Acoustics in water: synergies with marine biology

LAB - LIDO:

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ANTARES - AMADEUS:

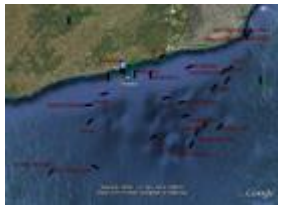
Robert Lahmann, Kay Graf, ANTARES Collaboration

Overview

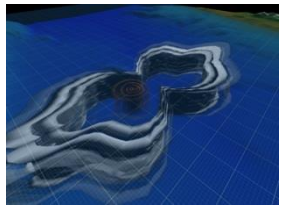
- Introduction LAB
- LIDO deployment at ANTARES
- Sperm whale presence
- MSFD 11.2 Noise Measurements

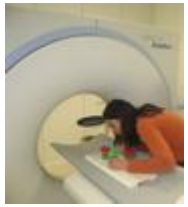
LAB Introduction

Environmental Monitoring



Noise Assessment and Modelling

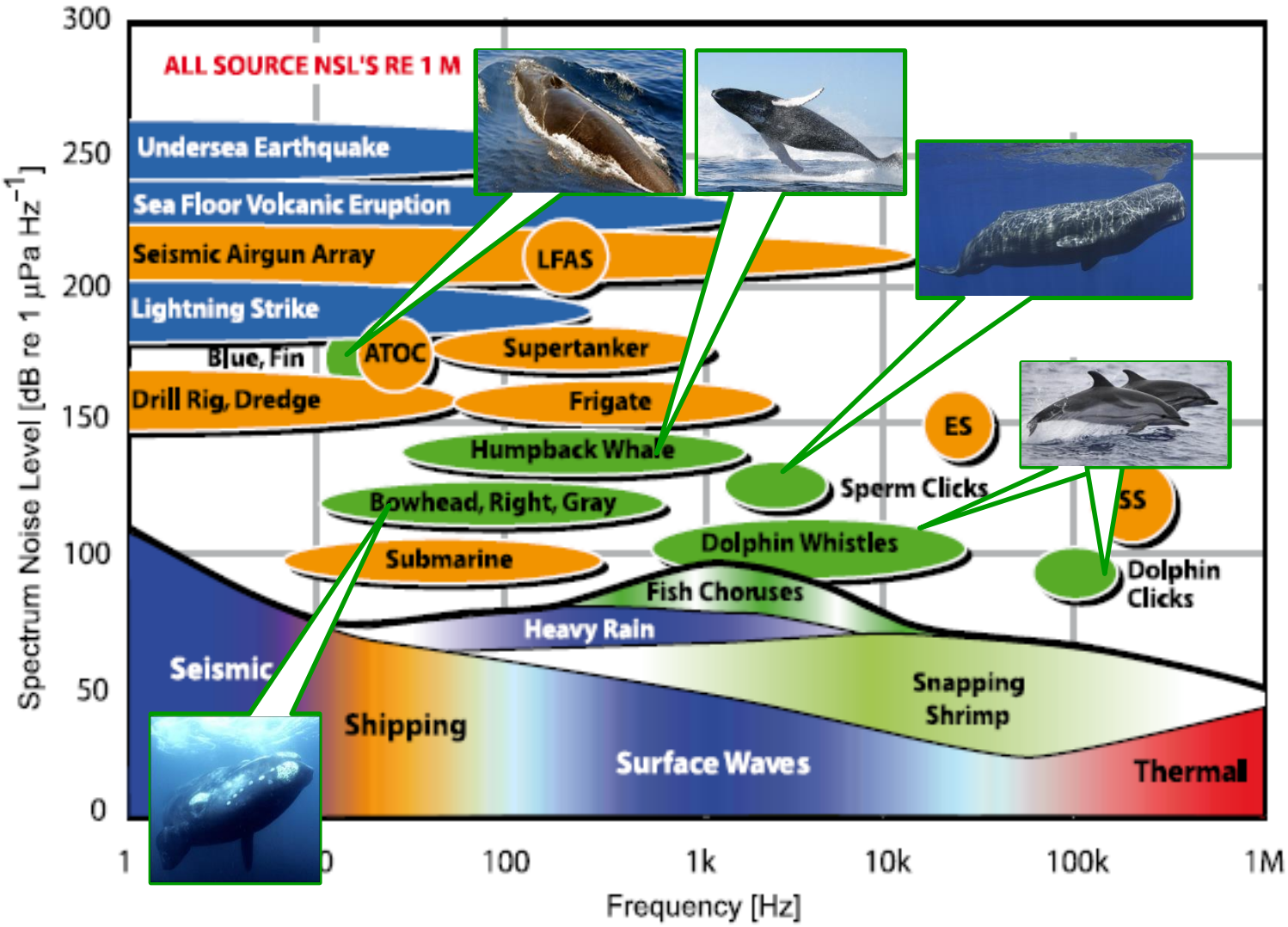




Physiological Affects

Acoustic Sensing

Underwater Sounds

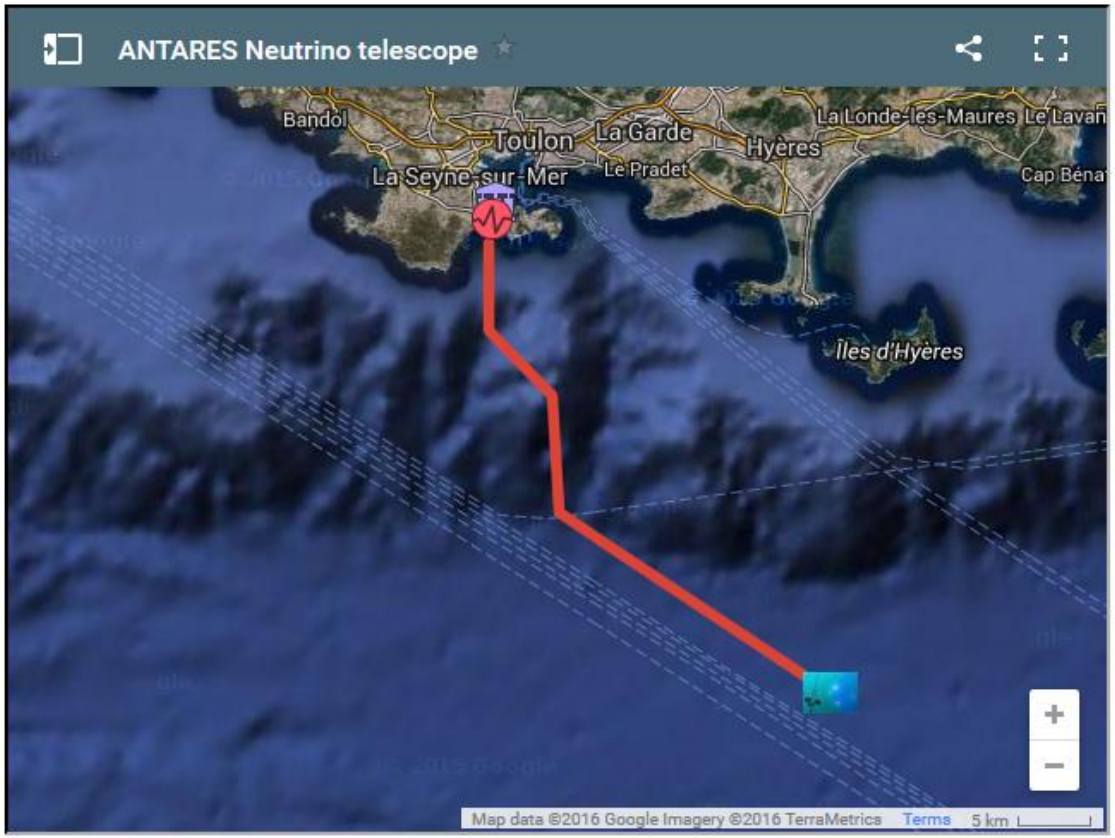


natural

biologic

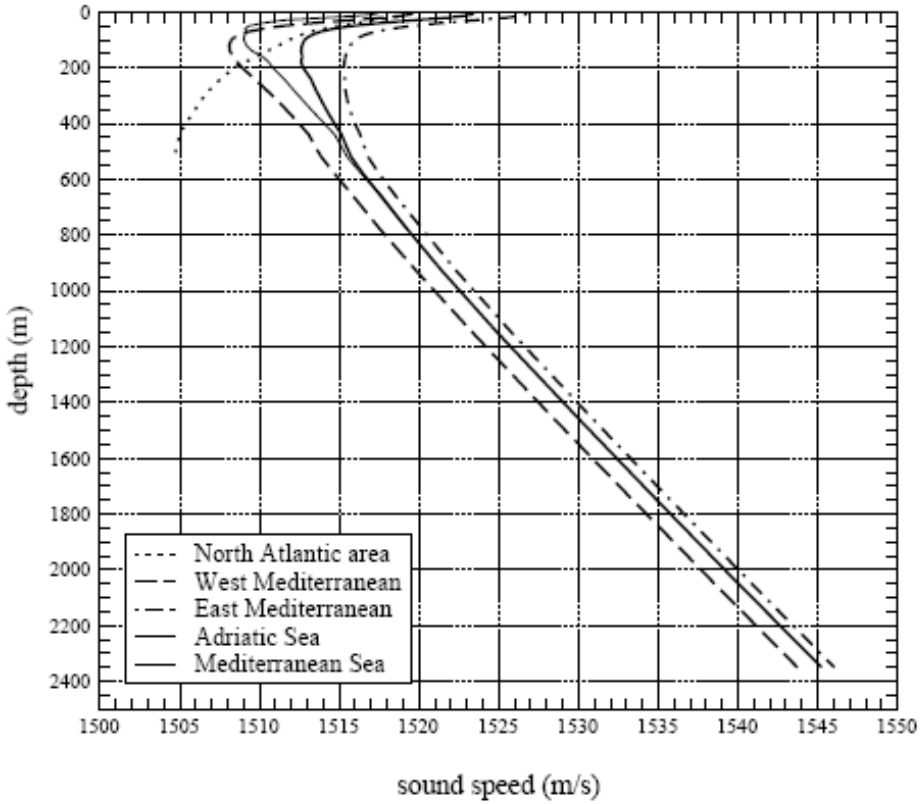
man made

LIDO at ANTARES



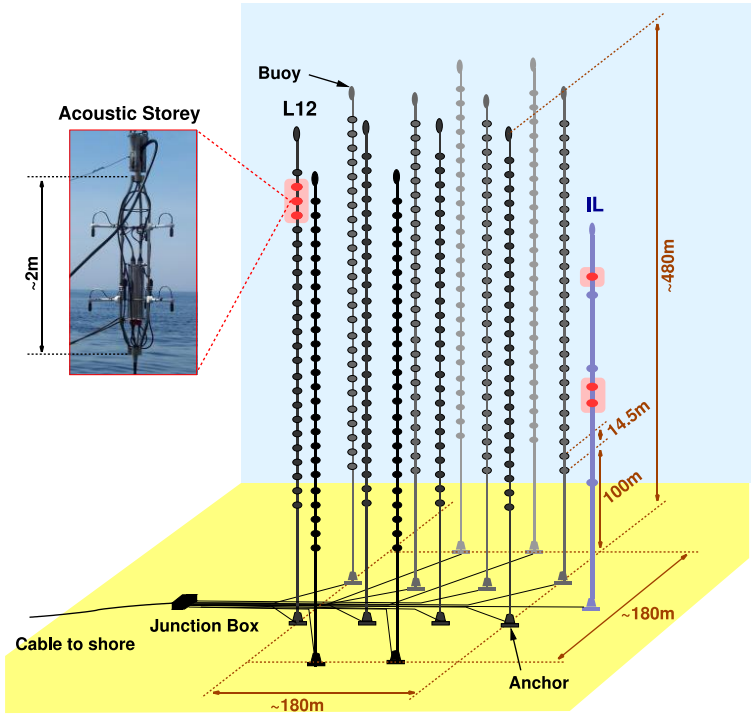
ANTARES is composed of 12 lines of about 350m each, covering a surface area of 0.1 km^2.

LIDO at ANTARES



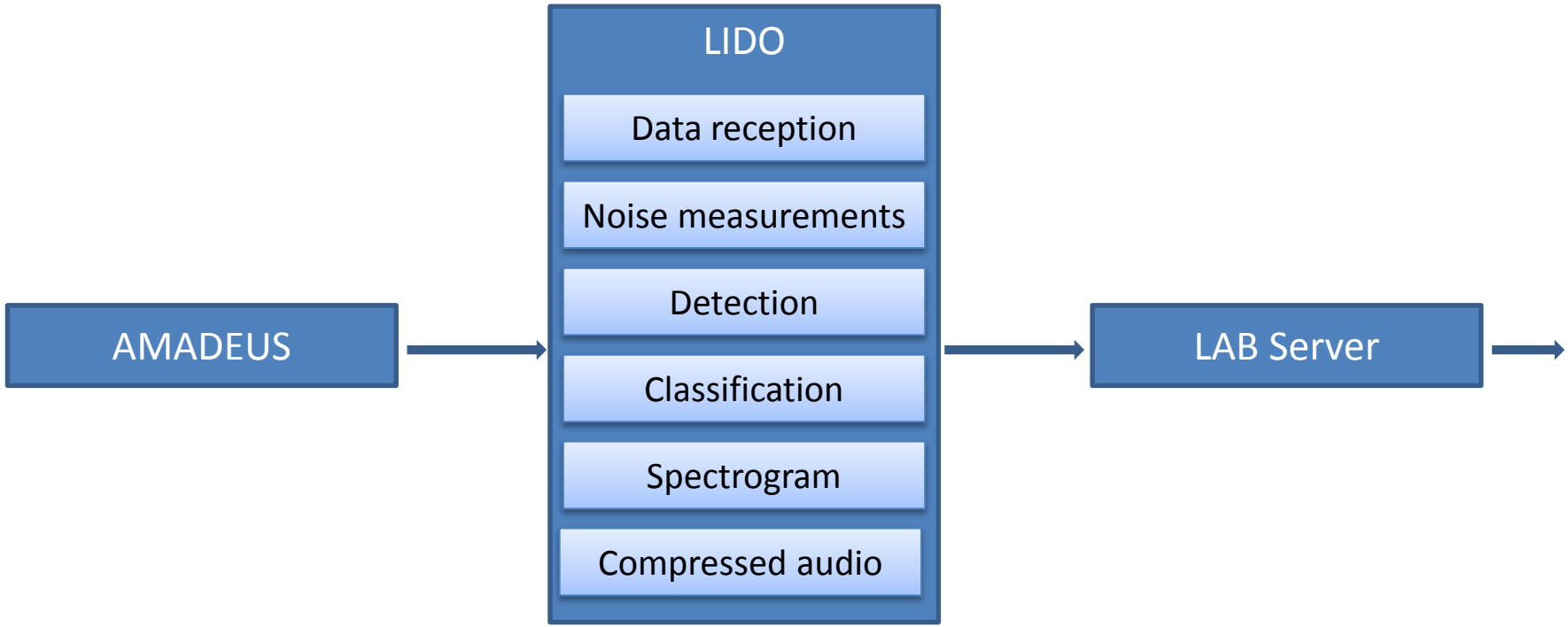
Sound speed in the Mediterranean Sea: an analysis from a climatological data set
S. Salon1**, A. Crise**1**, P. Picco**2**, E. de Marinis**3**, and O. Gasparini**3
Annales Geophysicae (2003) 21: 833–846

LIDO at ANTARES



The six AMADEUS acoustic storeys are highlighted in red.

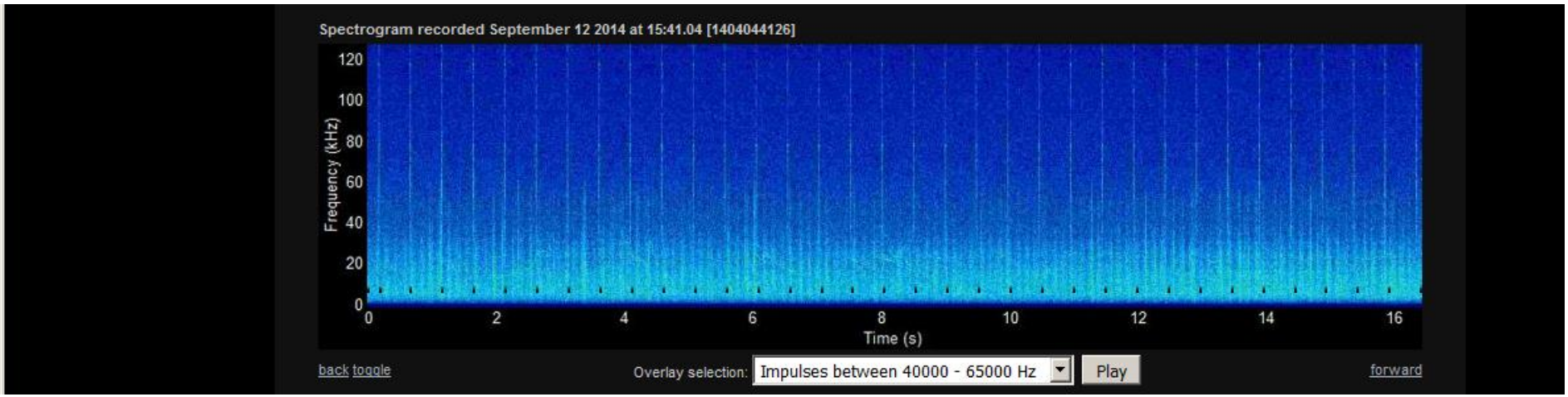
LIDO at ANTARES



LIDO at ANTARES

Impulsive signals:

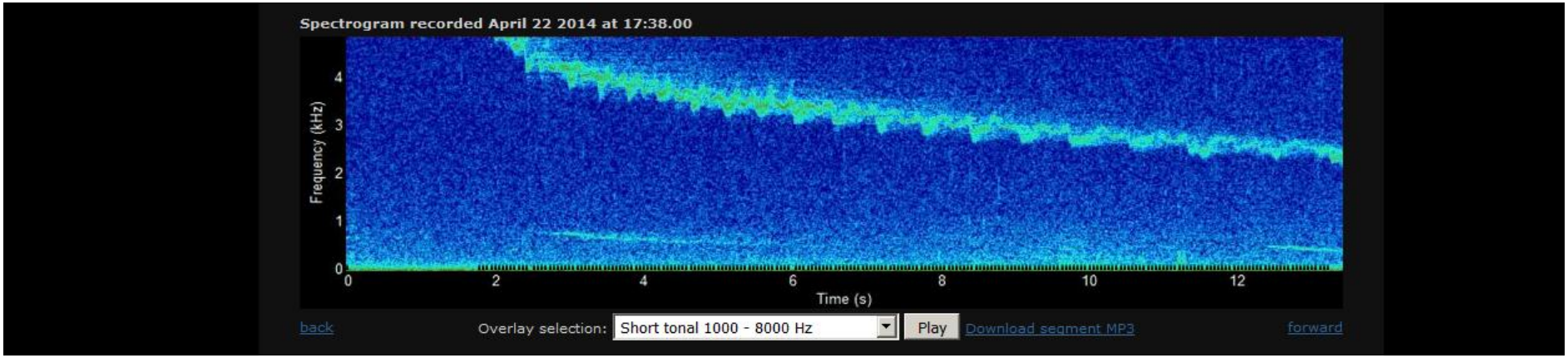
- Generally broadband
- Well defined in time
- Detected based on a dynamic energy threshold in a filtered time-domain
- Biosonar, shrimps, shipping, airguns



LIDO at ANTARES

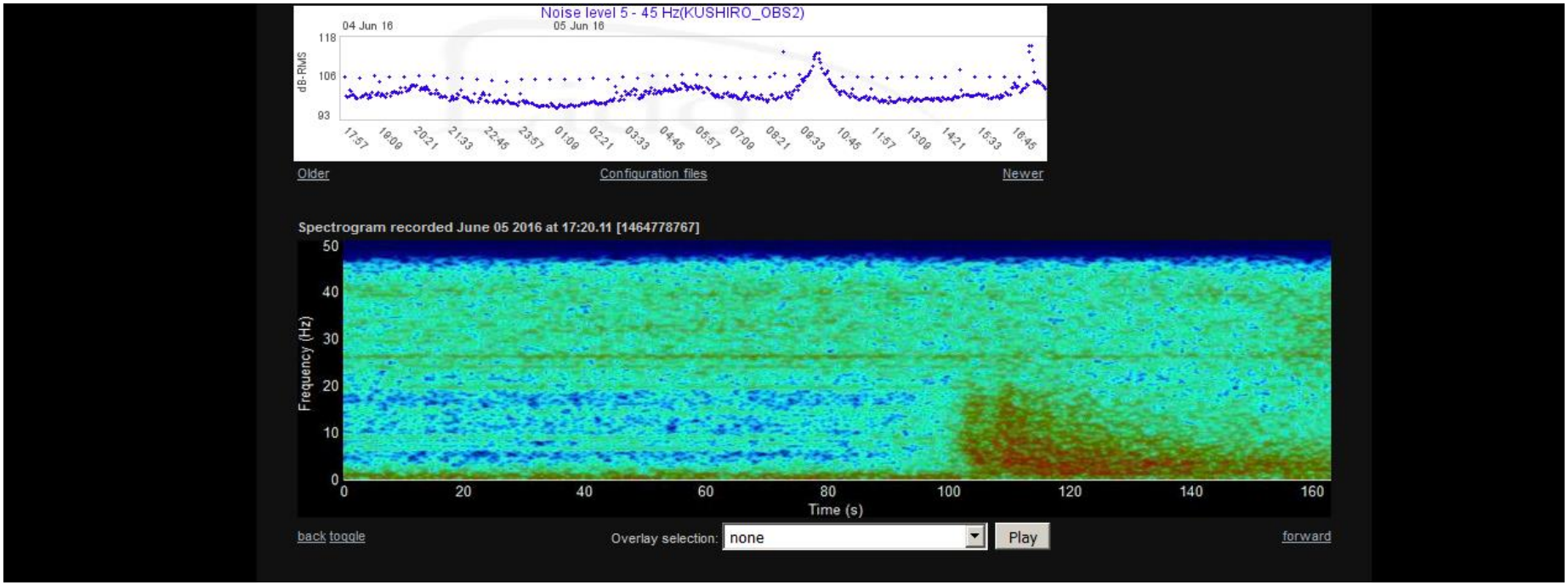
Short tonal signals:

- Well defined in frequency
- Long duration
- Detected based on contour extraction in time-frequency domain
- Constant tonal signals are removed
- Dolphin whistles, baleen whale calls, fish, chain noise, some shipping



LIDO at ANTARES

Signals with energy spread broadly over both time and frequency are not specifically detected, but registered with noise measurements (e.g. earthquakes, some fish).



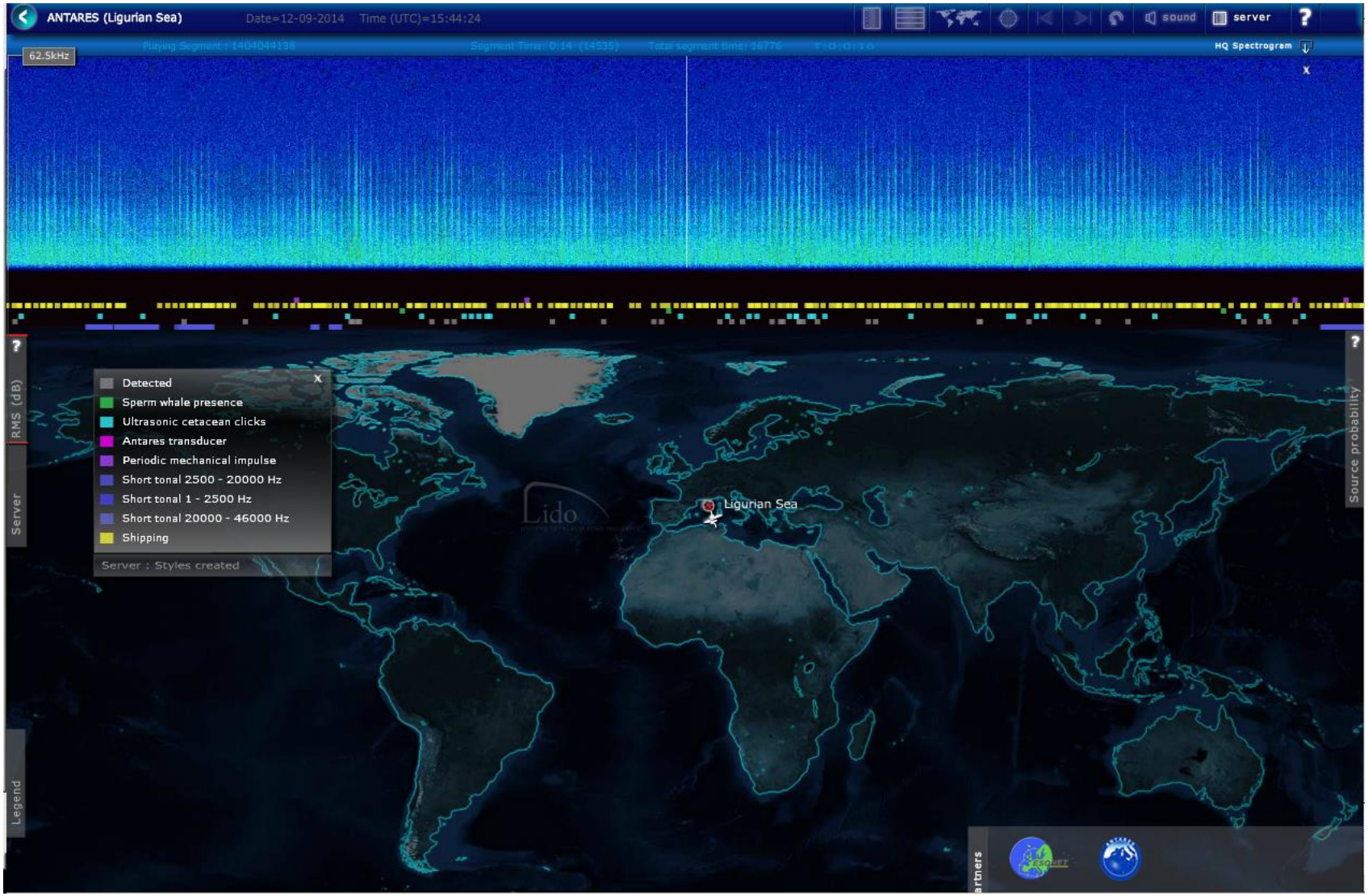
LIDO at ANTARES

Main interest at ANTARES is presence of cetaceans in relationship with anthropogenic sources, specifically:

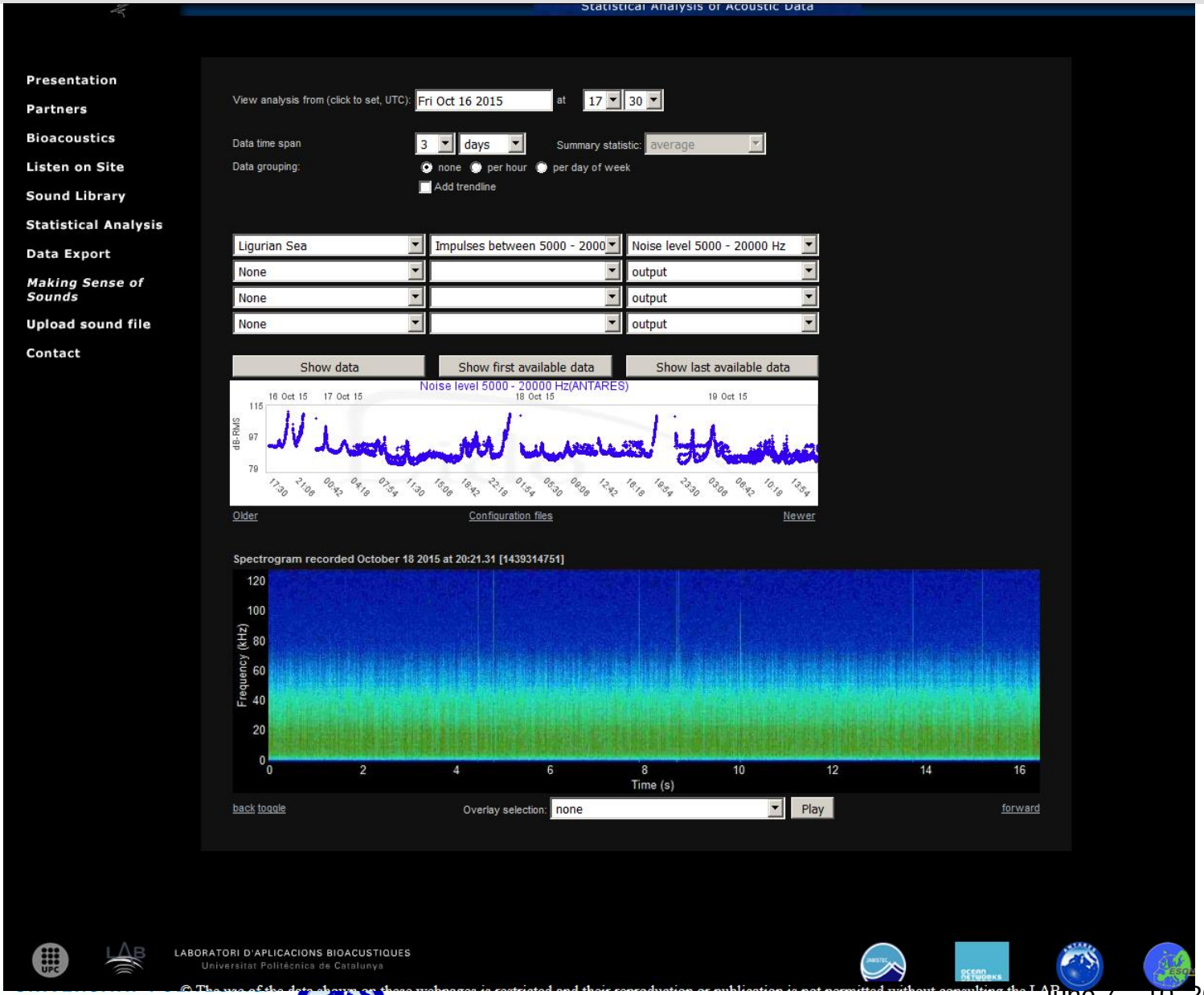
- Sperm whale presence
- Dolphin presence
- Beaked whale presence

This kind of analysis requires multiple year recordings.

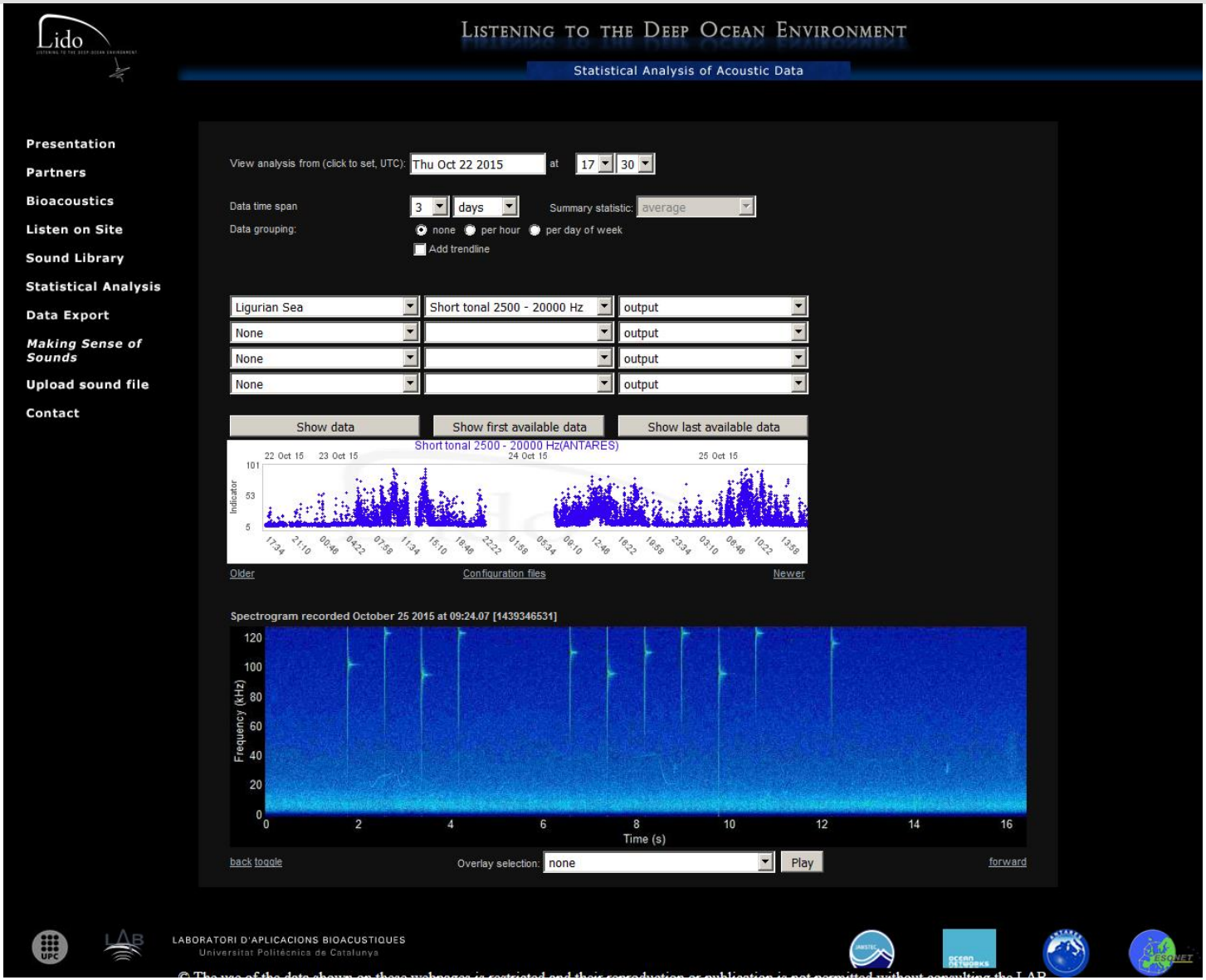
LIDO at ANTARES



LIDO at ANTARES

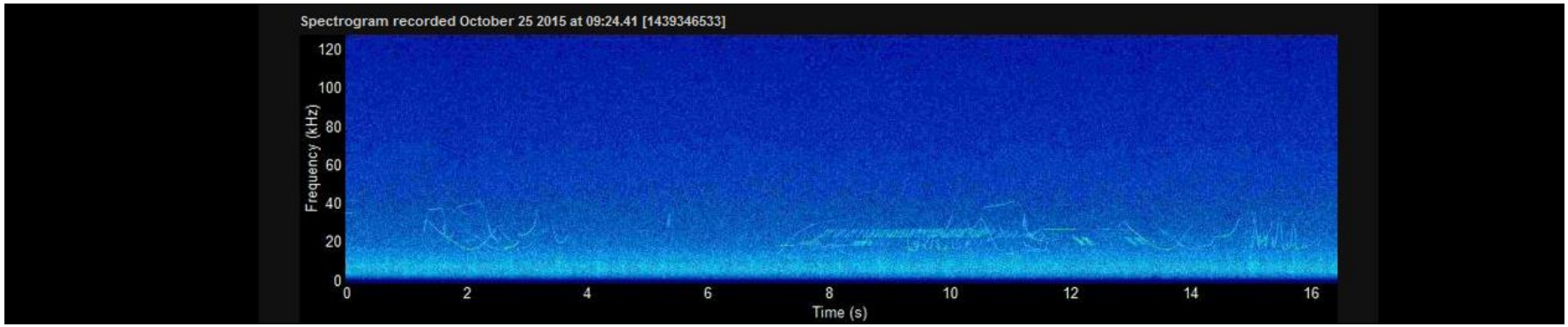


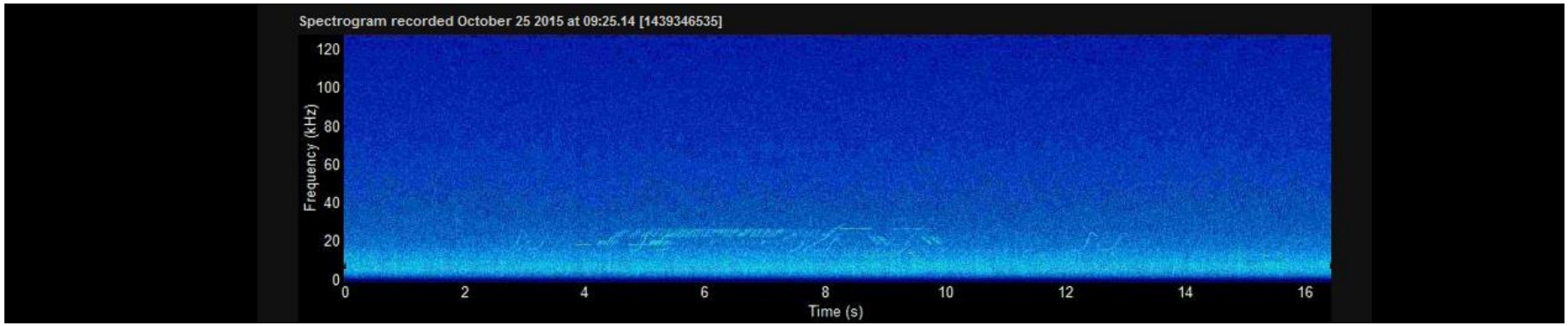
LIDO at ANTARES



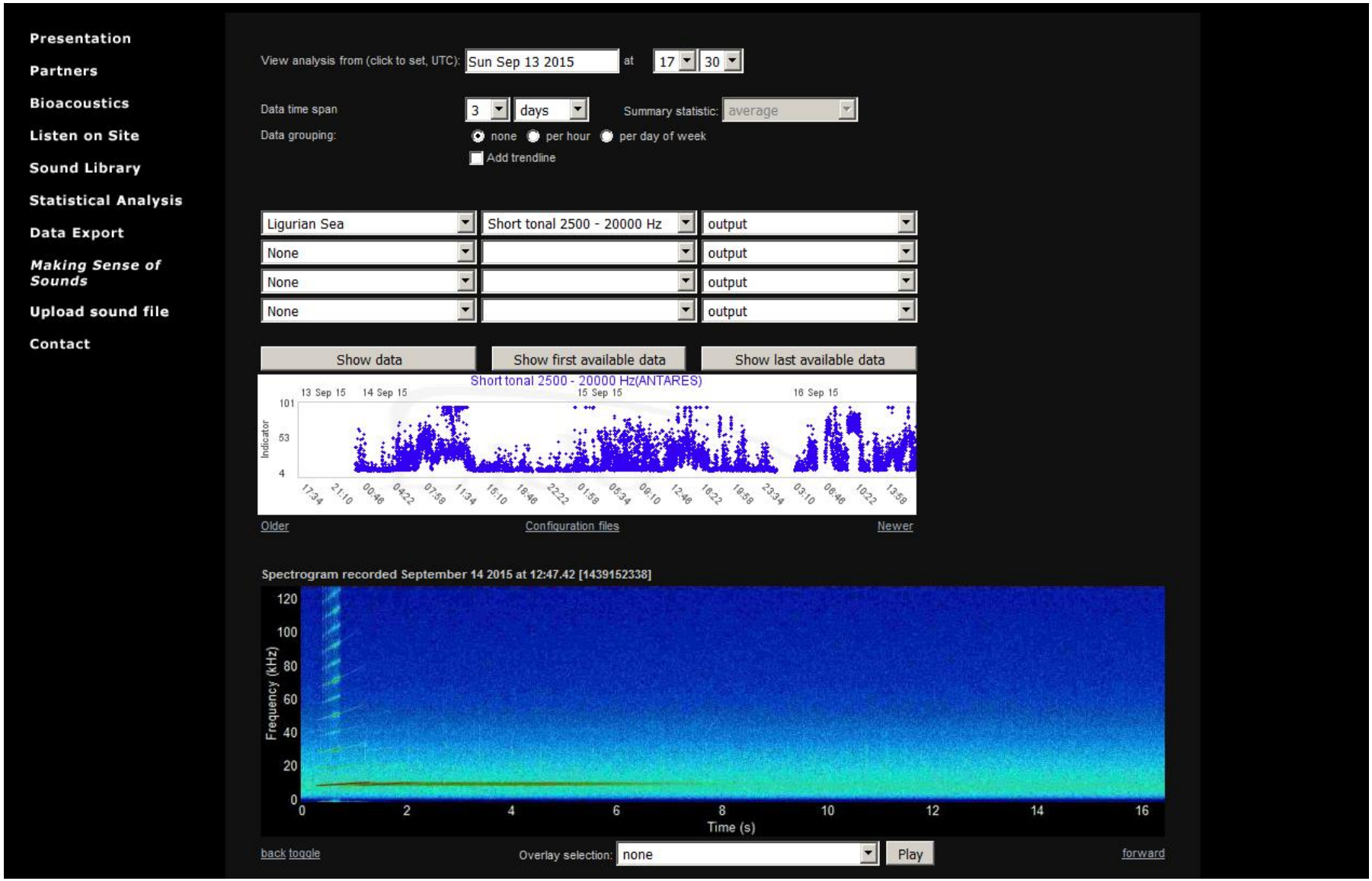
LIDO at ANTARES

Unknown short tonal signal:





LIDO at ANTARES



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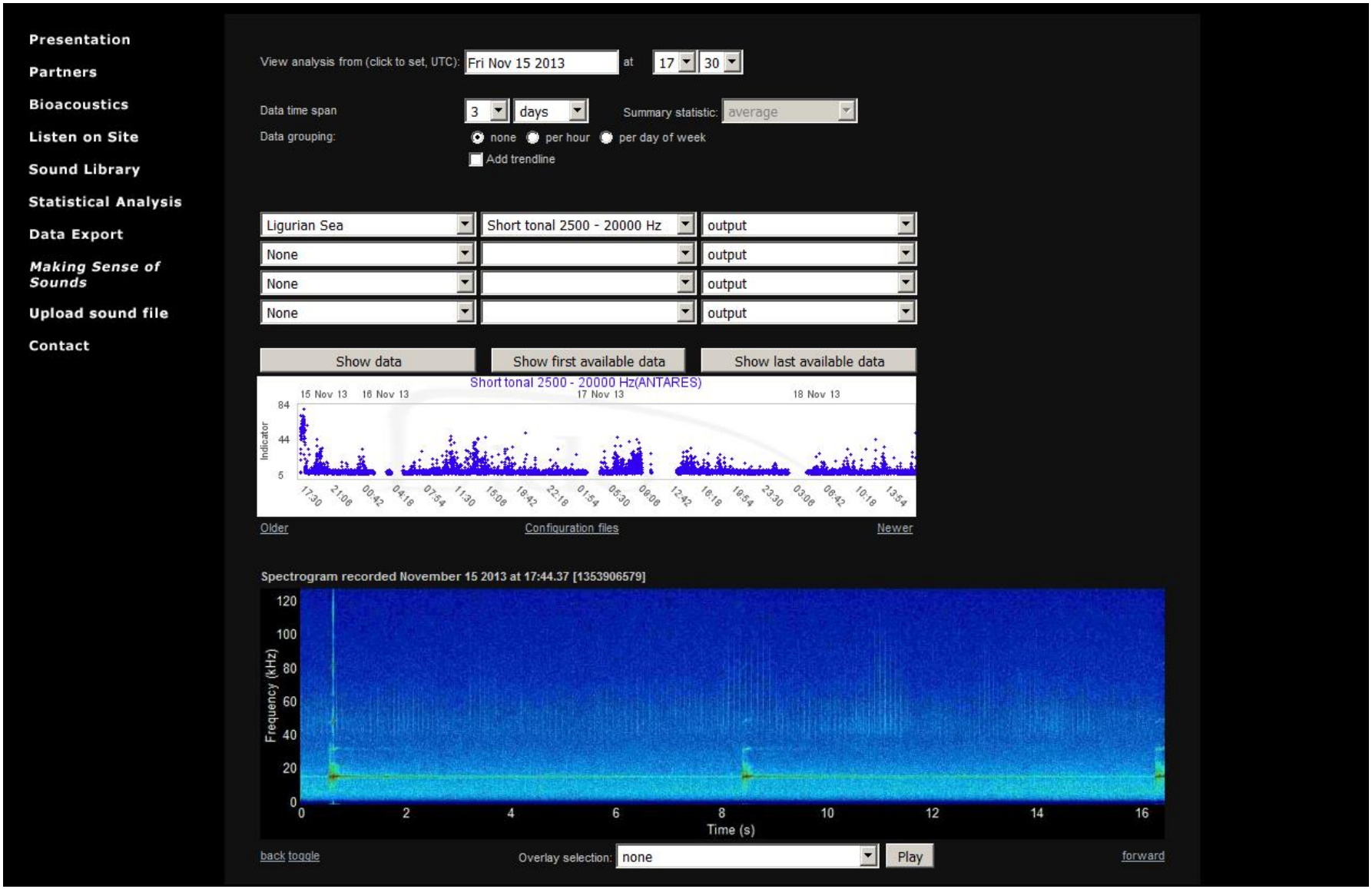

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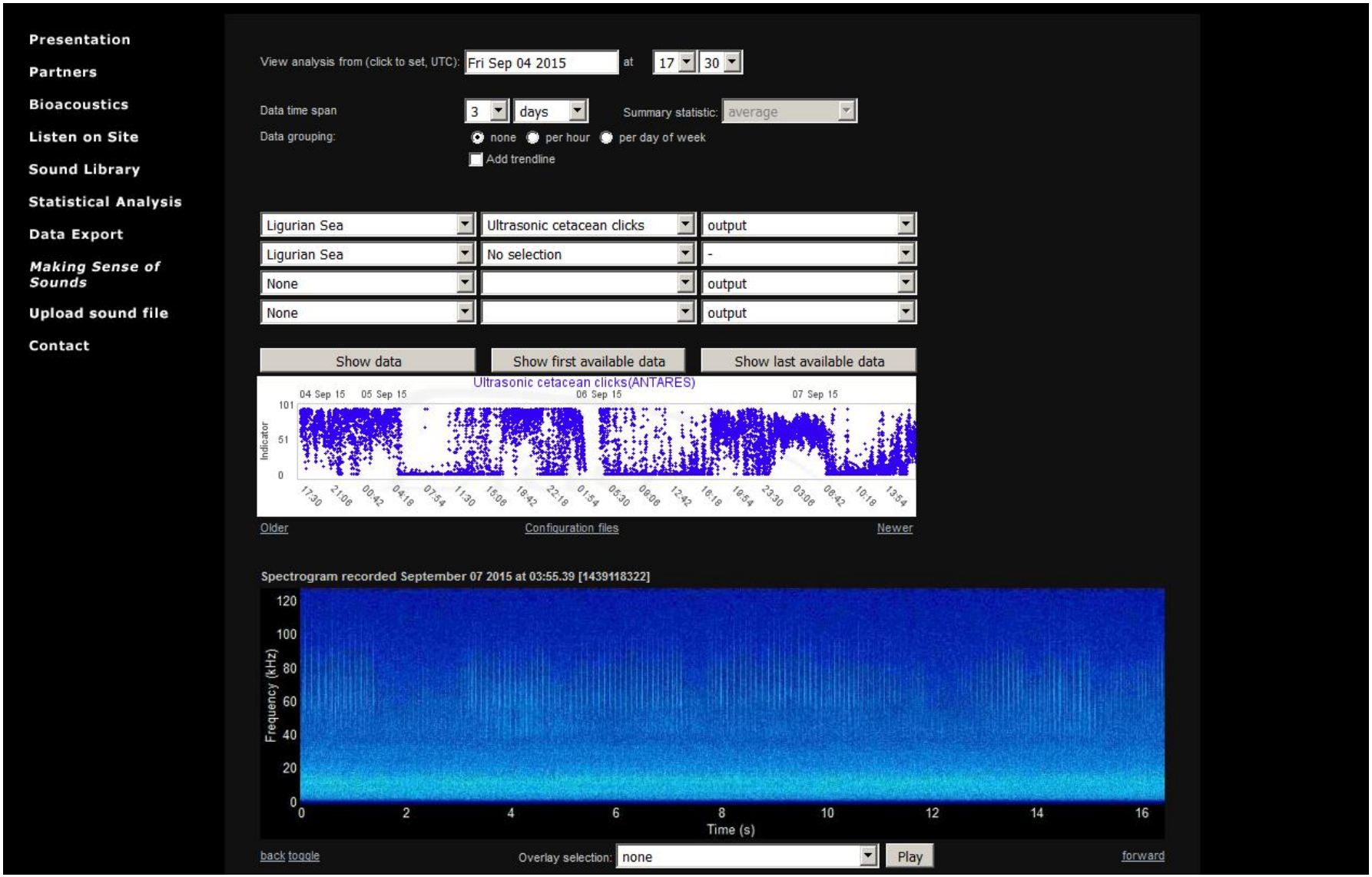
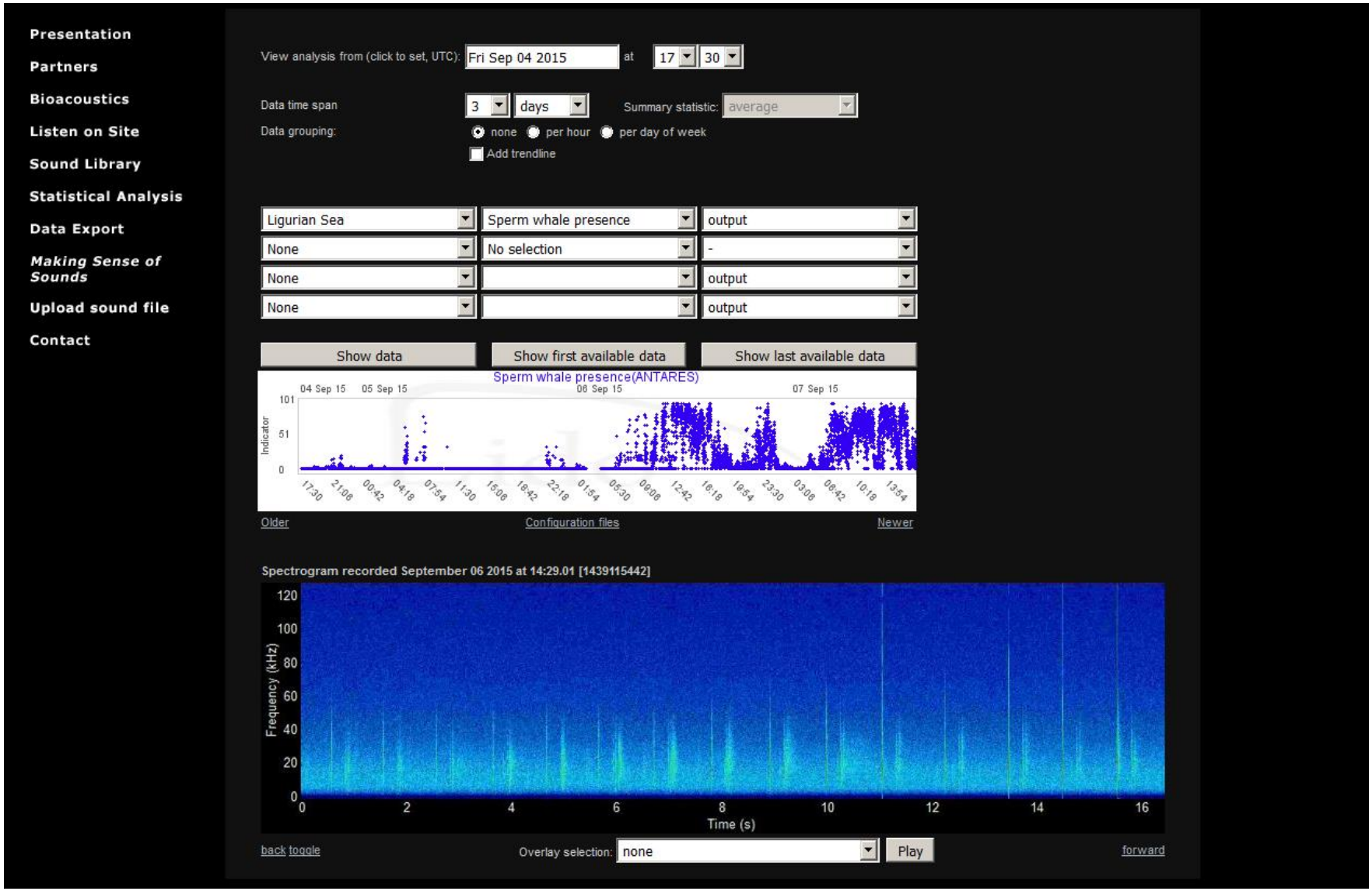


Sperm Whale Presence



http://www.listentothedeep.com:4444/acoustics/soundlibrary/listenrt.php?idSeg=1439115442&idLoc=9&idRun=62035&ts=1441549741

Sperm Whale Presence

Sperm whale presence decision process:

- Impulse detection 1000 – 5000 Hz and 5000 – 20000 Hz bands.
- Real-time GMM classifier for sperm whales, shipping and biosonar.
- Offline presence model based on acquired data.

Sperm Whale Presence

Feature extraction, 10 (normalized) energy features in time and frequency domain, combined with pulse repetition rate:

A measure of location was obtained by

$$m_1 = \sum_{k=1}^{n} kE_k \tag{1}$$

A measure of dispersion was obtained by

$$m_2 = \sqrt{\sum_{k=1}^{n} (k - m_1)^2 E_k} \tag{2}$$

A measure of asymmetry was obtained by

$$m_3 = \frac{1}{m_2^3} \sum_{k=1}^{n} (k - m_1)^3 E_k \tag{3}$$

A measure of concentration around a single value was obtained by

$$m_4 = \frac{1}{m_2^4} \sum_{k=1}^{n} (k - m_1)^4 E_k \tag{4}$$

A measure of the degree of peakiness was obtained by (5), which is identical to the Shannon entropy normalised for the total number of values n.

$$p = -\frac{1}{\log(n)} \sum_{k=1}^{n} E_k \log(E_k) \tag{5}$$

Sperm Whale Presence

$$p(\mathbf{x}) = \sum_{k=1}^{K} w_k \mathcal{N}(\mathbf{x}|\mu_k, \Sigma_k),$$

$$0 \leq w_k \leq 1, \quad \sum_{k=1}^{K} w_k = 1$$

Online classification is performed through a GMM; each class is described with a single model.

- The winner class is the one with highest likelihood.
- Unknown classes (ideally) receive low likelihood.
- A pattern can receive multiple class labels.

Sperm Whale Presence

Initial online classification results:

Statistic	λ	AUC	FPR	FNR	NPV	PPV
SWC	3	$0.84\ (0.78-0.90)$	$0.03\ (0.02-0.05)$	$0.42\ (0.30-0.54)$	$0.93\ (0.92-0.95)$	$0.75\ (0.64-0.85)$
ISN	5	$0.93\ (0.90-0.96)$	$0.09\ (0.06-0.13)$	$0.14\ (0.08-0.20)$	$0.93\ (0.90-0.95)$	$0.82\ (0.77-0.87)$
UCC	9	$0.93\ (0.89-0.96)$	$0.14\ (0.08-0.21)$	$0.07\ (0.04-0.10)$	$0.83\ (0.77-0.88)$	$0.94\ (0.92-0.96)$

Training data accuracy: threshold (λ), Area under the curve (AUC), false positive rates (FPR), false negative rate (FNR), Negative predictive value (NPV) and positive predictive value (PPV) from sperm whales, shipping and dolphins presence. Confidence intervals are at 95 %, with the AUC, FPR and FNR calculations using 2000 stratified bootstrap replicates and the NPV and PPV for the asymptotic limits.

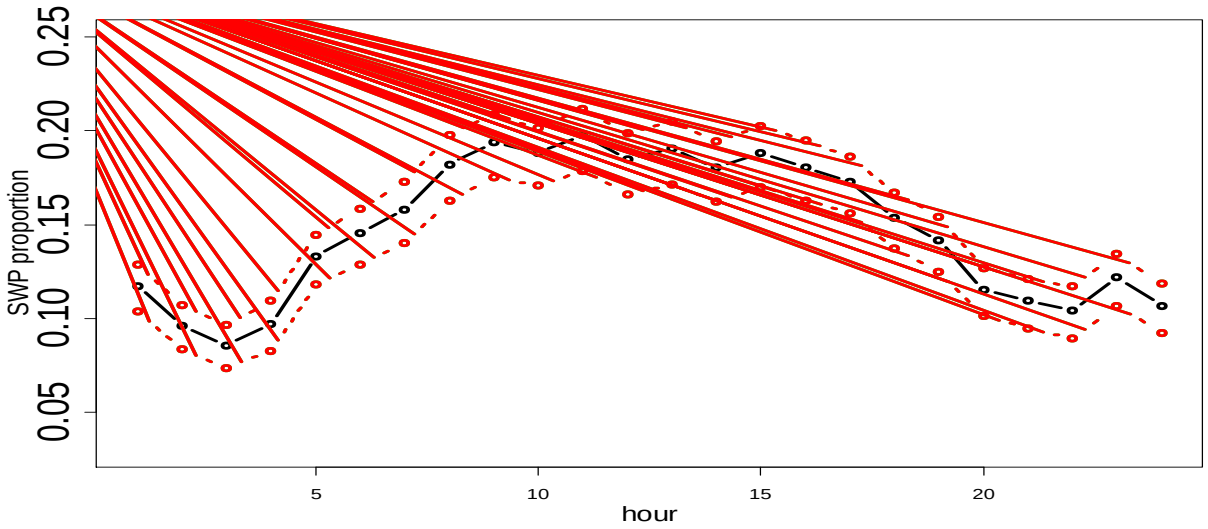
Sperm Whale Presence

Presence model (GLM) taking into account sequence of segments and presence of multiple classes.

Coefficient	Estimation	Std. Error	Z value	Pr(>|z|)
Intercept	-3.279	0.293	-11.180	<2e-16
SWC	1.205	0.191	6.296	3e-10
ISN	0.003	0.005	0.600	0.548
SWC * ISN	-0.007	0.003	-2.935	0.003

$$SWP = \frac{1}{1 + \exp(-X\beta)} = \frac{1}{1 + \exp\left(-(-3.279 + 1.205\ SWC - 0.007\ SWC * ISN)\right)}$$

Sperm Whale Presence



Proportion of sperm whale presence predictions considering only the segments with relative SPL lower than 1 (avoiding masking by shipping or other noise).

This pattern is persistent throughout all seasons.

Noise Measurements

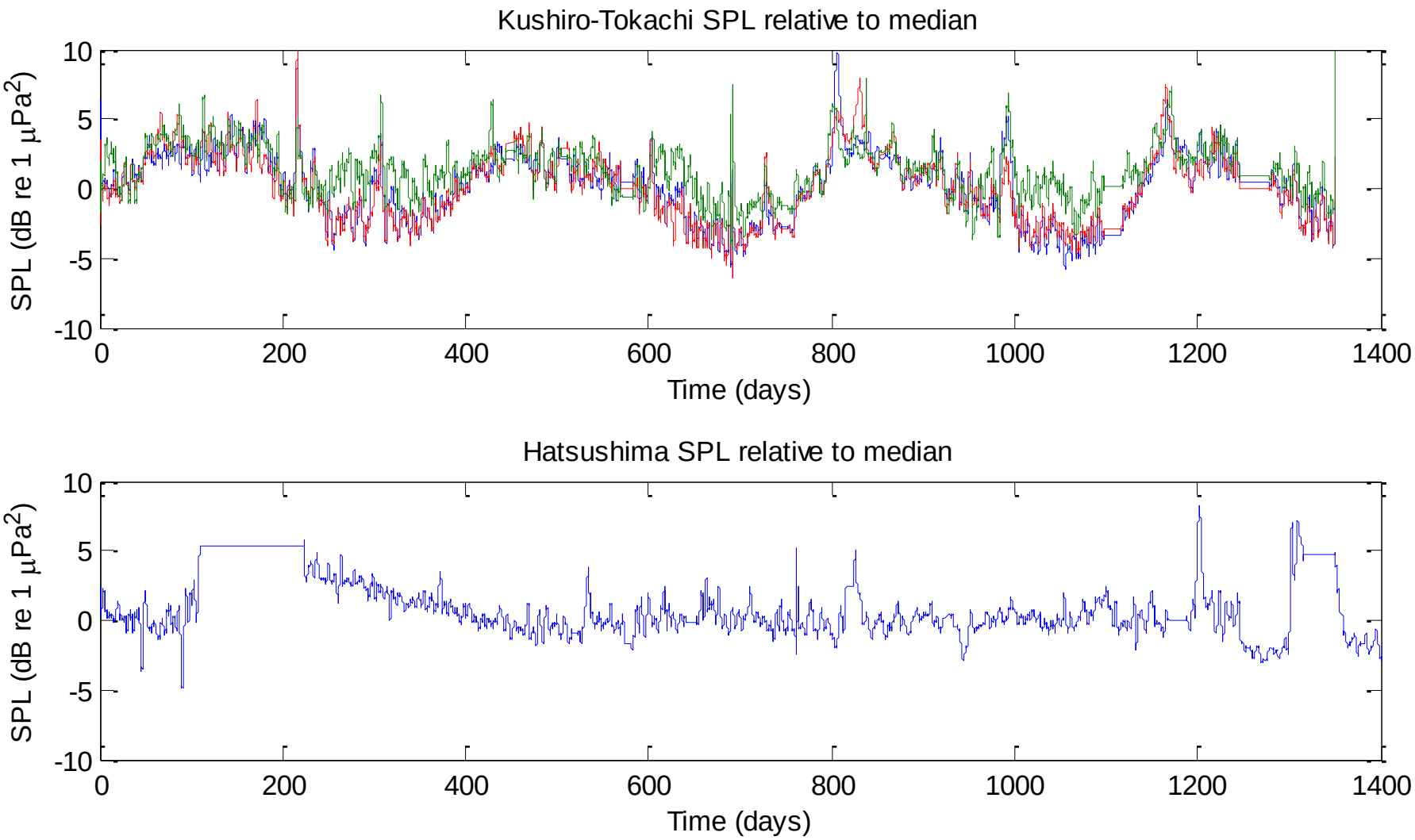
Good Environmental Status - Marine Strategy Framework Directive 11

1. Count the number of expected impulses based on modelling.
2. Measure noise in third octave bands centred on 63 and 125 Hz
   (shipping noise, pile driving, explosions, etc.)

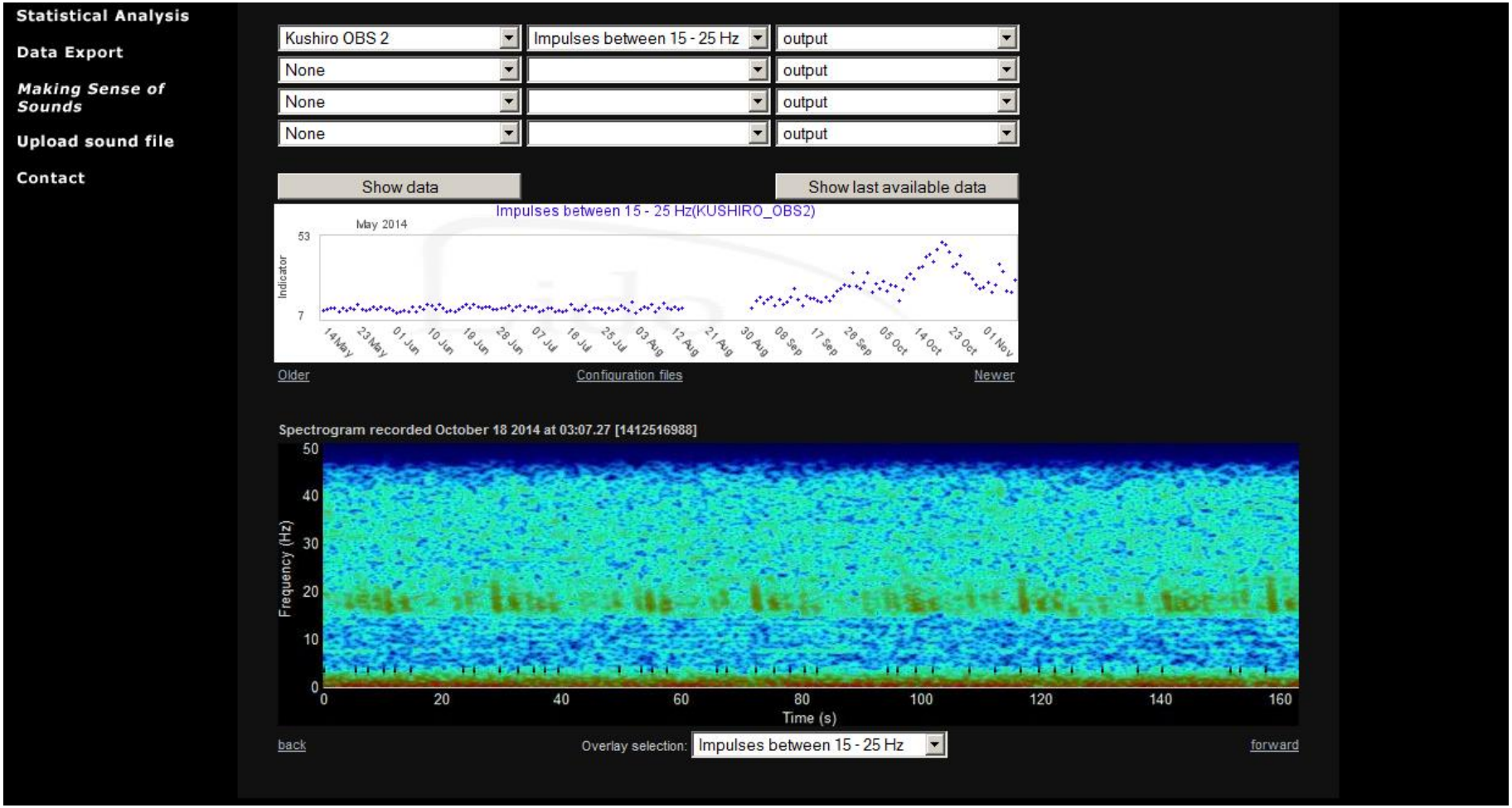
When can noise be considered harmful ?

- Audiograms only available for a few marine mammal species
- Hearing most sensitive in vocalization range?
- Fishes, cephalopods, bivalves?

Noise Measurements – Biological Contribution



Noise Measurements – Biological Contribution



Synergies

Bioacoustics (environmental monitoring in general) can greatly benefit from permanent installations.

When feasible, acoustic design should take into account the complete frequency bandwidth for optimal usage.

Installations can be used for regulation (MSFD) e.g. as control station.