



# CSD Annual Report 2025

*VISTA Center for Modeling of Coupled Subsurface Dynamics*



UNIVERSITY OF BERGEN  
*Center for Modeling of Coupled Subsurface Dynamics*

<b>Director’s comments .....</b>	<b>3</b>
<b>About the center .....</b>	<b>4</b>
<b>Research .....</b>	<b>7</b>
<b>Groundbreaking modeling concepts for deformation of porous rocks .....</b>	<b>7</b>
<b>P1.1 Mathematical framework for handling complex geometries.....</b>	<b>7</b>
<b>P1.2 Simulation tool for fully dynamic Biot equations .....</b>	<b>7</b>
<b>P1.3 Microseismic imaging using rock physics-based FWI .....</b>	<b>8</b>
<b>P2.1 Solvers for mixed dimensional flow and mechanics on the fractured-matrix interface .....</b>	<b>9</b>
<b>P2.2. Simulation technology for injection-related fault and fracture reactivation and induced seismicity .....</b>	<b>10</b>
<b>P2.3 Exploring the subsurface using a generalization of Dix’ classic time-to-depth mapping method .....</b>	<b>11</b>
<b>P2.4 Interpretation of fluid-induced seismicity patterns.....</b>	<b>12</b>
<b>Affiliated projects .....</b>	<b>13</b>
<b>Quantifying the relation between Carbon Capture and Storage and earthquake risk (CCS-ER) .....</b>	<b>13</b>
<b>Mathematical and Numerical Modelling of Process-Structure Interaction in Fractured Geothermal Systems (MaPSI).....</b>	<b>14</b>
<b>Network Inpainting via Optimal Transport (NIOT) .....</b>	<b>15</b>
<b>VISTA CSD Researcher Training Program.....</b>	<b>16</b>
<b>Bergen Conference on Modeling and simulation of Coupled Subsurface Dynamics .....</b>	<b>16</b>
<b>Communication workshop .....</b>	<b>17</b>
<b>VISTA Researcher Days in collaboration with the other VISTA centers.....</b>	<b>18</b>
<b>Honors and awards .....</b>	<b>18</b>
<b>Jakub Both awarded 2025 SIAG/GS Early Career Prize.....</b>	<b>18</b>
<b>Jan Martin Nordbotten awarded InterPore medal .....</b>	<b>19</b>
<b>Organization of the Center.....</b>	<b>19</b>
<b>The CSD Board.....</b>	<b>20</b>
<b>Scientific Advisory Board .....</b>	<b>21</b>

<b>Industry reference Group</b> .....	21
<b>Center Management Team</b> .....	21
<b>Journal publications 2025</b> .....	21

## Director's comments

The past year has been characterized by continued scientific progress and strong external recognition of the center's work, reflected in our high-quality, peer-reviewed publications and the interest in our work from the research community. Our interdisciplinary approach, bringing together applied mathematics and geoscience to address complex coupled subsurface processes, remains a strength of the center.

In 2025, we were pleased to secure funding for two new projects from the Research Council of Norway, underscoring the scientific quality of our research agenda. In parallel, our principal investigators have continued to engage in national and international collaborations, further extending the center's scientific network and impact. We were proud to see three PhD candidates successfully defend their doctoral degrees, representing an important milestone both for the individuals and for the center.

To mark the conclusion of our center, a dedicated scientific conference was held on 13–14 May 2025. The conference brought together researchers working on themes aligned with the center's core activities, including coupled deformation, reactive transport, multiphase flow, and seismic wave propagation. The event provided an important arena for scientific exchange and reflection, showing the breadth of the center's contributions and highlighting impactful results.

As we conclude the center's activities, I am encouraged by the solid foundation that has been established through new projects, collaborations, and research initiatives building on the results achieved over the past years. I extend my sincere gratitude to all members of the CSD team, our students, and our collaborators for their dedication and contributions!

Inga Berre  
Center Director



*Photo: Eivind Senneset*

## About the center

VISTA CSD's primary objective is to develop fundamental knowledge and educate next generation researchers to understand how subsurface fluid injection and extraction results in deformation, fault reactivation, and fracturing.

The two research pillars of the center address the potential of *Groundbreaking Modeling Concepts for Deformation in Porous Rocks* (P1) and the demand for understanding of *Fundamentals of Induced Subsurface Deformation* (P2). The third pillar of the center is dedicated to support education and career development for PhD and postdoctoral candidates: The *VISTA CSD Researcher Training Program* (P3). The structure of the center is shown in Figure 1.

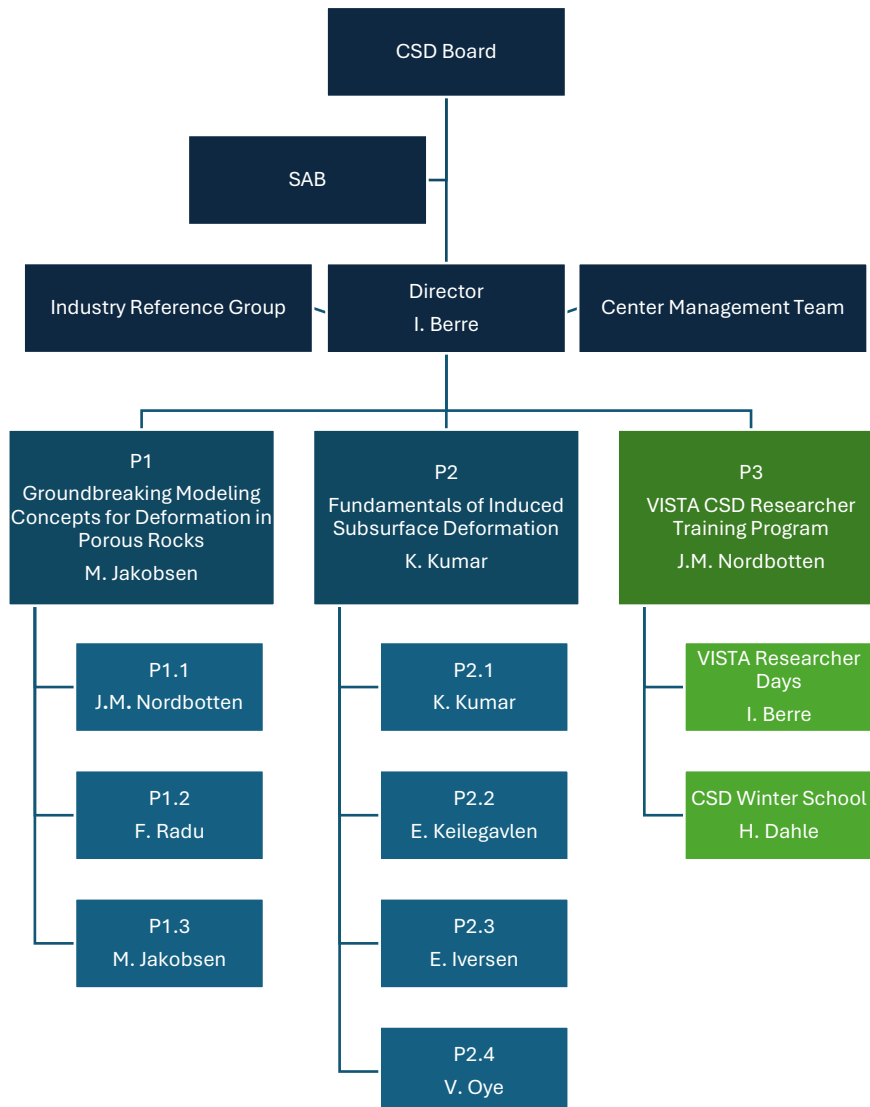


Figure 1 Schematic overview of the center organization structure.

Through mathematical and numerical modeling and data analysis VISTA CSD targets the critical and fundamental research questions: How do thermal, hydraulic, mechanical, and chemical processes interact with the geological structure of the formation to cause significant deformations under production and injection of fluids (Figure 2)? What are the appropriate mathematical models to handle the strong and nonlinear interactions between multiphysics couplings and the complex, but crucial, geometries of existing fault networks? How can new methods aid in seismic data analysis of deforming faulted and fractured formations? How can advanced mathematical and numerical modeling be combined with seismic data analysis in understanding governing mechanisms in induced deformation?

To achieve this, the VISTA CSD has the following secondary objectives:

- provide the mathematical models and simulation technology required to assess interaction between subsurface processes and geological structure
- develop geophysics methods for induced seismicity event location and characterization
- combine simulations with field observations and data analysis
- develop tools to assess the risk of geohazards related to fluid injection and extraction
- train early stage researchers in an integrated scientific environment with day-to-day interaction and collaboration with leading international groups

There are seven research projects funded by VISTA in CSD. These are the projects P1.1-P1.3 and P2.1-P2.4. In addition, three projects are affiliated with CSD. All projects are reviewed below and journal publications for 2025 associated with CSD are listed at the end, they are all open access.

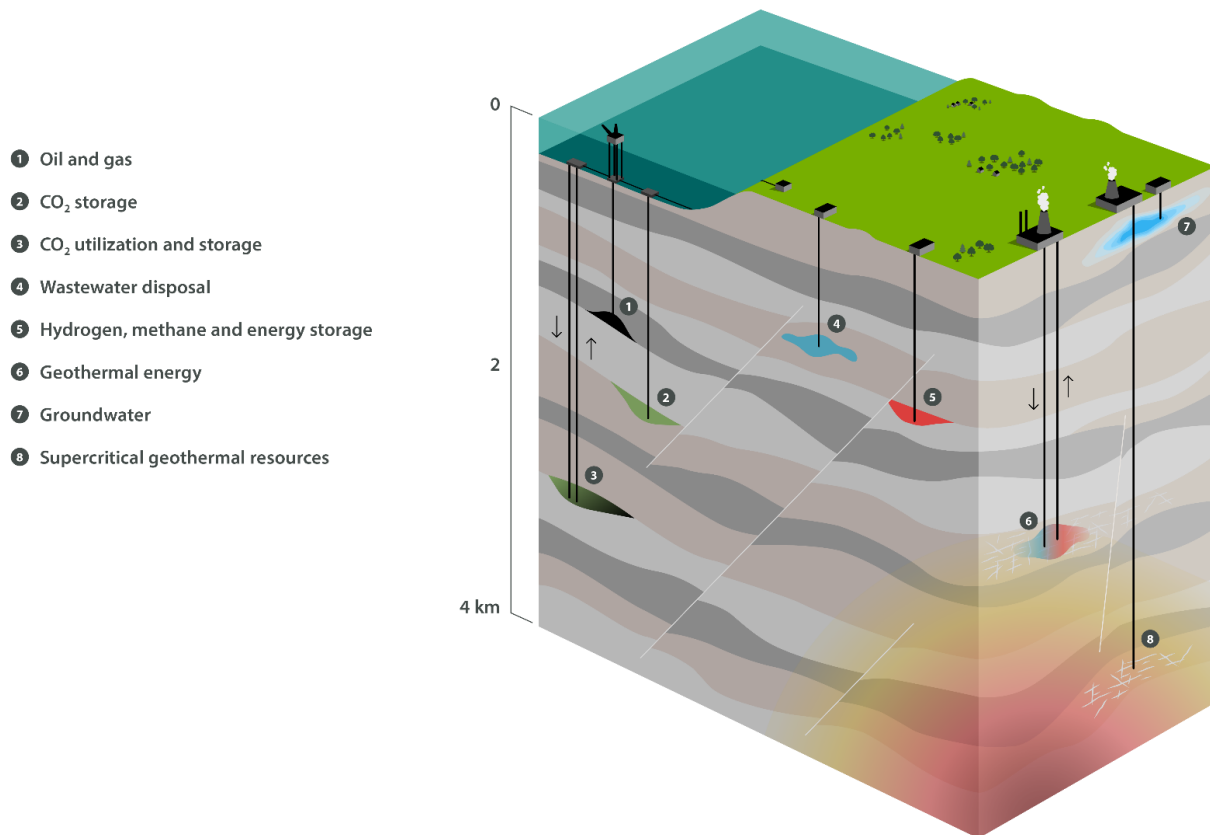


Figure 2 Injection and production of fluid in the subsurface



## Research

### Groundbreaking modeling concepts for deformation of porous rocks

#### P1.1 Mathematical framework for handling complex geometries

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<b>Duration</b>	2022-2025
<b>PI</b>	Jan M. Nordbotten, Dept. Math., UiB
<b>Team</b>	Daniel Førland Holmen (PhD student, started February 2022), Jon Eivind Vatne, Einar Iversen

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This project has reduced the gap between theoretical developments and efficient computational tools in the context of quasi-2D structures such as complex fault and fracture networks. This project already completed a major milestone in 2022, by developing a “roadmap” for the overall strategy for handling the intersection of fractures and wells within the CSD center.

In 2025, the team continued the work on establishing the theoretical foundations for implementing the “roadmap”. In Boon et al (2025), we established the fundamental property that several equidimensional coupled problems (such as fracture porous media and multiple porosity models) are equivalent to Hodge Laplace equations on the Cech-de Rham complex (Figure 3). This result complements earlier work from the group, where we established the link between mixed-dimensional models of fracture and Hodge Laplace equations on the mixed-dimensional and simplicial de Rham complexes. In Holmen et al. (2025) these two perspectives were unified, in the sense that a bounded cochain map was constructed from the simplicial de Rham complex to the Cech-de Rham complex. This construction is a fundamental tool that will allow for an approximation theory between mixed-dimensional and equidimensional models.

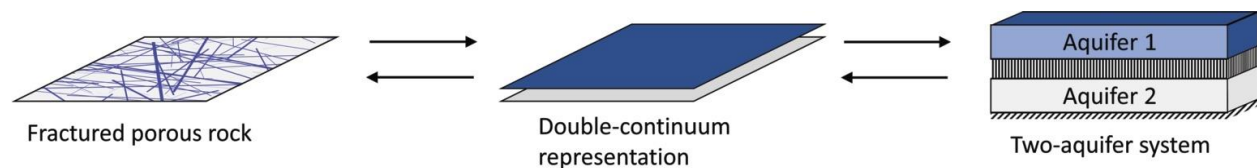


Figure 3 Illustration of physical systems (left and right), whose model equations correspond to Hodge Laplace equations on the Cech-de Rham complex (center). Figure from Boon et al (2025).

#### P1.2 Simulation tool for fully dynamic Biot equations

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<b>Duration</b>	2023-2026
<b>PI</b>	Florin A. Radu
<b>Team</b>	Jakob Stokke (PhD student, started February 2023), Kundan Kumar, Morten Jakobsen

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The aim of the project is to develop an advanced, energy-preserving numerical model and simulation tool for the fully dynamic Biot equations. This will include the prediction of seismic waves. In 2025, the focus has been on developing numerical methods for fully dynamic Biot models, known as the Biot-Allard model. It seems appropriate for the prediction of seismic waves, especially considering it is closely connected to the original Biot 1962 model. This is an interdisciplinary task, done together with the department of earth science.

In the time domain a higher order space-time element method for the fully dynamic Biot model is now implemented. The analysis of the convergence of the implemented finite element scheme is completed. Markus Bause from the Federal Army University Hamburg, Germany is involved in the numerical analysis regarding discretization for the Biot-Allard model.

This project has also included a new direction which overlaps with the techniques used in P1.3 in previous years. The goal has been to study the Biot-Allard system in the frequency domain and focusing on solving the forward problem. An iterative splitting scheme has been proposed, and the analysis of the splitting scheme has been performed. It has been implemented in 2D using the finite element method and the implementation in 3D uses the pseudo-spectral method (PSM) (Figure 4).

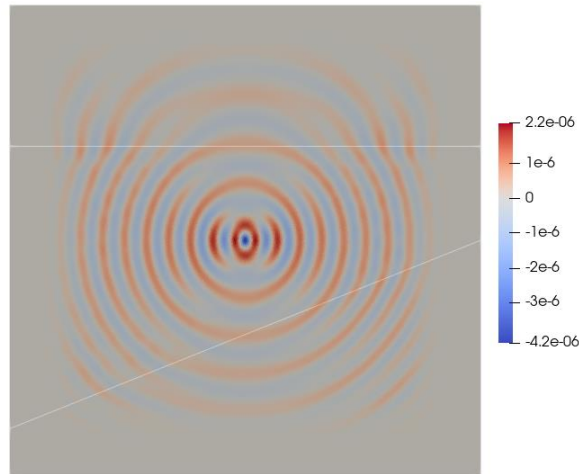


Figure 4 Real part of Y-component of the velocity displacement at 30Hz in a heterogenous medium.

### P1.3 Microseismic imaging using rock physics-based FWI

<b>Duration</b>	2021-2025
<b>PI</b>	Morten Jakobsen
<b>Team</b>	Ujjwal Shekhar (PhD student, started August 2021), Florin A. Radu, Inga Berre, Einar Iversen, Morten Jakobsen

The project advances methodology for microseismic source characterization in fractured anisotropic media using elastic waveform inversion in the time and frequency domains. The emphasis is on combining physically grounded forward models with inversion strategies that remain robust under realistic receiver coverage, moderate noise, and uncertainty in the background model.

The integral-equation solver for efficient wavefield modeling in anisotropic elastic media with moment-tensor sources—developed earlier in P1.3—was complemented in 2025 by functionally equivalent implementations based on finite elements (FEM) and a pseudo-spectral method (PSM). This activity, which solves the elastic wave equation in the frequency domain with a moment-tensor source, emerged from close interaction with Project P1.2 on the Biot-Allard theory.

The main contributions in 2025 focused on iterative inverse scattering algorithms: (i) a fracture-aware, matrix-free distorted Born iterative (DBI) workflow for building VTI/VFTI background models, including radiation-pattern analysis for acquisition design, approximate multi-parameter Hessian information to reduce cross-talk, and validation on synthetic cross-hole/borehole data (Shekhar et al., 2025); and (ii) a time-domain elastic inversion for double-couple microseismic sources that estimates event location and fault-geometry parameters (fault-normal azimuth, dip, rake, slip magnitude) within the fracture-consistent backgrounds (Shekhar, PhD thesis, 2025). Together, these advances deliver a coherent workflow from anisotropic, fracture-consistent background modeling to robust source characterization.

PhD candidate Ujjwal Shekhar successfully defended his PhD thesis in December 2025.

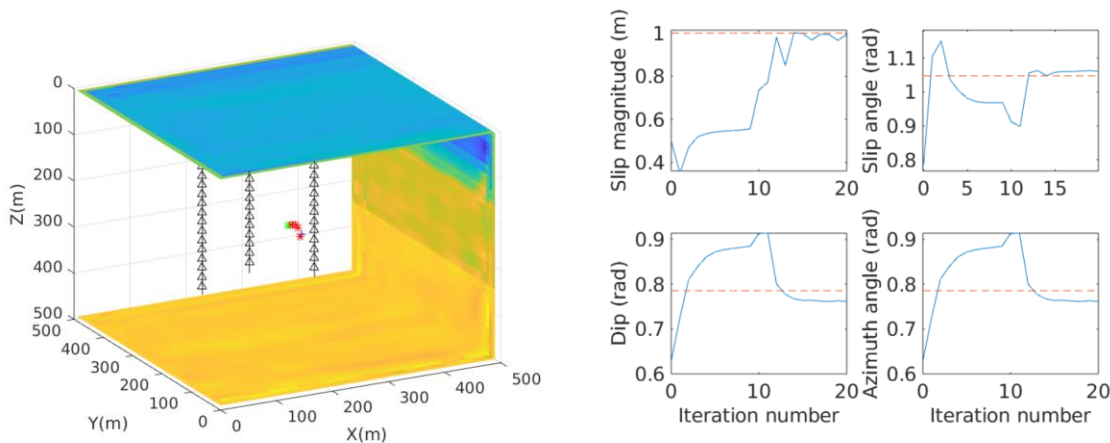


Figure 5 Example from Shekhar’s paper on microseismic source inversion in anisotropic fractured media (event location and fault-geometry recovery in a fracture-consistent VTI/VFTI background).

## P2.1 Solvers for mixed dimensional flow and mechanics on the fractured-matrix interface

<b>Duration</b>	2021-2025
<b>PI</b>	Kundan Kumar
<b>Team</b>	Inga Berre, Ivar Stefansson, Nadia S. Taki (PhD student, started August 2021), Jan M. Nordbotten

The goal is to develop mathematical model and solution approaches to rupture dynamics including advanced friction laws in the presence of fluids (Figure 6). The resulting model is based on coupled differential equations of different dimensions: Biot-Allard in the matrix coupled to flow (on 3D) on the fracture surface as well as friction laws on the fracture interfaces (2D surface embedded in 3D domain).

The project consists of several multi-physics effects coupled together; therefore, the project is divided into several sub-problems to understand the complexity and interaction of the fewer effects. The different ingredients include contact mechanics, friction, flow, and elasticity equations. So far, the following results have been obtained for the subproblems. 1. Linear elasticity including normal forces and friction and rate and state friction model – without considering the flow has been considered. The existence, uniqueness, and boundedness of solution to antiplane shear deformation of static frictional adhesive contact problems was also studied in (Taki, 2025). 2. Multi-rate schemes (different time stepping schemes for the different physical effects) for coupled mechanics and flow – without considering the friction and contact forces has been studied in collaboration with Almani. 3. Considering a continuous problem formulation for flow,

mechanics, friction for a fractured porous medium and proved the well-posedness of the continuous model. Item 1 above from this project forms part of the thesis of Nadia Taki.

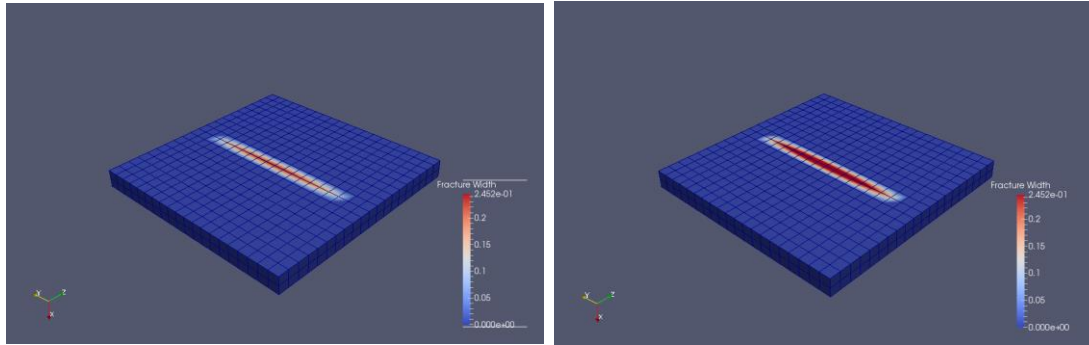


Figure 6 Width of the fracture at  $t = 0.05$  days (left) and at right ( $t = 10$  days).

## P2.2. Simulation technology for injection-related fault and fracture reactivation and induced seismicity

<b>Duration</b>	2021-2025
<b>PI</b>	Eirik Keilegavlen
<b>Team</b>	Inga Berre, Einar Iversen, Volker Oye, Ivar Stefansson, Yuri Zabegaev (PhD student)

The project goal is to develop simulation technology for studying reactivation of faults and fractures related to fluid injection, under influence of a combination of mechanical, fluid, and thermal forces.

In 2025, the project continued its focus on the development of linear solvers for simulations of injection-induced dynamics coupled to frictional deformation of fractures. The preconditioner that was previously (in 2024) developed for flow and mechanics was extended to also include thermal couplings. Furthermore, the machine learning framework for tuning parameters (which were a main focus for the project in 2023) were further extended and coupled to the full linear solver framework. Together, these developments have resulted in a framework that allows users to apply efficient linear solvers while to a large degree being shielded from the complex task of tuning solvers.

The project results from 2025 have been communicated in the PhD thesis of Yury Zabegaev, which was successfully defended in December 2025. The methodology developed in the project is also available in the form of open-source software.

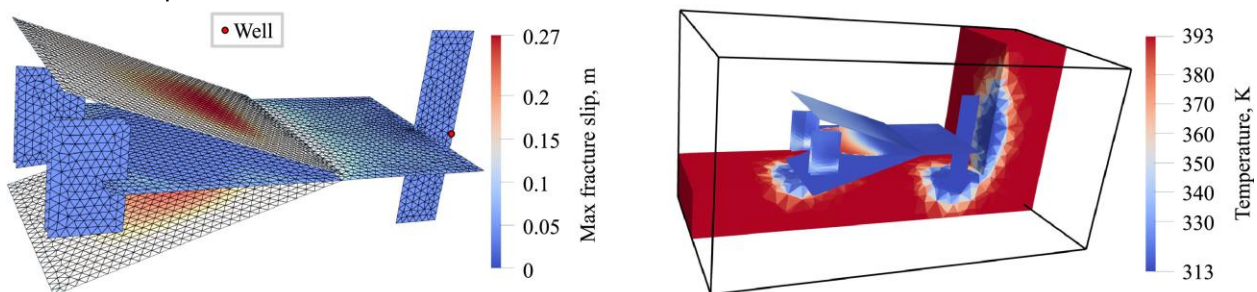


Figure 7 Snapshot of a simulation of cold-water injection, accounting for thermo-poromechanical deformation coupled to fracture contact mechanics.

### P2.3 Exploring the subsurface using a generalization of Dix' classic time-to-depth mapping method

<b>Duration</b>	2022-2025
<b>PI</b>	Einar Iversen
<b>Team</b>	Jokhongir Khayrullaev, Morten Jakobsen, Inga Berre, Einar Iversen

The ambition of this project is to develop new tools for seismic exploration of the subsurface, based on a generalization of Dix' classic time-to-depth mapping method. The main focus in 2025 has been to finalize the research tasks (1) *Estimation of interval P-wave velocities from Dix slowness using an implicit neural representation* and (2) *Seismic velocity inversion with noise evaluation from Dix slowness using a Bayesian neural representation*.

The algorithm in task 1 gives as output a trained neural network model, which can produce smooth interval velocity models with different resolution properties. In 2025, a numerical example using field data was conducted, with convincing results.

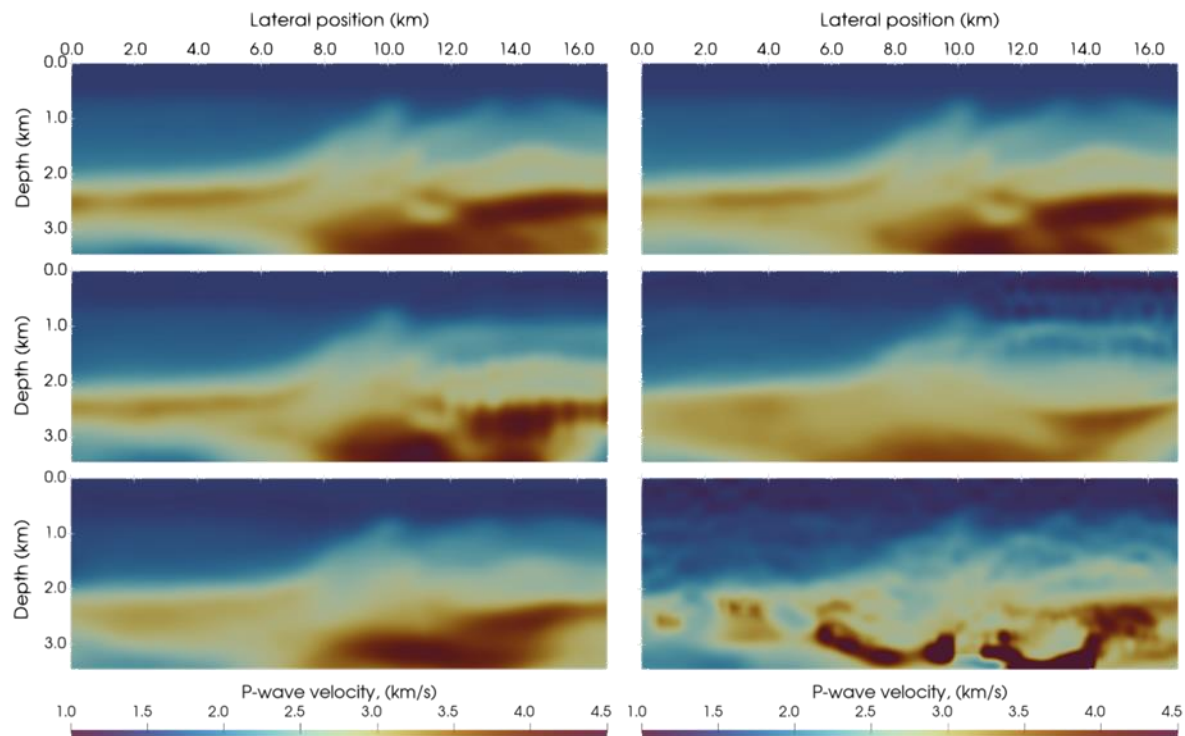


Figure 8 Estimation of P-wave velocities from Dix slowness. Left column: Inverted mean velocities by the implicit Bayesian neural-representations-based method (task 2). Right column: Inverted velocities using the deterministic implicit neural representation method (task1). Rows top-bottom correspond to input data with noise-free, spatially varying, and hybrid data-scaled noise models.

Task 2 arose from the need to account for noise/errors in the input time-migration velocities and to provide uncertainty estimates for the inverted seismic velocities. We introduced an implicit Bayesian neural-representations-based method, with the core idea to (i) invert seismic velocities, (ii) estimate their associated epistemic uncertainty, and (iii) evaluate noise in the input data via heteroscedastic aleatoric uncertainty to control the contribution from individual data points during inversion. The results show that the new approach inverts velocities more accurately from noisy data compared to the implicit deterministic neural representation method (task 1) and the classic Dix methods. The epistemic uncertainty provides meaningful information, and the heteroscedastic aleatoric uncertainty effectively

helps to evaluate noise, although these benefits come at the expense of increased computational cost. These findings indicate that the approach of the method has a potential to benefit other seismic inversion tasks as well.

## P2.4 Interpretation of fluid-induced seismicity patterns

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<b>Duration</b>	2023-2026
<b>PI</b>	Volker Oye
<b>Team</b>	Joanna Holmgren (postdoc, started June 2023), Joern Kaven, Inga Berre, Eirik Keilegavlen

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This activity focuses on the analysis and interpretation of geothermal field data collected continuously over 15 years from the Coso Geothermal Field (CGF) in California, US. The data types include earthquake catalogues, seismicity recordings, and fluid re-injection and production data. The project aims to gain insight into the evolution of the local stress field and how it is affected by long-term injection. The 15 years of data consist of some 130,000 detected and located earthquakes, of which 60,000 are from within the CGF, and production/re-injection data from 146 wellbores. Using 24 local seismic stations, Holmgren has investigated the spatial and temporal trends of earthquakes with magnitudes between -0.4 to 3.8 with respect to different types of geothermal operations. In Holmgren et al. (2025), increased seismicity rates were observed during shut-ins, which are operational pauses in production and re-injection periodically conducted for maintenance on wells and surface infrastructure. Spatial variations were found in the seismic response during shut-ins with some areas responding regularly and others rarely, likely highlighting local differences in stress within the CGF. Additionally, clustering the seismicity using waveform cross-correlation revealed several earthquake clusters primarily occurring during shut-in periods. These observations suggest that certain fracture and fault sections respond repeatedly and rapidly to changes in pore pressure and poroelastic stresses within the geothermal system, possibly highlighting main fluid pathways. In addition, a strong correlation was identified between short-term increase in seismicity rate and seasonal volumetric and temperature variations in the reinjected fluid at the CGF. Moreover, the seismic footprint during peak injection of colder fluids reveals a near-instantaneous response up to 2 km away from the injection well with a directional preference, indicating structural or permeability anisotropy within the reservoir. It is generally agreed that thermal effects mainly affect short distances, however these findings provide observations suggesting that thermal effects can also play an important role in triggering distant seismicity within short time frames. Throughout the whole project period, there have been productive and useful bi-weekly meetings with USGS collaborators.

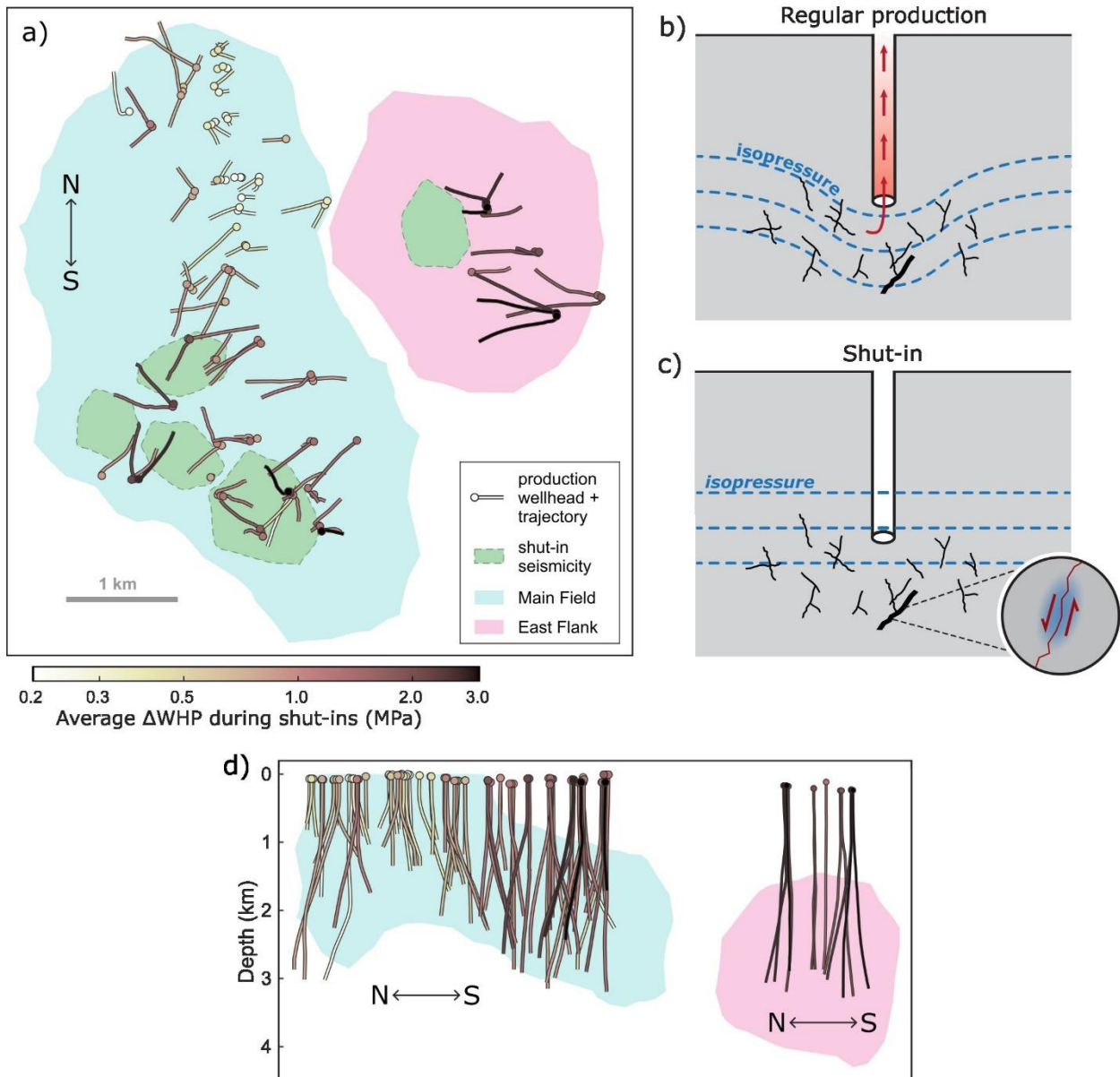


Figure 9 Production wellheads and trajectories in map view coloured by their average change in wellhead pressure ( $\Delta WHP$ ) during the 1996–2010 shut-in periods in (a) map view and (d) depth view. Schematic illustration of the isopressure lines (b) during production and (c) during shut-ins.

## Affiliated projects

### Quantifying the relation between Carbon Capture and Storage and earthquake risk (CCS-ER)

<b>Duration</b>	2021-2026
<b>PI</b>	Mathilde B. Sørensen
<b>Team</b>	Maren K. Karlsen, Mathilde B. Sørensen, Lars Ottemöller

This project aims to quantify the relation between CCS and seismic hazard and risk, the likelihood of earthquakes, and the risk of these earthquakes causing damage. The project will include a field example, evaluating the hazard and risk for a planned storage site at the Horda platform, off the coast of western

Norway. A thorough hazard and risk analysis will help inform industry and policy makers when making decisions towards the UN climate goals, as well as the strategic focus of the Norwegian government on CCS as a future industry.

Activity in 2025 has focused on finalizing a baseline probabilistic seismic hazard model for Norway. This includes compiling and quality checking a homogeneous earthquake catalogue for Norway, developing a model of seismogenic source zones, establishing earthquake activity rates for each source zone, and identifying ground motion prediction models (describing the level of ground shaking as a function of e.g., earthquake magnitude and distance). Input parameters for the hazard model were harmonized with those used for hazard models in the neighbouring Nordic countries through workshops and online meetings with the developers of those modes. This ensured consistency across national borders. A paper on the model was submitted for publication in December 2025. Building on the national model, work has started on expanding the model to an integrated Nordic seismic hazard model, in cooperation with Nordic colleagues. Work has also started towards developing ground motion simulations for scenario earthquakes offshore Western Norway. The aim of this effort is to evaluate the likelihood of earthquakes causing damage or disruption to offshore installations.

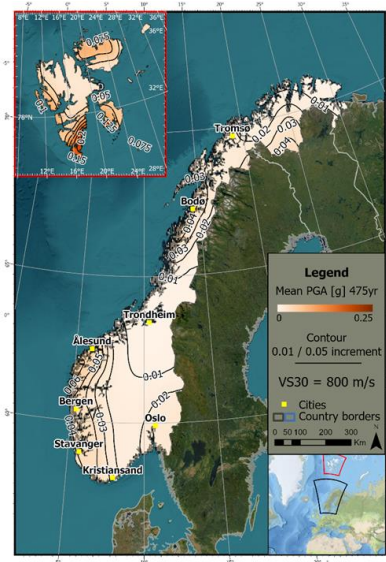


Figure 10 Baseline seismic hazard map for continental Norway and Svalbard, visualising the estimated peak ground motion with a 10% likelihood of exceedance within a 50-year timeframe.

## Mathematical and Numerical Modelling of Process-Structure Interaction in Fractured Geothermal Systems (MaPSI)

<b>Duration</b>	2021-2027
<b>PI</b>	Inga Berre
<b>Team</b>	Hau Trung Dang, Omar Duran, Ingrid Kristine Jacobsen, Jakub W. Both, Eirik Keilegalven, Veljko Lipovac, Jan Martin Nordbotten, Florin Radu, Ivar Stefansson, Micheal Oguntola, Ronghao Cui, Kundan Kumar

The development and production of high-temperature geothermal resources involve large injection-induced gradients in pressure and temperature, leading to complex, coupled subsurface dynamics,

including multiphase flow and deformation of fractured rock. The interaction between these processes and changes in fracture networks remains poorly understood, motivating the ERC-funded MaPSI project.

MaPSI develops advanced mathematical models and simulation tools to assess process–structure interactions in geothermal systems during hydraulic and thermal stimulation. The project focuses on multiphase flow and phase change in thermo-poroelastic media with deforming and propagating fractures, aiming to enhance understanding of complex and coupled physics in development and production of geothermal systems.

Key achievements of the project in 2025 include improved numerical methods for hydro-thermo-mechanical models that simulate fracture slip, and dilation in response to fluid injection, as well as formulations for phase equilibrium that allows simultaneous determination of phase stability and splits over a wide range of subsurface conditions. These models are modular, verified against benchmarks, and integrated into the open-source PorePy framework. The enhanced framework now supports simulations both within MaPSI and across other projects at CSD.

A central result of the project in 2025 was the simulation of a hydraulic stimulation based on field data from the Bedretto site, showing how the methodology can handle realistic scenarios in terms of complex fracture geometries and induced coupled hydro-mechanical dynamics. A substantial review of research literature on thermos-hydro-mechanical modelling of coupled processes in fractured rock was published with international colleagues (Vaezi et al., 2025).

The discretization of the systems of partial differential equations constituting the mathematical models in the MaPSI project is based on Finite Volume methods. In 2025, the project published a study of these methods for wave propagation in heterogeneous, anisotropic, and fractured media (Jacobsen et al., 2025). Tests show it produces accurate and stable results, making it suitable for modeling waves in complicated subsurface structures.

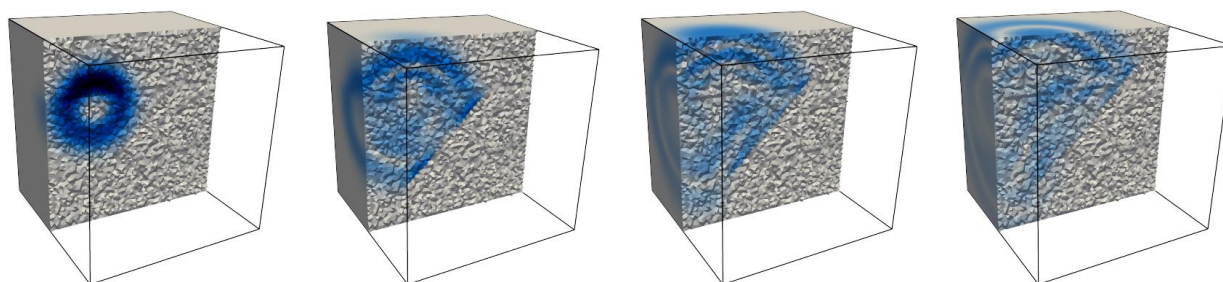


Figure 11 Snapshots of wave propagation in a layered, heterogeneous, and fractured medium. From Jacobsen et al. (2025).

### Network Inpainting via Optimal Transport (NIOT)

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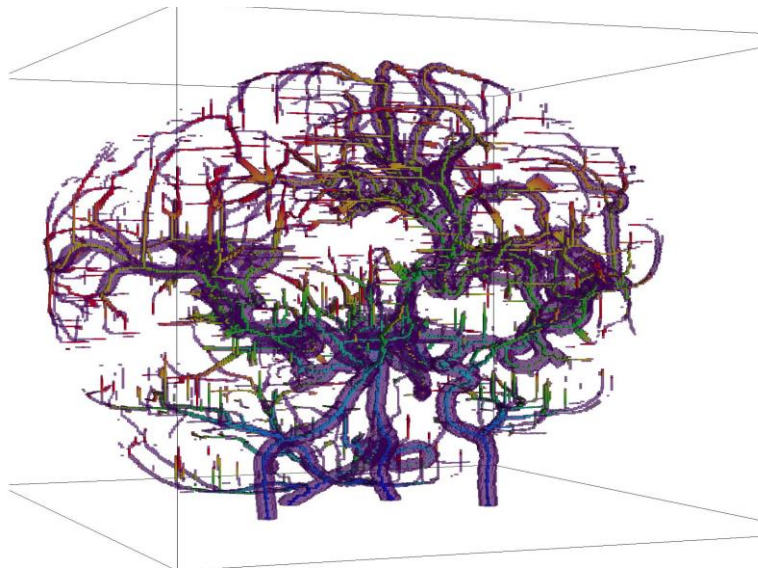
<b>Duration</b>	2023-2025
<b>PI</b>	Enrico Facca
<b>Team</b>	Enrico Facca, Jan M. Nordbotten

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Accurately digitally reconstructing natural networks, such as blood vessels or plant roots, is essential for the accuracy of simulation-driven predictions. However, these structures are often accessible only through non-invasive techniques, leading to artifacts that compromise the reliability of the data and the

derived simulations. No technological solution is currently able to recover digital reconstructions of "real" networks from corrupted images.

*The NIOT (Network Inpainting via Optimal Transport) project aims to fill this technological gap by defining for the first time a robust mathematical formulation of the image network reconstruction problem. In Figure 10 below, an example of a disconnected vascular network obtained by MRI imaging of a human brain is reconstructed using the NIOT approach, where other inpainting approaches fail in capturing the global structure of the network.*



*Figure 12 Illustration of a reconstructed human brain vasculature based on MRI data.*

## **VISTA CSD Researcher Training Program**

As of 31 December 2025, 26 PhD students, post-doctoral fellows, and early-career researchers have been affiliated with the VISTA CSD Researcher Training Program. The training program is progressing according to plan. In 2025, the following activities have been organized

- Weekly CSD seminars
- Bergen Conference on Modeling and Simulation of Coupled Subsurface Dynamics
- Communication workshop
- VISTA Researcher Day in collaboration with the other VISTA centers

## **Bergen Conference on Modeling and simulation of Coupled Subsurface Dynamics**

The Bergen Conference on Modeling and Simulation of Coupled Subsurface Dynamics was organized in collaboration with Interpore Norway's annual meeting on 13-14 May 2025 to celebrate the conclusion of the center. The first day began with presentations given by two of the PIs in the center, Morten

Jakobsen and Kundan Kumar, highlighting all of the work done within the center. It was followed by many interesting talks from international researchers discussing both mathematical modeling and numerical approaches of a range of subsurface phenomena, including induced seismicity and reactive transport. On both days, there were poster sessions given by PhD students in the CSD center, and also by external PhD students.

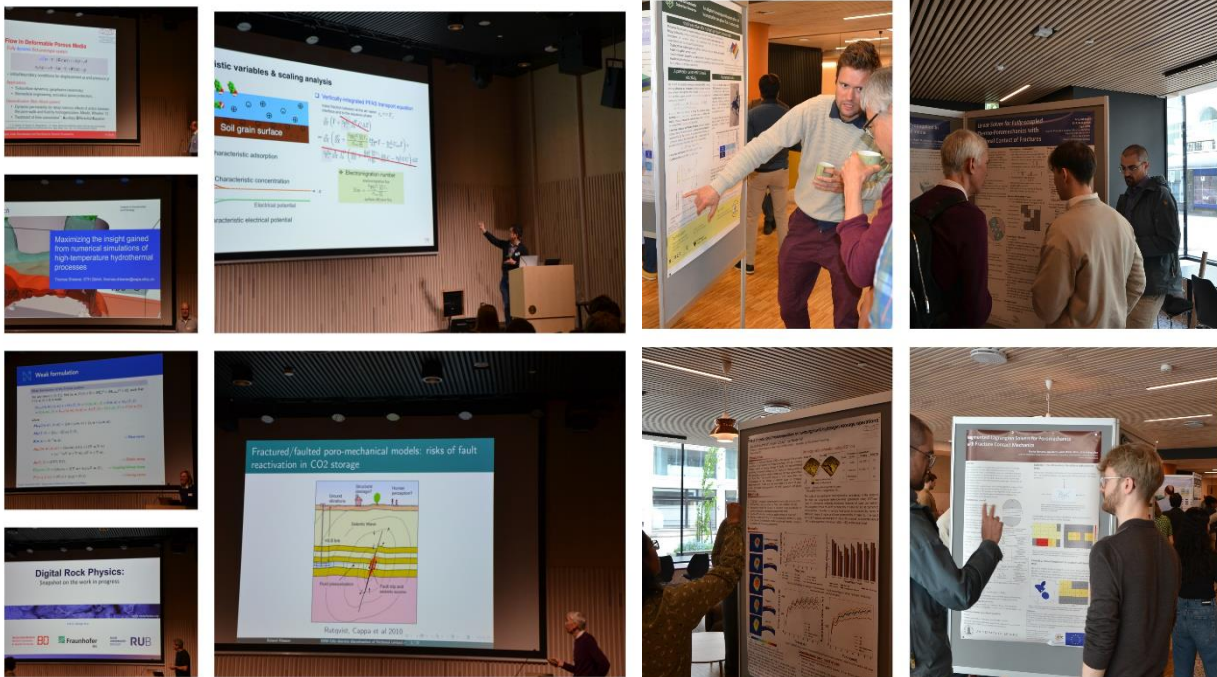


Figure 13 Presentations and poster presentations during the conference.

The Kimberly-Clark Distinguished Lectureship Award is selected by InterPore each year, and for 2025, it was awarded to Rainer Helmig from the University of Stuttgart. During the conference, he gave a talk on the coupling between free flow and porous-medium flow.

## Communication workshop

On the 5th of December, the group organized a workshop to discuss and develop a communication strategy and to improve our current websites. The workshop consisted of two parts. The first part was led by the Communication Division of the university. They presented ideas for visualizing and explaining our science to both specific and broader audiences. It was followed by group work on concrete tasks related to porous media applications. In the second part, the workshop focused on developing our websites and how we can use them more effectively to highlight our work.

## VISTA Researcher Days in collaboration with the other VISTA centers

On 6 February 2025, PhDs from CSD and the other VISTA centres participated in a Researchers day event organized at DNVA focused on how to create impact through science communication.

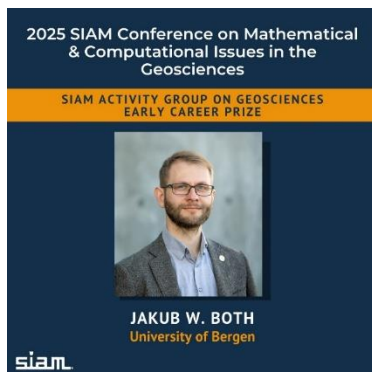
On 7 November 2025, VISTA centre members joined the Researcher Day on “Building Cross-disciplinary Collaboration for the Green Transition”. The day brought together professionals and academics from a range of disciplines to explore how different fields can contribute to the green transition



## Honors and awards

### Jakub Both awarded 2025 SIAG/GS Early Career Prize

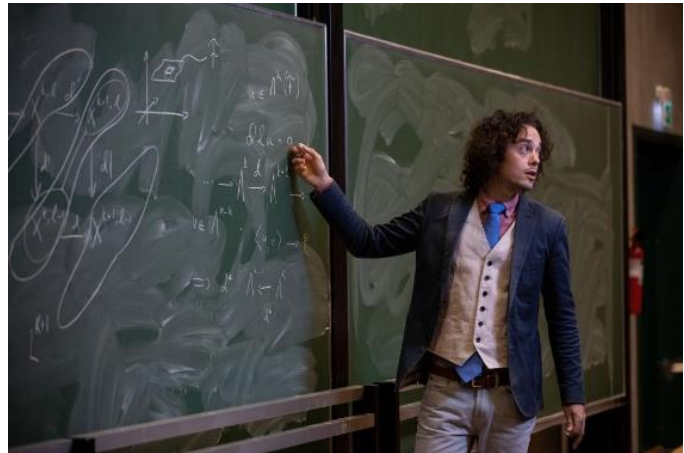
Jakub Both has been awarded the 2025 SIAG/GS Early Career Prize by the Society for Industrial and Applied Mathematics (SIAM). The Society of Industrial and Applied Mathematics (SIAM) was established in 1952 and has as its mission to build cooperation between mathematics and the worlds of science and technology.



## Jan Martin Nordbotten awarded InterPore medal

Jan Martin Nordbotten was awarded the InterPore Medal for porous media research in 2025. From the InterPore newsletter:

"Professor Jan Nordbotten is well-recognized as one of the leading experts in mathematical modelling and numerical simulation in connection with porous media applications. He earned his degree from the University of Bergen at 21 years old, becoming the youngest ever to obtain a Doctorate degree in Norway. He later became a Full Professor in Applied Mathematics at the age of 27. He has an extensive record of outreach and service all over the world and has made substantial contributions on relevant fields connected to porous media research."



## Completed PhDs

This year the two first PhD students in the centre finished. On the 15<sup>th</sup> of December Yury Zabegaev successfully defended his PhD thesis titled "Design and Optimization of Preconditioners for Contact Thermo-Hydromechanics in Fractured Porous Media". Also, on the 18<sup>th</sup> of December Ujjwal Shekhar successfully defended his PhD thesis titled "Microseismic source characterization in fractured anisotropic media using elastic waveform inversion".



## Organization of the Center

The Board is CSD's formal decision body. The Center Director is supported by the Center Management Team (MT) and the Industry Reference Group. The Scientific Advisory Board (SAB) reports to the CSD Board and gives advice to the Center Director. An overview of the organization structure of CSD is provided in the chart above.

## CSD PIs and project leaders



CSD Principal investigators and project leaders. From left: Jan M. Nordbotten, Jakub W. Both, Helge Dahle, Einar Iversen, Inga Berre, Kundan Kumar, Eirik Keilegavlen, Mathilde Sørensen, Morten Jakobsen, Florin Radu. Enrico Facca and Volker Oye were not present.

## The CSD Board

### Kenneth Ruud (Chair)

Director General at The Norwegian Defence Research Establishment (FFI)



### Antonella Zanna Munthe-Kaas

Professor and Head of Department, Department of Mathematics, University of Bergen



### Anne Marit Blokhus

Professor, Department of Chemistry, University of Bergen



**Atle Rotevatn**, Professor and Head of the Department of Earth Science, University of Bergen



### Unni Olsbye

Professor, Department of Chemistry, University of Oslo



**Roger Sollie**, Academia Program manager at Equinor



## Scientific Advisory Board

The task of the CSD Scientific Advisory Board (SAB) is to contribute to realizing the center's main goals and give advice to the center director and host institution. The CSD board has appointed the following Scientific Advisory Board for CSD:

- Prof. Paola Francesca Antonietti, Politecnico di Milano
- Prof. Stefan Buske, TU Freiberg
- Prof. Insa Neuweiler, University of Hannover

## Industry reference Group

The CSD industry reference group has eight members:

- Geir Terje Eigestad, Harbour Energy
- Ketil Hokstad, Equinor
- Leo Eisner, Seismik
- Gunnar Gunnarsson, Orkuveita Reykjavíkur
- Guðjón Helgi Eggertsson, HS Orka
- Lilja Magnúsdóttir, HS Orka
- Anette Mortensen, Landsvirkjun
- Hilmar Már Einarsson, Landsvirkju

## Center Management Team

The center management team consists of Prof. Inga Berre (Center Director), Prof. Morten Jakobsen (P1 Coordinator), Prof. Kundan Kumar (P2 Coordinator) and Prof. Jan Martin Nordbotten (P3 Coordinator).

## Journal publications 2025

Alghannam, M., Nordbotten, J., & Juanes, R. (2025). Stick-slip from heterogeneous Coulomb friction. *Physical Review E*, 111, 055505.

Banshoya, S., Berre, I., & Keilegavlen, E. (2025). A simulation of the impact of fracture networks on the co-production of geothermal energy and lithium. *Geothermal Energy*(1), 31.

Berre, I., Antonietti, P., Helmig, R., Hesse, M., & Nordbotten, J. (2025). Regional-Scale Subsurface Modeling. *InterPore Journal*, 2(2), IPJ040625-2.

Boon, W., Duran, O., & Nordbotten, J. (2025). Mixed Finite Elements for Cosserat Elasticity. *SIAM Journal on Numerical Analysis*, 63(1), 306-333.

Boon, W., Holmen, D., Nordbotten, J., & Vatne, J. (2025). The Hodge-Laplacian on the Čech-de Rham complex governs coupled problems. *Journal of Mathematical Analysis and Applications*, 129692.

- Both, J., & Cancès, C. (2025). A global existence result for weakly coupled two-phase poromechanics. *SIAM Journal on Mathematical Analysis*, 57(5), 4995-5038.
- Holmen, D., Nordbotten, J., & Vatne, J. (2025). Injective cochain map between the simplicial de Rham complex and the Čech-de Rham complex. *ESAIM: Mathematical Modelling and Numerical Analysis*, 59(5), 2491-2514.
- Holmgren, J., Kaven, J., & Oye, V. (2025). Long-Term Trends in Microseismicity During Operational Shut-Ins at the Coso Geothermal Field, California. *The Sesimic Record*, 5(1), 73-82.
- Jacobsen, I., Berre, I., Nordbotten, J., & Stefansson, I. (2025). A Finite Volume Method for Elastic Waves in Heterogeneous, Anisotropic and Fractured Media. *ARC Geophysical Research*, 1(1), 11.
- Nordbotten, e. a. (2025). Benchmarking CO<sub>2</sub> storage simulations: Results from the 11th Society of Petroleum Engineers Comparative Solution Project. *International Journal of Greenhouse Gas Control*, 148, 104519.
- Nordbotten, J., & Keilegavlen, E. (2025). Two-point stress approximation: A simple and robust finite volume method for linearized (poro-)mechanics and Stokes flow. *Computers & Mathematics with Applications*, 197(1), 259-294.
- Riethmueller, C., Storvik, E., Both, J., & Radu, F. (2025). Well-posedness analysis of the Chan-Hilliard-Biot model. (84), 104271.
- Shekhar, U. (2025). *Microseismic source characterization in fractured anisotropic media using elastic waveform inversion*. Bergen: University of Bergen, PhD Thesis.
- Shekhar, U., Jakobsen, M., Pšenčík, I., & Xiang, K. (2025). Seismic full waveform inversion for fracture parameters in anisotropic media. *Geophysical Prospecting*, 73(5), 1606-1634.
- Taki, N. S. (2025). Weak solvability of elliptic variational inequalities coupled with a nonlinear differential equation. *Nonlinear Analysis: Real world applications*, 81, 104216.
- Vaezi, I. Y.-C. (2025). A review of thermo-hydro-mechanical modeling of coupled processes in fractured rock: From continuum to discontinuum perspective. *Journal of Rock Mechanics and Geotechnical Engineering*.
- Zabegaev, Y. (2025). Design and optimization of preconditioners for contact thermo-hydromechanics in fractured porous media. Bergen: University of Bergen, PhD Thesis.

