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# SIMULATION AND INVERSION OF WAVE FIELDS

## WAVE

The aim of the project WAVE is to develop a toolbox that provides methods for the simulation and inversion of wave fields on high performance architectures. WAVE is funded by the BMBF (German National Ministry of Education and Research). The project started in March 2016 and ends by July 2019.

## Motivation / Challenge

Wave propagation plays an important role in many applications. In geophysical exploration, seismic and electromagnetic waves make geological layers and reservoirs visible. Seismology uses wave simulation to predict and estimate possible damages of earthquakes in high risk regions. Simulation models based on the theory of harmonic wave propagation are also used for the identification of tumors, for the localization of defects in materials, reducing the acoustic noise in a vehicle, or for the protection of places from electro-magnetic radiation.

For the numerical simulation of wave equations, finite difference methods are employed. They are based on grids that allow a simple parallelization based on domain decomposition. Variant grid sizes can be helpful to reduce simulations costs as the highest resolution is only required in complex parts with significant gradients but not for the full domain.
Full-waveform inversion (FWI) compares the wave fields generated in the computer simulations with the data recorded in the fields. By an iterative process, the simulation model is adapted until the measured and simulated data matches. FWI provides the most advanced geologically accurate insights for seismic imaging.
FWI algorithms are more computationally intensive and need much more memory since simulation data must be kept in the reverse time order for correlation.

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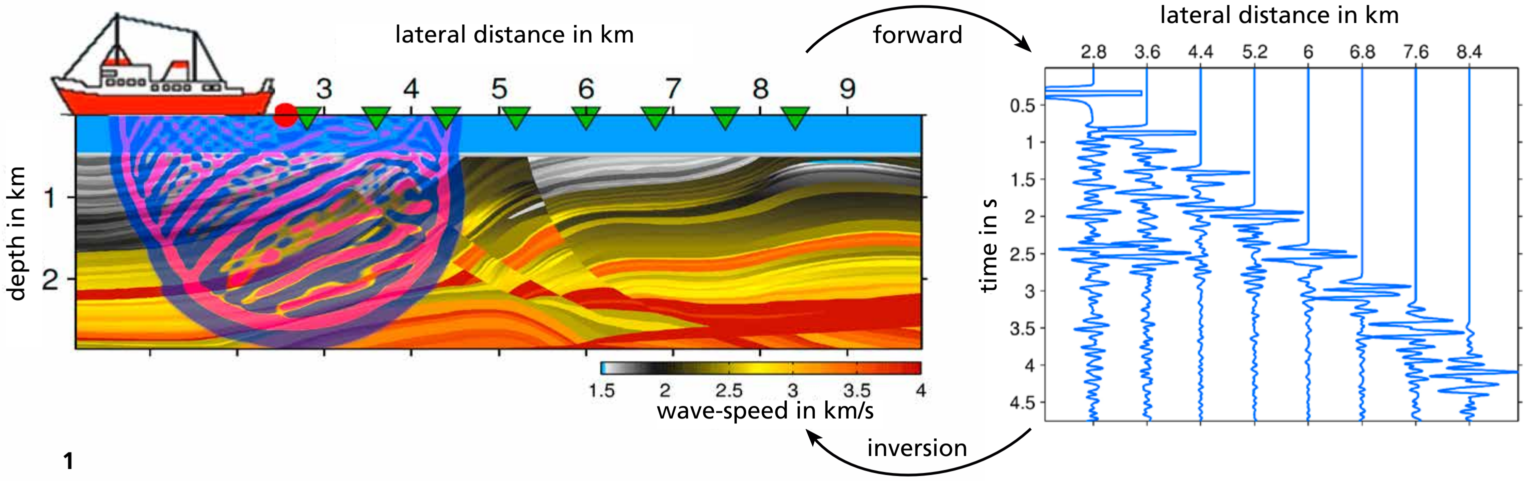
Project Partners:
Karlsruhe Institute of Technology;
Humboldt-Universität zu Berlin;
TEEC Geophysics, Isernhagen




1 *Geophysical imaging: full-waveform inversion.*

### The HPC Toolbox from WAVE

The HPC Toolbox from WAVE is free software that provides

- generic numerical data structures and algorithms,
- load balancing techniques to deal with different geometries and resolutions as well as varying computational costs throughout the domain,
- seismic modeling code using wave propagation based on finite difference methods,
- full-waveform inversion code to solve the inverse problem of seismic wave propagation,
- portability and scalability by using the LAMA library that provides high level data structures like distributed matrices and vectors as well as operations on them.

The WAVE toolbox enables wave simulations to run efficiently on all kinds of parallel architectures. The provided codes might be used either on its own or as libraries within other applications. Variant grid sizes reduce computational and memory costs and load balancing preserves scalability also for heterogeneous architectures.

Many of the provided techniques may also be useful for other simulation disciplines.

### Partners

The Geophysical Institute of KIT (Karlsruhe Institute of Technology) focuses on the theoretical challenges of seismology, compute-intensive modeling, and inversions of geophysical observations, as well as on seismological field work. For WAVE, it provides the algorithms and use cases, extends the models, and is also responsible for project management.
**Contact:** Prof. Dr. Thomas Bohlen (thomas.bohlen@kit.edu)

The chair "Modeling and analysis of complex systems" at the Humboldt-Universität develops and implements a new efficient geometric and combinatorial approach for the partitioning of data that supports load balancing of irregular grids and minimizes data exchange.
**Contact:** Prof. Dr. Henning Meyerhenke (h.meyerhenke@hu-berlin.de)

The High Performance Computing group of Fraunhofer SCAI provides the LAMA framework that is used for the development of all simulation codes and the partitioning tools.
LAMA has been designed to develop hardware-independent, high-performance code for heterogeneous computer systems. This tool helps the other partners to focus on the code development and to achieve high portability of the toolbox. LAMA is optimized within the project to reduce memory requirements for finite difference simulations and for achieving high scalability on dynamic load balancing and partitioning algorithms.
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TEEC Geophysics is the leading company for CRS seismic processing and provides geophysical and geological processing and interpretation techniques in close cooperation with its clients and partner companies. In the WAVE project, TEEC evaluates the toolbox by prototype implementations around their production codes.
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Find more information about WAVE on www.wave-toolbox.org

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