CSD Annual Report 2024

VISTA Center for Modeling of Coupled Subsurface Dynamics

UNIVERSITY OF BERGEN
Center for Modeling of Coupled Subsurface Dynamics

Director's comments

The past year was marked by significant achievements. I am pleased to acknowledge the Scientific Advisory Board's (SAB's) positive evaluation of our center's accomplishments. Their recognition of our research output, particularly the high-quality, peer-reviewed publications involving our PhD students, underscores the progress we have made over the last few years. The SAB's commendation of our interdisciplinary approach highlights one of our core strengths—bringing together applied mathematics and geoscience to address the multifaceted challenges in understanding coupled subsurface processes. In 2024, based on the recommendations from SAB, we have increased collaborations between projects and strengthened our public communication about the center's contributions.

In 2024, we reached 24 early career researchers affiliated with our researcher training program. Two new projects secured funding from the Research Council of Norway's FRIPRO program for basic, excellent research, and our PIs have partnered in several additional national and international projects that commenced this year.

As we enter the final year of the research center, I am delighted to see the launch of several new collaborations, research projects, and initiatives, building on the results we have achieved so far. I extend my heartfelt gratitude to the CSD team and our collaborators for their contributions to all our activities in the past year!

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). In addition, the center currently has six affiliated research projects, structured in a separate pillar. The structure of the center is shown in Figure 1.

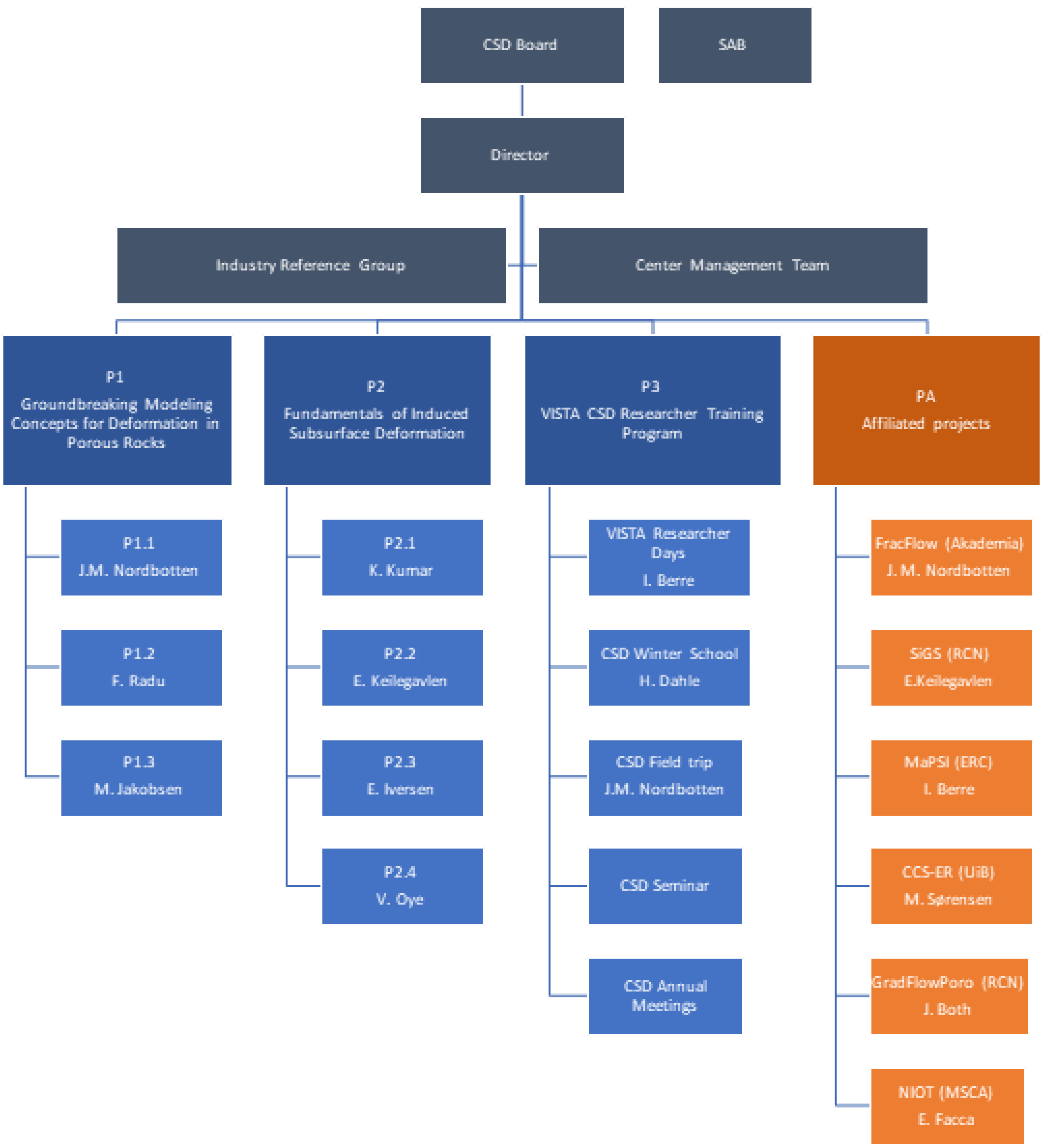

Figure 1 Center structure

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? 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, eight projects are affiliated with CSD. All projects are reviewed below.

Research

Groundbreaking modeling concepts for deformation of porous rocks

P1.1 Mathematical framework for handling complex geometries

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

The goal of this project is to further close the gap between theoretical developments and efficient computational tools in the context of quasi-2D structures such as complex fault and fracture networks and quasi-1D structures such as wells. This project already achieved a major milestone in 2022, by developing a “road-map” for the overall strategy for handling the intersection of fractures and wells within the CSD center.

In 2024, the team continued the work on establishing the theoretical foundations for implementing the “road-map”. Building on the two publications from 2023 there have been work on both establishing an a priori theory for the difference between equidimensional and mixed-dimensional models, realized in the setting of (respectively) Cech-de Rham complexes and simplicial de Rham complexes. Moreover, during fall of 2024 Holmen spent 5 weeks on initiating a collaboration with Kaibo Hu at Edinburgh University, which furthers some of our past work on mixed-dimensional and simplicial de Rham complexes as applied to elastic solids.

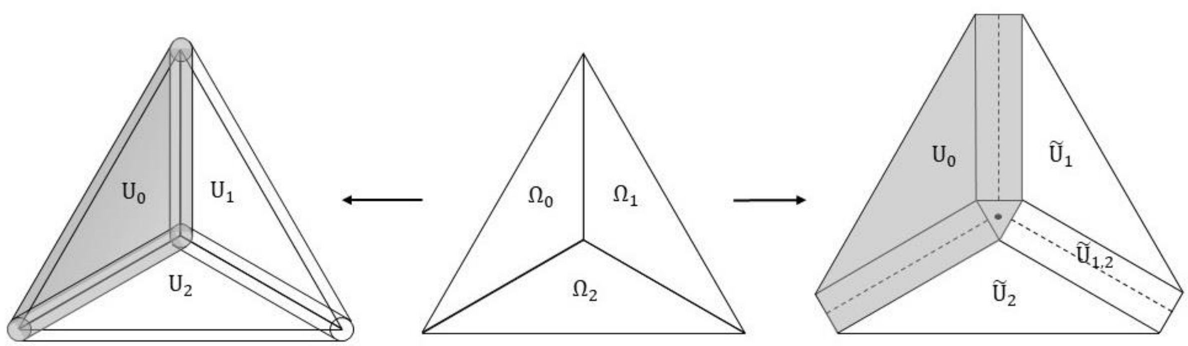

Figure 1: Illustration of two different equi-dimensional conceptualizations of the same mixed-dimensional geometry. Left: An equi-dimensional partitioning obtained by including all points ϵ-close to the mixed-dimensional geometry. Right: An equi-dimensional partitioning obtained by giving lower-dimensional components a generalized width 2ϵ.

The work in this project has been presented at various international conferences and workshops.

P1.2 Simulation tool for fully dynamic Biot equations

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

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 2024, there has been a continuation of the study of different fully dynamic Biot models, with the aim of identifying which one is the most appropriate for the prediction of seismic waves. This is an interdisciplinary task, done together with the department of earth science. A special focus has been given to the dynamic Biot models with and without history terms. This resulted in a proof of the existence and uniqueness of a solution for a dynamic Biot model with history (in terms of a convolution) in Stokke et al (2024).

The analysis of the convergence of higher – order space time elements for a simplified dynamic Biot model was performed by Bause et al. (2024). A fixed-stress splitting scheme was analyzed by Kraus et al. (2024) and new type of splitting schemes for the quasi-static Biot model were proposed by Nuca et al. (2024).

There is now a working implementation of higher order space-time elements for the dynamic Biot model (with and without history). At the moment the analysis of the convergence of the implemented finite element scheme and testing the differences between the models with and without history is nearly completed.

Markus Bause from the Federal Army University Hamburg, Germany is involved in the numerical analysis regarding discretization and splitting schemes for the fully dynamic Biot model. Moreover, Stokke spent a month in Hamburg with Bause during the winter.

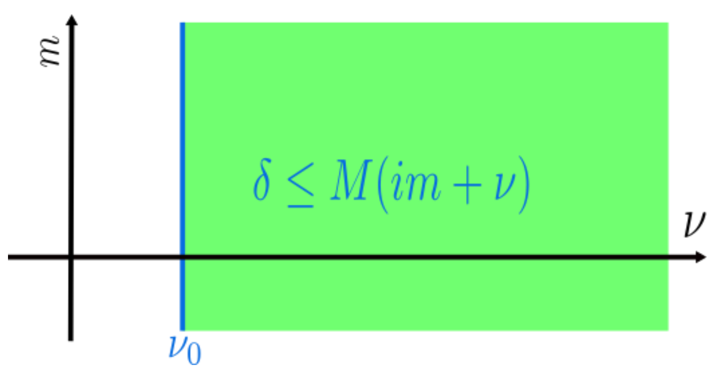

Figure 2 Illustration of the condition for well-posedness on the material law in Stokke et al 2024, i.e. that the material law stays positive in the complex half plane with a real part larger than zero.

P1.3 Microseismic imaging using rock physics-based FWI

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

The main goal of this project is still to develop scattering based approaches to microseismic full-waveform inversion (FWI). This includes developing efficient integral equation methods for solving the direct scattering problem; that is, to compute the microseismic wavefield in a heterogeneous anisotropic elastic medium due to a moment tensor source. Also, it includes the development of efficient nonlinear tensorial inverse scattering algorithms for reconstruction of the anisotropic elastic background model as well as the parameters of the microseismic source (source location, ignition time and moment tensor) from seismic and/or microseismic waveform data.

A paper reporting from the development of an efficient integral equation method for modelling the microseismic waveform data due to a moment tensor source in an anisotropic elastic media with variable stiffness tensor and mass density fields was accepted and published as an early view in 2023, but the final journal paper by Shekhar et al. (2024) is included in the reference list of this annual report.

PhD candidate Ujjwal Shekar has been working on the estimation of fracture parameters in VTI media where he has used a distorted Born Iterative method. In addition, a frequency domain full waveform inversion method for parameters in a 2D VTI media has been developed and presented at an international conference. In collaboration with Kui Xiang, both Shekhar and Jakobsen have worked on a new matrix-free approach for the full waveform inversion in anisotropic elastic media. Here they have included density variation by using the distorted Born iterative method. Shekar has also made progress towards the characterization of microseismic sources in anisotropic elastic background media.

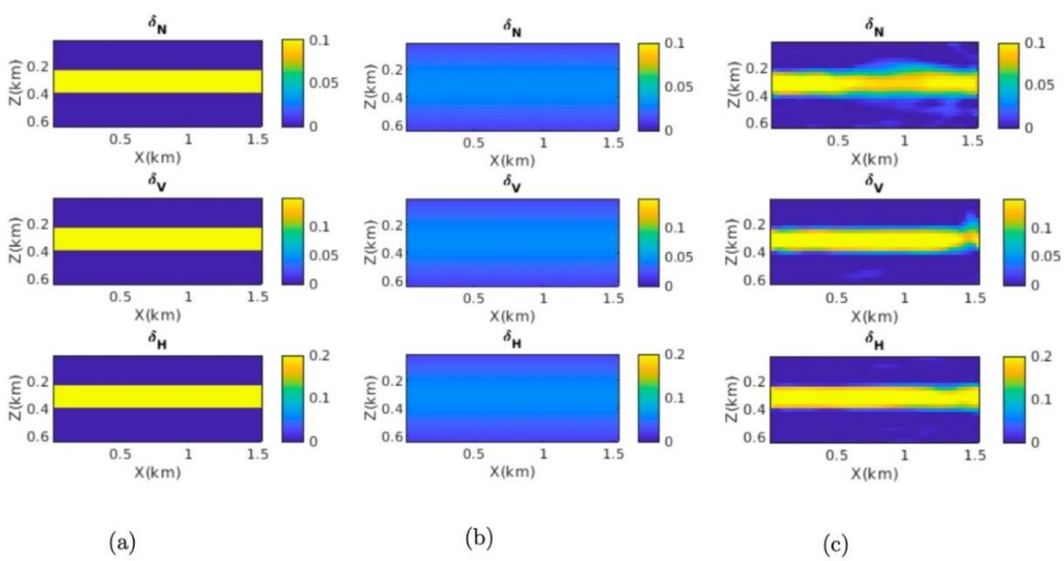

Figure 3: An example of the reconstruction of fractures in VTI media. A population of small-scale vertical fractures are represented by an anisotropic effective medium. The linear slip model parameters of the fractures are reconstructed from borehole seismic waveform data. It is important to account for anisotropy and fractures in the background model to obtain accurate microseismic imaging. The figure is taken from a paper submitted by Shekhar et al. to Geophysical Prospecting, which is currently under review. Images (a), (b) and (c) represent the true model, the initial model and the inverted model, respectively. Note the good match between the true and inverted models.

Work related to the direct scattering problem in acoustic media with variable density has also been performed. More specifically, developed a stabilized splitting scheme for solving two coupled integral equations for the pressure and pressure gradients fields generated by a controlled source in such acoustic media. Other examples of interdisciplinary research performed within the framework of P1.3 include the development of an efficient iterative method for solving coupled integral equations arising in poroelastic scattering. This is relevant for forward modelling in microseismic waveform data in fluid-saturated porous media and closely related to the activities in P.1.2.

Fundamentals for induced subsurface deformation

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

Duration	2021-2025
PI	Kundan Kumar
Team	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. 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 discussed in a paper by Taki and Kumar (2024). 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 discussed in the paper by Almani et al. (2024). 3. Considering a continuous problem formulation for flow, mechanics, friction for a fractured porous medium and proved the well-posedness of the continuous model. This is submitted and under reviewing process.

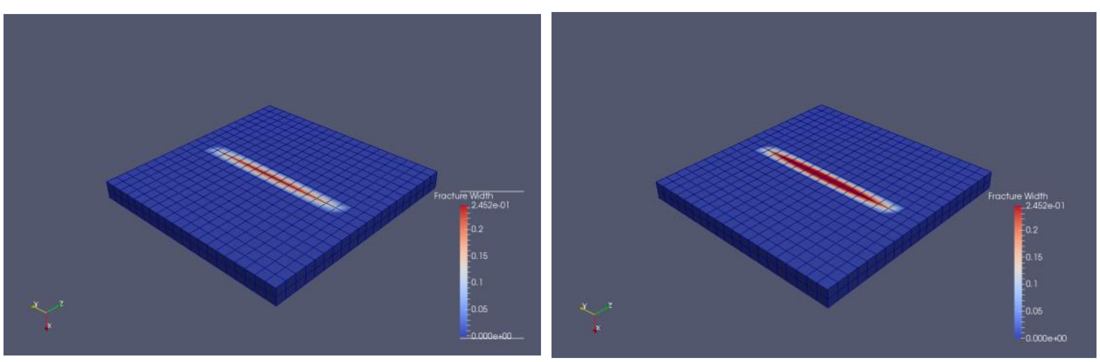

Figure 4 Width of the fracture at t = 0.05 days (left) and at right (t = 10 days).

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

Duration	2021-2025
PI	Eirik Keilegavlen
Team	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.

The focus of the project in 2024 has been the development of a preconditioner for linear systems arising from fully coupled simulations of poromechanics and frictional contact mechanics. The research has involved both theoretical analysis of the derived preconditioner, and the implementation of an efficient and robust preconditioner that can be applied for more practical simulations. The results have been published as a pre-print, moreover, the algorithm developed is available as open-source software.

Overall, the work on this project is progressing according to plans and the project goals are expected to be fully completed.

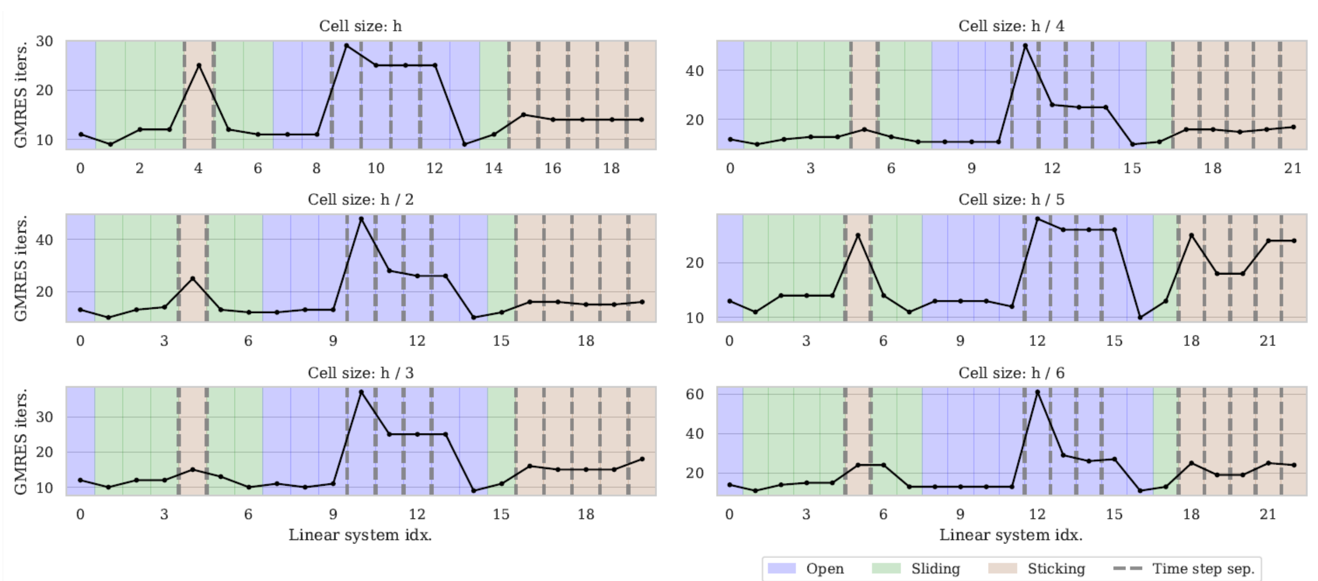

Figure 5: The number of linear solver iterations in a simulation of poromechanical deformation with fracture contact mechanics. Each point on the X-axis corresponds to a Newton iteration, vertical gray stippled lines mark the end of time steps. The background color shows the most prominent fracture state. The subfigures show increasingly fine grids.

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

Duration	2022-2025
PI	Einar Iversen
Team	Jokhongir Khayrullaev (PhD student, started August 2022), Morten Jakobsen, Inga Berre, Einar Iversen

The goal of the project is to develop new tools for seismic exploration of the subsurface, which rely on a generalization of Dix' classic time-to-depth mapping method.

In 2024 the main tasks have been to establish a functional algorithm for generalized Dix inversion and to write a first paper related to the chosen approach.

The main objective of the work is to estimate a smooth representation of the interval velocity from the Dix velocity. This is achieved by combining ray tracing (of so-called image rays) with the application of a deep neural network. It turned out useful for the stability of the inversion to express the objective function with respect to the inverse Dix velocity, rather than in terms of the Dix velocity itself. As output, the algorithm yields a model of the (depth-domain) interval velocity in Cartesian coordinates, as well as a trained neural network model. The latter can be used for generating smooth interval velocity models with different resolution properties.

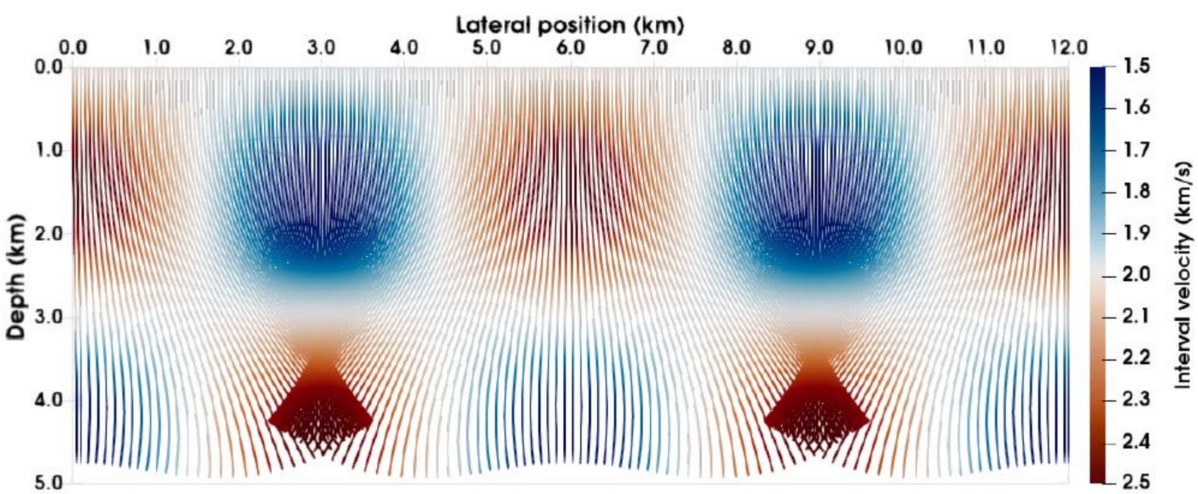

Figure 6 Image rays (lines) and interval velocity along the rays (line color), in an analytic test model referred to as the Sinusoidal model. The interval velocity has quite a strong variation locally, which results in the formation of caustics.

P2.4 Interpretation of fluid-induced seismicity patterns

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

This activity focuses on the analysis and interpretation of geothermal field data collected continuously over 14 years from the Coso Geothermal Field in California, US. The data types include earthquake catalogues, seismicity recordings, and fluid 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 14 years of data consist of some 133.000 detected and located earthquakes and production/injection data from 146 wellbores, including periods where injection and production were paused. Holmgren has investigated these so-called shut-in periods with respect to their relation to stress field changes and the potential to lead to induced seismicity. In geothermal fields, shut-ins are periodically conducted for maintenance on wells and surface infrastructure, thereby offering recurring means of estimating stress changes in the subsurface that lead to increased seismicity rates. Here, an examination of daily production and microseismicity data from the Coso Geothermal Field (CGF) in California between 1996 and 2010 is performed to investigate the repetitive trends of operational shut-in microseismicity. Using 24 local seismic stations, the spatial and temporal trends of over 60,000 earthquakes with magnitudes between -0.4 to 3.8 are analyzed. The northern region exhibits no significant seismicity changes during shut-ins, whereas the rest of the field experiences induced seismicity during almost every shut-in with an increasing intensity towards the southern and eastern portions of the field, possibly highlighting local differences in stress within the CGF. Additionally, by clustering the seismicity using waveform cross-correlation, revealing several earthquake clusters primarily occurring during shut-in periods. These observations suggest that certain fracture and fault sections respond rapidly to changes in pore pressure and poroelastic stresses within the geothermal system, possibly highlighting main fluid pathways.

Throughout the whole project period, there have been productive and useful bi-weekly meetings with USGS collaborators and Joanna Holmgren had the opportunity to have an external research stay at the USGS offices in California.

Affiliated projects

Simulation of governing processes in superheated and supercritical geothermal systems: mathematical models, numerical methods and field data (SiGS)

Duration	2020-2024
PI	Eirik Keilegavlen
Team	Shin Irgens Banshoya, Inga Berre, Sæunn Halldorsdottir

The project aims to combine simulation and field data analysis for thermal, hydraulic, mechanical, and chemical (THMC) processes in supercritical geothermal reservoirs. The project focuses on two mechanisms that are critical to understand superheated and supercritical geothermal systems: Heat transport from deep sources towards the geothermal reservoir and thermal stimulation caused by the introduction of cold fluids during drilling or reinjection. Development of simulation technology for multiphysics problems is also a core activity in the project.

In 2024, the project continued work on simulation technology for reactive transport of water-borne chemicals in fractured porous media. Previous work, that considered equilibrium reactions in relatively small reaction systems, has been extended to also include kinetic reactions in systems with dozens of chemical species and more than a hundred reactions. These results were reported in Banshoya et al.

(2024). The project has also investigated the feasibility of co-production of geothermal energy and lithium, with the findings reported in a preprint.

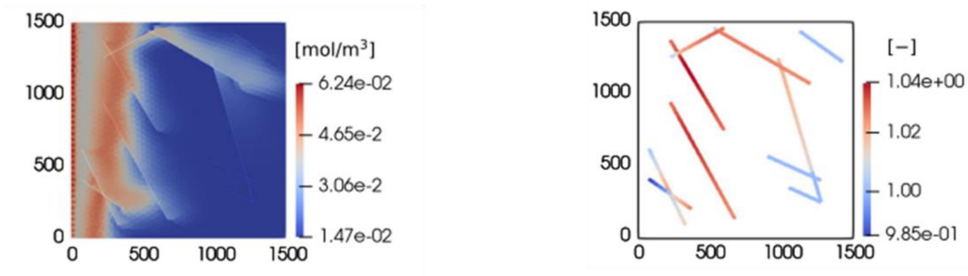

Figure 7 Propagation of a chemical species (left) and alteration of fracture permeability (right) during non-isothermal reactive flow in a fractured porous media.

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

Duration	2021-2025
PI	Mathilde B. Sørensen
Team	Maren K. Karlsen, Mathilde B. Sørensen, Lars Ottemöller, Corbett Grainger

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 2024 has focused on developing a baseline probabilistic seismic hazard model for Norway. This includes compiling and quality checking a homogeneous earthquake catalog 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 are harmonized with those used for hazard models in the neighboring Nordic countries through workshops and online meetings with the developers of those modes. This will ensure that the models are consistent across national borders. The planned next steps include expanding the model to an integrated Nordic seismic hazard model, in cooperation with Nordic colleagues, and developing a site-specific model for the Horda Platform where CO2 injection is planned to initiate soon.

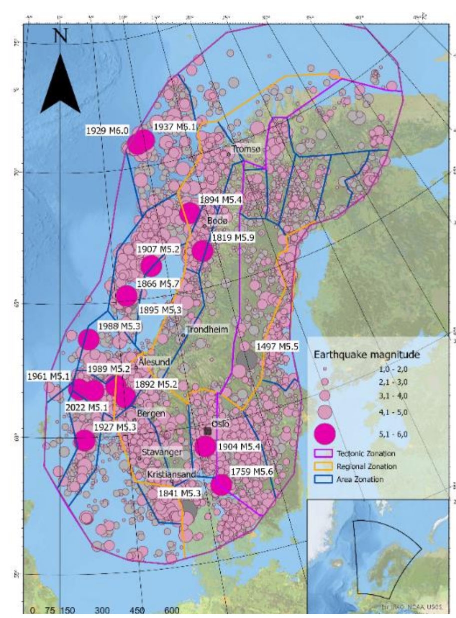

Figure 8 The earthquake catalog and seismogenic source zones considered in the probabilistic seismic hazard model being developed for Norway.

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

Duration	2021-2026
PI	Inga Berre
Team	Hau Trung Dang, Omar Duran, Ingrid Kristine Jacobsen, Jakub W. Both, Eirik Keilegalven, Veljko Lipovac, Jan Martin Nordbotten, Florin Radu, Ivar Stefansson, Isak Hammer, Micheal Oguntola

In the development and production of high-temperature geothermal resources, large, induced gradients in pressure and temperature during injection operations result in complex, coupled dynamics. This includes boiling of geothermal fluids and deformation of the fractured rock. The interaction of coupled processes with changes in formation structure related to deformation and propagation of fractures is currently not well understood. This provides a core motivation as well as challenging test cases for the mathematical and numerical developments in the MaPSI project. The MaPSI project has been funded by the ERC to establish mathematical models and simulation technology that assess subsurface process-structure interaction in geothermal systems during hydraulic and thermal stimulation.

The project aims to develop pioneering mathematical and numerical models that simulate multiphase flow and phase-change in thermo-poroelastic media with deforming and propagating fractures. Through this approach, MaPSI seeks to advance expertise in development and production of high-temperature geothermal systems, knowledge is crucial to promote sustainable resource exploitation.

In geothermal systems, networks of fractures provide main fluid pathways. Hydraulic stimulation of fractured geothermal reservoirs can increase the possibility of geothermal fluid to flow through the formation by causing sliding and dilation of preexisting fractures as well as fracture propagation. This represents a complex coupled process-structure interaction, where the fractured structure of the formation both dominates coupled fluid flow and rock deformation and conversely is altered because of these processes. A main result achieved in the project is a novel hydro-mechanical simulation models for hydraulic stimulation of fractured porous rock, where slip, dilation and propagation of fractures in a network result as a consequence of fluid injection Dang-Trung et al. (2024).

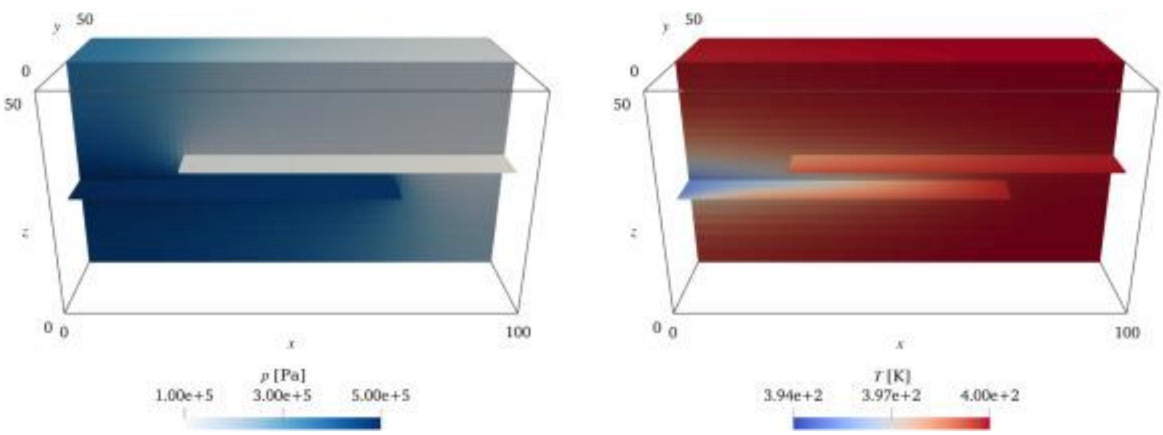

Figure 9 Simulated pressure and temperature in deforming fractures (Stefansson et al., 2024).

Fundamental progress has also been made in the simulation of thermal multi-phase flow in high-temperature geothermal systems. For the phase equilibrium problem, there has been developed a formulation that enables simultaneous determination of phase stability and splits for a wide range of subsurface conditions. The developed methodology provides a modular way to include and couple the local fluid phase equilibrium within compositional multi-phase flow simulations. The methodology is verified against benchmarks from the literature.

Substantial work has also been performed on novel mathematical and numerical models for deformable fractured media, numerical solution strategies, and necessary software improvements in the open-source framework PorePy Stefansson et al. (2024). This enhanced framework is currently being used for activities within this project and in other projects within CSD.

Network Inpainting via Optimal Transport (NIOT)

Duration	2023-2025
PI	Enrico Facca
Team	Enrico Facca, Jan M. Nordbotten

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 noninvasive 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. This year continued the development of the theoretical framework of the network inpainting method. In Figure 10 below, it is summarized how a disconnected network is reconstructed using the NIOT approach, while other inpainting approaches fail in capturing the global structure of the network.

A major ambition of the project is to pair theoretical analysis with robust simulation tools that are capable of handling real data arising from MRI acquisition techniques. In 2024 the software has been improved to tackle 3D simulations and tested on real MRI scans of human patients. The code is available on GitHub.

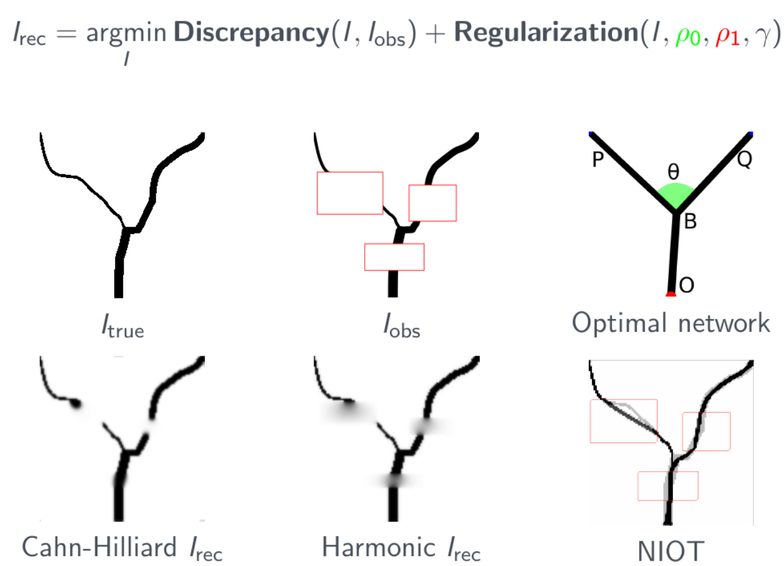

Figure 10 Illustration of an original image (Itrue) where some portions are lost (Iobs). Using classical regularization functionals leads to wrong reconstructions. The NIOT approach introduces a regularization functional that encodes transport information, leading to better reconstruction.

VISTA CSD Researcher Training Program

As of 31 December 2024, 24 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 2024, the following activities have been organized

- Weekly CSD seminars
- Student field trip 8-13 January 2024
- VISTA Researcher Days 5-6 February 2024 on research and researcher-driven innovation

Student field trip 2024

In January 2024, four MSc students and seven PhD candidates from the Porous Media Group at UiB visited three research groups. The study tour began with a trip to Oslo, where there was a workshop at the Simula Research Center. The focal point of the day was the presentation of research by PhD students from both Simula and PMG. The Simula group has a special interest in simulating blood flow in the brain, while PMG presentations focused on theoretical and practical aspects of subsurface simulations.

The trip continued the Institute of Mathematics and Applications (IUMA) in Zaragoza, Spain. PhD students and researchers from both PMG and IUMA presented discretization methods and numerical solution techniques.

Lastly, there was a workshop in Barcelona at the Universitat Politècnica de Catalunya (UPC). The main focus was on the hydrology research conducted at UPC, promoting a substantial exchange of ideas.

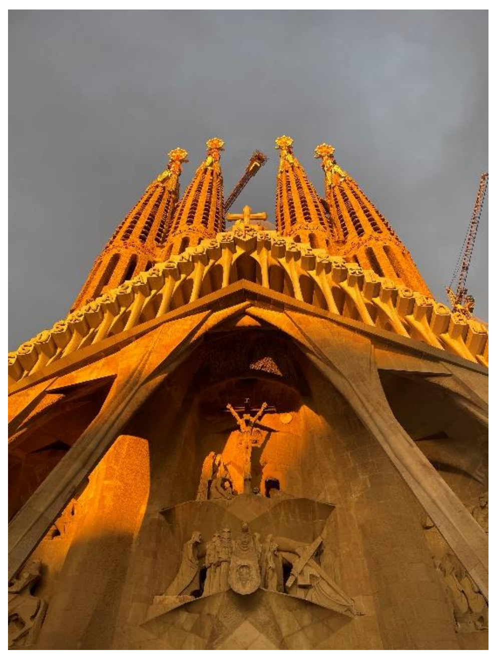

Figure 11 Presentation by Yury Zabegaev at UPC (left) and La Sagrada familia in Barcelona (right)

Honors and awards

Jakub Both elected chair of Interpore Norway 2025-2027

At the InterPore Norway 2024 meeting in Stavanger, Jakub Both was elected as the new chair of the new board, succeeding Alex Hansen (2017-2021) and Sarah Gasda (2022-2024).

The chapter is dedicated to advancing Norwegian porous media research. Annual workshops, rotating through Trondheim, Oslo, Stavanger, and Bergen, provide stimulating meeting places for the diverse and interdisciplinary research community of Norwegian institutions. Interpore Norway will host a conference in 2025 in collaboration with Vista CSD.

Inga Berre elected to the SIAM council 2025-2027

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. Professor and CSD Director Inga Berre was in 2024 elected to serve for a second 3-year period on the SIAM Council. In her candidate statement, she emphasizes the role of SIAM in uniting scientific communities and shaping academic careers.

Report from Scientific Advisory Board

The SAB delivered its first out of two evaluation reports in 2023, and the report was approved by the CSD Board in 2024. SAB commended VISTA CSD's progress, particularly in research quality, interdisciplinary collaboration, international cooperation, external funding, and early career researcher training. Recommendations from the SAB include utilizing high-performance computing resources, increasing subproject interactions, and enhancing public communication about the center’s contributions to sustainable development. Overall, the SAB is positive about the trajectory of CSD, and the journey ahead promises a deeper understanding of subsurface phenomena, contributing to a sustainable future. In 2024, CSD has worked to improve center activities in line with the SAB’s recommendations.

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 2024

Almani, T., & Kumar, K. (2024). Convergence of multirate fixed stress split iterative schemes for a fractured Biot model. *Computer Methods in Applied Mechanics and Engineering*, 117253.

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