AMBIENT NOISE MONITORING FOR THE ASSESSMENT OF THE ECOLOGICAL STATUS OF MARINE ENVIRONMENTS

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EMSO TIME SERIES CONFERENCE OBSERVING OCEAN SOUND
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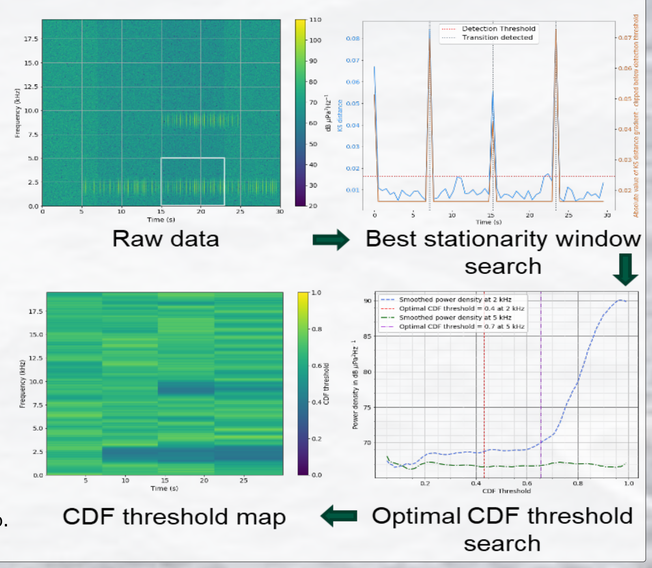
PCRA METHOD - PRIOR NOISE ESTIMATE WITH ADAPTATIVE PERCENTILE

- **Best stationarity window** search using a 2-sample KS test
- Sample **division in stationary segment** (KS statistics)
- Finding the **optimal CDF threshold p on each segment and for each frequency bin**
- Production of **CDF threshold map**
- Production of **prior noise** $\lambda_{N,p}(f)$ **estimate** from adaptative percentile $q_p(f)$

$$\lambda_{N,p}(f) = -\frac{q_p(f)}{\ln(1-p)} \quad \forall \text{ Segments}$$

B. G. Kinda, *et al.*, "Under-ice ambient noise in eastern beaufort sea, canadian arctic, and its relation to environmental forcing", J. Acoust. Soc. Am?, vol 134, pp. 1-11, 2013.



CONTEXT

GOAL : Evaluation of anthropic pressure on marine ecosystems through ambient noise study (continuous and impulsive) and transient signbals extraction & classification

MAMBO NETWORK : Acoustic monitoring and opportunity noise measurement

- 12 station spread over French Exclusive Economic Zone (EEZ)
- Expected amount of data ~ 50 To/yr

REQUIREMENTS : Production of reference time series of noise measurements to assess traffic noise models robustness

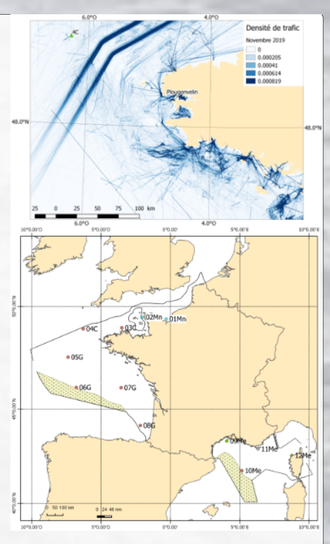
Automatic	**Signal Presence uncertainty**	**Continuous operation**
Complex noise		**Non-stationary environment**

CHOSEN APPROACH : **Recursive** me thod with joint production of **time-frequency map of noise** and **signal presence probability (SPP).**

Source method : IMCRA method (*)

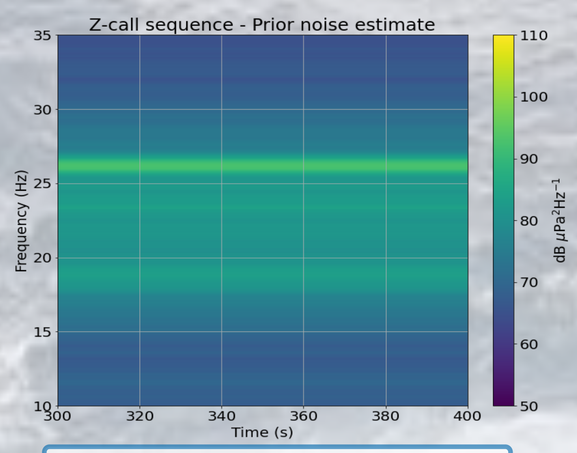
(*) I. Cohen, "Noise spectrum estimation in adverse environments : improved minima controlled recursive averaging", IEEE Transactions of Speech and Audio Processinf, vol. 11, no. 5, pp. 466-475, Sep. 2003

Presented method : Percentile Controlled Recursive averaging (PCRA) - see below



Cohen, I. and Berdugo, B. (2001). Speech enhancement for non-stationarynoise environments.Signal processing, 81(11):2403–2418

ENHANCED SIGNAL



PRIOR NOISE ESTIMATE

ADAPTATIVE PERCENTILE WITH BEST STATIONAITY WINDOW RESEARCH

SNR THRESHOLDS

BETA-PRIME DISTRIBUTIONS

SNR RATIOS

SPECTRAL SUBTRACTION

INITIALIZATION

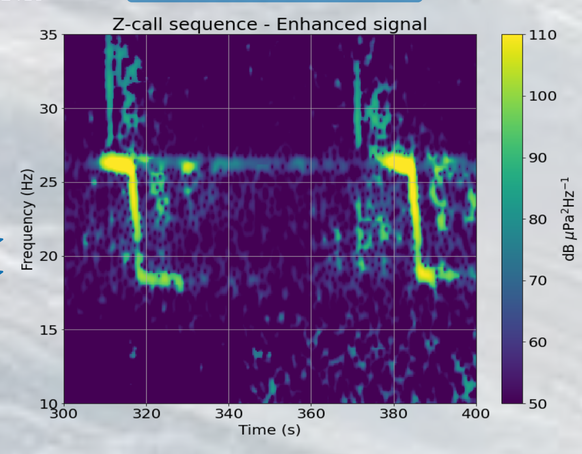
SIGNAL ABSENCE PROBABILITY

SPECTRAL GAIN - G(k,l)

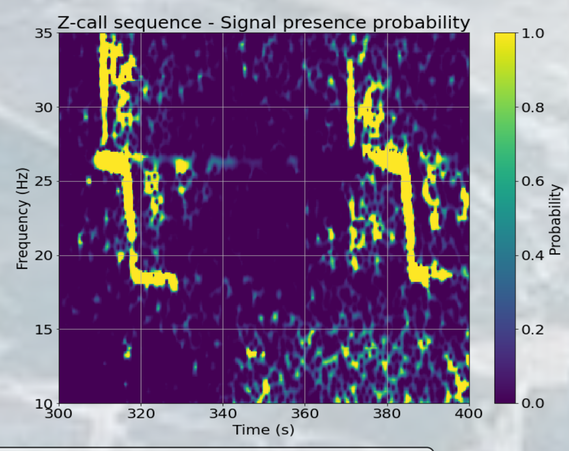
PERCENTILE CONTROLLED RECURSIVE AVERAGING METHOD (PCRA)

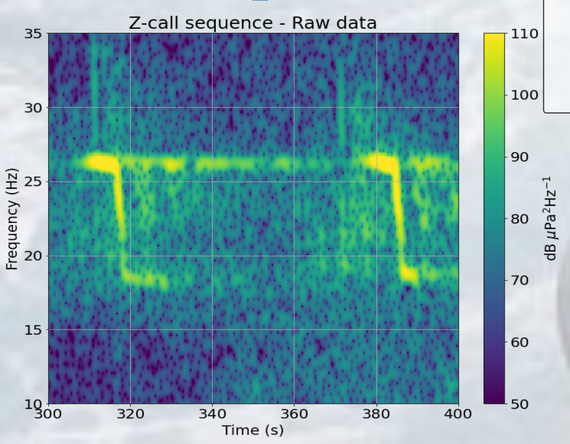
Loop over time step l

∀ frequency bin k



SIGNAL PRESENCE PROBABILITY - p(k,l)



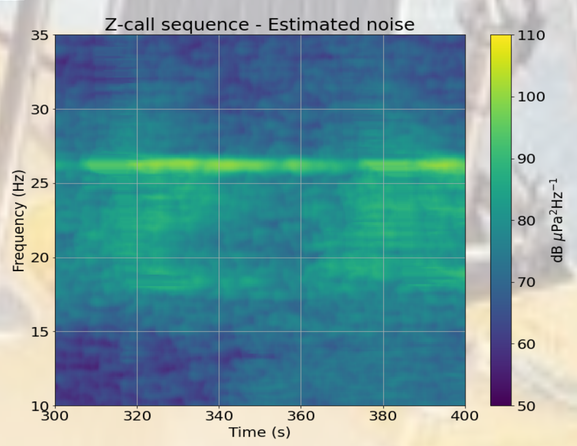


RAW DATA SPECTROGRAM

Blue Whale Z-call from Rhum-Rum data
https://www.rhum-rum.net/fr/

H. Pihan-Le Bars & B. G. Kinda, "Percentile COntrolled Recursive Averaging (PCRA) method for noise estimation in underwater acoustics", in prep.

NOISE ESTIMATION - λ(k,l)



RECURSIVE NOISE ESTIMATE

PAST NOISE ESTIMATE — PRESENT SPECTROGRAM COEFFICIENTS

$$\lambda(k,l) = \hat{\alpha}_n(k,l)\lambda(k,l-1) + (1-\hat{\alpha}_n(k,l))Y(k,l)$$

WEIGHTING FACTOR DEPENDING ON SPP

$$\hat{\alpha}_n(k,l) = \alpha_n + (1-\alpha_n)p(k,l)$$

RESULTS ON SIMULATED DATA

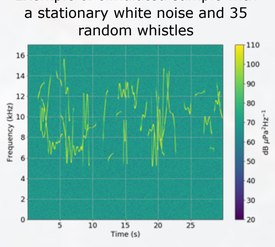
SIMULATED DATA : Monte-Carlo simulation (50 iterations) on different noise profile and with 2 types of noise (white and violet). Each 30s simulated sample contains 35 whistles (10 random profiles). The SNR of the signals vary from -10 to 20 dB.

SEGMENTAL LOGARITHMIC ERROR (SLE) : Mean value of log-ratio of estimated noise $\hat{N}(k,l)$ and true noise $N(k,l)$

$$SLE = \frac{1}{LK}\sum_{l=0}^{L-1}\sum_{k=0}^{K-1}\left|10\log_{10}\frac{\hat{N}(k,l)}{N(k,l)}\right|$$

k - frequency bin
l - time step

Exemple of simulated sample with a stationary white noise and 35 random whistles



profile 1 = stationary
profile 2 = smooth increase
profile 3 = smooth decrease
profile 4 = 3 abrupt transitions

PERFORMANCE :

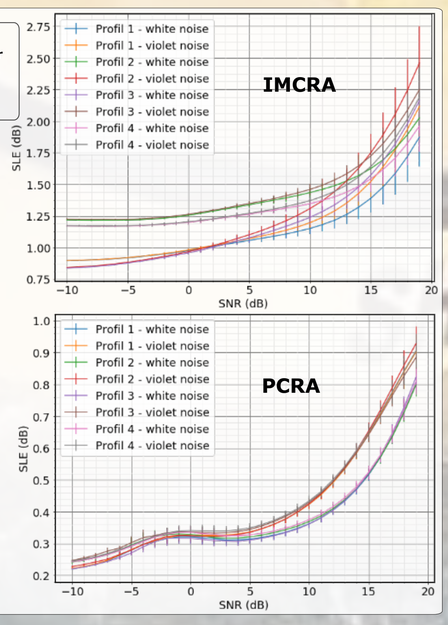
ORIGINAL METHOD IMCRA :

- Two trends, no clear link with any pattern or noise type
- Growing instabilitywith increasing SNR

PCRA

- Best results for error amplitude (0.2 to 1.0 dB) and variability
- Negligible effect of stationarity profile
- Increased sensitivity for violet noise due to simulation artefact

Each point of the curves and its error bar are respectively the mean and std of SLE over 50 simulations



RESULTS ON MAMBO DATA

MAMBO DATA : Noise level estimated on 1/3 octave band centered on 63 Hz. Each data point corresponds to a 10 s segment.

Recording is performed with hydrophones. The sampling frequency used here is 39062.5 Hz

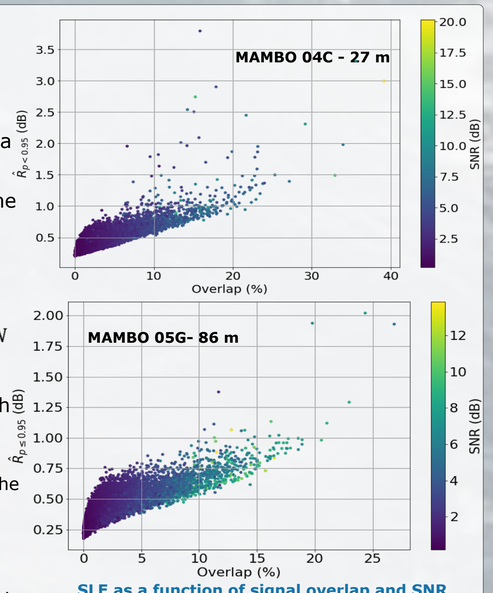
SEGMENTAL PERFORMANCE AND BEHAVIOUR INDICATORS :

- **Signal to noise ratio** (SNR) (dB): $R = Y/N$
- **Approximated SLE** (dB): $\tilde{R}_{0,95} = Y_{p<0,95}/N$
- **Signal overlap**: area covered by pixels with SPP > 0.95, i. e. $Y_{p>0,95}$

Notation : Y, N and $Y_{p<0,95}$ are respectively the noisy data, the estimated noise spectrogram and the noisy signal masked if SPP > 0.95

INTERPRETATION :

- Error related to the signal overlap
- Minimal error consistent with those obtained on simulated data
- For an overlap <20%, a large part of the errors are < 1 dB
- The error dispersion for 04C station is likely due to flow noise, negligible for deep-sea station such as 05G

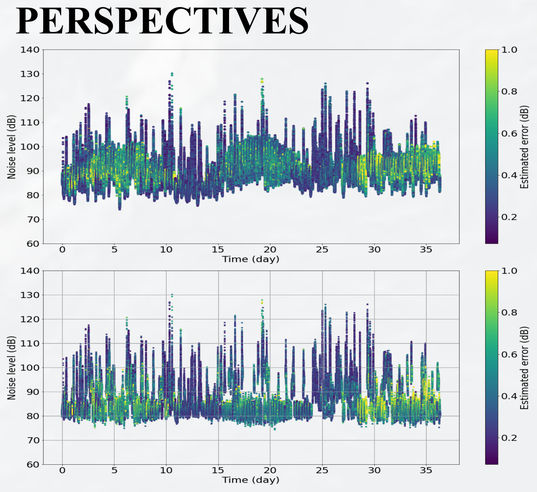


SLE as a function of signal overlap and SNR

Top figure : 41 days of continuous measurement from MAMBO-04C station (Celtic Sea)

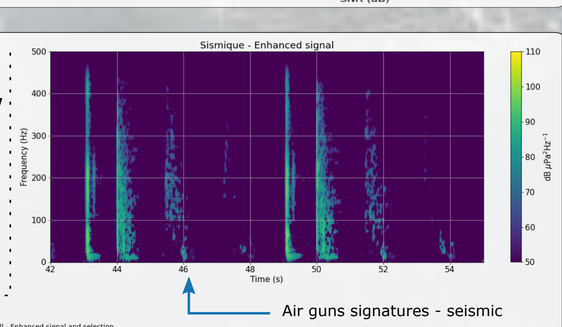
Bottom figure : 64 days of 45min/h measurements from MAMBO-05G (Bay of Biscay)

PERSPECTIVES



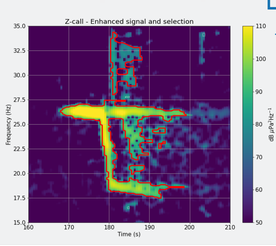
- For coastal stations, there is a significant modulation of noise which is related to **flow noise** generated by the **tidal current.**
- The **temporal filtering** of this effect is currently investigated, with **local current speed measurements** and **3D current models developed at SHOM.**
- The aim is to **limit data loss** as much as possible (ideally <10%).
- Such phenomena have already been observed in JOMOPANS community (https://northsearegion.eu/) and resulted in the loss of 90% of the data

For more details on long-term distributions of noise, see the poster of **D. Dellong et al. "Overview of noise map validation process"**



Air guns signatures - seismic

Blue Whale Z-call from Rhum-Rum data



- **Signal extraction** and **denoising** as basis for futur work on **features extraction** and **classification**
- Application to **various types of signals**

CONCLUSION

METHOD FEATURES :

- A statistical method adapted to non-stationary uncertain and complex environments
- An automatic parametrization suitable for production activities ans soon on embdded systems
- Enable noise estimation with high temporal resolution
- Provide a detection map and means of denoising without additionnnal computational complexity

INHERENT LIMITATION :

- Only transients signals short compared to the observation window can be efficiently discarded
- Quasi-continuous signals, e.g. shipping noise, will appear in the noise estimate