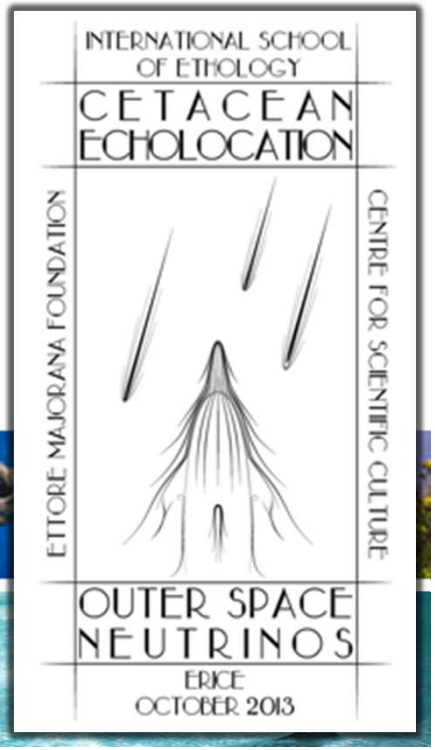
ARION - Systems for Coastal Dolphin Conservation in the Ligurian Sea

M.Taiuti on behalf of the ARION Collaboration



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THE PROJECT

ARION-LIFE+09 NAT/IT/190

- The ARION main objective is the creation of a virtual corridor for monitoring and surveillance of transient and resident bottlenose dolphins (*Tursiops truncatus*).
- Cofunded by EU, started on 1/10/2010 has now completed the infrastructure deployment
- The ARION protocol will become effective starting spring 2014 and will last two years (at least)

Partnership

- Università di Genova (DIFI e DISTAV)
- SOFTECO SISMAT srl
- Area Marina Protetta di Portofino
- Direzione Marittima di Genova

Authors

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(4) Softeco Sismat, Genoa, Italy
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Objectives

- Conservation of the *Tursiops Truncatus* by means of three actions
  - Continuous surveillance of the project area to detect the presence of the bottlenose dolphins and concurrent human activities (boats)
  - Prompt risk reduction
  - Long term activity to define regulations and protected area boundaries

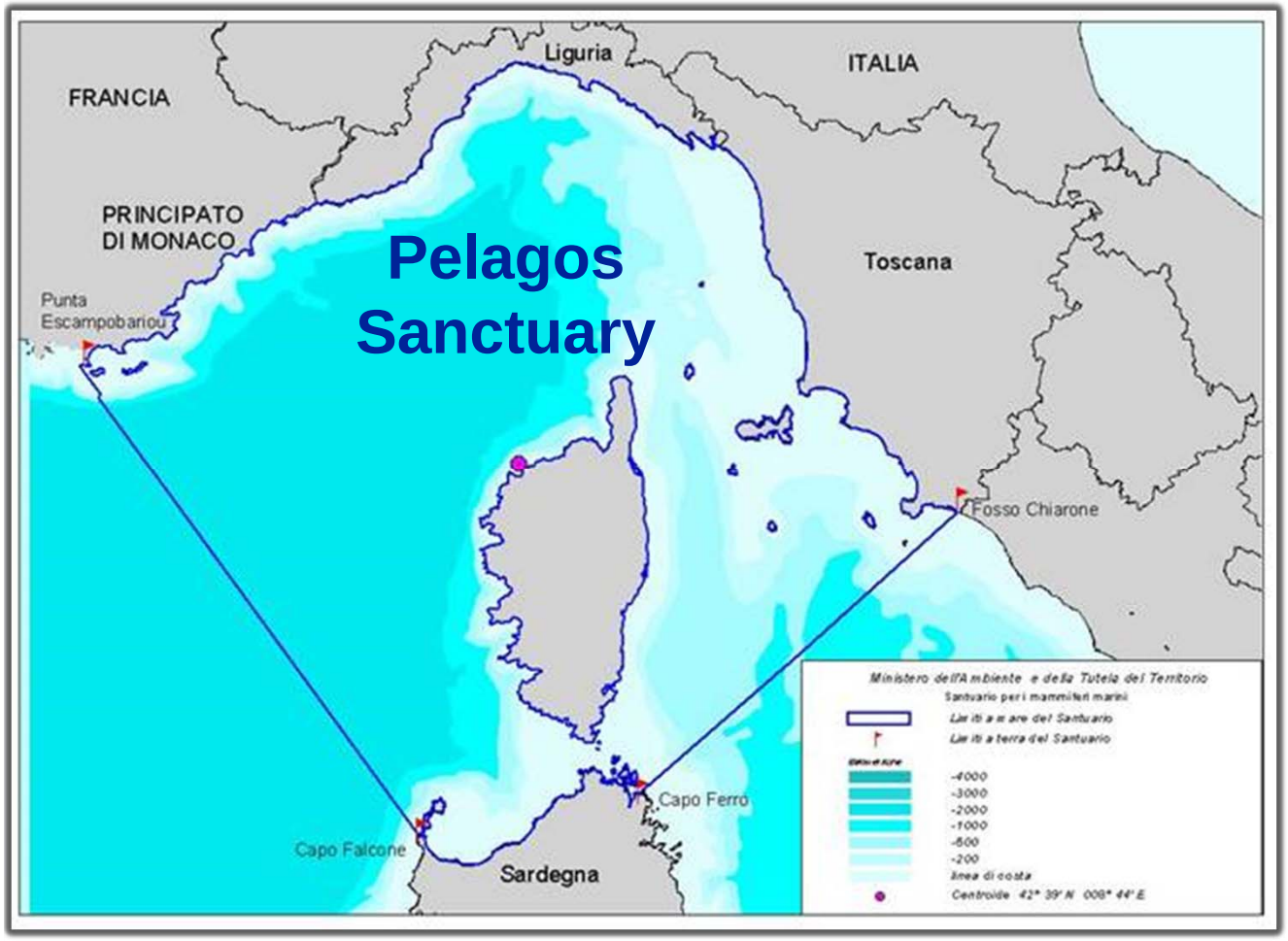
How?

- We deployed in the Portofino MPA two detection units, based on a particular type of marine buoy (elastic beacon) each equipped with four hydrophones and an acquisition system which can record the typical "social communication whistles" emitted by the dolphins and the sounds emitted by boat engines.

- Signals are pre-filtered and sent on shore, using a wi-fi bridge, where they are elaborated to get the position of dolphins and to track the boats in real-time.

Monitoring

THE PROJECT AREA



•Presence of high reproduction zones (*frontal zone*)

•*Up-welling* in the spring season generated by the prevailing north-westerly wind ("mistral“)

•*Meganyctiphanes norvegica:* important role in the diet of *Balaenoptera physalus*

High and stable cetaceans presence, in according to high levels of primary production

Portofino Marine Protected Area (MPA)

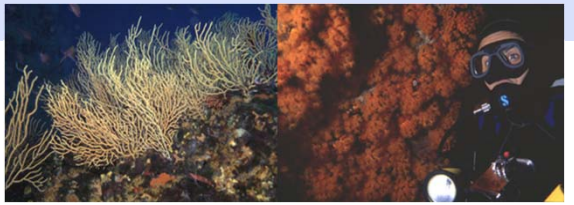
- Zona A (no take-no entry zone) – 19 ha
- Zona B (generally protected zone) - 167 ha
- Zona C (partially protected zone) - 188 ha

SPAMI (2005)
L-TER (2007) site

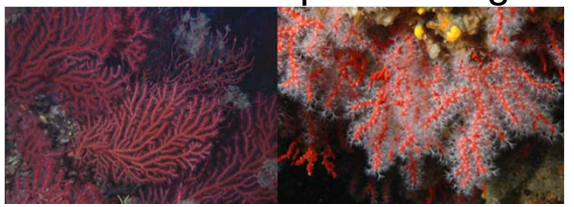
- established in 1999
- 374 ha
- 15 Km of coast
- includes the towns of Camogli, Portofino and S.Margherita Ligure

The Environment

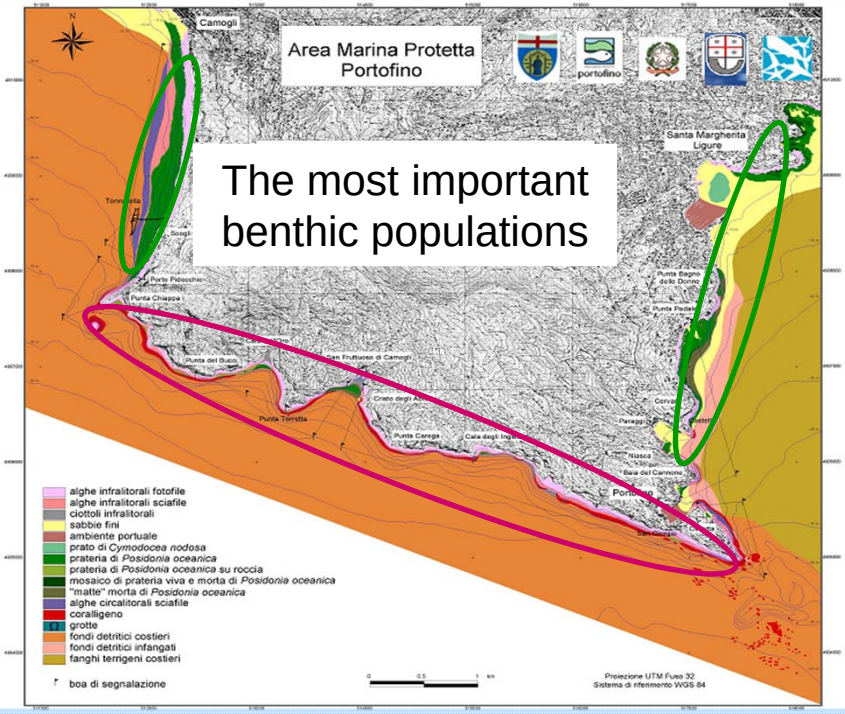
Seaweed environment



pre-coralligenous



Coralligenous and twilight environments



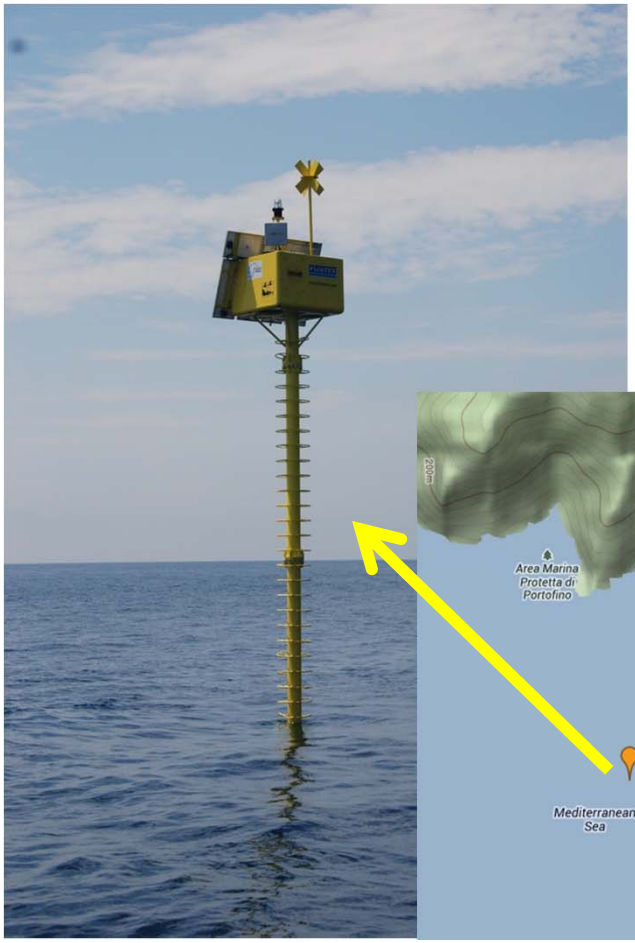
Along the western and eastern slopes of the Promontory: meadow of *Posidonia oceanica*

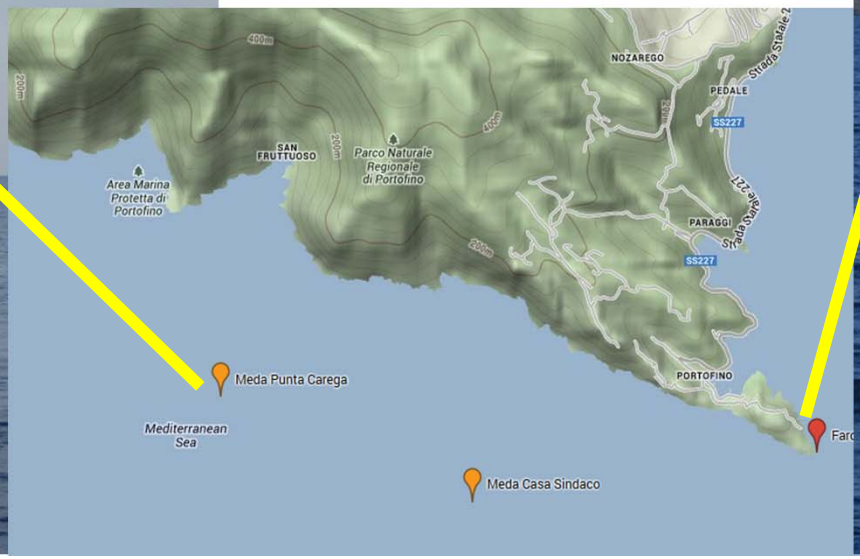
The typical biocenosis of the southern slope are the pre-coralligenous and coralligenous one

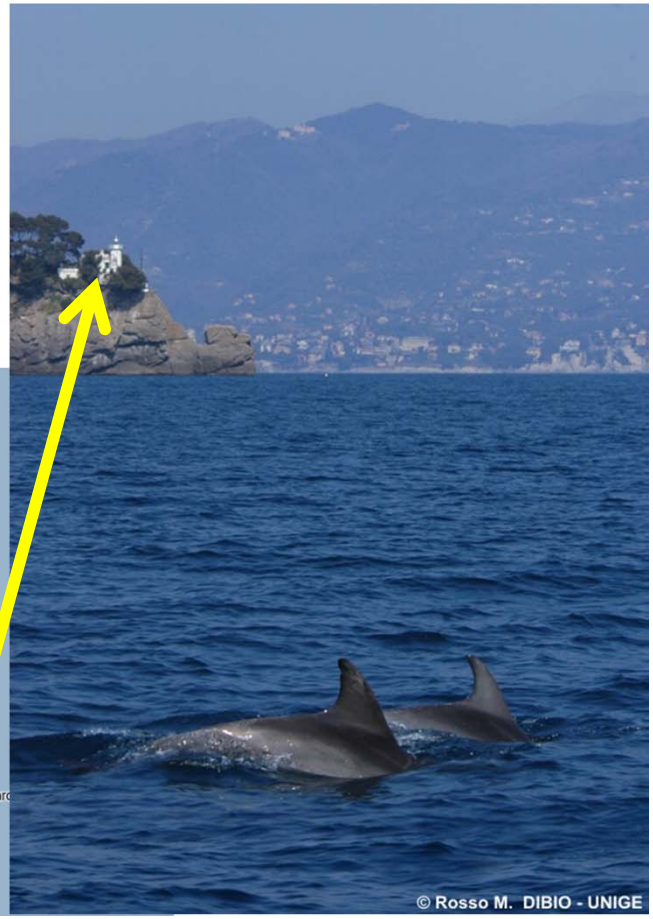
Portofino MPA -Zoning	A (19,05 ha)	B (167,02 ha)	C (188,061 ha)
Fine sand	0	0,13	11,49
Infralittoral plebbes (IP)	0,59	1,50	0
Photophilic infralittoral algae (PIA)	2,77	17,55	20,54
Sciaphilic red algae	1,15	11,50	15,53
Posidonia meadows(HP)	0,53	0,41	38,97
Mixed of living and dead *Posidonia*	0	0	0,99
Dead matte of *Posidonia*	0	0,35	3,83
Sciaphilic circalittoral algae	0		14,98
Coastal muddy bottoms (VTC)	0	0	15,58
Coralligenous assemblages (C)	0,74	17,21	2,75
Coastal detritus (CD)	10,75	144,94	42,15
Muddy detritus (MD)	0	0	14,48

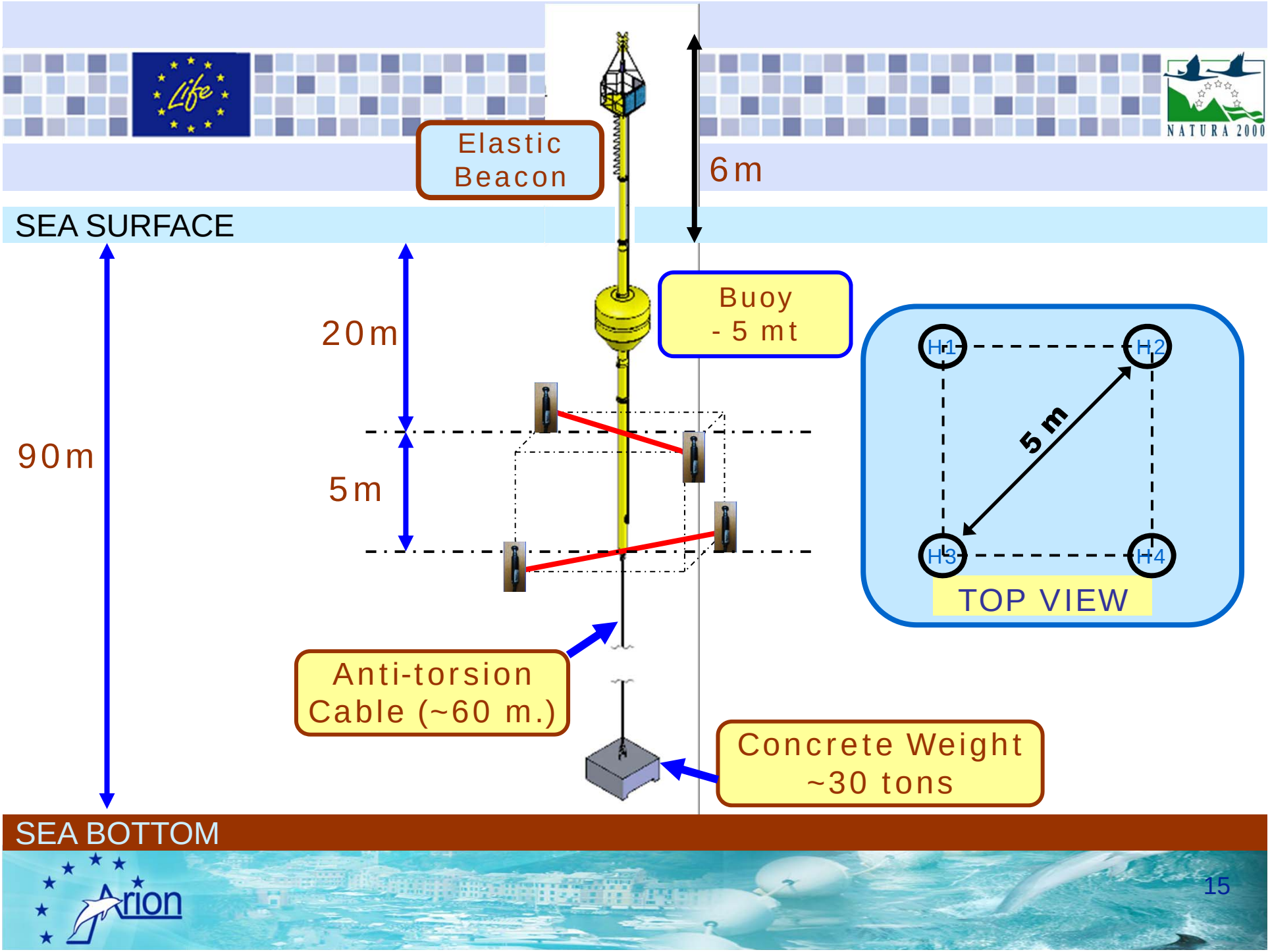
THE INFRASTRUCTURE

Realization of a permanent marine infrastructure for bottlenose dolphins and boats detection and tracking



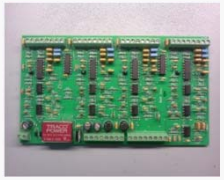





Elastic Beacon
6m
SEA SURFACE
90m
20m
5m
Buoy - 5 mt
H1
H2
H3
H4
5 m
TOP VIEW
Anti-torsion Cable (~60 m.)
Concrete Weight ~30 tons
SEA BOTTOM

water-tight instrum box

data acq digitaliz



filter-amplif board

tilt-heading

batteries & ch reg

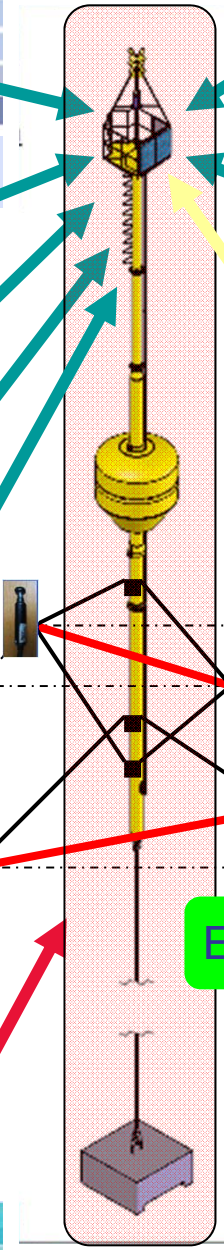
GSM remote switch

underwater instrum

current-wave meter

hydrophones

water param



transm. radio WiFi

photov. panel ~43 W

meteo station

outdoor instrum

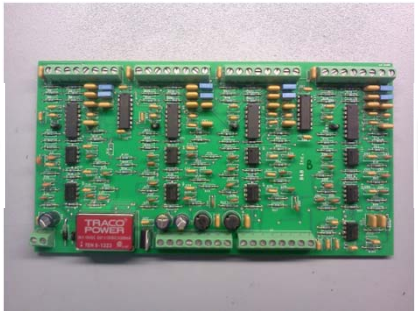
Elastic Beacon

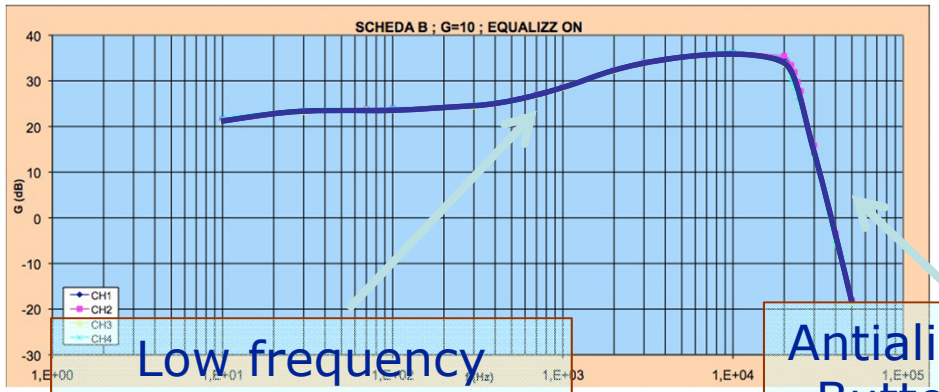
Hydrophone properties

- GP0280 by COLMAR

- Working band: 5 – 90.000 Hz
- Sensitivity differential output: -165 dB re 1V/μPa @5 kHz
- Directivity: spherical, omnidirectional
- Max working depth: 1000 m
- Gain @5 kHz: 36 dB (differential output)
- Input acoustic equivalent noise: 34 dB re 1μPa/√Hz @5 kHz

Acquisition System





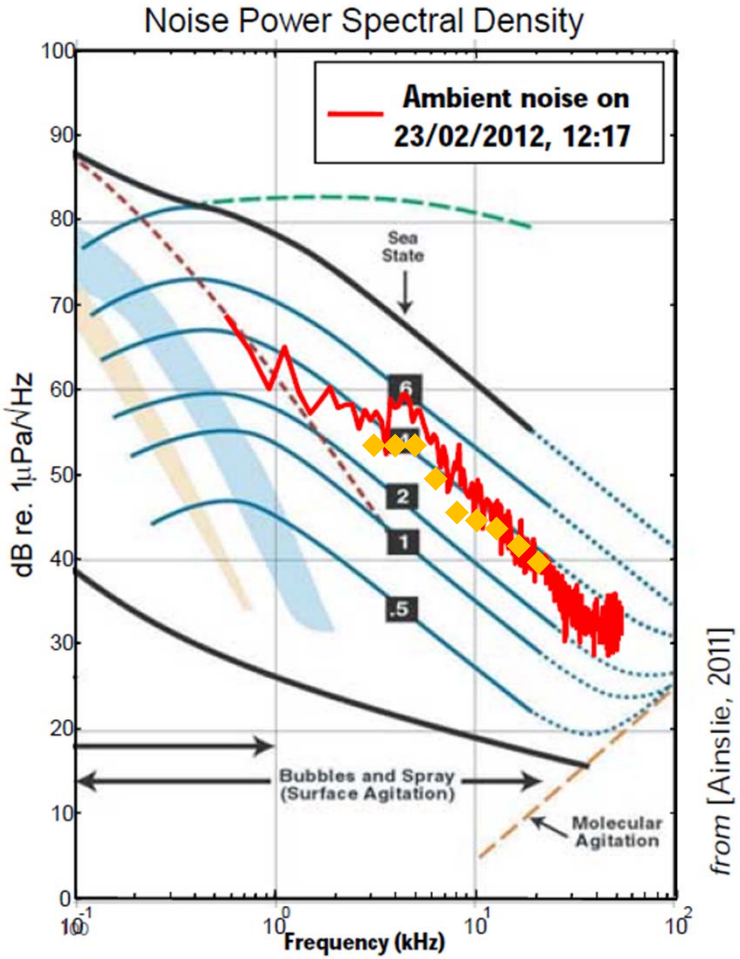
4-channel
16 bit ADC
Single clock
Up to 100 kS/s

Low frequency noise reduction filter (< 3kHz)

Antialiasing 8-poles Butterworth filter Sallen-Key type

Performances

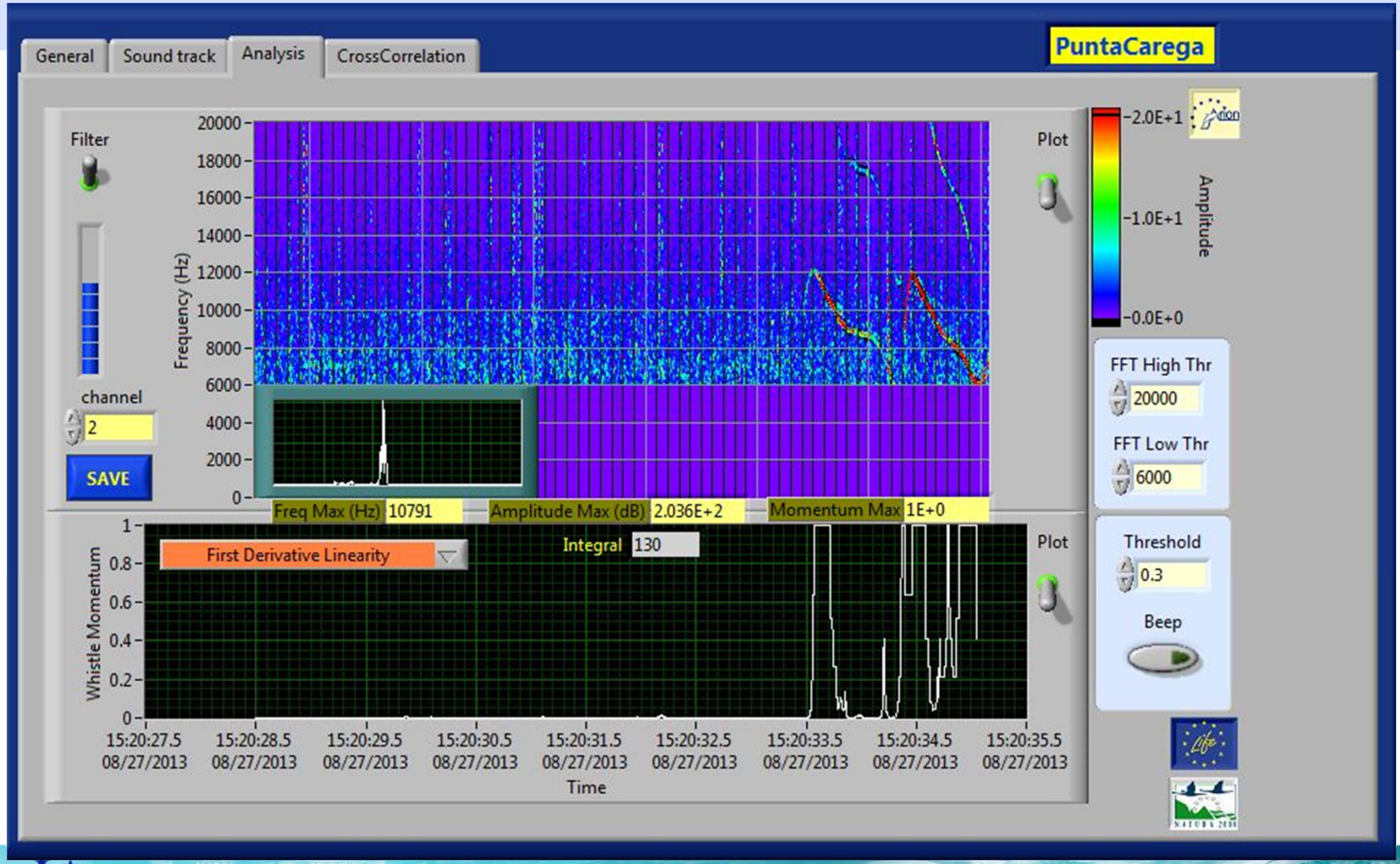
- Hydrophones absolutely calibrated
  - Ambient noise (Wenz curve)
  - Measurement with calibrated hydrophone shows noise higher than theoretically expected
  - Our system provides similar results
- Up-time 89%

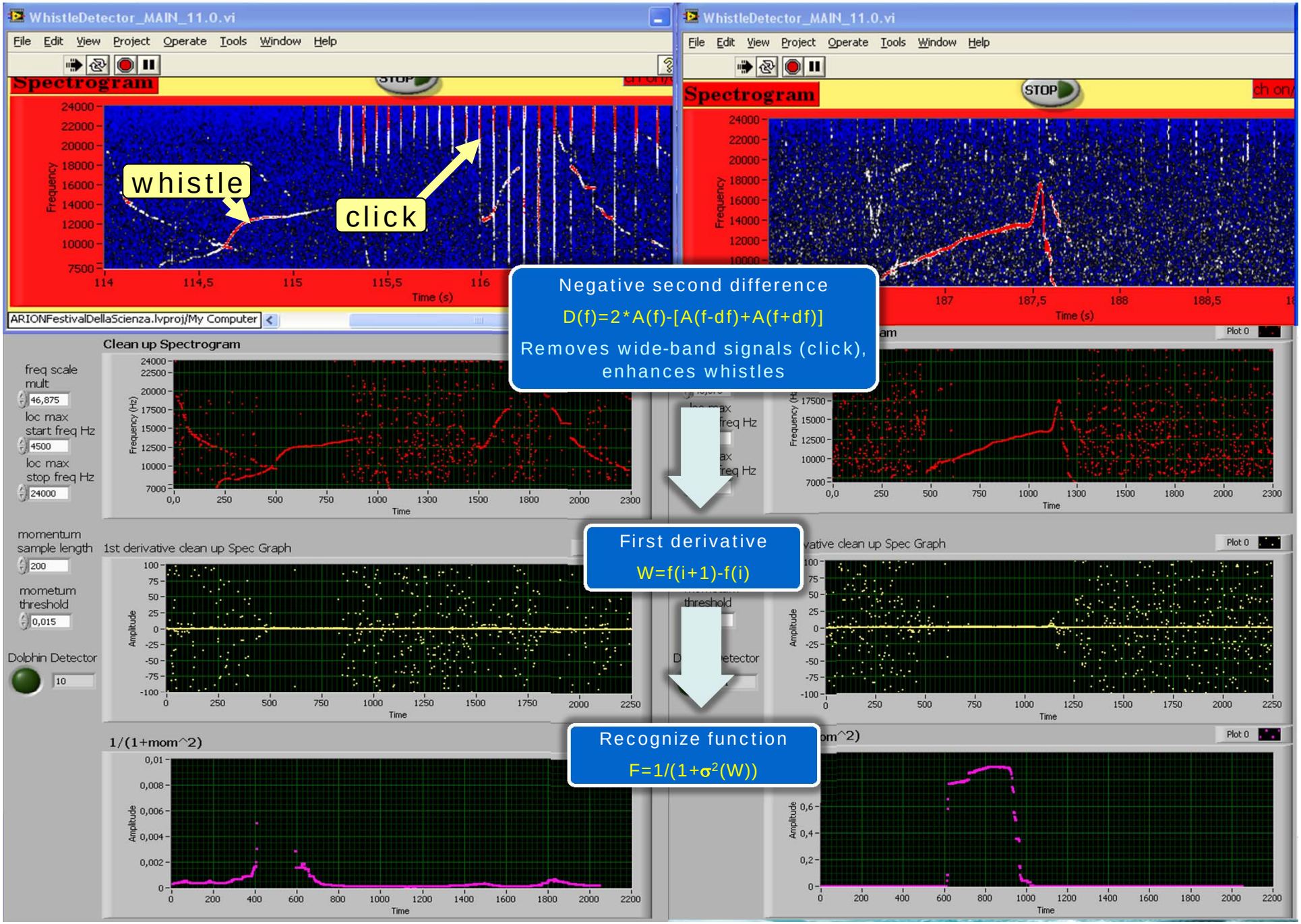


On-line analysis

- Whistle identification – Zimmer algorithm
- *Noise reduction – boats mis-identification (in progress)*
- Sound heading calculation
- *Sound source localization (in progress)*
- *Boat tracking (in progress)*

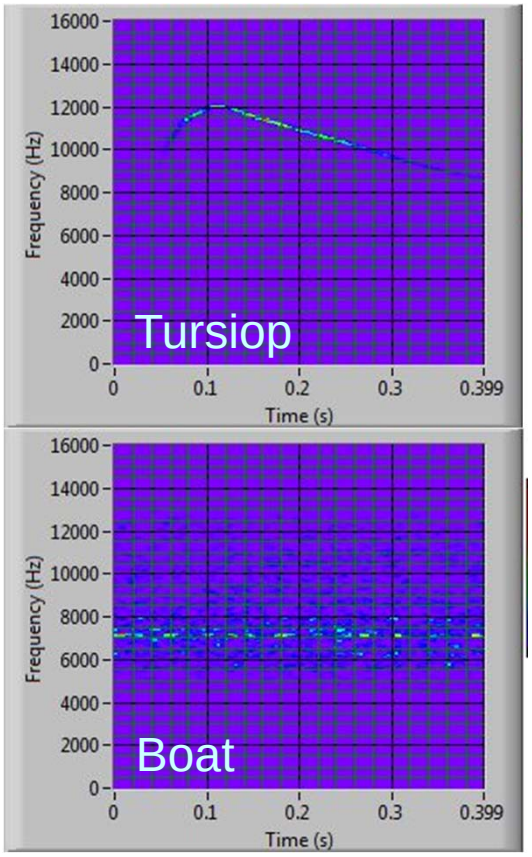
WHISTLE IDENTIFICATION

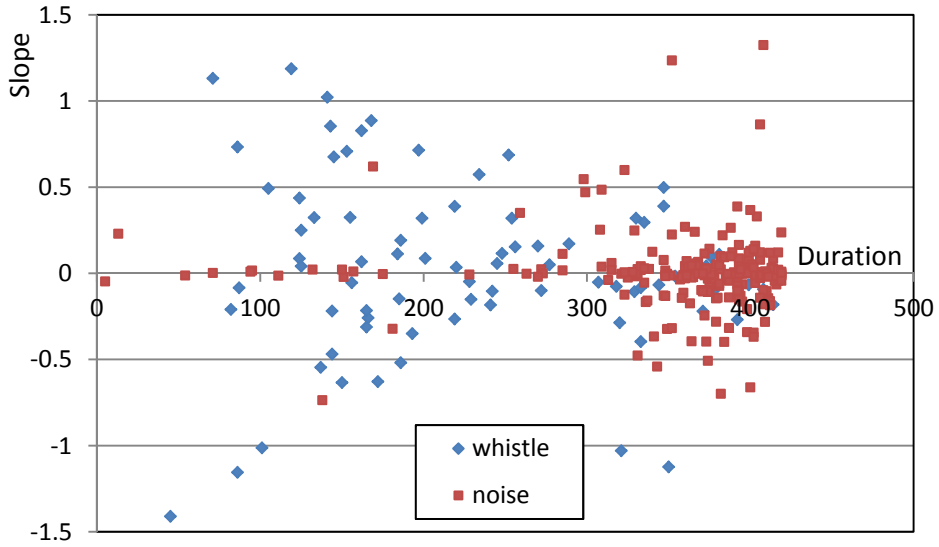

General
Sound track
Analysis
CrossCorrelation
PuntaCarega
Filter
channel
2
SAVE
Frequency (Hz)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Plot
2.0E+1
1.0E+1
0.0E+0
Amplitude
FFT High Thr
20000
FFT Low Thr
6000
Freq Max (Hz) 10791
Amplitude Max (dB) 2.036E+2
Momentum Max 1E+0
First Derivative Linearity
Integral 130
Whistle Momentum
1
0.8
0.6
0.4
0.2
0
Plot
Threshold
0.3
Beep
15:20:27.5 08/27/2013
15:20:28.5 08/27/2013
15:20:29.5 08/27/2013
15:20:30.5 08/27/2013
15:20:31.5 08/27/2013
15:20:32.5 08/27/2013
15:20:33.5 08/27/2013
15:20:34.5 08/27/2013
15:20:35.5 08/27/2013
Time


WhistleDetector_MAIN_11.0.vi
File Edit View Project Operate Tools Window Help
Spectrogram
STOP
Frequency
Time (s)
whistle
click
ARIONFestivalDellaScienza.lvproj/My Computer
Negative second difference
D(f)=2*A(f)-[A(f-df)+A(f+df)]
Removes wide-band signals (click), enhances whistles
Clean up Spectrogram
freq scale mult
46,875
loc max start freq Hz
4500
loc max stop freq Hz
24000
Frequency (Hz)
Time
momentum sample length
200
momentum threshold
0,015
Dolphin Detector
10
1st derivative clean up Spec Graph
Amplitude
First derivative
W=f(i+1)-f(i)
1/(1+mom^2)
Recognize function
F=1/(1+σ²(W))
Plot 0

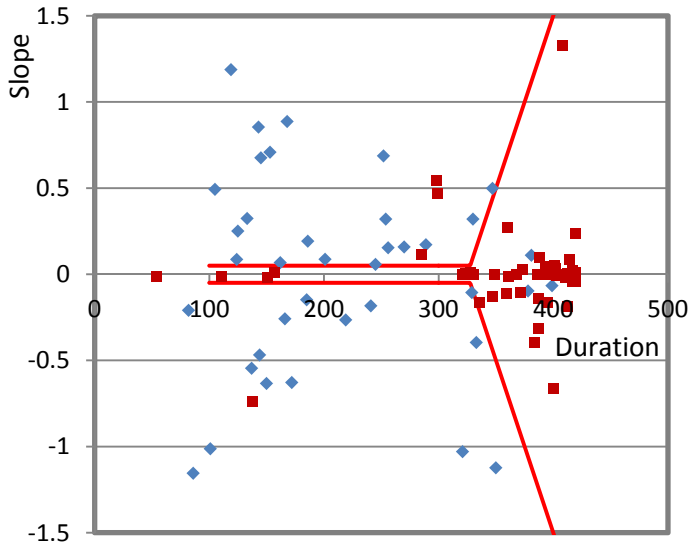
Noise reduction

- The algorithm is not sufficient
- Boats mimic the bottlenose dolphin signal
- Check on duration and slope – in progress





- Clear correlation between signal duration and slope



- >90% efficiency
- <5% contamination

SOUND HEADING CALCULATION

$$h_2(t) = h_0(t - \Delta T)$$

$$R_{02}(\tau) = R_{00}(\tau - \Delta T)$$

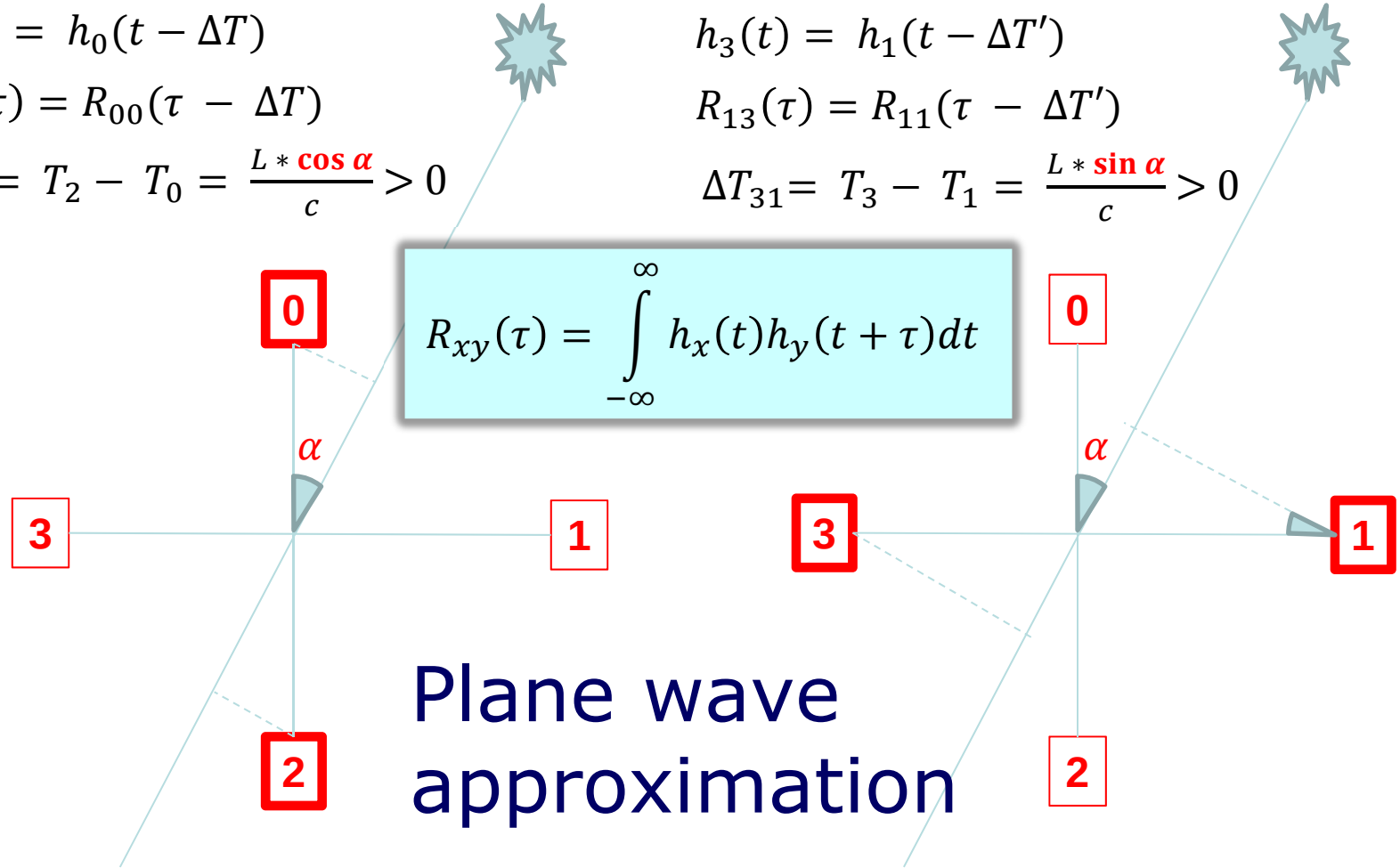
$$\Delta T_{20} = T_2 - T_0 = \frac{L * \cos\alpha}{c} > 0$$

$$h_3(t) = h_1(t - \Delta T')$$

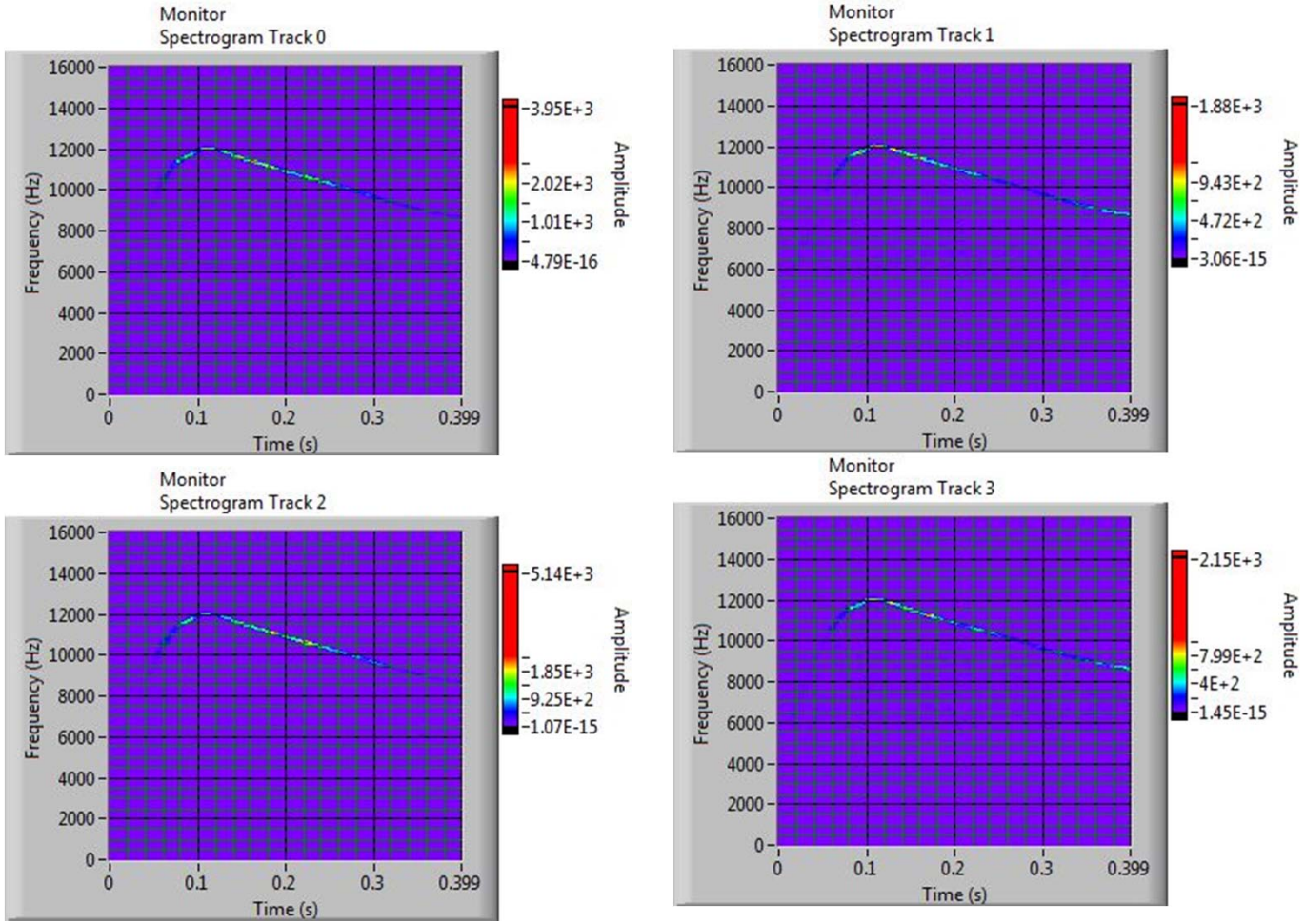
$$R_{13}(\tau) = R_{11}(\tau - \Delta T')$$

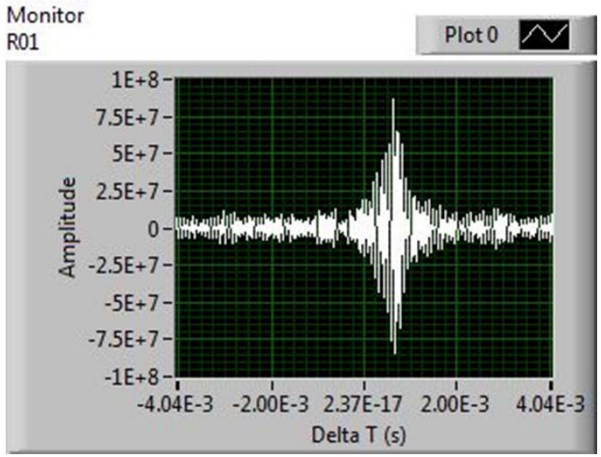
$$\Delta T_{31} = T_3 - T_1 = \frac{L * \sin\alpha}{c} > 0$$

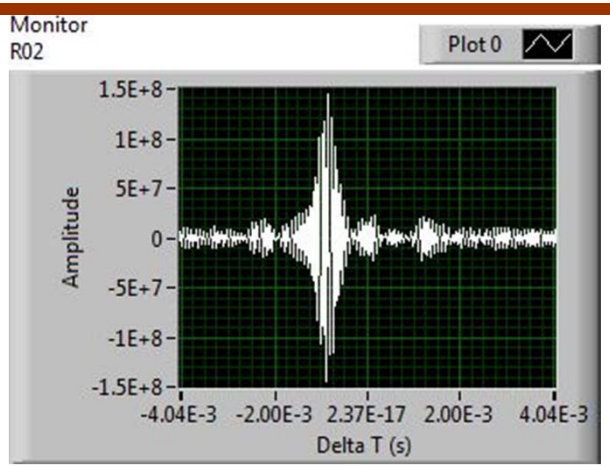
$$R_{xy}(\tau) = \int_{-\infty}^{\infty} h_x(t) h_y(t + \tau) dt$$

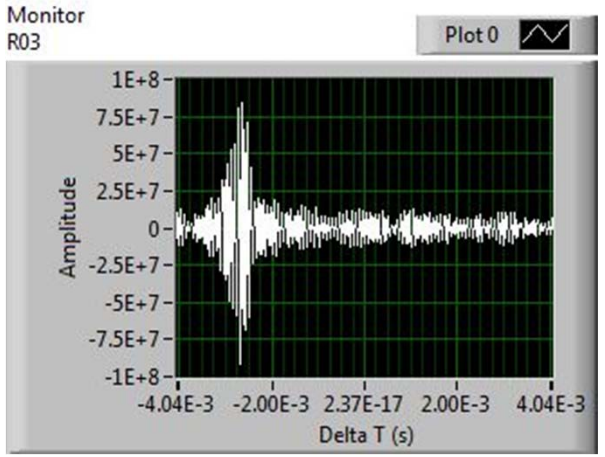


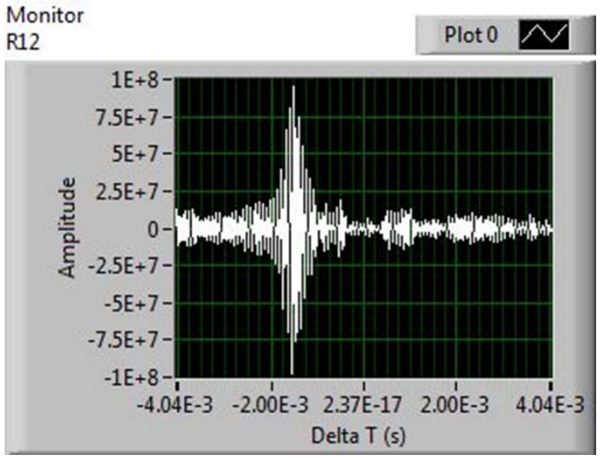
Plane wave approximation

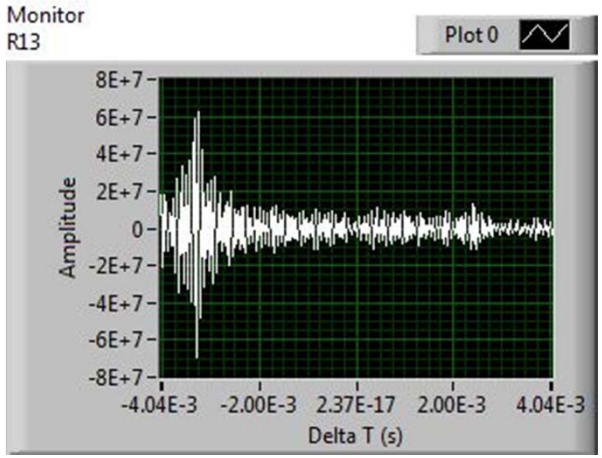

Monitor
Spectrogram Track 0
Frequency (Hz)
Time (s)
Amplitude
-3.95E+3
-2.02E+3
-1.01E+3
-4.79E-16
Monitor
Spectrogram Track 1
-1.88E+3
-9.43E+2
-4.72E+2
-3.06E-15
Monitor
Spectrogram Track 2
-5.14E+3
-1.85E+3
-9.25E+2
-1.07E-15
Monitor
Spectrogram Track 3
-2.15E+3
-7.99E+2
-4E+2
-1.45E-15

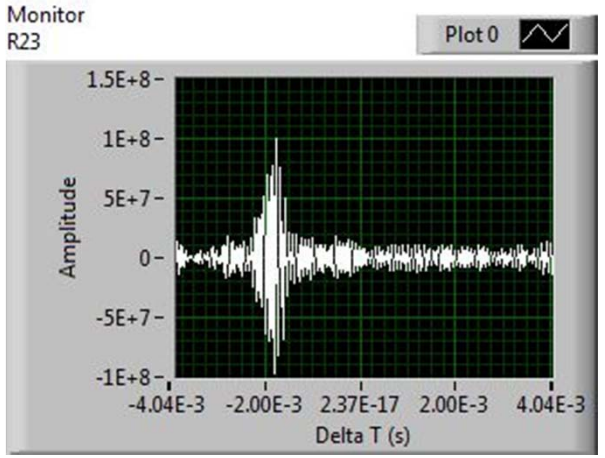

Monitor
R01
Plot 0
1E+8
7.5E+7
5E+7
2.5E+7
0
-2.5E+7
-5E+7
-7.5E+7
-1E+8
Amplitude
-4.04E-3
-2.00E-3
2.37E-17
2.00E-3
4.04E-3
Delta T (s)


Monitor
R02
Plot 0
1.5E+8
1E+8
5E+7
0
-5E+7
-1E+8
-1.5E+8
Amplitude
-4.04E-3
-2.00E-3
2.37E-17
2.00E-3
4.04E-3
Delta T (s)


Monitor
R03
Plot 0
1E+8
7.5E+7
5E+7
2.5E+7
0
-2.5E+7
-5E+7
-7.5E+7
-1E+8
Amplitude
-4.04E-3
-2.00E-3
2.37E-17
2.00E-3
4.04E-3
Delta T (s)


Monitor
R12
Plot 0
1E+8
7.5E+7
5E+7
2.5E+7
0
-2.5E+7
-5E+7
-7.5E+7
-1E+8
Amplitude
-4.04E-3
-2.00E-3
2.37E-17
2.00E-3
4.04E-3
Delta T (s)


Monitor
R13
Plot 0
8E+7
6E+7
4E+7
2E+7
0
-2E+7
-4E+7
-6E+7
-8E+7
Amplitude
-4.04E-3
-2.00E-3
2.37E-17
2.00E-3
4.04E-3
Delta T (s)


Monitor
R23
Plot 0
1.5E+8
1E+8
5E+7
0
-5E+7
-1E+8
Amplitude
-4.04E-3
-2.00E-3
2.37E-17
2.00E-3
4.04E-3
Delta T (s)

Angular resolution

- Maximum acceptable compatibility between cross-correlations set to $\pm 2 \cdot 10^{-4}$ s
- It corresponds to an average angular resolution of 1°

SOUND SOURCE LOCALIZATION

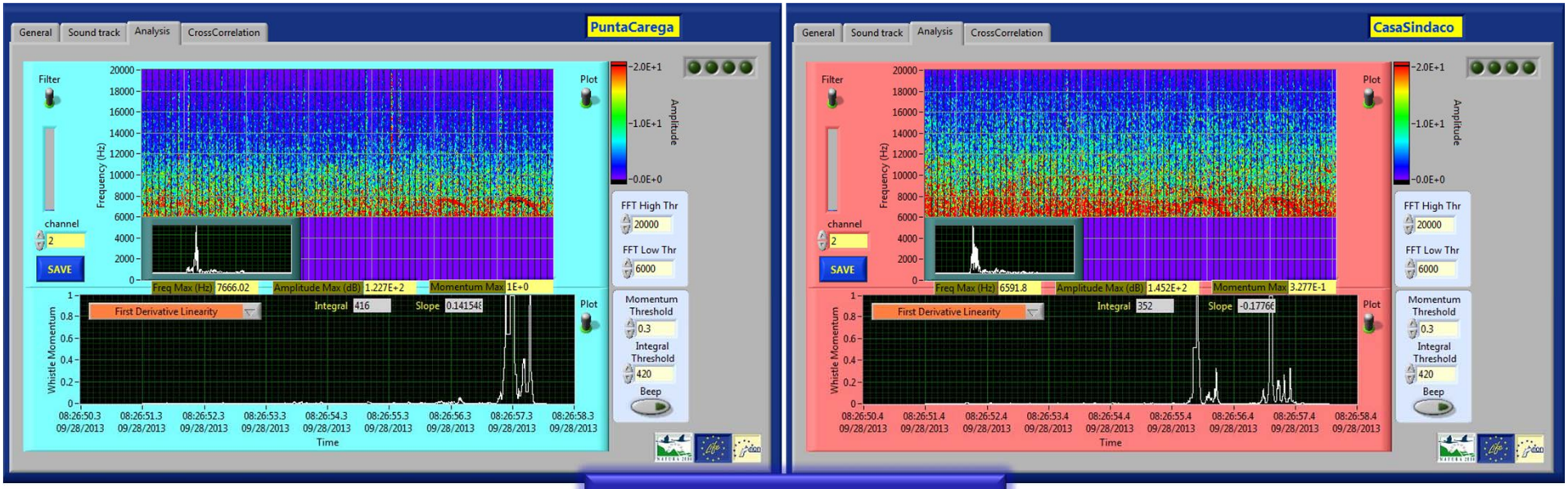
Sound Source

- Frequency range: 5 kHz – 20 kHz
- Duration: ~ 1 s
- Source level (**SL**): 160 dB re 1 μPa@1 m

- Assuming Passive Sonar Equation:
  - Average noise Level **NL** from Wenz curve for the Sea state
  - Noise is distributed over a Band Width **BW**=40 dB
  - Transmission Loss (spherical propagation including spreading and attenuation losses) **TL**=20·log(R) + C·R
  - Detection Threshold **DT**=5 dB
- $L_{S/N} = SL - TL - NL - BW \geq DT$

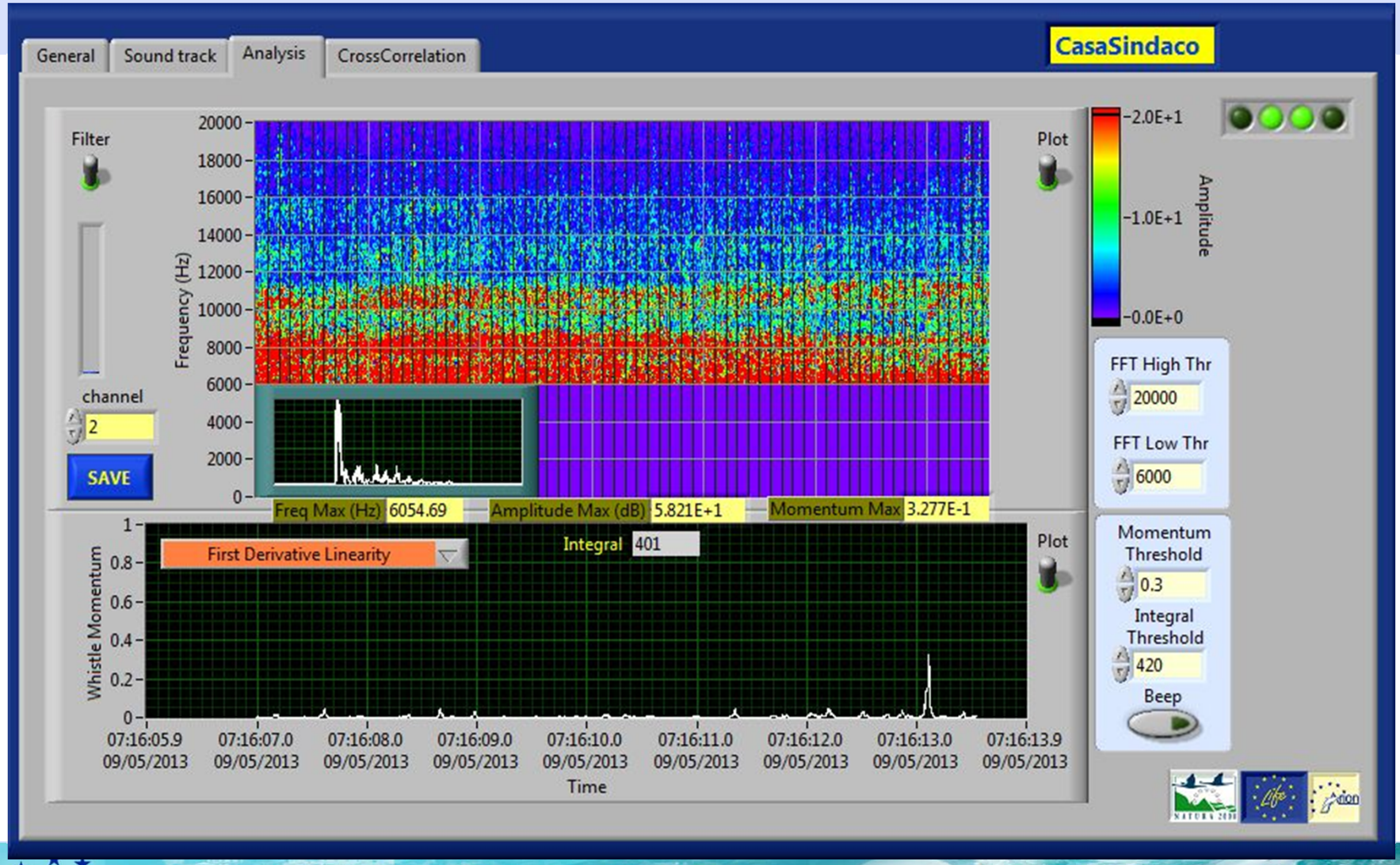
Expected maximum detection range

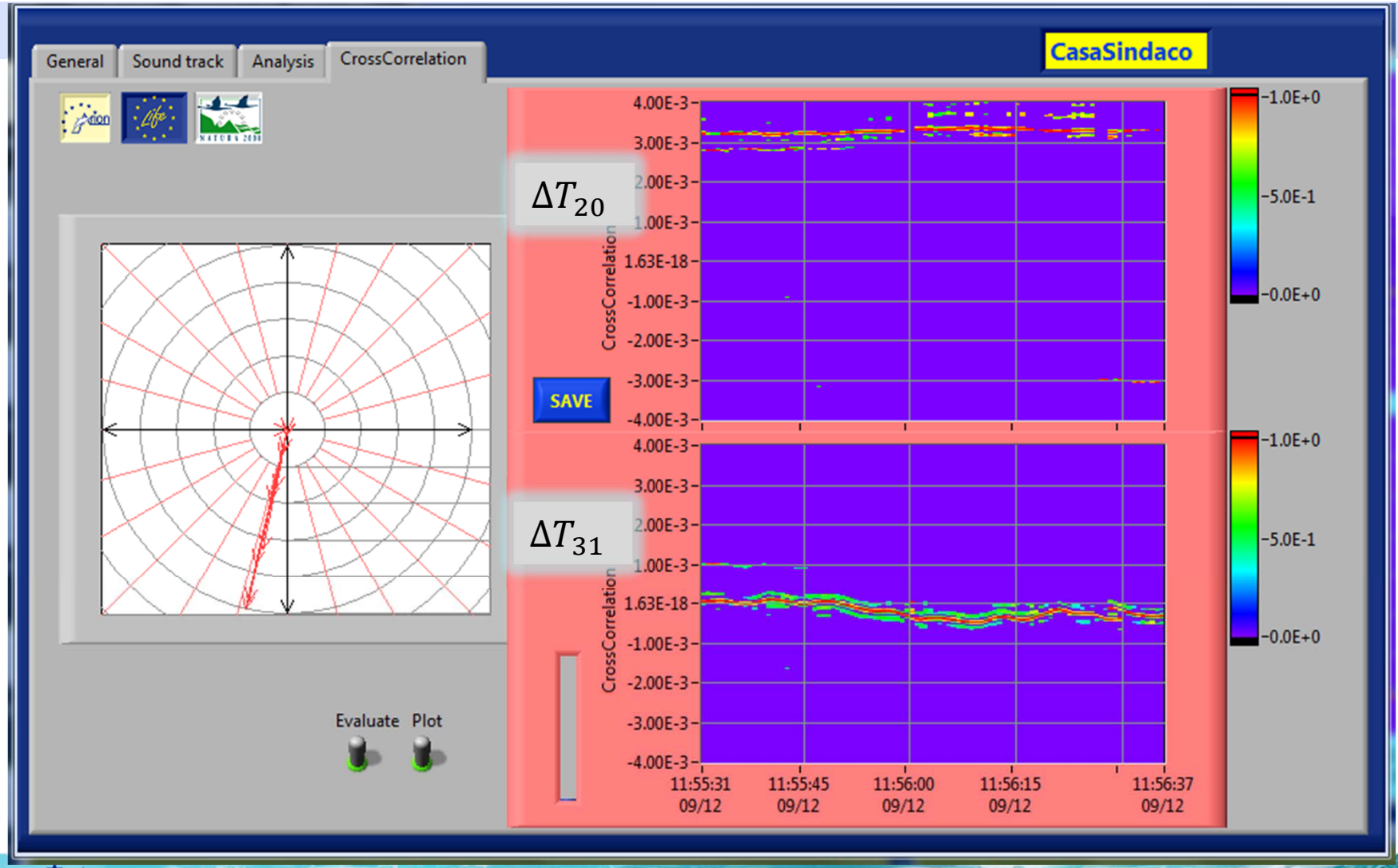
- @Sea State = 0 D_0=6.3 km
- @Sea State = 4 D_0=1.4 km



First observed whistle in coincidence

BOAT TRACKING


General
Sound track
Analysis
CrossCorrelation
CasaSindaco
Filter
Plot
channel
2
SAVE
Frequency (Hz)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2.0E+1
-1.0E+1
-0.0E+0
Amplitude
FFT High Thr
20000
FFT Low Thr
6000
Freq Max (Hz) 6054.69
Amplitude Max (dB) 5.821E+1
Momentum Max 3.277E-1
First Derivative Linearity
Integral 401
Plot
Whistle Momentum
1
0.8
0.6
0.4
0.2
0
Momentum Threshold
0.3
Integral Threshold
420
Beep
07:16:05.9 09/05/2013
07:16:07.0 09/05/2013
07:16:08.0 09/05/2013
07:16:09.0 09/05/2013
07:16:10.0 09/05/2013
07:16:11.0 09/05/2013
07:16:12.0 09/05/2013
07:16:13.0 09/05/2013
07:16:13.9 09/05/2013
Time


General
Sound track
Analysis
CrossCorrelation
CasaSindaco
ΔT_{20}
ΔT_{31}
SAVE
Evaluate
Plot
CrossCorrelation
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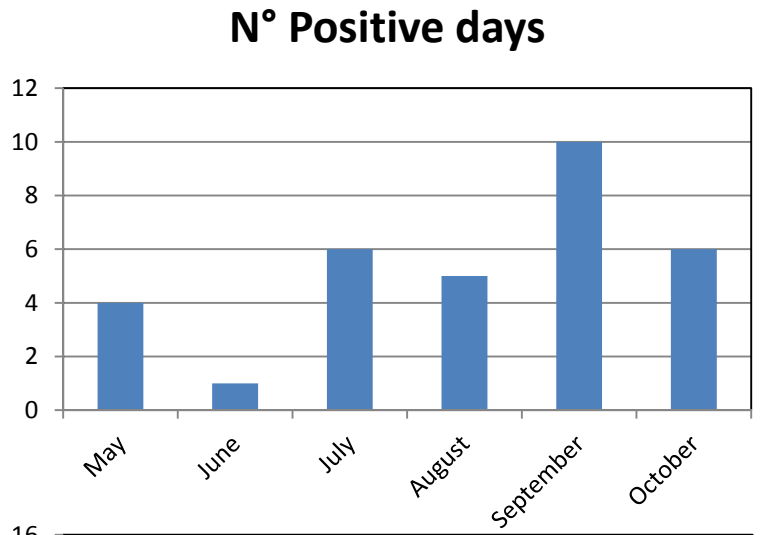
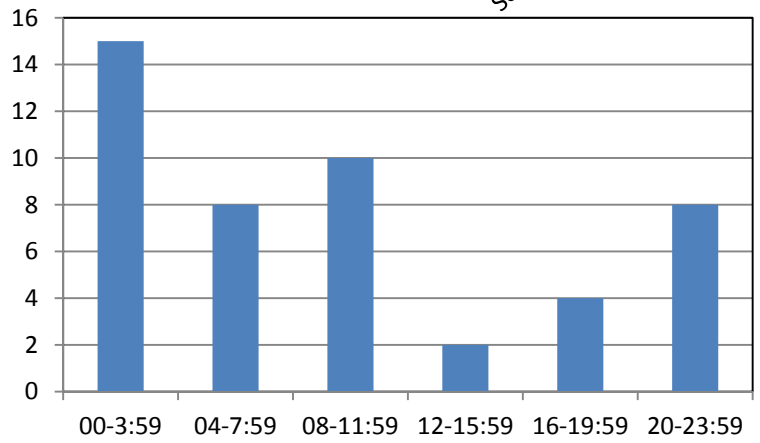
3.00E-3
2.00E-3
1.00E-3
1.63E-18
-1.00E-3
-2.00E-3
-3.00E-3
-4.00E-3
-1.0E+0
-5.0E-1
-0.0E+0
11:55:31
09/12
11:55:45
09/12
11:56:00
09/12
11:56:15
09/12
11:56:37
09/12

- On-line boat heading tracking already implemented and working
- Boat identification and route tracking in progress

BOTTLENOSE DOLPHINS OBSERVATION

- Monthly and hourly observation
  - Constant presence in the area (june affected by maintenance downtime)
  - Preferred hours with lower boat traffic





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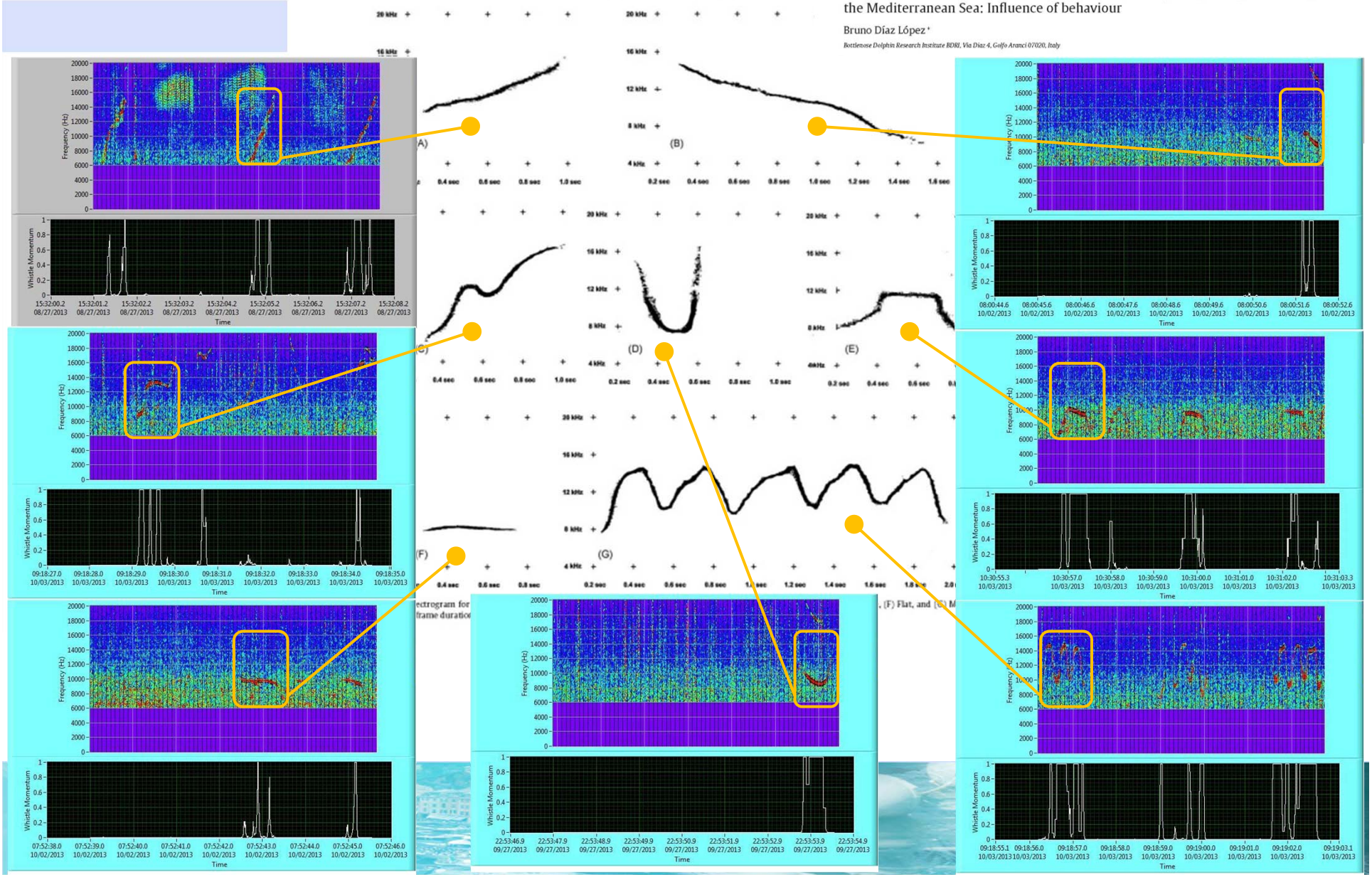
journal homepage: www.elsevier.de/mambio

Original Investigation

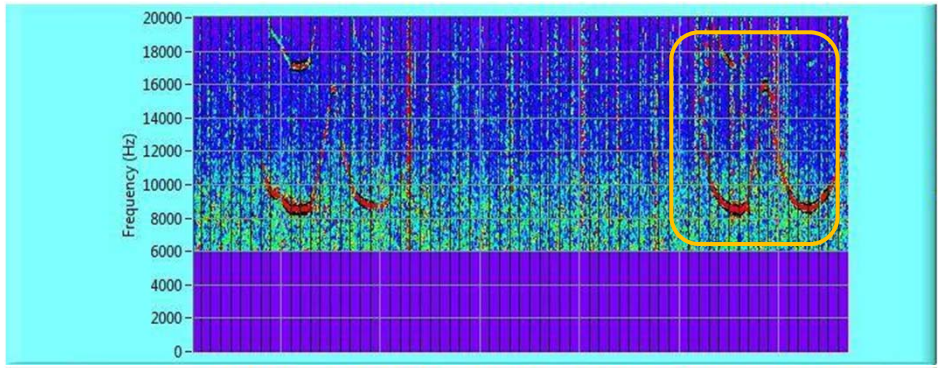
Whistle characteristics in free-ranging bottlenose dolphins (*Tursiops truncatus*) in the Mediterranean Sea: Influence of behaviour

Bruno Díaz López *

Bottlenose Dolphin Research Institute BDRI, Via Diaz 4, Golfo Aranci 07020, Italy



- Observed several additional signals not common in the Mediterranean Sea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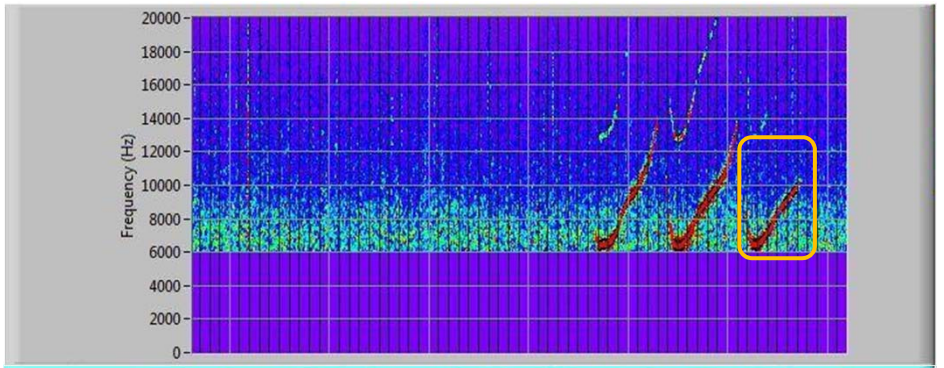
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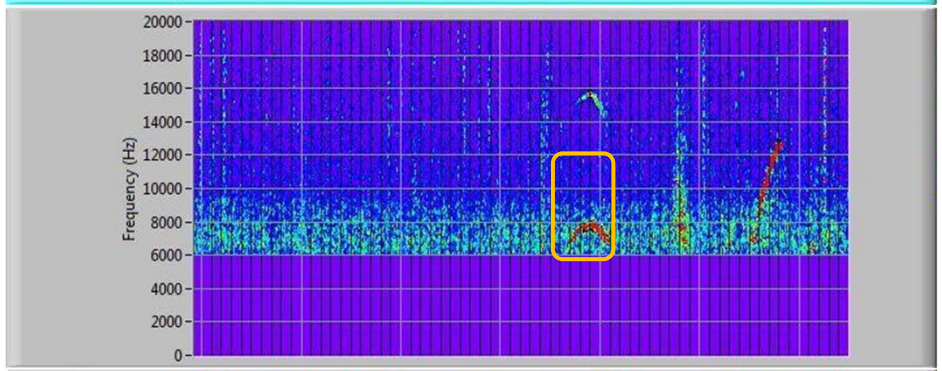
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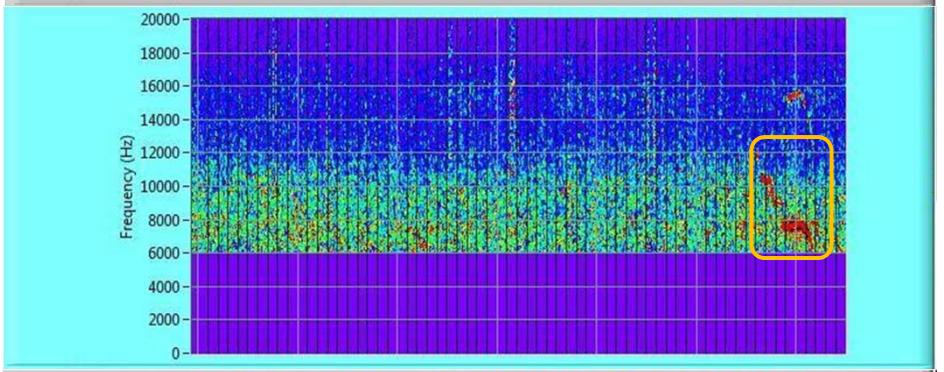
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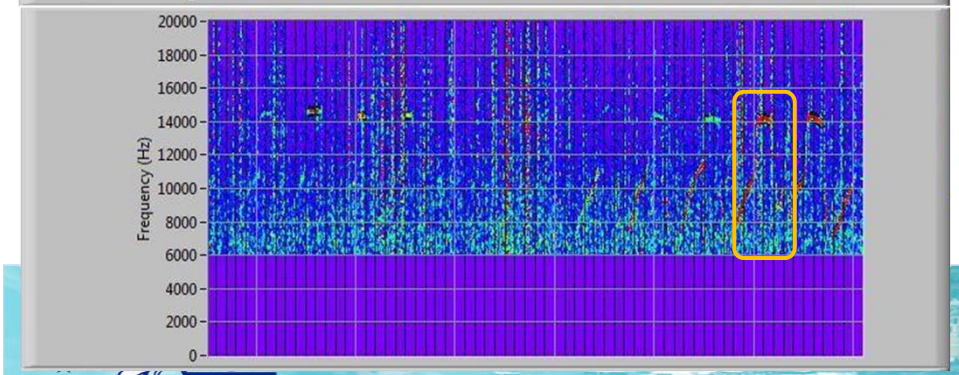
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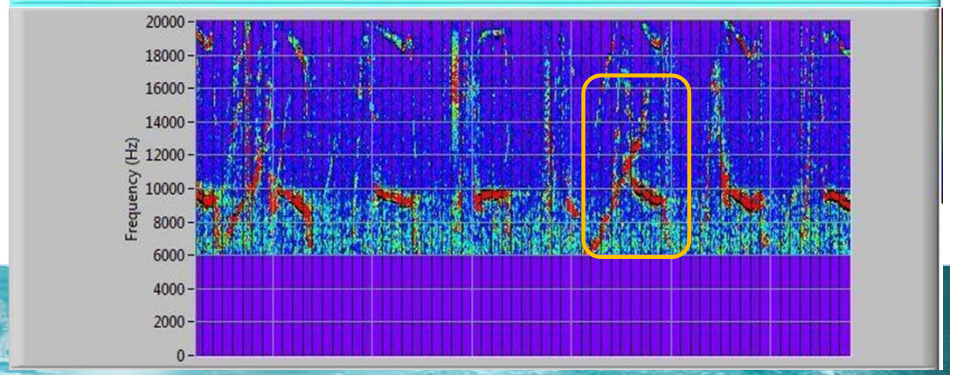
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Networks - present and future

- ARION
  - is hosting a regional meteo-marine station (it is the second in Liguria)
  - is entering in the LTER network
  - is willing to share data with the marine environment scientific community

Summary

- ARION is operating since June 2013
- Identification of bottlenose dolphins whistles with high efficiency
- Localization of sound sources in progress
- Tracking of boats in progress