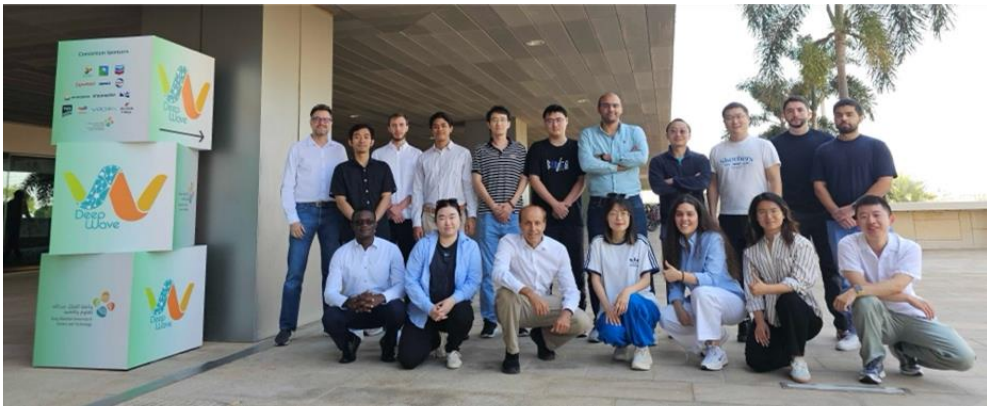
ISSUE
06
AUTUMN 2025

BIANNUAL NEWSLETTER

Deep Wave

IN THIS ISSUE



Overview

Welcome to the Autumn 2025 issue of the Consortium Newsletter! We are delighted to share the latest developments, milestones, and crucial insights from our vibrant team.

This edition is packed with information, beginning on page 3 with an in-depth spotlight on **standout research projects**, showcasing our team's determination in tackling complex geophysical challenges.

On page 6, you will find a curated selection of **recent publications** authored by our members, underscoring our commitment to advancing scientific knowledge.

Finally, check out the news roundup on page 7 for **important events and updates** from across the entire consortium.

We hope this issue leaves you informed and connected to the exciting momentum driving our work forward. Happy reading!

Find more about our consortium by either contacting us via e-mail [deepwave@kaust.edu.sa] or by visiting the DeepWave website [deepwave.kaust.edu.sa].

DeepWave is an industry funded research consortium at King Abdullah University of Science and Technology (KAUST), which focuses on the application of machine (deep) learning numerical algorithms to wave-equation-based processing, imaging, and inversion.

The application of these techniques extends to objectives ranging from global Earth discovery, to natural resources exploration, to subsurface monitoring as well as non-destructive testing and medical imaging.

Goal

To be a leading center for the research and development of machine learning algorithms on waveform data with applications ranging from the exploration and discovery of the Earth to reservoir characterization and monitoring for oil and gas, geothermal, and CO_2 storage purposes.

Mission

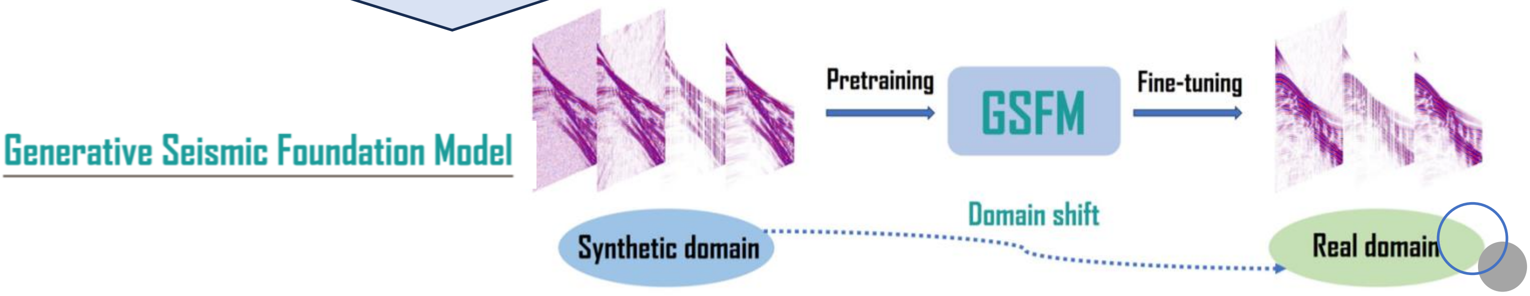
To foster an environment of effective research for the students and researchers that promotes seamless interaction with our sponsors.

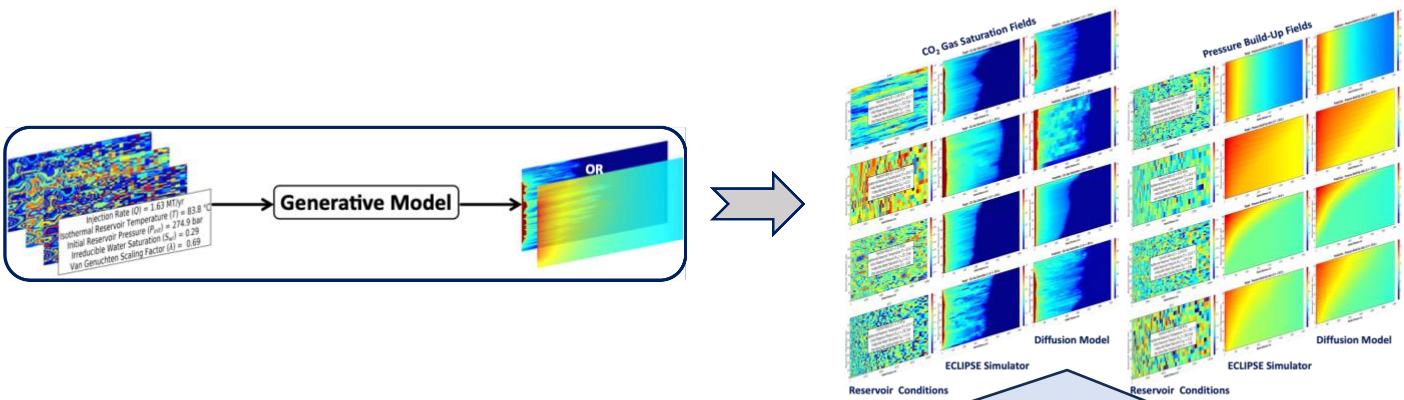
Samples of DeepWave Research

A Generative Foundation Model for an All-in-One Seismic Processing Framework

Shijun Cheng, Randy Harsuko, Tariq Alkhalifah

The generative seismic foundation model (GSFM) leverages generative diffusion models to address multiple seismic processing tasks through a dual-stage training strategy: the pre-training phase learns ideal seismic data distributions from synthetic datasets using class label encoding and target-oriented prediction; the fine-tuning phase employs an iterative self-supervised strategy to adapt the model to field data, overcoming generalization limitations of traditional methods. By predicting targets directly rather than noise, GSFM achieves high-quality results with a single sampling step, enhancing computational efficiency. Additionally, the probabilistic nature enables uncertainty quantification, providing insights into processing reliability. Experimental results demonstrate superior performance across diverse tasks without requiring field data labels, advancing adaptive multi-task seismic processing.





Towards Generating Modeling of CO_2 Geological Sequestration with Latent Conditional Diffusion Modelσ

Vittoria De Pellegrini, Tariq Alkhalifah

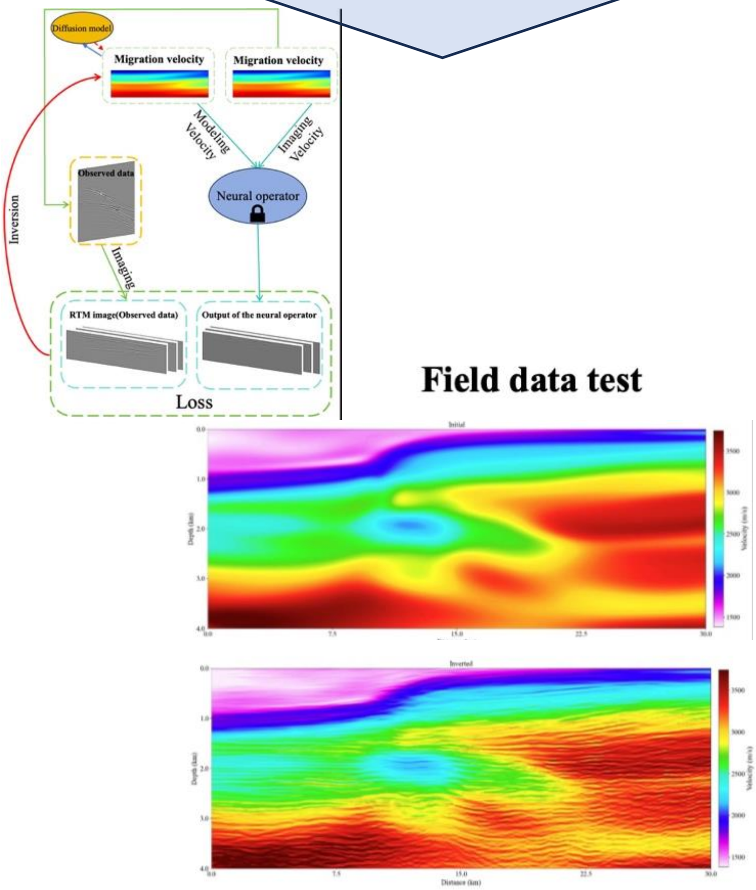
Geological CO_2 sequestration is a strategy for mitigating greenhouse gas emissions and supporting global decarbonization goals. Accurate modeling of CO_2 plume migration in the subsurface is essential for safe and effective storage. While traditional numerical reservoir simulations are widely used for this purpose, they are computationally expensive, especially when multiple forward simulations are required to account for the inherent geological uncertainty of the subsurface. To tackle this challenge, machine learning models have emerged as fast and reliable alternatives to traditional simulations. We propose a generative modeling framework based on latent conditional diffusion models for data-driven prediction of CO_2 gas saturation and pressure build-up fields under a wide range of reservoir input conditions.

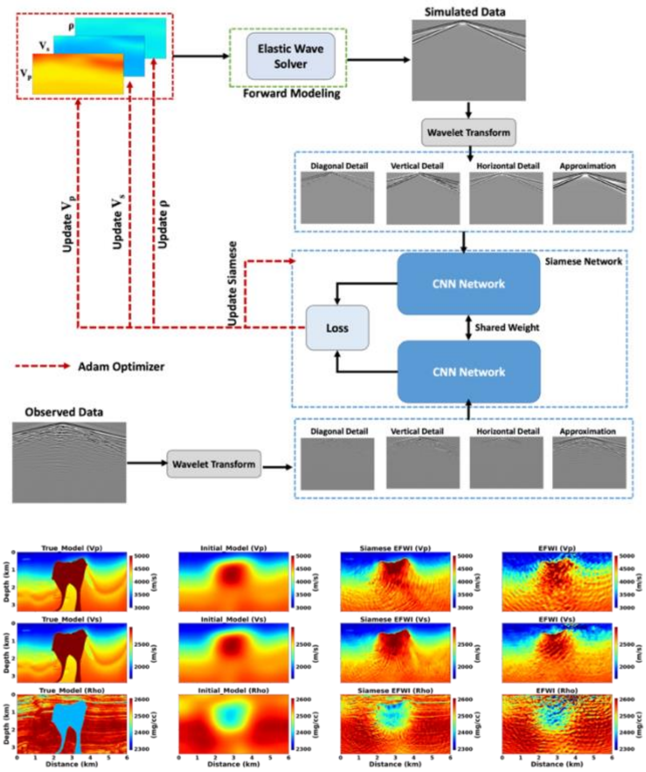
Samples of DeepWave Research

Diffusion priors enhanced velocity model building from time-lag images using a neural operator

Xiao Ma, Mohammad Hasyim Taufik, , Tariq Alkhalifah

In this study, we propose a novel framework that combines generative models with neural operators to obtain high resolution velocity models efficiently. Within this workflow, the neural operator functions as a forward mapping operator to rapidly generate RTM extended images from the true and migration velocity models as two input channels. The neural operator is acting as a surrogate for modeling followed by migration. The trained neural operator is then employed, through automatic differentiation, to gradually update the migration velocity placed in the true velocity input channel with high resolution components. Furthermore, by embedding a generative model, as a regularizer, the resulting predictions are cleaner with higher resolution information.





Enhancing Multi-parameter Elastic Full Waveform Inversion with a Siamese Network

Omar M. Saad, Tariq Alkhalifah

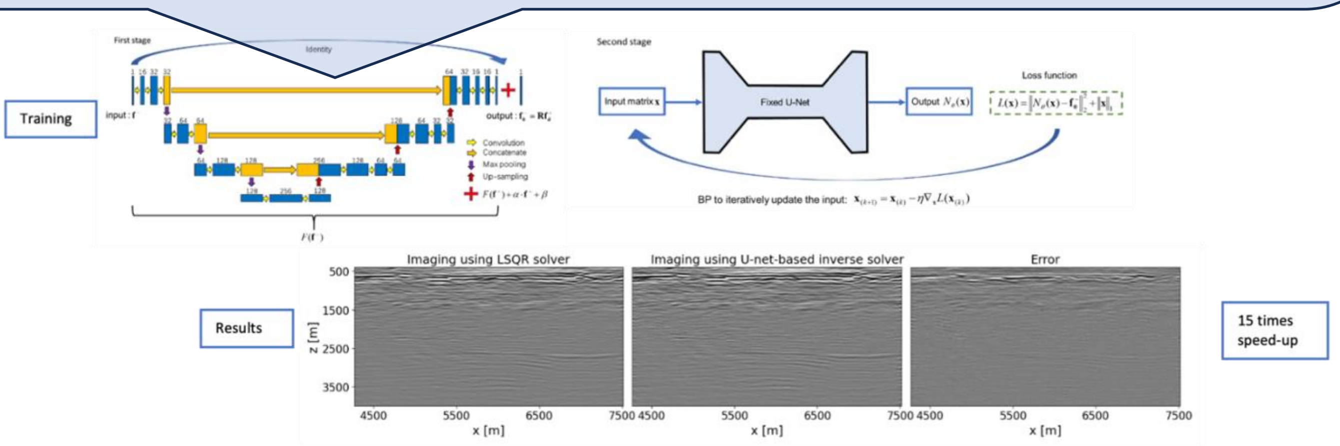
We extend the SiameseFWI framework for multi-parameter Elastic Full Waveform Inversion (EFWI) by integrating wavelet transforms, specifically the Haar mother wavelet, to enhance feature extraction from the seismic data. Our Siamese network operates on a self-supervised scheme and consists of two identical convolutional neural network branches with shared weights, which improve data comparison using Euclidean distance as a loss measure. By optimizing the parameters of the Siamese network during the iterative EFWI process and adding a skip connection for stability, we effectively invert the multi-parameter EFWI. We validate our framework with various synthetic and field data examples, demonstrating its enhanced inversion performance compared to traditional EFWI, with minimal additional computational cost.

Samples of DeepWave Research

A Deep-Learning-Driven Optimization-Based Inverse Solver for Accelerating the Marchenko Method

Ning Wang, *Tariq Alkhalifah*

Marchenko method is a powerful but computationally expensive framework for retrieving full-wavefield Green's functions. To overcome its limitation, we introduce a new optimization-based solver that leverages a neural network as a fixed forward operator within the Marchenko workflow. The network is trained on a small subset to map final up-going focusing functions back to their initial estimates. Once trained, it remains fixed and focusing functions at new target locations are obtained by iteratively updating an input through backpropagation to minimize the mismatch between the network output and the known initial focusing function. The resulting estimate is then used to derive the down-going component and compute the full Green's functions through the Marchenko equations. This approach dramatically reduces computational cost while retaining high imaging quality.



Recent Publications

Cheng, S.; Alkhalifah, T., "*Multi-frequency wavefield solutions for variable velocity models using meta-learning enhanced low-rank physics-informed neural network*", 2025, Geophysical Journal International, 10.1093/gji/ggaf417.

Cheng, S.; Harsuko, R.; Alkhalifah, T. *"A Generative Foundation Model for an All-in-One Seismic Processing Framework*", 2025, Surveys in Geophysics, 10.1007/s10712-025-09912-9.

Huang, X.; Alkhalifah, T., "*Learned frequency-domain scattered wavefield solutions using neural operators*", 2025, Geophysical Journal International, 10.1093/gji/ggaf113.

Huang, X.; Wang, F.; Alkhalifah, T., "*Physics-Informed Waveform Inversion Using Pretrained Wavefield Neural Operators*", 2025, IEEE Transactions on Geoscience and Remote Sensing, 10.1109/TGRS.2025.3624025.

Mu, X.; Cheng, S.; Alkhalifah, T., "*SeparationPINN: Physics-Informed Neural Networks for Seismic P- and S-Wave Mode Separation*", 2025, IEEE Transactions on Geoscience and Remote Sensing, 10.1109/TGRS.2025.3582289.

Romero, J.; Heidrich, W.; Ravasi, M., "*Bayesian seismic inversion with implicit neural representations*", 2025, Geophysical Journal International, 10.1093/gji/ggaf249.

Saad, O.M.; Alkhalifah, T., "*Enhancing multiparameter elastic full-waveform inversion with a Siamese network*", 2025, Leading Edge, 10.1190/tle44050416a1.1.

Recent Publications (cont'd)

Saad, O.M.; Ravasi, M.; Alkhalifah, T., "*Self-supervised multi-stage deep learning network for seismic data denoising*", 2025, Artificial Intelligence in Geosciences, 10.1016/j.aiig.2025.100123.

Taufik, M.H.; Alkhalifah, T., "*LatentPINNs: Generative physics-informed neural networks via a latent representation learning*", 2025, Artificial Intelligence in Geosciences, 10.1016/j.aiig.2025.100115.

Taufik, M.H.; Huang, X.; Alkhalifah, T., "*Latent Representation Learning in Physics-Informed Neural Networks for Full Waveform Inversion*", 2025, Earth and Space Science, 10.1029/2024EA004107.

Wang, H.; Chen, Y.; Alkhalifah, T.; Chen, T.; Lin, Y.; Alumbaugh, D., "*DeFault: DEep-Learning-Based FAULT Delineation Using the IBDP Passive Seismic Data at the Decatur CO2 Storage Site*", 2025, Earth and Space Science, 10.1029/2023EA003422.

Wang, N.; Ravasi, M., "*Imaging the Volve ocean-bottom field data with the upside-down Rayleigh–Marchenko method*", 2025, Geophysical Journal International, 10.1093/gji/ggaf116.

Wang, Z.; Song, C.; Alkhalifah, T.; Liu, C., "*Improved Training Convergence of Seismic Multifrequency Wavefield Simulation Based on GaborPINN With Halton Sequence*", 2025, IEEE Transactions on Geoscience and Remote Sensing, 10.1109/TGRS.2025.3602025.

Yang, Y.; Birnie, C.; Alkhalifah, T., "*Joint Microseismic Event Detection and Location With a Detection Transformer*" 2025, Geophysical Prospecting, 10.1111/1365-2478.70040.

Abedi, M.M.; Pardo, D.; Alkhalifah, T., "*Semi-blind-trace algorithm for self-supervised attenuation of trace-wise coherent noise*", 2024, Geophysical Prospecting, 10.1111/1365-2478.13448.

Alkhalifah, T.; Huang, X., "*Physics-informed neural wavefields with Gabor basis functions*", 2024, Neural Networks, 10.1016/j.neunet.2024.106286.

Birnie, C.; Liu, S.; Aldawood, A.; Bakulin, A.; Silvestrov, I.; Alkhalifah, T., "*Self-supervised denoising at low signal-to-noise ratios: A seismic-while-drilling application*", 2024, Leading Edge, 10.1190/tle43070436.1.

Birnie, C.; Ravasi, M., "*Explainable artificial intelligence-driven mask design for self-supervised seismic denoising*", 2024, Geophysical Prospecting, 10.1111/1365-2478.13480.

Chamorro, D.; Zhao, J.; Birnie, C.; Staring, M.; Fliedner, M.; Ravasi, M., "*Deep learning-based extraction of surface wave dispersion curves from seismic shot gathers*", 2024, Near Surface Geophysics, 10.1002/nsg.12298.

Huang, X.; Alkhalifah, T., "*Efficient physics-informed neural networks using hash encoding*", 2024, Journal of Computational Physics, 10.1016/j.jcp.2024.112760.

Taufik, M.H.; Alkhalifah, T.; Waheed, U., "*Stable neural network-based traveltime tomography using hard-constrained measurements*", 2024, Geophysics, 10.1190/geo2024-0040.1.

Wang, N.; Ravasi, M., "*Upside-down Rayleigh-Marchenko: A practical redatuming scheme for seabed seismic acquisitions*", 2024, Geophysics, 10.1190/GEO2023-0743.1.

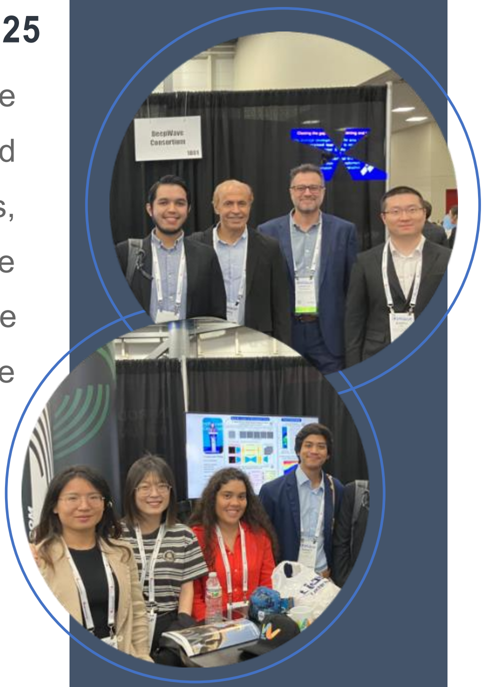
Zhang, W.; Ravasi, M.; Gao, J.; Shi, Y., "*Deep-unrolling architecture for image-domain least-squares migration*", 2024, Geophysics, 10.1190/geo2023-0428.1.

News

Annual Meeting 2025

The Consortium's 2025 Annual Meeting was held on 21–22 August in Houston (US). Over two days, participants attended presentations of our most recent research across five dedicated sessions, followed by lively discussions in which sponsors shared valuable perspectives and recommendations to shape the consortium's future direction. This open and constructive exchange remains essential for guiding our shared priorities ahead.

Presence in IMAGE 2025



DeepWave had a strong presence in IMAGE 2025 at Houston, where we showcased our work to the community through ten oral presentations and eleven posters this year. For a comprehensive list of all our presentations, click here. Additionally, DeepWave had a prominent presence in the technical exhibition, featuring a dedicated booth at the event. We had the chance to connect with fellow professionals and spread the word on the Consortium's mission and achievements.

PhD Student Internship in DeepWave

We are pleased to welcome two new visiting PhD students 🎓 who recently joined DeepWave in KAUST. **Linrong Wang** (PhD Student, Southwest Petroleum University) and **Lina Ren** (PhD Student, China University of Petroleum – East China) will be working closely with our team over the coming year. It's great to have fresh perspectives and new energy in the group — wishing them both a productive and inspiring year with us.

News (cont'd)

PhD Student Graduation

We are proud and delighted to celebrate our KAUST member, Sixiu Liu, who recently completed her PhD. She successfully defended her dissertation, "*The benefits of self-supervised learning for seismic processing*" and will continue her research journey as a Postdoctoral Fellow in the Platform of Geo-Energy & Mineral Resources within the Program of Earth Systems Science and Engineering at KAUST.

Mid-year Meeting planning

The DeepWave Mid-Year Meeting 2026 will take place on 9–10 February 2026, hosted at KAUST. As in previous years, the event will follow a hybrid format, welcoming both in-person and remote participants. We look forward to reconnecting, sharing updates, and engaging with colleagues from our sponsor organisations.

Student Internship in LBNL

In summer 2025, PhD candidate Randy Harsuko completed a two-month internship at Lawrence Berkeley National Laboratory (LBNL). Working with Nori Nakata's group in the Energy Geosciences Division, he helped build an agentic framework for seismic monitoring in geothermal field development. The effort culminated in an accepted submission to the 51st Stanford Geothermal Workshop.

DeepWave on Github

Our GitHub organization is on an upward trend thanks to the contributions of our team, now proudly hosting *63 stable repositories* and *46 in development*. These repositories are designed to facilitate seamless code sharing between DeepWave researchers and Consortium sponsors. A total of *27 public repos* which are linked to published research have become available to the whole community after completing a privacy period of 6 months.

Announcement

Student and Postdoc opening at DeepWave (KAUST)

Join our research group as a fully-funded KAUST **PhD candidate** and get the chance to work alongside a group of motivated individuals who explore cutting-edge techniques in machine learning, data-driven modeling, and computational geophysics while tackling real-world challenges!

Do you have a PhD in a relevant field and strong skills in Python and PyTorch? Join our team as a **Postdoctoral Fellow** and work on tackling complex geophysical challenges. We're looking for researchers eager to push the boundaries of AI-driven geophysics. Get in touch by sending your application to deepwave@kaust.edu.sa

We thank our **Industry Sponsors** for their support

Scope of research

The Consortium aims to deliver the most effective solutions to waveform processing, imaging, and inversion challenges across multiple scales.

4700 King Abdullah University of Science and Technology
Thuwal 23955-6900
Kingdom of Saudi Arabia

deepwave@kaust.edu.sa

deepwave.kaust.edu.sa