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A probabilistic approach to the discrimination of underwater acoustic signals due to P-waves generated by teleseismic events

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Seismic waves, arriving at the ocean bottom, generate acoustic signals ropagating vertically towards the ocean surface. The acoustic signals due to P-waves originating from teleseismic events are particularly useful to increase the resolution of tomographic Earth models beneath the oceans. The detection of P-wave signals is done by the deployment of an autonomous underwater robot equipped with a hydrophone, freely floating at a fixed depth and continuously monitoring the variations of the water pressure. The information on the robot's position at the moment of signal arriving can be obtained with the help of the GPS, which in its turn requires that the robot reaches the ocean surface as soon as possible after the signal detection to establish a satellite connection.

The prototype robots on which we report here are powered by 50 lithium batteries of size D. It is very important to limit the power consumed by the CPU analyzing the signal, by the surfacings of the robot for data transmission, and by the data transmission itself. We estimate that, given a correct identification of P-wave signals, the lifetime of a robot can be 2-3 years before power runs out.

A standard detection routine based on the ratio of the short-term to long-term moving averages (STA/LTA), operating in integer arithmetic to conserve power, is used to trigger the recording into the robot's memory once the signal arrives.

The oceanic environment is known to be full of signals generated by the sources other than teleseismic events, such as ships, marine animals, air gun exploration campaigns, etc. While each of such contaminant signals can be recorded by the STA/LTA routine, it is of the uttermost importance to find a method to automatically discriminate the detected signals and ensure that the robot surfaces only in case of a teleseismic P-wave signal detection. We propose a probabilistic discrimination scheme based on the statistical analysis of how the total power of a detected signal is split among different frequency bands.

We tested our method on the underwater acoustic records acquired by continuously recording hydrophones deployed at the sea bottom during the Grosmarin experiment in the Ligurian Sea in 2008. The information on the signal's power is obtained by calculating integer wavelet transform coefficients, whose absolute magnitudes at each scale are related to the amount of the power in the corresponding frequency band. For simplicity, the scale averages of the wavelet transform coefficients (the average value of the absolute magnitudes of the coefficients at the same scale) are calculated, one for each scale. Subsequently, the distributions of the scale averages are obtained for the sets of signals originating from the same source. The set of the mean values, derived from the distributions, along with the corresponding variances constitute a statistical model for signals
of a certain origin.

During the Grosmarin experiment, a set of 19 P-wave recordings from 4 teleseismic events (of magnitude 6.0 and more) was acquired. The statistical model for the teleseismic P-wave signals was found to be different from the models describing the signals originating from other sources. This makes it feasible to discriminate the signals due to P-waves generated by teleseismic events from signals viewed as acoustic contaminants. The final decision of whether the detected signal is worth (or not) sending the robot to the surface is taken after calculating the probability that the detected signal belongs to a certain statistical model.