84. Jahrestagung der Deutschen Geophysikalischen Gesellschaft

TAGUNGSBAND

10.– 14. März 2024 in Jena

FRIEDRICH-SCHILLER-
UNIVERSITÄT
JENA

Institut für
Geowissenschaften Jena

IMPRESSUM

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Herzlich Willkommen zur 84. Jahrestagung der Deutschen Geophysikalischen Gesellschaft in Jena!

Wir freuen uns, die 84. Jahrestagung der Deutschen Geophysikalischen Gesellschaft vom 10. bis 14. März 2024 nach 21 Jahren zum zweiten Mal an der Friedrich-Schiller-Universität Jena ausrichten zu dürfen. Die Jenaer Geophysikerinnen und Geophysiker feiern ein rundes Jubiläum: Das Geodynamische Observatorium Moxa wurde vor 60 Jahren eingerichtet.

Der lebendige wissenschaftliche Austausch steht im Mittelpunkt der Tagung, ebenso wie die Möglichkeit, sich informell über verschiedenste Themen mit Bezug zur Geophysik auszutauschen, alte und neue Bekannte zu treffen oder auch Kontakte für die weitere Karriere zu knüpfen. So ist bei der Vielzahl von Präsentationen zu aktuellen Entwicklungen geophysikalischer Methoden, neuen Daten und spannenden Forschungsergebnissen, den Ständen größerer und kleinerer Unternehmen, den Treffen der Arbeitskreise, beim Meet & Greet, bei der Jobbörse und vielem mehr dieser Woche vor allem: ein Ort der so wichtigen persönlichen Begegnungen und Diskussionen am Rande der zahlreichen Veranstaltungen. Hier entstehen neue Projektideen und Kooperationen. Viele Karrieren beginnen beim Schlendern durch die Firmenausstellung, bei angeregten Gesprächen an den Postern, deren Präsentation viel Zeit gegeben wird, oder in den Kaffeepausen nach den Vorträgen. Nachwuchswissenschaftlerinnen und -wissenschaftler erhalten die Möglichkeit, ihre Arbeiten einem breiten Fachpublikum vorzustellen und mit ganz verschiedenen Personen zu diskutieren.

Die vier Schwerpunktthemen haben wir vor dem Hintergrund der Jenaer Forschung ausgewählt, jedoch sind diese Themen gegenwärtig von weit überregionaler Bedeutung. Lange Zeitreihen dienen nicht nur der Identifizierung natürlicher Signale des Erdsystems, das wir als vom Erdkern bis zur hohen Atmosphäre und darüber hinaus reichend ansehen, sondern sie sind die wichtigste Dokumentation des globalen Wandels und somit unverzichtbare Grundlage von möglicher Mitigation und Prävention. Die „Model-Data-Integration" stellt eine der großen aktuellen Herausforderung nicht nur der Geophysik, sondern auch etlicher Naturwissenschaften dar. Hier freuen wir uns auf Beiträge sowohl der globalen als auch der angewandten Geophysik. Fluide in der Erdkruste und ihr Zusammenhang mit natürlicher und induzierter Seismizität werden ein weiteres Schwerpunktthema sein. Neben der Beobachtung und Modellierung der Prozesse ist hier auch das Abbilden von Fluiden im Untergrund von großem Interesse. Seismisches Rauschen und die seismische Coda werden trotz ihres komplexen Charakters zunehmend auch als wichtige Informationsquelle über die Erde wahrgenommen.

Allen Schwerpunktthemen ist gemeinsam, dass hier innovative Entwicklungen in der Simulation und Datenanalyse, oft mit modernen KI-Werkzeugen, im Mittelpunkt stehen.

Während die Schwerpunktthemen grundlagenwissenschaftliche und angewandte Aspekte von Forschung und Entwicklung vereinen, steht das Kolloquium „Geophysik aus der Praxis" ganz im Zeichen geophysikalischer Anwendungen in der Wirtschaft.

In den vielfältigen Sessions werden nicht nur methodische Entwicklungen, neueste multimodale Datensätze oder Fallbeispiele aus der Forschungs- und Industriepraxis vorgestellt, sondern sie bieten auch eine Plattform, aktuelle Themen wie „open source" oder die Rolle, Sichtbarkeit und Wahrnehmung der Geophysik in der Öffentlichkeit anzusprechen.

Wir hoffen, dass Sie eine inspirierende und erkenntnisreiche Woche auf der Tagung erleben werden und wünschen Ihnen eine angenehme Zeit im schönen Saaletal.

Das Organisationsteam

INHALTSVERZEICHNIS

84. JAHRESTAGUNG DER DEUTSCHEN GEOPHYSIKALISCHEN GESELLSCHAFT

TAGUNGSORT

Friedrich-Schiller-Universität Jena
Adresse: Carl-Zeiss-Straße 3 (Uni Campus), 07743 Jena
Webseite: https://dgg2024.dgg-tagung.de

VERANSTALTER

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ALLGEMEINE HINWEISE

	Early Bird (bis 26.01.24)	Pre-Registration (bis 23.02.24)	Late & On-Site (ab 24.02.2024)
DGG-Mitglied	180€	250€	300€
AGS, AEF, DPG, DMG oder DVGeo[1] Mitglied	180€	250€	300€
DGG-Mitglied Studierende*	30€	50€	70€
AGS, AEF, DPG, DMG oder DVGeo[1] Mitglied Studierende*	30€	50€	70€
Nicht-Mitglieder	230€	300€	350€
Nicht-Mitglieder Studierende*	50€	70€	100€
Personen im Ruhestand**, Schullehrer/innen** Arbeitssuchende, Elternzeit**	100€	150€	250€
Gesellschaftsabend	Anmeldung bis zum 26.01.2024		
Normal	60€		
Studierende*	35€		
Begleitpersonen	60€		
Tageskarte			180€

[1] Dem Dachverband der Geowissenschaften (DVGeo) zugeordnete Vereinigungen (Deutsche Geologische Gesellschaft - Geologische Vereinigung (DGGV), Deutsche Mineralogische Gesellschaft (DMG), Paläontologische Gesellschaft (PALGES), Deutsche Ton- und Mineralgruppe (DTTG)

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** bitte legen Sie bei der Anmeldung einen Nachweis vor

Der Beitrag für Schullehrer/innen gilt nur für Lehrkräfte an Schulen, jedoch nicht von Hochschulen.

Der Differenzbetrag zwischen Mitgliedern und Nichtmitgliedern wird bei einem Beitritt zur DGG auf den Jahresbeitrag angerechnet.

INTERNETZUGANG

Während der DGG-Tagung wird permanent kostenloser WLAN-Zugang möglich sein. Es werden zwei Verbindungsmöglichkeiten bereitgestellt:

1. Die Universität Jena ist Mitglied im weltweiten universitären EDUROAM Netz. Alle, die in ihrer Heimatuniversität einen EDUROAM-Zugang haben, können sich bei uns mit den üblichen Benutzerdaten mit dem Internet verbinden. Dies ist die einfachste und bevorzugte Variante.
2. Für alle anderen (oder falls es Login-Probleme geben sollte) stehen WLAN-Zugangsdaten im Tagungsbüro (SR120/121) zur Verfügung.

ESSEN

Auf dem Campus befinden sich eine Cafeteria und die Mensa des Studierendenwerks. In unmittelbarer Umgebung finden sich die Mensa am Philosophenweg, sowie zahlreiche Restaurants und das Einkaufszentrum Goethe-Galerie.

EINLADUNG ZUR DGG-MITGLIEDERVERSAMMLUNG AM 13. MÄRZ 2024 IN JENA

Im Namen des Vorstands der Deutschen Geophysikalischen Gesellschaft (DGG) e.V. laden wir alle Mitglieder der DGG im Rahmen unserer 84. Jahrestagung zur Mitgliederversammlung am **Mittwoch, den 13. März 2024, von 17:00 bis ca. 19:00 ein.**

Ausführliche Informationen zu den geplanten Änderungen der DGG-Satzung und Geschäftsordnung (TOP 6 der Tagesordnung) befinden sich auf der DGG-Seite ***https://dgg-online.de*** im Mitgliederbereich unter Mitgliederversammlungen.

Die Veranstaltung findet nur in Präsenz statt. Ort der Veranstaltung ist der **Hörsaal 2 (HS 2)**, Friedrich-Schiller-Universität Jena, Carl-Zeiss-Straße 3, 07743 Jena.

Kurzfristige Änderungen werden auf der Tagungswebseite ***https://dgg2024.dgg-tagung.de*** bekannt gegeben oder können im Tagungsbüro erfragt werden. Wir freuen uns auf Ihr zahlreiches Erscheinen.

TAGESORDNUNG FÜR DIE DGG-MITGLIEDERVERSAMMLUNG 2024

TOP 1: Begrüßung, Feststellung der fristgerechten Einberufung und der Beschlussfähigkeit

TOP 2: Genehmigung der Tagesordnung

TOP 3: Genehmigung des Protokolls der Mitgliederversammlung vom 8. März 2023 in Bremen

TOP 4: Bericht des Präsidenten

TOP 5: Bericht der Geschäftsführung

TOP 6: Änderungen der DGG-Satzung und Geschäftsordnung
- Einladung zur Mitgliederversammlung in Textform (z.B. auch digital)
- Möglichkeit zur hybriden Mitgliederversammlung und Online-Wahl
- Änderung der Mitgliederstruktur
- Änderung der Kündigungsfrist auf einen Monat
- Genderneutrale Formulierung der Satzung und Geschäftsordnung
- Loslösung der stimmberechtigten studentischen Vertretung im Vorstand von der vierjährigen Amtsperiode

TOP 7: DGG-Satzung und Geschäftsordnung

TOP 8: Bericht des Schatzmeisters

TOP 9: Bericht der Kassenprüferinnen und Entlastung des Schatzmeisters

TOP 10: Änderung der Mitgliedsbeiträge

TOP 11: Bericht zum Geophysical Journal International

TOP 12: Berichte der „Rote Blätter"- und der GMIT-Redaktionen

TOP 13: Kurzberichte der Leiterinnen und Leiter der DGG-Komitees: Publikationen, PRO - Public Relations & Outreach, Jahrestagungen, Ehrungen, Firmen, Mitglieder, Studierende, Studienfragen, Kooperationen, Chancengleichheit

TOP 14: Kurzberichte der Sprecherinnen und Sprecher der DGG-Arbeitskreise:

Angewandte Geophysik, Endlager-Geophysik, Elektromagnetische Tiefenforschung, Induzierte Polarisation, Seismik, Hydro- und Ingenieur-Geophysik, Dynamik des Erdinneren, Vulkanologie, Geschichte der Geophysik, DGG-Archiv, Geothermie, Geodäsie/Geophysik, Seismologie, Marine Geophysik, Kampfmitteldetektion, Geomagnetik

TOP 15: Neues vom Dachverband Geowissenschaften (DVGeo) und den geowissenschaftlichen Gesellschaften

TOP 16: Aussprache

TOP 17: Entlastung des Vorstands

TOP 18: Wahlen zum Vorstand

TOP 19: Protokollarische Feststellung des Vorstands

TOP 20: Wahl der Kassenprüfer und Kassenprüferinnen

TOP 21: Anträge und Beschlüsse

TOP 22: Verschiedenes

SCHWERPUNKTTHEMEN

S1: From pore space to whole Earth: understanding complex geoprocesses through Model-Data Integration in the 21st century

Anne Schulz (Jena), Katrin Huhn (Bremen),
Ingo Stotz (München), Peter Bunge (München),
Moritz Ziegler (Potsdam), Nina Kukowski (Jena)

Numerical and physical models are indispensable tools for an efficient and process-oriented data interpretation. They allow us to identify key data-sets that are sensitive to the processes in question, while data in turn allows us to improve model parametrisation, including boundary conditions, physical properties and rheological behaviour. Geophysics has a long history of model-data integration, for instance in tectonics and geodynamics or geo-hazard related research. Both fields address different geo-settings in terms of spatial scale and time, reaching from near surface sedimentary processes, sedimentary basins, crustal structure to whole Earth models. In particular when regarding uncertainties, an intelligent approach is required in order to keep CPU-time at a reasonable level. Even then, some simulations require HPC computing, such as also does joint inversion of data sets. Model-data integration will become even stronger in the upcoming era of exa-scale computing. The arrival of vast computing resources enables simulations with a more streamlined representation of key processes, and allows models to resolve a much broader range of spatial and temporal scales, necessitating even more to place observational constraints into the center of model formulation. To this end, growing modeling capabilities are going along with an equally impressive growth in publicly available data-sets and observational capabilities, enabled through satellite remote sensing, new sensor technology and the digitalisation of legacy data sets. We invite contributions to this focus theme from all areas in geophysics, both, marine and onshore, where model-data integration plays a key role to better understand complex geophysical processes and represent the subsurface in a model.

PLENARVORTRAG:

Ylona van Dinther (Department of Earth Sciences, Utrecht University):
Ensemble data assimilation for estimating earthquake and geodynamic states and parameters

(Montag, 14:00 Uhr, HS2)

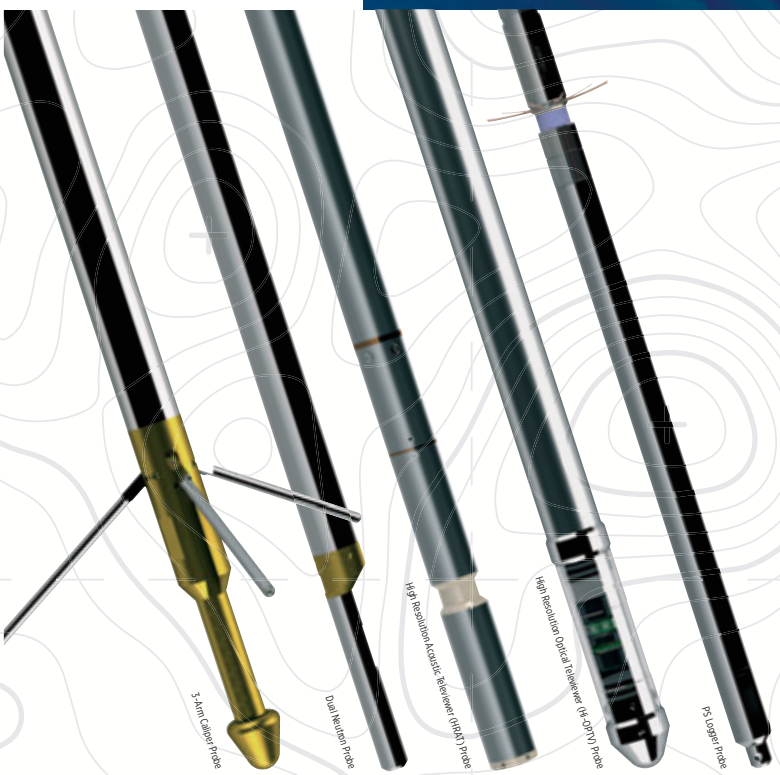
AKTUELLES THEMA

allied Associates Geophysical GmbH

HOCHAUFLÖSENDE BOHRLOCH-MESSUNGEN

Robertson GEO zur Charakterisierung von Aquifer-Eigenschaften uvm

ROBERTSON GEO
Unlocking Your GeoData



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SCHWERPUNKTTHEMEN

S2: Vom Erdkern bis zur hohen Atmosphäre und noch weiter: Erkenntnisse aus langen geophysikalischen Zeitreihen in der Wissenschaft und Industrie

Valentin Kasburg (Jena), Roman Leonhardt (Wien), Stephan Großwig (Jena), Nina Kukowski (Jena)

In den verschiedenen Schalen des Erdsystems laufen Prozesse mit sehr unterschiedlichen Raten ab. Diese können sowohl kontinuierlich, als auch episodisch sein. Etliche Prozesse ändern ihren Verlauf, falls Schwellenwerte (Kipppunkte) überschritten sind. Um solche Prozesse, etwa Massenumlagerungen (Schwereänderungen), hydrologische Ereignisse, tektonische Vorgänge, Magnetfeldänderungen, Wetter- und Klimaphänomene zu identifizieren und ihre Amplituden zu bestimmen, werden oft mindestens jahrzehntelange Beobachtungen benötigt. Dieses ist z.B. eine wichtige Aufgabe geophysikalischer und geodynamischer Observatorien, die in sehr verschiedenen geologischen Settings liegen. Als Beispiel sei hier das Geodynamische Observatorium Moxa der Friedrich-Schiller-Universität Jena genannt, das vor 60 Jahren eingerichtet wurde. Auf der anderen Seite dauern Einzelereignisse oft nur sehr kurze Zeit. Das macht Registrierungen mit sehr hohen Samplingraten notwendig. In den aufgenommenen Zeitreihen überlagern sich die Effekte von Langzeitprozessen mit denen von kurzen Ereignissen. Oft ist es notwendig mehrere Zeitreihen gemeinsam zu analysieren, um sowohl Prozesse als auch Ereignisse zu identifizieren und unterschiedliche Quellen zuzuordnen. Zur Analyse und Prozessierung dieser immer größeren Datenmengen wird neben den klassischen Methoden vermehrt auf KI-gestützte Methoden zurückgegriffen. Im Rahmen dieser Schwerpunktsession sollen Prozesse und Ereignisse aus den unterschiedlichen Schalen des Erdsystems genauso wie Fortschritte in der Sensorik und Methodik thematisiert werden. Wir laden zu Beiträgen über sensorische und methodische Arbeiten für die Erfassung, Verarbeitung und Analyse von Zeitreihen ein.

Unter diesem Schwerpunktthema laden wir daher Wissenschaftler aus Forschung und Industrie nicht nur aus der Geophysik, sondern aus den vielen assoziierten Arbeitsfeldern der Geowissenschaften, Physik und Technik ein, über mögliche Techniken und Anwendungsfelder zu berichten und die Bedürfnisse zukünftiger Entwicklungen zu formulieren.

PLENARVORTRAG:

Bruno Meurers *(Universität Wien)**:***
Massentransporte im System Erde und ihre Signale in gravimetrischen Zeitreihen
(Donnerstag, 14:00 Uhr, HS2)

SCHWERPUNKTTHEMEN

S3: Crustal Fluids and Seismicity: Observations, Modelling and Geophysical Imaging

Torsten Dahm (Potsdam), Sabrina Keil (München), Marcel van Laaten (Jena), Ulrich Wegler (Jena)

Crustal fluids are recognized as playing a major role in many geophysical processes including earthquakes and volcanism.

Fluids not only influence geochemical and magmatic processes such as the fracture healing, or rock melting, but can also affect the mechanical properties of faults and change the pore pressure in the rock. The pressure and friction changes can trigger shear ruptures if the faults are under stress. Strong overpressure can also lead to the formation of opening fractures, accompanied by earthquake swarms, which can cause the fluids or melts to migrate upwards in intrusions. Similar processes lead to the formation of deep low-frequency earthquakes.

Geotechnical applications such as geothermal heat production or hydraulic fracturing may also influence pore pressure and trigger earthquakes and may change the seismic hazard of a region. Some models also emphasize the role of fluids in the formation of natural aftershocks, foreshocks or remotely triggered earthquakes in hydrothermal regions. Changes in water levels in wells document the dynamic changes in pore pressure and permeability due to seismic waves.

For this special session, contributions and case studies are sought on naturally and anthropogenically induced and triggered seismicity, as well as on earthquakes associated with magmatic processes or changes in the hydrological system. Physical and numerical modelling on the interaction of fluids with the rock and existing fracture networks, and how these influence earthquakes, are welcome. We also invite contributions on geophysical imaging of fluids in the Earth's crust and upper mantle as well as presentations on seismic hazard caused by anthropogenic and natural fluid-induced seismicity.

PLENARVORTRAG:

Nikolai Shapiro *(ISTerre, CNRS, Grenoble):*
Low frequency seismicity driven by deep magmatic and metamorphic fluids
(Dienstag, 14:00 Uhr, HS2)

SCHWERPUNKTTHEMEN

S4: Seismic Noise and Coda Waves

Celine Hadziioannou (Hamburg), Ulrich Wegler (Jena)

Seismic noise is a continuous signal recorded by seismometers when there is no earthquake. The origin of this signal is a complex superposition of a large number of randomly distributed sources. Recently, seismic noise caused by wind turbines has interfered with the detection of earthquakes signals. Ambient vibrations are also one of the limiting factors for detecting gravitational waves in newly developed gravitational-wave observatories such as the planned third generation Einstein Telescope.

On the other hand, in the last decade ambient seismic noise has established itself as a new useful signal. Ambient seismic noise cross-correlations are used to study the structure of the Earth based on the principle of seismic interferometry. Changes in the phase information of ambient noise corss-correlation functions have been used to monitor minute changes in the Earth's structure The application of these methods requires detailed knowledge of the anthropogenic and natural sources as well as characteristics of ambient seismic noise.

Multiply scattered seismic coda waves are a related random seismic wave field which shares many characteristics with seismic noise. Coda waves carry information about small heterogeneities in the Earth and have been used to estimate the spatial distribution and the frequency dependence of the strength of seismic scattering attenuation and intrinsic absorption.

We would like to invite contributions on observations and modelling of seismic noise sources of anthropogenic and natural origin as well as presentations on the theory and application of seismic interferometry to the imaging and monitoring Earth's heterogeneous structure. We are also seeking contributions on theoretical and observational studies of coda waves, seismic attenuation and scattering.

PLENARVORTRAG:

Katharina-Sophie Isleif *(Helmut-Schmidt-Universität, Messtechnik, Hamburg)*
Advancing Gravitational Wave Astronomy through seismic noise reduction
(Mittwoch, 14:00 Uhr, HS2)

Die Vorträge wurden durch ein Michael Stifel Center Jena Grant finanziert:

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for Data-Driven and Simulation Science

SESSION – THEMENÜBERSICHT

S1: From pore space to whole Earth: understanding complex geoprocesses through Model-Data Integration in the 21st century

S2: Vom Erdkern bis zur hohen Atmosphäre und noch weiter: Erkenntnisse aus langen geophysikalischen Zeitreihen in der Wissenschaft und Industrie

S3: Crustal Fluids and Seismicity: Observations, Modelling and Geophysical Imaging

S4: Seismic Noise and Coda Waves

AG Airborne Geophysics / Fernerkundung

EP Extraterrestrische Physik

GD Geodynamik / Tectonophysics

GO Geophysik in der Öffentlichkeit und im Wandel der Zeit

GT Geothermie / Radiometrie

KI KI-Verfahren in der Geophysik

MG Marine Geophysik

MI Modellierung / Imaging

MP Erdmagnetismus / Magnetfeld / Paleomagnetik

OG Oberflächennahe Geophysik: Archäogeophysik / Bio- und Hydrogeophysik / Ingenieur- und Umweltgeophysik

OS Open Source in Forschung und Lehre

PV Potentialverfahren: EM / Geoelektrik / Georadar / Gravimetrie / IP / Magnetik

SG Schwerefeld / Geodäsie

SM Seismik

SO Seismologie

VU Vulkanologie

DGG-KOLLOQUIUM

Das **DGG-Kolloquium** beschäftigt sich in diesem Jahr mit dem Thema **„Geophysik aus der Praxis“.** Das Kolloquium findet am **Mittwoch, den 13. März 2024**, als Teil der Tagung am Tagungsort parallel zu den anderen Sessions statt. Das Kolloquium wird vom Arbeitskreis Angewandte Geophysik organisiert. Das Kolloquium findet im **HS2** statt.

PROGRAMM:

09:00–09:30 Uhr Rüdiger Misiek und Olaf Brenner (DMT GmbH & Co. KG):
Seismische Erkundung zur Exploration geothermaler Lagerstätten im städtischen Umfeld - Herausforderungen bei der Planung und Umsetzung

09:30–10:00 Uhr Jan-Philipp Schmoldt (K.A. Tauber Spezialbau GmbH & Co. KG):
Kampfmitteldetektion als modernes Fokusfeld der Angewandten Geophysik

10:00–10:30 Uhr Julia Wolf und Daniela Hofmann (DB Engineering & Consulting GmbH),
Georadaruntersuchungen bei der Deutschen Bahn

10:30–11:00 Uhr Kaffeepause

11:00–11:30 Uhr Burkhart Ullrich (Eastern Atlas GmbH & Co. KG):
Archäo-Geophysik aus der Praxis

11:30–12:00 Uhr Tobias Karp, Daniel Günther, Andreas Borchers und Jakob Schwabe (Geophysik GGD mbH):
Geophysikalische Baugrunderkundung bei der Trassenplanung

12:30–13:00 Uhr Thomas Fechner (Geotomographie GmbH):
Bohrlochseismische Cross-Hole Messungen für die Geotechnik

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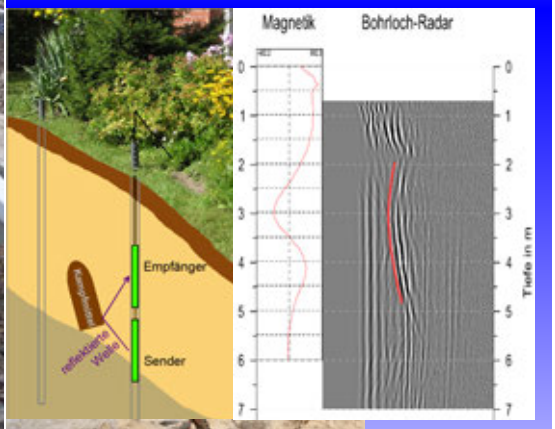

HINWEISE ZU VORTRÄGEN UND POSTERN

TAGUNSGPROGRAMM

Alle Abstracts sowie ein Online-Tagungsprogramm inklusive eines Online-Sitzungsplaners stehen Ihnen auf der Tagungswebseite zur Verfügung:

https://dgg2024.dgg-tagung.de

Ein kostenloses Pocket-Tagungsprogramm (ohne Abstracts) wird bei der Anmeldung vor Ort im Tagungsbüro in gedruckter Form ausgehändigt.

POSTER

Für die Poster werden Stellwände im A0-Hochformat (Portrait) sowie Befestigungsmaterial bereitgestellt. Pro Poster steht eine eigene Posterstellwand zur Verfügung. Alle Poster werden für die gesamte Dauer der Tagung im **Foyer** und im **Hörsaal HS4** ausgestellt. Die Anwesenheit eines/r Autor*in wird während der zwei zugeordneten Postersessions erwartet.

VORTRÄGE

Die Vortragszeit beträgt **15 Minuten zzgl. 5 Minuten** für die Diskussion. Die Präsentationen müssen auf einem geeigneten Datenträger (USB-Stick) im Format PDF oder Microsoft Powerpoint vorliegen und im **Raum SR 121** so bald wie möglich, spätestens jedoch **60 Minuten** vor Beginn der jeweiligen Session, auf den Server hochgeladen werden. Präsentationen für eine Sitzung am frühen Morgen sollten am Vorabend abgegeben werden.

Die Technik und Assistenz stehen täglich ab 8.00 Uhr zur Verfügung. Falls Sie Videos abspielen möchten, empfehlen wir dringend, die Präsentation vorher im Vortragsraum zu testen.

AUSZEICHNUNGEN

Die drei besten Poster und Vorträge des wissenschaftlichen Nachwuchses (Studierende und Promovierende mit noch nicht abgeschlossener Promotion) werden mit jeweils 150 € prämiert. Die Ausgezeichneten erhalten ihre Urkunde bei der Abschlussveranstaltung am Donnerstag.

ERÖFFNUNGSVERANSTALTUNG

Die feierliche Eröffnungsveranstaltung findet am **Montag, den 11. März 2024** von 16.00 Uhr bis ca. 17.00 Uhr im **Hörsaal H2** auf dem Campus der Friedrich-Schiller-Universität Jena (Carl-Zeiss-Straße 3) statt.

(Programm der ERÖFFNUNGSVERANSTALTUNG S. 22)

ERÖFFNUNGSVERANSTALTUNG

Montag, den 11. März 2024 von 16 bis ca. 17 Uhr im Hörsaal H2

PROGRAMM

Begrüßung durch die Tagungsleitung	**Prof. Dr. Nina Kukowski**
Musikalische Umrahmung durch das Quintetto Abbraccio	
Grußwort des Präsidiums der FSUJ	**Prof. Dr. Christoph Steinbeck**
Grußworte der Dekanin der Chemisch-Geowissenschaftlichen Fakultät	**Prof. Dr. Nina Kukowski**
Grußwort des Oberbürgermeisters der Stadt Jena	**Dr. Thomas Nitzsche**
Grußwort des Präsidenten der DGG	**Prof. Dr. Bodo Lehmann**
Musikalische Umrahmung durch das Quintetto Abbraccio	

ERÖFFNUNG DER TAGUNG

Verleihung der Ehrungen und Preise 2024

Emil-Wiechert-Medaille	**Prof. Dr. Andreas Weller** (TU Clausthal)
Günter-Bock-Preis	**Dr. Frederik Link** (Goethe-Universität Frankfurt, Yale University, USA)

Titel der Publikation: Link, F., and G. Rümpker. "Shear-Wave Splitting Reveals Layered-Anisotropy Beneath the European Alps in Response to Mediterranean Subduction." Journal of Geophysical Research: Solid Earth 128.9 (2023): e2023JB027192.

Preis für herausragende Lehre	**Dr. Henriette Sudhaus** (CAU Kiel)
Studierendenpreis	**M.Sc. Antonia Kiel** (Uni Hamburg)
Verleihung der DGG-Ehrenmitgliedschaft	**Dipl. Ing. Michael Grinat** (LIAG Hannover)

im Anschluss 17:00–17:30 Uhr

Company Slam	**Prof. Dr. Ulrich Wegler**

und anschließender Eröffnung der Firmenausstellung (ab 17:30 Uhr)
mit Getränken und Brezeln im Foyer des Uni Campus (Carl-Zeiss-Straße 3).

RAHMENPROGRAMM

BEGRÜSSUNGSABEND

Der Begrüßungsabend wird am Sonntag, den ***10. März 2024 ab 18 Uhr*** am Uni Campus (Carl-Zeiss-Straße 3, 07743 Jena, Zugang über Ernst-Abbe-Platz) stattfinden.

Registrierte Teilnehmerinnen und Teilnehmer, die sich für den Begrüßungsabend angemeldet haben, erhalten dort ihre Tagungsunterlagen.

STUDENTISCHER ABEND

Der studentische Abend findet am Montag, den ***11. März 2024 ab ca. 20:00 Uhr*** am Institut für Geowissenschaften (Burgweg 11, 07749 Jena) statt und wird durch die örtlichen Studierenden organisiert und wie üblich durch die DGG unterstützt.

Für die Teilnahme am studentischen Abend ist eine gesonderte Anmeldung bei der Registrierung erforderlich

GESELLSCHAFTSABEND

Der Gesellschaftsabend der DGG findet am Dienstag, den ***12. März 2024*** im Zeiss-Planetarium Jena (Am Planetarium 5, 07743 Jena) statt. Der Einlass erfolgt ***ab 18:00 Uhr*** am Haupteingang und das Programm beginnt um 19:00 Uhr.

Das Abendessen ist im Preis für den Gesellschaftsabend enthalten (60 € p. P./ 35 € für Studierende). Bitte beachten Sie, dass beim Bestellen von Getränken keine Kartenzahlung möglich ist.

„MEET & GREET"-FRÜHSTÜCK FÜR WISSENSCHAFTLERINNEN

Zum achten Mal wird das „Meet & Greet"-Frühstück für Wissenschaftlerinnen in diesem Jahr stattfinden. Ziel der Veranstaltung ist es, eine Plattform für den gegenseitigen Austausch anzubieten. Studentinnen und Studenten und Nachwuchswissenschaftlerinnen und Nachwuchswissenschaftler erhalten die Gelegenheit, erfahrene Geophysikerinnen und Geophysiker zu treffen und im persönlichen Gespräch verschiedene berufliche Werdegänge kennenzulernen.

Das Frühstück findet am Dienstag, den ***12. März 2024 von 8:00 bis 9:30 Uhr*** statt.

Für die Teilnahme ist eine gesonderte Anmeldung bei der Registrierung erforderlich.
Die Anzahl der Teilnehmenden ist auf 50 begrenzt (Kosten: 10€ p.P.).

ÖFFENTLICHER ABENDVORTRAG

Der öffentliche Abendvortrag der DGG findet am Mittwoch, den ***13. März 2024, 20:00–21:00 Uhr*** im HS2, Carl-Zeiss-Straße 3 statt.

Der Vortrag wird von **Prof. Dr. Torsten Dahm** (Sektion Erdbeben und Vulkanphysik, Deutsches GeoForschungsZentrum) mit folgendem Titel gehalten: ***Erdbebenschwärme, Magmatransport und Vulkanausbrüche***

LUNCH'N LEARN

Am Donnerstag, den ***14. März 2024, findet von 13:00–14:00 Uhr*** ein Lunch'n Learn statt. Ziel dieser Veranstaltung mit Impulsvorträgen und Mittagsimbiss ist die Vernetzung junger Geowissenschaftler*innen, um den Austausch sowohl auf der professionellen als auch auf der persönlichen Ebene zu fördern.

Die Teilnahme ist auf 30 Personen begrenzt. (Kosten: 10 € p.P.).
Es ist eine Anmeldung bei der Registrierung erforderlich.

Impulsvorträge (à 10 Minuten): **Bodo Lehmann** (DMT GmbH & Co. KG),
Wolfgang Süß (SENSYS – Sensorik & Systemtechnologie GmbH)

LUNCHSEMINAR KARRIEREPERSPEKTIVEN

Am Mittwoch, den ***13. März 2024, findet von 13:00–14:00 Uhr*** zum fünften Mal das „Lunch-Seminar Karriereperspektiven" statt. Geophysikerinnen und Geophysiker stellen exemplarisch ihre beruflichen Karrieren im Bereich der Geophysik vor und stehen für Fragen zur Verfügung.

Die Teilnahme ist auf 30 Personen begrenzt. (Kosten: 10 € p.P.).
Es ist eine Anmeldung bei der Registrierung erforderlich.

Vorträge (à 5 Minuten): **Filiz Bilgili** (Bundesgesellschaft für Endlager mbH),
André Fahl (Nolte Geoservice GmbH),
Stephan Großwig (GESO GmbH & Co. Projekt KG),
Tobias Karp/Daniel Günther (Geophysik GGD mbH),
Heidrun Kopp (GEOMAR)

ABSCHLUSSVERANSTALTUNG

Die Abschlussveranstaltung mit Preisverleihung findet am ***Donnerstag, 14. März 2024, von 15:00–16:00 Uhr*** im Hörsaal HS2 statt. Die besten Poster und Vorträge von jungen Erstautor*innen werden in diesem Rahmen prämiert.

SITZUNGSTERMINE

DGG-Vorstandssitzungen *(auf Einladung)*

Dienstag, 12.03.2024, 09:30–13:30 Uhr, Raum SR 113

Donnerstag 14.03.2024, 16:00–18:00 Uhr; Raum SR 114

Weitere Sitzungstermine

Arbeitsmeeting Fluid-Session: Montag, 11.03.2024, 17:30 – 18:30 Uhr, Raum SR 113

DGG Komitee Studienfragen: Montag, 11.03.2024, ca. 18:30–19:30 Uhr, Raum SR 114

FKPE-Arbeitsgruppe Observatorien: Dienstag, 12.03.2024, 11:00 – 12:00 Uhr, Raum SR 114

DGG Komitee Chancengleichheit: Dienstag, 12.03.2024, 13:00 – 14:00 Uhr, Raum SR 114

DGG AK Endlager Geophysik: Dienstag, 12.03.2024, 14:00 – 16:00 Uhr, Raum SR 113

Ausschuss geophysikalische Mess- und Beratungsunternehmen:
Dienstag, 12.03.2024, 15:00 – 17:00 Uhr, Raum SR 114

DGG AK EM: Dienstag, 12.03.2024, 17:00–18:00 Uhr, Raum SR 114

AG Induzierte Seismizität: Mittwoch, 13.03.2024, 08:00–09:00 Uhr, Raum SR 114

DGG AK Kampfmitteldetektion: Mittwoch, 13.03.2023, 15:00–17:00 Uhr, Raum SR 114

Für weitere Treffen der Arbeitskreise und Komitees der DGG stehen weitere Seminarräume während der Tagung zur Verfügung. Die Verantwortlichen werden gebeten, den Bedarf unter Angabe des Termins, der erwarteten Personenzahl und ggf. technischer Ausstattung bei Valentin Kasburg anzumelden ***(dgg2024@uni-jena.de)***.

ÜBERSICHT TAGUNGSPROGRAMM

SONNTAG, 10. MÄRZ 2024

ab 18.00 Uhr:	Begrüßungsabend am Tagungsort (Carl-Zeiss-Straße 3) Tagungsunterlagen liegen für angemeldete Teilnehmer*innen zur Abholung bereit

MONTAG, 11. MÄRZ 2024

ab 08.00 Uhr	Registrierung
09:00 – 10:00 Uhr	Vorträge
10.00 – 11.00 Uhr	Posterausstellung + Kaffeepause
11.00 – 13.00 Uhr	Vorträge
13.00 – 14.00 Uhr	Mittagspause
14.00 – 15.00 Uhr	Plenarvortrag ***Ylona van Dinther***
15.00 – 16.00 Uhr	Posterausstellung + Kaffeepause
16.00 – 17.30 Uhr	Eröffnungsveranstaltung mit Company Slam
ab 17.30 Uhr	Eröffnung Firmenausstellung
ab 20.00 Uhr	studentischer Abend

DIENSTAG, 12. MÄRZ 2024

08:00 – 09:30 Uhr	Meet & Greet
09:00 – 10:00 Uhr	Vorträge
10.00 – 11.00 Uhr	Posterausstellung + Kaffee
11.00 – 13.00 Uhr	Vorträge
13.00 – 14.00 Uhr	Mittagspause
14.00 – 15.00 Uhr	Plenarvortrag: ***Nicolai Shapiro***
15.00 – 16.00 Uhr	Posterausstellung + Kaffee
16.00 – 17.40 Uhr	Vorträge
Ab 18:00 Uhr	Gesellschaftsabend im Zeiss-Planetarium

MITTWOCH, 13. MÄRZ 2024

09.00 – 12:30 Uhr	Kolloquium „Geophysik aus der Praxis“
09:00 – 10:00 Uhr	Vorträge
10.00 – 11.00 Uhr	Posterausstellung + Kaffeepause
11.00 – 13.00 Uhr	Vorträge
13.00 – 14.00 Uhr	Mittagspause + Lunchseminar
14.00 – 15.00 Uhr	Plenarvortrag: ***Katharina Isleif***
15.00 – 16.00 Uhr	Posterausstellung + Kaffee
16.00 – 17.00 Uhr	Vorträge
17.00 – 19.00 Uhr	Mitgliederversammlung
20.00 – 21.00 Uhr	öffentlicher Abendvortrag: ***Torsten Dahm***

DONNERSTAG, 14. MÄRZ 2024

09:00 – 10:00 Uhr	Vorträge
10.00 – 11.00 Uhr	Posterausstellung + Kaffee
11.00 – 13.00 Uhr	Vorträge
13.00 – 14.00 Uhr	Mittagspause + Lunch´n´Learn
14.00 – 15.00 Uhr	Plenarvortrag ***Bruno Meurers***
15.00 – 16.00 Uhr	Abschlussveranstaltung mit Prämierung der besten Poster und Vorträge

DGG 2024 – PROGRAMM

MONTAG, 11.MÄRZ 2024

Oral — HS 2

09:00–10:00 **SO-A**

SO
Seismology

Moderation: S. Donner, *Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Deutschland*

09:00–09:20 SO-A-01 **On DAS-recorded strain amplitude**

T. Forbriger[1], N. Karamzadeh[1,2], J. Azzola[3], R. Widmer-Schnidrig[4], E. Gaucher[3], A. Rietbrock[1]

[1]Geophysical Institute, Karlsruhe Institute of Technology (KIT), Karlsruhe, Deutschland, [2]Institute of Geophysics, University of Münster, Münster, Deutschland, [3]Institute of Applied Geosciences, Karlsruhe Institute of Technology (KIT), Karlsuhe, Deutschland, [4]Institute of Geodesy, University of Stuttgart, Stuttgart, Deutschland

09:20–09:40 SO-A-02 **Valuable information gained from coseismic localized strain at secondary faults observed with InSAR**

H. Sudhaus[1], T. May[2]

[1]Christian-Albrechts-Universität zu Kiel, Institut für Geowissenschaften, Kiel, Deutschland, [2]Universität Kiel, Institut für Geowissenschaften, Kiel, Deutschland

09:40–10:00 SO-A-03 **Interseismic displacement rates along the Medlicott-Wadia Thrust in the Northwest Himalayas based on InSAR time series**

O. Stein[1], H. Sudhaus[1], R. Thiede[2]

[1]Institut für Geowissenschaften, Satelliten- und Aerogeophysik, Kiel, Deutschland, [2]Institut Geowissenschaften, Petrologie und Geodynamik, Kiel, Deutschland

Oral — SR 113

09:00–10:00 **S1-A**

S1
From pore space to whole Earth: understanding complex geoprocesses through Model-Data Integration in the 21st century

Moderation: M. Ziegler, *Technische Universität München, München, Deutschland*

09:20–09:40 S1-A-01 **Representativeness of petrophysical data - a digital rock physics approach, Part I: Geometrical modeling**

P. Menzel, J. Börner, M. Scheunert

TU Bergakademie Freiberg, Institut für Geophysik und Geoinformatik, Freiberg, Deutschland

09:40–10:00 S1-A-02 **Representativeness of petrophysical data - a digital rock physics approach, Part II: Geophysical application**

J. Börner, P. Menzel, M. Scheunert

Institut für Geophysik und Geoinformatik / TU Bergakademie Freiberg, Freiberg, Deutschland

Oral — HS 9

09:00–10:00 **PV-A**

PV
EM / geoelectrics / GPR / gravimetry / IP / magnetics

Moderation: J. Tronicke, *Universität Potsdam, Deutschland*

09:00–09:20 PV-A-01 **Changes in the complex conductivity response of sandstones due to $NaHCO_3$ infiltration, a time-lapse study**

A. M. Mansfeld, A. Kemna

Rheinische Friedrich Willhelms Universität Bonn, Institut für Geowissenschaften Abteilung Geophysik, Bonn, Deutschland

09:20–09:40 PV-A-02 **4D-GPR Messungen zur hochauflösenden räumlich-zeitlichen Abbildung präferentieller Fließprozesse**

S. M. Stephan[1], C. Jackisch[2], J. Tronicke[1], N. Allroggen[1, 3]

[1]Institut für Geowissenschaften Universität Potsdam, Angewandte Geophysik, Potsdam, Deutschland, [2]Technische Universität Bergakademie Freiberg, Zentrum für Wasserforschung Freiberg, Freiberg, Deutschland, [3]DB Engineering & Consulting GmbH, Georadar, Bremen, Deutschland

09:40–10:00 PV-A-03 **Investigation of a fault zone in Sub-Himalayan region (India) using Radiomagnetotellurics**

B. F. Göçer[1], W. Mörbe[1], B. Tezkan[1], M. Israil[2], P. Yogeshwar[1]

[1]Universität zu Köln, Institut für Geophysik und Meteorologie, Köln, Deutschland, [2]Indian Institute of Technology Roorkee, Department of Earth Sciences, Roorkee, Indien

Poster Foyer + HS 4

10:00–11:00 Poster + Coffee break | AG, MI, OS, SO

AG-P-01 **Data-driven Estimates: Forecasting Drone-towed Sensor Platform Orientation with Neural Networks**

P. Kotowski, M. Becken

Universität Münster, Institut für Geophysik, Münster, Deutschland

AG-P-02 **Linkage of Horizontal Magnetic Tensor and Energy Flux – An Evaluation for Three-Component Airborne Natural Source EM**

A. Thiede, M. Becken, and the DESMEX Working Group

Universität Münster, Institut für Geophysik, Münster, Deutschland

AG-P-03 **Ergebnisse einer aeroelektromagnetischen Untersuchung im Bereich ehemaliger Braunkohletagebaue in der Lausitz südlich von Finsterwalde**

B. Siemon[1], O. Cortés-Arroyo[2], S. Janetz[2], E. Nixdorf[2]

[1]Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Geophysikalische Erkundung – Technische Mineralogie, Hannover, Deutschland, [2]Bundesanstalt für Geowissenschaften und Rohstoffe, Forschungs- und Entwicklungszentrum Bergbaufolgen (FEZB), Cottbus, Deutschland

OS-P-01 **Open Educational Ressources and Open Source Software**

R.-U. Börner

TU Bergakademie Freiberg, Institut für Geophysik und Geoinformatik, Freiberg, Deutschland

MI-P-01 **WaterSim – Modellierung der instationären hydrogeologischen Interaktion zwischen Oberflächengewässern und Grundwasserleitern am Beispiel des Saaletals**

A. Schulz, N. Kukowski

Institut für Geowissenschaften, Allgemeine Geophysik, Jena, Deutschland

MI-P-02 **A hybrid joint inversion approach for electrical resistivity tomography and sparse transient electromagnetic data**

A. Jaron[1], P. Yogeshwar[2]

[1]Universität Bonn, Institut für Geowissenschaften, Abteilung Geophysik, Bonn, Deutschland, [2]Universität Köln, Institut für Geophysik und Meteorologie, Köln, Deutschland

MI-P-03 **Kooperative Inversion mit minimaler Entropie und Anwendung auf Geoelektrik-, Seismik- und Magnetik-Daten**

A. H. Ziegon[1, 2], M. S. Boxberg[1], F. M. Wagner[1]

[1]RWTH Aachen University, Geophysical Imaging and Monitoring, Aachen, Deutschland, [2]University of Calgary, CREWES, Calgary, Alberta, Kanada

MI-P-04 **Characterization of glacial sediments by seismic high-resolution crosshole SV-FWI**

S. Beraus[1, 2], D. Köhn[3], H. Buness[1], T. Burschil[4], T. Bohlen[5], G. Gabriel[1, 2]

[1]Leibniz Institute for Applied Geophysics, Seismics & potential field methods, Hannover, Deutschland, [2]Leibniz University Hannover, Institute of Geology, Hannover, Deutschland, [3]Christian-Albrechts-University, Institute for Geosciences, Kiel, Deutschland, [4]Federal Institute for Geosciences and Natural Resources, Hannover, Deutschland, [5]Karlsruhe Institute of Technology, Geophysical Institute, Karlsruhe, Deutschland

MI-P-05 **Testing the benefit of eikonal tomography for ambient noise recordings at a dense array in a complex 3D basin structure**

A. Olivar-Castaño[1], M. Ohrnberger[1], C. Papazachos[2], N. Chatzis[2]

[1]Universität Potsdam, Institut für Geowissenschaften, Potsdam, Deutschland, [2]Aristotle University of Thessaloniki, Thessaloniki, Griechenland

MI-P-06 **The potential of high-resolution X-ray µCT imaging to characterise natural sediments**

R. Gatter[1, 2], K. Huhn[1]

[1]MARUM - Zentrum für Marine Umweltwissenschaften, Universität Bremen, Bremen, Deutschland, [2]Universiät Bremen, Fachbereich Geowissenschaften, Bremen, Deutschland

SO-P-01 **Analyzing complex ruptures using a multiple-source joint optimization approach**

T. May, H. Sudhaus

Christian-Albrecht University of Kiel, Kiel, Deutschland

SO-P-02 **Rupture analysis of the Pütürge Segment of the East Anatolian Fault based on the large 2020 and 2023 Earthquakes**

A. Kuntze, H. Sudhaus

Institut für Geowissenschaften der CAU Kiel, Satelliten- und Aerogeophysik, Kiel, Deutschland

SO-P-03 **Stress Drop Variation After Large Earthquakes**

J. Folesky

Freie Universität Berlin, Geophysik, Berlin, Deutschland

SO-P-04 **Implementing global 3D earth models in dynamic rupture scenarios**

A. Schmidt, H. Sudhaus, J. Ebbing

CAU Kiel, Institut für Geowissenschaften, Satelliten- und Aerogeophysik, Kiel, Deutschland

SO-P-05 **Seismic wavefield visualizations with AlpArray and AdriaArray**

O. A. Wallner, J. Stampa, F. Eckel, T. Meier

Institut für Geowissenschaften, Christian-Albrechts-Universität zu Kiel, Kiel, Deutschland

SO-P-06 **The manual analysis of teleseismic events at the Federal Seismological Survey of BGR - including depth, secondary and core phases**

T. Plenefisch[1], M. Bischoff[2], L. Ceranna[1], S. Donner[1], P. Gaebler[1], N. Gestermann[1], G. Hartmann[1], P. Hupe[1], M. Hobiger[1], C. Pilger[1], O. Roß[1], K. Stammler[1], A. Steinberg[1]

[1]BGR, Hannover, Deutschland, [2]LBEG, Hannover, Deutschland

SO-P-07 **Understanding the influence of seismic mantle structures at the core-mantle boundary on intense magnetic flux regions**

Y. Fröhlich[1], H. Thiyagarajan[2], L. Tölle[2], J. R. R. Ritter[1], C. Thomas[2]

[1]Karlsruhe Institute of Technology, Geophysical Institute, Karlsruhe, Deutschland, [2]University of Münster, Institute of Geophysics, Münster, Deutschland

SO-P-08 **Anisotropy and XKS-splitting from geodynamic models of double subduction: Testing the limits of interpretation**

J. P. Kruse[1], G. Rümpker[1, 2], F. Link[1, 3], T. Duretz[1], H. Schmeling[1]

[1]Institut für Geowissenschaften, Goethe-Universität, Frankfurt am Main, Deutschland, [2]Frankfurt Institute for Advanced Studies, Frankfurt am Main, Deutschland, [3]Department of Geology and Geophysics, Yale University, New Haven, Vereinigte Staaten von Amerika

SO-P-09 **Discriminating lithospheric and asthenospheric anisotropy beneath Northern Oman: sharp contrast observed at the Semail Gap Fault Zone**

A. Komeazi[1], A. Kaviani[1], G. Rümpker[1, 2], C. Weidle[3], T. Meier[3]

[1]Goethe University Frankfurt, Geophysics, Frankfurt, Deutschland, [2]Frankfurt Institute for Advanced Studies, Frankfurt, Deutschland, [3]Christian-Albrechts-University Kiel, Institute of Geosciences, Kiel, Deutschland

SO-P-10 **Onshore dual-station monitoring of submarine volcanic activity through multi-band frequency analysis – the case of Kavachi, Solomon Islands**

L. Bitzan[1], G. Rümpker[1], P. Laumann[1], C. J. Roga[2], A. Kaviani[1], C. Tatapu[2], J. B. Gwali[2], T. Manker[1], C. S. Vehe[2]

[1]Goethe-University Frankfurt, Institute of Geosciences, Frankfurt am Main, Deutschland, [2]Geological Survey Division, Ministry of Mines, Energy and Rural Electrification, Honiara, Salomonen

SO-P-11 **Array analysis for onshore monitoring of submarine seismo-volcanic activity in the Solomon Islands**

P. Laumann[1], G. Rümpker[1], L. Bitzan[1], C. Rogar[2], A. Kaviani[1], C. Tatapu[2], J. B. Gwali[2], T. Manker[1], C. S. Vehe[2]

[1]Goethe Universität Frankfurt, Institut für Geophysik, Frankfurt am Main, Deutschland, [2]Ministry of Mines, Energy and Rural Electrification, Geological Survey Division, Honiara, Salomonen

SO-P-12 **Seismicity in Sri Lanka: New insights from a temporary, local seismic network**

C. Haberland[1], M. Seneviratne[2], T. Ryberg[1], K.-H. Jäckel[1]

[1]GFZ Potsdam, Potsdam, Deutschland, [2]Geological Survey and Mines Bureau GSMB, Pitakotte, Sri Lanka

SO-P-13 **Relocated catalog of earthquake swarms in Nový Kostel region of West Bohemia/Vogtland based on the Webnet recordings, period 1991–2023**

D. Konrádová[1, 2], J. Vlček[3], J. Doubravová[1], T. J. Fischer[3]

[1]Czech Academy of Science, Institute of Geophysics, Prague, Tschechische Republik, [2]Charles University, Faculty of Mathematics and Physics, Prague, Tschechische Republik, [3]Charles University, Faculty of Science, Prague, Tschechische Republik

SO-P-14 **Seismic GLOF analysis at Iceland's Vatnajökull glacier: Insights from the October 2015 jökulhlaup at Skaftá.**

T. Dietrich[1], E. P. S. Eibl[1], F. Pálsson[2], E. Magnússon[2], W. Schwanghart[3], M. Ohrnberger[1], S. Heimann[1], F. Lindner[4], S. Roessner[5]

[1]Universität Potsdam, Institut für Geowissenschaften, Potsdam, Deutschland, [2]University of Iceland, School of Engineering and Natural Sciences, Reykjavik, Island, [3]Universität Potsdam, Institut für Umweltwissenschaften und Geographie, Potsdam, Deutschland, [4]LMU München, Department für Geo- und Umweltwissenschaften, München, Deutschland, [5]GFZ Potsdam, Sektion 1.4, Potsdam, Deutschland

SO-P-15 **Towards a local velocity model from explosion monitoring**

C. Weidle[1], A. Omlin[2], T. Meier[1]

[1]Institut für Geowissenschaften, Kiel, Deutschland, [2]Landesamt für Umwelt, Schleswig-Holstein, Geologischer Dienst, Flintbek, Deutschland

SO-P-16 **Towards attenuation tomography in NRW**

N. Karamzadeh[1], L. Schumacher[1], K. Hannemann[1], C. Thomas[1], R. Abreu[2]

[1]University of Münster, Institute of Geophysics, Münster, Deutschland, [2]Institut de physique du globe de Paris, Paris, Frankreich

SO-P-17 **Providing Efficient Multi-disciplinary Geophysical Monitoring using common real-time seismic network infrastructure**

S. Uhlmann[1], M. Perlin[2], N. Trerice[2], T. Sommerville[2], M. Jusko[2]

[1]IGM GmbH, Überlingen, Deutschland, [2]Nanometrics, Inc., Kanata, Kanada

SO-P-18 **Erstellung eines Erdbebenkataloges mittels Time Reverse Imaging im Projekt SIEGFRIED – Ein interdisziplinäres Projekt für die seismische Risikoabschätzung in der Niederrheinischen Bucht**

M. Dietl[1], C. Finger[1], M. P. Roth[2], A. Verdecchia[2], R. M. Harrington[2], M. Kruszewski[3], A. Jones[3], J. Hannes[4], T. Oswald[4], K. Benisch[4]

[1]Fraunhofer-Einrichtung für Energieinfrastrukturen und Geothermie IEG, Bochum, Deutschland, [2]Ruhr-Universität Bochum, Bochum, Deutschland, [3]Rheinisch-Westfälische Technische Hochschule (RWTH) Aachen, Aachen, Deutschland, [4]RWE Power AG, Essen, Deutschland

SO-P-19 **SMORD: A database for improving meteoroid flux estimations on Earth using seismoacoustic data**

D. Eickhoff, R. Ostermeier, J. R. R. Ritter

Karlsruhe Institute of Technology, Geophysical Institute, Karlsruhe, Deutschland

SO-P-20 **Data Mining 20 Years of Microacoustic Events in a Salt Mine and Machine Learning Based Seasonal Prediction of Event Rates**

A. Steinberg[1], D. Kaiser[2], C. Friedrich[3], P. Gaebler[2], H. Schmitz[2], M. Krentz[2], J. Gerowski[2], T. Spies[2], L. Ceranna[1], S. Donner[1]

[1]Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) [Federal Institute for Geosciences and Natural Resources], B4.3 Erdbebendienst des Bundes, Kernwaffenteststopp Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Deutschland, [2]TU Clausthal, Institute of Geo-Engineering, Lehrgebiet Ingenieurseismologie, Clausthal-Zellerfeld, Deutschland, [3]Bundesgesellschaft für Endlagerung mbH (BGE), Peine, Deutschland

SO-P-21 **Determination of Seismic Velocities in Backfill Material for Nuclear Waste Disposal – an Experiment at Mont Terri Rock Laboratory**

M. Sobiesiak[1], K. Plenkers[1], T. Fischer[1], E. Manukyan[2], T. Spillmann[2]

[1]GMuG, Bad Nauheim, Deutschland, [2]Nagra, Wettingen, Schweiz

SO-P-22 **Microseismicity monitoring in materials for nuclear waste storage repositories**

A. M. Skłodowska[1], V. Lay[1], F. Baensch[2], E. Niederleithinger[1], H.-C. Kühne[3]

[1]Bundesanstalt für Materialforschung und –prüfung (BAM), 8.2 Non-DestructiveTesting Methods for Civil Engineering, Berlin, Deutschland, [2]Deutsches Institut für Normung (DIN), Berlin, Deutschland, [3]Bundesanstalt für Materialforschung und –prüfung (BAM), 7.4 Technology of Construction Materials, Berlin, Deutschland

SO-P-23 **In-situ Acoustic Emission monitoring during H2 and CO2 fracturing in salt rock**

K. Plenkers[1], J. Philipp[1], W. Minkley[2], M. Brandt[2], M. Wiedemann[2]

[1]GMuG, Bad Nauheim, Deutschland, [2]Institut für Gebirgsmechanik, Leipzig, Deutschland

Oral HS 2

11:00–13:00 SO-B

SO
Seismology

Moderation: H. Sudhaus, *Christian-Albrechts-Universität zu Kiel, Kiel, Deutschland*

11:00–11:20 SO-B-01 **A comprehensive analysis of relative earthquake localization methods and their implications in the Reykjanes Peninsula, Iceland**

D. Konrádová[1, 2], J. Doubravová[1], B. Růžek[1], J. Horálek[1]

[1]Czech Academy of Science, Institute of Geophysics, Prague, Tschechische Republik, [2]Charles University, Faculty of Mathematics and Physics, Prague, Tschechische Republik

11:20–11:40 SO-B-02 **Meteoroids: Tracing a moving acoustic source in a moving medium with seismic data**

D. Eickhoff, J.-P. Föst, J. R. R. Ritter

Karlsruhe Institute of Technology, Geophysical Institute, Karlsruhe, Deutschland

11:40–12:00 SO-B-03 **Challenges of Rotational Ground Motion Measurements in the Local Distance Range**

S. Donner[1], J. Lehr[1], F. Krüger[2], M. Hoffmann[1], S. Heimann[2], M. Hobiger[1]

[1]Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Deutschland, [2]Universität Potsdam, Institut für Geowissenschaften, Potsdam, Deutschland

12:00–12:20 SO-B-04 **Qseek: A data-driven Earthquake Detection, Localisation and Characterisation Framework**

M. Isken[1, 2], T. Dahm[2], P. Niemz[3], S. Cesca[1], S. Heimann[2], J. Münchmeyer[4]

[1]GFZ Potsdam, Physics of Earthquakes and Volcanoes, Potsdam, Deutschland, [2]University of Potsdam, Institute of Geosciences, Potsdam, Deutschland, [3]University of Utah, Salt Lake City, Department of Geology and Geophysics, Utah, Vereinigte Staaten von Amerika, [4]Univ. Grenoble Alpes ISTerre, ISTerre, Grenoble, Frankreich

12:20–12:40 SO-B-05 **Sustainable preservation and digitization of analogue seismic data in Germany**

G. Kulikova[1], F. Krüger[2], C. Hadziioannou[3]

[1]UP Transfer GmbH at the University of Potsdam, Institute of Geosciences, Potsdam, Deutschland, [2]University of Potsdam, Institute of Geosciences, Potsdam, Deutschland, [3]University of Hamburg, Department of Earth System Sciences, Institute of Geophysics, Hamburg, Deutschland

Oral HS 9

11:00–13:00 PV-B

PV
EM / geoelectrics / GPR / gravimetry / IP / magnetics

Moderation: U. Werban, *Helmholtz-Zentrum für Umweltforschung - UFZ, Deutschland*

11:00–11:20 PV-B-01 **High-frequency spectral induced polarisation to image permafrost features in Heliport, Abisko, Northern Sweden**

M. Sugand, A. Hördt

TU Braunschweig, Institute for Geophysics and extraterrestrial Physics, Braunschweig, Deutschland

11:20–11:40 PV-B-02 **Induction effects in High Frequency Induced Polarization**

R. Schulz, M. Sugand, A. Hördt

Institut für Geophysik und extraterrestrische Physik, Braunschweig, Deutschland

11:40–12:00 PV-B-03 **Inverting time-domain induced polarization field data using Debye discretization**

T. Günther

Leibniz-Institut für Angewandte Geophysik, Hannover, Deutschland

12:00–12:20 PV-B-04 **Modeling of the Stern-layer polarization in pore throats considering different mineral surfaces**

D. Kreith[1], P. Leroy[2], M. Bücker[1]

[1]TU Braunschweig, Institut für Geophysik und extraterrestrische Physik, Braunschweig, Deutschland, [2]BRGM, French Geological Survey, Orléans, Frankreich

12:20–12:40 PV-B-05 **Numerical modeling of the electrical polarization of microbial cells**

F. Keiser[1], A. Mellage[2], N. Klitzsch[3], M. Bücker[1]

[1]Technische Universität Braunschweig, Institut für Geophysik und extraterrestrische Physik, Braunschweig, Deutschland, [2]Universität Kassel, Civil and Environmental Engineering, Kassel, Deutschland, [3]RWTH Aachen, Lehrstuhl für Angewandte Geophysik 1: Computational Geoscience, Geothermie und Reservoirgeophysik, Aachen, Deutschland

12:40–13:00 PV-B-06 **Modellierung der Membranpolarisation für beliebige Elektrolytlösungen**

J. Marsel, D. Kreith, M. Bücker

Technische Universität Braunschweig, Institut für Geophysik und extraterrestrische Physik, Braunschweig, Deutschland

Veranstaltung SR 114

13:00–14:00 **DVGeo-Townhall-Meeting**

Keynotes HS 2

14:00–15:00 **S1**

From pore space to whole Earth: understanding complex geoprocesses through Model-Data Integration in the 21st century

Moderation: N. Kukowski, *Institut für Geowissenschaften, Jena, Deutschland*

S1-K : Ensemble data assimilation for estimating earthquake and geodynamic states and parameters

Y. van Dinther[1], H. Diab Montero[2], C. Marsman[1], A. Banerjee[2], P. J. van Leeuwen[3, 4], R. Govers[1], F. Vossepoel[2]

[1]Department of Earth Sciences, Utrecht University, Utrecht, Die Niederlande, [2]Department of Geoscience and Engineering, Delft University of Technology, Delft, Die Niederlande, [3]Department of Atmospheric Science, Colorado State University, Fort Collins, Vereinigte Staaten von Amerika, [4]Department of Meteorology, University of Reading, Reading, Vereinigtes Königreich

Poster Foyer + HS 4

15:00–16:00 **Poster + Coffee break**
AG, MI, OS, SO

Veranstaltungen HS 2

16:00–17:30 **Opening event**

17:30–18:30 **Opening of the company exhibition**

Veranstaltung Other places

20:00–22:00 **Student evening**

DIENSTAG, 12.MÄRZ 2024

Veranstaltung SR 114

08:00–09:30 **Meet & Greet**

Oral HS 2

09:00–10:00 **OG-A** **OG**

Near-surface Geophysics: Archaeogeophysics / Biogeoscience / Hydrogeophysics / Eng. & Environmental Geophysics

Moderation: J. Tronicke, *Universität Potsdam, Deutschland*

09:00–09:20 OG-A-01 **Mobile NMR-Relaxometrie zur Charakterisierung des Zersetzungsgrades von Torfböden**

S. Costabel[1], T. Splith[2], T. Hiller[1], M. Müller-Petke[2]

[1]Bundesanstalt für Geowissenschaften und Rohstoffe, Abteilung 2 Grundwasser und Boden, Berlin, Deutschland, [2]Leibniz-Institut für Angewandte Geophysik, Sektion 2 Geoelektrik & Elektromagnetik, Hannover, Deutschland

09:20–09:40 OG-A-02 **Mapping and characterizing peatland using ground-penetrating radar and nuclear-magnetic resonance**

B. Blanco-Arrué[1], M. Müller-Petke[1], J. Igel[1], T. Splith[1], S. Costabel[2]

[1]Leibniz Institute for Applied Geophysics, S2 - Geoelectrics & Electromagnetics, Hannover, Deutschland, [2]Federal Institute for Geosciences and Natural Resources, Berlin, Deutschland

09:40–10:00 OG-A-03 **Spurensuche rund um das Heiligtum: Geophysikalische Messungen und Ausgrabungen am Amyklaion bei Sparta, Griechenland**

V. Schmidt[1], S. Nomicos[2], S. Vlizos[3], M. Wendel[1], M. Becken[1], N. Nenci[4], V. Panagiotidis[5], A. Kazolias[5], N. Zacharias[5]

[1]Universität Münster, Institut für Geophysik, Münster, Deutschland, [2]Universität Münster, Institut für Klassische Archäologie und Christliche Archäologie, Münster, Deutschland, [3]Ionian University, Department of Archives, Library Science and Museology, Corfu, Griechenland, [4]University of Perugia, Perugia, Italien, [5]University of the Peloponnese, Laboratory of Archaeometry, Kalamata, Griechenland

Oral HS 9

09:00–10:00 **KI-A** **KI**

AI methods in geophysics

Moderation: M. Ziegler, *Technische Universität München, München, Deutschland*

09:00–09:20 KI-A-01 **A machine-learning approach for detecting P- and S-arrivals in continuous DAS data**

N. Boitz, S. Shapiro

Freie Universität Berlin, Geologische Wissenschaften - Geophysik, Berlin, Deutschland

09:20–09:40 KI-A-02 **Feasibility of Deep Learning in Shear Wave Splitting Analysis using Synthetic-Data Training and Waveform Deconvolution**

M. Chakraborty[1, 2], G. Rümpker[1, 2], W. Li[2], J. Faber[2], F. Link[3], N. Srivastava[1, 2]

[1]Goethe-University Frankfurt, Frankfurt, Deutschland,
[2]Frankfurt Institute for Advanced Studies, Frankfurt, Deutschland,
[3]Yale University, New Haven, Vereinigte Staaten von Amerika

09:40–10:00 KI-A-03 **Deep learning-based Causal Inference in Tectonic-Climate Time series**

W. Ahmad[1], V. Kasburg[2], N. Kukowski[2], M. Shadaydeh[1], J. Denzler[1]

[1]Friedrich Schiller University Jena, Faculty of Mathematics and Computer Science, Jena, Deutschland, [2]Friedrich Schiller University Jena, Institute for Geosciences, Chair of Applied Geophysics, Jena, Deutschland

Poster Foyer + HS 4

10:00–11:00 Poster + Coffee break
S3, EP, GD, GO, KI, MG, MP, PV, SG

S3-P-01 **Detection capability of the West Bohemian Seismic Network (WEBNET)**

E. Kaldy, T. Fischer

Charles University, Institute of Hydrogeology, Engineering Geology and Applied Geophysics; Faculty of Science, Prague 2, Tschechische Republik

S3-P-02 **High frequency 3D array analysis of April 2021 earthquake swarm and search for tremor-like source processes in Westbohemia/ Vogtland**

N. Rein[1, 2], K. Hannemann[3], M. Ohrnberger[1], F. Krüger[1]

[1]Universität Potsdam, Institut für Geowissenschaften, Potsdam, Deutschland, [2]Universität Leipzig, Leipzig, Deutschland [3]Universität Münster, Institut für Geophysik, Münster, Deutschland

S3-P-03 **The Earthquake Relocation Analysis (2018-2024) using Automatic Waveform Detection and Machine Learning Techniques in the NW Bohemia/Vogtland Region**

P. Büyükakpınar[1], A. Olivar-Castaño[2], M. Ohrnberger[2], M. Isken[1], T. Dahm[1, 2], J. Doubravová[3], T. Fischer[4], S. Funke[5], S. Wendt[6]

[1]GFZ, Potsdam, Deutschland, [2]University of Potsdam, Potsdam, Deutschland, [3]The Czech Academy of Sciences, Prague, Tschechische Republik, [4]Faculty of Natural Sciences, Charles University, Prague, Deutschland, [5]Leipzig University, Leipzig, Deutschland, [6]Leipzig University, Collm Geophysical Observatory, Collm, Deutschland

S3-P-04 **Spatiotemporal Variations of In Situ Vp/Vs Ratio During the Seismic Swarm Preceding the 2021 Eruption in Fagradalsfjall, Iceland**

A. Masihi, T. Fischer

Charles University, Institute of Hydrogeology, Engineering Geology and Applied Geophysics, prague, Tschechische Republik

EP-P-01 **Electron beams in Jupiter's equatorial magnetosphere**

J. Piasecki[1], J. Saur[1], A. Salveter[1], G. Clark[2], B. Mauk[2]

[1]Universität zu Köln, Institut für Geophysik und Meteorologie, Köln, Deutschland, [2]Johns Hopkins University, Applied Physics Laboratory, Laurel, Maryland, Vereinigte Staaten von Amerika

EP-P-02 **Ohmic heating within the Galilean satellites**

A. Große-Schware, J. Saur, A. Grayver

Institut für Geophysik und Meteorologie, Universität zu Köln, Köln, Deutschland

EP-P-03 **Seismic Exploration for the Emerging Moon Industry**

O. Cornelius, P. Koch, D. Solis Sanchez, A. Anil

IMENSUS UG, Stuttgart, Deutschland

GD-P-01 **Faults and the stress state – a complicated relationship**

M. Ziegler[1, 2], K. Reiter[3], O. Heidbach[2, 4], R. Seithel[5], M. Rajabi[6], T. Niederhuber[7], L. Röckel[7], B. Müller[7], T. Kohl[7]

[1]Technische Universität München, München, Deutschland, [2]Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Potsdam, Deutschland, [3]TU Darmstadt, Institute of Applied Geosciences, Darmstadt, Deutschland, [4]TU Berlin, Institute for Applied Geosciences, Berlin, Deutschland, [5]GHJ - Ingenieurgesellschaft für Geo- und Umwelttechnik mbH & Co. KG, Karlsruhe, Deutschland, [6]University of Queensland, School of the Environment, Brisbane, Australien, [7]KIT, Institute of Applied Geosciences, Karlsruhe, Deutschland

GD-P-02 **Ground-Penetrating radar investigation of the Marlborough Fault System, NZ**

J. Igel[1], C. Brandes[2], D. C. Tanner[1], S. Tsukamoto[1], A. Nicol[3]

[1]Leibniz-Institut für Angewandte Geophysik, Hannover, Deutschland, [2]Leibniz Universität Hannover, Institute of Geology, Hannover, Deutschland, [3]University of Canterbury, School of Earth and Environment, Christchurch, Neuseeland

GD-P-03 **Seismic reprocessing revealing detailed depth images of detachment and backthrust reflections of the Variscan Eifel Fold-Thrust Belt, Germany**

D. Eickhoff[1], S. Back[2], K. Reicherter[2], J. R. R. Ritter[1]

[1]Karlsruhe Institute of Technology, Geophysical Institute, Karlsruhe, Deutschland, [2]RWTH Aachen University, Aachen, Deutschland

GD-P-04 **New insights into the orogenic structure along TRANSALP from reprocessing of controlled-source seismic data**

K. Bauer[1], B. Schwarz[1, 2], R. Trichandi[1], B. Wawerzinek[1], P. McPhee[3], M. R. Handy[3]

[1]GFZ Potsdam, Potsdam, Deutschland, [2]Fraunhofer Institute for Wind Energy Systems IWES, Bremen, Deutschland, [3]FU Berlin, Institute of Geological Sciences, Berlin, Deutschland

GO-P-01 **Ein Exponat zur Veranschaulichung von seismischen Wellen für die Öffentlichkeitsarbeit**

M. S. Boxberg, J. van Meulebrouck, A. Balza Morales, N. Menzel, F. M. Wagner

RWTH Aachen University, Geophysical Imaging and Monitoring, Aachen, Deutschland

GO-P-02 **The Geophysical Instrument Pool Potsdam (GIPP)**

B. Wawerzinek[1], C. Haberland[1], O. Ritter[1, 2], C. Krawczyk[1, 3]

[1]GFZ Potsdam, Potsdam, Deutschland, [2]FU Berlin, Berlin, Deutschland, [3]TU Berlin, Berlin, Deutschland

KI-P-01 **When linear inversion fails: neural-network optimization for sparse-ray travel-time tomography of a volcanicedifice**

A. Komeazi[1], G. Rümpker[1, 2], J. Faber[2], F. Limberger[1], N. Srivastava[2]

[1]Goethe University Frankfurt, Geophysics, Frankfurt, Deutschland,
[2]Frankfurt Institute for Advanced Studies, Frankfurt, Deutschland

KI-P-02 **Comparing Different Neural Network Approaches Applied to DC Resistivity Problems**

S. Weit[1], K. Spitzer[1], M. Scheunert[1], O. Rheinbach[2]

[1]TU Bergakademie Freiberg, Institut für Geophysik und Geoinformatik, Freiberg, Deutschland, [2]TU Bergakademie Freiberg, Institut für Numerische Mathematik und Optimierung, Freiberg, Deutschland

MG-P-01 **P- and S-wave seismic velocity structure of the 25 °S OCC north of the Rodriguez Triple Junction at the Central Indian Ridge extracted from ocean bottom seismometer**

A. Dannowski[1], M. Engels[2], B. Schramm[2], M. Schnabel[2], O. Lucke[2], U. Barckhausen[2], I. Heyde[2], S. Ladage[2], R. Lutz[2], C. Filbrandt[1], A. Jegen[1], I. Grevemeyer[1], SO301 cruise participants

[1]GEOMAR Helmholtz Centre for Ocean Research Kiel, Marine Geodynamics, Kiel, Deutschland,
[2]BGR, Federal Institute for Geosciences and Natural Resources, Hannover, Deutschland

MP-P-01 **Estimating the depth of lithospheric magnetization from *L2L1* sparse inversion model of EMAG2.v3 data.**

O. B. Nwosu[1, 2], M. Becken[1]

[1]Universität Münster, Institut für Geophysik, Physics, Muenster, Deutschland,
[2]Nnamdi Azikiwe University, Physics and Industrial Physics, Anambra State, Nigeria

PV-P-01 **Geoelectrical monitoring of soil moisture in hugelcultures**

N. Müller[1], J. Hoppenbrock[1, 2], F. Feldmann[2], M. Bücker[1]

[1]Technische Universität Braunschweig, Institut für Geophysik und Extraterrestrische Physik, Braunschweig, Deutschland, [2]Julius Kühn-Institut, Institut für Pflanzenschutz in Gartenbau und urbanem Grün, Braunschweig, Deutschland

PV-P-02 **Monitoring spatial and temporal soil moisture dynamics with 3D Electrical Resistivity Tomography in a sandy soil under a pine forest**

E. Hemmens[1], U. Noell[1], K. Bosch[1], S. Stadler[1], B. Ahrends[2], S. Fleck[2], H. Meesenburg[2], C. Neukum[1]

[1]Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Deutschland,
[2]Nordwestdeutsche Forstliche Versuchsanstalt (NW-FVA), Göttingen, Deutschland

PV-P-03 **Spatio-temporal salinity dynamics of a coastal aquifer on Spiekeroog island**

N. Skibbe, T. Günther, M. Müller-Petke

Leibniz-Institut für Angewandte Geophysik, Hannover, Deutschland

PV-P-04 **Strategies for geoelectrical monitoring of subsurface fluid transport processes using Optimized Experimental Design**

N. Menzel[1], S. Uhlemann[2], F. M. Wagner[1]

[1]Geophysical Imaging and Monitoring, RWTH Aachen, Aachen, Deutschland, [2]Lawrence Berkeley National Laboratory, Earth & Environmental Sciences Area, Berkeley, CA, Vereinigte Staaten von Amerika

PV-P-05 **Direct Current-Induced Polarization Constrained by Ground Penetrating Radar for Improved Delineation of Geological Boundaries at test sites around Lake Bolmen, Sweden**

P. Pugacheva[1], T. Martin[2], T. Günther[3], J. Igel[3]

[1]Technical University of Munich, TUM School of Engineering and Design, Chair of Non-destructive Testing, Munich, Deutschland,
[2]Lund University, Division of Engineering Geology, Lund, Schweden, [3]Leibniz Institute for Applied Geophysics, Hanover, Deutschland

PV-P-06 **Shallow sub-surface faults detected by GPR in an alluvial fan mark recent tectonic activity in the Campo Imperatore Fault Zone (Italian Apennines)**

R. Drews, A. Neely, C. Glotzbach

University Tübingen, Department of Geosciences, Tübingen, Deutschland

PV-P-07 **Richtungssensitive Georadar Bohrlochmessungen in der Bohrung EBrg. 700-4 in der Schachtanlage Asse II**

V. Gundelach

BGR, B3, Hannover, Deutschland

PV-P-08 **Joint inversion of hydraulic tomography and cross-borehole induced polarization data for hydraulic conductivity imaging**

L. Römhild[1], G. Fiandaca[2], P. Bayer[3]

[1]Martin-Luther-Universität Halle-Wittenberg, Institut für Geowissenschaften und Geographie, Halle (Saale), Deutschland, [2]Università degli Studi di Milano, The EEM Team for Hydro & eXploration, Department of Earth Sciences "Ardito Desio", Milano, Italien, [3]Martin-Luther-Universität Halle-Wittenberg, Insitut für Geowissenschaften und Geographie, Halle (Saale), Deutschland

PV-P-09 **Marine Self-Potential, Electromagnetic and Magnetic Survey Models of Seafloor Massive Sulphide Mounds**

H. Müller, K. Schwalenberg, U. Barckhausen

BGR, Marine Rohstofferkundung, Hannover, Deutschland

PV-P-10 **The Mongolian MT array**

M. Becken, M. Comeau, H. Treppke, J. Plett, the MT Mongolia group, the MSc students

Universität Münster, Institut für Geophysik, Münster, Deutschland

PV-P-11 **Sharp horizontally constrained 1D inversion of 3D FD-EMI data set with structural constraints from GPR: performance evaluation with two field cases.**

T. Klose, J. Guillemoteau, P. Koyan, J. Tronicke

University of Potsdam, Institute of Geosciences, Potsdam, Deutschland

PV-P-12 **Imaging subsurface structures through synthetic modeling and inversion using semi-airborne electromagnetic method**

M. Bayat, T. Günther, R. Rochlitz, M. Ronczka

Leibniz Institute for Applied Geophysics, Hannover, Deutschland

PV-P-13 **Developing a Methodology for Estimating Natural Hydrogen Production in Serpentinization Zones: A Case Study from Eastern Morocco**

R. Christiansen[1], M. Sobh[1], G. Gabriel[1, 2]

[1]Leibniz Institute for Applied Geophysics (LIAG), Hannover, Deutschland,
[2]Leibniz University Hannover, Institute of Geology, Hannover, Deutschland

PV-P-14 **Modeling the induced polarization of partially saturated porous media**

B. Brömer[1], D. Kreith[1], A. Scheuermann[2], T. Bore[2], A. Sufian[3], M. Bücker[1]

[1]TU Braunschweig, Institute of Geophysics and Extraterrestrial Physics, Braunschweig, Deutschland, [2]University of Queensland, School of Civil Engineering, Brisbane, Australien, [3]University of New South Wales, School of Civil and Environmental Engineering, Sydney, Australien

PV-P-15 **Preliminary Transfer Function Estimates of AC Power Lines**

H. Hawighorst, M. Becken

Institut für Geophysik, Universität Münster, Münster, Deutschland

PV-P-16 **Possibilities of exploring the whole-mantle velocity-density relation using normal modes and gravity data**

W. Szwillus

Christian-Albrechts-Universität zu Kiel, Institut für Geowissenschaften, Kiel, Deutschland

SG-P-01 **Gravimetrische 3D-Modellierung des Granitkomplexes Schönbrunn/Eichigt**

E. Waiblinger[1], A. Al Hasan[2]

[1]Friedrich-Schiller-universität, Jena, Deutschland,
[2]Friedrich-Schiller-universität, Geowissenschaften, Jena, Deutschland

SG-P-02 **Seismic tomography derived 3D density models of the Alpine lithosphere and upper-mantle using forward gravity modelling**

S. Zarifikoliaee[1, 2], I. Ullah[1, 3], A. Kumar[1], M. Scheck-Wenderoth[1, 4]

[1]Helmholtz Centre Potsdam Deutsches GeoForschungsZentrum GFZ, Subsurface process, Potsdam, Deutschland, [2]Free University of Berlin, Berlin, Deutschland, [3]RWTH Aachen University, Aachen, Deutschland, [4]RWTH Aachen University, Aachen, Germany, Faculty of Georesources and Materials Engineering, Aachen, Deutschland

SG-P-03 **Parker-Oldenburg Inversion to infer Subglacial Topography in Antarctica – Results and Uncertainty Assessment**

T. Schaller[1], M. Scheinert[2], K. G. van den Boogaart[1]

[1]Helmholtz-Zentrum Dresden-Rossendorf, Helmholtz-Institut Freiberg, Dresden, Deutschland, [2]Technische Universität Dresden, Deutschland

Oral HS 2

11:00–13:00 SO-C SO
Seismology

Moderation: J. Folesky, *Freie Universität Berlin, Berlin, Deutschland*

11:00–11:20 SO-C-01 **Investigation of P-wave reflections from the lowermost mantle at seismic arrays in Germany**

R. Helk, S. Mader, J. Ritter

Karlsruher Institut für Technologie - Geophysikalisches Institut, Karlsruhe, Deutschland

11:20–11:40 SO-C-02 **A better understanding of seismicity in the European North Sea for risk mitigation of large-scale CO2 injections**

D. Kühn[1], E. Martuganova[2], T. Kettlety[3], J. Schweitzer[1], A. Jerkins[1], B. Goertz-Allmann[1], J. Asplet[3], T. Dahl-Jensen[4], P. Voss[4], B. Baptie[5], M. Fellgett[5], A. M. Dichiarante[1], J. Hopper[4], C. Huang[1], N. Langet[1], C. Weemstra[2]

[1]NORSAR, Kjeller, Norwegen, [2]Delft University of Technology, Delft, Die Niederlande, [3]University of Oxford, Oxford, Vereinigtes Königreich, [4]GEUS, Kopenhagen, Dänemark, [5]BGS, Edinburgh, Vereinigtes Königreich

11:40–12:00 SO-C-03 **Seismologische Forensik für die Ereignisse an den Erdgasleitungen von NordStream 1 und 2 – Beobachtungen**

N. Gestermann, A. Steinberg, L. Ceranna, G. Hartmann, P. Hupe, T. Plenefisch

BGR Hannover, Hannover, Deutschland

12:00–12:20 SO-C-04 **Seismologische Forensik für die Ereignisse an den Erdgasleitungen von NordStream 1 und 2 – Modellierungen**

A. Steinberg, N. Gestermann, L. Ceranna

Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) [Federal Institute for Geosciences and Natural Resources], B4.3 Erdbebendienst des Bundes, Kernwaffenteststopp Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover, Deutschland

12:20–12:40 SO-C-05 **Current station operations of the Ruhr University Bochum**

K. D. Fischer, M. Roth, W. Friederich, R. Harrington

Ruhr-Universität Bochum, Institut für Geologie, Mineralogie und Geophysik, Bochum, Deutschland

Oral HS 9

11:00–13:00 PV-C PV
EM / geoelectrics / GPR / gravimetry / IP / magnetics

Moderation: F. Wagner, *Geophysical Imaging and Monitoring (GIM), RWTH Aachen University, Aachen, Deutschland*

11:00–11:20 PV-C-01 **Modelling of Distorted Transient Electromagnetic Data: A Case Study from a Waste Site near Cologne, Germany**

F. Sharifi, B. Tezkan, I. Ibraheem, P. Yogeshwar, R. Bergers

University of Cologne, Institute of Geophysics and Meteorology, Cologne, Deutschland

11:20–11:40 PV-C-02 **Metal-bearing infrastructure as secondary source: An approach to deal with EM data afflicted with infrastructure effects**

H. Treppke[1], M. Becken[1], R. Rochlitz[2]

[1]Institute of Geophysics, University of Münster, Münster, Deutschland, [2]Leibniz Institute for Applied Geophysics, Hannover, Deutschland

11:40–12:00 PV-C-03 **Comparison of airborne natural source electromagnetics systems over Hatchet Lake target, Canada**

M. Schiffler[1], A. Thiede[2], M. Schneider[3], G. Chubak[4], J. Rudd[4], R. Stolz[1, 5]

[1]Leibniz-Institut für Photonische Technologien, Quantensysteme, Jena, Deutschland, [2]Universität Münster, Institut für Geophysik, Münster, Deutschland, [3]Supracon AG, Jena, Deutschland, [4]DIAS Geophysical Ltd., Saskatoon, Kanada, [5]Technische Universität Ilmenau, Fakultät für Elektrotechnik und Informationstechnik, Ilmenau, Deutschland

12:00–12:20 PV-C-04 **Multi-source 3D imaging of a graphite deposit using drone-based semi-airborne electromagnetics**

W. Mörbe[1], R. Rochlitz[2], P. Kotowski[3], B. Tezkan[1], P. Yogeshwar[1]

[1]Institut für Geophysik und Meteorologie, Universität zu Köln, Köln, Deutschland, [2]Leibniz-Institut für Angewandte Geophysik (LIAG), Hannover, Deutschland, [3]Institut für Geophysik, Universität Münster, Münster, Deutschland

12:20–12:40 PV-C-05 **3D Inversion of Loop-Source Time-Domain Electromagnetic Data – Application to Synthetic & Field Data**

P. Yogeshwar[1], Y. Liu[2], R. Peng[2], B. Blanco-Arrue[3], H. Nienhaus[1], X. Hu[2]

[1]University of Cologne, Institute of Geophysics and Meteorology, Cologne, Deutschland, [2]China University of Geosciences, Wuhan, China, Volksrepublik, [3]Leibniz Institute for Applied Geophysics, Hannover, Deutschland

12:40–13:00 PV-C-06 **Large-scale 3D electromagnetic modeling with custEM on small computing platforms using an iterative solver**

M. Weiss, R. Rochlitz

Leibniz Institut für Angewandte Geophysik, Elektromagentik, Hannover, Deutschland

Keynotes HS 2

14:00–15:00 **S3** **Crustal Fluids and Seismicity: Observations, Modelling and Geophysical Imaging**

Moderation: U. Wegler, *FSU Jena, Jena, Deutschland*

S3-K **Low frequency seismicity driven by deep magmatic and metamorphic fluids**

N. Shapiro[1], C. Journeau[2], J. Soubestre[1], G. Farge[3], W. Frank[4], C. Jaupart[5], O. Melnik[1], V. Lyakhovsky[6]

[1]ISTerre, CNRS, Grenoble, Frankreich, [2]University of Oregon, Department of Earth Sciences, Eugene, Vereinigte Staaten von Amerika, [3]Seismology Laboratory of UC Santa Cruz, Santa Cruz, Vereinigte Staaten von Amerika, [4]Massachusetts Institute of Technology, Cambridge, Vereinigte Staaten von Amerika, [5]Institut de Physique du Globe de Paris, Paris, Frankreich, [6]Geological survey of Israel, Jerusalem, Israel

Poster — Foyer + HS 4

15:00–16:00 **Poster + Coffee break**
S3, EP, GD, GO, KI, MG, MP, PV, SG

Oral HS 2

16:00–17:40 S3-A

S3
Crustal Fluids and Seismicity: Observations, Modelling and Geophysical Imaging

Moderation: S. Keil, *Ludwig-Maximilians-Universität München, München, Deutschland*

16:00–16:20 S3-A-01

Novel multi-disciplinary observations during hydraulic stimulations at 1km depth

K. Plenkers[1], A. Obermann[2, 3], M. Rosskopf[2, 3], N. Gholizadeh Doonechaly[3], A. Reinicke[4], V. Durand[3], Bedretto Team[5]

[1]GMuG, Bad Nauheim, Deutschland, [2]ETH Zurich, Swiss Seismological Service, Zurich, Schweiz, [3]ETH Zurich, Institut for Geophysics, Zurich, Schweiz, [4]TNO Rijswijk, Rijswijk, Die Niederlande, [5]ETH Zurich, Zurich, Schweiz

16:20–16:40 S3-A-02

Anti-repeating earthquakes and their role to identify fluid migration processes in the Earth

S. Cesca[1], P. Niemz[2], S. Ide[3], T. Dahm[1, 4]

[1]GFZ Potsdam, Section 2.1, Potsdam, Deutschland, [2]University of Utah, Salt Lake City, Vereinigte Staaten von Amerika, [3]University of Tokyo, Tokyo, Japan, [4]University of Potsdam, Potsdam, Deutschland

16:40–17:00 S3-A-03

What seismicity tells us about deformation cycles and fluid/magmatic intrusions in the Reykjanes Peninsula volcano-tectonic systems

T. Dahm[1], P. Büyükakpinar[1], M. Isken[1], G. Páll Hersir[2], E. Árni Gudnason[2], T. Walter[1], C. Wollin[1], P. Jousset[1], S. Cesca[1], J. Doubravova[3], T. Ágústsdóttir[2], Ó. G. Flóvenz[2]

[1]GFZ Deutsches Geoforschungszentrum, Geophysik, Potsdam, Deutschland, [2]ISOR, Reykjavik, Island, [3]Czech Academy of Science, Geophysics, Praha, Tschechische Republik

17:00–17:20 S3-A-04

Magma accumulation prior to the recent eruptions at Fagradalsfjall, Iceland, based on seismicity analysis

T. J. Fischer[1], A. Masihi[2], J. Vlček[1], P. Hrubcová[3]

[1]Charles University, Applied Geophysics, Praha, Tschechische Republik, [2]Charles University, Applied Geoophysics, Praha, Tschechische Republik, [3]Institute of Geophysics, Adad. Sci. CZech Reop., Praha, Tschechische Republik

17:20–17:40 S3-A-05

Pre-eruption 2021 seismic activity at Fagradalsfjall, Iceland as a sensitive indicator of volcano-tectonic movements

P. Hrubcová[1], J. Doubravova[1], T. Fischer[2], V. Vavrycuk[1]

[1]Institute of Geophysics Czech Academy of Sciences, Seismology, Prague 4, Tschechische Republik, [2]Faculty of Natural Sciences, Charles University, Prague 2, Tschechische Republik

Oral SR 113

16:00–17:40 EP+GO-A

EP + GO
Extraterrestrical Physics & Geophysics in PR

16:00–16:20 EG-A-01

Permittivity sensor for melting probes to investigate electromagnetic properties of cryospheres

F. Becker, E. Ellinger, K. Helbing

Bergische Universität Wuppertal, Astroteilchenphysik, Wuppertal, Deutschland

16:20–16:40 EG-A-02

Sub-Alfvénic plasma interaction around a planetary body with atmospheric tail

S. Hoffmann, J. Saur

Institut für Geophysik und Meteorologie, Universität zu Köln, Köln, Deutschland

16:40–17:00 EG-A-03

Exploration of planetary bodies by means of static magnetic fields - simulations of the asteroid (16) Psyche

S. S. Keßler[1], J. Börner[1], M. Scheunert[1], F. Sohl[2], K. Spitzer[1]

[1]TU Bergakademie Freiberg | Institute of Geophysics und Geoinformatics, Freiberg, Deutschland, [2]Deutsches Zentrum für Luft- und Raumfahrt | Institute of Planetary Research, Berlin, Deutschland

17:00–17:20 GO-A-04 **Eine (unerwartete) Plattform der Wissenschaftskommunikation**

A. Schmidt[1, 2, 3]

[1]Carl Zeiss Jena GmbH, Planetarien, Jena, Deutschland,
[2]Gesellschaft Deutschsprachiger Planetarien e.V. (GDP), Vorstand, Bochum, Deutschland,
[3]International Planetarium Society, Inc (IPS), Chicago, Vereinigte Staaten von Amerika

Oral HS 9

16:00–17:40 GD-A

GD
Geodynamics / Tectonophysics

Moderation: W. Szwillus, *Christian-Albrechts-Universität zu Kiel, Kiel, Deutschland*

16:00–16:20 GD-A-01 **The results of using a novel scheme of joint inversion of gravity and magnetic data for the crustal structure in central Dronning Maud Land**

M. Ginga[1], J. Ebbing[1], A. Ruppel[2], A. Läufer[2], G. Eagles[3]

[1]Kiel University, Institute of Geosciences, Kiel, Deutschland,
[2]Federal Institute for Geosciences and Natural Resources (BGR), Hanover, Deutschland,
[3]Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven, Deutschland

16:20–16:40 GD-A-02 **Geophysical modelling of vertical motion processes constrained by geodetic and geological observations (UPLIFT)**

H.-P. Bunge[1], Uplift Team[2]

[1]Dept Geowissenschaften, LMU München, München, Deutschland,
[2]LMU/TU München, München, Deutschland

16:40–17:00 GD-A-03 **Exploring the upper mantle dynamics through Earth surface observations and plate motion changes**

I. L. Stotz, B. Vilacis, H.-P. Bunge, J. N. Hayek, A. Friedrich, S. Carena

LMU Muenchen, Muenchen, Deutschland

17:00–17:20 GD-A-04 **Geomechanical Insights from the KTB Stress State Model**

M. Ziegler[1, 2], C. Boese[2], M. Bohnhoff[2, 3]

[1]Technische Universität München, München, Deutschland,
[2]Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Potsdam, Deutschland,
[3]Free University of Berlin, Department of Geophysics, Berlin, Deutschland

17:20–17:40 GD-A05 **Estimating Geothermal Heat Flow in polar regions by coupling Solid Earth and ice temperature models**

J. Freienstein[1], W. Szwillus[1], M. Leduc-Leballeur[2], G. Macelloni[2], J. Ebbing[1]

[1]Kiel University, Institute for Geosciences, Kiel, Deutschland,
[2]Institute of Applied Physics "Nello Carrara", National Research Council, Sesto Fiorentino, Italien

Veranstaltung Other places

18:00–23:00 **Conference dinner**

MITTWOCH, 13.MÄRZ 2024

Oral HS 9

09:00–10:00 **S4-A** **S4**
Seismic Noise and Coda Waves

Moderation: S. Schippkus, *Universität Hamburg, Hamburg, Deutschland*

09:00–09:20 S4-A-01 **Wave interferometry for damage detection in a reinforced concrete structure.**

M. Dominguez Bureos[1], C. Sens-Schönfelder[2], E. Niederleithinger[3], C. Hadziioannou[1]

[1]University of Hamburg, Institute of Geophysics, Hamburg, Deutschland, [2]German Research Center for Geosciences, GFZ Potsdam, Potsdam, Deutschland, [3]Bundesanstalt für Materialforschung und -prüfung (BAM), Division 8.2 „Non-Destructive Testing Methods for Civil Engineering", Berlin, Deutschland

09:20–09:40 S4-A-02 **Seismic velocity drop caused by the 2023 Turkey-Syria earthquakes**

J. Müller, M. van Laaten, T. Eulenfeld, U. Wegler

Friedrich-Schiller-Universität Jena, Jena, Deutschland

09:40–10:00 S4-A-03 **The breathing volcano - monitoring velocity changes at Campi Flegrei (Italy) with seismic noise interferometry**

M. van Laaten, J. Müller, U. Wegler

Friedrich-Schiller-Universität Jena, Jena, Deutschland

Veranstaltungen HS 2

09:00–10:30 **DGG-Kolloquium**

Poster Foyer + HS 4

10:00–11:00 **Poster + Coffee break**
S2, S4, GT, OG, SM, VU

S2-P-01 **Rotation sensors as an enabling technology for earth system observation**

S. Stellmer[1], F. Bernauer[2], L. Biskupek[3], J. Böhm[4], A. Brotzer[2], T. Forbriger[5], O. Gerberding[6], S. Glaser[1], A. Güntner[7], C. Hadziioannou[8], O. H. Heckl[9], U. Hugentobler[10], H. Igel[2], K.-S. Isleif[11, 12], T. Klügel[13], J. Kodet[10], U. Schreiber[10], H. Schuh[7], D. Thaller[13], J. Wassermann[2], A. Wickenbrock[14], R. Widmer-Schnidrig[15], H. Wziontek[13]

[1]University of Bonn, Bonn, Deutschland, [2]Ludwig-Maximilians-Universität, München, Deutschland, [3]University of Hannover, Hannover, Deutschland, [4]TU Wien, Wien, Österreich, [5]Karlsruher Institut für Technologie, Karlsruhe, Deutschland, [6]University of Hamburg, Institute for Experimental Physics, Hamburg, Deutschland, [7]GFZ, Potsdam, Deutschland, [8]University of Hamburg, Institute of Geophysics, Hamburg, Deutschland, [9]University of Wien, Wien, Österreich, [10]TU München, München, Deutschland, [11]Helmut-Schmidt-Universität, Hamburg, Deutschland, [12]DESY, Hamburg, Deutschland, [13]Bundesamt für Kartographie und Geodäsie (BKG), Wettzell, Deutschland, [14]University of Mainz, Mainz, Deutschland, [15]University of Stuttgart, Stuttgart, Deutschland

S4-P-01 **Towards the Clustering of Large Distributed Acoustic Sensing Datasets**

O. Bölt, C. Hammer, C. Hadziioannou

Institute of Geophysics, University of Hamburg, Hamburg, Deutschland

S4-P-02 **Predictive Modeling of Seismic Wave Fields: Approaching the Transfer Function across Seismic Stations with Encoder-Decoder Networks**

J. Klinge[1], J. Walda[2], S. Schippkus[1], C. Hadziioannou[1], D. Gajewski[1]

[1]Universität Hamburg, Institut für Geophysik, Hamburg, Deutschland, [2]Emetriq GmbH, Alumni Universität Hamburg, Hamburg, Deutschland

S4-P-03 **Whispers in the WAVEs: Decoding Campus Vibrations with Distributed Acoustic Sensing**

C. Hadziioannou[1], O. Bölt[1], S. Croatto[2], D. Gajewski[1], E. Genthe[2], O. Gerberding[3], M. Hoffmann[2], K.-S. Isleif[2, 4], A. Kiel[1], C. Krawczyk[5], R. Maaß[1, 6], I. Malucelli Barbosa[1], N. Meyners[2], R. Rading[4], H. Schlarb[2], W. Vossius[4], C. Wollin[5]

[1]University of Hamburg, Institute of Geophysics, Hamburg, Deutschland, [2]DESY, Hamburg, Deutschland, [3]University of Hamburg, Institute for Experimental Physics, Hamburg, Deutschland, [4]Helmut-Schmidt-Universität, Hamburg, Deutschland, [5]GFZ, Potsdam, Deutschland, [6]DIAS, Dublin, Irland

S4-P-04 **Imprints of persistent oceanic noise sources on the coda of correlation wavefields**

M. Safarkhani, S. Schippkus, C. Hadziioannou

Institute of Geophysics, University of Hamburg, Hamburg, Deutschland

S4-P-05 **Dynamic analysis of prestressed reinforced-concrete bridge using six-component measurements**

A. Dhabu[1], F. Bernauer[2], C.-M. Liao[3], C. Hadziioannou[1], E. Niederleithinger[3], H. Igel[2]

[1]University of Hamburg, Institute of Geophysics, Department of Earth System Sciences, Hamburg, Deutschland, [2]Ludwig-Maximillians Universitat Munich, Department of Earth and Environmental Sciences, Munich, Deutschland, [3]Bundesanstalt für Materialforschung und prüfung (BAM), Berlin, Non-destructive testing methods for construction, Berlin, Deutschland

S4-P-06 **On single-station, six degree-of-freedom observations of regional seismicity at the Pinon Flats Observatory in Southern California**

A. Brotzer[1], H. Igel[1], F. Bernauer[1], J. Wassermann[1], R. Mellors[2], F. Vernon[2]

[1]Ludwig-Maximilians-Universität München, Geophysik, München, Deutschland, [2]Scripps Institution of Oceanography, Institute of Geophysics and Planetary Physics, San Diego, Vereinigte Staaten von Amerika

GT-P-01 **Calculating radiogenic heat production from geochemical data for Greenland**

M. Zimmer[1], A. Wansing[1], B. Heincke[2], J. Ebbing[1]

[1]Insitute for Geosciences at CAU, Kiel, Deutschland, [2]Geological Survey of Denmark and Greenland, Kopenhagen, Dänemark

GT-P-02 **Hydraulic analysis of the GEOREAL fluid injection experiment at the KTB pilot hole, Germany**

C. Böse[1], G. Zimmermann[2], J. Kück[1], S. Kamrani[1], G. Dresen[1], M. Bohnhoff[1], U. Harms[1], I. Sass[2]

[1]Helmholtz Centre Geoforschungszentrum Potsdam, 4.2 Geomechanic and Scientific Drilling, Potsdam, Deutschland, [2]Helmholtz Centre Geoforschungszentrum Potsdam, 4.8 Geoenergy, Potsdam, Deutschland

GT-P-03 **Das Projekt "Restless" – Analyse des Einflusses der Lithologie auf das Risiko induzierter Seismizität in tiefengeothermischen Reservoirs**

S. Abe[1], H. Deckert[1], V. Toy[2], F. Hawemann[2], S. Fenske[2], R. Hass[2], J. Schmatz[3], W. Bauer[4], L. Hähnel[4], A. Henk[5], S. Homuth[6]

[1]Institut für geothermisches Ressourcenmanagement, Bingen, Deutschland, [2]Johannes Gutenberg Universität Mainz, Mainz, Deutschland, [3]MaP – Microstructure and Pores GmbH, Aachen, Deutschland, [4]FAU Friedrich-Alexander Universitaet Erlangen-Nuernberg, Erlangen, Deutschland, [5]Technische Universität Darmstadt, Darmstadt, Deutschland, [6]Deutsche ErdWärme GmbH & Co. KG, Karlsruhe, Deutschland

OG-P-01 **Application of a semi/fully Autonomous 4-wheeled Rover for Geophysical Data Acquisition**

M. R. Ershadi, R. Drews

University of Tübingen, Geosciences, Tübingen, Deutschland

OG-P-02 **Georadar measurements for archaeological prospection in the vicinity of the Amyklaion sanctuary near Sparta**

M. Wendel[1], V. Schmidt[1], S. Nomicos[2], S. Vlizos[3], N. Nenci[4]

[1]Institute of Geophysics, University of Münster, Münster, Deutschland, [2]Institute for Classical Archaeology and Christian Archaeology, University of Münster, Münster, Deutschland, [3]Ionian University, Department of Archives, Library Science and Museology, Corfu, Griechenland, [4]University of Perugia, Perugia, Italien

OG-P-03 **ZMvB – Zerstörungsfreies Monitoring von Bauteilfeuchte an historischen Bauwerksstrukturen mittels Georadar, Ultraschall und Thermographie**

Y. E. Esel[1, 2], E. Erkul[1], D. Schulte-Kortnack[1], T. Meier[1]

[1]Christian Albrechts-Universität zu Kiel, Geophysik, Kiel, Deutschland, [2]Deutsche Bundesstiftung Umwelt, Osnabrück, Deutschland

OG-P-04 **Geophysical investigation in ancient Olympia: The discovery of unknown structures of the Sanctuary of Olympia**

S. Bäumler[1], D. Wilken[1], L. Obrocki[2], P. Fischer[2], L. Slabon[2], T. Willershäuser[2], E.-I. Kolia[3], A. Vött[2]

[1]Institut für Geowissenschaften / Christian-Albrechts-Universität zu Kiel, Kiel, Deutschland, [2]Geographisches Institut / Johannes Gutenberg-Universität Mainz, Mainz, Deutschland, [3]Hellenic Ministry of Culture and Sports, Ephorate of Antiquities Ilia-Ancient Olympia, Patras, Griechenland

OG-P-05 **NFDI4Objects - Beiträge zum Forschungsdatenmanagement in der Archäogeophysik**

C. Schütze[1], U. Werban[1], T. Sonnemann[2], M. Lang[2]

[1]Helmholtz-Zentrum f. Umweltforschung GmbH, Department Monitoring- und Erkundungstechnologien, Leipzig, Deutschland, [2]Universität Bonn, Bonn Center for Digital Humanities, Bonn, Deutschland

OG-P-06 **Der Hera-Tempel auf Samos: Untersuchung des Baugrundes mittels seismischer Methoden**

N. Kallinich, M. Thorwart, F. Ojus, W. Rabbel

Institut für Geowissenschaften der CAU zu Kiel, Angewandte Geophysik, Kiel, Deutschland

OG-P-07 **Drone-borne magnetic prospection of the deserted town Blankenrode**

V. Schmidt[1], C. Paul[1], S. Klingen[1], J. Coolen[2]

[1]Universität Münster, Institut für Geophysik, Münster, Deutschland, [2]Landschaftsverband Westfalen-Lippe (LWL), LWL-Archäologie für Westfalen, Münster, Deutschland

OG-P-08 **Eignungsprüfungen geophysikalischer Sensoren zur Rissdetektion an Demonstrationsbauwerken**

C. Friedrich[1], S. Schennen[1], L. Pascharat[1], F. Mielentz[2], U. Effner[2], H. Stolpe[2], M. Behrens[2], F. Haamkens[2]

[1]BGE Bundesgesellschaft für Endlagerung, Peine, Deutschland, [2]BAM Bundesanstalt für Materialforschung und -prüfung, Berlin, Deutschland

OG-P-09 **Rational and efficient ground investigations for industrialised construction of new railways**

J. Robygd[1], T. Martin[1], M. Bastani[2]

[1]Lund University, Engineering Geology, Lund, Schweden, [2]SGU, Uppsala, Schweden

OG-P-10 **Untersuchung der hydraulischen Konnektivität in heterogenen Lockergesteinsaquiferen mittels SIP**

R. Herold[1], G. Beisembina[1], P. Dietrich[2], F. Börner[1]

[1]Technische Universität Berlin, Angewandte Geophysik, Berlin, Deutschland, [2]Helmholtz-Zentrum für Umweltforschung, Department Monitoring und Erkundungstechnologien, Leipzig, Deutschland

OG-P-11 **Experimentelle Untersuchung der Wirkung von Heterogenität und Anisotropie auf die Spektrale Induzierte Polarisation poröser Gesteine**

G. Beisembina[1, 2], R. Herold[1], P. Dietrich[3], F. Börner[1, 4]

[1]TU Berlin, Angewandte Geophysik, Berlin, Deutschland, [2]BGR, Berlin, Deutschland, [3]Helmholtz-Zentrum für Umweltforschung Leipzig, Monitoring und Erkundungstechnologien, Leipzig, Deutschland, [4]DGFZ Dresden, Dresden, Deutschland

OG-P-12 **Laboratory studies on the relationship between soil physical properties and NMR parameters of peat**

G. T. Beisembina, T. Hiller, S. Costabel

Federal Institute for Geosciences and Natural Resources (BGR), Groundwater and Soil, Berlin, Deutschland

OG-P-13 **Joint processing and inversion of active and passive ultrasonic data – first laboratory experiments**

A. Suchkova, V. Lay, E. Niederleithinger

Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Deutschland

OG-P-14 **Multimethodisches Monitoring von Infiltrationsexperimenten an urbanen Baumstandorten in Braunschweig**

L. Schirra[1, 2], S. Iden[1], J. Hoppenbrock[2], M. Beyer[1], M. Gerchow[1], I. Özgen-Xian[1], M. Bücker[2]

[1]Technische Universität Braunschweig, Institut für Geoökologie, Braunschweig, Deutschland, [2]Technische Universität Braunschweig, Institut für Geophysik und extraterrestrische Physik, Braunschweig, Deutschland

OG-P-15 **Geophysical investigation of soils contaminated with light non-aqueous phase liquids: A laboratory monitoring study with used engine oil**

H. Mohammed Nazifi[1, 2], L. Gülen[2], E. Pekşen[3], E. Gürbüz[2]

[1]University of Potsdam, Institute of Geosciences, Potsdam, Deutschland, [2]Sakarya University, Dept. of Geophysical Engineering, Sakarya, Türkei, [3]Kocaeli University, Dept. Geophysical Engineering, Kocaeli, Türkei

OG-P-16 **Utilizing SQUIDs for Compact SNMR Soil Moisture Sensors**

T. Splith[1], R. Dlugosch[2], T. Hiller[3], A. Chwala[4], R. Stolz[4], M. Müller-Petke[1]

[1]Leibniz-Institut für Angewandte Geophysik, Hannover, Deutschland, [2]Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Deutschland, [3]Bundesanstalt für Geowissenschaften und Rohstoffe, Berlin, Deutschland, [4]Leibniz-Institut für Photonische Technologien, Jena, Deutschland

OG-P-17 **Evaluierung eines optisch gepumpten Magnetometers hinsichtlich seiner Eignung zur Kampfmitteldetektion**

V. Braun[1], V. Schmidt[1], J.-P. Schmoldt[2]

[1]Universität Münster, Institut für Geophysik, Münster, Deutschland, [2]Tauber Geo-Consult Geowissenschaftler & Ingenieure GmbH, Greven, Deutschland

OG-P-18 **Seismic Imaging of the Weathering Zone: Unveiling the Impact of Climate and Bedrock Preconditioning**

R. Trichandi[1], K. Bauer[1], T. Ryberg[1], B. Heit[1], B. Wawerzinek[1], J. Araya Vargas[2], D. Scherler[3], F. von Blanckenburg[3], C. M. Krawczyk[1]

[1]GFZ Potsdam, Geophysical imaging, Potsdam, Deutschland, [2]Universidad de Atacama, Departamento de Geología, Copiapó, Chile, [3]GFZ Potsdam, Earth Surface Geochemistry, Potsdam, Deutschland

OG-P-19 **Investigating sedimentary sequences and basement geometry using loop source TEM:A case study from the Salar Grande, Atacama Desert, Chile.**

J. Roas Domingo, B. Blanco Arrué, T. Vondenhoff, B. Tezkan, P. Yogeshwar

University of Cologne, Köln, Deutschland

OG-P-20 **Geoelektrische Untersuchungen von Hochwasserschutzdeichen entlang der Schwarzen Elster bei Senftenberg**

M. F. Al Tawashi[1], D. Munstermann[2], T. Meier[1], L. Grimm[3], G. Fischenich[4], Seismologie-Gruppe[1]

[1]Institut für Geowissenschaften, Seismologie, Kiel, Deutschland, [2]GBM Geophysikbüro, Gommern, Deutschland, [3]Geotestbohrtechnik Grimm, Hohenstein-Ernstthal, Deutschland, [4]Arcadis Germany GmbH, Dresden, Deutschland

OG-P-21 **Evaluierung von Verdichtungsmaßnahmen auf verflüssigungsgefährdeten Kippen mittels Oberflächen-NMR**

T. Hiller[1], S. Costabel[2], G. Erdmann[1], E. Schönfeldt[1]

[1]Bundesanstalt für Geowissenschaften und Rohstoffe, Forschungs- und Entwicklungszentrum Bergbaufolgen, Cottbus, Deutschland, [2]Bundesanstalt für Geowissenschaften und Rohstoffe, Geophysikalische Erkundung - Technische Mineralogie, Berlin, Deutschland

SM-P-01 **Imaging the near-surface structure in the Syddenmark region utilizing shear wave reflection seismics**

U. Polom[1], A. T. Bentzen[2], R. Kirsch[3], P. B. Sandersen[4], C. Brandes[5], J. Bjergsted Petersen[6]

[1]Leibniz-Institut für Angewandte Geophysik (LIAG), S1, Hannover, Deutschland, [2]Region Syddanmark, Vejle, Dänemark, [3]Geoimpuls, Kiel, Deutschland, [4]GEUS, Aarhus, Dänemark, [5]Leibniz University Hannover, Hannover, Deutschland, [6]Aarhus University, Aarhus, Dänemark

SM-P-02 **Test einer Galperin-Quelle für die hochauflösende Multikomponenten-Reflexionsseismik**

L. Borchers[1], H. Buness[2], T. Burschil[3], C. Schmelzbach[4]

[1]Leibniz Universität Hannover, Hannover, Deutschland, [2]Leibniz-Institut für Angewandte Geophysik, Hannover, Deutschland, [3]Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover, Deutschland, [4]ETH Zürich, Zürich, Schweiz

SM-P-03 **Abbildung der Krustenstruktur im Bereich des Laacher See durch Re-Prozessierung der reflexionsseismischen Profile DEKORP 8701 und 8702**

L. Schreier, F. Hloušek, S. Buske

TU Bergakademie Freiberg, Institut für Geophysik und Geoinformatik, Freiberg, Deutschland

SM-P-04 **Auflösung als seismisches Attribut**

P. Musmann, G. Roos

BGR, B3.2, Hannover, Deutschland

SM-P-05 **Structural geological features and neotectonic evolution of the Bielefeld-Segment of the Osning Fault System**

S. H. Wadas, D. C. Tanner, U. Polom

Leibniz Institut für Angewandte Geophysik, S1 - Seismik und Potentialverfahren, Hannover, Deutschland

SM-P-06 **3D High-Resolution Velocity Model Building for the Characterization of a Nuclear Waste Disposal Site (Asse, Lower Saxony)**

L. Bräunig[1], N. Kühne[1], F. Hloušek[1], S. Buske[1], V. Becker[2], M. Scholze[2], H. Ding[2]

[1]TU Bergakademie Freiberg, Institut für Geophysik und Geoinformatik, Freiberg (Sachsen), Deutschland, [2]Bundesgesellschaft für Endlagerung, Peine, Deutschland

SM-P-07 **Characterisation of heterogeneities and anisotropy in the Opalinus Clay by seismic tomography, core and borehole investigations (Mont Terri underground rock laboratory, Switzerland)**

S. Lüth[1], F. Steegborn[2], F. Heberling[2], T. Beilecke[3], D. Bosbach[4], G. Deissmann[4], H. Geckeis[2], C. Joseph[5], A. Liebscher[5], V. Metz[2], D. Rebscher[3], K. Rink[6], T. Ryberg[1], S. Schennen[5]

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SM-P-08 **Seismic imaging of the Ivrea Zone and the Balmuccia peridotite**

B. Wawerzinek[1], T. Ryberg[1], K. Bauer[1], C. Haberland[1], M. Stiller[1], M. Weber[1], C. M. Krawczyk[1,2]

[1]Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum GFZ, Potsdam, Deutschland, [2]TU Berlin, Berlin, Deutschland

VU-P-01 **Volcanic Island Sector Collapse: Reconstruction of volcanic activity and implications for subsequent mass movements from marine records drilled with MeBo70 offshore Montserrat (Lesser Antilles)**

K. Sass[1], S. Kutterolf[2], T. Freudenthal[1], S. Watt[3], C. Berndt[2], S. Krastel[4], K. Huhn[1]

[1]MARUM – Center for Marine Environmental Sciences, University of Bremen, Bremen, Deutschland, [2]GEOMAR Helmholtz Centre for Ocean Research Kiel, Kiel, Deutschland, [3]School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham, Vereinigtes Königreich, [4]Institute of Geosciences, Christian-Albrechts-Universität zu Kiel, Kiel, Deutschland

Oral HS 9

11:00–13:00 **S4-B** **S4**

Seismic Noise and Coda Waves

Moderation: J. Umlauft, *ScaDS.AI, Leipzig University, Leipzig, Deutschland*

11:00–11:20 S4-B-01 **The coda of correlation wavefields is not dominated by multiply scattered waves**

S. Schippkus, M. Safarkhani, C. Hadziioannou

Universität Hamburg, Institute of Geophysics, Centre for Earth System Research and Sustainability (CEN), Hamburg, Deutschland

11:20–11:40 S4-B-02 **Investigating Subsurface Properties of the Shallow Lunar Crust using Seismic Interferometry on Synthetic and Recorded Lunar Data**

S. Keil[1,2], H. Igel[1], F. Bernauer[1], F. Lindner[1]

[1]Ludwig-Maximilians-Universität München, Geophysik, München, Deutschland, [2]Geosciences Barcelona - CSIC, Barcelona, Spanien

11:40–12:00 S4-B-03 **An improved high-resolution shear velocity model beneath the Iranian plateau using adjoint noise tomography**

A. Komeazi[1], A. Kaviani[1], G. Rümpker[1,2]

[1]Goethe University Frankfurt, Geophysics, Frankfurt, Deutschland, [2]Frankfurt Institute for Advanced Studies, Frankfurt, Deutschland

12:00–12:20 S4-B-04 **Characterizing the Seismic Impact of Wind Turbines on the Einstein Telescope**

N. Nippe[1], M. Boxberg[2], T. Niggemann[1], A. Stahl[1], F. Wagner[2]

[1]III. Physikalisches Institut B, RWTH Aachen, Aachen, Deutschland, [2]Geophysical Imaging and Monitoring, RWTH Aachen, Aachen, Deutschland

12:20–12:40 S4-B-05 **Methods to reduce Low-Frequency Noise of Wind Turbines for the Einstein Telescope**

T. Niggemann[1], M. Boxberg[2], N. Nippe[1], A. Stahl[1], F. Wagner[2]

[1]RWTH Aachen University, III. Physikalische Institut B, Aachen, Deutschland, [2]RWTH Aachen University, Geophysical Imaging and Monitoring, Aachen, Deutschland

Veranstaltungen HS 2

11:00–12:30 **DGG-Kolloquium**

Veranstaltungen SR 114

13:00–14:00 **Lunchseminar**

Keynotes HS 2

14:00–15:00 **S4 | Seismic Noise and Coda Waves**

Moderation: C. Hadziioannou, *University of Hamburg, Hamburg, Deutschland*

S4-K **Advancing Gravitational WIave Astronomy through seismic noise reduction**

K.-S. Isleif, the Einstein Telescope Collaboration

Helmut-Schmidt-Universität, Messtechnik, Hamburg, Deutschland

Poster Foyer + HS 4

15:00–16:00 **Poster + Coffee break**
S2, S4, GT, OG, SM, VU

Oral HS 2

16:00–17:00 **OG-B** **OG**
Near-surface Geophysics: Archaeogeophysics / Biogeoscience / Hydrogeophysics / Eng. & Environmental Geophysics

Moderation: R. Leonhardt, *GeoSphere Austria · Conrad Observatory, Österreich*

16:00–16:20 OG-B-01 **Impact of magnetic interfering bodies on the detection of unexploded ordnance**
C. Virgil
Institut für Geophysik und extraterrestrische Physik, TU Braunschweig, Deutschland

16:20–16:40 OG-B-02 **Highlighting discontinuity in 3D GPR reflection data using structure tensor-based attributes**
P. Koyan, J. Tronicke
Universität Potsdam, Institut für Geowissenschaften, Potsdam, Deutschland

16:40–17:00 OG-B-03 **GPR full-waveform inversion to characterize the Ahlen-Falkenberger peatland**
A. Klotzsche[1], N. Höring[2], H. Vereecken[1]
[1]Forschungszentrum Jülich, Agrosphere IBG-3, Jülich, Deutschland, [2]formerly Forschungszentrum Jülich, Agrosphere IBG-3, Jülich, Deutschland

Oral SR 113

16:00–17:00 **GT-A** **GT**
Geothermics / Radiometry

Moderation: J. Freienstein, Christian-Albrechts-Universität, Kiel, Deutschland

16:00–16:20 GT-A-01 **Identification of dominant heat transport mechanisms within the Thuringian Basin through terrestrial heat flow data analysis**
A. Schulz, N. Kukowski
Institut für Geowissenschaften, Allgemeine Geophysik, Jena, Deutschland

16:20–16:40 GT-A-02 **The duration of injection protocol likely controls the maximum magnitude of induced earthquakes**
M. J. Moein[1], C. Langenbruch[2], S. shapiro[2]
[1]Free Unievrsity of Berlin, Earth Sciences, Berlin, Deutschland, [2]Free University of Berlin, Berlin, Deutschland

~~16:40–17:00 GT-A-03 **Identification of a Potential Geothermal Resource in Colombia through the Application of Geoelectric Methods at the Aguas de Vichy Spring in the Municipality of San Andrés, Santander**~~
~~J. C. Mejía-Fragoso[1, 2], J. D. Sanabria-Gómez[1, 2, 3], R. Bernal-Olaya[1, 2]~~
~~*[1]Universidad Industrial de Santander, Bucaramanga, Kolumbien, [2]Grupo de Investigación en Geofísica y Geología Aplicada (IGGA), Bucaramanga, Kolumbien, [3]Grupo de Investigación en Relatividad y Gravitación (GIRG), Bucaramanga, Kolumbien*~~

Oral HS 9

16:00–17:00 **S4-C** **S4**
Seismic Noise and Coda Waves

Moderation: J. Müller, *Friedrich-Schiller-Universität Jena, Jena, Deutschland*

16:00–16:20 S4-C-01 **Unraveling Cryoseismological Records with Machine Learning**
J. Umlauft, A. Neumann, J. Peters, F. Roth, J. Zitt
ScaDS.AI, Leipzig University, Leipzig, Deutschland

16:20–16:40 S4-C-02 **Secondary microseisms in ice-covered areas - two examples from Antarctica**

M. C. Schmidt-Aursch[1], J. Almendros[2], W. S. Lee[3], BRAVOSEIS Working Group, EWARS Working Group

[1]Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Deutschland, [2]University of Granada, Granada, Spanien, [3]Korea Polar Research Institute, Incheon, Republik Korea (Südkorea)

16:40–17:00 S4-C-03 **Permafrost and Percolating Water at Mt. Zugspitze: Insights from Seismology and DAS**

F. Lindner[1], K. Smolinski[2], R. Scandroglio[3], A. Fichtner[2], J. Wassermann[1]

[1]Ludwig-Maximilians-Universität München, München, Deutschland, [2]ETH Zürich, Zürich, Schweiz, [3]Technische Universität München, München, Deutschland

Veranstaltungen HS 2

17:00–19:00 **General Assembly**

20:00–21:00 **Public evening lecture**

Erdbebenschwärme, Magmatransport und Vulkanausbrüche

DONNERSTAG, 14. MÄRZ 2024

Oral — HS 9

09:00–10:00 **S2-A** **S2**

From the Earth's core to the high atmosphere and beyond: insights from long geophysical time series in science and industry

Moderation: R. Leonhardt, *GeoSphere Austria · Conrad Observatory, Österreich*

09:00–09:20 S2-A-01 **Analysis and robustness of the absolute palaeointensity record of the Earth's magnetic field over geological timescales**

F. Lhuillier[1], V. P. Shcherbakov[2], N. Sycheva[2]

[1]Ludwig-Maximilians-Universität, Geophysik, München, Deutschland, [2]Institute of Physics of the Earth, Russian Academy of Sciences, Geophysical Observatory Borok, Borok, Russische Föderation

09:20–09:40 S2-A-02 **Attention to Deformation: Deep Learning Modeling of Local Noise in Laser Strainmeter Recordings at Moxa Geodynamic Observatory**

V. Kasburg[1], T. Jahr[1], A. Breuer[2], N. Kukowski[1]

[1]Institute of Geosciences FSU Jena, General Geophysics, Jena, Deutschland, [2]Institute of Informatics, FSU Jena, Advanced Computing, Jena, Deutschland

09:40–10:00 S2-A-03 **Analysing deep ocean heterogeneity using time series of offshore geodetic experiments**

A. Jegen[1], J. Karstensen[1], D. Lange[1], O. Pizarro[2], H. Kopp[1]

[1]Geomar Helmholtz Zentrum für Ozeanforschung, Kiel, Deutschland, [2]Universidad de Concepción, Concepción, Chile

Oral — HS 2

09:00–10:00 **OG-C** **OG**

Near-surface Geophysics: Archaeogeophysics / Biogeoscience / Hydrogeophysics / Eng. & Environmental Geophysics

Moderation: U. Werban, *Helmholtz-Zentrum für Umweltforschung - UFZ, Deutschland*

09:00–09:20 OG-C-01 **In-Situ Acoustic-Emission (Mikroakustik) zur Erkundung geologischer Strukturen im Salzbergwerk Asse II**

J. Philipp[1], K. Plenkers[1], D. Kemmler[2], M. Scholze[2]

[1]GMuG, Bad Nauheim, Deutschland, [2]BGE, Remlingen, Deutschland

09:20–09:40 OG-C-02 **Monitoring von Gefrier-Tau-Zyklen in einem experimentellen geologischen Eis-Wärme-Speicher mittels Bohrloch-Georadar**

P. Jung[1], G. Hornbruch[2], J. Nordbeck[2], S. Bauer[2], A. Dahmke[2], P. Dietrich[1], U. Werban[1]

[1]Helmholtz-Zentrum für Umweltforschung - UFZ GmbH, Department Monitoring- und Erkundungstechnologien, Leipzig, Deutschland, [2]Christian-Albrechts-Universität zu Kiel, Institut für Geowissenschaften, Kiel, Deutschland

09:40–10:00 OG-C-03 **Effektive Bestimmung der seismischen Baugrundklassen und der geologischen Untergrundklassen nach DIN**

T. Spies[1], M. Hobiger[2], S. Steuer[3]

[1]TU Clausthal, Institute of Geo-Engineering, Lehrgebiet Ingenieurseismologie, Clausthal-Zellerfeld, Deutschland, [2]Bundesanstalt für Geowissenschaften und Rohstoffe, Erdbebendienst des Bundes, Hannover, Deutschland, [3]Bundesanstalt für Geowissenschaften und Rohstoffe, Nutzungspotenziale des geologischen Untergrundes, Hannover, Deutschland

Oral SR 113

09:00–10:00 VU-A

VU
Volcanology

Moderation: K. Spitzer, Angewandte Geophysik, TU Freiberg, Deutschland

09:00–09:20 VU-A-01

TEM at breathtaking heights: Imaging the shallow fumarolic system of Lastarria volcano, Chile

T. Vondenhoff[1], B. Blanco-Arrué[2], J. Roas Domingo[1], B. Tezkan[1], D. Diaz[3], P. Yogeshwar[1]

[1]Institute of Geophysics and Meteorology, Köln, Deutschland, [2]Leibniz Institute for Applied Geophysics, Hannover, Deutschland, [3]Departamento de Geofísica, Santiago, Chile

09:20–09:40 VU-A-02

Deriving tectonic activity from sediment transport offshore Mt Etna using MBES data

J. Garbers[1], R. Barrett[1], E. Hadré[1], A. Bonforte[2], S. Gambino[3], H. Kolling[1], S. Krastel[1], F. Gross[1]

[1]Christian-Albrechts-Universität zu Kiel, Institut für Geowissenschaften, Kiel, Deutschland, [2]Istituto Nazionale di Geofisica e Vulcanologia, Catania, Italien, [3]Università degli studi di Catania, Dipartimento di Scienze Bio., Geo. e Amb, Catania, Italien

09:40–10:00 VU-A-03

Geomagnetic secular variation at high latitude at the end of the Cretaceous Normal Superchron: new data from the Okhotsk-Chukotka volcanic belt (NE Russia)

F. Lhuillier[1], I. E. Lebedev[2], P. L. Tikhomirov[2], V. E. Pavlov[2, 3]

[1]Ludwig-Maximilians-Universität, Geophysik, München, Deutschland, [2]Russian Academy of Sciences, Schmidt Institute of Physics of the Earth, Moscow, Russische Föderation, [3]Kazan (Volga) Federal University, Kazan, Russische Föderation

Poster Foyer + HS 4

10:00–11:00

Poster + Coffee break
open for all

Oral HS 2

11:00–13:00 OG-D

OG
Near-surface Geophysics: Archaeogeophysics / Biogeoscience / Hydrogeophysics / Eng. & Environmental Geophysics

Moderation: F. Wagner, *Geophysical Imaging and Monitoring (GIM), RWTH Aachen University, Aachen, Deutschland*

11:00–11:20 OG-D-01

Integrated model-data observations of water flow dynamics across bedrock and vegetation variations

S. Uhlemann[1], L. Peruzzo[2], C. Chou[1], K. Williams[1], S. Wielandt[1], C. Wang[1], N. Falco[1], Y. Wu[1], B. Carr[3], P. Meldrum[4], J. Chambers[4], B. Dafflon[1]

[1]Lawrence Berkeley National Laboratory, Berkeley, Vereinigte Staaten von Amerika, [2]University of Padua, Padova, Italien, [3]University of Wyoming, Laramie, Vereinigte Staaten von Amerika, [4]British Geological Survey, Nottingham, Vereinigtes Königreich

11:20–11:40 OG-D-02

Geoelectrical monitoring of tree-soil water interactions at urban sites

J. Hoppenbrock[1, 2], M. Gerchow[1, 3], M. Beyer[3], V. Hörmann[1, 3], M. Quambusch[3], M. Strohbach[1, 3], M. Bücker[2]

[1]Julius Kühn-Institut, Institut für Pflanzenschutz in Gartenbau und urbanem Grün, Braunschweig, Deutschland, [2]Technische Universität Braunschweig, Institut für Geophysik und Extraterrestrische Physik, Braunschweig, Deutschland, [3]Technische Universität Braunschweig, Institut für Geoökologie, Braunschweig, Deutschland

11:40–12:00 OG-D-03

Mountain permafrost degradation: How reliable are results from repeated ERT and refraction seismic surveys under changing subsurface conditions?

C. Hilbich, M. Boschung, C. Mollaret, C. Hauck

Universität Fribourg, Fribourg, Schweiz

12:00–12:20 OG-D-04 **Investigation of the Garzweiler Coal Deposit, Germany using Central and Fixed Loop Transient Electromagnetics**

E. Sen, P. Yogeshwar, W. Mörbe, B. Tezkan

University of Cologne, Institute of Geophysics and Meteorology, Köln, Deutschland

12:20–12:40 OG-D-05 **Subsurface Characterization of the Weidenpesch landfill, Cologne, Germany using geoelectric and electromagnetic techniques**

I. Ibraheem, P. Yogeshwar, R. Bergers, B. Tezkan

University of Cologne, Institute of Geophysics and Meteorology, Cologne, Deutschland

12:40–13:00 OG-D-06 **The contribution of geophysics in a combined approach of geosciences, historical archaeology and history**

S. Birnstengel[1], A. Köhler[2], M. Pohle[1], M. Kaniecki[2], V. Seeburg[3], N. Mehler[3], A. Linstädter[4], C. Zielhofer[2], U. Werban[1]

[1]Helmholtz-Zentrum für Umweltforschung - UFZ, Monitoring- und Erkundungstechnologien, Leipzig, Deutschland,
[2]Leipzig University, Institute of Geography, Leipzig, Deutschland,
[3]University of Tübingen, Departement of Medieval Archaeology, Tübingen, Deutschland,
[4]University of Potsdam, Biodiversity Research / Systematic Botany, Potsdam, Deutschland

Oral HS 9

11:00–13:00 SM-A **SM**
Seismics

Moderation: S. Buske, *Institute of Geophysics and Geoinformatics, TU Bergakademie Freiberg, Freiberg, Deutschland*

11:00–11:20 SM-A-01 **Advancing seismic imaging: Fresnel volume migration in anisotropic and anelastic media**

N. Kühne[1], F. Hlousek[1], S. Buske[1], H. Ding[2], M. Scholze[2]

[1]TU Bergakademie Freiberg, Freiberg, Deutschland,
[2]Bundesgesellschaft für Endlagerung, Peine, Deutschland

11:20–11:40 SM-A-02 **Imaging neotectonic faults in the Northern Upper Rhine Graben using a muliti-method geophysical approach**

J. Mair[1, 2], H. Buness[3], A. Henk[1], R. Lehné[4], D. C. Tanner[3]

[1]TU Darmstadt, Institute for Applied Geosciences, Engineering Geology, Darmstadt, Deutschland, [2]Federal Office for Radiation Protection, UR2, Berlin, Deutschland,
[3]Leibniz Institute for Applied Geophysics, S1, Hannover, Deutschland,
[4]Hessian Agency for Nature Conservation, Environment and Geology, Wiesbaden, Deutschland

11:40–12:00 SM-A-03 **On the assessment of fluid pathways along the southern flank of the Asse salt structure**

L. Y. Mejia Mendez[1], T. Bohlen[1], L. Houpt[1], T. Hertweck[1], M. Scholze[2]

[1]Karlsruhe Institute of Technology, Geophysics, Karlsruhe, Deutschland,
[2]Bundesgesellschaft für Endlagerung (BGE), Hannover, Deutschland

12:00–12:20 SM-A-04 **Potential of 3D matrix ultrasonic measurements to image complex concrete structures**

V. Lay[1], C. Büttner[2], N. Roumia[3], E. Niederleithinger[1]

[1]Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Deutschland,
[2]TU Bergakademie Freiberg, Freiberg, Deutschland, [3]University of Bologna, Italien

12:20–12:40 SM-A-05 **Geophysikalische Überwachung von Projekten zur Kohlendioxid Abscheidung und Speicherung in Norddakota**

C. Barajas-Olalde[1], D. C. Adams[1], T. L. Richards[1], W. D. Peck[1], K. Connors[1, 2], B. A. Kurz[1]

[1]University of North Dakota, Energy & Environmental Research Center, Grand Forks, North Dakota, Vereinigte Staaten von Amerika,
[2]Plains CO2 Reduction Partnership Initiative, Grand Forks, North Dakota, Vereinigte Staaten von Amerika

Veranstaltungen SR 114

13:00–14:00 **Lunch'n'Learn**

Keynotes HS 2

14:00–15:00 **S2 | Vom Erdkern bis zur hohen Atmosphäre und noch weiter: Erkenntnisse aus langen geophysikalischen Zeitreihen in der Wissenschaft und Industrie**

Moderation: V. Kasburg, *IGW, FSU Jena, Jena, Deutschland*

S2-K **Massentransporte im System Erde und ihre Signale in gravimetrischen Zeitreihen**

B. Meurers

Universität Wien, Institut für Meteorologie und Geophysik, Wien, Österreich

Veranstaltungen HS 2

15:00–16:00 **Closing Event**

ABSTRACTS

S1–Keynote

From pore space to whole Earth: understanding complex geoprocesses through Model-Data Integration in the 21st century

S1-K

Ensemble data assimilation for estimating earthquake and geodynamic states and parameters

Y. van Dinther[1], H. Diab Montero[2], C. Marsman[1], A. Banerjee[2], P. J. van Leeuwen[3,4], R. Govers[1], F. Vossepoel[2]

[1]Department of Earth Sciences, Utrecht University, Utrecht, The Netherlands,
[2]Department of Geoscience and Engineering, Delft University of Technology, Delft, The Netherlands,
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The large growth in observational data and compute power for physics-based models transforms our ability to understand, quantify, and forecast Earth processes. Geophysicist aim to efficiently exploit and combine both advances to unravel complex geo-processes across spatial and temporal scales. However, both streams of information face challenges when dealing with uncertainties. To be able to effectively extract information we need to deal with uncertainties in a mathematically rigorous manner. This is done in ensemble data assimilation methods, which have revolutionised e.g., weather forecasting and are now also explored in solid Earth geophysics. Sequential methods incorporating observations step by step have not yet been explored much in solid Earth sciences. Generally, we anticipate too few observations are available or that their errors are too large to be useful. We often find both issues are efficiently tackled through ensemble data assimilation. I will demonstrate this using different applications estimating states and parameters governing Earth processes on human and historical time scales. We use Ensemble Kalman Filters (EnKF) to estimate the fault stress state well enough to have very low miss rates when forecasting synthetic earthquakes and slow slip events. Exploring Adaptive Gaussian Mixture Filters and Particle (Flow) Filters addressing non-Gaussian prior distributions just prior to earthquakes suggests including model errors addresses parameter bias. Yet large parameter biases in rate-and-state friction parameters needs to be addressed by estimating both states and parameters. Long enough observational time series would then allow to separate error contributions from friction and shear stresses to estimate current and future shear stresses and slip rates. Latest results on large-scale laboratory experiments will address the importance of an inaccurate representation of the governing physics. Finally, zooming in time we focus on incorporating geodetic observations prior to and after the 2011 M9.0 Tohoku earthquake to quantify geodynamic parameters and understand processes. We find with an Ensemble Smoother with Multiple Data Assimilation that a power law rheology with a single set of parameters can explain surface velocities before and after the earthquake. These methods show great promise for probabilistically quantifying a range of earthquake, geodynamic and solid Earth processes.

S1– Mündliche Präsentation

From pore space to whole Earth: understanding complex geoprocesses through Model-Data Integration in the 21st century

S1-A-01

Representativeness of petrophysical data - a digital rock physics approach, Part I: Geometrical modeling

P. Menzel, J. Börner, M. Scheunert

TU Bergakademie Freiberg, Institut für Geophysik und Geoinformatik, Freiberg

Geophysical simulation studies and interpretation of inversion results depend on laboratory measurements and petrophysical correlations established from these lab-based datasets. The scarcity of sample material and the time-intensive nature of lab processes often result in relatively sparse data sets, raising concerns about the representativeness and dependability of the derived relationships. This is because the measured data is statistically representative only to each particular sample, and extrapolation becomes challenging due to the inherent heterogeneity and variable internal structure of geomaterials. We address this challenge with a workflow that includes random microstructure modelling, finite element simulation of physical rock properties, and subsequent statistical and petrophysical evaluation.

In Part I of this two-part contribution, we present our geometric modeling approach for generating ensembles of randomized microstructure geometries (in this case, specifically pore space geometries). For each ensemble, a set of hyperparameters (e.g., mean particle size, mean pore size, etc.) is defined to parameterize an underlying modeling algorithm. We use several different modeling algorithms to mimic realistic pore space generation processes. All algorithms used here are conceptually simple, but applicable in 2D and 3D, allow easy external parameterization, and do not require large amounts of real rock data. Nevertheless, they all follow the same basic premise: one phase, either mineral matrix or pore phase, can be modeled by the union of geometric objects randomly placed in the model space.

In each ensemble, all model realizations are individually unique but share common characteristics. Therefore, a statistical evaluation of basic geometric parameters such as absolute or connected porosity or fractal dimension can be performed for each ensemble to gain insight into the parameter variability for the particular pore space type. In a subsequent step, all geometrical realizations of these ensembles are used as a basis for FEM simulation of electrical properties (see Part II). These are, again, unique for each realization, allowing further statistical evaluation.

S1-A-02

Representativeness of petrophysical data - a digital rock physics approach, Part II: Geophysical application

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Geophysical simulation studies and interpretation of inversion results depend on laboratory measurements and petrophysical correlations established from these lab-based datasets. The scarcity of sample material and the time-intensive nature of lab processes often result in relatively sparse data sets, raising concerns about the representativeness and dependability of the derived relationships. This is because the measured data is statistically representative only to each particular sample, and extrapolation becomes challenging due to the inherent heterogeneity and variable internal structure of geomaterials. We address this challenge with a workflow that includes random microstructure modelling, finite element simulation of physical rock properties, and subsequent statistical and petrophysical evaluation.
In Part II of this two-part contribution, we present how the ensembles of random microstructures (see Part I) can be used for integration in geophysical applications. We focus on electrical resistivity as a petrophysical parameter that is particularly sensitive to pore space connectivity. The electrical resistivity of each random microstructure is calculated using the finite element method. The results are statistically evaluated and compared with laboratory data. We present data sets for three different rock types and their associated pore space types. The individual manifestation of microvariability in electrical resistivity and the ability of the approach to correctly mimic the porosity dependence of electrical resistivity are evaluated. The implications and possibilities of our approach for the integration and upscaling of petrophysical data in field-scale geophysics are discussed.

S2–Keynote

Vom Erdkern bis zur hohen Atmosphäre und noch weiter: Erkenntnisse aus langen geophysikalischen Zeitreihen in der Wissenschaft und Industrie

S2-K

Massentransporte im System Erde und ihre Signale in gravimetrischen Zeitreihen

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Das Schwerefeld der Erde erfährt zeitliche Änderungen durch die Wechselwirkung mit extraterrestrischen Massen sowie durch Massentransporte im System Erde. Letztere beeinflussen das Schwerefeld der Erde direkt, wenn sie mit Dichteänderungen verbunden sind und indirekt als Folge von Deformation sowie von Änderungen der Erdrotation. Die Erfassung und Interpretation von zeitlichen Schwereänderungen ist somit von großer Bedeutung für die Erforschung geodynamischer Prozesse, die in einem weiten zeitlichen und räumlichen Skalenbereich und in allen Regionen des Erdinneren, vom Erdkern bis zur Erdoberfläche, sowie in der Atmosphäre ablaufen. Dazu gehören Erdgezeiten, atmosphärische und hydrologische Prozesse, tektonische Deformation oder Vulkanismus. Moderne Instrumentation erlaubt die Detektion von Signalen mit Amplituden in der Größenordnung von nur 1 nm/s^2 im Zeitbereich. Allerdings überlagern sich die Signale verschiedener Quellen und ihre Trennung stellt eine besondere Herausforderung dar. Sie gelingt in vielen Fällen durch Anwendung geeigneter, oft interdisziplinärer Methoden, die häufig die Erfassung sehr langer Zeitreihen erfordern. Der Vortrag diskutiert die grundsätzliche Problematik und zeigt an Hand ausgewählter Beispiele Lösungen und Resultate aktueller Forschung.

S2–Mündliche Präsentation

Vom Erdkern bis zur hohen Atmosphäre und noch weiter: Erkenntnisse aus langen geophysikalischen Zeitreihen in der Wissenschaft und Industrie

S2-A-01

Analysis and robustness of the absolute palaeointensity record of the Earth's magnetic field over geological timescales

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The geomagnetic field, generated by a dynamo in the Earth's outer core, have significantly changed its strength (absolute palaeointensity, API) and frequency of polarity reversals through geological time. These changes are likely controlled by the geometry of the core, the thermal boundary conditions imposed by the mantle on the core, and/or bifurcations of the geodynamo. Based on the analysis of the API record, the existence of distinct energy regimes of the geodynamo has often been postulated to explain the occurrence of superchrons (20–40 Myr periods without polarity reversals) or hyperfrequency events (10–20 Myr periods with a reversal rate > 10 Myr−1). Nevertheless, their definition critically depends on the reliability and spatiotemporal distribution of the API record.

To better constrain the predictive power of the API record, we analyse the dependency between strength and inclination (angle made by the horizontal with the field lines). Statistical field models indicate that these two quantities should correlate for a wide range of Earth-like magnetic fields, even with enhanced secular variation, persistent nonzonal components, and severe noise contamination. More generally, we show that the strength of the correlation can be used as a proxy for the dipolarity of the Earth's magnetic field.

Focussing on the palaeomagnetic record, we observe that the correlation between strength and inclination is statistically significant for the 1–130 Ma interval but tends to vanish prior to 130 Ma. On the one hand, the absence of correlation prior to 130 Ma is likely ascribed to widespread error contamination in the observations, making a robust interpretation of the API record over geological timescales highly challenging. On the other hand, the significant correlation over the 1–130 Ma interval indicates that the observations within this interval can be robustly interpreted. As the strength of the correlation does not significantly vary, we conclude that the Cretaceous Normal Superchron (81–121 Ma) may not be associated with enhanced dipolarity of the geodynamo, as previously claimed.

Reference: Lhuillier, F., Shcherbakov, V. P., & Sycheva, N. K. (2023). Detecting dipolarity of the geomagnetic field in the paleomagnetic record. Proceedings of the National academy of Sciences of the United States of America, 120(25), e2220887120. 10.1073/pnas.2220887120

S2-A-02

Attention to Deformation: Deep Learning Modeling of Local Noise in Laser Strainmeter Recordings at Moxa Geodynamic Observatory

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Geodynamic observatories utilize long time series of high-resolution instruments such as gravimeters, tiltmeters, or strainmeters to study the Earth's interior. However, the analysis of geodynamic time series can be challenging, due to the influence of local noise, potentially masking signals of interest. In view of the advancing experience to apply artificial intelligence (AI) methods, such as artificial neural networks (ANNs), on time series , deep learning offers methodology for modeling the nonlinear effects of local noise in geodynamic recordings based on influencing local variables, such as precipitation, changes in barometric pressure or in groundwater levels.
We present a novel deep learning approach for modeling local noise in recordings from a laser strainmeter array, which is installed in a gallery at Moxa Geodynamic Observatory. Our approach integrates data from various sensors, including a weather station and groundwater monitoring wells, to explore the impact of local noise on individual laser strainmeter recordings. Our results emphasize the potential of ANNs to correct for local noise in geodynamic time series. By incorporating attention into our ANNs − a method which became famous through its application in large language models, our approach enables a nuanced evaluation of decision-making processes within the ANNs. The attention scores obtained surpass the explanatory power of traditional correlation statistics, presenting an advance in understanding the effects of individual local variables in geodynamic time series.

S2-A-03

Analysing deep ocean heterogeneity using time series of offshore geodetic experiments

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Despite the different observing objectives of offshore geodetic and oceanographic experiments, a great overlap in the measured parameter space exists, which has motivated analyses exploring possible cross-benefits. Here we present the evaluation of temperature, pressure, and sound speed observations from a 2.5-year offshore geodesy experiment centred along the northern Chilean subduction zone (~21.5°S and ~71.5°W to 70.5°W). The data allowed us to quantify the full spectrum of the sites' hydrographic variability from a multi-hourly to multiannual time scale and with average inter-station distances of less than 1 km. While our analysis could confirm multi-year warming trends that previous studies have reported for the deep ocean, it shows an additional regionalization of warming trends. Superimposed onto the multi-year warming trend are temperature fluctuations that show multi-hourly to multi-weekly periods and amplitudes that show both spatial and depth/regional dependencies. Aside from a general decrease in energy levels of the fluctuations with depth, we see evidence of ocean-topography interactions through barotropic topography waves. Taken together, the observations reveal de-coupled dynamical regimes seaward and landward of the deep-sea trench that mark the extent of the abyssal part of the eastern boundary current off Chile and demonstrate the potential of time series from offshore geodetic surveys for hydrographic analyses.

S2–Poster

Vom Erdkern bis zur hohen Atmosphäre und noch weiter: Erkenntnisse aus langen geophysikalischen Zeitreihen in der Wissenschaft und Industrie

S2-P-01

Rotation sensors as an enabling technology for earth system observation

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Laser optical technologies for the measurement of rotational motions on local and global scales are on the verge of achieving sensitivities that make them attractive for complementing classic approaches such as Very Long Baseline Interferometry (VLBI) in geodesy or ground motion measurements using standard seismometers in geophysics. The additional observables have tremendous potential to advance science questions associated with the monitoring of polar motion, length-of-day variations, understanding and inverting terrestrial, oceanic, volcanic, and planetary seismic wave fields, as well as monitoring their environmental, structural, and tectonic causes. In addition, high-precision ground motion observations are necessary to understand and remove Newtonian noise for gravitational wave detection. The challenge both for the observation of Earth's rotation as a whole, as well as the recording of complete ground motions, is understanding and disentangling the interaction between atmospheric/oceanic processes and the solid Earth through new generations of models and sensing technologies. This research network will build on decades of world leading research in the field of ring laser and fibre-optic technologies and their applications in geodesy and geophysics involving research groups in photonics, geodesy and geophysics. We aim at extending this lead by: (1) pushing the limits on the photonics side with novel experimental strategies that substantially improve the long-term stability and sensitivity of rotation observations for observatory and field type instruments, (2) establishing a stable, world-wide unique multi-component rotation sensing system adapted to geodesy and geophysics with controls of environmental effects, (3) developing new strategies for optic-based portable rotation sensing for terrestrial, oceanic, and planetary applications, and (3) transfer the observations into the various scientific application domains.

S3 – Keynote

Crustal Fluids and Seismicity: Observations, Modelling and Geophysical Imaging

S3-K

Low frequency seismicity driven by deep magmatic and metamorphic fluids

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Low frequency (LF) seismicity in form of swarms of earthquakes or nearly continuous tremors is regularly observed in association with volcano-magmatic systems and during recent decades has been discovered in subduction zones. In this presentation we will focus on LF signals originating in the fluid-rich parts of the lower crust and upper mantle. This deep LF seismicity can be used to detect the presence of such fluids as well as to understand their migration patterns and interaction with surrounding rocks. In the first part, we will consider how complex DLF signals can be studied with methods based on the data of seismic networks and adapted to detect spatially coherent signals without clear impulsive offsets, to measure their time-frequency properties, and to locate their sources. Examples of the network-based analysis of volcanic and tectonic DLF seismicity will be shown with comparing results obtained in Guerrero, Mexico and in Kamchatka, Russia. We will present physical models for the source processes of DLF events and discuss how their time and space variability can be explained by the influence of deep fluids and their migrations.

S3 – Mündliche Präsentation

Crustal Fluids and Seismicity: Observations, Modelling and Geophysical Imaging

S3-A-01

Novel multi-disciplinary observations during hydraulic stimulations at 1 km depth

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We built a hydraulic reservoir of 100m scale with novel multi-disciplinary monitoring at 1.1 km depth in the Bedretto underground laboratory in the Swiss Alps and performed a series of hydraulic stimulations. We achieved unprecedented detailed geomechanical and seismological observations that give new insights into the hydromechanical and seismic processes during hydraulic reservoir development. We will present the challenges to design and implement a multi-component sensor network at hectometer scale, and present first results from hydraulic stimulations.

The Bedretto Geothermal Testbed is located at 100m to 400m from the Bedretto tunnel in Rotondo Granite. It comprises a stimulation borehole of 405m length with a 12 interval multipacker and a future production borehole of 351m length. Additionally, there are seven monitoring boreholes of 101m to 304m length that build a multi-component sensor network to monitor induced seismicity, volumetric strain, pore pressure and temperature (Plenkers et al. 2023). Challenges in the network installation, including deep borehole installation, high pore pressures and the mandatory sealing of boreholes using advanced grouting techniques, required the development of novel sensors, especially acoustic emission sensor chains and cementable tube pore pressure sensors (CTPP).

Over the past two years, multiple injections were carried out in the top 8 injection intervals (Obermann et al. submitted). The volume impacted by the stimulations in different intervals differs significantly with a lateral extent from a few meters to more than 150 m. Most intervals activated multiple fractures. With our seismic network, we succeeded in characterizing induced seismicity down to the pico-seismicity level (Mw<-4). Hydromechanical observations, as well as pore pressure data illuminate elastic and aseismic fracture opening.

The resolution of the process monitoring is unprecedented for geothermal reservoirs located 1000m below surface. Co-located sensors allowing to observe various physical parameters simultaneously give new opportunities in understanding the full rock response.

S3-A-02

Anti-repeating earthquakes and their role to identify fluid migration processes in the Earth

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Repeating earthquakes, or repeaters, are earthquakes affecting overlapping rupture patches with a similar location and focal mechanism. They have important implications to track fault slip rates, aseismic deformation, slow earthquakes and earthquake nucleation processes. Repeaters are often detected based on highly similar waveforms. Here, we discuss earthquakes with highly anti-correlated waveforms, denoting a reversed seismogenic process at the same or a neighbouring location, which we refer to as true and quasi anti-repeaters, respectively. We first report a range such observations in different environments, including volcano seismicity, intermediate depth seismicity and injection-induced microseismicity. Then, we review conceptual models proposed to explain them. True and quasi anti-repeaters can be robustly identified via a three-component single station or distributed network data. They are key indicators for stress perturbation transients or local stress heterogeneities. Since most of these observations were explained as the response to fluid migration processes, they may help to identify and track fluid movements in the subsurface.

S3-A-03

What seismicity tells us about deformation cycles and fluid/magmatic intrusions in the Reykjanes Peninsula volcano-tectonic systems

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The Reykjanes Peninsula has been experiencing earthquake swarms and strong surface deformation over the last decades. In the past four years, five fissure eruptions have occurred at various locations between the geothermal high temperature fields at Svartsengi and Krýsuvík. GFZ has in cooperation with ÍSOR deployed several seismic networks on the Reykjanes Peninsula starting with the IMAGE project in 2014-2015, complementing the seismic network with a 17 km long fibre optic telecom cable (Jousset et al., 2018).

The Task Force activity in 2020 densified the seismic monitoring including the same fibre optic telecom cable owned by Mila telecom company, running from the tip of the Peninsula towards Svartsengi high temperature field near the Blue Lagoon Spa, and from there to the town of Grindavík in the south. During this period, a seismic unrest occurred on the Reykjanes Peninsula characterized by several uplift and deflation cycles beneath Mt. Thorbjörn and Krýsuvík. This activity was interpreted by Flóvenz et al. (2022) as the influx of magma-derived gases into an aquifer at about 4 km depth.

We analyzed the waveform data to analyse the seismicity during the volcanic unrest in 2020. We applied a machine-learning based detection and location algorithm and performed a full moment tensor Bayesian inversion for 83 earthquakes of magnitude Mw > 2.5. Focal mechanisms are predominantly strike-slip faulting with a few normal faulting events and are generally compatible with the regional tectonic regime. The earthquake foci are shallow, with

an average depth of only 3 km. Significant positive isotropic components are resolved, contributing up to 15% of the moment release. Travel times and polarities are included into the moment tensor inversion using both seismic waveforms and DAS data.

In 2021 and 2022, three fissure eruptions occurred about 10 km east of Mt. Thorbjörn within the Fagradalsfjall volcanic system. The second one impacted the town of Grindavík which had to be evacuated and is now inhabited. Following this activity, another Task Force was initiated. Six broadband stations were installed in the region together with the interrogation of the same fibre optic cable running from the tip of the Peninsula to Svartsengi.

The presentation discusses the ongoing unrest and seismicity in the light of recent eruptive and deformation cycles, and aims to evaluate the pros and cons of the proposed magmatic unrest models in the light of very recent observations.

S3-A-04

Magma accumulation prior to the recent eruptions at Fagradalsfjall, Iceland, based on seismicity analysis

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The Fagradalsfjall volcanic zone of the Reykjanes Peninsula, Iceland, experienced three eruptions of effusive character along a NE-SW oriented dyke in March 2021, August 2022 and July 2023. All these eruptions were preceded by seismic swarms elongated along the maximum horizontal stress component and lasted from several weeks to several months. The depth extent of hypocenters ranged from 0 to 7 km with majority of events with depths from 2 to 6 km. The focal mechanisms of events are consistent with the stress field and correspond to the preexisting structures.
We analyzed space-time distribution of precise hypocenter location and found multilateral migration of events whose character changed during the swarm evolution. However, a common feature of this migration was the fact that a few days before the eruption, an aseismic zone formed at depths above 5 km, adjacent to the site of the future eruption. We also applied the double-difference Wadati method to determine the Vp/Vs ratio in the focal zone of the 2021 swarm and found that the Vp/Vs ratio decreases during eruptions compared to the regional Vp/Vs of 1.78 found in Iceland. The analysis of lateral variations of Vp/Vs indicates that local minima of velocity ratio are found which correlate with aseismic zones along the dyke. We show the results of similar analysis applied to the swarms preceding the 2022 and the 2023 eruptions aimed at verifying the validity of the results for all the three pre-eruption earthquake swarms.

S3-A-05

Pre-eruption 2021 seismic activity at Fagradalsfjall, Iceland as a sensitive indicator of volcano-tectonic movements

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Iceland represents the onshore continuation of the Mid Atlantic Ridge separating the North American and Eurasian plates. It is the only section of the Mid-Atlantic Ridge exposed above sea level. The Reykjanes Peninsula in SW Iceland forms its active oblique spreading segment in place where the rift bends to its landward continuation. Such a setting produces transtensional tectonics characterized by increased seismicity, volcanism and high-temperature geothermal fields. The main tectonic features are expressed by a large number of NE-SW trending volcanic fissures and normal faults with grabens followed by several N-S striking faults from large earthquakes. The Fagradalsfjall volcanic system in the southern part of the Reykjanes Peninsula featured an increased seismic activity in late February 2021, which led to the first present volcanic eruption in this area on March 19, 2021. This eruption was succeeded by several other volcanic and tectonic unrests expressed by thousands of earthquakes, local and regional surface inflation, and four effusive eruptions over a span of three years.

We focused on the Fagradalsfjall 2021 pre-eruption seismic activity and interpreted seismic data recorded by local REYKJANET seismic network. The earthquakes with local magnitudes up to 5.3 (February 24, 2021) were located at depths 2-6 km and indicated activation of several fault segments related to dike and transform setting. Focal mechanisms and moment tensors with non-double-couple (non-DC) volumetric components of these earthquakes revealed complex evolution with three different regimes of faulting. They comprised (1) shearing at WSW-ENE trending strike-slip faults accompanied by north-south trending strike-slips, (2) collapses at normal faulting with negative volumetric components above or close to the magmatic dike with the same strike as the volcanic fissures and coinciding with the March 19 eruption, and (3) reverse faulting with positive volumetric components connected to magma movements and/or over-pressurized fluids migrating through the fractures. The spatiotemporal evolution revealed the interactions between tectonic and magmatic processes in this volcano-tectonic area.

S3 – Poster

Crustal Fluids and Seismicity: Observations, Modelling and Geophysical Imaging

S3-P-01

Detection capability of the West Bohemian Seismic Network (WEBNET)

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Earthquake swarm activity in West Bohemia is monitored by the WEBNET seismic network since the early nineties. The minimum magnitudes detected reach ML -1; however, no deeper analysis of the magnitude of completeness has been carried out.

We present a methodology to derive the network sensitivity from seismic noise level, and the minimum amplitude-to-noise ratio of the detectable events. In parallel, we analyze the automatic detections of selected earthquake swarms obtained by the PEPiN picker and locator, which is implemented at WEBNET, and we derive the completeness magnitude and its dependence on events location. As a result, we present a 3D map of the magnitude of completeness for the Nový Kostel area of the West Bohemia seismic swarm region. Additionally, a calibration of the method determining the completeness magnitude using seismic noise analysis is provided. The performance test on swarms in years 2016–2021 shows magnitude of completeness ML -0.3 at depth 9 km in the area of Nový Kostel.

S3-P-02

High frequency 3D array analysis of April 2021 earthquake swarm and search for tremor-like source processes in Westbohemia/ Vogtland

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The ICDP Project "Drilling the Eger rift" investigates the geodynamic processes in the Czech-German border region in Westbohemia and the Vogtland. It especially focuses on the relationship between the frequently occurring earthquake swarms and the CO_2 degassing in the region. For this purpose, several boreholes were drilled to install seismic sensors and gas probing devices to gain new knowledge of this relation. One aim is to improve the high-frequency observations of the frequently occurring earthquake swarms by using 3D arrays as novel observational instruments recording at high sampling frequencies (1000 Hz). One of the sub-projects focuses on the analysis and localization of the continuous wave field trying to image the hypothesized fluid movements in the area. The pilot 3D array in the West of the swarm area at the ICDP site 1.5 km south of Landwüst (Vogtland, Germany) is recording since December 2020. The installation consists of a 12 surface station array and and a 10 level almost vertical borehole array. This new instrument recorded the 2020 December activity as well as the earthquake swarm in April 2021. A first analysis using differential power spectral density (PSD) levels at stations in the area revealed a slight increase in the continuous wave field energy levels before the main phase of the swarm in April 2021 took place. There has

been speculations whether this observations could be interpreted as an indication for fluid movements within the crust. In order to confirm or reject this hypothesis we used the 3D array to separate body and surface wave components in the continuous wave field both for this special time period of enhanced energy levels as well as for the period of the swarm itself. Our analysis reveals that the 3D array is capable of clearly identifying the distinct arrivals of body waves from the swarm earthquakes even for very low SNR ratios. However, in the pre-swarm period which showed increased differential PSD levels we rather observe a diffuse mixture of surface waves originating from different directions without any clear body wave content. For the moment we therefore reject the hypothesis of a deeper crustal fluid related signature of the pre-swarm phenomenon.

S3-P-03

The Earthquake Relocation Analysis (2018-2024) using Automatic Waveform Detection and Machine Learning Techniques in the NW Bohemia/Vogtland Region

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The Chasing project (BU 4346/1-1) aims to unravel the geodynamic setting and causes of reoccurring earthquake swarms in the NW Bohemia/Vogtland region. Our study focuses on the accurate detection and localization of earthquakes and temporal changes within earthquake swarms. Using a dense network, we have for the first time combined waveform data from seven different seismic networks, including the Landwüst 3D array, from more than sixty seismic stations. In addition, two permanent stations are planned to be installed near Plauen in March 2024 to further improve azimuthal coverage. With the combined waveform data, we aim to increase the resolution of earthquake locations and create a unified catalog in a larger region, identifying swarm regions beyond the most active spots at Luby and Nový Kostel, including Plauen, North and South Oelsnitz, Klingenthal, Františkovy Lázně, and Mariánské Lázně regions. This will help to determine the hypothesized thermal controlled upwelling of the brittle-ductile transition in the crust. To achieve this, we implemented machine learning phase detection and robust migration and stacking techniques using the "qseek" software, which is an evolution of Lassie/Pyrocko. The detector algorithm uses SeisBench for picking, and localization is performed by adaptive octree search, including source-specific station corrections. Preliminary results indicate that two times more events were detected than in catalogs for local magnitudes ranging between -0.5 - 3.0. The earthquake-relative relocations are similar to those of the existing sub-catalogs but are more comparable across the region. Most of the seismicity occurred at a depth of 5-8 km in Luby, while the depth in Nový Kostel is between 7-12 km. Interestingly, deeper events at depths of 15-20 km occur in the wider region, but not below Luby and Nový Kostel. Our results are compared with the joint relocation of pick arrival data from the distinct bulletins in light of the MUSE project. Future research will focus on quantifying and comparing the migration patterns during the multiple earthquake swarms and investigating the remote triggering of earthquake activity during the swarm periods.

S3-P-04

Spatiotemporal Variations of In Situ Vp/Vs Ratio During the Seismic Swarm Preceding the 2021 Eruption in Fagradalsfjall, Iceland

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Fagradalsfjall is situated in the central part of the Reykjanes Peninsula, forming part of the volcanic belt between the Svartsengi and Krsuvik systems in Iceland. This paper delves into the 2021 Fagradalsfjall swarm, initiated by a 5.3 magnitude ML earthquake on February 24, persisting for approximately a month, concluding with an eruption on March 19. This swarm was a continuation of the July 2017 (ML < 3.7), December 2019 (ML < 3.7), and July 2020 (ML < 5) events in this region all recorded by 15 stations of the local Reykjanet seismic network. Utilizing the robust double-difference Wadati method, we assess the in-situ Vp/Vs ratio as a tool for monitoring magma presence across various temporal and spatial intervals. Our findings reveal a declining trend in the cumulative Vp/Vs ratio throughout the entire pre-eruption swarm period. Additionally, the calculated Vp/Vs value for this swarm is lower than that observed in previous swarms and in the background seismicity. The dataset, initially consisting of 38,500 events, is refined to about 21,000 events through relocation by GrowClust, employing preprocessing constraints such as cross-correlation below 0.85, phase arrivals from at least 6 stations, and a Vp/Vs ratio in each event pair between 0.5 and 3.

S4–Keynote

Seismic Noise and Coda Waves

S4-K

Advancing Gravitational Wave Astronomy through seismic noise reduction

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Gravitational wave astronomy, akin to seismology, interprets waves in spacetime to uncover the universe's most intensive events. Gravitational waves offer insights into cosmic phenomena such as merging black holes, neutron stars, or the collapse of whole galaxies. Since 2015, we've been „hearing" these spacetime ripples with ground-based instruments and we've been studying over 100 cosmic sources until today. Nonetheless, ground-based detectors encounter challenges, particularly a significant noise level at lower frequencies, mainly due to Earth's seismic noise.

This presentation will address the seismic challenges in current ground-based detectors, which achieve a displacement sensitivity of 10^{-18} m/√Hz at audio frequencies. Future detectors, like the Einstein Telescope, aim to enhance this sensitivity, significantly below 10 Hz, necessitating additional seismic noise reduction and management of new noise types, like Newtonian Noise. Newtonian noise directly results from seismic noise: Mass density changes in the Earth induce gravitational fluctuations, limiting the envisioned performance of future gravitational wave detectors. Innovative strategies are required to address this, such as deploying extensive underground seismic sensor arrays to measure seismic noise and predict Newtonian Noise. In this context, we will discuss the development of new seismic sensors, seismic network designs, and noise cancellation systems. These advancements in sensor technology and research methodologies are not just pivotal for the future of gravitational wave astronomy, they might also hold significant potential for advancing the field of seismology.

S4–Mündliche Präsentation

Seismic Noise and Coda Waves

S4-A-01

Wave interferometry for damage detection in a reinforced concrete structure.

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It has been demonstrated in laboratory setups that non-destructive tests (NDTs) based on nonlinear wave propagation models are more sensitive to the presence of very small damages and imperfections in concrete structures than linear models. Intending to incorporate these methodologies into real-condition structures, we carried out a 1-day multifrequency vibration experiment in a 24-meter-long reinforced concrete test bridge equipped with a pretension system, to investigate the possible presence of internal damage with vibration-based methodologies.

We used the pretension system to subject the specimen to eight compression states in its longitudinal direction (forces of 400kN at the highest, and 280kN at the lowest). At every compression state, we struck the structure in the vertical direction three times on the north and south sides of the bridge with an impulse drop weight. Throughout the whole experiment, we recorded ambient seismic noise at different frequency bands with a 14-six-component sensor array to measure the acceleration in the conventional translational components and the angular velocity (rotation rate), a 14-geophone array of 4.5 Hz of natural frequency, and four pairs of embedded ultrasound transducers were used to estimate relative velocity changes (dv/v) by applying the Coda Wave Interferometry (CWI) stretching technique. internal temperature of the concrete was also recorded to correct our measurements by first-order thermal effects.

At the material scale (ultrasound regime) we observe stress-dependent dv/v at four different locations in the specimen and describe them by using the acoustoelastic effect concept regarded as a classical nonlinear phenomenon. We also analyze the relative velocity drop and the subsequent healing process in the concrete triggered by the action of the drop weight. We used the model of Snieder and Sens-Schönfelder (2017) to numerically describe the relaxation process happening at different time scales in the specimen through a deterministic inversion procedure. The north side of the structure showed to have a higher acoustoelastic effect and higher velocity drops, as well as longer relaxation times, it is important to mention that there is evidence of external cracking in this span of the bridge.

S4-A-02

Seismic velocity drop caused by the 2023 Turkey-Syria earthquakes

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The M_w 7.8 earthquake in Turkey on 6 February 2023 was extraordinary for various reasons. It originated in depth of only 10 km, ruptured along a fault plane around 300 km long and the surface was covered by an extensive network of high-quality seismic instruments. The strong motions resulted in a vast number of tragic casualties and huge material losses in Turkey and Syria. However, abundant and proximate seismic observations of this event and numerous aftershocks give an opportunity to deepen the understanding of earthquake processes. In this study, we carried out an assessment of coseismic changes of seismic velocity using passive image interferometry. We used data from one strong-motion and twenty-four broadband sensors. We observed coseismic drops of seismic velocity, which reached up to -1.79 per cent at a location directly at the ruptured East Anatolian Fault Zone. Along the M_w 7.8 earthquake fault, we observe frequency dependence of the velocity changes. At frequencies above 0.5 Hz, the velocity drops seem to be higher at locations close to the ruptured faults than in the more distant areas.

S4-A-03

The breathing volcano - monitoring velocity changes at Campi Flegrei (Italy) with seismic noise interferometry

M. van Laaten, J. Müller, U. Wegler

Friedrich-Schiller-Universität Jena, Jena

Campi Flegrei is a volcanic field located in the immediate vicinity of the densely populated area of Naples, Italy. Since 2005, the area has been experiencing a new bradyseismic crisis, i.e., a slow uplift of the subsurface caused by rising fluids in the subsurface. The uplift is accompanied by earthquake activity that has been steadily increasing for years, culminating in the strongest earthquake (ML 4.2) in the last 40 years on September 27, 2023. Such uplift and earthquakes can cause changes in seismic velocity and are often succeeded by a volcanic eruption. In this study, we utilize seismic noise to calculate velocity changes at different levels/frequencies over a 7-year period using passive image interferometry. The observed long-term velocity decrease of 1.39 % near the surface over the period from 2016 to 2023 can be explained by a volume increase of the hydrothermal system at the depth of 3 km. In 2023, the Campi Flegrei underwent several phases of velocity change. After a period of minor velocity changes, there was a gradual 0.7 % increase in velocity starting in May. Following the onset of the earthquake swarm in August, the velocity slowly decreased once again.

S4-B-01

The coda of correlation wavefields is not dominated by multiply scattered waves

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Seismic monitoring of environmental processes and earthquake fault damage is often based on measurements of seismic velocity variations. To achieve repeated measurements with high temporal resolution, ambient seismic noise is exploited. Cross-correlation of the noise wavefield yields a new wavefield, the so-called correlation wavefield, which is closely related to the Green's function of the medium under the condition of uniformly distributed noise sources. Monitoring of seismic velocities exploits the coda of the correlation wavefield under the assumption that the coda is exclusively comprised of multiply scattered waves. This approach is routinely used for seismic imaging and monitoring today.

We demonstrate that persistent isolated noise sources can dominate the coda of correlation wavefields instead. Such sources induce repeating waves throughout the correlation wavefield, emerging from these sources. We showcase this with two data examples: a large-N array in the Vienna basin that is affected by a local wind farm, and recordings of ocean microseisms on the Gräfenberg array in Germany. Persistent isolated noise sources potentially have far-reaching implications for the current theoretical and methodological foundations of noise-based velocity monitoring and motivate further investigations.

S4-B-02

Investigating Subsurface Properties of the Shallow Lunar Crust using Seismic Interferometry on Synthetic and Recorded Lunar Data

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Ground motion observations on planetary objects are a prerequisite for a detailed understanding of their interior structure and evolution. The imaging of the near surface structure - in particular on the Moon - has strong practical implications. First, the race is on to detect ice-bearing rocks near the surface from which water could be extracted and used as a resource for crewed missions. Second, due to the substantial bombardment of the lunar surface with meteorites and the lack of an atmosphere, observatories or habitats may have to be built underground. It has been proposed that cavities from ancient lava flows below the lunar surface could be used to place infrastructure.
Scientific challenges in this endeavor include the understanding of wavefield effects of icy rocks and caves in a strongly scattering environment and developing appropriate imaging strategies. Seismic interferometry seems to be a promising method due to the scattering characteristics of the lunar crust and it´s sensitivity to subsurface structure and lateral variations. Previous studies have shown that Rayleigh wave dispersion curves can be extracted by correlating seismic noise recorded by four sensors placed on the Moon during the Apollo 17 mission. However, variations in the quality of the cross-correlated signals between station pairs indicate a potential influence of their separation distance and azimuthal orientation. Since we are dealing with high-frequency data, it is likely that attenuation effects, both intrinsic and due to scattering, must be playing an important role. As part of the DFG-funded NEPOS (Near-Surface Seismic Exploration of Planetary Bodies

with Adaptive Networks) project, we investigate this observation further using numerical simulations. We first developed a Digital Twin for wave propagation in the strongly heterogeneous lunar crust using the spectral element code SALVUS. We compared the synthetic seismograms to data from the Apollo 17 Lunar Seismic Profiling Experiment (LPSE) and find that their main characteristics coincide. We further generated synthetic seismograms for a variety of network configurations and subsurface heterogeneities. Subsequently, seismic interferometry was applied to both LPSE data and synthetic seismograms to assess the impact of station distance.
Our findings carry implications for the deployment of seismic arrays in future missions.

S4-B-03

An improved high-resolution shear velocity model beneath the Iranian plateau using adjoint noise tomography

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We perform an adjoint waveform tomography using Rayleigh wave Empirical Green's Functions (EGFs) at 10-50 s periods to improve a prior 3-D velocity model of the crust and uppermost mantle beneath the Iranian Plateau. EGFs were derived from cross-correlations of ~8 years of continuous vertical component seismic noise recorded by 119 broadband stations within the region. Adjoint tomography refines the initial model by iteratively minimizing the frequency-dependent travel- time misfits between the synthetic Green's Functions (SGFs) and EGFs measured in different period bands. The total misfit is dropped by ~75 percent after 6 iterations. Overall, the adjoint tomography provides images with more realistic and improved resolutions and amplitudes due to the inclusion of finite-frequency waveforms. The use of a numerical spectral-element solver in adjoint tomography provides highly precise structural sensitivity kernels, resulting in more robust images compared to those generated by ray-theory tomography. Our study also demonstrates improvement in lateral resolution and depth sensitivity. The final model adjusts the shapes of velocity anomalies at crustal and uppermost mantle depths especially in the Zagros convergence zone. These improvements include a high-resolution image of delamination of the subducting Arabian lithosphere from Zagros lower crust beneath the central and NW Zagros. The refine, high- resolution images also better show the geometry of low-velocity anomalies, which represent diachronous underthrusting of Arabian crust beneath central Iran.

S4-B-04

Characterizing the Seismic Impact of Wind Turbines on the Einstein Telescope

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Knowing the seismic impact of nearby wind turbines is crucial for future gravitational wave detectors like the Einstein Telescope. In the low frequency regime, seismic and gravity gradient noise are the dominant effects impacting the sensitivity. Vibrations of nearby wind turbines are expected to be significant contributions. A deep understanding of these vibrations and the coupling into the ground are necessary to define buffer zones around the detector. I will present measurements of seismic noise at the Einstein Telescope candidate site close to Aachen and their impact on the definition of buffer zones.

S4-B-05

Methods to reduce Low-Frequency Noise of Wind Turbines for the Einstein Telescope

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Seismic vibrations from nearby wind turbines are expected to be a significant noise source in the Einstein Telescope, a future third-generation gravitational wave detector in Europe. Direct and gravitational couplings are a limiting factor for detection of gravitational waves in the low-frequency range. This talk will discuss and evaluate methods to produce less vibrations in the first place and to reduce their coupling to the ground. Measurements of the vibrations from different types of wind turbines will be explicated.

S4-C-01

Unraveling Cryoseismological Records with Machine Learning

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The highly dynamic cryospheric environment is characterized by a multitude of physical processes that emit elastic and acoustic signals in active Alpine glaciers. These signals can be sensed by seismic instruments, such as conventional geophones or state-of-the-art DAS (Distributed Acoustic Sensing) infrastructure installed on the surface of or even deep within the ice body. Over the last decade, we have been able to identify a variety of processes within the cryoseismic signatures, such as surface icequakes (crevassing), basal stick-slip icequakes, or water flow. Despite the rapid growth of data archives, the high noise level from meteorological forcing or nearby mass movements, along with the superposition of signals in space and time, hinders continuous monitoring of pure processes. This limitation impedes our ability to understand the long-term dynamics of glaciers.

In this light, machine learning models are becoming increasingly important as they can handle both the heterogeneous data characteristics and the high volume of data. Here, we present an overview of ML-based methods and conventional array processing techniques that we have adapted, combined, and further developed to unravel cryoseismological records. Specifically, we (1) tested the suitability of MFP (matched field processing) derived locations as a source of information for glacier sliding on Glacier d'Argentière using a regression model, (2) show how deep learning/autoencoders can be used to uncover stick-slip events in noisy DAS datasets based on spatio-temporal coherence and (3) present a pipeline and preliminary results of effective and efficient DAS data clustering.

In addition, we present an interactive visualization tool to explore rich archives of heterogeneous ambient noise data from sensor arrays or DAS infrastructure.

S4-C-02

Secondary microseisms in ice-covered areas - two examples from Antarctica

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Oceanic microseisms are the most prominent noise peaks in seismograms. Especially the secondary microseisms dominate the recordings over a broad period range. In some areas, they split up into a high frequency (HF, approx. 1-5 s) and a low frequency (LF, approx. 5-10 s) band. Two main mechanisms lead to the excitation of secondary microseisms, coastal reflected waves in shallow waters and ocean standing waves in deep water. Sea ice coverage affects the generation and spreading of these waves. Data recorded by ocean-bottom seismometers (OBS), which are situated directly in the propagation medium, are not only strongly affected by secondary microseisms, but also can help to study these effects.

In this contribution, we show two examples from intermittent ice-covered areas in Antarctica. Within the EWARS project, three broadband OBS were deployed in the Ross Sea for one year, the fourth station recorded data for 17 months. Recordings from (semi-)permanent onshore stations complete this data set. During the BRAVOSEIS project, several broadband onshore stations and eight broadband OBS were deployed for one year in the Bransfield Strait. High-resolution probabilistic power spectral densities were calculated for all broadband stations to study the noise-generating processes. An analysis of tidal signals was performed. Noise cross-correlations between stations within one area were computed to determine the source directions of the secondary microseisms.

All stations show seasonal amplitude variations of the secondary microseisms, which can be linked to the local sea ice coverage. Nevertheless, there are major differences between the study areas. In the Ross Sea a clear splitting into HF and LF microseisms is visible. The HF noise disappears during the austral winter, while the Ross Sea is completely frozen. The LF noise amplitude decreases during this time, but is still abundant. Both parts reveal different tidal signatures. Separate noise sources most probably account for this. In contrast, the secondary microseisms in the Bransfield Strait show no distinct frequency bands. A moderate decrease of amplitudes during the austral winter, a high signal coherence of all stations, and consistent asymmetries of noise cross-correlations give evidence for noise sources outside the basin. In summary, secondary microseisms are affected by sea ice coverage; the extent of interaction depends not only on the amount of sea ice, but also on type and location of the noise sources.

S4-C-03

Permafrost and Percolating Water at Mt. Zugspitze: Insights from Seismology and DAS

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Mountain permafrost degradation in response to global warming reduces the stability of steep rock slopes, which poses increased hazard potential for infrastructure, settlements and mountaineers. Continuous monitoring of such environments remains challenging, but recent studies have shown that seismology is able to capture seasonal and long-term permafrost changes with high temporal resolution.

To investigate lateral differences in permafrost dynamics at Mt. Zugspitze (German/Austrian Alps), we installed three small seismometer/geophone arrays and a fiber-optic cable for DAS in a tunnel beneath the ridge to the west of the summit. While the seismometers were operational for up to two years, DAS was employed campaign-wise during the same time span. We exploit the cable car operations at the summit as stationary noise sources for cross-correlation computation to extract direct and coda waves between the deployment sites and along the fiber-optic cable.

From the seismometer data, we find dominant time-lapse changes in seismic velocity in the western part of the ridge. While the onset of freezing in fall results in steadily increasing seismic velocities, percolating water from (snow) melt and precipitation causes the velocity to drop again in spring. Despite lower quality of DAS recordings, preprocessing and cross-correlating them with the seismometer data yields high-quality seismic responses. These can be exploited to further pinpoint the velocity changes to areas of major freeze-thaw processes as seen by electrical resistivity tomography (ERT) studies.

In contrast to more classical methods including ERT, seismology combines high temporal resolution and spatial insights over comparatively large areas and thus constitutes a valuable contribution to permafrost monitoring. Being sensitive to both rock temperatures and cleft water has further advantages, as both parameters play an important role in permafrost rock mechanics.

S4–Poster

Seismic Noise and Coda Waves

S4-P-01

Towards the Clustering of Large Distributed Acoustic Sensing Datasets

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Distributed Acoustic Sensing (DAS) measures strain or strain rate along an optical fiber with a high spatial and temporal resolution. The typical channel distance is in the order of a few meters while the sampling frequency can reach 1 kHz or higher, which makes it possible to record a wide range of seismic signals. The optical fibers used for DAS can be several kilometers long and measurements take place over days, weeks or months, resulting in very large datasets of up to several tens of TB per day. However, due to this large amount of data, it is challenging to get a good impression of the different types of seismic signals present in the data, since a manual inspection can become immensely time-consuming.
In this study we aim to automatize this process by clustering the data to detect and categorize different types of seismic signals. 2D Gabor wavelets are used to automatically extract features from the data. In contrast to many other approaches, this allows to not only use temporal information, but to also include the spatial dimension to further distinguish between different seismic sources and wave types.
The clustering is performed in two steps. First, a Gaussian Mixture Model (GMM) is used to cluster the features. Then, the final clusters are obtained by merging similar components of the GMM.
A first application to several days of DAS data shows very promising results, with the clusters exhibiting potentially insightful temporal and spatial patterns.

S4-P-02

Predictive Modeling of Seismic Wave Fields: Approaching the Transfer Function across Seismic Stations with Encoder-Decoder Networks

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In geophysical data analysis, Machine Learning has become a prominent methodology with significant potential, offering diverse techniques and approaches to learn relationships within datasets. We aim to make use of an encoder-decoder network from the subfield of Deep Learning and modify it in a way that it is able to predict the development of seismic wave fields between two seismic stations. With this supervised approach, we approximate the principle of the transfer function, using one-dimensional time series measurements from two seismic stations as input and target data. To make sure that the dataset includes multiple sources and thus provides various features, we use field data gathered at a seismic exploration site in an area containing several roads, wind turbines, oil pump jacks and railway traffic. Using the well-known encoder-decoder network structure and applying it in the context of transfer learning enables us to automatically determine a representation of the wave field and predict its spatial development considering the phase and time information of

the signal. Diverging significantly from encoder-decoder works that estimate time series forecasts by analyzing historical trends, our approach focuses on mapping the features influencing the waves between locations. The gained knowledge can find application in future directions, among others, to consider temporary seismic arrays and exclude non-relevant parts of the data in the context of denoising.

S4-P-03

Whispers in the WAVEs: Decoding Campus Vibrations with Distributed Acoustic Sensing

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Dense seismic sensor networks, especially distributed acoustic sensing, and methods of big-data processing, such as artificial intelligence, are revolutionizing our capabilities to monitor, understand and predict seismic and seismo-acoustic processes and disturbances. In May 2021, we have deployed a seismic network, consisting of seismometers, geophones and a 12.6 km DAS fiber loop. The network was deployed on a scientific campus in Hamburg, Germany, which comprises the Deutsches Elektronen-Synchrotron (DESY), the European XFEL, PETRA III and Physics institutes of the University of Hamburg and further institutes and infrastructures. Our measurements provide insight into the sources of anthropogenic and natural vibrations and how they couple into large-scale and ultra-precision measurement research facilities that are otherwise limited by such disturbances. Here, we will present a selection of initial observations, along with a summary of the lessons learned while deploying fiber inside existing infrastructure.

S4-P-04

Imprints of persistent oceanic noise sources on the coda of correlation wavefields

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Continuous recordings of seismic ambient noise allow seismologists to study the properties of the Earth's subsurface without relying on active seismic sources. The use of cross-correlations of ambient noise between two seismic stations allows an approximation of Green's function, providing insight into the propagation of seismic waves. In monitoring seismic velocities, the focus is on coda waves reconstructed by cross-correlation, as their scattered paths make them more sensitive to material changes than direct arrivals. This is exemplified in the temporal monitoring of ambient noise velocities, where the time difference between long-term reference cross-correlations and short-term ones is used. The interpretation of this delay time measurement is considered equivalent to a change in seismic velocity, assuming a uniform noise source distribution.
However, in real conditions, ocean noise generation violates this assumption, which is fundamental to the theory behind seismic interferometry. This study investigates the impact of continuous oceanic noise sources on the coda of the correlation wavefield between station pairs. The hourly correlation wavefield between six master stations and the

Gräfenberg array in Germany was extracted within the microseism frequency band (0.05-0.3 Hz). Next, frequency domain beamforming was employed on the correlation wavefields to identify dominant incidence directions. This analysis reveals that oceanic source regions are detected throughout the coda of the correlation wavefield. This contradicts the common perception that the coda is a scattered wavefield. These outcomes were then compared with raw data beamforming results, maintaining the same three-year time resolution. The investigation's findings highlight the coda's dependence on oceanic microseisms and their seasonal fluctuations.

S4-P-05

Dynamic analysis of prestressed reinforced-concrete bridge using six-component measurements

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The catastrophic losses to infrastructure and human life caused by earthquakes have motivated civil engineers across the globe for decades to develop earthquake-resistant designs of buildings to vigorously minimize these losses. In the past, earthquakes were understood to cause horizontal and vertical motions; therefore, the buildings were designed to withstand these forces. However, with the development of new sophisticated seismic instruments, it is now known that earthquakes cause rotational and translational motions. With this additional information, it is crucial to recheck if the existing structural design strategies can help the buildings withstand rotational ground motions. In this direction, the present work makes a novel attempt to obtain the dynamic properties of a large-scale prototype prestressed reinforced concrete bridge structure using six component (6C) ground motions. The bridge is 24m long with two spans of 12m each and was instrumented using (i) conventional translational sensors, (ii) rotational sensors, and (iii) newly developed 6C IMU50 sensors for a total duration of 18 days. The instruments recorded ambient noise under operating conditions for 16 days and active data on the bridge under experimental conditions for two days. The recorded data is used to determine the dynamic properties of the structure using Operational Modal Analysis (OMA) and Experimental Modal Analysis (EMA). It is observed that, under the ambient noise conditions, the translational motions along the vertical direction and the rotational motions about the transverse direction of the bridge capture the maximum number of natural frequencies. Also, the number of natural frequencies captured is irrespective of the number and location of these instruments on the bridge. Under experimental conditions, the eigenfrequencies obtained from both the translational and rotational data show a shift to a lower/higher value depending on whether the prestress is decreased/increased. The IMU50 sensors show an excellent comparison of natural frequencies with conventional sensors and can be further explored for structural health monitoring (SHM) purposes. The mode shapes obtained from the translational data are in accordance with the analytical mode shapes expected for a 2-spanned simply-supported bridge. However, there is a need to understand the rotational boundary conditions for such structures through enhanced experiments.
Keywords: Rotational sensors, OMA, EMA, SHM

S4-P-06

On single-station, six degree-of-freedom observations of regional seismicity at the Pinon Flats Observatory in Southern California

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In September 2022, a portable, three-component rotational rate sensor, namely a blueSeis-3A, has been deployed at the underground vault of the Pinon Flats Observatory (PFO) in southern California. A three-component broadband seismometer is co-located on a granite pier, forming a 6 degree-of-freedom station for long-term observations of local and regional seismicity and wavefield studies. The seismic recordings are streamed online via the IRIS FDSN service, thus openly available with all required metadata as PY.BSPF (blueSeis at Pinon Flats).

The PFO provides observations of strain by optical-fiber and vacuum laser strainmeters, allowing to study 7 components of the seismic wavefield in a quiet area with regard to seismic noise, but high seismicity (e.g. San Andreas fault, San Jacinto fault). Moreover, the seismic array at PFO provides array derived rotations which serve as a validation of the direct, single-station measurements of one year of seismicity. This dataset enables to infer a magnitude scale calibration for rotational rate in southern California. Established six degree-of-freedom data analysis methods (e.g. backazimuth estimation) are applied to selected events and compared to classic approaches as a proof of concept and to highlight current sensor limitations.

AG–Poster

Airborne Geophysics / Fernerkundung

AG-P-01

Data-driven Estimates: Forecasting Drone-towed Sensor Platform Orientation with Neural Networks

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The growing availability of performance metrics and sensory data from various devices, including smartphones, watches, cars, drones, often results in underutilized information. Our study explores the potential of predicting complex instrument readings by incorporating multiple simpler data streams.
We focused on forecasting orientation angles of a drone-towed sensor platform, information crucial among others for quantifying the direction-dependent magnetic flux density in magnetic and electromagnetic techniques. Achieving < 1° accuracy in orientation often involve sophisticated and bulky instruments that influence the nearby magnetic field and are prone to data failures in regular, harsh usage.
Applying a Feedforward Neural Network to drone autopilot log files, we achieved predictions of the drone's attitude with an accuracy of less than 1°, predicted the orientation of a rod-mounted sensor platform with an accuracy of less than 5° and forecasted the alignment of a rope-towed sensor platform suspended by 10 meters with an accuracy of less than 10°. These promising results not only suggest the possibility of eliminating expensive instruments with a suitable training data set but also highlight new opportunities for calibrating low-priced sensors using Deep Learning algorithms and rudimentary sensory data.

AG-P-02

Linkage of Horizontal Magnetic Tensor and Energy Flux – An Evaluation for Three-Component Airborne Natural Source EM

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Airborne natural source electromagnetics (EM) can provide large-scale, densely gridded magnetic field recordings. Commercial one-component airborne recordings are processed into vertical-to-horizontal magnetic transfer functions (VMTF); three-component airborne recordings are used to determine some invariants relative to the horizontal field, both making use of horizontal recordings at a reference station on the ground. Here, we present for the first time airborne natural source EM horizontal magnetic transfer functions in terms of a horizontal magnetic tensor (HMT) in addition to VMTF. We estimate the HMT from a linear relation between horizontal airborne and ground reference recordings using a multivariate processing scheme. While the HMT only plays a minor role in ground data interpretation, natural source airborne EM applications benefit from exploiting the tensor by gaining a more robust and complete EM field description.
A visual analysis of the four complex-valued tensor elements, though, is cumbrous and so far, a physically meaningful depiction of the tensor has not been established. We propose a

depiction that is conceptually based on a thin-sheet model. Thereby, the HMT is associated with the vertical component of the Poynting vector belonging to the tangential electric mode EM fields and representing the corresponding energy flux. Relative subsurface conductivity variations can then be identified by energy flux direction. Applications to simulated and field data from a DESMEX survey in Namibia (Gobabis) are used for reliability evaluation. We find that the vertical energy flux depiction shows a clear correlation to induction arrows from VMTF estimates, suggesting that the linkage of the HMT and Poynting vector is meaningful. The new depiction supports an intuitive understanding of subsurface conductivity contrasts from airborne natural source EM processing results.

AG-P-03

Ergebnisse einer aeroelektromagnetischen Untersuchung im Bereich ehemaliger Braunkohletagebaue in der Lausitz südlich von Finsterwalde

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Zur Rekultivierung ehemaliger Gebiete des Braunkohletagebaus in der Lausitz werden großflächig Informationen zu Grundwasserleitern benötigt. Im Rahmen einer Pilotstudie im Bereich der „Kleinen Restlochkette“ wurden mit dem Hubschraubermesssystem der BGR im Sommer 2021 aerogeophysikalische Daten erhoben. Das Tagebaugebiet liegt etwa 60 km südwestlich von Cottbus in der Niederlausitz. Das Messgebiet hat eine Größe von ca. 250 km² und die Gesamtlänge aller Messprofile (mittlerer Abstand 250 m) beträgt etwa 1700 km (≈300.000 Messpunkte). Diese Erkundung erfolgte in Zusammenarbeit mit der Lausitzer und Mitteldeutschen Bergbau-Verwaltungsgesellschaft (LMBV) sowie in Absprache mit dem Landesamt für Bergbau, Geologie und Rohstoffe Brandenburg (LBGR). Die allgemeinen Ergebnisse der Befliegung sind über das BGR-Geoportal verfügbar (Siemon et al., 2022). Neben magnetischen und radiometrischen Daten wurden insbesondere auch Daten der Elektromagnetik (HEM) in 4 m Punktabstand auf den Messprofilen gewonnen. Diese wurden mit einer 10 m langen Flugsonde, die von dem BGR-Hubschrauber an einem Seil in etwa 50 m Höhe über Grund geschleppt wurde, erfasst. Die HEM-Daten zu sechs Messfrequenzen wurden in einfache Modelle (homogener bzw. geschichteter Halbraum) der elektrischen Leitfähigkeit gewandelt, um daraus einige für das Grundwasser relevante Parameter abzuleiten. Hierzu zählen vor allem der Grundwasserspiegel, die Verbreitung von Grundwasserleitern und -stauern sowie die elektrische Leitfähigkeit des Grund- und Oberflächenwassers. Aufgrund der in den Messstellen der LMBV beobachteten Korrelationen zwischen der elektrischen Leitfähigkeit des Grundwassers und einigen Mineralgehalten (Fe^{2+}, SO_4^{2-}) ließen sich diese mithilfe der HEM-Ergebnisse im ehemaligen Bergbaugebiet räumlich abbilden. Jedoch waren in den Bergbaufolgeseen selbst keine eindeutigen Korrelationen nachzuweisen, vermutlich wegen der Einträge von Niederschlags- und Oberflächenwasser.

Die Aerogeophysik lieferte Grundlagendaten, aus denen am Forschungs- und Entwicklungszentrum Bergbaufolgen (FEZB) der BGR unter Anwendung modernen Techniken (maschinelles Lernen) räumliche Verteilungen hydrogeologische Parameter ermittelt werden, die in die geohydraulische Modellierung des Untersuchungsgebietes einfließen.

Siemon, B., Ibs-von Seht, M. & Pielawa, J., 2022. Gebietsbericht D-AERO-Finsterwalde HEM/HMG/HRD-Befliegung 191 Finsterwalde Mai/Juli 2021. BGR-Bericht, Archiv-Nr. 137050, Hannover, doi: 10.25928/t7pz-1369.

EP–Mündliche Präsentation

Extraterrestrische Physik

EP-A-01

Permittivity sensor for melting probes to investigate electromagnetic properties of cryospheres

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To explore glaciers, sea ice, and other cryospheres, the emerging method employs melting probes equipped with a controllable melting head that can be heated to drill into the ice. Similar to borehole geophysics, logging can be conducted within these melting holes. The University of Wuppertal (BUW) has developed a sensor system designed to measure electric parameters, such as complex permittivity, encompassing relative permittivity and conductivity. This sensor is integrated as a module in the rear section of the melting probe. While primarily serving as part of a navigation system for guiding a melting probe through a cryosphere, it also has the potential to collect scientific data for constructing profiles of glaciers or ice bodies.

The measurement concept revolves around calculating permittivity from the reflection coefficient, also known as the S_{11}-Parameter. This involves connecting a vector-network analyzer (VNA) to a coaxial head through various cables, connectors and high-frequency switches. The BUW developed a pressure-neutral module with integrated measuring heads that can be extended from the melting probe using linear units powered by stepper motors, establishing contact with the ice. Four heads are stacked atop one another, enabling the measurement of electrical parameters at different orientations and depths.

The overarching objective of the project is to employ the permittivity sensor for extraterrestrial applications, measuring values within the ice crusts of icy moons where these parameters are unknown. For such space missions, it is imperative to determine the velocity of radar waves in the medium to correct radar signals by considering the phase velocity, which could be directly calculated from the permittivity. To validate the system, the fully integrated sensor was tested in alpine glaciers, and preliminary data will be presented as confirmation of the feasibility of this concept.

EP-A-02

Sub-Alfvénic plasma interaction around a planetary body with atmospheric tail

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Electromagnetic star-planet interaction is a phenomenon at exoplanets, orbiting in close distance to their host star. In this configuration, the ambient stellar plasma interacts with the planet's atmosphere, causing magnetohydrodynamic wave modes, modifying the ambient stellar magnetic field, and eventually generating Alfvén wings. Some of these close orbiting planets appear to continuously lose atmosphere, resulting in the formation of comet-like gas tails. In this work, the effects on a sub-Alfvénic interaction, caused by such an asymmetric structure, are modeled with the MHD-solver PLUTO. The deformed atmosphere is

approximated by different elliptical shapes. Main objectives are: (1) to picture the interaction strength of the Alfvén wings, (2) calculate the Alfvén wing current, (3) calculate the energy flux through the wings under varying eccentricity. All three quantities concentrate on the upstream side of the wing and decrease on the downstream side, when the eccentricity is increased. We also compare the Alfvén currents and energy fluxes with analytical expressions from earlier work.

EP-A-03

Exploration of planetary bodies by means of static magnetic fields - simulations of the asteroid (16) Psyche

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In this study, we developed two distinct methods for simulating the static magnetic field of planetary bodies using Matlab, showcasing their application on the asteroid (16) Psyche. Given the potential presence of up to 60 vol.-% metallic elements in Psyche, we anticipated high magnetic susceptibilities exceeding 1. Consequently, we carefully considered the influence of strong demagnetizing fields. The simulations also accounted for the inherent heterogeneity of the bodies under consideration. For the forward calculation, the considered bodies were placed in a homogeneous magnetic field that resulted from currents outside the region of interest. Two methods were applied in this work. The first approach assumes that the magnetic field inside the body corresponds to the external field. Analytic formulas were applied to calculate the magnetic anomaly of a homogeneously magnetized body with arbitrary shape. Firstly, the heterogeneous bodies were divided into parts with homogeneous susceptibility distribution. For each part, the magnetic field was simulated separately. Afterwards, all results were superposed to acquire the final anomaly field. However, this solution is physically not correct in terms of heterogeneity but leads to approximately correct results outside of the observed body. The integration of demagnetization is only possible to a limited extent since it depends on the geometry of the magnetized body. The second method utilized the finite element method to calculate the magnetic field, solving the underlying partial differential equation that considers the correct physics for heterogeneous and arbitrarily shaped bodies. The implementation employed the Finite Element Matlab Library FEMALY that was developed in Freiberg. According to our results, this method is up to 300 times faster than the first one for 10,000 evaluation points and a mesh consisting of 3075 nodes. With known analytic solutions for the magnetic field of a sphere, both approaches could be verified. Regarding the NASA mission to Psyche that was launched in October 2023, the magnetic anomaly field for different models of Psyche was simulated. Those models differed internally and depicted possible inner structures of Psyche. The simulation results of different models were compared in order to investigate which characteristics the magnetostatic anomaly fields of different models have and how those scenarios can be differentiated.

EP–Poster

Extraterrestrische Physik

EP-P-01

Electron beams in Jupiter's equatorial magnetosphere

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Jupiter has the most powerful aurora in the solar system and it is a current research aim to better understand the underlying mechanisms which cause the aurora. Recent observations by the Juno spacecraft over Jupiter's polar regions found that electrons accelerated towards Jupiter's atmosphere, contributing to auroral emissions, are often accompanied by electrons accelerated away from Jupiter. Traveling along the magnetic field, these electrons should be observable in the equatorial magnetosphere as bidirectional electron beams. In our work, we investigate the energetic electron data in this region, measured by Juno's JEDI-instrument within 30–1,200 keV. We show that electron beams are present in the equatorial middle magnetosphere and occur on timescales ranging from a few minutes to a few hours. We analyze the pitch angle distributions of these electrons and fit a 'beamness'-function for further characterization.

EP-P-02

Ohmic heating within the Galilean satellites

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As frequently observed by the Galileo spacecraft, the Galilean satellites - Io, Europa, Ganymede, and Callisto - experience periodic variations of the external magnetic field, primarily caused by the tilt of Jupiter's magnetic dipole axis relative to the orbital plane of the satellites. The Galileo mission discovered, that electromagnetic induction occurs within the conductive interior of Europa and Ganymede and possibly also within Io and Callisto. The analysis of magnetic field data provides insights into the satellites' internal electrical conductivity structure. Using the analytical solution of the governing Helmholtz equation in an electrically conductive body with radially symmetric conductivity distribution, we determine the magnetic field, the induced electric currents, and the resulting Ohmic heating in the interior. Initially, we assume a sphere of constant conductivity featuring an insulating surface layer in the presence of a linearly polarized time-varying external magnetic field. Using this simplified model, we investigate the total heating rate and the spatial structure of resulting Ohmic heating as functions of the conductivity of the sphere and the period of the inducing field.

EP-P-03

Seismic Exploration for the Emerging Moon Industry

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IMENSUS, a young startup based in Germany, is leading the way in space resource exploration. Supported by the ESA Business Incubation Center (ESA-BIC Program, Baden-Württemberg), our international and multidisciplinary team, combining expertise in aerospace engineering and geophysics, serves as the first link in the In-Situ Resource Utilization (ISRU) process chain. We strive to be a service provider specializing in underground exploration within the mission area, facilitating economically efficient and risk-minimized planning for ISRU missions. Our poster covers two main aspects: We introduce our first concept of our seismic exploration rover to explore the lunar subsurface. With applications spanning commercial and scientific domains. We detail the seismic methods employed by our rover, encompassing both reflection and refraction seismic. Leveraging proprietary synthetic data and data from the Apollo missions, we demonstrate our rover's vast potential. In conclusion, our work underscores the substantial advantages of our system and methodology, showcasing their pivotal role in ISRU missions. IMENSUS is pioneering lunar near surface exploration, offering indispensable tools and techniques for the future of ISRU.

GD–Mündliche Präsentation

Geodynamik / Tectonophysics

GD-A-01

The results of using a novel scheme of joint inversion of gravity and magnetic data for the crustal structure in central Dronning Maud Land

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Topography and physical conditions at the base of the Antarctic ice sheet are critical inputs for studies of its present and future ice discharge, and of subglacial geology and hydrology. Airborne gravity and magnetic data, especially when interpreted jointly can help us to link the geology from outcrops towards the coastal areas to unknown subglacial regions further inland. Here we use airborne geophysical data obtained during the joint AWI-BGR campaign WEGAS/GEA between 2015 and 2017 in central Dronning Maud Land (DML) as input for a novel joint inversion scheme. With regard to Gondwana reconstruction, this region is critical because it hosts the ice-covered Forster Magnetic Anomaly, a prominent lineament crossing central DML for some 100s of kilometres south of the main mountain chain. This lineament, originally interpreted as the main pan-African suture of East and West Gondwana, likely represents the eastern margin of Kalahari and its boundary to the Tonian Oceanic Arc Super Terrane (TOAST). In the inversion using the jif3D software, sources of the gravity and magnetic field are combined through a coupling method which decreases the variation of information (VI), so data misfit and model dissimilarity are minimized simultaneously. The model results can be classified in geologically meaningful provinces by applying cluster analysis based on machine learning. Our joint inversion approach improves previous interpretations and sheds light on the crustal architecture of the study area, contributing to further studies on the interaction between the ice sheet and the underlying solid earth.

GD-A-02

Geophysical modelling of vertical motion processes constrained by geodetic and geological observations (UPLIFT)

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Vertical motion of the Earth's lithosphere (uplift) occurs on different spatial and temporal scales. Commonly assumed to be primarily related to plate tectonic mechanisms and isostatic adjustment, it has become clear that mantle related forcing and in particular mantle plumes are a significant contributor to uplift events in many regions of the world, making vertical motions a powerful probe into sublithospheric processes. Significant improvements of observational methods (e.g. satellite missions) and publicly-accessible databases (e.g. digital geological maps) make it now feasible to map vertical motions from geodetic to geologic time scales. This in turn provides invaluable constraints to inform key, yet uncertain, parameters (e.g. rheology) of geodynamic models. Such models also contribute powerful insight into complex landscape evolution processes at interregional to continental scales. Here we report on a new (starting date April 2022) Research Training Group (RTG) 2698, with 10 individual dissertation projects and a Post-doc project, funded by the German Research

Foundation. An interdisciplinary approach of Geodynamics, Geodesy and Geology aims to answer questions related to how the interaction of exo- and endogenic forcing shapes a diverse array of earth processes from landscape evolution to the occurrence of earthquakes. The RTG uses a combined interpretation of interdisciplinary observations with different spatial and temporal sensitivity, in conjunction with physical models, to disentangle different uplift mechanisms, including the plume, plate and isostatic mode, based on their specific spatial and temporal patterns. We will give an overview on the key philosophy and main architecture of the RTG. Core components include an integrated geophysical process model, composed of an adjoint geodynamic model that accounts for seismic tomography and mineralogy, coupled with a landscape evolution model, with the lithosphere as a filter function, and targeted observations that include geodetic (geometric and gravimetry) data to reflect contemporary uplift processes combined with high precision, geological, magnetostratigraphic and geomorphologic data to reflect uplift processes and sedimentation rates on geological time scales. The modeling will be complemented by a thorough uncertainty analysis and an enhanced visualization of the key results.

GD-A-03

Exploring the upper mantle dynamics through Earth surface observations and plate motion changes

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Our understanding of plate tectonics and mantle convection has made significant progress in recent decades, both numerically and in the acquisition of geological observations. The motions of the lithosphere serves as a powerful lens into the dynamic of Earth interior, specifically to study the behavior of the asthenosphere. Among these observations, the record of plate motion changes stands out, as it enables the geographical identification of torque sources.

The analytical Poiseuille flow model applied to upper mantle flux in the asthenosphere offers a robust and testable prediction: Poiseuille flow induced plate motion changes should coincide with regional scale mantle convection induced elevation changes. Mantle plumes can generate such pressure driven flows, along with intraplate magmatism and induce buoyancy-driven uplift that leaves an imprint in the sedimentary record.

Here, I will present a synthesis of geological and geophysical observations, supported by analytical calculations, to illustrate that a significant number of plate motion changes can be attributed primarily to torques arising from plumes in the upper mantle.

GD-A-04

Geomechanical Insights from the KTB Stress State Model

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The Continental Deep Drilling Project (KTB) in Germany is one of the deepest research wells worldwide. Several ground-breaking scientific advancements have been achieved in the frame of this project. In particular, the understanding of the mechanics and evolution of continental crust as well as unique stress measurements were significantly advanced and made possible by the 4 and 9 km deep wells, respectively. Determination of stress orientations and magnitudes as well as their variation with depth are amongst further key observations. The observed interaction of the geomechanical parameters in conjunction with several fault zones intersected by the KTB wells allows to study the characteristic response of the stress state to changes in the rock properties.
Herein, we present for the first time a 3D geomechanical-numerical model of the KTB drill site. The model volume of approx. 20 x 20 x 12 km^3 is discretized with approx. 6 million elements and is refined along the well trajectory. It contains five relevant lithological units as well as three fault zones indicated by the seismic reflectors SE1, SE2, and SE4, respectively. The model is populated with the corresponding rock properties Young's modulus, Poisson ratio, and density for the lithological units. The fault zones are parametrized with accordingly weaker stiffness. The model is calibrated using displacement boundary conditions in a way that available stress magnitude data records from the KTB project are well represented in the model. This provides a continuous 3D stress field in the entire model volume around the KTB area.
Furthermore, the model allows to improve the general understanding of geomechanical parameters at crustal depth levels in two ways. 1) The model indicates the influence on the modelled stress state of variability in rock properties as a result of measurement errors and inherent variability. In particular, the large influence of the Young's modulus on the stress state is shown and provides an approximate guideline on the inherent uncertainties in the stress state that must be considered. 2) The parametrization of the fault zones is examined by comparison of the modelled principal stress component rotation with the borehole breakout orientations. The rotations depend on the material contrasts which in turn allows to estimate minimum and maximum contrasts between host rock and fault zone.

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GD-A-05

Estimating Geothermal Heat Flow in polar regions by coupling Solid Earth and ice temperature models

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Polar regions are only sparsely covered with heat flow determinations from boreholes, so one must rely on interpolation or indirect methods to derive a regional map of geothermal heat flow (GHF). Still, interpolation and indirect methods depend strongly on the available sparse boreholes, which can distort the resulting regional map.
For the ice-covered regions of Greenland and Antarctica, additional information is available from ice temperature profiles, and on a regional scale from remote sensing microwave radiometer data, e.g. from the SMOS satellite mission. From the microwave radiometer data, GHF is estimated with a Bayesian inversion, where, geothermal heat flow is used as a free parameter so that it provides a posterior distribution of the GHF needed to explain the ice temperature profiles.
Reconcile geophysical geothermal heat flow models with the ice temperature profiles can improve the GHF models. For this, we use stationary thermal modelling where we force the ice temperature and lithospheric temperature model to converge at the base of the ice. Using stochastic inversion, we estimate the thermal parameters in the lithosphere. The posterior distribution of the ice temperature retrieval is included as prior distribution to the inversion to constrain the GHF within the stationary thermal modelling. At the end, we estimate the highest likelihood for the GHF valid for both the ice temperature and Solid Earth models.

GD–Poster

Geodynamik / Tectonophysics

GD-P-01

Faults and the stress state – a complicated relationship

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The impact of faults on the stress field is observed at borehole scale and investigated with geomechanical models. However, a systematic generalisation of the feedback between fault kinematics and dynamics has not been investigated so far. We use two generic geomechanical models to investigate the impact of faults on the stress field on different spatial scales. We focus on two different aspects of faults and their influence on the magnitudes and orientations of the principal stress axes. We examine (1) the influence of faults on the stress field at distance of several hundred meters from the fault and considered it as the far-field and (2) the impact on the stress field of different rock properties in the damage zone compared to those of the host rock within a fault considered as the near-field. The impact of faults in the far-field is tested with different numerical representations of faults to account for the different material properties, fault orientations w.r.t. the stress field, fault sizes, and boundary conditions. It has been shown that the impact on the far-field is negligible the principal stress magnitudes and orientations. Only in extreme cases, changes in the remote stress field can be observed, but these not significant considering the general uncertainties in stress field observations. However, in the near-field significant stress variations are observed.
These are investigated in the second part of the study, which focusses on the fault zone itself. Particularly, the material contrast between the intact rock and the damage zone is regarded. This can be responsible for a dramatic change in the stress tensor observed as a rotation of the principal stress axes. In general, the larger the material contrast, the larger is the change in the stress field. Additional impact has the orientation of the fault w.r.t. the background stress field and the relative stress magnitudes, in particular the differential stress. A small angle between the fault and the maximum principal stress axis and a small differential stress promote stress changes.
The study indicates that the impact of faults on the stress field is mostly limited to the fault's near-field. However, the changes depend on the acting processes and material properties. The same is true for models used for investigation, where the implementation method and the mesh resolution can play an important role.

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GD-P-02

Ground-Penetrating radar investigation of the Marlborough Fault System, NZ

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The Marlborough Fault System (MFS), on the South Island of New Zealand, is a highly-active splay of faults that join the Alpine Fault with the Hikurangi subduction zone. The MFS consist of an anastomosing fault system with four major strike-slip faults (the Wairau, Awatere, Clarence and Hope Faults), with intermittent dip-slip faults that form bridges between the strike-slip faults. The last major rupture on this system was the 2016 Kaikōura Earthquake, which activated at least 20 faults in the MFS. In this ground-penetrating radar (GPR) study, we focused on two locations, one at the Awatere Fault and one at the Hope Fault.

At Site 1 on the Awatere Fault, we collected a sparse grid of 2D GPR profiles perpendicular and parallel to the fault, covering a tributary-junction fan of the Saxton River as it confluences with the Acheron River. In the crossing sections, the GPR data indicate (based on displaced reflectors and the geometry of small fault-related basins) that there had been at least two faulting events in this location. The GPR data identify a promising location for a trench study, in order to derive the timing of the youngest activity of the Awatere Fault in this area. In the GPR sections collected parallel to the fault, we could identify a number of abandoned paleo-channels that were laterally displaced by the fault. These displacements, in combination with age dating of sediments from the individual channels, could be used to derive a slip rate of the Awatere Fault, independently of the common terrace dating approach.

Site 2, at the Greenburn stream, is close to the Hope Fault. Here, we collected a detailed pseudo 3D survey with 0.5 m line spacing, covering an area of 20 x 50 m, that gives insight into a shallow basin-structure that is linked to the major fault. At least two reflectors can be mapped that are part of the basin-fill and are interpreted to reflect different subsidence events. The position of the basin above the main trace of the Hope fault implies that the different subsidence events could result from individual earthquakes, and thus could give us the youngest movement on the fault. C14 dating on a sample of the lower reflector sediment suggests the basin is younger than 500 years old.

GPR, in combination with trenching and sediment age dating, proves to be an effective tool to reveal details about the near-surface structure of fault zones and the timing of their activity.

GD-P-03

Seismic reprocessing revealing detailed depth images of detachment and backthrust reflections of the Variscan Eifel Fold-Thrust Belt, Germany

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This study presents novel reprocessed DEKORP87-1A seismic reflection data in conjunction with borehole information from the deep well RWTH-1 and new geological field observations.
The geological and structural architecture of the fold-thrust front of the Variscan orogen is important for applied studies, including geothermal subsurface exploration. To analyze the structure of the Variscan orogen in the Eifel area of central Germany, we utilized the long-range deep-reaching seismic-reflection line DEKORP87-1A, which was recorded in the late 1980s. The original interpretations of the time-migrated subsurface images suggested the presence of various shallow and deep-reaching faults related to the northern Variscan deformation front. Our seismic reprocessing enhanced the coherence of the subsurface image, allowing for detailed interpretations of individual reflections, including their size and dip angles. Fresnel-Volume migration unveiled additional significant structural features of the Eifel Fold-and-Thrust Belt. These include reflections of the Eupen and Malsbenden backthrusts, as well as distinct detachment reflections. The detachment is about 80 km long, and dips between 8 ° to 10 ° in southeastern direction over its entire length along line 1A. Reflection features associated with the Tertiary High Eifel Volcanic Field are present at depth beneath the southeastern end of the seismic line.
The reprocessed depth-migrated subsurface image of line DEKORP87-1A provides new constraints for interpreting the Paleozoic subsurface structures beneath the Eifel Mountains. This allows a re-evaluation of existing surface-subsurface models of the northern Variscan Eifel Fold-Thrust Belt.

GD-P-04

New insights into the orogenic structure along TRANSALP from reprocessing of controlled-source seismic data

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The TRANSALP project carried out around the Millenium provided unique geophysical sections across the orogenic structure in the Eastern Alps. Active and passive seismic investigations were conducted along a 300 km long profile between Munich and Venice. More recently, new geophysical experiments in the Central and Eastern Alps followed within the framework of the priority programme "Mountain Building Processes in Four Dimensions" (4D-MB) as part of the AlpArray mission. The general scope of this programme is to image the structure of the Alps from their surface down to lithospheric depth and to improve understanding of linked processes between surface and mantle beneath mountain belts.

In the Eastern Alps, the pre-existing geophysical transects along TRANSALP (around 12°E) and EASI (around 13.3°E) are often used as reference sections to compare and discuss new 3D and 4D models along these 2D high resolution profiles. Yet, there are remaining questions in the interpretation of these previous cross-sections. Of particular interest are crustal structures which can be used to test the hypothesized change of subduction polarity from S-directed subduction along TRANSALP towards N-directed subduction along the EASI profile,

more eastward. We reprocess the pre-existing seismic reflection data along TRANSALP with more recently developed methods that were not applied to this data set so far. The first approach is based on the extraction and usage of diffractions for subsurface seismic imaging. Application to the northernmost part of TRANSALP reveals a number of sub-vertical structures which match with the location of known faults and fracture systems both in the Molasse and the Northern Calcareous Alps. The second approach is based on coherency analysis of pre-stack data. For the subsequent depth migration we test a wide range of existing velocity models, both from previous work and new results from the 4D-MB project. Most prominent sub-vertical structures are imaged in the central part of the Tauern Window and around the Periadriatic fault system. The results are reconciled with surface geology and other geophysical studies, and will ultimately provide additional constraints for 3D and 4D geodynamic modeling.

SITZUNGSTHEMEN

GO – Mündliche Präsentation

Geophysik in der Öffentlichkeit und im Wandel der Zeit

GO-A-04

Eine (unerwartete) Plattform der Wissenschaftskommunikation

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Geophysikalische Forschungen bieten im Allgemeinen grundsätzliche Möglichkeiten der visuellen Aufbereitung und Simulation. Häufig kann für die Ergebnisse sogar ein starker Bezug zu akuten Ereignissen, sowie dem alltäglichen Leben hergestellt werden. Der nächste logische Schritt ist die verständliche Präsentation innerhalb und außerhalb des eigenen Fachbereichs.
Projektions-Planetarien bilden seit nunmehr 100 Jahren eine etablierte Plattform der Wissenschaftkommunikation. Anfangs noch auf die Vermittlung erdgebundener astronomischer Sachverhalte beschränkt, ist spätestens seit Einführung digitaler Darstellungstechniken das Potential für ein breites Themenspektrum gesetzt. Heutige Besucher fliegen virtuell durch Galaxien, begegnen hautnah Dinosauriern oder begeben sich auf eine Reise ins Innere des menschlichen Körpers.
Jenseits der öffentlichen Wahrnehmung als verstaubte Kultureinrichtung, verstehen sich moderne Planetarien als wesentliche außerschulische Lernorte, immersiver als es ein Klassenzimmer oder Hörsaal je sein könnte. Ein erheblicher Teil der angebotenen Programme sind exklusiv für Schulklassen und die Erwachsenenbildung konzipiert. Manche Institutionen werden sogar von der Industrie als Simulationslabore genutzt. So besteht natürlich auch der Anspruch, aktuelle Forschungsergebnisse aufzubereiten und für unterschiedliche Interessengruppen erlebbar zu machen. Nicht zuletzt dadurch entsteht eine Förderungskultur und Interessenbildung für MINT-Berufe.

GO – Poster

Geophysik in der Öffentlichkeit und im Wandel der Zeit

GO-P-01

Ein Exponat zur Veranschaulichung von seismischen Wellen für die Öffentlichkeitsarbeit

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Die Vorführung von seismischen Experimenten in Innenräumen für die Öffentlichkeitsarbeit ist oftmals nicht direkt möglich. Idealisierungen oder Miniaturisierungen sind in solchen Fällen erforderlich. Daher haben wir ein Exponat zur Veranschaulichung von seismischen Wellen in Tischgröße konzipiert. Mit unterschiedlich schweren und großen Fallgewichten, die von einem Gestell aus verschiedenen Höhen fallen gelassen werden, können seismische Wellen erzeugt und mit einem RaspberryShake aufgezeichnet werden. Es wurden verschiedene Materialien (Sand, Schaumstoff und Styropor) verwendet, um deren Einfluss auf die Wellenform zu illustrieren. Für die Aufzeichnung und Visualisierung wurde eine Webapplikation entwickelt, welche die Daten des RaspberryShakes kontinuierlich anzeigte. Dazu wurde über einen STA-LTA-Trigger eine Aufzeichnungsmöglichkeit implementiert, so dass verschiedene Seismogramme verglichen werden konnten. Darüber hinaus wurden Gamification-Elemente eingebaut. So konnten Teilnehmer versuchen vorab aufgezeichnete Seismogramme zu reproduzieren. Außerdem konnten, ähnlich wie bei der Jahrmarktattraktion „Hau den Lukas", Signale einer bestimmten Stärke erzeugt werden. Hier sollte dann aber nicht eine möglichst starke Amplitude erzeugt werden, sondern eine vorgegebene Amplitude möglichst genau getroffen werden. Ergänzend wurden noch didaktisch aufbereitete Materialien zur Erklärung von aktiver Seismik und der Untergrunderkundung geliefert. Das Exponat wurde bereits erfolgreich auf der RWTH-Wissenschaftsnacht „5 vor 12" im Herbst 2023 eingesetzt und wird stetig weiterentwickelt.

GO-P-02

The Geophysical Instrument Pool Potsdam (GIPP)

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Geophysical field observations are making an essential contribution to the research of the Earth structure and the ongoing processes since a long time. To support temporary field experiments - in addition to permanent monitoring networks and observatories - the "Geophysical Instrument Pool Potsdam" (GIPP) at the "Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences" provides mobile seismic and magnetotelluric recorders and sensors. This research infrastructure facility is open to all academic applicants (research institutes, universities, etc.; national and international). Since its foundation roughly 30 years ago, the GIPP supported more than 460 geoscientific projects (each year approx. 20 to 40). The land stations of the "German Pool for Amphibious Seismology" (DEPAS) are also managed at the GIPP. The instruments are provided free of charge following a transparent application and evaluation process (www.gfz-potsdam.de/gipp). The applications are evaluated by an external steering committee. The instruments are used in experiments targeting a wide range of topics including Earth structure, geodynamics, earthquakes,

exploration for geo-resources, volcano monitoring, soil investigations and many more. Over the years the instrumentation changed due to new developments in technology, methods and scientific topics. In any case, their number steadily increased. Today the seismological part of the GIPP consists of > 1000 digital recorders, > 250 broadband sensors, numerous geophones and the necessary accessories. We also provide instruments for controlled source experiments (autonomous nodes and cable based system). Available for magnetotelluric experiments are > 50 real-time data-loggers, >150 induction coils, >500 electrodes as well as a large number of cables and accessories. All in all, this makes it the largest geophysical instrument facility in Europe. The devices are in high demand and overbooking regularly occurs. A major part of our work is related to the development of innovative hardware (i.e. digital recorders) and software. In addition we operate a data repository to archive the collected data. The GIPP has also been working on data management projects in recent years, particularly within the framework of EPOS and ORFEUS. We are currently active in networking European device pools as part of ORFEUS.

SITZUNGSTHEMEN

GT – Mündliche Präsentation

Geothermie / Radiometrie

GT-A-01

Identification of dominant heat transport mechanisms within the Thuringian Basin through terrestrial heat flow data analysis

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Terrestrial heat flow is a measure of thermal energy transport from the earth's interior to the earth's surface and so mirrors the regional and temporal temperature distribution in the subsurface. Thus, heat flow data are essential for the characterization of geodynamic processes and tectonic structures. In this study, we estimate the averaged surface heat flow density in the Thuringian Basin, with the aim of identifying the contribution of conduction and advection to heat transport. For this purpose, numerous thermal data sets are compiled, including thermal conductivities of different stratigraphic units of the Thuringian Basin and borehole temperature measurements. Following a comprehensive correction of temperature data, heat flow maps for various depth intervals and the surface are elaborated. From this, an average surface heat flow density of 88 mW/m^2 for the Thuringian Basin is obtained. Small-scale positive anomalies in the order of > 100 mW/m^2 are identified in the area of the Schlotheimer Graben and its extension, the northwestern part of the Eichenberg-Gotha-Saalfeld fault zone and Bad Langensalza. The large-scale separation of the Thuringian Basin into a "cold" eastern and a "warmer" western part can be attributed to the depth of the lithosphere-asthenosphere boundary (LAB) and thus conduction most probably controls the large-scale heat flow distribution. Differently, the small-scale anomalies cannot be explained solely by heat transfer via conduction. The application of the Bullard and Interval methods suggests that heat flow distribution is probably influenced by fluid movements in parts of the Thuringian Basin, e.g. fault zones.

GT-A-02

The duration of injection protocol likely controls the maximum magnitude of induced earthquakes

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High-pressure fluid injection into subsurface is often carried out to enhance the permeability of deep geothermal reservoirs. The operation sometimes triggers induced earthquakes that may be as large as natural earthquakes. Novel injection protocols such as cyclic injection schemes have been proposed to mitigate the risk of inducing larger events. Currently, the of impact cyclic injection schemes on the maximum magnitude M_{max} is not fully understood. Here, we adopt the working hypothesis that the pore-pressure diffusion is the dominant triggering mechanism of induced events and the maximum induced earthquake scales with the pressure-perturbed fault size. Hence, we developed a first-order hydrogeological model and simulated the fluid injection into a porous rock with an embedded large-scale fault zone. Different injection scenarios were implemented, and the pressure-perturbed fault size was computed and translated to the maximum induced earthquake magnitude. The numerical models showed that the duration of the injection protocol plays an important role and likely controls the occurrence of larger-magnitude events. Our numerical models can provide significant insight into the effectiveness of mitigation strategies during the engineering of Enhanced Geothermal Systems and underground storage reservoirs.

SITZUNGSTHEMEN

GT – Poster

Geothermie / Radiometrie

GT-P-01

Calculating radiogenic heat production from geochemical data for Greenland

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Abstract to be submitted to the DGG 2024 in *GT Geothermie / Radiometrie*

Calculating radiogenic heat production from geochemical data for Greenland

Maja Zimmer, Agnes Wansing, Björn Heincke, Jörg Ebbing

Most of Greenland is covered by ice and therefore the surface geology is mainly known in the ice-free coastal regions. Still, the tectonic history of Greenland is expected to be imprinted in the geological domains under the ice as well. These different geological domains are likely associated with lateral variable thermal parameters which influence the thermal state of the bedrock and with this may affect the evolution of the ice sheet as well.
So far, no Greenland specific petrophysical database is yet published although samples from the coastal regions are available at different institutions. Here, we utilize a new compilation of petrophysical measurements of density, susceptibility and thermal conductivity for c. 150 samples over Greenland. The samples were selected from the storage at the Geological Survey of Denmark and Greenland (GEUS) and analysed at the Geological Survey of Finland (GTK).
In addition, we used an available geochemical database to calculate the radiogenic heat production based on empirical equations found in literature. Hereby, the density and the

concentration of heat producing elements are used to estimate radiogenic heat production. To demonstrate the implication of a lateral variable radiogenic heat production (and thermal conductivity) of sub-glacial heat flow, we subsequently calculated the geothermal heat flow from crustal sources. Our results indicate possible significant variations in sub-glacial heat flow related to the crustal setting and underline the need to use petrophysical data to support geophysical models of sub-glacial parameters.

GT-P-02

Hydraulic analysis of the GEOREAL fluid injection experiment at the KTB pilot hole, Germany

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During the period 6-15 November 2023, a total of 600 m^3 of water was injected into the 4 km deep pilot hole of the Kontinentales Tief-Bohrprogramm (KTB) in Windischeschenbach, Germany, as part of the GEOREAL hydraulic stimulation experiment. This volume was injected through a stuck packer in the cased borehole pressurizing the open borehole section at the depth interval of 3.85 - 4 km. Flow rates were variable ranging from 10 l/min to 220 l/min. Pressure was monitored at the well head of the pilot borehole and also at 200 m lateral distance in the nearby 9 km deep KTB main borehole. Pressure data is analyzed and related to recordings from a year-long injection experiment into the same formation performed in 2004/5. The hydraulic parameters show similar values as previously obtained when the influence of the packer on the injection was low. The GEOREAL experiment had to be stopped prematurely due to a leak in the casing cement. No microseismic events were detected during the injection using a combined surface seismic and shallow borehole (150m-deep) network of seismometers as well as a 10-level geophone chain at 2000 m depth in the KTB main hole. Results of the analysis of hydraulic parameters from the GEOREAL and previous injection tests are discussed and related to known characteristics of the reservoir at 4 km depth in the light of potential heat extraction in the future. This is relevant since conditions at the KTB deep crustal lab are representative for large parts of Germany.

GT-P-03

Das Projekt "Restless" – Analyse des Einflusses der Lithologie auf das Risiko induzierter Seismizität in tiefengeothermischen Reservoirs

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Eines der entscheidenden Kriterien für die öffentliche Akzeptanz der Energiegewinnung aus tiefer Geothermie ist die Vermeidung induzierter Seismizität. In diesem Kontext werden im vom Bundesministerium für Wirtschaft und Klimaschutz geförderten Projekt „Restless" mögliche Einflüsse der Reservoirlithologie auf das Risiko induzierter Seismizität in der tiefen Geothermie analysiert und möglichst auch quantifiziert. Die Arbeiten konzentrieren sich dabei auf Reservoire, deren Permeabilität von Klüften dominiert wird sowie auf Differenzen zwischen kristallinem Grundgebirge und mesozoischen Sedimenten wobei der regionale

Fokus auf dem Oberrheingraben liegt. Das Projekt kombiniert dazu Gelände-, Labor- und numerische Methoden, insbesondere (1) quantitative Untersuchung der Struktur und Kinematik von Störungen in den relevanten Reservoirgesteinen basierend auf Aufschlussstudien sowie geophysikalischen und hydraulischen Bohrlochdaten, (2) palinspastische Rekonstruktion tektonisch deformierter Strukturen um den Anteil der Deformation abseits der Störungen zu quantifizieren, (3) Laboruntersuchungen zur Charakterisierung der geomechanischen Eigenschaften der Reservoirgesteine, insbesondere der Reibungseigenschaften, (4) numerische Simulation der Spannungsentwicklung und potentieller Störungsreaktivierung beim Betrieb einer geothermischen Dublette auf mehreren Skalen und (5) numerische Simulationen induzierter Seismizität mit Hilfe von thermo-hydro-mechanischen Modellen und Berechnungen der resultierenden Bodenbewegungen zur Abschätzung des Risikos induzierter Seismizität. Der numerische Workflow wird, neben generischen Modellen zur Gewinnung eines verbesserten Prozessverständnisses, auch auf einen Teststandort im Oberrheingraben angewendet. Auf Grund der Bedeutung der öffentlichen Akzeptanz für die weitere Nutzung der tiefen Geothermie werden Information und Beteiligung der allgemeinen Öffentlichkeit ebenso Teil des Projektes sein wie eine möglichst breite Veröffentlichung der Projektergebnisse. Zum Abschluss des Projekts wird erwartet, dass die kombinierten Ergebnisse der verschiedenen Untersuchungen zu einem besseren Verständnis beitragen, welche Reservoirlithologien und Strukturen geeignete Ziele für die Gewinnung geothermischer Energie bei minimalem seismischem Risiko sind.

SITZUNGSTHEMEN

KI – Mündliche Präsentation

KI-Verfahren in der Geophysik

KI-A-01

A machine-learning approach for detecting P- and S-arrivals in continuous DAS data

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The usage of distributed acoustic sensing (DAS) for seismological and microseismic applications has increased in the past decade. For DAS, a fiber-optic cable is placed on the ground or cemented into a borehole that can measure the strain or strain-rate in the surrounding rock along the cable. In microseismic applications, DAS might replace the usage of borehole geophones in the future, since cables are rather cheap and more robust against borehole conditions (e.g. high temperatures, etc.). However, the signal-to-noise ratio of DAS registrations is currently worse than borehole geophones. Furthermore, standard processing workflows as they exist for geophone data do not exist for DAS for several reasons. We present a machine-learning approach for picking P- and S-arrivals in continuous DAS data using a convolutional neural network (CNN). We apply this idea to microseismic data registered at the Utah FORGE enhanced geothermal system (EGS) test site. The CNN is trained on DAS
registrations and arrival picks from geophones installed in the same well and synchronized in time. Using arrival picks from geophones, we can assign P- and S-arrivals to the DAS recordings although they might be invisible. Incorporating also synthetic data during training significantly improves the network performance. After training (using only three

hours of data including around 150 microseismic events), the CNN can accurately reproduce the training picks. It can even reliably pick and distinguish arrivals of a stimulation that took place 3 years after the training in a different borehole. This shows the robustness of the approach against changing noise conditions and different P- and S-moveouts. The data processing using the CNN is quick (tens of seconds for one hour of recorded data). Thus, such a network combined with a permanently installed fiber can be used for real-time long-term observation.
With the CNN-picks automatic, real-time event localization and potentially also magnitude estimation is possible. The approach can be adapted for any case study where long-term seismic monitoring is required (CO_2 sequestration, EGS, etc.).

KI-A-02

Feasibility of Deep Learning in Shear Wave Splitting Analysis using Synthetic-Data Training and Waveform Deconvolution

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Teleseismic shear-wave splitting analyses are often performed by reversing the splitting process through the application of frequency- or time-domain operations aimed at minimizing the transverse-component energy of waveforms. These operations yield two splitting parameters, the fast-axis orientation and the delay time. In this study, we investigate the applicability of a baseline recurrent neural network, SWSNet, for determining the splitting parameters from pre-selected waveform windows. Due to the scarcity of sufficiently labelled real waveform data, we generate our own synthetic dataset to train the model. The model is capable of determining the two parameters with a root mean squared error (RMSE) of 9.7° and 0.14 s on noisy synthetic test data. Splitting parameters obtained from synthetic data generated for models with two anisotropic layers exhibit the expected characteristic variation as functions of backazimuth. The application to real data involves a deconvolution step to homogenize the waveforms. When applied to data from the USArray dataset, the results exhibit similar patterns to those found in previous studies with mean absolute differences of 9.6° and 0.16 s in the calculation of the fast-axis orientation and the delay time, respectively.

KI-A-03

Deep learning-based Causal Inference in Tectonic-Climate Time series

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At the Moxa Geodynamic Observatory (MGO), highly sensitive laser strainmeters are employed to capture the subtle movements of the Earth's upper crust. Due to the relatively low mountain overburden where the strainmeters are installed within the observatory gallery, recorded time series are significantly affected by local meteorological phenomena. To comprehend the nonlinear impact of meteorological variables on strain measurements in this dynamic environment, there is a demand for sophisticated techniques capable of learning nonlinear relationships and revealing causal connections within the non-stationary multivariate tectonic-climate time series.

This study introduces a novel causal discovery method rooted in deep learning, referred to as CDMI (Causal Discovery using Model Invariance), specifically designed to model intricate interactions within a system of multivariate nonlinear time series. The CDMI employs model invariance testing via interventions to deduce cause-and-effect relationships among variables of the multivariate time series. Addressing the non-stationary nature of the tectonic-climate time series recorded at MGO, we further propose a regime identification approach applied before causal analysis. This approach generates segments of time series with locally consistent statistical properties, allowing for a more accurate examination of causal relationships underlying the dynamic interplay in tectonic-climate time series.

Our investigation focuses on the hypothesized influence of meteorological variables on strainmeter measurements, providing valuable insights into tectonic-climate causal interactions. Our findings reveal that variations in ground water levels (GWLs) resulting from precipitation events, in conjunction with temperature and barometric pressure, consistently exhibit a causal impact on strainmeter measurements in the north-south as well as east-west direction across various regimes, aligning with our initial hypotheses. The evolving causal relationships observed over identified regimes underscore the dynamic behavior inherent in the nonlinear time series recorded at MGO, emphasizing the significance of prolonged time series in strain data observation. In future work, we intend to expand our method to assess the collective impact of climatic variables on strainmeter measurements over extended time periods.

SITZUNGSTHEMEN

KI – Poster

KI-Verfahren in der Geophysik

KI-P-01

When linear inversion fails: neural-network optimization for sparse-ray travel-time tomography of a volcanicedifice

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In this study, we present an artificial neural network (ANN)-based approach for travel-time tomography of a volcanic edifice. We employ ray tracing to simulate the propagation of seismic waves through the heterogeneous medium of a volcanic edifice, and an inverse modeling algorithm that uses an ANN to estimate the velocity structure from the "observed" travel-time data. The performance of the approach is evaluated through a 2-dimensional numerical study that simulates i) an active source seismic experiment with few (explosive) sources placed on one side of the edifice and a dense line of receivers placed on the other side, and ii) earthquakes located inside the edifice and receivers placed on both sides of the edifice. The results are compared with those obtained from conventional damped linear inversion, demonstrating that the ANN-based approach outperforms the classical approach, particularly in situations with sparse ray coverage. Our study emphasizes the advantages of employing a relatively simple ANN architecture in conjunction with second-order optimizers to minimize the loss function. The ANN-based approach is computationally efficient and capable of providing high-resolution velocity images of anomalous structures within the edifice, making it a potentially valuable tool for the detection of low velocity anomalies related to magmatic intrusions or mush.

KI-P-02

Comparing Different Neural Network Approaches Applied to DC Resistivity Problems

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In recent years, Machine Learning approaches have found applications in a variety of fields. For typical applications, large amounts of data are used to train neural networks to perform a variety of tasks to a satisfactory accuracy.
Particularly, Convolutional Neural Networks have shown promising results.
However, for applications in physics, the classic, data-informed way of training neural networks can pose a problem.
Even given large and diverse data sets, geophysical forward or inverse problems solved using neural networks do not yield solutions true to the underlying physics.
This means that although conventional approaches are easy to implement and train, they often cannot be generalized well enough for physical applications.
Recently, so-called Physics Informed Neural Networks have been proposed that attempt to incorporate the underlying partial differential equations into the training process.
This approach allows for more accurate reflection of physics in machine learning approaches, but greatly complicates training. Moreover, training results cannot be used to solve problems in different settings.
A synthesis of both approaches lies in the use of recently developed Physics Informed Neural Operators, which aim to combine the physics information of Physics Informed Neural Networks with the re-usability and architectures of standard approaches.
We present different approaches to solve DC resistivity Problems using neural networks of different architecture and discuss their respective advantages and drawbacks.

MI – Poster

Modellierung / Imaging

MI-P-01

WaterSim – Modellierung der instationären hydrogeologischen Interaktion zwischen Oberflächengewässern und Grundwasserleitern am Beispiel des Saaletals

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Die Entwicklung nachhaltiger Lösungsansätze zur Sicherstellung der Wasserverfügbarkeit und -qualität ist eine der wichtigsten Aufgaben unserer heutigen Gesellschaft. Der von der Friedrich-Schiller-Universität Jena gemeinsam mit dem Fraunhofer-Institut für Keramische Technologien und Systeme IKTS und der Ernst-Abbe-Hochschule Jena initiierte "Thüringer Wasser-Innovationscluster" (ThWIC) will sich dieser Augabe als Teil der Initiative Clusters4Future des Bundesministeriums für Bildung und Forschung (BMBF) widmen und Lösungen für einen nachhaltigen Umgang mit Wasser entwickeln.
Auf diesem Poster möchten wir das Teilprojekt WaterSim vorstellen, das das grundlegende Ziel verfolgt, den Prozess des natürlichen Wassertransports im geologischen Untergrund unterschiedlicher Regionen zu visualisieren und die Interaktion zwischen Grundwasser und Oberflächengewässern zu erfassen. Zu diesem Zweck werden umfangreiche numerische 4D-Simulationsrechnungen des gekoppelten Fluid- und Wärmetransports durchgeführt, welche die Möglichkeit bieten, Volumina, Fluidtransportraten und Verweildauern tiefer Grundwässer abzuschätzen. Als erstes Beispielobjekt dient das Saaletal, da in diesen geologische Formationen angetroffen werden, wie sie für große Teile Deutschlands und Mitteleuropas typisch sind.
Neben der Modellierung aktueller und zukünftiger Szenarios nimmt zudem die Erstellung einer petrophysikalischen Datenbank einen wichtigen Stellenwert ein. Durch die Nutzung dieser Daten als Randbedingungen erhalten die Simulationen einen prädiktiven Charakter, der es in den späteren Projektphasen erlauben wird, gezielt Einflüsse des globalen Wandels wie Wasserknappheit oder die Folgen extremer Wettersituationen zu visualisieren und somit die Basis für mögliche Maßnahmen der Mitigation zu schaffen. Durch die Kopplung des erarbeiteten thermohydraulischen Untergrundmodells an das Wasser-Systemmodell des Teilprojektes WaterLab trägt WaterSim dazu bei, das Verständnis von Bürgerinnen und Bürgern für komplexe Wasserkreisläufe zu erweitern.

MI-P-02

A hybrid joint inversion approach for electrical resistivity tomography and sparse transient electromagnetic data

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Different measurement methods in subsurface geophysical prospecting offer specific advantages and disadvantages. For example, they are sensitive to different physical parameters, such as the electrical resistivity or the density. But also methods that resolve the

same physical parameter, may have different resolution characteristics, due to for example their source-receiver configurations. Similarly, the investigation depths can differ. To provide an improved subsurface image, measurements from different methods can be efficiently combined in a joint inversion process.
Here we present a novel joint inversion development based on the framework pyGIMLi. We combine the loop source Transient Electromagnetic Method (TEM) and Electrical Resistivity Imaging (ERT) in hybrid joint inversion scheme. ERT is commonly collected in a 2D manner and has a superior lateral resolution, whereas TEM provides a much larger depth of investigation as well as has a superior layer resolution, particularly for conductors. However, TEM is usually collected comparably sparse and the multi-dimensional inversion is extremely challenging. In the past, various 1D TEM and Vertical Electrical Sounding joint inversion techniques were presented. For weak 2D problems, more sophisticated quasi 2D approaches using a for example laterally constrained inversion (LCI) can be efficiently applied. However, until now there is no development that combines 2D ERT with 1D TEM in an inversion scheme.
Our developed 2D-1D hybrid joint inversion approach is capable of handling 2D ERT data and integrating TEM soundings along a profile line, using a fast 1D TEM forward operator. The model is parameterized in 2D using quadrilaterals, and for TEM model columns are extracted below each sounding. A very sparse Jacobian matrix is constructed and combined with the full 2D ERT Jacobian. The cost-function is minimized incorporating both data terms plus a 2D smoothness constraining functional. Systematic synthetic modeling studies are carried out to evaluate the performance and assure an optimal model reconstruction. Further we examine to which extent this approach is limited when applied highly 2D affected TEM data. Subsequently the algorithm shall be applied to ERT and TEM measurements on Svalbard, Norway to detect permafrost and so-called ice pingos.

MI-P-03

Kooperative Inversion mit minimaler Entropie und Anwendung auf Geoelektrik-, Seismik- und Magnetik-Daten

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Die Interpretation unabhängiger geophysikalischer Datensätze kann aufgrund des Mehrdeutigkeitsproblems eine Herausforderung darstellen. Daher wurden Inversionstechniken entwickelt, die verschiedene Datensätze zusammen invertieren, um weniger mehrdeutige multiphysikalische Bilder des Untergrunds zu erzeugen. Jüngst wurde ein neuer kooperativer Inversionsansatz vorgeschlagen, der minimale Entropiebeschränkungen verwendet. Das Hauptmerkmal dieses Ansatzes ist, dass er in der Lage ist, schärfere Grenzen innerhalb des Modells zu erzeugen. Wir haben diesen Ansatz in einem Open-Source-Software-Framework implementiert und systematisch seine Fähigkeiten und Anwendbarkeit auf Geoelektrik (ERT), Refraktionsseismik (SRT) und Magnetik untersucht.

Zunächst führten wir eine Studie mit synthetischen 2D ERT- und SRT-Daten durch, um den Ansatz zu demonstrieren und den Einfluss der zu kalibrierenden Inversionsparameter zu untersuchen. Die Ergebnisse zeigen, dass die Verwendung des JME-Stabilisators (Joint Minimum Entropy) separaten, konventionellen glättungsbeschränkten Inversionen überlegen ist und verbesserte Bilder liefert.

Als Nächstes haben wir die Methode mit 3D ERT- und Magnetfelddaten vom Rockeskyller Kopf, Westeifel, verwendet. Die unabhängige Inversion der Magnetfelddaten deutete bereits auf einen unterirdische vulkanische Diatrem hin, aber die gemeinsame Inversion mit JME bestätigte nicht nur die erwartete Struktur, sondern lieferte auch verbesserte Details im Abbild. Die multiphysikalischen Bilder beider Methoden sind in vielen Regionen des Modells konsistent, da sie ähnliche Grenzen erzeugen. Aufgrund der Empfindlichkeit der ERT-Messungen gegenüber den hydrogeologischen Bedingungen im Untergrund sind einige Strukturen nur in den ERT-Daten sichtbar. Diese Merkmale scheinen sich im Modell der magnetischen Suszeptibilität nicht durchzusetzen, was einen weiteren Vorteil und die Flexibilität des Ansatzes unterstreicht.

Die Ergebnisse sowohl der synthetischen als auch der Felddaten lassen jedoch darauf schließen, dass vor der gemeinsamen Inversion eine sorgfältige Parameterprüfung erforderlich ist, um ein geeignetes Parameter- und Referenzmodell zu erhalten. Unsere Arbeit zeigt, dass die kooperative Inversion mit minimaler Entropie ein vielversprechendes Werkzeug für die geophysikalische Bildgebung ist, vorausgesetzt, dass die richtigen Einstellungen gewählt werden, und sie identifiziert auch einige Ziele für die zukünftige Forschung, um den Ansatz zu verbessern.

MI-P-04

Characterization of glacial sediments by seismic high-resolution crosshole SV-FWI

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By excavating deep valleys and refilling them with sediments, glaciers shaped the Alps during the Quaternary. An example is the Tannwald Basin (ICDP site 5068_1), which was formed by the Rhine Glacier in several glacial cycles. Hence, these overdeepened structures provide information about climate variations and offer an archive for understanding landscape evolution.
We study these glacial sediments in terms of their small-scale structure and deposition by means of seismic crosshole experiments, where we acquired P- and S-wave data using high-frequency borehole sources. The P-wave excited by a sparker source was recorded by a 24-station hydrophone array. Whereas, the horizontally and vertically polarized S-waves were recorded by an 8-station 3C geophone string.
Due to the complexity of the S-wave data, we run an elastic mono-parameter full-waveform inversion (FWI) to avoid erroneous S-wave picks. In preprocessing, we rotate the data into a ray-based coordinate system, where the SV- and the SH-wave dominate the vertical and transverse horizontal components, respectively. In an FWI of the vertical SV-component, we apply the global correlation norm and precondition the gradient to ensure proper and fast convergence of the inversion. Furthermore, we adopt the multistage approach in order to handle the non-linearity of the problem. At higher frequency stages, we apply an anisotropic Gaussian filter to the gradients depending on the S-wave wavelength to increase the vertical resolution of the S-wave velocity model to below 1 m. This significantly improves the resolution compared to surface seismic and traveltime tomography methods. Thus, our approach overcomes the scaling problem between traditional surface seismic imaging and borehole methods. Comparing the SV-wave velocity model with the lithology of the cored drilling reveals an extraordinary correlation.

Future research will treat the SH-dataset with the same approach. If we find structural similarities with a systematic difference in the S-wave velocities, we will interpret this as evidence for seismic anisotropy. This phenomenon will then have to be characterized and quantified in order to infer the sedimentation processes that will help us to understand the evolution of the Alpine landscape. In addition, we will use FWI to derive a more comprehensive, high-resolution image of the subsurface at the drill site from the P-wave data.

MI-P-05

Testing the benefit of eikonal tomography for ambient noise recordings at a dense array in a complex 3D basin structure

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Ambient noise tomography is nowadays a staple of geophysical research. However, this term encompasses a large number of different techniques for measuring the velocity (phase or group) of the surface waves and for inverting velocity measurements to generate tomographic maps, each with their own theoretical assumptions and limitations. One common way to perform the tomographic inversion is by solving an equivalent regularized inverse problem. While regularization can help stabilize the results, a trade-off usually exists between the different regularization parameters, which can affect the quality or reduce the resolution of the resulting maps. Moreover, some theoretical assumptions about the trajectory of the surface waves between virtual sources and receivers are necessary (e.g., straight or bent rays), as well as about the sensitivity kernels (e.g., "thin" rays). In contrast, the so-called eikonal tomography involves neither regularization, nor assumptions about the propagation of the surface waves. It employs the traveltimes measured from cross-correlations to build a spatially varying traveltime field for each station, and the local phase slowness is computed from the average of the magnitude of the gradient of these traveltime fields, using the eikonal equation. The downside of the eikonal approach is that it requires a dense array in order to provide robust and meaningful results.

In this work, we compare the performance of the eikonal approach with a regularized inverse approach using data from a dense three-component node array deployed by the DARE project in southern France. This dataset was acquired in a heavily industrialized area in the Rhône river valley, situated above a deeply incised, sediment-filled Messinian erosional canyon. The extreme subsurface topography, the existence of strong lateral velocity contrasts and the complex ambient noise wavefield (i.e., both higher mode propagation and non-uniformly distributed sources of ambient noise have been observed) makes this dataset an interesting target for comparing the performance of both approaches.

MI-P-06

The potential of high-resolution X-ray µCT imaging to characterise natural sediments

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Natural sediments (and rocks) are characterised by a wide range in composition, textures and structures. Even basic properties, such as porosity, may strongly vary throughout a sedimentary sequence and cause significant differences in the sediments' behaviour. For many years, most sediment characterisation relied on laboratory experiments that yield directly or indirectly required sediment properties and process interpretation. Recent studies, however, suggest that sedimentary structures may be divers on much smaller scales. Such small-scale variations are difficult to resolve with standard methods that are usually conducted on relatively large (several centimetres) samples. Imaging techniques such as Scanning Electron Microscopy may resolve this issue, however, the 2D nature of such measurements may in turn cause significant errors in 3D structural reconstructions and interpretations. The investigation of small-scale sedimentary structures, in 3D, therefore, requires new analytical methods. Here, we test and discuss the potential of high-resolution X-ray Computed Tomography (µCT) to investigate 3D sediment structures. In particular, we ask can µCT provide information that is currently missing from standard analytical methods?
We present novel high-resolution µCT data of marine sediments. µCT is used to visualise, and qualitatively and quantitatively investigate structural differences, in particular porosity and pore space variability, between sediment samples taken from (1) a sandy layer and (2) a silty-clay unit. Our results show clear compositional and structural differences between the two layers, as well as between individual samples. These differences can be attributed partly to different sediment types, i.e. coarse- versus fine-grained sediments, but also reveal a dependency on the sedimentation regime. We find that pore space distribution is highly spatially variable and works on a sub-millimetre scale. Such high variability may be masked by standard bulk porosity measurements, which require larger sediment samples and only provide information averaged over the entire sample. The identification of small-scale changes in pore space, however, may be crucial to understand e.g. fluid flow or the storage capacity of sediments. Our results, therefore, demonstrate the huge potential of µCT to investigate the internal structure of natural sediments, obtaining information that is not resolved or lost in data acquired through other analytical methods.

MG – Poster

Marine Geophysik

MG-P-01

P- and S-wave seismic velocity structure of the 25 °S OCC north of the Rodriguez Triple Junction at the Central Indian Ridge extracted from ocean bottom seismometer

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Three tectonic plates meet at the Rodriguez Triple Junction in the Central Indian Ocean. The plates are separated by the Central Indian Ridge (CIR), the South-East Indian Ridge (SEIR) and the South-West Indian ridge (SWIR), which all show highly different spreading behaviours. While the northernmost segment of the SEIR is magmatically robust, the eastern tip of the SWIR is highly amagmatic. The CIR appears to oscillate between opening mechanisms, associated either with magmatic or magma-starved spreading processes, which can be observed over a very confined stretch of crust. Even though the area has been studied thoroughly, using a variation of geophysical and geological methods in the past decades, seismic images of the region were missing. From November 2023 to January 2024, RV Sonne (SO301 - SCIROCCO) set out for a seismic reflection and refraction survey to fill this gap and to provide a database for a better understanding of the tectonic setting and evolution of the area. A special focus was put on studying the structure and extent of the Oceanic Core Complex (OCC) at 25 °S.
Here we present preliminary results of an east-west trending 150 km long profile crossing the OCC and the CIR. Along the profile, 33 ocean bottom seismometers were deployed with a spacing of 4-5 km that grew denser over the OCC. The shot spacing was between 50-110 m. Clear crustal refracted P- and S-phases were observed to offsets of up to 40 km in the shot sections and mantle reflections, as well as Pn-phases could be identified sporadically. First results of travel time tomographies, which were executed separately for P- and S-waves, and used for the calculation of a Vp/Vs-ratio section indicate a strongly variable crustal construction. Highly fractured areas seem to interchange with highly hydrated areas within short distances. Correlations of the new bathymetric data to the seismic images and the integration of the new gravimetric and magnetic data will sharpen the geophysical image and its tectonic interpretation along the profile.

MP – Poster

Erdmagnetismus / Magnetfeld / Paleomagnetik

MP-P-01

Estimating the depth of lithospheric magnetization from *L2L1* sparse inversion model of EMAG2.v3 data.

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The thermal state of the crust can be revealed from the magnetic data because the magnetic properties of ferromagnetic minerals responsible for crustal rock magnetization are strongly dependent on temperature. A widely used approach to doing this is by power spectrum analysis and thermal modelling. However, power spectral analysis relies on assumptions about the magnetization distribution and the outcome depends on the window size and selected wavelength range. Here, we propose to infer the depth of magnetization from 3D inversion models. We employ a dipole distribution to approximately predict the surface magnetic field and use an *L2L1* sparse inversion scheme to estimate a compromised smooth-sparse magnetization distribution. The model represents a trade-off between an overly sparse L1 regularized model estimate and a smooth L2 estimate that is smeared and sometimes difficult to interpret geologically. We realised that, in addition to reflecting 3D lithospheric magnetization, the model carries information concerning the temperature beyond which magnetization ceases to exist. The non-zero component of the sparse model corresponds to the susceptibility distribution that explains the observed EMAG2.v3 data and can be related to lithological and other geological interpretations, while the deepest non-zero sparse coefficients appear to define the Curie temperature boundary. We show the results from Namibia and compare our estimates to independent models, and the proposed approach is a possibility.

OG – Mündliche Präsentation

Oberflächennahe Geophysik: Archäogeophysik / Bio-und Hydrogeophysik / Ingenieur-und Umweltgeophysik

OG-A-01

Mobile NMR-Relaxometrie zur Charakterisierung des Zersetzungsgrades von Torfböden

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Aufgrund ökologischer Notwendigkeit im Zusammenhang mit dem Klimawandel erfährt die Bewirtschaftung von Torflandschaften derzeit weltweit einen enormen Wandel. Die Planung und Optimierung spezifischer Maßnahmen, z.B. die Wiedervernässung zur Verringerung von CO_2-Emissionen, erfordern umfangreiche Bodenuntersuchungen. Der Zersetzungsgrad von Torfböden ist dabei von besonderem Interesse, da er ihre hydrologischen und chemischen Funktionen maßgeblich steuert. Unsere Forschung konzentriert sich daher auf die Anwendung mobiler NMR-Relaxometrie für die Analyse von Torfböden.

Das NMR-Signal gibt neben der Angabe des volumetrischen Wassergehaltes auch Aufschluss über die Mobilität von Wassermolekülen und ihre physikochemischen Wechselwirkungen mit dem komplexen polymeren Porennetzwerk. Wenig zersetzter organischer Torfboden ist überwiegend hydrophil, weil die organischen Moleküle mit einer hohen Anzahl von polaren Gruppen ausgestattet sind. Diese funktionalen Gruppen limitieren die Beweglichkeit der Wassermoleküle und damit auch die der Protonenspins während des NMR-Experiments. Anders als bei mineralischen Böden und Sedimenten weisen Torfböden dadurch charakteristische Unterschiede im longitudinalen (T1) und transversalen (T2) Relaxationsverhalten auf, was durch T1/T2 Korrelationskarten darstellbar ist. Die NMR-Relaxationsmuster verändern sich mit den strukturellen und chemischen Transformationen, die sich während der Zersetzung der organischen Substanz abspielen, u.a. weil sich die ursprünglichen polaren Gruppen durch andere funktionelle Molekülgruppen ersetzt werden und das Material potentiell hydrophob wird.

Wir haben die Messung von T1/T2 Karten mit verschiedenen mobilen NMR-Methoden im Hinblick auf deren Einsatzmöglichkeiten für in-situ Torfuntersuchungen getestet. Mit der hochfrequenten single-sided NMR (13.1 MHz) lassen sich die Relaxationsmuster am besten ausdifferenzieren. Die wesentlichen Effekte nehmen mit abnehmender Frequenz ab, so dass die messbaren Unterschiede im T1/T2-Verhältnis bei NMR-Anwendungen im Erdmagnetfeld (~2 kHz) deutlich geringer werden. Wir zeigen jedoch, dass selbst für die Oberflächen-NMR noch signifikante Unterschiede zwischen frischem und zersetztem Torf nachweisbar sind.

Die spezifische Beziehung zwischen der Beweglichkeit der Protonenspins im organischen Polymernetzwerk in Torfböden und dem NMR-Relaxationsverhalten ist noch weitgehend ungeklärt und erfordert daher weitere Forschung.

OG-A-02

Mapping and characterizing peatland using ground-penetrating radar and nuclear-magnetic resonance

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Peatlands are of importance for a number of environmental and ecological processes. They are a crucial component of the global carbon cycle and, therefore, of special interest in times of climate change. On the one hand, drained peatlands irreversibly degenerate when used for agriculture and lose their physicochemical functionality. On the other hand, activities on renaturation or joint use are in discussion or already in practice. Consequently, there is a demand for knowledge of the state of the peat layers and for the ability to monitor their changes, most preferably in high detail and on a large scale. Airborne geophysics and remote sensing (e.g. opticalimages, radar or electromagnetic induction) are approaches to gain large-scale information on the lateral extent of peatlands. However, covering the large scale comes along with limitations and uncertainties on knowledge about thickness, internal structure, or degradation states.

We conducted a ground-penetrating-radar (GPR) and nuclear-magnetic-resonance (NMR) survey at a peatland site in northern Germany, which has been in agricultural use for decades. The site is characterized by a peat layer of varying thicknesses between 0-4 m covering mineral sediments.While GPR provides a fast 3D insight into the extent, thickness and internal structure of the peat layers, NMR enables the characterization of the peat material of these layers and may provide information on the degradation states. The results are compared to visually inspected vertical soil sampling data. Our study demonstrates that ground-based geophysics can provide the demanded detailed information and may easily be upscaled to effectively cover areas at the kilometre scale.

OG-A-03

Spurensuche rund um das Heiligtum: Geophysikalische Messungen und Ausgrabungen am Amyklaion bei Sparta, Griechenland

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Auf dem Agia-Kyriaki-Hügel ca. 6 km südlich von Sparta befand sich in der Antike das sogenannte Amyklaion, eines der Hauptheiligtümer der Polis Sparta. Während die Bebauung im Inneren des Heiligtums nahezu vollständig archäologisch untersucht ist, richtet sich nun das Interesse auf die unmittelbare Umgebung des Heiligtums, denn hier müssten sich Strukturen befinden, die zum Unterhalt des Heiligtums und den hier stattfindenden Festen dienten. Da an der Oberfläche keine eindeutigen Hinweise auf solche Strukturen vorliegen, wurden 2022 und 2023 geophysikalische Messungen und ein LIDAR-Scan durchgeführt, um Verdachtsflächen zu bestimmen, welche durch Ausgrabungen näher untersucht werden können. Die angewandten geophysikalischen Methoden umfassten Magnetik, Georadar, Geoelektrik und Suszeptibilitätsmessungen. Wegen der großen Fläche des Areals, des teilweise dichten Bewuchses und steiler Hänge war keine flächendeckende Messung mit

allen Methoden möglich. Anhand der magnetischen Messungen gelingt es aber, Gebiete mit Häufungen von magnetischen Anomalien zu identifizieren, welche auf eine anthropogene Beeinflussung schließen lassen. Eine auffällige, mehrere Meter lange magnetische Anomalie im Süden des Gebietes konnte durch Ausgrabungen auf eine mit zahlreichen Artefakten und Votivgaben gefüllte Grube zurückgeführt werden. Der Hügel besteht im Wesentlichen aus gut leitfähigem kalkigem Mergel, welcher Radarwellen stark dämpft. Es kommen darin aber Konglomeratschichten vor und an vielen Stellen besteht die oberste Schicht aus umgelagertem Material, z.B. von früheren Ausgrabungen. Mit Georadar können die Mächtigkeit dieser Schichten und darin enthaltene Strukturen erkundet werden. So konnte der Verlauf einer Konglomeratschicht bestimmt werden, an deren Rand eine Grubenbestattung gefunden wurde. Es wird vermutet, dass es sich um eine Straßenbestattung aus der Zeit des Mittelhelladikums handelt. Durch 3D-geoelektrische Messungen liegen am Westhang des Hügels Informationen über die Widerstandsverteilung unterhalb der Schuttschicht vor, welche aber noch nicht durch Grabungen validiert wurden. Durch Integration aller Resultate aus geophysikalischen Messungen, Fernerkundung und archäologischen Ausgrabungen in einem digitalen Modell des Untergrundes erhoffen wir uns in der Zukunft die Identifikation weiterer archäologischer Strukturen.

OG-B-01

Impact of magnetic interfering bodies on the detection of unexploded ordnance

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During the Second World War, many thousands of tons of bombs were dropped over Germany. The main targets were cities, industrial facilities, and transportation routes, such as railway installations. Many of these bombs did not explode upon impact and are partially still lying as unexploded ordnance in the ground today. As these still pose a significant danger, it is essential to investigate the ground of potentially hazardous areas before construction activities starts in order to issue a clearance for explosive ordnance.
For these surveys, magnetometers are commonly used, which, either from the surface or along boreholes, detect the magnetic signature of the ordnance. A major problem in this process is that the suspected areas may contain other magnetic interference, making magnetic surveying difficult or even impossible.
To investigate the impact of interfering objects on the measurement data, numerical simulations are carried out for typical sources of interference, such as sheet piles or railway ties, as well as for real unexploded ordnance geometries. The goal is to examine under what conditions (e.g., distance, spatial location, relative positioning, etc.) the magnetic anomaly from the interfering objects can prevent the detection of unexploded ordnance.

OG-B-02

Highlighting discontinuity in 3D GPR reflection data using structure tensor-based attributes

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Ground-penetrating radar (GPR) is a well-established geophysical imaging tool to investigate near-surface environments in different fields of application. When interpreting 2D/3D GPR reflection images in terms of subsurface structures, we typically rely on concepts addressing amplitudes, geometry, and continuity of the imaged reflector patterns. In applications

targeting abrupt breaks and changes in reflector continuity (e.g., associated with buried faults and fractures or buried objects such as the remains of walls and foundations) attributes such as coherency and similarity are often used to aid the interpretation. They rely on a pairwise comparison of traces in a user-specified time window and neighborhood and quantify discontinuity by different measures of variance including covariance, (weighted) correlation, and semblance. For large 3D GPR data sets comprising several hundred thousand traces and more, computing these attributes and parameter selection is often time-consuming and cumbersome, respectively.

As an alternative to commonly used coherency and similarity attributes, we investigate discontinuity attributes derived from the gradient structure tensor (GST). In image and video processing, the GST is a well-known computationally efficient tool for analyzing local structures by comprising amplitude gradients in all spatial directions. Decomposing the GST into its eigenvectors and eigenvalues allows to locally analyze and characterize structures in a given image or data set. From the eigenvectors, estimates of local dip and azimuth are derived in 3D data sets. The eigenvalues can be used to define the total energy of the GST (sum of all eigenvalues) or to quantify local structures such as lines and planes by defining various measures that compare the magnitudes of the ordered eigenvalues. Using 3D GPR data sets from typical archaeological and geological applications, we demonstrate the applicability and the potential of such GST eigenvalue-based attributes. Our results show that the resulting GST attribute images are comparable to coherency-/similarity-based attribute images. Because the GST can be computed by simple convolutions using Gaussian derivatives as filter kernels without the need for major parameter tuning, it is an efficient tool, especially, for analyzing large-scale 3D GPR data sets.

OG-B-03

GPR full-waveform inversion to characterize the Ahlen-Falkenberger peatland

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Peatlands play a crucial role in climate change due to their significant global warming potential. Depending on various factors, such as mean annual water level and land use, they can act as sources or sinks of greenhouse gases. Therefore, it is essential to have a detailed characterization of peatlands to determine their specific gas retention and emission capacities. Crosshole ground penetrating radar (GPR) full-waveform inversion (FWI) can provide high-resolution images of the subsurface, enhancing small-scale characterization. In the last decade, the method has successfully characterized and monitored flow and transport processes in various aquifers including time-lapse experiments. The GPR FWI can provide the subsurface's relative dielectric permittivity and electrical conductivity. These properties are linked to important hydrological characteristics, such as soil water content and clay content, respectively. Here, we investigate the potential and challenges of applying the crosshole GPR FWI to peatlands. The study site is the Ahlen-Falkenberger peatland in North Germany, where different types of land use, e.g., natural, grasslands and rewetted areas, can be analyzed. To investigate short- and long-term variations within the peatlands, we measured and inverted datasets of different seasons. To account for air-filled boreholes during measurements, starting models for FWI and effective source wavelets needed to be adapted by reducing the high angle data. The FWI results are compared to surface GPR data measured between the boreholes. The GPR FWI provided high-resolution images of both permittivity and electrical conductivity, allowing for the description of peatlands and their

seasonal variations. Additionally, variations within permittivity and hence soil water content between the different land type usages can be observed, which can be related to the different porosities and internal structures.

OG-C-01

In-Situ Acoustic-Emission (Mikroakustik) zur Erkundung geologischer Strukturen im Salzbergwerk Asse II

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Wir berichten von der erfolgreichen Erkundung großräumiger geologischer Strukturen in der Schachtanlage Asse II mittels Mikroakustik, wobei detaillierte Kenntnisse der Geologie im Bereich der Salzstruktur bei der Umsetzung der Rückholung der schwach- und mittelradioaktiven Abfällen eine wichtige Rolle spielen.

Mikroakustik wird unter Tage eingesetzt, um die Bildung von Mikrorissen in spannungsbelasteten Bereichen zu beobachten (Pikoseismizität). Hierbei werden üblicherweise Reichweiten von einigen 10er Metern, im Salz auch jenseits von 100 m erreicht. Auf der Schachtanlage Asse II wird seit 2013 eine mikroakustische Überwachung zur Beurteilung der Firststabilität auf der obersten (490 m-) Sohle durchgeführt. Dabei werden gelegentlich auch Ereignisse aus einer Distanz von über 150 m geortet, die geologischen Grenzflächen zugeordnet werden können.

Von Oktober 2019 bis März 2021 wurde eine mikroakustische (Test-)Messung mit kontinuierlicher Datenaufzeichnung (Abtastrate 500 kHz) mit einem neuen Sensor-Array auf der 574 m-Sohle durchgeführt. Die gewonnenen Daten wurden speziell im Hinblick auf die Ereignisse von geologischen Strukturen abseits der Grubenbaue ausgewertet. Die Ergebnisse ermöglichen es, die erkannten Strukturen besonders deutlich mit hoher Auflösung in ihrem räumlichen Verlauf abzubilden. Im Anschluss wurden die kontinuierlichen Messungen in 2022 in einer neunmonatigen Messkampagne auf die 490 m-Sohle ausgeweitet. Dadurch konnten die Lage und der Verlauf von Südflanke und Anhydritmittel und deren Feinstruktur lokal abgebildet werden.

Die Ortungsergebnisse der beiden genannten Messkampagnen bilden sehr deutlich den genauen Verlauf von geologischen Grenzflächen im Bereich des Übergangs Salinar/Deckgebirge an der Südflanke sowie der Grenze Steinsalz/Anhydritmittelsalz im Norden des Bergwerks ab. Die Erkenntnisse sind zwar auf Teilbereiche des Salzstockes begrenzt, können dort jedoch bezüglich Auflösung und Genauigkeit neue Erkenntnisse liefern. Die 3D-Seismik und die Mikroakustik zeigen übereinstimmende und sich ergänzende Ergebnisse für die kartierbaren Schichtverläufe. Durch die hohe räumliche Genauigkeit konnten die Daten der Mikroakustik zudem verwendet werden, um das Tiefengeschwindigkeitsfeld der 3D-Seismik zu kalibrieren und eine lagerichtige Abbildung der Südflanke zu gewährleisten. Die Mikroakustik-Ortungen sind somit Teil der wichtigsten Grundlagendaten bei der Interpretation der Salzeinhüllenden für die strukturgeologische Modellierung.

OG-C-02

Monitoring von Gefrier-Tau-Zyklen in einem experimentellen geologischen Eis-Wärme-Speicher mittels Bohrloch-Georadar

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Eis-Wärme-Speicher (EWS) basieren auf der Nutzung freigesetzter latenter Wärme beim Gefrieren eines Speichermediums. Gefrorenes Medium dient als Kältespeicher für Kühlperioden. Statt der bisher angewendeten kosten- und flächenintensiven Nutzung konventioneller Eis-Wärme-Speichersysteme (z.B. vergrabene Tanks), fokussiert sich das BMBF-geförderte Verbundprojekt von CAU Kiel, UFZ Leipzig und IEG Bochum „GEWS" (Entwicklung und Bau eines tiefenhorizontierten Geologischen Eis-Wärme-Speichersystems als Demonstrationsanlage auf dem Testfeld TestUM / Wittstock) auf die Übertragung des Eisspeicherprinzips auf den geologischen Untergrund und die Nutzung von Grundwasserleitern als Speichermedium. Als Versuchsanlage wurden Erdwärmesonden zur Vereisung eines oberflächennahen quartären Aquifers installiert. Während mehrerer Tau- und Gefrierzyklen werden energetische Effizienz, Bodendeformation und geochemische und mikrobiologische Veränderungen im Grundwasserleiter untersucht und mit numerischen Simulationen sowie Laborversuchen begleitet.
Um den aktuellen thermischen Zustand im Untergrund beurteilen zu können, hilft es die Größe des gefrorenen Volumens zu kennen. Durch die Änderung von Permittivität und Widerstand beim Gefrieren des wassergesättigten Bodens weist Bohrloch-Georadar eine hohe Sensitivität für den Übergang von gefrorenem zu ungefrorenem Untergrund auf. Die Eindringung ist aufgrund der hohen elektrischen Leitfähigkeit jedoch stark begrenzt. Zwei Frier-Tau-Zyklen wurden mit Crosshole- und Reflexionsmessungen begleitet mit dem Ziel den Gefrierprozess abzubilden. Anhand der durch Crossholemessungen bestimmten Geschwindigkeitsverteilung kann aus den Laufzeiten der auftretenden Eiskörperreflexionen die räumliche Ausdehnung der Vereisung rekonstruiert werden. Mit Wiederholungsmessungen wird so der zeitliche Fortschritt des Gefrierens abbildbar. Die Ergebnisse zeigen eine vertikale Variabilität der Vereisung aufgrund des Erdwärmesondendesigns. Vergleiche mit *in situ* Temperaturmessungen und Lotungen validieren diese Annahme. Zudem lässt sich ein unterschiedliches Auftauen in Grundwasseran- und abstromrichtung abbilden. Mit dem Versuchsaufbau konnten wir zeigen, dass der Einsatz von Bohrloch-Georadar, in dem für Georadar schwierigen Umfeld von wassergesättigten glazialen Sedimenten, eine einfache und schnelle Erfassung des Untergrundzustands von GEWS-Systemen erlaubt.

OG-C-03

Effektive Bestimmung der seismischen Baugrundklassen und der geologischen Untergrundklassen nach DIN

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Im deutschen Anhang der Norm Eurocode 8 (EC8; DIN EN 1998-1/NA:2011-01; "Auslegung von Bauwerken gegen Erdbeben") wird der Einfluss der örtlichen Untergrundverhältnisse auf die Erdbebeneinwirkung generell mit einer Einstufung in eine von drei geologischen Untergrundklassen und in eine von drei Baugrundklassen vorgenommen. Für die Bestimmung der Baugrundklasse werden die Gesteine bis 30 m Tiefe berücksichtigt, während es für die Bestimmung der geologischen Untergrundklasse die Gesteine darunter bis in einige 100 m Tiefe sind.
Die Baugrundklassen können anhand aufwändiger geotechnischer Messungen bestimmt werden. Als Alternative werden hier passive seismische Messungen mit Einzelstationen und Arrays vorgestellt, die eine effektive Bestimmung der Geschwindigkeiten der S-Wellen bis in 30 m Tiefe ermöglichen. Anhand ihrer ermittelten Dispersionskurven werden Rayleigh- und Lovewellen simultan invertiert, das Tiefenprofil der seismischen Geschwindigkeiten erhalten und die seismische Baugrundklasse des Standortes bestimmt.
Im Zuge der Aktualisierung der DIN EN 1998-1/NA:2011-01 wurde die Karte der geologischen Untergrundklassen überarbeitet, die ein Bestandteil der Norm ist. Dazu wurden für diese Karte erstmalig die Methoden der geologischen 3D-Modellierung herangezogen. Basierend auf aktuellen Daten aus den geologischen 3D-Modellen der von der Norm betroffenen Bundesländer Baden-Württemberg, Bayern, Hessen, Nordrhein-Westfalen, Rheinland-Pfalz, Sachsen, Sachsen-Anhalt und Thüringen wurden zunächst die Schichtmächtigkeiten für quartäre und tertiäre Sedimente ermittelt. Anhand dieser Mächtigkeiten wurden die geologischen Untergrundklassen „R" (Fels), „T" (flache Sedimentbecken) und „S" (tiefe Sedimentbecken) nach DIN ausgewiesen. Die geologischen Untergrundklassen wurden auf einem Raster mit einer Zellengröße von 1 km x 1 km dargestellt. Im Vergleich zur bisherigen Ausweisung der geologischen Untergrundklassen, in der geologische Strukturen mit weniger als 20 km Erstreckung bzw. Durchmesser nicht berücksichtigt werden konnten, wurde damit eine deutlich höhere räumliche Auflösung erreicht. Im Beitrag wird die Methodik zur Erstellung der Karte dargestellt und die Anwendung der Karte in der Praxis erläutert.

OG-D-01

Integrated model-data observations of water flow dynamics across bedrock and vegetation variations

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Hydrological processes in mountainous watersheds, and the interactions between soil, bedrock, and plants are still poorly understood. Using a dense network of soil moisture and temperature sensors, high resolution electrical resistivity tomography monitoring, and weather data we assess the processes driving the hydrological response of a hillslope during

snowmelt and summer monsoon. The monitoring transect covers different bedrock and vegetation types, with a steep upper part characterized by shallow bedrock and covered by pine trees, and a gentle lower part underlain by colluvium and covered mostly by grass and veratrum. Coupling the monitoring data with a simplified hydrological model, we observe several important hydrological processes that show how variations in bedrock type and topography, and vegetation type change subsurface flow patterns. These observations allow us to gain a better understanding of the interactions between vegetation, bedrock types and subsurface flow dynamics.

While on the steep section, characterized by thin soil and shallow bedrock, we observe mostly shallow and rapid lateral flow, on the gentle slope underlain by colluvium vertical flow is prevailing. Timelapse resistivity patterns indicate that for shallow bedrock, fractures and tree roots may provide preferential flow pathways into deeper bedrock units during snowmelt, which may provide means to mitigate summer drought conditions. Shading of the trees seems to further mitigate drought conditions by limiting evaporation of summer monsoon rainfall, leading to less drying of the shallow soil layer. In the lower, gentle part of the profile snowmelt is contributing to vertical flow recharging the aquifer, while in the summer upwelling groundwater is providing moisture to sustain plant growth.
These observations show that variations in bedrock and vegetation pose a strong control on hillslope hydrology, creating spatially complex flow patterns. These results highlight the spatial heterogeneity of hydrological processes in mountainous watersheds, which need to be understood to predict how watersheds respond to disturbances.

OG-D-02

Geoelectrical monitoring of tree-soil water interactions at urban sites

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The impact of climate change is increasingly restricting water availability in the soil, posing a significant challenge in urban areas where plants have to deal with limited space and sealed surfaces hinder rainwater infiltration. However, the amount of plant-available soil moisture plays a crucial role in plant vitality and is therefore important for ecosystem health. In urban environments, obtaining information on soil moisture is challenging. Commonly used methods, such as soil-moisture sensors, are often not applicable or do not provide a spatially resolved picture of soil moisture.

Within the context of the interdisciplinary project CliMax, we explore the applicability of geophysical methods to characterize soil moisture in the rhizosphere in urban areas. Over the past year, monthly monitoring Electrical Resistivity Tomography (ERT) measurements were conducted at nine different tree locations in Braunschweig, Germany, characterized by diverse tree species and degrees of sealing of the surface. Additionally, temporally and spatially higher-resolution measurements were selectively taken. Various time-lapse inversion approaches implemented in the open geophysical inversion library pyGIMLi were tested and applied. Furthermore, Time-Domain Reflectometry (TDR) soil-moisture sensor data from different depths are available at each site, allowing calibration of ERT results with respect to soil moisture.

The time-lapse inversion reveals well-resolved variation in soil moisture over the observed period, distinguishing between weather fluctuations and the influence of trees on the water balance. The water uptake is evident through increased resistivity values directly beneath the trees. Our study indicates that, depending on tree species and degree of sealing, the investigated urban trees predominantly extract water from the upper 1–4 meters. This finding is substantiated at specific locations by the data from deployed soil-moisture sensors.

OG-D-03

Mountain permafrost degradation: How reliable are results from repeated ERT and refraction seismic surveys under changing subsurface conditions?

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Geophysical monitoring has become more and more popular in permafrost environments due to its remarkable success to detect permafrost thawing and associated spatio-temporal changes in the ground ice content. Hereby, mainly geoelectric methods such as Electrical Resistivity Tomography (ERT) are usually applied due to the strong differences in the electrical properties between frozen and unfrozen state, but also seismic properties change markedly upon freezing/thawing and time-lapse refraction seismic tomography (RST) has been shown to be applicable to permafrost.
Numerous publications demonstrate a considerable permafrost degradation based on repeated ERT and/or RST surveys, and in many cases the results are confirmed by independent observations from borehole or ground surface temperature monitoring, by degradation phenomena visible at the surface, or by changes in kinematic patterns in the case of creeping permafrost. A prominent example is the annual ERT monitoring time series of several mountain permafrost sites in the Swiss Alps, showing a consistent long-term resistivity decrease in the permafrost layer over the last two decades that is related to the advanced melting of ground ice (www.permos.ch).
However, it is also well-known that the sensitivity of geophysical methods to subsurface characteristics can be influenced by the subsurface composition, and usually decreases significantly with depth.
In general, permafrost degradation can include both, a warming of the frozen layer (affecting the ratio of frozen and unfrozen water at subzero temperatures), and an increasing thickness of the active layer (maximum thaw depth of the surface layer in summer). To analyse to what extent the sensitivity of observed resistivities and seismic P-wave velocities in the permafrost layer is affected by increasing thaw depths, we set up synthetic models which represent the permafrost degradation as observed in borehole temperature time series at Swiss monitoring sites. The synthetic models further resemble the site characteristics and the geometry of the operational geophysical monitoring profiles. We discuss the inversion results for different degradation scenarios and their implications in comparison with field data from the existing monitoring profiles.

OG-D-04

Investigation of the Garzweiler Coal Deposit, Germany using Central and Fixed Loop Transient Electromagnetics

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The transient electromagnetic method (TEM) is widely applied for the detection of mineral deposits, geothermal reservoirs, and other earth resources such as coal-bearing layers. The study area, Garzweiler, is located in the Rheinland Lignite deposit where three open-pit coal mines exist. Our main objectives are the detection of the thickness and depth of the coal-bearing layers, and the comparison of different TEM configurations. In addition, we aim at providing information about faults, and water-bearing layers since both can be key information in a mining safety context. We applied the conventional central loop setup and large fixed loop TEM using two receiver components. One central and three fixed loop profiles with different loop sizes were deployed along a 2 km long survey line. Only the time derivative of B_z component was recorded in the central loop setup while both time derivative of B_z and B_x components were measured in fixed loop configuration. The observed data is of high quality, with low stacking error that are increasing at later transient times. Due to setup geometry, systematic sign reversals are observed for the fixed loop data outside of the transmitter loop. Initially, one-dimensional resistivity depth models are derived using conventional Occam and Marquardt-Levenberg techniques for the central and fixed loop data (z-component). Quasi-2D resistivity depth sections are created by stitching 1D models. The shallow conductive layer is resolved well as expected in the central loop results. For the fixed loops, a deeper conductive layer is observed. Subsequently, a joint inversion was applied to combine the two configurations and provide an improved model. Overall, the combined interpretation of the central and fixed loop results improves the resolution of the conductive layers. For interpretation, the resistivity distribution is correlated with the geological cross-section and borehole data as well as existing faults. Due to the very different transmitter source footprint of the two TEM configurations, the applicability of the 1D joint inversion is limited. The 2D inversion of the data set is in progress and shall improve our interpretation.

OG-D-05

Subsurface Characterization of the Weidenpesch landfill, Cologne, Germany using geoelectric and electromagnetic techniques

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Landfills pose a significant global environmental concern, as they often involve the uncontrolled dumping of various domestic and industrial wastes. The challenge in initiating the remediation of these sites is to determine the distribution of buried waste. Geophysical methods play a key role in addressing this problem, offering a rapid and noninvasive means to characterize the geometry of buried waste materials within landfills. They enable a comprehensive understanding of landfill contents and aid in estimating contamination risks, contributing significantly to effective landfill management and environmental protection.

At the Weidenpesch landfill, Electrical Resistivity Tomography (ERT), Radio-Magnetotelluric (RMT), and Transient Electromagnetic (TEM) measurements were carried out to characterize the landfill structure and its influence on the surrounding hosting layers of various depth and spatial scales. In this study, the lateral and vertical demarcations of the landfill were

effectively delineated, revealing that the waste body extends to a depth of roughly 10 meters. Discrepancies in resistivity values observed between the western and eastern sectors of the landfill suggest the deposition of distinct materials in these areas. A conspicuously conductive layer beneath the landfill imaged from TEM, in contrast to the adjacent surroundings, implies the potential for downward contaminant seepage.

The results obtained from various geophysical investigative methods demonstrate a notable level of consistency. The study demonstrates the efficiency of these methods in landfill characterization, providing crucial insights for environmental monitoring. It highlights the advantage gained through the combination of these methods, emphasizing their significant role in understanding and managing landfill environments.

OG-D-06

The contribution of geophysics in a combined approach of geosciences, historical archaeology and history

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Floodplains represent particularly sensitive socio-environmental systems concerning anthropogenic impact [Werther et al. 2021, Zielhofer et al. 2022].
In our interdisciplinary project, we assess the human impact and corresponding ecological shifts on the natural environment within two Fluvial Anthropospheres: the Lower Havel River Region and the Greater Donaumoos Region.
Geophysics plays an important connective role within our unique multi-method approach to reconstruct socio-ecological processes ranging from historical archaeology and early modern history (old maps, written sources) to geosciences (geophysics, drilling) and plant ecology (botanical findings, pollen analytics).
Our geophysical observations with non-invasive methods (Electromagnetic Induction, Electrical Resistivity Tomography) provide a comprehensive picture of the electrical conductivity distribution in the subsurface, area-wide and transect-wise. Affected mainly by clay and soil water content, our investigations allow for delineating sediment patterns characterized by a coarse-grain distribution and identifies regions featuring fine-grained floodplain deposits. The following comparison with soil profiles and preliminarily defined vegetation communities (dry grassland, alluvial meadows, and reeds) allow for defining the floodplain extent. The additional integration of historical findings from archived documents enables a precise and holistic reconstruction of the human influence on the floodplains and peatlands. Geophysical exploration forms an area-wide and depth-oriented basis for geomorphological investigations, and plays a key role in developing transferable models and collective interpretations.

Werther, L. et al.: On the Way to the Fluvial Anthroposphere - Current Limitations and Perspectives of Multidisciplinary Research. Water 2021, 13, 2188. https://doi.org/10.3390/w13162188

Zielhofer, C. et al.: The Lower Havel River Region (Brandenburg, Germany): A 230-Year-Long Historical Map Record Indicates a Decrease in Surface Water Areas and Groundwater Levels. *Water* **2022**, *14*, 480. https://doi.org/10.3390/w14030480

OG – Poster

Oberflächennahe Geophysik: Archäogeophysik / Bio-und Hydrogeophysik / Ingenieur-und Umweltgeophysik

OG-P-01

Application of a semi/fully Autonomous 4-wheeled Rover for Geophysical Data Acquisition

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We present a 4-wheeled rover, engineered for semi/fully autonomous geophysical data acquisition. The rover's design features dual-wheel types (rubber and metal) for various terrains and utilizes RTK GPS for navigation. Its control system is equipped with multiple inputs/outputs and powered by the Robotic Operation System (ROS2), ensuring adaptability and efficiency. This setup enables compatibility with various sensors, offering flexibility in triggering options such as time, position, manual intervention, or continuous operation. In a proof of concept study, the rover was deployed at the Ekström Ice Shelf in Antarctica, where it successfully collected polarimetric phase-coherent radar data. The integration of autonomous capabilities allows for increased efficiency and reliability in data collection, making it an ideal tool for geophysical exploration also when using other geophysical sensors such as for magnetic surveys. The poster aims to discuss the technical aspects of the rover's design and functionality and explores potential applications in various geophysical domains and possible collaboration with industry. Your ideas for sensor integration are very welcome.

OG-P-02

Georadar measurements for archaeological prospection in the vicinity of the Amyklaion sanctuary near Sparta

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Ground-penetrating radar (GPR), electrical resistivity tomography (ERT) and magnetometry were applied for archaeological prospection of the surroundings of the ancient Amyklaion sanctuary at the hill Agia Kyriaki near Sparta (Greece). The measurement area extended about 50 meters around the outer walls of the sanctuary and was mostly steep and covered with olive trees.

In this work, we present the results of the GPR measurements. In total, 36 profiles were measured using a 300/800MHz dual-frequency antenna, and seven small areas were studied in more detail with pseudo-3D measurements. Only data from the 800-MHz-antenna yielded usable data.
The bedrock consisted mainly of a highly conductive clayey marl, in which the penetration depth was limited to about 20 centimeters. In some places, the ground consisted of conglomerate layers and debris from previous excavations. At these locations, a penetration depth of up to one meter was achieved.

The most prominent result is a 3 m wide linear feature, which extends more than 10 m across the southern area. Here, an increased penetration depth is observed due to the low conductivity, which was confirmed by ERT measurements. The excavations following the measurements identified the material as conglomerate with a shallow burial pit, which probably dates to the Middle Helladic period and marks an important finding.
The results from areas covered with excavation debris show numerous complex reflections, which are difficult to interpret even in GPR depth sections. Excavations revealed heterogeneous layers of debris as well as a few archaeologically interesting objects.

These results show that despite challenging conditions due to conductive bedrock, heterogeneous overburden and tree coverage, important information was collected at this site that led to archaeological findings.

OG-P-03

ZMvB – Zerstörungsfreies Monitoring von Bauteilfeuchte an historischen Bauwerksstrukturen mittels Georadar, Ultraschall und Thermographie

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Die Restaurierung und Instandhaltung von Denkmälern und historischen Gebäuden erfordert fundierte Kenntnisse über die bauliche Geschichte und die innere Struktur des Bauwerkes sowie ein hohes Maß an Kompetenz von den beteiligten Akteuren. Um eine effiziente Sanierung zu ermöglichen, bedarf es bei der Umsetzung von Sanierungsmaßnahmen eines Konzeptes bzw. einer Methode, die eine umfassende Betrachtung der anstehenden Herausforderungen ermöglicht. So stellt insbesondere eindringende Feuchtigkeit in die Bausubstanz oft eine erhebliche Bedrohung für das Bauwerk dar. Kenntnisse über Mechanismen, die zu Feuchteeinträgen führen können, sind von entscheidender Bedeutung.
Die Bewertung und Analyse von Feuchtigkeit in Bauwerken erfolgt bisher z.B. durch Materialentnahme mittels Kernbohrungen. Diese invasive und selektive Probenentnahme wird in der Regel durch eine visuelle Beurteilung von oberflächennahen Veränderungen ergänzt. Dadurch können zwar genaue Aussagen über den Feuchtegehalt und den Zustand gemacht werden, die Aussagekraft ist jedoch lokal beschränkt.
Aus diesem Grund sind Methoden erforderlich, die eine zerstörungsfreie und idealerweise schnelle Bewertung großer struktureller Bereiche ermöglichen. Hierbei sind neben einem integrativen Ansatz zur Behebung akuter Schäden auch präventive Maßnahmen zum Erhalt der historischen Bausubstanz nötig.
Ziel dieses Beitrags ist es, zu zeigen, dass durch die Anwendung geophysikalischer Messverfahren, wie Infrarot-Thermografie (IR), Ultraschall (US) und Ground-Penetrating-Radar (GPR), eine großflächige zerstörungsfreie Detektion von Feuchtigkeit, begleitend zum Sanierungsprozess, möglich ist. Hierbei liegt der Fokus auf der Anpassung von Messprinzipien mit dem Ziel, diese in praxistaugliche Mess- und Evaluationsmethoden für historische Bauwerke zu überführen, um den Nachweis von Feuchtigkeit zu erbringen. Wir präsentieren Ergebnisse von unseren Arbeiten an denkmalgeschützten Bauten in Norddeutschland in denen wir Bereiche erhöhter Feuchtigkeit identifizieren und die inneren Eigenschaften von Ziegelmauerwerk und Holzkonstruktionen erfolgreich erfassen, um eine bessere Beurteilung der Schäden zu ermöglichen. Die Kombination von Ultraschall, Bodenradar (GPR) und Thermographie ermöglicht die quantitative Erfassung und Überwachung von Materialeigenschaften während des Restaurierungsprozesses durch wiederholende Messungen.

OG-P-04

Geophysical investigation in ancient Olympia: The discovery of unknown structures of the Sanctuary of Olympia

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Ancient Olympia was one of the most important sanctuaries and the venue for the Olympic Games in Greek and Roman times. Its remains are located on the Olympia Terrace (Peloponnes, Greece) at the present-day confluence of the two Rivers Alpheios and Kladeos and at the base of Mount Kronos. Olympia is situated on the northern fringe of the Makrisia Basin which is bound to prominent east-west oriented faults. Here, the so-called Lake of Olympia existed from the 8th/7th century BCE until at least the 1st century CE. After the sanctuary was abandoned in the 5th century CE, it was covered by several metres of sediment which is why it has not yet been fully explored and excavated. During a geophysical and geoarchaeological campaign in October 2021, Electromagnetic Induction and Electrical Resistivity Tomography measurements were performed between the excavated parts of the sanctuary and the edge of the original Olympia Terrace in the southwest of the archaeological zone as well as on the eastern slope of Mount Kronos north of the sanctuary. The data from the southwestern area show evidence of a channel in which the River Kladeos was redirected, but especially structures that can be interpreted as foundations of an ancient road and a highly conductive rectangular structure, possibly a building, heading south towards the present Alpheios River valley. On the slope of Mount Kronos, covered by landslide deposits, another rectangular structure was found which could be the remains of a temple.

OG-P-05

NFDI4Objects - Beiträge zum Forschungsdatenmanagement in der Archäogeophysik

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NFDI4Objects (N4O) ist eine Initiative zum Aufbau eines multidisziplinären Konsortiums innerhalb der Nationalen Forschungsdateninfrastruktur (NFDI). Die Initiative richtet sich an Forschende sowie und Praktiker*innen, deren Arbeitsschwerpunkte auf dem materiellen Erbe von rund drei Millionen Jahren Menschheits- und Umweltgeschichte liegen und adressiert die Herausforderungen moderner Forschungsdateninfrastrukturen. Zu den angesprochenen Disziplinen gehören nicht nur verschiedene Archäologien, sondern u.a. auch Anthropologie, Bauforschung, Geoarchäologie, Archäobotanik und Geophysik.

Das Arbeitsprogramm von NFDI4Objects ist an dem Datenlebenszyklus archäologischer Objekte ausgerichtet: Von der Erkundung und Bergung über die Sammlung zur Analyse und dem Erhalt der Objekte. Dabei spielen die Speicherung und die Verbreitung der Forschungsdaten sowie die Überführung der Ergebnisse in die Ausbildung zentrale Rollen. Die verschiedenen Aufgabenbereiche sind in sieben Task Areas (TA) strukturiert. Insbesondere in den TA 1-4 werden die komplexen Anforderungen für Datenmanagement, Datendokumentation und Datenarchivierung im Rahmen der Erfassung und Erforschung von Primärdatenquellen, wissenschaftlichen Objektsammlungen und für die Erhaltung von Kulturdenkmälern adressiert.

Mit einer innerhalb der TA1 entwickelten Umfrage möchten die beteiligten Wissenschaftler*innen des BCDH und des UFZ einen Überblick zur Anwendung geophysikalischer Prospektion in der Archäologie gewinnen. Sie richtet sich deshalb besonders an langjährige Expert*innen, die in diesem Themenfeld in Forschungseinrichtungen, Landesämtern oder kommerziellen Unternehmen arbeiten. Mit Hilfe der gewonnenen Daten sollen Vorschläge für Boa_Image_Frameisierungen in der Datenaufnahme, Prozessierung, Analyse und Archivierung bedarfsorientiert entwickelt werden. Die Antworten liefern die Grundlage, um im ***Community Cluster Geophysik der NDFDI4Objects*** allgemeingültige Boa_Image_Frames im Umgang mit geophysikalischen Daten und Metadaten zu diskutieren. Ein standardisiertes Vorgehen mit archäogeophysikalischen Daten ist wünschenswert und notwendig, um nachhaltigen Zugang sowie die Langzeitarchivierung zu verbessern und besonders fachfernen Datennutzer*innen den Umgang mit diesen Daten zu erleichtern.

Die Posterpräsentation bietet die Möglichkeit mit interessierten Geophysiker*innen ins Gespräch zu kommen und für die aktive Teilnahme am Community Cluster zu werben.

OG-P-06

Der Hera-Tempel auf Samos: Untersuchung des Baugrundes mittels seismischer Methoden

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In der archaischen Antike (800−500 v. Chr) war Samos ein wichtiger Handelsknoten im Kreuzungsbereich der Handelsrouten zwischen Griechenland, dem Schwarzen Meer und Ägypten. Dadurch erlangte Samos Wohlstand, der sich durch den Bau des Großtempels (einer der größten Großtempel des antiken Griechenlands) innerhalb des Heraions verdeutlicht. 10 Jahre nach der Fertigstellung eines ersten Großtempels (um 560 v. Chr) wurde (fast) an gleicher Stelle ein zweiter Großtempel errichtet, dessen Überreste heute noch zu sehen sind.

Folgende mögliche Hypothesen, warum der erste Großtempel aufgegeben wurde, werden als Ursache diskutiert:
Der sumpfige Baugrund konnte den ersten Großtempel nicht tragen, so dass dieser durch Setzungserscheinungen beschädigt wurde (I).
Der Tempel wurde durch ein Erdbeben zerstört, da Samos in einem seismisch aktiven Gebiet, wie das M7 Erdbeben vom 30.10.2020 zeigt, liegt (II).
Der Untergrund innerhalb des Heraions wurde um den Großtempel herum mittels seismischer Methoden untersucht. Zum einen wurden entlang 7 Profile eine aktive SH-Wellen-Seismik durchgeführt und tomografisch ausgewertet. Des Weiteren wurden flächendeckende passive seismische Tiefensondierungen mittels Mini-Arrays durchgeführt, um lokale Dispersionskurven zw. 2 und 60 Hz zu bestimmen. Durch Inversion der Dispersionskurven wurden Untergrundmodelle abgeleitet. Auch wurden HV-Spektren berechnet.

Die Ergebnisse zeigen im oberflächennahen Bereich S-Wellen-Geschwindigkeiten von 100 m/s bis 200 m/s bis in eine Tiefe von 4 m bis 8 m. Daraus ergeben sich Resonanzfrequenzen der obersten Schicht im Bereich von 3 Hz bis 10 Hz. Dies ist in einer ähnlichen Größenordnung wie die Eigenfrequenz des Großtempels. Daher war der erste Großtempel wegen des Untergrunds besonders durch Erdbeben gefährdet. Es ist möglich, dass der erste Großtempel durch ein starkes Erdbeben, wie das M7 Erdbeben vom 30.10.2020, zerstört wurde.

OG-P-07

Drone-borne magnetic prospection of the deserted town Blankenrode

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The deserted medieval town of Blankenrode near Paderborn lies in a forested area, which complicates archaeological prospection and especially the application of magnetometry. However, part of the area is currently only covered with low vegetation, because tall trees were removed after storm damages a few years ago. Although the area is still not completely accessible on the ground, this allows magnetic measurements with a drone at a height of a few meters above ground. We used an octocopter drone to carry a bird containing a total field magnetometer and an inertial measurement unit (IMU), which was attached with ropes 3 m below the drone. The main challenge of such a measurement is a safe low-altitude flight above the irregularly overgrown area. We used a publicly available Digital Terrain Model with 1 m resolution as well as raw data from a drone-based LiDAR scan to map the vegetation height. This information was crucial for planning the flight route. A large part of the area could be surveyed at a height of 3.5 m above ground. The heading error was corrected based on the data from the IMU using various approaches including machine learning. The results show several distinct magnetic anomalies with amplitudes of up to 11 nT for 4.5 m sensor height and up to 40 nT at 3.5 m sensor height. These results provide a basis for targeted investigation in this difficult to access area, although the lateral resolution is relatively low compared to state-of-the-art ground measurements.

OG-P-08

Eignungsprüfungen geophysikalischer Sensoren zur Rissdetektion an Demonstrationsbauwerken

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Bei der Betonage von Abdichtbauwerken können Temperaturen bis 110 °C und hohe Drücke bis 5 MPa erreicht werden. Mittels Technikumsversuchen wurde nachgewiesen, dass Mikroakustik- und Ultraschallsensoren zum Einbau in Demonstrationsbauwerke geeignet sind.

Die Untersuchungen wurden bei der BAM (Bundesanstalt für Materialforschung und -prüfung) in Berlin durchgeführt. Es ist vorgesehen, die Sensoren in Morsleben am Demonstrationsbauwerk im Anhydrit einzusetzen.

OG-P-09

Rational and efficient ground investigations for industrialised construction of new railways

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To complete a new Swedish railway line in a shorter timeframe than usually done, alternatives to the traditional methods need to be explored for example the use of prefabricated concrete slabs elevated on piers. The method has the advantage of directly tackling the barrier effects exhibited by traditional methods.
A methodology is under development where a stepwise refinement of the ground conditions is achieved by extensive use of existing databases followed by targeted geophysical and geotechnical investigations. An early classification of ground suitability is made using experience-based weighting of spatial data through discussions in an analytical hierarchical process (AHP). To add a vertical component, a predictive model targeting lithological complexity is trained and deployed. By combining the two statistical approaches a single 2D view can serve as a field planning base. A predictive model targeting undiscovered archaeological sites is also applied for early identification, investigation or if possible, avoidance.
The field investigations in selected areas start with geophysical surveys using unmanned aerial vehicles (UAV). Two instruments are fitted to two UAVs. One is an 80/120 MHz GPR system aimed to resolve near surface lithological boundaries and the second one is an electromagnetic system, with lower frequencies (10-350 kHz) and deeper penetration used to model geological units such as hard rock surface and lithological variations.
Based on lithological complexity, drone measurements and synthetic models, subsequent ground based electrical and seismic measurements settings are chosen. Individual and joint evaluations of the geophysical profiles are used to infer soil mechanical parameters. In a final step, geotechnical soundings are performed for ground truthing, and one of four pre-designed foundation types is assigned to each pier location based on the suitability classification of step one and the accumulated field-data.
This methodology is targeting specific areas for field investigations allowing for an optimized geotechnical field campaign, thereby decreasing the number of point-based soundings and drillings in the pre-investigation stage.

OG-P-10

Untersuchung der hydraulischen Konnektivität in heterogenen Lockergesteinsaquiferen mittels SIP

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Die Erkundung präferenzieller Fließpfade im Untergrund und damit die Bestimmung der hydraulischen Konnektivität in heterogenen Grundwasserleitern ist z.B. für die Prognose der Schadstoffausbreitung in der Grundwasserzone von Interesse. Zurzeit werden diese Informationen hauptsächlich mit aufwändigen hydraulischen Messungen gewonnen.
Mit dem Ziel eine Methode zu entwickeln, die Rückschlüsse auf die hydraulische Konnektivität von Grundwasserleitern erlaubt, wird experimentell und numerisch die Nachweisbarkeit von Heterogenitäten der hydraulischen Durchlässigkeit und damit von präferentiellen Fließwegen in den Messdaten der Spektralen Induzierten Polarisation (SIP)

untersucht. Dieses geophysikalische Messverfahren wird als geeignet angesehen, da ein enger Zusammenhang zwischen hydraulischen Eigenschaften poröser Gesteine und deren komplexen elektrischen Eigenschaften besteht.
Im Rahmen eines gemeinsam von TU Berlin und UFZ Leipzig/Halle bearbeiteten DFG-Vorhabens wurde eine Versuchsanlage im Technikumsmaßstab aufgebaut, in der für einen definiert heterogenen Modellgrundwasserleiter die hydraulische Durchlässigkeit und die komplexen elektrischen Eigenschaften gemessen werden können. Der Untersuchungsraum wird dabei in Segmente für verschiedene Sande oder auch andere Gesteine mit unterschiedlichen elektrischen und hydraulischen Eigenschaften unterteilt. Die Versuchsanlage in Form einer geschlossenen Versuchsrinne ist leicht zugänglich, was es ermöglicht, diverse geometrische Anordnungen der hydraulischen Homogenbereiche zu realisieren.
In dem Modell können gespannte Grundwasserverhältnisse erzeugt und SIP-Messungen im homogenen, linearen elektrischen Feld unternommen werden. Die Messung der integralen hydraulischen Durchlässigkeit erfolgt mittels Durchströmung in paralleler Richtung zum elektrischen Feld. Die bisher realisierten Versuchsreihen mit verschiedenen Feinsand-Grobsand-Kombinationen zeigen, dass die Spektren Informationen zur hydraulischen Heterogenität enthalten. Die Effekte lassen sich durch Modellrechnungen z.B. unter Nutzung der Relaxationszeitverteilungen erklären.

OG-P-11

Experimentelle Untersuchung der Wirkung von Heterogenität und Anisotropie auf die Spektrale Induzierte Polarisation poröser Gesteine

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Die Kenntnis der Heterogenität und Anisotropie sedimentärer Formationen ist von Interesse für die Prognose verschiedener Transportprozesse, z.B. der Ausbreitung von Schadstoffen oder die Wirksamkeit von Entwässerungsmaßnahmen. Da diese Eigenschaften mittels direkter Tests nur schwer und dann auch nur lokal bestimmbar sind, ist ihre indirekte Messung mittels raumerfassender nichtinvasiver geophysikalischer Messungen von Interesse. Aufgrund der engen Verknüpfung hydraulischer und elektrischer Eigenschaften in porösen Materialien wird dieser Zusammenhang näher mittels SIP untersucht. Unser Ziel ist hierbei, anhand einfacher kleinskaliger Experimente mit möglichst vielen synthetischen Proben die Wirkung von Heterogenität und Anisotropie der hydraulischen Leitfähigkeit und Konnektivität auf die frequenzabhängige komplexe elektrische Leitfähigkeit systematisch zu untersuchen.
Dazu wurden aus 2 verschiedenen Sandsteinarten und einem künstlichen Filtermaterial kleine Würfel mit 6 mm Kantenlänge hergestellt. Aus je 225 Würfeln wurden in einer gering elastischen Halterung von 50 mm Länge und einem quadratischen Querschnitt von 30x30 mm^2 Proben mit unterschiedlicher Komposition zusammengesetzt. Diese wurden vollständig mit Wasser bekannter elektrischer Leitfähigkeit gesättigt. An diesen Proben wurden die Spektren der komplexen Leitfähigkeit und die hydraulische Leitfähigkeit gemessen.
Folgende 3 Versuchsreihen wurden durchgeführt und erste Ergebnisse abgeleitet:
Ein Vergleich der Leitfähigkeit von kompakten Proben mit den aus Würfen zusammengesetzten homogenen Proben zeigt, dass der Realteil und Imaginärteil sich erwartungsgemäß vergrößern, der Effekt beim Imaginärteil der Sandsteine aber überraschend gering ist. Die unvermeidbare Entstehung von Rissen wirkt sich kaum auf die Spektrenform aus.

Anisotropie beeinflusst sowohl den Real- als auch den Imaginärteil, wobei der Effekt auch vom Parameterkontrast der homogenen Materialien und den Rissen abhängig ist.
Die Mischproben aus 2 Materialien mit statistischer innerer Struktur zeigen, dass das Volumenverhältnis der beteiligten Materialien maßgeblich Einfluss auf die Spektren hat.
Die Untersuchungen erfolgten im Rahmen eines gemeinsam von TU Berlin, Dresdner Grundwasserforschungszentrum und dem Helmholtz-Zentrum für Umweltforschung Leipzig bearbeiteten DFG-Vorhabens zur Untersuchung der hydraulischen Konnektivität von Grundwasserleitern.

OG-P-12

Laboratory studies on the relationship between soil physical properties and NMR parameters of peat

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Peat soils have important ecological functions, e.g. as natural water and carbon reservoirs. The drainage of moor areas, for example for agricultural use, leads to a release of a large amount of carbon originally stored in the moorland and the water storage capacity is irreversibly reduced. In addition to biogeochemical analyses, suitable renaturation measures also require detailed investigations of the water balance and the soil physical properties. The method of nuclear magnetic resonance (NMR) is expected to provide a potential contribution to that application field.

Within the scope of the DFG-funded MORESPIN2 project, a sensor for non-invasive soil moisture detection based on surface-NMR has been developed and tested in moor areas. For the preliminary exploration on one of our test sites in the Gnarrenburger Moor in northwest Germany, we analyzed a series of undisturbed soil samples in order to compare NMR and hydraulic parameters along a profile covering the transition from mineral to peat soil.

Up to now, the evaluation provided the following results: (1) a general differentiation between peat- and mineral-dominated soils, based on the NMR signal amplitude, is possible, because peat has a significantly higher water content (up to more than 90 vol.%) than normal mineral soils, (2) the NMR relaxation times decrease as the degree of decomposition of the peat increases. Our future studies aim on estimating the hydraulic conductivity (e.g., using the Schlumberger-Doll Research equation) and on predicting the water retention properties of peat soils from NMR measurements. In doing so, and especially with the focus on the adaptation for the MORESPIN sensor, we implement a bootstrapping method to determine and handle the uncertainties of the resulting NMR relaxation time distributions.

OG-P-13

Joint processing and inversion of active and passive ultrasonic data – first laboratory experiments

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To ensure the safety of critical infrastructure, non-destructive testing and structural health monitoring find widespread application in civil engineering. The recently started European project "USES of novel UltraSonic and Seismic Embedded Sensors for the non-destructive evaluation and structural health monitoring of infrastructure and human-built object" (USES2 www.uses2.eu) aims to combine novel sensing technologies, advanced processing, and innovative imaging for better monitoring of industrially relevant applications such as energy, mobility, and construction related structures.

To enhance the imaging of complex concrete structures, a combination of active and passive measurement data with advanced imaging based on simulating the elastic wave propagation inside the investigated object will be employed here. The primary objectives of ultrasonic concrete inspection are thickness measurements, geometry determinations, localization of built-in components, and quality assurance of the tested material. However, as concrete is a complex and heterogeneous, multi-phase material, challenges such as strong dispersion, scattering, and attenuation affecting acoustic waves occur. Consequently, detecting small defects or revealing the interior of engineered objects becomes a challenging task. Within the project, we will apply a combination of conventional Non-Destructive Testing (NDT) and geophysical imaging methods that all require full wavefield simulations such as Full Waveform Inversion (FWI), Time Reversal (TR) methods, Reverse Time Migration (RTM), and Coda Wave Interferometry (CWI).

Here, preliminary results from first laboratory tests will be shown. Measurements from the surface of a homogeneous laboratory polyamide specimen, which contained a borehole, were conducted using an ultrasonic tomography system A1040 MIRA 3D. The recorded wavefields are analyzed in detail and compared to preliminary finite-difference modelling results. Further steps will gradually increase both the complexity of the test specimens (from polyamide to concrete to in-situ structures) as well as the combination of the individual analysis methods to provide one common framework. Overall, the developed tools will serve as a powerful diagnostic tool to detect heterogeneities in solid media by providing highly consistent and accurate images of the analyzed structures.

OG-P-14

Multimethodisches Monitoring von Infiltrationsexperimenten an urbanen Baumstandorten in Braunschweig

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Eine ausreichende Wasserversorgung spielt für die Vitalität von Stadtbäumen und die von ihnen erbrachten Ökosystemleistungen eine wichtige Rolle. Die Wasserverfügbarkeit in der Stadt wird jedoch durch den hohen Grad an Oberflächenversiegelung stark eingeschränkt. In dieser Studie wird die Infiltrationskapazität von Böden an urbanen Baumstandorten gemessen, um die Wasserverfügbarkeit von Stadtbäumen als Folge von Niederschlag und

oberflächlichen Bewässerungsmaßnahmen zu bewerten. Hauptziele der experimentellen Untersuchungen sind die Bestimmung der hydraulischen Leitfähigkeit des Bodens und die Erfassung der Heterogenität des Fließfelds mit geophysikalischen Methoden.

An urbanen Baumstandorten in Braunschweig mit unterschiedlichen Versiegelungsgraden (unversiegelt, teilversiegelt, vollversiegelt) wird die gesättigte hydraulische Leitfähigkeit in situ mittels eines Dual-Head-Ringinfiltrometers bestimmt. Diese Infiltrationsexperimente werden durch ein kleinskaliges geoelektrisches Monitoring begleitet. Dabei werden widerstandstomographische Messungen mit einem Elektrodenabstand von 5 cm einmal vor und mehrmals in halbstündlichen Abständen nach der Infiltration durchgeführt. Die gemessenen geoelektrischen Daten werden mittels Time-Lapse-Inversion in pyGIMLi invertiert. Bodenfeuchtedaten von in verschiedenen Tiefen installierten Time-Domain-Reflectometry-Sensoren werden in diesem multimethodischen Monitoring-Ansatz ebenfalls einbezogen.

Erste Testmessungen ergeben gesättige hydraulische Leitfähigkeiten, die es ermöglichen, die Infiltrationskapazitäten verschiedener Baumstandorte miteinander zu vergleichen. Vorläufige Ergebnisse verdeutlichen aber auch Herausforderungen bei dem kleinskaligen geoelektrischen Monitoring, insbesondere durch die im Vergleich zum Fließfeld geringe Eindringtiefe der geoelektrischen Messungen und ein hohes Rauschlevel in den Daten. Zudem erschwert der metallische Ring des Infiltrometers eine kontinuierliche Aufzeichnung geoelektrischer Daten während des Infiltrationsversuchs. Der entwickelte Messaufbau erfasst die Infiltrationseigenschaften zwar punktuell, eine Auflösung kleinskaliger räumlicher Heterogenitäten, die durch das geoelektrische Monitoring erfasst werden sollten, bleibt jedoch eine Herausforderung.

OG-P-15

Geophysical investigation of soils contaminated with light non-aqueous phase liquids: A laboratory monitoring study with used engine oil

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Mapping and monitoring light non-aqueous phase liquids (LNAPLs) is an important topic in contaminated site characterization to protect human health and the environment. One approach to map and monitor organic contaminants such as LNAPLs relies on non-invasive geophysical methods. Ground-penetrating radar (GPR) and electrical resistivity tomography (ERT) are the most commonly used geophysical methods for mapping and monitoring such contaminations. Used engine oil (UEO) is one of the most common sources of LNAPLs contaminations threatening groundwater resources; especially, in underdeveloped and developing countries due to improper handling and disposal of the oil. However, the geophysical signatures of field sites contaminated by UEO are considered to be complex and not well understood.
In order to understand the time-lapse geophysical responses of sand aquifer systems contaminated with UEO, a semi-continuous contamination experiment in a laboratory setting has been performed. The time-lapse experiment comprised of four parts, i.e., a control experiment and three seasonal simulations mimicking winter, spring (rainy), and summer seasons. Each part lasted five weeks, resulting in a total experiment duration of twenty weeks. For geophysical monitoring, we used 2.0 GHz antennas for acquiring GPR data and 24 electrodes arranged in a specially designed miniature resistivity array for acquiring

ERT data. The GPR results revealed an increase in GPR signal amplitude in the UEO contaminated zones with increasing volume of contamination. Furthermore, our GPR results suggested a dominant vertical UEO migration. Our ERT results revealed an overall increase in resistivity values with increasing volume of contamination. We interpret our findings with the displacement of porewater and air in the contaminated zone by the UEO causing changes in the relative dielectric permittivity and electrical resistivity. In summary, our laboratory monitoring studies suggest that the geophysical characteristics of contaminated environments are largely linked to the contrast between the UEO and the physical properties of the aquifer system. These results increase our understanding of geophysical signatures of UEO contaminated soils and groundwater and pave the road for further research in this field.

OG-P-16

Utilizing SQUIDs for Compact SNMR Soil Moisture Sensors

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In recent years, strong efforts have been made to use surface nuclear magnetic resonance (SNMR) not only to characterize aquifers in the subsurface, but also to determine soil moisture distribution. Compared to SNMR measurements in the saturated zone, a significantly reduced signal amplitude with shorter relaxation times is expected in partially saturated soils. To counter this, a prepolarization field, which significantly increases the received signal, needs to be applied prior to the SNMR experiment. Furthermore, a short prepolarization switch-off time, short pulse durations and short dead times of the instrument are necessary to enable measurements for these reduced relaxation times. Combined with precise modelling and an inversion scheme, the method can yield depth resolved soil moisture distributions without the use of any additional parameters. For soil moisture investigations, the relevant depth range is relatively small and, therefore, a compact layout can be used. This enables a better portability, thus paving the way for mapping of soil moisture in a larger area.
We present a new approach, which is especially suited for these compact SNMR soil moisture sensors: the detection of the SNMR signal by a three-axis SQUID magnetometer. While during a typical SNMR experiment the current induced in a surface coil by the oscillating magnetic fields of the NMR response is detected, the instrument allows a direct and simultaneous measurement of all three magnetic field components. While the z-component mostly contains information about the depth distribution of water, the x- and y-components are primarily influenced by the horizontal water distribution in the sensitive volume. This may enable 3D inversion of the SNMR data yielding additional information about the homogeneity of the moisture distribution in the subsurface.
We show data from a proof of concept measurement on containers filled with water. Since the SQUID SNMR experiment is susceptible to ambient electromagnetic noise, a second three-axis SQUID magnetometer in a distance of 12m meters is used as noise reference. A sequence with short prepolarization switch-off times and short pulse durations is applied. Under these conditions, the prepolarization switch-off is non-adiabatic in a significant part of the sensitive volume. Furthermore, at high pulse intensities the Bloch-Siegert effect becomes relevant. We evaluate the influence of both effects by comparing the experimental results to simulated data.

OG-P-17

Evaluierung eines optisch gepumpten Magnetometers hinsichtlich seiner Eignung zur Kampfmitteldetektion

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Für magnetische Messungen in der Kampfmitteldetektion werden üblicherweise Fluxgate-Gradiometer (Differenzmagnetometer) und nur selten optisch gepumpte Totalfeldmagnetometer eingesetzt. Jedoch könnte die höhere Empfindlichkeit der Letzteren für die Detektion tiefliegender Objekte von Vorteil sein. In dieser Arbeit wird die Eignung eines optisch gepumpten Magnetometers für die Kampfmitteldetektion anhand von Messdaten untersucht, die auf dem mit verschiedenen Objekten in unterschiedlichen Tiefen versehenen Testfeld der „Stiftung kampfmittelfreier Lebensraum" in Greven (NRW) erhoben wurden. Zu Vergleichszwecken wurde zusätzlich eine Messung mit einem in der Kampfmitteldetektion etablierten Vertikaldifferenz-Magnetometer mit fünf Sonden durchgeführt.

Die Evaluierung der Ergebnisse erfolgt anhand von qualitativer Dateninterpretation und der Genauigkeit der automatisch ermittelten Objektpositionen, wobei die Positionen aus den Totalfelddaten und den Gradientendaten mit unterschiedlicher Software bestimmt wurden. Beide Magnetometer erzielen sehr gute Ergebnisse bei der Detektion und Ortung von Abwurfmunition, während das Identifizieren von Kleinmunition im magnetischen Anomalienfeld für beide Verfahren eine Herausforderung darstellt. Die Messung mit dem Totalfeldmagnetometer war aufgrund der Handhabung und der Verwendung von nur einem Sensor weniger effektiv. Dennoch liefert es gute Ergebnisse hinsichtlich Signalstabilität, Orientierungsabhängigkeit und Konsistenz der Messdaten. Im Vergleich zum Vertikaldifferenz-Magnetometer erreichten wir unter Verwendung der Daten des Totalfeldmagnetometers eine leicht verbesserte Tiefenbestimmung der Objekte, wobei dies auch auf das verwendete Auswerteverfahren zurückzuführen sein könnte.

OG-P-18

Seismic Imaging of the Weathering Zone: Unveiling the Impact of Climate and Bedrock Preconditioning

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The weathering zone, the transitional layer between the Earth's surface and unweathered bedrock, undergoes dynamic transformation under the influence of diverse factors, including climate, topography, and bedrock composition. Seismic methods have emerged as powerful tools to explore this subsurface realm, offering insights into the structure, extent, and evolution of the weathering zone. By analyzing the propagation of seismic waves through the weathered material, we can delineate the weathering front, the boundary between the weathered and unweathered zones.
This study utilizes seismic methods to investigate the weathering zone in three contrasting climatic regions: arid, humid, and mediterranean. The seismic data reveals distinct patterns in the velocity distribution of seismic waves, reflecting the varying degrees of weathering in each region. In arid environments, the weathered zone is typically shallow and characterized

by low seismic velocities due to the intense weathering processes driven by infrequent but intense rainfall events. In contrast, humid regions exhibit deeper and more extensive weathering zones, with higher seismic velocities reflecting the pervasive weathering processes under sustained moisture conditions.
While climate undoubtedly plays a pivotal role in shaping the weathering zone, our study also highlights the significance of bedrock preconditioning. Bedrock characteristics, such as inherent fractures and mineral composition can influence the weathering rate and the resulting seismic velocity profile. For instance, rocks with higher inherent fracture density tend to weather more readily, leading to lower seismic velocities.
Integrating seismic data with geological information, we can develop models that simulate the evolution of the weathering zone under varying climate conditions. These models can inform predictions about the future distribution and extent of the weathering zone, providing valuable insights for land-use planning, infrastructure development, and environmental management.
The application of seismic methods to study the weathering zone has opened up new avenues for understanding the complex interplay between climate, bedrock properties, and the weathering process. By unraveling the temporal and spatial variations in weathering, these studies can contribute to our broader understanding of Earth's surface dynamics and its influence on ecosystems, infrastructure, and human activities.

OG-P-19

Investigating sedimentary sequences and basement geometry using loop source TEM:A case study from the Salar Grande, Atacama Desert, Chile.

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The transient electromagnetic (TEM) method is a powerful technique for imaging the distribution of the electrical resistivity in the Earth's subsurface. Primarily used to characterise layered structures, it is also useful in delineating zones of high subsurface conductivities. As a part of the CRC 1211: 'Earth- Evolution at the dry limit', we carried out a field survey in the Atacama Desert, during the months of March and April, 2023. Focusing on arid and hyperarid systems, where both biota and surface processes are predominately limited by the accessibility of water, the project aims to understand how the shaping of land-surfaces by past episodes of wetter climate co-evolved with the evolution of life.

Here, we present preliminary 1D inversion results of TEM soundings collected over the Salar Grande in the Atacama, Chile. We used conventional Marquardt-Levenberg and Occam inversion techniques, in order to date and reconstruct the formation of the Salar Grande basin as depocenter for sediments, and to provide key information for understanding its evolution to a salar environment. An alluvial fan towards the East of the basin was also explored, aiming to study the fan architecture, in order to better comprehend the chronology of the filling of the SG. From East to West, a clear conductive transition to the salar can be appreciated. On the alluvial fan, different layers are imaged that may correspond to different fan deposition stages. In the middle of the basin, the Salar Grande halite body is clearly detected. Below, it is likely that the conductive layers correspond to clay rich sediments that correspond to pale lake deposits. The basement is only detected towards the basin periphery due to a limited depth of exploration. Since conventional inversion techniques do not provide an un-biased uncertainty estimate for the derived subsurface models, we pursue probabilistic Bayesian inversion and provide a comparative analysis of both techniques.

OG-P-20

Geoelektrische Untersuchungen von Hochwasserschutzdeichen entlang der Schwarzen Elster bei Senftenberg

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Die Deiche der Schwarzen Elster bei Senftenberg schützen Wohngebiete und Infrastruktur wie ein Klärwerk und eine Umspannstation. Der Aufbau der Deiche ist weitgehend unbekannt. Durch Bäume an und auf den Deichen kommt es zu Durchwurzelung und damit zu Drainagegefahr bei Hochwasser. Deshalb ist eine Sanierung vorgesehen. Im Vorfeld wurde ein umfangreiches Untersuchungs-programm durchgeführt, das Trockenbohrungen, Rammkernsondierungen, Drucksondierungen, Untersuchungen an Bohrkernen und geoelektrische Untersuchungen umfasst. Hier werden Auszüge der Ergebnisse von den geoelektrischen Multielektrodenmessungen (Sondierungskartierungen) aus zwei Abschnitten mit Längen von ca. 500 m entlang eines Deichs vorgestellt. Die Analyse der elektrischen Widerstände mittels Widerstands-Tiefenschnitten bis zu einer Tiefe von 6 m an den vor und hinter dem Deich befindlichen Deichfüßen sowie entlang der Deichkrone bis zu einer Tiefe von 8 m deutet darauf hin, dass die Deiche größtenteils aus Sand bestehen und einen sehr hohen elektrischen Widerstand aufweisen.
Es wurde festgestellt, dass es im Bereich der Deichfüße kaum bindige Deckschichten gibt und diese hauptsächlich aus Sand bestehen.

OG-P-21

Evaluierung von Verdichtungsmaßnahmen auf verflüssigungsgefährdeten Kippen mittels Oberflächen-NMR

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In den letzten 15 Jahren kam es vermehrt zu Verflüssigungsereignissen auf den Innenkippen im Lausitzer Revier, in deren Folge ca. 30.000ha Fläche gegen unbefugtes Betreten/Befahren gesperrt werden mussten. Damit stehen diese Flächen nicht mehr für ihre eigentliche Nachnutzung zur Verfügung. Das gegenwärtig praktizierte Sanierungs- bzw. Verdichtungsverfahren ist die schonende Sprengverdichtung (sSPV), bei der in festgelegten Teufenhorizonten (unterhalb des Grundwasserspiegels) minimale Sprengladungen eingebracht und nacheinander von unten nach oben gezündet werden. Primäres Ziel ist hierbei eine Verbesserung der Stabilität des Untergrundes mittels eines lokal begrenzten Gefügezusammenbruchs, welcher die Lagerungsdichte des Kippenmaterials erhöht, respektive den luft- und wassergefüllten Anteil des Porenraums verringert.

Da zum Nachweis einer erfolgreichen Verdichtung üblicherweise vor allem direkte Aufschlüsse eingesetzt werden, wollen wir im Projekt „VerLaUf" die Eignung verschiedener luft- und bodengestützter geophysikalischer Methoden für einen nichtinvasiven Verdichtungsnachweis untersuchen. Ein Hauptaugenmerk liegt hierbei u.a. auf dem Einsatz der Oberflächen-NMR (SNMR). Durch den direkten Zusammenhang zwischen NMR-Signalamplitude und Wassergehalt (Porosität) sowie NMR-Abklingzeit und Porengröße, verspricht das SNMR Verfahren nicht nur qualitative, sondern auch quantitative Aussagen über die Veränderung des wassergefüllten Porenraums nach einer Sprengverdichtung.

Die ersten Ergebnisse der SNMR Vorerkundung (1D Messungen entlang eines Profils) zeigen, trotz der Nähe zu potentiellen anthropogenen Störeinflüssen (<2000m), eine sehr gute Datenqualität. Vor allem innerhalb des Zielhorizontes, der gesättigten Kippe, zeigen die individuellen Blockinversionsergebnisse einen engen Konfidenzbereich von <10% beim Wassergehalt und <5% bei der Abklingzeit. Die Variabilität zwischen den einzelnen 1D Smooth-Inversions-Ergebnissen ist ein Indikator für die Heterogenität innerhalb des Kippenkörpers. Eine numerische Studie zur Auflösbarkeit verschiedener Verdichtungsszenarien zeigt, dass vor allem die Abklingzeit ein zuverlässiger Indikator sein wird, um die Verdichtung nachzuweisen. Die Wiederholungsmessungen im Anschluss an die ersten Sprengungen werden in Abhängigkeit vom Sanierungsfortschritt bis Mitte 2024 erfolgen. Im weiteren Projektverlauf wird ein multimethodischer Ansatz erarbeitet, der die Oberflächen-NMR mit einer flächenhaften Datenerfassung kombiniert.

SITZUNGSTHEMEN

OS – Poster

Open Source in Forschung und Lehre

OS-P-01

Open Educational Ressources and Open Source Software

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Open Educational Resources (OER) and open source software (OSS) have jointly revolutionized academic research and education. OER, offering freely accessible and openly licensed materials, eliminates cost barriers and facilitates global collaboration. Open access journals and datasets, integral to OER, democratize research dissemination. Concurrently, OSS empowers education infrastructure through customizable learning management and content systems.

OER's adaptability fosters personalized learning, encouraging collaboration among educators and students in resource creation. OSS strengthens this collaboration, supporting real-time editing and version control. The integration of OER and OSS enhances learning environments with interactive features, forums, and multimedia integration, providing a cost-efficient alternative to traditional resources.

Cost savings extend beyond OER, as OSS eliminates licensing fees associated with proprietary software, ensuring affordability. The transparent nature of OSS development aligns with academia's principles, promoting continuous improvement through peer review and collaborative problem-solving.

In essence, the synergy between OER and OSS transforms academia, creating an adaptable, inclusive, and continually evolving educational ecosystem. As the global academic community embraces these principles, the potential for positive impacts on teaching, learning, and research is immense, embodying a future where education is accessible, collaborative, and forward-thinking.

PV – Mündliche Präsentation

EM / Geoelektrik / Georadar / Gravimetrie / IP / Magnetik

PV-A-01

Changes in the complex conductivity response of sandstones due to $NaHCO_3$ infiltration, a time-lapse study

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Fluid chemistry in surface waters absent of organic life is governed by the interactions between atmospheric carbon dioxide, water, and the mineral water interfaces. Here, the inorganic aqueous species of carbon dioxide can act as acid, base, or buffer. For most near-surface waters, the hydrogencarbonate ion [HCO_3^-] is the most common one. The carbon-driven pH of water is not only important in agricultural fields as it controls nutrient availability but also in carbon storage and sequestering, given the chemical stability of the potential reservoirs. Even though the effects of high carbon concentrations on these systems are known and can be predicted, non-invasive monitoring and control of the pH in rocks and soils still face difficulty, due to inaccessibility of pore spaces. We propose the use of spectral induced polarisation (SIP) to measure the complex electrical conductivity of the subsurface. This method is based on the injection of alternating currents and can not only capture the real part conductivity used to estimate the salinity of the pore fluid, but also gain information on the structure of the porous medium via measuring imaginary part or polarisation.
The imaginary part is assumed to originate in the electrical double layer formed by the accumulation of dissolved ions, attracted by the surface charge of minerals. Charge migration in these layers in response to an external harmonic electrical field leads to relaxation processes, which can vary in strength and time in response to different properties of the sample. The timescales of these relaxation processes are controlled by the pore geometry and the mobility of the adsorped ions. Information at which rates the relaxation times respond to changes in the surface assemblage and the pH however is limited. In this study, we provide three sets of data obtained from diffusion experiments where the diffusion of a sodium hydrogen carbonate solution into quartz-rich sandstones was monitored with SIP at high temporal resolution. Our results show that even at high salinities with a corresponding reduction in chargeability, dynamic changes at the mineral water interfaces in response to the changing pH can be captured in the dominating relaxation times of the electrical polarisation. This suggests that the SIP method remains a useful tool to characterize mineral water interfaces and pore space geometries even at high salinity.

PV-A-02

4D-GPR Messungen zur hochauflösenden räumlich-zeitlichen Abbildung präferentieller Fließprozesse

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In der Hydrologie ist das Verständnis von kleinräumigen, oberflächennahen Fließprozessen von großem Interesse. Solche Fließprozesse sind häufig mit präferentiellen Fließpfaden verknüpft, die eine geringe räumliche Ausdehnung (Millimeter bis Zentimeter) aufweisen können. Diese Prozesse zeigen in der Regel eine hohe zeitliche Dynamik (Sekunden bis Minuten). Die Beobachtung (Monitoring) solcher präferentieller Fließprozesse erfordert daher Messstrategien, die eine schnelle Datenaufzeichnung mit einer hohen räumlichen und zeitlichen Auflösung, bei gleichzeitig hoher Datenreproduzierbarkeit erlauben. Aus geophysikalischer Sicht verspricht das Ground-Penetrating Radar (GPR) diese Messanforderungen erfüllen zu können. Auch besteht ein klarer petrophysikalischer Zusammenhang zwischen GPR Ausbreitungsgeschwindigkeit und Wassergehalt, so dass das Verfahren sich zur Abbildung relativer Bodenfeuchteänderungen anbietet. Auch wenn in der Literatur verschiedene Beispiele für 4D GPR-Messungen zur Abbildung von oberflächennahen Fließprozessen zu finden sind, fehlen systematische Untersuchungen hinsichtlich Auflösungsvermögen, Datenreproduzierbarkeit und Wiederholbarkeit solcher Monitoring-Experimente.

Wir präsentieren eine 4D GPR-Messstrategie zum hochauflösenden Monitoring von kleinräumigen, oberflächennahen Fließprozessen. Hierbei kombinieren wir eine 3D GPR-Messplattform (zur geführten Positionierung eines Zweikanal-GPR-Antennen-Arrays) und ein Beregnungs-Pad (zur Simulation von moderaten Regenereignissen mit 20 l/m² pro Stunde). Zur Untersuchung der Anwendbarkeit dieser 4D GPR-Messstrategie inklusive einer Abschätzung des räumlich-zeitlichen Auflösungsvermögens und Reproduzierbarkeit der Daten, wurden an einem ausgewählten Feldstandort systematisch mehrere Beregnungsexperimente durchgeführt. Unsere Ergebnisse zeigen, dass unsere Messstrategie die Abbildung lokaler, oberflächennaher Fließprozesse mit einer bisher nicht erreichten räumlichen Auflösung (< 5 cm) und zeitlichen Auflösung (< 10 min) ermöglicht. Diese Ergebnisse konnten während allen durchgeführten Beregnungsexperimenten bestätigt werden. Daher betrachten wir unsere 4D GPR-Messstrategie als geeignete Grundlage für weitere Entwicklungen, auch im Hinblick auf den routinemäßigen Einsatz im Gelände und einer quantitativen Abschätzung von relativen Änderungen der Bodenfeuchte.

PV-A-03

Investigation of a fault zone in Sub-Himalayan region (India) using Radiomagnetotellurics

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We conducted radio-magnetotelluric (RMT) measurements to investigate the Himalayan frontal thrust fault (HFT) in the Sub-Himalayan region Uttarakhand in India in the framework the Indo-German joint research collaboration (DST-DAAD). The overarching aim is the geo-electrical characterization of the fault zone, including the investigation of the fault inclination and orientation, as well as the determination of the sediment thickness in the survey area.

The data acquisition was carried out using the RMT-F system, which consists of a receiver unit, two electrical antennas to observe the electric fields, and three magnetic coils to measure the magnetic fields. We measured on eight parallel profiles with a profile separation and a station interval of 10m. In total data was acquired at 312 stations in an area of 500x70 square meters. This dense station distribution allows for a 2D as well as a 3D inversion of the dataset.

Here, we provide an overview over the data quality and the most crucial data processing steps. We performed 2D and 3D inversions of scalar and tensor impedance tensor data, as well as a joint inversion with Tipper data. Based on the derived subsurface models, we give a preliminary interpretation of the HFT zone and its geo-electrical characteristics within the area of investigation.

PV-B-01

High-frequency spectral induced polarisation to image permafrost features in Heliport, Abisko, Northern Sweden

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The geoelectrical method of induced polarisation (IP) can detect and quantify subsurface constituents that polarise under the influence of an alternating electric current, owing to established correlations between the electrical and physical properties. In permafrost regions, IP can be used to measure the polarisation of ice, and the method is termed high-frequency induced polarisation (HFIP) to reflect the frequency range (1 kHz to 200 kHz) required to observe this phenomenon.

Heliport Mire, situated in northern Sweden close to Abisko, is a peat plateau with a known presence of permafrost and is surrounded by dwarf forest vegetation. It is classified as *warm* permafrost, with ground temperatures expected close to 0°C and the active layer thickness (i.e., the thickness of the layer that thaws within the annual cycle) reported to be 44–91 cm. Despite being particularly susceptible to permafrost thaw due to climate change, this peat mire and numerous similar sites in the Arctic have been relatively underexplored. This study aims to undertake a first-of-its-kind geophysical measurement campaign at Heliport to study permafrost distribution and estimate its ice-content percentage.

The results from 50 m and 10 m HFIP transects are presented. The long transect successfully images the permafrost distribution within the mire boundary and its transition into the

neighbouring forest, where no permafrost is expected. The short transect resolves the transition from the upper unfrozen layer to the lower frozen layer. A 2-D inversion is carried out, treating all data from the different frequencies independently. The resulting true conductivity spectra of the subsurface are then used as input for an inversion in which we estimate ice content using a two-component mixture model. The HFIP dataset is complemented with ERT, GPR, unfrozen layer probing, and gravimetric water content measurements from an extracted soil core. Comparing the gravimetric ice content (converted from water content) with the HFIP-derived ice content for the short transect reveals a tendency of the model to underestimate. This underestimation may be linked to residual pore water being present even below the freezing point. Therefore, high-frequency IP measurements can be a useful tool for surveying and monitoring ground types characterised by ice-rich permafrost.

PV-B-02

Induction effects in High Frequency Induced Polarization

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Induced Polarization (IP) is a geophysical method utilizing alternating current to measure the frequency-dependent impedance of subsurface materials. The "Chameleon II" device, developed by Radic Research, extends impedance measurements in the field to high frequencies (up to 230 kHz). In this case the measurement is called High Frequency Induced Polarization (HFIP). A primary application of HFIP is the estimation of ice content in permafrost regions.

In IP data analysis it is a common assumption that induction effects can be neglected in favor of polarization mechanisms. This can be justified at low induction numbers, reflecting a small ratio of investigation scale to skin depth. When using higher frequencies than usual and working in arctic permafrost mires with relatively low resistivities compared to alpine permafrost, induction effects cannot categorically be disregarded.

The objective of this work is to interpret HFIP data while accounting for induction effects. We investigated the conditions under which induction can be considered negligible by comparing results from 1D simulations with and without induction effects. To do so, we use the scaling property of induction simulations: by scaling down layer thickness and electrode spacing in the same way we eliminate the influence of induction effects without changing other aspects of the model.

Our results highlight the significance of induction effects in some cases, particularly for the application in arctic permafrost. In order to correct for induction effects, we developed a 1D inversion program based on the simulation methods. The inversion code can fit data with induction effects and, if the fit was successful, calculates data free of induction that may then be used in conventional SIP inversion codes. The program was tested with synthetic datasets and with field data, proving its usefulness in practical application.

Understanding induction mechanisms in HFIP not only enhances the reliability of this method but may also be an opportunity to collect further information useful for interpretation.

PV-B-03

Inverting time-domain induced polarization field data using Debye discretization

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Induced polarization (IP) can provide important insight into the subsurface properties if measured in a wide spectral range. However, this requires appropriate inversion of the whole spectrum of the measured data. Frequency domain (FD) data in the lab can be decomposed into Debye distribution. Field data can be spectrally constrained in order to reveal spectral properties, but lack robust data acquisition. In contrast, time-domain (TD) IP instruments can efficiently provide the information, but cannot be easily be inverted in a general ways. State-of-the-art inversion approaches discretize the subsurface by Cole-Cole type models. However, this assumption does not hold in general. We present a new approach where we use a Debye distribution for every model cell so that every spectral behaviour can be described. Using the pyGIMLi toolbox, we constrain the inversion both spatially and spectrally in the Debye domain. The full wave train of on and off times is taken into account in the forward modelling. As a result, one can retrieve total chargeability or log-mean relaxation time as subsurface function.
We exemplify the method by synthetic and several field data set, demonstrating that both the images are robust and meaningful, and the retrieved parameters can be used for subsurface characterization based on the spectral information and agrees with FDIP data acquired at the same site.

PV-B-04

Modeling of the Stern-layer polarization in pore throats considering different mineral surfaces

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Spectral induced polarization (SIP) is a geophysical method based on measuring the frequency-dependent complex electrical conductivity. The frequency dependency is caused by polarization processes on the micro scale and varies for different geologic materials. Commonly, polarization processes in the low-frequency range are related to the electrical double layer (EDL) at the mineral-water interface: Due to chemical reactions with the aqueous electrolyte, material surfaces are usually electrically charged. On the electrolyte side, this surface charge is counter-balanced by ions of opposite charge forming the EDL.
The formation of the EDL can be described by surface-complexation models (SCM) that take reactions at the mineral surface into account. Here, we present SCMs for both a montmorillonite surface and a quartz surface in contact with a NaCl electrolyte. Depending on the type of mineral surface and the electrolyte composition, the counter-charges in the EDL are either adsorbed to the surface in the Stern layer (SL) or accumulated in the diffuse layer (DL) with a concentration decreasing (counter-ions) or increasing (co-ions) with the distance from the surface.
Mechanistic models can provide insight into the polarization processes at the microscopic scale. Existing models attribute the frequency-dependent complex conductivity in the low-frequency range to both the polarization of the SL, particularly around particles, and the polarization of the DL, which is often argued to become important in constrictions along the pore channel.

We present a semi-analytical model for the polarization of the SL in such a pore-constriction geometry consisting of a sequence of two cylindrical pores. The modeling results show that the model is sensitive to the structure of the EDL, i.e. both the equilibrium charge density in the SL and the radial variation of the ion concentration in the DL.
We discuss modeling results for montmorillonite and quartz surfaces, for which the observed polarization response behaves vastly different: Most of the charges in the EDL at a montmorillonite surface are accumulated in the SL, which leads to SL polarization being the dominant polarization process. On the other hand, due to the more balanced partition of charges between SL and DL at the quartz surface both SL polarization and membrane polarization have a significant contribution to the overall polarization response.

PV-B-05

Numerical modeling of the electrical polarization of microbial cells

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The spectral induced polarization (SIP) method enables the exploration of the frequency-dependent complex conductivity of subsurface materials. This technique is versatile, allowing the observation of signals emanating from biological soil components. Notably, a substantial portion of these signals originates from bacteria and their activity. Various bacterial cultures have already been studied in the laboratory using SIP. Distinct low-frequency peaks in the imaginary part of the conductivity have been related to the presence of bacterial cells and their activity. The experimental evidence thus far however have relied on existing mineral grain based polarization models to interpret results. Here, we aim to develop a mechanistic model for polarization on the surface of bacterial cells.

Our conceptualization involves a single spherical bacterial cell immersed in an electrolyte. As a first approximation, we treat the cell membrane as having negligible thickness, but acting as a barrier to ion flow. The system's ion transport and electrical field are described by the Nernst-Planck and Poisson equations, which we solve numerically using a finite-element approach.

Our simulations reveal that the presence of an external field induces the formation of diffuse layers both inside and outside the cell membrane. The resulting frequency-dependent conductivity exhibits two distinct peaks in the imaginary part at high frequencies (100 kHz to 100 Mhz). We attribute one of these peaks to the Maxwell-Garnett effect. For the second peak, we fit the conductivity to a Cole-Cole model, conducting empirical parameter studies to understand the model's sensitivity to these parameters and their impact on relaxation time.

Furthermore, we compare our numerical results with a so-called analytical single-shell model for biological cells. This model describes the effective complex conductivity of a spherical cell filled with electrolyte and includes the effect of a characteristic capacitance of the membrane. By defining the membrane capacitance as the cumulative capacitance of the diffuse layers, which form inside and outside of the membrane, we obtain good agreement of the adapted analytical model with our simulations.

PV-B-06

Modellierung der Membranpolarisation für beliebige Elektrolytlösungen

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Mit der Methode der spektralen induzierten Polarisation (SIP) wird die Frequenzabhängigkeit der komplexen Leitfähigkeit der Materialien im Untergrund vermessen. Ein Modell zur Erklärung der Polarisationsprozesse, die zu dieser Frequenzabhängigkeit führen, ist die Membranpolarisation. Dabei findet eine Polarisation der im Porenwasser gelösten Ionen im Porenraum des untersuchten Gesteins oder Sedimentes statt. Voraussetzung für das Zustandekommen der Membranpolarisation ist die durch chemische Prozesse an der Porenoberfläche verursachte elektrische Doppelschicht. In Porenengstellen führen die ungleichen Konzentrationen unterschiedlich geladener Ionen in der elektrischen Doppelschicht zu einem Unterschied der Transportraten für die verschiedenen Ionensorten. Beim Anlegen eines elektrischen Feldes führen diese dann zur Ausbildung der Membranpolarisation. Bisherige Modelle zur Beschreibung der Membranpolarisation gehen von einem symmetrischen und einwertigen Elektrolyt aus.
Wir stellen ein Modell der Membranpolarisation vor, das beliebige Elektrolyte, d.h. insbesondere mehrwertige und asymmetrische Elektrolyte berücksichtigen kann, da reale Grundwässer in der Regel auch solch komplexe Elektrolytzusammensetzungen aufweisen. Dafür gehen wir von einem bereits existierenden semi-analytischen Modell für die Membranpolarisation von einem Porenraum aus, der aus einer eindimensionalen Abfolge von weiten und engen Poren besteht. Das bestehende Modell erweitern wir auf den Fall beliebiger Elektrolytzusammensetzungen. Die Modellvorhersagen gleichen wir für den Grenzfall eines einwertigen Elektrolyts mit existierenden analytischen Lösungen ab und validieren sie außerdem für den Fall mehrwertiger, asymmetrischer Elektrolyte mit numerischen Finite-Elemente-Simulationen. Neben einer meist guten Übereinstimmung des neuen Modells mit numerischen und analytischen Lösungen ergibt die Untersuchung der Modellvorhersagen zudem, dass hohe Valenzen die Membranpolarisation verstärken, während hohe Konzentrationen sie schwächen. Das neue Modell stellt einen wichtigen Schritt zur Integration relevanter, bisher unberücksichtigter Aspekte in ein vollständigeres Membranpolarisationsmodell dar. Damit verbessert es auch unser grundlegendes Verständnis der frequenzabhängigen Polarisation von Materialien im Untergrund.

PV-C-01

Modelling of Distorted Transient Electromagnetic Data: A Case Study from a Waste Site near Cologne, Germany

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Transient electromagnetic (TEM) data can be significantly distorted by induced polarization (IP) and geometrical effects, leading to sign reversal features and, if overlooked, false geological interpretation. The aim of this study is to incorporate these effects in the forward modelling and to recover the IP parameters from distorted TEM data using an efficient inversion algorithm. To achieve this aim, we developed a 1D forward and inversion code to investigate the incorporation of IP effects using different parameterizations. Moreover, we used 3D TEM modelling to study the effect of 3D geometry. Subsequently, we modelled the effect of a 3D chargeable target on TEM data using the novel custEM toolbox. For 1D inversion of distorted TEM data we used the Levenberg-Marquardt algorithm. However, the result of inversion strongly depends on the starting model.

To evaluate the performance of our algorithm using field data, we carried out a 1D inversion of TEM data acquired along a profile that traverses a waste site located near Cologne, Germany. Furthermore, to obtain a priori information and validate the results of TEM data modelling, we conducted an electrical resistivity tomography (ERT) and time-domain IP (TDIP) survey along the TEM profile. A 2D inversion was used to retrieve the Cole-Cole parameters as input for TEM interpretation. By including the IP information, the TEM field data can be explained quantitively, and a consistent and improved interpretation of the waste body is achieved.

PV-C-02

Metal-bearing infrastructure as secondary source: An approach to deal with EM data afflicted with infrastructure effects

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The presence of metal-bearing infrastructure can lead to significant distortion of electromagnetic (EM) measurements and thus give rise to artefacts in inversion models. As the demand for exploration geophysics in populated areas grows, so does the need to understand and reduce the impact of railway tracks, steel-casings of pipelines, power lines, conveyor belts and the like on EM investigations. These objects are characterized by high conductivities, strong material property contrasts compared to the surrounding Earth and small-scale geometries. Physically, to understand how infrastructure electromagnetically couples with the underground is challenging; numerically, accurate modelling of infrastructure effects is highly computationally expensive.

We investigate approaches to include metal-bearing objects in 3D inversion schemes of semi-airborne electromagnetic (sAEM) synthetic and field data. We focus on induced currents in metal-bearing infrastructure caused by grounded transmitters, rather than on the effects of infrastructure that is actively carrying a current, such as pipeline corrosion protection. Due to very specific frequencies at which the latter effects occur, their influence on EM investigations is assessable straightforwardly.

Based on an established procedure for modelling of strong material property contrasts, highly conductive objects can be treated as 1D perfect electric conductors (PECs), implying corresponding boundary conditions on mesh element edges. We exploit the potential of this approach for sAEM data in 3D inversion and expand on this by developing an approach to treat metal-bearing infrastructure as secondary source − comparable to transmitters used in sAEM. The secondary source approach overcomes limitations associated with the PEC approach, like the assumption of perfect electric conduction, and is more reflective of the prevailing physical conditions. Following inversion for the actual current in infrastructure segments, arising secondary field contributions can be estimated. Including them in a workflow to invert sAEM data for the conductivity distribution of the subsurface, infrastructure effects in synthetic and field data are shown to be attenuated. The secondary source approach contributes to a better understanding of prevailing induction mechanisms and could enable reasonable interpretation of EM data afflicted with infrastructure effects.

PV-C-03

Comparison of airborne natural source electromagnetics systems over Hatchet Lake target, Canada

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In this study we compare the capabilities of the new airborne quantum-sensor based audiomagnetotellurics (QAMT) system from DIAS Geophysical powered by Supracon to measurement data recorded in 2017 with the Z-axis tipper electromagnetics (ZTEM) system from Geotech. These two airborne electromagnetic measurement systems for the airborne natural source electromagnetics method were tested over the Hatchet Lake target in the Archean Western Wollaston Domain which is located approx. 8 to 20 km from the north-eastern margin of the Athabasca Basin, Canada. The region is known for Uranium deposits exhibiting strong electrical conductivity contrasts. The ZTEM receiver is a well-established, commercial system and thus suited for comparison of our novel airborne electromagnetic receivers.

The results show a good agreement of the data for four frequencies from 22 Hz to 90 Hz. The QAMT data were processed by bivariate and multivariate estimation techniques for calculation of the magnetic transfer functions between the magnetic field vectors recorded in the air and horizontal magnetic field components recorded with a ground-based magnetic receiver station. The QAMT survey was completed on the central part of ZTEM survey lines which provides a good opportunity for data comparison.

Finally, preliminary inverted electrical conductivity results of the QAMT data are shown and compared to ZTEM data.

PV-C-04

Multi-source 3D imaging of a graphite deposit using drone-based semi-airborne electromagnetics

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The transition towards renewable energies demands secure supply with critical raw material and requires efficient non-invasive methods for deep earth resources exploration. The novel DESMEX (Deep electromagnetic sounding for mineral exploration) semi-airborne electromagnetic (semi-AEM) exploration concept aims at efficient exploration of resources down to 1 km depth. Here we present an exploration study combining ground based controlled source electromagnetics (CSEM) with drone-based semi-AEM in a graphite mining district in eastern Bavaria, Germany.

At the ground, several horizontal electrical dipole transmitters were deployed, utilizing a rectangular current function with a base frequency between 1 Hz and 12 Hz. Drone-towed magnetic field sensors measure the EM field along flight lines with dense spacing and within several overlapping flight areas, providing a fast data acquisition and a high spatial coverage. As sensors, a three-component induction coil triple and a total-field magnetometer was

utilized. In addition, multi component magnetic as well as electric field measurements on a 3D grid were conducted at the ground, adding complementary information to the drone-based dataset. We will present the concept and first results from the conducted survey, including an overview over the obtained transfer functions and preliminary 3D inversion results. Imaged shallow high conductivity structures can be correlated with graphite-rich zones and match well with existing helicopter-borne EM results.

PV-C-05

3D Inversion of Loop-Source Time-Domain Electromagnetic Data – Application to Synthetic & Field Data

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Multi-dimensional inversion of Transient electromagnetic data is a computationally expensive task. Only few developments and practical interpretation tools exist. Here, we present a multi-dimensional inversion framework for loop source time-domain electromagnetic data. The developed algorithm is a robust, efficient, and user-oriented tool for the multi-dimensional inversion of typical loop source time-domain electromagnetic configurations. A time-domain finite volume discretization and the direct solver MUMPS are utilized to solve the 3D TEM forward problem. An iterative Gauss-Newton optimization method is implemented for the inversion kernel. The code is parallelized for calculating multiple sources simultaneously to accelerate the inversion. Based on exploration tasks, different configurations exist for commonly used loop source TEM configurations and typical field scales. Synthetic examples are used to verify the effectiveness and benchmark the developed 3D algorithm. Considering that TEM data is often gathered along profiles, adjusting the model roughness along the different modeling domain directions, sufficiently constrains to allow for 2D imaging. In addition to the vertical signal components, we also included horizontal components for large scale fixed loop applications. Subsequent to synthetic validation, the inversion algorithm is further verified using ~120 dense TEM soundings collected over a clay pan site in the Atacama Desert, Chile, to provide bedrock geometry information and suitable coring sites. The 3D inversion result provided an excellent depth estimate of sedimentary infill as well as the bedrock topography and was later confirmed by deep coring. Another interesting site is the Roter Kamm impact crater in Namibia. Our preliminary results obtained from largescale multi-component fixed loop TEM data reveal a sedimentary infill down to ~300 m depth. In conclusion, our presented 3D inversion code is capable to handle data from various exploration scenarios and provides a robust tool for advanced EM interpretation.

PV-C-06

Large-scale 3D electromagnetic modeling with custEM on small computing platforms using an iterative solver

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Forward modelling of large and geometrically complex models and the inversion of three-dimensional (3D) electromagnetic data with direct solvers require comparatively high computational costs. These solvers are widely used due to their generality and robustness, but their memory requirements scale proportionally to the order of N^2 in 3D, with N being

the number of degrees of freedom. Therefore, the available computational resources may limit the size of feasible problems even on high-performance computing platforms. The latter have become increasingly available but the worldwide accessibility to such infrastructure can still pose a major restriction for researchers.
In light of this, we added an iterative solver to the customizable electromagnetic modelling toolbox custEM in order to reduce the time and memory requirements for calculating complex 3D electromagnetic fields with the finite-element method. We present an evaluation of the computational requirements of the iterative framework for various models based on calculations on laptop and small cluster platforms. Further, we compare the resource requirements, performance and scalability of the iterative solver with the default direct solver MUMPS used by custEM. Our examples clearly indicate the superiority of the new iterative framework in all regards for forward modeling tasks.
First experiments with the iterative solver for inverse modeling applications show that using an iterative instead of a direct solver as forward operator in the inversion is feasible for small data sets of around two hundred receivers and yields acceptable simulation times while benefiting from the reduced memory requirements. This could potentially allow for inversions with more inversion parameters in exchange for longer simulation times. Finally, we address challenges and alternative approaches for solving inverse problems with thousands of right-hand sides with the iterative framework. They are the main reason for the prolonged simulation times when employing an iterative instead of a direct algorithm.

SITZUNGSTHEMEN

PV – Poster

EM / Geoelektrik / Georadar / Gravimetrie / IP / Magnetik

PV-P-01

Geoelectrical monitoring of soil moisture in hugelcultures

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Climate change increasingly affects soil water availability. Due to prolonged dry periods and elevated temperatures, fields, gardens and plantations dry out, leading to a reduction in the production of vegetables, fruits, and grains. Gardeners face a major challenge: Achieving high-yielding harvests despite adverse conditions and limited water availability. One promising possibility to attain profitable harvests with minimal watering is through hugelcultures. Hugelculture (translated from German as "mound culture") is a gardening and permaculture practice that involves creating raised beds using decaying wood and organic matter.
Hugelcultures are expected to offer several advantages for successful crop planting and harvesting. One advantage is that they might contain a moisture reservoir in the core, supplying plants with water during dry periods. An Electrical Resistivity Tomography (ERT) monitoring of soil moisture shall prove this hypothesis and can make an important contribution to the planning and maintenance of hugelcultures.
For accurate insights, three hugelcultures of varying ages situated in two gardens in Braunschweig, Germany, were examined. Each bed had two to three ERT profiles with a 0.2 m electrode spacing. Additionally, Time Domain Reflectometry (TDR) sensors were installed at

depths between 20 and 70 cm for complementary soil moisture information. Weekly ERT measurements were recorded over a period of 5 months, enabling observations of seasonal fluctuation. TDR sensors continuously monitored soil moisture and temperature every 15 minutes during the same period, providing high temporal resolution. We also investigated the impact of irrigation on hugelcultures. One bed was watered daily for half an hour, while the other two received irregular irrigation.
Initial TDR sensor analyses revealed dry and moist periods correlate with weather events. The soil moisture measurements indicate that deeper sensors near the core of the hugelculture were moister than surface sensors. Raw ERT data and soil moisture data correlate well. First individual inversions of the ERT data indicate a dry surface and moister core of the hugelculture as well as lateral variations of moisture, which might reflect spatial patterns in maintenance and irrigation intensity. Upon comparing the results of the various hugelcultures it becomes evident that intensive watering is unnecessary especially when deep rooting plants are used for cultivation.

PV-P-02

Monitoring spatial and temporal soil moisture dynamics with 3D Electrical Resistivity Tomography in a sandy soil under a pine forest

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Within a joint project between the Federal Institute for Geosciences and Natural Resources (BGR) and the Northwest German Forest Research Institute (NW-FVA) we applied 3D electrical resistivity tomography. Our study investigated the spatial and temporal soil moisture dynamics of an albic podzol under a pine forest in the North German Lowlands. In the sandy soil with deep groundwater, we installed a 3D array with 300 electrodes with 0.5 m and 1 m spacing. We took measurements every 6h from September 2022 until December 2023 and applied 3D inversion to each measurement separately.

We observed large spatial heterogeneities in the forest soil, with anomalies of lower resistivity at the positions under trees and stumps. These anomalies persisted across all seasons. To gain better understanding of the resistivity dynamics and the spatial differences, 1D curves were extracted from all time steps by applying volumetric averaging for discrete depth steps over the whole model grid. We found different resistivity development with depth, comparing the 1D curves at a certain location between seasons. The comparison between the locations under trees with locations without trees revealed spatial differences in the resistivity development with depth. Under wet conditions during winter, the resistivity showed an increase from the surface to a depth of approx. 1.5 m, where our model resolution falls below a critical threshold. During June the resistivities were much higher but exhibited spikes towards lower resistivities. The spikes were mainly observed beneath the positions of the trees. Compared to root density data we discuss the relationship between the ERT measurement results, soil moisture dynamics and the influence of the roots themselves.

PV-P-03

Spatio-temporal salinity dynamics of a coastal aquifer on Spiekeroog island

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Coastal aquifers at the transition zone between freshwater and saltwater show large salinity contrasts. Salinity is a key parameter to understand coastal groundwater flow dynamics and consequently geochemical and microbial processes in subterranean estuaries. Within the project DynaDeep, we apply geophysical and hydrogeological methods accessing either bulk or fluid conductivity to monitor the temporal and spatial salinity changes. Investigation area is a high-energy beach on the North Sea Island of Spiekeroog.
A unique dataset has been acquired since 2022, covering a 2D transect from the dune base to the low water line including strong topographic changes over the seasons. We use electrical resistivity tomography (ERT) to get access to 2D distributions in a six-week cycle.
Additionally, continuous monitoring is carried out using a saltwater monitoring system (SAMOS) down to a depth of 20 meters located at the high-water line. Direct push (DP) data at various locations and EC values from fluid samples gathered via DP provide high-resolution 1D information. In three multi-level wells (6, 12, 18, and 24 meters depth) we log the fluid EC and temperature and take samples on a regular basis.
For a dense dataset between January and March 2023 we compare the applied EC methods in detail and found a general agreement after suitable calibration and temperature correction. We furthermore derive a formation factor model for the conversion to salinity. We use a combined inversion of the ERT data with the additional data aiming for fluid EC directly under the assumption of this temporally fixed formation factor model. In contrast to standard inversion techniques, this allows for a naturally occurring smooth transition of salinities over the different geological units, which is critical when analyzing the spatial and temporal changes. As a result, we show salinity distributions based on the combined dataset along with the temporal dynamics of the dataset in six-week steps of the ERT campaigns.

PV-P-04

Strategies for geoelectrical monitoring of subsurface fluid transport processes using Optimized Experimental Design

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In highly sensitive and complex environments, such as closed repositories, it is crucial to enhance the information content of planned (geo)physical measurements while keeping the costs to a minimum. Previous studies have proposed methods to optimize both sensor positions and measurement configurations for Electrical Resistivity Tomography (ERT) surveys in subsurface environments with static or moving targets. This study extends Optimal Experimental Design (OED) strategies for geoelectrical measurements by incorporating information from active time-dependent transport processes in the subsurface. Three distinct approaches for process monitoring are presented and applied to a simulated diffusive-advective transport process across multiple time steps. The methods aim at focusing the survey only on the relevant part of the model, in this case the model region that is affected by the transport process. All methods consider uncertain model input parameters by introducing an uncertainty factor in the ranking function. The study introduces a purely model-driven and a purely data-driven time-dependent OED approach. The former relies solely on model predictions to focus the survey, while the latter utilizes

previously acquired data to generate predictive focusing masks for the next dataset. Additionally, a hybrid approach combining simulated transport distance and already acquired datasets is outlined.
Comparative analyses show that the adaptively designed, time-dependent OED approaches result in increased image quality compared to both standard surveys as well as time-independent OED methods. For slow transport processes or small monitoring intervals, the purely data-driven approach is deemed most suitable, as it does not involve model predictions and, therefore, avoids potential uncertainties in model parametrization. Conversely, for faster transport processes or monitoring strategies with larger intervals, the approaches that (partly) incorporate model predictions show the most promising results.

PV-P-05

Direct Current-Induced Polarization Constrained by Ground Penetrating Radar for Improved Delineation of Geological Boundaries at test sites around Lake Bolmen, Sweden

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The browning of lake water in boreal forest regions negatively affects the ecosystem, the drinking water treatment, and the recreational value. Lake Bolmen, located in the South of Sweden is surrounded by coniferous forests and peatlands, and by numerous ditches that drain directly into the lake and deliver dissolved organic matter which increases the browning. The geophysical part of the project "Preventing the brownification of water" aims to explore the hydrogeological system of the region and identify its main features that contribute to the brownification. In this study, direct current-induced polarization (DCIP), which has proven effective in monitoring hydrological and ecosystem processes, was applied to characterize the geology of the region surrounding the lake and the thickness of organic-rich sediments. Ground Penetrating Radar (GPR) complemented the geoelectrical method to determine interfaces between adjacent geological layers more accurately. Using a two-channel frequency 170/600 MHz antenna, GPR data was collected at the exact locations of DCIP lines and then processed to pick continuous high-amplitude reflections indicative of geological interfaces. The results showed that integrating GPR reflectors into the mesh and removing the smooth transition between adjacent layers during the DCIP inversion facilitates the identification of geological horizons and regions with different electrical properties for most of the six investigated sites. The effectiveness of using structural constraints from GPR in DCIP inversion has been demonstrated by comparing inversion models across diverse locations around Lake Bolmen.

PV-P-06

Shallow sub-surface faults detected by GPR in an alluvial fan mark recent tectonic activity in the Campo Imperatore Fault Zone (Italian Apennines)

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As part of a geological mapping course we surveyed several alluvial fans on the Campo Imperatore in the Italian Apennines. These fans are formed by outwash material originating from the footwall of the main fault of the active Campo Imperatore Fault zone. It is deposited in the flatter valley planes by successive flood events and forms characteristic lobes which in parts overly young glacial sediments. The fans increase in age in the down-valley direction. We find that the post-glacial fans have not yet developed an appreciable stratigraphy which can be imaged by radar. However, an older and larger fan situated beyond the glacial extent of the last glacial maximum shows clear stratigraphy in the upper tens of meters in multiple kilometers of 50 MHz GPR profiles. The stratigraphy crops out at the fan's toes indicating previous glacial erosion of fan material. We also find multiple characteristic offsets consistent with comparatively recent tectonic (normal) faulting. These structures can be traced laterally in high-resolution surface elevation models derived from drone-based structure from motion imagery. This joint dataset therefore provides opportunities to constrain the tectonic history of the area and also to study the coupled geomorphological response.

PV-P-07

Richtungssensitive Georadar Bohrlochmessungen in der Bohrung EBrg. 700-4 in der Schachtanlage Asse II

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Die Messmethode Georadar eignet sich aufgrund der üblicherweise geringen Leitfähigkeit im Salz und damit verbundenen hohen Eindringtiefe hervorragend zur Strukturerkundung des inneren Aufbaus von Salzstrukturen.
Besonders im östlichen Teil der Salzstruktur um die Schachtanlage Asse II werden zurzeit die existierenden geologischen Modellvorstellungen ergänzt und überarbeitet. Hierzu wurden in den vergangenen Jahren alle durchgeführten Erkundungsbohrungen durch richtungssensitive Georadar-Bohrlochmessungen der Mittenfrequenzen 50 MHz und wo möglich auch 250 MHz begleitet. So konnten umfangreiche räumliche Strukturinformationen gewonnen werden, die es erlauben ein detailliertes geologisches 3D-Modell zu konstruieren. Am Beispiel der Bohrung EBrg. 700-4, gestoßen von der 700-m-Sohle aus nach Südosten werden die Messergebnisse von der richtungssensitiven 50 MHz AT-Sonde vorgestellt.

PV-P-08

Joint inversion of hydraulic tomography and cross-borehole induced polarization data for hydraulic conductivity imaging

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Accurate and high-resolution information about hydraulic conductivity K within an aquifer is an essential precondition for modeling groundwater flow and transport processes correctly. Hydrological methods, such as hydraulic tomography (HT), are based on pumping tests, and they typically yield very reliable K-estimates, because those can be inferred directly from the hydraulic processes. However, these tests are time-consuming and expensive, so that data are mostly sparse and structural features can only be imaged with very limited spatial resolution. In contrast, geophysical methods like induced polarization (IP) have the ability to provide structural images of much higher resolution, but they depend on approximate petrophysical relations that can introduce significant uncertainties to the estimation of K. For this reason, a joint inversion procedure for both HT and IP data has been developed that allows for combining the complementary abilities of both methods. Within this approach, a travel time inversion is applied to the HT data, while the IP inversion is based on a full-decay time-domain forward response, as well as a re-parameterization of the Cole-Cole model to invert for K directly. We test the new inversion procedure, as well as individual HT and IP inversions, on a simple synthetic model, and thereby illustrate how the imaging results can be improved by combining the complementary sensitivities of both methods within the joint inversion. It is also shown how the novel approach can correct biases within the petrophysical relations automatically, by taking into account both the reliable K-information from hydraulic tests and the high-resolution structural information from IP. The quality of the different inversion results is assessed by using the structural similarity index (SSIM), which underlines the robustness of the joint inversion compared to using the data individually. Therefore, we conclude that the combined application of HT and IP within field surveys and a subsequent joint inversion of both data sets has the potential to improve our understanding of hydraulically relevant subsurface structures, and thus the reliability of groundwater modeling results.

PV-P-09

Marine Self-Potential, Electromagnetic and Magnetic Survey Models of Seafloor Massive Sulphide Mounds

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We conducted three-component electric self-potential, EM induction-loop and magnetic mapping of seafloor massive sulphides (SMS) in the Indian Ocean. Two different deep-towed vehicles have been used to perform high resolution mapping at altitudes of 50 m and 2-3 m above seafloor, respectively. The multi-parameter datasets are expected to provide more accurate models of the 3D structure and especially the subsurface extension of SMS mounds. We present exemplary results of finite element modelling to discuss how multi-geophysical and multi-resolution datasets can be used to explore the individual assets of the applied methods, reduce ambiguities, derive sound interpretations, and finally to gain a better understanding of the resource potential, i.e. the volume and composition of SMS deposits in the deep ocean.

PV-P-10

The Mongolian MT array

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In an ongoing effort, we have acquired broad-band MT data at more than 500 stations covering now approximately 60 % of the country of Mongolia with a 50 km spaced backbone grid filled in with mainly north-south oriented profiles with denser site spacings between 5-10 km. Subsets of the data have so far been used to study lithospheric structure, fluid-related processes in the lower crust, geodynamic phenomena that can explain the uplift of the Hangai dome, the formation of prominent mineral belts in the context of the mineral system approach, faulting along lithospheric scale fault zones, Cenozoic volcanism and geothermal exploration.
In addition to these scientific problems, we used the project for capacity building and for teaching purposes. Our Mongolian partners have recently established their own MT lab at the Institute of Astronomy and Geophysics of the Mongolia Academy of Sciences. For teaching, we have developed a modular Matlab based time series processing code that can handle data from a variety of MT recorders in an automated fashion and uses optionally scripts or a graphical user interface to control processing and data analysis steps. A html-manual has been setup to support writing dedicated MT processing scripts. We tested this code in a student project in the context of a lecture on MT, where students processed brand-new MT data from Mongolia.
In this contribution, we present the status of the Mongolian MT array, and we introduce our processing code. We will also report our teaching experience.

PV-P-11

Sharp horizontally constrained 1D inversion of 3D FD-EMI data set with structural constraints from GPR: performance evaluation with two field cases.

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3D frequency domain electromagnetic induction (FD-EMI) surveying with portable multi-configuration loop-loop sensors is an efficient method to image the spatial distribution of electrical conductivity in the subsurface with a relatively high lateral resolution. In this study, we present the application of a recently developed pseudo-3D sharp inversion procedure (sharp horizontally constrained 1D inversion), which works with structural information obtained from 3D GPR surveying. We notably show how both structural constraint and model sharpness constraint yield to pseudo-3D models, which are significantly different than models resulting from more classical approaches (e.g., non-structurally constrained and/or based on smoothness constraints). This study highlights how non-unique are the electrical conductivity models, and by this fact, how non-unique is the subsequent geological interpretation.

PV-P-12

Imaging subsurface structures through synthetic modeling and inversion using semi-airborne electromagnetic method

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Electromagnetic (EM) methods in geophysics are widely used in geological mapping, mineral exploration, geotechnical investigations, environmental studies, and groundwater studies. EM surveys can be employed in different ways such as semi-airborne, airborne, and ground-based EM methods. Semi-airborne EM (SAEM) methods can provide a balance between resolution and depth penetration compared to grounded and airborne EM methods. They have the advantage of avoiding difficult terrain, such as mountains areas, forests, rivers, and rough topographies. Additionally, they are more cost efficient and environmentally friendly compared to airborne methods for which helicopters are used.
We have studied the magnetic response of a conductive clay layer and a fault zone with SAEM method, employing both helicopter and drone survey methods. To conduct the study, synthetic data were generated using the custEM Python toolbox, an open-source development for customizable 3D finite-element modeling of natural-source electromagnetic data. Forward modeling was performed for various scenarios, including a clay layer, a clay layer with a hole, and a fault zone. To simulate real-world conditions, 5% random noise was added to the synthetic data. Subsequently, inverse models were calculated using the custEM toolbox, and their accuracy was validated through the chi-square statistic. The results of the study demonstrated the successful characterization of synthetic clay layers and fault zone, highlighting the effectiveness of SAEM methods in resolving subsurface structures. While these findings are accurate for synthetic models, the study acknowledges the potential complexities associated with real-world data, which may lead to different and more complecated results. This research demonstrates that the SAEM methods have the ability to model details near the surface with high resolution and the ability to penetrate deeper into the subsurface. This compromise makes semi-airborne methods suitable for a variety of applications in various geological and environmental settings.

PV-P-13

Developing a Methodology for Estimating Natural Hydrogen Production in Serpentinization Zones: A Case Study from Eastern Morocco

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Exploring for natural (white or golden) hydrogen is worthwhile as natural hydrogen offers a sustainable and clean energy source, producing only water as a byproduct, and, thus, significantly reduces environmental impact compared to fossil fuels. It contributes to energy security, diversification, and can even stimulate economic growth through the development of new industries and technologies in some parts of the world. In response to this, part of our research in the LEAP-RE project "HyAfrica" aims to develop a methodology for estimating natural hydrogen production rates in serpentinization environments, focusing on a specific region in Eastern Morocco. Our approach integrates multiple levels of analysis, including "surface", "shallow", and "deep" components of the natural hydrogen system. We identify potential hydrogen seeps or semi-circular structures at the surface using the Natural

Hydrogen Seeps Detection (NHSD) algorithm and examine surface faults with detailed geophysical data. The near-surface analysis involves constructing a comprehensive 3D geological model of the potential reservoir seal, potentially extending to great depths. For the deep component, we employ the new Quantifying Natural Hydrogen Generation (QNHG) algorithm in the inversion of potential field data, i.e. gravity and magnetic anomalies, to evaluate the extent of serpentinization in rocks, their volumes, and impacted areas. These results, combined with temperature data, help to determine which rock segments can generate hydrogen. We then extrapolate laboratory-generated hydrogen values from rock samples to our full-scale model to estimate hydrogen production rates from the identified ultramafic rocks.

PV-P-14

Modeling the induced polarization of partially saturated porous media

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Many existing models describing the induced polarization effect of porous media assume fully saturated conditions. In reality, however, this is not always the case and partially saturated media with a pore space not exclusively filled with electrolyte are of interest in a range of applications. Although laboratory measurements have already been conducted, numerical models are needed to improve our basic understanding of the polarization effect in partially saturated media.

This work introduces initial investigations with a simple numerical model to study the induced polarization of air inclusions in the electrolyte using a finite-element approach. It is assumed that the polarization of the electric double layer at the water-air interface of air bubbles could be approximated by a pure Stern layer polarization. 2D simulations reveal that the polarization strength in this scenario increases with decreasing saturation for high saturation levels between 85% and 100%.

However, the assumption of pure Stern layer polarization is a significant simplification. A likely pronounced polarization of the diffuse layer at the water-air interface, owing to the high zeta potential, is neglected by the above model. Therefore, we also present first approaches for a model that appropriately considers the polarization of the diffuse layer at the water-air interface.

In order to achieve more realistic outcomes, plans for future investigations also presented here incorporate different geometries of air bubbles at various saturation levels. This approach is expected to allow a more accurate prediction and understanding of the polarization effect of partially saturated porous media.

PV-P-15

Preliminary Transfer Function Estimates of AC Power Lines

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When performing semi-airborne electromagnetic (sAEM) measurements in populated areas we encounter different additional active sources of EM signals, mainly from infrastructure such as power lines or the corrosion protection of pipelines. In general, there are two possibilities to treat additional EM emitters. Either we understand them as noise and remove them from the signal or we may treat them as an additional transmitter and infer information from the distribution of its signal. This poster presents the processing of EM signals emitted from power lines treating them as an EM signal analogue to a transmitter.
While the injected current of a dipole transmitter can be recorded directly, the EM signal emitted from power lines remains unknown. Therefore, a ground station was setup to record the magnetic field at a fixed position in the vicinity of the power line. This ground station recordings contain encoded information about the current in the powerline and is used as a reference for the transfer function estimates. As both recordings are linearly dependent on the current, the current cancels out in the estimates for the transfer function.
We apply this method to a data set recorded in September 2023 as part of the DESMEX-REAL project in the Harz. Transfer functions are calculated for various frequencies between 50 and 850 Hz. The resulting estimates are consistent over up to 4 km from the power line. To use this type of transfer functions for inversion, the next steps would be an adaption of the inversion schemes to use a ground station as reference. This should take the inductive contributions to the magnetic field at the ground station as well as the geometry of the power line into account.

PV-P-16

Possibilities of exploring the whole-mantle velocity-density relation using normal modes and gravity data

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A key indicator for mantle thermochemical structure is the relationship between seismic velocity and density variations. Seismic velocity and density can become uncorrelated due to compositional variations or phase changes, whereas temperature variations alone would only lead to correlation (i.e. less dense = slower). However, even in a purely thermal scenario, the relationship between velocity and density can be non-linear (especially due to attenuation and partial melting) and depth-dependent.
Using long period seismological data, models of the Earth's normal mode frequency variations can be estimated, which can be described in term of splitting functions. Functioning similarly to a surface wave phase velocity map, the normal mode data can be used to infer seismic velocity (mainly shear waves) and density within the mantle. To improve the recovery of the density structure (to which normal modes are only weakly sensitive), gravity data are included.
The inverse problem is formulated in terms of a collection of discrete anomalous volumes, so that the location, size and velocity/density of each anomaly become the sought unknowns. When the number of volumes is also unknown, a Bayesian formulation of the inverse problem leads to a trans-dimensional setup. This model setup enforces parsimony in the sense that models with less anomalous volumes are preferred over more complicated models.
We present initial results using the normal mode catalogue of Deuss et al. in combination with satellite gravity data from the XGM2019 gravity model.

SM – Mündliche Präsentation

Seismik

SM-A-01

Advancing seismic imaging: Fresnel volume migration in anisotropic and anelastic media

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Advanced seismic imaging techniques play a crucial role in generating reliable, high-resolution subsurface images across diverse applications, such as exploring hydrocarbons and minerals, characterizing geothermal reservoirs, and selecting sites for radioactive waste disposal. In this study we present the extension of the seismic imaging technique, Fresnel volume migration (FVM), to anisotropic and anelastic media.

A wavefront construction method for 3D anisotropic (TTI) velocity models was employed to compute the Green's functions required for FVM. This wavefront construction method was further developed by calculating complex traveltime fields (t*) for predefined quality factor (Q) models, describing the anelastic attenuation of seismic waves. Subsequently, these resulting traveltime fields (t*) were used in the migration process to facilitate the corresponding anelastic compensation of the amplitudes.

The developed method was applied to synthetic 2D data and a real 3D dataset obtained over the Asse salt structure in Lower Saxony, Germany (2020). The migration with anelastic compensation demonstrated a correct enhancement of amplitudes in the synthetic data. Furthermore, the application of the anisotropic FVM to the real 3D dataset resulted in a significant improvement in the imaging quality of reflectors throughout the area surrounding the salt structure.

Our findings underscore the pivotal role played by considering both anisotropy and anelastic attenuation in complex 3D models for achieving a reliable and high-resolution subsurface image using the further developed FVM approach. The latter lays the foundation for subsequent quantitative analyses of reflectors and hence supporting dependable geological interpretations.

SM-A-02

Imaging neotectonic faults in the Northern Upper Rhine Graben using a muliti-method geophysical approach

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As part of the Neotectonics in the Northern Upper Rhine Graben (NeoNORG) project, a comprehensive multi-method geophysical strategy was used to investigate two faults in the Northern Upper Rhine Graben. The study combined 3D seismic data from the petroleum industry with 2D P-wave and S-wave seismic, Electrical Resistivity Tomography (ERT), and Ground Penetrating Radar (GPR) surveys to create a detailed structural model of two major faults.

The 3D seismic data provided details of structures between 450 m to 4 km depth, while the 2D P-wave survey, designed for high resolution, supplemented this data for shallower depths (50-600 meters). S-wave seismic imaging revealed disrupted layering and synsedimentary features, while ERT measurements further supported the identification of offset horizons and indicated synsedimentary activity, particularly up to 10 meters in depth. GPR results remained ambiguous, though they suggested potential geological features related to tectonics. It was found that both faults had varying dip angles and offsets in different stratigraphic units, proving tectonic movement occurred during sedimentation in the Neogene and Quaternary layers. In general, the faults both steepened upwards, forming typically listric shapes. They both offset the base Quaternary by approximately 35 meters. Finally, the very-near-surface methods show that the faults extend up to the Earth's surface, proving their neotectonic activity.

The study's integrated approach not only helps to comprehensively understand the shallow subsurface but also underscores the importance of detecting neotectonic fault activity for seismic risk assessment. The methodology adopted in this NeoNORG project serves as a precedent for similar geological investigations, i.e., by exploiting the potential of multi-method geophysical surveys in neotectonic research. It also contributes to our understanding of potential gas migration along fault zones to the Earth's surface.

SM-A-03

On the assessment of fluid pathways along the southern flank of the Asse salt structure

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From 1967 to 1978, nuclear waste was deposited in the former salt and potash mine Asse II in Lower Saxony. Since 1988, water inflow and structural instabilities have occurred and pose risks to the secure storage of the nuclear waste. In response, the German parliament decided in 2013 to abandon this nuclear repository. For the safe retrieval of the radioactive waste and construction of a new shaft, a detailed understanding of the geological structure of the Asse is required. In 2020, the operator Bundesgesellschaft für Endlagerung (BGE) therefore acquired new high-quality 3D seismic data.

As the water inflow plays a crucial role regarding the integrity of the repository, this study investigates details of the Asse geology along the southern flank of the salt structure, which is associated with potential fluid pathways. The prevailing hypothesis suggests that fluids travel from the top of the salt dome to the mine's ingress point through the fractured Röt-Anhydrite-B formation, which has a thickness of about 16 meters. To understand the influence of this formation on the seismic data, several geological models were built and used to simulate seismic data by finite-difference modelling.

This allowed us to study the influence of changes in various properties such as, for instance, the layer's wave propagation velocities, density, or thickness, leading to changes in the reflection coefficients or tuning and scattering effects. Furthermore, we could study where such changes would show up at the surface in the recorded seismic data. In a final stage, migrated common-image gathers (CIG) from the field data were analyzed and checked for potential signatures that resemble effects seen in the synthetic studies.

With this comprehensive approach we were able to identify characteristics of changes in the critical angle and waveforms varying with the alteration of the parameters of the anhydrite layer. An expected decrease in the velocity and density in this formation due to fractures results in an increased critical angle and a decrease in the amplitude of the reflection coefficient prior to reaching the critical angle. From the modelled tuning effects, we can infer the thickness of the anhydrite layer. With these learnings, current investigations focus on the question of whether the very weak seismic signatures of the fluid paths observed in the modelling can be identified in the 3D seismic field data.

SM-A-04

Potential of 3D matrix ultrasonic measurements to image complex concrete structures

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Ultrasonic echo testing is a well-established non-destructive testing technique used to investigate the interior of concrete structures in civil engineering. For the reconstruction of internal features, methods similar to seismic imaging are applied. To improve the ultrasonic imaging capabilities, we investigate the potential of a newly available 3D matrix mode measurement device in combination with advanced imaging techniques.

Commonly used ultrasonic array measurement devices rely on several ultrasonic transducers coupled to act as one transducer that transmits or receives transversal ultrasound waves. Although this approach is well suited to detect elongated structures such as pipes and rebars, it has limitations if 3D embedded objects are present. Hence, the ultrasonic device MiraA1040Pro used here is designed to measure the ultrasonic wavefield on a 4 by 16 matrix of individual transducers.
For testing, we used laboratory specimens with linear and spheric embedded structures first. Both linear and matrix mode measurements were conducted and analysed using the Synthetic Aperture Focusing Technique (SAFT) which is similar to Kirchhoff migration. Second, we used a data set from Teutschenthal mine at a shotcrete specimen constructed to simulate engineered barriers tailored for nuclear waste repositories. Ultrasonic measurements were investigated as a tool for quality assurance of these structures. The specimen contains both artificial 3D artifacts as well as naturally occurring defects such as a delamination. To make use of the advanced data acquisition, focusing 3D imaging techniques are applied to further improve the imaging quality.

Generally, the reconstructed images from the 3D matrix mode data have a lower level of Signal-to-Noise-Ratio than the 2D linear mode because the source signal is weaker compared to the linear mode. Moreover, complex wave conversions of the SH-transversal wave occur that are reduced in the 2D linear scenario. However, clearer images can be achieved at non-linear features, particularly with focusing imaging methods.
Thus, combining 3D data acquisition techniques with advanced imaging methods improves the success in imaging complex concrete structures. This is of particular interest for thick concrete structures in nuclear barrier systems or foundations. Additionally, we demonstrate opportunities to use well-constrained test laboratory scenarios from non-destructive testing as a practical test case for geophysical methods.

SM-A-05

Geophysikalische Überwachung von Projekten zur Kohlendioxid Abscheidung und Speicherung in Norddakota

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Staatliche und regionale Bemühungen zur Erschließung geologischer Kohlendioxid (CO_2)-Speicherstätten in Norddakota (ND), USA, haben zu laufenden kommerziellen Projekten zur CO_2-Abscheidung und -Speicherung (CCS) geführt. Der Energy & Environmental Research Center, das CarbonSAFE-Programm des Energieministeriums, die Plains CO_2 Reduction Partnership und Industriepartner unterstützen Standortwahl, Charakterisierung, Gestaltung und Überwachung der ND CCS-Projekte.

Veränderungen des geologischen Reservoirgesteins und Fluideigenschaften aufgrund einer CO_2 Injektion lassen sich gut mit geophysikalischen Methoden überwachen, da diese Änderungen geophysikalische Anomalien der Elastizität, Dichte und Widerstandsfähigkeit darstellen. Diese Veränderungen können quantifiziert werden, wenn die geophysikalischen Methoden vor und nach CO_2-Injektion angewendet werden.

Seismische Untersuchungen sind die geophysikalische Boa_Image_Framemethode zur Überwachung der CO_2-Injektion in unterirdische Lagerstätten und der Integrität des Deckgesteins. Controlled-Source Elektromagnetische (CSEM) und Schwerkraftmethoden wurden als alternative oder ergänzende CO_2-Überwachungsmethoden in einem ND-Projekt untersucht, bei dem die sichere, dauerhafte geologische Speicherung von CO_2 im kommerziellen Maßstab bewertet wurde, das von einem Kohlekraftwerk erzeugt wurde.

Es wurden Machbarkeitsstudien für seismische, CSEM und Schwerkraftmethoden durchgeführt, um die Wirksamkeit dieser Methoden bei der Überwachung von CO_2 in der Broom Creek Formation (Fm) und Deadwood Fm im Untersuchungsgebiet zu bestimmen.

Während alle drei Methoden zur Überwachung des in die Broom Creek Fm injizierten CO_2 verwendet werden können, erwiesen sich nur die seismischen und CSEM-Methoden als anwendbar für die Überwachung des in die Deadwood Fm injizierten CO_2. Basierend auf den positiven Ergebnissen dieser Studien wurden Baseline seismische, CSEM-, magnetotellurische und Mikrogravitationsdaten erfasst. Bewältigung der Herausforderungen bei der Datenerfassung im Zusammenhang mit natürlichen Hindernissen und elektrischer Infrastruktur rund um das Kraftwerk, Datenverarbeitung, Modellierung und Inversion der geophysikalischen Basisdaten zeigte, wie wichtig qualitativ hochwertige Daten für ein geophysikalisches CO_2-Überwachungsprogramm sind.

Die Kombination fortschrittlicher Techniken, z. B. Join Inversionsmethoden mit gleichzeitiger Anwendung seismischer und CSEM-Methoden würden sich positiv auf die Daten Interpretation auswirken.

SM – Poster

Seismik

SM-P-01

Imaging the near-surface structure in the Syddenmark region utilizing shear wave reflection seismics

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In the framework of the EU funded project BlueTransition (www.interregnorthsea.eu/blue-transition) a shear wave reflection seismic pilot survey was carried out in southern Denmark in June 2023 by LIAG in cooperation with project partners Region Syddenmark and the Geological Survey of Denmark and Greenland (GEUS). In the region, climate change affects the groundwater table balance due to increased precipitation and sea-level rise. This implicates rising groundwater level and river flooding, imparing urban settlement, agriculture, and industry. As a climate change adaption, integrated water management solutions based on a 3D geological model and hydrology modelling are in focus to mitigate the environmental impacts in the pilot areas Bylderup-Bov and Aabenraa.
The subsurface structure in depth range of 0-200 m was influenced by several glaciations and postglacial tectonic activity. The Quaternary succession reaches a thickness of up to 160 m, whereas a detailed knowledge on the lithology is mostly restricted to the uppermost 50 m depth (based on groundwater production wells). Shallow subsurface structure data e.g. based on geophysics is only partly available in the area. Aims of the investigations are a) to illuminate the subsurface structures as a basis for a sustainable groundwater management in the future, b) to enhance the knowledge about the glacial processes and postglacial tectonic activity in the study area, and c) to evaluate the applied methods.
By partly parallel operation of two seismic acquisition crews, nearly 7 km high-resolution profiling was carried out within 9 days (partly nights). Field operation was supported by mostly perfect weather conditions, slightly hampered by delays in the permitting process regarding traffic safety, leading also to an unexpectedly cost increase.
The survey results image geological structures down to a depth of 150 m. Lateral variations of the resolution challenges the interpretation. The upper part of the aquifer is imaged in great detail, including the top of the main aquitard layer, as a distinct reflector. The observed structural elements imply a young, partly syn-sedimentary tectonic activity. The top Oligocene (Tertiary/Paleogene), encountered by one well in the investigation area in a depth of nearly 160 m, is partly imaged in the seismic sections. Based on the results of the seismic interpretation, EM surveys will be subsequently carried out to characterize the hydrologic subsurface structure.

SM-P-02

Test einer Galperin-Quelle für die hochauflösende Multikomponenten-Reflexionsseismik

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Im Rahmen eines ICDP Projektes (5068_2) hat das LIAG in Basadingen/Schweiz u.a. ein P-Wellen Profil mit einem hydraulischen P-Wellen Vibrator (30 kN peak force) über eine fast 300 m tiefe quartäre Rinne gemessen. Auf einem Teilstück mit 37 Anregungspunkten (144 m) des insgesamt 1,2 km langen Profils wurden zudem S-Wellen mit der ELVIS-7 Quelle (1 kN peak force) in zwei horizontale Richtungen angeregt und die Galperin-Quelle der ETH Zürich getestet. Letztere besteht aus einem Stahlblock mit drei 20 x 20 cm² großen Flächen, die um 120° gegeneinander horizontal versetzt sind und eine Neigung von 54,7° gegenüber der Horizontalen besitzen. Die Anregung erfolgt auf jeder Fläche separiert mit einem Hammerschlag. Registriert wurde mit 200 3-Komponenten Geophonen in kartesischen Koordinaten. Zunächst wurden die orthogonalen Quellvektoren der Galperin-Quelle ein kartesisches System mit horizontalen (Nord-Süd/Ost-West) und vertikalen Komponenten transformiert. Für die horizontalen Anregungsrichtungen wurden dann mit einer Komponentenrotation (Alford 1984) die S_h- und S_v- Wellenfelder separiert.
Beide Quellen liefern Abbildungen bis zur Quartärbasis in fast 300 m Tiefe mit jeweils beiden Polarisationsrichtungen der S-Wellen. Dabei unterscheiden sich die Abbildungen jeweils mit S_h und S_v Polarisation nur wenig, bei beiden Quellen zeigen die S_h-Sektionen leichte Vorteil bei der Abbildung von Reflektoren im oberen Bereich (<100 m). Im Vergleich der Quellen wiederum zeigen dort die Anregungen mit der Galperin-Impulsquelle eine kontinuierlichere Abbildung als diejenigen mit der Elvis-Vibrationsquelle. In größeren Tiefen reicht jedoch die Energie der Galperin Quelle nicht mehr aus, um eine zum Vibrator vergleichbare Bandbreite der Reflexionen aufrecht zu erhalten. Die vertikale Komponente der Galperin Quelle bildet hingegen den gesamten Tiefenbereich der Rinne ab, wenngleich auch nicht mit der Qualität des hydraulischen Vibrators.
Die Galperin Konfiguration bietet damit ein sehr interessantes Konzept für eine Mehrkomponentenanregung, da (1) eine vertikale Komponente mit erzeugt wird (2) die Ankopplung tendenziell besser als bei rein horizontal anregenden Quellen ist (3) die Quelle nicht (wie bei vielen anderen Quellen) zwischen den unterschiedlichen horizontalen Anregungen versetzt werden muss.

SM-P-03

Abbildung der Krustenstruktur im Bereich des Laacher See durch Re-Prozessierung der reflexionsseismischen Profile DEKORP 8701 und 8702

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Im Rahmen von DEKORP (Deutsches Kontinentales Reflexionsseismisches Programm) wurden im Jahr 1987 mehrere tiefenseismische Profile im Rheinischen Schiefergebirge akquiriert. Im Gebiet des Laacher Sees erfolgte ein reflexionsseismisches Experiment zur detaillierten Abbildung der Untergrundstruktur. Aufgrund der relativ schlechten Datenqualität ließen sich aber bei früheren Bearbeitungen der Daten keine direkten Hinweise auf eine Magmakammer finden. Wir haben die reflexionsseismischen Profile der Messung mit aktuellen seismischen Abbildungsverfahren prozessiert und die Ergebnisse interpretiert.

Dazu erfolgte zunächst die Aufbereitung der seismischen Daten sowie die Qualitätskontrolle. Darauf folgte die Bestimmung der Ersteinsätze der Teilprofile 8701 und 8702.
Für jedes Profil wurde ein individuelles Geschwindigkeitsmodell mit Hilfe von Ersteinsatzlaufzeittomographie erstellt. Das so erhaltene P-Wellen-Geschwindigkeitsmodell stellte die Grundlage für die Anwendung der folgenden Prestack-Tiefenmigration dar. Als Methoden kamen dabei die Kirchhoff-Migration und die Kohärenzmigration zum Einsatz. Es zeigte sich, dass in den Ergebnissen der Kohärenzmigration (verglichen mit der Kirchhoff-Migration) deutlicher Reflektoren abgebildet wurden. Die migrierte Sektion des Profils 8701 zeigt klare Reflektoren unterhalb des Laacher Sees in einer Tiefe von ca. 3,5 km. Aufgrund der Einfallsrichtung und Position der Reflektoren kann es sich dabei um den Rand der Magmakammer handeln. Die Ergebnisse von Profil 8702 sind weniger deutlich und aussagekräftig, unterstützen jedoch generell die des Profils 8701. Zur genauen Bestimmung der Lage der Magmakammer unter dem Laacher See sind allerdings neue seismische Messungen mit deutlich dichterer Akquisitionsgeometrie erforderlich.

SM-P-04

Auflösung als seismisches Attribut

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Die Reflexionsseismik ist eines der wichtigsten Verfahren zur zerstörungsfreien Erkundung des Untergrundes. Sie kann unterirdische Strukturen über weite Gebiete und Tiefenbereiche mit hoher Auflösung abbilden. Um die Ergebnisse zuverlässig beurteilen zu können, ist es wichtig, die Unsicherheiten der Seismik zu quantifizieren. Eine zentrale Größe hierfür ist die räumliche Auflösung. Sie gibt den minimalen Abstand zwischen zwei seismischen Einsätzen an, bei denen diese gerade noch als zwei diskrete Merkmale wahrgenommen werden können.
Theoretische Betrachtungen der seismischen Auflösung werden in zahlreichen Lehrbüchern behandelt, jedoch wird der praktische Nutzen für die Interpretation kaum diskutiert. Das mag daran liegen, dass die zugrundeliegenden Parameter, wie Bandbreite und Geschwindigkeit des seismischen Signals, im finalen Abbild nicht explizit ersichtlich sind. In Folge dessen findet oftmals keine räumlich differenzierte Betrachtung des Auflösungsvermögens statt, sondern lediglich eine pauschale Abschätzung.
Zur Quantifizierung und Visualisierung von Unsicherheiten in verschiedenen seismischen Datensätzen (2D-/3D-Seismik) wurden dominante Wellenlänge und Größe der Fresnelzone als seismische Attribute berechnet. Beide Attribute lassen sich dabei mit Funktionen, die in Interpretationssystemen üblicherweise zur Verfügung stehen, aus den finalen seismischen Abbildern berechnen und anschließend transparent über die Seismik blenden.
Die Ergebnisse zeigen die Vorteile, den der Attribut-Ansatz mit sich bringt. Neben dem allgemein üblichen Trend, dass die Auflösung mit zunehmender Tiefe abnimmt, wird offensichtlich, dass sich unterschiedliche geologische Einheiten z. T. durch erhebliche Auflösungsunterschiede auszeichnen können und dass die Auflösung entlang einzelner Einheiten auch deutlich variieren kann. Insbesondere Störungen und Schichtauskeilungen zeichnen sich dabei i. d. R. lokal durch eine signifikant herabgesetzte Auflösung ab. Über die Unterstützung bei der Interpretation hinaus lässt sich der Attribut-Ansatz vor allem auch zur Quantifizierung der Unsicherheiten der interpretierten Strukturen selbst nutzen. Indem vertikale und laterale Auflösung als Fehlergrenzen für jeden Datenpunkt im Seismogramm aufgefasst werden, können auch für alle interpretierten seismischen Strukturen implizit Fehlergrenzen mit angegeben werden. Die Auflösung als seismisches Attribut zu berechnen, stellt somit einen echten Mehrwert für die Seismik dar.

SM-P-05

Structural geological features and neotectonic evolution of the Bielefeld-Segment of the Osning Fault System

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Neotectonic movements present significant hazards and are relevant for seismic hazard assessment and subsurface utilization. To improve our understanding, investigating recently-active fault zones like the Osning Fault System (OFS) in North Rhine-Westphalia, is crucial. The OFS has a history of seismic activity, with notable earthquakes in 1612 and 1767. Unlike other faults in the region, the OFS extends to the basement and dips northeastward. The fault system was thus influenced by glacial isostatic adjustment and subsequent fault reactivation.

Our approach combines 2D P- and SH-wave reflection seismics with retrodeformation of previously-published cross-sections, along with surface geological maps and limited drilling information. The seismic surveys, measured to the west and east of the city of Oerlinghausen across the Bielefeld-Segment of the OFS, comprised of three P-wave profiles to image the subsurface down to ca. 600 to 700 m and four SH-wave profiles resolving structures down to ca. 100 m depth.

These seismic profiles effectively outline the fault structures of the Bielefeld-Segment of the OFS. The P-wave profiles image several northward-dipping faults that partly form fault splays. They upthrust the Cretaceous and Triassic formations toward the south and are interpreted as hitherto unknown extensions of the OFS. More to the south, southward-dipping normal faults are imaged, which are interpreted as basin faults of the margin of the Münsterland Basin dipping towards the basin centre.

While the P-wave profiles do not adequately capture the Quaternary layers, there are indications that the faults continue into this formation. The SH-wave profiles, offering superior near-surface resolution due to much smaller wavelengths, validate these assumptions by exposing additional faulting and deformation features within the Quaternary sediments.

The interpretation and fault imaging were further improved by evaluation of various migration methods for the SH-wave data and seismic attribute analysis.

Furthermore, retrodeformation and balancing of both existing cross-sections and interpreted seismic profiles were employed to evaluate the fault geometry and kinematics. Through this process, we identified and implemented necessary adjustments to improve the geological plausibility of the profiles. This integrated geophysical and geological approach contributed to a deeper understanding of the neotectonic evolution of the OFS.

SM-P-06

3D High-Resolution Velocity Model Building for the Characterization of a Nuclear Waste Disposal Site (Asse, Lower Saxony)

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The DOSIS project aims at the design of an optimized, combined, and high-resolution seismic imaging workflow to answer geological questions for the site investigation of radioactive repositories in Germany. Methods like full-waveform inversion for velocity model building and focusing prestack depth migration techniques (e.g. Fresnel-volume migration) for structural imaging are further developed to compensate for seismic anisotropy and anelastic attenuation. Precise mapping of structures in depth requires a well resolved velocity model, which is vital for prestack depth imaging.

For validation, a massive 3D seismic data set acquired in 2020 over the Asse salt structure in Lower Saxony is used. The principal aim of this 3D seismic survey was to increase the understanding of structural formations around the Asse salt mine for monitoring and planned retrieval of the radioactive waste which was put into storage there between 1967 and 1987.
In the presented study, we used the 3D surface seismic dataset for the derivation of a highly resolved velocity model for the shallow part of the study area (< 1 km) by first-arrival traveltime tomography. The dataset comprises more than 1.5 billion traces acquired by Vibroseis and explosive sources over an area of approximately 7.5 km x 5 km. Careful evaluation of inversion parameters, testing of different initial models and editing of picks with high misfit lead to a very good fit of the observed and modelled first break times. The results revealed a shallow 3D velocity model with well resolved structural details that will not only serve as input for the further application of prestack depth imaging and full waveform inversion but also directly contribute to the interpretation of the geological setting and the planned retrieval of the radioactive waste in the near future.

SM-P-07

Characterisation of heterogeneities and anisotropy in the Opalinus Clay by seismic tomography, core and borehole investigations (Mont Terri underground rock laboratory, Switzerland)

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A multidisciplinary investigation of heterogeneities in a clay rock formation, based on seismic tomography, logging, and core analysis, has been performed as a reconnaissance study for a diffusion experiment. Diffusion experiments in clay rock formations provide crucial experimental data on diffusive transport of radionuclides (RN) in extremely low hydraulic conductivity media. The sandy facies of the Opalinus Clay exhibits a significantly more pronounced heterogeneity compared to the shaly facies, and a combined characterisation and RN diffusion study has been initiated to investigate various approaches of heterogeneity

characterisation and subsequent diffusion in a heterogeneous environment. As an initial step, two inclined exploratory boreholes have been drilled to access the margins of the experiment location. These boreholes have been used to acquire a cross-hole tomographic seismic data set. Optical, natural gamma and backscattering logging were applied and rock cores were analysed. The integrated results of these investigations allowed the identification of an anomalous brighter layer within the investigated area of the sandy facies of approximately 1 m thickness and with its upper bound at roughly 10 m depth within the inclined exploratory wells. Mineralogical analyses revealed only slight variations throughout the rock cores and indicated that the anomalous layer exhibited a slightly higher quartz content, and locally significantly higher calcite contents, accompanied by a lower content of clay minerals. The anomalous layer was characterised by reduced natural gamma emissions, due to the lower clay content, and increased neutron backscattering likely indicating an increased porosity. Seismic P-wave velocities, derived from anisotropic tomography, exhibited a maximal gradient near the top of this layer. The transition from the overlaying darker rock matrix into this layer has been identified as an appropriate location for the setup of a tracer diffusion experiment in a heterogeneous environment.

SM-P-08

Seismic imaging of the Ivrea Zone and the Balmuccia peridotite

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Outcrops of isolated mantle peridotite bodies can be found in the Ivrea Verbano Zone (IVZ). To investigate an exposed peridotite body near Balmuccia (Italy) and its connection to the Ivrea geophysical body (e.g. Scarponi et al. 2021) a controlled-source seismic experiment was carried out in the area around Balmuccia. Two crossing profiles ran along (10 km, NNW-SSE) and across (17 km, W-E) the Balmuccia peridotite body. Three vibro trucks were used to acquire 432 vibro points (~60 m spacing) which were recorded on 110 3C receivers (~250 m spacing, fix-spread setup) and 330 1C receivers (~20 m spacing, roll-along setup).
Different seismic techniques are utilized to obtain a structural image of the Balmuccia peridotite body and its surroundings and to characterize its properties. A Markov chain Monte Carlo travel time tomography is performed using first-break picks of the fix-spread data set (Ryberg et al. 2023). The resulting 3D P-wave velocity model shows a high-velocity body (Vp > 6 km/s) that extends from the surface down to 3 km depth. It reaches the surface East of Balmuccia which coincides with the location of the exposed Balmuccia peridotite. The location of the Insubric Zone correlates with a sharp velocity change that limits the high-Vp body to the West. The extend of the seismically imaged peridotite body is larger than interpreted from previous geological cross-sections (e.g. Quick et al. 2002).
To characterize the shallow sub-surface (<1 km depth) with higher resolution, P-wave travel time analyses are also performed using the roll-along data set. The occurrence of strong shear waves enables additional Vs and Vp/Vs analyses. Neural network-based cluster analysis reveals distinct model regions with well-defined seismic properties (Vp, Vs, Vp/Vs) which can be correlated with lithological units and structures at the surface. Due to difficult terrain settings (deep mountain valleys with sedimentary filling, large altitude variations) complex wave propagation is observed (e.g. converted waves) that is challenging for conventional seismic reflection processing. Therefore, pre-stack migration techniques are applied to image steep dipping structures.

References: Quick et al. (2002): https://doi.org/10.3133/i2776
Ryberg et al. (2023): https://doi.org/10.1093/gji/ggad182
Scarponi et al. (2021): https://doi.org/10.3389/feart.2021.671412

SO – Mündliche Präsentation

Seismologie

SO-A-01

On DAS-recorded strain amplitude

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The power of distributed acoustic sensing (DAS) lies in its ability to sample deformation signals along an optical fiber at hundreds of locations with one interrogator only. While the interrogator is calibrated to record 'fiber strain', the properties of the cable and its coupling to the rock control the 'strain transfer rate' and hence how much of 'rock strain' is represented in the recorded signal.

We use DAS recordings carried out with a Febus A1-R interrogator in an underground installation colocated with an array of strainmeters in order to measure the 'strain transfer rate' in situ. A tight-buffered cable and a standard loose-tube telecommunication cable (running in parallel) are used, where a section of both cables covered by sand and sandbags is compared to a section, where cables are just unreeled on the floor.

Signals from the Mw 7.7 and Mw 7.6 earthquakes that took place on the East Anatolian Fault on February 6th 2023 allow us a proper comparison of signals in the frequency-band between 50 mHz and 0.2 Hz. At lower frequencies the DAS signal-to-noise ratio is insufficient. At higher frequencies the invar-wire strainmeters show a parasitic response to vertical ground motion. For frequencies up to 1 Hz we use seismometer recordings to estimate strain for an incoming plane wave, based on the ray parameter and in this way extend the bandwidth of the comparison. The ray parameter varies along the recording but is sufficiently well known and can be validated against the strainmeter recording.

The 'strain transfer rate' is largely independent of frequency in the band from 0.05 Hz to 1 Hz and varies between 0.15 and 0.55 depending on cable and installation type. The sandbags show no obvious effect and the tight-buffered cable generally provides a larger 'strain transfer rate'. The noise background for 'rock strain' in the investigated band is found at about an rms-amplitude of 0.1 nstrain in 1/6 decade for the tight-buffered cable. This allows a detection of the marine microseisms at times of high microseism amplitude.

SO-A-02

Valuable information gained from coseismic localized strain at secondary faults observed with InSAR

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We observe that surface strain caused synseismically by large earthquakes sometimes localizes at neighbouring faults that have not been part of the actual rupture. With the space-borne InSAR technique and under good conditions we may quantify this locally increased strain down to the centimeter with very high spatial resolution. Excellent examples of this synseismic effect have been observed for the 2019 Ridgecrest earthquake sequence in California. These strain localizations highlight tectonic faults in coseismic displacement maps as weak zones in the surface material, may they be known and mapped or not. The direction of strain varies spatially and the variation patterns suggest that the localized plastic strain accommodates coseismic stress changes due to the mainshock. E.g. we observe tectonic normal faults that show a reverse character of synseismic strain localization in areas under compression and also strain direction changes along faults.

We will present examples of synseismic strain localizations found in Sentinel-1 SAR interferograms of M~6 normal-faulting earthquakes. The InSAR products have been processed to full resolution and with weak filtering, which gives them an astounding clarity. With estimations of the east-west and vertical displacement components and predicted coseismic strain based on finite-fault source models, we can show that the direction of localized strain follows the regimes of coseismically induced dilatation and compression. Furthermore, the variations of strain directions can be very characteristic and support the estimation of more realistic, multi-segment source models.

SO-A-03

Interseismic displacement rates along the Medlicott-Wadia Thrust in the Northwest Himalayas based on InSAR time series

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Investigations at active faults in interseismic times can give us insights into earthquake hazard. We study an area located in the Sub-Himalayan zone in the northwest Himalayas in a so-called "seismic gap", where the last major earthquake occurred more than 500 years ago. In our work here, we determine relative ground displacement rates based on InSAR time series that occur in the interseismic phase of the earthquake deformation cycle. Our aim is to detect currently active motion on the morphologically well expressed Medlicott-Wadia Thrust (MWT) for which geological slip rates have been estimated. However, the annual monsoon season and farming in the area strongly reduce the data quality, particularly the interferometric coherence, required for estimations of surface displacement rates.

For the estimation of displacement rates, we use in 2023 updated and improved data sets from ascending and descending orbits of the Sentinel-1 radar satellites, which we downloaded from the database "Looking inside the Continents from Space" (LiCS) of the Center for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET). The data span a time frame from 2014 to 2022. We apply the LiCSBAS open-source software

to create InSAR time series based on the small baseline subset (SBAS) technique and to estimate displacement rates with a high spatial resolution of about 200 m. In addition to extracting areas with sufficiently high interferometric coherence close to the MWT, we derived displacement rates from line-of-sight into east/west and up/down components. With the interferometric coherence and the precision of the time series analysis, we also assign data error estimates to displacement rates.

We were able to detect clear gradients of ground displacement rates across the Medlicott-Wadia Thrust. With the help of statistical analyses and a segmentation method, we were able to quantify and classify rate differences along the MWT and in the immediate vicinity. We observe variations in the movement along the fault, which are often found at morphologically distinct fault sections. We classify our InSAR results together with displacement rates found in geological analyses for longer periods of time as well as with displacement rates from GNSS stations in the region.

SO-B-01

A comprehensive analysis of relative earthquake localization methods and their implications in the Reykjanes Peninsula, Iceland

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Accurate earthquake localization is essential for advancing seismic processing and understanding geological structures. In this study, we explore the application of relative relocation methods—HypoDD (HD), GrowClust (GC), and Master Event (ME)—to refine event locations and analyze their implications beyond specific fault structure determination. While the primary focus is not exclusively on geological structures, the outcomes also serve broader purposes, contributing to critical aspects of seismic processing.
Our investigation employs a dataset from the REYKJANET seismic network located on the Reykjanes Peninsula in Iceland. The comparative assessment of these methods reveals significantly focused clusters in contrast to absolute event locations. Notably, individual event locations exhibit variations dependent on the chosen relocation method.
Furthermore, it is essential to note that Master Event (ME) is a program developed for event localization, offering the unique capability of sequential use. This feature proves valuable, especially in dynamic geological settings, such as the Reykjanes Peninsula in Iceland, where volcanic eruptions occur.
Additionally, we delve into the influence of control parameters for HD, GC, and ME on final location results, aiming to optimize these parameters while considering computational and memory demands. This research contributes to a comprehensive understanding of relative localization methods, emphasizing their broader applications and significance in seismic event analysis within the REYKJANET network.

SO-B-02

Meteoroids: Tracing a moving acoustic source in a moving medium with seismic data

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Meteorites are rare on Earth and are important for research in astronomy and geology to understand the genesis of our solar system and the universe. Recovering meteorites quickly is crucial because the earthly weathering processes greatly diminish their research value. The best way to find meteorites is by tracing the corresponding meteoroid in the atmosphere before it falls onto Earth's surface. Meteoroids that enter Earth's atmosphere can produce meteors under certain conditions, such as sufficient velocity. These meteors are often tracked by night-sky cameras, radio telescopes, and human observers. Although these methods are effective in low cloud coverage and nighttime conditions, they often lack spatial coverage and leave the daytime hours mostly unmonitored. Knowledge of the exact meteoroid flight path enables narrowing down possible fall areas. When optical and radiometric methods fail to observe a meteoroid downfall during the dark flight phase, the seismological method provides a viable alternative. Seismic stations are placed all around the globe and record continuously during all weather conditions. Using seismic stations to constrain a meteoroid's flight path can help facilitate a fast recovery of meteoritic rock.

Tracing a moving source such as a meteoroid with seismic stations is a challenging task that requires knowledge of the atmospheric conditions during the meteoroid's entry into the atmosphere. In this study, we investigate the atmospheric entry of a meteoroid over Germany and demonstrate the influence of wind effects on our meteoroid trajectory reconstruction.

SO-B-03

Challenges of Rotational Ground Motion Measurements in the Local Distance Range

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Since almost two decades, there is a fast and steady progress in understanding the rotational part of the seismic wavefield and exploring possible applications. These achievements are based on studies using simulated data, array-derived measurements, and direct measurements of large (M > 5), teleseismic earthquakes by ringlasers. Since only a couple of years, direct measurements of smaller (M < 3) earthquakes in the local distance range are also feasible. This was made possible due to new instrumentation developments such as portable rotation sensors.
From experience with translational measurements, seismology has developed a relatively simple description of the seismic wavefield, as long as the observation is recorded in the source far-field, and site-effects at the point of observation can be neglected by choosing an appropriate frequency range for the analysis.
Within the NonDC-BoVo project two portable rotational sensors have been installed in the Vogtland/West-Bohemia earthquake swarm region with the goal to incorporate the rotational waveform data into the inversion for seismic moment tensors. Both sensors are

located in an epicentral distance of ~10 km to the center of the swarm activity. So far, we have recorded 197 events with ML ≥ 1 and 6 events with ML ≥ 2.5.
Although we are positively surprised how well we can record rotational ground motion of earthquakes with even very small magnitudes, we encountered challenges in the details of the waveform recordings. At the sensor location in Landwüst (D) we recorded events down to ML ~ 0.5 with good signal-to-noise ratio in a frequency range of 5 to 25 Hz. At the second location in Skalna (CZ) the signal-to-noise ratio is worse and we recorded earthquakes only with ML ≥ 1.5. Relocating the sensor to Wernitzgrün (D), about 25 km to the North of Skalna, did not improve the quality of the waveform recordings. Technical issues with the sensor can be ruled out for all station locations.
Here, we want to present details of the challenges with the rotational ground motion data from these small and local earthquake recordings. First analyses hint to a much stronger effect of local site conditions onto rotational than translational ground motion data. In addition, with the above-mentioned setting, we have to consider the complexities of the near-field part of the wavefield as well. With our contribution we aim to add another aspect to the understanding of the rotational wavefield.

SO-B-04

Qseek: A data-driven Earthquake Detection, Localisation and Characterisation Framework

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Seismic and microseismic event detection and localization offer insights into the dynamic processes within the Earth's crust and mantle, influenced by both natural volcanic and tectonic phenomena as well as human activities. The evolution of seismic monitoring networks has significantly amplified our observational capabilities, capturing a diverse range of seismic events. However, traditional detection methods often struggle with noise-dominant micro-seismic events. Waveform-stacking methods have been developed to address these challenges, emphasizing the coherency of seismic energy across networks. Our research introduces an automated, data-driven, and machine learning-based method to detect and locate seismic events in extensive datasets. This method, underpinned by a stacking and migration approach, leverages a neural network trained to identify seismic phase arrivals. To refine the method, we incorporate a spatial octree, iteratively honing in on the seismic source region. Our software framework integrates the Pyrocko and SeisBench platforms and offers feature extraction capabilities, such as moment and local magnitude calculation from peak ground motions. To enhance the location accuracy we incorporate station corrections and source specific station corrections into the algorithm. We validate our approach using seismic data from the Eifel region, Germany, and the Reykjanes Peninsula, Iceland, capturing diverse seismic activities, including tectonic earthquakes and volcanic swarm activity.

SO-B-05

Sustainable preservation and digitization of analogue seismic data in Germany

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At last year's DGG conference we announced the beginning of our feasibility study aiming to estimate the effort necessary to digitize all analogue seismic data in Germany, which is funded by the BGR. This project was initiated as a result of many years discussion, within the german seismological community, about the importance of preserving analogue data. Several groups in the world who develop strategies for preserving these data and have ongoing projects. However, until now, Germany was lacking such a project, although its importance has been often discussed.
Here we would like to present and discuss the first findings of our study. The rough inventory of the analogue seismic data archives content has now been completed. Altogether 12 german institutions, which have seismic records in analogue form and corresponding metadata stored in their archives, have participated. The information has been collected from all 12 institutions in different forms and have been complied in one consistent database. The database, together with the description report, will be then published as a catalogue of all existing analogue seismic data archives in Germany with detailed information about their content.
Additionally, we would like to present the further steps planned in the project. Next a test run will be performed in order to estimate the workload for continuous scanning and digitizing of seismic records. This includes the paper seismograms from maximum 3 seismic stations, which will be collected for a certain time period (depending on workload) continuously. Corresponding metadata information will be collected accordingly. These data will be scanned and digitized. After extensive discussion, 3 appropriate time periods of 1 continuous month were selected. Each of these time periods covers a very important epoch in the development of seismic instrumentation, and thus in the quality of seismic data. Additionally, a specific event will be selected to test the methods of determining an earthquake's source parameters (e.g. hypocentre location, magnitude) based on digitized analogue data.
At the end of the project, we expect to present long-term concept for preservation und digitization of all analogue seismic records and corresponding metadata available in Germany.

SO-C-01

Investigation of P-wave reflections from the lowermost mantle at seismic arrays in Germany

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The lowermost (D") mantle as well as the core-mantle transition zone are rather complex areas in terms of seismology. In this work we search for reflections from the lowermost mantle in recordings from two arrays in Germany, the permanent Gräfenberg Array and the semi-permanent Eifel Array. As sources about 120 earthquakes are analyzed at distances from 70°-80° all around the world to find anomalous P-phases such as PdP originating from the lowermost mantle. By applying array techniques such as beamforming and frequency-wavenumber analysis each earthquake has been individually checked whether the

waveforms contain anomalous P-phases (PdP) or not between direct P and the core reflection PcP. The ray paths and the reflection points in the depth of the D" layer are plotted on top of known anomalies in the core-mantle transition zone. This allows to outline regions where the anomalous P-phases originate and compare them with the known anomalies and previous studies. Using two arrays increases the size of the investigated area and the detection of new anomalies.

SO-C-02

A better understanding of seismicity in the European North Sea for risk mitigation of large-scale CO_2 injections

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Carbon capture and storage technologies are an essential part of EU's decarbonisation efforts. Combined with sustainable energy resources, they are necessary to move Europe towards a net zero carbon emissions economy. Currently, several Mt-scale CO_2 storage projects are being developed in the North Sea. Containment risk evaluation includes analysing tectonic earthquake patterns to potentially map faults, reveal their orientation and failure style, invert for stress directions and at later stages, enable the discrimination of natural and induced seismicity. In addition, seismological information may contribute to the geomechanical understanding of the reservoir and caprock response to large-scale CO_2 injection over time.

A wealth of data exists from various European seismological agencies, but much of it has not been reported to the ISC and consequently not analysed collectively. Within the framework of the ACT project SHARP Storage, an extensive unique seismic event catalogue including the phase readings was compiled from the bulletins available from all relevant data centres. Preliminary processing included duplicate removal and explosion identification. In total, 15,230 events were observed between the years 1382 and 2022, of which 3,305 were identified as likely or potential explosions. The magnitude of completeness of this data set varies both spatially and temporally. The most seismically active regions in the study area are the Viking and Central grabens. Coastal areas are populated with more events than the central part of the North Sea due to the denser distribution of seismic stations onshore allowing for the detection of smaller (M<3) magnitude events.

For events occurring after 1990 and possessing magnitudes larger than M > 3.5, waveforms are currently being collected as a basis for further analysis, including event relocation and magnitude homogenisation.

SO-C-03

Seismologische Forensik für die Ereignisse an den Erdgasleitungen von NordStream 1 und 2 – Beobachtungen

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Am 26.09.2022 wurden seismische Ereignisse in der Ostsee nahe der Insel Bornholm detektiert und lokalisiert, die zeitlich und räumlich mit Leckagen an den Gas-Pipelines NordStream-1 und -2 in Verbindung gebracht werden können. Das erste Ereignis mit einer Lokalmagnitude ML 2.6 fand um 00:03 UTC 37 km ost-südöstlich von Bornholm statt. Eine weitere Folge von Ereignissen wurde etwa 17 Stunden später um 17:03 UTC rund 60 km nordöstlich von Bornholm mit einer maximalen ML 3.0 registriert. Dies führte zu einem komplexen registrierten Wellenfeld aus sich überlagernden seismischen Wellenzügen. Anhand der identifizierten Einsätze konnten insgesamt 3 seismische Ereignisse im Abstand von etwa 8 bis 9 Sekunden nachgewiesen werden. Die Epizentren der drei Ereignisse konnten durch Relativlokalisierung und dem zeitlichen Verlauf der Druckabfälle in den Leitungen den Lokationen der Leckagen an den Leitungen von Nordstream-1 und -2 zugeordnet werden.
Anhand von Vergleichsereignissen in der Region, die sowohl tektonische Beben als auch Sprengungen umfassen, kann der Explosionscharakter aller vier Ereignisse nachgewiesen werden. Dabei unterscheiden sich die Ereignisse noch im Vergleich zu (Munitions-)Sprengungen in der Ostsee in ihrem Frequenzgehalt, der deutlich tiefere dominante Frequenzen aufweist.
Die berechneten Momenten-Magnituden betragen 2.3 Mw für das frühe Ereignis und 2.7, 2.6 und 2.5 Mw für die drei späteren Ereignisse, was einer Energiefreisetzung zwischen 158 und 629 MJ entspricht.
Anhand der Spektren konnte für die Ereignisse eine Quelle am Meeresboden nachgewiesen werden. Als Quelle kommen sowohl eine Sprengladung in Frage als auch die impulsive Freisetzung des unter Druck stehenden Gases in den Leitungen nach einer initialen Beschädigung. Versuche der Bundesanstalt für Materialforschung und –prüfung an unter hohen Drücken stehenden Röhren unterstützen, dass bereits relativ kleine Sprengstoffmengen ausreichen, um ein Versagen der Stabilität der Röhren zu initiieren, was wiederum aufgrund des immensen Innendrucks zu ihrer extrem schnellen und vollständigen Öffnung führt.
Infraschall-Signale der Ereignisse wurden an zwei Stationen (I26DE im Bayerischen Wald und IKUDE bei Kühlungsborn) registriert. Insbesondere nach der Ereignisfolge um 17:03 UTC wurden deutliche Signale registriert, deren Charakteristik auf ein explosives Ereignis mit nachfolgendem Gasaustritt an der Oberfläche hindeutet.

SO-C-04

Seismologische Forensik für die Ereignisse an den Erdgasleitungen von NordStream 1 und 2 – Modellierungen

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Die seismischen Ereignisse im Zusammenhang mit der Nord Stream Beschädigung vom 26. September 2022, sind relativ komplex aufgrund der Einwirkung des unter hohen Druck stehenden Gases in den beschädigten Leitungen. Die vorhandenen Modelle zur Bestimmung der Ladungsstärke von Unterwasserexplosionen müssen entsprechend angepasst werden. Ohne die Berücksichtigung der impulsiven Freisetzung des Gases mit jeweils über 100 und 160 bar wird mit bestehenden Methoden, basierend auf den Spektren des Blasenpulses, eine unrealistische hohe Ladungsstärke abgeschätzt von 100-400 kg TNT-Äquivalent.

Wir stellen ein Modell vor, das sowohl die Explosionsblase als auch den Austritt von Methan aus der Pipeline unter Druck in die Explosionsblase besser berücksichtigt, wobei letzteres durch Lösung der Euler-Gleichungen der kompressiblen Gasdynamik innerhalb des Rohrs erfolgt. Dieses Modell liefert das zeitabhängige Volumen der Gasblase bzw. der Gaswolke, das wir bei der Modellierung seismischer Wellenformen als Quelle eines isotropen Momententensors verwenden. Die Gasentladung erfolgt unter gedrosselten Strömungsbedingungen durch ein Loch im Rohr. Wir passen die Lochgröße und die Ladungsstärke an um die beobachteten seismischen Wellenformen und Spektren zu erklären.

Basierend auf diesen Modellierungen für die Ereignisse an Nordstream 1- und -2 kann eine Amplituden-Energie-Relation angepasst werden, die eine verlässlichere Stärkebestimmung und Energieabschätzung erlaubt. Für den modellierten Gasaustritt liegen die Momenten-Magnitude M_W bereits zwischen 2.3 und 2.7, was einem TNT-Äquivalent von knapp 40 bzw. 150 kg Ladungsstärke entspricht. Die Modellierungen zeigen daher, dass die gemessenen seismischen Signale hinreichend durch einen impulsiven Gasentlass am Meeresboden ähnlich einer Airgun beschrieben werden können. Die modellierten synthetische Seismogramme für eine solche Quelle weisen große Übereinstimmungen mit den gemessenen Signalen auf. Die Modellierungen können eine Obergrenze für die Ladungsstärke der Sprengung von weniger als 50 kg TNT-Äquivalent festlegen.

Für die seismischen Signale des Ereignisses an der Balticconnector-Pipeline zwischen Finnland und Estland am 8. Oktober 2023 wurde eine vergleichbare Analyse durchgeführt und festgestellt, dass auch hier die sofortige Gasfreisetzung die beobachteten Daten ausreichend erklären kann. Dies spricht für eine mechanische Schadensursache.

SO-C-05

Current station operations of the Ruhr University Bochum

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Since the 1980s, Ruhr University Bochum has been involved in several seismological projects. This presentation describes the current operation and data management of the stations. It includes the monitoring of post-mining in the Ruhr area through a permanent network of stations, as well as temporary station networks for ongoing research projects. Currently, we operate almost 90 seismological stations in Germany, Greece, and Northern Macedonia.
All stations transmit recordings in near real-time to the observatory in Bochum via cellular routers or direct internet access. This feature enables ongoing assessment of seismic activity, monitoring of stations, and evaluation of data quality. The collected data is then shared with cooperative partners. Most of the data can be accessed by the seismological community from an EIDA server. In 2023, around 1 TByte of data have been acquired.
This presentation offers an overview of the deployment of permanent and temporary stations, including their general setup. It then focuses on assessing data quality and availability and explains how to access the different datasets. All deployments are assigned an FDSN network code and a DOI. The scientific background of the different deployments is also briefly addressed, along with upcoming developments.

SITZUNGSTHEMEN

SO – Poster

Seismologie

SO-P-01

Analyzing complex ruptures using a multiple-source joint optimization approach

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Earthquakes are a significant geological hazard, and analyzing them along with the surrounding fault system is crucial for future risk assessments. Due to their inherently unpredictable nature, characterization of the sources of large magnitude earthquakes are key to understanding the triggering mechanisms.
This study focuses on unraveling the source geometry and mechanisms of the 2021 Tyrnavos Earthquake Sequence, where two shallow, but blind earthquakes with magnitudes Mw 6.3 and M_w 6.0 occurred in a period of 32 hours. The complex and not fully understood extensional fault system existing there, potentially linked to a large scale relay zone, makes it challenging to determine the rupture process. Such earthquake doublets, with their near-field effects superposed in the observed data, often raise the need for a simultaneous optimization approach. The simultaneous optimization of both mainshocks, using Global Navigation Satellite System (GNSS) and Synthetic Aperture Radar (SAR) data, as well as seismic waveforms jointly, allows for different rupture scenarios of simple or more complex faulting to be created, further improving the understanding of the source characteristics.
In this work we analyse this earthquake doublet and conduct a kinematic Bayesian finite-source optimization with a large model space to explore. With the utilization of a combined

set of data and based on an extensive optimization, we were able to create more plausible source models with respect to the observations, describing the rupture process better, compared to previously published models.
Detailed comparisons between different source models for the earthquake on the 3rd of March reveal an overall agreement on a shallow WNW-ESE striking, N-E dipping source. A subsequent strain analysis indicates the existence of a secondary, antithetic rupture plane. For the second earthquake on the 4th of March, a S-W dipping source produces the best data fits, emphasizing its plausibility compared to N-E dipping sources proposed in the literature.

SO-P-02

Rupture analysis of the Pütürge Segment of the East Anatolian Fault based on the large 2020 and 2023 Earthquakes

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The East Anatolian Fault (EAF) is a left-lateral strike-slip fault zone that marks the plate boundary between the Anatolian, Arabian and Eurasian plates. During the last centuries, seismic activity at the EAF varied seemingly in correspondence with the North Anatolian Fault (NAF), with high activity when seismicity along the NAF was lower and vice versa. Recently, seismic activity at the EAF seems to be elevated. The last severe events were the M_w 7.8 Kahramanmaraş and M_w 7.5 Elbistan Earthquake series on 6*th* February 2023, which occurred along the EAF and the neighbouring Çardak Fault, respectively. Surface rupture and aftershocks reveal coseismic faulting at the three westernmost of the seven EAF segments up to the Pütürge segment. Three years earlier, on 24*th* January 2020, the M_w 6.8 Sivrice event had already ruptured ~45 km of the Pütürge segment.
We want to understand why the 2020 rupture did not propagate into the western segments even though they were apparently already seismically loaded. Moreover, we are interested why the 2023 rupture propagation stopped at the Pütürge segment and whether the fault planes of the different events touch or even overlap. One explanation for the shared location of the respective rupture tips could be a strong asperity that keeps the area from further rupturing until even higher stresses are reached than induced by the 2023 event. There is also the possibility of the fault segment being still rather relaxed from the 2020 event. Additionally, aseismic creep, that continuously releases stress and thus prevents high stresses to build up, could play a role.
We investigate surface displacements based on InSAR (radar interferometry), pixel offset and GNSS data. In order to resolve the Kahramanmaraş and Sivrice ruptures in depth, we model coseismic slip at the EAF Pütürge and nearby segments for the 2023 event using the open-source seismology toolbox Pyrocko. A simultaneous forward modelling of the mentioned geodetic data of static ground displacement for the near and far field with recorded seismic waveforms and a finite pseudo-dynamic seismic rupture model is planned. In addition, we carry out a spatio-temporal aftershock analysis and consider aseismic creep data.

SO-P-03

Stress Drop Variation After Large Earthquakes

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Megathrust earthquakes affect a large area around their rupture zone. Their effects on the fault on which they occur, on adjacent faults, and on the surrounding medium are of great interest, for example, for hazard assessment. In this study, the effect of megathrust earthquakes on the median stress drop of background seismicity and aftershocks is investigated using datasets from three megathrust events in northern Chile, the MW7.7 2007 Tocopilla earthquake, the MW8.1 Iquique earthquake and its largest MW7.6 aftershock. A very recent stress drop catalog of the area is filtered for events in the spatio-temporal vicinity of the large events, and the average stress drop curves are found to be elevated immediately after the main event. The effect disappears after a few days. The elevated stress drop appears to be due to two effects: the moment release during this period is elevated, that is, the average magnitude is increased; and the corner frequencies of the earthquakes that occurred during this time interval are also increased, which have a more significant effect on the calculated stress drops.
At present, it is unclear whether the observation is caused by a change in fault properties, such as increased rigidity, possibly due to the temporal decrease of water pressure, which would increase the observed stress drop, or whether different classes of events are activated during the early aftershock period compared to the surrounding time windows. Such events could be predominantly located at the rim of the high slip zone where stress change is highest and thus allow for higher than average stress drop events to occur.
In any case, the observation of the temporal increase of stress drop and its possible explanation will add to the understanding of early postseismic processes in the earthquake cycle.

SO-P-04

Implementing global 3D earth models in dynamic rupture scenarios

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Many factors control the seismic wavefield and the destructiveness of the shaking during an earthquake. There is the earthquake source itself with many characteristics influencing the radiation of seismic waves. And there is the heterogeneous earth structure through which the seismic waves are traveling until they reach a location at the surface. The varying seismic velocities and scattering characteristics of the subsurface medium influence the wave amplitudes and frequencies. This means, both source and medium have to be considered when simulating earthquakes to assess risk.

However, the source characteristics of a future earthquake are very hard to foresee. There may be estimates of earthquake potential at certain active tectonic faults and there may be expectations about likely mechanisms based on the tectonic regime. Similarly, earth structure is only known to some extent and we have to account for considerable uncertainties. With earthquake scenarios based on different assumptions these uncertainties can be incorporated and considered.

We are building a framework to run such earthquake scenarios. We aim to estimate the impact of current global and low resolution 3D earth models, which have been estimated based on seismic data and gravity data, in predicting the seismic wavefield in dynamic rupture simulation. We use finite rupture models based on seismic potential estimates in dynamic rupture simulations applying the Seissol software package. Our current simulations are conducted in the western part of the North Anatolian fault zone, in the region of the 1999 Izmit earthquake with wavefield simulations that reach the city of Istanbul.

SO-P-05

Seismic wavefield visualizations with AlpArray and AdriaArray

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With dense networks of stations equipped with three-component broadband seismometers across the broader alpine region like AlpArray and AdriaArray, a new possibility for visualizing seismic wavefields is emerging. The data collected by these seismometers allows to resolve seismic wavefields as they move through the array with fine spatial resolution. Using animations, visualization opportunities emerge that might enhance viewers' understanding of seismic eventsinduce a higher understanding of seismic events to viewers, showcase data quality and might provide an insight into problems like polarity errors or strong station noise level. To achieve this, data processing needs to be meticulously managed to ensure that amplitudes for all seismic phases can be shown in a clear and useful way, while still separating them from the shorter period noise. Although this has proven to be challenging, a normalization method relying on the envelopes of the long-period lowpass filtered waveforms yieldswaveforms yields good results. Following the normalization, the waveforms undergo band-pass filtering. An estimate for the wave propagation of the most important seismic waves is calculated viacalculated via TauPy in a one dimensional background model. In the final visualization, amplitudes are represented as a colour scale, and the estimate of the important phases is drawn into the animation as coloured lines at the theoretical wavefronts. In addition, horizontal waveforms are visualized by using a color wheel to encode the horizontal components and the size of markers to indicate amplitudes.

SO-P-06

The manual analysis of teleseismic events at the Federal Seismological Survey of BGR - including depth, secondary and core phases

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The Federal Seismological Survey of BGR is one of the few institutions in Germany that also analyzes teleseismic earthquakes manually. In the daily seismic routine regional and teleseismic earthquakes are analyzed in addition to local earthquakes. The parameters of the events, i.e. onset times of seismic phases, hypocenter coordinates and magnitudes are transmitted to the EMSC immediately after manual analysis. Furthermore, monthly bulletins are send to the ISC as well as made available via the BGR website.

For the routine analysis of teleseismic events we use the seismic stations in Germany and in some cases stations from surrounding countries. Since the stations are far away from the events we apply array methods to identify distinct seismic phases and to locate the events.

This is mainly done with an f-k analysis for the waveforms of the densely spaced Gräfenberg array sites (GRF) or by coherent phase picking at waveforms of the large aperture German Regional Seismic Network (GRSN) stations.

Here we present a summary of the analyses of the years 2017 to 2023. On the one hand we focus on the determined epi- and hypocenters as well as on statistics of distinct phases which in the majority are P waves travelling through the mantle. On the other hand we put emphasis on more special phases like depth phases (pP and sP) and later phases such as S, PcP, ScS, PP, SS or SKS. These phases are identified by their slowness values and travel times and they are analyzed in case of stronger events, mostly for events above magnitude 6.

A large number of our located events are in the distance range greater than 140 degrees and contain core phases. These events are mostly located within the subduction zone at Fiji and Tonga. Due to the epicentral distances around 145 degrees the German stations are close to the caustic of PKP branches. Therefore, PKPdf, PKPbc and PKPab often show up with comparably strong amplitudes. In some cases all three branches as well as their corresponding depth phases are visible and can be picked.

On the poster we show and discuss some selected events with depth and later phases as well as examples with pronounced core phases.

SO-P-07

Understanding the influence of seismic mantle structures at the core-mantle boundary on intense magnetic flux regions

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Within the Priority Program 2404 "Reconstructing the Deep Dynamics of Planet Earth over Geologic Time" (DeepDyn) we investigate possible seismic signatures at magnetic high-latitude flux lobes (HLFL). The focus is on four target regions on the northern hemisphere: Siberia, Canada, North Atlantic and Indonesia. While Siberia and Canada show the HLFL, the North Atlantic should be the location of a third postulated flux lobe, but this area shows no high-flux signal in the magnetic field. The region beneath Indonesia and the Indian Ocean is characterized by an area of high magnetic flux that changes direction and moves westwards over time. Our aim is to understand whether mineralogy and seismic structure (i.e., thermal constraints) could be responsible for the different magnetic signatures at the core mantel boundary (CMB). This is done by combining two approaches: seismic anisotropy and seismic reflections near the CMB.
To study anisotropy, we measure shear wave splitting of SKS, SKKS, and PKS phases as well as of S and ScS phases. Thereby, we determine the splitting parameters, the fast polarization direction ϕ and the delay time δt as well as the splitting intensity SI. Especially, we search for phase pair discrepancies, e.g., between SKS and SKKS phases, as they are a clear indication for a lowermost mantle contribution to the anisotropy. Based on our shear wave splitting measurements, we will derive structural and mineralogical anisotropy models using the *MATLAB Seismic Anisotropy Toolbox* (Walker and Wookey 2012). To test these models, we simulate synthetic seismograms using *AxiSEM3D* (Leng et al. 2016, 2019). Besides comparing synthetic and observed seismograms, we plan to measure the shear wave splitting of the synthetic phases and compare splitting parameters and splitting intensity to the observed values.

The second approach uses seismic reflections (P and S waves) from the D" discontinuity, located 300 km above the CMB, and measures their arrival time, slowness, polarity and waveform, using array analysis. We aim to cover the regions with a number of crossing paths, for verification and also for determining whether anisotropy is present (Pisconti et al., 2022). Especially the polarity of the reflected waves, when taken together with the splitting analysis, can help to find the mineralogy that leads to the observed structures near the CMB, which in turn will help to understand the influence of the mantle on core dynamics.

SO-P-08

Anisotropy and XKS-splitting from geodynamic models of double subduction: Testing the limits of interpretation

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We utilize three-dimensional geodynamic models to predict XKS-splitting in double subduction scenarios characterized by two outward-dipping slabs. These models are highly applicable in various realistic settings, such as the central Mediterranean. Our primary focus is on the analysis of XKS-splitting, a key geophysical observable used for inferring seismic anisotropy and mantle flow patterns.
Our models simulate the concurrent subduction of two identical oceanic plates separated by a continental plate. The variation in the strength of the separating plate causes a transition from a retreating to a stationary trench. The models offer detailed insights into the temporal evolution of mantle flow patterns, particularly the amount of trench-parallel flow induced by this specific type of subduction.
In the subsequent step, we employ the well-known D-Rex model to estimate Crystallographic Preferred Orientation (CPO) development in response to plastic deformation resulting from mantle flow. Based on the D-Rex model results, which incorporate the full elastic tensor of a deformed multiphase polycrystalline mantle aggregate, we derive synthetic apparent splitting parameters and splitting intensities at virtual receivers placed at the surface using multiple-layer anisotropic waveform modeling. To identify regions with pronounced depth-dependent variations of anisotropic properties, particularly the fast polarization directions, we define a complex anisotropy factor dependent on the apparent splitting parameters and splitting intensities.
Finally, using the apparent splitting parameters, we conduct two-layer model inversions at selected locations characterized by a large complex anisotropy factor. The two-layer model provides apparent splitting parameters as a result of analytical waveform modeling for two anisotropic layers. We observe that while several models can effectively explain the apparent splitting parameters, only a subset can accurately reproduce the depth-dependent anisotropic properties.
Our findings unequivocally demonstrate that a classical XKS-splitting analysis can effectively identify areas characterized by complex anisotropy and provide accurate approximations of the depth-dependent variations of anisotropic properties within these regions. However, caution is warranted when interpreting results obtained through inversion based on a two-layer analysis.

SO-P-09

Discriminating lithospheric and asthenospheric anisotropy beneath Northern Oman: sharp contrast observed at the Semail Gap Fault Zone

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To gain a deeper understanding of the extensive and varied lithospheric deformations beneath northern Oman, we examine seismic anisotropy in this region using splitting analysis of teleseismic shear wave data. Our study utilizes data from a dense network consisting of 13 permanent and 45 temporary seismic stations, which were operational for approximately 2.5 years starting from October 2013. By examining the azimuthal distribution of shear wave splitting (SWS) parameters, we were able to divide the study area into three sub-regions. The stations located to the west of the Hawasina window exhibit relatively azimuthally invariant SWS parameters suggesting a single anisotropic layer. On the other hand, most of the stations located in the central and eastern regions display variations versus back-azimuth, indicating the potential presence of depth-dependent anisotropy.

The General NW-SE trend of the Fast Polarization Directions (FPDs) of the one-layer anisotropy in the west and FPDs of the upper layers in the east is concordant with the strike of the structures resulting from the collision between the continental and oceanic plates. Notably, a clear contrast in SWS parameters is observed in the Semail Gap Fault Zone (SGFZ), suggesting that the SGFZ can be a lithospheric-scale structure that hampers the intrusion of mafic magma from the southeast. Furthermore, the FPDs of the lower layer in the east exhibit an NE-SW trend, which may be indicative of the large-scale mantle flow resulting from the present-day plate motion.

SO-P-10

Onshore dual-station monitoring of submarine volcanic activity through multi-band frequency analysis – the case of Kavachi, Solomon Islands

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The January 2022 eruption of Hunga Tonga-Hunga Ha'apai on Tonga highlights the critical need for more advanced monitoring of shallow submarine volcanoes, particularly for those near inhabited regions, where they pose significant hazards to people, infrastructure, marine and air traffic. Kavachi, a highly active submarine volcano, is located about 27 km offshore from Nggatokae Island in the Solomon Islands. In a pilot project that began in February 2023, two temporary seismic arrays were deployed about 8 km apart in the south and north-east of the island, gathering essential data over a period of approximately 7 months.
Our strategy involves using a multi-band detection method to quantify volcanic activity and its temporal variations more accurately. This method requires the use of at least two remote onshore seismic stations. We assigned several specific characteristic frequency bands to each station to effectively capture the spectral energy of seismic activity induced by the volcano. By analysing the time series and their time shift, we computed an appropriate volcanic activity index. The monitoring and eruption detection rely on an empirical trigger mechanism. Additionally, the method enables the estimation of apparent seismic velocities across the island.

Promising preliminary results demonstrate that this method can be effectively used to monitor volcanic activity. A further goal is to assemble an event catalogue and to utilise the method as a tool for monitoring and early warning. This successful pilot project validates the effectiveness of a simple dual-station approach for easy-access monitoring of shallow submarine volcanic activity using onshore seismometers in its proximity.

SO-P-11

Array analysis for onshore monitoring of submarine seismo-volcanic activity in the Solomon Islands

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Submarine volcanoes present a significant hazard to nearby populations, as demonstrated by the impact of the 2022 Hunga Tonga-Hunga Ha'apai eruption. This highlights the necessity for enhanced monitoring of shallow underwater volcanoes. A potentially promising and cost-effective approach to achieving this goal is the implementation of onshore seismic arrays. This study focuses on Kavachi, an active, shallow submarine volcano located about 27 km southwest of Nggatokae Island in the Solomon Islands. In February 2023, we started a pilot project to assess the effectiveness of array-based seismic monitoring techniques for Kavachi. We set up two seismic arrays, approximately 8 km apart, in the south and northeast of the island, collecting data over a period of about seven months. The latter array consisted of eight short-period and one broadband station with an aperture of approximately 900 meters. The other included three stations (one equipped with a broadband seismometer) with an aperture of about 250 meters. Our analysis employed cross-correlation analysis to estimate delay times between the stations and applied a robust linear regression model for determining the direction of incoming seismic waves and their apparent velocity.
The preliminary results from this study show the effectiveness of onshore seismic arrays in monitoring submarine volcanic activity. Additionally, the arrays have proven useful in detecting and discriminating tectonic events from the nearby New Britain subduction zone. This dual capability underscores the significant potential of onshore seismic arrays for monitoring and early warning of volcanic hazards in remote locations.

SO-P-12

Seismicity in Sri Lanka: New insights from a temporary, local seismic network

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The vast majority of seismic energy is released at the edges of tectonic plates, particularly at convergent plate margins. Nevertheless, earthquake activity is also found within the plates and on passive continental margins. Sri Lanka, a large island just south of India, is one such place where small to medium magnitude earthquakes have been reported in the past. The island is mainly formed by three different crustal blocks made from high-grade metamorphic rocks of Precambrian age (amphibolite to granulite facies metamorphic rocks of sedimentary and igneous origin). These blocks have been amalgamated during the assembly of Gondwana.

To gain a new view on the seismicity and the deeper structure of Sri Lanka we installed a temporary seismic network in 2016 and 2017. This network consisted of 30 broadband seismic stations continuously recording at 100 sps. Data of three permanent seismic stations complemented the dataset. In a first step we detected events using 2 different approaches involving automatic picking and source scanning. P- and S-phase arrival time picking was then manually/visually performed. We detected more than 300 seismic events, of which ~150 could be identified as blasts in most cases related to the construction of dams. The phase picks of a subset of 58 high-quality events located inside the network were then simultaneously inverted for the hypocenter locations, the 1-D velocity structure (Vp and Vp/Vs) and station corrections using a Markov chain Monte Carlo method. Afterwards, the final set of 102 local events (as well as the blasts) was located using the velocity model and station corrections determined in the previous step.
Most of the seismicity is located in the SE of Sri Lanka, however, sparse seismicity is also found throughout the island. The earthquakes are located in the top 15 km as well as in a deeper band around 25 km depth. Local magnitudes range from 1 to 3. The larger events could be observed throughout the whole island. Fault plane solutions of a subset of events could also be calculated from first motion polarities. The structure of the P- and S-velocity model is rather simple, featuring P-wave velocities of ~6 km from the surface to ~18km depth, increasing to ~6.7 km/s below. The crustal Vp/Vs ratio is close to 1.73, except for a depth range between 6-17 km where it is slightly decreased. Mantle velocities could not be recovered due to the limited aperture of the network.

SO-P-13

Relocated catalog of earthquake swarms in Nový Kostel region of West Bohemia/Vogtland based on the Webnet recordings, period 1991-2023

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The seismic swarms in the West Bohemia/Vogtland area occur in several focal zones where the area of Nový Kostel dominates the activity since the eighties when a magnitude 4.6 swarm occurred in 1985/86. It was followed by nine swarms whose maximum magnitudes exceeded M_L 3. Overall, a slow northward migration of the activity occurs forming a belt of 10 km length in the depth range from 10 to 6 km. Precise manually obtained arrival time picks are available for more than 40 000 events forming a robust high-quality dataset available for comparative analyses with modern automatic pickers. However, the size of the dataset did not allow for joint relocation using standard methods available until several years ago.
In this study, we present the relocation of seismicity recorded between 1991 and 2023 leveraging the GrowClust code, which allows for joint double-difference relocation of large datasets. This allowed to reveal space - time relations among distinct clusters occurring during more than 30 years of the activity and migration patterns within seismic clusters. Notably, the research emphasizes the repetitive nature of seismic swarms in this region. The analysis not only highlights the clear spatial evolution of seismic clusters but also attention is devoted to identifying and rectifying location errors, providing a comprehensive understanding of the seismic dynamics in West Bohemia. The findings contribute significantly to broader geological knowledge and can be used as a benchmark for developing contemporary automatic processing algorithms.

SO-P-14

Seismic GLOF analysis at Iceland's Vatnajökull glacier: Insights from the October 2015 jökulhlaup at Skaftá.

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Jökulhlaups ('glacier runs') is the icelandic name for **GLOFs**, glacier lake outburst floods. Sometimes, they propagate subglacially. These subglacial floods can only be observed indirectly using observations of the related glacier's surface deformation derived by **GNSS** and InSAR techniques. Many processes remain unknown below the ice. However, some properties of these subglacial floods may be assessed by the seismic signals they generate, such as: **Flood tremor** caused by turbulent water or carried sediment loads, ice quakes, and others.

At **Iceland's** Vatnajökull glacier, floods from the **Skaftá** cauldrons travel more than 40km below the ice before feeding into the Skaftá river. Two seismic arrays were installed west and southwest of Vatnajökull between 2014 and 2016. To locate the generated tremor along the flood propagation path, frequency-wavenumber-analysis **(fk-analysis**) and match field processing **(MFP)** were used.

Based on these techniques, we were able to track the subglacial propagation of flood tremors seismically for four GLOF events occurring between 2014 and 2016.
We relate the seismic signals to hydrometric and GNSS observations, measured outside and on the glacier respectively. For the flood with the largest discharge occurring in October 2015, we were able to identify seismic signals related to the rising water level downstream at rapids outside of the glacier.
Furthermore, point pattern **analysis of tremor locations allows estimating** the flood's subglacial **propagation speed** and its associated vertical deformation of the glacier. Previously, these processes could not or only partly be observed.

These findings contribute to a better process understanding and may thus improve early warning strategies.

SO-P-15

Towards a local velocity model from explosion monitoring

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Marine explosions constitute a significant portion of observed seismic events in Northern Germany. They mostly relate to either military exercises or destruction of unexploded ordnance (UXO) from World War II. Monitoring of offshore explosive events is relevant for various reasons: known, „ground truth" events can be used to derive a local velocity model that can improve seismic event locations on- and offshore, irrespective of the source. In

addition, unexpected seismic events, such as the destruction of the Nord Stream pipelines or a suspected UXO detonation in summer 2023 in the bay of Lübeck, require precise localisation to support authorities in quick response. Currently used velocity models do not provide sufficiently precise epicenter locations that allow to locate the source area on the seafloor in a short amount of time.

We use a series of controlled explosions with known locations and charge sizes in the bay of Kiel to derive a best-fit velocity model based on observed waveform arrivals. In addition to seismic stations of the permanent monitoring network, we temporarily deployed additional stations closer to the source area. P-wave arrival times are fit against a range of gradient-over-halfspace velocity models using a gridsearch scheme. Initial results suggest that a consistent velocity model for this specific source location and station network geometry can be derived. We compare event locations of other events along the German Baltic Sea coast using standard and the newly derived velocity model and discuss the transferability of this local model to a regional scale.

SO-P-16

Towards attenuation tomography in NRW

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Wind turbines are increasingly recognized as a viable alternative energy source, acclaimed for their clean and renewable energy production. This surge in popularity aligns with the urgent global demand for sustainable energy solutions. Nonetheless, concerns about their environmental impact, particularly regarding acoustic emissions and seismic noise levels, persist.

The DBMISS project explores a challenging aspect of the environmental impact of wind energy - the seismic emissions produced by wind turbines and their effect on the overall seismic noise environment. This issue becomes especially significant in regions equipped with seismic networks for detecting natural earthquakes, as the seismic activity from turbines might complicate the analysis of seismic data. We therefore want to understand the complexities of the seismic emissions generated through the mechanical workings and the aerodynamics of the wind turbines and their impact on the seismic recordings, particularly in areas with many turbines.

A crucial element in understanding the effect of wind turbines on seismic recordings is the attenuation factor, which is the rate at which the amplitude of seismic waves decreases with distance from the source. This factor is greatly influenced by the geological features of the region and is essential for understanding how vibrations from turbines move through the ground and affect nearby areas. In North Rhine-Westphalia (NRW), the DBMISS project is undertaking a study on attenuation tomography. We utilize a variety of data, including local earthquakes, explosions, and background noise recordings. Our primary sources of information are the Geological Service (Geologischer Dienst) and the Ruhr-University Bochum, which provide us with catalogs and waveform of seismic events.

Our approach involves using the MuRAT code, which relies on a method that works independent of the seismic source and the location of recording sites. This method calculates the frequency-dependent ratios of P-to-coda and S-to-coda energy, using a velocity structure to ascertain the attenuation factor.

We present the available data and explain how the uneven distribution of this data set affects our results. Additionally, we outline our plan to obtain more consistent attenuation tomography results across NRW.

SO-P-17

Providing Efficient Multi-disciplinary Geophysical Monitoring using common real-time seismic network infrastructure

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Geophysical monitoring projects require a high level of performance and reliability from deployed instruments, typically found in purpose-built instrumentation. In the past, this had led to unnecessary parallel efforts between complementary research groups in order to provide permits, datalogging, telemetry and power systems, raising total costs of monitoring networks.
However, modern seismic dataloggers like the Nanometrics Centaur present an opportunity to serve as a foundational element for a multi-disciplinary station. These dataloggers offer the capacity to manage inputs and metadata from diverse geophysical and environmental sensors (both analog and digital, encompassing seismic, magnetic, meteorological, geodetic, and infrasonic sensors). Notable features include low power consumption, precise timing, and dependable data delivery using open formats.
In this poster, we showcase the effective utilization of a seismic-focused datalogger, such as the Nanometrics Centaur, in a multi-disciplinary context. Our analysis demonstrates how this specialized datalogger can be seamlessly integrated into a diverse range of sensors, enhancing the overall efficiency and cost-effectiveness of geophysical monitoring networks.

SO-P-18

Erstellung eines Erdbebenkataloges mittels Time Reverse Imaging im Projekt SIEGFRIED – Ein interdisziplinäres Projekt für die seismische Risikoabschätzung in der Niederrheinischen Bucht

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Für das Erreichen der globalen Klimaziele ist umweltverträgliche und grundlastfähige Energie- und Wärmegewinnung ein essenzieller Bestandteil. Geothermie bietet hierbei die Möglichkeit einer wetterunabhängigen erneuerbaren Energiequelle. Dem gegenüber stehen sozioökonomische Risiken wie induzierte Seismizität und Unsicherheiten über geologische Strukturen im Untergrund. Die Anwendung innovativer Methoden bietet das Potenzial, die Standortfindung für Geothermieprojekte nicht ausschließlich auf statische, geologische Untergrundmodelle zu stützen, sondern mittels Spannungsvoraussagen auch das Spannungsfeld einzubeziehen.

Mit dem Forschungsprojekt SIEGFRIED setzen wir uns zum Ziel, das seismische Risiko tiefengeothermischer Projekte in der Niederrheinischen Bucht durch die Entwicklung eines Erdbebengefährdungsindexes sowie durch Erdbebengefährdungskarten abschätzbar zu machen. Dafür werden wir seismologische, geologische und geomechanische Methoden und Datensätze kombinieren und gezielt ergänzen.

Die Erstellung eines Erdbebenkataloges bildet einen Grundpfeiler des Projektes, da die Hypozentren von Erdbeben Rückschlüsse auf die Lage kritisch gespannter Störungen

ermöglichen. Im ersten Teil des Projekts werden wir mittels Time Reverse Imaging (TRI) Kleinsterdbeben lokalisieren, die mit laufzeitbasierten Methoden nicht lokalisierbar sind. TRI ist auch bei geringen Signal-zu-Rausch („signal-to-noise") Verhältnissen, wie sie in der Niederrheinischen Bucht vorliegen, anwendbar, da einzelne seismische Ereignisse nicht in den Wellenformen identifiziert werden müssen. Dies ermöglicht, bestehende Erdbebenkataloge zu erweitern. Beim TRI werden wir das aufgezeichnete, zeitlich invertierte Wellenfeld in einem Geschwindigkeitsmodell der Region zurückpropagieren. Das Wellenfeld konvergiert dabei an Hypozentren von Erdbeben. Indem wir während der Simulation auch Spannungstensoren aufzeichnen, ist es außerdem möglich, die Herdmechanismen der Erdbeben zu bestimmen und somit Rückschlüsse auf die Ausrichtung des Spannungsfeldes zu ziehen. Diese Informationen fließen in die geologischen und geomechanischen Modelle mit ein und helfen, die seismische Gefährdung abzuschätzen. Anschließend versuchen wir, die Entstehungsmechanismen der katalogisierten Erdbeben zu verstehen und prüfen einen eventuellen Einfluss starker Niederschläge, um Prognosen für die seismische Reaktion des Untergrunds bei Fluidzirkulation zu machen.

SO-P-19

SMORD: A database for improving meteoroid flux estimations on Earth using seismoacoustic data

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The Earth is constantly bombarded by interplanetary matter, primarily in the form of interplanetary dust. However, larger bodies such as meteoroids also deposit matter into Earth's atmosphere, which must be taken into consideration. While meteoroids with masses above 10^8 g, which could potentially cause impacts, are closely monitored, those with masses between 10^3 g to 10^8 g are often too small to be reliably detected by telescopes. Meteoroids are typically only detectable when they interact with Earth's atmosphere, producing the luminous phenomenon known as a meteor. Conventional methods, such as optical and radiometric measurement systems, can be used to track these meteoroids. Another method for tracking meteoroids in Earth's atmosphere is the seismological method, which involves using multiple single-station observations to reconstruct the meteoroid's trajectory. Compared to optical and radiometric methods, the seismological method does not depend on low cloud coverage or night-sky conditions. Therefore, seismic observations can be used alongside conventional meteoroid observation methods to achieve a more accurately estimate of the meteoroid flux for masses ranging from 10^3 g to 10^8 g.

This study presents the SMORD, the first **s**eismoacoustic **m**eteoroid **o**bservation **r**ecord **d**atabase, which contains over 300 meteoroid events from the past 12 years. The database contains more than 40,000 seismic records, including over 6,000 meteoroid signals. SMORD provides the basis for near real-time seismoacoustic meteoroid detection and improved estimation of the meteoroid flux.

SO-P-20

Data Mining 20 Years of Microacoustic Events in a Salt Mine and Machine Learning Based Seasonal Prediction of Event Rates

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Acoustic emission (AE) measurements are carried out in a salt mine in northern Germany since 1994 as part of geomechanical investigations into mine safety and the stability of underground cavities. The focus is on three selected sections of the mine with dimensions of approximately 1 to 4 million m^3, each covered by a network of up to 32 piezoelectric sensors installed in boreholes in the mine. Except for short gaps due to non-operation of the recording system, continuous monitoring is performed.

Ongoing salt movement creates microcracks at the anhydrite-salt interface and in the vicinity of cavities. These microcracks, of the order of mm to cm, are detected and located by analyzing high-frequency seismic energy in the frequency range between 1 and 100 kHz, with a sampling rate of 400 kHz. Currently, about 7 million microacoustic events are located per year, with a current total catalog of about 210 million events. The event rates and the slopes of the magnitude-frequency distributions show distinct spatial and temporal variations. We first quantitatively compare the AE event activity with the detections of a local seismic network of accelerometers measuring at 1 Hz to 1 kHz.

We focus on an exemplary investigation of the seasonality of AE event rates in one of the three study areas. Most events in this area occur close to the chamber boundaries. Co-located measurements of temperature and humidity show a strong correlation with AE event activity. We use the event, time and location, and temperature and humidity as labels to learn simple linear and deep learning-based prediction models of event rates and locations. We find that the simple linear model performs similarly to the deep learning model when only predicting event rates, but when also predicting event locations, the deep learning model provides an advantage.

The huge catalog provides an opportunity to investigate data-driven stress interactions and the temporal and spatial sensitivity of event rates to environmental variables, and may be of interest to the larger earthquake physics community.

SO-P-21

Determination of Seismic Velocities in Backfill Material for Nuclear Waste Disposal - an Experiment at Mont Terri Rock Laboratory

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An important aspect of deep underground nuclear waste repositories is the physical characterization of buffer material which fills the voids between waste containers and ambient host rock. The Mont Terri Rock Laboratory in NW Switzerland, operated by swisstopo, is an international underground research facility which offers the environment to carry out experimental tests on such barrier systems. We report on eight years of ultrasonic monitoring in the bentonite backfill, simulating radioactive waste repository under the conditions of constant thermal load and increasing humidity in Opalinus clay. It simulates the

construction, waste emplacement, backfilling and early post-closure evolution of a high level waste (HLW) repository tunnel (Mueller et al., 2017).
The monitoring method we use is based on the generation of seismic signals in the frequency range of 1000 Hz to 100 kHz emitted and received by acoustic sensors. In total, 17 sensors (4 emitters and 13 receivers) manufactured by GmuG, form two different arrays. One is a permanent array installed within the bentonite material itself, responsible for measuring the ultrasonic transmission on a cross section through the tunnel in front of the first heater. The second array is installed within fiberglass pipes that were mounted in the roof area of FE tunnel. Each night, from 22:00 to 06:00 the next morning, repeated delta signals are generated by the emitters and respective wavefields are recorded by the receivers.
The P and S phase first arrival onsets are used then to estimate seismic velocities. Besides a general increase in velocities over time, the measurements resolve distinct differences in various areas within the backfill. Dividing the monitored area into different sections, we find that seismic velocities in the floor area of the tunnel show higher seismic velocities than in the roof area. Considering the entire wavefields at each sensor over time, we observe also strong changes in waveform characteristics by disappearing or emerging of phases or changing of amplitudes. All observations reflect changes in material properties over time. The reasons for different seismic velocities in roof and floor area of the tunnel might lie in the graveled texture and swelling of particles due to increasing humidity or in a compaction process which is faster at the bottom of the tunnel than in the roof area. The process of velocity increase is still ongoing at most of the emitter − receiver combinations.

SO-P-22

Microseismicity monitoring in materials for nuclear waste storage repositories

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One of the major tasks in nuclear waste management is to design safe and reliable sealing structures for radioactive waste repositories. Particularly for salt as a host rock, engineered barrier systems for underground waste disposal must be constructed of well-understood (cementitious) materials that will sustain environmental conditions and ensure high durability.
Within the SealWasteSafe project, we studied two materials with a potential for sealing structures for nuclear waste repositories: an innovative alkali-activated material (AAM) and standard salt concrete (SC). To analyze the development of microstructural changes within the materials, we monitored microseismicity (aka acoustic emission monitoring) occurring during the hardening and setting period in two 340-liter-cubic specimens for up to ~250 days.
The monitoring results showed, that in the first 61 days, fewer events occurred in AAM compared to SC. After this time the number of events in AAM sharply increased and significantly exceeded those observed in SC. However, the source localization analysis revealed that the increase of microseismicity in AAM material was not related to the formation of macro-cracks within the material but was mainly caused by the surface effects. Accompanying analysis of the test specimens with additional methods (such as e.g., X-ray CT) proved that no macro-cracks were observed inside the AAM specimen. Further analysis in the time and frequency domains helped to characterize the tested materials and to estimate their potential to be used for engineered barriers in nuclear waste repositories. Overall, our study shows the potential of microseismicity monitoring for feasibility studies and quality assurance in a broad range of applications, also in structural health monitoring.

SO-P-23

In-situ Acoustic Emission monitoring during H2 and CO_2 fracturing in salt rock

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Understanding the response of salt rock to fracture processes is a relevant topic of research in the context of nuclear waste deposition as well as the storage of CO_2 and H2 in salt caverns. A series of hydraulic fracturing experiments were recently conducted at the underground test site Springen in the Merkers Salt Mine/Germany under the lead of Institut für Gebirgsmechanik Leipzig. Experiments taking place in July and September 2022 were conducted using hydrogen (H2); experiments taking place end of 2023 used carbon dioxide (CO_2) as pressurized medium.

Here, we present the results of in-situ acoustic emission monitoring observing the seismic response of the fracs in both experiments. Acoustic emission represents very small seismic events with source sizes on cm-scale or below. In the context of (hydraulic) fracturing acoustic emissions outline the orientation and size of the generated fracture. In the context of these experiments the results show the variability in rock response not only in the fracture generated, but also in activating pre-existing planes of weakness. Interestingly the temporal response differs significantly: Whereas the activity in newly generated fracs dies off shortly after shut-in, pre-existing planes can remain active for weeks.

SITZUNGSTHEMEN

SG – Poster

Schwerefeld / Geodäsie

SG-P-01

Gravimetrische 3D-Modellierung des Granitkomplexes Schönbrunn/Eichigt

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Im Rahmen des Projekts E4Geo des LfULG Sachsen zur Erschließung störungsgebundener Tiefengeothermie wurde das geothermische Reservoir des Granitkomplexes Schönbrunn/Eichigt (Sbr/Eig) im Vogtland gravimetrisch untersucht. Ziel war eine 3D-Modellierung der geometrischen Ausbildung und Einbettung des Körpers in den lokalen und regionalen Kontext, sowie der gravimetrische Nachweis des Körpers, der Trennung der Granite Sbr und Eig als auch Aussagen über Dichtewerte der Granite. Hierfür wurden Modelle für lokale und regionale Betrachtungen mit IGMAS+ erstellt.
Als Datenbasis dienen Bouguer-Karten mit über 10.000 Werten. Zur Einschränkung der Mehrdeutigkeit von Potentialfeldmethoden wurden vor Beginn der Modellierungen Ergebnisse aus der Seismik, der Geologie und Gravimetrie, sowie Daten aus Bohrkernen als Randbedingung berücksichtigt. Es wurden zwei lokale Modelle (Tiefe 6km, Profillänge ~23km), im Streichen des Komplexes und senkrecht dazu, sowie ein regionales Modell (Tiefe 20km, Profillänge ~70km, N-S orientiert) mit IGMAS+ erstellt. An den fertigen 3D-Modellen wurden durch die Variation von einzelnen Parametern und Inversionen weitere Untersuchungen zu Dichtewerten und Geometrien durchgeführt.
Das lokale 3D-Modell zeigt zwei benachbarte Granitkörper Sbr und Eig mit Ausbuchtungen

an der Oberkante. Die Granite besitzen eine Dichtedifferenz von 40 kg/m^3. Trotz dieser geringen Dichtedifferenz konnte die mögliche Grenze zwischen den beiden Granitkörpern nachgewiesen werden. Das Modell zeigt eine getemperte Kontaktzone geringerer Dichte zwischen dem Granitkomplex und dem umgebenden Gestein. Die Ergebnisse des lokalen Modells deuten auf einen wassergesättigten, alterierten Komplex hin. Das regionale Modell zeigt einen Granitkörper, der bis zu einer Tiefe von 10 km in Phylliten und Paragneisen eingebettet ist. Die postulierten Dichtewerte des lokalen Modells werden durch das regionale Modell bestätigt. Das regionale Modell bietet Einblicke in die Beziehungen zu anderen geologischen Strukturen wie dem Schwerhoch von Hof und dem Schwerminium des Eibenstock- und Karlovy-Vary-Granits, die auf eine Granitmächtigkeit bis in 14 km Tiefe hinweisen.

SG-P-02

Seismic tomography derived 3D density models of the Alpine lithosphere and upper-mantle using forward gravity modelling

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Present-day lithosphere and upper mantle architecture (e.g., lithospheric thickness, slab geometries) and physical state (e.g., density) of the Alps is crucial to understand its geodynamic evolution as well as the coupling with surface-processes. Previous studies have addressed the variability in the seismic tomography models using statistical clustering and their geodynamic implications using forward geodynamic modelling (Kumar et al., 2022). In this study, we present a 3D density model of the Alpine lithosphere and upper-mantle (up to 300 km depth) derived from the conversion of shear-wave tomography models and their statistical cluster using Gibbs-free energy minimization. Therefore, we have integrated the 3D density distribution in the mantle as voxels-cubes with a 3D density model of the crust that has previously been built based on various geological, seismic and satellite gravity data (Spooner et al., 2019). We forward computed the gravity response of these models (crust and mantle-voxel) using IGMAS+ software (Anikiev et al., 2023) and quantitatively compared the results with the recently developed pan-Alpine surface-gravity database (Zahorec et al., 2021). Finally, we discuss the performance of individual tomography models using the residuals of the calculated and observed gravity fields, especially in the light of mantle depth sensitivity to the gravity field. Additionally, we have focused on identifying and understanding systematic errors in the misfit distributions, providing deeper insights into the relations between upper mantle shear-wave velocity distribution and gravity fields. The workflow developed in this study has broader application potentials beyond the Alpine region, offering a versatile data-integrated approach to constrain the 3D density structure of upper mantle structures using gravity data.

SG-P-03

Parker-Oldenburg Inversion to infer Subglacial Topography in Antarctica – Results and Uncertainty Assessment

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The Antarctic continent with its vast ice sheet of up to 4000 m thickness is of great importance in geoscientific and cryospheric research. The thickness of the Antarctic Ice Sheet together with the structure and roughness of its subglacial topography are key parameters for the stability of the Antarctic glaciers. Consequently, these have to be carefully considered in climate modelling. Subsurface models based on the inversion of gravity field data can help to improve our knowledge about the subglacial topography. For this inversion, a sound knowledge of the gravity field in Antarctica is central.
Within the AntGrav project, the gravity data of more than 45 campaigns (airborne, shipborne and ground-based) were processed in a consistent way. Based on these data a continent-wide gravity field solution was calculated using the collocation technique in order to infer consistent grids of gravity disturbances, gravity anomalies and geoid heights.
Now, the gravity disturbance solution was used to calculate a new map of the subglacial topography applying Parker-Oldenburg Inversion.
Three inversion parameters (density contrast across the interface, average depth and the upper cut-off wavelength of the filter), different a-priori datasets together with some theoretical assumption that Parker-Oldenburg Inversion is based on are crucial for the determination of the subglacial topography. In order to calculate the uncertainty of the calculated subglacial topography model one has to firstly calculate the error propagation for different parameter combinations, secondly calculate or estimate the influence of the uncertainty of the a-priori datasets and thirdly estimate the effect of the theoretical assumptions.

In this contribution, we present inversion results of the subglacial topography in Antarctica. We will also discuss the uncertainty assessment in detail and show first results.

VU – Mündliche Präsentation

Vulkanologie

VU-A-01

TEM at breathtaking heights: Imaging the shallow fumarolic system of Lastarria volcano, Chile

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Volcanic activities around the world pose significant threats to both human life and infrastructure, underscoring the importance of comprehending the underlying processes within volcanic systems. Furthermore, volcanoes can be a window to better understand subsurface processes on a larger scale. This study presents the results of transient electromagnetic (TEM) measurements conducted on Lastarria volcano in Chile, aimed at unravelling the subsurface dynamics that govern volcanic activity. The investigation employs state-of-the-art electromagnetic sensing and inversion techniques, focusing on the electrical conductivity variations at shallow depths (~250m) around a field of fumarolic vents emitting hot sulphuric gases.
Here, we present preliminary 1D inversion results using conventional Marquardt-Levenberg and Occam inversion techniques. The data shows interesting results, with a high agreement between consecutive stations. The first significant discovery is a double conductive layer situated at shallow depths beneath the volcano's edifice. The second noteworthy finding involves a deep-seated conductor identified within the subsurface, which adds a layer of complexity to the volcanic system. Unravelling the properties and implications of this deep conductor might be instrumental in comprehending the overall behaviour of the fumarolic fields.
Both structures could be confirmed by sensitivity modelling studies. Although the precise resistivity and thickness of the double-layer remains uncertain, its presence is evident, and the structure is robust. The depth and spatial extent of the deep conductor comes with a high uncertainty, since the sensitivity of the TEM method is greatly decreased below the shallow conductor. Still, it is
vital for a good fit of the data. Overall, our results indicate a good correlation with the surface manifestations and EMI mapping data.

VU-A-02

Deriving tectonic activity from sediment transport offshore Mt Etna using MBES data

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Mount Etna, located on the eastern coast of Sicily, is one of the most active and well-studied volcanoes in the world. While the onshore processes of its tectonic activity have been extensively documented, the offshore sector remains less understood. The eastern flank of Mt Etna is sliding seaward at a rate of a few centimeters per year. This is mostly gravity driven

but is also influenced by volcanic and tectonic processes. Understanding the driving mechanism of this instability is essential for the evaluation of geohazard potential in densely populated regions, like the Mediterranean coastline. The area around Mt Etna itself has a population of more than 700.000, and a tsunami event would likely affect a wide area. Repeated bathymetric surveys have previously been utilized to investigate topographic changes in other settings, such as the Mississippi Delta and Stromboli volcano. Here, we make use of data collected during *RV Meteor* cruises M86-2 (2011) and M178 (2021) with hull-mounted Kongsberg multibeam echosounders (EM122 and EM710). These data sets, which were collected 10 years apart, enable us to investigate changes in seafloor morphology and sediment distribution. We used the two bathymetric surveys to calculate depth difference maps of the regions covered by both surveys, and the EM710 data, in particular, allows us to discern subtle but significant depth changes of the seafloor. Depending on the water depth in the survey area, the method can reliably detect vertical changes of under two meters. This differential map covers a 50 km^2 area between Riposto and Acireale and shows significant changes in the Acireale- / Santa Tecla-canyon, which are indicative of active sediment transport. These results were further strengthened by employing and analyzing geomorphologic techniques. Preliminary findings suggest that depositional patterns are influenced by a complex interplay between regional tectonics and sediment transport, but further analysis is needed to assess the role and influence of active fault systems in this area. These findings represent a baseline for further modelling of active processes in the region.

VU-A-03

Geomagnetic secular variation at high latitude at the end of the Cretaceous Normal Superchron: new data from the Okhotsk-Chukotka volcanic belt (NE Russia)

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The Cretaceous Normal Superchron (CNS, 84−121 Ma) is a singular period of the geodynamo's history, identified by a prolonged absence of polarity reversals. To better characterise the palaeosecular variation (PSV) of the geomagnetic field at the end of this interval, we sampled seven continuous sequences of lava flows from the Okhotsk-Chukotka Volcanic Belt, emplaced 84−89 Ma in the vicinity of the Kupol ore deposit (NE Russia). From a collection of 1024 paleomagnetic cores out of 82 investigated lava flows, we successfully determined the paleodirections of 78 lava flows, which led to 57 directional groups after removing the serial correlations. The resulting palaeomagnetic pole is located at 170.0°E, 76.8°N (A_{95} = 5.2°, N = 57), in good agreement with previous estimates for north-eastern Eurasia. Aiming at quantifying PSV at a reconstructed paleolatitude (λ) of ~80°N, we obtained a VGP scatter S_b = 21.5° (19.3−24.0°, N = 57), the value of which was corrected for within-site dispersion and is little dependent on the choice of the selection criteria. Compared to previous palaeodirectional datasets characterizing PSV at various paleolatitudes during the CNS, our S_b estimate confirms a relative latitudinal increase $S_b(\lambda = 90°)/ S_b(\lambda = 0°)$ on the order of 2−2.5. Focussing on PSV at high paleolatitude within the 70−90° range, we show that was ~15% lower at the end of the CNS than during the past 10 Myr, confirming that the singular polarity regime of the geodynamo observed during the CNS is likely accompanied with reduced PSV

Reference: Lhuillier, F., Lebedev, I. E., Tikhomirov, P. L., & Pavlov, V. E. (2024). High-Latitude Geomagnetic Secular Variation at the End of the Cretaceous Normal Superchron Recorded by Volcanic Flows From the Okhotsk-Chukotka Volcanic Belt. *Journal of Geophysical Research: Solid Earth, 129*, e2023JB027550. 10.1029/2023jb027550

VU – Poster

Vulkanologie

VU-P-01

Volcanic Island Sector Collapse: Reconstruction of volcanic activity and implications for subsequent mass movements from marine records drilled with MeBo70 offshore Montserrat (Lesser Antilles)

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Volcanic island sector collapses produce some of the volumetrically largest mass movements on earth. Understanding their potential catastrophic impact on human lives and infrastructure is crucial for risk assessment. Key to the general comprehension of these processes is understanding the interplay between volcanic activity and subsequent mass wasting events.
This project aims at contributing to this by reconstructing volcanic activity and establishing a mass wasting event chronostratigraphy from marine sediment drill cores. These were obtained during the Meteor expedition M154-2 offshore Montserrat, Lesser Antilles, in 2019 in sectors south to east of the island. They cover a depth range of up to 63 mbsf. We present samples from four drill sites analyzed regarding their sediment componentry and geochemical composition of volcanic materials.
In all cores, sediments predominantly comprise mud-rich facies interbedded with fine to coarse-grained sands with variable proportions of volcanic and biogenic clasts. In a small number, coarse volcanic sands to volcaniclastic gravels were encountered. Tuffaceous deposits are less frequent.
Selected coarse-grained and tuffaceous layers from the drill site GeoB23711 at the eastern undisturbed slope were utilized to gain an insight into differentiation between primary volcanic layers, flank collapse deposits, and turbidites. Additional ash layers from southeastern drill sites in the vicinity of the large landslide complex Deposit 2 (GeoB23702, GeoB23725) and south of Montserrat (GeoB23731) provide an insight into regional volcanic activity. Semi-quantitative petrographic analyses of all samples by polarized light microscopy enable the investigation of clast inventories to differentiate sediment units. Geochemical fingerprinting of major and trace elements of volcanic glasses by electron microprobe and LA-ICPMS elucidates this differentiation. The geochemical glass analyses further show different basaltic to rhyolitic compositions in the range of Arc Tholeiitic and Calc-alkaline series. Trace element analyses enabled the possibility to better distinguish between single eruptions and also to narrow down their source area(s) as well as that of the sedimentary material.
The analyzed samples represent different stages of volcanic island evolution with periods of increased volcanic activity and eruptions, dome/flank collapses, submarine mass wasting events, and periods of relative inactivity.

Index of authors

(bold = first author)