Journée Défense & Intelligence Artificielle / PFIA2021
ONERA-AIRBUS

Chaire IA “ADvanced underSea Intelligent Listening”

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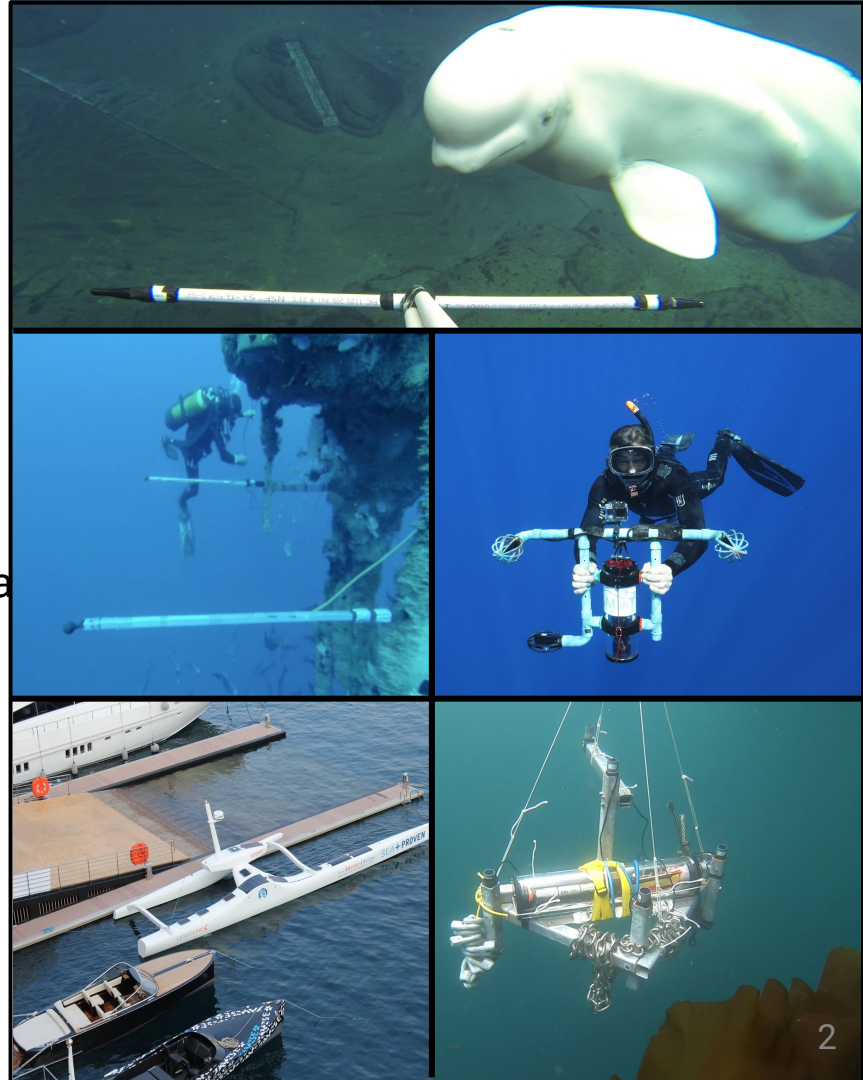
DYNI team
LIS CNRS Univ Toulon

We are research group of the
Laboratoire d'Informatique et Systemes LIS UMR 7020
CNRS hosted at the Univ. Toulon (UTLN).

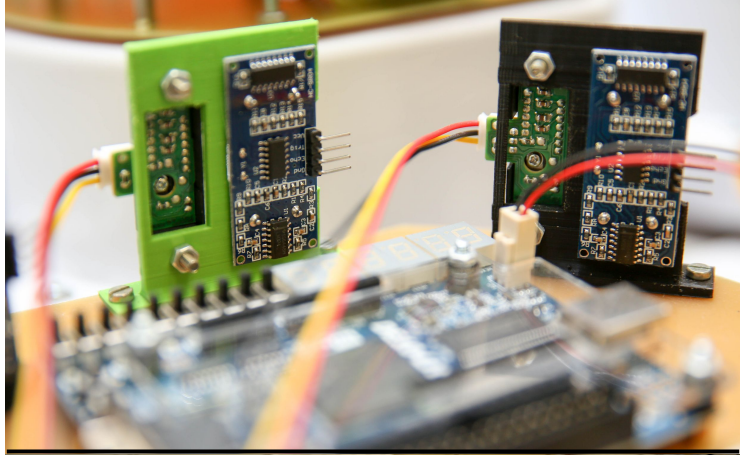
In ADSIL, we aim to innovate in methods of machine learning, signal processing and data analysis in order to improve our knowledge and understanding in physica natural subsea acoustics.

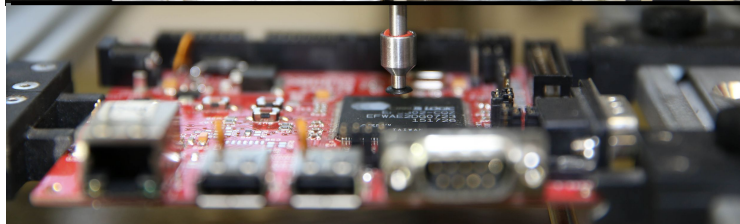


SMIoT: Scientific Microsystems for the Internet of Things

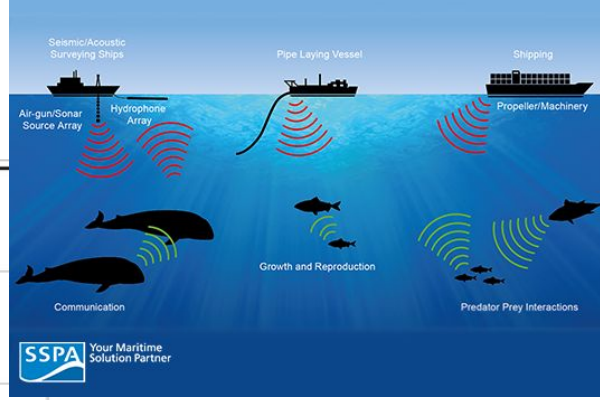
Design of electronic hardware (conception et routage des PCB), front-end, RF.
Assembly and testing of electronic prototypes
Industrialization of connected objects

Design, Test and Construction / PCB print of **ULP AI**

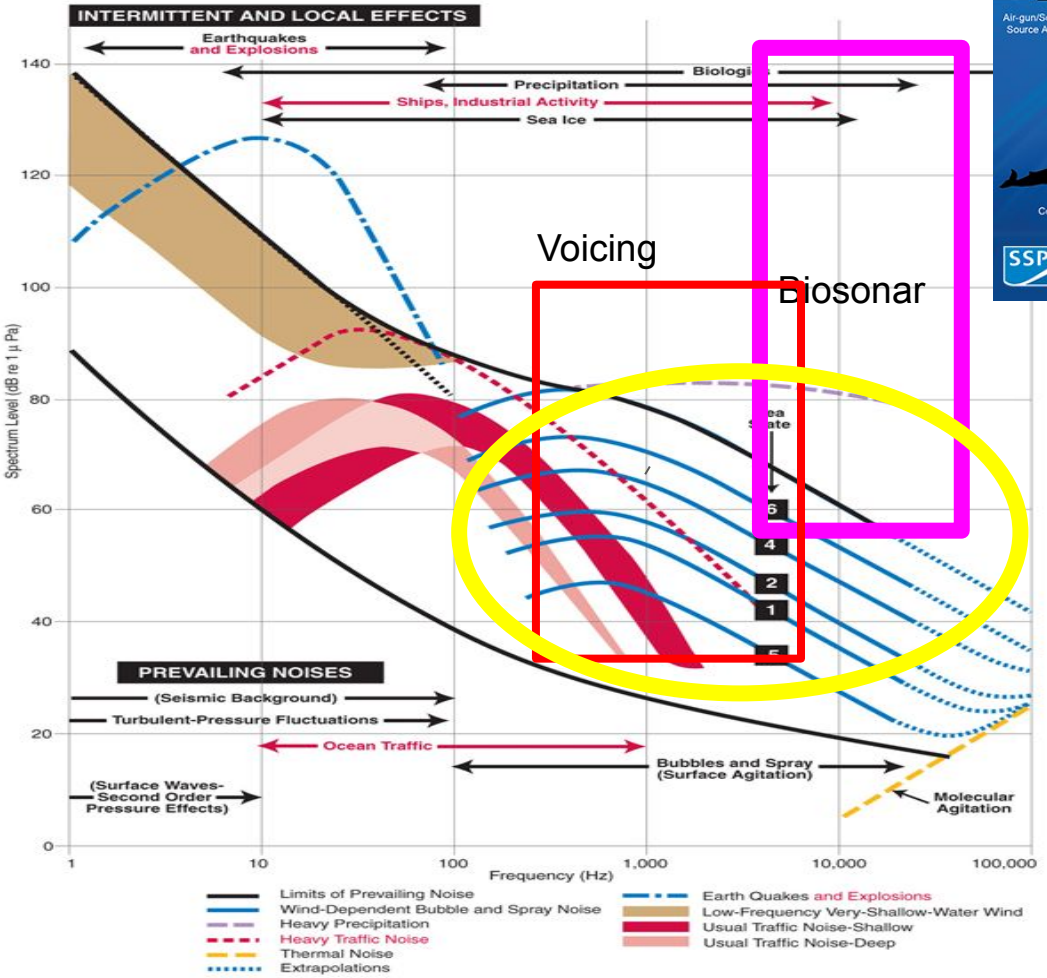




Context :
Anthropic Pressures In the Sea & Impacts to Biodiversity (Marine Mammals) & Awareness

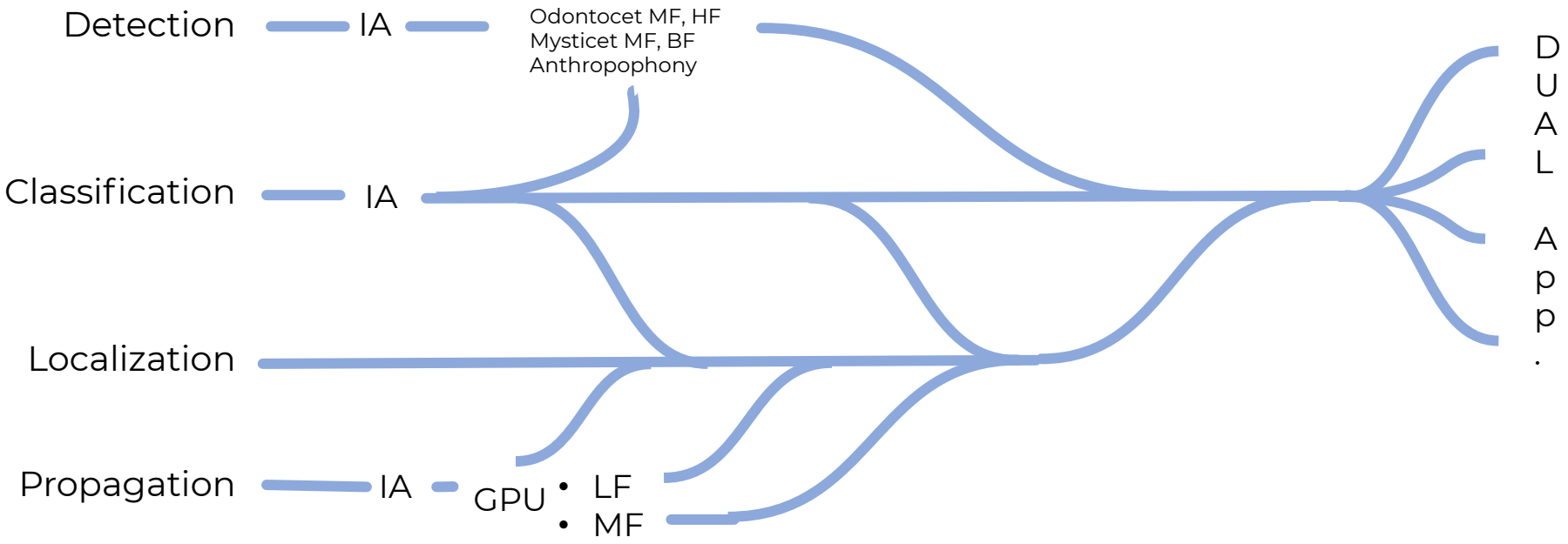


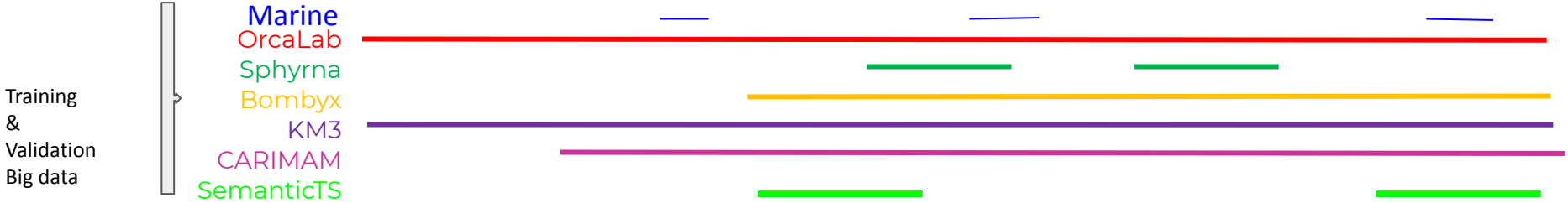
dB level



Anthropogenic underwater noise is continually changing. New waterborne technologies can be modeled so that new designs are optimized to reduce impact on marine life. Still, All forms of underwater radiated noise caused by human activities must be continuously measured in-situ.

Overview of ADSIL

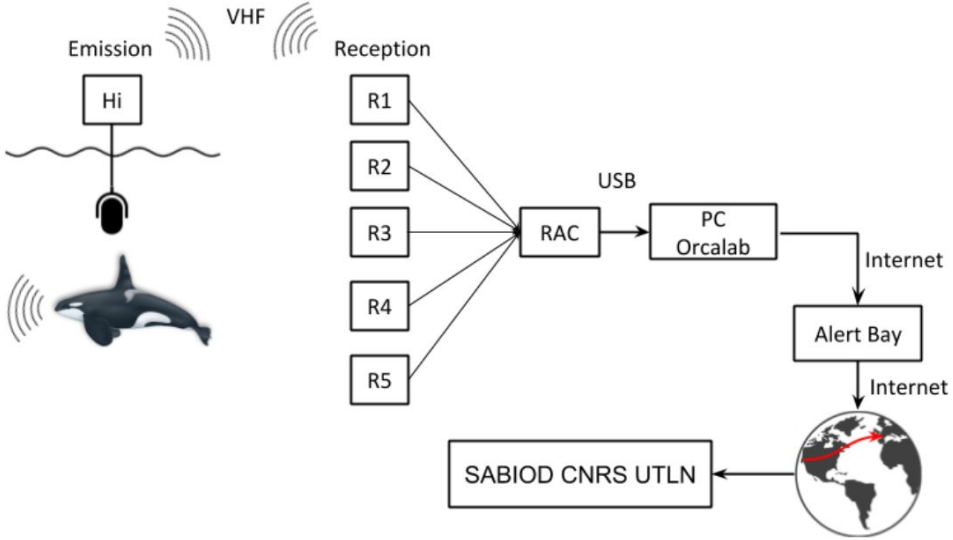


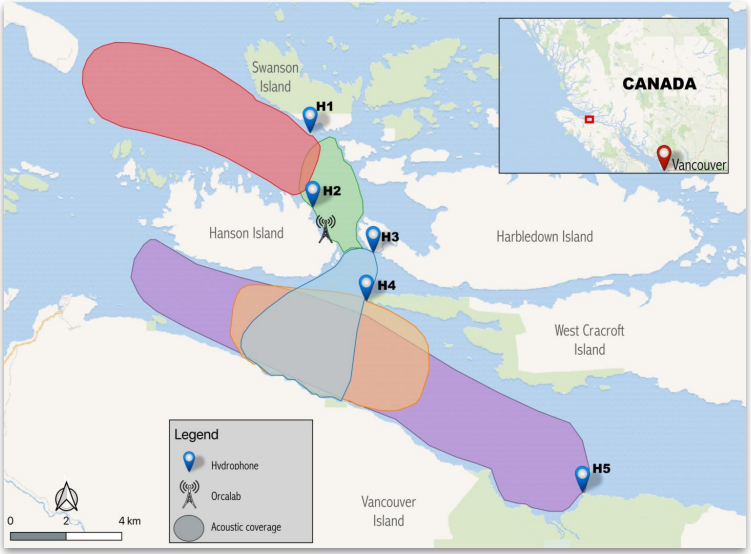


A) AI for massive Detection & Classification of voicings

Orca Vocalization Detection
Context - OrcaLab

- Northern resident orcas community
- In situ observatory since 1970
- 5 Hydrophones (recording at 22kHz)
- Full time recording since 2015 (50 TB)





Hydrophone layout in Johnstone Strait

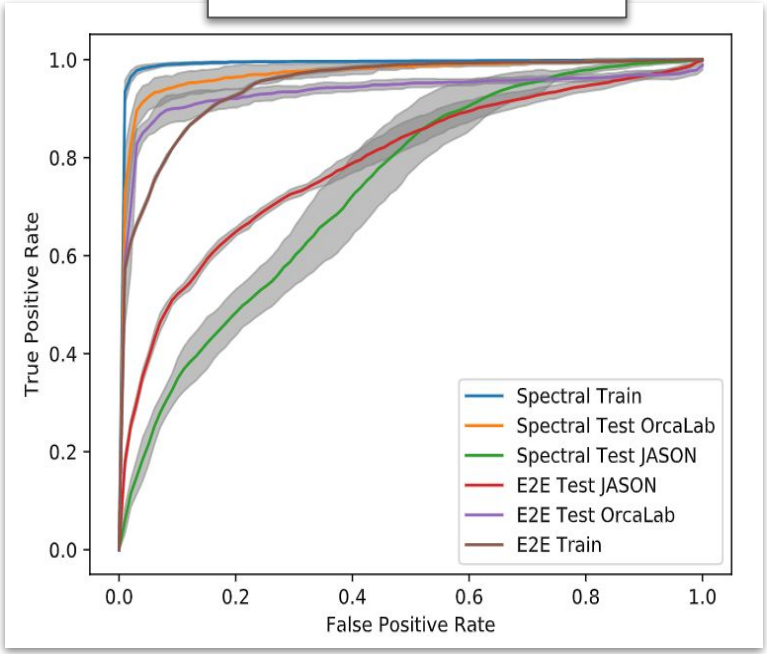
Orca Vocalization Detection
Models' Performances

Averaged over 10 runs

Spectral Model			
	Precision	Recall	AUC
Training	0.91 ± 0.017	0.97 ± 0.005	0.99 ± 0.001
Test OrcaLab	0.91 ± 0.105	0.90 ± 0.044	0.98 ± 0.010
Test JASON	0.51 ± 0.04	0.87 ± 0.030	0.74 ± 0.027

End-to-end Model			
	Precision	Recall	AUC
Training	0.63 ± 0.004	0.87 ± 0.002	0.95 ± 0.002
Test OrcaLab	0.50 ± 0.019	0.96 ± 0.005	0.94 ± 0.008
Test JASON	0.63 ± 0.023	0.70 ± 0.032	0.79 ± 0.010

Input	1x1x1x110250
Conv1D(5)	1x1x32x55125
Conv2D(3,5)	1x32x32x27563
MaxPool	1x32x32x13781
Conv3D(3,3,5)	8x16x16x3446
Conv3D(3,3,5)	32x8x8x862
Conv3D(3,3,5)	64x4x4x431
Conv3D(2,2,5)	128x3x3x216
Conv3D(1,1,1)	128x1x1x216
MaxPool	128x1x1x1
Linear	64
Linear	1

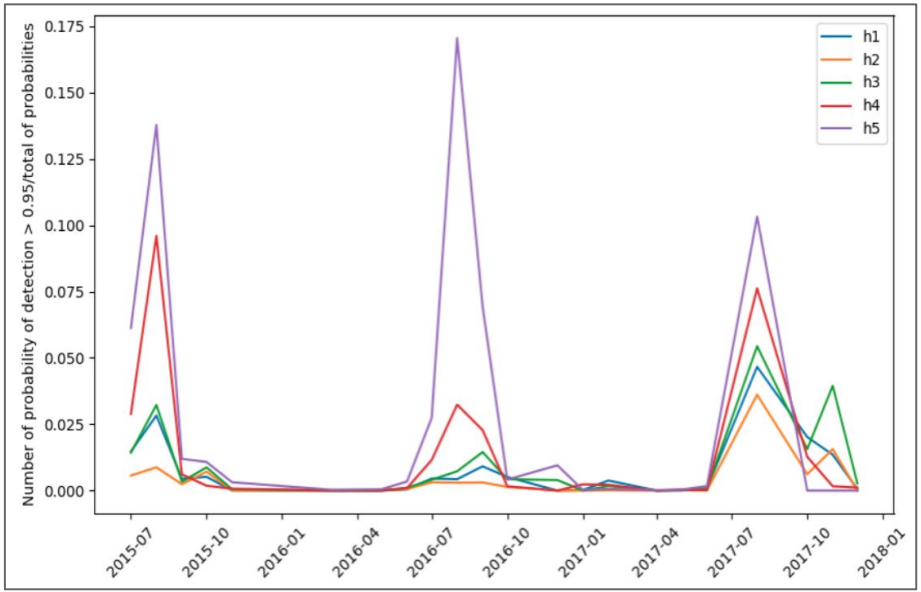


ROC

Best et al. 2020, IJCNN

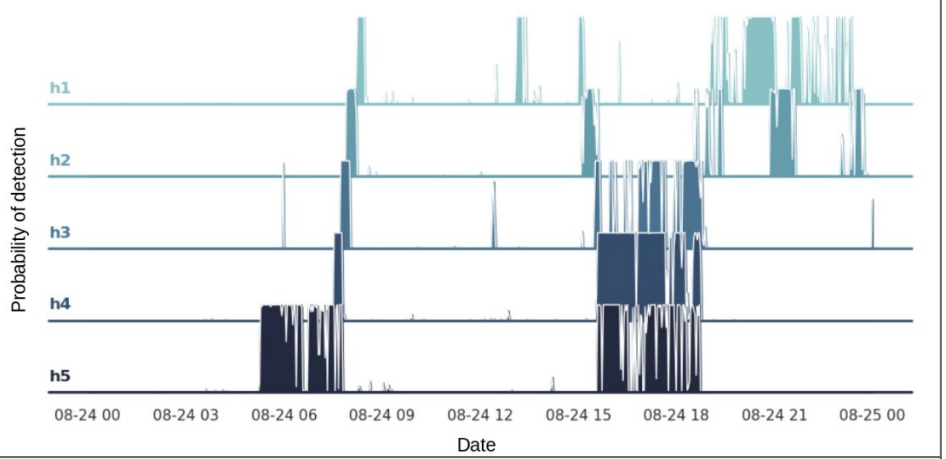
Orca Vocalization Detection

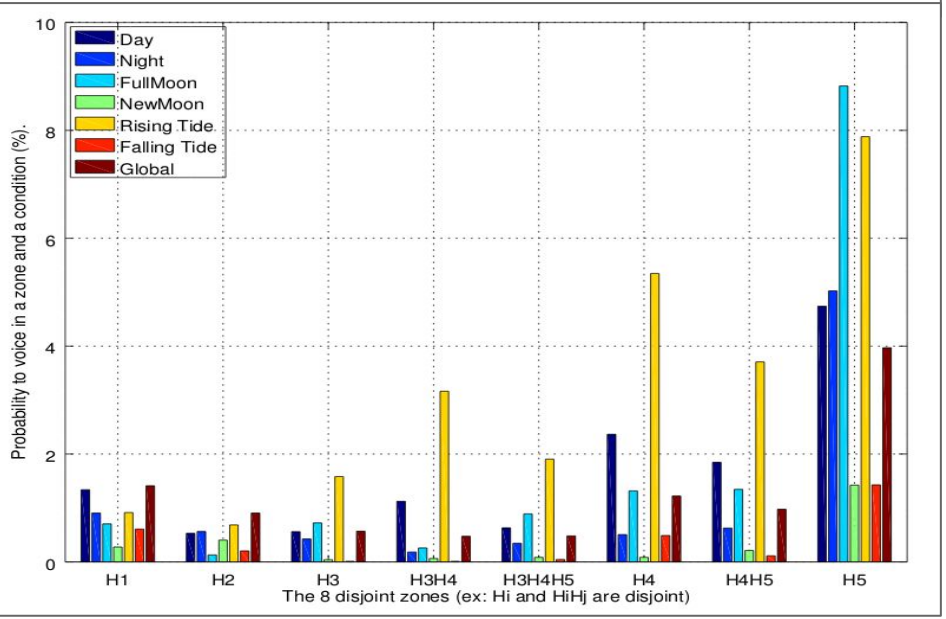
- Run over 3 years (2015 to 2017)
- Over 420k detected vocalizations



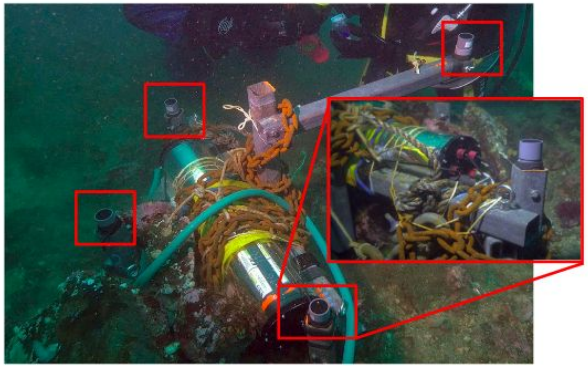
Probability of vocalization detection through time

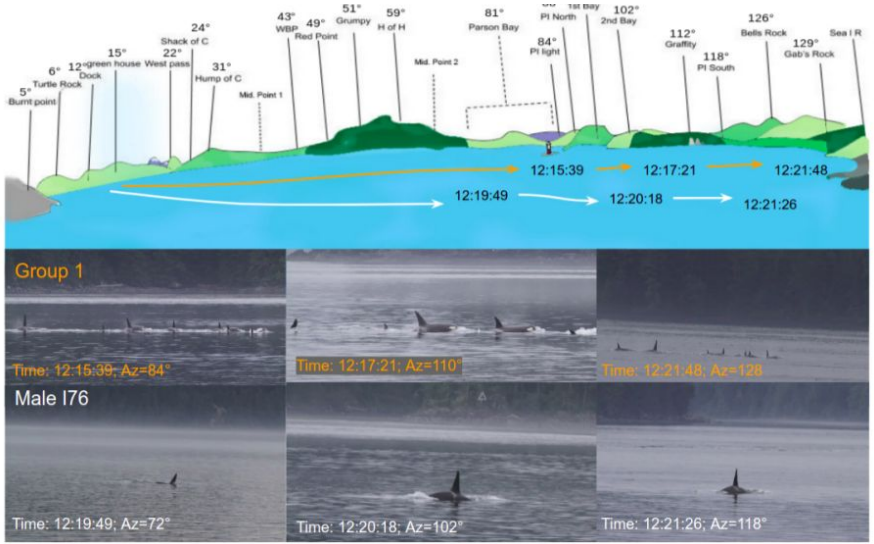
Best et al. 2020, IJCNN; Poupard et al. Ocean 2019

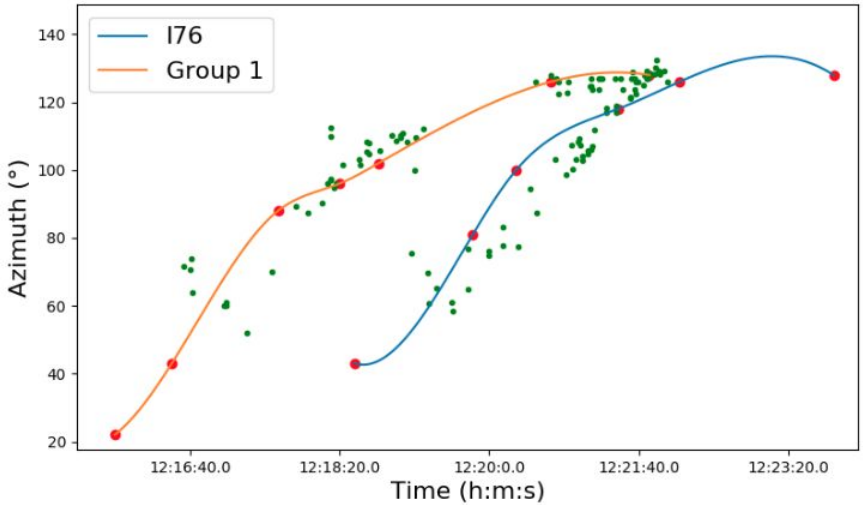


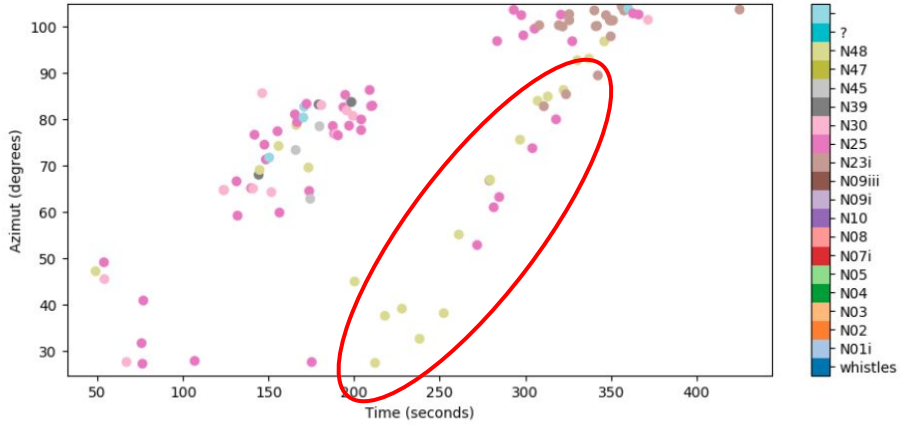


Individual separation and identification of orcas calls in the wild: Learning Individual signature ?



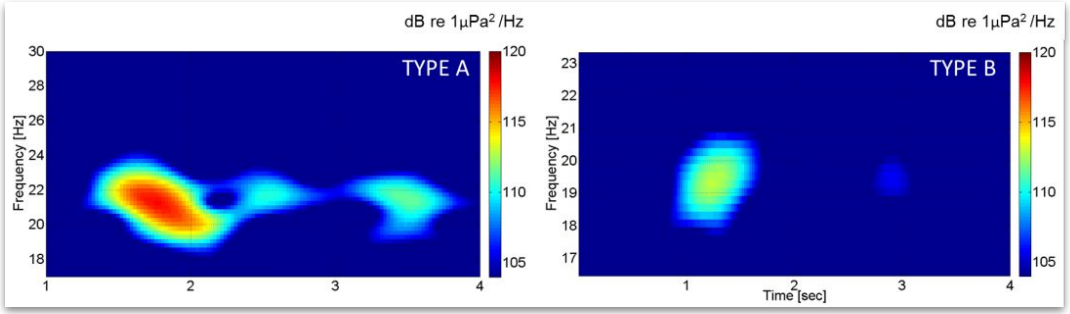






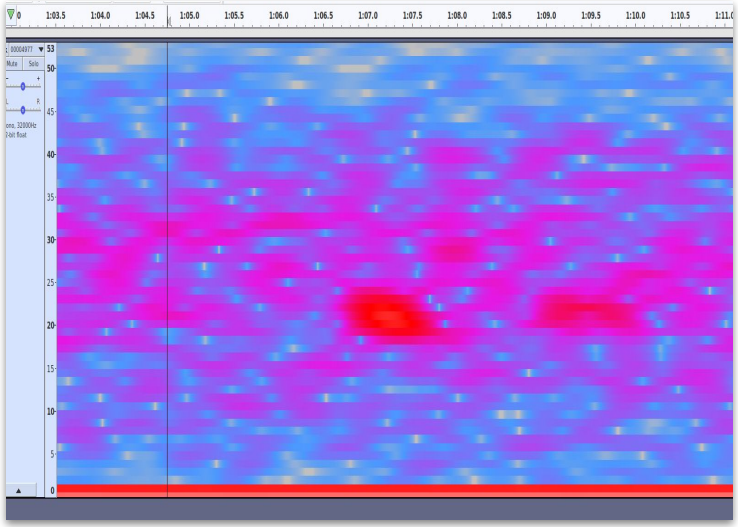
Poupard et al, in Sub to SR

Deep learning for Fin whale pulse detection (low frequency, 20 Hz)



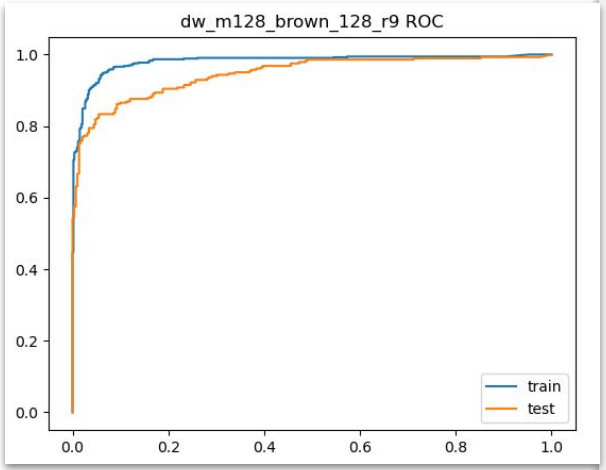
Monitoring fin whale (Balaenoptera physalus) acoustic presence by means of a low frequency seismic hydrophone in Western Ionian Sea - EMSO site. Gianni Pavan

- Centroid frequency : 20Hz
- Bandwidth : 5-7Hz
- Length : 1sec
- Periodicity : 15-40sec

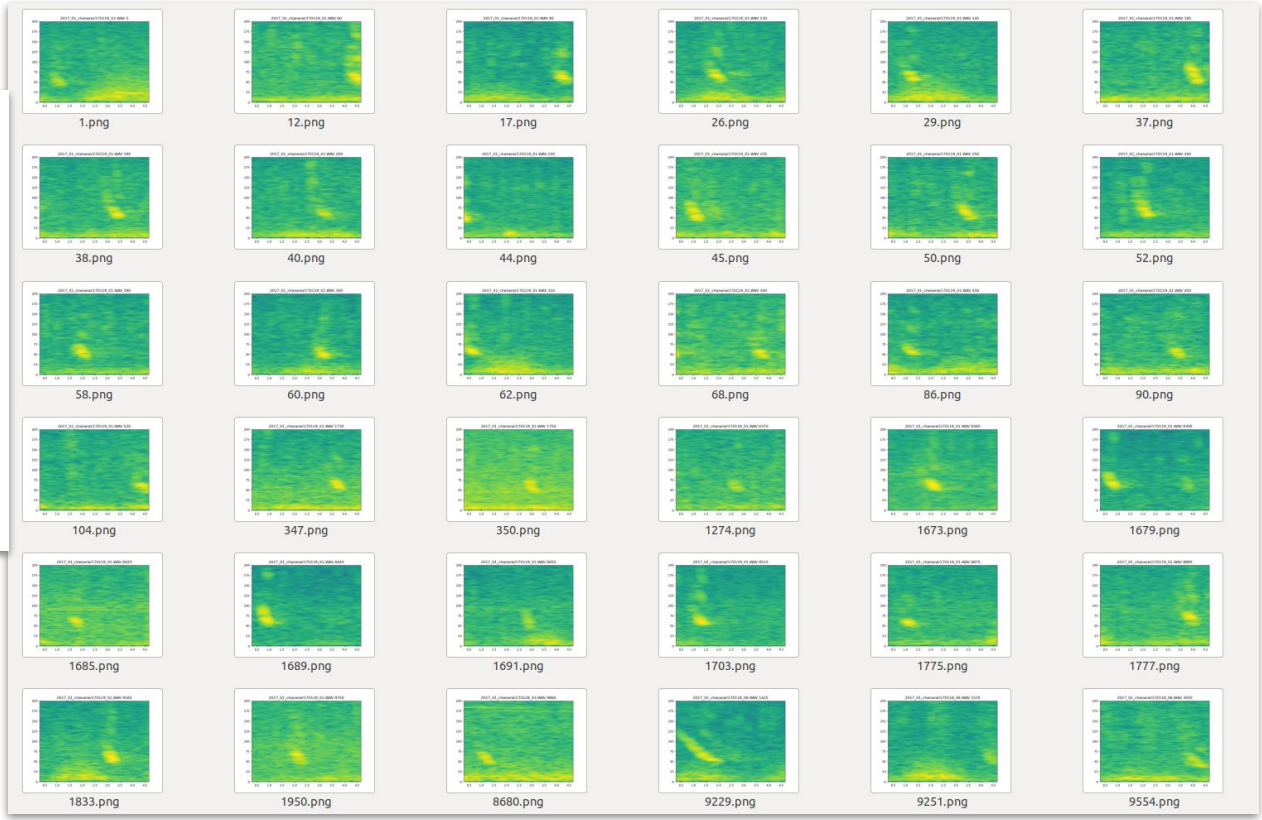


Sample from sonobuoy Boussole 2009 dataset

Low Frequency event classification : Fin whale pulse detection



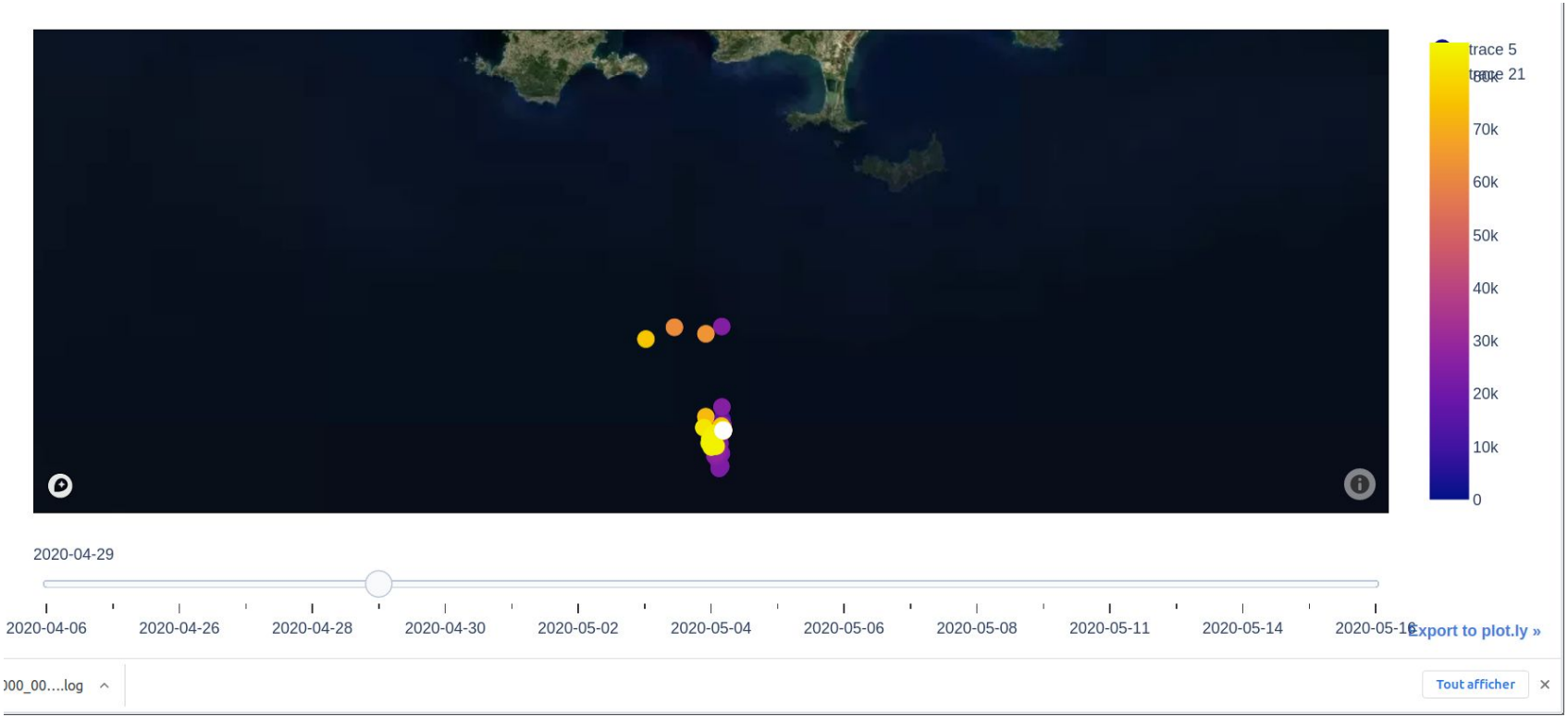
Sample of high predictions over Chilian dataset
(rec. Patris, Malige, Glotin 2017, Chanaral, Humbold loop…)



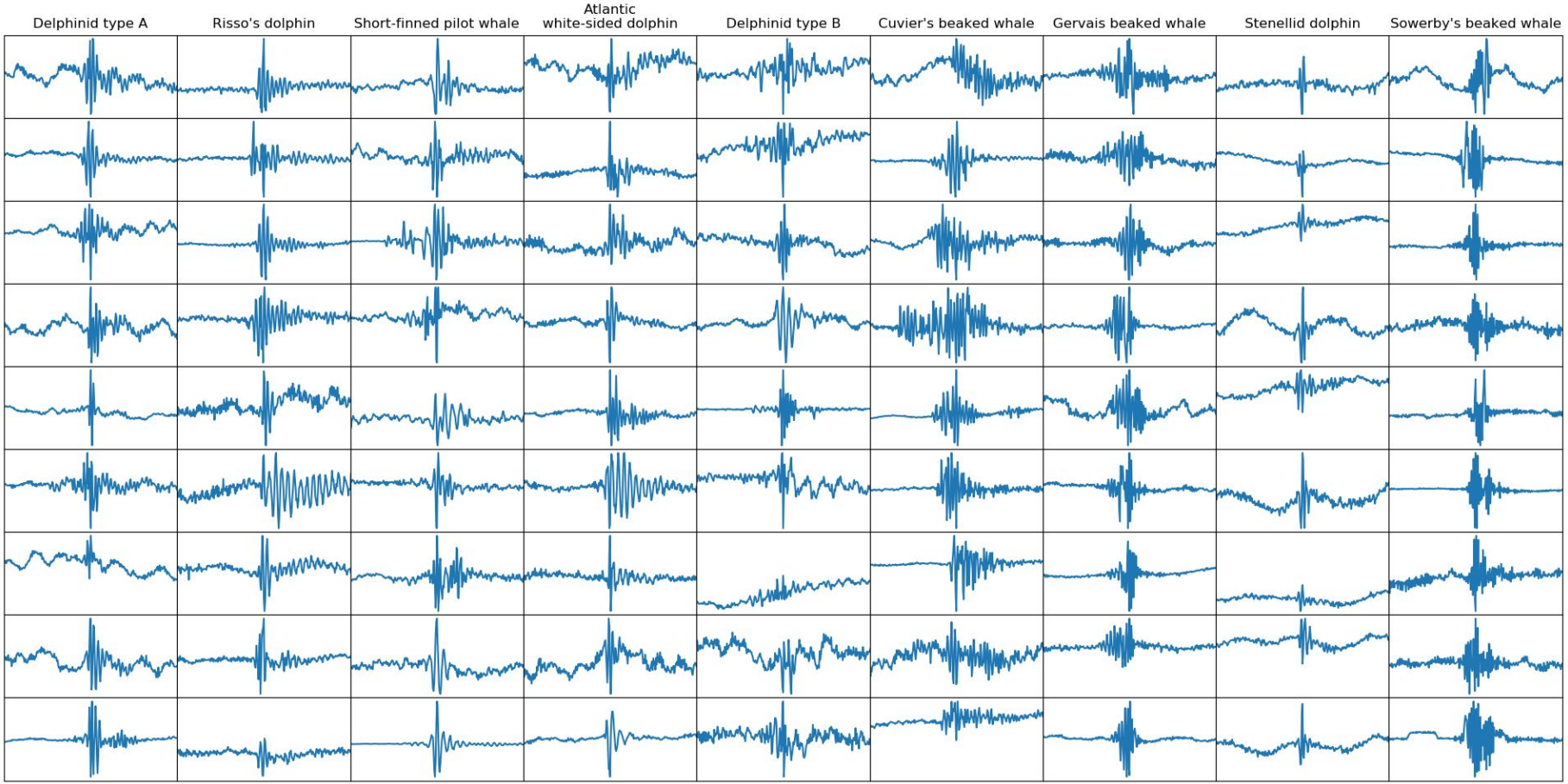
Best et al 2021

Tracking Fin Whale with KM3 (Neutrino detector), 3 hydrophones, from april to may 2020

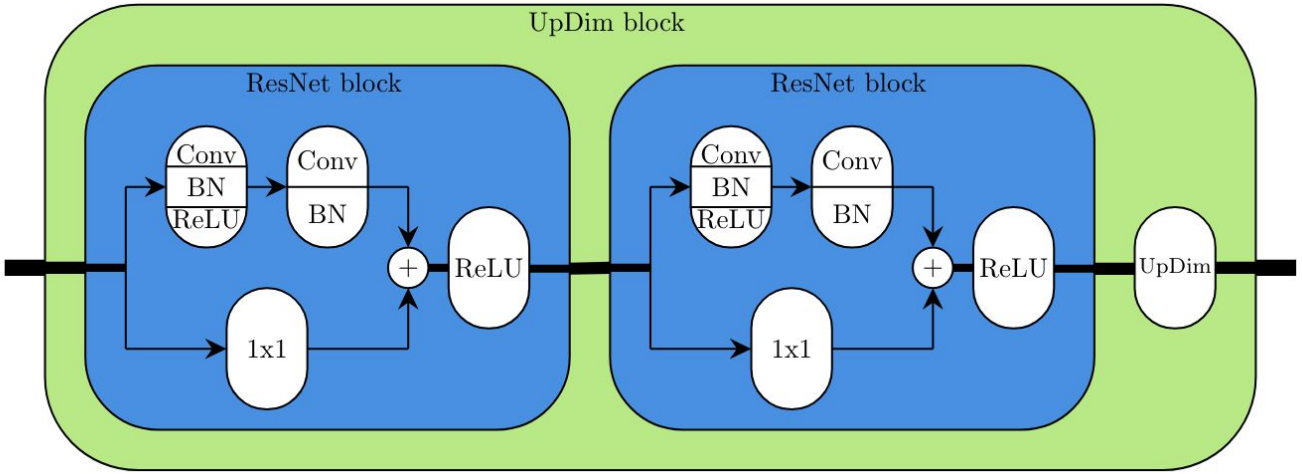
http://sabiod.univ-tln.fr/pub/bp.html



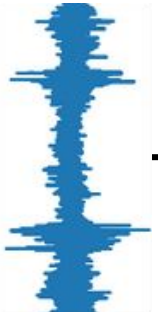
B) Machine Learning for transient analysis : 9 species samples of few ms

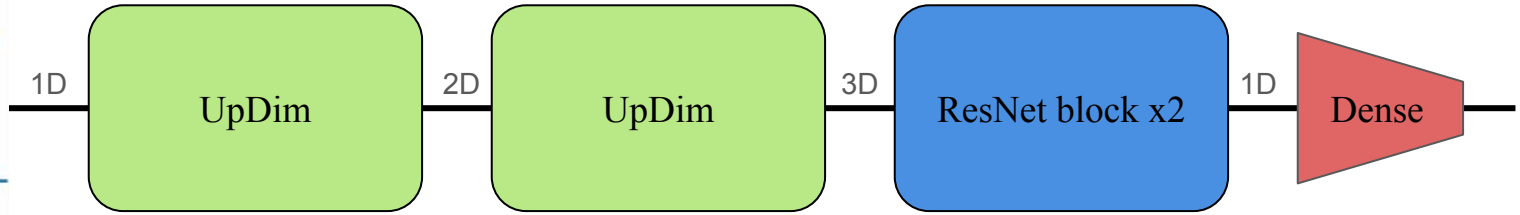


Baseline architecture : UpDim V2 model



RAW Input signal





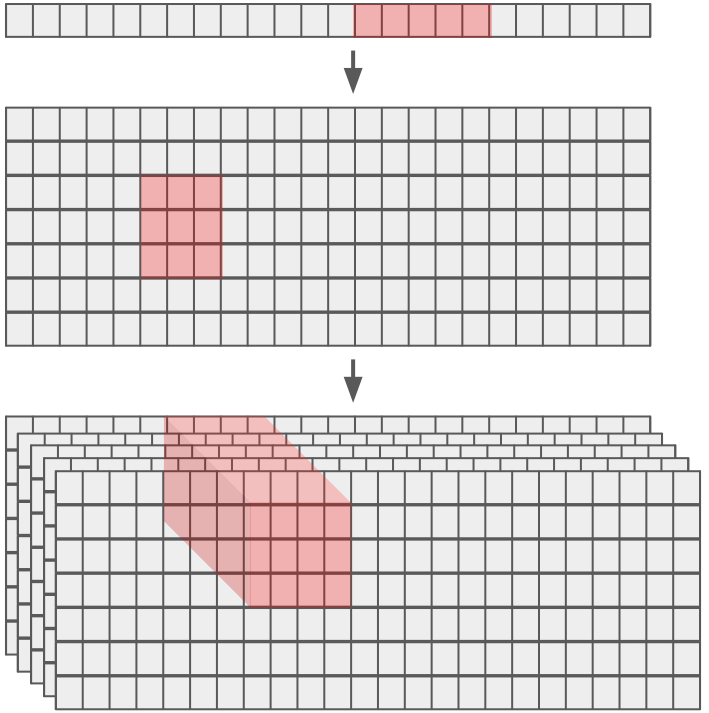
Output probabilities

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

M. Ferrari, H. Glotin, R. Marxer, and M. Asch, “Docc10: Open access dataset of marine mammal transient studies and end-to-end cnn classification,” in IJCNN , 2020.

Multiscale Hierarchical Convolutional Networks

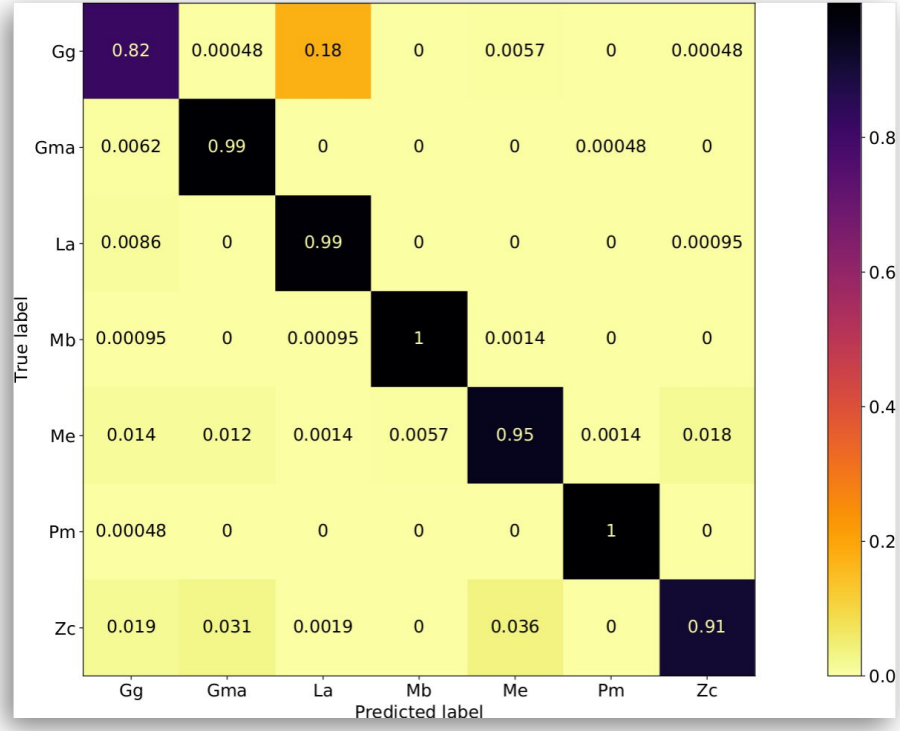
- Have the advantage of **invariance** to translation
- Map the symmetry group to the translation group
- Increasing dimension helps to deal with more complex **symmetries**



S. Mallat, “Understanding deep convolutional networks,”Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 374, no. 2065, p. 20 150 203, 2016
J. Jacobsen, E. Oyallon, S. Mallat, and A. W. Smeulders, “Multiscale hierarchical convolutional networks,”arXiv preprint arXiv:1703.04140, 2017.

Confusion Matrix: Results of the UpDim model

accuracy = 95.1 % on the 7 classes

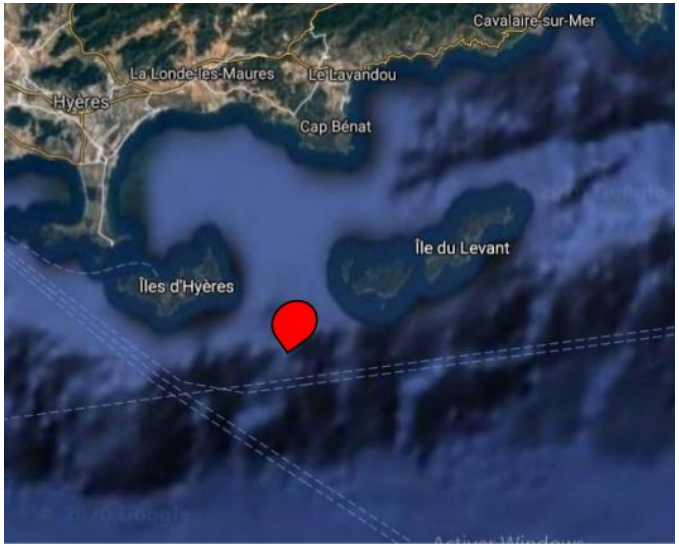


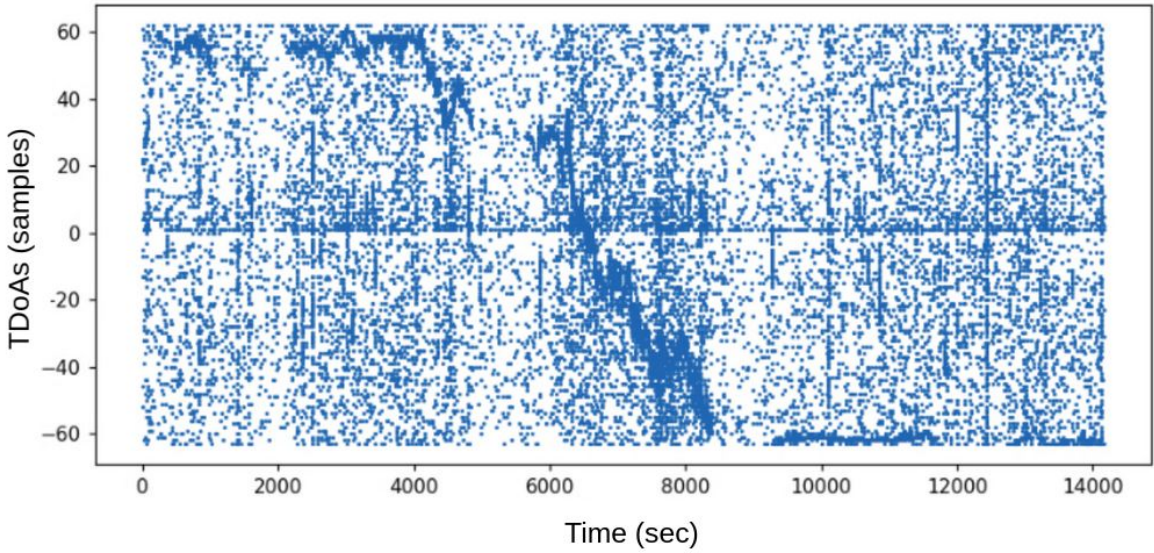
In use into Reinforce (see Remy et al)

=> Extension to acoustic Neutrino Dectection !!

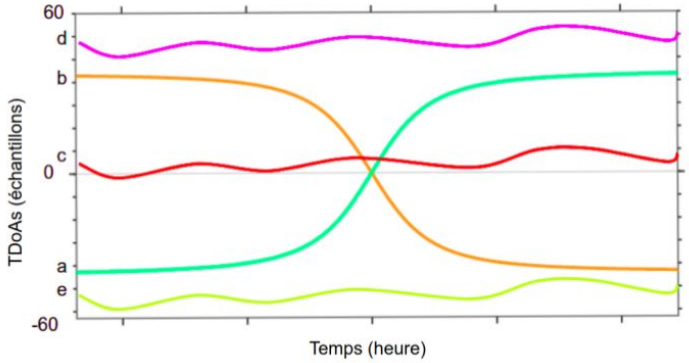
The BOMBYX 2015-2018

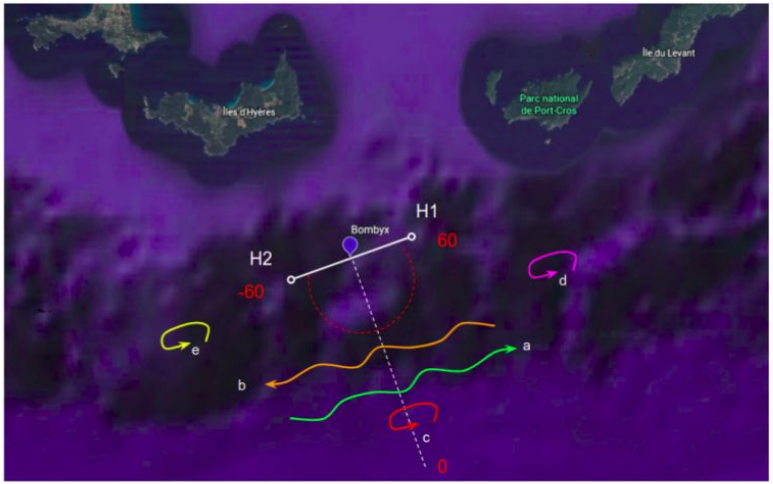
- Bombyx station, stereophonic
- 25 of depth
- Env 2700 hours of recordings, stereo
- Detection of sperm whales clics on Bombyx
- Data for future training

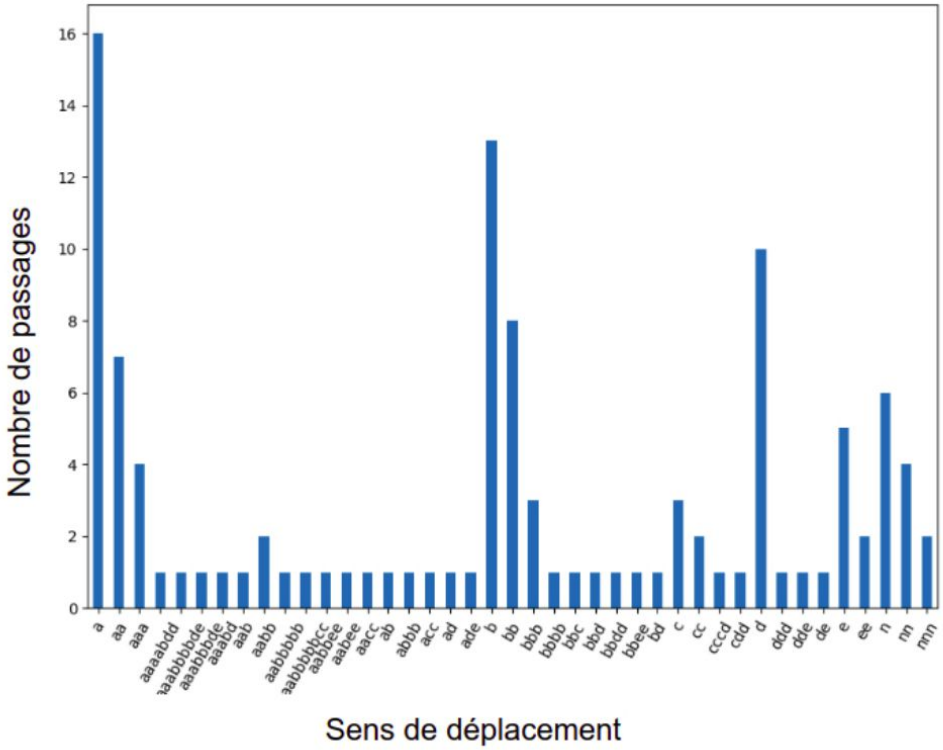




The BOMBYX station







BOMBYX1 effort and detection of Physeter

-

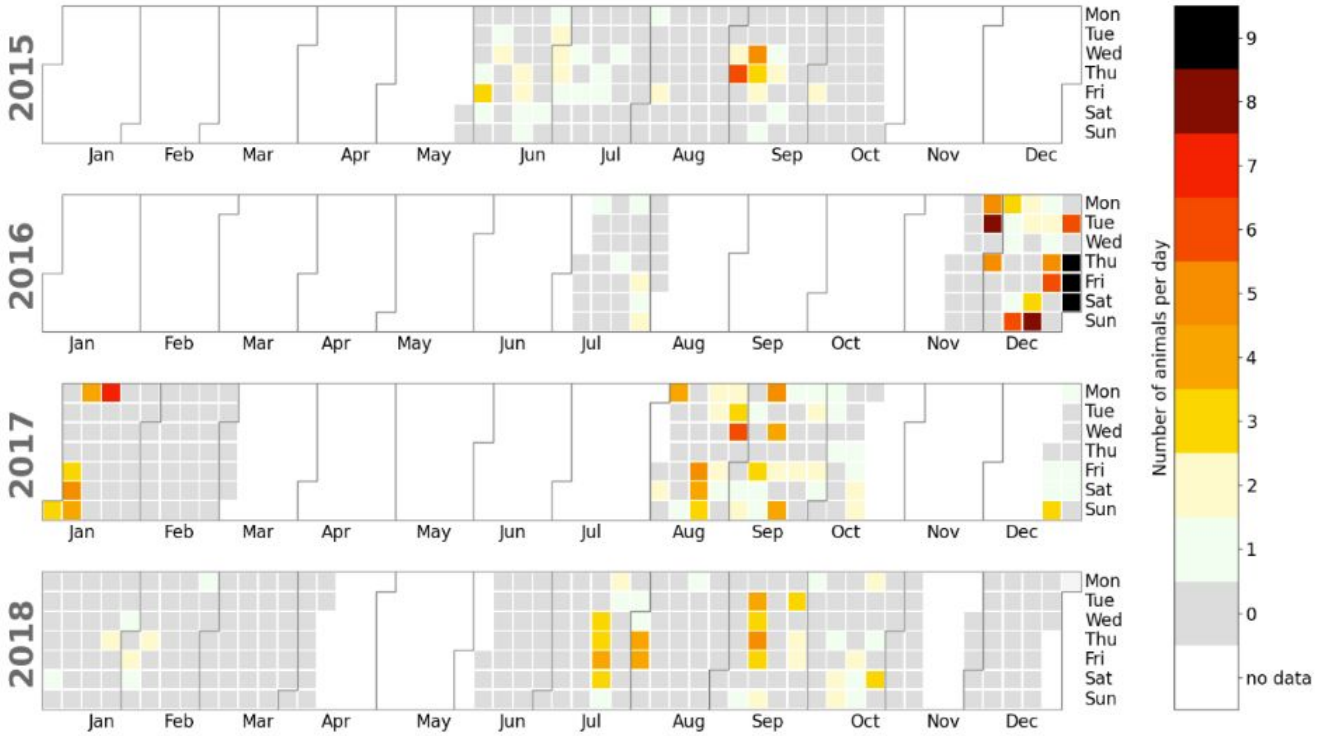
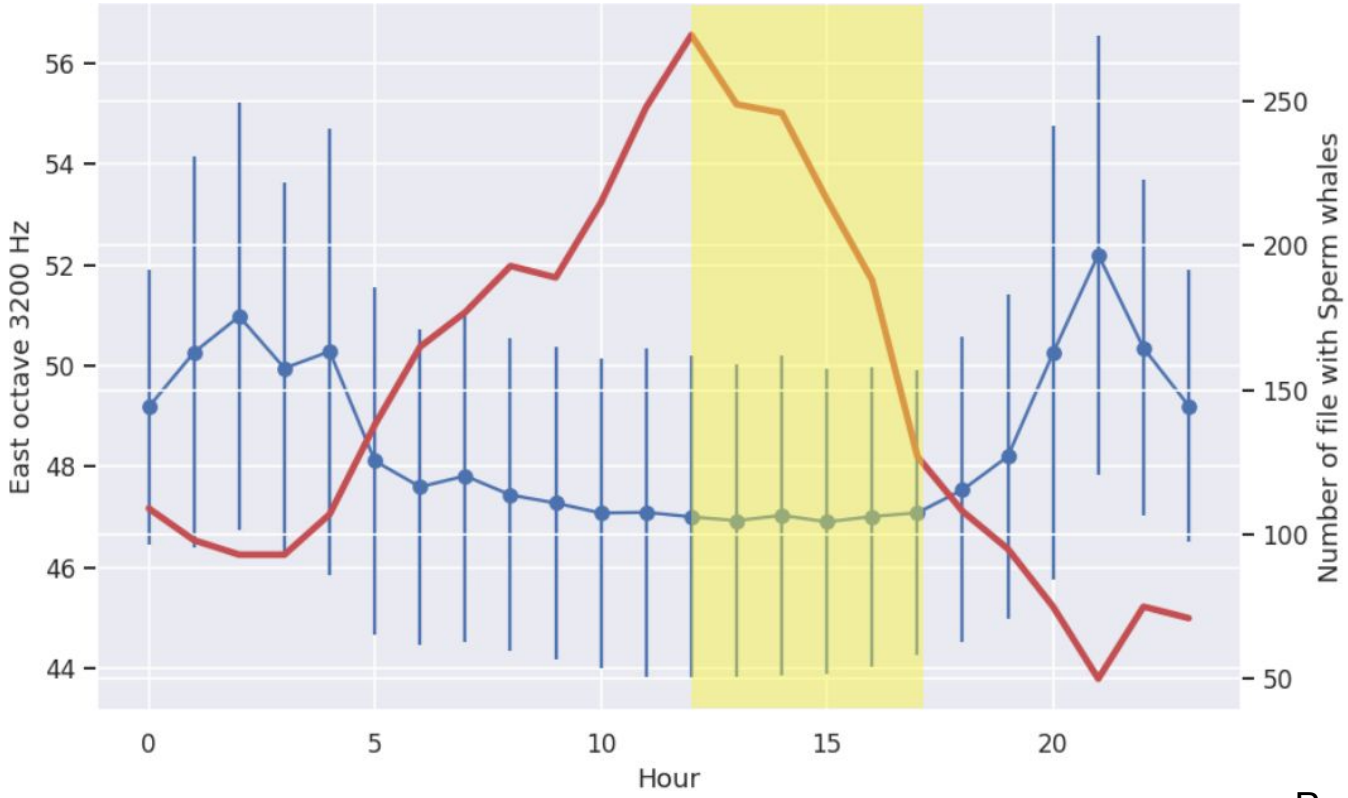


Figure 1. Number of animal per day during the 4 years of recordings

Summary of Bombyx1 : Physeter avoid traffic noise

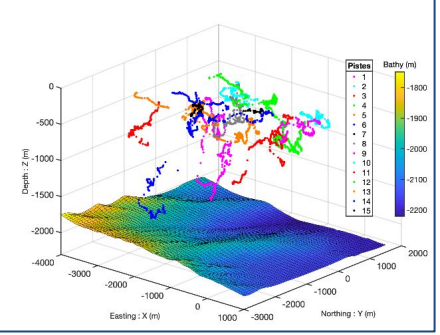
Cachalot frequentation (range 30 km from Bombyx1) vs ship noise

dB level re 1uPa



Count of whale detections (#file)

Poupard et al. 2021



FONDATION PRINCE ALBERT II DE MONACO

Explorations de Monaco
Monaco Explorations

ACCOBAMS

SEA PROVEN

UNIVERSITÉ DE TOULON

SMIoT
Scientific Microsystems for Internet of Things

SABIOD.ORG
Scaled Acoustic Biodiversity
Mastodons Big Data

Toulon Univ. LSIS CNRS
DYNI

cnrs

C) Etho-acoustics of Megafauna

from short 4D mobile hydrophone array

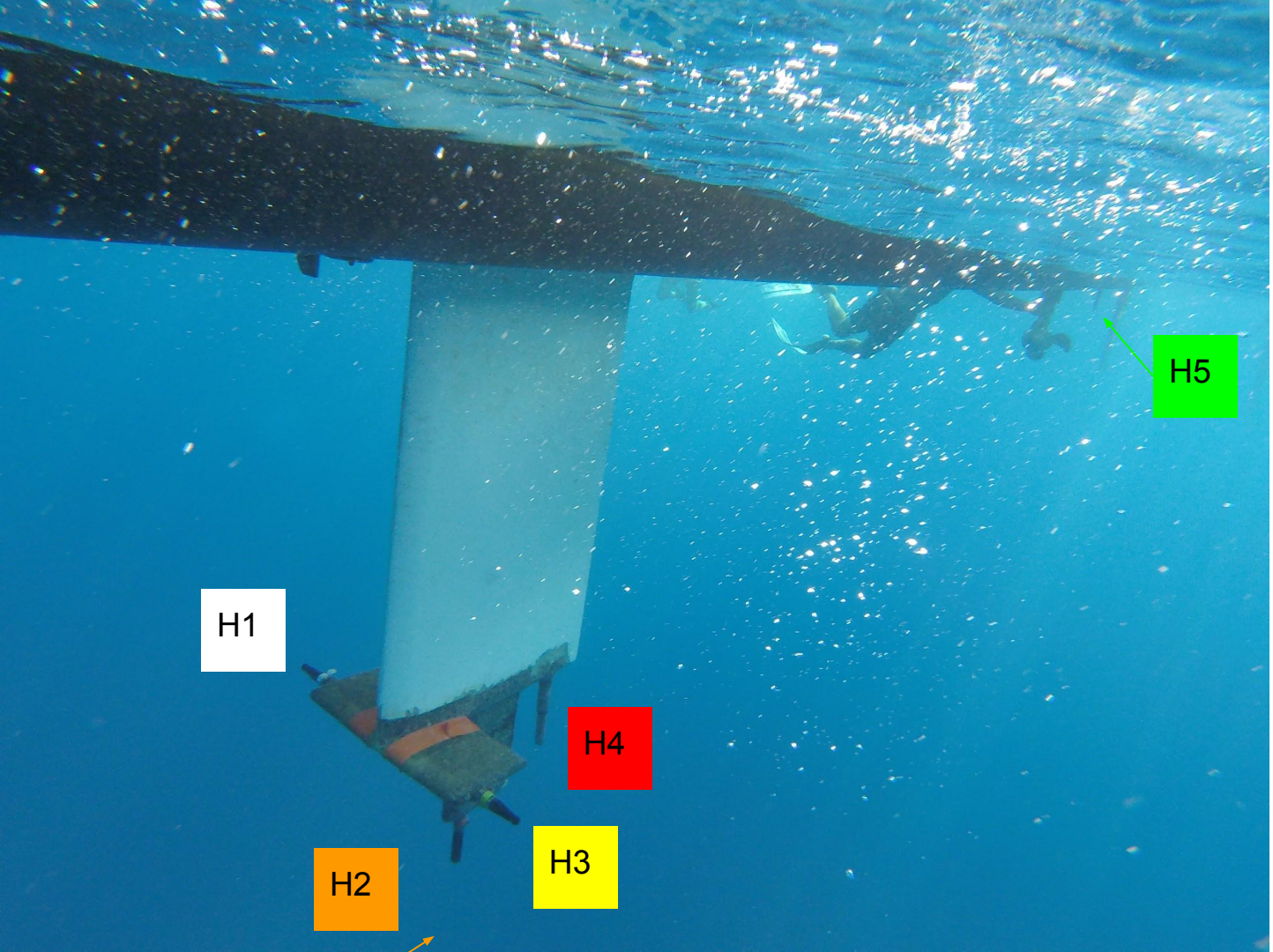
The ASV Sphyrna

ALV Sphyrna (SeaProven)

Polynesian Design, 20 m, Stable

Hydrodynamic, Low acoustic print

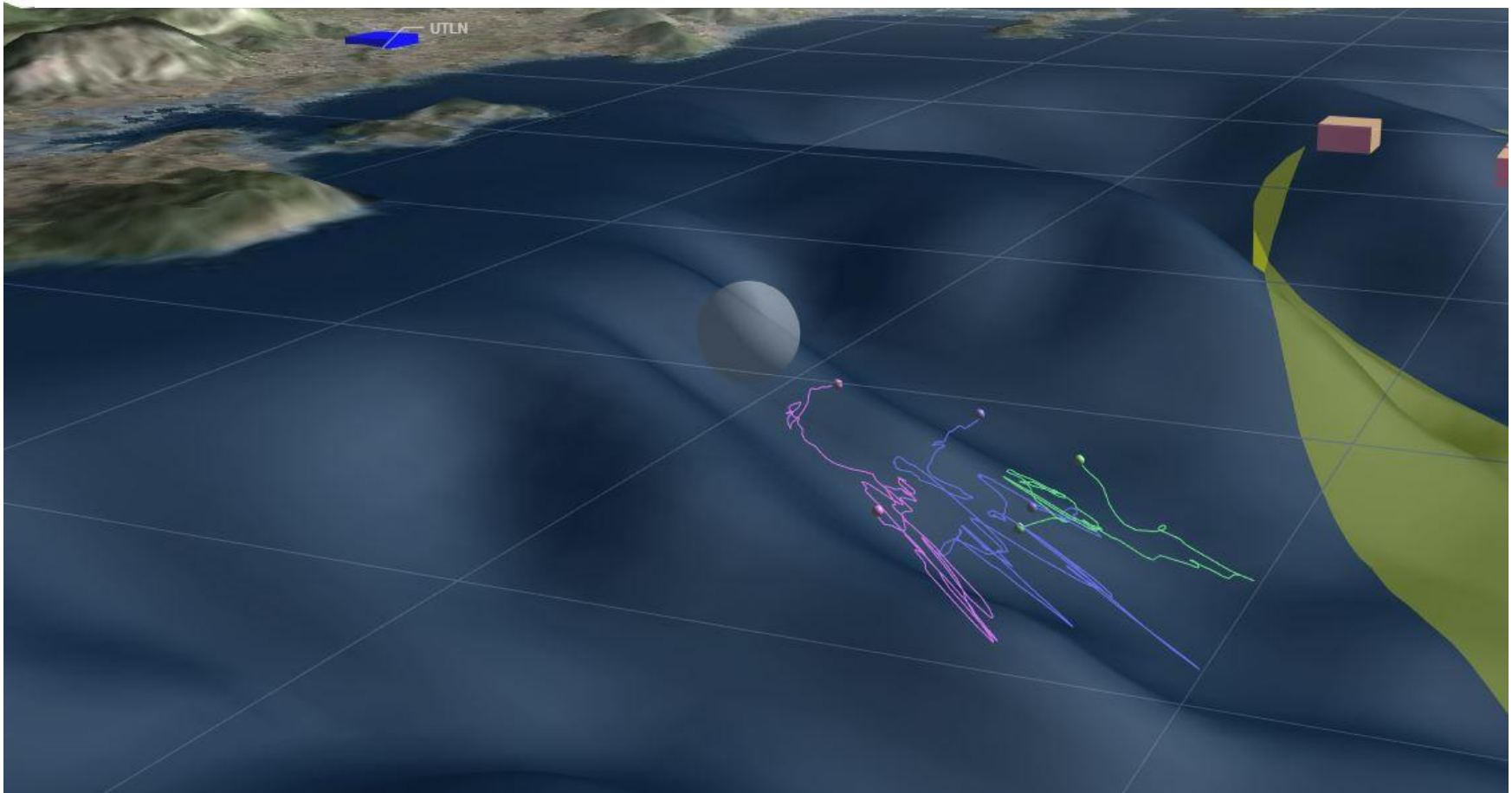
1 t. useful charge.



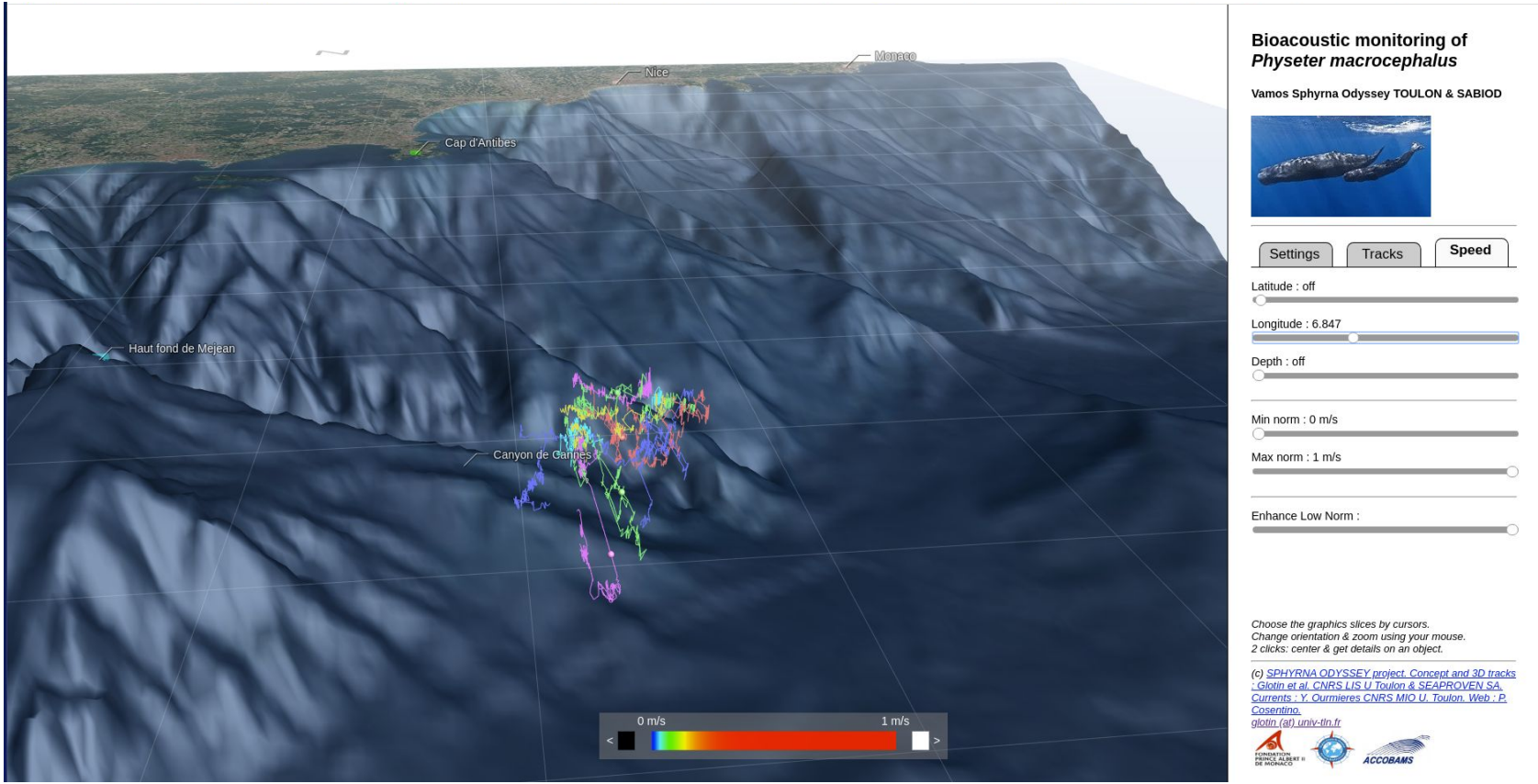
The 5 hydros fixed under the keel of the ASV.

Clear dolphin clicks, TDOA measures, recorded on 5 channels, Chan 1, 4, 5 = gain x 4, Chan 2, 3 = gain 1/2

August 2018, 1 Physeter, 3 tracks, 50 minutes each, down to -1000 m



January 2020, South of Antibes



https://sabiod.lis-lab.fr/pub/SPHYRNA/3D/current_norm/

Matching poursuit & tracking 3D : Missions Sphyrna 2018, 2020, 2021…

Bio-Multistatisme ?

=> corpus & AI

Det Class Loc & Propagation joints

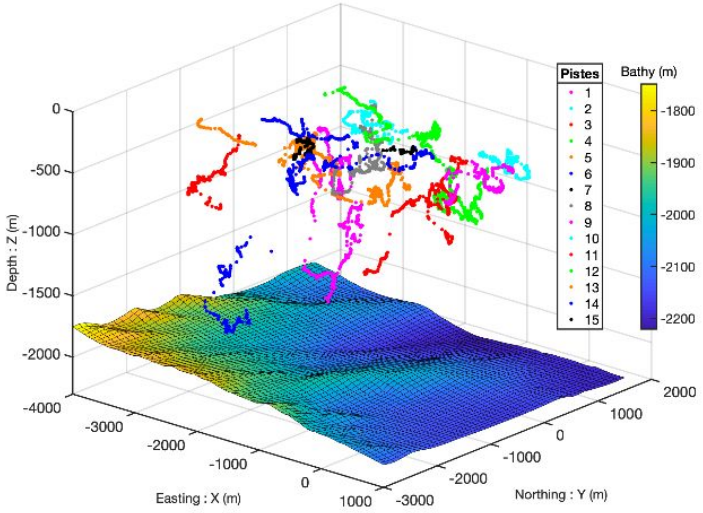
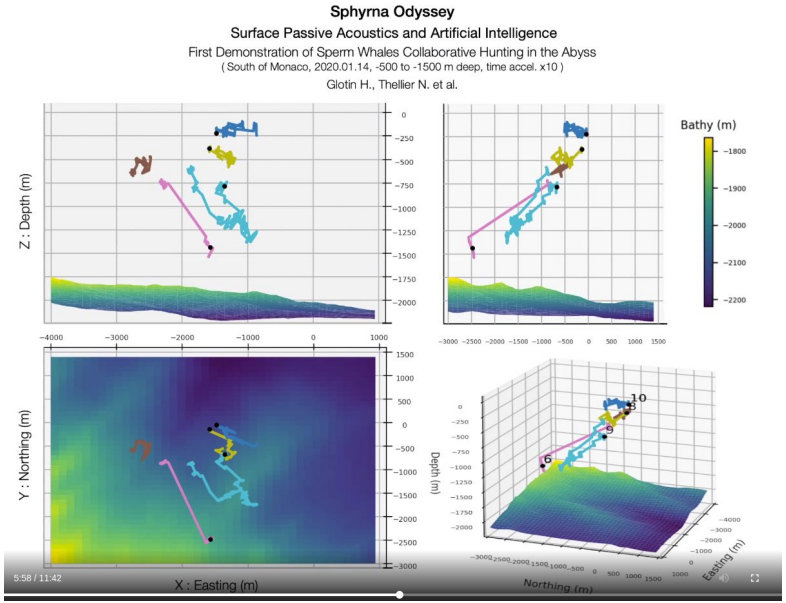
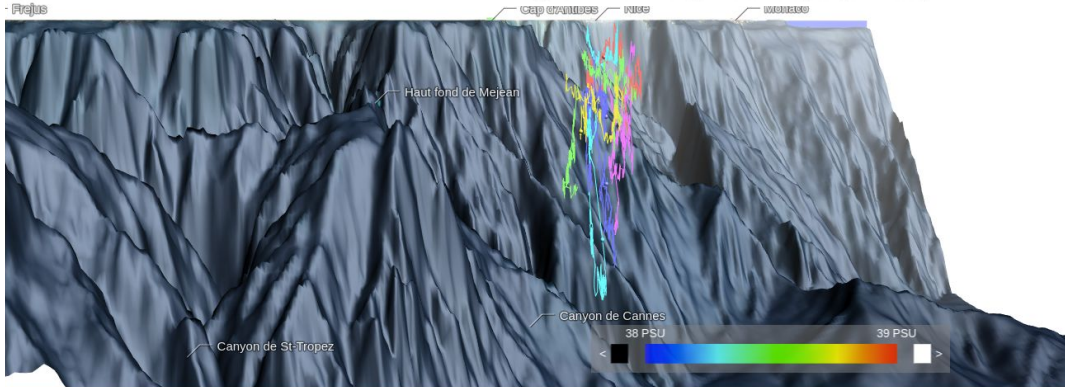
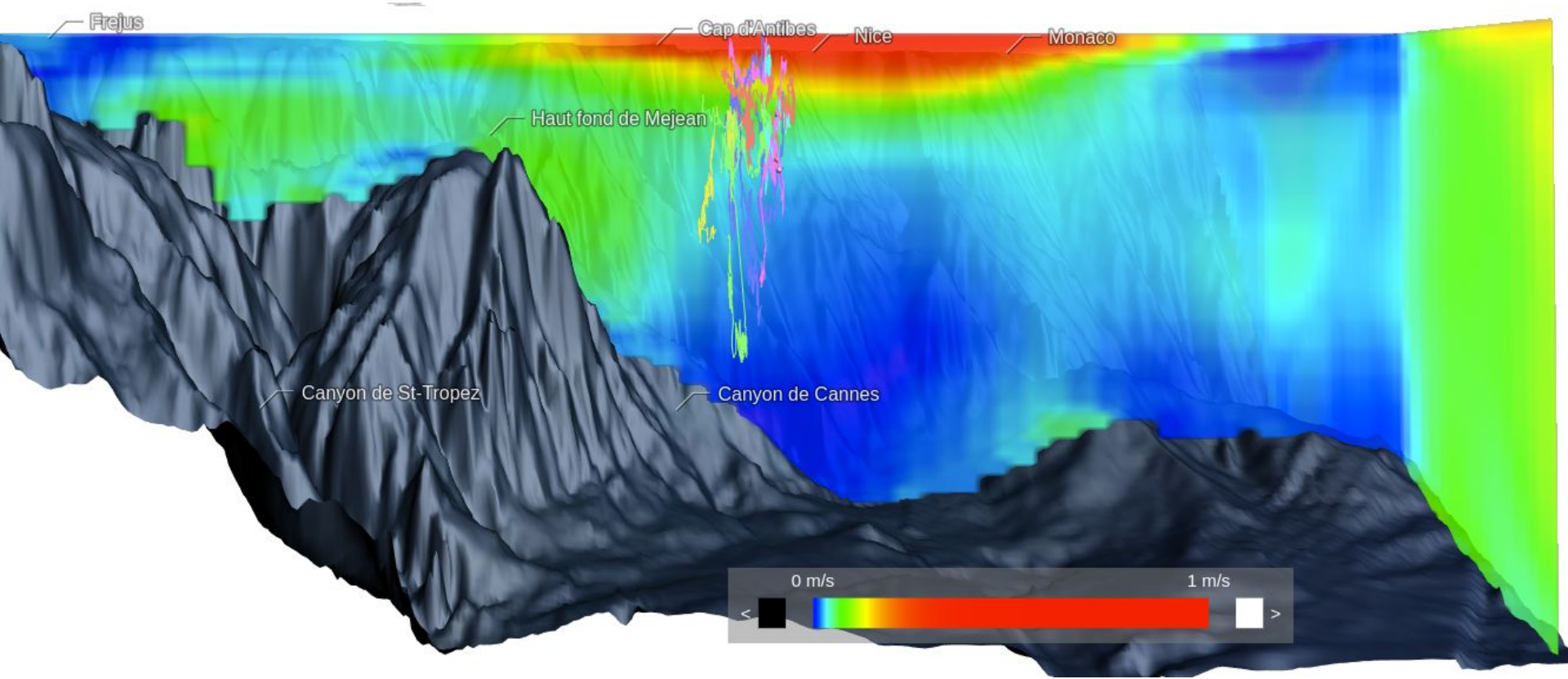


Figure 3.1: Traces 3D des déplacements des 15 pistes (record entier)



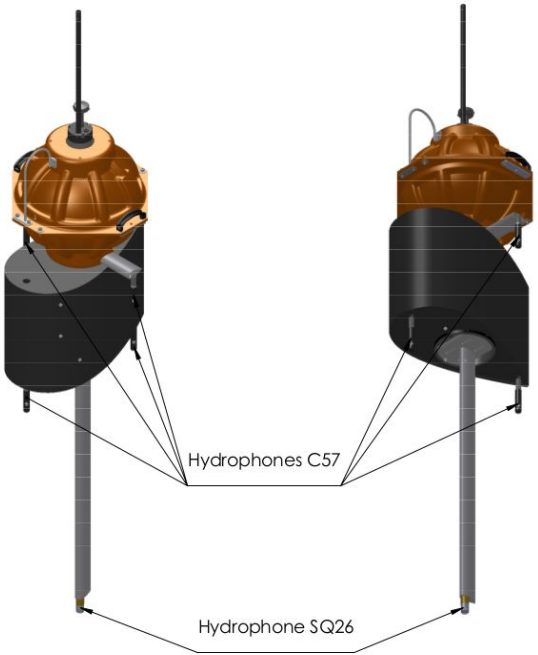


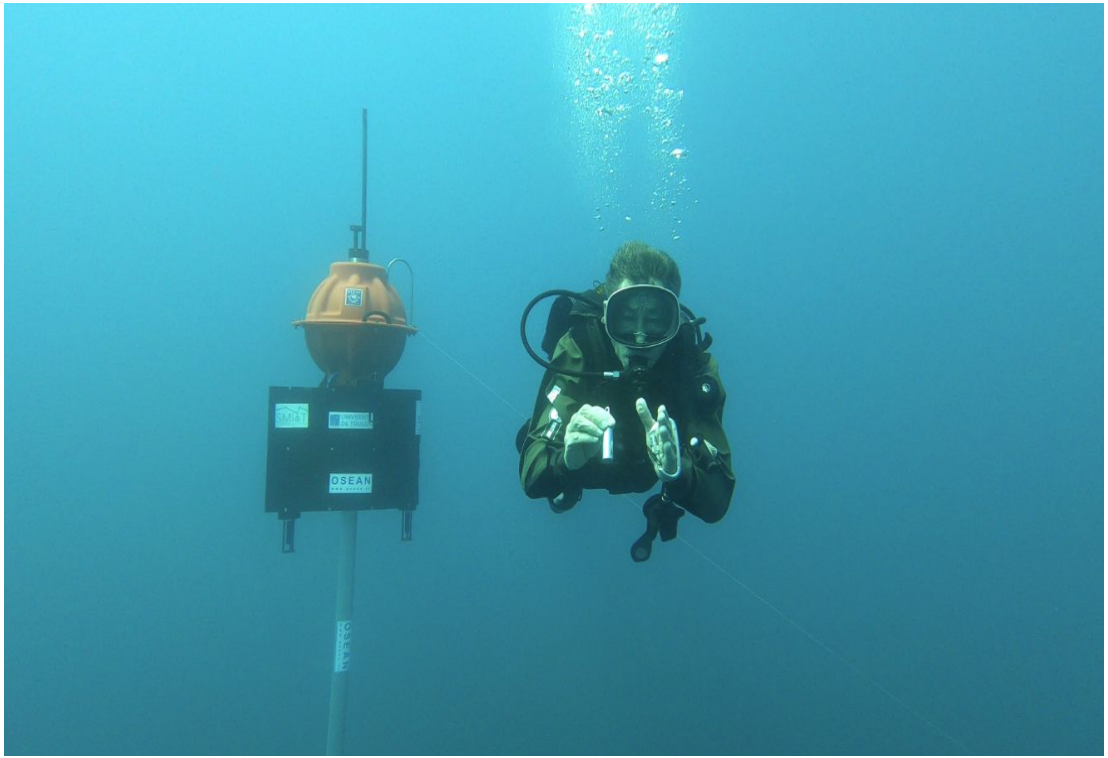
Deep divers and streams velocity / vortex



D) Extension to Embedeed AI : BOMBYX2 : pentaphonic real-time alert

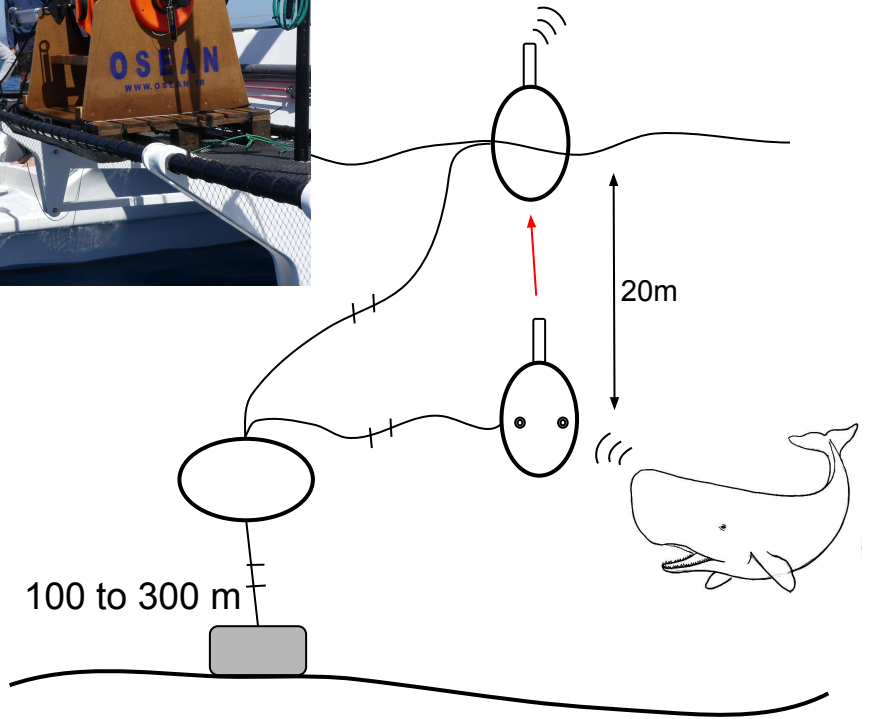
=> Ship whale anticollision





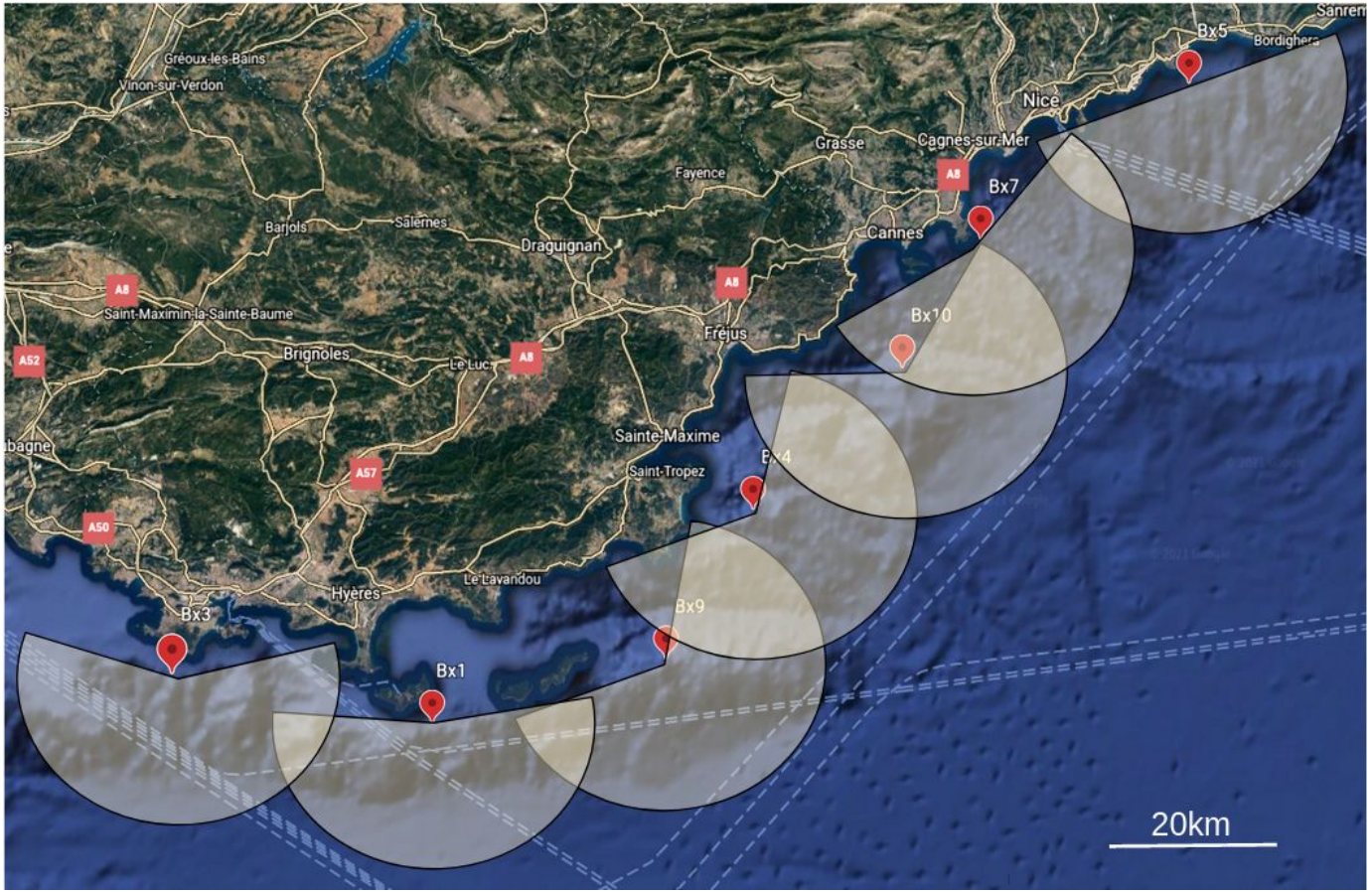
GIAS MARTTIMO Glotin et al 2018-2025

Application to Online AI
Bombyx2



- To be placed in 2021
  - South of Port-Cros Island and Cape Corsica
- Floatability variation system
  - 20m deep recording and surface 4G communications
- Alert system for sperm whale and fin whale presence
  - Mitigate ship strikes risk
- 5 hydrophones
  - Azimuth and distance estimation
- Battery powered (approx. 6 month)
- PIC32-Mz microprocessor

BOMBYX2 ADSIL GIAS Observatory



E) Emb. AI : DAQ QHB (FA2020) http://sabiod.org/pub/QHB.pdf

A NOVEL LOW-POWER HIGH SPEED ACCURATE AND PRECISE DAQ WITH EMBEDDED ARTIFICIAL INTELLIGENCE FOR LONG TERM BIODIVERSITY SURVEY

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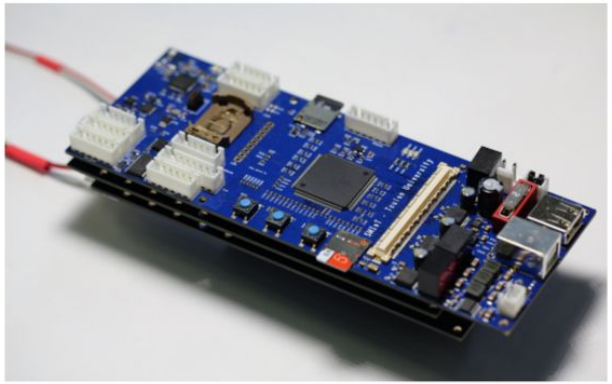
ABSTRACT

Acoustic monitoring is a key feature for studying biodiversity. Recent works on very high frequency animal sounds open new insights and challenges on biodiversity survey. In order to set a scaled monitoring, and to cover most of the frequencies of the present species, a novel multi-channel ultra high velocity recorder has been designed, called Qualilife HighBlue. This paper presents its architecture and characteristics. One of its most innovative features is an always-on ultra-low power wake-up, triggering recordings when temporal and/or spectral interesting



Embeded AI
Bombyx2 - Analog wake-up

- Background noise estimation
- >8kHz Energy thresholding
- State Machine consistency validation
- 75% AUC on Bombyx 1
- Ultra low power **12.5µA**

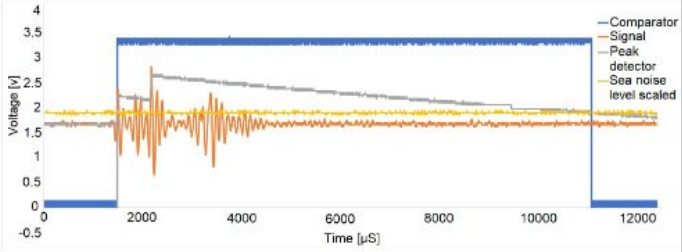


Fig. 7. Clicks of cetacean (Pm) with ULP processing, acquired on real signals (High-pass filtered input signal (orange), V_{Ref} (yellow), click envelope (grey), output of the comparator (blue)).

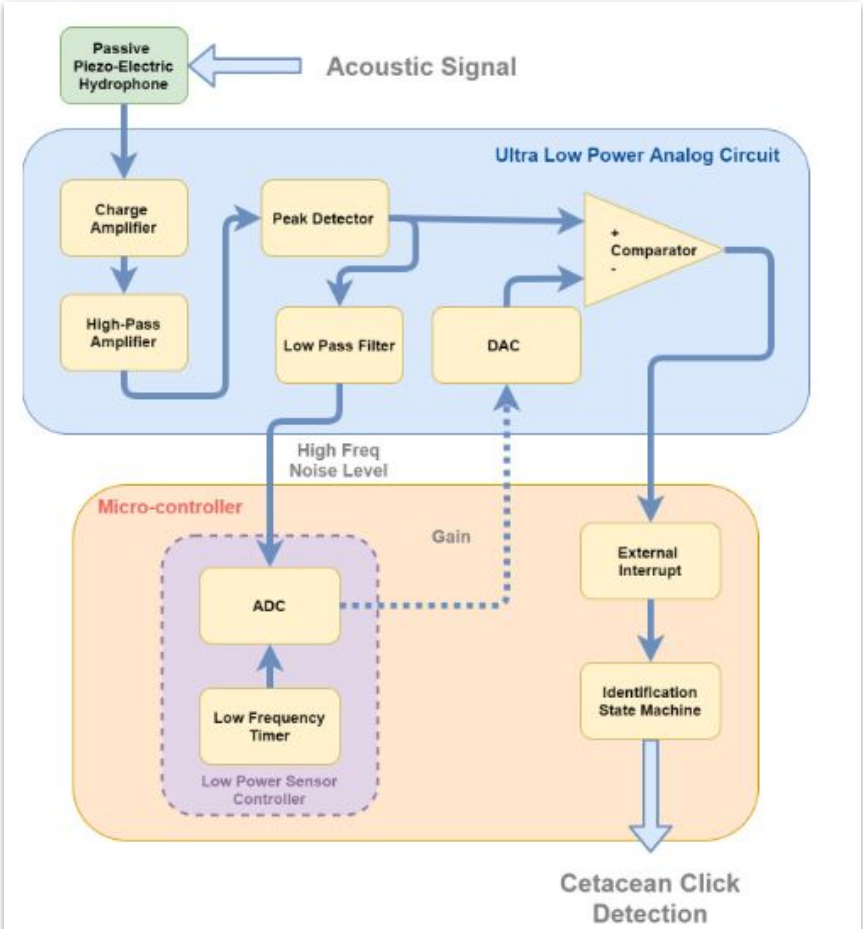
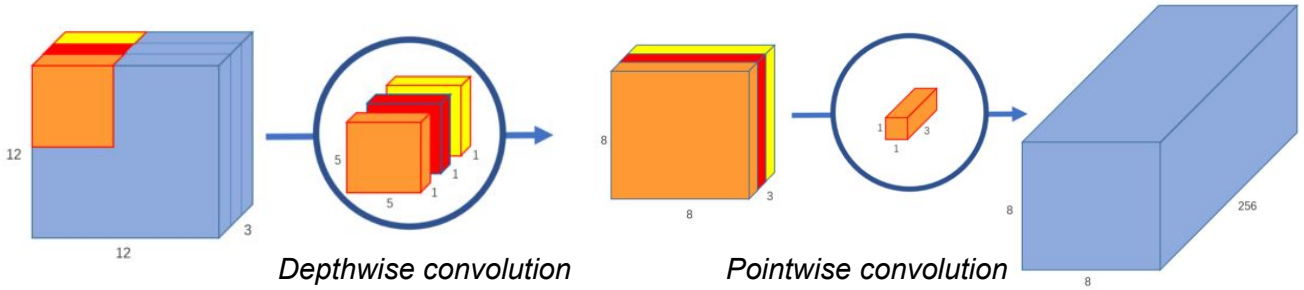


Fig. 4. Block diagram of the detector of a train of pulses of a Sperm Whale.

S. Marzetti, V. Gies, V Barchasz, P. Best, S. Paris, H. Barthelemy, H. Glotin (2020), Ultra-Low Power Wake-Up for Long-Term Biodiversity Monitoring, in proc. IEEE IoTAIS

Embeded AI
Depthwise separable convolution, decimated CNN



Conv : 5 x 5 x 3 x 256
DW Conv : 5 x 5 x 3 + 3 x 256

	# parameters	# mutliplications
Traditionnal	272 $x10^3$	309 $x10^6$
Depthwise	11 $x10^3$	13 $x10^6$

- Conv 64 - 512
- Conv 512 - 512
- Conv 512 - 1

L. Bai, Y. Zhao and X. Huang, "A CNN Accelerator on FPGA Using Depthwise Separable Convolution," in *IEEE Transactions on Circuits and Systems II: Express Briefs*, vol. 65, no. 10, pp. 1415-1419, Oct. 2018, doi: 10.1109/TCSII.2018.2865896.

Embeded AI
Into Low power micro-processor (PIC)

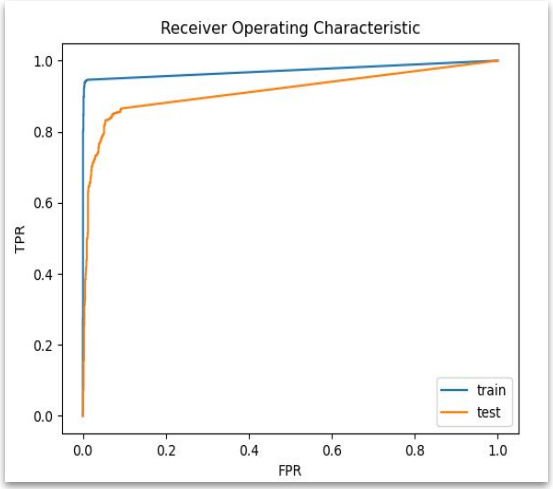
Analyse pour 5 secondes de signal

	Fin Whale	Sperm Whale
Sampling rate	200 Hz	50 kHz
Spectrogram size	128 x 46	64 x 974
Spectrogram computation time	0.2 sec	4.5 sec
Forward pass time	0.5 sec	2.1 sec

PIC 32MZ by Microchip

Embeded AI
Bombyx 2 - CNN validation / Localization

- **Convolutionnal neural network validation**
  - Relatively low compleity (~10k parameters)
  - Input : Mel-scaled spectrum between 2kHz and 25kHz
  - 98% AUC train, 93% AUC test
- **Azimuth and distance estimation**
  - Click onset recording using the analog detector
  - 50ns time resolution
  - All hydrophones pointing downwards
  - Integration of the triangulation of multiple pulses



- Sampling frequency = 50kHz
- STFT (winsize=512, hopsize=256)
- Mel (64 features from 2 to 25kHz)
- Log
- Conv 64 - 64
- Conv 64 - 64
- Conv 64 - 1
- MaxPool

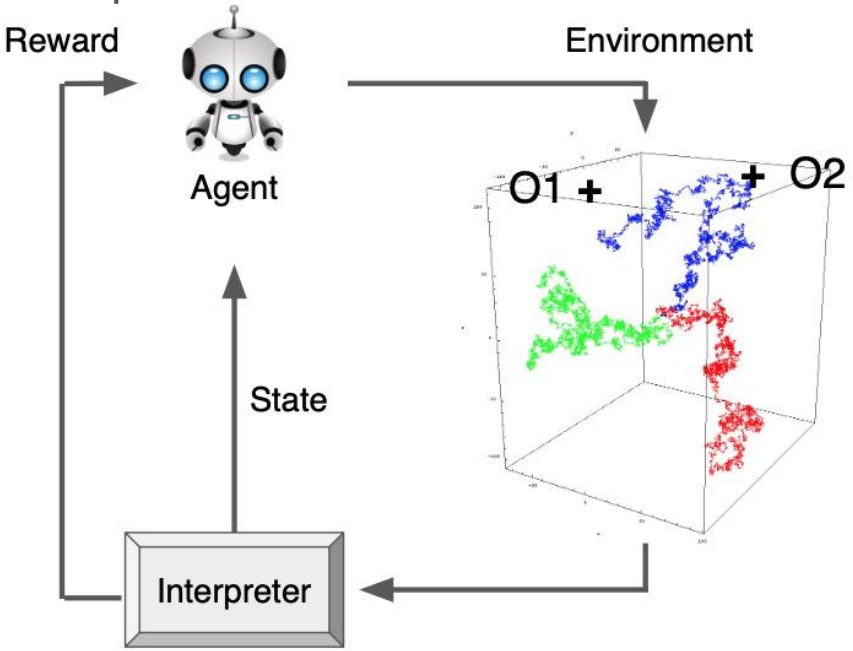
Conv = batch norm, depthwise conv, dropout, Relu
Valid AUC = 0,93

F) Conclusion & Perspectives

AI & Serious Game to learn to better track targets

Obs 1, Obs 2 : fixed (GIAS) or mobile (Sphyrna)

Simple model to start : Reinforcement Learning



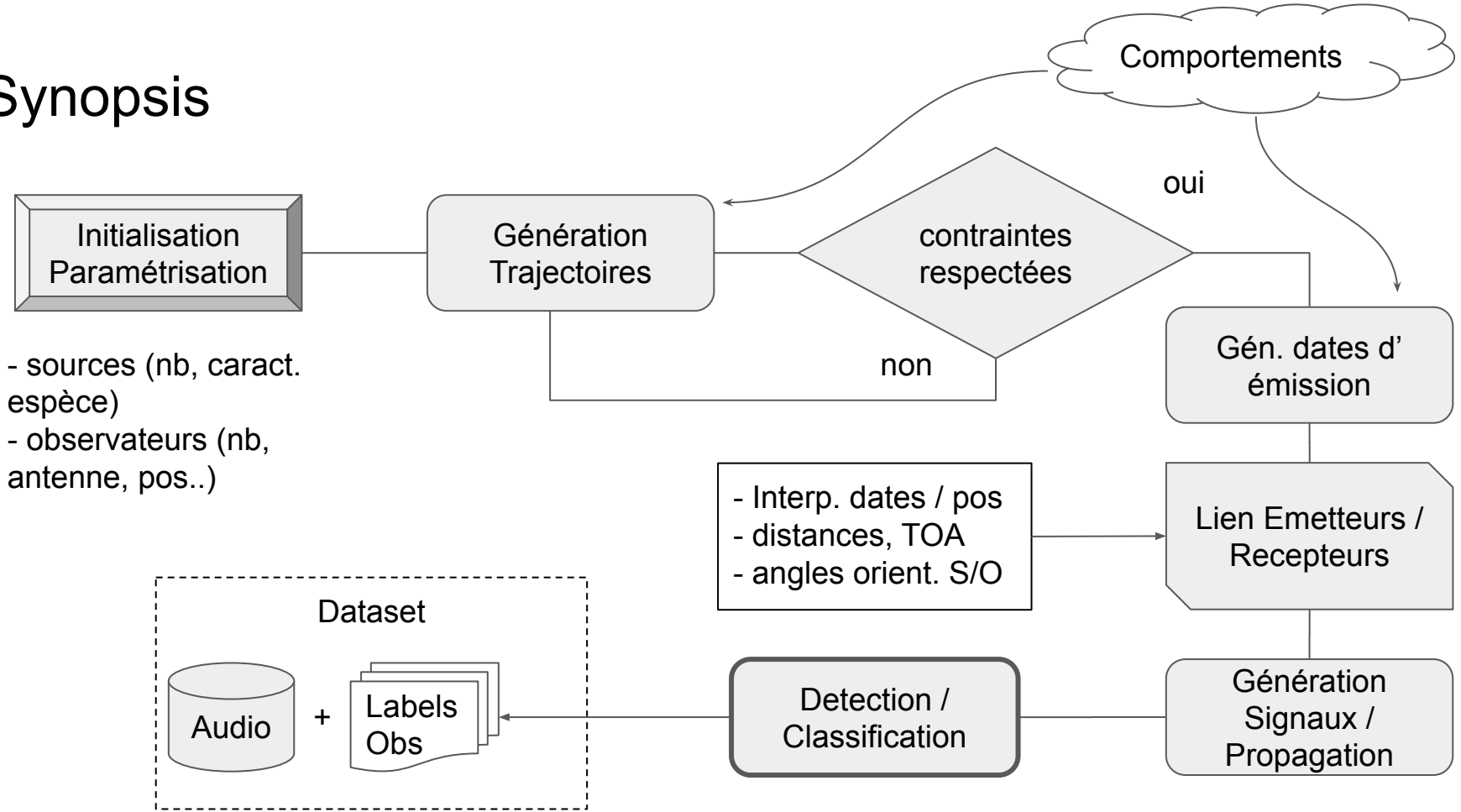
INPUT : millions of trajectories generated
(based on Markov Model)

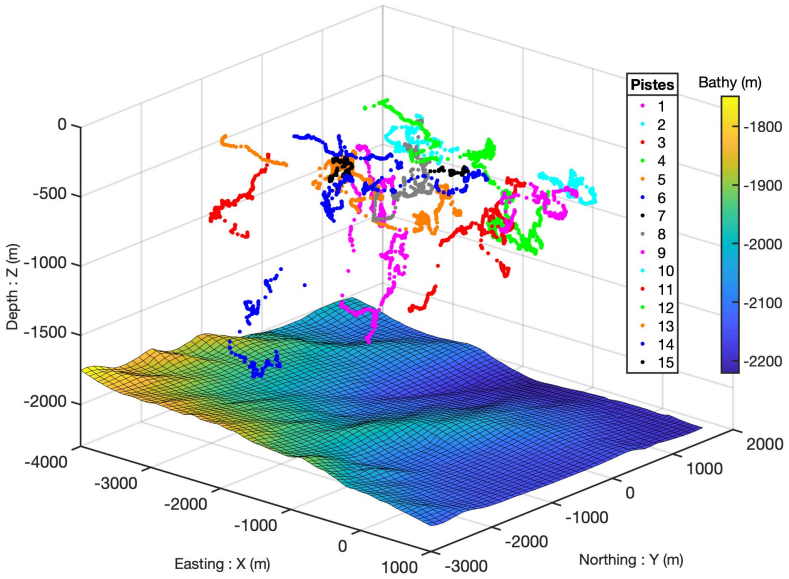
The goal(s) :

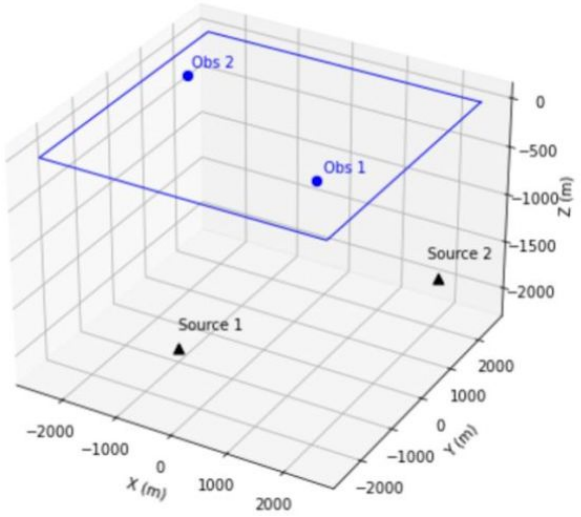
- Not losing track of target
- Optimise criterias such as :
  - SNR
  - error on position of sources (range estimation)

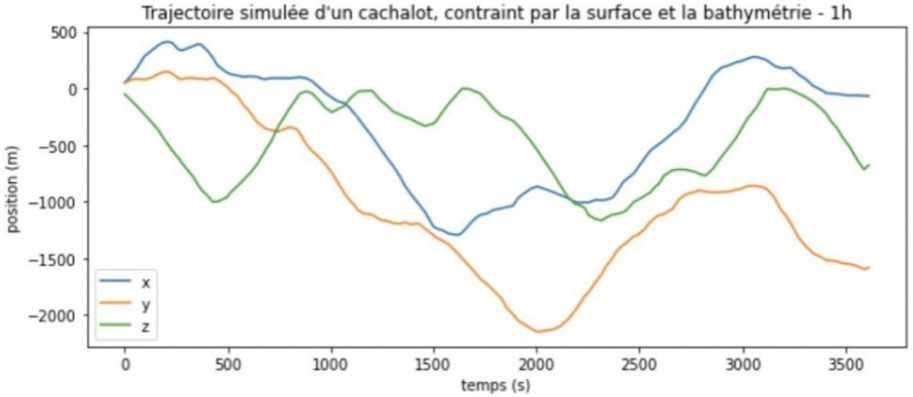
Kaelbling, Leslie P.; Littman, Michael L.; Moore, Andrew W.(1996). "Reinforcement Learning: A Survey". *Journal of Artificial Intelligence Research*. **4**: 237–285. arXiv:cs/9605103. doi:10.1613/jair.301. S2CID 1708582. Archived from the original on 2001-11-20.

Synopsis


Comportements
oui
Initialisation
Paramétrisation
Génération
Trajectoires
contraintes
respectées
non
Gén. dates d'
émission
- sources (nb, caract. espèce)
- observateurs (nb, antenne, pos..)
- Interp. dates / pos
- distances, TOA
- angles orient. S/O
Lien Emetteurs /
Recepteurs
Dataset
Audio
+
Labels
Obs
Detection /
Classification
Génération
Signaux /
Propagation







Rejouer résultats de mission
Sphyrna Odyssey 2020
(meute de cachalots localisée)
SO_report Glotin & al

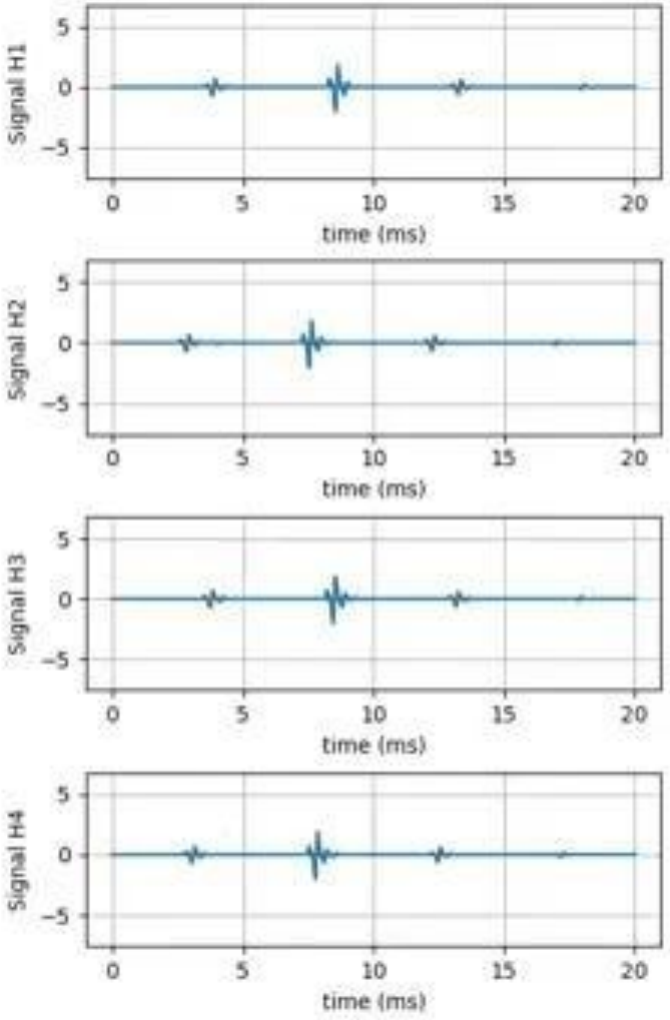
Demo

Tdoas

+

Directivité

émission



Simulation d'observation

clics de cachalot

Observateur :

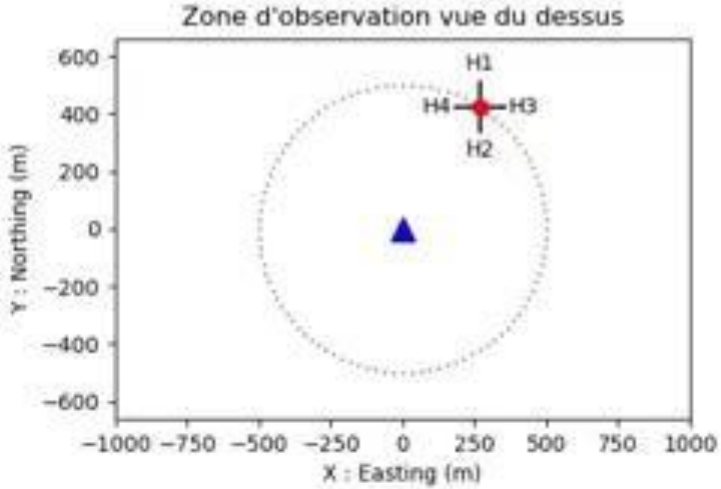
en mouvement (r=500m), orientation fixe

Antenne à 4 hydros : 2x2 orthog

Source :

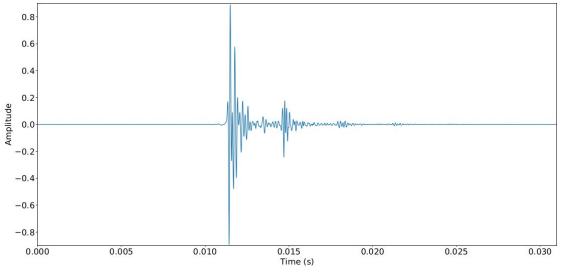
cachalot fixe, orientation fixe, à 100m de prof.

Directivité des clics / beam pattern selon Zimmer & al



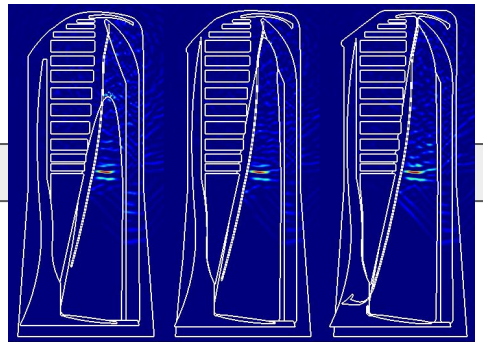
Inverse Problem & biosonar model

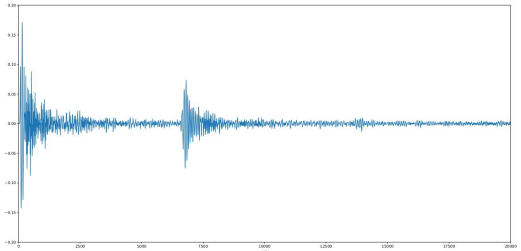
Source



Cost J

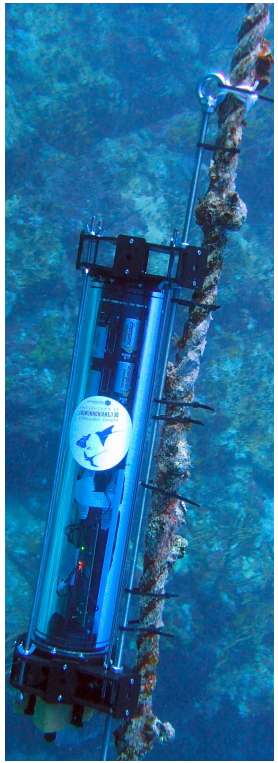
Model of the source

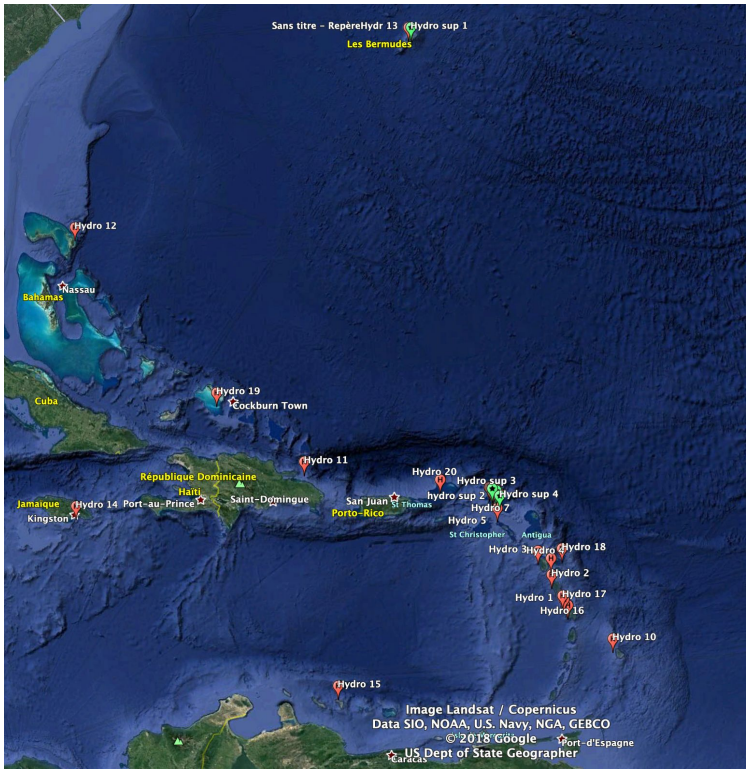




Extension to Carimam (OFB / EU) 2019-22+
Tracking of 20 species of all Antilles during 1 year

- 20 stations built by SMIoT UTLN / IM2NP / LIS distributed to 20 international ONGs
- Recording @ 256 kHz * 40 days / 60 days * 1 year
- 300 Go x 10 sessions x 20 stations = 60 To of submarine soundscape
- Automatic Identification of 20 species by ADSIL / DYNI LIS UTLN over 60 To to assess biopopulation





Some publications of ADSIL since june 2020

Ferrari, Glotin, Marxer, Asch (2021) Classification of Marine Mammal Clicks by Raw Audio Multiscale Hierarchical Convolutional Neural Network and a Study of Learned Representation, submitted to JASA

Poupard, Symonds, Spong, Glotin (Submitted to Scientific Report Nature 2021) Evidences of Intra-Group Orca Call Rate Modulation Using A Small-Aperture Four Hydrophone Array.
https://assets.researchsquare.com/files/rs-116685/v1_stamped.pdf

Barchasz, Gies, Marzetti, Glotin (2020) A novel low-power high speed accurate and precise DAQ with embedded artificial intelligence for long term biodiversity survey, Eu. Forum Acusticum
http://sabiod.univ-tln.fr/pub/QualiHighBlue_DAQ_FA2020.pdf

Best, Ferrari, Poupard, Paris, Marxer, Symonds, Glotin (2020) Deep Learning and Domain Transfer for Orca Vocalization Detection. In International joint conference on neural networks. IEEE IJCNN,
https://hal.archives-ouvertes.fr/hal-02865300/document

Ferrari, Glotin, Marxer, Asch (2020) End to end raw audio deep learning of transients, application to bioacoustics, Eu. Forum Acusticum https://hal.archives-ouvertes.fr/hal-03078665/document

Ferrari et al. (2020) 3D diarization of a sperm whale click cocktail party by an ultra high sampling rate portable hydrophone array for assessing individual cetacean growth curves, Eu. Forum Acusticum
https://hal.archives-ouvertes.fr/hal-03078655/document

Ferrari et al. (2020) DOCC10: Open access dataset of marine mammal transient studies and end-to-end CNN classification, in 2020 International Joint Conference on Neural Networks (IJCNN). IEEE
https://hal.archives-ouvertes.fr/hal-02866091/document

Marzetti, Gies, Barchasz, Best, Paris, Barthelemy, Glotin (2020) Ultra-Low Power Wake-Up for Long-Term Biodiversity Monitoring, in proc. IEEE IoTAIS

Poupard, Best, Ferrari, Spong, Symonds, Prevot, Soriano, Glotin (2020) From massive detections and localisations of orca at orcalab over three years to real-time survey joint to environmental conditions in Eu. Forum Acusticum

Ferrari (2020) Study of a Biosonar Based on the Modeling of a Complete Chain of Emission-Propagation-Reception with Validation on Sperm Whales, Phd Thesis, Université Picardie Jules Verne, (dir Glotin & Asch)
https://hal.archives-ouvertes.fr/tel-03078625/document

Poupard (2020) Contributions en Méthodes Bioacoustiques Multiéchelles: Spécifiques, populationnelles, individuelles et comportementale, Phd Thesis, Université de Toulon (dir Glotin Soriano Lengagne)
http://sabiod.univ-tln.fr/pub/poupard/cv/m_poupard_phd_08012021.pdf

Glotin, Thellier, Best, Poupard, Ferrari, et al. (2020) Rapport Mission Sphyrna Odyssey : Découvertes Ethoacoustiques de Chasses Collaboratives de Cachalots en Abysse & Impacts en Mer du Confinement COVID19
,http://sabiod.univ-tln.fr/pub/SO1.pdf