UMR LSIS

Univ. Toulon

CIBRA – Univ. of Pavi

ANTARES :

Detection and Localization

of Marine Mammals

using Passive Acoustics

ANTARES Meeting - CPPM

Sept. 2008

Our research team, since 2003…

Pr Jean-François MOTSCH

Dr Olivier ADAM, Habilitate Assistant Professor

Laboratoire d'Images, Signaux et Systèmes Intelligents (LiSSi)
group Ingénierie des Signaux NeuroSensoriels (iSnS)
University of Paris

Dr Hervé GLOTIN, Habilitate Assistant Professor

Ing. Frédéric CAUDAL, PhD Candidate

Laboratoire des Sciences de l'Information des Systèmes (LSIS CNRS)

Dr Pascale GIRAUDET, Assistant Professor
Département de Biologie
University of Toulon

Dr Christophe GUINET, Habilitate Researcher

Centre d'Etudes Biologiques de Chizé (CEBC)
group Ecology of Birds and Marine Mammals
Centre National de la Recherche Scientifique (CNRS)

Pr Giani Pavan – CIBRA – Univ Pavi

Observation of Marine Mammals ?

Goals

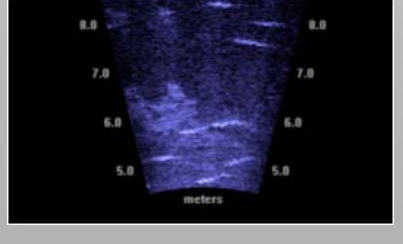
Observation of animals during their dives
Biological marker
Evaluation of the acoustic pollution
Anti-collision program

Usual methods

Visual observations
random

DTAG
unstable

Active acoustics
repulsive



Sounds emitted by marine mammals

A large set of differents sounds

Harmonic sounds (vocalizations, whistles…) and non-harmonic sounds (clicks, buzz…)

A vast diversity of vocalizations from one species to another
and from one individual to another within a species

diverse acoustic pressures (20-220 dB re1uPa at 1m)
wide band of frequencies (20Hz – 200 kHz)

Illustrations

Sperm whales: regular clicks, creaks, codas

Striped dolphins: clicks, whistles

Our proposal : Passive Acoustics Marine Mammal Monitoring

=> No interactions with the animal neither its environment, low cost & long term survey

Objectives

Endeavour for the inventory of marine mammal species
Distinction between resident, semi-resident and non-resident species
Localization of possible hot-spot in front of Hyères
Study of the behavior and their displacements

Method

Passive acoustics
Detection and identification of the local marine mammal species
Localization of individuals in the same time

Difficulties

Variant underwater noise
Variant size of the group
Large bandwidth and large variability in the sounds they emit

Challenge

Extraction of individual emission inside a “WHALE COCKTAIL PARTY”
Estimation of the number of individuals from their sounds
Extraction of parameters for acoustic signature
Behavior analyses

The strongest points of our proposal

Our experience

More than 20 journal papers since 2004,
Development of real time tools for detection and tracking of marine mamals

Benchmarks on : NEMO,
NAVY/AUTEC Bahamas,
Porquerolles,
DGA tremail,
Madagascar,…

What we propose

Software for automatic analysis and classification of marine mammals sounds recorded by Nemo and Antares

Real-time processing

Estimation of the localization of individuals

Organization and gestion of the cetacen dataset (stock, access, XML structuration)

What we need

Access to all acoustic recordings

1 Post-doctorant, 18 months

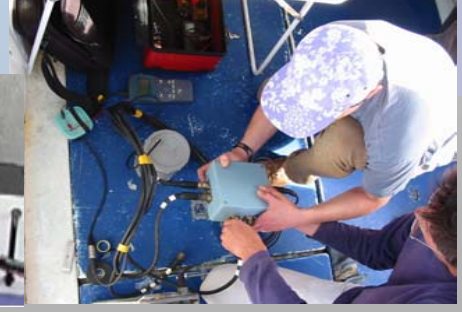
1 technician, 18 months

Passive Acoustics data…

Recordings of underwater sounds using hydrophones

Difficulties

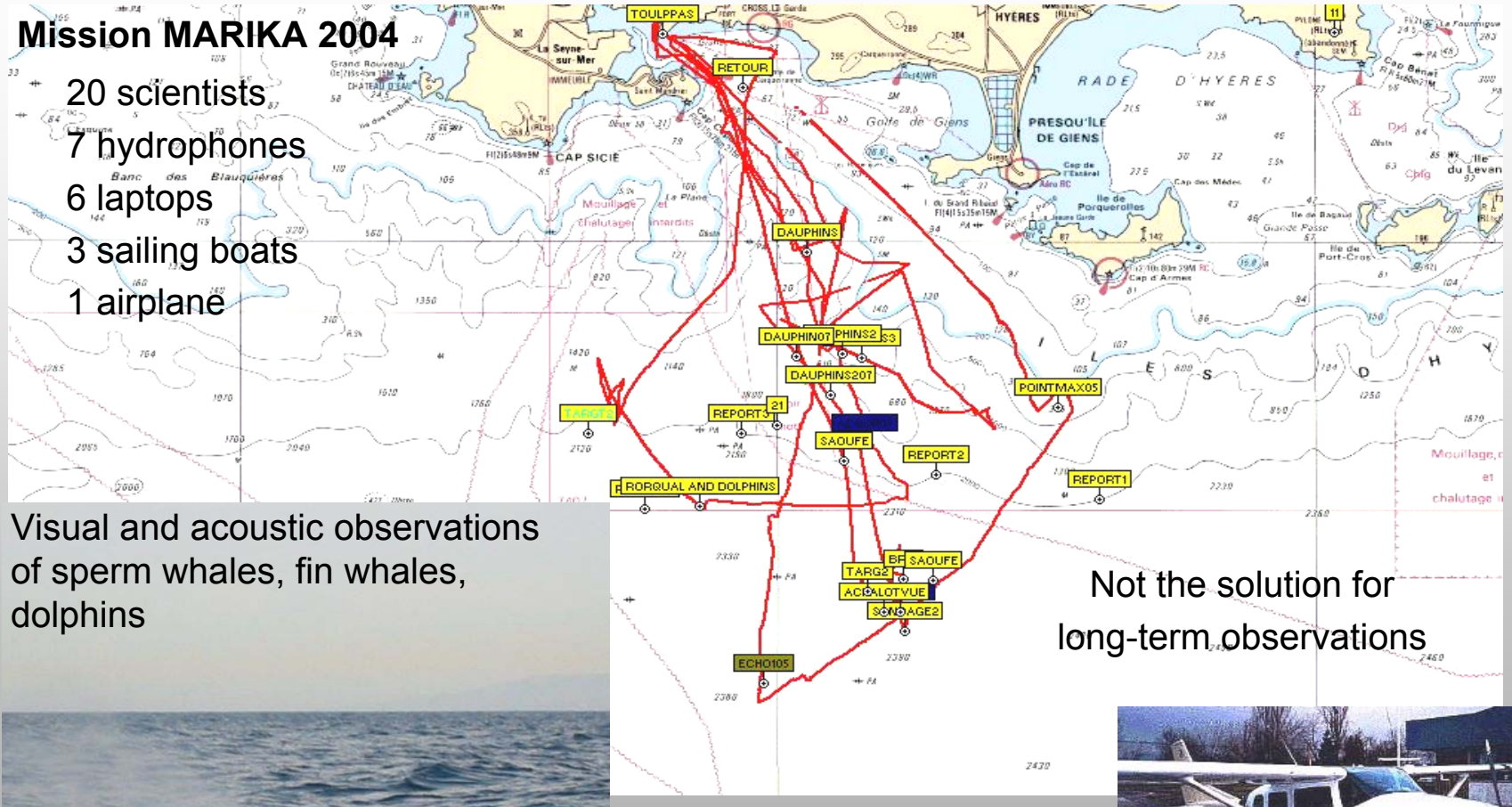
Alignement of the hydrophones
Position of the hydrophones
Time synchronization



Our acoustic observations (TOULON 2004)

Mission MARIKA 2004

- 20 scientists
- 7 hydrophones
- 6 laptops
- 3 sailing boats
- 1 airplane



Visual and acoustic observations of sperm whales, fin whales, dolphins

Not the solution for long-term observations

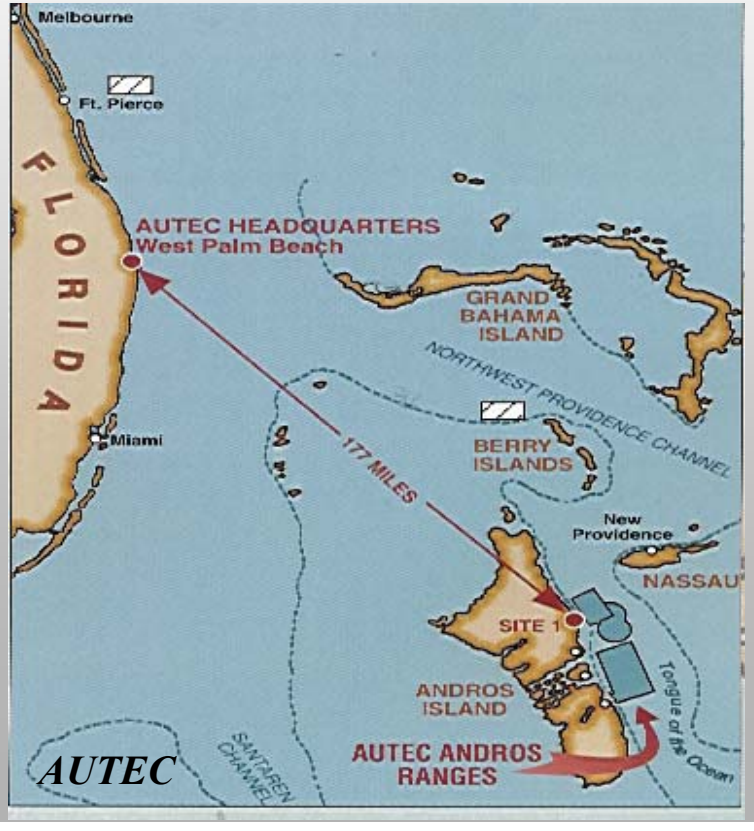
huge organization for one week

Hydrophone array acquisition

Dataset of the

2nd International Workshop of Detection and Localization of Marine Mammals using Passive Acoustics (Monaco, 2005)

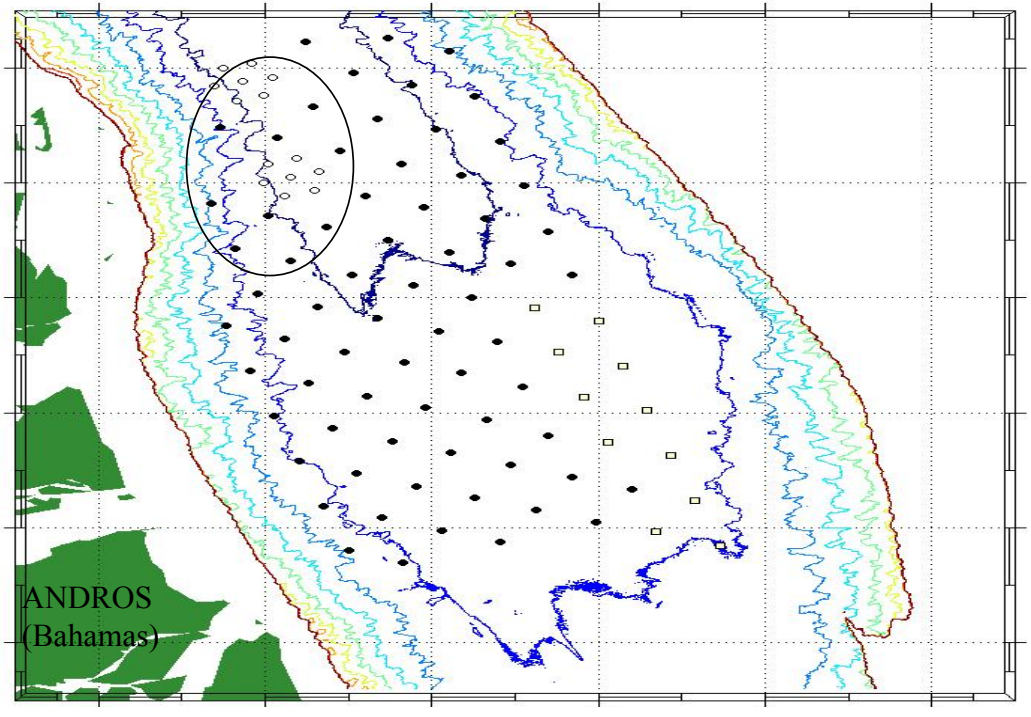
Data from Atlantic undersea Test & Evaluation Center (AUTEC) / Tongue of The Ocean (TOTO)



Satellite Image from NASA

Hydrophones position

Hydro phone	X (m)	Y (m)	Z (m)
1	10 658	-14 953	-1 530
2	12 788	-11 897	-1 556
3	14 318	-16 189	-1 553
4	8 672	-18 064	-1 361
5	12 007	-19 238	-1 522



- 25 audio files
- Total of 25 min
- Recorded on 5 hydrophones
- FS = 48 KHz
- Data set 2 of the workshop

[map from AUTEC]

RESULTS : Detection and Localization of Sperm Whales

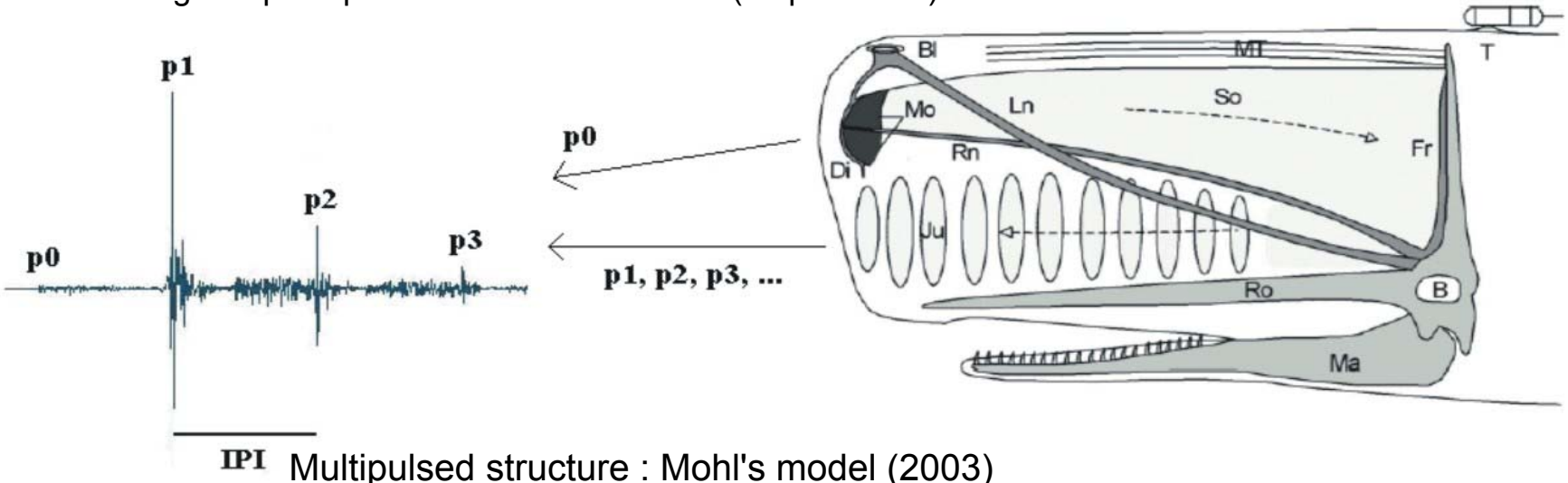
Click analyses : a specific structure

Sperm whales emit high level click

for **communication**, these clicks are omnidirectional

for **echolocation**, these clicks are directional.

With a click at **185 dB** re: 1 *μ*Pa (resp. **225 dB** re: 1 *μ*Pa), the sperm whale could detect a 10-cm length cephalopod at a distance of **100m** (resp. **1000m**)



Multipulsed structure : Mohl's model (2003)

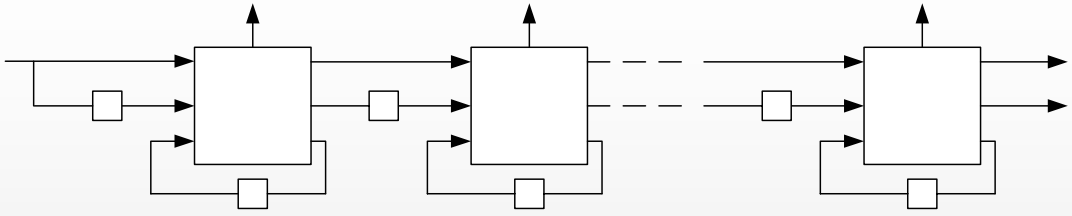
Remark

Length of the animal deducted from $\mathrm{IPI} = \frac{2DF}{c_s}$

Detection and Localization of Sperm Whales

Schur Method

Parametric approach

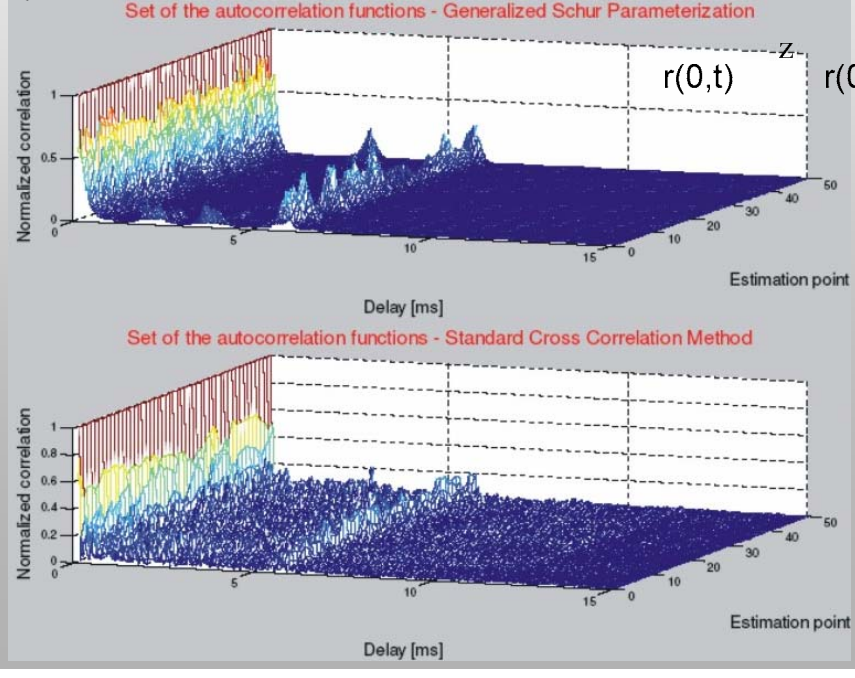


Interest

- Fast convergence
- Instantaneous tracking of features
- Stability of the algorithm
- Time-frequency representation
- Real-time applications
- Robust to noise

$$\begin{cases} \rho_{n+1}(t) = \rho_{n+1}(t-1)\left(1-e_n^2(t)\right)^{\frac{1}{2}}\left(1-r_n^2(t-1)\right)^{\frac{1}{2}} - e_n(t)r_n(t-1) \\ e_{n+1}(t) = \left(1-\rho_{n+1}^2(t)\right)^{-\frac{1}{2}}\left(1-r_n^2(t-1)\right)^{-\frac{1}{2}}\left[e_n(t)+\rho_{n+1}(t)r_n(t-1)\right] \\ r_{n+1}(t) = \left(1-\rho_{n+1}^2(t)\right)^{-\frac{1}{2}}\left(1-e_n^2(t)\right)^{-\frac{1}{2}}\left[\rho_{n+1}(t)e_n(t)+r_n(t-1)\right] \end{cases}$$

y(t) e(0,t)



Applications

- Detection of the clicks
- **Robust measure of the IPI**
- **Recognition of the clicks**

Detection and Localization of Sperm Whales

Localization using a single hydrophone

Advantages

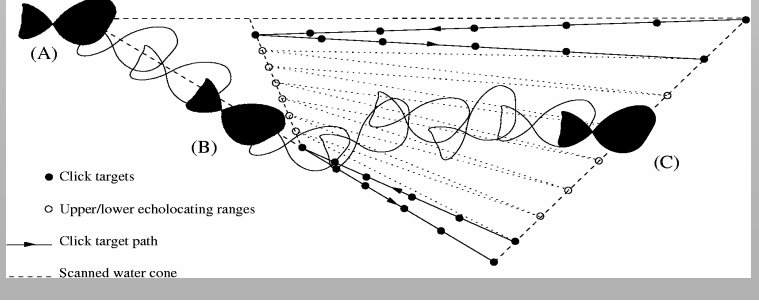
- Detection and localization
- Material easily portable
- No extern synchronization
- Less sensitive to the directivity
- Hydrophone at an unknown depth

Method

- Direct path and echoes
- Measurement of the delays
- Measurement of the relative amplitude

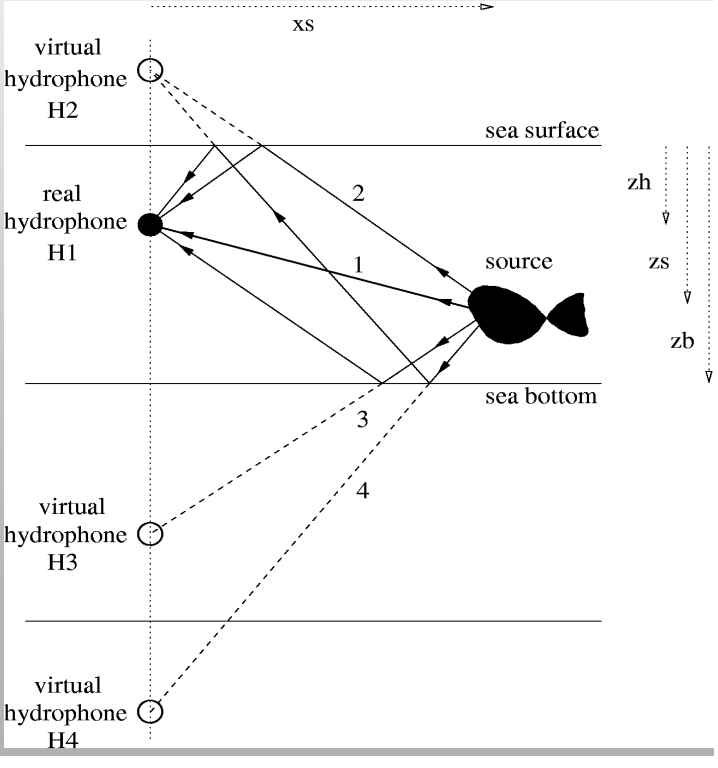
Results

- Extraction of the depth of the animal
- Distance from the hydrophone
- Using the law, roll, pitch



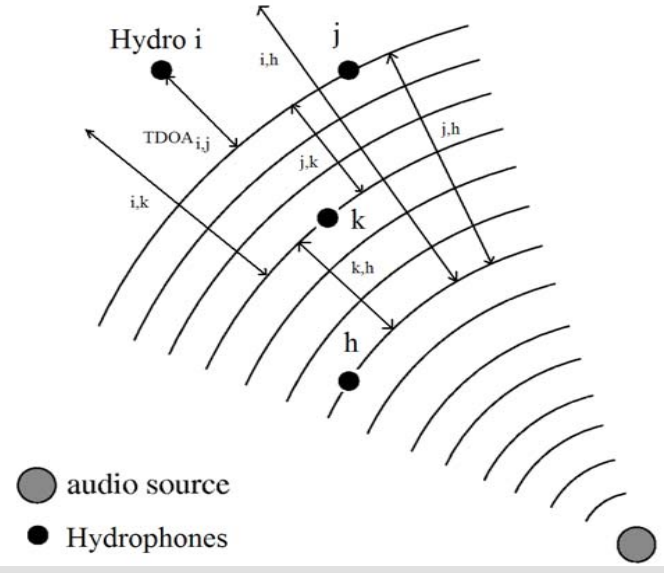
With the direct signal and one echo in 3D : hyperboloïde

$$\frac{\left(z_e - \frac{d_{12}}{2}\right)^2}{a_{12}^2} - \frac{x_e^2}{b_{12}^2} - \frac{y_e^2}{b_{12}^2} = 1$$



Detection and Localization of Sperm Whales

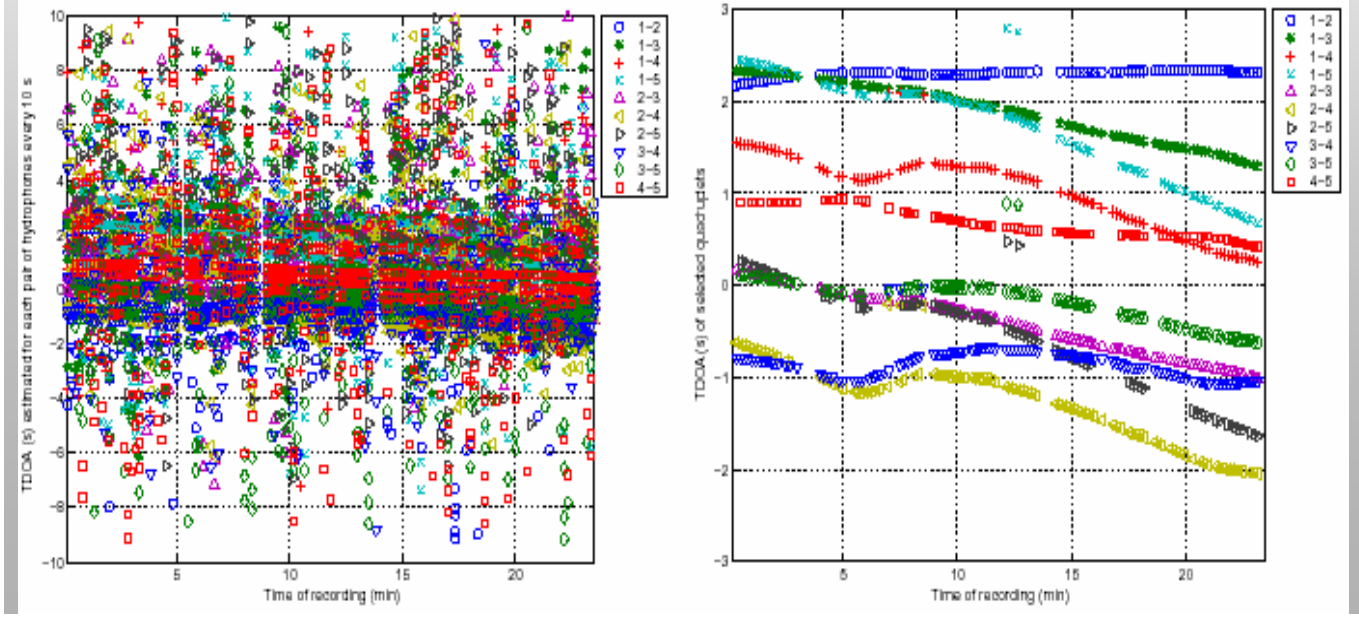
Localization using multiple hydrophones



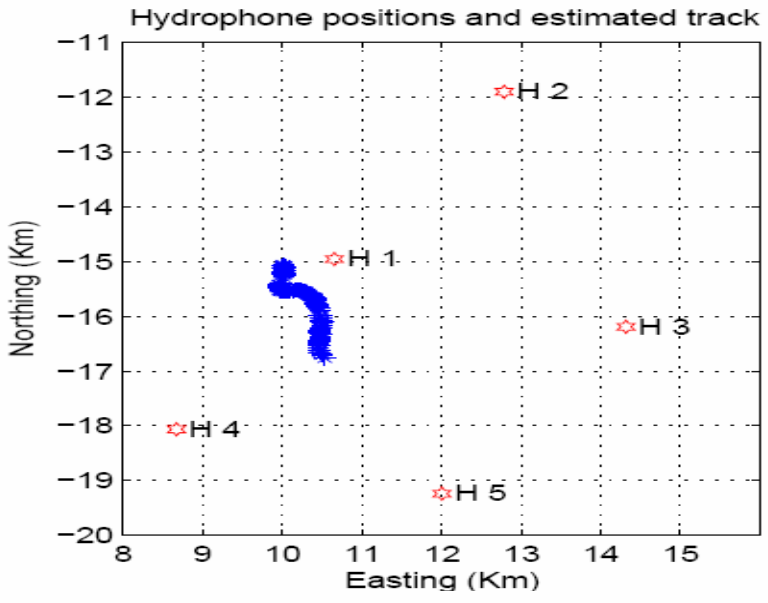
Filtering TDOA

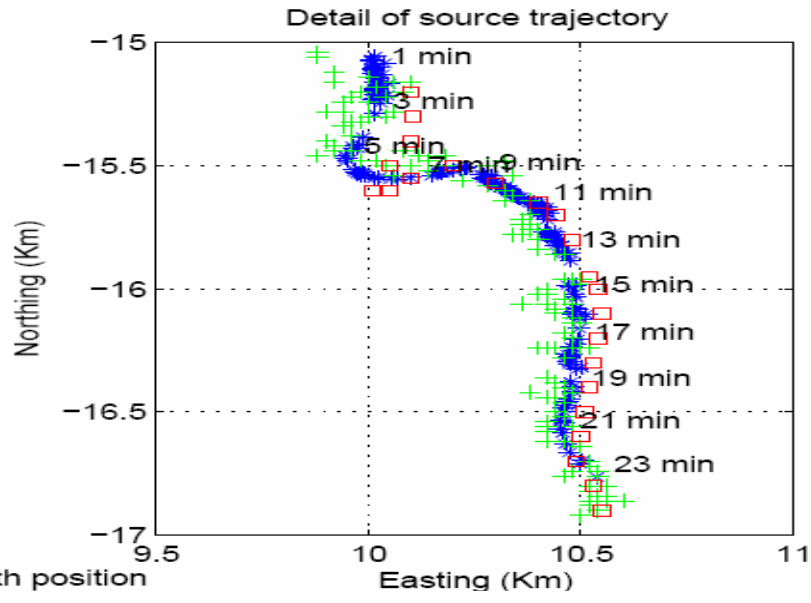
$$TDOA(i,j) + TDOA(j,k) = TDOA(i,k) \pm err$$

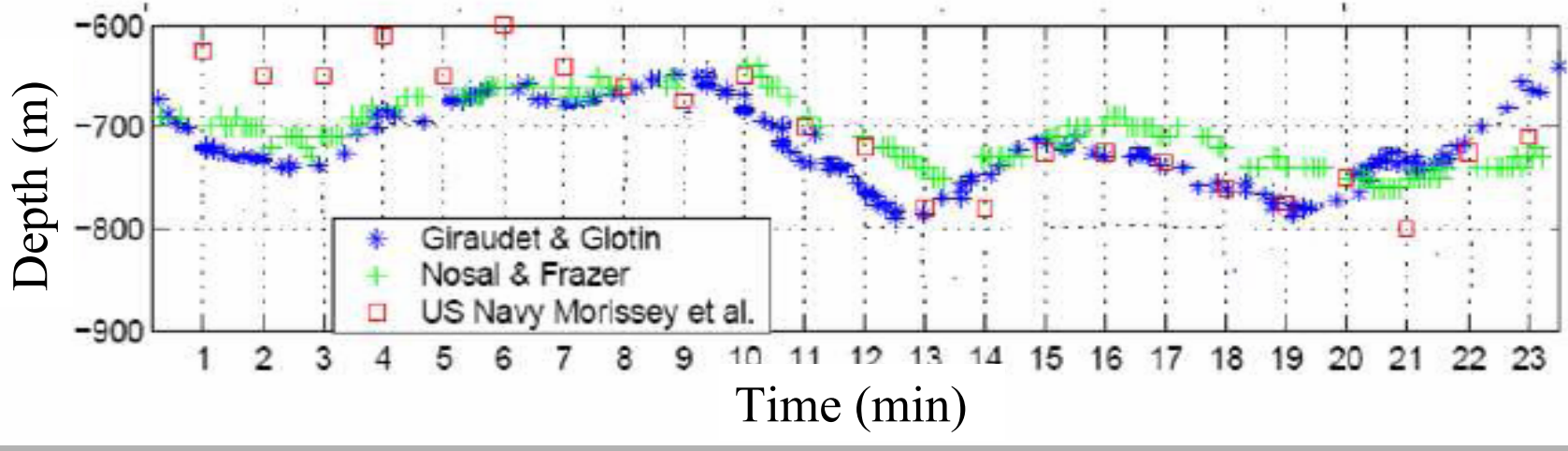
initial TDAOs → **Selected TDAOs**



1 whale tracking with 3 different models: PIMC (LSIS), Bellop (SOEST), M3R (US Navy)







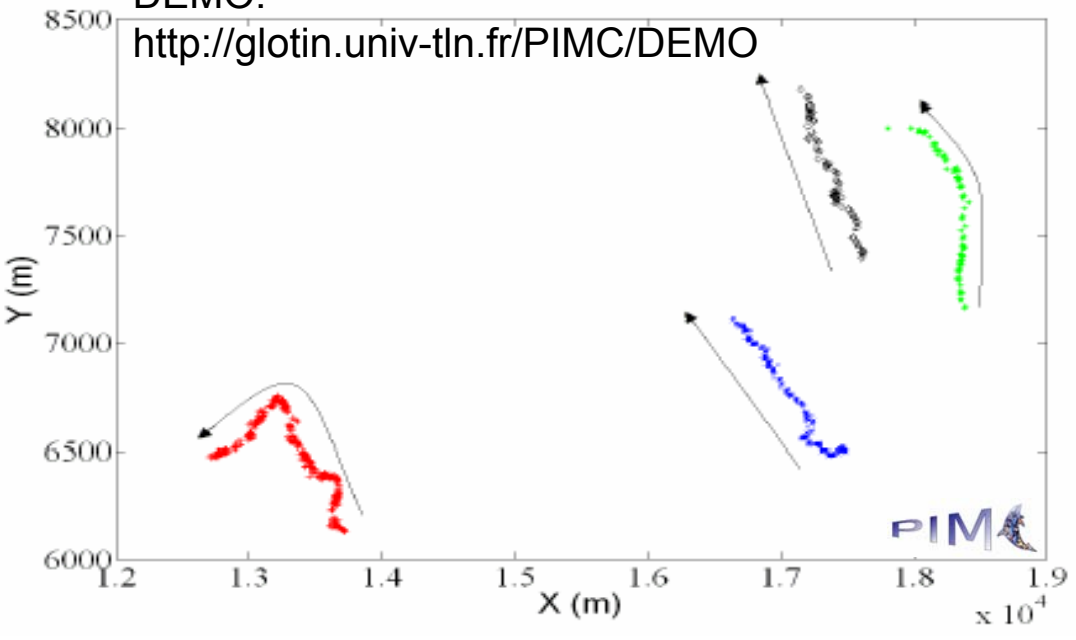
Detection and Localization of Sperm Whales

Localization using multiple hydrophones

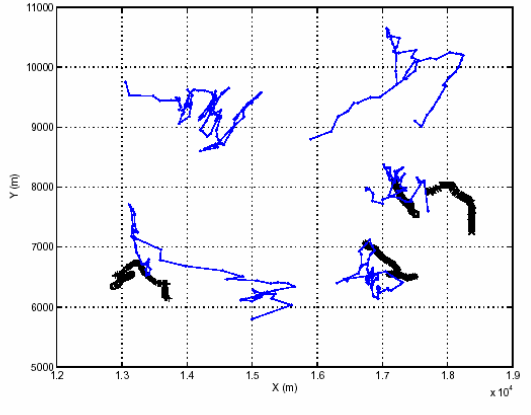
Advantages

- Multiple tracking of simultaneous clicking whales (patented)
- Confidence regions: 30m large
- Real-time
- Behavior analyses

DEMO:
http://glotin.univ-tln.fr/PIMC/DEMO

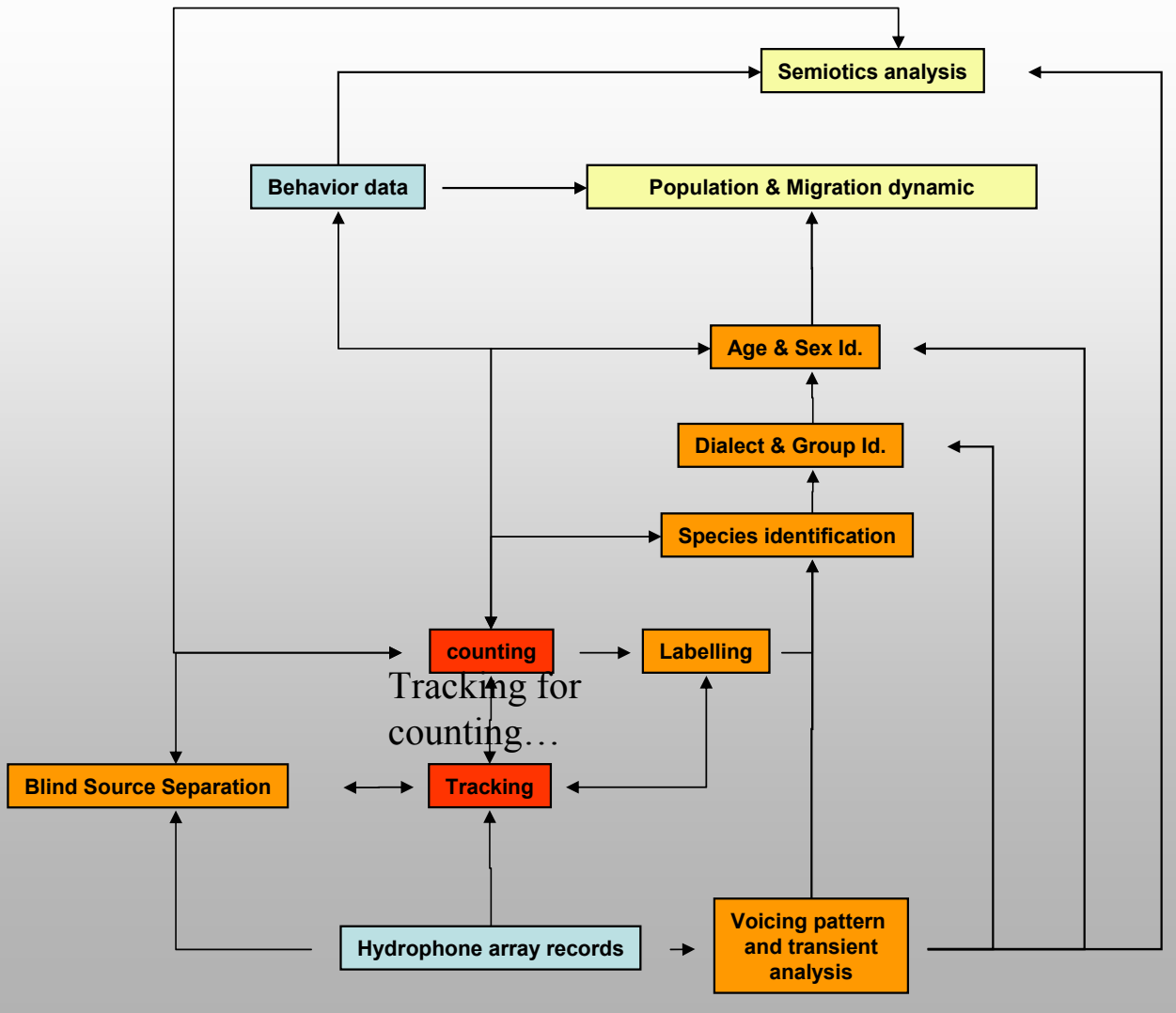


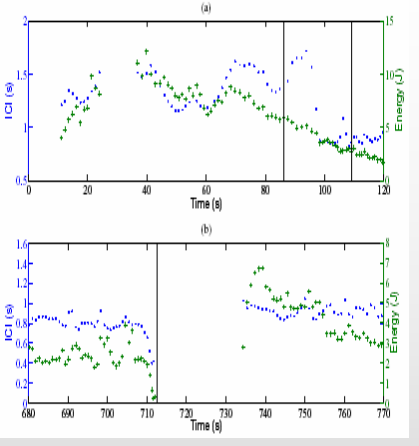
Compared to Hawaï univ estimates :



3.9 – Comparaison, sur les 20 minutes du set 1, entre les trajectoires estimées p

PIMC project : integrating multimodal analyses for cetology





Ingestion …

SPECIES the ANTARES site :

	dB 1uPa 1m	frequency (Hz)
sperm whale (Physeter macrocephalus)	160-220	[100 ; 30000]
fin whale (Balaenoptera physalus)	150-190	[30 ; 750]
long finned pilot whale (Globicephala mela)	180	[500 ; 24000]
Risso's Dolphin (Grampus Griseus)	120	[5000 ; 65000]
striped dolphin (Stenella coeruleoalba)		[6000 ;150000]
bottlenose dolphin (Tursiop truncatus)	125-220	[800 ;130000]

credits H. Peltier – Risso's dolphin

credits NOAA – striped dolphin

credits F. Gally – bottlenose dolphin

Last inventory of marine mammals species done in 1990 :
incomplete and submitted to discussions
A new inventory is planned for the next two years (2008-09)
program supported by **Accobams**, **PELAGOS Sanctuary**

credits S. Mizroch –pilot whales

Selected References

- **O. Adam, and H. Glotin**, “Passive acoustic storey of the ANTARES neutrino detector for real-time cetaceans detection, localization and behavior studies”, in IEEE Passive 2008, Hyères.
- **H. Glotin**, P . Giraudet, F. Caudal, "Procédé de trajectographie en temps réel sur ordinateur portable de plusieurs cétacés par acoustique passive" - sept 2007 - 56 pages Brevet N° dépôt à l'Institut Nat. Propriété Intellectuelle 07/06162
- P. Giraudet, **H. Glotin**, "Real-time 3D tracking of whales by precise and echo-robust TDOAs of clicks extracted from 5 bottom-mounted hydrophones records of the AUTEC", in int. journ. Applied Acoustics, Elsevier Ed., Vol. 67, 12p, nov 2006.
- **H. Glotin**, F. Caudal, P. Giraudet, "Whale cocktail party: a real-time tracking of multiple whales", invited paper In int. Journal Canadian Acoustics, sp. ed. on Detection and localisation of MM using Passive Acoustics, March 2008, pages 139-145.
- F. Caudal, **H. Glotin**, ‘’Stochastic Matched Filter outperforms Teager-Kaiser-Mallat for tracking a plurality of clicking whales’’, in IEEE Passive 2008, Hyères.
- F. Caudal, **H. Glotin** ‘’High level automatic oceanic data structuration: from whale click sequence modulations to behavior analyses’’, in IEEE Passive 2008, Hyères.
- F. Lelandais, **H. Glotin**, Mallat’s Matching Pursuit of Sperm Whale Clicks in Real-Time using Daubechies 15 wavelets, in IEEE Passive 2008, Hyères.
- **Pavan G**., G. La Manna, F. Zardin, G. Riccobene, G. Cosentino, F. Speziale, NEMO Collaboration, 2006. Long term acoustic monitoring of sperm whales off Catania with onde. INFN LNS Reports 2006: 148-150.
- Podestà M., A. D’Amico, **G. Pavan**, A. Drougas, A. Komnenou and N. Portunato, 2006. A Review of Ziphius cavirostris (G. Cuvier, 1823) Strandings in the Mediterranean Sea. J. CETACEAN RES. MANAGE. 7(3): 251–261.
- Riccobene G. for the NEMO Collaboration and L.Cosentino, **G.Pavan**, F.Speziale, 2005. On-line monitoring of underwater acoustic background at 2000 m depth. Proc. 29th International Cosmic Ray Conference, Pune, India. CDROM.
- **Pavan G.**, Cosentino G., Musumeci M., Riccobene G., Speziale F., NEMO Collaboration, 2005. Noise spectra and biological signals from the NEMO test site. LNS Activity Report 2005, INFN: 156-157.
- **Pavan G.**, Manghi M., 2004. Tools for underwater noise monitoring, marine mammals’ surveys, and acoustic risk mitigation policies’ implementation. Marine Mammals Commission, USA. Published online http://www.mmc.gov
- M. Lopatka, **O. Adam**, C. Laplanche, J.F. Motsch and J. Zarzycki, Sperm whale click analysis using a recursive time-variant lattice filter, Applied Acoustics, éd. Elsevier, 2006, 67, p. 1118-1133.
- M. Lopatka, **O. Adam**, C. Laplanche, J. Zarzycki and J.F. Motsch, Effective analysis of non-stationary short-time signals based on the adaptive Schur filter, Transactions on Systems, Signals & Devices, éd. Shaker-Verlag, 2006, 1(3), p. 295-319.
- C. Laplanche, **O. Adam,** M. Lopatka, J.F. Motsch, Measuring the off-axis angle and the rotational movements of phonating sperm whales using a single hydrophone, Journal of the Acoustical Society of America (JASA), 2006, 119(6), p. 4074-4082.
- M. Lopatka, **O. Adam,** C. Laplanche, J. Zarzycki, J.F. Motsch, An Attractive Alternative For Sperm Whale Click Detection Using the Wavelet Transform in Comparison to the Fourier Spectrogram, Aquatic Mammals, 2005, 31(4), 463-467, DOI 10.1578/AM.31.4.2005.463
- C. Laplanche, **O. Adam**, M. Lopatka, J.F. Motsch, Male sperm whale acoustic behavior observed from multipaths at a single hydrophone, Journal of the Acoustical Society of America (JASA), 2005, 118(4), p. 2677-2687
- **O. Adam**, M. Lopatka, C. Laplanche, JF Motsch, Sperm whale signal analysis: comparison using the autoregressive model and the wavelet transform, International Journal of Information Technology, ISSN: 1305-2403, 2005, 2(1), p. 1-8

Any questions ?