

Global passive acoustic monitoring of the oceans with MERMAID Argo floats

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Sigloch

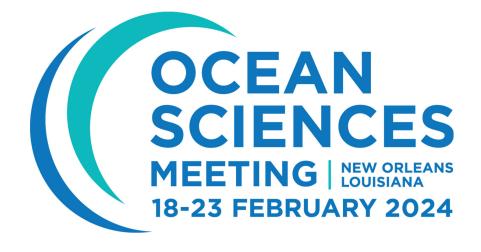
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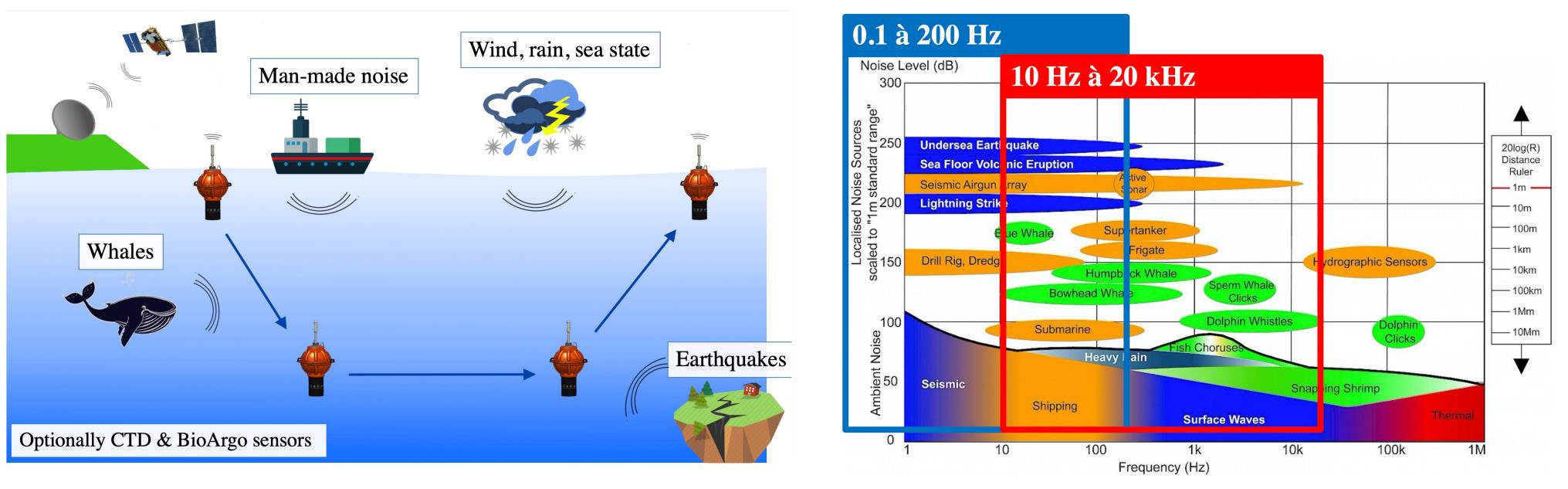
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OT24G-1580

MERMAID-MULTI

The MERMAID [1] is an autonomous seismometer floating at a depth of 2000 meters in the oceans. It rises to the surface every week to transmit data. We are developing a multidisciplinary version for passive acoustic monitoring from 0.1 Hz to 20 kHz, separated into 2 acquisition channels.



A typical MERMAID cycle (left) and monitored acoustic frequency bands (right)

Applications development

Acoustic data must be processed/compressed on board before being transmitted in near real time by satellite. A dedicated programming language (MeLa) aware of energy and processing power limits is used to develop algorithms without requiring embedded software expertise [2]. Several applications can be programmed over the air even after instrument deployment.

Project	simplefft.mela	
Apps	1 Mission:	
	2 ParkTime: 7 days	
	3 ParkDepth: 1500 meters	
melaOverlapApp.rtf	4	
Simple.mela	5 Coordinator:	
	6 ParkAcqModes: helloFFT during 10 minutes every 1 hour	
	7	
	8 ContinuousAcqMode helloFFT:	
	9 Input:	
	10 sensor: HydrophoneLF(20)	
	11 data: x(1024)	
	12 overlap: 256	
	13	
	14 Variables:	
	15 ArrayInt spectrum(1024)	
	16 Int mean 17 File f(TRANSMIT)	
	<pre>17 File f(TRANSMIT) 18</pre>	
	19 RealTimeSequence main:	
	20 spectrum = $fft(x, 1024, HANNING)$	
	<pre>20 speecrum = hre(x) 102 h, hadding) 21 mean = mean(spectrum)</pre>	
	22 if mean > 1000:	
	23 <i>@probability</i> 1 per day	
	24 f.record(spectrum)	
	25 endif	
	26 endseq	
	27 endmode	

Example of a MeLa application in the Pulsar editor with energy and satellite transmission estimation on the right panel

References:

[1] Hello Y, Nolet G (2020) Floating Seismographs (MERMAIDS). Encyclopedia of Solid Earth Geophysics. Springer [2] Bonnieux S, Cazau D, Mosser S, Blay-Fornarino M, Hello Y, Nolet G (2020). MeLa: A Programming Language for a New Multidisciplinary Oceanographic Float. Sensors. [3] Sukhovich A, Irisson J-O, Simons F J, Ogé A, Hello Y, Deschamps A, Nolet G (2011). Automatic discrimination of underwater acoustic signals generated by teleseismic P-waves: A probabilistic approach. Geophysical Research Letters. [4] Reinicke I (2023) An acoustic detection and classification algorithm for rainfall measured on the oceans by autonomous underwater floats. University of Duisburg-Essen master thesis

[5] EarthScope-Oceans website: http://earthscopeoceans.org

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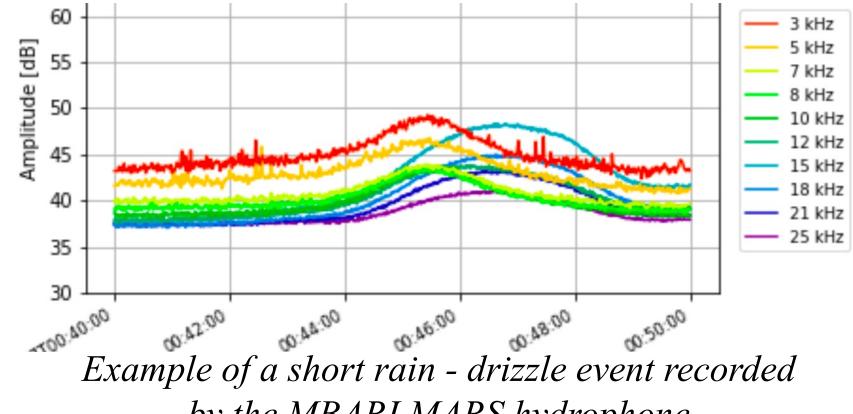
MeLa tools Success 9.2 cycles 4 years ergy consumption rate Transmission Sensors (%) Actuators (%) Processor (%) **Mission step** (%) 2.7 0.7 Descent 22.5 2.7 Surface 0.1 Success tellite transmission: kB/cycle 7.2 kB/month 4 euros/mont LF UTF-8 MeLa 🌎 GitHub - Git (0) 🌣

Application examples

<u>App 1:</u> -1×10^{5} THE FLORE

<u>App 3</u>: Continuous recording at a sampling frequency of 80 Hz to be compatible with apps 1 and 2 operating at 40 and 80 Hz respectively.

<u>App 4</u>: Sound pressure level is recorded at several frequency bands to monitor rain and anthropogenic noise pollution [4].



Toward a global network

Records of seismic waves traveling through the earth's mantle are used to compute the earth tomographic image. More than 50 floats have been deployed by the Earthscope-Oceans organization since 2016 [5].

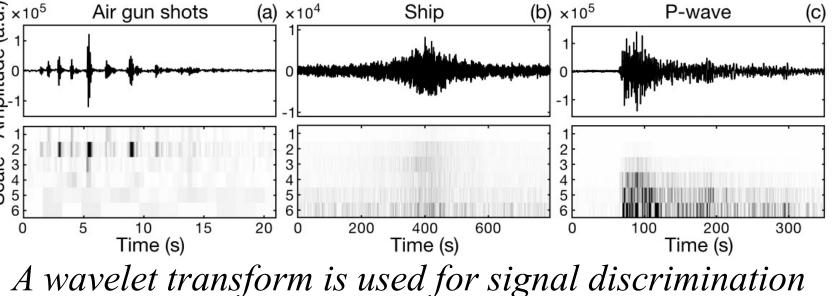
Lander and moored versions

The float can be configured to settle down to the ocean floor with a small anchor, preventing drifting on the ocean floor. This operating mode has been thought for local seismic crisis monitoring.

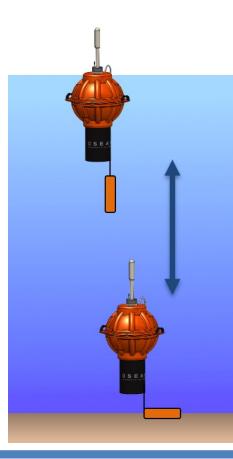
Contacts:



Detection of seismic waves with the default MERMAID algorithm [3].

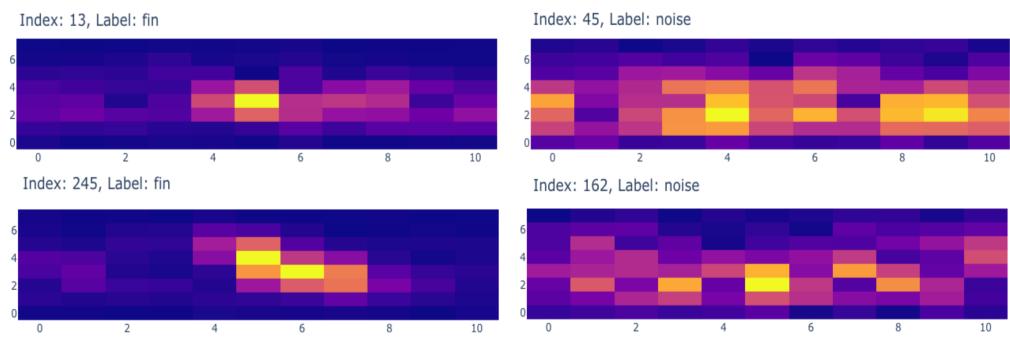


by the MBARI MARS hydrophone



<u>App 2</u>:

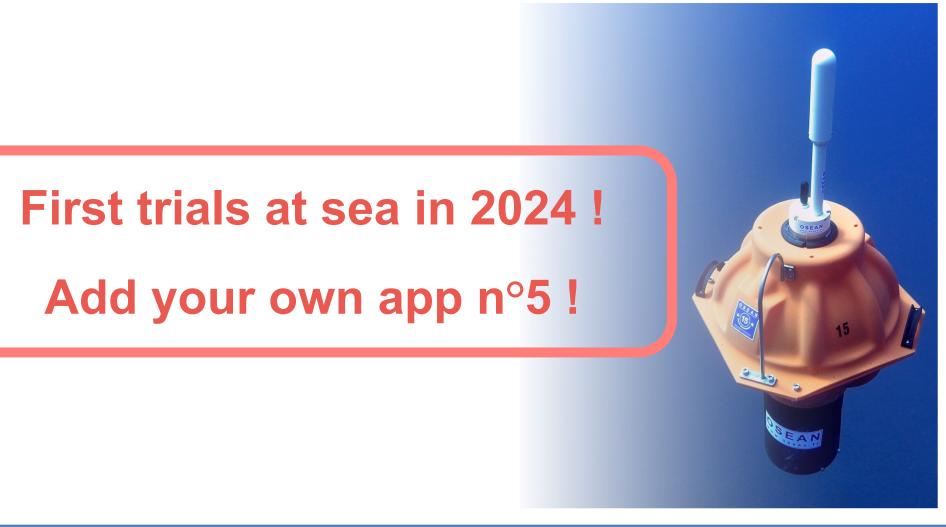
Detection of fin whales calls using a Dense Neural Network (DNN) trained on the Watkins Marine Mammal Sound Database.



The DNN is made of two layers of 10 and 5 neurons and trained with TensorFlow Lite. Precision is 99 % i.e., 1 detection over 100 is not a fin whale call Recall is 96 % i.e., 4 fin whales calls over 100 are not detected

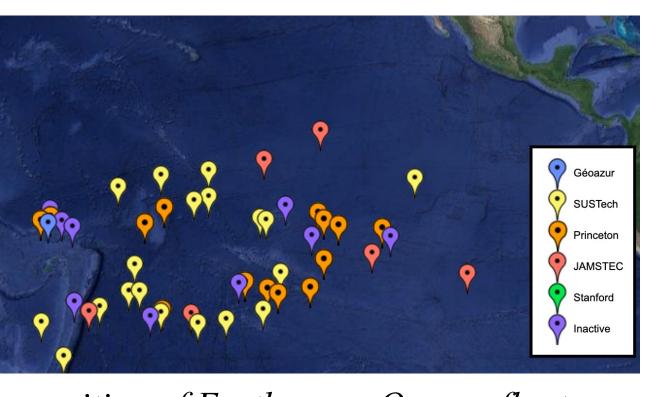
Resource usage:

The MeLa language estimates the autonomy at 6 years, with an average processor utilization rate of 3 %, and 600 kB of data transmitted by satellite each month.



The float can be fixed on a subsurface mooring to avoid any drift. This is useful for coastal operation, but deployment requires more resources.





Maps of the last known position of Earthscope-Oceans floats

