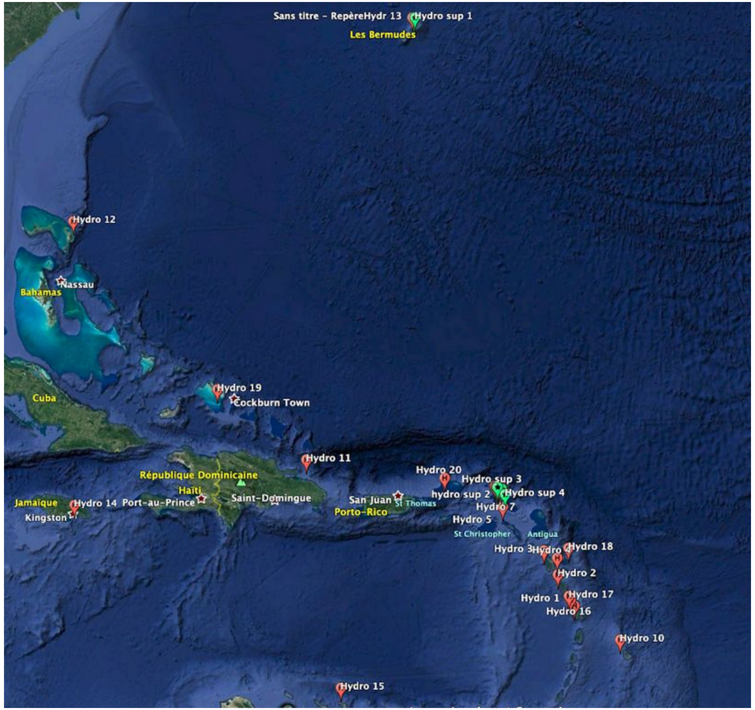
5. Automatic classification, first results on Cariman

Result on complete 2 days, full time of SABA 2nd to 4th April 2019



5. Perspectives : Network of joint observations

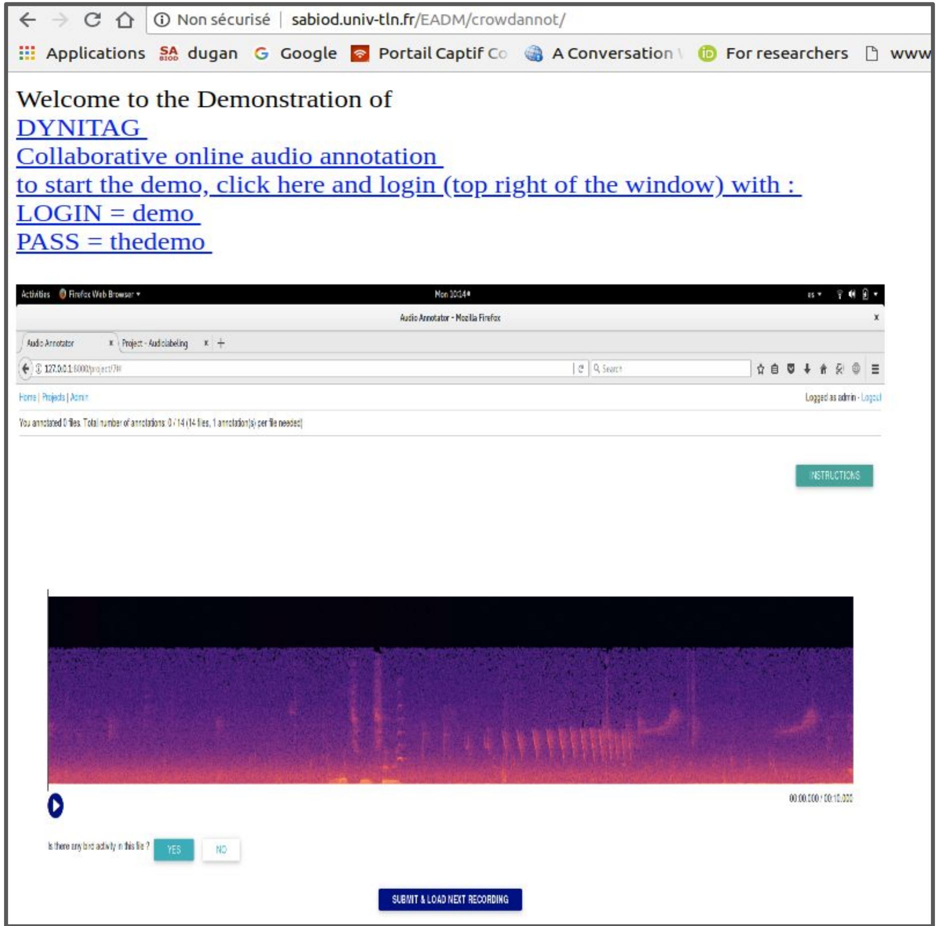
Maps of the study area : There will be joint observations between several stations

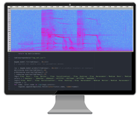


5. Perspectives : Online collaborative validation

Importance of collaborative annotations for data set construction

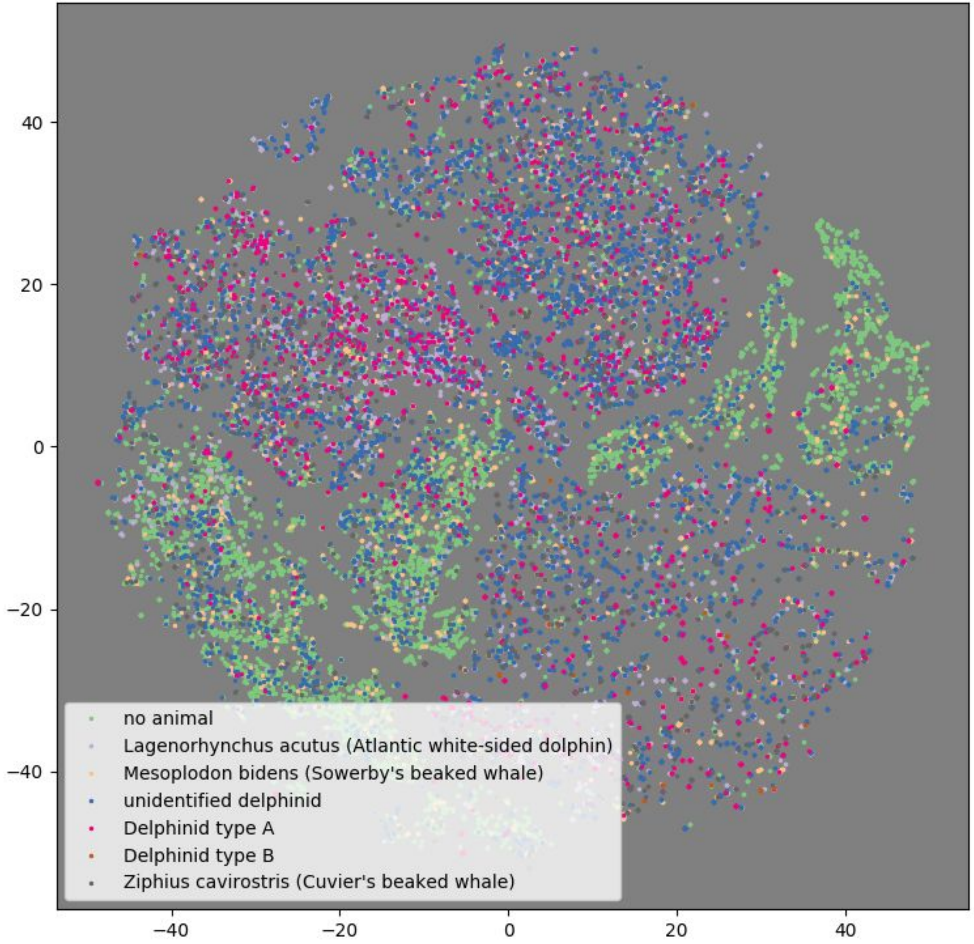
=> Crowd annotation, online tools : Dynitag



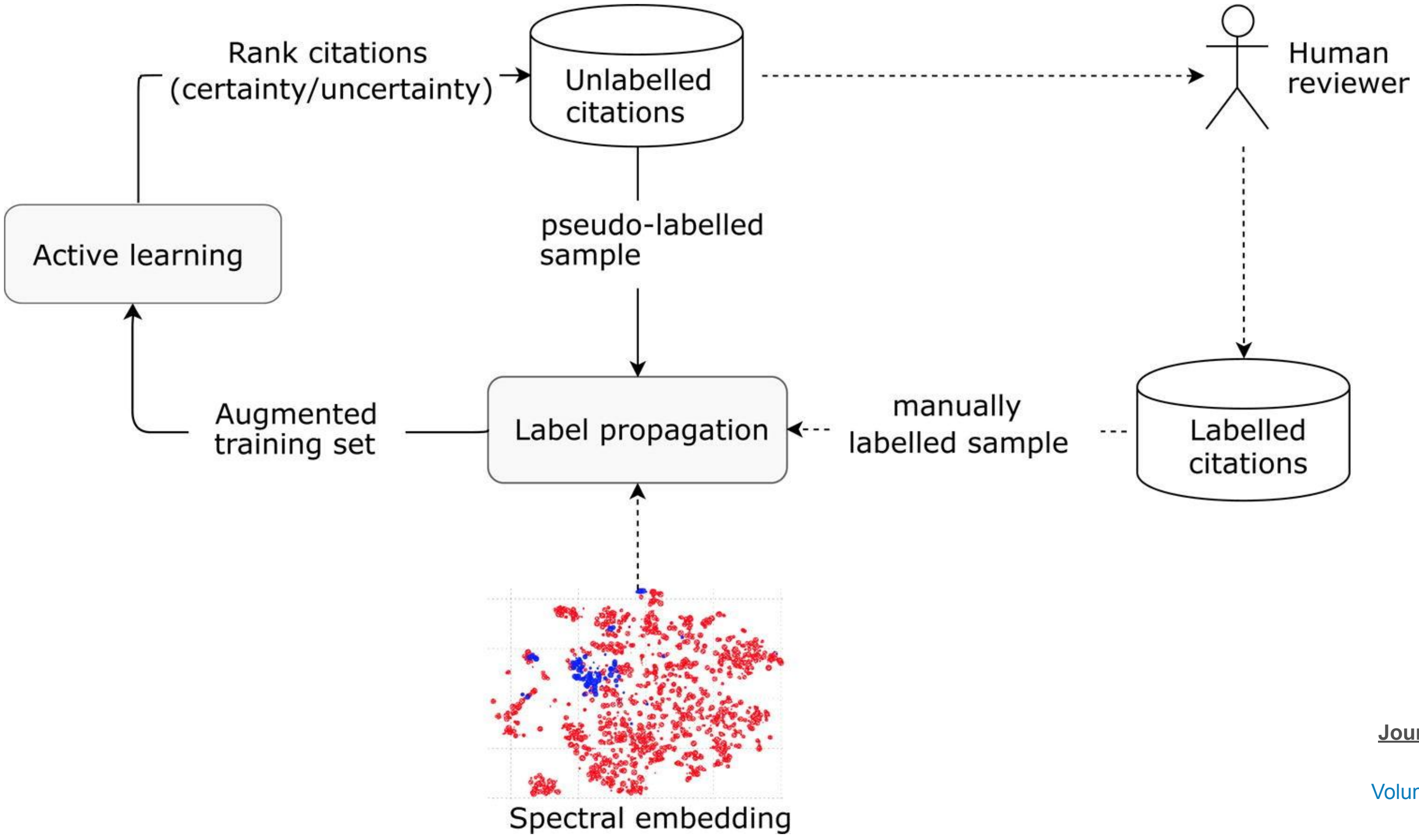


5. Perspectives : unsupervised approach & crowd annotation

Projection from raw audio
of clicks of DCLDE (will be
Carimam), showing
groups that are partialy labeled :
crowd annotation
will add label of the centroids
and we will propagate labels
(Schlüter Glotin 2019)



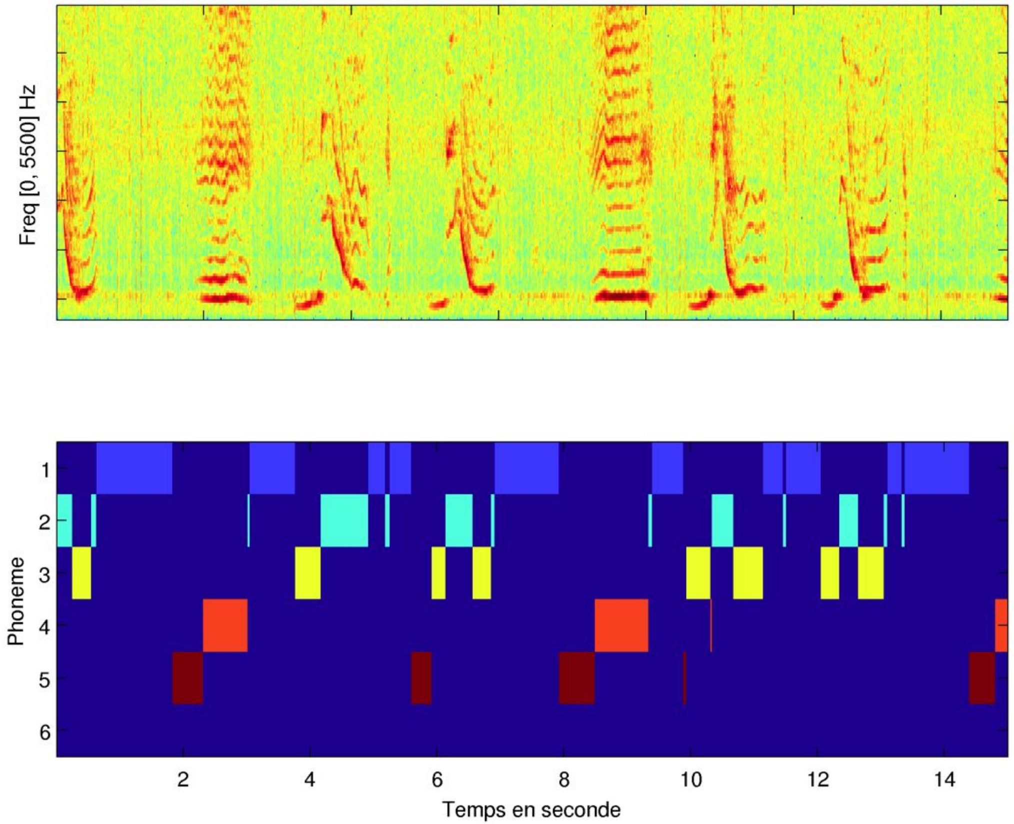
5. Perspectives : semi-sup and active learning in Carimam

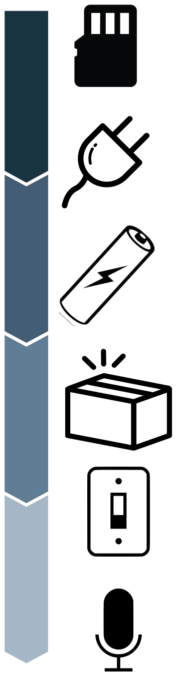


Journal of Biomedical Informatics
Volume 72, August 2017,
Pages 67-76

5. Perspectives : unsupervised approach and song analysis

Automatic
writting of the score
of the song
(Bartcus, Glotin 2015)





6. Explanation of the material and the experiment

Hervé Glotin
Maxence ferrari
Marion Poupard

Steps for the installation

Step 1

Set up the hydrophone and transport to the mooring

Step 2

Deploy underwater and retrieve after 40 days

Step 3

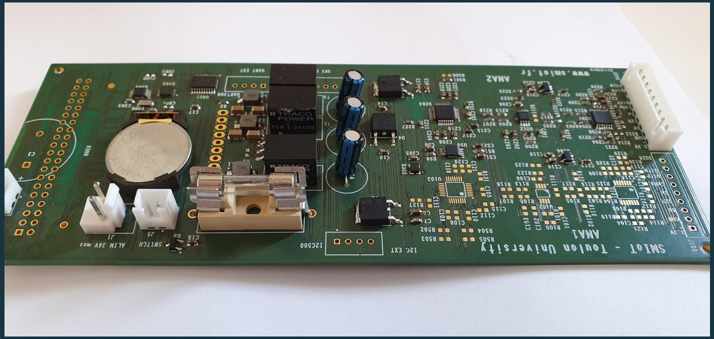
Make a local copy of the data and send a hard drive with the 2nd copy in France

Step 4

Store in a secure place and Repeat

Step 1: Set up the hydrophone and transport to the mooring

- SD card information
- Electrical connections
- Setting up the batteries
- Close the tube
- Turn on the switch
- Setting up the hydrophone



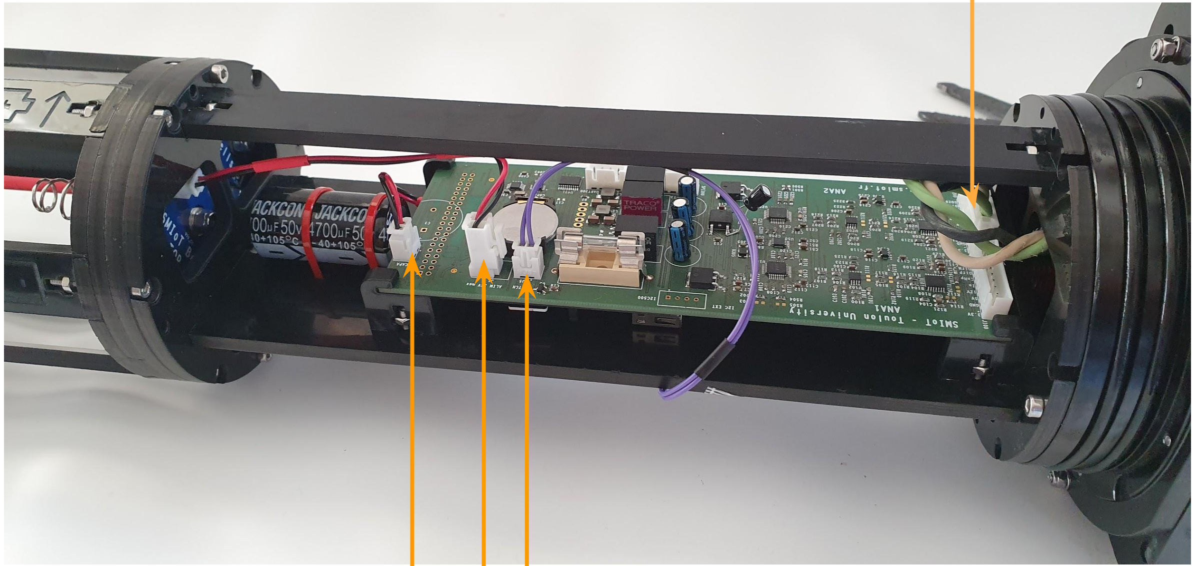
SD card informations : set up of the card

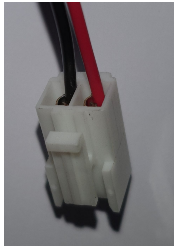
```
// uSD operating system

Sampling_Resolution=16;
Sampling_Freq=512000;

Filter_Selection=1;
AutoStart=true;
FILE_Size_Limit=150000000;
Record_Use_TimeInterval=true;
Record_Time=60;                        //records 1 min then stops
Record_Interval=300;                   //stops 5 min then records
```

The script must be like this one

SD card

Electrical connection





Setting up batteries

First row

Second row

Third row in the center

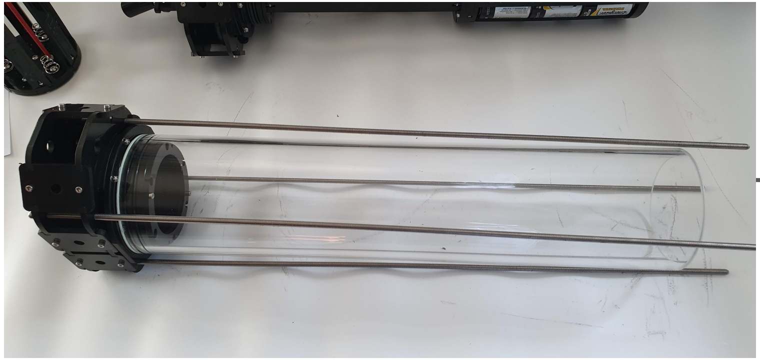
Raise the second row

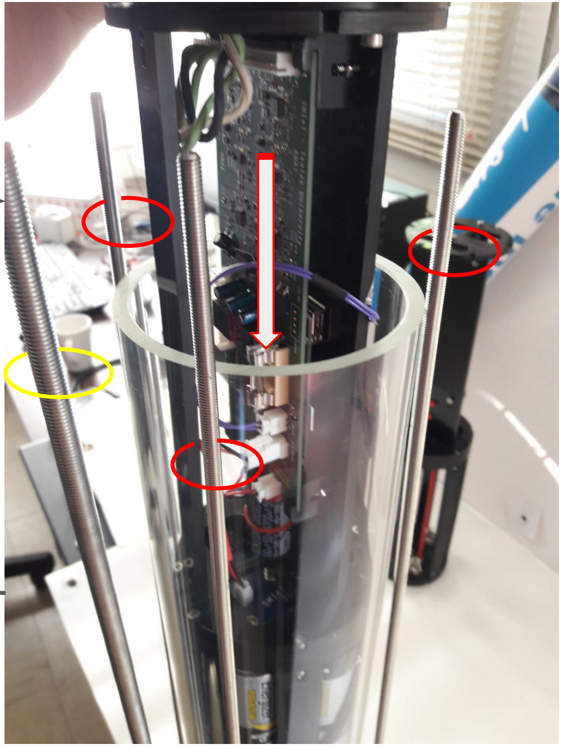
Introduce the third stack in the middle *

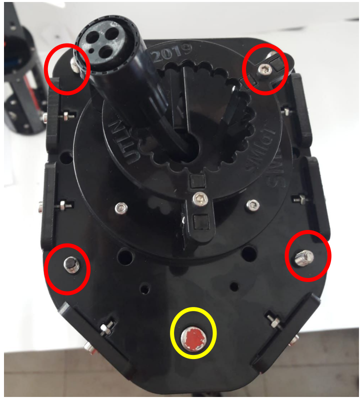
Repeat * 5 times

Ribbon on the last stack

Close the tube

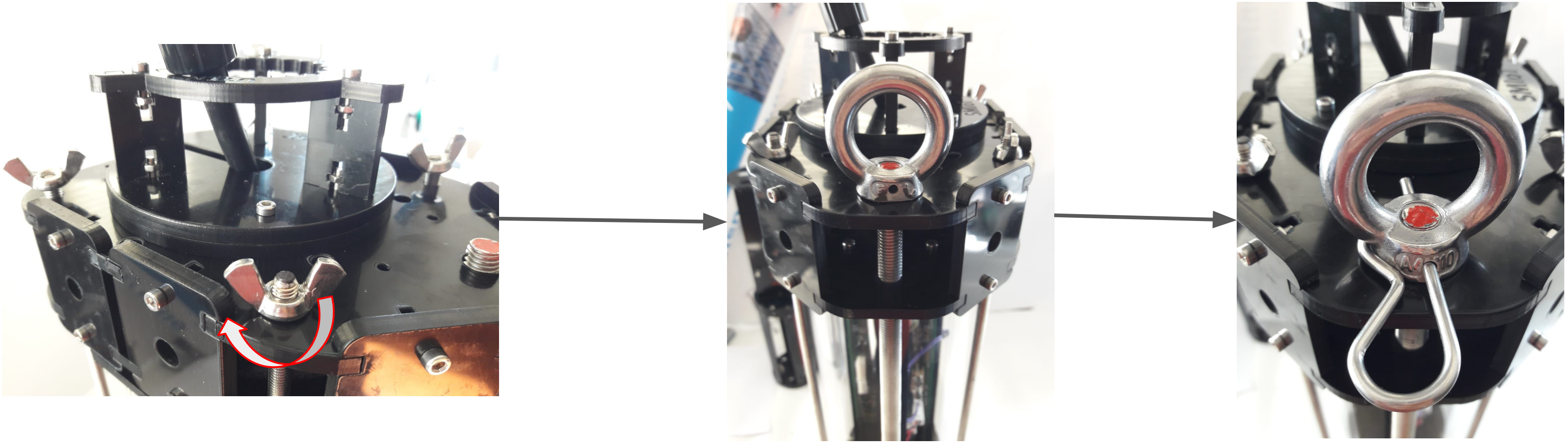






Slide the assembly into the tube with the 4+1 threaded shaft

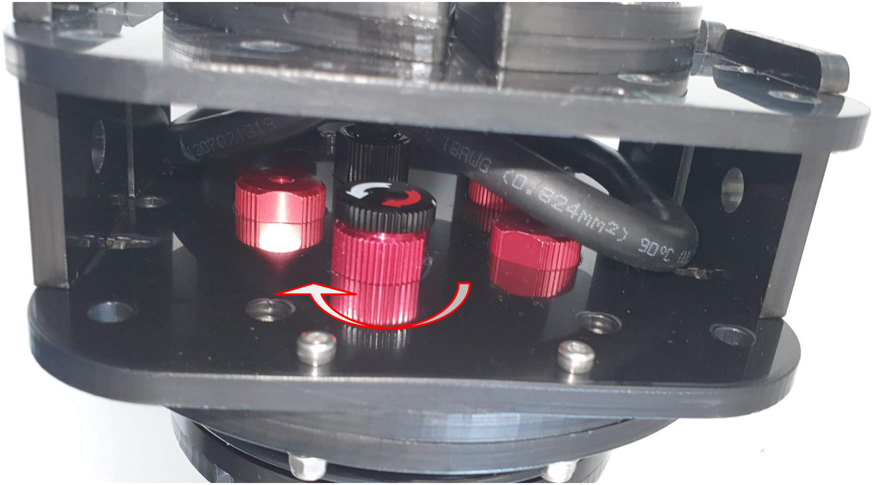
Close the tube



- Screw the upper nuts (4) + the big screw (ring)
- Put the locking pin

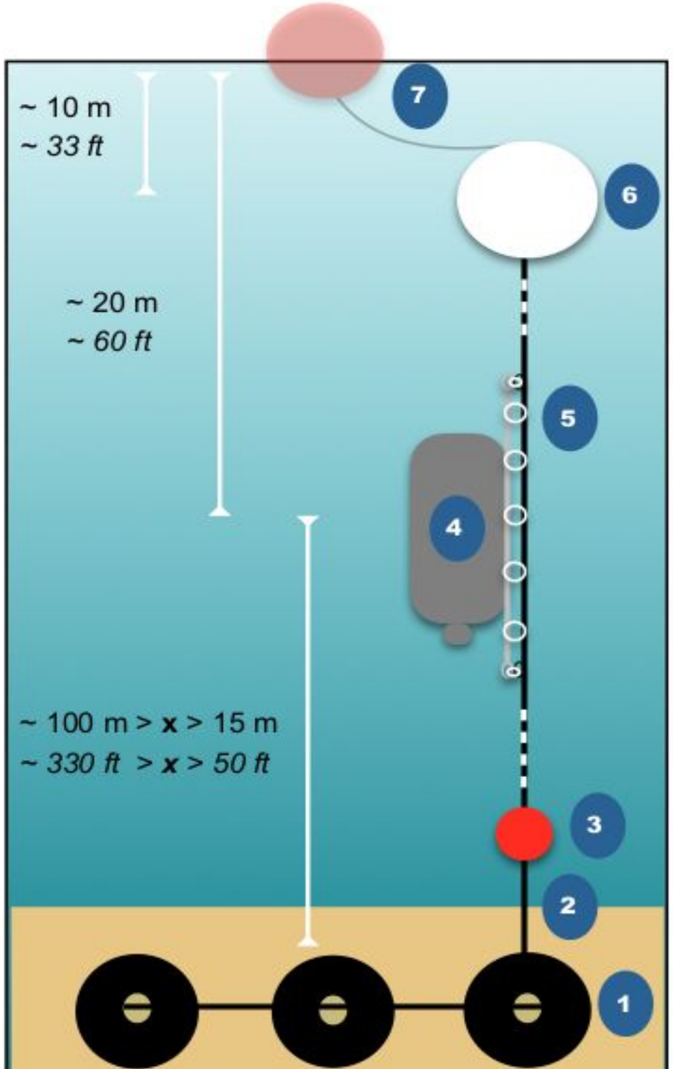
Turn on the switch

- Turn the switch all the way to turn on the card
- Check that there are orange and green LED



Setting up the hydrophone

Do not expose to direct sun.

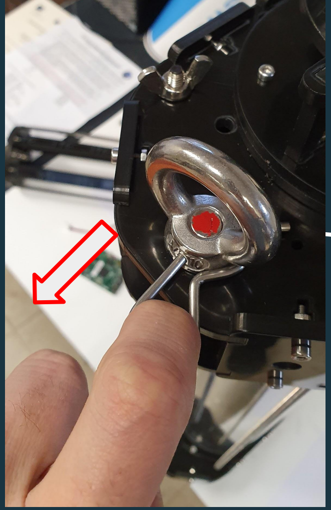


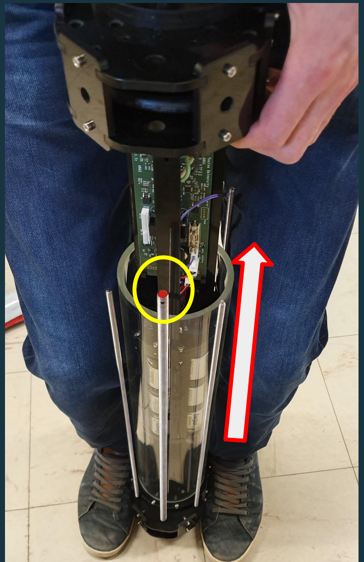
Set up the Station

1 - Rugged Barvell plates (20kg) as an anchor: easy to handle on boat and sustainable underwater.
2 - Dyneema rope: good resistance for low drag
3 -Deep water-adapted low volume buoy to avoid entanglement
4 - JHB hydrophone system at a depth accessible to divers (20m) at mid depth (far enough from the bottom
5 - Zip ties to attach hydrophones to the mooring line
6 - White sub-surface buoy
7 - Surface buoy

Step 2: Retrieve after 40 days

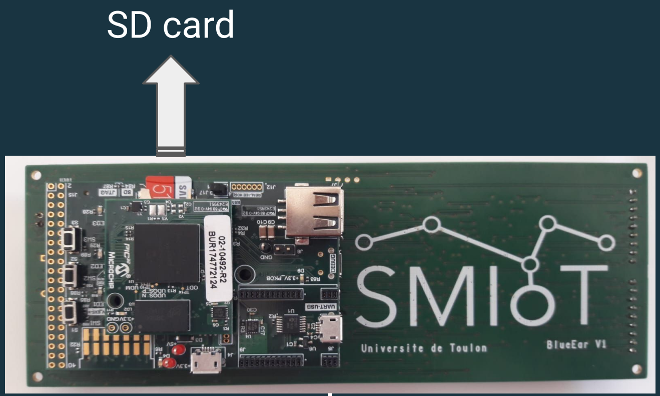
- Open the tube after being dried
- Remove the split pin
- Unscrew the axle nut
- Check that there is no water inside the tube
- Open the tube



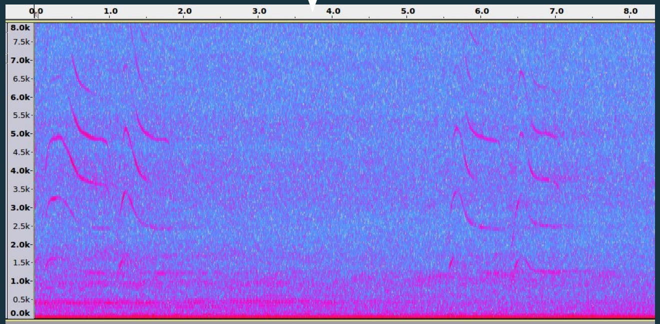


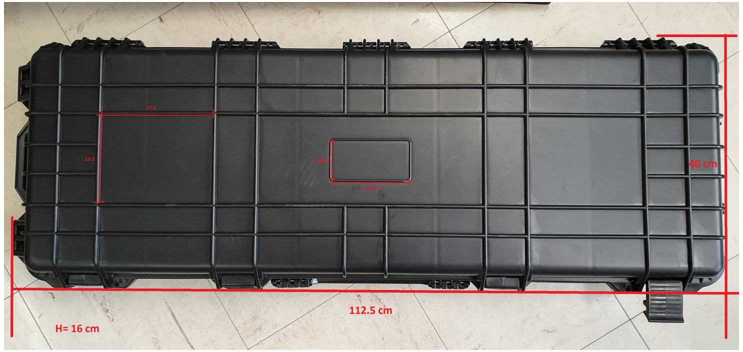
Step 3:Retrieve data, copy, and prepare new installation

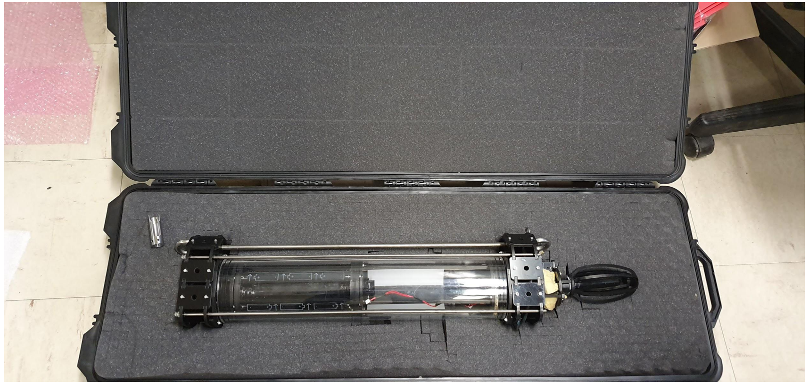
- Remove the uSD card
- Make a local copy of the data, keep it in a safe place (dry, no sun, medium temp.)
- Make and send another copy to France
- Open the sound with Audacity to check the quality of the signal
- Prepare the uSD for the next recording (check scripts and clear .wav files)
- Reset the clock (UTC) of the recorder before to reinstall it, so all stations of CARI’MAM are always synchronous.



Name	Size	Type	Modified
20190731_200829UTC_V03OS30.wav	180,0 MB	Audio	sept. 12
20190731_201026UTC_V03OS30.wav	180,0 MB	Audio	sept. 12
20190731_201223UTC_V03OS30.wav	180,0 MB	Audio	sept. 12
20190731_201421UTC_V03OS30.wav	180,0 MB	Audio	sept. 12
20190731_201618UTC_V03OS30.wav	180,0 MB	Audio	sept. 12
20190731_201815UTC_V03OS30.wav	180,0 MB	Audio	sept. 12
20190731_202012UTC_V03OS30.wav	180,0 MB	Audio	sept. 12
20190731_202209UTC_V03OS30.wav	180,0 MB	Audio	sept. 12
20190731_202406UTC_V03OS30.wav	180,0 MB	Audio	sept. 12
20190731_202603UTC_V03OS30.wav	180,0 MB	Audio	sept. 12







Step: storage of the material

- Rinse the outside of the tube and the hydrophone
- Store dry in the suitcase

Recording Interval

The final analysis yields to
1 min recording for 5 min stop,
512 kHz Sampling Rate, 16 bits
as sum up in this table.

Fe	conso record (W)	conso veille (W)	Ah par pile (*)	Voltage par pile	# piles	total energie dispo (W)	durée ON (min)	durée OFF (min)	ratio ON/TOTAL (%)	durée TOTALE run (jour)	vol. généré (Go)	durée TOTALE (jour) sur 512 Go	rem
256000	1.3	0.4	17	1.5	21.0	539.1	1	4	20.0	38.7	319.1	id	pas Kogia
256000	1.3	0.4	17	1.5	21.0	539.1	1	5	16.7	40.8	280.4	id	pas Kogia
512000	1.3	0.4	17	1.5	21.0	539.1	1	4	20.0	38.7	638.2	31.1	Kogia parfait sur 31j
512000	1.3	0.4	17	1.5	21.0	539.1	1	5	16.7	40.8	560.8	37.3	Kogia parfait sur 37j
512000	1.3	0.4	17	1.5	21.0	539.1	1	6	14.3	42.5	500.2	id	Kogia parfait sur 42j

Thank you !

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References

-Teixeira D, Maron M, van Rensburg BJ. Bioacoustic monitoring of animal vocal behavior for conservation. Conservation Science and Practice. 2019;1:e72
-Rossing, T. (Ed.). (2007). Springer handbook of acoustics. Springer Science & Business Media.
-Au, W. W., & Hastings, M. C. (2008). Principles of marine bioacoustics (pp. 121-174). New York: Springer.
-Laiolo, P. (2010). The emerging significance of bioacoustics in animal species conservation. Biological conservation, 143(7), 1635-1645.
-Teixeira, D., Maron, M., & van Rensburg, B. J. (2019). Bioacoustic monitoring of animal vocal behavior for conservation. Conservation Science and Practice, e72.
-Snaddon, J., Petrokofsky, G., Jepson, P., & Willis, K. J. (2013). Biodiversity technologies: tools as change agents.
- Sueur, J., Pavoine, S., Hamerlynck, O., & Duvail, S. (2008). Rapid acoustic survey for biodiversity appraisal. PloS one, 3(12), e4065.
-Sueur, J., & Farina, A. (2015). Ecoacoustics: the ecological investigation and interpretation of environmental sound. Biosemiotics, 8(3), 493-502.
- Au W.W.L., 1993. The Sonar of Dolphins. Springer-Verlag: 1-277
- Richardson, W. J., Greene Jr, C. R., Malme, C. I., & Thomson, D. H. (2013). Marine mammals and noise. Academic press.
- Whitehead, H. (2010). Conserving and managing animals that learn socially and share cultures. Learning & Behavior, 38(3), 329-336.
- Glotin, Pavan, Dugan, Zhao, 'Environmental Acoustic Data Mining', IEEE ICDM 2015, http://sabiod.org/eadm, Atlantic city
- Glotin, Alecu, Big Data Sciences for Bioacoustic Environmental Survey 21 and 22 April 2015, Toulon - http://glotin.univ-tln.fr/ERMITES15
- Chamroukhi, Glotin, Dugan, Clark, Artières, LeCun, et al., Proc. of the second workshop on Machine Learning for bioacoustics - Unsupervised bioacoustics ICMLulb, joint to ICML, China Beijing, to appear dec. 2014.
- Glotin, LeCun, Mallat, Artières, Tchernichovski, Halkias, Proc. of the 1st wkp on Neural Information Processing for Bioacoustics NIPS4B, joint to NIPS Alberta USA, Ed. 2013.
- Glotin, Clark, LeCun, Dugan, Halkias, Sueur, Proc. of the 1st wkp on Machine Learning for bioacoustics, ICML4B, joint to ICML Atlanta USA, 2013.
- Dugan, Zollweg, Glotin, Popescu, Risch, LeCun, Clark, High Performance Computer Acoustic Data Accelerator (HPC-ADA): A New System for Exploring Marine Mammal Acoustics for Big Data Applications, in Proc. of ICML Unsupervised learning for Bioacoustics wkp, ICMLULB2014, 2014.
-Glotin, J Ricard, R Balestriero, Fast Chirplet Transform Injects Priors in Deep Learning of Animal Calls and Speech, ICLR 2017.
- Halkias, Paris, Glotin, Machine Learning for Whale acoustic classification, Int. Journal of Acoustical Society of America, JASA, 2013, 5(5), 3496-3505