ISSUE 07
SPRING 2026

BIANNUAL NEWSLETTER

IN THIS ISSUE

Overview

Welcome to Spring 2026

We're excited to bring you the latest updates from our consortium. In this issue, you'll find the latest research breakthroughs, publications, and consortium news all in one place.

Start on page 3 for an in-depth look at our *standout research projects* — a testament to our team's commitment to solving some of geophysics' toughest problems. Then head to page 5 to discover *recent publications* from our members, reflecting our ongoing contributions to scientific advancement. Finally, wrap up with the *news roundup* on page 6 to stay current on important developments across the consortium as well as get to know members who recently joined the team.

We hope you enjoy this issue and feel connected to the momentum of our work. 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 CO2 storage purposes.

Mission

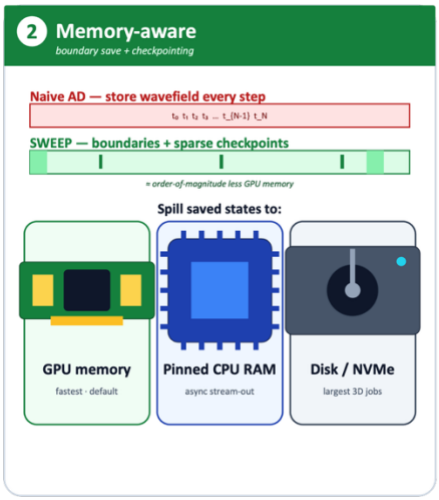
To foster an environment of effective research for the students and researchers that promotes seamless interaction with our sponsors.

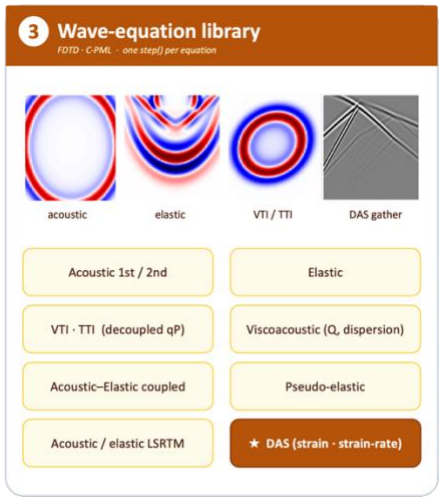
Samples of DeepWave Research

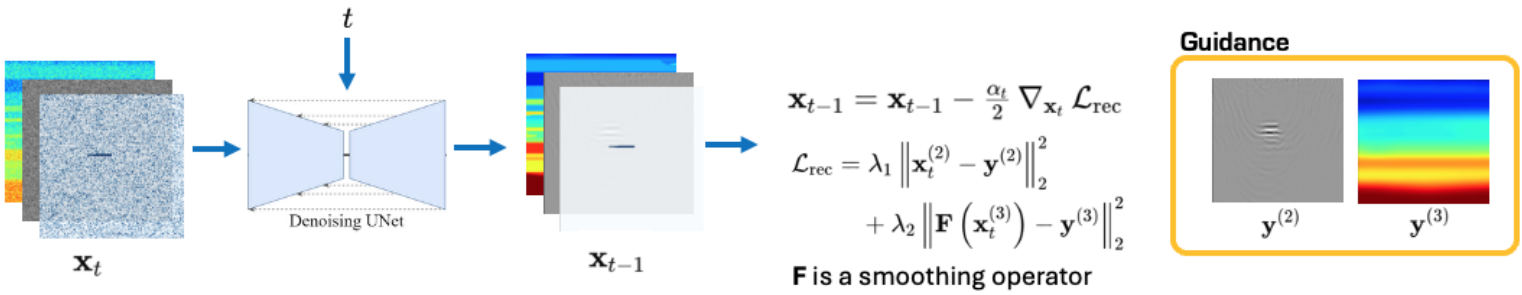
SWEEP — Seismic Wave Equation Exploration Platform: a unified solver framework for differentiable wave physics

Shaowen Wang, Tariq Alkhalifah

SWEEP is an open-source package for differentiable seismic wave-equation modeling, migration, and inversion. Users define one-step updates; the framework handles sources, receivers and the adjoint via automatic differentiation. **Cross-platform:** one solver, three interchangeable backends — PyTorch eager, JAX (XLA JIT), and hand-tuned CUDA — plus multi-GPU via DDP and pmap. **Memory-aware:** MemoryOptions, BoundaryOptions and CkptOptions combine boundary-saving with checkpointing and spill saved states to GPU, CPU RAM or disk, cutting adjoint memory by ~90%. **DAS modeling:** a DASElastic equation simulates strain and strain-rate on straight or helical fibers with finite gauge length.







Direct Time-lapse Velocity Change Estimation Using a Guided Diffusion Model

Muhammad Iqbal Khatami, Mohammad Hasyim Taufik, Tariq Alkhalifah

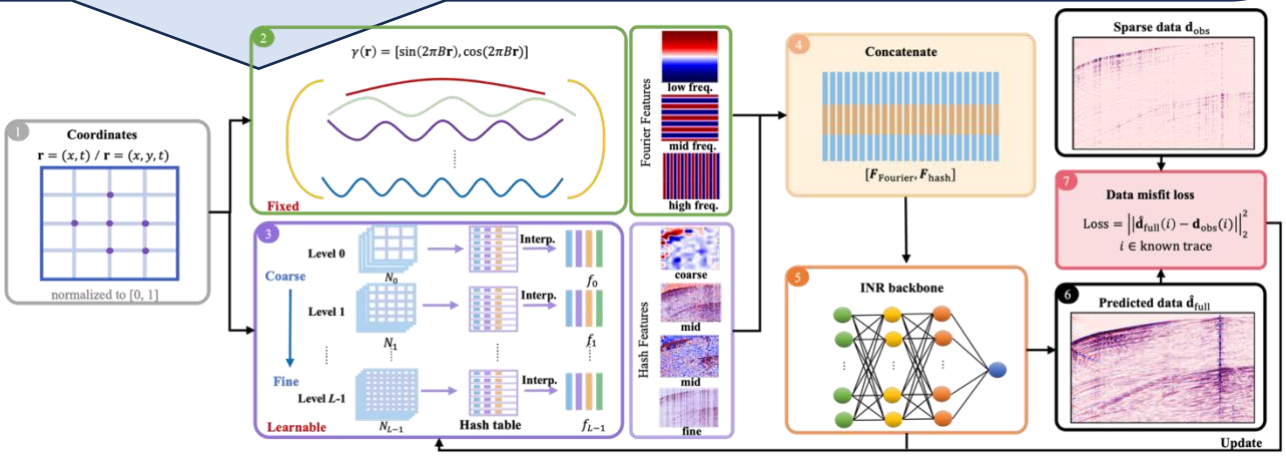
Time-lapse seismic monitoring is widely used to track subsurface changes, but conventional methods such full-waveform inversion are computationally expensive, highly nonlinear, and sensitive to non-repeatability. We propose a guided diffusion framework to directly estimate time-lapse velocity changes from noisy seismic image differences between baseline and monitor surveys. The diffusion model is trained on synthetic data to generate three channels: (1) true velocity changes, (2) image differences, and (3) the true baseline velocity. During inference, we guide the latter two channels to match the observed image differences, and the migration velocity. These guidance indirectly steers the velocity-changes estimation toward accurate and plausible solutions.

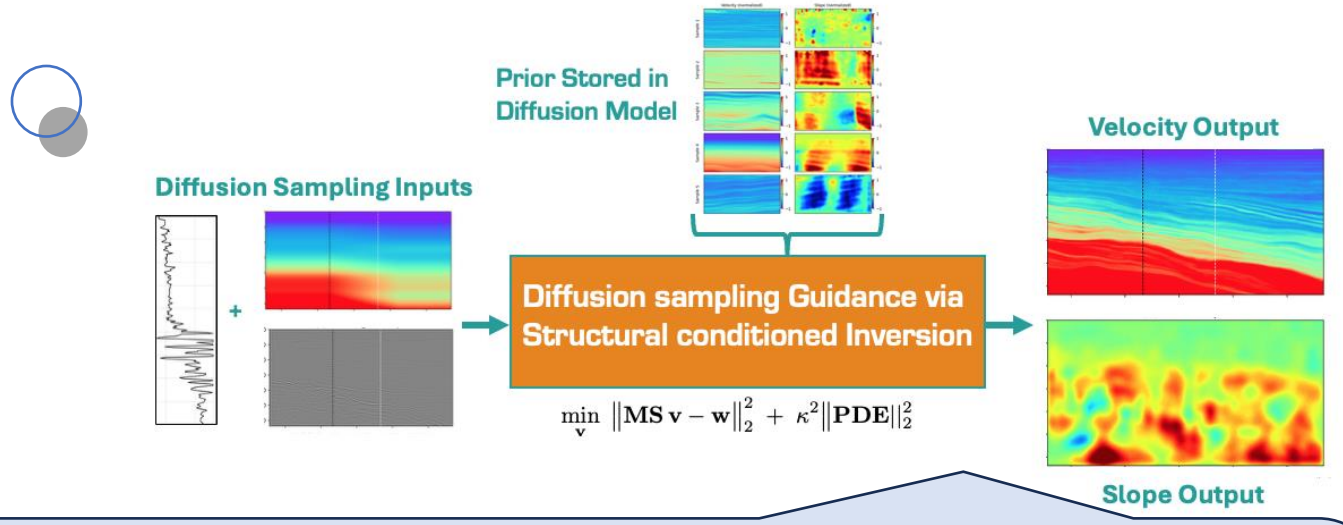
Samples of DeepWave Research

Seismic data interpolation using implicit neural representations with Fourier–hash features

Linrong Wang, Omar M. Saad, Shaowen Wang, Fan Min, Tariq Alkhalifah

Seismic data interpolation is critical for imaging and velocity analysis, but severe undersampling makes reliable reconstruction challenging. Implicit neural representations provide a continuous reconstruction framework, yet spectral bias limits high-frequency detail recovery. A hybrid INR framework is proposed by combining Fourier encoding with multi-resolution hash encoding through adaptive feature weighting. Fourier features are used to preserve global smoothness and structural continuity, while hash features provide learnable local representations for high-frequency recovery. The contributions of both encodings are balanced during optimization, enabling stable global reconstruction and local refinement. Experiments demonstrate improved accuracy and structural coherence under sparse sampling.





Diffusion sampling Guidance via Structural conditioned Inversion

Francesco Brandolin, Tariq Alkhalifah

Developing physics-guided diffusion models for structurally preconditioned velocity inversion, combining generative AI with geophysical constraints **to reconstruct high-resolution subsurface velocity model**s from wells and local slope estimates.

The research integrates **learned geological priors** with structural regularization **to improve the stability, continuity, and geological consistency** for velocity model building workflows.

Recent Publications

Abedi M.M.; Pardo D.; Alkhalifah T., "*Gabor-enhanced physics-informed neural networks for fast simulations of acoustic wavefields*", 2026, Neural Networks, 10.1016/j.neunet.2025.107978.

Abedi M.M.; Pardo D.; Alkhalifah T., "*Least-squares-embedded optimization for accelerated convergence of PINNs in high-frequency acoustic wavefield simulations*", 2026, Computers and Geosciences, 10.1016/j.cageo.2026.106162.

Brandolin F.; Ravasi M.; Alkhalifah T., "*Multichannel Wavefield Reconstruction With Physics-Informed Neural Networks and Transfer Learning*", 2026, Geophysical Prospecting, 10.1111/1365-2478.70149.

Ma X.; Alkhalifah T., "*An Effective Physics-Informed Neural Operator Framework for Predicting Wavefields*", 2026, Journal of Geophysical Research: Machine Learning and Computation, 10.1029/2025JH000899.

Mu X.; Saad O.M.; Alkhalifah T., "*Full waveform inversion with CNN-based velocity representation extension*", 2026, Geophysical Journal International, 10.1093/gji/ggag034.

Saad O.M.; Alkhalifah T., "*Distributed Acoustic Sensing Denoising Using a Self-supervised Conditional Diffusion Model*", 2026, Geophysical Prospecting, 10.1111/1365-2478.70154.

Saad O.M.; Chen Y.; Alkhalifah T., "*U-Trans: a foundation model for seismic waveform representation and enhanced downstream earthquake tasks*", 2026, Scientific Reports, 10.1038/s41598-026-41454-x.

Taufik M.H.; Alkhalifah T., "*Accelerating Bayesian full waveform inversion using reconstruction-guided diffusion sampling*", 2026, Geophysical Journal International, 10.1093/gji/ggag066.

Wang N.; Alkhalifah T., "*A Deep-Learning-Driven Optimization-Based Inverse Solver for Accelerating the Marchenko Method*", 2026, Geophysical Prospecting, 10.1111/1365-2478.70121.

Zhou Z.; Saad O.M.; Liu S.; Liu Y.; Alkhalifah T., "*Enhancing Seismic Data Quality With Gabor-Kernel Unsupervised Denoising of Near-Surface Scattering Noise*", 2026, Geophysical Prospecting, 10.1111/1365-2478.70179.

Alfarhan M.; Ravasi M.; Chen F.; Alkhalifah T., "*Robust full waveform inversion with deep Hessian deblurring*", 2025, Geophysical Journal International, 10.1093/gji/ggae378.

Brandolin F.; Ravasi M.; Alkhalifah T., "*Slope assisted Physics-informed neural networks for seismic signal separation with applications on ground roll removal and interpolation*", 2025, Geophysical Prospecting, 10.1111/1365-2478.70004.

Cheng S.; Alkhalifah T., "*Meta Learning for Improved Neural Network Wavefield Solutions*", 2025, Surveys in Geophysics, 10.1007/s10712-024-09872-6.

Cheng S.; Alkhalifah T., "*Discovery of Physically Interpretable Wave Equations*", 2025, Surveys in Geophysics, 10.1007/s10712-024-09857-5.

Recent Publications (cont'd)

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

Cheng S.; Zhang H.; Alkhalifah T., "*Self-Supervised Seismic Resolution Enhancement*", 2025, IEEE Transactions on Geoscience and Remote Sensing, 10.1109/TGRS.2025.3528414

Park J.-Y.; Saad O.M.; Oh J.-W.; Alkhalifah T., "*Transformer-Based Seismic Image Enhancement: A Novel Approach for Improved Resolution*", 2025, IEEE Transactions on Geoscience and Remote Sensing, 10.1109/TGRS.2024.3510863.

Taufik M.H.; Alkhalifah T., "*Wavenumber-aware diffusion sampling to regularize multiparameter elastic full waveform inversion*", 2025, Geophysical Journal International, 10.1093/gji/ggae437.

News

Mid-year Meeting 2026

The Consortium's Mid-year 2026 Meeting took place on February 9–10, 2026, at KAUST. Organized in a hybrid format, the event featured five focused sessions covering Neural Wavefield Processing and Modeling, Velocity Model Building, Supporting FWI, The Reservoir, and FWI Misfit. We were pleased to welcome both online participants, along with colleagues attending in person, which fostered lively discussions and valuable feedback during the Q&A sessions. Next stop: the Annual Meeting in Houston (Aug. 2026).

Conferences

DeepWave will have a strong presence at two major upcoming conferences. At **EAGE** in Aberdeen, our members will deliver 20 oral presentations and one poster, and at **IMAGE** in Houston, we will continue sharing our latest research with the broader geoscience community. DeepWave will also host a dedicated **exhibition booth** at IMAGE — a great opportunity to highlight recent achievements and connect with collaborators and industry peers.

News (cont'd)

Release of the 4th Annual Report

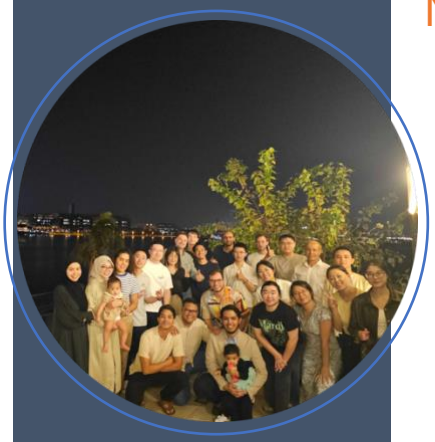
The Annual Report is a dedicated resource for our valued sponsors, offering a transparent account of how their support has driven meaningful progress over the past year — from key research milestones to the tangible outcomes delivered through our collaborations. Our last report (3rd) included 35 papers with associated codes. We look forward to sharing the 4th report in the coming weeks.

Editors' Choice Recognition for Consortium Paper

We are proud to share that a paper co-authored by our own Francesco Brandolin, Matteo Ravasi, and Tariq Alkhalifah has been selected as an **Editors' Choice** article in *Geophysical Prospecting*. The paper, *Slope-Assisted Physics-Informed Neural Networks for Seismic Signal Separation with Applications on Ground Roll Removal and Interpolation* presents a novel approach combining slope information with physics-informed neural networks to tackle seismic signal separation — with promising results in both ground roll removal and data interpolation. This distinction highlights papers that showcase good practice, innovative approaches, and noteworthy advances in our science.

Academic Visitor – Assoc. Prof. Qi Hao

Prof. Hao is based in the College of Geoexploration Science and Technology of Jilin University. He has worked on seismic anisotropy for over 15 years. He was once a postdoc at the Department of Geosciences and Petroleum in the Norwegian University of Science and Technology, where he was supervised by Dr. Alexey Stovas (NTNU) and Dr. Tariq Alkhalifah (KAUST) to study various research problems on seismic anisotropy. He has published 40 papers in international peer-reviewed journals and his current work focuses on seismic attenuation anisotropy.



News (cont'd)

Celebrating Our Recent Alumni Graduates

Hasyim Taufik and **Randy Harsuko**, who both recently graduated in December 2025, are already setting their sights on exciting next steps. Hasyim will be joining Oxy as a Geophysicist, while Randy will continue his research as a Postdoctoral Scholar in the Civil and Environmental Engineering Department at UC Berkeley, concurrently serving as a Research Affiliate at the Energy Geoscience Division of Lawrence Berkeley National Laboratory. We wish them both a bright and successful future ahead!

Our Newest PhD Graduates

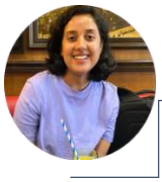
We are thrilled to congratulate two members of our KAUST research group, **Ning Wang** and **Yuanyuan Yang**, on the successful completion of their PhD degrees. Ning defended her dissertation on deep-learning-enhanced multi-dimensional seismic processing and imaging, while Yuanyuan's thesis focused on machine-learning-driven real-time subsurface monitoring using passive and active seismic data. We wish both Ning and Yuanyuan every success as they embark on the next chapter of their careers!

PhD Proposals Passed

We are delighted to congratulate two of our students on successfully passing their PhD proposals! **Vittoria de Pellegrini** and **Xiao Ma** have both cleared this important milestone, demonstrating impressive depth of knowledge and a compelling vision for their research ahead. We wish them every success as they continue their doctoral journeys and look forward to seeing what they achieve.

PhD Qualifying Exam Success

Congratulations to **Muhammad Iqbal Khatami** on successfully passing his qualifying exam! This is a fantastic milestone and we wish him all the best as he moves forward in his PhD journey.



Anjali Dixit | *Postdoctoral Fellow*

New Members

Our team is growing. Learn more about our new additions here.

Tell us a bit about your educational background and previous research roles.

I hold a Ph.D. degree in the field of Earth Sciences with core specialization in development of artificial intelligence (AI) and machine learning (ML) based models to augment the efficiency of oil and gas exploration. Prior to Ph.D., I completed my Master's and Bachelor's in the field of Geosciences and Geo-Informatics respectively. This academic qualification provided a strong interdisciplinary foundation spanning across earth sciences, data analysis, and computational problem-solving. My academic journey is further strengthened by the early-career job experience gained through industry exposure in the multinational companies including CGI, SLB, and Cairn India as full-time employee and summer intern. Wherein I worked on subsurface analysis for mitigating the geohazard and automation of exploration workflows with an aim to reduce the manual errors and redundancies.

What research projects have you completed or contributed to recently?

Recently, I have been working on **estimating elastic parameters from angle-stack seismic data using guidance-based diffusion models**. The key aspect lies in leveraging the probabilistic nature of diffusion models not just for point estimation, but for **uncertainty quantification**. This is particularly valuable in subsurface characterization, where understanding the confidence in predicted elastic parameters (i.e., P-wave velocity, S-wave velocity and density) is as important as the predictions themselves.

Prior to that, I worked on a project related to **Vp/Vs ratio estimation using domain adaptation-based transfer learning**, with a focus on real-world field data applications under limited well control. By applying transfer learning with domain adaptation strategies, the model trained on data-rich source domains could be adapted to target domains where only sparse well control is available and improving generalization and reducing the dependency on extensive ground truth labels for practical deployment.

What are your first impressions being in the KAUST DeepWave team?

My first impressions of joining the DeepWave team at KAUST have been extremely positive. From day one, the team was welcoming and supportive, making my transition into the new research environment smooth and comfortable. The depth of knowledge and helpfulness among its members is impressive. Interactions—whether during research meetings, weekly lunches, or informal discussions—have been intellectually enriching, and I've learned something new from almost every conversation. What I appreciate most is the highly collaborative environment. There's a strong culture of knowledge sharing, constructive discussions, and mutual support, which I believe directly contributes to the team's high-quality research. I was also pleasantly surprised by how the team actively promotes bonding beyond research through sports and recreational activities. It's inspiring to see every member enthusiastically participating, and I genuinely enjoy being part of these activities, finding it exciting to learn a new sport each time. I've also been doing my best to keep up with the team in that aspect as well :P. Overall, my experience so far has been both professionally motivating and personally rewarding.

Hao Zhang | *PhD Student*

Hao Zhang received both his Bachelor's and Master's degrees in **Exploration Geophysics** from China University of Petroleum (East China), where his research focused on seismic processing and velocity inversion using generative diffusion models.

His research interests include the application of deep generative models to FWI, velocity model building, and seismic data processing. Currently, he is applying Flow Matching models to post-FWI prior injection for seismic velocity model refinement.

New Members

Our team is growing. Learn more about our new additions here.

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