

High-fidelity simulations of sound propagation in the oceans

Ken Mattsson^{1,*} and Gustav Eriksson¹

¹ Department of Information Technology, Uppsala University
P O Box 337, S-751 05 Uppsala, Sweden
* ken.mattsson@it.uu.se

ABSTRACT

To simulate acoustic waves in the ocean requires a numerical model that takes the properties of the seabed, bathymetry and variable sound speed in the ocean into consideration. This is especially important considering low frequency sound in shallow water environments. Low frequency sound can propagate long distances due to relatively small absorption in both seawater and seabed. Seasonal changes of the temperature affect the sound speed profile in the shallow oceans. Properties of the seabed is often the biggest uncertainty in the model.

It is well-known that higher-order finite difference methods capture wave propagation efficiently due to small dispersion errors. For long-time simulations, it is imperative to use finite difference approximations that do not allow growth in time if the PDE does not allow growth—a property termed *time stability*. Time stability is achieved by combining summation-by-parts (SBP) finite difference operators [1] and the projection method [2]. We will present a novel 3D time-dependent solver for acoustic waves suitable for low frequency sound in realistic shallow water envi-

ronments. The bathymetry, properties of the seabed and the ocean are included in the numerical model. The sound sources are modeled as point sources, and can be located both in the water and in the seabed. Typical applications are low frequency sound propagation from offshore wind farms (where the sound sources are typically in the seabed) and large ships (where the sound sources are below the sea surface).

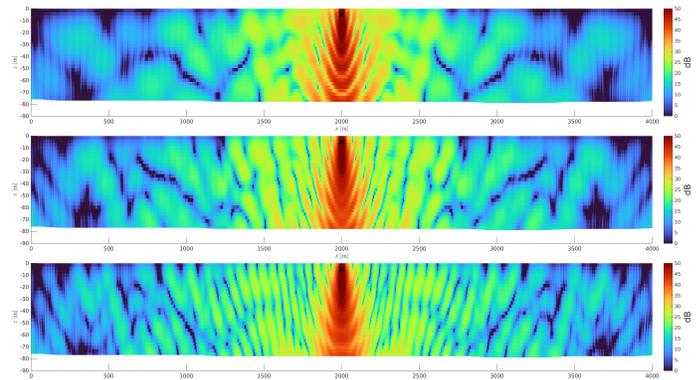


Figure 1: 3D Sound propagation (50 Hz), three different depths (10, 100, 300 m) of bedrock in the ocean sediment.

3D Sound propagation in the Baltic Sea is simulated in Figure 1, for various seabeds. A 50 Hz point source is located 10 m below the sea surface. We simulate to $t=6$ seconds. The computational domain has size $4000 \times 4000 m^2$ in the xy -plane. The depth of the ocean is roughly 80 meter, meeting a 20 meter layer of sand and ending with a bedrock of different thicknesses: 10, 100 and 300 m. To achieve fast simulations, the numerical model is implemented on a large GPU (RTX A6000 with 48 GB vram). The simulations presented in Figure 1 involves 76549239, 137396070, and 274792140 number of grid-points, respectively (depending on the different thicknesses of the bedrock layer), corresponding to runtimes of 366, 602 and 1200 seconds.

REFERENCES

- [1] Ken Mattsson and Jan Nordström. Summation by parts operators for finite difference approximations of second derivatives. *J. Comput. Phys.*, 199(2):503–540, 2004.
- [2] Ken Mattsson and Pelle Olsson. An improved projection method. *J. Comput. Phys.*, 372:349 – 372, 2018.