The 57th Nordic Seminar in Seismology

Organized by

Icelandic Meteorological Office

and

Reykjavik University

Reykjavik, Iceland

9-11 June 2026

Photo by Linda Ohde Pexels

Dear participants,

It is our great pleasure to welcome you to the 57th Nordic Seismology Seminar, held at the Reykjavík University. This year, around 75 participants from across the Nordic countries and beyond are gathering to share new research, exchange ideas, and strengthen our community. We are sincerely grateful for your enthusiasm and participation, and we hope you find the program both inspiring and enjoyable. We wish you a wonderful time in Iceland.

Seminar web page can be found at: https://nordicseismology2026.com/

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Abstracts

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The 57th Nordic Seminar in Seismology

Reykjavik, 9-11 June 2026

Seminar Programme

🎉 ***Social Programme***

Day 1

Registration & Welcome Coffee, Reykjavik University (8:15 – 9:00)
Kick-Off Cocktail Reception & Posters, Reykjavik University (16:00 – 18:30)

Day 2

Conference Dinner, Höfnin Restaurant, Geirsgötu 7c (20:00 – 22:00)

Day 3

Field Excursion (Departure from Reykjavik University at 09:00)
A round trip around the Reykjanes Peninsula (~10 hours)

9 June 2026 Day 1 Schedule

Session 1	***Seismic Networks, Collaboration, Monitoring and Services*** *Chair: Benedikt Halldórsson*
9:00 - 9:15	Matthew James Roberts (Invited) *Opening Remarks and Welcome*
9:15 - 9:30	Carlo Cauzzi *ORFEUS & the Nordic Countries: Current Collaborations and Outlook*
9:30 - 9:45	Dmitry Storchak *Supplementary ISC services for Seismology*
9:45 - 10:00	Daniel McNamara *Improving Uptime, Noise Performance, and Detection Capability in the GSN*
10:00 - 10:15	Claire Perry *Seismic Monitoring and Network Design for Arctic Canada*
10:15 - 10:30	Matt Gardine *Renewal of the LUOVA Natural Disaster notification system in Finland*
10:30 - 10:45	Coffee Break
Session 2	***Seismic Networks, Collaboration, Seismic Monitoring*** *Chair: Benedikt Halldórsson*
10:45 - 11:00	Suvi Heinonen *Updates and Future Plans from Institute of Seismology, University of Helsinki*
11:00 - 11:15	Michael Roth *The Swedish National Seismic Network - News and Status 2026*
11:15 - 11:30	Viesturs Zandersons *Recent Advances in Seismic Monitoring in Latvia*
11:30 - 11:45	Sigríður Kristjánsdóttir and Salóme J. Bernharðsdóttir *We Pick the Future: Changing from Lokimp to SeisComP at the Icelandic Met Office*
11:45 - 12:00	Jan Burjanek *Comprehensive geophysical analysis of the ongoing volcanic eruption at the Reykjanes Peninsula, the PROVOKE project*
12:00 - 13:30	Lunch Break
Session 3	***Fiber-Optic Sensing*** *Chair: Yesim Cubuk-Sabuncu*
13:30 - 13:45	Guro Kristin Svendsen *Distributed Acoustic Sensing for Avalanche Detection: Insights from Multi-Site Monitoring in Norway*
13:45 - 14:00	Monika Ivandic *Distributed Acoustic Sensing for explosion monitoring at the Hagfors seismo-acoustic array, Sweden*
14:00 - 14:15	Bettina Goertz-Allmann *Offshore Microseismic Monitoring for CO_2 Storage Using Seabed Fiber-Optic DAS*
14:15 - 14:30	Aude Lepère *Observations of P-wave phase arrivals from major earthquakes with the IRIS fiber-optic subsea cable*
14:30 - 14:45	Franck Latallerie *Estimating Vp/Vs ratios beneath Hengill volcano, using large seismic nodes deployments and DAS data*
14:45 - 15:00	Coffee Break
Session 4	***Forensic Seismology*** *Chair: Björn Lund*
15:00 - 15:15	Heidi Soosalu *Read between the seismogram lines: military seismological observations near Estonia*
15:15 - 15:30	Jon Grumer *Seismo-acoustic forensics at FOI*
15:30 - 15:45	Jon Grumer and Monika Ivandic *A national early-warning system for nuclear explosions: a new seismo-acoustic array in N Sweden*
15:45 - 16:00	Andreas Steinberg *Ice Signals: Seismic and Infrasound Events in Atka Bay, Antarctica*
16:00 - 16:05	*Closing Remarks, Organizers*

10 June 2026 Day 2 Schedule

Session 5 ***Machine Learning, Microearthquakes, Modern Catalogs and Magnitudes*** *Chair: Thomas E. B. Winder*

9:00 - 9:15 Lars Ottemöller
Leakage During Hydropower Tunnel Construction: A Trigger Mechanism for the Eq. Swarm at Sørfjorden

9:15 - 9:30 Miguel Neves
Unsupervised Discrimination of Earthquakes and Blasts in Norway Using Representation Learning

9:30 - 9:45 Catalina Ramos
Combining spectrogram-based and feature-based machine learning for seismic event classification in Germany

9:45 - 10:00 Pierre Wislez
New insight into the Storfjorden fault system from OBS data.

10:00 - 10:15 Björn Lund
The effects of current glacial rebound on seismicity in Sweden

10:15 - 10:30 Hamed Davari
A Regional SeisComP Magnitude Module for Real-Time Proxy M_w Estimation in Iceland

10:30 - 10:45 Coffee Break

Session 6 ***Seismic Hazard, Risk, and Earthquake Modeling in Iceland*** *Chair: Milad Kowsari*

10:45 - 11:00 Benedikt Halldórsson
State-of-the-art probabilistic seismic hazard revision and risk assessment of the Reykjanes Peninsula in Iceland

11:00 - 11:15 Milad Kowsari
Uncertainty in Ground Motion Models and Its Impact on PSHA

11:15 - 11:30 Atefe Darzi
Performance of ETAS Model Variants in Modeling Icelandic Seismicity

11:30 - 11:45 Pariya Yavarirad
Stress-Informed ETAS Modeling of Aftershock Clustering in the South Iceland Seismic Zone

11:45 - 12:00 Benedikt Halldórsson
On the earthquake source scaling and near-fault seismic wavefield in Icelandic Transform zones

12:00 - 13:30 Lunch Break

Session 7 ***Volcano Seismology in Iceland*** *Chair: Vala Hjörleifsdóttir*

13:30 - 13:45 Tom Winder
Repeated dike injections beneath the Sundhnúkur crater row, RP, imaged by relatively relocated seismicity

13:45 - 14:00 Ylse Anna de Vries
An enhanced catalogue of ring fault seismicity at Bárðarbunga caldera since the 2014 Holuhraun eruption

14:00 - 14:15 Isabel Siggers
Earthquake focal mechanisms reveal a complex response to re-inflation at Askja caldera, Iceland

14:15 - 14:30 Þorbjörg Ágústsdóttir
Lateral Dyke Intrusions During the 2021-2023 Fagradalsfjall Volcano-tectonic Rifting Event, Relative Relocations

14:30 - 14:35 Marco Roth
ICEPLUME Land proposal: Understanding the influence of the Iceland mantle plume on the opening of the NE Atlantic Ocean, plate tectonics and volcanism

14:35 - 14:50 Coffee Break

Session 8 ***Seismic Imaging*** *Chair: Þorbjörg Ágústsdóttir*

14:50 - 15:05 Alvaro Josué Campos Ramos
Seismotectonic Characterization of the Ahuachapán Geothermal Field, El Salvador

15:05 - 15:20 Sonja Kõrvits
2D imaging of Moho structure beneath Estonia using common conversion point stacking

15:20 - 15:35 Thomas O'Hara
Teleseismic Tomography of the Northern Volcanic Zone, Iceland.

15:35 - 15:50 William Pizii
New images of volcanic systems on the RP, from ambient noise tomography using a regional node array

15:50 - 15:55 *Closing Remarks, Organizers*

POSTER PRESENTATIONS – will be on display both days

Akmaral Amanturdieva
Numerical Simulation of Vehicle-Induced Seismic Signals on Distributed Acoustic Sensing Cables Using the Elastic Lattice Method

Asbjørn Gjengedal Madsen
Stakeholder interaction in the management and dissemination of seismic risk from Carbon Capture and Storage projects in the North Sea region

Behnam Maleki Asayesh
Non-stationary ETAS Modeling of Volcano-Tectonic Seismicity in the Reykjanes Peninsula

Cécile Driou
Seismic tomography and geothermal potential at the Sveifluháls volcanic ridge, SW Iceland

Chloé Delbet
Seismicity characterization for CO_2 storage in contrasting tectonic settings – Iceland versus the Norwegian continental shelf

Johanna Malen Skúladóttir
Cross-correlation of deep earthquakes within the intraplate volcanic system of Ljósufjöll, West-Iceland

Jonathan Vänskä
Kymenlaakso Seismic Experiment

Laurent Geoffroy
The ISLAB program

Maren Kjos Karlsen
A joint Nordic seismic hazard analysis using a harmonized catalogue and source zonation

Niina Junno
Legacy Data
Digitization of Analog Seismograms at the Institute of Seismology, University of Helsinki

Oana Lorena Slupic
Explainable Machine Learning for Ground Motion Prediction in the Vrancea Intermediate Depth Seismic Zone

Þorbjörg Ágústsdóttir
Micro-seismicity in the Hverahlíð high-temperature geothermal field, Hengill, SW-Iceland

Aurélien Mordret
DAS acquisitions at GEUS

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Abstracts

ORFEUS & the Nordic Countries: Current Collaborations and Outlook

Carlo Cauzzi[1,2], Angelo Strollo[3], Anastasia Kiratzi[4] and The ORFEUS Executive Committe

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ORFEUS (Observatories and Research Facilities for European Seismology, www.orfeus-eu.org; orfeus.readthedocs.io; forum.orfeus-eu.org) is a non-profit foundation that coordinates the collection, archival, and distribution of seismic waveform (meta)data, services and products based on international standards. It serves a broad community of seismological data users, on behalf of the Euro-Mediterranean seismic networks and monitoring agencies (orfeus.readthedocs.io/en/latest/governance.html). ORFEUS core domains comprise: (i) the European Integrated waveform Data Archive (EIDA; orfeus-eu.org/data/eida), providing access to raw seismic waveform data and basic station metadata; (ii) the European Strong-Motion databases (orfeus-eu.org/data/strong), offering automatically/manually processed waveforms, advanced station/site metadata, and associated products ; and iii) the European Mobile Instrument Pools (orfeus-eu.org/data/mobile), facilitating access to seismic instrumentation for temporary deployments. Currently, ORFEUS services distribute waveform data from more than 33,000 stations, including DAS deployments and dense temporary regional experiments (eg., orfeus.readthedocs.io/en/latest/adria_array_main.html), with an emphasis on FAIR principles, open access, and high data quality. ORFEUS services constitute a core component of EPOS (www.epos-eu.org/tcs/seismology) and are seamlessly integrated into the EPOS Data Access Portal (www.ics-c.epos-eu.org). Access to data and products relies on state-of-the-art information and communication technologies, with a strong emphasis on web services (www.orfeus-eu.org/data/eida/webservices; https://esm-db.eu/webservices) enabling programmatic interaction. ORFEUS promotes transparent data policies and licenses and acknowledges the indispensable contribution of data providers. Ongoing activities focus on further development of existing services and on facilitating access to massive and multidisciplinary datasets through collaboration with global and regional initiatives, including the FDSN (www.fdsn.org) and EarthScope (www.earthscope.org), as well as through support from EC-funded projects (e.g., www.geo-inquire.eu). ORFEUS implements community-oriented services that include software and travel grants, a sustained training/outreach programme of webinars and workshops (www.orfeus-eu.org/other/workshops), and editorial initiatives supporting best practices in seismological data use and dissemination. This presentation highlights the current contributions of Nordic seismological agencies to ORFEUS programmes and activities, as well as the encouraged directions for future developments.

(https://orfeus.readthedocs.io/en/latest/governance.html)

Supplementary ISC services for Seismology

Dmitry Storchak[1], James Harris[1], Domenico Di Giacomo[1], Kathrin Lieser[1]

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The main mission of the International Seismological Centre (ISC) is to maintain the most long-term comprehensive list of instrumentally recorded seismicity on a global scale by running seismic event data exchange with ~150 networks in ~100 countries. The ISC Bulletin, the ISC-GEM catalogue, the ISC-EHB and GT datasets, and the International Seismograph Station Registry are a direct result of this work.

In addition, the ISC maintains several supplementary services useful in geophysical research. The Electronic Archive of Printed Station/Network Bulletins holds the most comprehensive of all available global collections of observatory catalogues, including station parameters, produced between 1879 and 2001. The invited Network Articles in the Summary of the ISC Bulletin describe the history, current status, and procedures used by these networks to determine locations of seismic events, magnitudes, source parameters, event types, etc. So far, the articles from 21 networks regularly reporting to the ISC are accessible via relevant agencies in the ISC Agency Registry and their hypocentre solutions in the ISC Bulletin. The ISC Event Bibliography provides references to scientific publications that describe seismic events (1904-2026) within the region of interest. The ISC Seismological Dataset Repository makes individual researcher’s datasets openly available long-term and thus also helps to provide access to data used in scientific publications. The International Seismological Contacts assist seismologists in finding colleagues in other countries in an emergency as well as facilitating joint research and capacity building worldwide.

Improving Uptime, Noise Performance, and Detection Capability in the Global Seismographic Network (GSN)

Daniel McNamara[1], Jacob Walter[1], Glen Mattioli[1], Annie Zaino[1], Wade Johnson[1]

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The Global Seismographic Network (GSN) provides broadband seismic observations fundamental to studies of Earth structure, earthquake source processes, and nuclear test monitoring through the CTBTO International Monitoring System (IMS). Network performance is governed by both data availability and signal-to-noise ratio (SNR) across a wide frequency band (10^{-4}–10 Hz), with detection capability at regional distances strongly dependent on noise levels in the 1–10 Hz band. Current performance (~85% monthly uptime) reflects known structural challenges and recent reductions in data availability. The 2015 GSN review identified aging infrastructure, lack of standardization, and operational complexity as key contributors to reduced reliability. A 2024 digitizer working group further identified increasing risk in legacy Q330 systems and recommended transition to Q8 digitizers. While Q8 improves long-period performance relative to Peterson noise models, the review emphasized testing high-resolution mode in collaboration with the USGS Albuquerque Seismological Laboratory (ASL) to optimize performance in the 1–10 Hz band, where digitizer noise, sensor response, and site conditions jointly control SNR.

Recent reductions in real-time data availability from a subset of high-latitude stations have decreased network density across parts of northern Eurasia. This reduction in station coverage increases magnitude detection thresholds, delays phase arrival picking, and degrades hypocenter location accuracy, particularly in regions with limited azimuthal coverage. These effects are especially relevant in Arctic environments, where seismic observations contribute to studies of cryoseismic processes, including glacial earthquakes and ice–ocean interactions. A coordinated modernization strategy is underway to address these limitations. Instrumentation upgrades (Q8 digitizers, sensors), power system redesign, and telemetry improvements are coupled with standardized pre-deployment acceptance testing aligned with USGS ASL and Sandia approaches and standards. Station performance is evaluated using MUSTANG-derived PSDPDFs relative to reference noise models, with network metrics computed from long-term median noise levels. Enhanced network performance monitoring integrates cloud-based observability, real-time quality control, and automated diagnostics to provide end-to-end visibility from station to archive. These approaches enable rapid detection of data gaps and systematic identification of performance limitations. Together, these developments aim to increase uptime to ≥90% while improving SNR, lowering detection thresholds, and enhancing event characterization across Arctic and northern regions.

Seismic Monitoring and Network Design for Arctic Canada

Claire Perry[1], Nicholas Ackerley[1], David McCormack[1]

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We examine the challenges for seismic monitoring across Canada's Arctic, with a focus on minimum detection magnitude. The Canadian National Seismograph Network (CNSN) operated by Natural Resources Canada (NRCan) currently includes 28 seismic stations and one large aperture teleseismic array north of 60°N. Discrepancies between the magnitude of completeness of the National Earthquake Data Base and the CNSN minimum detectable magnitude indicate instrumentation gaps in the Arctic. Despite sparse station coverage, the network generally meets NRCan's target to detect earthquakes of magnitude 4 and greater when station availability exceeds 95% for Canadian stations and international stations in northern Alaska and Greenland. However, logistical constraints related to terrain, climate, power supply, and high installation and maintenance costs limit long-term station performance and network expansion in northern Canada. Trans-Arctic cooperation between seismological agencies should help, but in Greenland in particular it has been difficult for NRCan to identify a subset of permanent stations that are consistently available. Medium-aperture seismic arrays provide a potential pathway to improving detection thresholds in remote regions, because azimuths from only two arrays are sufficient to locate an event, compared to detections from 4-6 single stations. We present a feasibility study that evaluates potential improvements in detection magnitude and location accuracy for several proposed network geometries combining new arrays and single stations. Our approach is based on 90th-percentile probabilistic power spectral density (PPSD) velocity statistics for existing CNSN stations and predicted statistics at proposed sites. Ground motion attenuation is modeled using a peak P-wave regional velocity model. A detection is declared when predicted peak ground velocity exceeds the 90th-percentile noise level in the 2–8 Hz band by an SNR of at least 3. Events require detections at six stations or three arrays, assuming some SNR improvement for arrays. Results indicate that optimized configurations could reduce the network magnitude threshold by approximately one magnitude unit.

Renewal of the LUOVA Natural Disaster notification system in Finland

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The LUOVA system was designed as a way for relevant agencies to send authoritative reports about natural disasters to the Finnish government for immediate action as the event requires. After the 2004 Sumatra-Andaman earthquake and tsunami, earthquakes were added as potential events for the system and the Institute of Seismology was designated as the primary reporting agency. Since then, then system has run nearly unchanged for twenty years. During the spring of 2026, we renewed the system to include a direct interface into our global Seiscomp system, converted from flat-files to a Postgresql database, integrated PostGIS tools, and rebuilt the web interface for improved usability, accessibility, and to make the entire framework sustainable using modern frameworks and tools. This presentation highlights some of the changes, enhancements, and lessons learned along the way.

Updates and Future Plans from Institute of Seismology, University of Helsinki

Suvi Heinonen[1] and the ISUH team[1]

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Change in the geopolitical situation is reflected in the operations of the Institute of Seismology, University of Helsinki (ISUH). It has increased the demand for reliable, real time seismic monitoring and underscored the Institute's role in national situational awareness. At the same time, heightened regional tension reinforces the need for collaboration among trusted partners, particularly within the Nordic countries.

ISUH is coordinating the Nordic DAS project funded by NordForsk and, together with its partners, is actively exploring the development of Distributed Acoustic Sensing as an additional tool for seismic monitoring. Beyond only monitoring, DAS has the potential to contribute to early warning systems aimed at preventing damage to subsea critical infrastructure. In addition to DAS, ISUH is also seeking to integrate infrasound sensors into its monitoring capacity. Infrasound sensors would improve the detection of atmospheric explosions and supplement seismic and infrasound data from neighbouring Nordic networks.

In this presentation, I will provide an overview of the various projects and initiatives currently underway at ISUH.

The Swedish National Seismic Network - News and Status 2026

Michael Roth[1] and Björn Lund[1]

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The Swedish National Seismic Network (SNSN) currently operates and maintains 69 permanent seismic broadband stations. Two of the stations were part of the temporary Hälsingland seismic network, that was deinstalled in 2025 after a deployment period of about 4 years. In 2025 we had 26 on-site maintenance instances at 19 stations, and we achieved a data availability of almost 98%. We plan to extend our seismic network with six new permanent stations, and we have conducted site surveys for four stations in Northwestern Sweden, for one in the Southeast close to Blekinge and one in the Southwest at Ringhals. For the new stations we will use a new vault design - the vaults will be much smaller than our standard vaults and they will be completely sealed.

SNSN is using Earthworm and Seiscomp for realtime regional monitoring and the generation of a practically spurious-free automatic bulletin. Following a thorough testing period we implemented the Seiscomp scanloc module into our automatic processing. The scanloc module facilitates a lower detection threshold and it provides automatic S-picks. The automatic bulletin is made available in simple form (i.e., map and table) on SNSN's web page. Complete event parameters inclusive phase picks and station magnitudes are stored in QuakeML files and forwarded to interested parties. Seismic events classified as earthquakes and with magnitude ML>2 are automatically submitted to EMSC.

Parallel to the production Seiscomp system, we have established a testbed environment for trials and tuning. The Seiscomp testbed version is processing data in 2 pipelines - one for local/regional monitoring and another one for global monitoring. Such a setup decreases the number of spurious events that otherwise can be generated from teleseismic signals propagating over the regional network. Another medium-term goal of SNSN is to migrate the manual event analysis from our current Lokimp/SIL system to Seiscomp. To that end, we have setup the import of automatic SIL event solutions into the Seiscomp testbed version. SNSN analysts are currently testing and customizing the graphical user interface, and we expect to have completed the transition in autumn.

Recent Advances in Seismic Monitoring in Latvia

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Latvia has recently seen increased funding and research activity in the field of seismic monitoring. Although it is located in a relatively seismically inactive region, developments driven by both the civil and military defence sectors have helped strengthen seismic monitoring in Latvia over the past five years. While conventional seismograph infrastructure is still limited, the University of Latvia (UL) has recently expanded its inventory with new short-period seismic nodes and distributed acoustic sensing (DAS) interrogator and has also conducted tests for potential broadband seismograph installations across the country.

In this presentation, we focus on recent advances in the field of seismology in Latvia. We present the institutions and personnel involved, the custom semi-automatic event detection system, which integrates instrumentation from Latvia and neighbouring countries, the latest deep learning developments using the SeisBench package, and the routine processing workflow within SeisComP v7.0. We highlight the most interesting events from 2025. In addition, we showcase the expansion of our team within the Department of Geology at the UL, as well as projects related to applied seismic exploration and DAS. Finally, we address the latest discussions on regional cooperation within the Baltic states.

We Pick the Future: Changing from Lokimp to SeisComP at the Icelandic Met Office

Sigríður Kristjánsdóttir[1], Salome Jorunn Bernharsdttir[1], and the SeisComP team[1]

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The Icelandic Met Office (IMO) started using SeisComP for manual review of earthquakes in February 2026. Before the IMO was using the legacy software Lokimp, developed by SNSN and IMO in the 90‘s. Many people were involved in developing and tuning the various parts of SeisComP, but this talk will be about the experience of the operators. Switching from an old tool that most operators had years of experience in into a totally new enviroment was challenging. All operators went through training which was mostly set up as hands on exercises in scolv, the review module in SeisComP. The advantages of SeisComP over Lokimp are e.g.

- seeing all available waveforms for each event in the review window,
- using shortcuts on the keyboard instead of the mouse exclusively, and
- customization of the picking module.

Lokimp has always had the advantage of being really fast for manual review. In the months that we have been using SeisComP we have not seen a significant decrease in the number of reviewed events, although the real test of a large seismic swarm has not yet presented itself. We are confident that other aspects of scolv will make up for the speed of Lokimp. E.g. the operator on duty can start reviewing an event while picks and waveforms are still being sent to the system, and preliminary information about the size and location of events is readily available. Both these things are an advantage when it comes to communicating with the public and the media.

Comprehensive geophysical analysis of the ongoing volcanic eruption at the Reykjanes Peninsula - the PROVOKE project

Jan Burjánek[1], Catherine Annen[1], Jana Doubravová[1], Graham Hill[1], Pavla Hrubcov[1], Jiř Málek[2], Prokop Závada[1]

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This contribution introduces a scientific project, PROVOKE aimed at constraining the development and dynamics of the transcrustal magmatic plumbing system in the oblique rift segment of the Reykjanes peninsula on Iceland using data from the existing seismic network REYKJANET, magnetotelluric surveys, geological fieldwork, and the new analogue / numerical modeling. The Reykjanes Peninsula in SW Iceland, which has been hosting a local seismic network REYKJANET for a decade, recently entered a new eruptive era after eight centuries of quiescence. Since spring 2020, when a notable uplift and earthquakes issued the first serious warning of volcanic eruption, there have been twelve effusive eruptions between 2021 and 2025, lasting from months to hours. It is expected that such a turbulent rifting period with prominent volcanic activity will continue in the next few years or decades. The proposed multidisciplinary research will leverage the unique dataset of seismic records containing both the current and preceding activity. It integrates the experience of the team members in various fields of seismology, applied geophysics, structural geology, and volcanology. Our comprehensive approach can provide an understanding of the volcanic plumbing system, which will establish a framework for possible operational monitoring.

Distributed Acoustic Sensing for Avalanche Detection: Insights from Multi-Site Monitoring in Norway

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Distributed Acoustic Sensing (DAS) provides an efficient approach for reusing existing fiber-optic infrastructure as a long-range sensing system with high spatial resolution. This makes it a promising technology for monitoring natural hazards along critical infrastructure such as roads and transport corridors.

However, roadside fiber deployments are often exposed to complex and highly variable noise environments, which can significantly challenge automated signal analysis and reliable event detection.

Drawing on observations from multiple installations across Norway since 2023 - primarily focused on snow avalanche detection - we highlight both recurring challenges and site-specific variations. At the same time, the results illustrate the broader potential of DAS for natural hazard monitoring, and point to opportunities for improving detection performance and supporting more robust early warning systems.

Distributed Acoustic Sensing (DAS) for explosion monitoring at the Hagfors seismo-acoustic array, Sweden

Monika Ivandic[1], Christopher Juhlin[2], Henrik Olsson[1], Patrik Kekkonen[1], Eva Hirvonen[1], Niranjan Joshin[1], Jon Grumer[1]

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A pilot study was conducted at Sweden's seismo-acoustic array in Hagfors to evaluate Distributed Acoustic Sensing (DAS) for explosion monitoring. Four fiber configurations were tested: the site's existing multi-mode fiber and three temporarily deployed 100 m-long cables buried in a shallow trench: a multi-mode, a single-mode in flexible housing, and a single-mode in stiff housing. The study examines DAS as a means of improving observational coverage for explosion detection and characterization without large-scale sensor deployment. Measurements were performed in early April 2026, and initial results from the campaign will be presented, with a focus on detection capability and the influence of fiber configuration and installation on signal quality.

Offshore Microseismic Monitoring for CO_2 Storage Using Seabed Fiber-Optic DAS

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Microseismic monitoring is essential for the safe and transparent operation of geological CO_2 storage, providing insight into subsurface deformation, pressure evolution, fault stability, and caprock integrity during injection. Reliable event detection and accurate locations are critical for regulatory compliance, public confidence, and long-term risk management. While monitoring strategies are well established for onshore storage, offshore environments present additional challenges. Conventional seabed seismic networks are costly to deploy and maintain, and sparse sensor coverage can limit detection sensitivity and increase location uncertainties, particularly in depth.

These challenges are directly relevant for the Northern Lights CO_2 storage project offshore western Norway, where CO_2 injection into the Aurora reservoir (~2600 m depth) began in 2025. Northern Lights is the first commercial open-access CO_2 transport and storage infrastructure in Europe, with Phase 1 providing up to 1.5 Mt CO_2 storage per year and an approved expansion targeting approximately 5 Mt per year by around 2028. Given the scale and expected lifetime of the project, robust and cost-effective microseismic monitoring is essential.

Current monitoring integrates the Holsnøy seismic array (HNAR), stations from the Norwegian National Seismic Network (NNSN), and selected offshore sensors, improving detection capability relative to single onshore stations. However, the large distance (>80 km) between onshore sensors and the injection site still results in significant location uncertainties.

To improve offshore monitoring, we investigate Distributed Acoustic Sensing (DAS) on existing seabed fiber-optic telecommunication cables near the injection site. We develop processing strategies tailored to DAS data, including advanced denoising methods, and detection algorithms. We further explore slowness-guided migration, combining beamforming-derived slowness estimates with traveltime migration to constrain source locations for linear DAS arrays. Integrating DAS observations with conventional seismic data may improve event association and hypocenter estimation, demonstrating the potential of seabed DAS to enhance offshore microseismic monitoring in a scalable and cost-effective manner.

Observations of P-wave phase arrivals from major earthquakes with the IRIS fiber-optic subsea cable connecting Iceland and Ireland

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Approximately 70% of the Earth's surface is covered by the oceans. Installing permanent seismic sensors on the seafloor is both difficult and costly, resulting in a gap in the the global seismic monitoring. Recently, the potential of using the existing network of submarine fiber-optic cables for the observation of seismic waves has been investigated, several works demonstrating the feasibility of using trans-oceanic subsea cables as seismic sensors (f.ex. Marra 2018, 2022; Zhan, 2021; Mazur 2024).

In this work, we use a distributed fiber optic sensing (DFOS) prototype capable of measuring the integrated strain between each repeater along the entire length of a fiber optic cable (the repeaters are typically placed 100 km from each other). This instrument is used on the IRIS telecommunication cable, an operational subsea cable connecting Iceland to Ireland, transforming 17 spans of the cable into an array of 17 individual seismic sensors. Signals from several large earthquakes can be observed on the recorded data from the cable and surface waves as well as multiple seismic body wave phases can be tracked across the spans.

To assess the capability of the monitoring system to detect the P-wave phase, we use an STA/LTA algorithm to automatically detect the arrival of P-waves in the data and we compare the phase detections to those predicted by travel-time curves from a catalogue of major earthquakes from the USGS database (with a magnitude above 6 and a distance of 30 to 100° from the fiber-optic subsea cable). We manage to retrieve 40% of our earthquake catalogue with our detection algorithm. However, a large part of our detections are not pickings of the P-wave phase.

Estimating Vp/Vs ratios beneath Hengill volcano, SW Iceland, using large seismic nodes deployments and DAS data

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There are several active volcanic systems in SW Iceland, of which four are used for power production, together producing about 20% of Iceland's electricity and providing 80% of the population with district heating. The volcano Hengill, to the east of Reykjavík, has two major geothermal stations (Nesjavellir & Hellisheiði). Seismicity in the area is highly clustered, with activity in the form of earthquakes swarms, but the origin for this seismicity remains unclear.

In this project, we aim to clarify the possible role of geothermal fluids, and thus to inform on the potential of the area for geothermal energy production. To this end we estimate Vp/Vs ratios. These ratios are heavily perturbed by the presence of fluids, and estimating them can thus shed new light on the origin of the clusters of seismicity. We use data from the two recent large seismic deployments (DEEPEN and COSEISMIQ), and DAS data obtained on two dark fibres crossing the area. We implement the double-difference method on P- & S-wave travel-times from local earthquakes to estimate `in-situ' Vp/Vs ratios within clusters of earthquakes. We also apply the adjoint eikonal tomography to obtain a complementary global tomography model of Vp/Vs for the area.

Read between the seismogram lines: military seismological observations near Estonia

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Seismic monitoring in Estonia is a subprogramme of national environmental monitoring programme regulated by the Environmental Monitoring Act. Accordingly, the main concern is preservation and protection of the nature. However, security aspects regarding monitoring of man-made seismicity have become increasingly important in the current geopolitical circumstances.

Geological Survey of Estonia monitors seismicity within a rectangular area around Estonia, that is 57–60°N and 20–30°E. Events within this region are analysed and reported annually. Throughout the recent years numerous events of military interest have been detected. A few examples of events are discussed, such as Russian military exercises within the Hogland archipelago in eastern Gulf of Finland and in Tugany polygon some 40 km to the east of NE Estonia, the infamous case of anchor damaging the Balticconnector gas pipeline between Finland and Estonia in October 2023, and Ukrainian drone attacks against the Russian Ust Luga port some 30 km to the north-east of NE Estonia. Those with expert knowledge can acquire valuable pieces of intelligence information “between the seismogram lines” of such events.

Seismo-acoustic forensics at FOI

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For decades, seismo-acoustic monitoring and analysis at FOI were largely limited to nuclear test verification and carried out by a small staff. In recent years, however, the demand for rapid event detection and characterization in this signal domain has increased significantly. In this presentation, we summarize our current efforts to modernize and expand our work in seismo-acoustic forensics.

We are upgrading our array station in Hagfors (IMS AS101/HFS), including new seismic instrumentation and the addition of infrasound sensors, forming a new co-located acoustic array, HFSI. FOI is also constructing a new permanent seismo-acoustic array station in Västerbotten County in northern Sweden. To enable reliable and resilient analysis, we are establishing a new processing pipeline from the ground up. The processing is based on an array detection scheme for both seismic and infrasound signals, combined with coherent integration of seismo-acoustic network events from national and international collaborators, most notably the Swedish National Seismological Network (SNSN) at Uppsala University and the International Data Centre of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna.

Joint analysis of seismic and infrasound data improves detection capability and source characterization, while the inclusion of radionuclide observations strengthens event interpretation in complex cases. A key component of our workflow is therefore data fusion across these signal domains. Linking of radionuclide detections to seismo-acoustic events remains challenging due to the requirement of detailed atmospheric transport modeling, especially in automated processing.

A selection of case studies will be presented as part of the contribution.

A national early-warning system for nuclear explosions: establishing a new seismo-acoustic array in northern Sweden

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As part of national efforts to strengthen monitoring of nuclear explosions and other nuclear events, FOI is establishing a new seismo-acoustic array in Västerbotten, northern Sweden.

Following a site-selection process based on several criteria, including geological conditions, distance from traffic and industrial noise sources, topography, accessibility, and installation feasibility, an area northeast of Lycksele in the county of Västerbotten was identified as the preferred location. Temporary background-noise measurements were then carried out at selected candidate sites to compare local conditions. These studies provide an important basis for the design and future installation of the array and support the development of enhanced seismo-acoustic monitoring capability in northern Sweden.

In this contribution we introduce the project as a whole, and summarize the current status of the new array station.

Ice Signals: Seismic and Infrasound Events in Atka Bay, Antarctica

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Calving, iceberg collapse or collision can emit seismic signals and micropressure fluctuations which can be monitored using seismic and infrasound arrays. We carry out a joint analysis of infrasonic and seismic data acquired near the German Antarctic Neumayer Station III. We detect and locate events which emit both types of signals in and around Atka Bay and on the Ekström ice shelf. Atka Bay has sea ice coverage during the austral winter, which starts to break apart in December. The Bay is clear of sea ice in January-February. The infrasound array IS27, consisting of 9 elements with an aperture of 2 km, is operated by the Federal Institute for Geosciences and Natural Resources (BGR) at the German Neumayer Station III Antarctic Research base as one of up to 60 globally distributed elements of the infrasound network of the International Monitoring System (IMS), around 5-6 km from Atka Bay. A seismic array, the Watzmann array, is operated by the Alfred Wegener Institute (AWI) on Halvfarryggen, around 45 km southeast of the Atka Bay. It consists of 15 short-period vertical seismometers arranged in three concentric rings, with the outer ring having a diameter of 2 km. We monitor cryospheric changes in joint detections of ice related events in the Atka Bay of both arrays in the austral summer since the relocation of IS27 (from Neumayer II to Neumayer III) in 2009 till today. The results of this study show that seismic and infrasound signals are useful to detect and locate ice related events, such as for tracking of the ice edge and iceberg movement.

Leakage During Hydropower Tunnel Construction: A Possible Trigger Mechanism for the Earthquake Swarm at Sørfjorden, Norway

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Variations in subsurface fluid pressures, driven by natural processes or anthropogenic activity, are often considered the driving force behind earthquake swarms. Earthquake swarms are common in the Nordland area of northern Norway and have previously been linked to fluid saturated fracture zones. When an intense earthquake swarm initiated at Sørfjorden in Nordland during June 2023, close to a recently completed system of hydropower tunnels, we questioned whether there could be a physical connection. Using Interferometric Synthetic Aperture Radar, we observed subsidence following the paths of the tunnels, which can be explained by significant water leakage encountered when drilling through weakness zones. The earthquake swarm initiated about three years after tunnel completion at a distance of about 3 km from the tunnel. No previous swarm activity had been observed in this area. We built a catalog of the swarm to analyse its spatio-temporal distribution. We propose that changes in pore pressure and stress linked to the leakage, may have played a role in triggering the swarm. The time delay between water leakage and onset of the swarm can be consistent with pore pressure diffusion through a system of connected fractures. We suggest that fault valving or pumping are possible mechanisms to explain the cascading nature of the earthquakes in the swarm, where an increase in pressure differential is the initial trigger mechanism.

Unsupervised Discrimination of Earthquakes and Blasts in Norway Using Representation Learning

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Accurately distinguishing natural earthquakes from anthropogenic seismic sources is essential for compiling reliable earthquake catalogs. This is particularly important in intraplate regions like Norway, where low to moderate magnitude seismicity coexists with abundant anthropogenic sources such as quarry blasts. Traditional supervised deep learning approaches rely heavily on labeled training data, which can be limited or biased. To address this, we test a self supervised strategy for discriminating earthquakes and blasts using seismic data from the Norwegian National Seismic Network.

We apply a representation learning framework based on Bootstrap Your Own Latent (BYOL), which learns latent seismic features by aligning augmented views of the same event recorded across multiple stations, eliminating the need for ground truth labels. The model receives no prior information beyond the training hyperparameters. After training, we apply kmeans clustering to the learned embeddings, specifying only the number of expected clusters (two). Using these self supervised representations, derived from 33,433 spectrograms corresponding to 9,311 events detected in southern Norway, we obtain a clear separation between earthquake and blast signals, achieving an accuracy of 0.93 when evaluated against all available labels and 0.96 when aggregating information across stations at the event (network) level. As an additional test, we freeze the BYOL feature extractor and train a lightweight supervised classifier on the fixed embeddings using event labels. This minimal supervised layer achieves accuracies of 0.94 at the station level and 0.97 at the network level, demonstrating that the structure learned during the self supervised stage can be effectively exploited with limited supervision. Inspection of the embedded clusters reveals likely misclassified events, highlighting the potential of self supervised learning to improve earthquake catalog quality even when labeled datasets are sparse or biased.

Future work will analyze the learned latent features to gain insight into the physical attributes driving the separation between earthquakes and blasts.

Combining spectrogram-based and feature-based machine learning for seismic event classification in Germany

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This contribution presents the first results of an ongoing study exploring two complementary machine-learning approaches for classifying local seismic events in Germany and surrounding regions.

The study is based on a multi-agency event catalog spanning more than a decade and consisting of local events reported by several regional seismic networks. Two models are investigated in parallel. The first is a convolutional neural network trained on spectrograms. The second is an XGBoost classifier based on physically motivated waveform attributes.

This combined approach is motivated by recent studies suggesting that learned waveform representations and physics-based features can capture different but complementary aspects of seismic signals, potentially improving robustness and transferability across regions.

The results shown are an initial step toward a robust and transferable classification workflow for automatic seismological monitoring applications.

New insight into the Storfjorden fault system from OBS data

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The Svalbard archipelago, despite its intraplate setting, exhibits notable seismic activity. Most of that seismicity is located in the Storfjorden area, between Spitsbergen and Edgeøya. Since 1970, five $M_w > 5$ events have been recorded, the largest of which was a M_w 6.1 earthquake that occurred in February 2008. Routine monitoring by the Norwegian National Seismic Network (NNSN) cataloged ~2800 earthquakes in the region between 2008 and 2020, with seismicity predominantly aligned along SW-NE trending structures. Yet, constraining depths and fault geometries has remained challenging using land-based networks alone. Here, we leverage new data from three ocean-bottom seismographs (OBS) deployed in the Storfjorden area to improve event detection, hypocenter locations, and depth resolution.

We develop an enhanced seismicity catalog for the Storfjorden region using continuous waveforms from 9 stations recorded over a ~10 month period (August 2019 – June 2020), combining six permanent land stations with the three OBSs. The OBSs were placed in a triangular configuration over an area of prior known seismicity to minimize hypocentral distance and azimuthal gap. We perform phase picking using two different versions of the automated picker PhaseNet: PickBlue, a model specifically trained for OBS data, is applied to the three OBSs, while PhaseNet trained on the INSTANCE dataset is used for land stations. Phase associations are performed with the Gaussian Mixture Model Associator (GaMMA). Events are initially located using NonLinLoc (NLLoc) with a 1-D velocity model derived from the regional Barents3D model. Then, we compute source-specific station term corrections using well constrained events. We manually reviewed a small subset of the catalog to evaluate the quality of picks and association. Based on this we filter according to the number of phases and horizontal uncertainty given by NLLoc to remove spurious associations. Relative relocations are subsequently performed using HypoDD to improve spatial resolution and reveal fault structure.

The resulting catalog contains 1251 events, 7 times more than what is documented in the routine catalog prepared by the NNSN for this time period. The new catalog shows two active areas that had also been identified in earlier studies. One is a well defined cluster in the northern part of Stordjorden with hypocentre depths mostly between 8 and 16 km. The second is a significant cluster in the southern area of Storfjorden where most of the activity lies on top of the 2008 M_w 6.1 rupture zone with shallow activity between 0 and 7 km depths. While seismicity in this location has been previously described, we resolve a clearer lineation with an SE-NW trend. Our results demonstrate that a deployment of three OBSs in Storfjorden can significantly enhance the detection, location accuracy, and absolute depth estimates of earthquakes in this region of Svalbard.

The effects of current glacial rebound on seismicity in Sweden

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The driving forces for seismicity in Fennoscandia has been discussed intensely over the years, especially the role glacial isostatic adjustment (GIA). Do the remaining glacially induced stresses drive seismicity, does it trigger seismicity or does it not affect the seismicity. As there is no general correlation between uplift rate and seismic activity, other potential effects of the glacial rebound needs to be explored. Here we present seismic data from the Hälsingland region and investigate to which level this could be affected by GIA. We explore various models of glaciation and earth structure to infer how the stress field is changing through a glaciation and how the remaining stresses acts on the known fault structures.

A Regional SeisComP Magnitude Module for Real-Time Proxy M_w Estimation in Iceland

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Accurate and stable real-time magnitude estimation is a key requirement for operational seismic monitoring, particularly in regions where local attenuation and near-source amplitudes differ from those represented by standard magnitude relations. In SeisComP, routine magnitudes are commonly obtained from established amplitude-based procedures, but these estimates may be sensitive to sensor type, distance range, and the regional calibration of the underlying scaling relation. This study presents a new SeisComP magnitude module designed to provide a real-time proxy estimate of moment magnitude, M_w, by directly linking observed waveform amplitudes to empirical ground-motion models. The module combines custom amplitude and magnitude modules within the SeisComP processing chain. The amplitude module extracts peak ground velocity (PGV) and peak ground acceleration (PGA) from both weak-motion seismic sensors and strong-motion accelerometers, with consistent treatment of waveform units and sensor response. The resulting amplitudes are then used by a magnitude module that estimates proxy M_w by inverting regional ground-motion models as a function of observed amplitude, source-to-station distance, and site condition. This formulation allows weak- and strong-motion observations to contribute to a common magnitude estimate while preserving the regional attenuation characteristics of the monitoring area. The approach is applied to Iceland, where shallow crustal earthquakes may produce relatively large local amplitudes and rapid decay of ground motion with distance. These conditions can affect the stability of operational magnitudes when non-regionalized scaling relations are used. Using SeisComP playback, we test the module on M_w 4.5–6.0 earthquakes recorded during 2020–2025 and compare the resulting proxy M_w values with catalog magnitudes from operational and international agencies, including the USGS. The results indicate that the PGV- and PGA-based proxy magnitudes are generally consistent with reference moment magnitudes and show improved coherence across stations and sensor types. The proposed module therefore provides a practical seismological tool for regional real-time magnitude estimation in SeisComP, and the framework can be adapted to other monitoring networks where suitable ground-motion models and station metadata are available.

State-of-the-art probabilistic seismic hazard revision and risk assessment of the Reykjanes Peninsula in Iceland

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The probabilistic seismic hazard assessment (PSHA) for the Reykjanes Peninsula in southwest Iceland (including the Capital Region) has been completely reassessed using new and state-of-the-art models. This updated PSHA explicitly quantifies the uncertainties and expresses hazard levels in terms specified probabilities of exceedance of horizontal peak ground acceleration (PGA) and pseudo-acceleration spectral response (PSA) at multiple oscillating periods. Specifically, the study introduces new hazard maps that meet the requirements of the latest Eurocode 8 revision, reflecting that PGA is no longer the primary seismic design parameter in updated codes. For the Reykjavik capital region new hazard maps illustrating PGA and PSA with a 10% probability of exceedance in 50 years are presented and the hazard values for various exceedance probabilities are tabulated for municipalities across the peninsula. For a 10% probability of exceedance in 50 years, PGA levels (as a fraction of gravity, $g = 9.81\ m/s^2$) range approximately from 7% to 22% across the Capital Region, with higher values in the southern part and lower values in its northern part. A comparison with the current hazard map (National Annex to Eurocode 8) for the Capital region indicates broadly similar overall patterns and hazard levels, with differences generally within the bounds of hazard uncertainty. Greater spatial variations in the hazard levels are observed along the peninsula however. Furthermore, a comprehensive seismic risk assessment is being carried out, focusing on risk sensitivity and quantitatively evaluating at what stage in the hazard-to-risk chain uncertainties compound and to what extent. The results of this work not only expose the actual reliability of the revised hazard and the corresponding risk, but enable a more confident and efficient earthquake-resistant design of structures across the region.

Uncertainty in Ground Motion Models and Its Impact on PSHA

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Ground motion models (GMMs) constitute a fundamental component of probabilistic seismic hazard assessment (PSHA). They provide quantitative relationships between earthquake ground motion intensity measures and the key independent variables that characterize source, path, and site effects. The GMM uncertainties are typically classified as aleatory or epistemic, and they play a critical role in shaping seismic hazard levels and their variability. The standard deviation of a GMM, which represents the variability of ground motion intensity measures around the median prediction, is commonly interpreted as aleatory variability. In contrast, uncertainty in the median ground motion prediction is treated as epistemic and has traditionally been addressed in PSHA through logic-tree frameworks that incorporate alternative GMMs or through the use of a backbone approach. In this study, we first present the backbone approach and its application to Southwest Iceland. We then investigate the effects of both aleatory and epistemic uncertainties on PSHA results in this region. The PSHA results indicate that uncertainties in GMMs exert a significant influence on hazard estimates, particularly at longer return periods. These findings underscore the importance of a more rigorous treatment and explicit incorporation of epistemic uncertainty to better constrain and reduce the overall uncertainty in PSHA for Iceland.

Performance of ETAS Model Variants in Modeling Icelandic Seismicity

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The Epidemic-Type Aftershock Sequence (ETAS) model is one of the most widely used statistical frameworks for describing earthquake clustering in space and time and forms a cornerstone of operational earthquake forecasting. Over the past decades, a range of advanced ETAS variants has been developed to better capture the complexity of seismic triggering and improve forecasting performance. These include formulations with magnitude-dependent spatial kernels to reduce biases in aftershock spatial decay, three-dimensional implementations accounting for depth, and anisotropic spatial kernels to account for directionally dependent triggering following large earthquakes. In addition, the ETAS-Incomplete (ETASI) model introduces a blind-time parameter that accounts for short-term aftershock incompleteness (STAI), enabling more reliable estimation of key parameters such as aftershock productivity and the Gutenberg–Richter b-value. Because the performance of these model variants depends strongly on regional tectonic conditions and catalog characteristics, their systematic evaluation is essential before applying ETAS-based forecasting in a given region.

In this study, we evaluate a suite of advanced ETAS model variants using a high-resolution Icelandic earthquake catalog. The tested models include standard two-dimensional (2D) ETAS and ETASI formulations, as well as their three-dimensional (3D) and depth-dependent extensions. Our objective is to identify the model structures that most effectively capture the spatial and temporal characteristics of Icelandic seismicity patterns and are therefore best suited for future forecasting applications.

This study is based on a newly compiled, high-quality Icelandic SIL catalog specifically prepared for statistical seismology applications, representing the observational data stream most relevant for near-real-time forecasting. The work contributes to advancing ETAS-based forecasting frameworks in tectonically complex regions such as Iceland.

Stress-Informed ETAS Modeling of Aftershock Clustering in the South Iceland Seismic Zone

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The Epidemic-Type Aftershock Sequence (ETAS) model, formulated as a self-exciting point process, is a widely used framework for describing earthquake clustering and short-term seismicity forecasting. Over the past two decades, the original formulation has been extended in several directions to better represent the physical processes governing earthquake triggering and to improve predictive performance. However, the standard ETAS model relies on isotropic spatial kernels, which do not adequately capture the physically controlled distribution of aftershocks along fault structures and stress perturbations. This limitation becomes particularly critical in regions with complex fault systems and intense aftershock activity, such as the South Iceland Seismic Zone (SISZ).

In this study, we investigate the application of stress-informed spatial kernels within the ETAS-family framework to improve the modeling of a well-recorded, high-resolution aftershock sequence in the SISZ. This transform zone is characterized by right-lateral strike-slip faulting on near-vertical N–S-oriented faults, leading to strongly anisotropic patterns of seismicity. We replace the conventional isotropic triggering kernel with physically informed kernels derived from stress changes, including Coulomb stress changes and stress invariants such as maximum shear and von Mises stress. These formulations aim to better capture the spatial organization of aftershocks governed by stress redistribution.

Previous studies on well-documented mainshock–aftershock California sequences have demonstrated that incorporating stress-based and geometry-informed kernels significantly improves spatial forecasting performance and parameter estimation within ETAS and ETASI (ETAS-Incomplete) frameworks. Building on these developments, we systematically compare standard isotropic ETAS models with stress-informed variants of ETAS-family models in the SISZ.

Our objective is to assess the added value of physically informed spatial kernels in capturing the spatiotemporal characteristics of aftershock sequences in Iceland. Ultimately, this work aims to support the development of hybrid ETAS approaches that integrate physical information into statistical seismicity models and to explore their potential for integration into operational earthquake forecasting (OEF) frameworks in tectonically active regions such as SISZ.

On the earthquake source scaling and near-fault seismic wavefield in Icelandic transform zones

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We present an empirical scaling law for finite-fault ruptures on short, near-vertical strike-slip faults in Iceland's transform zones, the South Iceland Seismic Zone (SISZ) and Reykjanes Peninsula Oblique Rift (RPOR) in Soutwest Iceland, and the Tjörnes Fracture Zone (TFZ) in North Iceland). This empirical law quantifies how fault dimensions, average slip, maximum slip, and characteristic subevent (asperity) sizes are likely to increase with earthquake magnitude on relatively short fault areas that have disproportionately large slip, indicating higher stress drops compared to global averages. In addition, near-fault ground-motion records of the last three strong earthquakes (M_w6.3-6.5) in the SISZ reveal prominent velocity pulses with fundamental pulse-periods of ~1–2 s. The hypocentral locations on the faults, the pulse amplitudes, periods, and narrow-band character provide important information on the relationship between rupture scaling and near-fault wavefield characteristics. We interpret these findings within the framework of the specific barrier model – a physics-based earthquake source model where a fault is envisioned as an array of high-stress-drop subevents separated by barriers. The model provides a simple, yet physically consistent and parsimonious framework relating subevent sizes with the pulse periods. Thus, the new scaling law is physically grounded as larger-magnitude strike-slip events in Iceland's transform zones are expected to involve proportionally larger subevents that produce longer-period velocity pulses. To further quantify near-fault ground-motion effects, we performed physics-based earthquake rupture simulations using the CyberShake platform focusing exclusively on achieving high spatial resolution in the near-fault wavefield. We have adjusted the Graves–Pitarka pseudo-dynamic rupture generator of CyberShake to conform to the empirical source scaling law. The corresponding slip distributions and ground motion simulations are shown to capture well both the scaling law and the character of the recorded near-fault velocity pulses. Simulating earthquake in the range from 5.5 to 7.2 with multiple fault rupture variations of each magnitude we produce a large dataset of the near-fault velocity wavefield. Current efforts are focused on the calibration of new spatial ground motion models based on isochrone theory and neural operators, respectively. This work will contribute to more realistic seismic hazard assessment in the near-fault region in Iceland's seismically active transform zones.

Repeated dike injections beneath the Sundhnúkur crater row, Reykjanes Peninsula, Iceland, imaged by relatively relocated seismicity

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Between November 2023 July 2025 there have been ten dike intrusions and nine fissure eruptions beneath the Sundhnúkur crater row, on the Reykjanes Peninsula, Iceland. Geodetic and geochemical analyses show that these have been fed by a common source, located at 3-4 km depth beneath the harnessed Svartsengi geothermal area. This remarkable sequence of magmatic activity has been marked by abundant seismicity. Relative quiescence on the Peninsula following the July-August 2023 Fagradalsfjall eruption was interrupted in late October by elevated seismicity and surface uplift measured at Svartsengi, 8 km further west. As during inflation episodes at Svartsengi in 2020 and 2022, intense shallow seismicity accompanied the deformation, dominantly consisting of strike-slip faulting above an inferred sill.

From around 15:00 on 10th November 2023, intense migrating seismicity and rapid metre-scale horizontal deformation marked the intrusion of a NNE-SSW oriented dike, which reached approximately 15 km length in just 8 hours, and propagated under the town of Grindavík, which was evacuated. On 18th December, similar (though smaller amplitude) signals marked a second, smaller intrusion, but in contrast this dike quickly breached the surface and culminated in a 4 km long fissure eruption. A similar pattern has repeated in the following 2 years, with cyclical re-inflation beneath Svartsengi, and repeated dike intrusions and fissure eruptions along a common lineament. Through analysis of high-resolution relative relocations of the dike-induced seismicity, we investigate the relative geometry of the repeated dike intrusions, and the relationship between the seismicity and distribution of dike opening and location of eruption onset.

We find that most dikes initiate from a common point, likely marking a repeatedly used connection to the shallow magma storage region beneath Svartsengi. The dikes vary in propagation direction, forming a complementary pattern of seismicity and inferred opening, and occupy at least two sub-parallel planes, which closely match the geometry of eruptive fissures at the surface.

An enhanced catalogue of ring fault seismicity at Bárðarbunga caldera since the start of the 2014 Holuhraun eruption

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The 2014-2015 Bárðarbunga dike intrusion and caldera collapse, leading to the six-month Holuhraun eruption, featured more than 80 recurring $M_w \geq 5$ earthquakes located on the caldera ring fault. The caldera floor, covered by the Vatnajökull ice cap, subsided by 65 meters during the eruptive period. Continuous monitoring using an extensive seismic network has shown evidence of fault slip reversal and repeating earthquakes. The sequence of moderate-sized ring fault earthquakes resumed in 2017, suggesting a continuation of the same type of fault slip behaviour in response to the reversal of the collapse.

We re-examine the data prior and post fault slip reversal in the 2014-2016 period to improve our understanding of the processes governing the recurring earthquake sequence observed since the eruption starting in 2014.

We use the seismic data collected since 2014 to build a new earthquake catalogue for the caldera ring fault. We use waveform cross correlation for earthquake classification and template matching to detect previously undetected low magnitude earthquakes. We developed a tailored data processing pipeline, leveraging the Icelandic HPC computing cluster and its GPU nodes, to optimize template matching and earthquake cross correlations, with an emphasis on finding repeating earthquakes on the caldera ring fault.

We present an enhanced earthquake catalogue for the 2014-2016 period, with particular focus on the post-eruptive fault slip reversal, including a repeating earthquake analysis. Using parallelisation, we can speed up our processing on the HPC clusters. With new better-constrained catalogues generated using dense temporary networks from recent field campaigns, we are working towards improving locations for catalogues based on older data using double-difference relocation techniques.

When the resurgence period is included, the Bárðarbunga caldera collapse event has effectively lasted for almost 12 years and includes more than 100 $M_w \geq 5$ earthquakes. Re-examining older data with state-of-the-art processing techniques and computing resources offers a unique opportunity to build further context and aid holistic interpretation for the on-going events at the caldera, as well as to increase our broader understanding of faults undergoing large slip movements and the evolution of caldera collapse cycles.

Earthquake focal mechanisms reveal a complex response to re-inflation at Askja caldera, Iceland

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Askja, an active basaltic caldera volcano in Icelands Northern Volcanic Rift Zone, has experienced more than 85 centimetres of surface uplift since August 2021, following several decades of subsidence. Geodetic modelling of the observed uplift suggests an inflating sill type source at around 3 km below the surface, and recent tomography work images a shallow low-velocity anomaly, centred on the area of maximum uplift. In the same month that uplift began, there was a clear increase in the rate of shallow microseismicity, observed primarily in clusters surrounding the youngest lake-filled caldera Öskjuvatn.

To gain more insight into how the change in rate of microseismicity relates to the observed reversal in surface deformation, moment tensor solutions were constructed for a subset of events beneath Askja, both before and after the start of re-inflation. The Cambridge Volcano Seismology Group has maintained a dense seismic network around Askja since July 2007, which provides sufficient azimuthal coverage to produce well constrained moment tensor solutions. An expanded network deployed within Askja caldera in summer 2023 improves this azimuthal coverage significantly, extending the smallest well constrained events from magnitude 0.5 to just below magnitude 0.

Our results provide new constraints on the ring fault geometry beneath Öskjuvatn where the microseismicity rate increase was most prominent complementing previous insights from mapping of surface faults. Surprisingly, there is no evidence for a reversal in earthquake slip direction associated with the start of re-inflation, and only the modelled stress changes during the re-inflation period favour slip that aligns with our moment tensor solutions. We therefore propose that the microseismicity prior to the onset of re-inflation may have been driven primarily by regional deformation processes, not the long-term subsidence within Askja caldera. Our future work will exploit this expanded dataset of manually picked earthquake phase arrivals to improve our resolution of the velocity structure at the shallowest depths beneath Askja. This will contribute to a full structural model linking surface deformation, ring faulting and the underlying magma storage region.

Lateral Dyke Intrusions During the 2021-2023 Fagradalsfjall Volcano-tectonic Rifting Event, Based on Relative Earthquake Relocations

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Magmatic unrest within the Reykjanes Peninsula oblique rift, SW Iceland, has been closely monitored by a dense seismic and geodetic network. The 2021–2023 Fagradalsfjall volcano-tectonic sequence comprised four dyke intrusions, three of which resulted in surface eruptions. The first, in February 2021, produced intense seismicity along a 10 km path and fed a six-month-long eruption - the first on the Peninsula in ~780 years. The three subsequent intrusions (December 2021, July–August 2022, and July 2023) propagated over 5–7 km paths in ~5 days, reactivating sections of the 2021 dyke. Out of the subsequent dykes, the December 2021 dyke was the most seismically intense, propagating SW without breaching the surface. The July–August 2022 dyke had more diffuse seismicity, while the July 2023 dyke propagated primarily NE. Both the 2022 and 2023 intrusions fed short-lived eruptions. High-resolution relative relocations show that all four intrusions initiated at 6–8 km depth within ~1 km^2 and propagated laterally at 2–6 km depth. Seismicity depths varied: 2–6 km (2021), 4–6 km (Dec 2021), 1.5–3 km (2022), and 2.5–5.5 km (2023). All initiated above a deep cluster of long-period earthquakes at 8–14 km depth (Greenfield et al., 2022), located between the 2022 and 2023 eruption sites, suggesting magma ascent from near-Moho levels. The Fagradalsfjall dykes were governed by N–S strike-slip faulting despite their NE-SW orientation, suggesting that pre-existing plate-boundary structures control the orientation of faulting.

Greenfield, T., Winder, T., Rawlinson, N., Maclennan, J., White, R.S., Ágústsdóttir, T., Bacon, C.A., Brandsdóttir, B., Eibl, E.P.S., Glastonbury-Southern, E., Gudnason, E.Á., Hersir, G.P. and Horálek, J. (2022). Deep long period seismicity preceding and during the 2021 Fagradalsfjall Eruption, Iceland. Bulletin of Volcanology, 84,101. https://doi.org/10.1007/s00445-022-01603-2.

Seismotectonic Characterization of the Ahuachapn Geothermal Field, El Salvador, Based on 1D Velocity Modeling, Earthquake Relocation, and Focal Mechanism Analysis

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Continuous seismic monitoring is a fundamental tool for understanding the structural framework, reservoir dynamics, and fluidrock interactions in geothermal systems. A comprehensive seismological workflow has been applied to the Ahuachapn geothermal field in El Salvador combining velocity modeling, non linear probabilistic earthquake relocation, focal mechanism analysis, and migration studies to improve the characterization of subsurface processes. A new 1D velocity model has been obtained using the VELEST software, providing a more realistic representation of local lithological heterogeneities. The updated model was implemented in the NonLinLoc software to relocate a seismic catalog from January 2023 to July 2025, comprising 1038 events. Thereby, significantly reducing horizontal and vertical uncertainties and revealing spatially coherent seismic clusters aligned with major structural trends of the field. These results also allow an estimation of the brittleductile transition (5-7 km), constrained using a 3D electrical resistivity model. The Vp/Vs ratio derived from the 1D model shows low values (1.43-1.5) in shallow layers and near the production zone, suggesting the presence of a steam dominated region. Focal mechanisms computed with the SKHASH software indicate a mixture of normal oblique, strike slip, and reverse oblique faulting, reflecting the extensional regional stress regime and local reservoir scale variations. Migration analyses reveal changes in propagation rates and complex temporal patterns, suggesting the interplay of permeability pathways, pore pressure diffusion, and possible aseismic slip; however, a larger number of events would be required to fully constrain the dominant migration mechanism. The b value analysis (0.68) indicates that the field is currently under relatively high differential stress. Cross correlation between seismicity and injection rates during the study period, does not reveal a consistent or causal relationship.

The integrated workflow developed here strengthens the structural interpretation of the Ahuachapn system and provides a methodological foundation that can be replicated in other geothermal fields in El Salvador and the region to improve reservoir management and understanding.

2D imaging of Moho structure beneath Estonia using common conversion point (CCP) stacking

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The structure and thickness of the continental crust provide key constraints on the tectonic evolution of stable cratonic regions. In Estonia, Moho depth has been investigated using seismic and gravity methods. While these approaches provide important constraints on crustal thickness, their results differ in resolution and sensitivity, making it challenging to interpret the lateral continuity and geometry of the crust-mantle boundary.

We apply common conversion point (CCP) stacking, in which converted seismic phases are projected to their subsurface conversion points and stacked within spatial bins to produce laterally continuous images of the crustal structure. Although CCP stacking has been successfully applied in regions such as the Alps and Apennines, its use for crustal-scale imaging in the Nordic-Baltic region remains limited.

The resulting 2D profiles reveal pronounced variability in the character of the crust-mantle boundary. A profile across northern Estonia shows a strongly segmented Moho rather than a single coherent boundary; an abrupt transition from 55 km depth to 3540 km and back to deeper levels can be traced. The shallow segment corresponds to a local feature of the crystalline basement. In contrast, a profile from southeastern Estonia indicates a broad Moho transition zone of up to 20 km thickness, suggesting a gradual increase in seismic velocity instead of a sharp discontinuity.

These observations highlight significant heterogeneity in crust-mantle structure beneath Estonia and demonstrate that CCP stacking provides a powerful framework for 2D crustal imaging. The results suggest that the Moho cannot always be treated as a sharp interface, but may locally represent a complex and laterally variable transition.

Teleseismic Tomography of the Northern Volcanic Zone, Iceland.

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Iceland's Northern Volcanic Zone (NVZ) lies at the junction of the Mid-Atlantic Ridge and a deep mantle plume, forming a region of significant volcanic and tectonic complexity. We analyse multiple phase types of teleseismic P-waves (31,000 binned picks) and S-waves (15,000 binned picks), recorded by over 200 stations across the NVZ and surrounding areas, with data spanning from 2011 to the present. Relative arrival-time residuals are inverted using the FMTOMO package to produce tomographic images of the lithosphere. Chequerboard resolution tests demonstrate robust recovery of lithospheric structures from the upper crust to depths of approximately 150 km.

Our results reveal a rift-axis-parallel low-velocity anomaly in the upper mantle, extending from the Moho to ~80 km depth. Below this depth, the anomaly becomes more focused and shifts slightly westward relative to the current spreading axis. The mid-upper crust exhibits significant heterogeneity along the rift, with particularly low velocities concentrated beneath the northwestern region of Vatnajökull. In addition to presenting our finalised models, we also discuss their implications for rift-plume interactions.

New images of volcanic systems on the Reykjanes Peninsula, Iceland, from ambient noise tomography using a regional node array

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Unrest has been ongoing on the Reykjanes Peninsula, Iceland, since 2019, with inflation in the Fagradalsfjall and Eldvörp-Svartsengi volcanic centres resulting in a series of volcanic eruptions beginning in 2021. We have operated a permanent broadband seismometer network on the peninsula since June 2020, complemented by networks run by several other groups. Recently, these were supplemented by 24 three-component nodes for two months starting in September 2025, which provided improved coverage in the western part of the peninsula, and further enhanced both the spatial footprint and density of the combined arrays.

Using this new dataset, and taking advantage of a period of relative volcanic and seismic quiescence, a new 3D shear wave velocity model for the peninsula is constructed from inter-station surface wave dispersion curves extracted from ambient seismic noise cross-correlations. The dense node deployment also allows analysis of shallow crustal anisotropy, thus helping to locate magmatic storage regions and areas of shallow fractures. In conjunction with an analysis of deeper seismicity, magma pathways at depth can be located. The final model spans the shallow crust from the surface to 8 km depth, with lateral model resolution approaching 1 km above the brittle-ductile transition. This allows imaging of the Reykjanes, Fagradalsfjall and Eldvörp-Svartsengi volcanic systems, as well as of geothermal fields on the peninsula.

Poster Session

Numerical Simulation of Vehicle-Induced Seismic Signals on Distributed Acoustic Sensing (DAS) Cables Using the Elastic Lattice Method

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Distributed Acoustic Sensing (DAS) is increasingly used to monitor traffic-induced ground vibrations, yet interpreting these signals quantitatively remains challenging. The signal recorded at each channel depends on vehicle properties, subsurface structure, cable geometry. Most critical effect comes from the mechanical coupling between the cable and the surrounding medium, which varies with burial depth, soil type, and installation method and is difficult to characterize from field data alone. Understanding and parameterizing these coupling conditions is essential both for interpreting DAS measurements and for any downstream application, such as training of detection algorithms that should generalize across different deployments.

This work presents an end-to-end pipeline which connects the vehicle dynamics with full-waveform DAS simulation to produce synthetic data and systematically explore how coupling parameters shape the recorded signal. This is done in three stages. First, a quarter-car model drives over a road profile to generate a realistic tire force over time, capturing the main vibration effects of the vehicle. Second, this force is used in the ELM2D-DAS model, the elastic lattice particle model, which simulates both wave propagation and the DAS cable as a physical object. It allows to configure different mechanical properties of the cable, such as density, wave velocities, and coupling to the surrounding medium. As the source moves along the predefined trajectory, the model computes resulting wavefield. Third, virtual DAS gauges record strain rate along the cable, producing synthetic data that can be linked to specific coupling choices.

The simulation pipeline was validated and compared against field data from the Holmbuktura DAS experiment provided by NORSAR, where a heavy tractor was driven past a fiber-optic cable at a known speed and lateral offset near Tromso, Norway. The synthetic records reproduce the characteristic move-out pattern and capture the first-order amplitude and frequency content of the observed signals. Because coupling parameters can be varied independently while all other conditions remain fixed, the framework provides a controlled environment for studying how cable-ground interaction impacts the DAS response. In addition to that, the framework can be used to generate labeled synthetic training datasets spanning diverse coupling conditions, directly addressing the domain shift and data scarcity problems that currently limit cross-deployment generalization of machine learning methods for DAS-based detection.

Poster Session

Stakeholder interaction in the management and dissemination of seismic risk from Carbon Capture and Storage projects in the North Sea region

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Seismic activity associated with Carbon Capture and Storage (CCS) projects presents both operational and societal risks. The Safe-C research project aims to advance seismic monitoring for offshore CCS in the North Sea region, which offers substantial geological storage capacity close to major European emission sources. As CCS becomes a central component of European green transition strategies, several offshore storage projects are entering development or early operational phases, increasing the importance of robust monitoring and incident-management frameworks for induced seismicity.

Beyond the technical aspects of seismic monitoring, effective risk communication and coordination between stakeholders are essential for managing incidents across varying levels of severity. This poster presents preliminary findings from a stakeholder analysis conducted as part of the Safe-C project. Drawing on semi-structured stakeholder interviews and a review of existing literature, the analysis focuses on two main areas.

First, the analysis examines collaborative relations between seismological agencies, CCS operators, and public authorities involved in risk and incident management. Key issues include translating scientifically robust monitoring results into actionable political decisions, as well as establishing clear structures for coordination, communication, and responsibility during potential operational incidents.

Second, the analysis investigates how seismic monitoring and risk communication interact with processes of social license and public acceptance. CCS is generally regarded as a low-risk technology, and previous studies conclude that public acceptance of offshore CCS is higher than for onshore or near-shore projects (Ladenburg et al., 2026). However, larger and felt seismic incidents - particularly when combined with ineffective communication or limited public understanding - may trigger public or political resistance toward individual projects, thereby creating significant operational and financial risks.

Preliminary findings indicate important variations between national contexts regarding authorities perceptions of operational risk, the influence of historical experiences with subsurface industrial projects on social license negotiations, and the form and maturity of relations between seismic agencies, authorities, and operators.

Non-stationary ETAS Modeling of Volcano-Tectonic Seismicity in the Reykjanes Peninsula

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Magma intrusion and dyke propagation on the Reykjanes Peninsula, Southwest Iceland, have driven significant ground deformation since late 2019 and initiated a sequence of volcanic eruptions beginning in March 2021. This ongoing volcanic unrest, occurring within the Reykjanes Peninsula has generated intense earthquake swarms superimposed on background tectonic activity, resulting in pronounced spatial and temporal clustering of seismicity. Given the proximity of this active system to the capital region, understanding and forecasting such seismicity is of high societal and scientific importance.

To characterize these patterns, we use the Epidemic-Type Aftershock Sequence (ETAS) framework to high-resolution seismicity recorded by SIL seismic network of the Icelandic Meteorological Office. However, the Reykjanes sequences are strongly influenced by transient magmatic forcing, leading to rapid changes in seismicity rates, short-term fluctuations in the magnitude of completeness (Mc), i.e., highly non-stationary background seismicity. These effects challenge the core assumptions of conventional ETAS models, which typically assume stationarity and constant catalog completeness.

To address these limitations, we implement both the standard ETAS model and its extension, ETASI, which accounts for short-term aftershock incompleteness during periods of elevated seismicity introduced by Hainzl (2022). In addition, we incorporate a spatiotemporal background rate using joint smoothing in space and time. The models are applied to both synthetic datasets and a dense instrumental earthquake catalog for the Reykjanes Peninsula covering the period of recent unrest.

Our results demonstrate that models incorporating non-stationary background rates significantly outperform stationary formulations, with ETASI providing the most stable and consistent parameter estimates. The inferred temporal evolution of the background rate closely follows episodes of magma intrusion and dyke propagation, while its spatial distribution aligns with deformation zones, eruptive fissures, and inferred magma pathways.
These findings highlight the importance of explicitly accounting for non-stationarity and transient magmatic forcing in statistical seismicity models. The results provide a key step toward integrating physics-informed approaches into operational earthquake forecasting (OEF) frameworks in Iceland and similar volcano-tectonic environments.

Poster Session

Seismic tomography and geothermal potential at the Sveifluháls volcanic ridge, SW Iceland

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Sveifluháls, to the southwest of the Reykjavík capital area, has geothermal activity at the surface (Seltún), and recent seismic activity and ground inflation/deflation has been detected. Its potential for geothermal exploitation has motivated research for decades, but further information remains needed to start activities. For this project, we have deployed a line of seismic nodes (SmartSolo) across the Sveifluháls ridge, and are planning on using DAS on an optic fibre lying parallel to the ridge lying along Krýsuvíkurvegur, the road to Krýsuvík. We will apply the adjoint Eikonal tomography method to image the structure beneath the ridge, and especially infer Vp/Vs ratios that are highly sensitive to the presence of fluids.

Poster Session

Seismicity characterization for CO_2 storage in contrasting tectonic settings Iceland versus the Norwegian continental shelf

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The study of natural CO_2 fluxes across diverse tectonic settings offers valuable analogues for understanding long-term CO_2 migration and retention in varying geological environments. These insights can help assess the effectiveness of geological storage of CO_2, both in basalts (e.g., Iceland) and saline aquifers (e.g., on the Norwegian Continental Shelf (NCS)). Despite its strategic location, the North Atlantic (NA) region is underexplored, with natural CO_2 emissions primarily driven by the Mid-Atlantic Ridge (MAR) activity and occurring within sedimentary basins on the NCS.

This study focuses on regional seismicity across the NA, especially in Iceland, through the construction of a unified earthquake catalogue using records from regional networks, including NORSAR, NNSN, IMO, and ISC, along with two published unified catalogues: ICEL_NMAR from Jonasson et al. (2021) and SHARP from Kettlety et al. (2024), to enhance data quality and consistency. To reconcile these datasets, we used a workflow adapted from established methodologies and merged over 520k events through the definition of space-time criteria. The resulting catalogue contains around 500k entries and is dominated by micro-seismicity in Iceland, particularly after 2010, reflecting improved data availability. There, seismicity is strongly concentrated over the volcanic zones, outlining the MAR structure, and occurs primarily between 0 and 10 km depth, with more than 10k events recorded annually.

To characterize the seismicity over Iceland, we calculate the evolution of the b-value from 1900 to 2021 using the Gutenberg-Richter relationship across two depth intervals: 0-10 km and below 10 km. The b-value reveals the ratio of small to large earthquakes and is inversely correlated to stress, and proportional to the thermal gradient. While b-values are typically close to 1 in normal tectonic settings, they are often higher in volcanic regions, due to the increased low-frequency seismicity associated with magma movement. However, processes such as dyke intrusions and stress accumulation can reduce b-values, particularly during seismic swarms (Greenfield et al., 2020). Deeper than 10 km depth, we find that the b-value is close to one, while at shallower depths it is often higher, up to 1.9, highlighting the depth dependency of seismicity and the influence of active volcanic and geothermal processes in the upper crust. Future work will focus on space-time mapping of b-values to constrain their relationship with the tectonic context in Iceland and in the wider NA region.

Cross-correlation of deep earthquakes within the intraplate volcanic system of Ljósufjöll, West-Iceland

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Seismicity in the intraplate volcanic system Ljósufjöll in West-Iceland increased significantly in 2021 in a cluster near the lake Grjótárvatn at depths of 15-20 km, deeper than the bulk of seismicity in Iceland which occurs in the top 10 km. Previous to 2021 seismicity in the area was near non-existent, but in the years following 2021 the activity remained consistent with 0-20 events >M1 registered every month of 2022 and 2023. In August 2024 the activity increased again with around 70 recorded events >M1 in the area. The increase in activity continued in 2024 and 2025, with a maximum of around 90 events above a >M1 recorded in June 2025. So far in 2026 the activity seems to be decreasing again, with no more than around 20 events >M1 recorded per month. The activity is curious due to the depth, clustering and location in an area of minimal tectonic strain. Along with the high-frequency earthquakes, some tremor bursts and lower frequency (LF) events have been recorded. This, along with the depth, has strengthened the interpretation of magmatic origin of this activity.

To further understand this seismicity, we sorted events into families with waveform cross-correlation using the REDPy (Hotovec-Ellis, A.J. (2025)) python package. Events from the period of May-November 2025 were used, the threshold for the correlation coefficient was set at 0.9 and a minimum of 5 events were required for each family, resulting in 25 families and around 1/3 of all events assigned to a family. The cross-correlation found both LF families of around 2-6 Hz as well as more typical volcano-tectonic (VT) families with frequencies closer to 10-20 Hz, which was the more dominant group. Also notable within the different families was a strong reflection signal, possibly from the Moho, that differed in both polarization and strength depending on families. Further analysis using relative relocation shows some clustering depending on family, but the LF events and the VT are located at similar depth and location. LF deep earthquakes are known in other Icelandic volcanic systems, such as in Askja, Katla and Bárðarbunga, but in these the LF events are located much deeper than the VT events as well as being clearly spatially offset. The last eruption of the Ljósufjöll volcanic system occurred in the 10th century CE, but even with magmatic origin being the most likely interpretation of this recent activity, no surface deformation has been observed so far.

Poster Session

Kymenlaakso Seismic Experiment

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The Kymenlaakso rapakivi granite region exhibits a higher level of seismicity when compared to other regions in Finland. The KySe 2026 project aims to collect seismic data in the coastal and archipelago regions around the municipalities of Kotka, Hamina and Virolahti in southeastern Finland. The motivation for the project is to better understand offshore earthquakes in the rapakivi region and to learn more about existing fault systems using seismic imaging techniques.

The deployment will run between May and September 2026 and include 20-30 Güralp 3ESPC 3-component broadband seismometers from FINNSIP (The Finnish Seismic Instrument Pool). The instruments will be installed on exposed bedrock to ensure good coupling. Existing power and infrastructure will be used where possible and solar panels and batteries where needed. The instruments will be protected from rain and wind noise will be minimized. The temporary network will include both single seismometer installations and small arrays. The network will include both offline and online stations to enable the use of the data in daily seismic analysis.

The deployment is expected to improve the detection of small earthquakes in the region which may not be easily detected or located using the existing permanent seismic network. The temporary network will function as a test of whether new permanent seismic stations in the area would provide a benefit to the detection of earthquakes and explosions in southeastern Finland. The experiment will provide a useful insight into seismic risk in the coastal rapakivi environment.

Poster Session

The ISLAB program

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The international ISLAB 2025-2028 project aims at demonstrating whether a link exists between the triggering or intensity of hydrothermal activity and stochastic or cyclic active volcano-tectonic processes in Iceland, and the related adaptations of microbial communities both over short and long time scales (Holocene). The ISLAB project follows previous seismological results from the tectonically and volcanically active Reykjanes peninsula suggesting that active faults modulate hydrothermal convection over time. The flow, temperature (T) and chemical composition of hydrothermal fluids would then be time-dependent and linked to seismic cycles along major faults and, potentially, also to current fissural volcanic eruptions (diking).

The geophysical part of the project aims to characterize the dependence of the permeability of the active rift upper crust on transient volcano-tectonic phenomena (earthquakes and dyking) over the duration of the scientific project. We focus our study on the Krýsuvík volcano-tectonic segment, which contains a deep endoreic lake, Kleifarvatn. A dense network of 14 seismic stations including 2 OBS has been settled in 2025 as well as a network of piezometers and T sensors at lake bottom close and away lake-bottom hydrothermal outflows. CTD and Mapper analysis were formerly performed. We also investigated Kleifarvatn basement structure with a HR Boomer seismic survey and cored sediments at 3 locations to investigate the microbiote and sediment record of past events.

This ongoing project is very active and consists in a first step for a broader one in Iceland for which an international cooperation will be required.

Poster Session

A joint Nordic seismic hazard analysis using a harmonized catalogue and source zonation

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Probabilistic Seismic Hazard Analysis (PSHA) is a standard method for estimating the likelihood that ground motion levels will be exceeded within a given time window. In the Nordic countries, where seismicity levels are low to moderate, reliable hazard estimates are especially important for mandatory seismic risk analyses of nuclear power plants (NPPs) and other critical infrastructure.

In this work, we improve PSHA in Northern Europe by refining seismicity rate estimates and harmonizing hazard models across Finland, Sweden, Norway, and Denmark. Our effort focuses on compiling a harmonized earthquake catalogue and developing a unified SSZ model.

A key challenge in the Nordic region is the low level of seismicity, which limits the number of available earthquake records and increases epistemic uncertainty. The short seismic history and the small number of moderate magnitude events make recurrence estimates poorly constrained. To address this, we developed SSZ models that extend across national borders and integrated seismic data from multiple countries. We also standardized methods for compiling the earthquake catalogue and estimating Gutenberg-Richter parameters, improving the consistency of hazard estimates across the region.

The analysis provides an up-to-date, open-access evaluation of seismic hazard in the Nordic countries. The new model offers insights that support the planning and design of critical infrastructure, support better preparedness, and improve understanding of the potential economic and societal impacts of earthquakes. The methods, input data, and preliminary results will be presented.

Poster Session

Legacy Data - Digitization of Analog Seismograms at the Institute of Seismology, University of Helsinki

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Seismological observations in Finland began in 1924, when the first seismograph station was founded at the University of Helsinki located in the basement of the Department of Physics in downtown Helsinki. The next milestones were achieved in late 1950s and in early 1960s when several short period and long-period seismograph stations were established around Finland, driven by large nuclear tests in Novaya Zemlya in late 1950s. The development led to the establishment of the Institute of Seismology in 1961.

The Finnish seismic archive, located in the basement of the Institute of Seismology on the Kumpula Campus, consists of nearly 500 000 paper seismograms dating back to 1924. As part of EPOS (European Plate Observing System) Finland development project, the analog seismograms are digitized to expand the digital continuous time series for better understanding of the medium and long-term evolution of intraplate earthquake hazard. The ageing of the paper sheets increases the risk of losing the original data. Therefore, the current digitization project aims to preserve the invaluable records by converting the analog traces into digital form for modern research. The digitization process consists of a three-step workflow. First, we create an inventory of the archive and select seismograms for the scanning. Priority is given to seismograms with traces of local or teleseismic earthquakes or human-made seismic events (e.g., nuclear tests, large explosions). The second step is the outsourcing and scanning of the selected paper seismograms. The third final step involves the extraction of the time series data from the photographs by using published software (such as Digitseis) and by developing AI-based methods for automatic extraction of the waveforms. The digitized data are calibrated and validated using metadata notes on the paper sheets and on observatory yearbooks before the data are published.

Poster Session

Explainable Machine Learning for Ground Motion Prediction in the Vrancea Intermediate Depth Seismic Zone

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Ground motion prediction for intermediate depth earthquakes remains challenging as conventional log linear empirical equations cannot capture complex source, path, and site interactions. This study presents the first machine learning ground motion model for intermediate depth earthquakes in Romania, using 1,627 recordings from 156 events (M 4.0-5.98, 2006-2025) across 19 stations operated by the National Institute for Earth Physics (INFP). The eXtreme Gradient Boosting (XGBoost) achieved R^2 = 0.885 for peak ground acceleration (PGA) and R^2 = 0.875 for peak ground velocity (PGV), outperforming the empirical baseline (R^2 = 0.495). Residual = 0.291 falls within the range of published models (0.28 to 0.35). Temporal validation on post 2020 events yielded R^2 = 0.724. A ResNet18 CNN on wavelet scalograms achieved R^2 = 0.684, lower than XGBoost. Three explainability methods, SHapley Additive exPlanations (SHAP), LIME, and Grad-CAM, were applied independently. SHAP identified magnitude and epicentral distance as dominant predictors, with azimuthal dependence consistent with Moesian Platform waveguide amplification. Grad-CAM revealed ResNet18 focused on the S wave arrival window. Convergent findings establish a triple XAI framework for seismic hazard assessment in data scarce intermediate depth regions.

Poster Session

Micro-seismicity in the Hverahlíð high-temperature geothermal field, Hengill, SW-Iceland

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The Hverahlíð high-temperature geothermal field is located in the southern part of the Hengill volcanic complex in southwest Iceland. Prior to the onset of geothermal production in 2016, seismic activity in the area was limited. Since then, persistent micro-seismicity has been detected, characterised by a diffuse spatial pattern and only minor swarm activity. Despite covering just ~2 km^2, Hverahlíð hosts some of Iceland's most productive geothermal wells, with measured temperature exceeding 300°C at around 1.5 km depth.

In this study, we analyse seismicity in Hverahlíð from 2016 to 2025, recorded by a varying number of seismometers (14 to 40) deployed across the wider Hengill area. The core network consists of permanent stations operated by Iceland GeoSurvey (ÍSOR) for ON Power, supplemented by the regional SIL-network of the Icelandic Meteorological Office. Additionally, 30 temporary stations were installed during the COSEISMIQ project (2018–2021), significantly improving the local detection capability and spatial resolution.

Seismicity in Hverahlíð is dominantly micro-seismicity, with ~90% of the activity of ML < 1.0, and a magnitude range of ML -0.3 to 3.5. High-resolution relative relocations show that seismicity is confined to 2-3.5 km depth below sea level, i.e., located slightly below the bottom of the production wells and organised in one main cluster and another significantly smaller cluster, both trending NNE-SSW within the production area.

Although the Hverahlíð area is highly fractured with cross-cutting faults trending from NNE-SSW to ENE-WSW, the observed seismicity does not directly illuminate known surface faults. Instead, the earthquake distribution reflects the geothermal production zone, closely matching the geometry of the geothermal system as inferred from existing resistivity models. The earthquake depth distribution may reflect, at least partially, cooling and thermal contraction of the hot host rock induced by deep fluid convection linked to the heat source of the geothermal system. Comparison with other high-temperature geothermal systems in Iceland suggests that the seismicity may delineate the base of a highly permeable convective geothermal reservoir.

Despite considerable production driven pressure draw-down in Hverahlíð, only around 18% of earthquake source mechanisms show pure normal faulting, whereas 55% show pure strike-slip faulting. As the production area will grow in lateral extent in coming years through planned step-out-wells, a corresponding increase in the lateral extent of seismicity is possible.

Poster Session

DAS acquisitions at GEUS

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In this poster we present examples of the Distributed Acoustic Sensing (DAS) acquisition we have conducted at the Geological Survey of Denmark and Greenland (GEUS) with our two interrogators. We give an overview of our DAS equipment and our fiber trenching tools. A focus for the DAS acquisition at GEUS has been and still is as an application for carbon capture and storage (CCS) both in terms of passive monitoring of seismicity but also in connection with active seismics. In the poster we give examples of both. DAS is a novel instrument for the monitoring of critical infrastructure; we give examples of applications for infrastructure monitoring where DAS is used and integrated with data from networks of seismic sensors. Furthermore, we show recordings of complex seismic wavefields from earthquakes and explosions with a very high resolution. Today the two interrogators are recording continuously on a fiber in the North Sea and on a fiber in the Baltic Sea.