ACOUSTIC DETECTION

MULTIDISCIPLINARY APPLICATIONS

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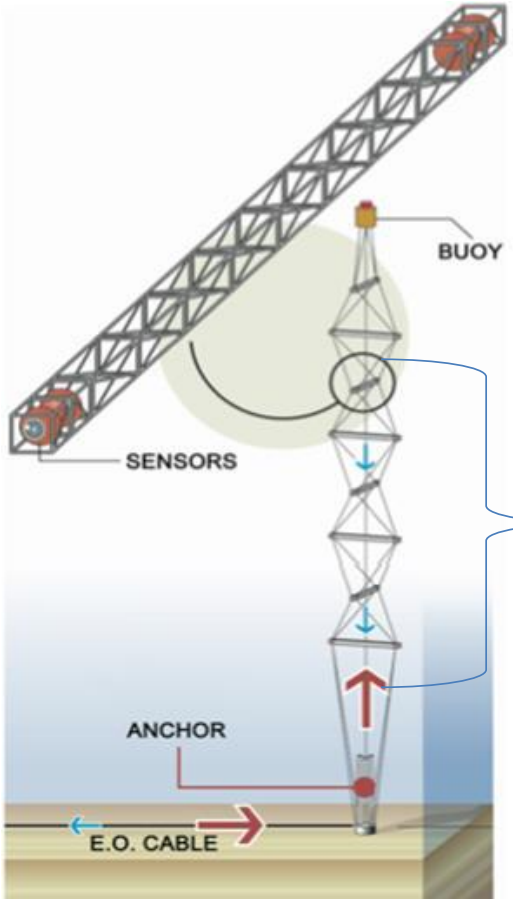
KM3NeT-Italy Collaboration Meeting

Rome, November 12-13 2013

SMO (Submarine Multidisciplinary Observatory)

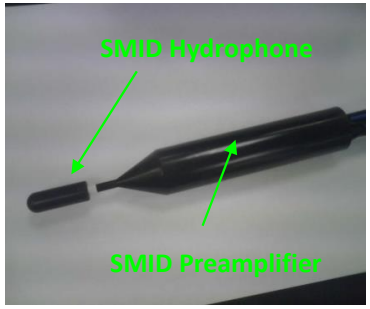
The SMO antenna consists of 10 high sensitivity and broadband (10Hz 70kHz) hydrophones and some environmental sensors required in underwater acoustic research.

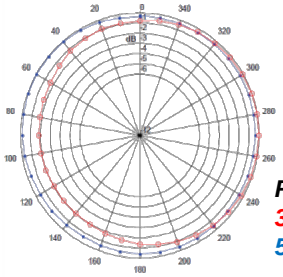
(CTDs, currentmeters…)



Acoustic Data:

- 192 kHz/24 bit
- Analyzed in real-time on shore
- 5min/h are stored on shore

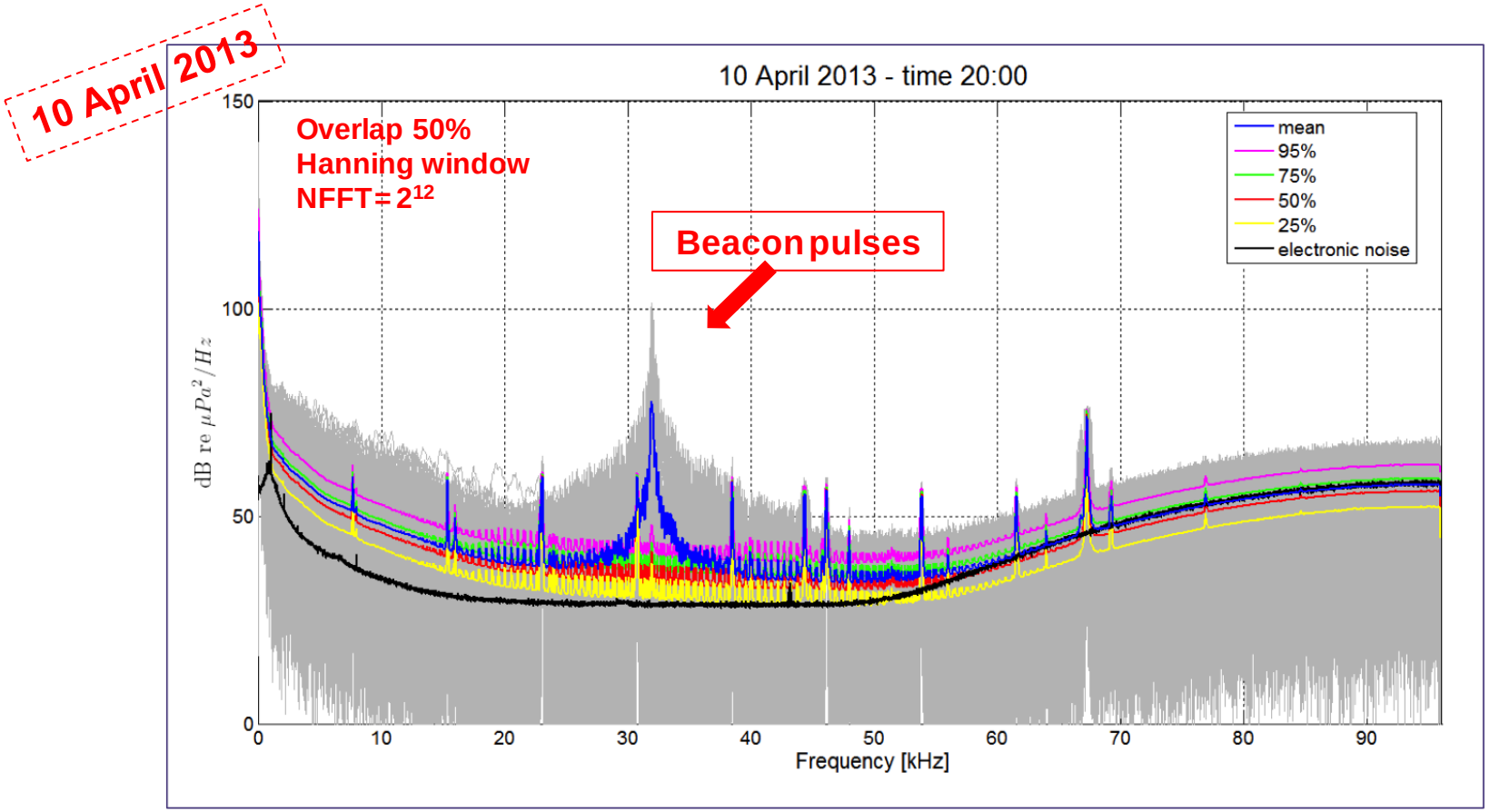




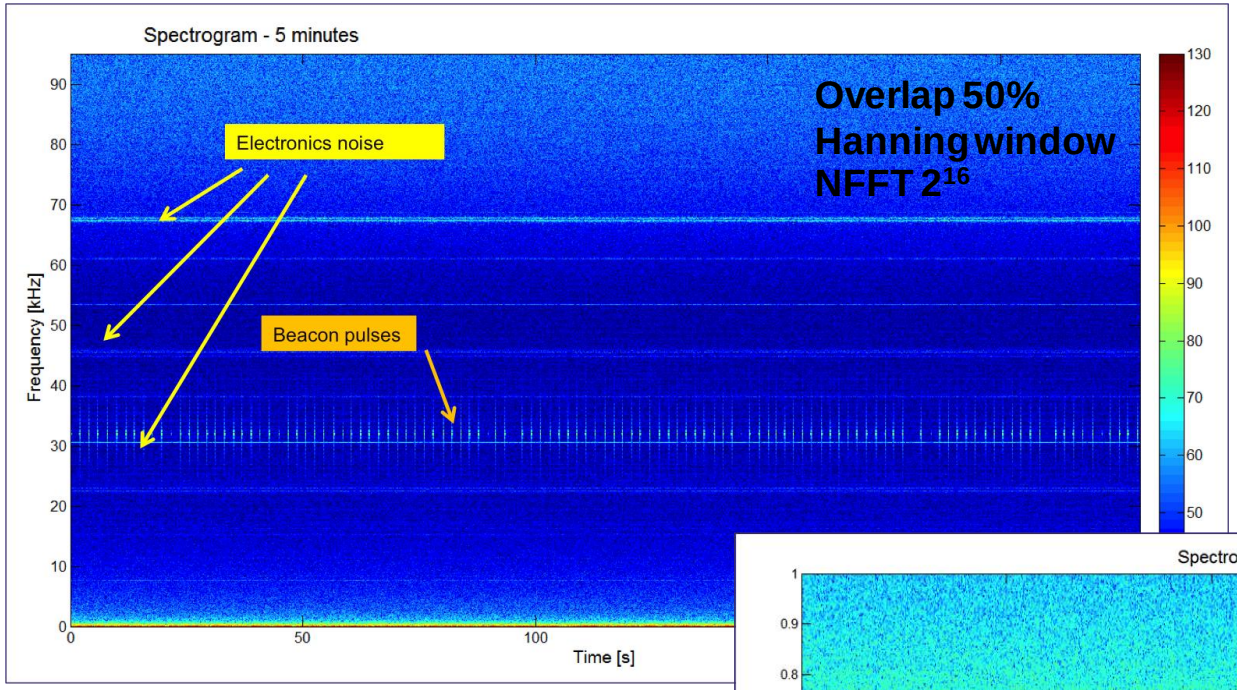
Radiation lobe
30 kHz
50 kHz

Acoustic Data

The Power Spectral Density (**PSD**) calculated every 21 ms time-slice for a 5 minutes recording (grey area). The average value, some percentiles of the distribution and the electronic noise are shown.

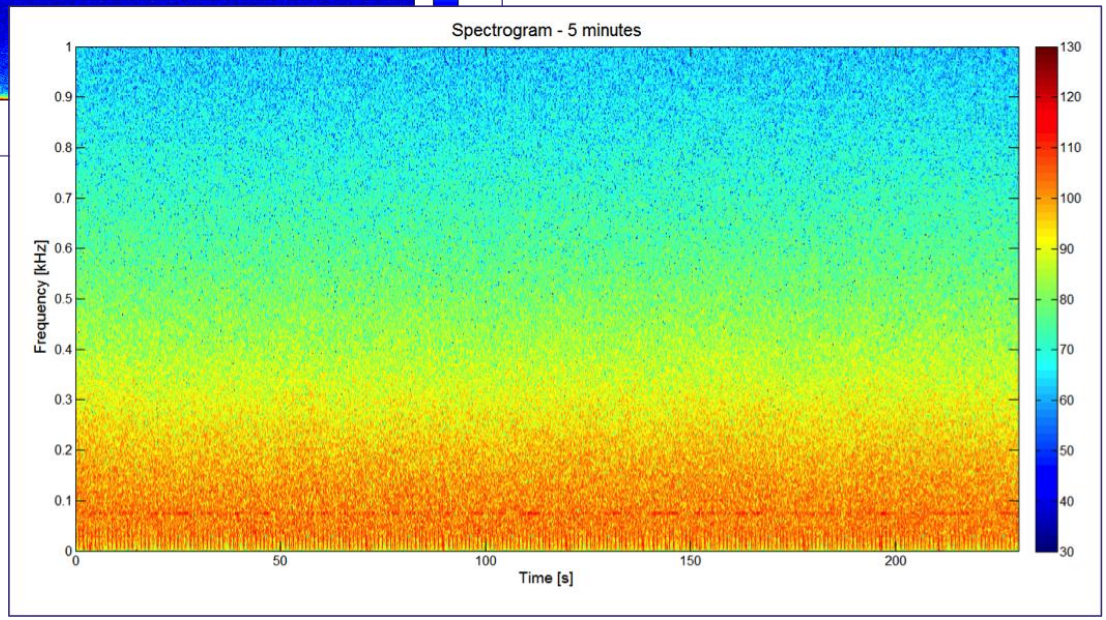


Acoustic Data



10 April 2013

Spectrogram of 5 minutes recording



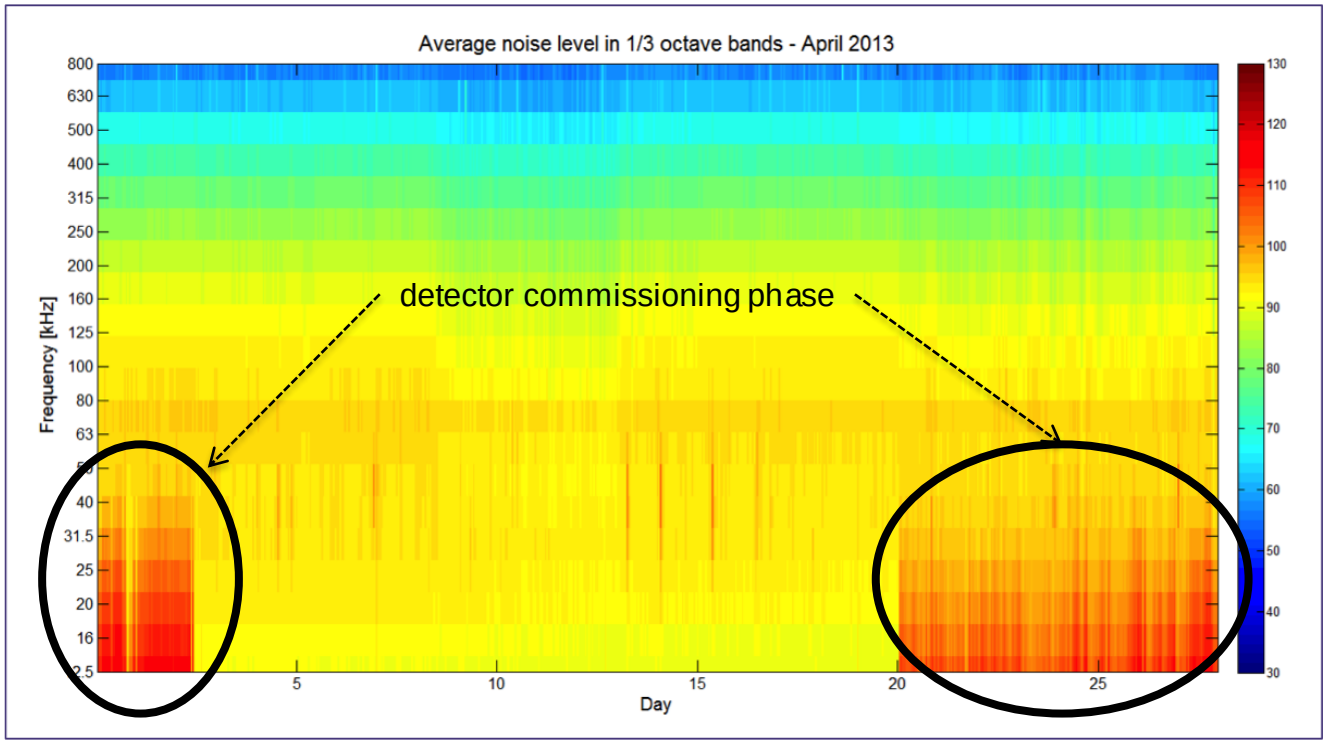
Zoom at low frequencies (< 1 kHz)

Continuous low frequency sound

The European Marine Strategy suggests to valuate the trends of the environmental noise in the 1/3 octave bands with 63 and 125 Hz central frequencies.

Acoustic noise measured in these bands as indicator of the good environmental status of the sea.

April 2013



Spectrogram of the average PSD in 1/3 octave bands (April 2013 – 5 min per hour).

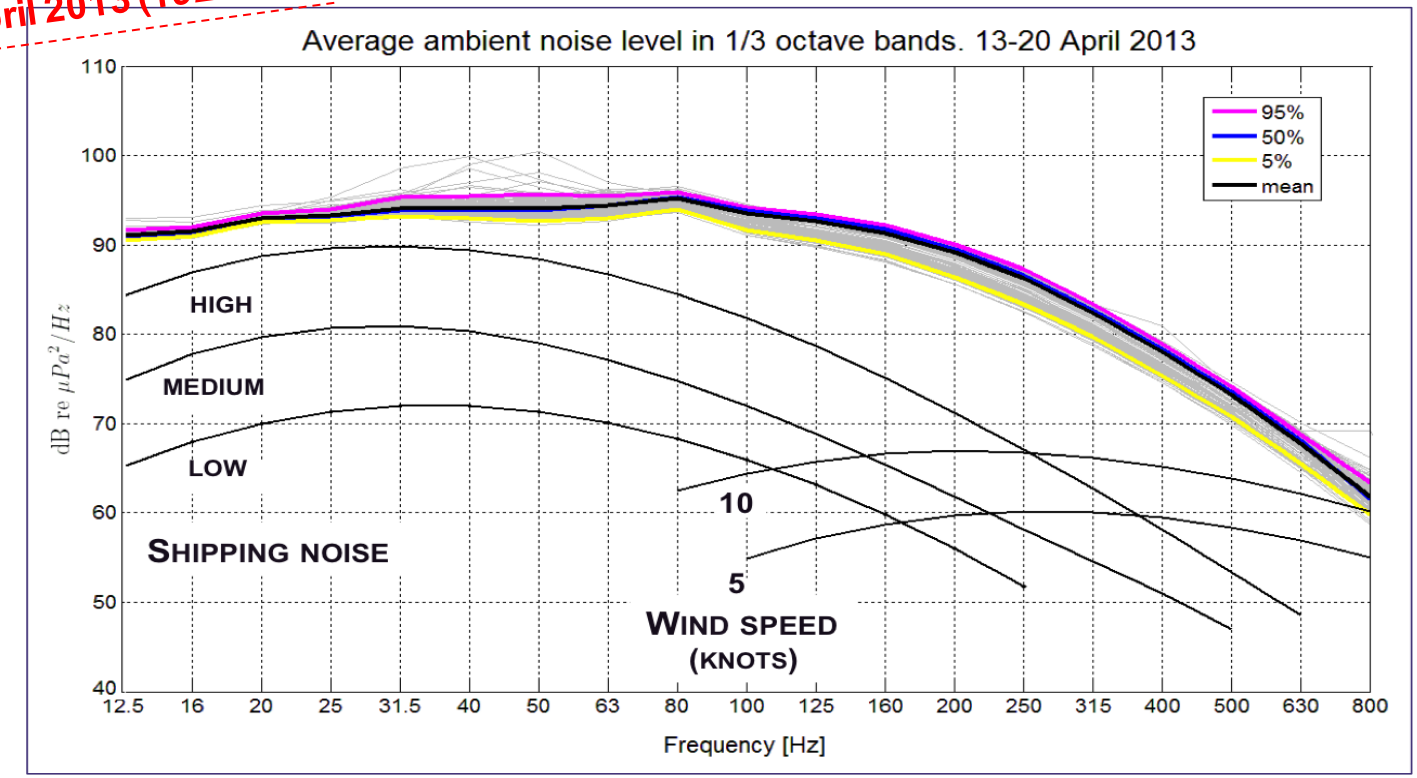
Marine Strategy Framework Directive – Underwater noise and other forms of energy – April 2010.

European Marine Strategy Framework Directive Good Environmental Status (MSFD-GES) – Report of the technical Subgroup on Underwater Noise and other forms of energy – 27 February 2012

Continuous low frequency sound

The acoustic noise level in 1/3 octave bands of 5 min recordings (grey lines), percentiles and mean value. Shipping noise (high, medium and low) and noise introduced by wind speed is also shown for comparison **(Knudsen et al., 1948; Wenz, 1962; reviewed in Urik, 1983)**

13-20 April 2013 (192 files)



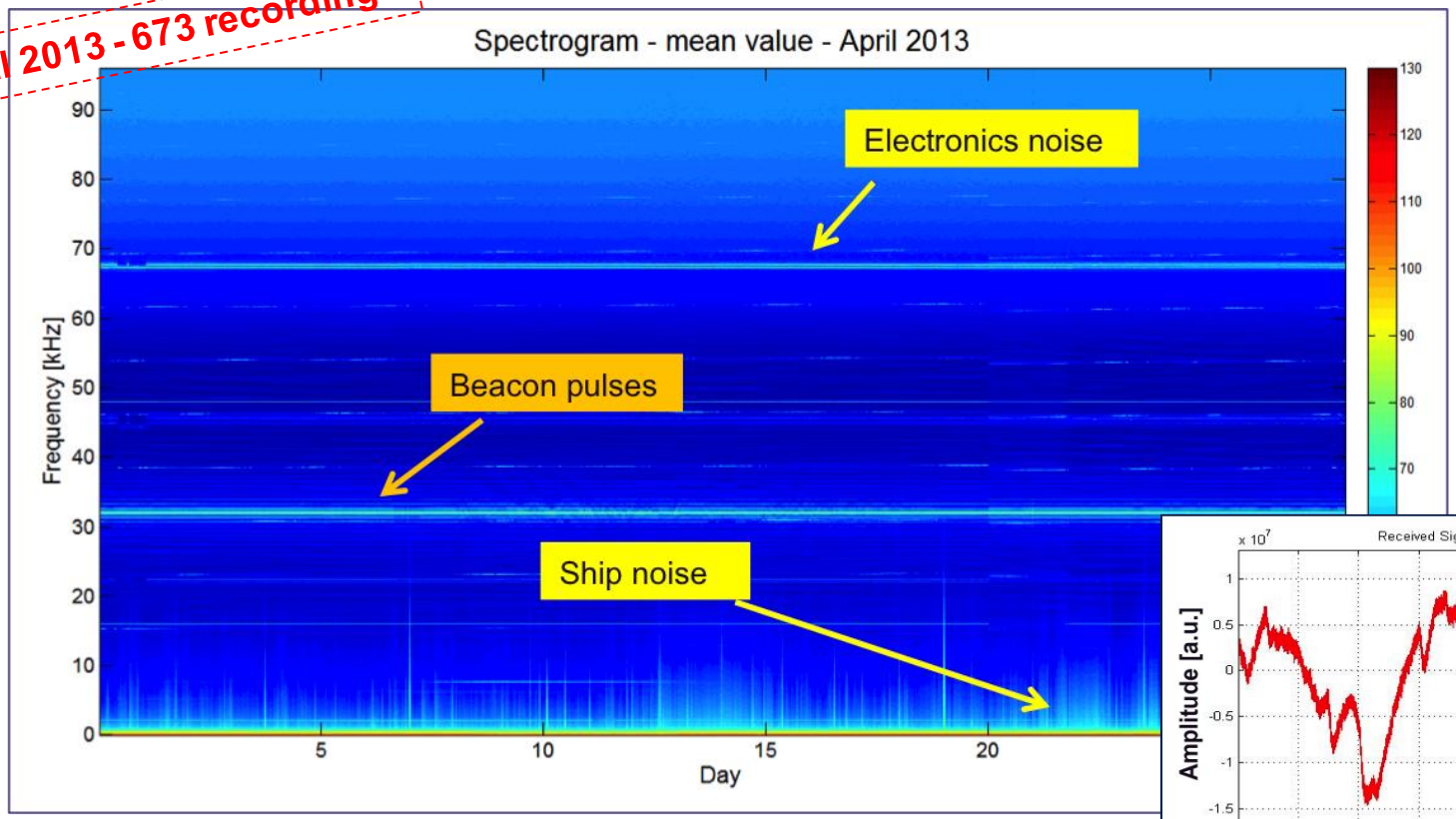
Grasso et al., for the SMO-NEMO, KM3NeT Italia and SN1 Teams. **"First results in underwater acoustic background in SMO – NEMO Phase II"**

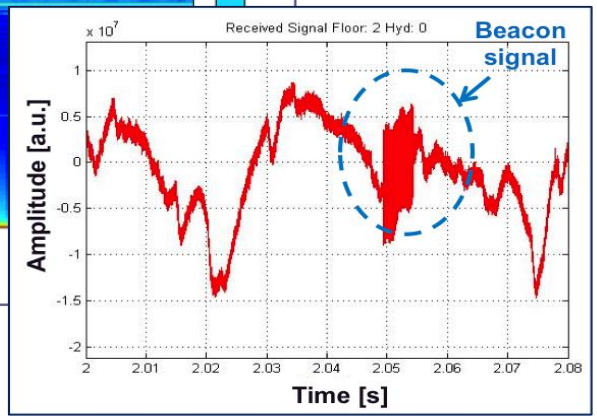
Erice International School of Ethology, Erice (Sicily – Italy), 18 – 21 October 2013

Impulsive sounds

The KM3NeT positioning beacon pulses (frequency of 32 kHz, time duration of 5 ms and power of 180 dB re 1µPa to 1m) were identified and they were used as calibration source.

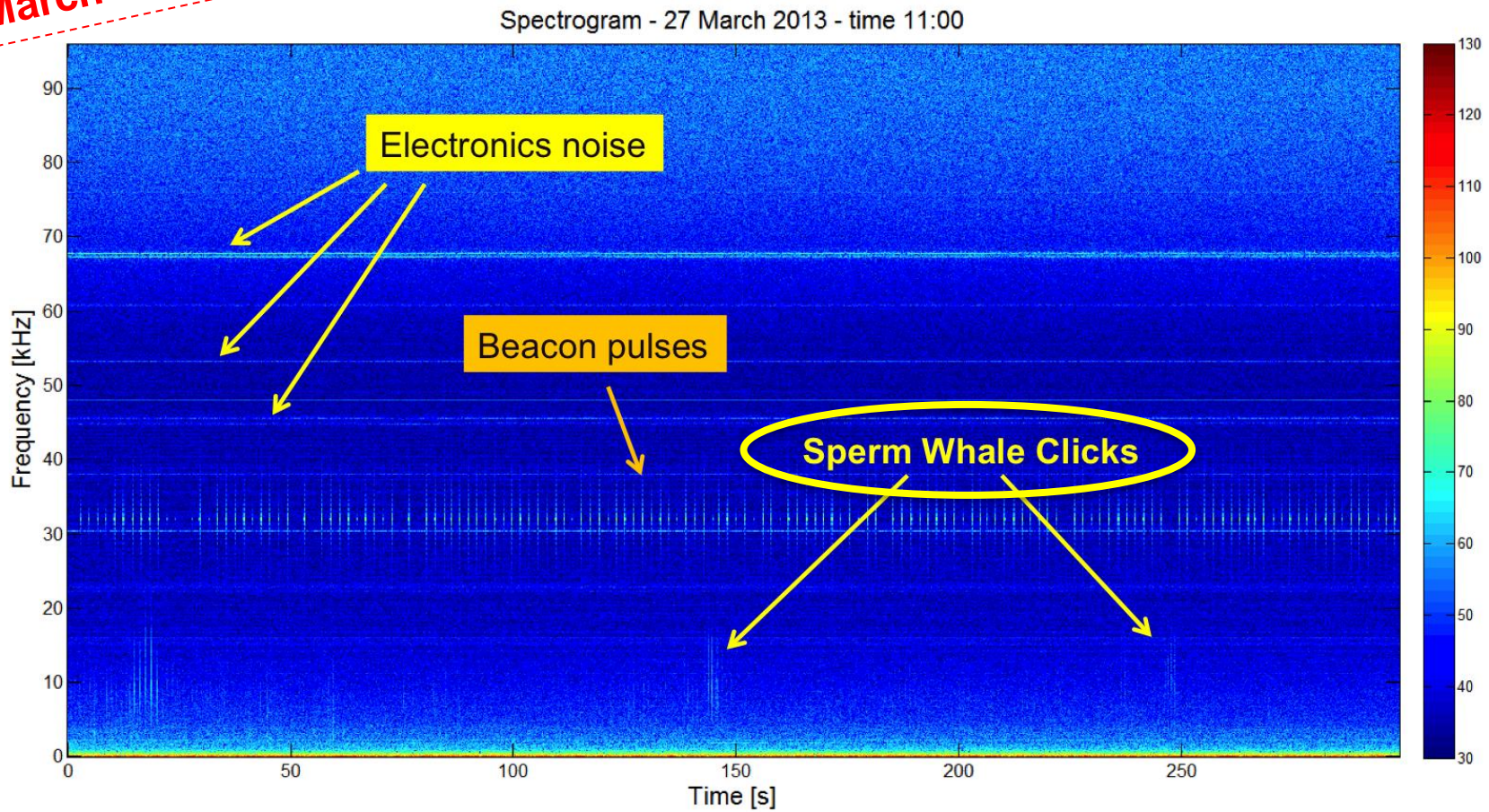
April 2013 - 673 recordings





The Sperm Whale

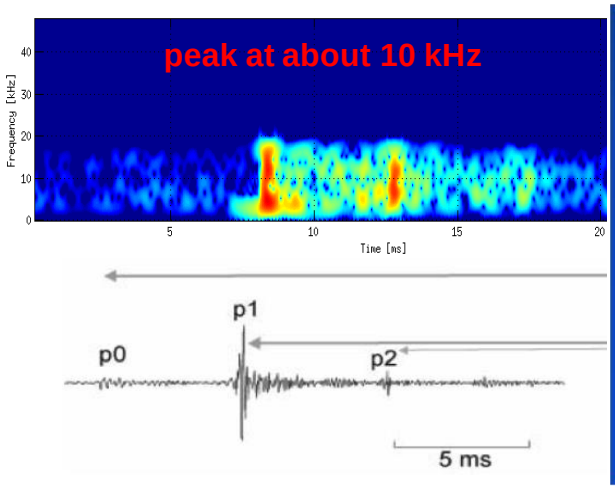
27 March 2013

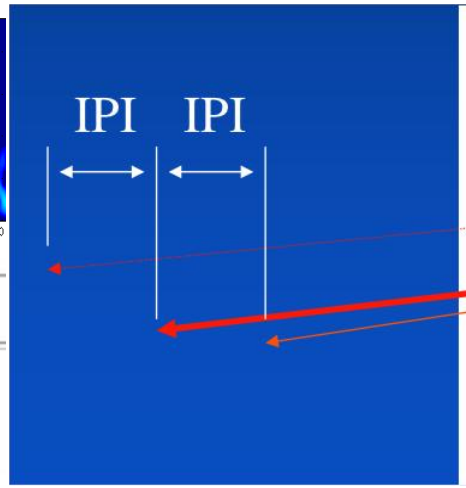


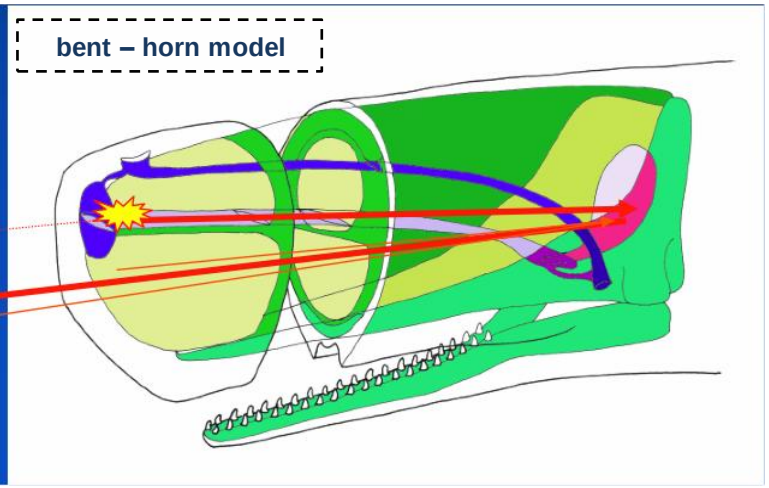
F. Caruso et al., for the SMO-NEMO, KM3NeT Italia and SN1 Teams. "**An algorithm to measure the size of sperm whales recorded by INFN deep-sea observatories in the Ionian Sea (Eastern Sicily)".**

Erice International School of Ethology, Erice (Sicily – Italy), 18 – 21 October 2013

Automatic acoustic detection of sperm whale







p0 – p1 = Varies according to the recording geometry
p1 – p2; p2 – p3 = **Stable → "Nominal IPI" [from 2 to 10 ms]**

Equations to transform IPI value in total length:

- Gordon (1991)

(1) $TL = 9.75 - 0.521\,SL + 0.068\,SL^2 + 0.057\,SL^3$
(2) $TL = 4.833 + 1.453\,IPI - 0.001\,IPI^2$

- Growcott et al. (2011)

$TL = 1.258\,IPI + 5.736$

SO= 1430 m/s
(sound speed in the spermaceti organ – Gold 1996)
SL = IPI * SO / 2
TL = Total length
SL = Spermaceti organ length

Automatic acoustic detection of sperm whale

1. Select Clicks

- 3-16 kHz Band-pass **Filter** (Butterworth)
- **Search Peaks** in Energy → Threshold
- **Select** Time Interval (60 ms)

2. Cepstrum Analysis

- **Single Interval** → $C = | FFT^{-1} (\log | FFT (x) |) |$
- **Average** → **Cepstral Peak** from 2 – 10 ms
- **IPI Variation** → max 0.3 ms (0 – 1500 m depth)
- **Reliability** of the Results
- **Animal Size** → Growcott Formula

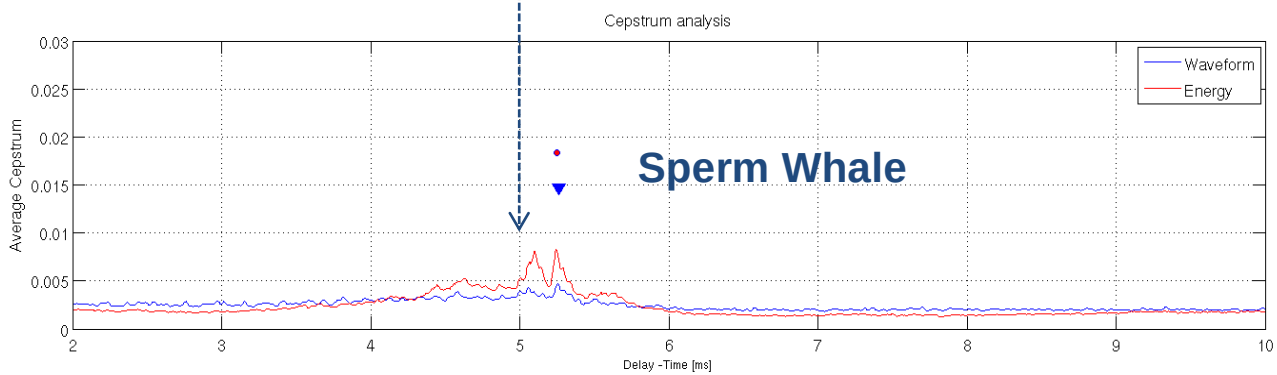
3. Autocorrelation Analysis

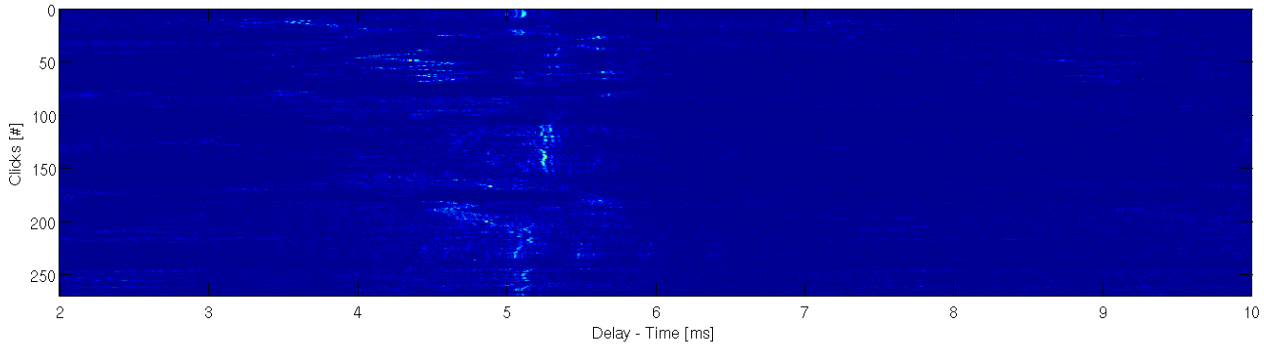
- **Check** the Cepstrum Results

Automatic acoustic detection of the sperm whales

27 March 2013

IPI Variation ???





Nominal IPI

5.25 [ms]
[ms]
[ms]

5.2604 [ms]
[ms]
[ms]

HIGH

GOOD

1 SW [#]

1 SW [#]

Animals[#]

12.3405 [m]
[m]
[m]
Growcott

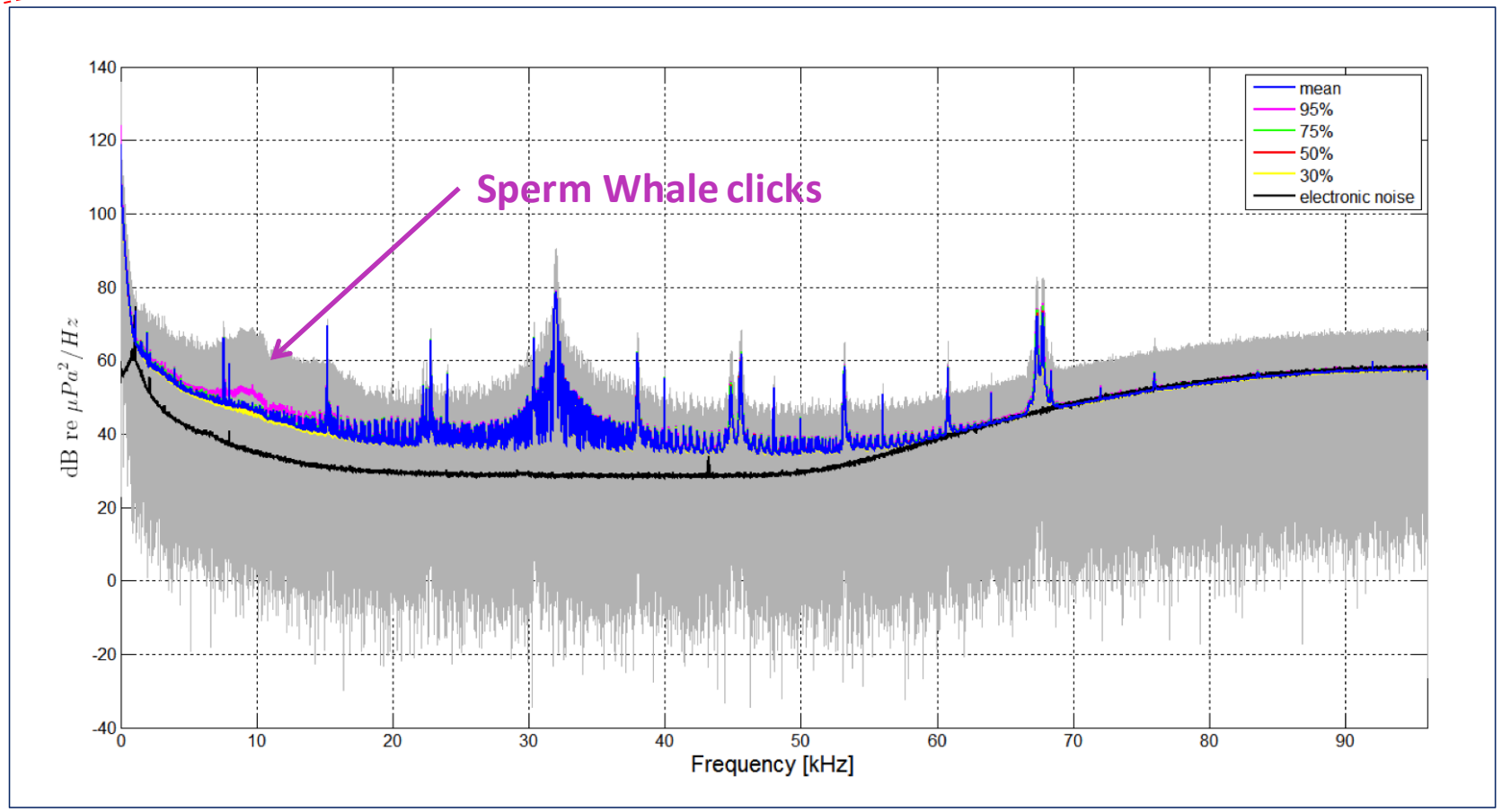
12.3536 [m]
[m]
[m]
Growcott

Size [m]

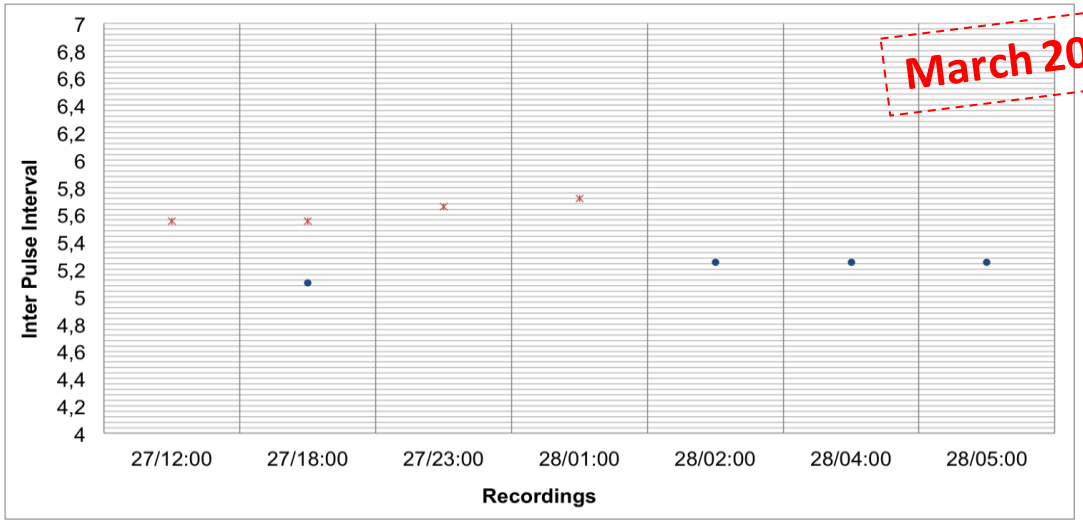
The Sperm Whale

27 March 2013

The 95 percentile is useful to identify the sperm whale clicks.



The Sperm Whales



Identification and measurement of the size of two sperm whales recorded few days after the deployment of the tower.

Sperm Whale	Marker	IPI Mean (ms)	IPI σ (ms)	IPI Variation (ms)	Mean Size (m σ)	Sex
SW1303A	x	5.62	0.08	0.17	12.8 0.1	Adult male
SW1303B	●	5.21	0.06	0.15	12.29 0.09	Adult male

August 2013

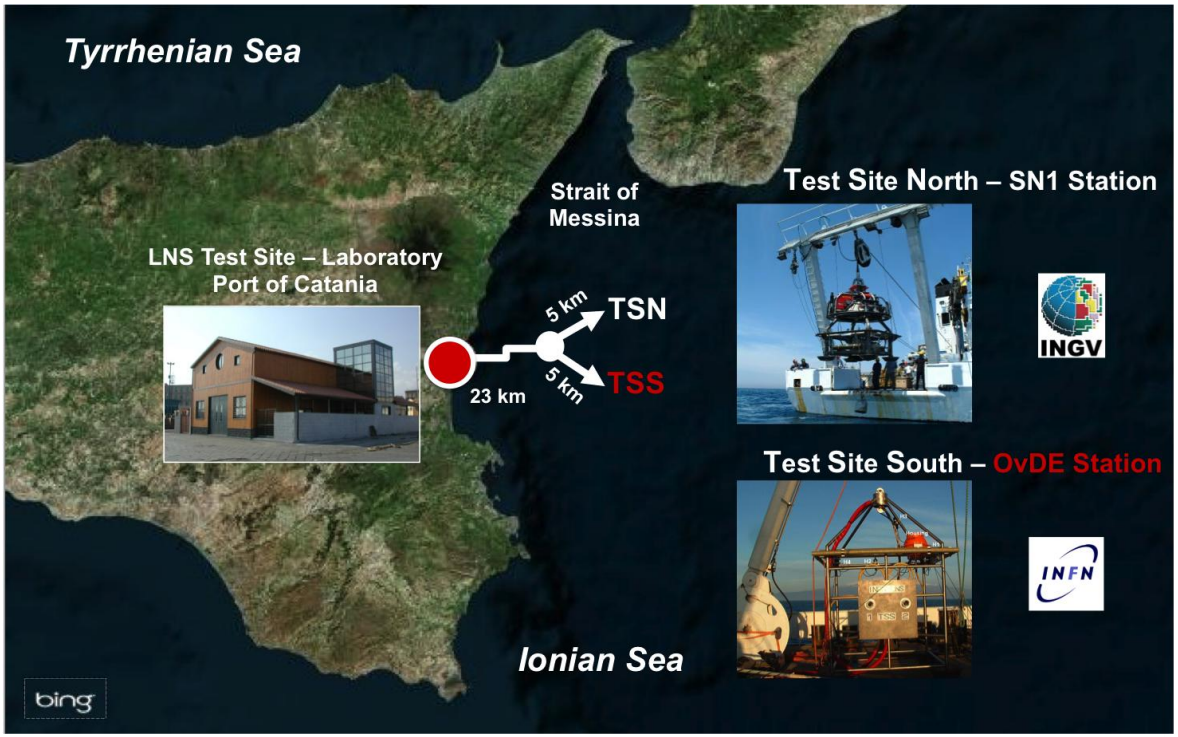
Le Scienze
EDIZIONE ITALIANA DI SCIENTIFIC AMERICAN

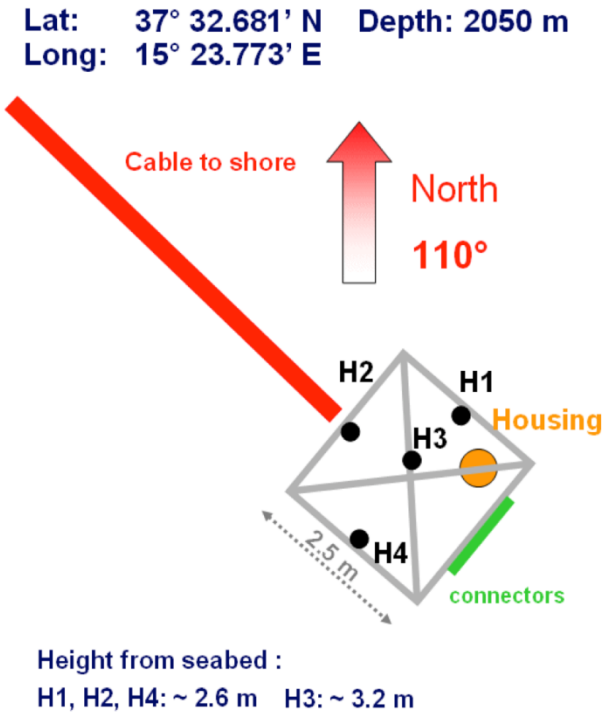
Neutrini e capodogli: le strane rilevazioni di NEMO

la Repubblica.it | Scienze (/scienze)

A caccia di neutrini, scoprono i capodogli le torri sottomarine nel mar Mediterraneo

OnDE Station (2005-2006)





OnDE Data (96 kHz/24 bit) – CIBRA Listening Analysis (5'/hour):

2005 → sperm whales have been detected 117 days out of 231 recorded days (50.6%)

2006 → they have been detected 31 days out of 83 recorded days (37%)

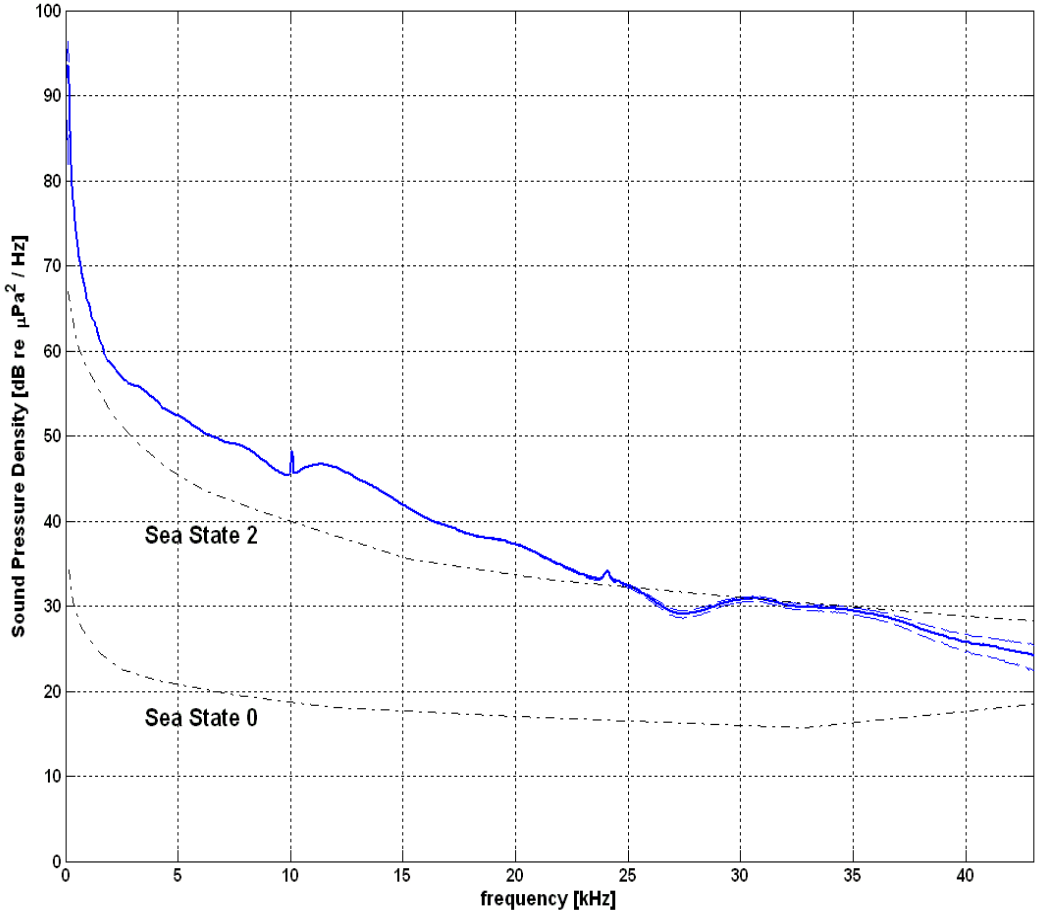
Nosengo N., Pavan G., Riccobene G., Nature 426 (2009)


NEWS FEATURE NATURE|Vol 462|3 December 2009

The neutrino and the whale

OnDE Station (2005-2006)

Study of acoustic background level and its variation as a function of time (due to weather, seismic, biological and anthopogenic sources).



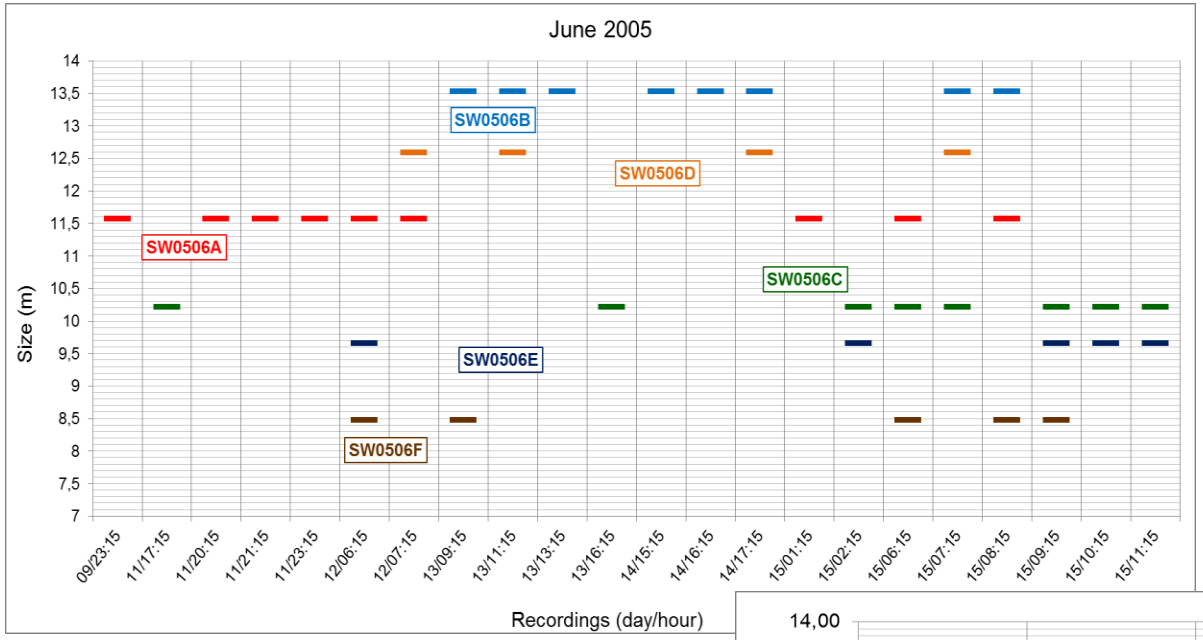
For the first time in the Mediterranean Sea

The average SPD is close to SS2, with increase at low frequency probably due to diffuse anthropogenic noise.

Peaks are due to pingers and shipping instrumentations continuously present in the area.

G. Riccobene et al., NIM-A 604 (2009), S149

Sperm Whale Population Assessment

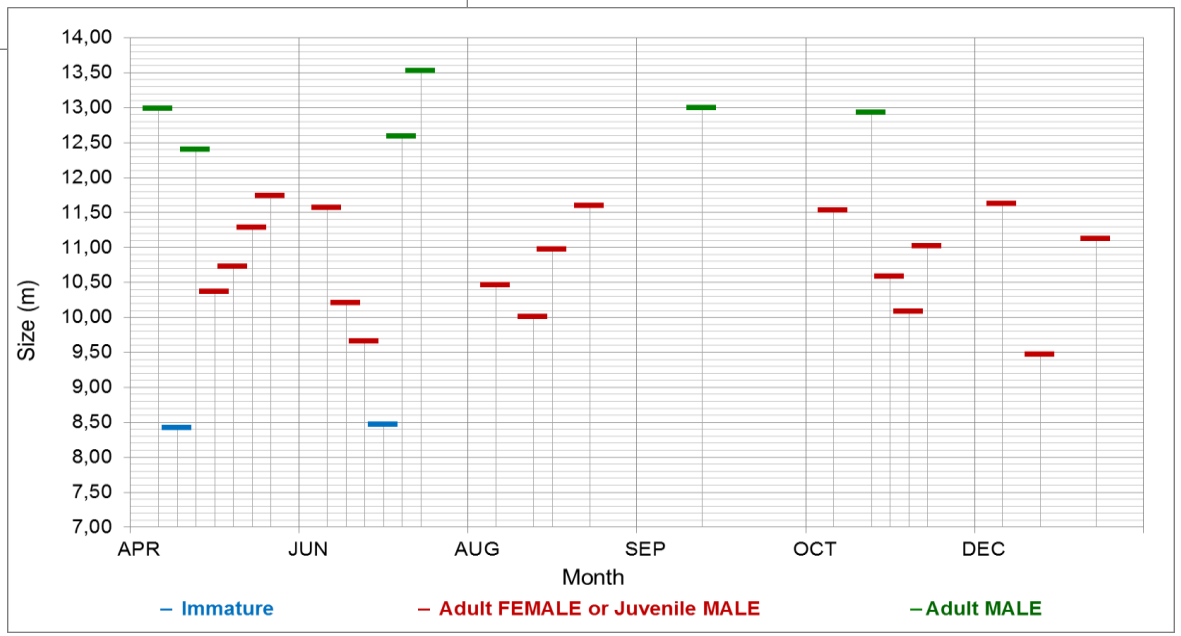


Data Selection – Listening Analysis

Files with HIGH QUALITY clicks:
DURATION
INTENSITY

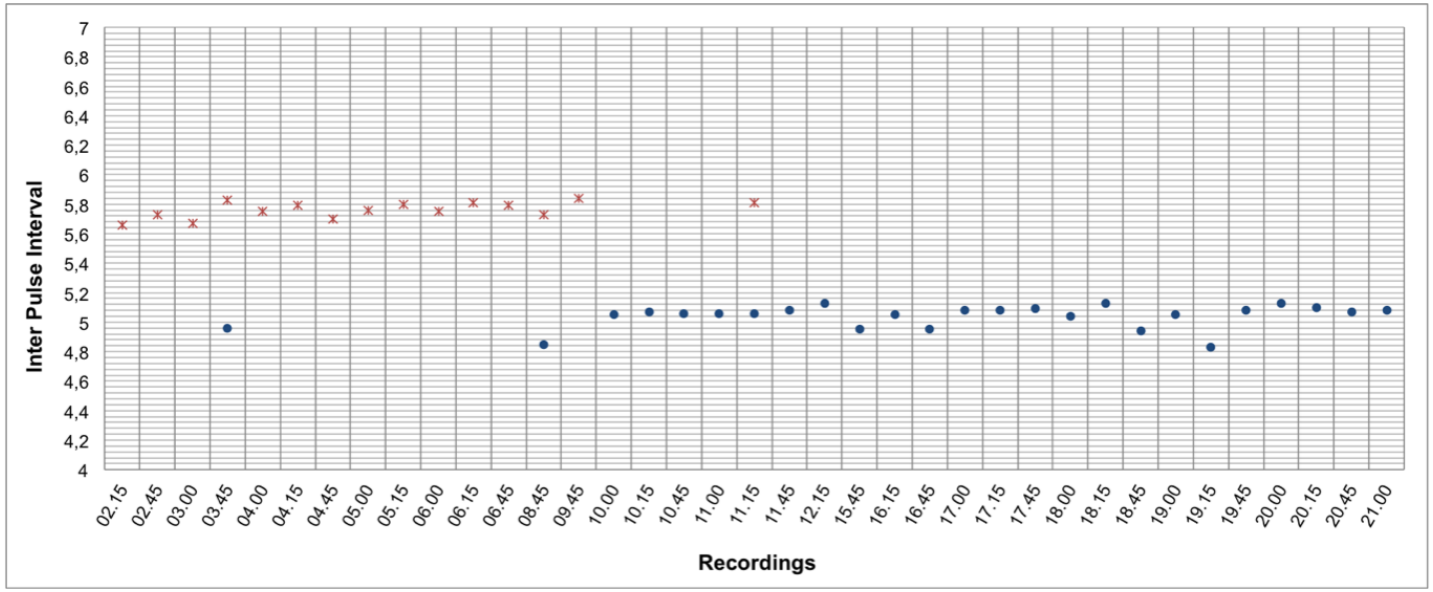
Sperm Whale Population Assessment

Immature: < 9 m
Adult females or Juvenile males: 9 - 12 m
Adult males: >12 m



Semi – automatic acoustic identification

A semi-automatic method allows to identify and to measure the size of the animals recorded through the inter pulse interval (IPI) value . The result in a single day highlight the presence of same animals in consecutive recordings (2006/10/09 - 3files/hour).



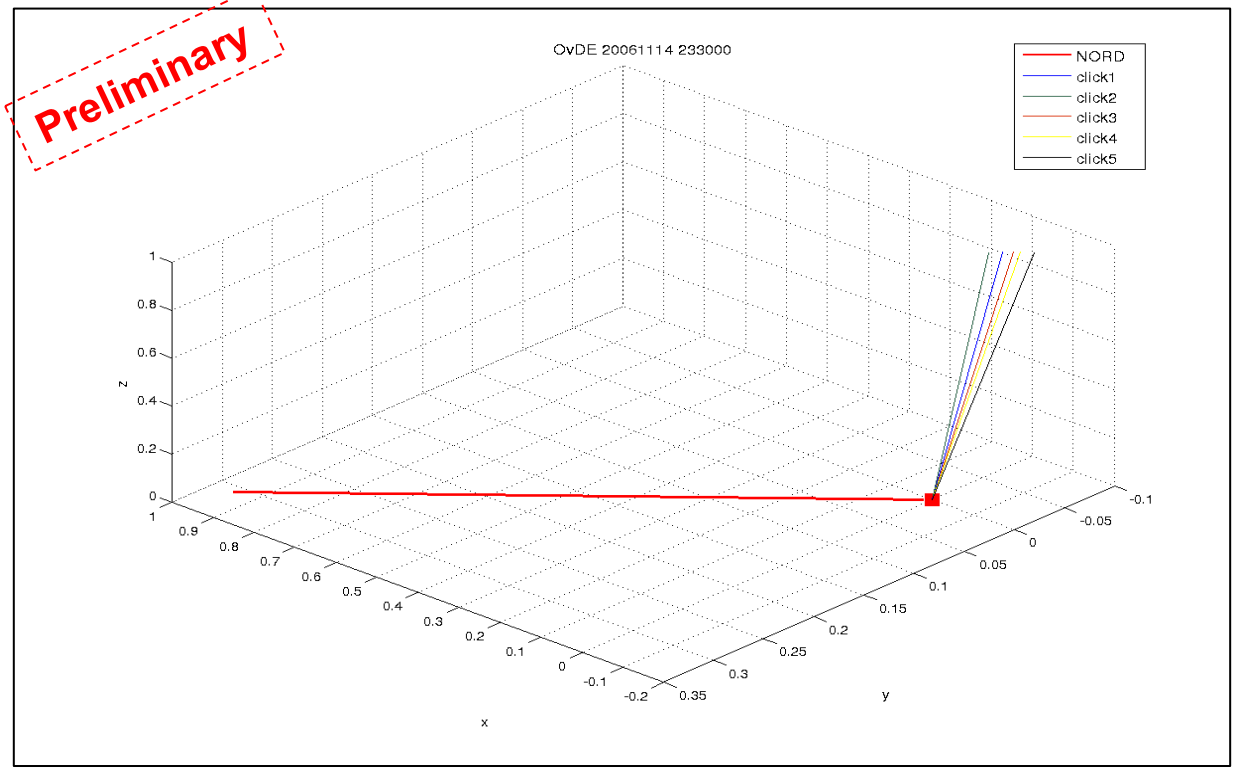
Sperm Whale	Marker	IPI Mean (ms)	IPI σ (ms)	IPI Max (ms)	IPI Min (ms)	IPI Variation (ms)	Mean Size (m±σ)	Sex
SW061009A	x	5.76	0.05	5.84	5.66	0.18	12.98±0.07	Adult male
SW061009B	●	5.03	0.08	5.13	4.83	0.3	12.07±0.1	Adult male

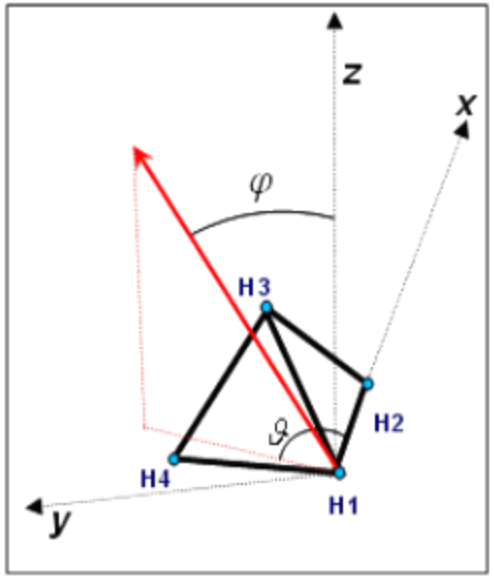
Spatial reconstruction *(TDOA method)*

SOURCE DIRECTION

TDOA (Time Difference Of Arrival) measurement between each pairs of hydrophones, knowing hydrophones position.

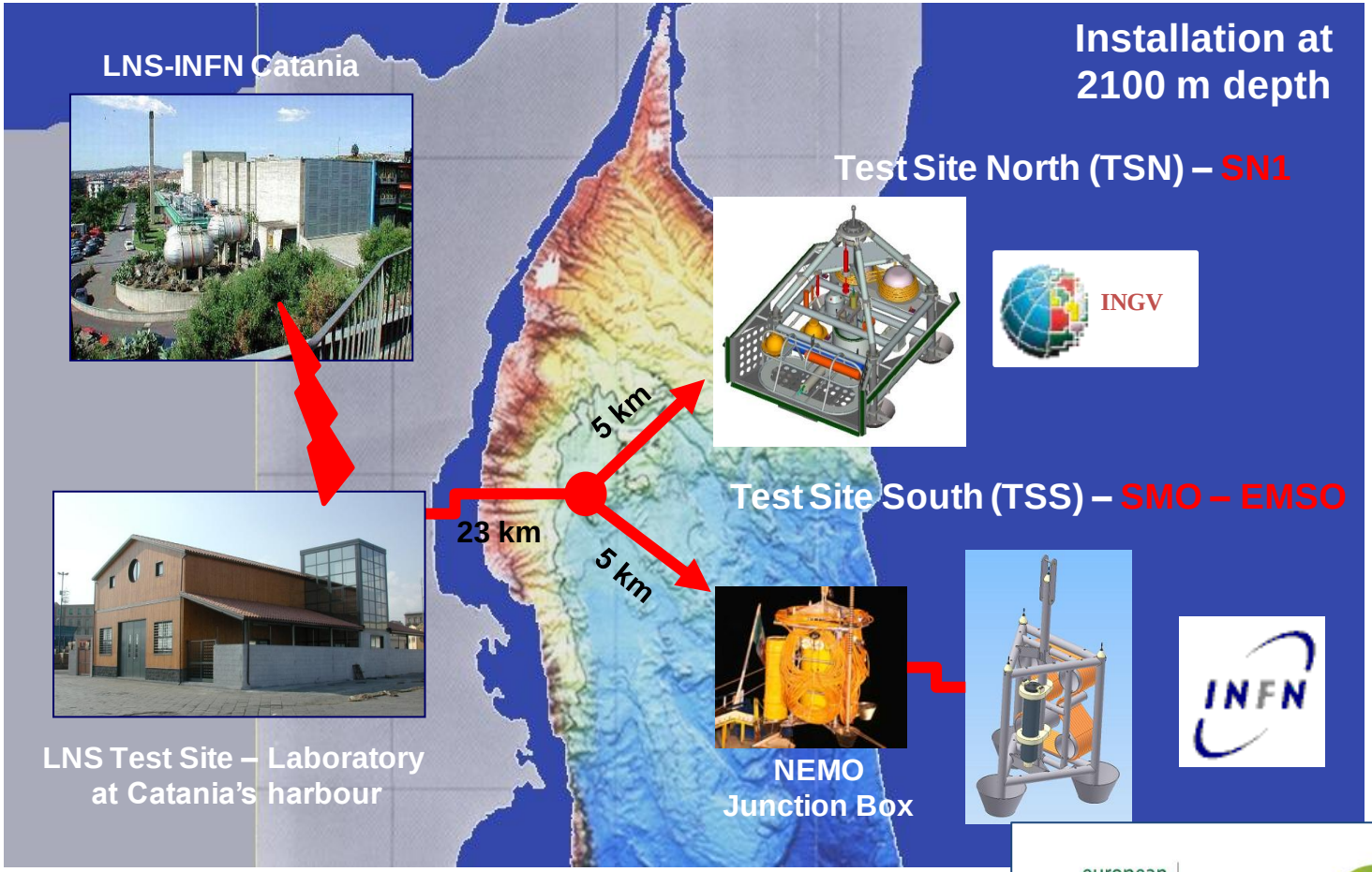
Preliminary





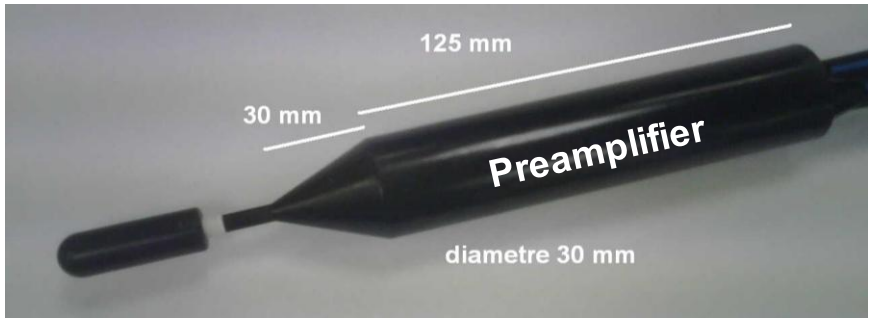
Catania Test Site (2012 – 2013)

June 2012



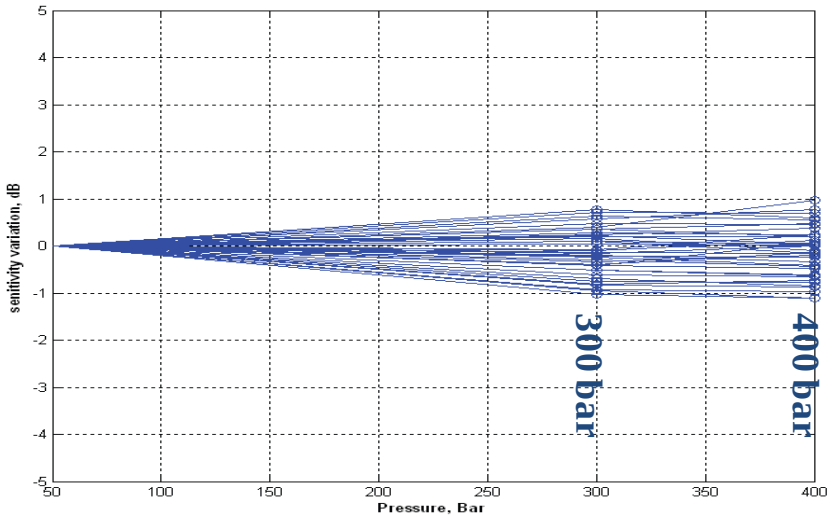
INFN - Wideband Hydrophones

Bandwidth: 10 Hz – 70 kHz
Sensibility: - 169 3 dB re 1 V/µPa
Preamplifier: 38 dB "low self noise"



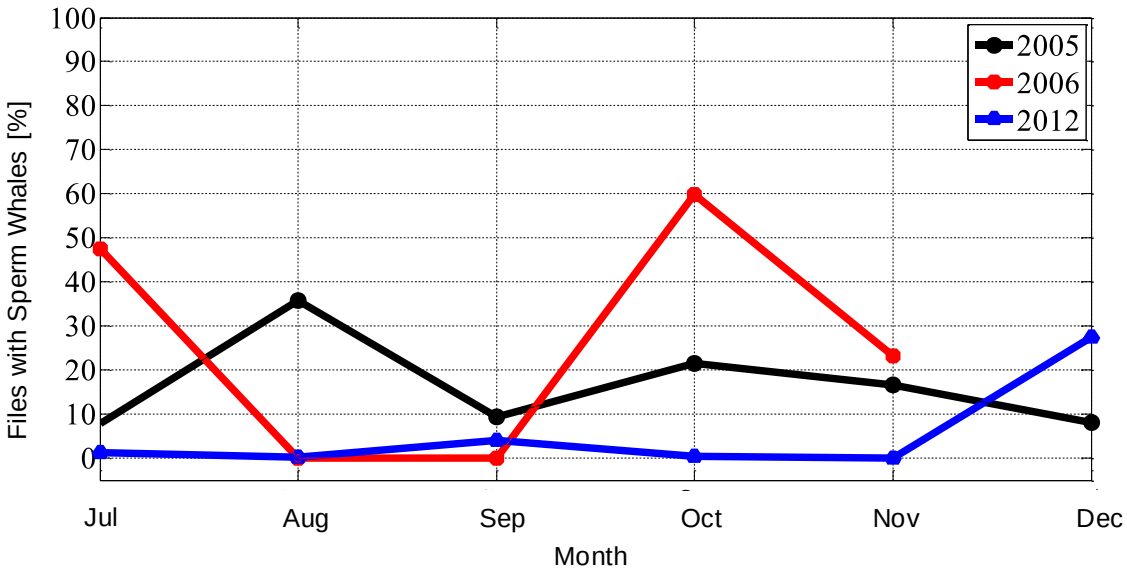
Sampling frequency:
SN1 → 96 kHz
SMO – EMSO → 192 kHz

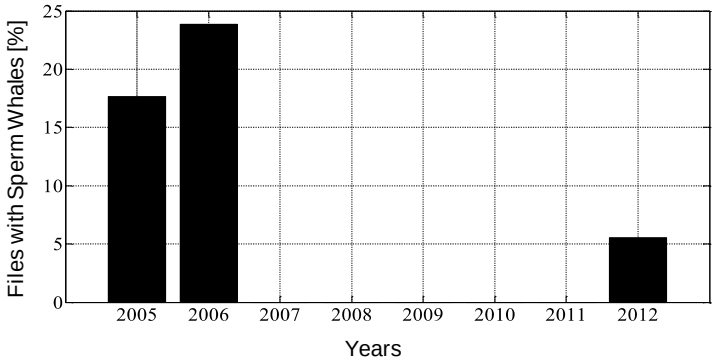
Relative hydrophone sensibility variation with hydrostatic pressure (NURC – La Spezia)



Measured variation ≤ 2 dB

SN1 – Listening Analysis 5 min/h (2005 – 2006 – 2012)



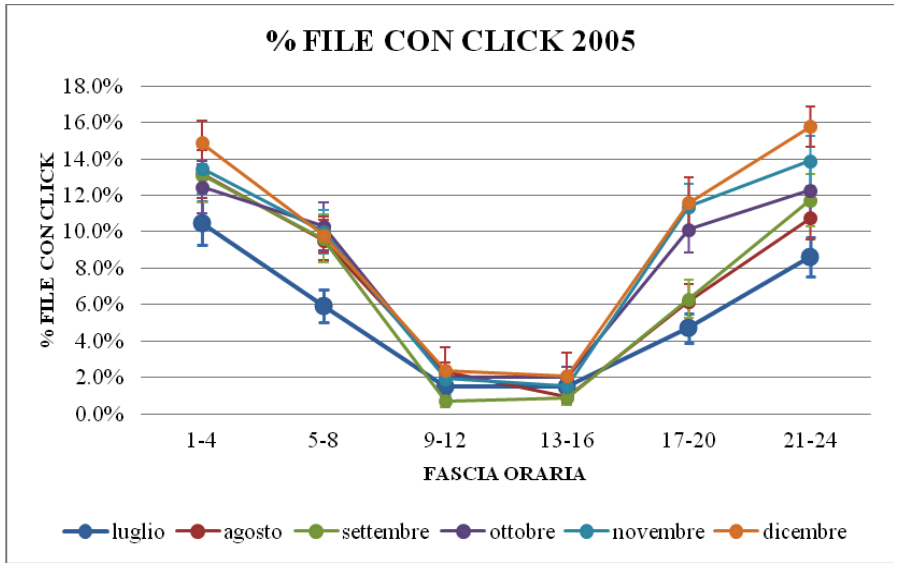


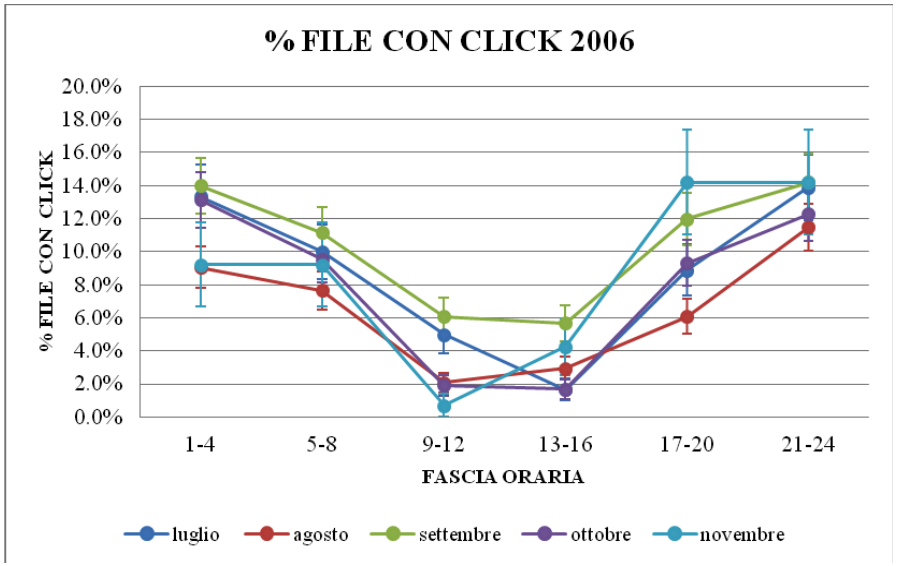
The deep-sea observatories of INFN and INGV (EMSO) facilitate a long term monitoring of the sperm whale in the Ionian Sea.

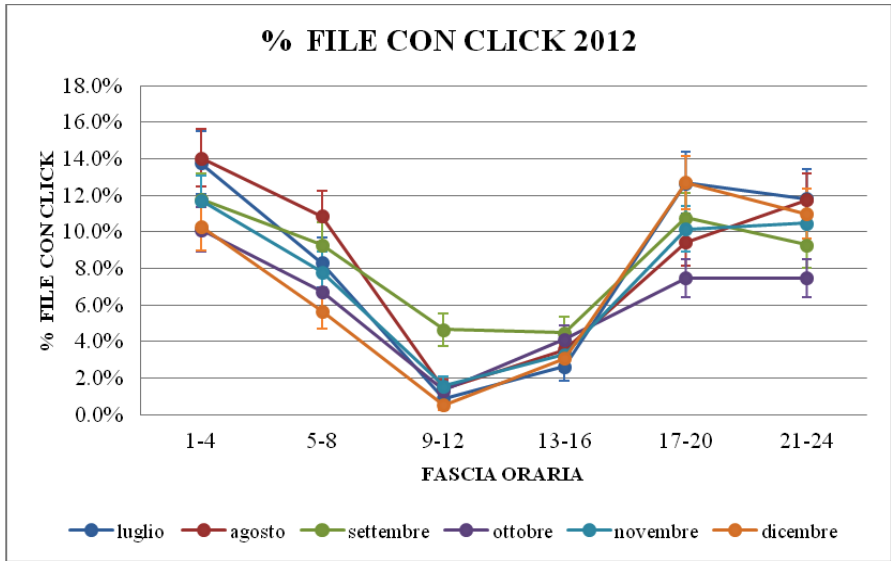
Thus, INFN and INGV support the European Project LIFE + CABIRIA 2013 (CApodogli, BIodiversità e RIschi Ambientali)

UNIVERSITÀ DEGLI STUDI DI TORINO
UNIVERSITÀ di CATANIA
Università degli Studi di Messina
Università degli Studi di Pavia
Consiglio Nazionale delle Ricerche
ENEA ENTE PER LE NUOVE TECNOLOGIE, L'ENERGIA E L'AMBIENTE

SN1 – Listening Analysis 5 min/h (2005 – 2006 – 2012)







Listening Analysis (5min/h): from July to December

Striped dolphin

Stenella coeruleoalba

Delphinus delphis

Common dolphin

Automatic Analysis???

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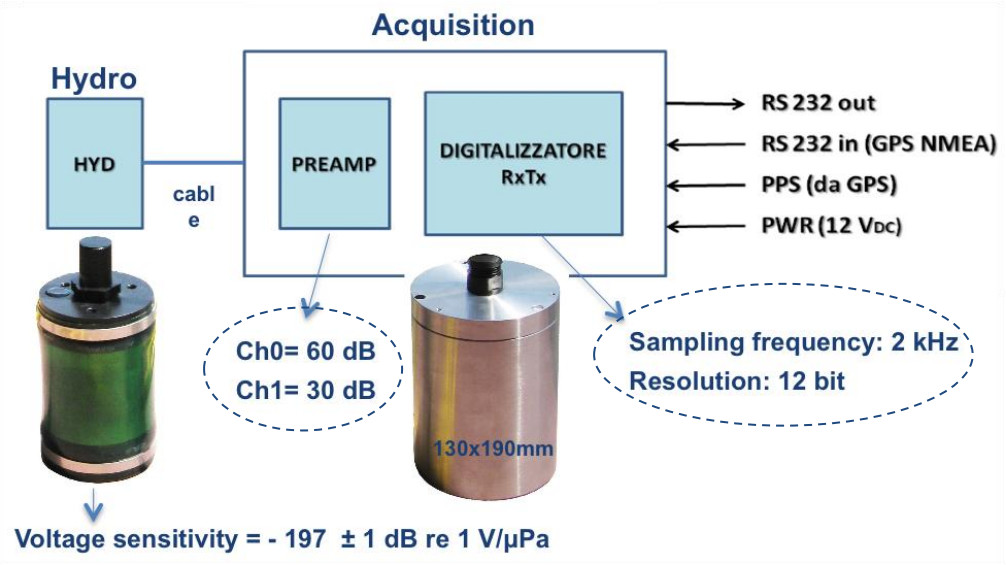
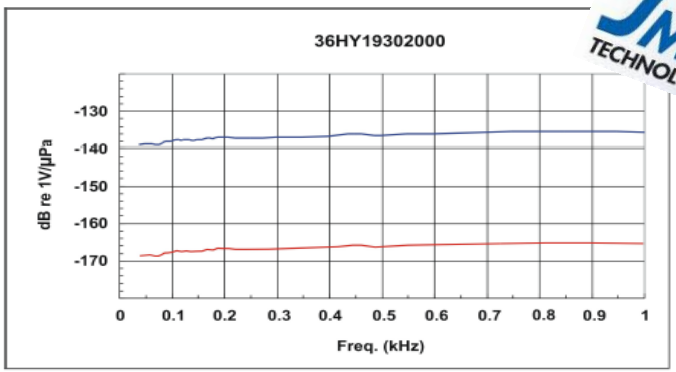
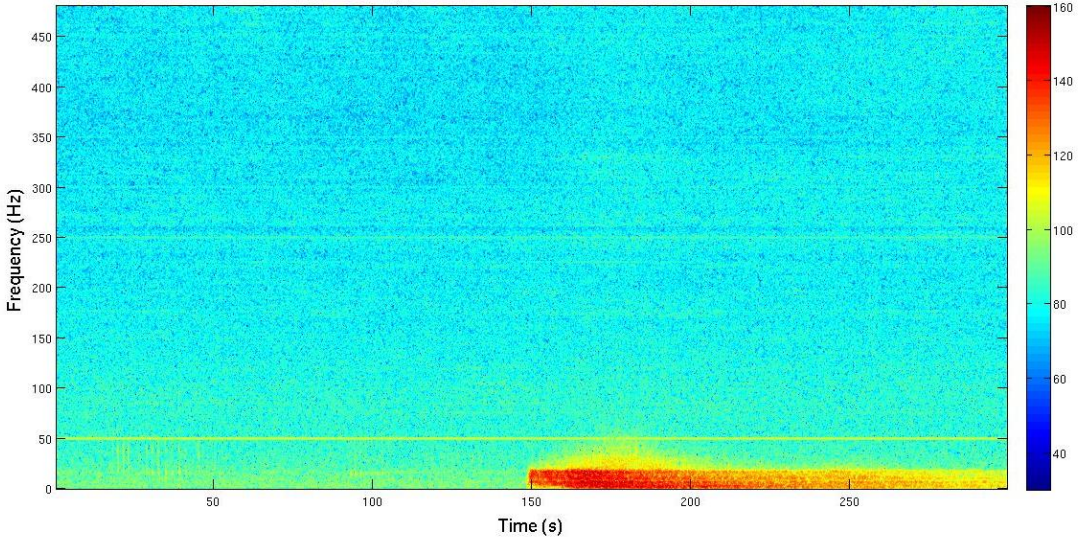
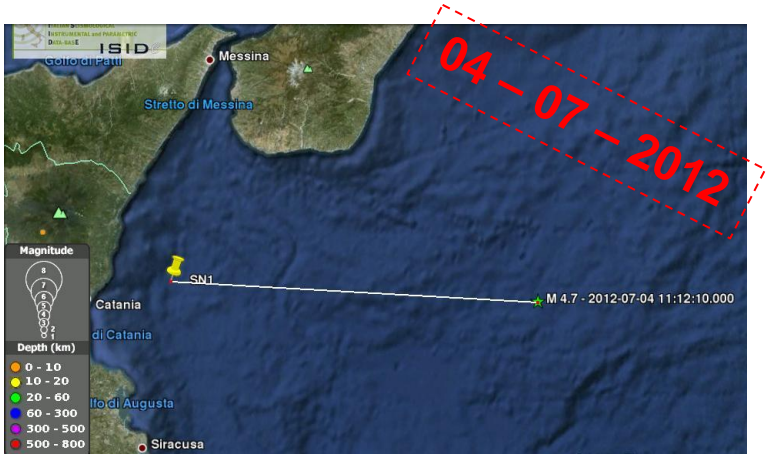
SN1 - INGV - Digital Seismic Hydrophone





High Gain Channel	+ 60 dB
Low Gain Channel	+ 30 dB

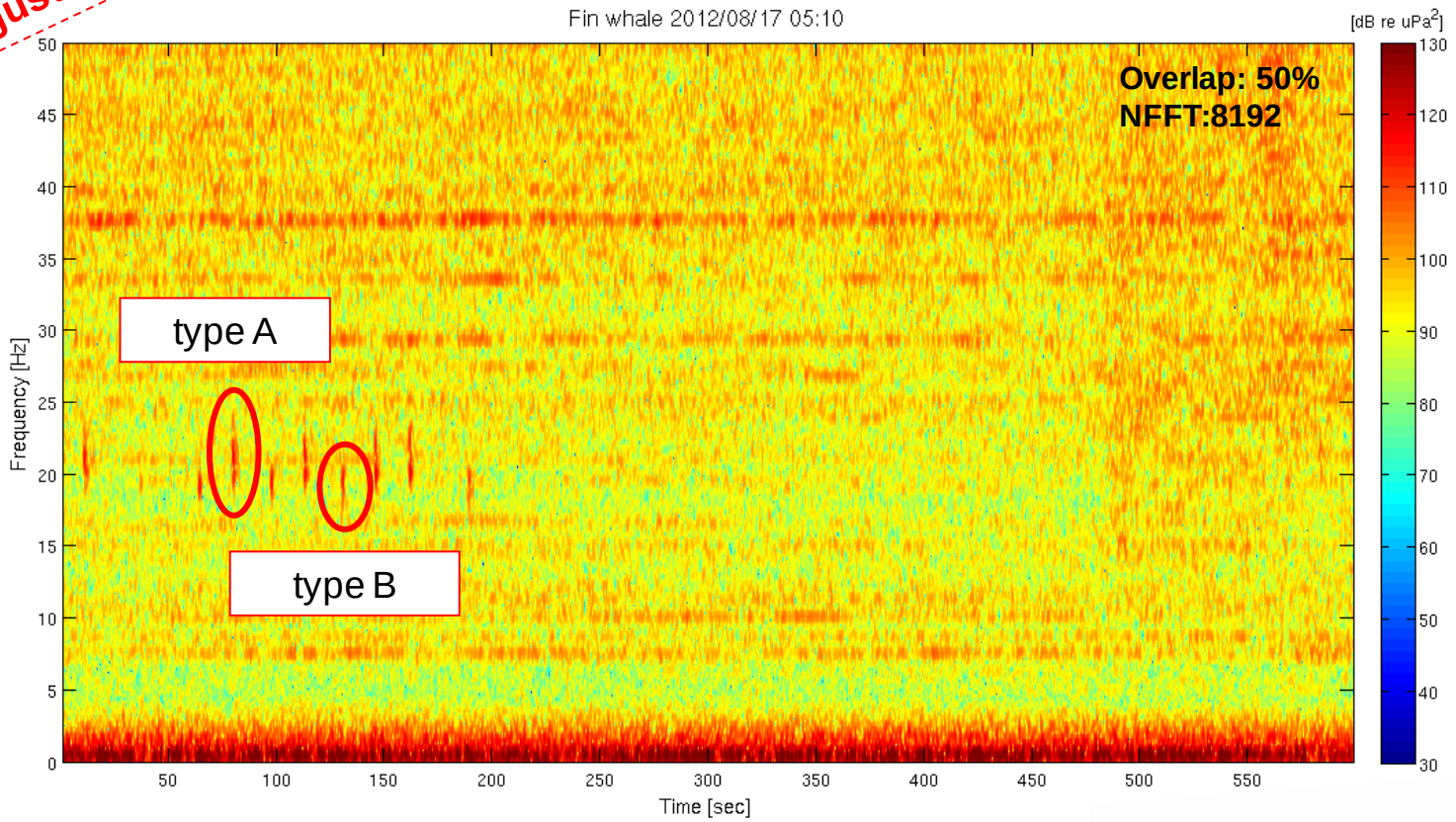




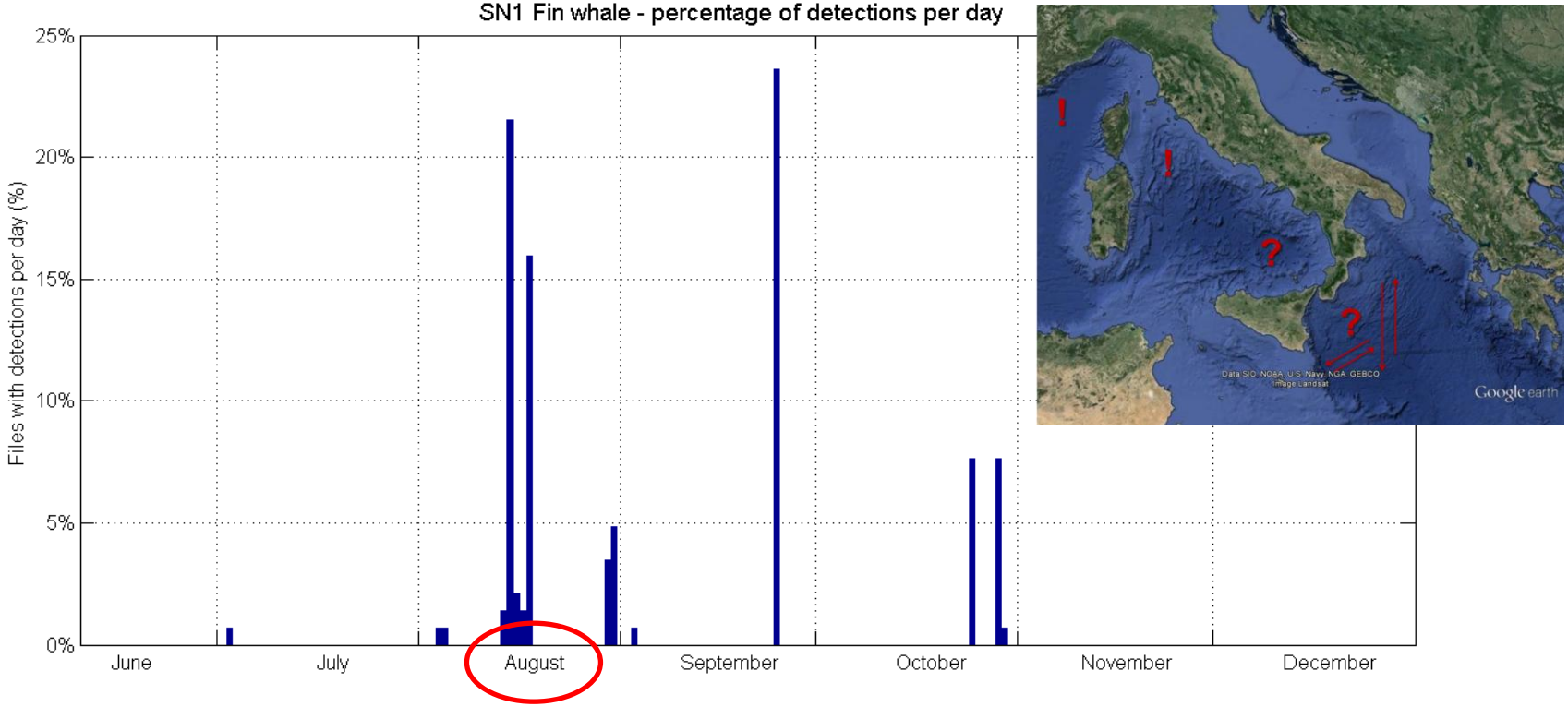
Fin Whale (< 50 Hz)

What we found? Sequences of the typical 20 Hz fin whale pulses of type A and type B

17 August 2012



Fin Whale Acoustic Detection



Analyzed Time Period : 9th of June - 31st of December 2012 (~ 7 months for 24h/24h)

Analyzed Files : 29.520

Files with Fin Whale Calls: 127

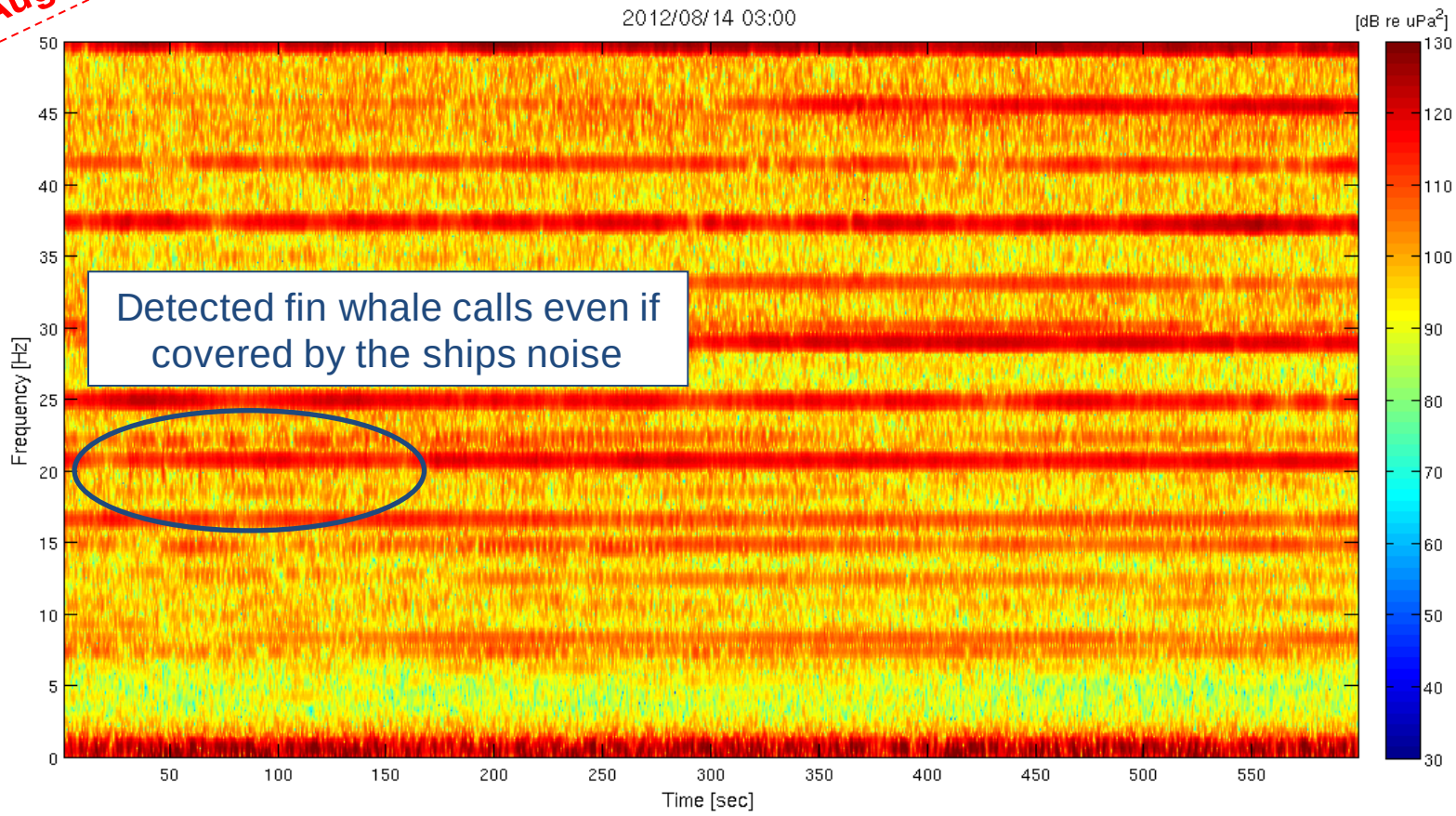
V. Sciacca et al., for the SMO-NEMO, KM3NeT Italia and SN1 Teams. **"Acoustic detection of fin whales vocalizations offshore Eastern Sicily, Ionian sea"**

Erice International School of Ethology, Erice (Sicily – Italy), 18 – 21 October 2013

Fin Whale and Ships Noise

Recordings with high noise level in the 20 Hz band due to ship traffic

14 August 2012

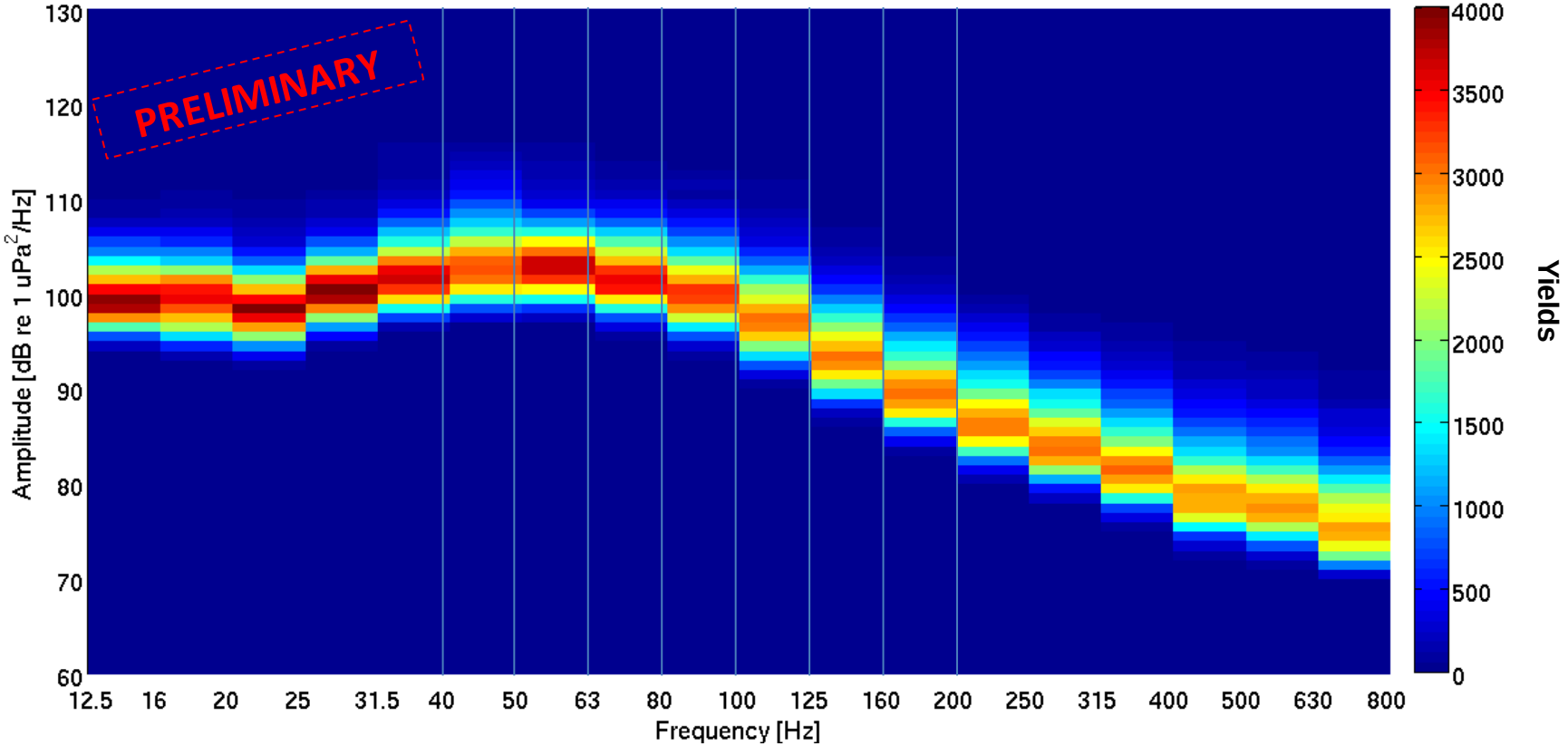


SN1 – Environmental Noise – Statistical analysis in 1/3 octave bands

Analysed data set: 2012/09 – 2013/02

Continuous recordings divided in files of 10 minutes (26050 Recordings).

Average power spectral density (Nfft =2^14) calculated for each file - 1/3 octave bands.



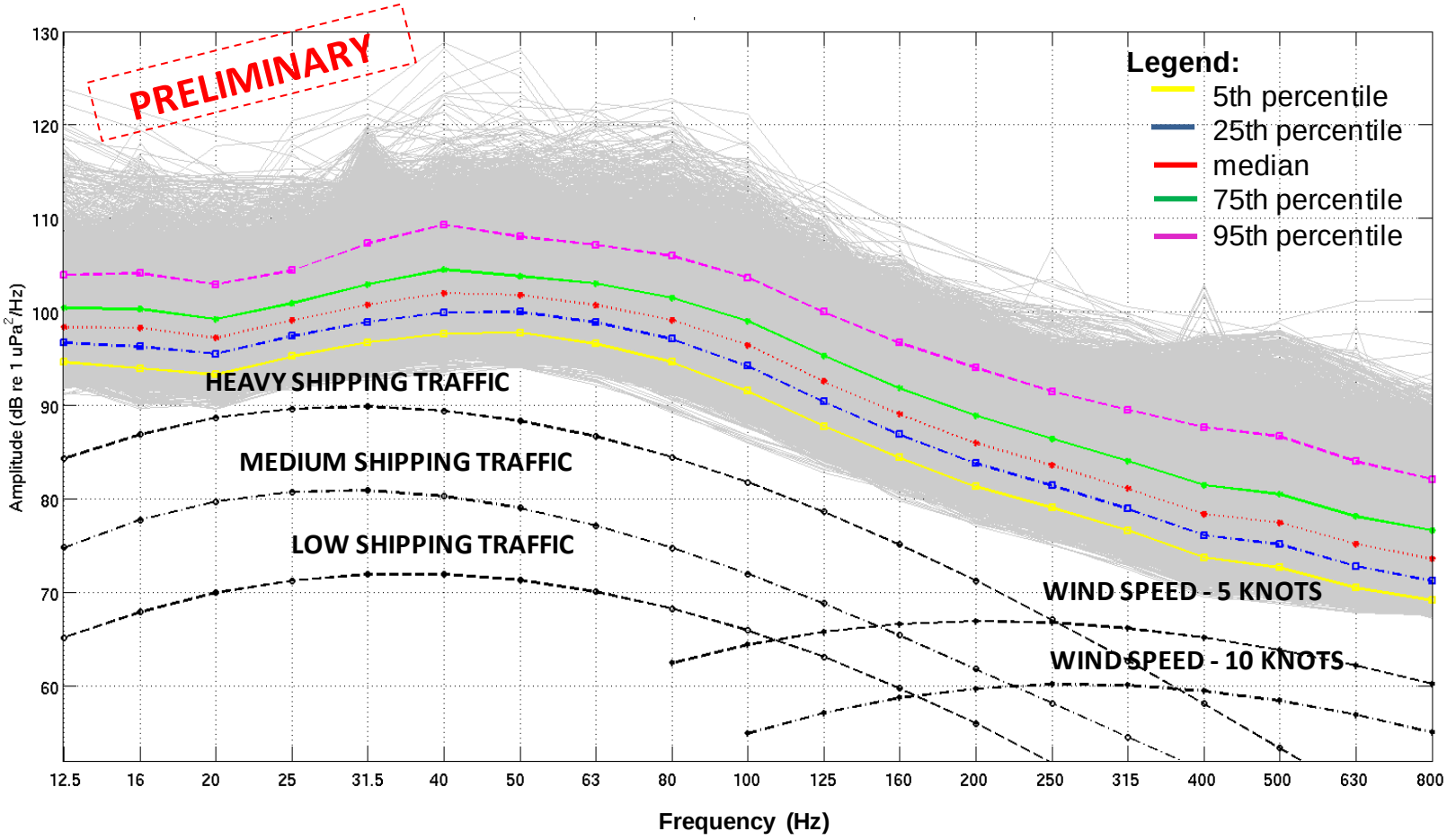
S. Pulvirenti et al., for the SMO-NEMO, KM3NeT Italia and SN1 Teams. **Correlation between underwater noise level and AIS data in the Gulf of Catania (Sicily).**

Erice International School of Ethology, Erice (Sicily – Italy), 18 – 21 October 2013

SN1 – Environmental Noise – Statistical analysis in 1/3 octave bands

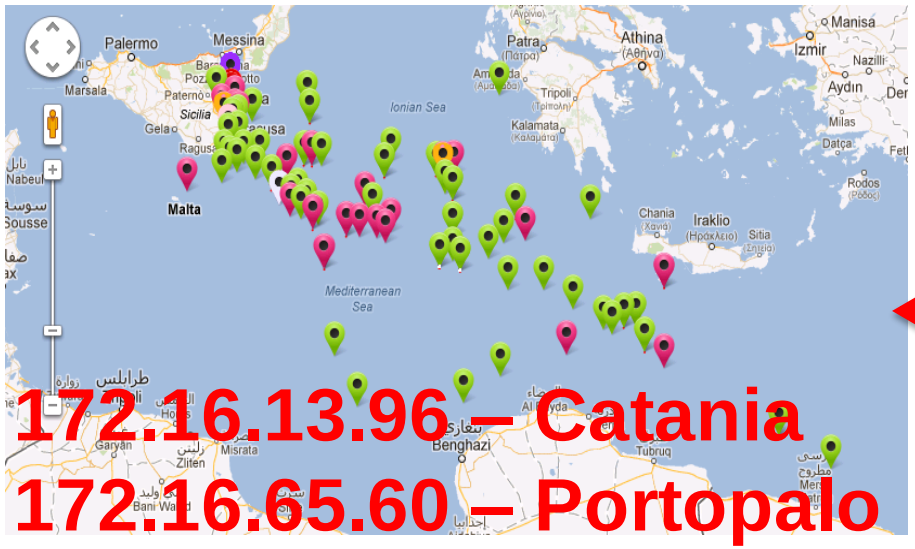
Comparing our dataset to the literature…SN1 measurements have been compared with the Wenz curves (ships and wind noise).

(Knudsen et al., 1948; *Wenz*, 1962; reviewed in. *Urik*, 1983)

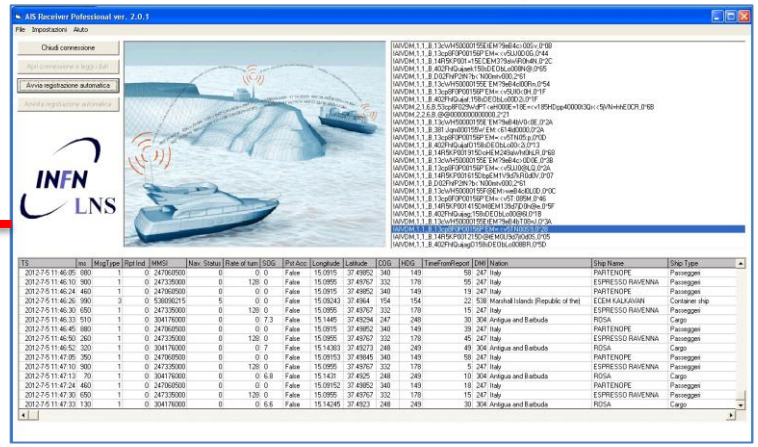


AIS data acquisition at LNS laboratory

AIS Receiver



Google Map



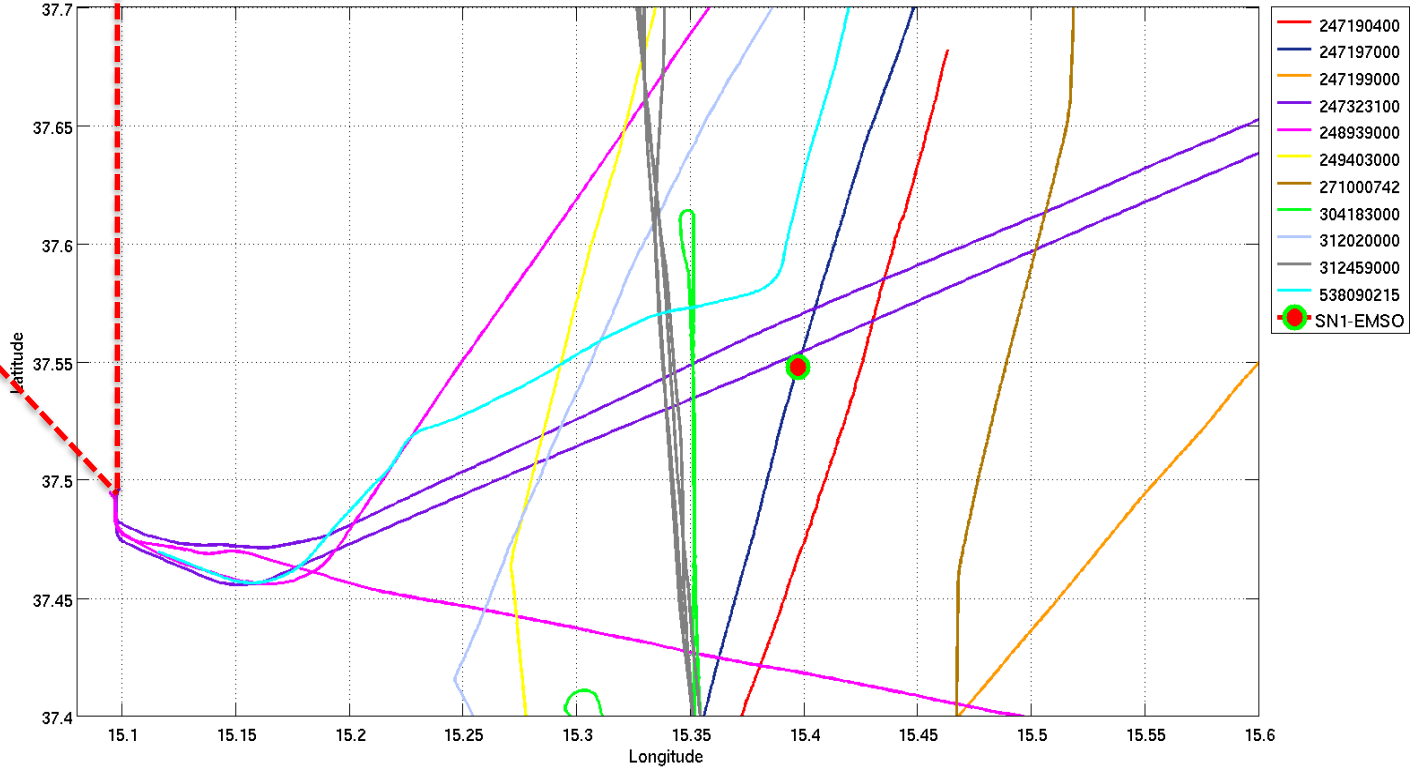
AIS Software

AIS statistical analysis

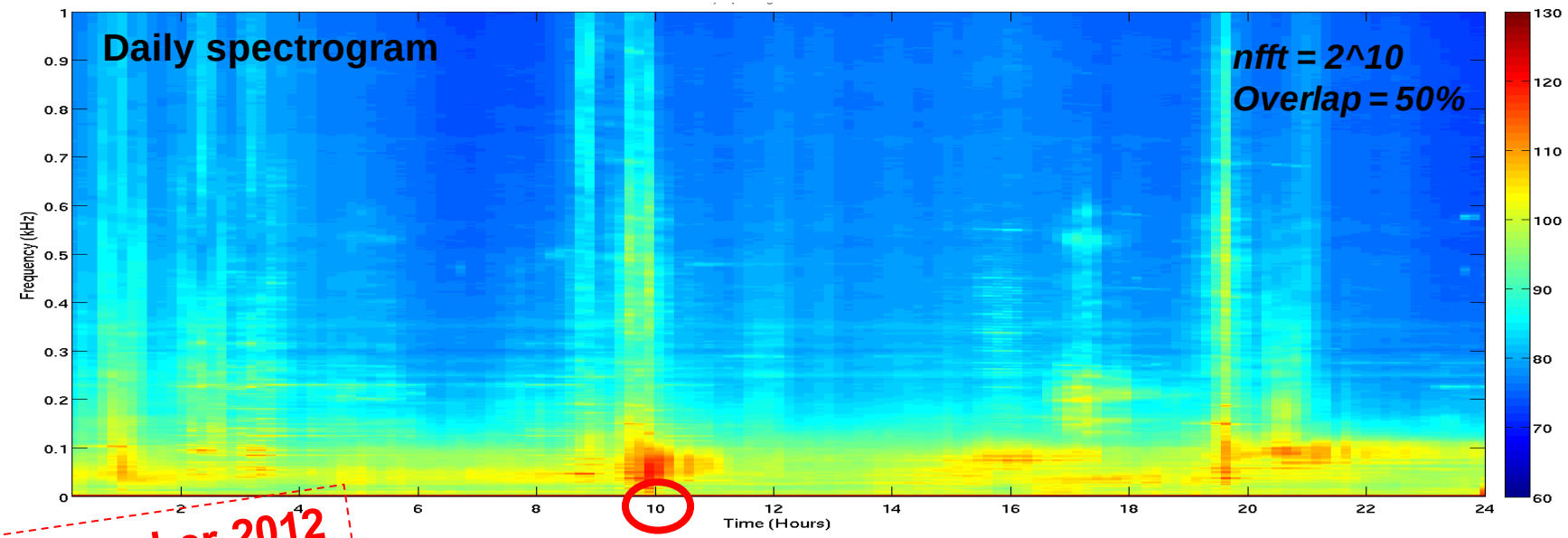
Example of daily tracks within 18 km SN1-EMSO coordinates (using MATLAB scripts).

29 November 2012

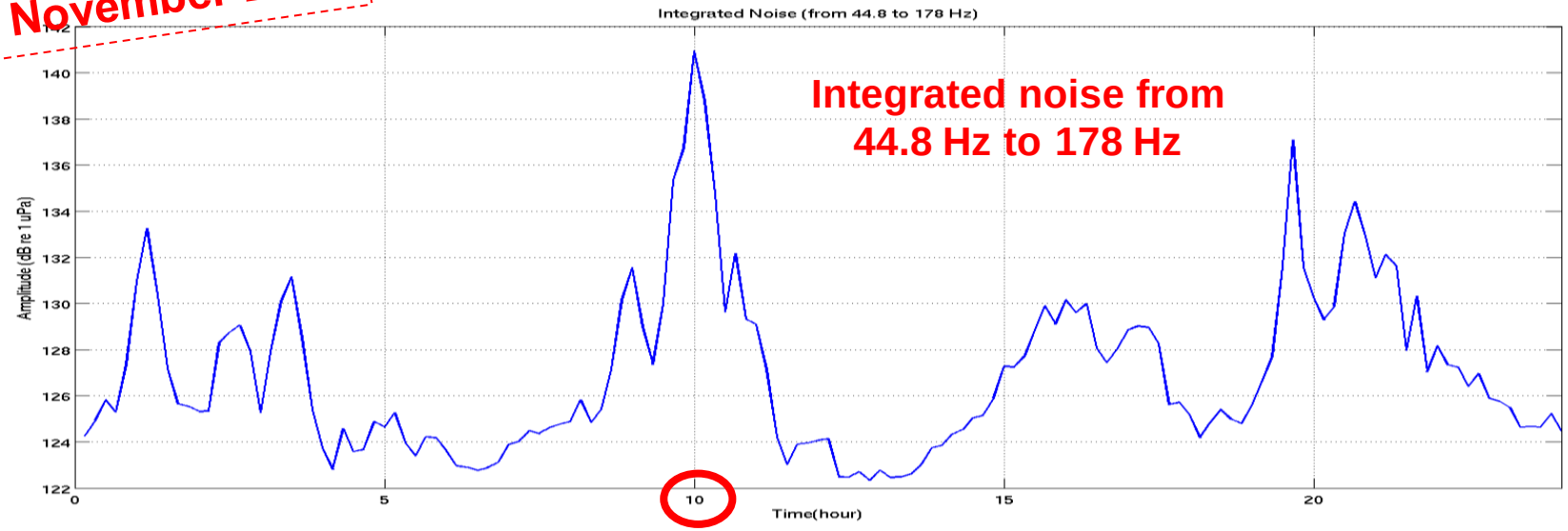
PORT OF CATANIA



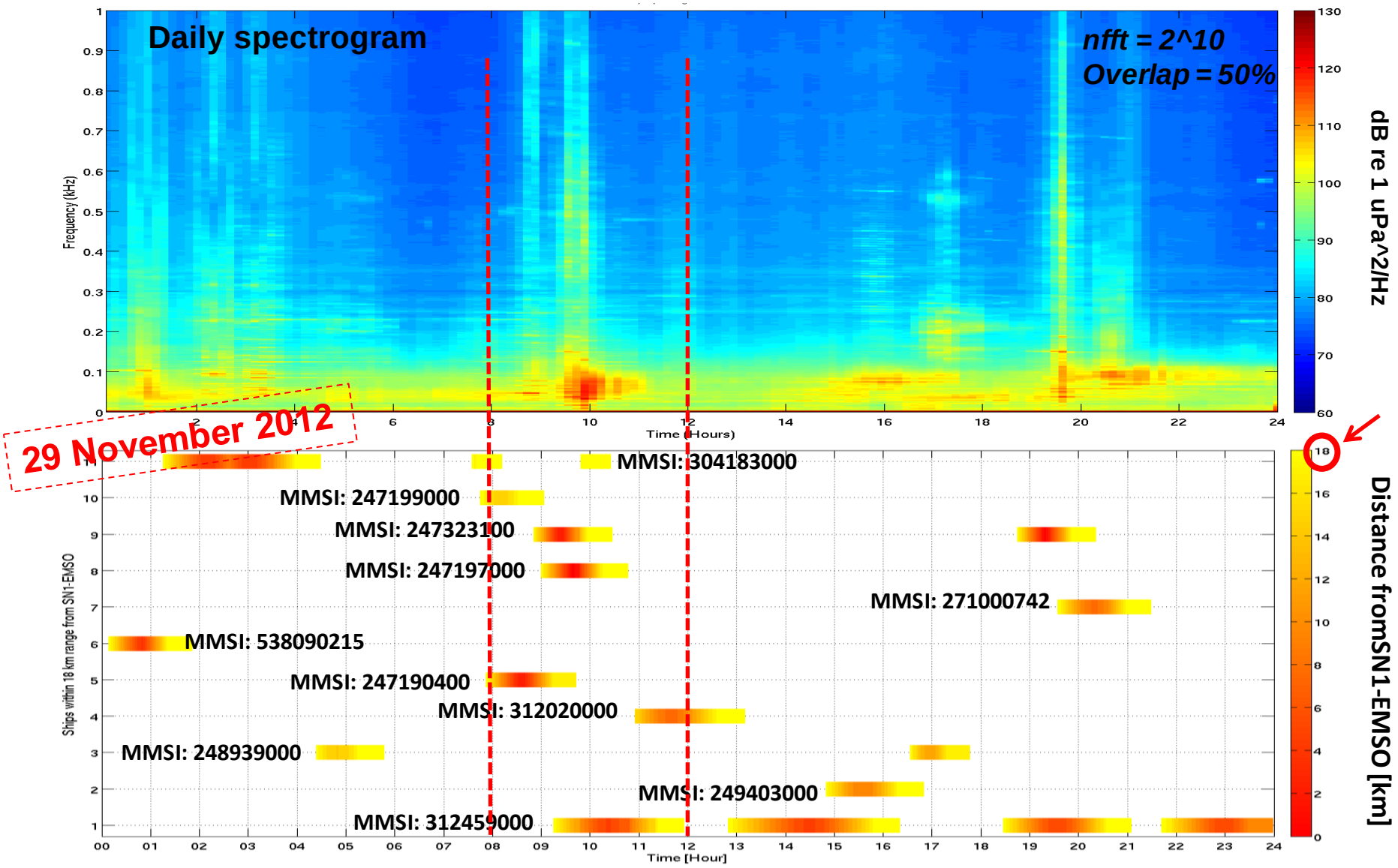
AIS data correlation with acoustic data



29 November 2012

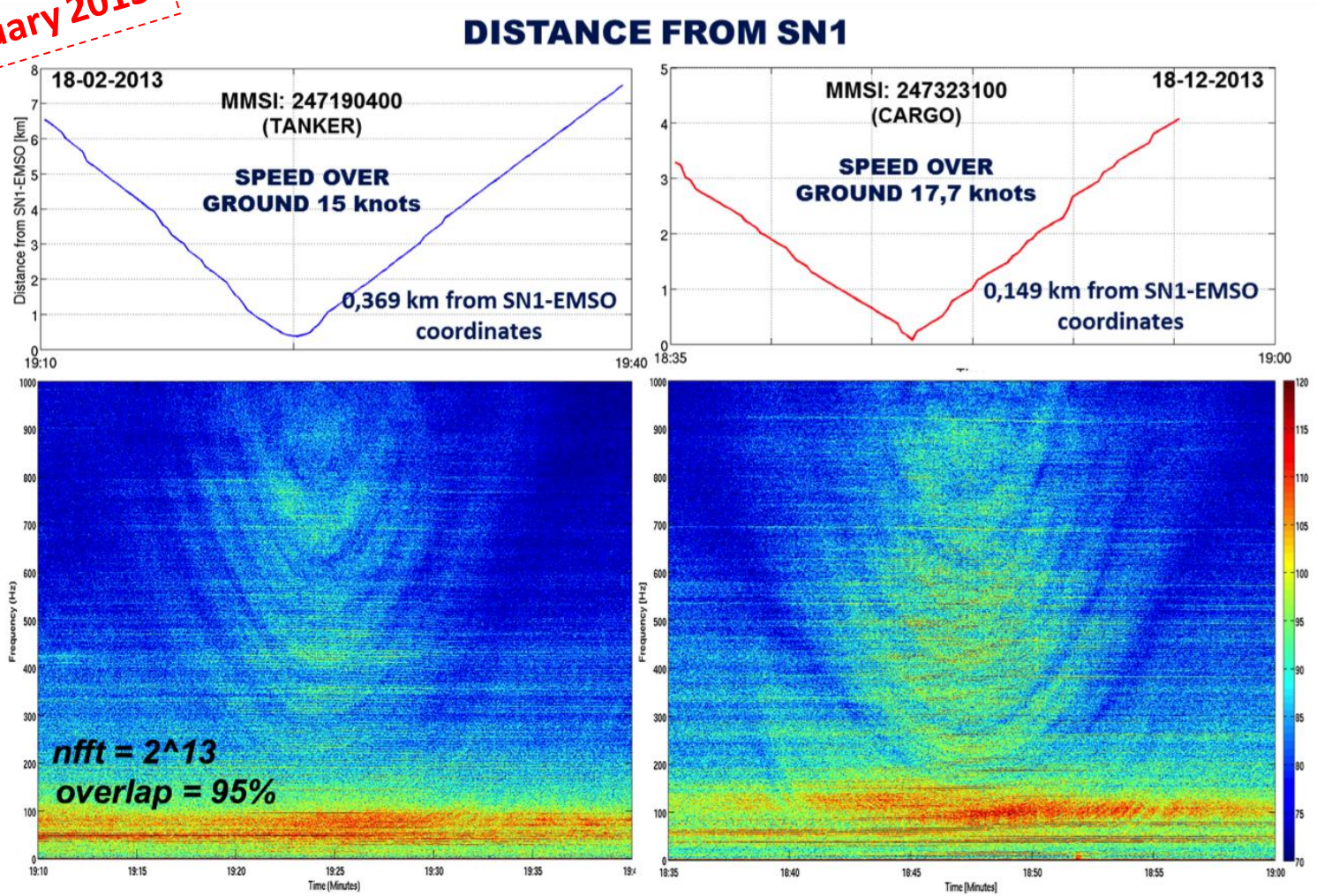


AIS data correlation with acoustic data



Acoustic signatures of the different vessel types

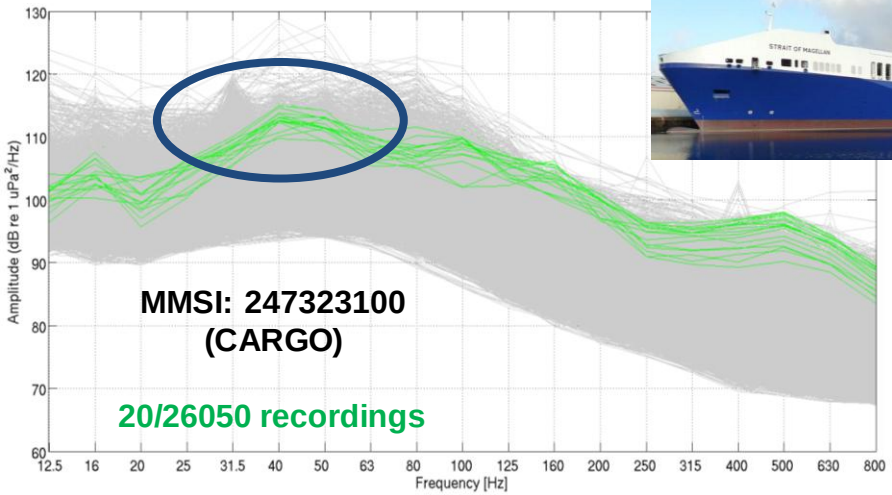
18 February 2013

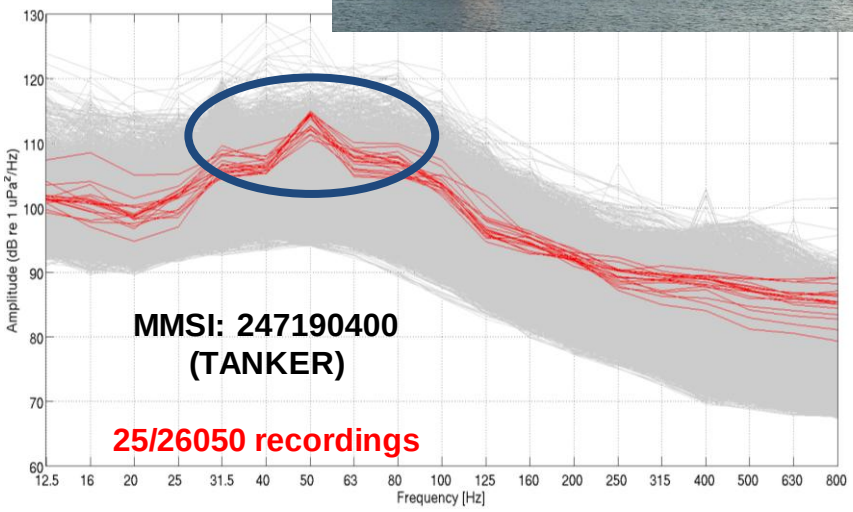


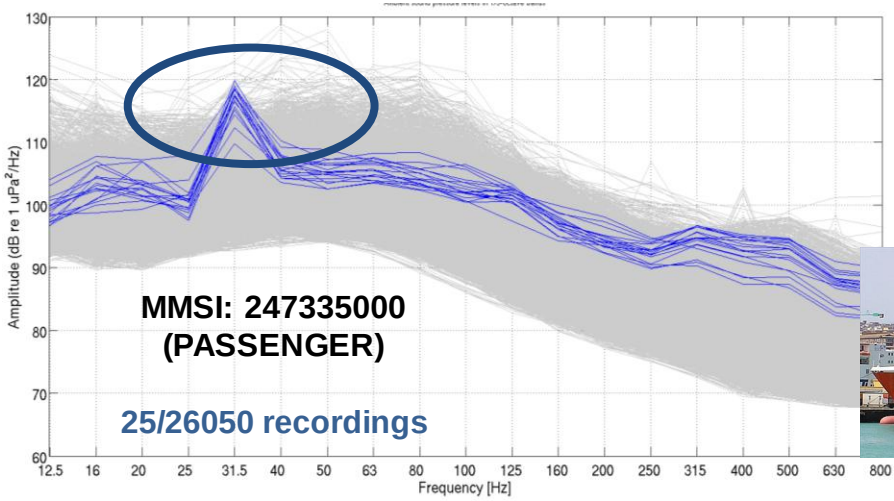
Example of half an hour of ship passage within 1 km from SN1 station.
Spectra from different vessel have been studied.

Acoustic signatures of the different vessel types

PSD of acoustic noise produced from different vessels. The grey area represents the noise curves recorded for the whole analysis period. The colour lines → the ships were within a range of 2 km from SN1 station.







Conclusions

- **ENVIRONMETAL UNDERWATER NOISE**

These results show that SMO acoustic antenna has optimal performances in terms of frequency and time resolution. The SMO project facilitate a real-time and long term monitoring of the underwater acoustic noise.

- **EUROPEAN MARINE STRATEGY (ACOUSTIC POLLUTION)**

In the European Marine Strategy, the value of 100 dB re 1uPa2/Hz, for the low frequency bands indicated, is a threshold for acoustic risk pollution, mainly due to shipping noise. The SMO data analysed shows that this value is often exceeded.

- **ACOUSTIC NOISE – AIS DATA (SHIP TRAFFIC)**

This approach allows to distinguish the acoustic contribute which every single vessel gives to underwater noise. We can correlate the ship distance from the station with the relative acoustic impact; we can identify the signatures of the different vessel types and, knowing the AIS data, we can hypothesize the ship noise related.

- **THE SPERM WHALE**

A new automatic algorithm is available to identify the sperm whale clicks and to measure their size. This tool works in real-time (few seconds for 5 min recording), but the processing of the clicks analysis in run time with the acoustic data acquisition will allow us to collect more information about the sperm whale population in a strategic ecological area of the Mediterranean Sea.

- **THE FIN WHALE**

In the Ionian Sea the fin whale presence is scarcely documented. Nevertheless, analyzing the acoustic data acquired from the stations located in the Catania Test Site, we found a clear presence of the specie in the area.

- **THE DOLPHINS**

In the Ionian Sea several information about the ecological dynamics of the dolphin specie present are unknown.

This work has been developed at the INFN-LNS also by:
Bellia G., De Luca V., Grasso R., Inserra P., La Rosa G., Pavan G., Pellegrino C., Pulvirenti S., Riccobene G., Rocca C., Scandura D., Sciacca V., Simeone F., Viola S.