Using a global optimization method for localizing acoustic sources under water

Snellen, Mirjam; Simons, Dick

Publication date
2016

Document Version
Final published version

Published in
Maxwell-periodiek der electrotechnische vereeniging

Citation (APA)
Snellen, M., & Simons, D. (2016). Using a global optimization method for localizing acoustic sources under water. *Maxwell-periodiek der electrotechnische vereeniging*, *20*(1).

Using a global optimization method for localizing acoustic sources under water

By Dr.ir. Mirjam Snellen & Prof. dr. Dick G. Simons
Section Aircraft Noise and Climate Effects, Delft University of Technology

One of the research themes within the section Aircraft Noise and Climate Effects (ANCE) is acoustic source localization using acoustic arrays. These arrays are used, for example, for measuring the noise of aircraft fly-overs, quantifying the noise from the various aircraft components such as flaps, slats, engines and landing gear, and in wind tunnel measurements. However, acoustic arrays are also used under water for source localization, for example with the goal of determining the position of a submarine. Although in many aspects similar, there are differences when considering acoustic source localization under water compared to the situation in air. The reason is that, especially in regions with shallow water, the propagation of sound from source to receiver is heavily affected by the interaction of sound with the sediment on the seafloor and by varying sound speeds in the water column. Not accounting for these propagation effects results in an erroneous localization.

A major problem is that although 70% of the earth is covered by water, the majority of underwater media are still unexplored, and consequently often both the sediment characteristics and water column properties are unknown and therefore cannot be properly accounted for. To still allow for accurate source localization, the technique of matched field inversion, also called focalization, has been developed. The approach is to not only search for the unknown position of the source, but to also estimate all parameters of the envi-

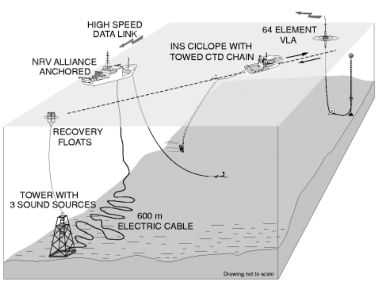

Figure 1: Overview of the measurement configuration. The data are acquired on a 64 hydrophone vertical line array (VLA). A sound source was mounted on a tower placed on the bottom. A ship (INS Ciclope) was measuring the sound speeds in the water column with conductivity-temperature-depth (CTD) sensors.

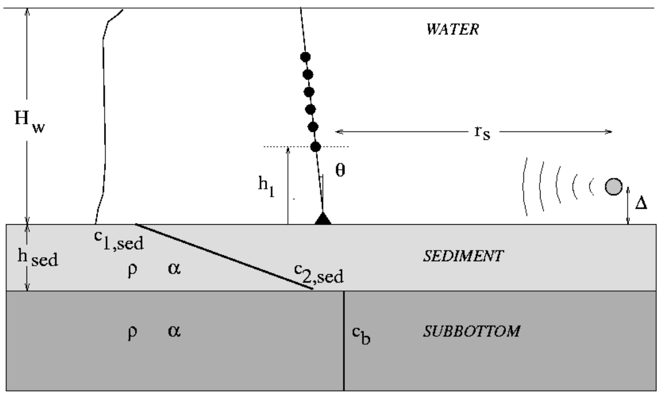

Figure 2: The environment is assumed to consist of three layers, a water column of thickness H_w, a sediment layer of thickness h_{sed} and a subbottom. The acoustic source is located at a distance Δ from the sediment at a range r_s from the receiver. The receiver is a line array consisting of 64 hydrophones, with the lower hydrophone at a distance h_1 from the bottom and the array tilted at an angle θ. Sound speeds in the sediment and subbottom are $c_{1,sed}$, $c_{2,sed}$ and c_b, respectively. The density ρ and absorption coefficient α are assumed to be equal in sediment and subbottom.

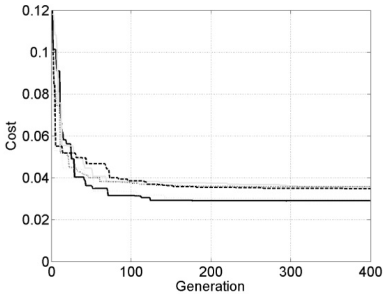

Figure 3: Example of GA convergence behavior for 5 independent runs.

ronment that do affect the sound propagation but are not known. We will illustrate this idea by applying it to a dataset acquired in a configuration as shown in Figure 1. Figure 2 presents a schematic of the situation. All environmental parameters indicated are unknown and need to be determined to allow for localizing the acoustic source.

By using an appropriate acoustic propagation model that accounts for the effects of all above unknowns, the received signals are predicted for a large number of realizations of the unknown parameters. For every realization the agreement between measured and predicted acoustic pressure field is quantified through a cost function. Due to the huge number of possible combinations of values for all unknown parameters, an efficient optimization method is required to determine those values for the unknowns that provide a maximum agreement between measured and predicted pressure field. In addition, the optimization method needs to be capable of escaping local optima, i.e. combinations of values that provide good, but not the best agreement between measurements and predictions. For the application at hand a genetic algorithm (GA) has been used. The method works with populations of solutions and finds the global optimum by combining promising solutions in subsequent iterations. Figure 3 illustrates the convergence behavior of the algorithm. Since with these type of optimization methods there is always a possibility to end in a local optimum, five independent runs have been carried out. The resulting environmental parameters have been used for localizing both a source positioned at the bottom (see Figure 4), and the surface ship Ciclope (see Figure 5). For both acoustic sources the so-called ambiguity surfaces are shown. These quantify the agreement between the measured and modelled pressure fields for a grid of potential source positions. High levels, indicating good agreement between modelled and measured pressure fields, are indicated in red, whereas lower levels are shown in blue. Clearly, the estimates for the environmental parameters are accurate as the ambiguity surfaces indicate the presence of the source (red spots) at the correct positions.

Although started as a method for the localization of acoustic sources under

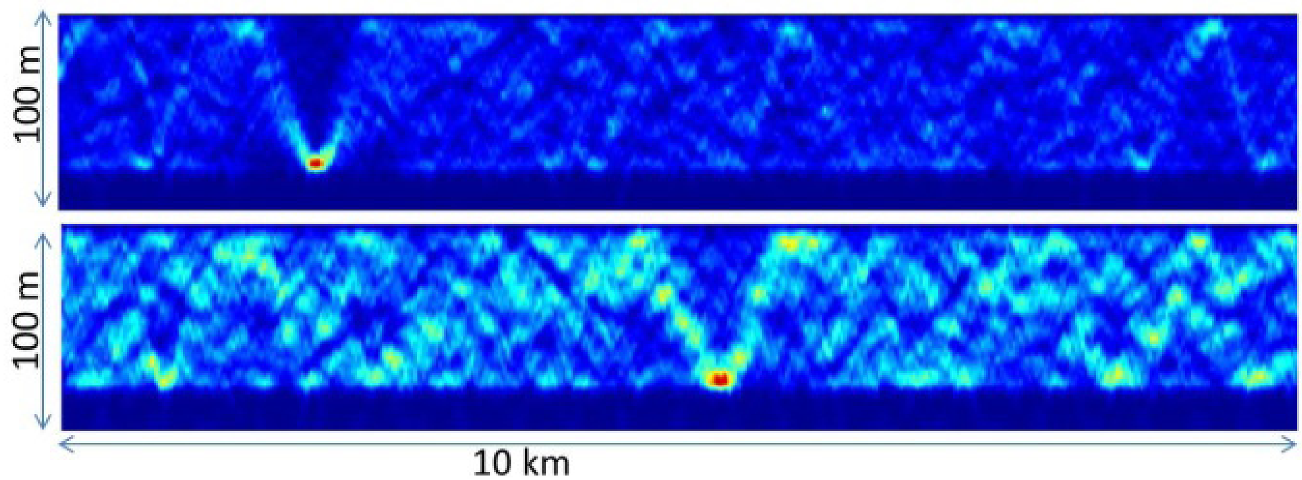

Figure 4. Ambiguity surfaces for measurements with the acoustic source mounted at the bottom at 2 and 5 km distance from the array, respectively. The water depth is ~100 m.

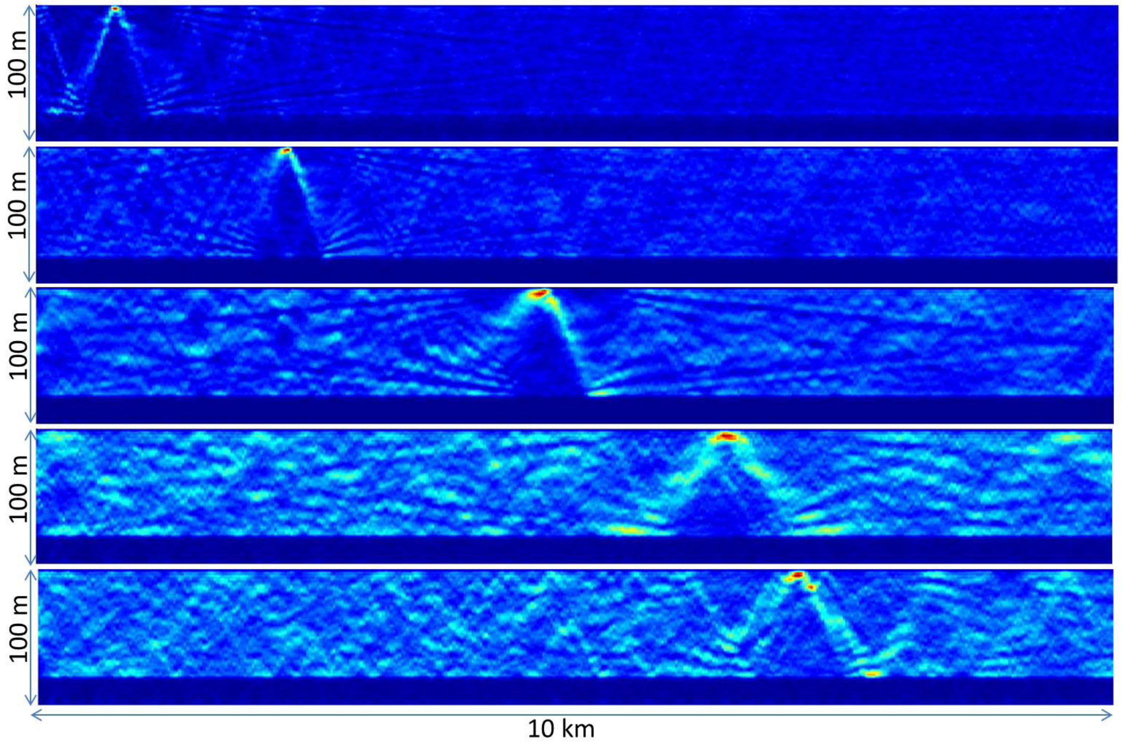

Figure 5. Ambiguity surfaces indicating the location of the surface ship Ciclope at various times, corresponding to various distances of the Ciclope to the acoustic array.

water, nowadays the application has broadened towards also using the method for the assessment of the underwater environment. Applications requiring this information are manifold, and include for example the area of mine hunting where bottom information is essential, since mines behave differently for different types of bottoms. In a soft bottom, mines get buried in the bottom, whereas they stay on top of hard sea bottoms. Having information about the sediment properties is also an essential element for dredging, investigating the sea bottom for off-shore activities, e.g. when considering an airport on the sea, or tracing the sea bottom for certain types of material.