KIEL 2021

Christian-Albrechts-Universität zu Kiel

81. Jahrestagung der Deutschen Geophysikalischen Gesellschaft in Kiel

01. - 05. März 2021

Mit freundlicher Unterstützung von:

ALT Advanced Logic Technology
Allied Associates Geophysical GmbH
BGE Bundesgesellschaft für Endlagerung mbH
CDM Smith Consult GmbH & Guideline Geo
DIGOS Potsdam GmbH
DMT GmbH & Co. KG
European Space Agency
GeCon Geophysik GmbH
Geotomographie GmbH
GGL Geophysik und Geotechnik Leipzig GmbH
Ingenieurgesellschaft für geophysikalische Messtechnik GmbH
(Nanometrics/GemSys)
Innomar Technologie GmbH
Lennartz Electronic GmbH

Inhaltsverzeichnis

Liebe Teilnehmerinnen und Teilnehmer der 81. Jahrestagung der Deutschen Geophysikalischen Gesellschaft!

Eine rein virtuelle Jahrestagung ist ein Novum in der fast 100-jährigen Geschichte der DGG! Wir freuen uns in den kommenden Tagen auf gänzlich neue Eindrücke, auf spannende wissenschaftliche Ergebnisse und auf den intensiven Austausch mit den Teilnehmenden der 81. Jahrestagung.

Es erwarten uns im Hauptprogramm der Tagung 30 Vorträge von Nachwuchswissenschaftlerinnen und Nachwuchswissenschaftlern, die von ihren jeweiligen Heimatinstituten nominiert wurden, um ihre Ergebnisse auf dem Jahrestreffen zu präsentieren. Damit legen wir dieses Jahr im Vortragsprogramm bewusst den Fokus auf die junge Generation, aber nutzen zugleich die Vorteile eines digitalen Formates bei den ePostern, die für 12 Monate nach der Tagung weiterhin zugänglich sind und zum wissenschaftlichen Austausch einladen. Mein besonderer Dank gilt dem Kieler Organisationsteam der 81. Jahrestagung, das mit viel Motivation, Innovation und Kreativität in dieser Form Neuland für die DGG betreten hat.

Mit dem digitalen Format erfinden wir uns als Fachgesellschaft ein Stück weit neu und doch werden Sie feststellen, dass sich viele bewährte Komponenten unserer Jahrestagungen auch im diesjährigen Programm an gewohnter Stelle wiederfinden. Die Treffen der Arbeitskreise wie auch die zahlreichen Workshops finden ebenso wie die Mitgliederversammlung statt. Ein tägliches Highlight werden sicherlich die Plenarvorträge sein. Ich freue mich aber insbesondere darauf, viele Kolleginnen und Kollegen, viele Freunde und Forschungspartner in den Themenräumen zu treffen und bin gespannt, wie wir zusammen das digitale Format mit Leben füllen. Sollte es doch mal an der einen oder anderen Stelle technisch oder organisatorisch etwas ”ruckeln”, dann bitte ich alle Teilnehmenden um etwas Geduld, Flexibilität und Gelassenheit zusammen bekommen wir das schon hin! Das Wichtigste ist am Ende doch, dass wir untereinander den Kontakt halten können, neue Kontakte herstellen können und die Gelegenheit haben, über aktuelle wissenschaftliche Ergebnisse zu diskutieren!

Die Jahrestagungen sind die Seele der DGG und ein Fixpunkt im Kalender vieler Geophysikerinnen und Geophysiker in Deutschland. So freue ich mich besonders, dass wir auch in 2021 trotz der Pandemielage zu einem Jahrestreffen zusammenfinden. Nicht nur für die jüngeren Kolleginnen und Kollegen ist die DGG-Tagung als nationales Treffen von herausgehobener Bedeutung, da sie ein Forum nicht nur für die Präsentation von Ergebnissen und informellen Austausch bietet, sondern für das Knüpfen von Kontakten und das Kennenlernen und Eintauchen in die deutsche geophysikalische Gemeinschaft essentiell ist.

Die erste digitale Jahrestagung wird für uns alle aufregend sein, denn es gilt unsere bewährten Inhalte in neuen Formaten zu kommunizieren. Für Geophysikerinnen und Geophysiker ist dies im Grunde aber fast Alltagsgeschäft, denn auch in der Forschung erkunden wir permanent neues Terrain. So sind wir als DGG bestens aufgestellt, unsere Jahrestagung mit einem virtuellen Format weiter zu entwickeln und wir laden alle Mitglieder ein, diese Transformation mit uns zu gestalten denn eines ist sicher: die Vorteile des digitalen Austausches wollen wir auch in Zukunft weiterhin nutzen!

Ich wünsche allen Teilnehmerinnen und Teilnehmern eine spannende Woche mit aufregender Wissenschaft, vielfältigen Gesprächen und vor allem viel Spaß beim Austausch untereinander!

Ihre

Heidrun Kopp

Heidrun Kopp

Präsidentin der Deutschen Geophysikalischen Gesellschaft DGG

Einladung zur Mitgliederversammlung

Dr. Katrin Schwalenberg, kommissarische Geschäftsführerin,
geschaeftsfuehrung@dgg-online.de

Im Namen des Vorstands der Deutschen Geophysikalischen Gesellschaft (DGG) e.V. laden wir alle Mitglieder der DGG im Rahmen unserer 81. Jahrestagung zur Mitgliederversammlung am

Mittwoch, den 03. März 2021, von 17:30 bis ca. 19:30 Uhr

ein. Die Mitgliederversammlung wird, wie auch die Jahrestagung, aufgrund der gegenwärtigen Corona-Maßnahmen und damit verbundenen Hygiene- und Abstandsregeln als rein virtuelle Veranstaltung stattfinden. Der Link für den Livestream zur Teilnahme an der Mitgliederversammlung sowie kurzfristige Änderungen im Tagungsprogramm werden rechtzeitig auf der Tagungswebseite https://dgg2021.dgg-tagung.de/ bekanntgegeben.

Tagesordnung:

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

TOP 2: Genehmigung der Tagesordnung

TOP 3: Genehmigung des Protokolls der Mitgliederversammlung vom 28. September 2020 in Kiel

TOP 4: Bericht der Präsidentin

TOP 5: Bericht der Geschäftsführung

TOP 6: Bericht des Schatzmeisters

TOP 7: Bericht der Kassenprüfer und Entlastung des Schatzmeisters

TOP 8: Bericht zum Geophysical Journal International

TOP 9: Berichte der Rote Blätter- und GMit

TOP 10: Kurzberichte der Leiterinnen und Leiter der DGG-Komitees
Publikationen, PRO -Public Relations & Outreach, Jahrestagungen, Ehrungen, Firmen, Mitglieder, Studierende, Studienfragen, Kooperationen, Chancengleichheit, 100-Jahre DGG

TOP 11: Kurzberichte der Sprecherinnen und Sprecher der DGG-Arbeitskreise
Angewandte Geophysik, EndlagerGeophysik, Elektromagnetische Tiefenforschung, Induzierte Polarisation, Seismik, Hydro- und Ingenieur-Geophysik, Dynamik des Erdinneren, Vulkanologie, Geschichte der Geophysik, Geothermie, Seismologie, Marine Geophysik

TOP 12: Neues vom Dachverband Geowissenschaften (DVGeo) und den geowissenschaftlichen Gesellschaften

TOP 13: Aussprache

TOP 14: Entlastung des Vorstands

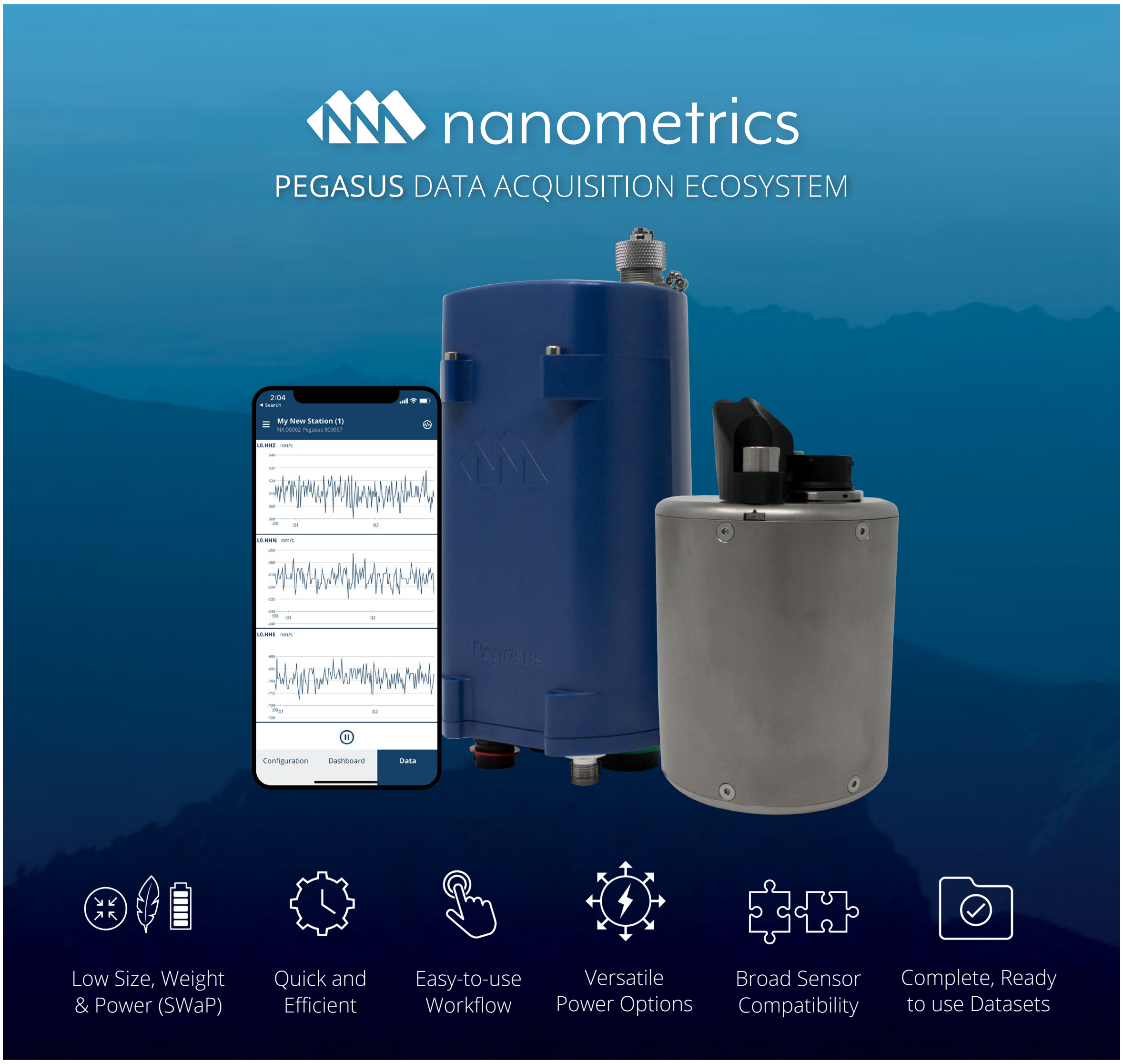
TOP 15: Wahlen zum Vorstand (Beisitzerinnen und Beisitzer)

TOP 16: Protokollarische Feststellung des Vorstands

TOP 17: Wahl der Kassenprüfer und Kassenprüferinnen

TOP 18: Anträge und Beschlüsse

TOP 19: Verschiedenes


nanometrics
PEGASUS DATA ACQUISITION ECOSYSTEM
Low Size, Weight & Power (SWaP)
Quick and Efficient
Easy-to-use Workflow
Versatile Power Options
Broad Sensor Compatibility
Complete, Ready to use Datasets

Allgemeine Hinweise
für Tagungsteilnehmer

Veranstalter
Deutsche Geophysikalische Gesellschaft e.V.
Geschäftsstelle: c/o Dr. Katrin Schwalenberg
Bundesanstalt für Geowissenschaften und Rohstoffe, Stilleweg 2
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Eventmanagement
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Kerstin Biegemann, Quintschlag 37, 28207 Bremen
E-Mail: dgg2021@witago.com

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SEG Workshop	Sebastian Krastel	sebastian.krastel@ifg.uni-kiel.de

Tagungsort
Die Jahrestagung 2021 wird aufgrund der aktuellen Situation nicht wie in den letzten Jahren vor Ort in Kiel stattfinden können. Stattdessen wird es eine digitale Tagung geben mit:

- Vorträgen von JungwissenschaftlerInnen (Livestream für alle Tagungsteilnehmer)
- Posterpräsentationen als ePoster
- Plenarvorträgen (Livestream für alle Tagungsteilnehmer)
- weiteren digitalen Programmpunkten

Tagungsbüro
Internetadresse der Tagung: **https://dgg2021.dgg-tagung.de/**

Anmeldung zur Tagung
Die Tagungsleitung bittet um frühzeitige Anmeldung zur Tagung mit dem Online-Formular auf der Internetseite der Tagung

https://dgg2021.dgg-tagung.de/.

Da die Tagung in einem Online-Format stattfindet, ist eine Anmeldung vor Ort nicht möglich. Tagungsunterlagen können von der Internetseite der Tagung heruntergeladen werden.

Tagungsgebühren

	Ermäßigt (bis 31.1.2021)	Voll (ab 1.2.2021)
DGG-Mitglied, normal	125 Euro	160 Euro
DGG-Mitglied, Junior/innen*	20 Euro	25 Euro
AGS, AEF, DPG oder DMG Mitglied, normal	125 Euro	160 Euro
AGS, AEF, DPG oder DMG Mitglied, Junior/innen*	20 Euro	25 Euro
Nichtmitglieder, normal	175 Euro	210 Euro
Nichtmitglieder, Junior/innen*	40 Euro	45 Euro
Senior* / Schullehrer/innen	40 Euro	45 Euro

*Junior/innen sind am 1.3.2021 jünger als 30 Jahre und Senior/innen älter als 65 Jahre.

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

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

Tagungsprogramm

Eröffnungsveranstaltung

Die Eröffnungsveranstaltung findet am Montag, 01.03.2021
von 09:00 - 10:00 Uhr statt.

- Begrüßung durch die Tagungsleitung
- Ankündigungen
- Preisverleihungen

Studentischer Abend

Der Studentische Abend findet am Montag, dem 01.03.2021, ab 19:00 Uhr statt. Aufgrund der aktuellen Situation wird der Studentische Abend in diesem Jahr als Online-Veranstaltung stattfinden. Details über die digitale Plattform und das Programm werden folgen. Wir planen einen interaktiven, kommunikativen und vor allem unterhaltsamen Abend für euch!

Meet & Greet

Das Meet & Greet wird virtuell am Donnerstag den 04.03.2021 von 15:30 bis ca. 17:00 Uhr stattfinden. Auf dem Programm steht **Baltic Gender**, ein von der EU (Horizon 2020) gefördertes Projekt rund um Themen zur Gleichstellung mit 8 Partner Institutionen der Ostsee Region, das von 2016-2020 lief (www.baltic-gender.eu). Wir freuen uns auf unsere Gäste, **Dr. Başak Kisakürek Ibsen** (GEOMAR) Project Manager von Baltic Gender und Falling Walls Finalist und **Dr. Iris Werner**, Gleichstellungsbeauftragte der Uni Kiel und Baltic Gender Work Package Leader WP3 Structural Changes, die uns jeweils für 10-15 min eine Einführung zu Baltic Gender und zu Structural Changes geben mit anschließender offener Diskussion.

DGG Mitgliederversammlung

Die DGG Mitgliederversammlung findet am Mittwoch, den 03.03.2021 von 17:30 -19:30 Uhr statt.

Podiumsdiskussion: Lehren in Zeiten von Corona

Eine Diskussionsrunde mit Experten, Professor*innen und Studentinnen widmet sich dem Thema, wie wir digitale Lehre in der Praxis umsetzen und erleben und wie wir die Zukunft dieser Formate sehen. Die Runde, die auch für Beiträge aus dem Publikum offen sein wird, wird moderiert von Alexander Rudloff.

Podiumsgäste: Philip Marquardt, Mitarbeiter der wissenschaftlichen Weiterbildung CAU Kiel mit Schwerpunkt ”Digitale Lehre”, Prof. Christine Thomas (Uni Münster), Prof. Tilo von Dobenek (Uni Bremen), Carolin Wallmeier, Studierendenvertreterin Master Geophysik CAU Kiel, Hannah Treppke, Studentin Master Geophysik Uni Münster. Die Podiumsdiskussion findet am Dienstag, den 02.03.2021 von 16:30 - 18:00 Uhr statt.

Pyrocko Workshop
We will offer a series of brief introductions to various tools in the Pyrocko ecosystem (pyrocko.org). We are planning to give a mixture of short presentations, demos, and for those who want, some very short hands-on tutorials. The workshop will take place on BBB (video conference in web browser): Thursday, 2021-03-04, 14:30-17:00. Further details are available here.

Workshop ”FAIR research data publication”
Interaktives Seminar zu aktuellen Standards und der best practice bei der Veröffentlichung von Forschungsdaten, insbesondere im Zusammenhang mit Journal-Publikationen. Diskutiert werden Möglichkeiten, Vorteile und Herausforderungen von wissenschaftlichen Datenveröffentlichungen. Das Seminar findet am 04.03.2021, 14:30 - 18:00 Uhr statt.

Virtueller DGG-SEG Workshop ”Scientific Drilling”
Wissenschaftliche Bohrungen ermöglichen den Zugang zu Fluiden und Gesteinen im Untergrund, die für die Bestimmung von Gesteinen, die Interpretation von geophysikalischen Daten, die Gewinnung von Gesteinsproben, und als Input für Modelle unerlässlich sind. Dieser Workshop bietet einen Überblick über wissenschaftliches Bohren, einschließlich der geophysikalischen Vorerkundung, Bohrtechniken, Logging-Verfahren, Probennahme, in-situ Monitoring, Bohrlochexperimente, sowie der in jedem Teil des Prozesses durchgeführten wissenschaftlichen Arbeiten. Der Workshop findet am Donnerstag- und Freitag (04/05. März) jeweils nachmittags statt.

Am Freitag den 5.3.2021 findet zwischen 14:00 und 15:00 Uhr die SEG-Lecture statt. Vortragender ist Brandon Dugan - Associate Professor, Department of Geophysics, Colorado School of Mines - zum Thema: Investigating Submarine Slope Failures with Geophysical Data, Scientific Drilling, Laboratory Experiments, and Numerical Modeling.

Weitere Informationen entnehmen Sie bitte dem folgenden Flyer und dem Workshop Programm

DGG-Kolloquium

Das alljährliche DGG-Kolloquium mit dem diesjährigen Thema "**Endlagergeophysik**" findet am Mittwoch, den 03.03.2021, statt.

Programm des DGG –Kolloquiums:

Zeiten	**Vortragende/Autoren**	**Titel**
14:30-15:00	<u>Rücker, C.</u> (BASE - Bundesamt für die Sicherheit der nuklearen Entsorgung)	Auf dem Weg zu bestmöglicher Sicherheit – Das deutsche Standortauswahlverfahren für die Endlagerung hochradioaktiver Abfälle - Forschung, Regularien und die Rolle der Geophysik
15:00-15:45	<u>Schuck, A.</u> (GGL Geophysik und Geotechnik Leipzig GmbH), Bilgili, F., Teichmann, L., Gärtner, G., Ding, H. und Köhler, J. (BGE Bundesanstalt für Endlagerung)	Vorbereitung und Durchführung der 3D-Seismik Asse
15:45-16:30	<u>Giese, R.</u>, Lueth, S., Richter, H., Wawerzinek, B., Jaksch, K. und Esefelder, R. (GFZ - Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum)	3D-Untertage-Seismik in Kristallin-, Salz- und Tongestein - Modulares Erkundungssystem schließt die Lücke zwischen Oberflächen- und Bohrlocherkundung
16:30-17:15	<u>Gundelach, V.</u>, Furche, M., Schuster, K., Kaiser, D., Schennen, S. und Beilecke, T. (BGR - Bundesanstalt für Geowissenschaften und Rohstoffe)	Beispiele untertägiger Erkundung durch Geophysik im Ton, Kristallin und Salz

Schwerpunktthemen

Amphibische Geophysik

Der Übergangsbereich zwischen Land und Wasser (amphibische Zone) ist für viele wissenschaftliche Fragen z.B. in der Archäologie, dem Küstenschutz, oder der Küstendynamik eine besonders interessante Zone, stellt aber aus geophysikalischer und messtechnischer Sicht eine Herausforderung dar. In dieser Session wollen wir uns daher den Herausforderungen der amphibischen Geophysik widmen, die ein breites Spektrum geophysikalischer Methoden abdecken wie z.B. Magnetik, Geoelektrik, Georadar, Seismik und Hydroakustik.

Ambient Noise

Lange Zeit als Störquelle in seismischen Signalen verkannt, bildet das allgegenwärtige seismische Rauschen heute eine wichtige Signalquelle im Bereich der Seismik/Seismologie. Anwendungen decken eine große Bandbreite an Skalen ab, von der zerstörungsfreien Materialprüfung im Zentimeter Bereich bis zur globalen Seismologie im Kilometer Bereich ab. Neben der Auswertung des Rauschens beispielsweise in der Strukturerkundung ist die Beschreibung der Quellen ein wichtiges Forschungsfeld. Wir freuen uns über Beiträge zum seismischen Rauschen auf allen Skalen.

Satellitengestützte Erdbeobachtung

Satellitengestützte Messungen haben neue Möglichkeiten in der Erdbeobachtung eröffnet. Wir bitten um Beiträge von Studien über das System der festen Erde und ihren dynamischen Prozessen, in denen satelliten-gestützte Beobachtungen einfließen, allein oder in Kombination mit Beobachtungen am Boden. Willkommen sind dabei Beiträge mit Modellierungen sowie über neuartige methodische Entwicklungen.

Richtlinien zur Poster-Erstellung

Wichtiger Hinweis

Das Hochladen der e-Poster sollte bis zum **Freitag, den 26.2. 2021**, erfolgen. Bis dahin können Sie sich jederzeit erneut am System anmelden, um Änderungen und Korrekturen vornehmen.

Hinweise zum Copyright/Urheberrecht/Good Scientific Practice

Bei der Erstellung und Einreichung eines digitalen Posterbeitrages ist es sehr wichtig, die Regeln des geltenden Urheberrechts/Copyrights und die Auflagen der Good Scientific Practice im Blick zu haben und einzuhalten: Zitieren Sie korrekt und ausgiebig. Legen Sie in Ihrem ePoster ein ausgiebiges Literaturverzeichnis an. Schützen Sie sich vor Plagiatsvorwürfen!

Anforderungen

- Poster können in deutscher und englischer Sprache erstellt werden
- Anzahl der Seiten: **Eine Seite (1)**
- Dateiformat: PDF
- Format: Landscape/Querformat
- Verwenden Sie **keine** animierten Effekte, ”Animationen” und Videos.

Empfehlungen

- Größe: 40.97 x 23.04 inch bzw. 103,86 x 58,42 cm (Seitenverhältnis: 16:9)
- Schriftgröße: mind. 28pt, 24 für Referenzen
- Schrift: Arial, Calibri oder Times New Roman
- Achten Sie darauf, dass Text und Hintergrund einen großen Kontrast aufweisen (dunkle Schrift auf hellem Hintergrund oder umgekehrt).
- Für eingebettete Bilder bevorzugte Dateiformate sind .jpeg oder .png in einer Auflösung von 72 oder 96 dpi.

Erstellung des Posters

Speichern Sie Ihr Poster vor dem Einreichen als PDF-Datei. Alle neueren Versionen von PowerPoint und die meisten anderen Software-Anwendungen ermöglichen es Ihnen, Ihr Poster über das Menü ”Datei Speichern unter” oder über die Option ”Datei Drucken als .PDF” als PDF-Datei zu speichern.

Upload des ePosters

Um ihr ePoster (PDF-Poster) einzureichen, befolgen Sie bitte die folgenden Schritte:

- Melden Sie sich im Abstractportal mit Ihren Zugangsdaten an, die für die Abstract-Einreichung verwendet werden. (Falls nicht vorhanden, benutzen Sie bitte den Link ”Neues Passwort senden”)
- Nach dem Login wird die Liste der Abstracts automatisch im Menüpunkt ”Meine Abstracts” geöffnet.
- Für die als Poster-Präsentation ausgewählten Abstracts ist ein Upload-Formular zum Hochladen des ePoster als PDF vorbereitet.
- Klicken Sie auf die Schaltfläche ”Durchsuchen”, um Ihr lokales Dateiverzeichnis zu öffnen. Wählen Sie hier die bereits vorbereitete PDF-Datei aus und klicken Sie auf ”Speichern”. Achtung, die Datei muss lokal auf dem Rechner gespeichert sein (nicht in der Cloud). Der erfolgreiche Upload wird direkt im System bestätigt.
- Bis zum Einsendeschluss am 26.2.2021, 24:00 Uhr (MEZ) können Sie jederzeit Änderungen an Ihrer ePoster-PDF-Datei vornehmen, indem Sie eine neue Version hochladen. Die vorherige Version wird nach dem Hochladen einer neuen Datei gelöscht.

Publikationsmöglichkeit der Poster

Die DGG bietet ihnen in Kooperation mit dem Fachinformationsdienst Geowissenschaften FID GEO die Möglichkeit, Ihr Poster nach aktuellen Standards auf dem Publikationsserver GEO-LEOe-docs zu publizieren. Damit ist ihr Poster dauerhaft verfügbar und mit DOI zitierbar. Für das Einstellen des Posters müssen Sie sich bei GEO-LEOe-docs anmelden, in einem Webformular die publikationsrelevanten Einträge vornehmen und dann die PDF-Datei des Posters hochladen. Bitte wählen Sie unter ”Bereiche & Sammlungen” den Bereich ”Konferenzen” und dann ”DGG 81. Jahrestagung 2021”. Wir empfehlen eine Open-Access-Publikation mit einer Creative Commons Namensnennung 4.0 International (CC BY 4.0) Lizenz.

Ausstellung

Wir freuen uns, dass wir in diesem Jahr eine große Anzahl von Firmen, Institutionen und Forschungsverbünden erstmals in einem digitalen Format begrüßen können.

Angemeldet sind (in alphabetischer Reihenfolge):

ALT Advanced Logic Technology
Allied Associates Geophysical GmbH
BGE Bundesgesellschaft für Endlagerung mbH
CDM Smith Consult GmbH & Guideline Geo
Deutsche Geophysikalische Gesellschaft
DIGOS Potsdam GmbH
DMT GmbH & Co. KG
European Space Agency
GeCon Geophysik GmbH
Geotomographie GmbH
Ingenieurgesellschaft für geophysikalische Messtechnik GmbH
(Nanometrics/GemSys)
Innomar Technologie GmbH
Lennartz Electronic GmbH

Die Adressen, Websites und Kontaktpersonen entnehmen Sie bitte unserer Website https://dgg2021.dgg-tagung.de/

Sessions

AR	Archäogeophysik und Geoarchäologie
BL	Bohrloch-Geophysik
EM	Elektromagnetik und Georadar
EX	Extraterrestrische Geophysik
GD	Geodynamik
GE/IP	Geoelektrik und Induzierte Polarisation
GR/MA	Gravimetrie und Magnetik
GS	Geschichte der Geophysik
DLO	Geophysik in der Lehre und Öffentlichkeit
GT	Geothermie und Radiometrie
MA	Marine Geophysik
NM/ML	Numerische Modellierung, bildgebende Verfahren und maschinelles Lernen
AG	Angewandte Geophysik
SE	Seismik
SO	Seismologie
UI/ZP	Umwelt- und Ingenieurgeophysik, Zerstörungsfreie Prüfung
VU	Vulkanologie

Übersicht Tagungsprogramm

Montag, 01. März 2021

Eröffnungsveranstaltung

Montag, 01. März 2021 | 09:00 - 10:00

Moderation: Jörg Ebbing & Henriette Sudhaus

Vorträge

Montag, 01. März 2021 | 10:10 - 11:40

Moderation: Mareen Lösing & Heidrun Kopp

10:10-10:30 **V1-01**
Possibilities of transdimensional inversion for estimating deep Earth velocity and mantle structure
Wolfgang Szwillus (Günther-Bock Preisträger der DGG)

10:30-10:50 **V1-02**
The 2013 Wind River earthquake: an example of a ductile seismic rupture?
M. Thielmann

10:50-11:00 **Pause (Schreibtischyoga)**

11:00-11:20 **V1-03**
Earthquakes induced by ice-mass loss: A case example for southern Greenland
R. Steffen, H. Steffen, R. Weiss, 3, B. Lecavalier, G. Milne, S. Woodroffe, O. Bennike

11:20-11:40 **V1-04**
A Multidisciplinary approach to constrain the dynamics of the Altiplano-Puna magmatic system
A. Spang, T. S. Baumann, B. J. P. Kaus

Mittagspause

Montag, 01. März 2021 | 11:40 - 12:20

Company-Slam & Digitale Firmenausstellung

Montag, 01. März 2021 | 12:20 - 13:20

Moderation: Anke Dannowski & Martin Thorwart

Live Postersession B1 MA 1

Montag, 01. März 2021 | 13:20 - 13:50

Moderation: Christoph Böttner

MA1-01
Imaging the crustal structure of the southern plate boundary of the Niuafo'ou microplate, Lau Basin, southwest Pacific, with reflection and refractions seismic data
A. Beniest, A. Dannowski, M. Schnabel, F. Schmid, R. Werner, H. Kopp, M. Riedel, I. Heyde, U. Barckhausen, F. Petersen, B. Schramm, M. Hannington, SO267 Shipboard Scientific Party

MA1-02
Reflection seismic indicators for submarine permafrost and gas hydrate distributions on the Canadian Arctic Beaufort Shelf
H. Grob, M. Riedel, S. Krastel, J. Bustamante Restrepo, M. J. Duchesne, G. Fabien-Ouellet, Y. K. Jin, J. K. Hong

MA1-03
Crustal structure of the Ligurian Basin revealed by seismic travel time tomography
A. Dannowski, H. Kopp, I. Grevemeyer, G. Caielli, R. de Franco, D. Lange, M. Thorwart, C. Filbrandt, MSM71 cruise participants, AlpArray Working Group

MA1-04
Einsatz von mobiler mariner Geoelektrik zur Kartierung von Pockmark-Clustern in der Eckernförder Bucht
E. Erkul, S. Fischer, M. Gräber, D. Schulte-Kortnack, D. Wilken, J. Scholten, W. Rabbel

MA1-05
Drift formation history off MacRobertson Land Shelf, East Antarctica, reveals paleo-distribution of Cape Darnley Bottom Water
R. Nielsen, G. Uenzelmann-Neben

MA1-06
A multimethodical approach to decipher extensional processes in the northern Lau Basin at 16 °S
A. Jegen, A. Dannowski, H. Kopp, U. Barckhausen, I. Heyde, M. Schnabel, F. Schmid, A. Beniest, M. Hannington

MA1-07
POS538: High-resolution 2D and 3D reflection seismic analysis of tsunamigenic volcanic eruptions in the Southern Aegean Sea (Greece)
J. Karstens, G. Crutchley, P. Nomikou, J. Preine, M. Kühn, J. Elger, F. Schmid, G. Dalla Valle, C. Hübscher, C. Berndt

MA1-08

Glacial dynamics of the Laurentide Ice Sheet and Quaternary geological evolution of the Labrador Shelf, Canada: Analysis of high-resolution reflection seismic and sub-bottom profiler data

O. Martínez, K.-F. Lenz, F. Gross, C. Gebhardt, A. Lohrberg, F. Riefstahl, S. Krastel

MA1-09

Seismogenic up-dip limit of the 2014 Mw 8.1 Iquique earthquake links subduction erosion and upper plate deformation

F. Petersen, D. Lange, B. Ma, I. Grevemeyer, J. Geersen, D. Kläschen, E. Contreras-Reyes, S. Barrientos, A. M. Tréhu, E. Vera, H. Kopp

MA1-10

New acoustic and gravity core data suggesting multiple failures in the headwall area of Sahara Slide Complex off northwestern African continental margin

Q. Tang, A. Düring, D. Unverricht, K.-F. Lenz, W. Li, S. Krastel

Live Postersession B2 AG-BL-DLO

Montag, 01. März 2021 | 13:20 - 13:50

Moderation: Dennis Wilken

AG-1

Joint structural and joint petrophysical full waveform inversion of shallow seismic and multi-offset GPR data

T. Qin, T. Bohlen, Y. Pan

AG-2

Focused methane migration formed pipe structures in permeable sandstones: Insights from UAV-based digital outcrop analysis in Varna, Bulgaria

C. Böttner, B. J. Callow, B. Schramm, F. Gross, J. Geersen, M. Schmidt, A. Vasilev, P. Petsinski, C. Berndt

AG-3

Dipolinversion mit Komponentengradienten in der Aeromagnetik

C. Kulüke, C. Virgil, J. Stoll, A. Hördt

AG-4

Severe meteorological events in Jena, Thuringia: observations on the seismological footprint at the geodynamic Observatory Moxa

A. Zech, H. Flores Estrella

AG-5
Can DAS on dark fibers contribute to active exploration in urban settings ? - First results of a case study in Potsdam, Germany
C. Wollin, S. Lüth, M. Lipus, C. Cunow, A. Siebert, P. Jousset, S. Fuchs, C. Krawczyk

AG-6
Detecting ground motion in Schleswig-Holstein from radar satellite data
D. Hoogestraat, H. Sudhaus, A. Omlin

BL-1
Petrophysikalische Untersuchungen zur Bestimmung elastischer und lithologischer Eigenschaften von Karbonatgesteinen
G. Beisembina, F. Börner

BL-2
Dreikomponentige Bohrlochmagnetik in der COSC-2 Bohrung
C. Virgil, C. Kulüke, A. Hördt

BL-3
A conversion rule for vintage natural gamma-ray logs in oil/gas exploration boreholes of the former GDR - GE and μR/h unit to API unit
C. O. Mueller, A. Malz

DLO-1
Research and Educational Mine FLB Reiche Zeche (Freiberg) within the European Underground Laboratories (EUL) network
V. Lay, S. Buske, K. Jaksch, R. Giese, J. Garcia del Real, H. Mischo

Poster Free Roaming

Montag, 01. März 2021 | 13:50 - 14:20

Plenarvortrag PV-1

Montag, 01. März 2021 | 14:30 - 15:25

Moderation: Heidrun Kopp

Die Rolle des Ozeans im Klimawandel - Chancen und Risiken
K. Matthes

Vorträge

Montag, 01. März 2021 | 15:35 - 17:05

Moderation: Felix Wolf

15:35-15:55 **V1-05**
Seismic signals can help to improve the early-warning of subglacial floods
E. P. S. Eibl, C. Bean, K. S. Vogfjörd, B. Einarsson, F. Palsson

15:55-16:15 **V1-06**
Buried glacial landforms in the southeastern North Sea: evidence of a pre-Elsterian glaciation?
A. Lohrberg, S. Krastel, D. Unverricht, K. Schwarzer

16:15-16:25 **Pause**

16:25-16:45 **V1-07**
Seismic reconstruction of seafloor sediment deformation during volcanic debris avalanche emplacement offshore Sakar, Papua New Guinea
M. Kühn, J. Karstens, C. Berndt, S. Watt

16:45-17:05 **V1-08**
Bathymetric models beneath ice shelves based on gravity inversion: merits and room for improvement
H. Eisermann, G. Eagles, A. Ruppel, W. Jokat

Studentischer Abend

Montag, 01. März 2021 | ab 19:00

Dienstag, 02. März 2021

Vorträge

Dienstag, 02. März 2021 | 09:00 - 11:35

Moderation: Daniel Köhn

09:00-09:20 **V1-1**

Machbarkeitsstudie eines seismischen cross-hole Monitorings vor, während und nach einem Methaneintragsversuch auf der Feldskala

S. Birnstengel, K. Peisker, M. Pohle, G. Hornbruch, A. Dahmke, P. Dietrich, U. Werban

09:20-09:40 **V1-2**

Large Scale Geomechanical Modelling of Hydrocarbon Production Effects: A Case Study for the Groningen Gas Field

L. Johann, S. A. Shapiro, I. Abakumov

09:40-10:00 **V1-3**

Cable coupling noise in wireline DAS-VSP data

E. Martuganova, M. Stiller, K. Bauer, J. Henninges, C. M. Krawczyk

10:00-10:10 **Pause (Schreibtischyoga)**

10:10-10:30 **V1-4**

Nachweis einer Störungszone unterhalb des Geodynamischen Observatoriums Moxa: ein Ergebnis geophysikalischer Detektivarbeit mit Hilfe von gesteinsphysikalischen Daten und Bohrlochlogs

V. Kasburg, A. Goepel, C. O. Schwarze, T. Valchev, N. Kukowski

10:30-10:50 **V1-5**

Cavity Detection at Mt. Erzberg with elastic Full-waveform Inversion

K. Peters-Poethke, F. Bleibinhaus

10:50-11:00 **Pause**

11:00-11:20 **V1-6**

Multiscale and -disciplinary Investigation of the Fracture Network in the Odenwald Crystalline Complex, Germany

M. Frey, C. Bossennec, K. Bär, I. Sass

11:20-11:40 **V1-7**

Zielgerichtete Kombination geophysikalischer und hydrogeologischer Methoden zur Erkundung ausgedehnter feinkörniger Talfüllungen

S. Klingler, S. Martin, O. A. Cirpka, P. Dietrich, 2, C. Leven

Mittagspause

Dienstag, 02. März 2021 | 11:40 - 12:20

Digitale Firmenausstellung

Dienstag, 02. März 2021 | 12:00 - 14:30

Moderation: Anke Dannowski

Live Postersession A1 GE/IP

Dienstag, 02. März 2021 | 12:20 - 13:05

Moderation: Tina Wunderlich

GE/IP-01
Messungen der Spektralen Induzierten Polarisation an trockenen Marinen Massivsulfiden
M. Lührs, R. Glebe, J. Hoppenbrock, A. Hördt

GE/IP-02
Impedanzelektrische Vermessung von eingebetteten Marinen Massivsulfiden
M. Lührs, R. Glebe, J. Hoppenbrock, A. Hördt

GE/IP-03
Schnellst- oder genauestmöglich? - Die multifrequente SIP Anregung ermöglicht die optimale Adaption des Messablaufs an das Untersuchungsobjekt.
T. Radic

GE/IP-04
Classification of slag material in the laboratory and field scale with spectral induced polarisation
T. Martin, T. Günther, A. Weller

GE/IP-05
Prognose der Permafrostverbreitung im Qugaqie-Tal (Tibet-Plateau) in Abhängigkeit von Hangneigung, Exposition und Solarstrahlung
J. Schiffmann, J. Buckel, M. Bücker, A. Hördt

GE/IP-06
Ein Ansatz zur Eisgehaltsbestimmung im Permafrost auf Basis zweidimensionaler Feldmessungen der Hochfrequenten SIP
J. Mudler, J. Mudler, D. Kreith

GE/IP-07
Ein neues Modell zur Beschreibung des Einflusses der Stern-Schicht auf die Membranpolarisation
D. Kreith, M. Bücker, A. Hördt

GE/IP-08
SIP laboratory data: frequency-domain versus time-domain
T. Martin, K. Titov, A. Tarasov, A. Weller

GE/IP-09
Retrieving IP and surface properties of carbonate rocks from measurements on crushed samples
J. Börner, V. Herdegen, K. Spitzer

GE/IP-10
SIP field measurements at a gas discharge zone and black schist locality near the Main Central Thrust shear zone in the Himalayas of Central Nepal
J. Börner, B. Wagner, F. Girault, S. Thapa, L. B. Adhikari, F. Perrier

GE/IP-11
SIP-Messungen an künstlichen Mischproben aus Sand und technischen Ionentauscherharzen im Labor- und Technikumsmaßstab
M. Sonntag, J. Börner

GE/IP-12
Eine neue Auswertungsroutine von Gleichstromgeoelektrikdaten zur Erkundung von Sedimentablagerungen in Seen
J. Hoppenbrock, M. Bücker, J. Gallistl, A. Flores Orozco, J. Buckel, A. Hördt, L. Pérez

GE/IP-13
Ableitung von dielektrischen Bodenparametern zur GPR-Modellierung durch Inversion von Labor-Messdaten einer Koaxialzelle
S. Schennen, N. Wagner, T. Günther, J. Igel

GE/IP-14
Akquisition und Inversion 2D/3D-geoelektrischer Daten: Ableitung eines tektonischen Untergrundmodells des Geodynamischen Observatoriums Moxa
T. Valchev, A. Goepel, V. Kasburg, N. Kukowski

GE/IP-15
Comparison of measuring strategies for frequency- and time-domain induced polarization in the field
T. Günther, T. Martin

Live Postersession A2 MA2

Dienstag, 02. März 2021 | 12:20 - 13:05

Moderation: Arne Lohrberg

MA2-11
Investigation of the development of Lake Manicouagan (Canada) using high-resolution reflection seismic data
K.-F. Lenz, C. Gebhardt, F. Gross, S. Krastel

MA2-12
CAYMAN: Characterizing the crust using 2D & 3D seismic tomographic methods
L. Gómez de la Peña, I. Grevemeyer, A. Dannowsky, A. Meléndez, C. Peirce, H. van Avendonk

MA2-13
Self potential signatures of deep sea sulfide deposits at the central and SE Indian Ridge
K. Schwalenberg, H. Müller, D. Hagedorn, R. Freitag, H. Wedemeyer

MA2-14
Seismic reflection character of the plate interface in the rupture zone of the 2014 Iquique earthquake sequence
B. Ma, J. Geersen, D. Klaeschen, F. Petersen, H. Kopp, A. Tréhu, E. Contreras-Reyes

MA2-15
Comparison of Earth models of the Namibian continental margin derived from Joint MT and Gravity Inversions
G. Franz, M. Moorkamp, M. Jegen, C. Berndt, W. Rabbel

MA2-16
Compressional and shear wave velocity structure of shallow sediments in the north-western Black Sea revealed by OBS data
H.-S. Hilbert, A. Dannowski, J. Bialas, F. Gross, J. Hoffmann

MA2-17
Architecture of the Monte Amarelo flank collapse deposits offshore Fogo, Cape Verdes
E. Klein, E. Lebas, R. Ramalho, R. Barrett, S. Krastel

MA2-18
Using machine learning workflows to identify seafloor massive sulfides based on disparate geophysical data
A. Haroon, H. Paasche, M. Jegen, S. Graber, S. Petersen

MA2-19
Joint integration of velocity and resistivity to improve gas hydrate estimates - A case study from SO227/266
K. Reeck, M. Jegen, J. Elger, C. Berndt

MA2-20
Characterization of the seismic velocities in a gas chimney blow the actively seeping Lunde pockmark, Vestnesa Ridge, Svalbard Margin: Preliminary results
B. Schramm, S. Singhroha, A. Dannowski, S. Vadakkepuliyambatta, P. Domel, C. Berndt, S. Bünz

MA2-21
Seismic study of glacial sediments of the Chukchi Shelf, Arctic Ocean
C. Lehmann, W. Jokat

MA2-22
Mass wasting at the Siberian End of Lomonosov Ridge, Arctic Ocean
U. Schlager, W. Jokat, E. Weigelt

MA2-23
Lomonosov Ridge: seismic images of its two margins and conclusions on Arctic Paleoceanography
E. Weigelt, W. Jokat, U. Schlager

MA2-24
The erosive power of the Malvinas current: Influence of bottom currents on morpho-sedimentary features along the northern Argentine Margin (SW Atlantic Ocean)
H. Wilckens, E. Miramontes, T. Schwenk, C. Artana, W. Zhang, A. Piola, M. Baques, C. Provost, V. Spieß, F. J. Hernandez-Molina, M. Felgendreher, S. Kasten

MA2-25
Joint inversion of marine LOTEM and DED data from the Bat Yam coastal aquifer, offshore Israel
C. Lieber, A. Haroon, W. Mörbe, J. Cai, K. Lippert, P. Yogeshwar, B. Tezkan

Poster Free Roaming

Dienstag, 02. März 2021 | 13:05 - 13:15

Live Postersession B1 SE

Dienstag, 02. März 2021 | 13:15 - 14:00

Moderation: Daniel Köhn

SE-01
3D seismic imaging of the Alpine Fault and the glacial valley at Whataroa, New Zealand
V. Lay, S. Buske, J. Townend, R. Kellett, M. Savage, D. R. Schmitt, A. Constantinou, J. Eccles, D. Lawton, M. Bertram, K. Hall, R. Kofman, A. Gorman

SE-02
Reprocessing of the hessian DEKORP seismic profiles
B. Homuth, K. Bär, S. Weinert, M. Stiller

SE-03
Diffraction imaging and depth-velocity inversion with 3D P-Cable seismic data
A. Bauer, B. Schwarz, D. Gajewski

SE-04
Die Form und Füllung des glazial-übertieften Basadingen-Beckens, abgeleitet aus hochauflösenden reflexionsseismichen Messungen
A.-C. Brandt, D. C. Tanner, H. Buness, T. Burschil, G. Gabriel

SE-05
Seismic tomography at the scale of a underground rock laboratory in anisotropic host rock
R. Esefelder, B. Wawerzinek, S. Lüth, R. Giese, C. M. Krawczyk

SE-06
Performance test of seismic sources in clay
B. Wawerzinek, S. Lüth, R. Esefelder, R. Giese, C. M. Krawczyk

SE-07
Constructing and validating a large-scale velocity-model for the North German Basin in Schleswig-Holstein and Hamburg - A part of the joint project TUNB
L. Dzieran, F. Hese, K. Lademann, T. Liebsch-Dörschner

SE-08
Neubearbeitung und strukturelle Interpretation der reflexionsseismischen Datensätze DEKORP 1-Laacher See 1987
T. Agafonova, C. M. Krawczyk, M. Stiller, T. Dahm

SE-09
Cavity detection by 2D shear wave full waveform inversion - field data application at a monumental burial mound in Bergama, Turkey
R. Mecking, D. Köhn, W. Rabbel

SE-10
Cyclic Depositional Processes on a Mixed System in Northern Campos Basin, SE Brazil
B. T. Pandolpho, A. H. d. F. Klein, I. Dutra, M. M. Mahiques, A. R. Viana, G. V. Bueno, A. A. Machado, Y. L. Camargo, C. M. Hercos, Y. Lima, A. F. H. F. Filho, C. E. Theodoro

SE-11
Full Waveform Sonic Log imaging and its application to a dataset from the Ludvika/Blötberget mining area (Sweden)
R. Kramer, L. Bräunig, S. Buske

SE-12
Vintage crustal-scale seismic profiling data made available for future applications: DEKORP 1984 - 1999
L. Kaerger, M. Stiller, T. Agafonova, C. M. Krawczyk, O. Oncken, M. Weber

SE-13
Über die Anwendbarkeit einer 2D SH Wellenforminversion zur hochauflösenden Abbildung von heterogenen 3D Untergrundstrukturen
D. Köhn, M. Thorwart, D. De Nil, W. Rabbel, J. Albert, F. Sirocko

SE-14
Charakterisierung einer Störungszone im Bereich der Eckernförder Bucht mittels NIP-Wellentomographie und akustischer 2D Wellenforminversion
D. Köhn, M. Thorwart, D. De Nil, W. Rabbel

SE-15
Anisotropic velocity models for (3D) seismic imaging of the Lower Seve Nappe in Jämtland, Sweden
F. Kästner, D. Kläschen, C. Berndt, S. Pierdominici

SE-16
Ermittlung der Einflüsse des flachen lokalen Untergrunds auf seismische Wellenausbreitung mittels Auswertung von 3D-Seismik Daten
A. Wilczek, S. Kremers

Live Postersession B2 VU + SO 1

Dienstag, 02. März 2021 | 13:15 - 14:00

Moderation: Peter Haas

VU-1
Identification and interpretation of seismic short-duration events inside the Kolumbo submarine volcano in the Southern Aegean
F. Schmid, J. Karstens, P. Nomikou, POS538 Science Team

VU-2
The 2019 Eruption Dynamics and Morphology at Ebeko Volcano Monitored by geophysical instrument networks and remote sensing
T. Walter

VU-3
Classifying infrasound signals at Mount Etna using pattern recognition techniques
F. Eckel, H. Langer, M. Sciotto

VU-4
Monitoring of ground deformation at Sakurajima volcano using Sentinel-1 InSAR time-series
A. Vásquez-Castillo, M. Hort

VU-5
Inferring a shallow degassing model for Villarrica Volcano from seismic explosion signals and SO_2 flux
J. Lehr, W. Rabbel, S. Bredemeyer

SO1-01
Imaging Surface Wave Phase and Amplitude Wave-Fields with AlpArray and Neighboring European Networks
M. Tesch, T. Meier, AlpArray Working Group

SO1-02
Basin inversion in the Ligurian Sea revealed by local seismicity
M. Thorwart, A. Dannowski, I. Grevemeyer, D. Lange, F. Petersen, W. Crawford, A. Paul, The AlpArray Working Group

SO1-03
New Small Aperture Broadband Arrays in the European Arctic
J. Schweitzer, J. M. Christensen, M. Sickel, S. Mykkeltveit, A. Köhler

SO1-04
Architecture of the crust and lithosphere beneath the Semail Ophiolite from ambient noise tomography and Receiver Functions: insights on the tectonic evolution of the eastern Arabian Plate
C. Weidle, L. Wiesenberg, A. Scharf, P. Agard, A. El-Sharkawy, F. Krüger, T. Meier

SO1-05
Seismizität im Omangebirge
E. Glück, C. Weidle, T. Meier

SO1-06
Investigation of mantle flow pattern beneath the Iranian plateau and Zagros by seismic anisotropy
A. Kaviani, M. Mahmoodabadi, G. Rümpker, S. Pilia, M. Tatar, F. Nilfouroushan, F. Yamini-Fard, A. Moradi, M. Y. Ali

SO1-07
Robust finite earthquake source models from the combination of geodetic and seismic data
H. Sudhaus, A. Steinberg, M. P. Isken, S. Heimann, H. Vasyura-Bathke

SO1-08
Slip-deficit estimation with a 3D fault model of the North Anatolian Fault by using InSAR time series
A. Seidel, H. Sudhaus

SO1-09
Characterisation of seismic events using time-reverse imaging
C. Finger, E. H. Saenger

SO1-10
A study of thermoelastic effects in seismic monuments and their signature in low-frequency seismic data collected on Earth and on Mars
R. Widmer-Schnidrig, W. Zürn, T. Forbriger

Poster Free Roaming

Dienstag, 02. März 2021 | 14:00 - 14:20

Plenarvortrag PV-2

Dienstag, 02. März 2021 | 14:30 - 15:25
Moderation: Sebastian Krastel

Offshore freshened groundwater: State of knowledge and future directions
A. Micallef

Vorträge

Dienstag, 02. März 2021 | 15:35 - 16:15
Moderation: Wolfgang Szwillus

15:35-15:55 **V1-8**
On the effects of planetary rotation on the dynamics of a terrestrial magma ocean
C. Maas, U. Hansen

15:55-16:15 **V1-9**
Der seltsame Fall des Planeten Merkur
D. Heyner

Podiumsdiskussion: Lehren in Zeiten von Corona

Dienstag, 02. März 2021 | 16:30 - 18:00

Moderation: Alexander Rudloff

AK Sitzungen

Dienstag, 02. März 2021 | 18:00 - 19:00

Mittwoch, 03. März 2021

Vorträge

Mittwoch, 03. März 2021 | 09:00 - 10:30

Moderation: Johanna Lehr

09:00-09:20 **V3-1**
Random-objective waveform inversion of shallow-seismic wavefield
Y. Pan, L. Gao, T. Bohlen

09:20-09:40 **V3-2**
Combination of 3D Borehole Radar and Underground Reflection Seismic - A Case Study for In-Mine Exploration
T. Hupe, D. Orlowsky, U. Swoboda, B. Lehmann, M. Sniehotta

09:40-10:00 **V3-3**
Scherwellenseismik als Werkzeug zur Lokalisierung erdfallgefährdeter Gebiete in Schleswig-Holstein
R. Mecking, U. Polom, A. Omlin

10:00-10:10 **Pause (Schreibtischyoga)**

10:10-10:30 **V3-4**
Deep mineral exploration using semi-airborne electromagnetics: First results from an experiment over the graphite deposit Kropfmühl
W. Mörbe, P. Yogeshwar, B. Tezkan, P. Kotowski, A. Thiede, M. Becken, A. Steuer, H. Petersen, M. Schiffler, R. Stolz, M. Tauchnitz

Plenarvortrag PV-3

Mittwoch, 03. März 2021 | 10:40 - 11:40

Moderation: Thomas Meier

Listening to ambient seismic noise: what can it tell us about the Earth?
C. Hadziioannou

Mittagspause

Mittwoch, 03. März 2021 | 11:40 - 12:20

Digitale Firmenausstellung

Mittwoch, 03. März 2021 | 12:00 - 14:30

Live Postersession A1 SO1

Mittwoch, 03. März 2021 | 12:20 - 13:05

Moderation: Johannes Stampa

SO1-01
Das Zollernalb-Erdbeben vom 1. Dezember 2020: Makroseismik und Herdparameter
A. Brüstle, S. Stange

SO1-02
Anwendung des Ausschlusskriteriums ”Seismische Aktivität” bei der Suche und Auswahl eines Standortes für ein Endlager für hochradioaktive Abfälle in Deutschland
D. Kaiser, T. Spies

SO1-03
Seismotectonic regions in Germany based on a new concept
T. Hahn, J. Kley, D. Kaiser, T. Spies, C. Geisler

SO1-04
Risikoanalyse eines Erdbebenszenarios für die Stadt Köln und die Niederrheinische Bucht
M. Pilz, F. Cotton, C. Nievas, K. Prehn, H. Razafindrakoto, D. Schorlemmer, G. Weatherill, T. Spies, T. Lege

SO1-05
Die ungewöhnliche Intraplattenrotation in Deutschland und ihre mögliche Rolle zur Quantifizierung der seismischen Gefährdungszonen
T. Dahm, Z. Deng

SO1-06
Robust, an Earthquake Early Warning System in the Lower Rhine Embayment, Germany
B. Najdahmadi, M. Pilz, D. Bindi, H. Njara Tendrisoa Razafindrakoto, A. Oth, F. Cotton

SO1-07
Induced micro seismicity due to raising mine water level in former coal mines in the eastern Ruhr area (Germany)
M. Rische, K. D. Fischer, W. Friederich

SO1-08
Analysis of frequency-dependent amplitude decay of seismic emissions from wind turbines
M. Lindenfeld, F. Limberger, G. Rümpker, H. Deckert

SO1-09
Wind Turbine Noise Reduction from Seismological Data
J. Heuel, W. Friederich

SO1-10
Array-Detektion am Helgoland-Array (HELGA)
A. Schmidt, C. Weidle, T. Meier

SO1-11
The seismological signature of cyclonic storms through the ears of a sensor array
J. Pelaez, D. Becker, C. Hadziioannou

SO1-12
Source locations of microseisms in the North Atlantic from Matched Field Processing using full Green's Functions
S. Schippkus, C. Hadziioannou

SO1-13
Can we measure shallow groundwater content with urban seismic noise?
A. Kiel, R. Steinmann, E. Larose, C. Hadziioannou

SO1-14
Coupling Spectral decomposition results with hybrid ground-motion simulations: Application to Rhine Graben area
H. Razafindrakoto, F. Cotton, D. Bindi, M. Pilz, R. Graves

SO1-15
Regional probabilistic seismic hazard assessment in Bangladesh
A. Azari Sisi, D. Kaiser, T. Spies, J. Schlittenhardt

Live Postersession A2 UI/ZP

Mittwoch, 03. März 2021 | 12:20 - 13:05
Moderation: Tina Wunderlich

UI/ZP-01
Kontinuierliche Überwachung von Temperaturfeldern mit Bohrloch-Geoelektrik und Georadar - erste Ergebnisse von Modellversuchen am idealisierten Sandkörper "GeoModel-Kiel"
S. L. Fischer, E. Erkul, M. Gräber, B. Wang, P. Liedtke, S. A. al Hagrey, W. Rabbel

UI/ZP-02
Optimierung von Methoden zur Standortcharakterisierung anhand passiver seismischer Messungen am Beispiel der Weserterrassen bei Hameln
S. Beiers, M. Hobiger, T. Spies, C. Thiel, B. Goebel, C. Geisler

UI/ZP-03
Porositätsbestimmung und Verdichtungsnachweis von Bergbaukippen mittels SIP
D. Branka, C. Rücker, F. Börner

UI/ZP-04
19th September: a date marked by earthquakes in Mexico City
H. Flores Estrella, A. Villaseñor Franco

UI/ZP-05
Seismic investigation of the Critical Zone in Santa Gracia National Park, Chile using controlled-source generated Rayleigh waves
R. Trichandi, K. Bauer, T. Ryberg, C. M. Krawczyk, K. Bataille

UI/ZP-06
Untersuchung der hydraulischen Konnektivität in heterogenen Lockergesteinsaquiferen mittels SIP
R. Herold, C. Rücker, F. Börner

UI/ZP-07
Monitoring Reinforced Concrete Structures with Coda Waves - The Influence of Temperature on Ultrasound Velocity Changes Calculated with Coda Wave Interferometry
N. Epple, D. Fontoura Barroso, J. Hau, E. Niederleithinger

UI/ZP-08
Seismic resonance vulnerability assessment on buildings with different typologies: The case of Guadalajara, Mexico
A. Ramírez-Gaytán, A. Preciado, H. Flores Estrella, J. C. Santos, L. Alcántara Nolasco

UI/ZP-09
Feuchtemessungen an Fußböden mit Radar und Neutronensonde - Ein Vergleich von Labor und Praxis
T. Klewe, C. Strangfeld, T. Ritzer, S. Kruschwitz

UI/ZP-10
Abschätzung der Wasserretentionsfunktion und der kapillarbasierten ungesättigten hydraulischen Leitfähigkeit durch NMR unter Verwendung kreis- und dreieckförmiger Kapillarmodelle
S. Costabel, T. Hiller

UI/ZP-11
Zerstörungsfreie Untersuchung von Stahlfaserbewehrung in Beton mittels Computertomographie, Spektral Induzierter Polarisation und Ultraschalltransmission
S. Kruschwitz, T. Oesch, F. Mielentz, D. Meinel, H. Stolpe, P. Spyridis

UI/ZP-12
Geophysikalische Untersuchungen an mittelalterlichen Malereien in der St. Petri zu Schleswig (S-H) mit Georadar und Thermographie
Y. E. Esel, E. Erkul, D. Schulte-Kortnack, C. Leonhardt, T. Meier

UI/ZP-13
Delamination Detection on a Concrete Bridge Deck Using Fast Scanning Impact Echo
J. F. Scherr, C. U. Grosse

Poster Free Roaming

Mittwoch, 03. März 2021 | 13:05 - 13:15

Live Postersession B1 NM/ML+GD+GT

Mittwoch, 03. März 2021 | 13:15 - 14:00

Moderation: Nils Holzrichter

NM/ML-01
Interdisciplinary 3D potential field modelling of complex lithospheric structures by IGMAS+
H.-J. Götze, D. Anikiev, J. Bott, M. L. Gómez Dacal, A. M. Gómez-García, C. Rodriguez Piceda, C. Meeßen, C. Plonka, C. Spooner, M. Scheck-Wenderoth, S. Schmidt

NM/ML-02
Simulation of Seismic Wave Propagation in Porous Rocks Considering the Exploration and the Monitoring of Geological Reservoirs
M. S. Boxberg, W. Friederich

NM/ML-03
NEXD: A Software Package for Seismic Wave Simulation in Complex Geological Media - New Developments
M. S. Boxberg, A. Lamert, T. Möller, W. Friederich

NM/ML-04
TRIPLE - Ice Data Hub, Model-based Mission Support and Forefield Reconnaissance System
M. S. Boxberg, J. Audehm, F. Becker, L. Boledi, B. Burgmann, Q. Chen, P. Friend, N. Haberberger, D. Heinen, C. T. Nghe, A. Simson, M. Stelzig, J. Kowalski

NM/ML-05
Using Machine Learning for Antarctic Geothermal Heat Flow Prediction
M. Lösing, J. Ebbing

NM/ML-06
Workflow for filling large-scale data gaps based on geostatistical simulation and uncertain constraints with an application to EMAG2 data over Africa
P. Menzel, M. Sobh

NM/ML-07
Interpretation geoelektrischer Sondierungsdaten mittels neuronaler Netze
R. Zywczok, M. Bücker

GD-1
Glacially-Induced Faults: Classification Criteria and Occurrence in Germany
H. Steffen, O. Olesen, R. Sutinen

GD-2
Mapping the area possibly affected by glacially-triggered faulting with numerical models: indications in Germany?
H. Steffen, R. Steffen, C. Brandes

GD-3
Glacially-induced stresses and their effect on pre-existing faults: Insights from numerical models
R. Steffen, H. Steffen

GD-4
Computational Modelling of Coupled Heat Transport between the Heterogeneous Earth and an Overlying Ice Sheet
S. B. Bodenburg, S. Reiche, W. Blachut, C. Hübscher, J. Kowalski

GD-5
Estimating the lithospheric architecture and geothermal heat flow of Greenland
A. Wansing, J. Ebbing, S. Lebedev, N. L. Celli

GD-6
Einfluss von lateralen Variationen in der Erdstruktur auf Meeresspiegelrekonstruktionen: Modelle zur glazial-isostatischen Anpassung in Oregon und Patagonien
M. Bagge, V. Klemann, B. Steinberger, M. Latinović, M. Thomas

GD-7
Bestimmung geothermischer Reservoireigenschaften im Süddeutschen Molassebecken mittels seismischer Attributanalyse und Inversion
S. H. Wadas, H. von Hartmann

GT-1
Evolutionary development and volume balance calculations of the Ana Slide in the Eivissa Channel, Western Mediterranean
T. F. Sager, M. Urlaub, P. Kaminski, G. Lastras, M. Canals, C. Berndt

GT-2
A Subducting Seamount Imaged in the Rupture Zone of the 1994 Java Earthquake, and Its Implication on Co-seismic Slip Propagation and Tsunami Generation
Y. Xia, J. Geersen, D. Kläschen, B. Ma, D. Lange, M. Riedel, M. Schnabel, H. Kopp

Live Postersession B2 EM1

Mittwoch, 03. März 2021 | 13:15 - 14:00
Moderation: Dennis Wilken

EM1-01
2D Joint Inversion Algorithms for Semi-Airborne and LOTEM Data: A Data Application from Eastern Thuringia, Germany
J. Cai, P. Yogshwar, W. Mörbe, M. Smirnova, A. Haroon, M. Becken, B. Tezkan

EM1-02
A 2D transient electromagnetic tipper study on a landfill near Cologne, Germany
H. Nienhaus, P. Yogeshwar, B. Tezkan, I. Ibraheem

EM1-03
Three-dimensional controlled-source radio-magnetotelluric forward modeling and inversion in the transition zone
M. Smirnova, A. Shlykov, S. Fadavi Asghari, B. Tezkan, A. Saraev, P. Yogeshwar

EM1-04
Experimentelle Untersuchung der Signalqualität von Georadardaten bei verschiedenen Stapelraten
S. Stephan, N. Allroggen, J. Tronicke

EM1-05
Sub-seafloor Pore-fluid Salinity Estimation in the Canterbury Bight, New Zealand, based on Bayesian Inversion of Controlled-source Electromagnetic Data
Z. Faghih, A. Haroon, M. Jegen, R. Gehrmann, J. Dettmer, A. Micallef, C. Berndt, S. E. Dosso, K. Schwalenberg, B. A. Weymer

EM1-06
Bodenfeuchtebestimmung mit präpolarisierter Oberflächen-NMR - Erste Ergebnisse
T. Hiller, S. Costabel, T. Radic, R. Dlugosch, M. Müller-Petke

EM1-07
Transient electromagnetic investigations of sedimentary deposits for paleo-climate research in the Atacama Desert, Chile
B. Blanco Arrue, P. Yogeshwar, B. Tezkan, W. Mörbe, V. Wennrich, S. Buske, D. Díaz, B. Farah

EM1-08
A Multidimensional Interpretation of Controlled-Source Radio-Magnetotelluric (CSRMT) Experiment in Aleksandrovka, Russia
S. Fadavi Asghari, M. Smirnova, A. Shlykov, B. Tezkan, A. Saraev, P. Yogeshwar

EM1-09
Möglichkeiten und Grenzen der zerstörungsfreien Erfassung niedriger Feuchtegehalte in teilgesättigten Sandsteinen mit ^{1}H-NMR
S. M. Nagel, C. Strangfeld, S. Kruschwitz

EM1-10
Charakterisierung eines für die Baustoffuntersuchung entwickelten NMR-Tomographen
T. Bintz, S. M. Nagel, L. Stelzner, S. Kruschwitz

EM1-11
Electromagnetic experiments for the detection and characterization of seafloor massive sulfides at the Palinuro Seamount
S. Hölz, K. C. Barnscheidt, K. Reeck, M. Jegen

EM1-12
Qualitative and quantitative analysis of the new marine electromagnetic "Coil2Dipole" experiment
K. C. Barnscheidt, S. Hölz

EM1-13
Optimized estimation of Long Period Magnetotelluric transfer functions using closely spaced recording sites
S. Zhian, A. Junge, C. Castro

Poster Free Roaming

Mittwoch, 03. März 2021 | 14:00 - 14:20

DGG-Kolloquium Endlagergeophysik

Mittwoch, 03. März 2021 | 14:30 - 17:15

Moderation: Stefan Buske & Mike Müller-Petke

DGG-Mitgliederversammlung

Mittwoch, 03. März 2021 | 17:30 - 19:30

Moderation: Heidrun Kopp

Donnerstag, 04. März 2021

Vorträge

Donnerstag, 04. März 2021 | 09:00 - 10:30

Moderation: Jens Schneider von Deimling

09:00-09:20 **V4-1**

Einfluss von Textur und Mineralogie auf temperaturabhängige SIP-Eigenschaften von Sediment- und Kristallingesteinen in Einfrier- und Auftauzyklen

J. K. Limbrock, M. Weigand, A. Kemna

09:20-09:40 **V4-2**

Oberflächenrauigkeit, tote Poren und Korn-Korn-Wechselwirkung in der spektralen induzierten Polarisation: Neue Erkenntnisse aus der numerischen Modellierung

M. Bücker, K. Knappe, A. Haji

09:40-10:00 **V4-3**

Small-Scale ERT in the Field: Benefits and Challenges

J. Ochs, N. Klitzsch, F. M. Wagner

10:00-10:10 **Pause (Schreibtischyoga)**

10:10-10:30 **V4-4**

Adaptive Mesh Refinement using Hanging Edges in 3D Time-domain Electromagnetic Modeling

C. Schneider, K. Spitzer, M. Hort

Plenarvortrag PV-4

Donnerstag, 04. März 2021 | 10:40 - 11:40

Moderation: Henriette Sudhaus

Satellite InSAR: from opportunistic science to routine monitoring

J. Biggs

Mittagspause

Donnerstag, 04. März 2021 | 11:40 - 12:20

Live Postersession A1 GR/MA

Donnerstag, 04. März 2021 | 12:20 - 13:05

Moderation: Agnes Wansing

GR/MA-01
3D gravity modelling to improve geological model harmonization - Methods and benefits for the Saxony-Anhalt/Brandenburg cross-border region (North German Basin)
C. O. Mueller, J. Waechter, A. Malz

GR/MA-02
Numerical analysis of gravity and magnetic fields prior to structural modelling
H.-J. Götze, P. Tabelow

GR/MA-03
Zerstörungsfreie Bestimmung der remanenten Magnetisierung von archäologischen Fundstücken
R. Kahn, T. Wunderlich, N. Pickartz, N. Nowaczyk, W. Rabbel

GR/MA-04
Spectral consistency of the LCS-1 satellite model and the magnetic anomaly map of Australia
Y. Dilixiati, E. Baykiev, J. Ebbing

GR/MA-05
Determining the Sub-Ice Topography of Edgeøya and Barentsøya (Svalbard) using Gravity Data: A feasibility study
J. Liebsch, J. Ebbing

GR/MA-06
DFG priority programme 1788 "Dynamic Earth": A joint interpretation of geomagnetic, geodetic and ionosphere/thermosphere data from low-orbit satellite missions
B. Fluche, C. Stolle, J. Baerenzung, J. L. Chau, E. Kronberg, J. Kusche, J. Vogt

GR/MA-07
Neues Schwerefeldmodell und daraus abgeleitete Untergrundmodellierung in der Antarktis
T. Schaller, P. Zingerle, M. Scheinert, R. Pail, M. Willberg

GR/MA-08
Inverse and forward gravity modeling for revealing the crustal structure of Volga-Uralian subcraton
I. Ognev, J. Ebbing, P. Haas

GR/MA-09
Modellierung der Dichteverteilung in der unteren Kruste des Semail Ophiolithen
R. Horstmann, C. Weidle, J. Ebbing, L. Wiesenberg

GR/MA-10
A new magnetic anomaly map for Greenland from the combination of aeromagnetic and satellite data
J. Freienstein, B. Heincke, A. Wansing, I. Budde, R. Horstmann, Y. Dilixiati, J. Ebbing

GR/MA-11
A forward and inversion python package calculating contrained Moho depth from gravity and effective elastic thickness estimations
N. Holzrichter, J. Ebbing, P. Haas

GR/MA-12
Kalibrierung eines Inertialen Messsystems für aeromagnetische Anwendungen
H. Mersmann, C. Kulüke, C. Virgil, A. H ördt

GR/MA-13
A 3D model of the Red Sea using magnetic and gravity data
R. Issachar, J. Ebbing, D. Yixiati, N. Holzrichter

GR/MA-14
Global oceanic and continental mass change from 18+ years of GRACE/-FO satellite gravimetry — and its potential joint implementation with multi-sensor seismology in the assessment of recent sea level variations
B. D. Gutknecht, M. Willen, D. Cáceres, M. Horwath

GR/MA-15
A Bayesian framework for simultaneous determination of susceptibility and magnetic thickness from magnetic data
W. Szwillus, J. Ebbing, D. Yixiati

GR/MA-16
Methodische Untersuchungen zur Entwicklung einer hochauflösenden Magnetsensoreinheit für Drohnen
P. Gödickmeier

Live Postersession A2 EM2 + AR

Donnerstag, 04. März 2021 | 12:20 - 13:05

Moderation: Tina Wunderlich

EM2-1
3D FDTD Georadar Antennenoptimierung mittels PSO
S. Stadler, J. Igel

EM2-2
First experiments on the suitability of grounded dipoles as receivers for the detection of surface NMR signals
N. Skibbe, A. Davis, T. Günther, M. Müller-Petke

EM2-3
First measurements using a new drone-based controlled-source electromagnetics system
T. Guenther, M. Ronczka, O. Cortes Arroyo, P. Kotowski, M. Becken

EM2-4
Open-Source 3D Finite-Element Modeling of Electromagnetic data with custEM 1.0
R. Rochlitz, T. Guenther

AR-1
Georadar-Messung im Bereich des Nordtors in Haithabu
S. Bäumler, T. Wunderlich, D. Wilken

AR-2
Inverse Filtering of Magnetic Prospection Data - Revisiting a Method for archaeological targets
N. Pickartz, W. Rabbel, K. Rassmann, J. Müller, R. Hofmann, R. Ohlrau, D. Wilken, T. Wunderlich

AR-3
From coarse to small high-resolution ground penetrating radar (GPR) measurements: a comparison for geoarchaeological prospection
E. Corradini, T. Wunderlich, E. Erkul, D. Wilken, D. Groß, H. Lübke, W. Rabbel

AR-4
UAV-borne archaeomagnetic prospection of a Celtic site in Schwarzenbach (Saarland)
V. Schmidt, M. Chrzon, S. Klingen, T. Fritsch, M. Becken

AR-5
Archaeogeophysical investigation at Neuss-Norf, Germany
I. Ibraheem, R. Bergers, S. Schiebel, L. Reineccius, B. Tezkan

AR-6

Structural investigation of the Danewerk using seismic full-waveform inversion (FWI)

M. Zolchow, D. Köhn, D. Wilken, W. Rabbel

AR-7

Geophysikalische und geoarchäologische Untersuchung des versunkenen mittelalterlichen Niedam Deichsystems von Rungholt

D. Wilken, H. Hadler, T. Wunderlich, B. Majchczack, M. Schwardt, A. Fediuk, P. Fischer, T. Willershäuser, S. Klooß, A. Vött, W. Rabbel

Poster Free Roaming

Donnerstag, 04. März 2021 | 13:05 - 13:15

Live Postersession B1 SO3

Donnerstag, 04. März 2021 | 13:15 - 14:00

Moderation: Thomas Meier

SO2-01

Determination of non-linear OBS clock drift by means of noise cross-correlations

M. Schmidt-Aursch, J. Almendros, W. Geissler, B. Heit, W. Wilcock, X. Yuan

SO2-02

Leveraging coherent wave field analysis and deep learning in fiber-optic seismology

B. Schwarz, K. Sager, P. Jousset, G. Currenti, C. Krawczyk, V. Tsai

SO2-03

An automatized XKS-splitting procedure for large data sets: Extension package for SplitRacer and application to the USArray

F. Link, M. C. Reiss, G. Rümpker

SO2-04

High frequency array observations of December 2020 swarm at surface and borehole stations at ICDP Eger Rift site Landwüst (Vogtland)

K. Hannemann, M. Ohrnberger, N. Lerbs, D. Domigall, M. Isken, R. Voigt, D. Vollmer, R. Bauz, L. Sonnabend, M. Korn, F. Krüger, T. Dahm

SO2-05

Nutzung von statistischen Momenten höherer Ordnung zur automatischen Detektion von Erdbebenphasen

N. Kühne, O. Hellwig, S. Buske

SO2-06
Spektrale Untersuchung von Schwarmereignissen an Bohrloch- und Oberflächenstationen am Standort Landwüst (Vogtland), ICDP Projekt Drilling the Eger Rift
D. Domigall, M. Ohrnberger, F. Krüger, K. Hannemann, N. Lerbs, M. Korn, T. Dahm

SO2-07
How strong lateral heterogeneities affect the azimuthal anisotropy measured with the Eikonal tomography method - an example from the AlpArray network
E. Kästle, I. Molinari, L. Boschi, E. Kissling

SO2-08
Automatic Picking of Teleseismic P- and S-Phases using an Autoregressive Prediction Approach
J. Stampa, T. Meier

SO2-09
Improving seismic deployments using Borehole, Posthole- and SlimPosthole sensors
T. Parker, V. Hamilton, S. Uhlmann

Poster Free Roaming

Donnerstag, 04. März 2021 | 14:00 - 14:20

Pyrocko Workshop

Donnerstag, 04. März 2021 | 14:30 - 17:00

Moderation: Henriette Sudhaus

DGG SEG Workshop Scientific Drilling 1

Donnerstag, 04. März 2021 | 14:30 - 16:15

Workshop "FAIR research data publication"

Donnerstag, 04. März 2021 | 14:30 - 18:00

Moderation: Andreas Hübner

Meet & Greet

Donnerstag, 04. März 2021 | 15:30 - 17:00

Moderation: Katrin Schwalenberg & Tina Martin

DGG SEG Workshop Scientific Drilling 2

Donnerstag, 04. März 2021 | 16:30 - 18:45

Freitag, 05. März 2021

Vorträge

Freitag, 05. März 2021 | 09:00 - 12:00

Moderation: Thomas Meier & Henriette Sudhaus

09:00-09:20 **V5-1**
Teleseismic P-wave travel time tomography of the Alpine upper mantle using AlpArray seismic network data
M. Paffrath, W. Friederich, the AlpArray Working Group

09:20-09:40 **V5-2**
Current research in earthquake seismology at the University of Bergen: Monitoring, imaging and modeling of ridge, continent, and subduction zone seismicity
F. Halpaap, Earthquake Seismology Group

09:40-10:00 **V5-3**
Seismische VSP Tomographie am ICDP Bohrloch S1 in Landwüst, Vogtland
N. Lerbs, M. P. Isken, D. Domigall, K. Hannemann, D. Vollmer, R. Bauz, M. Ohrnberger, F. Krüger3, M. Korn, T. Dahm

10:00-10:10 **Pause (Schreibtischyoga)**

10:10-10:30 **V5-4**
Source location and evolution of the 26 s microseism from 3-C beamforming
C. Bruland, S. Mader, C. Hadziioannou

10:30-10:50 **V5-5**
Entwicklung einer Mikrozonierungskarte für das Stadtgebiet München unter Verwendung von 6-Komponenten und Array Messungen
S. Keil, A. Wilczek, J. Wassermann

10:50-11:10 **V5-6**
Seismic radiation from wind turbines: observations and modeling of frequency-dependent amplitude decays
F. Limberger, M. Lindenfeld, G. Rümpker, H. Deckert

11:10-11:20 **Pause**

11:20-11:40 **V5-7**
Automated wave type classification and isolation using strain and rotation recordings
D. Sollberger, P. Edme, C. Schmelzbach, J. O. A. Robertsson

11:40-12:00 **V5-8**
Estimating Seismic Moment Tensors based on Bayesian Machine Learning
A. Steinberg, H. Vasyura-Bathke, P. Gaebler, L. Ceranna

Abschlussveranstaltung

Freitag, 05. März 2021 | 12:00 - 12:40

Moderation: Jörg Ebbing & Henriette Sudhaus

Mittagspause

Freitag, 05. März 2021 | 12:40 - 14:00

Plenarvortrag PV-5

Freitag, 05. März 2021 | 14:00 - 14:45

Moderation: Sebastian Krastel

Investigating Submarine Slope Failures with Geophysical Data, Scientific Drilling, Laboratory Experiments, and Numerical Modeling
B. Dugan

DGG SEG Workshop Scientific Drilling 3

Donnerstag, 04. März 2021 | 15:00 - 16:30

DGG SEG Workshop Scientific Drilling 4

Donnerstag, 04. März 2021 | 16:45 - 18:45

Abstracts

AR

Archäogeophysik

AR Archäogeophysik: e-Poster

AR Archäogeophysik: e-Poster
AR-1

Georadar-Messung im Bereich des Nordtors in Haithabu

Bäumler, Sarah, Wunderlich, Tina, Wilken, Dennis
Institut für Geowissenschaften, Abteilung Geophysik, Kiel, DE

Abstract
Am 19.06.2019 wurde im Bereich des nördlichen Durchgangs des Halbkreiswalls um Haithabu, einer im Jahr 1066 aufgegebenen wikingerzeitlichen Handelsstadt, eine GPR-Messung durchgeführt. Dazu wurde eine MALÅ MIRA 400 MHz Antenne der Firma MALÅ Geoscience, welche mit acht Kanälen gleichzeitig Daten aufnahm, benutzt. Durch die enge Profildichte wurde eine 3D-Analyse des Untergrunds möglich. In den Daten konnten drei äußere Wallflanken nachgewiesen werden, die verschiedene Baustufen des Walls aufzeigen. Außerdem ließen sich zwei nahezu horizontal verlaufende Schichtgrenzen über große Teile des Messgebiets verfolgen, wovon die obere dem Heideboden, welcher vor Bau des Walls die Erdoberfläche ausmachte, zugeordnet wird. Anhand der Daten gelang die Lokalisierung von zwei archäologischen Ausgrabungsschnitten aus den Jahren 1910 bis 1912, deren Maße im zu der Zeit angefertigten Lageplan nicht mit denen in Literatur und Grabungszeichnungen übereinstimmen. Es konnten keine hölzerne Überreste in dem gemessenen Gebiet nachgewiesen werden, wodurch mittels ^{14}C-Datierung eine genaue zeitliche Einordnung der Tor- und Wallkonstruktionen möglich gewesen wäre.

AR Archäogeophysik: e-Poster
AR-2

Inverse Filtering of Magnetic Prospection Data - Revisiting a Method for archaeological targets

Pickartz, Natalie[1], Rabbel, Wolfgang[1], Rassmann, Knut[2], Müller, Johannes[3], Hofmann, Robert[3], Ohlrau, René[3], Wilken, Dennis[1], Wunderlich, Tina[1]
[1]Universität Kiel, Institut für Geowissenschaften, Angewandte Geophysik, Kiel, DE, [2]Deutsches Archäologisches Institut, Römisch-Germanische Kommission, Frankfurt am Main, DE, [3]Universität Kiel, Institut für Ur- und Frühgeschichte, Kiel, DE

Abstract
Magnetic prospection of archaeological sites is commonly performed. Mostly, processing aims to prepare an easily interpretable image of measured data. In many cases, motivation for processing steps emerges from image editing methods rather than from the geophysical background of the structures that shall be altered. Here, we highlight the method of inverse filtering, which is derived from geophysical theory, deduces the magnetization distribution, and acts as an image enhancement filter at the same time.

In general, the magnetic anomaly field can be understood as a convolution of an ‘amplitude’ and a ‘shape’ function (cf. Tassis et al., 2008 and references therein). The amplitude function equals the magnetization distribution and the shape function equals the magnetic field of a geometrical entity with unit magnetization, that can be used to recreate the magnetic source bodies. Conversely, when the inverse (in terms of convolution) of the shape function is known and convolved with the anomaly field, this yields the magnetization distribution.

For archaeological targets, we assume a magnetized block in the depth range of the finds with the size of a grid cell as the geometrical entity. Its shape function and the inverse are derived to perform inverse filtering. The resulting map of magnetization is an image that is easier to interpret than the magnetic anomaly map since the dipole character is reduced. Moreover, the magnetization allows quantifying the archaeological remains. Our targets are the Megasites of the Cucuteni-Tripolye Culture spanning areas up to 300 ha and comprising up to 3000 buildings. Sites of this dimension demand a fast determination of the magnetization to quantify buildings and other features, calculate the mass of building remains and use these data for classifications e.g. of architectural characteristics. The potential of the method becomes obvious when applied to a complete site and not just on a test area.

Tassis, G.A., Hansen, R.O., Tsokas, G.N., Papazachos, C.B., and Tsourlos, P.I., 2008. Two-dimensional inverse filtering for the rectification of the magnetic gradiometry signal. Near Surface Geophysics, 6 (2), 113–122.

AR Archäogeophysik: e-Poster
AR-3

From coarse to small high-resolution ground penetrating radar (GPR) measurements: a comparison for geoarchaeological prospection.

Corradini, Erica[1], Wunderlich, Tina[1], Erkul, Ercan[1], Wilken, Dennis[1], Groβ, Daniel[2], Lübke, Harald[2], Rabbel, Wolfgang[1]
[1]University of Kiel, Applied Geophysics, Kiel, DE, [2]Centre for Baltic and Scandinavian Archaeology (ZBSA), Schleswig, DE

Abstract
Ground-penetrating radar (GPR) measurements for near-surface geophysical prospection are traditionally conducted with single-channel systems. The GPR antennae are mounted in a cart or pulled by the operator, delivering a coverage rate commonly between a quarter hectare and half hectare per day and often with coarse measurement spacing. The recent development of multi-channel GPR antenna array systems has increased the survey efficiency and spatial sampling resolution. We present a comparison between different surveys performed using two GPR systems investigating 63 ha at ancient Lake Duvensee, which is one of the most known locations in Northern Europe for Early Holocene research. The first survey was conducted in 2016 with a single channel GSSI 200 MHz frequency antenna with the aim to identify the location of former islands left by the retreating of the Fennoscandian ice sheet. The location of these small sand hills, hosting Mesolithic camps, is crucial for understanding human occupation in northern Europe. A coarse rectangular grid of GPR profiles was established with 30 m spacing in the northern part of the area and 100 m in southern sector, delivering 2D maps of the main sediment reflections. In 2018 a second GPR investigation was carried out employing a 16 Channel 400 MHz MALÅ Imaging Radar Array (MIRA) with 8 cm in-line spacing aiming a detailed definition of the stratigraphy, the location of the shoreline and islands' extension. The considerably increased spatial sampling allows a high-resolution imaging of the stratigraphy using depth-slices with 8cm resolution. With this computation it was even possible to distinguish with two twin islands which appeared being one with the single channel system. A pinpointed test excavation delivered a hand-made blade, which proves human occupation. Moreover, we discuss the pros and cons of each systems, in particular the correlation between spatial resolution and depth of investigation. The 200 MHz antenna provided dataset with a vertical resolution of about 5 to 8 cm, while the MIRA System 3 to 5 cm, which makes the latter more suitable for detecting small features. However, the 200 MHz antenna can reach a higher depth of investigation which can be an advantage for imaging the deeper part of the former lake. The increase in resolution and coverage rate by the MIRA system has a positive effect on the reduction of costs for GPR surveys making this method more suitable for archaeology.

UAV-borne archaeomagnetic prospection of a Celtic site in Schwarzenbach (Saarland)

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Abstract
The place Schwarzenbach (Nonnweiler, Saarland) is known in archeology for its Celtic princely tombs, which were discovered in the 19th century. The accidental discovery of the graves, which contained iron goods and gold vessels, stimulated further excavations and intensive archaeological research in this region. The research in the last years concentrated on understanding of the “archaeological landscape” on a regional scale including infrastructure, economy, settlements and their interrelationships in space and time. To this end, large-scale remote sensing methods such as airborne laser scanning have been employed.
Magnetic prospection could provide further valuable information about archaeological features in the region; this was already demonstrated by small-scale ground measurements. But costs and efforts of a large-scale ground survey are high. We propose UAV-borne magnetic measurements as an efficient and economic possibility to undertake archaeomagnetic prospection on a larger scale. The advantage of UAVs is that they provide great flexibility in survey design, which is important in regions with rough topography and heterogeneous land use. Also, permitting issues are usually less complicated.
We present first UAV-borne magnetic measurements in the area. A miniature cesium vapour total field magnetometer was carried by a medium-sized octocopter drone. Measurements at different altitudes have been performed to evaluate the signal decay with height. This allows forecasts of which archaeological anomalies are still detectable at greater altitude. Although the measurements were carried out in challenging conditions due to wind and rain, the results show several interesting anomalies, which could be generated by archaeological artifacts like tombs and pathways. We plan to investigate the sources of the anomalies using further geophysical methods and archaeological excavations.
The data processing workflow was adopted to the special conditions of UAV-borne measurements. The heading error, which is generated by complex oscillations of the magnetometer, is analyzed and correction algorithms are discussed. We tested the application of a Kalman filter on the IMU data to improve the calculation of the magnetometer’s attitude and the resulting heading error correction.

AR Archäogeophysik: e-Poster
AR-5

Archaeogeophysical investigation at Neuss-Norf, Germany

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Abstract
A combination of noninvasive geophysical magnetic gradiometery and electrical resistivity tomography (ERT) was employed to locate the remains of an old church form the 9th century in Neuss-Norf, Germany. The gradiometery survey was carried out along 27 parallel profiles oriented approximately E–W with a profile spacing of 1 m and a sampling spatial interval of 0.5 m along each profile in order to detect the distributions of the possible buried walls of the church and other related archaeological remains. The vertical gradient of the magnetic field, with a fixed distance of 1.04 m between the sensors, was measured. The lower sensor was fixed at a height of 0.32 m from the ground surface. The magnetic data were transferred to the frequency domain using Fast Fourier transform then reduced to the magnetic pole. The analytic signal and power spectrum techniques were applied to the obtained magnetic data.
Moreover, ERT measurements were performed based on the results of the magnetic survey along 12 profiles utilizing the Wenner and Dipole-Dipole arrays with 0.5 m electrode spacing. The ERT data from both arrays were merged into one dataset to form a non-conventional mixed array. The ERT data were inverted into 2D resistivity models using robust (blocky) inversion technique, and then a 3D resistivity prospective was created.
The combined interpretation of the magnetic and ERT showed that the archaeological structures are close to the ground surface with a maximum depth of up to 2 m. We successfully detected anomalous zones that could be associated with the walls of at least one ancient church-building in addition to several possible archaeological structures in the survey area. A considerable agreement between the results of both methods was observed. Highly magnetic sources that could be associated with metallic objects within tomb-like structures were detected. An archaeological map of the possible location of the old church and the assumed surrounding tombs and features was constructed. Finally, some promising places were suggested in order to start an archaeological excavation in the site based on the findings of our research.

Keywords
Archaeogeophysics; ERT; Magnetic gradiometery; Neuss-Norf, Germany

Structural investigation of the Danewerk using seismic full-waveform inversion (FWI)

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Abstract
Seismic full-waveform inversion (FWI) has recently been established within the field of archaeogeophysics. However, many questions regarding practical applications are still unclear, since only a small amount of field data examples have been examined so far. To analyze the applicability of the method to archaeological targets with strong topography and complex heterogeneous subsurface, our project is focused on shear wave seismic data from the Danewerk (Schleswig-Holstein, Germany). Aim of the investigation was to identify wall and foundation structures as well as their conservation status within the rampart.
The data was analysed using two-dimensional, elastic FWI in time-domain based on inversion of dispersive Love- and refracted SH-waves. The data fit was improved by inverting for shear wave velocity and density simultaneously. The required initial model was determined using ray-based traveltime tomography on the basis of refracted SH-waves. In order to obtain stable and interpretable results despite the strong non-linearity of the FWI, a multi-stage inversion strategy was specifically designed for this dataset. Sensitivity analysis as well as checkerboard tests clearly prove, that the method can theoretically resolve all relevant structures within the rampart construction.
The results of the FWI could be structurally compared with archaeological records. The comparison shows that FWI can reproduce most of the structures, which are essential in order to understand the Danewerk‘s construction history. These include older rampart phases and trench structures as well as various wall sections and foundations made of field and brick stones. A quantitative analysis of the inverted seismic model parameters indicates that these differ significantly for structures made of field stone or brick stone. Therefore, both wall types can be clearly identified without extensive archaeological excavation. Overall, the results show the potential of FWI for the high resolution characterization of near surface archaeological targets.

AR Archäogeophysik: e-Poster
AR-7

Geophysikalische und geoarchäologische Untersuchung des versunkenen mittelalterlichen Niedam Deichsystems von Rungholt

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Abstract
Archäologische Funde und historische Karten deuten darauf hin, dass sich der hochmittelalterliche Handelsplatz Rungholt in den Wattflächen rund um die Hallig Südfall in der Nordsee befand. Während des Mittelalters und der frühen Neuzeit verursachten extreme Sturmereignisse große Landverluste und verwandelten kultivierte Gebiete in Wattflächen. Insbesondere die 1. Grote Mandrenke (oder St. Marcellus Flut), ein Sturmflutereignis im Jahr 1362, wird als das Hauptereignis bezeichnet, das den größten Teil der Rungholt-Kulturlandschaft überflutete und zerstörte. Einige im Watt anstehende Überreste dieser Landschaft wie Deichreste, Entwässerungsgräben, Sieltore, oder Wohnhügel (Warften) wurden zu Beginn des 20. Jahrhunderts von mehreren lokalen Forschern kartiert. Aufgrund der Gezeitendynamik mit sich bewegenden Prielen und Sandbänken ändert sich die Verteilung der an der Oberfläche sichtbaren kulturellen Überreste jedoch sehr schnell. Heute ist der größte Teil des Gebiets von Sedimenten bedeckt, so dass die meisten Überreste nicht mehr archäologisch untersucht werden können. Da wenig über den genauen Ort oder den Erhaltungszustand dieser Überreste bekannt ist, zielte die vorgestellte Arbeit auf die Wiederentdeckung und Untersuchung des mittelalterlichen Deichbereichs südlich von Südfall mit geophysikalischen und geoarchäologischen Methoden ab. Die magnetische Gradiometrie zeigt dabei einen großen Teil des mittelalterlichen Deichs und mehrere Warften, die an der dem Landesinneren zugewandten Seite mit dem Deich verbunden waren. Auf dieser Grundlage können die bisher ungenauen und unvollständigen Kartierungen dieses Teils von Rungholt spezifiziert und vervollständigt werden. Darüber hinaus geben seismische Reflexionsprofile in Kombination mit Bohrkernanalysen einen ersten tiefenauflösenden Einblick in die Überreste des Deichsystems und zeigen eine ernsthafte und akute Bedrohung der Kulturspuren aufgrund von Erosion. Der untersuchte Standort ist beispielhaft für die gesamte nordfriesische Küste, die von mehreren Hochwasserereignissen im Mittelalter bis in die Neuzeit beeinflusst wurde und zeigt das Potential des vorgestellten Prospektionskonzeptes für die Erfassung von nicht freiliegenden Kulturspuren im Watt auf.

BL

Bohrlochgeophysik

BL Bohrlochgeophysik: e-Poster

BL Bohrlochgeophysik: e-Poster
BL-1

Petrophysikalische Untersuchungen zur Bestimmung elastischer und lithologischer Eigenschaften von Karbonatgesteinen

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Abstract
Intensive technische Feldarbeiten, wie etwa Tiefbohrungen und Bergbau über- oder untertage, führen zu Spannungen in den Gesteinsschichten, deren plötzlicher Abbau in manchen Gebieten zu anthropogenen Erdbeben führen kann.
Gegenstand dieser Untersuchungen ist die petrophysikalische und bohrlochgeophysikalische Analyse von Gesteinen aus Gebieten Kasachstans, wo intensive Bergbau- und andere Explorationsarbeiten zu anthropogenen Erdbeben führten. Ziel ist die Ableitung petrophysikalischer Charakteristika, die die Entstehung anthropogener Beben beeinflussen bzw. begünstigen können.
Neben diversen Gesteinen, besitzen in der Kaspischen Region Kasachstans insbesondere Karbonatformationen wirtschaftliche Relevanz in Verbindung mit Öl- und Gas-Vorkommen, aber auch mit Bergbau und mit der Gewinnung von Baumaterial.
Die Probenserie aus Kasachstan wurde mit Proben aus Deutschland (Rüdersdorf), Somalia und den Bahamas erweitert, um möglichst viele unterschiedliche Porenraumstrukturen und lithologische Eigenschaften mit der detaillierten mineralogischen und petrophysikalischen Analyse erfassen zu können.
Die petrophysikalische Untersuchung aller 39 Proben umfasste u.a. die Messung der NMR-Parameter, die komplexe elektrische Leitfähigkeit, die Geschwindigkeiten elastischer Wellen sowie Porosität, Permeabilität und innere Oberfläche.
Neben dem Zusammenhang der komplexen elektrischen Eigenschaften mit den Porenraumeigenschaften wurden insbesondere aus den Wellengeschwindigkeiten die elastischen Eigenschaften für die verschiedenen Karbonatlithologien abgeleitet. Im Weiteren wurden die experimentellen longitudinalen- und transversalen Wellengeschwindigkeiten mit den mittels Gassmann's-Fluid-Substitution-Modell berechneten verglichen und eine befriedigende Übereinstimmung gefunden. Ergänzend wurden ein porenraumbasiertes Inklusionsmodell von Kuster und Toköz (1974) und der Ansatz von Budianskiy und O'Connel (1974) an den Karbonatproben getestet.
Die modellbasierte Auswertung der Korrelationen führte im Wesentlichen zu folgenden Ergebnissen: (1) grobe Differenzierung der Karbonattypen anhand der seismischen und elektrischen Parameter, (2) Abschätzung der Permeabilität aus elektrischen Messungen und (3) Ableitung elastischer Moduli auf Basis einer komplexen petrophysikalischen Analyse.

BL Bohrlochgeophysik: e-Poster
BL-2

Dreikomponentige Bohrlochmagnetik in der COSC-2 Bohrung

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Abstract
Im Rahmen des ICDP-Projektes „Dreikomponentige Bohrlochmagnetik in der COSC-2 Bohrung" wurden im September 2020 mehrere Messungen mit einer Dipmeter Bohrlochsonde in Zentralschweden durchgeführt. Die Sonde trug unter anderem ein dreikomponentiges Magnetometer und einen dreikomponentigen Beschleunigungsmesser. Diese werden normalerweise nur zu Orientierungsberechnung der gemessenen elektrischen Widerstände verwendet. In diesem Projekt soll jedoch aus den gemessenen Magnetfeldern die magnetische Anomalie entlang der Bohrung bestimmt werden. Daraus soll dann mit Hilfe der Lagesensoren und des Bohrlochverlaufs der Vektor der remanenten Magnetisierung des umliegenden Gesteins ermittelt werden. Die remanente Magnetisierung enthält wichtige Informationen um den Gebirgsbildungsprozess der skandinavischen Kaledoniden zu verstehen.
Die in der Sonde verbauten Magnetometer entsprechen nicht der Qualität der normalerweise für die Bohrlochmagnetik verwendeten. Allerdings kommen solche oder ähnliche Sensoren bei einer Vielzahl von Bohrlochsonden zum Einsatz, sodass eine Auswertung der magnetischen Messungen zusätzliche Informationen ohne weitere Bohrlochmessungen erbringt.
Um die magnetische Anomalie mit der für uns nötigen Genauigkeit zu erhalten, muss die Bohrlochsonde zunächst kalibriert werden. Hierzu gibt es zwei mögliche Methoden: Die erste ist die Kalibrierung in dem magnetischen Laboratorium des Instituts für Geophysik und extraterrestrischen Physik „Magnetsrode" in Braunschweig. Hier wird die Sonde in einem Spulensystem platziert und ein Referenzmagnetfeld erzeugt, mit dessen Hilfe die Kalibrierparameter (Nullpunktsverschiebung, Skalenfaktor und Winkelfehler) bestimmt werden können. Die zweite Methode stellt einen komplett neuen Ansatz dar. Hier wollen wir die Messungen in der Bohrung selber nutzen und aus dem Vergleich von mehreren Befahrungen die Kalibrierparameter berechnen. Diese Methode könnte dann auch für zukünftige und vergangene Messungen mit ähnlichen Sonden verwendet werden, um eine bessere Datenqualität zu erhalten.
Ein weiterer Schritt in der Datenaufbereitung ist die Bestimmung der Systemübertragungsfunktion der Magnetometer. Aufgrund von schnellen Drehungen, hauptsächlich um die vertikale Achse, werden die gemessenen Magnetfelder verzerrt. Diese Anomalien überdecken dann teilweise das magnetische Signal des umliegenden Gesteins. Durch die Bestimmung eines optimalen Systemfilters können diese Effekte minimiert werden.

BL Bohrlochgeophysik: e-Poster
BL-3

A conversion rule for vintage natural gamma-ray logs in oil/gas exploration boreholes of the former GDR - GE and µR/h unit to API unit

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Abstract
Between 1950 and 1990, more than 800 deep-reaching boreholes (up to 5000m depth) were drilled in Saxony-Anhalt and geophysically logged during the intense oil and gas exploration of the former German Democratic Republic (GDR – part of the "Eastern Bloc"). A quantitative interpretation of the natural gamma ray (NGR) logs provides valuable information for e.g. lithological interpretation, well to well correlation, radioactive mineral exploration and estimation of clay content or radiogenic heat production. However, NGR logs in the oil/gas boreholes of the former GDR are documented in "Gamma-Einheiten" (GE), µR/h or counts per minute (cpm). For comparability and correlation to logs of the "Western Bloc" and modern logs, these vintage units have to be converted to the modern API unit. Previous studies either linked vintage and modern NGR logs of adjacent boreholes or used constant factors, based on the conversion of shallow NGR logs from brown coal exploration (probes with scintillation detector). In contrast, conversion of oil/gas borehole measurements of the former GDR (probes equipped with Geiger-Mueller counter tubes) does not follow a linear relationship.

To obtain an adequate conversion rule we analysed three boreholes, where logs were recorded twice: (1) with the analogue system of the GDR in the GE unit and (2) with a digital American system in the API unit (used in the GDR since March 1987). Relevant information and parameters of the probes, measuring systems and workflow for log processing were gathered from former technicians, field workers and interpreters. Subsequently, the NGR logs were plotted (about 10.000 pairs of values) and a regression analysis was applied to obtain a rule for the conversion of the GE and µR/h unit to the API unit (including standard deviation).

The resulting conversion rule is based on a substantial amount of data pairs and allows a conversion with sufficient certainty. Noticeable is a decrease of the conversion factor for rocks of lower natural gamma radiation. The converted NGR logs are now usable for e.g. investigation of clay content or radiogenic heat production.

BL Bohrlochgeophysik: Oral presentation (by invitation only)

BL Bohrlochgeophysik: Oral presentation (by invitation only)
V1-4

Nachweis einer Störungszone unterhalb des Geodynamischen Observatoriums Moxa: ein Ergebnis geophysikalischer Detektivarbeit mit Hilfe von gesteinsphysikalischen Daten und Bohrlochlogs

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Abstract
In Observatorien aufgenommene Zeitreihen enthalten die Signale von verschiedenen Prozessen aus unterschiedlichen Bereichen des Erdinneren. Da solche Signale, z.B. Änderungen der Deformation oder der Temperatur, oft sehr klein sind, ist es unverzichtbar, komplementäre Daten zur Korrektur und Evaluation etwa mit Klimastationen zu registrieren sowie eine sehr gute Kenntnis der geologischen Strukturen in der Umgebung eines Observatoriums zu erlangen. Das Geodynamische Observatorium Moxa der Universität Jena liegt im Thüringer Schiefergebirge in einer sehr rauscharmen Umgebung, ist jedoch durch eine komplexe hydrologische Situation sowie vielfältige geologische Strukturen im Untergrund gekennzeichnet, darunter eine vermutete Störungszone.
Informationen über den Untergrund unterhalb des Observatoriums und den geologischen Strukturen liegen aus verschiedenen oberflächennahen geophysikalischen Untersuchungen vor, darunter zahlreiche geoelektrische Profilmessungen. Diese wurden genutzt, um eine 3D-Widerstandstomographie durchzuführen.
Im Rahmen dieses Beitrags werden gesteinsphysikalische Messungen der Wärmeleitfähigkeit, Permeabilität und seismischen Geschwindigkeiten an Kernmaterial aus einer 100 m tiefen Forschungsbohrung auf dem Gelände des Observatoriums genutzt um die anstehenden siltigen Grauwacken zu charakterisieren. Dieser Datensatz wird durch Logging-Daten und kontinuierliche faseroptische Temperaturmessungen in dem Bohrloch ergänzt. Diese Datensätze ermöglichen die Identifizierung von Tiefenabschnitten, in denen effizienter Grundwassertransport vermutet wird und die Teil der vermuteten Störungszone sein könnten. Gemeinsam mit den Ergebnissen einer 3D Widerstandstomographie (vgl. Beitrag Valchev et al.) werden die Puzzlestücke zu einem Untergrundmodell zusammengefügt, das es auch ermöglicht, Aussagen über den Bewegungssinn der Störungszone zu machen.

BL Bohrlochgeophysik: Oral presentation (by invitation only)
V1-3

Cable coupling noise in wireline DAS-VSP data

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Abstract
Distributed Acoustic Sensing (DAS) is a versatile novel method that enables efficient acquisition of seismic data in terms of time and costs compared to the use of conventional borehole seismometers. Nevertheless, the quality of the data acquired using wireline DAS suffers from variable coupling conditions. Cable intervals with poor contact with the borehole wall are likely subjected to reverberations, caused by different sources such as vibroseis signal, liquid injection, etc. Coupling noise creates a sequence of distinct peaks and notches in the frequency spectrum, and as a result, the usable bandwidth of the measured wavefield is reduced.
We perform a coupling noise problem analysis, and revise different S/N ratio improvement approaches using data acquired at the Groß Schönebeck geothermal research site, NE German Basin. An extensive vertical seismic profiling (VSP) survey using the wireline DAS technology was performed in February 2017. Data was recorded in two 4.3 km deep wells with a depth sampling of 5 meters along the borehole. We use 61 vibroseis source points with various offsets, ranging from 200 to 2000 meters, organised in a spiral pattern around the target area to create an azimuthal distribution.
Based on the noise pattern and spectral behaviour examinations, we conclude that a certain percent of the energy, emitted by the vibrators, is converted into standing waves on the wireline cable. Furthermore, we are able to identify noise characteristics by applying the matching pursuit decomposition (MPD) method. This approach aims to find the input signal representation using an overcomplete dictionary based on the Gabor basic functions. Consequently, signal parts, representing the slapping and ringing of the cable, can be identified and modelled through analysis of noise properties and then subtracted from the recorded seismic trace.
The new MPD-based denoising approach has two key advantages if compared to other methods: 1) it can separate signal and noise, even if those are superimposed, and 2) it can be adapted to a specific signal. Thereby, proper denoising increases the S/N of wireline DAS data and thus helps to assess small-scale effects during exploration of any kind.

EM

Elektromagnetik und Georadar

EM Elektromagnetik und Georadar: e-Poster

EM Elektromagnetik und Georadar: e-Poster
EM2-1

3D FDTD Georadar Antennenoptimierung mittels PSO

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Abstract
Mittlerweile sind numerische FDTD Simulationen auch in 3D möglich und werden zur Analyse komplexer Szenarien herangezogen. Genutzt werden dafür jedoch üblicherweise infinitesimal kleine Dipole, die exakte Implementierung der Antenne wird vernachlässigt. Nur mit exakten Antennenmodellen können komplexe Prozesse im Nahfeld der Antenne wiedergegeben werden. Da sich die allermeisten Georadar Szenarien im Nahfeld der Antennen abspielen, spielt die Berücksichtigung dieses Bereichs eine wichtige Rolle. Wir zeigen ein 3D Modell einer kommerziellen 400 MHz Georadarantenne, dessen Geometrie auf 2 mm angenähert wurde. Die elektrischen Parameter der Einzelkomponenten wurden durch eine Full-Waveform Inversion von Daten unter kontrollierten Bedingungen mittels einer Partikelschwarmoptimierung (PSO) bestimmt. Obwohl Georadar Antennen komplexe 3D Strukturen sind, können die Geometrie und elektrischen/dielektrischen Eigenschaften der Antennenmaterialien so gut angenähert werden, dass das optimierte Antennenmodell Messdaten auf unterschiedlichen Untergrundmaterialien sehr gut replizieren kann und die Ankopplungseffekt der Antenne korrekt wiedergegeben werden.

First experiments on the suitability of grounded dipoles as receivers for the detection of surface NMR signals

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Abstract
Surface NMR measurements allow imaging of subsurface hydrogeological parameters such as soil moisture, porosity or hydraulic conductivity. Recent developments show that the surface NMR method is capable of imaging the two-dimensional distribution of subsurface structures and parameters with high spatial resolution and, in combination with ERT and GPR, provides a unique opportunity to characterize the subsurface hydrogeologically. This insight is countered by a comparatively high logistical cost for two-dimensional investigations. A large number of coils for excitation and detection of the NMR signals of several tens of meters in diameter are usually laid out semi-overlapping in profile direction to achieve the necessary spatial resolution and penetration capability.
The project "Simple and rapid imaging of groundwater using magnetic resonance and grounded bipoles (SIRIUS B)" is an experimental project funded by the Volkswagen Foundation to investigate the applicability of dipoles instead of coils for the excitation and detection of NMR signals. Should dipoles emerge as a possible alternative in this context, this could reduce the effort in the field and thus increase the measurement progress and consequently reduce the logistic effort for investigations on two-dimensional structures and processes.
SIRIUS B is working out both the theoretical foundations and the practical challenges of this new approach and is conducting initial experimental trials. As a first milestone, the applicability of dipoles as receivers has been tested. We present the first successful measurement of surface NMR signals with grounded dipoles. Future studies will mainly investigate the transmitter properties of the dipoles when exciting the NMR signal. The individual algorithms for the calculations will be added as new functionalities to the open-source modeling and inversion software COMET, which deals specifically with the analysis and inversion of surface NMR data.

EM Elektromagnetik und Georadar: e-Poster
EM1-01

2D Joint Inversion Algorithms for Semi-Airborne and LOTEM Data: A Data Application from Eastern Thuringia, Germany

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Abstract
Various electromagnetic (EM) measuring techniques were developed to fulfil the requirements in diverse earth or resources explorations, such as the long-offset transient electromagnetic (LOTEM) and the semi-airborne EM methods. The novel semi-airborne frequency-domain electromagnetic system takes advantages of both ground and airborne techniques by combining ground-based high power sources with large scale and spatially dense covered data. However, its signal-to-noise ratio is still smaller in comparison with the ground-based method like LOTEM due to the limited stacking time. From the perspective of inversion, the data of different EM methods have distinct resolutions towards the subsurface resistivity structures and therefore they can provide complementary earth information. However, these distinct resolutions could also lead to different inversion results if each dataset is inverted individually, which may introduce confusions to the following interpretations. To reduce the ambiguities and parameter uncertainties, joint inversion algorithms are developed to couple spatially dense sampled semi-airborne data and horizontal electric fields (Ex) measured using LOTEM. Nevertheless, the 1D joint inversion faces convergence problems due to 2D effects in the field data. The synthetic modelling suggests that the 2D effects in different datasets lead to distinct artificial structures in the 1D inversion, which makes the 1D joint inversion unfeasible. Therefore, a 2D joint inversion algorithm was further developed for the frequency-domain semi-airborne EM data and the LOTEM transient electric fields. With its application, the newly developed 2D joint inversion of the semi-airborne and LOTEM Ex field data acquired in eastern Thuringia, Germany, converged successfully and a 2D conductivity model could be derived for the survey area. In the consequent 2D synthetic modelling studies, it is demonstrated that part of the discrepancies between the individual inversion result of each field dataset can be explained by the resolution differences leaded by the different observed quantities and by the measurement configurations, and the 2D joint inversion result of field data is validated to be one effective equivalent model.

EM Elektromagnetik und Georadar: e-Poster
EM1-02

A 2D transient electromagnetic tipper study on a landfill near Cologne, Germany

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Abstract
Strong horizontal conductivity contrasts can be found for various different geophysical targets like landfills or hydrogeophysical exploration sites. Loop source transient electromagnetics (TEM) is especially sensitive to conductive structures. The multidimensional interpretation of electromagnetic data is often very time consuming, in particular for time domain methods like TEM. For the magnetotelluric method the tipper concept can be applied to get a first impression on areas that are affected by 2D/3D inhomogenities in the subsurface. A similar concept can be used to evaluate 2D/3D effects in TEM data, the so called TEM tipper. Its value is the time derivative of the horizontal magnetic field component normalised by the vertical one. The tipper has high values at locations with strong horizontal subsurface resistivity gradients.

For this study the TEM tipper concept was applied to data of a 2D central-loop TEM survey on a landfill near Cologne. Prior geophysical measurements showed a high resistivity contrast between the natural geology and the waste material, providing ideal preconditions to conduct a methodical study on 2D TEM measurements using the TEM tipper approach.

The vertical and one horizontal field component, perpendicular to strike direction, measured on a profile crossing the landfill, revealed a strong TEM tipper response close to the landfill's boundaries. Even values around 1 could be detected, denoting very strong horizontal variations in conductivity along the profile. This indicated that a 1D interpretation of the data was not sufficient. Furthermore, the vertical component data had sign reversals at two locations, directly over the waste body. These strong distortion effects could be caused by the subsurface physical properties such as 2D/3D geometry or even IP effects.
Based on observations from different complementary geophysical measurement techniques (TEM, geoelectrics and conductivity mapping using a 2 coil frequency domain system), a 3D model of the landfill was derived and used for 2D and 3D TEM forward modeling. The synthetic data displayed a similar space-time pattern of TEM tipper values as the field data. Further 2D/3D modelling demonstrated that the sign reversals originate from the subsurface geometry.
The successful 2D/3D modeling of TEM tipper field data as well as sign reversal central-loop TEM data are the key features of the study.

EM Elektromagnetik und Georadar: e-Poster
EM1-03

Three-dimensional controlled-source radio-magnetotelluric forward modeling and inversion in the transition zone

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Abstract
A classical radio-magnetotelluric (RMT) method, well-developed in the past decades, is now routinely applied to various environmental, engineering, and exploration problems. The method uses the military and civilian radio-transmitters broadcasting in the frequency range between 10 kHz and 1 MHz. Electromagnetic (EM) fields induced by these sources diffuse in the conductive earth, generating a secondary EM field. By measuring the resulting EM field at the earth surface a multi-dimensional conductivity model of the sub-surface can be derived. A significant disadvantage of RMT is the lack of stable radio-transmitters in remote areas. Additionally, there are no radio-transmitters broadcasting at frequencies below 10 kHz, which limits the depth of investigation. To overcome these problems, controlled sources can be used as an active source. This modification is called CSRMT, and allows measurements in remote areas and in the extended frequency range, e.g., from 1 kHz to 1 MHz.

We developed and tested new procedures for modeling and inversion of the CSRMT data. Current work focuses on the CSRMT data collected in the vicinity of the source. In this case, the geometry of the source field must be taken into account. Such approach allows us to improve the signal-to-noise ratio and to increase the penetration depth. Since we are primarily focusing on 3D structures, full impedance tensor and vertical magnetic transfer functions are considered as data. The CSRMT modeling and inversion were implemented within our own object-oriented framework – MR3DMod, in Matlab[R]. This framework was initially created as a prototype of the ModEM3D MT software, for development and testing purposes. Later, MR3DMod was extended and currently accommodates magnetotelluric, controlled-source EM, among other methods.

Here, we present a synthetic verification study of our newly developed CSRMT algorithm. Subsequently, we show the 3D inversion models obtained from CSRMT field data in the Alexandrovka village (Russia). This area is a test-site for the geophysical department of the Moscow State University. Therefore, the geology of the sub-surface is well-known and various geophysical models are available for comparison. Our CSRMT 3D models agree well with the geological settings and 2D ERT models. Therefore, the proposed CSRMT method is feasible and the developed procedures for modeling and inversion are reliable.

EM Elektromagnetik und Georadar: e-Poster
EM1-04

Experimentelle Untersuchung der Signalqualität von Georadardaten bei verschiedenen Stapelraten

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Abstract
Georadar ermöglicht die zerstörungsfreie Abbildung des oberflächennahen Untergrundes. Dazu wird ein hochfrequentes elektromagnetisches Wellenfeld (10 - 1000 MHz) angeregt und aufgezeichnet. Das bedeutet, dass die elektromagnetischen Signale innerhalb von Nanosekunden verarbeitet werden müssen. Durch die Entwicklung neuer Aufzeichnungssysteme (z. B. pulseEKKO® Ultra Receiver) ist es möglich, die Aufzeichnungsgeschwindigkeit deutlich zu erhöhen oder durch Stapelung der aufgezeichneten Spuren die Datenqualität zu verbessern.
In dieser Arbeit wird untersucht, inwieweit eine erhöhte Stapelrate eine Verbesserung der Signalqualität von Georadardaten bewirkt. Zunächst wird dazu anhand von Laborexperimenten die Aufzeichnungsgeschwindigkeit des verwendeten GPR-Systems in Abhängigkeit von verschiedenen Messparametern untersucht. Weiterhin wird in Felddaten die Veränderung des Signal-Rausch Verhältnisses (S/N) in Abhängigkeit von der Stapelrate in Common-Midpoint-Messungen (statische Messung) über glazialen Sedimentstrukturen untersucht. Darauf aufbauend werden am selben Standort sowie über einem komplexen Torfkörper Georadardaten in der Bewegung (kinematische Messung) mit verschiedenen Stapelraten aufgezeichnet. Neben der qualitativen und quantitativen Untersuchung der Signalqualität werden die Daten im Hinblick auf realisierbare Stapelraten sowie mögliche Messgeschwindigkeiten analysiert.
Die Ergebnisse zeigen unabhängig von einer statischen bzw. kinematischen Datenakquisition, dass Stapelraten bis zu 256-facher Stapelung eine erhebliche Hervorhebung des Nutzsignals gegenüber des Rauschsignals bewirken können. Gerade im Torf kann durch die Anwendung des Stapelns in Kombination mit einer gezielten Signalbearbeitung die Eindringtiefe und Strukturauflösung verbessert werden. Aus den Messungen geht außerdem hervor, dass ein Stapelgrad > 256 lediglich bei statischen Messungen realistisch anwendbar ist und nur eine geringfügige visuelle Verbesserung der Ergebnisse sowie eine minimale Steigerung des S/N bewirkt. Insgesamt konnte durch unsere Untersuchungen die Faustformel, dass das S/N proportional zur Quadratwurzel der Stapelrate ansteigt, bestätigt werden.

EM Elektromagnetik und Georadar: e-Poster
EM1-05

Sub-seafloor Pore-fluid Salinity Estimation in the Canterbury Bight, New Zealand, based on Bayesian Inversion of Controlled-source Electromagnetic Data

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Abstract
Offshore groundwater systems have been suggested as unconventional sources of portable water in islands and densely populated coastal regions, where terrestrial groundwater resources are over-extracted or contaminated. In this study, we evaluate how well pore-water salinity can be efficiently estimated from controlled-source electromagnetic (CSEM) resistivity models. Time-domain CSEM methods are an effective tool to explore offshore groundwater bodies since the electrical resistivity of the seafloor is primarily determined by the characteristics of the pore-water within the sub-surface sediments. We integrate offshore TD-CSEM data with borehole data and multichannel seismic reflection to identify an offshore groundwater system in the Canterbury Bight. The Canterbury margin is located off the eastern coast of the South Island of New Zealand and was previously investigated during IODP Expedition 317 in which a pore-fluid salinity anomaly was recorded in borehole U1353. By focusing on the low-salinity zone, we carry out synthetic modelling, implement Bayesian inversion to derive probability density functions for resistivity as a function of depth, and finally transform it to distribution of probability density for pore-fluid salinity using Archie’s equation. Subsequently, we use a trans-dimensional Bayesian inversion to interpret measured CSEM data, and consequently use the derived probability density functions to estimate uncertainty of pore-water salinity. Having done the same procedure for different waypoints in the Canterbury Bight, we extrapolate salinity values on a basin scale and estimate the probability density distribution for pore-water salinity as a function of depth. We show that using the Bayesian sampling algorithm provides us with a more precise estimation of hydrogeological model parameters with their uncertainties by generating an ensemble of models instead of inferring only one model using deterministic inversion approaches.

EM Elektromagnetik und Georadar: e-Poster
EM1-06

Bodenfeuchtebestimmung mit präpolarisierter Oberflächen-NMR - Erste Ergebnisse

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Abstract
Oberflächen-NMR ist ein etabliertes Verfahren der angewandten Geophysik zur zerstörungsfreien hydrogeologischen Charakterisierung des Untergrundes bis in ca. 150m Tiefe. Aufgrund der Beziehung zwischen der Spulengröße, dem angeregten Volumen und damit der detektierten Signalstärke sind Spulengrößen zwischen 20m und 150m gebräuchlich. Derart große Spulen verringern aber sowohl die vertikale als auch die laterale Auflösbarkeit von Strukturen und das Monitoring von Prozessen. Mit Hilfe einer Präpolarisations-Spule (d<2m), welche das messbare NMR Signal signifikant um mehr als eine Größenordnung erhöhen kann, ist der Einsatz von Oberflächen-NMR zur Untersuchung von kleinräumigen Strukturen und Prozessen mit geringem Wassergehalt möglich. Im Rahmen des DFG-Projektes MoreSpin wurde die prinzipielle Eignung der präpolarisierten Oberflächen-NMR zur Bestimmung der Bodenfeuchte untersucht.

Im ersten Teil des Feldversuches wird der gesamte Versuchsaufbau über einem Wasserbassin (ca. 1m Tiefe und 5m Durchmesser) installiert und das NMR-Signal für 100% Wassergehalt bestimmt. Dies dient nicht nur der Erprobung der neuentwickelten Gerätekomponenten und den dazugehörigen Messschemata, sondern auch als Verifikation für die numerische Modellierung. Aufgrund des komplexen Zusammenwirkens der zwei Anregungsfelder (Präpolarisations- und herkömmliches Wechselfeld) war es notwendig, die klassische Modellierung um eine exakte Implementierung der zugrundeliegenden Spindynamik zu erweitern. Nur dadurch konnte eine sehr gute Übereinstimmung zwischen der Modellierung und den realen Daten erreicht werden.

Im zweiten Teil des Experiments wurde mit einem identischen Versuchsaufbau ein Beregnungsversuch auf einer Testfläche in der Nähe von Hannover realisiert. Um die Bodenfeuchte mit einem unabhängigen und anerkannten Verfahren zu kontrollieren, wurden TDR Sonden unterhalb des NMR-Aufbaus installiert. Diese erlauben somit eine Überprüfung der NMR Ergebnisse. Es wurden NMR Messungen in vier oberflächennahen Tiefenbereichen vor und nach der Beregnung durchgeführt. Als Folge der Beregnung kann man ein Ansteigen der Initialamplitude (Wassergehalt) und der Abklingzeit (Porensättigung) in den NMR Daten erkennen. Qualitativ zeigt sich eine gute Übereinstimmung zwischen NMR Daten und den TDR Messungen. Durch weiterführende numerische Modellierungen, welche sowohl Labordaten als auch die effektive Geräte-Totzeit von 10ms berücksichtigen, konnte auch eine quantitative Übereinstimmung gezeigt werden.

EM Elektromagnetik und Georadar: e-Poster
EM1-07

Transient electromagnetic investigations of sedimentary deposits for paleoclimate research in the Atacama Desert, Chile

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Abstract
Claypans in endorheic basins along the Atacama Desert, Chile, host unique records of the precipitation history of one of the major hyper-arid deserts on Earth. In order to provide detailed information about the sedimentary architecture and bedrock topography of selected claypans, a geophysical survey using the Transient Electromagnetic (TEM) method was performed. This study was conducted within the collaborative research center CRC 1211 (EARTH - Evolution at the dry limit).

The presented work will focus on the Paranal site. The major objective of the geophysical survey is to derive suitable drilling locations for paleoclimatic studies and to obtain a better understanding of the deposition regime. Central loop TEM measurements were performed with a transmitter size of 40x40 m and a central receiver. More than 160 soundings were measured along parallel profiles forming a spatial 3D grid over the claypan. Active seismic was carried out on the same site to complement and validate the TEM results. In addition, a magnetic survey was performed to better assess the subsurface distribution of magnetic sources.

1D TEM models indicate a strong contrast between the conductive sediments and the resistive bedrock. Inversion of the TEM data using Occam and Marquardt inversion techniques suggests a sedimentary thickness of about 120 m for the Paranal site. Subsequently, a 2D forward modeling study was performed to investigate possible 2D effects. The 2D models were based on 1D inversion results and indicate 2D effects towards the claypan borders. Compared to seismic tomography results, there is a high correlation between the depth TEM-derived of the upper layer of the conductive strata and the depth of high contrast of seismic velocity. The analytical signal, total horizontal derivative, and tilt derivative filters were applied to study magnetic sources. The derived radially averaged power spectrum indicating a sedimentary infill of 100-150 m is in good agreement with the TEM results.

The 1D models obtained for each station are consistent, providing the 3D subsurface geometry with respect to the sedimentary infill, bedrock topography, and possible deposition regimes down to a depth of 200-250 m. These results provide valuable information on the spatial extent of the paleo-lake sediments and significantly support the selection of optimal coring positions as well as support the core interpretation and understanding of the basin genesis.

EM Elektromagnetik und Georadar: e-Poster
EM1-08

A Multidimensional Interpretation of Controlled-Source Radio-Magnetotelluric (CSRMT) Experiment in Aleksandrovka, Russia

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Abstract
Radio-Magnetotelluric (RMT) method is based on measurements of the electromagnetic (EM) field using military and civilian radio transmitters broadcasting in a frequency range between 10 to 1000 kHz as the source. In order to reach to higher signal to noise ratio and a deeper penetration depth, CSRMT measurements are performed using a controlled-source in a wider frequency range of 1 to 1000 kHz.
The survey accomplished in Aleksandrovka village in the Kaluga region in Russia, where there are sedimentary rocks from a paleo-valley with a high resistivity lens of roughly 15 m thickness at about 15 m depth.
Two perpendicular transmitters with 800 meters long, were setup to obtain the full impedance tensor and the tipper elements. In order to validate the far-field condition, RMT measurements also was carried out when the transmitters were off. The far-field data have been acquired from eight profiles with 400 to 600 m distance from the transmitters. The separation between the stations and the profiles was 20 and 40 meter respectively.
RMT and CSRMT data acquired in this field experiment, processed separately using two different software and different approaches. Afterwards the corresponding apparent resistivity, phase and tipper were calculated. Also, 2D inversion of the computed transfer functions were made using an NLCG inversion program.
The interpretation results, highly confirm the previously obtained results from the region that indicates the reliability of the data acquisition, processing and inversion.

EM Elektromagnetik und Georadar: e-Poster
EM1-09

Möglichkeiten und Grenzen der zerstörungsfreien Erfassung niedriger Feuchtegehalte in teilgesättigten Sandsteinen mit ^{1}H-NMR

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Abstract
Die zerstörungsfreie Ermittlung der Materialfeuchte in Baustoffen ist für das Bauwesen von großer Bedeutung, denn ein erhöhter Feuchteeintrag kann zu Schimmelbildung, Alkali-Kieselsäure-Reaktionen, Korrosion etc. führen und somit ein hohes Schadenspotential mit sich bringen. Auch wenn zur qualitativen Lokalisierung möglicher Schad- und Risikostellen bereits zahlreiche zerstörungsfreie Verfahren in der Praxis Anwendung finden, besteht ein Mangel an quantitativen Verfahren, die auch bei niedrigen Feuchtegehalten sensitiv sind.
Eine Methode zur zerstörungsfreien und quantitativen Bestimmung des Feuchtegehaltes und der effektiven Porosität ist die ^{1}H-Kernspinresonzanzmethode (NMR). Da NMR sensitiv für die molekulare Beweglichkeit von Wasserstoffprotonen ist, lassen sich Informationen über die Bindungsform und -stärke sowie der Umgebung (Porengröße und Mineralzusammensetzung) der Wasserstoffprotonen gewinnen. Obwohl es bereits seit über 20 Jahren mobile NMR-Messeräte gibt, wird NMR heutzutage immer noch weitestgehend im Labor eingesetzt. Dies liegt daran, dass sie aufgrund der verwendeten Permanentmagnete schwer sind und nur äußerst geringe Eindringtiefen ermöglichen.
In einer derzeit laufenden Forschungsarbeit wird deshalb ein speziell für Bohrkerne entworfener NMR-Tomograph eingesetzt. Mit seiner minimalen Echozeit von 50 µs lässt sich (abhängig von der Oberflächenrelaxivität) Wasser bis in nanometergroßen Poren erfassen. Um die Sensitivität von NMR bei Teilsättigung zu untersuchen, wurden verschiedene Sandsteinproben in Exsikkatoren mit relativen Luftfeuchten im Bereich von 33 % bis 96 % gelagert. Als Referenzen dienen zum einen das NMR-Signal bei Vollsättigung und zum anderen die Porengrößenverteilung aus Quecksilberporosimetriemessungen (MIP). Um die NMR-Sensitivität zu bewerten, wird die Korrelation der NMR-Amplitude mit den gravimetrisch ermittelten Feuchtegehalten sowie ein Vergleich der Porosität aus NMR und MIP betrachtet. Zu beachten ist in diesem Zusammenhang, dass sowohl die Reduzierung der Wasserfilmdicke als auch die Verkleinerung von Porengrößen zu einer ähnlichen Verkürzung der T_2-Relaxationszeit führt. Als Ausblick wird ein Lösungsansatz vorgestellt, bei dem die NMR-Signale mit der Wasserfilmdickenberechnung basierend auf der relativen Luftfeuchte im Material korreliert werden.

EM Elektromagnetik und Georadar: e-Poster
EM1-10

Charakterisierung eines für die Baustoffuntersuchung entwickelten NMR-Tomographen

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Abstract
Mit der ^{1}H Kernspinresonanz- (engl: NMR; nuclear magnetic resonance) Methode können Wasserstoffatome aufgrund ihres nicht ganzzahligen Spins magnetisch angeregt und nachgewiesen werden. So lassen sich Gesteins- oder Baustoffproben hinsichtlich ihrer Wassersättigung und ihrer Porengrößenverteilungen untersuchen.
An der Bundesanstalt für Materialforschung und -prüfung (BAM) wurde ein speziell für die Untersuchung von Baustoffproben optimierter NMR-Tomograph beschafft, mit dem sich Bohrkerne mit Durchmessern bis zu 70 mm bei minimalen Echozeiten zwischen 50 µs und 80 µs untersuchen lassen. Der Beitrag soll die Leistungsfähigkeit sowie die messtechnischen Grenzen des beschafften Messsystems aufzeigen, das aktuell nur als spezifische Einzelanfertigung existiert
Die Verwendung kleiner Echozeiten erlaubt Messungen in sehr kurzen Zeitabständen. Durch diese vielen Pulse in kurzer Zeit wird so auch viel Energie in das System übertragen. Jedoch können sich damit auch Gerätekomponenten sowie das in der Probe befindende Wasser während der Messung erwärmen und das Messergebnis beeinflussen. Während die Gerätekomponenten gekühlt werden können, ist dies für das Porenfluid unmöglich. Der Temperatureinfluss auf das Messsignal von Prüfkörpern wurde durch systematische Messungen untersucht.
Weiterhin wurden gerätetechnische Eigenschaften ermittelt, wie die Präzision der angeregten Schichtdicken (bei 1D Messungen) und Voxelgrößen (bei 3D Untersuchungen) im Messvolumen oder mögliche Störeinflüsse durch protonenhaltige Gerätematerialen um das sensitive Volumen. Hierzu wurden definierte Referenzproben hergestellt und systematische Messungen z.B. mit Glaskugelschüttungen durchgeführt. Zusätzlich wurden die sensitiven Volumina für die verschiedenen Spulen und Messmodi charakterisiert.
Am Ende wurden praktische Untersuchungen hinsichtlich der Ortsauflösung bei kapillarer Wasseraufnahme und Evaporation in geschichteten Sandsteinproben durchgeführt. Die Messergebnisse wurden über die Dauer des Versuchs mit den gravimetrisch ermittelten Feuchtegehalten verglichen und die graphische Darstellung der Feuchtegehalte zu unterschiedlichen Zeitpunkten anhand der vorangegangenen Untersuchungen optimiert. Die Ergebnisse zeigen, dass der NMR-Tomograph eine hohe räumliche Sensitivität und Messgenauigkeit aufweist. Dies erlaubt perspektivisch die Untersuchung verschiedenartigster Materialien mittels integral, schichtselektiv und dreidimensional aufgelösten NMR-Untersuchungen.

EM Elektromagnetik und Georadar: e-Poster
EM1-11

Electromagnetic experiments for the detection and characterization of seafloor massive sulfides at the Palinuro Seamount

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Abstract
Seafloor massive sulfides (SMS) are regarded as a potential future resource to satisfy the growing global demand of strategic metals. Aside from mining and retrieving profitable amounts of massive sulfides from the seafloor, the present challenge is to detect and delineate significant SMS accumulations, which are generally located near mid-ocean ridges and along submarine volcanic arc and backarc spreading centers.

In the past years we have used the marine transient electromagnetic induction system MARTEMIS, a coincident-loop TEM system developed at GEOMAR (Kiel, Germany), in various marine geological settings for the detection and characterization of SMS in the shallow seafloor down to a depth of ~30m. The system was also used in combination with remote EM receivers (Coil2Dipole experiment) to allow for investigations of conductive structures, which are covered by up to ~100m of sediments.

During two research cruises (2015: POS483, 2017: POS509), several types of EM experiments were carried out at the Palinuro Seamount located about 141km to the SSE of Naples (Italy) in the Tyrrhenian Sea. At this hydrothermally practically inactive site, previous investigations had confirmed the occurrence of SMS by drilling down a depth of 5m, the maximum depth reached by the drill (BGS Rockdrill I). For all EM experiments we used the marine transient induction system (MARTEMIS) - a mobile marine coil system - as source. For TEM experiments a coincident loop receiver integrated into the MARTEMIS system was used to investigate the shallow conductivity structure of the seafloor down to a depth of about 30m. In the TEM experiments we were able to show that the lateral extent of the SMS body is larger than previously known from drilling. In a second set of experiments, which we have named "Coil2Dipole", we used remote OBEM (ocean bottom EM) receivers to measure the electrical fields excited by the MARTEMIS coil source. In this experiment, OBEM receivers were able to detect the transmitted signal up to distances of about 250m, which yields an increased penetration depth of about 120m as compared to the TEM experiment. A first evaluation of the OBEM data indicates a conductor to the SW of the known mineralization at greater depth, which we interpret as the mineralized feeder channels to the known SMS site.

Qualitative and quantitative analysis of the new marine electromagnetic “Coil2Dipole” experiment

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Abstract
The formation of marine massive sulfides is connected to offshore hydrothermal circulation, where minerals from the underlying crust are mobilized and transported towards the seafloor. These sulfides have a high electrical conductivity, which can be detected by electromagnetic systems. To study potential occurrences of massive sulfides at the Grimsey Vent Field, which is located to the North of Iceland, two research cruises were in 2018 and 2019. Even though the Grimsey Vent Field is hydrothermally active, previous geoscientific studies were not able to detect these massive sulfides in the seafloor.
In order to detect potential occurrences of massive sulfides, several electromagnetic (EM) experiments were done. One of those experiments is the ”Coil2Dipole” experiment, in which the mobile MARTEMIS transmitter system (developed at GEOMAR), which uses a coil antenna, is used to generate a time varying magnetic field. After turning off the electrical current in the transmitter, the induced EM fields are measured with stationary Ocean Bottom EM-receiver (OBEM-receiver) on the seafloor. Through the receivers placed on the seafloor the signal is detectable up to distances of 250m, which yield depth of investigation of about 120m. A ranging system allows for the precise distance measurements between MARTEMIS and OBEM-receivers. This is important for the correct interpretation of acquired data, since the offset has great influence on detected signal.
In previous studies (Safipour et al., 2017, Geophysics; Safipour et al., 2018, Geophysical Prospecting) it was demonstrated that the “Coil2Dipole” is suitable to detect conductive targets, like massive sulfides in the seafloor. In this study we carry out a qualitative analysis in terms of 1D modelling of the data. Generally, we observed increasing resistivities with larger depth of investigation, which we attribute to the compaction of the seafloor. In the vicinity of one OBEM-receiver, which is located to the West of the active vent field, we detect a conductive layer, which indicates massive sulfides. Models of other receivers show a resistive seafloor. Finally, a parameter analysis confirms the results of the quantitative analysis.

EM Elektromagnetik und Georadar: e-Poster
EM2-3

First measurements using a new drone-based controlled-source electromagnetics system

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Abstract
Electromagnetic measurements can contribute to a large number of hydrological questions like the interaction between saltwater and freshwater or the delineation of aquitards. When carried out airborne, they can cover large areas and generate three-dimensional groundwater models with salinities derived from conductivity. However, helicopter surveys mean logistic effort and expenses. Moreover, they can lack resolution. For investigations on the intermediate scale (a few square kilometres) drone measurements are the method of choice. They can be repeated more often than helicopter based geophysics and are less depended on the terrain compared to surface based geophysics. As the transmitter cannot be mounted on the drone, we use a semi-airborne approach developed in the DESMEX project, where the signal is transmitted by current dipoles on the surface and magnetic fields are measured along flight lines that cover a predefined area.
We present data from a new CSEM drone system involving both induction coils and a fluxgate sensors. Additionally, inertial motion units are used to register position and attitude of the sensors. We carried out first test flights on two different sites in Northern Germany, one of them close to a groundwater observation system SAMOS. We used a 600 m long electrical dipole as transmitter and the Metronics TXM-22 signal source to generate a square wave of 32 Hz basic frequency. After processing the data using the WWU software, we can observe reliable magnetic signals in the harmonics up to frequencies of about 6kHz. The processing includes filtering, rotation and the removal of motion noise. With the resulting transfer functions we can generate subsurface models, using laterally constrained 1D inversion, that is able to deliver valuable information on the hydraulic system at hand. Drone based measurements represent the future of geophysics for rough terrain and three dimensional resistivity models.

EM Elektromagnetik und Georadar: e-Poster
EM1-13

Optimized estimation of Long Period Magnetotelluric transfer functions using closely spaced recording sites

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Abstract
In order to obtain reliable and smoothly changing transfer functions, the identification and characterization of noise signals for various MT datasets at closely spaced field sites is performed in time and frequency domain.
After the pre-selection of appropriate time segments in time domain, various parameters are compared, such as power spectral density, polarization of the horizontal magnetic and telluric field components, and statistical relations between them in form of partial coherencies and the distribution of impedances in the complex plane. With the boundary condition that the transfer functions are allowed to change continuously with frequency, a wide frequency range is included in the statistical approach, in contrast to conventional methods.
The data base are several months of long-period MT data collected during Sep2020-Jan2021 at four 10-20 km spaced stations in the Hochtaunus, a part of the Rhenish Massif. Magson and Lemi sensors were used for recording the magnetic field variations, whereas the telluric fields were measured by silver-silverchoride electrods, the sampling frequency being 4 Hz.

EM Elektromagnetik und Georadar: e-Poster
EM2-4

Open-Source 3D Finite-Element Modeling of Electromagnetic data with custEM 1.0

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Abstract
We present enhancements and simulation capabilities of the open-source Python toolbox custEM, which was primarily designed for the 3D finite-element (FE) modeling of controlled-source electromagnetic (CSEM) surveys with arbitrary geometries on unstructured meshes. Recently, we extended the capabilities of custEM by implementing multiple approaches for time-domain (transient) electromagnetic (TEM) and magnetotelluric (MT) data.
Of the implemented approaches, we prefer the total electric-field formulation using *Nédélec basis functions.* Second-order basis functions usually represent a good trade-off between accuracy and computational effort. We support general anisotropic petrophysical parameters, including conductivity, magnetic permeability, electric permittivity, and Cole-Cole parameters for induced-polarization effects. We improved all sub-modules of custEM which enabled more robust, accurate, and computationally efficient simulations. In addition, reusing the factorization of the system matrix significantly accelerates the solution of problems with multiple right-hand sides which is beneficial for multiple transmitters, time-domain approaches or sensitivity computation.
We present simulations for the three fields of electromagnetic modeling to demonstrate the accuracy and computational performance of custEM. The CSEM example is motivated by multi-frequency semi-airborne surveys as conducted in the DESMEX project. A 3D LOTEM example compares three different 3D time-domain approaches. Support for magnetotelluric data is demonstrated by comparing our solutions of the Dublin test model 1 with community solutions. In combination with the automated online documention of the source code, the variety of provided modeling example can help interested users to gain first experiences in custEM. Our implementation can support the community in forward modeling studies, inverse modeling applications, cross-validations, as well as understanding or teaching purposes.

EM Elektromagnetik und Georadar: Oral presentation (by invitation only)

EM Elektromagnetik und Georadar: Oral presentation (by invitation only)
V3-4

Deep mineral exploration using semi-airborne electromagnetics: First results from an experiment over the graphite deposit Kropfmühl

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Abstract
The overarching objective of the BMBF funded collaborative project DESMEX-II is the development of methods for efficient exploration of mineral deposits at great depths (~1000 m). In order to obtain a high data coverage as well as a high spatial and depth resolution, airborne and ground-based methods are combined in a semi-airborne concept. Within the framework of the project, a large scale semi-airborne controlled source electromagnetic (CSEM) survey was conducted in summer 2020 over a graphite deposit in eastern Bavaria, Germany. Due to the presence of graphite, an additional focus of this survey is the investigation of induced polarization (IP) effects on electromagnetic data and subsequently the development of suitable interpretation schemes.

On the ground, several horizontal electrical dipole transmitters with lengths between 1-3 km were deployed, utilizing a rectangular current function with a base frequency of 11.9 Hz. Helicopter-towed sensors measure the EM field on flight lines with a dense spacing and within several overlapping flight areas, covering offsets of several km to the ground-based transmitter. In addition, multi component magnetic as well as electric field measurements utilizing a low transmitter base frequency were conducted on the ground.

For the airborne and ground-based data, high quality transfer functions were derived over several decades of frequency. Electric field data was evaluated in time and frequency domain and is utilized to identify effects of induced polarization on the EM dataset and to improve the overall modelling resolution of the semi-airborne CSEM data. Here, we will present the concept and first results from the conducted survey, including preliminary inversion results.

EM Elektromagnetik und Georadar: Oral presentation (by invitation only)
V4-4

Adaptive Mesh Refinement using Hanging Edges in 3D Time-domain Electromagnetic Modeling

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Abstract
Electromagnetic modeling is a crucial tool for understanding the behavior of electromagnetic fields in realistic geological settings and, thus, supports the identification of reasonable measurement scenarios. However, sufficient spatial resolution is necessary in order to reduce numerical errors. Therefore, appropriate meshes consist of an enormous number of elements which require extensive storage capacities and result in high computational effort.
To avoid these drawbacks, we incorporate adaptive mesh refinement into our transient electromagnetic (TEM) modeling routine, which combines vector finite elements (FE) on unstructured tetrahedral meshes with a variable step-length Euler scheme. Starting from an initially coarse grid the mesh is refined during simulation runtime, i.e., on the fly. Since only a subset of the computational domain is refined, hanging edges emerge. They represent the vector FE equivalent to the better known hanging nodes and are incorporated by transferring geometrical constraints to the properties of edge elements. During the refinement process, only a limited number of additional degrees of freedom are added to the initial mesh using an error estimator, resulting in a compact mesh size and yet sufficient accuracy.
During the presentation, we summarize the key features of our simulation routine for three-dimensional TEM modeling. Furthermore, we introduce the novel hanging edge technique and demonstrate its benefit.

EX

Extraterrestrische Geophysik

Extraterrestrische Geophysik: Oral presentation (by invitation only)

Extraterrestrische Geophysik: Oral presentation (by invitation only)
V1-9

Der seltsame Fall des Planeten Merkur

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Abstract
Die ESA/JAXA-Mission BepiColombo ist auf dem Weg zum Merkur. Diese Mission hat unter anderem zum Ziel, mittels Magnetometern das Magnetfeld des Planeten zu erforschen. Dazu gilt es, die Feldanteile, die durch den Dynamo und der Magnetosphäre erzeugt werden, separat zu bestimmen, um damit Erkenntnis über den Aufbau und thermischen Entwicklung des Planeten sowie seine Wechselwirkung mit dem Sonnenwind zu bestimmen. Das Magnetfeld des Merkur ist aus Sicht der Dynamotheorie erstaunlich schwach. Eine besondere geophysikalische Struktur oder auch die Langzeitwechselwirkung mit der Magnetosphäre kann dafür verantworlich sein. Weiterhin ist es möglich, durch die Studie von induzierten Magnetfeldern die Leitfähigkeitsstruktur des Planeten einzugrenzen. Hinzu kommt, dass durch das fehlen einer Ionosphäre feldparallele Ströme aus der Magnetosphäre zumindest teilweise über den Planeten selbst geschlossen werden. Die zwei Satelliten der BepiColombo-Mission werden in polare Orbits einschwenken und dann die Reaktion der Magnetosphäre auf Änderungen im Sonnenwind ergründen. Im Extremfall, kann sogar die Magnetosphäre unter einem sprunghaften Anstieg des Sonnenwinds nahezu vollständig kollabieren. In diesem Vortrag werden die einzelnen wissenschaftlichen Ziele konkret vorgestellt, und wie wir uns bemühen, unser Wissen über diesen rätselhaften terrestrischen Planeten zu erweitern.

GD

Geodynamik

GD Geodynamik: e-Poster

GD Geodynamik: e-Poster
GD-1

Glacially-Induced Faults: Classification Criteria and Occurrence in Germany

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Abstract
Glacially-triggered faulting is the release of stresses induced by the advances and retreats of ice sheets in addition to other stresses that accumulated in the lithosphere. The faulting typically occurred along pre-existing faults or weakness zones before, during or after the last ice melting. This type of faulting is mainly recognized in intraplate regions but is also proposed for some plate boundary areas. Past reactivations were probably accompanied by great-magnitude seismic events triggering hundreds of landslides and seismically-induced soft-sediment deformation structures in the region surrounding the glacially-induced faults (GIFs). Classification criteria were developed in the 1980s and 1990s to correctly identify a GIF and distinguish it from the vast number of other faults around the globe.
Reliable field evidence for reactivated faults in and (even) around many formerly-glaciated areas has considerably increased the number of confirmed and probable GIFs in recent years, which were recently unified in an international database (Munier et al., 2020). It has been generally thought that GIFs, especially the so-called postglacial faults in northern Fennoscandia, were developed during a short period of time towards the end of and shortly after the deglaciation, however, new dating results from Fennoscandia documenting several episodes of fault rupture within the past 14,000 years challenge this idea. The youngest fault scarp was formed less than 600 years ago.
The new findings warrant a discussion of the classification criteria. In our poster, we suggest revised classification criteria for GIFs, modified from the previous criteria and for easier application expressed as a checklist (Steffen et al., 2021). Furthermore, we introduce the international database of GIFs, highlighting occurrences in Germany, which may be of interest in view of nuclear waste repository search.

References
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Steffen, H., Olesen, O., Sutinen, R. (2021). Glacially-Triggered Faulting – A Historical Overview and Recent Developments. In H. Steffen, O. Olesen, R. Sutinen, eds., Glacially-Triggered Faulting. Cambridge University Press.

GD Geodynamik: e-Poster
GD-2

Mapping the area possibly affected by glacially-triggered faulting with numerical models: indications in Germany?

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Abstract
Glacially-triggered faulting describes fault movement caused by a combination of tectonic and glacially-induced isostatic stresses. Ice sheet load induced stresses are released during or after ice melting with the potential to reactivate pre-existing faults. The most prominent, so-called glacially-induced faults (GIFs) were identified in the Nordic countries in Europe. It was mainly assumed that these features are unique although similar fault structures, but by far not of such dimensions, were also described from the United Kingdom and from eastern Canada. In other formerly glaciated areas in Europe reliable field evidence of GIFs increased in recent years. The estimated fault movements are of minor magnitude though as compared with those in northern Fennoscandia. Finally, a few studies in Germany even point to glacially-triggered faulting outside the former glaciated area.
Using the latest generation of three-dimensional high-resolution models of glacial isostatic adjustment we explore in which areas of Europe glacially-triggered faulting can be expected. We highlight the geographical limits of glacially-triggered faulting in Europe and discuss the likelihood of this type of faulting especially in Germany.

GD Geodynamik: e-Poster
GT-1

Evolutionary development and volume balance calculations of the Ana Slide in the Eivissa Channel, Western Mediterranean

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Abstract
Submarine landslides are widespread phenomena on continental slopes and act as prime sediment transport processes between shallow and deep marine regions. In addition, they pose significant risk to coastal communities worldwide. Within this study, we focus on the Ana Slide, a relatively small landslide with areal extent of 4.7 km^2 located at water depth between 635 – 905 m on the eastern slopes of the Eivissa Channel, western Mediterranean. Predominant sediment types are high-water content, carbonate-dominated hemipelagic deposits susceptible to high pore pressures and liquefaction. Available data include very-high resolution bathymetric and a 3D seismic dataset completely covering the landslide.
The Ana Slide is characterised by three landslide domains: the 1) evacuational or headwall domain, 2) translational domain, and 3) accumulational or toe domain. While the headwall domain demonstrates classic features of material evacuation and poses as the exclusive source of material within the landslide process, the translational domain documents extensive in-situ remnant blocks which were unaffected during failure. Instead, landslide material from the evacuational domain moved up and over the translational domain. The toe domain exhibits extensive chaotic seismic facies with compressional ridges throughout the deposit and imprinted onto the seafloor.
Even though extensive chaotic seismic facies characterise the toe domain, its volume differs significantly from the volume of the evacuated material from the headwall domain. Thus, we conclude that the chaotic seismic facies does not represent landslide material. Instead, the in-situ sediment underwent a range of soft-sediment deformation processes. We propose two mechanisms responsible for this deformation: loading- and shearing-induced soft-sediment deformation resulting from rapid deposition of overburden material. Under consideration of the likely elevated pore pressure and liquefaction potential of deposits, these mechanisms lead to the destruction and disturbance of internal reflections.
Our analysis demonstrates the difficulties in distinguishing between actually failed landslide material and deformed but not translated sediment, which may well lead to erroneous landslide volume estimations. Our new model of the evolutionary development of the Ana Slide may well hold for many other submarine landslides globally, the volumes of which could be significantly overestimated.

GD Geodynamik: e-Poster
GT-2

A Subducting Seamount Imaged in the Rupture Zone of the 1994 Java Earthquake, and Its Implication on Co-seismic Slip Propagation and Tsunami Generation

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Abstract
The 2 June 1994 Java (Indonesia) tsunami earthquake ruptured in a seismically quiet subduction zone and generated a larger-than-expected tsunami. Since the peak of the co-seismic slip occurred underneath a local bathymetric high, the 1994 event was previously interpreted as being caused by a subducting seamount. Combining a re-processed seismic reflection line across the rupture area with a refraction tomography P-wave velocity model, multibeam bathymetry, and gravity data suggests that rupture over a subducted seamount is unlikely to explain the seismo-tectonic genesis of the event. The forearc high is rather related to the enhanced back-thrusting activity and an island arc crust backstop in the upper plate. We newly resolve a shallow subducting seamount seaward of the forearc high and up-dip of the rupture area. We propose that this seamount acted as a seismic barrier and may have diverted the co-seismic rupture into the overlying splay faults, which may have contributed to the larger-than-expected tsunami.

GD Geodynamik: e-Poster

Estimating the lithospheric architecture and geothermal heat flow of Greenland

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Abstract
The lithospheric structure of Greenland is still poorly known due to its thick ice sheet, the sparseness of seismological stations, and the limitation of geological outcrops near coastal areas. As only a few geothermal measurements are available for Greenland, one must rely on geophysical models. Such models of Moho and LAB depths and sub-ice geothermal heat-flow vary largely.
In this study, we use a new shear wave tomography model of Greenland to estimate the surface heat flow. This is done by comparing Vs-depth profiles from Greenland with velocity profiles from the US Array, where a statistical link between Vs profiles and surface heat flow has been established. A similarity function determines the most similar areas in the U.S. and assigns the mean heat-flux from these areas to the corresponding area in Greenland. The heat flow values from this model ranges from 34 to 74 mW/m^2 with a mean of 50 mW/m^2. These values are lower than previous heat flow models for Greenland, but in some areas higher than the sparse direct measured values.
As this is a statistical determination, we model in the next step the lithospheric architecture by geophysical-petrological modelling with LitMod3D in agreement with the statistical predictions.

GD Geodynamik: e-Poster
GD-6

Einfluss von lateralen Variationen in der Erdstruktur auf Meeresspiegelrekonstruktionen: Modelle zur glazial-isostatischen Anpassung in Oregon und Patagonien

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Abstract
Die Wechselwirkung zwischen Eisschilden und der festen Erde spielt eine wichtige Rolle für Eisschildstabilität, Meeresspiegeländerungen und damit für die globale Klimadynamik. Modelle zur glazial-isostatischen Anpassung (GIA) ermöglichen die Simulation der Reaktion der festen Erde aufgrund von Variationen der Eisschild- und Ozeanlast und die Simulation von Meeresspiegeländerungen und Oberflächendeformationen. Da die viskoelastische Reaktion der festen Erde sowohl von der Eisschildverteilung als auch von der Rheologie der festen Erde abhängt, ist die Verwendung von unabhängigen Erdstrukturen in GIA-Modellen von entscheidender Bedeutung. Eine Möglichkeit besteht darin seismische Tomographiemodelle zu verwenden, die Hinweise auf laterale Variationen geben. Die Umrechnung von seismischen Geschwindigkeitsvariationen in für GIA-Modelle relevante Viskositätsvariationen hängt von Transferfunktionen ab und ist von Unsicherheiten belastet. Unter Verwendung einer Reihe von GIA-Modellen untersuchen wir den Einfluss von Erdstrukturen auf Meeresspiegelrekonstruktionen. Das Ensemble aus 3D-Erdstrukturen unterscheidet sich dabei im Reduktionsfaktor des Arrhenius-Gesetzes sowie bezüglich des radialen Viskositätsprofils. Die Wahl einer 3D-Erdstruktur anstelle einer radial symmetrischen 1D-Erdstruktur ist insbesondere in Regionen mit starker lateraler Variation von Bedeutung, weshalb wir die Regionen der Cascadia-Subduktionszone (Oregon) sowie des Golf San Jorge (Patagonien) untersuchen. Beide Regionen sind durch Erdstrukturen mit starken Viskositätskontrasten gekennzeichnet und befinden sich in unmittelbarer Nähe zu ehemals und zum Teil rezent vergletscherten Gebieten. Der Vergleich der berechneten Meerespiegelkurven mit Beobachtungsdaten (Meeresspiegelindikatoren) zeigt, dass 1D-Modelle den Meeresspiegelanstieg während des Jungpleistozäns unterschätzen. Die 3D-Modelle können die Beobachtungsdaten in der Regel besser rekonstruieren, wobei die betrachteten Unsicherheiten in der abgeleiteten Viskositätsstruktur zu Abweichungen von mehreren Metern innerhalb der letzten 10.000 Jahre führen können.

Glacially-induced stresses and their effect on pre-existing faults: Insights from numerical models

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Abstract
The deformation due to an ice load is accompanied by displacement and stress changes. These stress changes are known to have created large magnitude earthquakes during and after the last deglaciation. These so-called glacially-induced faults have been found to have various orientations in their respective stress regime. Here, we present the analysis of the effect of glacially-induced stresses on pre-existing faults. A finite-element model is used to estimate the glacially-induced stresses and combined with the background stress magnitudes. We test the three different stress regimes: thrust-faulting, normal-faulting, and strike-slip-faulting. In addition, the effect of the stress magnitudes is tested via the stress ratio. Faults can be reactivated by glacially-induced stresses within thrust-faulting, strike-slip-faulting, and normal-faulting stress regimes, depending on their location. While faults with large variations of dip and strike outside of the ice sheet are prone to reactivation when the background stress field is a normal- or strike-slip-faulting stress regime, faults within a thrust-faulting stress regime can be reactivated within the ice margin during and after the deglaciation. In addition, instability exists also along the intermediate principal stress axis in a thrust-faulting stress regime. Changes of the stress regime lead to a switch from strike-slip- to thrust-faulting beneath the ice sheet for a high stress ratio. Thus, a strike-slip-faulting stress regime could also explain the observed glacially-induced faults in northern Europe and recent earthquakes there.

GD Geodynamik: Oral presentation (by invitation only)

GD Geodynamik: Oral presentation (by invitation only)
V1-01

Possibilities of transdimensional inversion for estimating deep Earth velocity and mantle structure

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Abstract
Commonly, the physical properties of the Earth (e.g., velocity, density) are parameterized as continuous fields. The most popular representation are grids and basis functions like spherical harmonics or splines. In an inversion context it is quite common that not all the parameters are fully constrained by the available input data. This relates to the common issues of insufficient resolution, incomplete coverage, and trade-offs due to non-uniqueness. By applying some form of regularization to the inverse problem, a well-behaved and unique solution can be obtained, but this solution depends on the details of the chosen regularization.
Transdimensional approaches address the regularization problem by using a model representation with a variable number of parameters. The number of parameters is adjusted according to the requirements of the input data using the reversible jump Monte Carlo Markov Chain (rj-MCMC) algorithm. The output is an ensemble of variable resolution models that provides insight into the required model complexity and trade-off between parameters.
Here, I present synthetic tests from a joint inversion of satellite gravity gradients and normal modes for the Earth's velocity and density structure. The mantle's seismic velocity and density inside a 2-D spherical annulus are described by a variable number of discrete anomalous volumes, each with a variable size, shape, location and strength of velocity and density anomaly. The discrete anomalies are adjusted using the transdimensional approach in order to fit the gravity and normal mode data. This synthetic example shows promising results, because the synthetic model can recovered reasonably well.

GD Geodynamik: Oral presentation (by invitation only)
V1-03

Earthquakes induced by ice-mass loss: A case example for southern Greenland

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Abstract
Due to their large mass, ice sheets induce significant stresses in the Earth's crust. Stress release during deglaciation can trigger large-magnitude earthquakes, as indicated by surface faults in northern Europe. Thus, the current ice-mass loss in Greenland can be accompanied by earthquakes. Here, we will present an example of a possible large magnitude earthquake that occurred during the large melting period of the Greenland Ice Sheet in the early Holocene. The glacially induced stresses showed an instability occurring at 10,600 years ago. An offset in past sea level indicators falls within the same time frame, which gave us indications that the stresses have been released by an earthquake. The potential fault could have slipped up to 47 m, resulting in a large magnitude earthquake, if only one event occurred. The earthquake may have shifted relative sea level observations by several meters. In addition, as the potential fault is located offshore, the earthquake could have produced a tsunami in the North Atlantic Ocean with runup heights of up to 7.2 m in the British Isles and up to 7.8 m along Canadian coasts. Thus, ice-mass loss is strongly linked to the occurrence of earthquakes and even earthquakes-related tsunami. These scenarios due to a changing cryosphere can have effects for all countries bordering the North Atlantic Ocean and are in addition to the well-known sea-level rise.

GD Geodynamik: Oral presentation (by invitation only)
V1-8

On the effects of planetary rotation on the dynamics of a terrestrial magma ocean

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Abstract
About 4.5 billion years ago, an impact of a mars-sized body caused a deep magma ocean of global extent on Earth. An important but mostly neglected process in studies on such magma oceans is the effect of planetary rotation. Early Earth rotated much faster than today, with a minimum period of 2-5 hours. Owing to the small viscosity of the vigorously convecting melt, planetary rotation may have far-reaching consequences for magma ocean solidification and Earth's early differentiation. It may not only be of key importance for the chemical structure and the development of chemical heterogeneities, but it may also set the stage for the initiation of plate tectonics. In addition to that, impacts of differentiated projectiles into the magma ocean are thought to deliver additional metal to Earth during a stage called late accretion. To understand to what extent the present-day geochemical signature of the Earth's mantle reflects the processes of core formation and late accretion, it is important to comprehend how the metal delivered by impacts is dispersed and settles within a terrestrial magma ocean.
Therefore, by means of numerical experiments in a rotating spherical shell, we demonstrate the crucial effect of planetary rotation on two processes occurring in a magma ocean, namely on the dynamics of silicate crystals during an early stage of magma ocean solidification and on the settling of impact-delivered metal within a magma ocean.
During magma ocean crystallization, we reveal that rotation may induce an inhomogeneous solidification of a terrestrial magma ocean with respect to depth and latitude, leading to the formation of large-scale heterogeneities. Consequently, the origin and distribution of large mantle heterogeneities being observed at present may be an imprint of the effect of planetary rotation on the magma ocean crystallization.
Due to rotation, also the settling of impact-delivered metal shows crucial differences in metal dispersion depending on the impactor's target latitude. The chemical metal-silicate equilibration may differ depending on the target latitude, being limited to certain locally delimited magma ocean domains.
Overall, planetary rotation may provide a possible mechanism for the generation of chemical heterogeneities and isotopic anomalies within Earth's mantle, and for heterogeneous metal-silicate equilibration, potentially shaping the geochemical signatures being observed today.

GD Geodynamik: Oral presentation (by invitation only)
V1-02

The 2013 Wind River earthquake: an example of a ductile seismic rupture?

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Abstract
In 2013, the usually seismically quiet Wind River area in the Northwestern US was struck by a 4.7 Mw earthquake. It is not only its location that makes this earthquake particularly interesting, but more so its hypocentral depth, which was determined to be at approximately 75 km. At this depth, the pressure-temperature conditions inhibit brittle failure and thus no earthquakes would be expected. Even though these deep earthquakes were already discovered by Kiyoo Wadati more than 90 years ago, their underlying physical mechanisms remain enigmatic. As brittle failure is unlikely, ductile mechanisms have to be invoked to explain this event.
One of the mechanisms that has been proposed to initiate earthquakes at this depth is thermal runaway. This process is a result of viscous dissipation during deformation. As rocks become weaker with increasing temperature, viscous dissipation results in thermal weakening and ultimately rock failure. However, the stresses required for thermal runaway are relatively large, thus calling for additional weakening mechanism. It has been found that grain size reduction may provide the needed weakening, thus forming a positive feedback loop with viscous dissipation.
Here, I investigate whether this mechanism of grain size assisted thermal runaway could cause deep earthquakes. To do so, I employ numerical models of a viscoelastic slab where ductile deformation is governed by a complex rheology with multiple deformation mechanisms acting in parallel. During loading, grain size reduction and viscous dissipation result in progressive weakening of the slab. At certain conditions, this weakening is sufficient to induce thermal runaway and thus also ductile rupture. Based on results from seismic tomography, I then apply this model to the Wind River earthquake to determine whether grain size assisted thermal runaway could explain the occurrence of the 2013 Wind River earthquake.

GE/IP

Geoelektrik und Induzierte Polarisation

GE/IP Geoelektrik und Induzierte Polarisation: e-Poster

GE/IP Geoelektrik und Induzierte Polarisation: e-Poster
GE/IP-01

Messungen der Spektralen Induzierten Polarisation an trockenen Marinen Massivsulfiden

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Abstract
Die Spektrale Induzierte Polarisation (SIP) ist eine Methode, bei der im Gegensatz zur Gleichstromgeoelektrik ein Wechselstrom eingespeist wird, sodass neben dem spezifischen Widerstand auch eine Phasenverschiebung gemessen werden kann. Beide Größen lassen Rückschlüsse auf das vermessene Material zu.

Bei Labormessungen der SIP an Festgestein werden meist zylindrische Proben in passenden Probenhaltern vermessen. Häufig werden sie dazu mit einer NaCl-Lösung gesättigt und auch mit dieser angekoppelt. In der Vergangenheit wurden darauf basierend Theorien entwickelt, um die auftretenden Polarisationsmechanismen zu erklären. In diesen Theorien ist der Elektrolyt von entscheidender Bedeutung. Im Zusammenspiel mit dem Porenraum kommt es beim Anlegen eines Feldes zu Ladungsverschiebungen im Elektrolyt und somit zur Polarisation.

Auch an Marinen Massivsulfiden, also erzhaltigen Proben von Schwarzen Rauchern, wurden bereits SIP-Messungen durchgeführt, mit dem Ergebnis, dass diese Materialien vergleichsweise hohe Phasenverschiebungen und große Leitfähigkeiten aufweisen. Diese Messungen wurden ebenfalls mit gesättigten Proben durchgeführt. Bei vorläufigen Messungen haben sich Hinweise ergeben, dass auch trockene Proben Polarisation zeigen. Ob auch ohne Elektrolyt Polarisationseffekte nachgewiesen werden können, soll nun systematisch untersucht werden.

Die trockenen Proben wurden zunächst mit Agar-Agar angekoppelt und vermessen. Dabei zeigte sich, dass stets Fluid aus dem Agar-Agar in die Probe diffundiert. Demnach kann daraus nicht geschlossen werden, dass die gemessenen Polarisationseffekte auch bei trockenen Proben auftreten. Aus diesem Grund wurden nun Messungen an Erzproben durchgeführt, bei denen die trockene Probe mit Knetmasse angekoppelt wurde. Die Messungen zeigen, dass auch bei den trockenen Proben im hohen Maße Polarisation statt findet. Dies deutet darauf hin, dass die auf einem elektrolytgefüllten Porenraum beruhenden Theorien zur Erklärung nicht ausreichen.

Impedanzelektrische Vermessung von eingebetteten Marinen Massivsulfiden

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Abstract
Bei der Spektralen Induzierten Polarisation (SIP) wird neben dem spezifischen elektrischen Widerstand auch die Phasenverschiebung von Strom und Spannung gemessen. Bei Labormessungen werden dazu häufig zylindrische Proben in passenden Messzellen vermessen.

Oft liegt Probenmaterial als Handstück vor. Wenn nicht erwünscht ist dieses durch eine Bohrung zu beschädigen oder eine Bohrung technisch nicht möglich ist, ist es notwendig ein alternatives Messprozedere zu entwickeln, damit auch an irregulär geformten Proben impedanzelektrische Messungen durchgeführt werden können.

Der hier verwendete Ansatz ist, dass Proben in einen hinreichend großen Zylinder aus einem möglichst unpolarisierbaren Medium eingebettet und in dieser Konfiguration vermessen werden. Untersucht werden soll die Frage ob aus den so gemessenen Werten die Phasenverschiebung der eingebetteten Probe an sich bestimmt werden kann und was für einen Korrekturfaktor gelten muss, der aus den Messwerten der eingebetteten Probe die Phasenverschiebung der Probe bestimmt.

Für die Studie liegt ein Probensatz aus 40 zylindrischen Proben vor, die aus den Gebieten um Schwarze Raucher stammen. Es handelt sich dabei um Ozeanbodenbasalte sowie zahlreiche erzhaltige Marine Massivsulfide. Die Proben wurden zunächst in passenden Messzellen vermessen. Anschließend wurden die selben Proben auch in Quarzsand eingebettet vermessen. Durch die Verwendung von zylindrischen Proben bei beiden Messungen ist es möglich die gemessenen Phasenwerte zu vergleichen.

Die gröbste Abschätzung des frequenzunabhängigen Korrekturfaktors ist der Volumenanteil der eingebetteten Probe. Der Faktor ermöglicht bei etwa 8 % der Messungen eine mittlere Abweichung von weniger als 25 % der Phasenwerte der Zylinderprobe. Allerdings weisen 44 % der korrigierten Messungen mittlere Abweichungen von mehr als 50 % auf. Mittels nummerischer Simulation berechnete frequenzabhängige Korrekturfaktoren ermöglichen in 29 % der Messungen eine mittlere Abweichung der Phasenwerte von weniger als 25 %. Somit können die Abweichungen der korrigierten Phasenwerte aus den eingebetteten Messungen von den direkten Messungen der Zylinder lediglich zum Teil über die verwendeten Korrekturen erklärt werden. Bei etwa der Hälfte der Messungen waren die Spektren zu unterschiedlich. Die große Abweichung könnte daher rühren, dass die Grenzfläche von Probe zu Sand eine wichtige Rolle bei der Polarisation spielt.

Schnellst- oder genauestmöglich? - Die multifrequente SIP Anregung ermöglicht die optimale Adaption des Messablaufs an das Untersuchungsobjekt.

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Abstract
Die Methode der Spektrale Induzierte Polarisation (SIP) misst die Frequenzabhängigkeit des spezifischen elektrischen Widerstandes von Gesteinen nach Betrag und Phase. In der Frequenzabhängigkeit des Widerstandes spiegelt sich unter anderem die Geometrie des Porenraumes und den darin befindlichen Fluiden wieder. Üblicherweise wird das Widerstandsspektrum mit monofrequenten Signalen sequentiell vermessen. Diese Vorgehensweise erweist sich bei großskaligen Messanordnungen mit hohen Störspannungen als vorteilhaft da die Energie des Messgerätes auf einen schmalen Frequenzbereich konzentriert und eine Unterscheidung von Nutz- und Störfrequenzen erleichtert wird. Bei Labormessungen spielen Störspannungen häufig nur eine untergeordnete Rolle. Wichtiger ist hier ein möglichst hoher Messfortschritt. Am schnellsten ist die sequentielle SIP Messung, wenn jeweils nur Einzelperioden verwendet werden. Bei einer Frequenz pro Oktave, dauert die Gesamtmessung idealerweise doppelt so lange wie die längste Periode andauert. Überlagert man jedoch sämtliche Einzelfrequenzen (multifrequente Anregung) dann benötigt man nur die halbe Zeit. Der höhere Messfortschritt geht jedoch einher mit einer verringerten Messgenauigkeit. Ursache hierfür ist, dass die Einzelamplituden soweit verringert werden müssen, dass die Summenamplitude nicht die maximale Ausgangsspannung des Messgerätes überschreitet. Im Poster wird ein neu entwickeltes 88-kanaliges SIP-Labor-Messgerät (SIP-LAB-FAST) vorgestellt, das eine Anregung mit 1 - 24 Frequenzen gleichzeitig erlaubt. Bei z.B. einer Frequenz pro Octave lässt sich so ein Frequenzbereich von über 7 Dekaden mit einer Einzelmessung vermessen. Eine multifrequente Anregung erfordert auch eine leistungsfähige Hardware zur Echtzeit-Verarbeitung der Zeitreihen von Strom und Spannung. Hierzu wurde für jede Frequenz eine Diskrete Fourier Transformation (DFT) implementiert. Mittels einer multivariaten Kohärenzanalyse werden dann aus den Fourier Koeffizienten das komplexwertige Impedanz-Spektrum, sowie den zugehörigen Vertrauensintervallen berechnet. Durch die freie Wahl des Anregungssignales erhält der SIP Anwender eine erweiterte Möglichkeit den Messablauf optimal an die Fragestellung anzupassen. Ein Vergleich der mono- und multifrequenten Messergebnisse von verschiedenen Materialproben belegt die Leistungsfähigkeit der neuartigen Messtechnik.

GE/IP Geoelektrik und Induzierte Polarisation: e-Poster
GE/IP-04

Classification of slag material in the laboratory and field scale with spectral induced polarisation

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Abstract
Since the demand for raw material is still growing, historical mining dumps are in the focus of geophysical investigations because they can still bear valuable minerals. Moreover, the risk assessment of groundwater contamination due to solutions processes within slag dumps is an important part of dump characterisations. One suitable technique to use is the spectral induced polarisation (SIP) method. Together with accompanying methods, it can lead to an estimation of the potential re-usable mineral resources of slag dumps.
In our study, we investigated several slag samples from five different dumps located in the Harz Mountains. We also conducted laboratory SIP measurements at original Harz ore samples (Rammelsberg ore, Oberharzer vein) and host rock samples (clay shale, greywacke, claystone) for comparison. At a historical mining dump near Goslar, we also carried out field measurements at two SIP profiles.
Based on the spectrum of the imaginary part of the conductivity, σ‘‘, we were able to assign the SIP results to different groups and to classify the samples. Measuring the polarisation magnitude σ‘‘ at a medium frequency (around 1 Hz) enables discrimination between slag material, ore material and host rock, since they could be assigned in a low-polarisable, medium-polarisable or high-polarisable group. Additional information could be obtained by considering the full spectral behaviour of σ‘‘. Since the spectra of the slag samples vary significantly, any pre-defined models (e.g., Pelton models, constant phase model, etc.) cannot take into account the variability of the observed curves. Instead, we classified five different types of σ‘‘ spectra in the field frequency range (0.1 – 100 Hz): the ascending, descending, constant, maximum and minimum type. Our results show that these types could be recognized in both laboratory and field measurements. In particular, the increasing and maximum type indicated highly polarisable slag material. Our findings enabled a zonation of different slag types within the dump and a delineation from the host rock. We believe that this classification is more suitable to compare laboratory with field results since the spectral shape depends only to a minor degree on saturation, fluid conductivity, and the representative volume.

GE/IP Geoelektrik und Induzierte Polarisation: e-Poster
GE/IP-05

Prognose der Permafrostverbreitung im Qugaqie-Tal (Tibet-Plateau) in Abhängigkeit von Hangneigung, Exposition und Solarstrahlung

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Abstract
Auf dem Tibet-Plateau spielt Permafrost (über zwei oder mehr aufeinanderfolgende Jahre gefrorener Untergrund) eine wichtige Rolle bei der Formung der Landschaft. Auch für das Verständnis des Wasserhaushaltes und dessen Veränderung als Folge der globalen Erwärmung ist die aktuelle Permafrostverteilung ein wichtiger Faktor. In dieser Studie untersuchen wir daher das etwa 60 km^2 große, semi-aride Qugaqie Einzugsgebiet (4700 – 6100 m ü.NN) im Nyainqêntanglha Gebirge südlich des NamTso Sees genauer.
Ein bereits existierendes, überregionales Modell sagt Permafrost auf über 90% der Fläche des Untersuchungsgebietes voraus. Die Grenze zwischen Permafrost und saisonal gefrorenem Untergrund befindet sich in diesem Modell bei etwa 5000 m ü. NN. Laut einer aktuellen Feldstudie (Auswertung periglazialer Landformen sowie gleichstromgeoelektrischer Messungen) liegt diese Grenze dagegen mit etwa 5400 m ü. NN deutlich höher; Permafrost wird somit nur auf ca. 55% der Fläche des Untersuchungsgebietes erwartet.
Obwohl die Ergebnisse dieser Feldstudie im Vergleich zu dem überregionalen Modell bereits eine deutliche Verbesserung darstellen, entspricht die Festlegung auf eine Höhenlinie als einheitliche Permafrostgrenze kaum den realen Bedingungen. So sollte die Permafrostverteilung unter anderem stark von der mesoskaligen Topographie abhängig sein.
Mit einer Geoinformations-Software leiten wir daher im Rahmen dieser Studie Geländeparameter (Hangneigung, Exposition, Abschattung und Solarstrahlung) ab und untersuchen deren Zusammenhang mit der prognostizierten Permafrostverbreitung. Dazu nutzen wir die mittlere Höhe jeder kartierten periglazialen Landform (Blockgletscher, Protalus Rampart) und die Eigenschaften des Untergrundes an Standorten, die mit gleichstromgeoelektrischen Messungen auf den Eisgehalt hin untersucht wurden.
Unsere Hypothese ist, dass aufgrund der extremen Höhe, der geringen Bewölkung und der niedrigen Jahresdurchschnittstemperaturen (-6,8°C) die mittlere jährliche Sonneneinstrahlung der maßgebliche Parameter für eine höhenvariable Grenze zwischen sporadischem und kontinuierlichem Permafrost ist. Hangneigung und Exposition hingegen wirken sich weniger auf die höhenvariable Grenze aus als es z.B. für die Alpen typisch ist.

Somit können einzelne geophysikalische Profile und Beobachtungen vor Ort genutzt und in die Fläche interpoliert werden um die Variation der Permafrostuntergrenze um die 5400 m Höhenlinie für das Qugaqie-Tal zu prognostizieren.

GE/IP Geoelektrik und Induzierte Polarisation: e-Poster
GE/IP-06

Ein Ansatz zur Eisgehaltsbestimmung im Permafrost auf Basis zweidimensionaler Feldmessungen der Hochfrequenten SIP

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Abstract
Eis weist ein sehr charakteristisches Polarisationsverhalten im Frequenzbereich zwischen etwa 1 kHz und 100 kHz auf. Unsere Methode der Hochfrequenten Spektralen Induzierten Polarisation ermöglichen es uns, dieses Verhalten über seinen gesamten Frequenzbereich zu vermessen und dadurch eine aussagekräftige Indikation über das Vorhandensein von Eis zu erhalten. Mit unserer spektralen 2-D Inversion können wir die Verteilung der elektrischen Parameter bestimmen und damit Aussagen über die Struktur des Untergrundes treffen.
In einem weiteren Schritt wollen wir nun aus diesen Ergebnissen den Eisgehalt im gefrorenen Untergrund abschätzen. Der Eisgehalt ist ein wichtiger Parameter in der Permafrostforschung. Er kann als Indikator für seine Stabilität gelten und kann über längere Zeiträume Aufschluss über den lokalen Einfluss der globalen Erwärmungsprozesse geben.
Es existieren verschiedene Modelle zur Eisgehaltsbestimmung auf Basis frequenzabhängiger elektrischer Informationen, die jedoch meist nur theoretisch erarbeitet und, wen überhaupt, lediglich anhand von Labordaten getestet wurden. Durch unsere zweidimensionale Auflösung spektral-elektrischer Informationen, ist es uns nun möglich, diese Modelle auf Felddaten anzuwenden. Wir nutzen ein Modell aus der Literatur, welches ein Materialgemisch anhand seiner frequenzabhängigen Permittivität beschreibt, das hier erstmals auf Permafrostdaten aus Sibirien angewandt wird. Die ersten Ergebnisse zeigen, dass der Eisgehalt sinnvoll abgeschätzt werden kann. Dadurch kann nicht mehr nur eine qualitative Aussage über das Vorhandensein von Eis, sondern auch eine quantitative Information extrahiert werden, die einen Mehrwert zur Interpretation von Permafrost liefern kann.

GE/IP Geoelektrik und Induzierte Polarisation: e-Poster
GE/IP-07

Ein neues Modell zur Beschreibung des Einflusses der Stern-Schicht auf die Membranpolarisation

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Abstract
IP-Messungen stellen eine vielseitig anwendbare Methode für geophysikalische Untersuchungen dar. Geeignete Polarisationsmodelle tragen zu einem besseren Verständnis der zugrundeliegenden Prozesse bei und helfen bei der Interpretation der Messdaten. Ein wichtiges Modell beruht auf der Membranpolarisation (MP): Durch unterschiedliche Transportraten der am Stromfluss beteiligten Ionensorten im Elektrolyt bilden sich Konzentrationsgradienten aus, die zur Polarisation führen.

Die unterschiedlichen Transportraten entstehen durch den Einfluss der elektrischen Doppelschicht, die sich aus zwei Schichten zusammensetzt: Die Stern-Schicht (SL) besteht unter Annahme einer negativen Oberflächenladung aus adsorbierten Kationen. In der diffusen Schicht (DL) liegt eine im Vergleich zum ungestörten Elektrolyt erhöhte Kationen- und eine verringerte Anionenkonzentration vor. Mit zunehmendem Abstand zur Porenoberfläche nähern sich beide Konzentrationen dem Wert im ungestörten Elektrolyt an. Der Effekt der MP tritt vor allem dann deutlich hervor, wenn der Radius von Engstellen im Porenkanal in der Größenordnung der Mächtigkeit der DL liegt und sich die Transportraten der beiden Ionensorten stark unterscheiden.

Bisherige Modelle zur Beschreibung der MP berücksichtigen die SL-Ionen lediglich in Form einer erhöhten Kationenkonzentration in der DL. In dem hier vorgestellten neuen Modell wird die Polarisation der SL dagegen als zusätzlicher Prozess berücksichtigt; die SL-Ionen koppeln als eigene Ionensorte an die Ladungsverteilung in der DL. Durch eine semi-analytische Lösung des resultierenden Gleichungssystems wird die Leitfähigkeit eines 1D-Porensystems berechnet.

Bei der MP hängt das Polarisationsverhalten stark von der Geometrie der beteiligten Poren ab. Für ein System aus zwei zylinderförmigen Poren ist die Geometrie durch Länge und Radius der beiden Poren festgelegt. In Parameterstudien untersuchen wir den Einfluss der Porengeometrie auf das Polarisationsverhalten und vergleichen die Ergebnisse dieser Studien mit den bisherigen Modellen.

Variiert man die Porenlänge, liefern das alte und unser neues Modell vergleichbare Ergebnisse. Hierbei wird das Polarisationsverhalten dadurch bestimmt, ob die Konzentrationsgradienten über die enge oder die weite Pore relaxieren. Bei der Variation der Radien zeigen sich signifikante Unterschiede zwischen den Modellen, da die Bewegung der SL-Ionen auf die Porenoberfläche beschränkt ist, während sich die Ionen in der DL frei bewegen können.

SIP laboratory data: frequency-domain versus time-domain

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Abstract
Spectral information from induced polarisation (IP) measurements can be used for several applications as the characterisation of the lithology, the estimation of hydraulic parameters, the localization of contaminated areas and many more.
So far, the spectral content has been mainly determined in frequency domain (FD). Due to significant instrumental developments and advanced data processing and inversion tools, it is nowadays also possible to extract spectral information from time-domain (TD) measurements. Even though the results from both domains should be theoretically identical, differences can be observed in the practical application. To compare both domains, we started with numerical models and measurements at test circuits. Thereafter, we conducted measurements on different types of well-known material (e.g., sandstones and wood samples) in a controlled laboratory environment. For the TDIP measurements, the AIE-2 instrument was used and the FDIP spectra were recorded with the SIP Fuchs III device.
Besides the measurement results, shown as decay curves in TD and amplitude and phase spectra in FD, also the Differential Polarisation parameter (DP) is presented. This parameter is calculated from the TD decay curve and proves to be well correlated with the phase in FD. The comparison of DP and phase curves enables a first visual check and a discrimination between different samples.
To compare both domains qualitatively, the relaxation time distribution (RTD) was calculated for all data. The results are in (partly very) good agreement between both domains, depending on the data quality. We found that the RTDs are in better agreement for the wood samples than for the sandstone samples. We attribute the differences to the lower data quality of the TD measurements of sandstones, which were performed with lower current in comparison to the wood samples. Therefore, the TD decay curves at later times are more affected by noise.

Retrieving IP and surface properties of carbonate rocks from measurements on crushed samples

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Abstract
Carbonate rocks are in the focus of geophysics and reservoir engineering. Their behaviour during e.g. EOR or CO_2 storage is challenging to understand and predict due to the reactive nature of the carbonate rock matrix and the complexity of carbonate pore space and genesis.

For studying reactive rock-fluid-gas interactions - e.g. in CO_2 storage - working with crushed rock material - instead of full plugs - has several advantages: enlarged interfaces for interaction, increased permeability, controlled reduction of the pore space heterogeneity, facilitated access for fluids to the pore space. All this reduces the equilibration - and therefore experiment - time span during chemical interaction experiments. In a first step however, we have to understand the relation between the properties of the undisturbed and the crushed material in order to enable a transfer of experimental results from crushed to undisturbed rock lateron.

We therefore systematically investigated the electrical and structural properties of four different carbonate rocks (covering mud-dominated micritic, grain-dominated oomoldic and dense clean carbonates), and one sandstone (for comparison) in both crushed (8 different particle sizes, between 0.03 mm and 10 mm particle size) and plug form with a vast set of methods at normal conditions: SIP, NMR, mercury intrusion porosimetry, nitrogen adsorption, XRD, µCT, scanning electron microscopy. By means of the huge data set we are able to quantify the pore-space, surface and electrical properties as functions of particle size, understand their relations, differentiate between intra- and inter-particle responses. The samples show significant variation in their SIP response depending on salinity, porosity, pore-space heterogeneity and - due to the peculiarities of the crushed samples - the organization of particles in the packing.

We found that the particle size dependent SIP and specific surface properties of the investigated particle packings can be described by a differential effective medium approach, which accounts for particle size and inner structure. Based on this model for crushed samples, it is possible to computationally recover the corresponding properties of the original, undisturbed material. We realize this by means of a shared inversion of SIP and specific surface data for each rock. The presented approach allows for taking advantage of the crushed material characteristics, while maintaining the direct connection to the original rock.

GE/IP Geoelektrik und Induzierte Polarisation: e-Poster
GE/IP-10

SIP field measurements at a gas discharge zone and black schist locality near the Main Central Thrust shear zone in the Himalayas of Central Nepal

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Abstract
We conducted an SIP field survey at both a CO2/H2S discharge zone and two characteristic outcrops of graphitic black schist in the Himalayas of central Nepal (Langtang area). The investigated sites are associated with the Himalayan Main Central Thrust shear zone. The area was heavily affected by the deadly Mw7.8 Gorkha earthquake in 2015.

Building on a previously conducted laboratory study, the field survey aims at increasing our knowledge of the electrical properties of the Himalayan rocks, which might help to improve both the interpretation of deep crustal geophysical surveys and our understanding of the Himalayan orogeny. The data further is supposed to enhance our understanding of reactive gas migration and discharge in the Nepalese hydrothermal systems, which are known to relate to the earthquake activity in the region.

We present the survey, as well as the collected data set and the experimental and computational challenges arising from working in a pronouncedly mountainous area like the Himalayas. Furthermore, preliminary inversion results and interpretations are presented.

SIP-Messungen an künstlichen Mischproben aus Sand und technischen Ionentauscherharzen im Labor- und Technikumsmaßstab

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Abstract
Künstlich hergestellte Ionentauscherharze (ITH) besitzen volumenspezifische, reaktive Oberflächen mit spezifischen, ionenselektiven Ionenaustauschkapazitäten hinsichtlich der jeweiligen Gegenionen.
Für die SIP-Laboruntersuchungen wurden zylindrische Mischproben (d=2 cm & l=3 cm) mit unterschiedlicher Zusammensetzung aus Quarzsand und diversen technischen Ionentauscherharzen hergestellt, um die Abhängigkeit der komplexen elektrischen Eigenschaften der Proben vom Massenanteil des ITH sowie dessen Partikelkorngröße zu untersuchen.
Die kugelförmigen Ionentauscherharzpartikel weisen eine verhältnismäßig geringe Dichte bzgl. des Quarzsandes auf. Um möglichst homogene Mischproben herzustellen, wurde wasserbasierendes Agar-Agar-Gel mit einer definierten elektrischen Leitfähigkeit als Trägermedium eingesetzt. Weiterhin wurde die Interaktion von Kat- und Anionentauscherharzen sowie der Einfluss des Agar-Agar-Gels untersucht.
Bereits die Anwesenheit von geringen Mengen ITH in den Mischproben führt zu einer signifikanten Steigerung der Polarisierbarkeit der Proben. Sowohl der Realteil als auch der Imaginärteil der komplexen elektrischen Leitfähigkeit sind sensitiv gegenüber dem Massenanteil an Ionentauscherpartikeln. Der Imaginärteil steigt proportional zum Massengehalt an ITH an und bildet gleichzeitig eine starke Frequenzcharakteristik aus. Der Realteil der komplexen elektrischen Leitfähigkeit hingegen zeigt eine schwache Frequenzabhängigkeit unabhängig vom Massengehalt des ITH. Nichtsdestotrotz ist ein deutlicher Niveauanstieg des Realteils mit zunehmenden Massenanteil an Partikeln zu beobachten.
Weiterhin weist der frequenzabhängige Imaginärteil der komplexen elektrischen Leitfähigkeit eine partikelgrößenabhängige Frequenzcharakteristik auf, wobei mit zunehmender Partikelgröße die Peakfrequenz sinkt.

Abschließende wurde eine größere zylindrische Mischprobe (d=10 cm & l=10 cm) hergestellt und als Störkörper in ein Sandkastenmodell eingebettet. Hierbei wurde die gleiche NaCl-Lösung mit einer definierten elektrischen Leitfähigkeit für die Wassersättigung des Lockersediments im Sandkasten sowie zur Herstellung der Mischprobe genutzt.
Am Sandkastenmodell wurden profil- und flächenhafte SIP-Messung zur Lokalisierung des Störkörpers durchgeführt. Die Frequenzcharakteristik der SIP-Messungen am Störkörper im Sandkastenmodell zeigt dabei ein ähnliches Verhalten, wie die SIP-Laboruntersuchungen an einer kleinen Probe von gleicher, materialspezifischer Zusammensetzung.

GE/IP Geoelektrik und Induzierte Polarisation: e-Poster
GE/IP-12

Eine neue Auswertungsroutine von Gleichstromgeoelektrikdaten zur Erkundung von Sedimentablagerungen in Seen

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Abstract
Seen dienen zur Rekonstruktion von Klima- und Umweltbedingungen der aquatischen und umgebenden terrestrischen Ökosysteme. Informationen über die Vergangenheit lassen sich aus Umweltbioindikatoren (z.B. fossile Kleinstlebewesen, Pollen oder Rußpartikel) in Sedimentschichten am Seeboden ableiten.

Mittels gleichstromgeoelektrischer Messungen mit auf dem Wasser schwimmenden Elektroden lässt sich die Widerstandsverteilung des Seegrundes messen und insbesondere die Sedimentmächtigkeit abschätzen. Im März 2018 wurden daher auf verschiedenen Karstseen der Selva Lacandona, einem Urwaldgebiet im Süden Mexikos, Gleichstromgeoelektrikmessungen mit einem hinsichtlich Transport und Ausführung möglichst einfachen Aufbau aus 13 hinter einem Boot hergezogenen Elektroden (5 m Elektrodenabstand) durchgeführt.

Ziel der Studie ist es, eine Auswertungsroutine für den schwimmenden Messaufbau zu entwickeln, mit der an beliebigen Seen effizient und schnell ein Bild des Untergrundes gewonnen werden kann.
Dafür wurden im ersten Schritt zunächst einzelne Profile mit weitestgehend konstanter Wassertiefe in 1D und 2D frei invertiert. Ein Vergleich mit Sonardaten (Sub-Bottom Profiler) zeigt, dass bei Wassertiefen >10 m mit diesem Ansatz jedoch einzelne Sedimentschichten nicht aufgelöst werden können. Durch die Verwendung von a-priori Informationen wie Seetiefe, Wasserwiderstand und Sedimentwiderstand aus zusätzlichen Messungen vor Ort und an Sedimentproben im Labor, konnte das Inversionsergebnis deutlich verbessert werden. Es zeigt sich, dass auf diese Weise aus den Daten des verwendeten Messsystems eine erste schnelle Einschätzung der Sedimentmächtigkeit bei Seetiefen bis zu 20 m möglich ist.

Für ein genaueres und weiträumigeres Bild der Widerstandsverteilung des Seebodens sollen in einem zweiten Schritt alle auf dem See gemessenen Profile einbezogen werden. Die Positionen der einzelnen Elektroden entlang der teils stark gekrümmten Messlinien des Datensatzes sind allerdings unbekannt und werden aus den GNSS-Positionen des Bootes rekonstruiert. Hier stellen wir daher außerdem eine Möglichkeit vor, die Positionen der einzelnen hinter dem Boot schwimmenden Elektroden mittels Spline-Interpolation zu rekonstruieren. Die so gewonnenen Elektrodenpositionen sollen dann später als Grundlage für eine 3D Inversion der Gleichstromgeoelektrikdaten dienen.

Ableitung von dielektrischen Bodenparametern zur GPR-Modellierung durch Inversion von Labor-Messdaten einer Koaxialzelle

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Abstract
Um die Ausbreitung elektromagnetischer Wellen im Untergrund realitätsnah zu modellieren, sind Kenntnisse über das Hochfrequenzverhalten des Untergrundes nötig. So können z.B. dielektrische Relaxationsmechanismen im Untergrund zu einer Frequenzabhängigkeit der komplexen dielektrischen Permittivität führen und in einer dispersiven Wellenausbreitung resultieren.
Um das Hochfrequenzverhalten einer Bodenprobe zu bestimmen, wird diese in eine Koaxialleitung eingebaut und für beide Messrichtungen Transmission- und Reflektionskoeffizient mittels eines Netzwerkanalysators gemessen. Die frequenzabhängige komplexe dielektrische Permittivität wird aus diesen Streuparametern mit Hilfe einer Levenberg-Marquardt Inversion unter Berücksichtigung des Vorwärtsmodells der Messzelle abgeleitet und mit den Ergebnissen einer etablierten kommerziellen „black-box“ Messsoftware verglichen. Des Weiteren werden petrophysikalische Funktionen in Form mehrpoliger Debye-Modelle angepasst, welche als Grundlage realitätsnaher FDTD Simulationen der Ausbreitung von Georadarpulsen in dispersiven Medien dienen.

GE/IP Geoelektrik und Induzierte Polarisation: e-Poster
GE/IP-14

Akquisition und Inversion 2D/3D-geoelektrischer Daten: Ableitung eines tektonischen Untergrundmodells des Geodynamischen Observatoriums Moxa

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Abstract
Das Geodynamische Observatorium Moxa ist mit einer Vielzahl von Messsystemen zur Erfassung physikalischer Größen instrumentiert um unter anderem die Deformationen der Erdkruste, sowie Variationen des Schwerefeldes zu untersuchen. Zur Auswertung dieser Zeitreihen sind zahlreiche Korrekturen und Reduktionen notwendig, da die erhaltenen Messgrößen insbesondere von der Topographie, den geologischen Verhältnissen und insbesondere von hydrologischen Einflüssen abhängig sind.

Im besonderen Fokus des Interesses stehen daher Untersuchungen zum Verlauf und Mechanismus, sowie der hydraulischen Eigenschaften möglicher Störungszonen im Umfeld des Observatoriums Moxa, um so bisher nicht erfasste Migrationspfade von Fluiden zu entschlüsseln. Mit Hilfe der im Rahmen dieser Arbeit durchgeführten elektrischen Widerstandstomographie kann das bereits vorhandene tektonische Modell erweitert und verfeinert werden.

Um Informationen über die Struktur des Untergrundes am Geodynamischen Observatorium Moxa zu erhalten, wurden mehrere geoelektrische 2D Profile mit verschiedenen Messanordnungen aufgenommen. Diese Daten wurden mit Hilfe von BERT 2 (Günther et al., 2006; Rücker, 2010) invertiert. Der Fokus bei der Auswahl der Profile wurde dabei hauptsächlich auf verschiedene vermutete Störungszonen gelegt. Zusammen mit den bereits vorhandenen geoelektrischen Profilen bildet sich so eine gute Grundlage für eine 3D-Inversion des gesamten Datensatzes. Die Ergebnisse der einzelnen 2D- sowie der 3D-Inversion werden in Hinblick auf die Strukturgeologie des Untergrundes interpretiert. In den Ergebnissen der elektrischen Widerstandstomographie bilden sich Störungen durch unterschiedlich stark definierte laterale Kontraste des spezifischen elektrischen Widerstands bzw. durch gut leitfähige steile Anomalien ab. Auf diese Weise konnten verschiedene Störungszonen nachgewiesen und abgebildet werden.

GE/IP Geoelektrik und Induzierte Polarisation: e-Poster
GE/IP-15

Comparison of measuring strategies for frequency- and time-domain induced polarization in the field

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Abstract
Spectral induced polarization (SIP) is an increasingly interesting technique for field investigations since it can provide valuable information on the properties of the subsurface deposits or groundwater units. Field measurements can be carried out in the frequency domain (FD) or in the time domain (TD) but should lead to the same spectral subsurface description. IP measurements are superimposed by other phenomena like cable crosstalk, capacitive coupling and induction effects, hindering IP data analysis. There is a number of ways to avoid these distortions, like separating current and potential cables.
We applied TDIP and FDIP on two test sites using a ABEM Terrameter LS2 and a Radic SIP256C instrument. We used different layouts and measuring schemes (multi-gradient vs. dipole-dipole forward and backward) or waveforms (50 vs. 100% duty cycle) and compared the results. The comparison between forward and reverse arrays enables to assess reciprocity as a measure of data quality.
On the test site in Sweden with good coupling and strong IP effects, there is an excellent reciprocity agreement for the dipole-dipole array, but the 50% and 100% data differ from each other. Separated cables cannot improve the data quality further, also for multi-gradient data. In contrast, the FDIP data show also a good quality but some discrepancies which origin is not fully clear. After inversion, we obtain similar subsurface models of Cole-Cole behaviour with a comparable frequency range.
The test site in Germany is totally different: The electrode coupling in dry sand was very bad and the IP effects are weak. Consequently the ratio of coupling and IP effects is much bigger. Here, we can see a clear improvement by using separated cables. Processing requires far more effort. Furthermore, the subsurface does not follow a Cole-Cole model but shows rather a constant phase angle. Hence, the spectral content of the data is limited, even though the spectral content is again comparable.

GE/IP Geoelektrik und Induzierte Polarisation: Oral presentation (by invitation only)

GE/IP Geoelektrik und Induzierte Polarisation: Oral presentation (by invitation only)
V4-1

Einfluss von Textur und Mineralogie auf temperaturabhängige SIP-Eigenschaften von Sediment- und Kristallingesteinen in Einfrier- und Auftauzyklen

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Abstract
Zur Charakterisierung und zum Monitoring von Permafroststandorten werden unter anderem geoelektrische Methoden genutzt, da sich mit dem Phasenwechsel von flüssigem Wasser zu gefrorenem Eis die elektrischen Eigenschaften des Untergrunds ändern. Hierbei wird am häufigsten die Elektrische Widerstandstomographie (ERT) angewendet, wobei der spezifische Widerstand als Proxy für Temperatur oder Eisgehalt genutzt wird. Dabei kann allerdings kaum zwischen der gering leitfähigen Luft und dem ebenfalls gering leitfähigen Eis unterschieden werden. Aufgrund der charakteristischen Polarisationssignatur von Eis wird zunehmend auch die SIP-Methode (Spektrale Induzierte Polarisation) eingesetzt. Zur Interpretation von SIP-Messungen an Permafroststandorten ist es notwendig, die frequenzabhängigen elektrischen Eigenschaften von Gesteinen in Abhängigkeit von Temperatur, Eisgehalt, Textur und Mineralogie für gefrorene und teilgefrorene Zustände zu verstehen.
In der hier vorgestellten Studie wurde an verschiedenen wassergesättigten Sediment- und Kristallingesteinen sowie an Lockermaterialproben, von alpinen Permafroststandorten, während kontrollierter Einfrier- und Auftauzyklen (+20°C bis -40°C) die elektrische Impedanz im Frequenzbereich von 10 mHz bis 45 kHz kontinuierlich gemessen. Für alle untersuchten Proben zeigt der Betrag der Impedanz eine ähnliche Temperaturabhängigkeit mit zunehmendem Widerstand für abnehmende Temperatur. Ebenfalls ist eine Hysterese zwischen Einfrieren und Auftauen bei allen Messungen zu beobachten. Für die Phase der Impedanz, deren (absoluter) Betrag direkt von der Stärke der Polarisation abhängt, ist das bekannte Relaxationsverhalten von Eis im Bereich von 1 kHz bis 45 kHz bei allen Proben erkennbar. Dessen unterschiedliche Ausprägung ist auf die jeweiligen Texturen der Gesteine und damit die jeweiligen temperaturabhängigen Eisgehalte zurückzuführen. Bei niedrigeren Frequenzen (1 Hz - 1 kHz) konnte bei allen Proben im ungefrorenen Zustand Membranpolarisation von unterschiedlicher Ausprägung beobachtet werden, abhängig von Textur sowie Mineralogie, die während des Einfrierens teilweise zusammengebrochen sind.
Insgesamt zeigen die untersuchten SIP-Eigenschaften nicht nur eine Abhängigkeit von Textur, Mineralogie und Temperatur, sondern vor allem eine Abhängigkeit vom Eisgehalt, welcher ebenfalls von Textur und Temperatur abhängig ist. Somit scheint die SIP-Methode zur thermischen Charakterisierung sowie zur Bestimmung des Eisgehalts geeignet zu sein.

GE/IP Geoelektrik und Induzierte Polarisation: Oral presentation (by invitation only)
V4-2

Oberflächenrauigkeit, tote Poren und Korn-Korn-Wechselwirkung in der spektralen induzierten Polarisation: Neue Erkenntnisse aus der numerischen Modellierung

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Abstract
Die Methode der Spektralen Induzierten Polarisation basiert auf der Vermessung der komplexen Leitfähigkeit heterogener Medien. Polarisationseffekte an den mikroskopischen Grenzflächen zwischen festen und flüssigen Bestandteilen geologischer Materialien führen zu charakteristischen frequenzabhängigen Variationen der komplexen Leitfähigkeit. Im Frequenzbereich bis etwa 1 kHz werden dafür vor allem Polarisationseffekte in der elektrischen Doppelschicht verantwortlich gemacht, die im Elektrolyt gelegen die meist negativ geladenen Mineraloberflächen bedeckt.
Mechanistische Modelle dieser Polarisationseffekte können bereits viele experimentelle Beobachtungen erklären. Dazu gehören etwa die Variation der Relaxationszeit der Polarisation mit dem Quadrat der dominierenden geometrischen Längenskala oder die Abhängigkeit der Polarisationsstärke mit der Ladungsstärke in der Doppelschicht. Lange Zeit standen für die Erklärung solcher experimentellen Daten lediglich analytische Modelle für sehr einfache Modellgeometrien wie z.B. Kugeln oder Ellipsoide zur Verfügung. Nach der Einführung eines relativ einfach handhabbaren numerischen Finite-Elemente-Modells für die Polarisationsprozesse in der Doppelschicht, können nun aber auch komplexere Geometrien modelliert werden.
Hier präsentieren wir Ergebnisse von Simulationen, mit denen wir den Einfluss (1) der Oberflächenrauigkeit kugelförmiger Mineralkörner, (2) toter Poren, sowie (3) der Wechselwirkung zwischen benachbarten Körnern untersucht haben. So macht sich die Oberflächenrauigkeit durch das Auftreten eines zusätzlichen Peaks im Imaginärteil bzw. der Phase der Leitfähigkeit bemerkbar. In toten Poren, d.h. in elektrolytgefüllte Poren, die von allen Seiten von einer nichtleitenden Matrix umschlossen sind, beobachten wir eine Polarisation der elektrischen Doppelschicht, die die gleiche Relaxationszeit aufweist wie ein gleichgroßes Mineralkorn. Die Wechselwirkung zwischen benachbarten Körnern führt schon bei großen Abständen (relativ zur Ausdehnung der Doppelschicht) zu einer merklichen Abnahme der Stärke des Polarisationseffekts. Unsere Studien illustrieren damit die Nützlichkeit des verwendeten numerischen Modells und das damit verbundene Potential zur Verbesserung unseres grundlegenden Verständnisses der Polarisationsprozesse auf der Mikroskala.

GE/IP Geoelektrik und Induzierte Polarisation: Oral presentation (by invitation only)
V4-3

Small-Scale ERT in the Field: Benefits and Challenges

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Abstract
Electrical Resistivity Tomography (ERT) is a well-established geophysical method in near-surface investigations, e.g., for delineating soil structure and determining the groundwater table. However, the decreasing resolution with depth in surface ERT surveys hinders, e.g., the detection of thin layers in the subsurface. One way to compensate for the sensitivity reduction with depth is to add borehole electrodes. We developed a small-scale ERT setup for usage in the field, combining surface electrodes with a borehole electrode tool in the middle of the surface array, aiming at the resolution of thin soil layers, which can have an influence on water infiltration.
In the talk, we will present some of the challenges associated with small-scale ERT setups in general and our surface-borehole setup specifically. We conducted a synthetic study to assess the different aspects and deduce the following main recommendations for small-scale ERT. (i) Small-scale ERT requires 3D modelling with accurate representation and placement of the electrodes. For surface ERT, we found that: (ii) Long electrodes (compared to their separation) decrease the model recovery and depth of investigation. For borehole-to-surface (b2s) ERT, the following main points can be stated: (iii) b2s ERT gives a high resolution of a layered subsurface, but the model resistivities are only well recovered in the near electrode regions. (iv) High resistivity contrasts between layers lead to artefacts, which can be suppressed by introducing a separate region surrounding the borehole electrodes.
Finally, when we go to the field with our borehole-surface set-up, we address two questions. How well do we know the positions of our borehole electrodes and what influence does a conductive mud have? We use the latter for electric coupling of the borehole electrodes to the ground. In a second study, we explored possibilities of using the data for optimization on the borehole electrode positions. We developed a correction mechanism for the installation angle of the tool, which works well for a horizontal layering of the subsurface. We demonstrate our findings on synthetic data and apply them to example data from the field, measured over a paleochannel. Finally, we assess the impact of our findings on the inversion results of our field b2s data.

GR/MA

Gravimetrie und Magnetik

GR/MA Gravimetrie und Magnetik: e-Poster

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-01

3D gravity modelling to improve geological model harmonization – Methods and benefits for the Saxony-Anhalt/Brandenburg cross-border region (North German Basin)

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Abstract
3D geological modelling is a common tool for local studies that deal with scientific and economic challenges. For the incorporation of neighbouring small-scale models into country-wide compilations, these often heterogeneous models need to be merged. However, in areas of high complexity and sparse, restricted or ambiguous available information, the independently prepared models mostly do not fit at their common or overlapping boundaries and require an alignment for further investigation. Here, gravity data and modelling hold enormous potential to improve structural interpretations and allows for cross-validation and harmonization of formerly individual geological models.

In the scope of our study, we demonstrate an integrated approach of gravity interpretation and modelling to refine and harmonize two existing geological 3D SKUA-GOCAD models in the south of the North German Basin (Saxony-Anhalt/Brandenburg cross-border region). We combined several gravity surveys to a consistent database and applied wavelength filtering and gravity gradient calculation to gain additional insights into the local fault system. 3D Euler deconvolution was used to assess the source depth of main gravity anomalies. Subsequently, all available a-priori information was integrated in an initial density model. Forward and inverse 3D gravity modelling (software IGMAS+) was used to (i) test different structural scenarios, (ii) obtain new evidence for the geological setting and (iii) harmonize the (SKUA-GOCAD) input models. In a last step, we evaluated the density model's significance and incorporated the adjusted layers into a volumetric, parameterized 3D geological model.

The application of our integrated modelling approach resulted in a harmonized 3D geological model, which is consistent with the observed gravity field. Furthermore, indications for the geological setting are obtained: Gravity gradients allow for precise tracing of faults and provide indications for outlines of basement structures. 3D density modelling reveals the extent and shape of anticlines in the Mesozoic cover and provides insights into the facial composition of the Zechstein formation at the southern edge of the North German Basin. Finally, new evidence about the basement setting in the Mid-German Crystalline Rise is obtained.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-02

Numerical analysis of gravity and magnetic fields prior to structural modelling

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Abstract
The work presented here is part of ongoing studies in the AlpArray initiative and the priority program "MB-4D" regarding the modelling of the lithosphere in the Ligurian Sea (northwestern Mediterranean Sea). It will be based on constraining data from LOBSTER and LISA campaigns of past GEOMAR projects and a study in our research group at CAU Kiel. Our motivation is the combination and interdisciplinary interpretation of independent information from geology, tectonics, geophysics, and petrology.

The existing gravity fields especially the new compilation of the AlpArray Gravity Research Group (AAGRG) is considered as database (high resolution Free Air- and Bouguer anomalies) and the isostatic residual field, besides data of the ICGEM Potsdam (disturbance) and the GOCE gradients (ESA) for gravity and data for the magnetic field anomaly.

The gravity and magnetic fields are analysed using Euler deconvolution with regularization (R. Pašteka, Comenius University Bratislava) and the application of curvature analysis we use both, the fields themselves and their gradients. Besides the calculation of the so-called "3rd deviation" of the gravity potential, we also investigate a possible use of the invariants of the gravity field based on gradient data and compare and correlate the results with structural and tectonic maps in the area of the Ligurian Sea and the adjacent French and Italian mainland. The findings from these comparisons will later be used to initiate the compilation of 3D density and susceptibility models for the studied region.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-03

Zerstörungsfreie Bestimmung der remanenten Magnetisierung von archäologischen Fundstücken

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Abstract
Die Bestimmung der remanenten Magnetisierung von archäologischen Fundstücken kann Hinweise z.B. auf den Zustand eines Gebäudes nach einem Brand geben (d.h. verstürzt oder noch stehend). Eine genaue Messung der remanenten Magnetisierung ist normalerweise im Labor möglich, welche allerdings würfelförmige oder runde Proben voraussetzt. Da archäologische Fundstücke möglichst nicht zerstört werden sollen, stellen wir eine einfache und vor allem zerstörungsfreie Methode zur Messung der remanenten Magnetisierung vor die intakte unregelmäßige Probekörper nutzt. Dazu wird die Probe per Photogrammetrie in ein 3D-Modell mit Voxeln von konstanter Kantenlänge (5 mm und 2.5 mm) überführt. Desweiteren wird eine volumengleiche Kugel als weiteres vereinfachtes Modell angenommen. Das archäologische Fundstück wird in der Mitte einer kardanischen Aufhängung fixiert und in 45° Schritten um zwei senkrecht zueinander stehende Achsen rotiert. Zu jeder der 64 Drehpositionen der Probe wird das Magnetfeld des Fundstücks mit zwei Cäsiummagnetometern an feststehenden Positionen registriert. Die Messwerte setzen sich zusammen aus einem konstanten Anteil, der von der induzierten Magnetisierung herrührt, und aus dem Anteil der remanenten Magnetisierung, deren Richtung sich bei jeder Drehung ändert. Durch die Rotation des Remanenzvektors ändert sich auch die Richtung und Stärke des resultierenden Gesamtmagnetisierungsvektors. Unter der Annahme, dass alle Voxel die gleichen Magnetisierungseigenschaften haben, kann dann durch eine Inversion der Betrag und die Richtung der remanenten Magnetisierung bestimmt werden. Die erhaltenen Werte stimmen sehr gut mit im Labor gemessenen Remanenzvektoren überein: Abweichungen der Magnetisierungsstärke liegen bei 0 – 650 mA/m und Abweichungen der Richtung betragen maximal 22 °. Außerdem zeigte sich, dass (1) das vereinfachte Modell einer volumengleichen Kugel und (2) nur 22 Drehpositionen ausreichend sind um genaue Ergebnisse zu erzielen. Die magnetische Suszeptibilität der Proben muss dabei vorgegeben werden und kann nicht mit invertiert werden, da der durch die induzierte Magnetisierung hervorgerufene konstante Faktor unterhalb der Messgenauigkeit liegt.
Die Vorteile der vorgestellten Methode sind die Nutzung bereits vorhandener Magnetometer (also kostengünstig) sowie der transportable Messaufbau, der auch mit ins Feld genommen werden kann um vor Ort Proben zerstörungsfrei zu untersuchen.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-04

Spectral consistency of the LCS-1 satellite model and the magnetic anomaly map of Australia

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Abstract
We present a novel approach for the combination of aeromagnetic and satellite data applying an equivalent dipole layer and spherical harmonic expansion of the dipoles. The method involves two steps, the inversion of the magnetic parameters of the equivalent dipole layer and conversion of magnetic parameters into spherical harmonic coefficients. Therefore, spherical harmonic analysis can be utilized for regional areas.
We apply our method to three different editions of the Magnetic Anomaly Map of Australia for which different levels of long-wavelength correction were previously applied. The results show that the magnetic compilations levelled to long-haul control lines have a good agreement with LCS-1 satellite model in range of spherical harmonic degree 40-110 (corresponding to wavelengths between 180-500 km), whereas the earlier 3rd edition of the Magnetic Anomaly Map which is not corrected for long-wavelength component has poor control over long-wavelengths in this spectral range. Our analysis suggests that even the carefully processed 5th edition does benefit from the replacement of long-wavelength data with satellite data.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-05

Determining the Sub-Ice Topography of Edgeøya and Barentsøya (Svalbard) using Gravity Data: A feasibility study

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Abstract
Sub-ice topography is of great importance for many glaciology related problems.
The aim is to investigate whether or not airborne gravity data could improve the latest sub-ice topography estimation for the islands Edgeøya and Barentsøya of the Svalbard archipelago.
Therefore, we developed a quick adaptive forward modeling algorithm to simulate airborne gravity measurements. As input a random variation of an existing sub-ice topography dataset is used. The prism based algorithm accelerates the forward modeling by a factor of 100 to 200 compared to a non-adaptive computation.

An inversion based on generalized Tikhonov regularization retrieves the random topography variation by taking the available sub-ice topography model and its errors into account. Recovering the sub-ice topography for a 1.6 km grid is especially efficient for ground clearances of 750 m and 1250 m. A flight line spacing of up to 3km decreases the error between random variation and inverted model by more than 50 % in comparison to the original data. Larger variations are recovered better, but with a limited lateral resolution. Hence, the suggested survey suits better for ice volume estimations, than for detailed morphological studies.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-06

DFG priority programme 1788 „Dynamic Earth“: A joint interpretation of geomagnetic, geodetic and ionosphere/thermosphere data from low-orbit satellite missions

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Abstract
The dynamic changes in the system Earth require a multidisciplinary approach for the analysis and interpretation of potential field parameters like the geomagnetic and gravimetric field. Long-term observations of these potential fields over decades provide results like a detailed description of magnetic anomalies (magnetic north pole, South Atlantic anomaly) as well as of reduction of the icecaps or of rising sea levels due to global warming. Monitoring these data together with other geophysical parameters like electron and neutral density, electric fields, temperature, and pressure in the near-Earth space helps to obtain detailed information about relevant external-driven processes like space weather events, e.g., being responsible for disturbance in radio communication. Low-orbit satellite missions like CHAMP, GRACE(-FO) and GOCE are invaluable tools to complement ground-based observations like magnetic observatories, lidar and ionosondes. A ground-breaking progress in obtaining data with unprecedented accuracy was made with the launch of the ESA multi-satellite mission Swarm in 2013 that provides a continuously simultaneous, 3D observation of all relevant geophysical observables in the upper atmosphere and the near-Earth space. The investigations of these topics initiated concepts for new satellite missions with similar aims, such as Daedalus, a ESA’s candidate for the Earth Explorer 10 competition.

Dynamic Earth consists of 4 focus research topics: geomagnetism, gravity, ionosphere-magnetosphere and thermosphere-ionosphere coupling. Each of these topics provides valuable results that describe different phenomena from the Earth’s core up to the near space environment. Though the scientific highlight of Dynamic Earth is the combined interpretation of the results derived from potential fields components, plasma densities, electric current density, neutral density, and more are done jointly and their analysis. Newly developed methods yield very new insights in the dynamic processes of the system Earth.

This submission will present the SPP’s timeline, strategies and discusses its outcome from highlighted scientific results.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-07

Neues Schwerefeldmodell und daraus abgeleitete Untergrundmodellierung in der Antarktis

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Abstract
Die Antarktis gehört zu den abgelegensten Gebieten der Erde. Darüber hinaus ist die kristalline Kruste nicht nur von großen Sedimentbecken bedeckt, sondern auch unter einem bis zu 4000 m mächtigen Eisschild verborgen. Daher sind boden- bzw. luftgestützte geophysikalische Untersuchungen in dieser Region extrem schwierig. Untersuchungen der Untergrundstruktur und daraus berechnete Modelle der tektonischen Entwicklung sind jedoch von entscheidender Bedeutung u.a. für das Verständnis der globalen Tektonik. Die genaue Subglazialtopographie zusammen mit der Mächtigkeit des Eisschilds bilden die Basis für glaziale Studien und die daraus abgeschätzte Entwicklung des Eisschilds. Eine genaue Kenntnis des Schwerefelds bildet die Grundlage um Subglazialtopographie, Mohotiefen und Dichteanomalien innerhalb der Kruste mittels Inversion zu bestimmen. Mit Hilfe von Satelliten können die langen Wellenlängen des Schwerefelds mit hoher Genauigkeit abgeleitet werden. Um die mittleren und hohen Frequenzen des Spektrums zu erhalten, werden zusätzlich luft- und bodengestützte Messungen benötigt. Diese wurden in den letzten Jahrzehnten in der Antarktis in großer Zahl durchgeführt. Die Daten aus diesen Kampagnen weisen allerdings große Unterschiede aufgrund unterschiedlicher Messgeräte, verschiedener Frequenzbereiche und stark variierender Genauigkeiten der Schweremessungen selbst und der Positionierung auf. Ein erster gegitterter Datensatz terrestrischer Schwereanomalien wurde von Scheinert et al. 2016 veröffentlicht. Im Rahmen des DFG-Projekts AntGrav ist dieser Datensatz nun aktualisiert und bestmöglich in die globale Schwerefeldbestimmung eingebunden. Basierend auf der Remove-Compute-Restore Methode wurden Daten aus rund 40 verschiedenen Kampagnen zunächst in ein einheitliches Bezugssystem gebracht und dann gemeinsam validiert und reduziert. Mittels Kollokation wurde danach eine konsistente Schwerefeldlösung berechnet. Im nächsten Schritt sollen mittels Parker-Oldenburg-Inversion Subglazialtopographie, Mohotiefen und Sedimentmächtigkeiten bestimmt und in ein einheitliches Modell zusammengeführt werden. Der Lösungsraum der Schwerefeldinversion wird dabei mit Ergebnissen aus anderen geophysikalischen Verfahren begrenzt. Dieser Beitrag stellt die einzelnen Schritte der Schwerefeld- und Untergrundmodellierung dar. Außerdem werden Zwischenschritte und das Ergebnis der kombinierten Schwerefeldlösung und erste Ergebnisse der Untergrundmodellierung für die Antarktis vorgestellt.

Inverse and forward gravity modeling for revealing the crustal structure of Volga-Uralian subcraton

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Abstract
A new crustal model of the Volga-Uralian subcraton was built. The compilation of the model was subdivided in two steps: (1) inverse gravity modeling followed by (2) thorough forward gravity modeling.

For inverse gravity modeling GOCE gravity gradients were used. The effect of the Earth sphericity was taken into account by using tesseroids. Density contrasts between crust and mantle were varied laterally according to the tectonic units present in the region. The model is constrained by the available seismic data including receiver function studies, and deep reflection and refraction profiles.

The Moho discontinuity obtained during the gravity inversion was consequently modified, and complemented by the sedimentary cover, upper crust, lower crust, and lithospheric mantle layers in the process of forward gravity modeling. Obtained model showed crustal thickness variation from 34 to more than 55 km in some areas. The thinnest crust with the thickness below 40 km appeared on the Pericaspian basin with the thickest sedimentary column. A relatively thin crust was found along the central Russia rift system, while the thickest crust is located underneath Ural Mountains as well as in the center of the Volga-Uralian subcraton. In both areas the crustal thickness exceeds 50 km. At the same time, the gravity misfit of ca. 95 mGal between the measured Bouguer gravity anomaly and forward calculated gravity field was revealed in the central area of the Volga-Uralian subcraton. This misfit was interpreted and modeled as high-density lower crust which can possibly represent an underplated material.

In the end, the new crustal model of Volga-Uralian subcraton respects the gravity and seismic constraints, and reflects the main geological features of the region. This model will be used for further geothermal analysis of the area.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-09

Modellierung der Dichteverteilung in der unteren Kruste des Semail Ophiolithen

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Abstract
Der Semail Ophiolith im Osten der arabischen Halbinsel ist einer der größten und am besten zugänglichen Ophiolithkomplexe der Welt. Um die Obduktion und die weiteren Prozesse, die bei seiner Entstehung eine Rolle gespielt haben, umfassend verstehen zu können, wird eine genaue Kenntnis seiner Struktur und der darunter liegenden Kruste benötigt.
Während das Material des Ophiolithen selbst, sowie die obere Kruste bereits in mehreren Studien eingehend untersucht wurde, fehlen vor allem in der unteren Kruste Informationen über ihren Aufbau und dort vorherrschende Dichteverteilungen.
Ein vorhandenes 2D Modell der Kruste stützt sich auf Informationen aus 2D Seismik, Bohrlöchern und Reciever Funktionen. Kombiniert mit geologischen Informationen liefert dieses Modell detaillierte Schichtungen und Dichtewerte bis in 15 km Tiefe und ist konsistent zur dort oberflächlich gemessenen Bougueranomalie. Es enthält allerdings nur wenige Informationen zur Geometrie der Unterkruste und der Krusten-Mantel-Grenze, welche nun basierend auf einer neuen seismischen S-Wellen-Tomographie ergänzt werden. Zur Anpassung des modifizierten Modells an die Bougueranomalie, wurde anhand der Geschwindigkeitsverteilung in der seismischen Tomographie die Dichteverteilung der unteren Kruste abgeschätzt, so dass das Modell konsistent zu den vorhandenen Beobachtungswerten ist. Neben diesem 2D Modell bietet das neue 3D-Vs-Modell die Möglichkeit, laterale Variationen in der Bouguerschwere im gesamten Omangebirge genauer zu untersuchen.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-10

A new magnetic anomaly map for Greenland from the combination of aeromagnetic and satellite data

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Abstract
We develop a new magnetic anomaly map for Greenland based on a new compilation of aeromagnetic data in combination with satellite data. Our new compilation is based on the most up to date and exhaustive aeromagnetic survey data from Greenland and a 200 km wide surrounding zone. In total, 51 aeromagnetic surveys were merged in a combined meta database. In areas where both old magnetic datasets that were acquired without GPS positioning and modern aeromagnetic data sets exist, the former were omitted from the compilation. If needed the data sets were reprocessed (tie-line levelling and replacement of applied IGRF with DGRF corrections) to merge them into one database to a uniform model.
For correction of the long-wavelength component of the surveys, we conform the data to a recent satellite model. For this step, we apply an approach that combines an equivalent dipole source layer with a spherical harmonic representation. The spherical harmonics are used to replace the long-wavelength component of the aeromagnetic data with the long wavelengths data from the satellite model. This equivalent dipole layer furthermore allows to reduce the impact of low quality data, data errors and effects associated with varying flight heights.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-11

A forward and inversion python package calculating contrained Moho depth from gravity and effective elastic thickness estimations

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Abstract
Elastic thickness (Te) is a mechanical property of Earth lithosphere and important to understand the lithospheric evolution of an area. The approach is to calculate the flexural response caused by a load on an elastic plate, which has a specific elastic thickness. In its simplest case, the load is caused by topography/bathymetry and sedimentary loads. In addition, crustal density variations can also be considered for load calculation. In a second step, several forward calculated flexural responses are compared to a pre-calculated crustal root from gravity inversion by a rolling window. For each window the RMS error is calculated and the best Te value is selected. The result is a map of best fitting elastic thickness values. These can be interpreted as geological clusters with same rigidity properties. These can be also linked to temperature and age of the lithosphere, because cold and old areas are also rigid areas compared to hot and young lithosphere.The presented software package can be easily used in Python to calculate a gravity inverted Moho depth in a first step and use this as input for the inversion of elastic thickness.
Test calculations are shown globally and compared to existing lithospheric thickness models and regionalization/classifications of the crust.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-12

Kalibrierung eines Inertialen Messsystems für aeromagnetische Anwendungen

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Abstract
Magnetische Kartierung mittels unbemannter Drohne (UAV) findet in den vergangenen Jahren ein immer breiteres Einsatzgebiet. Gerade bei oberflächennahen Messungen, zum Beispiel in der Kampfmitteldetektion, ist die genaue Kenntnis über die Position der Magnetometer für die Auswertung entscheidend. Im Rahmen des EFRE-Projektes „Ultraleichtes Gradiometersystem für geophysikalische Magnetfeldmessungen mit unbemannten kleinen Luftfahrzeugen“ haben wir ein System bestehend aus zwei Inertialen Messsystemen (IMUs: Gyroskop/Beschleunigungssensor) und zwei Fluxgate Magnetometern entwickelt.

Um die Reorientierung der gemessenen Magnetfeldgradienten in das geographische Koordinatensystem mit Hilfe der IMU-Daten mit der nötigen Genauigkeit zu erreichen, müssen zunächst alle Sensorgruppen für sich kalibriert werden. Für jeden Sensor müssen der Skalenfaktor, die Nullpunktsverschiebung und die Fehlwinkel zu den anderen beiden Sensorachsen bestimmt werden. Da der Reorientierungsalgorithmus die Messdaten von den Magnetometern, Kreiseln und Beschleunigungssensoren für die Lageberechnung verwendet, müssen auch die Fehlwinkel zwischen den drei Sensorgruppen bekannt sein.

In einem ersten Schritt wird die Güte der Sensoren mittels einer Allan-Varianz Analyse beurteilt und somit die jeweils besten Sensoren ausgewählt. Im Anschluss wird eine Kalibrierung der Kreisel und der Beschleunigungssensoren durchgeführt. Hier wird ein Verfahren aus der Kalibrierung von dreikomponentigen Magnetometern verwendet, das ohne einen dreiachsigen Präzessionsdrehtisch auskommt.
Weiterhin wird die richtungsabhängige Beschleunigungsabhängigkeit der Kreiseldrift bestimmt, sowie die Fehlwinkel des Kreiselsystems zu den Beschleunigungssensoren und zu den Magnetometern. Die bestimmten Kalibrierparameter werden in den Reorientierungsalgorithmus eingearbeitet.

Durch einen kontrollierten Bewegungsablauf wird die Güte der Ergebnisse anhand der Reproduzierbarkeit der Raumlage überprüft.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-13

A 3D model of the Red Sea using magnetic and gravity data

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Abstract
In this study, we explore the lithosphere structure of the Red Sea using gravity and magnetic data.
We re-processed marine data form past surveys conducted during the 70’s and the 80’s, available at the NGDC database. By correcting the magnetic measurements according to the DGRF (definitive magnetic reference field), leveling and replacing the long wavelengths with satellite data (LCS1 model) we managed to generate a consistent magnetic anomaly map for the entire length of the Red Sea that is composed of 10 different surveys and contain overs 100,000 measuring points. The magnetic anomaly map highlights structural differences between the southern, central and northern parts of the Red Sea.
Using forward gravity approach, constrains from seismic, wells and petrophysical data, and by integrating insights from magnetic analysis, we define the lithospheric model of the Red Sea to address key questions regarding rifting, sea floor spreading and transition processes. For example, the southern parts of the Red Sea are characterized by shallow and wide asthenosphere upwelling, while in the axial trough lithosphere is thin with thicknesses of less than 15 km. The lithosphere thickness increase asymmetrically towards the rift shoulders. In general, the lithosphere is thicker on the eastern sides than on the western sides. In the central parts of the Red Sea, the lithosphere structure is not significantly different from the southern parts, however, asthenosphere upwelling is slightly narrower. In northern parts of the Red Sea asthenosphere upwelling significantly narrows and focused mainly beneath the axial trough and the lithosphere is thicker. This architecture reflects the currently transition from continental rifting (in the north) to oceanic seafloor spreading (in the south) in the Red Sea.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-14

Global oceanic and continental mass change from 18+ years of GRACE/-FO satellite gravimetry --- and its potential joint implementation with multi-sensor seismology in the assessment of recent sea level variations

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Abstract
Thanks to the GRACE satellite mission and its successor GRACE-FO, today we have a monthly resolved observation series of Earth's gravity field and its changes at ~300 km resolution that spans more than 18 combined years into the past. Data gaps and transition periods have been bridged by analysing orbit perturbations of other Earth observing missions.

We can trace back temporal gravity changes to a variety of mass redistributions: both land- and ocean-wide assessments of linear mass trends show - within uncertainty bounds - a closed budget with independently addressed estimates, e.g. from radar altimetry and hybrid-modelling. Global ocean mass gain and its contributing sources, i.e. mass loss from ice sheets, glaciers and landwater, both show an identic linear mass change rate of 2.2 ± 0.2 mm sea level equivalent per year, over 2003-2016 (plus steric expansion). Similar consistency was found for seasonal signals and inter-/multi-annual residuals like ENSO.

Since the standard uncertainty of the budget closure (0.0 ± 0.3 mm/a combined) is minor, we can now attempt to analyse additional components of the Earth system more closely. In order to minimise one of the largest uncertainty factors in these type of assessments further, it must be a joint interdisciplinary effort to develop refined global correction models for Glacial Isostatic Adjustment, i.e. with laterally variable viscosity with the aid of tomography, improved surface-mass-balance, gravimetry, deformation rates from GNSS and more.

The impact of tectonic (mega-)thrust events on estimates of long-term mass change is, as yet, a scarcely regarded effect. Large-scale crustal/lithospheric mass redistributions may erroneously be misinterpreted as water mass change, in particular when neglecting steady interseismic activity. Gravity perturbations from several major events have already been verified and analysed thoroughly with GRACE/GOCE and simple differential 'post−pre' corrections are available. However, those do generally not allow for the more complex interseismic variability and visco-/elastic dynamics, such that their repetitive application would require unrealistic changes of Earth's shape and volume.

We now aim for the employment of geophysical information from moment tensors, GNSS-based inversion, interferometry and more to allow for systematically derived corrections for gravity field solutions and, thus, for revised oceanic and hydrological mass change products.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-15

A Bayesian framework for simultaneous determination of susceptibility and magnetic thickness from magnetic data

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Abstract
The thickness of the magnetized layer in the crust (or lithosphere) holds valuable information about the thermal state and composition of the lithosphere. Commonly, maps of magnetic thickness are estimated by spectral methods that are applied to individual data windows of the measured magnetic field strength. In each window, the measured power spectrum is fit by a theoretical function which depends on the average magnetic thickness in the window and a 'fractal' parameter describing the spatial roughness of the magnetic sources. The limitations of the spectral approach have long been recognized and magnetic thickness inversions are routinely calibrated using heat flow measurements, based on the assumption that magnetic thickness corresponds to Curie depth. However, magnetic spectral thickness determinations remain highly uncertain, underestimate uncertainties, do not properly integrate heat flow measurements into the inversion and fail to address the inherent trade-off between lateral thickness and susceptibility variations.
We present a linearized Bayesian inversion that works in space domain and addresses many issues of previous depth determination approaches. The 'fractal' description used in the spectral approaches translates into a Matérn covariance function in space domain. We use a Matérn covariance function to describe both the spatial behaviour of susceptibility and magnetic thickness. In a first step, the parameters governing the spatial behaviour are estimated from magnetic data and heat flow data using a Bayesian formulation and the Monte-Carlo-Markov-Chain (MCMC) technique. The second step uses the ensemble of parameter solution from MCMC to generate an ensemble of susceptibility and thickness distributions, which are the main output of our approach.
The newly developed framework is applied to synthetic data at satellite height (300 km) covering an area of 6000 x 6000 km. These tests provide insight into the sensitivity of satellite magnetic data to susceptibility and thickness. Furthermore, they highlight that magnetic inversion benefits greatly from a tight integration of heat flow measurements into the inversion process.

GR/MA Gravimetrie und Magnetik: e-Poster
GR/MA-16

Methodische Untersuchungen zur Entwicklung einer hochauflösenden Magnetsensoreinheit für Drohnen

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Abstract
In der vorliegenden Masterarbeit werden methodische Grundlagen zur Entwicklung einer neuen technischen Anwendung in Form eines multisensoriellen Magnet-Arrays für die Detektion kleinskaliger Magnetfeldanomalien, speziell für die Anwendung in der Kampfmittelsuche, mit uniaxialen Fluxgate-Sensoren behandelt. Das Sensor-Array dient der Verifikation eines separaten hochauflösenden Magnetsensors, unter der Voraussetzung, dass eine grobe Erfassung und Lokalisation ferromagnetischer Störobjekte bereits mit dem Array selbst möglich ist. Dafür wurde die Sensorik hinsichtlich ihrer Funktionsweise und ihres Messverhaltens in Bezug auf verschiedenartige externe und sensoreigene Einflussfaktoren und die damit einhergehende Eignung für die vorgesehene Anwendung untersucht. Außerdem wurde ein konzeptioneller Aufbau auf Basis eines gradiometrischen Messansatzes für eine versetzte Sensorkonfiguration entwickelt. Im direkten Vergleich liefert diese Messanordnung nach Rückrechnung des Versatzes ähnlich gute Messergebnisse wie konventionelle Gradiometer. Für die Analyse und Beurteilung realer magnetischer Felddaten wurde zusätzlich eine Simulationssoftware implementiert, welche für ausgewählte Störkörpergeometrien das zu erwartende Anomaliefeld anhand synthetischer Daten berechnet. Somit ließ sich der allgemeine Funktionsnachweis für das Anwendungsprinzip erbringen.

GR/MA Gravimetrie und Magnetik: Oral presentation (by invitation only)

GR/MA Gravimetrie und Magnetik: Oral presentation (by invitation only)
V1-08

Bathymetric models beneath ice shelves based on gravity inversion: merits and room for improvement

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Abstract
Basal melting and iceberg calving currently constitute the main ice mass loss processes for Antarctica's ice shelves. These mass losses are counterbalanced by increased drainage of the terrestrial ice sheets that the ice shelves buttress. If this drainage outpaces snowfall over the ice sheet, the difference contributes to global sea level rise. The rate of basal melting beneath an ice shelf largely depends on its interactions with the ocean. To correctly assess water and heat exchange into the cavities, it is therefore vital to attain consistent bathymetric models beneath the ice shelves.

Unfortunately, these cavities are some of the least explored features in Antarctica due to their inaccessibility. During the recent decade, the implementation of gravity inversion towards modeling bathymetry beneath unexplored ice shelves has grown in popularity. We have used this method to develop bathymetric models in Dronning Maud Land, East Antarctica, including the Ekström, Fimbul and Roi Baudouin ice shelves. Auxiliary geophysical data from seismic, ice thickness radar and magnetic measurements were used to calibrate and verify these models. The models reveal that the seafloor beneath Dronning Maud Land's ice shelves is characteristically crossed by deep glacial troughs running between the landward grounding lines and bathymetric sills close to the present-day continental shelf break. Gateways through these sills arbitrate on whether, and where, warm bottom waters intrude into the cavities and, hence, the occurrence and pattern of basal melting, and the likelihood and extent of reduced ice shelf stability.

Generally, bathymetric models based on inverting gravity data serve as a useful tool to explore ice shelf cavities and provide a significant addition to already-existing depth information. However, first order estimations of water depths originating from gravity inversions are afflicted by unavoidable errors. Among other limitations, they are prone to fail in regions with strong bathymetric gradients. The steeper the slope, the higher the differences between model and reality. Integrating topographic corrections into the bathymetric modeling process can yield improvements in accurately depicting strong bathymetric gradients.

DLO

Geophysik in der Lehre und Öffentlichkeit

DLO Geophysik in der Lehre und Öffentlichkeit: e-Poster

DLO Geophysik in der Lehre und Öffentlichkeit: e-Poster
DLO-1

Research and Educational Mine FLB Reiche Zeche (Freiberg) within the European Underground Laboratories (EUL) network

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Abstract
Within the European Underground Laboratories (EUL) network, Reiche Zeche plays an important role in forming an efficient platform for future, innovative research and business concepts. Each of the collaborating underground laboratories in the (northeastern) European network is unique in its geology and thus provides different challenges and opportunities for geophysical characterization and subsequent usage.
The Reiche Zeche mine is a reputed and unique location for research and education. Since 1919, the former ore mine has been used for educating and training of miners, engineers and mine surveyors by the TU Bergakademie Freiberg. Drifts and tunnels of the mine stretch over several kilometres at depths down to 230 m. Today, the Reiche Zeche mine plays a major role in mining research and related activities including various research institutes and industrial partners. Several underground test facilities and laboratories are in use and important in university education. A variety of local (15 institutes of TU Bergakademie Freiberg) and external partners (30 from 26 countries) are actively shaping research and education in the mine. Real-world applications and cutting-edge technologies are tested in a stimulating environment underground, in order to improve creativity and critical thinking, as well as knowledge and technology transfer. Reiche Zeche is a unique place for geophysical training in specific underground practicals, where students get to know the challenges and specifications of geophysical surveys performed in a mine.
Additional research taking advantage of geophysical methods is also undertaken in the mine and will shortly be shown. Particularly, the Helmholtz Innovation Lab for 3D underground seismic intends to establish 3D underground seismology as a key technology for effectively and safely constructing and using underground structures. The Reiche Zeche mine offers an efficient research and innovation environment including state-of-the-art underground spaces and high-quality support and services which are further strengthened in the EUL network.

GT

Geothermie und Radiometrie

GT Geothermie und Radiometrie: e-Poster

GT Geothermie und Radiometrie: e-Poster
GD-7

Bestimmung geothermischer Reservoireigenschaften im Süddeutschen Molassebecken mittels seismischer Attributanalyse und Inversion

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Abstract
Das Projekt Regine (BMWi: FKZ 0324332B) untersucht den Geothermiestandort Schäftlarnstraße (Sls) in München mittels seismischer Methoden. Ziel ist eine verbesserte und nachhaltige Gewinnung geothermischer Energie. Der Zielhorizont für die hydrothermale Exploration ist der Grundwasserleiter in den Karbonaten des Oberjura. Ein großes Problem stellt dabei die starke Heterogenität der Karbonate dar. Im Vergleich zu Quantität und Qualität der strukturellen Daten des Reservoirs ist die Datenbasis der Reservoireigenschaften wie Porosität und Permeabilität, die das geothermische Potenzial beschreiben, unzureichend. Daher ist es notwendig solche Daten zu generieren, um den Wert der Strukturinformationen zu verbessern. Eine 3D-Seismik kann nicht nur strukturelle Informationen liefern, sondern auch wichtige Eigenschaften wie elastische Parameter und seismische Attribute. Eines der wichtigsten Attribute ist die akustische Impedanz, welche mittels einer seismischen Inversion bestimmt werden kann, und als Grundlage zur Abschätzung eines Porositätsvolumens dient.

Als Datenbasis dienten die in München gemessene GRAME-3D-Seismik, ein strukturgeologisches Modell, und Bohrungs- und Loggingdaten vom Geothermiestandort Sls.

Die Inversionsergebnisse zeigen niedrige Impedanzwerte am Top Reservoir, aber auch im mittleren Teufenbereich. Räumlich gesehen zeigt die Mittelscholle des Münchner Verwurfs auffällig niedrige Werte aber auch der östliche Bereich der Hochscholle und der westliche Bereich der Tiefscholle zeigen niedrige Impedanzen. Basierend auf einer Bohrungskorrelation konnte eine eindeutige Beziehung von akustischer Impedanz zur Porosität ermittelt und ein 3D-Porositätsvolumen bestimmt werden. Im oberen, aber auch im mittleren Reservoirbereich zeigen sich Gebiete mit erhöhter Porosität (>10%), die auf ein erhöhtes geothermisches Potenzial hindeuten.
Für eine bessere Klassifizierung wird auch eine Attributanalyse durchgeführt. Auffällig sind die Mittelscholle und der östliche Teil der Hochscholle, wo sich stark verbrochenes Gestein andeutet. In der westlichen Tiefscholle gibt es hingegen kaum Auffälligkeiten, obwohl auch hier hohe Porositäten zu erwarten sind. Dies deutet an, dass die Anwesenheit von Störungen nicht der einzige Faktor ist, der hohe Porosität im Karbonat begünstigt. Wahrscheinlicher ist eine Kombination mit Verkarstungsprozessen, weshalb auch Bereiche eine erhöhte Porosität zeigen, die keine verstärkte tektonische Deformation aufzuweisen scheinen.

GT Geothermie und Radiometrie: e-Poster
GD-4

Computational Modelling of Coupled Heat Transport between the Heterogeneous Earth and an Overlying Ice Sheet

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Abstract

Due to a complex interplay between the Earth and overlying ice sheets, a large variety of subglacial landforms developed. One example is the in the North German Basin widely spread phenomenon of tunnel valleys. An observed correlation to underlying salt structures is often explained mechanically. We focus on an alternative hypothesis based on thermodynamic processes: As salt better conducts heat than the surrounding rocks, the geothermal heat flux is augmented above salt structures. This leads to melting processes at the interface between the Earth and the ice sheet. The subglacial rivers finally erode the tunnel valleys. To test this hypothesis, we model related hydrothermal processes by means of a finite-difference open-source code (SHEMAT-Suit). The model accounts for heat conduction, groundwater flows, processes in the glaciothermal system such as the motion and spatiotemporal temperature evolution within the ice, and finally the coupling of both at the subglacial interface to account for the feedback mechanisms. Glaciothermal system and coupling processes are incorporated based on an idealized 1D model for the ice cover. We present a scaling analysis to discuss dominant processes. Our results show that a purely conductive subsurface (complete absence of groundwater flow) leads to a very moderate increase of the geothermal heat flux above salt structures. This implies a slight increase of the melting rates, which by itself is not enough to trigger tunnel valley erosion. Additional hydrothermal flows e.g. through fault zones may increase the subglacial melting rates. In this contribution, we will present results from a case study in the Southern North Sea. A 2D seismic section includes two tunnel valleys above salt structures. To model the state prior to erosion and sedimentation during and after the Quaternary glaciations, the Quaternary strata is replaced by strata with the same physical properties and thicknesses than the Paleocene to Miocene strata. Simulation runs with SHEMAT-Suite calculated the subsurface temperature distribution and the geothermal heat flux distribution at the subglacial interface. This allows assessing the subglacial melting rates along with the temperature profile within the ice cover for a number of glaciation scenarios. Current results show that thermodynamic processes reinforce the formation of tunnel valleys together with e.g. mechanical weakening by faulting.

MA

Marine Geophysik

MA Marine Geophysik: e-Poster

MA Marine Geophysik: e-Poster
MA1-01

Imaging the crustal structure of the southern plate boundary of the Niuafo’ou microplate, Lau Basin, southwest Pacific, with reflection and refractions seismic data

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Abstract
At the Australian-Pacific plate boundary, the northern Lau Basin is one of the fastest opening back-arc basins on earth. The current configuration of micro-plates, plate boundaries and motions within the northern Lau Basin is quite well understood, but in the southern part of the Lau Basin questions remain about the crustal structure. Here, the Central Lau Spreading Center (CLSC) and the southern tip of the Fonualei Rift and Spreading Center (FRSC) define the diffuse southern boundary of the Niuafo’ou microplate. It remains unclear where the southern plate boundary is located and what kind of boundary it is.

We present 1) seismic refraction data of a 200-km long, E-W transect acquired in the transition zone from the eastern side of the CLSC to the southern tip of the FRSC and 2) seismic reflection data of four E-W profiles of varying length, acquired in both the southern part of the Niuafo’ou microplate and the transition in between the CLSC and the FRSC. The seismic data acquisition was accompanied by parametric sediment echosounder, gravimetric and magnetic measurements and was complemented by heat flow probes and dredged samples of the seafloor in the vicinity of the profile.

Our travel time tomography reveals a pronounced lateral variation in seismic P-wave velocities from west to east, within the 7-8 km thick back-arc crust. Towards the east, the crust gradually thickens to 13 km of arc crust. The reflection seismic data reveals sediment pockets, varying between 300m to 1000m depth, located on both the thinner back-arc crust and thicker arc crust. In the abyssal regions, faults that cross-cut the basement, but do not reach the surface, are observed on all reflection seismic profiles and are considered inactive today. Towards the west of the profiles, faults reach the surface and are considered active. Rock sampling from this area retrieved predominantly massive aphyric basalts from the back-arc crust in the west. Olivine-rich basalts, andesites, and a broad spectrum of volcaniclastic rocks are the most common rock-type collected from the arc crust in the east.

The lack of a thinner crust near the southern tip of the FRSC, the presence of inactive faults that cross-cut the basement, and the presence of active faults in the CLSC suggest that the southern plate boundary of the Niuafo’ou microplate accommodated extension in a wide-rift tectonic setting in the past. Today, this extension is accommodated in the CLSC in a narrow extensional tectonic setting.

MA Marine Geophysik: e-Poster
MA1-02

Reflection seismic indicators for submarine permafrost and gas hydrate distributions on the Canadian Arctic Beaufort Shelf

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Abstract
Since the last glaciation the Canadian Arctic Beaufort Shelf is subjected to marine transgression. From subaerial mean annual temperatures during terrestrial exposure of ≤ -20°C, thermal conditions changed up to present submarine bottom water temperatures near -1°C. While conditions during the Pliocene favoured extensive formation of permafrost and gas hydrates, present occurrences are exposed to degradation due to the warmer climate. Today, submerged offshore permafrost is still responding to this thermal change. Ongoing degradation creates the potential of methane release of previously trapped biogenic gas within the relic permafrost and from gas hydrate dissociation. The mobilisation of methane and its possible release to the atmosphere plays a significant role in climate change. Yet, both the extent of permafrost and underlying gas hydrates is still poorly known. Here, we present seismic indicators for offshore permafrost and gas hydrates in 2D multichannel reflection seismic data acquired in the Canadian Beaufort Sea. Seismic lines that run from the shallow shelf towards deeper water show layer-crossing reflections that become gradually shallower towards the north-west into deeper water. These reflections show an amplitude-varying characteristic and are phase-reversed. We first use shot gathers from a synthetic model based on the field seismic acquisition characteristics and borehole geophysical data to verify our general ability to detect permafrost- and gas hydrate-related reflections. The synthetic data were processed using the same data processing applied to the field data and reveal clear top and base of permafrost and gas hydrate reflections. With this encouraging result, we can exclude any potentially misleading processing artefacts in the field seismic data. We interpret the amplitude-varying, phase-reversed and layer-crossing reflections seen in the field data as seismic indicators for the base of permafrost and base of gas hydrates. In contrast to the synthetic data, top of permafrost and top of gas hydrates are not clearly identified in the field data. However, additional seismic indicators support the interpretation of the presence of permafrost including attenuation of acoustic penetration and velocity pull-up effects at presumably horizontal strata. Furthermore, strong amplitude variations beneath the current base of gas hydrates and bright spots indicate trapped free gas accumulations from possible previously dissociated gas hydrates.

MA Marine Geophysik: e-Poster
MA1-03

Crustal structure of the Ligurian Basin revealed by seismic travel time tomography

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Abstract
The Ligurian Basin is located north-west of Corsica at the transition from the western Alpine orogen to the Apennine system. The Back-arc basin was generated by the southeast retreat of the Apennines-Calabrian subduction zone. The opening took place from late Oligocene to Miocene. While the extension led to extreme continental thinning little is known about the style of back-arc rifting. Today, seismicity indicates the closure of this back-arc basin. In the basin, earthquake clusters occur in the lower crust and uppermost mantle and are related to re-activated, inverted, normal faults created during rifting.
To shed light on the present day crustal and lithospheric architecture of the Ligurian Basin, active seismic data have been recorded on short period ocean bottom seismometers in the framework of SPP2017 4D-MB, the German component of AlpArray. An amphibious refraction seismic profile was shot across the Ligurian Basin in an E-W direction from the Gulf of Lion to Corsica. The profile comprises 35 OBS and three land stations at Corsica to give a complete image of the continental thinning including the necking zone.
The majority of the refraction seismic data show mantle phases with offsets up to 70 km. The arrivals of seismic phases were picked and used to generate a 2-D P-wave velocity model. The results show a crust-mantle boundary in the central basin at ~12 km depth below sea surface. The P-wave velocities in the crust reach 6.6 km/s at the base. The uppermost mantle shows velocities >7.8 km/s. The crust-mantle boundary becomes shallower from ~18 km to ~12 km depth within 30 km from Corsica towards the basin centre. The velocity model does not reveal an axial valley as expected for oceanic spreading. Further, it is difficult to interpret the seismic data whether the continental lithosphere was thinned until the mantle was exposed to the seafloor. However, an extremely thinned continental crust indicates a long lasting rifting process that possibly did not initiate oceanic spreading before the opening of the Ligurian Basin stopped. The distribution of earthquakes and their fault plane solutions, projected along our seismic velocity model, is in-line with the counter-clockwise opening of the Ligurian Basin.

MA Marine Geophysik: e-Poster
MA1-04

Einsatz von mobiler mariner Geoelektrik zur Kartierung von Pockmark-Clustern in der Eckernförder Bucht

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Abstract
Ein signifikanter Eintrag von gelösten Pflanzennährstoffen in die Küstenumwelt kann eine Eutrophierung auslösen. Um die Auswirkungen der Eutrophierung auf die Umwelt einschätzen zu können, ist es notwendig die räumliche Ausdehnung und die Menge des Grundwasserabflusses in die Küstenregionen zu bestimmen.

Um die hydrologisch relevanten Schichten, die Grundwasserverteilung und Austrittsstellen entlang und vor der Küste möglichst großräumig zu erfassen, nutzen wir den signifikanten Kontrast im elektrischen Widerstand zwischen dem Frischwasser und dem Meereswasser als Indikator für Frischwasseraustritte und wenden die folgende Messstrategie an:

a) Wir führen geoelektrische und seismische Messungen senkrecht und parallel der Küstenlinie an Land und zur See inkl. der Übergangszone durch.

b) Dabei dient die Geoelektrik zur Detektierung von Frischwasser im Sediment sowie in der Wassersäule und die Boomer-Seismik zur Erkundung der Stratigraphie.

c) In-situ Messung des elektrischen Widerstands mittels CTD-Sonden in der Wassersäule und in Bohrlöchern im Sediment dienen mit der Wassertiefe zusammen als Randbedingungen bei der Berechnung von elektrischen Widerstandsmodellen.

In diesem Beitrag werden Messergebnisse im Bereich von Pockmark-Clustern der Eckernförder Bucht vorgestellt, deren Lokation uns durch führere hydroakustische Messungen bekannt waren. Mittels mobiler geoelektrischer Messungen mit einem 200 m langen Geoelektrik-Streamer konnten an der Lokation Mittelgrund bis zu 10-fach höhere elektrische Widerstände im Sediment nachgewiesen werden. Dabei betrug die geoelektrische Eindringtiefe in die Seesedimente ca. 20 m.

MA Marine Geophysik: e-Poster
MA1-05

Drift formation history off MacRobertson Land Shelf, East Antarctica, reveals paleo-distribution of Cape Darnley Bottom Water

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Abstract
Within Meridional Overturning Circulation, formation of Antarctic Bottom Water (AABW) plays an essential role and is widely accepted to be the engine of global Thermohaline Circulation (THC), which is sensitive to climate changes. Studying paleo conditions and changes of AABW distribution during warm and cold periods is fundamental to gain knowledge about its interaction and response to climate changes, which helps to understand recent and future changes of THC due to global warming.

Along MacRobertson Land Shelf area, west of Prydz Bay in East Antarctica, a recent production of dense shelf water has been recognized in the Cape Darnley Polynya and outflow as so-called Cape Darnley Bottom Water (CDBW) along the Wild Canyon. CDBW contributes around 6-13% to the total circumpolar AABW. In order to understand the paleo conditions of AABW, it is necessary to investigate the paleo-evolution of CDBW. To do this, we have studied the formation history of a 200 km long sediment drift (Darnley Drift herein) at the western flank of the Wild Canyon. We utilized more than 13.000 km of multi-channel seismic reflection data and lithological Data of ODP Site 1165.

We characterized Darnley Drift to be a mixed turbiditic-contourite drift formed by an interplay of downslope and along-slope processes. Turbiditic outflow along the later formed Wild Canyon dominated during the Oligocene. An onset of CDBW can be inferred during the early Miocene, forming an asymmetric channel-levee system along the Wild Canyon. After the mid-Miocene Climatic Optimum a major climate change occurred, resulting in a strong intensification of bottom currents and major growth of the drift with simultaneous areas of non-deposition and erosion. This was followed by a sharp reduction of sedimentation rates. Since the late Miocene the growth of Darnley Drift is further dominated by contourite bottom currents.

MA Marine Geophysik: e-Poster
MA1-06

A multimethodical approach to decipher extensional processes in the northern Lau Basin at 16 ºS

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Abstract
The Lau Basin is a young back-arc basin steadily forming at the Indo-Australian-Pacific plate boundary, where the Pacific plate is subducting underneath the Australian plate along the Tonga-Kermadec island arc. As a result of the asymmetric roll back of the Pacific plate, the Lau basin's divergence rates decline southwards hence dictating an asymmetric, V-shaped basin opening. Further, the decentralisation of the extensional motion over 11 distinct spreading centres and zones of active rifting has led to the formation of a composite crust formed of a microplate mosaic. One of these centres of extensional motion, and the subject of this study, are two overlapping spreading centres (OLSC), the southern tip of the eastern axis of the Mangatolu Triple Junction (MTJ-S) and the northern tip of the Fonualei Rift spreading centre (FRSC).
In 2018, the research vessel Sonne (cruise SO267) set out to conduct seismic refraction and wide-angle reflection data along a 185 km long transect crossing the Lau Basin at ~16 °S from the Tonga arc in the east, the overlapping spreading centres, FRSC1 and MTJ-S2, and extending as far as a volcanic ridge in the west. Additionally, 2D MCS reflection seismic data as well as magnetic and gravimetric data were acquired.
The results of our Monte-Carlo P-wave traveltime tomography show a crust that varies between 4.5-6 km in thickness. Underneath the OLSC the upper crust is 2-2.5 km thick and the lower crust 2-2.5 km thick. The velocity gradients of the upper and lower crust differ significantly from tomographic models of magmatically dominated oceanic ridges. Compared to such magmatically dominated ridges, our final P-wave velocity model displays a decreased velocity gradient in the upper crust and an increased velocity gradient in the lower crust more comparable to tectonically dominated rifts with a sparse magmatic budget.
The dominance of crustal stretching in the regional rifting process leads to a tectonical stretching, thus thinning of the crust under the OLSC and therefore increasing the lower crust's velocity gradient. Due to the limited magmatic budget of the area, neither the magnetic anomaly nor the gravity data indicate a magmatically dominated spreading centre. We conclude that extension in the Lau Basin at the OLSC at 16 °S is dominated by extensional processes with little magmatism, which is supported by the distribution of seismic events concentrated at the northern tip of the FRSC.

MA Marine Geophysik: e-Poster
MA1-07

POS538: High-resolution 2D and 3D reflection seismic analysis of tsunamigenic volcanic eruptions in the Southern Aegean Sea (Greece)

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Abstract
Volcanic eruptions and earthquakes in the Christiana-Santorini-Kolumbo rift have repeatedly triggered devastating tsunamis including the 1600 BC Late Bronze Age eruption of Santorini, the 1650 eruption of Kolumbo and the 1956 Amorgos earthquake. The Late Bronze Age eruption tsunami affected large areas of the eastern Mediterranean and contributed to the demise of the Minoan culture on Crete, while the effects of the 1650 Kolumbo and the 1956 Amorgos tsunamis were limited to the islands around the Christiana-Santorini-Kolumbo rift. Although intensively studied in recent decades, the potential tsunami source parameters of these events remain poorly constrained. The THESEUS project aims to parameterize various potential source parameters associated with these tsunami events using marine high-resolution reflection seismics. For this purpose, we conducted high-resolution 2D and 3D reflection seismic surveys as well as ocean-bottom seismometer refraction seismic experiments covering the Christiana-Santorini-Kolumbo rift during expedition POS538 onboard RV Poseidon in October 2019. Here, we present the first results of the ongoing analysis of our P-Cable 3D seismic dataset, which covers most of the Kolumbo volcanic edifice and a prominent fault zone to the north. In addition, we present 2D seismic profiles covering the Santorini Caldera and pyroclastic flow deposits associated with the Late Bronze Age eruption.

MA Marine Geophysik: e-Poster
MA1-08

Glacial dynamics of the Laurentide Ice Sheet and Quaternary geological evolution of the Labrador Shelf, Canada: Analysis of high-resolution reflection seismic and sub-bottom profiler data

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Abstract
Oceanographic dynamics at the northeastern and eastern side of Canada play an important role in climate variations in the Northern Hemisphere. Palaeoceanographic evidence has shown that freshwater pulses from the Laurentide Ice Sheet (LIS) released through the Labrador fjord-trough systems into the North Atlantic, modified the Atlantic meridional overturning circulation (AMOC), unleashing climate instability during the Last Glacial period and the early Holocene. The LIS extended during the Wisconsian glaciation not only along the present Labrador Peninsula but also even further off the coast at the Labrador Shelf. Therefore, it is believed that the shelf could store key information to decipher the climatic, oceanographic and geological processes that occurred during the last thousands of years. However, large areas of the shelf are not explored in detail and evidence from glacial features is largely lacking. In this study the main targets are the trough systems of the Labrador Shelf. Parasound and high-resolution 2D seismic reflection data, acquired during expeditions MSM45 and MSM85, are used to reconstruct the Quaternary geological evolution on the Labrador Shelf and to identify structures potentially formed during the last glaciation. In order to achieve this reconstruction, surface and sub-surface observations were analyzed to establish a seismic stratigraphic framework for the Quaternary deposits and delimit the most prominent features. First observations show a clear unconformity between Cartwright Saddle and Okak Bank, which separates pre-Quaternary from Quaternary units. Additionally, erosive surfaces and channels have been recognized as well as potential glacial deposits covered by well-stratified sediments, evidencing the geological transition from glacial times to a marine influence system. The data analysis provides new important constrains for the reconstruction of the LIS evolution at the Labrador shelf.

MA Marine Geophysik: e-Poster
MA1-09

Seismogenic up-dip limit of the 2014 Mw 8.1 Iquique earthquake links subduction erosion and upper plate deformation

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Abstract
The 2014 Mw 8.1 Iquique earthquake ruptured the boundary between the subducting Nazca Plate and the overriding South American Plate in the North Chilean subduction zone. The broken segment of the South American subduction zone had likely accumulated elastic strain since an M~9 earthquake in 1877 and what therefore considered a mature seismic gap. The moderate magnitude of the 2014 earthquake and its compact rupture area, which only broke the central part of the seismic gap, did not result in a significant tsunami in the Pacific Ocean. To investigate the seismo-tectonic segmentation of the North Chilean subduction zone in the region of the 2014 Iquique earthquake at the shallow seismic/aseismic transition, we combine two years of local aftershock seismicity observations from ocean bottom seismometers and long-offset seismic reflection data from the rupture area. Our study links short term deformation associated with a single seismic cycle to the permanent deformation history of an erosive convergent margin over millions of years. A high density of aftershocks following the 2014 Iquique earthquake occurred in the up-dip region of the coseismic rupture, where they form a trench parallel band. The events spread from the subducting oceanic plate across the plate boundary and into the overriding continental crust. The band of aftershock seismicity separates a pervasively fractured and likely fluid-filled marine forearc farther seaward from a less deformed section of the forearc farther landward. At the transition, active subduction erosion during the postseismic and possibly coseismic phases of the 2014 Iquique earthquake leads to basal abrasion of the upper plate and associated extensional faulting of the overlying marine forearc. Landward migration of the seismogenic up-dip limit, possibly at similar rates compared to the trench and the volcanic arc, leaves behind a heavily fractured and fluid-filled outermost forearc. This most seaward part of the subduction zone might be too weak to store sufficient elastic strain to nucleate a large megathrust earthquake.

MA Marine Geophysik: e-Poster
MA1-10

New acoustic and gravity core data suggesting multiple failures in the headwall area of Sahara Slide Complex off northwestern African continental margin

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Abstract
Submarine mega-slides with an involved material of several hundreds of km^3 occur at continental margins and on the flanks of volcanic islands. They pose a major threat due to their potential to destroy offshore infrastructure (e.g. submarine power and communication cable) and to trigger devastating tsunamis. The Sahara Slide Complex is such a mega-slide off the northwestern African continental margin, which affected an area of about 48,000 km^2. Previous studies focused on its distal depositional zone and the upper headwall area. Reconstruction of sequence events were impossible due to less knownledge of the headwall region. New hydroacoustic and gravity core data covering the new part of headwall region were collected during cruises MSM82/2 and MSM87. The data reveal a heterogeneous headwall area including three major scarps (the upper, lower and south scarp), slide blocks, flow streams, longitudinal ridges and depressions. Three dominant acoustic facies were differentiated by sedimentological settings: background hemipelagic sediments (F1); thin (<30 m) slide deposits covering undisturbed sediments (F2); stack slide deposits without clear strata below (F3). The large distance (~55 km) between the upper and lower headwall, no apparent inner scarps between these two scarps and vertically stacked separated slide deposits beneath the lower headwall area suggest that the failures of lower and upper headwall were independent events. Multiple glide planes which are close to each other in upper and south headwall area indicate retrogressive failures for these individual headwalls while such indications are absent for the lower scar, which we interpret to be formed by a single large failure. Observed bedding-parallel glide planes and highly compressible organic deposits suggest weak layers as the potential preconditioning factor for the Sahara Slide Complex. Based on age dating and acoustic data, we propose a multi-phase slope failure forming the present headwall area of Sahara Slide Complex: the failure of the lower headwall occurred at around 60 ka, followed by the failure from the northeastern part of the upper headwall area at about 15 ka. Then the main slide event of the upper headwall area occurred at around 6 ka, with younger subsequent failures as young as 2 ka. The ages of the failures of the southern headwall are difficult to date but most likely occurred between 6-2 ka. This scenario suggests a long-lasting history of slope failures in this area.

MA Marine Geophysik: e-Poster
MA2-11

Investigation of the development of Lake Manicouagan (Canada) using high-resolution reflection seismic data

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Abstract
The eastern Canadian provinces Québec, Newfoundland and Labrador are key areas of Cenozoic to present climate change. During glaciations, vast areas of Northern North America were covered by thick ice sheets such as the Laurentide Ice Sheet (LIS). Lakes, fjords and inlets on the Canadian shield have long been considered as having been completely excavated by glaciers during the last glaciation (Wisconsin glaciation). Hence, they comprise deposits of glacial and post-glacial age, but not from ages before the last glaciation. Recent studies, however, show that deep lakes exist, which have been subglacial water bodies during glaciated periods and hold sedimentary deposits of pre-Wisconsin age. Lake Manicouagan is an old meteorite impact crater, located in the province of Québec, 220 km north of the Saint Lawrence River. In 2016 we carried out an expedition to Lake Manicouagan to image the basement morphology and sedimentary infill with a high-resolution reflection seismic system. The dataset reveals an incised valley, which is narrow in the lower part and wider in the upper part. The data support the theory that the lower part of the valley is the relict of a pre-Wisconsin, fluvial system and was not, or only partly, eroded by the LIS during the Quaternary glaciations. The upper part of the valley was possibly modified by Quaternary glaciers leading to a wider cross section and a decrease in sinuosity. Seismic data show that the valley is filled with sedimentary sequences of more than 250 m in thickness. This suggests that the sedimentary infill of the lake provides records of pre-Wisconsinan age due to its thickness. Hence, Lake Manicouagan holds a unique archive to study paleoclimate history and the evolution of the LIS from an area that was directly affected and generally overprinted by the ice shield.

MA Marine Geophysik: e-Poster
MA2-12

CAYMAN: Characterizing the crust using 2D & 3D seismic tomographic methods.

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Abstract
About 25% of the Earth's mid-ocean ridges spread at ultraslow rates of less than 20 mm/yr. However, most of these ultraslow spreading ridges are located in geographically remote areas, which hamper investigation. Consequently, how the crust forms and ages at such spreading centres, which traditional models predict to be magma-starved and cold, remains poorly understood. One of the most accessible ultra-slow spreading centres is the Mid Cayman Spreading Centre (MCSC), in the Caribbean Sea, with spreading rates of ~15-17 mm/yr.
CAYSEIS project was proposed to survey the Cayman Trough area in order to obtain new data that constraints the nature of the crust, tectonic structures, lithologies outcropping and hydrothermal processes taking place in this area. Understanding the sub-seabed geophysical structure of the MCSC is key to understanding not only the lithologies and structures exposed at the seabed, but more fundamentally, how they are related at depth and what role hydrothermal fluid flow plays in the geodynamics of ultraslow spreading. CAYSEIS was a joint and multidisciplinary programme of German, British and US American top tier scientists designed for the obtaining of a new high-quality dataset, including 3D Wide-Angle Seismic (WAS), magnetic, gravimetric and seismological data.
During the CAYMAN project, we took leverage of the CAYSEIS dataset to invert a 3D tomographic model of the Cayman Trough lithosphere using the Tomo3D code (Meléndez et al., 2015; 2019). This is one of the first times that the Tomo3D code is used for 3D inversion of real datasets. Thus, we are checking our results comparing them with tomographic inversions of 2D lines and testing the different parameters to obtain the more accurate and higher resolution model as possible. The results of this experiment will show not only the lithospheric structure along and across the MSCS, including the exhumed Ocean Core Complexes in the surrounding areas, but the 3D lithospheric configuration of the region which is important to understand the crustal formation processes and the evolution of ultra-slow spreading settings.

MA Marine Geophysik: e-Poster
MA2-13

Self potential signatures of deep sea sulfide deposits at the central and SE Indian Ridge

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Abstract
Measurements of the electric self potential have demonstrated their use to image seafloor massive sulfide targets which have formed at deep sea hydrothermal systems. The underlying model of the self potential effect is Sato and Mooney's (1960) geo-battery model where a conductive body (i.e. sulfide-enriched deposit) connects two different electrochemical environments causing a gradient in the redox potential. Among other electric and electromagnetic methods, BGR has developed different instrumental setups for self potential measurements which we apply for the exploration of sulfide deposits in the German license areas along the central and south eastern Indian Ridge.
A vertical electric dipole-dipole system (2 and 5 m offsets) hanging below a deep-towed multibeam sled (HOMESIDE) provides a fast and easy method to qualitatively image anomalies likely caused by hydrothermal fluid flow in conjunction with possible sulfide targets, and has been successfully used to guide subsequent video and sampling dives. A three-component electric field recorder installed on the GOLDEN EYE deep-sea electromagnetic platform measures the complete electric field vector. Oriented three-component measurements describe the full electric field vector and support 3D interpretation of conductive structures, i.e. potential ore deposits, in the sub-seafloor. We will present electric field data collected over an area with both active and inactive hydrothermal systems, and discuss interpretation and future survey strategies.

MA Marine Geophysik: e-Poster
MA2-14

Seismic reflection character of the plate interface in the rupture zone of the 2014 Iquique earthquake sequence

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Abstract
On 1 April 2014, the Mw 8.1 Iquique earthquake broke the plate-boundary along the North Chilean margin in the region between 19.5°S and 21°S. During this event, seismic rupture concentrated under the marine forearc with an updip limit at a plate-boundary depth of 17 km under the middle continental slope. In late 2016, wide-aperture seismic reflection and refraction data were acquired aboard the R/V *Marcus G. Langseth* offshore Northern Chile as part of the “Pisagua/Iquique Crustal Tomography to Understand the Region of the Earthquake Source” (PICTURES) project. Utilizing multiple suppression techniques and ray-based tomographic inversion, we have achieved enhanced pre-stack depth migrated images to a depth of 40 km.

Seismic lines MC23 and MC25, located in the southern part of the 2014 rupture area, display a pronounced plate boundary reflection that can be tracked to a depth of ~16 km. In contrast, on line MC04, located north of the 2014 rupture area, a plate boundary reflection is clearly visible to ~40 km depth. We consider that changes in fluid pressure cause the observed spatial variations in the downdip extent of the reflective plate boundary and thus may exert an influence on seismic rupture. However, the processes that control the spatial variations in fluid pressure over short distances remain enigmatic. Temperature controlled dehydration processes within the shallow subduction zone are expected to change only gradually along the margin and may therefore not explain short wavelength changes in the downdip extent of high reflectivity between line MC04 in the north and the other lines farther south. We notice, however, that the vertical displacement induced by bending related normal faults in the oceanic plate is significantly smaller along line MC04 compared to lines MC23 and MC25. This may lead to a delayed vertical flow of pore-fluids from the oceanic basement towards the plate boundary along line MC04. In contrast to lines MC23 and MC25, where fluids are expelled from the oceanic basement at relatively shallow depth along the plate boundary (i.e. under the outermost wedge), they are subducted to greater depths at the location of line MC04.

MA Marine Geophysik: e-Poster
MA2-15

Comparison of Earth models of the Namibian continental margin derived from Joint MT and Gravity Inversions

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Abstract
Combined analysis of multiple geophysical methods is a key practice to reduce model uncertainties and improve geological interpretations. Various approaches to combine several data sets or physical models in joint inversion have different advantages and challenges. We present a comparison of two ways to integrate marine magnetotelluric (MT) with gravity data along the Namibian passive continental margin and also compare them to a single-method MT inversion. This study area offers an excellent setting, because multiple tectonic processes (e.g. rifting, magmatism, post-breakup sedimentation) lead to various lithological units with distinct physical properties (e.g. continental-, transitional-, and oceanic crust, fault systems or sedimentary depocenters). The two joint inversions are a cross-gradient coupled 3D inversion of marine magnetotelluric data with a fixed structural density model based on gravity modeling, and a joint inversion of the same MT data with satellite gravity data. Structural coupling with the blocky density model enforces harsh resistivity changes in an otherwise smooth model and helps reducing excessively smeared inversion artifacts. Although the edge-like features complicate direct model interpretation, they indicate alternative ways to fit the MT data, while simultaneously matching seismic observations integrated in the density cross-model. For the second approach, the large solution space of the satellite gravity data inversion limits the improvements through joint inversion compared to a single method MT inversion. The resulting joint inversion resistivity model differs only marginally from the single-method resistivity model, while the joint density model inherits some of the rather questionable resistivity model features. Our study demonstrates how joint inversion of multiple data aids model interpretation. The resulting resistivity models provide equally well-fitting alternatives to single-method evaluation, and additionally fit other geophysical method’s observations (i.e. gravity and seismic methods). The direct comparison of the impact of constraining MT inversion with either a fixed structural model or a coupled data inversion highlights how well the MT solution space may be confined. In our study, the fixed structural model constraint outperforms the joint MT-gravity data analysis.

MA Marine Geophysik: e-Poster
MA2-16

Compressional and shear wave velocity structure of shallow sediments in the north-western Black Sea revealed by OBS data

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Abstract
The Danube deep-sea fan complex in the north-western Black Sea, with its ancient channel-levee systems, hosts multiple bottom-simulating reflections (BSRs) that have been observed in high-resolution reflection seismic data. The multiple BSRs indicate the presence of gas hydrates and free gas. To image the distribution of free gas and gas hydrates on the western flank of the S2 canyon, simultaneously, ocean bottom seismometer (OBS) data and 2-D high-resolution multichannel reflection seismic (HRMRS) data were acquired during the R/V Maria S. Merian (MSM-34) expedition. Along two parallel HRMRS-OBS profiles we recorded the wave field for a wide range of incidence angles. The velocity-structure models for both, P- and S-wave traveltimes, cover a depth down to 1.2 km, providing seismic velocity information below the BSR. For identification of the P-wave phases from OBS to OBS, we aligned the OBS data at zero offset to the 2-D HRMS data at each OBS location. The P-wave velocities show a gradual increase with depth from 1510 m/s directly beneath the seafloor up to 1900 m/s at 1.2 km depth. As the S-waves travel at slower speed than P-waves, S-waves reflection could be traced only in a small source-receiver offset with a maximum of ~0.9 km. We assume the reflection horizon to be the point of P-to-S conversion. Seismic S-wave velocities increase from 140 m/s beneath the seafloor up to 860 m/s at 1.2 km depth. These observations allow the determination of the P-to-S-ratio that decreases from 10.6 beneath the seafloor down to 2.2 at 1.2 km depth. The seismic velocities and P-to-S-ratio exclude the presence of gas hydrates above the BSR, but endorse the accumulation of a low concentration of free gas below. The distribution of the gas is predominately controlled by lithology.

MA Marine Geophysik: e-Poster
MA2-17

Architecture of the Monte Amarelo flank collapse deposits offshore Fogo, Cape Verdes

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Abstract
The ongoing, geologically fast build-up of a volcanic island can lead to an unstable edifice that might be prone to collapse. Evidence for major flank-collapse events are found on and offshore a wide range of volcanic islands, suggesting this phenomena to be a common process. These can generate large tsunamis with potentially disastrous consequences. Fogo Island is situated in the southeastern part of the Cape Verdean Archipelago, about 700 km west of Dakar, NW Africa. During the Monte Amarelo event, 73,000 years ago, its eastern flank collapsed into the ocean, triggering a mega-tsunami with run-up heights of up to 270m as evidenced by dated tsunami deposits found on the neighboring island of Santiago, located 60 km east of Fogo. Whether the collapse occurred in a single event or in multiple phases has been debated. Furthermore previous volume estimation of the collapse has been difficult, as the base of the deposit offshore has not been imaged before. Such information, however, is essential for understanding the hazards (including tsunami potential) linked to such an event. During the research cruise M155 in June 2019, a set of high-resolution multichannel (MCS) seismic reflection data along with hydroacoustic data was gathered. It was thus possible to image, for the first time, a prominent seismic reflection that is interpreted as the base of the Monte Amarelo flank collapse deposit. The new information allowed the volume of failed and remobilized material to be reassessed, resulting in a value (1371±50 km3) that greatly exceeds previously estimated volumes. In addition, an internal prominent and continuous reflection was identified, interpreted to separate two chaotic deposits related to the Monte Amarelo collapse, highlighting its multi-phase nature. These observations are critical to better assess the hazards associated with volcanic flank collapses, especially when even single phases of a multi-stage event are large enough to potentially cause a mega-tsunami.

MA Marine Geophysik: e-Poster
MA2-18

Using machine learning workflows to identify seafloor massive sulfides based on disparate geophysical data

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Abstract
Many current research questions in Earth Sciences are related to understanding the complex geological processes that dictate the location of resource formation. Multivariate and multi-disciplinary measurements across disparate spatial scales are common and generate databases that cross traditional geoscientific domains such as geophysics, geochemistry and geology. To cope with this mass of information, integrative data assessment approaches are essential for optimal information extraction from the available data, enabling more accurate prognoses of where to find previously undiscovered natural resources. This is especially true in the deep ocean, where data collection is inherently more difficult than on land. Here, we present an example from predicting the spatial distribution of seafloor massive sulfides (SMS) at the Trans-Atlantic Geotraverse (TAG) hydrothermal field using various sources of marine geophysical data, including high-resolution bathymetry and magnetics collected with an autonomous underwater vehicle (AUV), as well as conductivity data derived from Controlled-Source Electromagnetic (CSEM) measurements. Electrical conductivities are considered a direct SMS indicator as these exhibit a substantial conductivity variation to the surrounding host rock. Due to the size of the survey area, a spatial sampling of conductivity on a dense grid is not economical and would require many years of data acquisition. As a result, robust extrapolation of sparsely sampled conductivity data onto a regional scale seems efficient for predicting additional occurrences of SMS by integrating the acquired marine geophysical data into a Data Science framework. We show that this framework may improve current SMS predictions through associated prediction uncertainty, thereby detecting observational gaps and informing further sparse sampling of ground-truthing data (e.g. sampling or visual observations).

MA Marine Geophysik: e-Poster
MA2-19

Joint integration of velocity and resistivity to improve gas hydrate estimates - A case study from SO227/266

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Abstract
Gas hydrate dynamics may impact the global carbon cycle and global warming. They may be used as a possible future energy source, but their dynamics may also influence slope stability. Therefore, their occurrence, formation, dissociation, and mobilization are of high interest. The quantification of gas hydrates in continental margins, either by drilling or geophysical methods, is the bases to understanding gas hydrate dynamics. To provide estimates of the gas hydrate saturation the common methodology reaches from the simple detection of gas hydrates by seismic imaging to more sophisticated approaches using the combination of geological, geochemical and geophysical methods. While most geophysical experiments use empirical relationships like Archie's Law to derive saturations from remotely sensed data, a coupling of rock physics and geophysics by effective medium modeling offers new perspectives to directly invert for porosity, gas and gas hydrate saturations. We apply a joint elastic and electric approach by using a self-consistent approximation/differential effective medium model (SCA-DEM) on data from downhole P-wave velocity and induction sensors, recorded in a sedimentary setting at Formosa Ridge south-west off Taiwan. In a first step, we construct a background model and derive porosity distributions from the data. Subsequently, we invert the complete borehole dataset for gas and gas hydrate saturations. A sensitivity analysis shows how the joint elastic and electric approach is able to distinguish between gas and gas hydrate saturations and thereby overcomes the widely observed disagreement in saturation levels between seismic and electromagnetic methods. This approach lays the foundation to directly derive saturation levels from an existing joint geophysical electromagnetic and seismic dataset at Formosa Ridge.

MA Marine Geophysik: e-Poster
MA2-20

Characterization of the seismic velocities in a gas chimney blow the actively seeping Lunde pockmark, Vestnesa Ridge, Svalbard Margin: Preliminary results

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Abstract
Hydrocarbon gases are actively seeping from pockmarks in the eastern part of the Vestnesa Ridge, western-Svalbard Margin. One of these is Lunde pockmark which is characterized by a seismic chimney below. Such seismic anomalies are widely believed to represent fluid migration pathways. However, their detailed structure and the physical properties of such structures is poorly understood and might be highly variable. Tomographic seismic velocity analysis can resolve the inner structure of the chimney beneath the Lunde pockmark. The aim is to understand the distribution of gas hydrate, free gas and carbonates within the gas chimney. Here, we present first results of our detailed 3D seismic travel time tomography using newly acquired high-resolution ocean bottom seismometer data guided by high-resolution 3D multi-channel seismic data. These models were generated with the Jive3D software. Our initial results show the variability of the seismic velocity structure beneath the Lunde pockmark. Our analysis, combined with earlier datasets and results shows that fluid pathways through the gas hydrate stability zone are anything but simple and highlights the importance of understanding the evolution of methane seepage pathways through time.

MA Marine Geophysik: e-Poster
MA2-21

Seismic study of glacial sediments of the Chukchi Shelf, Arctic Ocean

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Abstract
Ongoing research aims to constrain the extent of grounded ice shelves around the Arctic Ocean during the last glacial periods. Here, the Chukchi region is of special interest because of its broad, shallow shelf. It is under debate if any ice sheets existed on the Chukchi Shelf, as well as their possible sources and areal extent.
Bathymetric and sub bottom profiler studies of the last two decades recorded on the Chukchi Sea margins and the Arlis Plateau image complex patterns of glaciogenic erosion of the shallow sediments like Mega Scale Glacial Lineations (MSGL) at present-day water depths of more than 350 m. The different directions of those MSGL indicate the presence of several ice shelves and streams and point to an East Siberian Ice Sheet of unknown size. On the Chukchi Shelf, no evidences for the existence of a large ice shelf for water depths shallower than 350 m have been described yet.
We re-processed 2D multi-channel seismic data acquired in 2011 from R/V Marcus G. Langseth to investigate glaciogenic features on the shallow shelf. Our presented data will reveal, along with sediment echosounder and bathymetric data, new insights into the glacial history of the outer Chukchi Shelf and Borderland. The first up to 300 ms TWT of the seismic data indicate eroded strata and reworked sediments separated from preglacial material by a high amplitude glacial base reflection. These layers are characterized by different seismic reflection characteristics indicating different erosion and deposition environments. Furthermore, the glacial-base reflection underlies a grounding zone wedge and recessional moraines within a bathymetric trough in modern water depths between 400 m and 600 m, indicating a stepwise glacial retreat towards the Chukchi Shelf. Moreover, one grounding zone wedge with a dimension of 48 km x 75 km as a product of several advance and retreat cycles built up on the Chukchi Rise. Our data indicate multiple glacial periods of this region as well as they document the presence of an ice shelf close to the present-day shelf edge during the Last Glacial Maximum, but provide no evidence that it extended onto the subaerial Chukchi Shelf.

MA Marine Geophysik: e-Poster
MA2-22

Mass wasting at the Siberian End of Lomonosov Ridge, Arctic Ocean

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Abstract
The Lomonosov Ridge is an 1800 km long continental sliver in the center of the Arctic Ocean. Beside its tectonic relevance it hosts glaciogenic features caused either by deep reaching icebergs or grounded ice shelves as well as indications for mass wasting events. Swath bathymetry data acquired in 2014 provide an almost complete image of these shallow disturbances from almost 84˚ N to the foot of the Laptev Margin. Twelve arcuate shaped transverse escarpments are present on both sides of the crest at the Siberian termination of Lomonosov Ridge between 81˚ - 84˚ N and 140˚ - 146˚E. Eight of them are 2.1 - 10.2 km wide, 1.7 – 8.2 km long, 125 - 851 m deep, with height of headwall between 58 - 207 m and 0.09 - 7.58 km^3 volume of moved sediments. Due to the absence of scientific drill holes, only a tentative seismic stratigraphy has been used for a rough age estimate. The mass wasting events likely happened in a wide time corridor between mid Pliocene and mid Miocene. We will introduce the different geometries and statistics of these mass wasting features.

MA Marine Geophysik: e-Poster
MA2-23

Lomonosov Ridge: seismic images of its two margins and conclusions on Arctic Paleoceanography

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Abstract
The Lomonosov Ridge (LR) presents a major morphologic feature in the Arctic Ocean. Its tectonic evolution controls ocean circulation, sedimentation environment, glacial processes and ecosystem through time. We present findings of regional seismic transects across the southeastern LR and into the adjacent Amundsen and Makarov Basins. The data image thick sedimentary sequences that provide constraints on Paleoceanography.
In the early Cenozoic the LR still was above or close to sea level and experienced erosion of its Mesozoic core strata. Its crest, faulted flanks and the initial Amundsen Basin were covered with syn-rift sediments of Paleocene to early Eocene age likely eroded off the Barents-Kara and Laptev Sea shelves. The connection to North Atlantic waters via the Fram Strait was not yet established, and anoxic conditions prevailed in the young, still isolated Eurasian Basin. Also, the LR was above or close to sea level and posed an obstacle for water exchange between the Eurasian and Amerasian basins.
The time between early Eocene and late Oligocene, as indicated by a regional and prominent high-amplitude-reflector sequence (HARS) was an era of widespread changes in depositional conditions, likely controlled by the ongoing subsidence of the LR and gradual opening of the Fram Strait. Episodic incursions of water masses from the North Atlantic and erosion of the ridge's crest probably were the consequences, and led to the deposition of sediments of strongly different lithology.
The seismic units above the HARS show reflection characteristics and thicknesses similar all over the southeastern Arctic Ocean indicating that basin-wide pelagic sedimentation prevailed at least since late Oligocene. Drift bodies, sediment waves, and erosional structures indicate the onset of a modern ocean circulation system and paleo-bottom current activity in the early Miocene in the Arctic Ocean. At that time, the LR no longer posed an obstacle between the Amerasia and Eurasia Basins. Finally, a drape of high-amplitude reflectors is associated with the onset of glacio-marine deposition since the Pliocene.

MA Marine Geophysik: e-Poster
MA2-24

The erosive power of the Malvinas current: Influence of bottom currents on morpho-sedimentary features along the northern Argentine Margin (SW Atlantic Ocean)

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Abstract
Sediment deposits formed mainly under the influence of bottom currents (contourites) are widely used as high-resolution archives for reconstructing past ocean conditions. However, the driving processes of Contourite Depositional Systems (CDS) are not entirely understood. The aim of this study is to establish a clearer link between contourite features and the oceanographic processes that form them. During RV SONNE cruise SO260 (January-February 2018), a large CDS together with the current dynamics along the continental margin off northern Argentina were analysed. This study combines multibeam bathymetry, seismo-acoustic data, sediment cores, Acoustic Doppler Current Profiler (ADCP) data and numerical modelling of ocean currents.
Several sedimentary features have been interpreted together with the ocean currents. These features include large contourite terraces (La Plata Terrace, Ewing Terrace) and an abraded surface connecting the terraces, as well as smaller erosional and depositional features like moats, erosion surfaces on the terrace, sediment waves and contourite drifts. Measured and modelled near-bottom currents are strong (up to 63 cm/s at 150 - 350 m above the seafloor) where abraded surfaces and moats are present, and weak (below 30 cm/s) on the La Plata Terrace and the Ewing Terrace. Generally, the bottom currents follow the upper and middle slope morphology. Decreasing velocity of water masses flowing northward leads to less erosion and finer sediment deposits. ADCP data and the hydrodynamic model show the formation of eddies near the seafloor which probably lead to the small erosion surfaces on the Ewing Terrace, even though it is mainly a depositional environment. Furthermore, modelled data show that a subsurface branch of the Malvinas Current continues flowing northwards beyond the confluence (~36°S). Overall, this study contributes to a better understanding of the formation of CDS and can help future reconstructions of past ocean conditions based on sedimentary structures.

MA Marine Geophysik: e-Poster
MA2-25

Joint inversion of marine LOTEM and DED data from the Bat Yam coastal aquifer, offshore Israel

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Abstract
Groundwater aquifers are important for the freshwater supply all over the world, especially in dry regions. It occurs that the water bearing rock matrix extends offshore below the sea floor, and as a consequence fresh water is embedded within good conducting seawater-saturated sediments. Whether an aquifer is open to seawater intrusion or closed, depends on the local hydrogeological setting. Prior studies showed that for high demand on fresh water and high exploitation rates, it is necessary to understand the interaction between sea and fresh water to prevent deterioration of the aquifer. Several geophysical surveys have been carried out in the past to investigate a coastal aquifer in the Palmahim region of Israel, which serves as one of the main reservoirs of the national water supply system. Time domain marine LOTEM and DED data have thereby been recorded on similar profiles. Both results show a resistor at an assumed aquifer depth of roughly 100 m with a comparable offshore extension of 3.5 km from the coastline. However, until now the LOTEM and DED data have only been interpreted separately using 1D inversion and extensive 2D forward modeling. This study presents the first joint 1D and 2D inverse modeling studies of marine LOTEM and DED techniques using synthetic and field data. The synthetic results indicate large benefits of using a joint inversion of both applied survey techniques. However, a joint inversion of the field data is still in progress. Yet, a 2D inversion of the DED data is promising and indicates a brackish transition zone at the expected lateral aquifer boundary. This finding seems consistent with prior studies and suggests an open aquifer scenario with seawater intrusion. This outcome is essential for the groundwater management and supply in Israel.

MA Marine Geophysik: Oral presentation (by invitation only)

MA Marine Geophysik: Oral presentation (by invitation only)
V1-06

Buried glacial landforms in the southeastern North Sea: evidence of a pre-Elsterian glaciation?

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Abstract
Ice sheet dynamics and ice margins in the southeastern North Sea are still poorly constrained, mainly due to the lack of high-resolution seismic data. We collected approx. 1000 km of 2D high-resolution multi-channel reflection seismic data between Amrum and Helgoland in summer 2017 as part of the project Nordfriesland-Süd* to map and analyze the shelf architecture.
The dense grid of high-resolution seismic data allowed us to identify and trace multiple generations of tunnel valleys incised under an ice sheet that covered our survey area during glaciations. Deep buried tunnel valleys (>2.5 km wide, >200 mbsf deep) incised into inclined Neogene and Paleogene strata, which have been deformed by salt tectonics. We found a glaciotectonic complex consisting of multiple thrust sheets, which documents a highly dynamic ice sheet margin. These thrust sheets point northwest and westwards and they moved along an undisturbed décollement. The deepest and largest tunnel valleys incised into the glaciotectonic complex, which indicates a formation of the glaciotectonic complex before the formation of the tunnel valleys.
The identified features document the glacial history of the study area and allow us to infer models for its highly dynamic glacial history. Combining the findings leads us to believe that the data document an arcuate ice lobe that advanced over the survey area during several glaciation and deglaciation cycles. From cross-cutting relationships, it is evident that the glaciotectonic complex predates the Elsterian tunnel valleys.

*Nordfriesland Süd – the geological/sedimentological architecture and habitat distribution in the transition area Wadden Sea – Shelf between the Amrum Bank and the Eider Channel (North Sea) – Expedition AL496, funded by the Schleswig-Holstein Agency for Coastal Defence, National Park and Marine Conservation (LKN.SH) and the State Agency for Agriculture, Environment and Rural Areas Schleswig-Holstein (LLUR).

MA Marine Geophysik: Oral presentation (by invitation only)
V1-07

Seismic reconstruction of seafloor sediment deformation during volcanic debris avalanche emplacement offshore Sakar, Papua New Guinea

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Abstract
Volcanic island sector-collapses have produced some of the most voluminous mass movements on Earth and have the potential to trigger devastating tsunamis. In the marine environment, volcanic landslide deposits often consist of a mixture of volcanic material and incorporated seafloor sediments. The interaction of the initial volcanic failure and the seafloor is highly complex and has an impact on both the total landslide deposit volume and its emplacement velocity, which are important parameters during tsunami generation and need to be correctly attributed during numerical landslide-tsunami simulations. Here, we present a 2D seismic analysis of two previously unknown volcanic landslide deposits north-west of the island of Sakar (Papua New Guinea) in the Bismarck Sea. The younger deposit directly overlies the older one and both are separated by a package of well-stratified sediment. Despite both originating from the same source, with the same broad failure direction, and having similar deposit volumes (~15.5-26 km^3), the interaction of these landslides with the seafloor is markedly different. High-resolution seismic reflection data show that the lower deposit comprises a proximal, chaotic, volcanic debris avalanche component and a distal, frontally confined seafloor-sediment failure component. Deformation of this sediment unit was probably caused by interaction of the debris avalanche component with the substrata. The unit shows various compressional structures, including thrusting and folding, over a downslope distance of more than 20 km, generating a shortening by >27 % in the deposit’s toe. The volume of the deformed sediments is almost the same as the driving debris avalanche deposit. In contrast, the younger landslide deposit does not show evidence for similar seafloor sediment incorporation and is a relatively simpler block-rich volcanic debris avalanche deposit. Our observations show that the nature of the slide plane, i.e., the geological characteristics of the underlying material, control the amount of seafloor incorporation and secondary seafloor failures far more than the nature of the original slide material or other characteristics of the source region. Our results indicate that estimating the volume of volcanic sector collapses based solely on the surface morphology and extent of their deposits may overestimate the primary volcanic component, which is much more important for tsunami generation than secondary sediment failure, by a factor of 2.

MA Marine Geophysik: Oral presentation (by invitation only)
PV-2

Offshore freshened groundwater: State of knowledge and future directions

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Abstract
Offshore freshened groundwater (OFG) is water with a total dissolved solid concentration below that of seawater that is stored in sediments and rocks in the sub-seafloor. In this talk I will present: (i) the current understanding of the general characteristics and controlling factors of OFG; (ii) the geophysical, geochemical, and modelling approaches that are used to detect and characterise OFG; (iii) the major knowledge gaps in OFG research and recommendations on how to address these; and (iv) frontier applications that will benefit from an improved understanding of OFG.
OFG has a global volume of 1 million km^3 and predominantly occurs within 50 km of the coast and down to water depths of 100 m. OFG is mainly hosted in siliciclastic aquifers on passive margins and recharged by meteoric water during Pleistocene sea level lowstands. Key factors influencing OFG distribution are topography-driven flow, salinisation by haline convection, permeability contrasts, the continuity/connectivity of permeable and confining strata, and high permeability conduits.
Geochemical and stable isotope measurements of pore waters from boreholes have provided insights into OFG emplacement mechanisms. Recent improvements in marine electromagnetic systems have allowed electrically resistive sub-seafloor freshened groundwater to be resolved. Inversion and interpretation of electromagnetic and seismic reflection data provide important constraints on lithologies, geologic structures and palaeo-environmental evolution. OFG systems have been numerically modelled since the 1980s. Analytical methods, numerical solutions using sharp-interface theory, and finite difference and element methods have provided a cost-effective method for estimating OFG volumes and emplacement.
Key knowledge gaps include the extent and function of OFG, and the timing of its emplacement. These can be addressed by the application of isotopic age tracers, joint inversion of electromagnetic and seismic reflection data, and development of three-dimensional hydrological models. Such advances, combined with site-specific modelling, are necessary to address frontier applications of OFG, such as its potential use an unconventional source of water and its role in sub-seafloor geomicrobiology.

MA Marine Geophysik: Oral presentation (by invitation only)
PV-1

Die Rolle des Ozeans im Klimawandel – Chancen und Risiken

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Abstract
Die Erde erwärmt sich aufgrund des anthropogen verursachten Anstieges von Treibhausgasen. Im Weltrisikobericht des Weltwirtschaftsforums, der alljährlich analysiert, mit welchen Gefahren die Welt in den kommenden Jahren konfrontiert sein wird und wo der dringendste Handlungsbedarf besteht, führt der Klimawandel die Liste der größten Risiken an. Die Folgen des Klimawandels werden besonders im Ozean offensichtlich, der wiederum eine Schlüsselrolle im Klimasystem spielt.

Was wissen wir eigentlich über den Klimawandel? Was sind seine Ursachen und welche Folgen hat er für den Ozean? Welche Handlungsoptionen bietet der Ozean um dem Klimawandel zu begegnen?

Im Vortrag werden der aktuelle Wissensstand zur Rolle des Ozeans im Klimawandel sowie Chancen und Risiken möglicher Handlungsoptionen präsentiert.

NM/ML

Numerische Modellierung, bildgebende Verfahren und maschinelles Lernen

NM/ML Numerische Modellierung, bildgebende Verfahren und maschinelles Lernen: e-Poster

NM/ML Numerische Modellierung, bildgebende Verfahren und maschinelles Lernen: e-Poster
NM/ML-01

Interdisciplinary 3D potential field modelling of complex lithospheric structures by IGMAS+

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Abstract

We introduce an approach for 3D joint interpretation of potential fields and its derivatives under the condition of constraining data and information. The interactive 3D gravity and magnetic application IGMAS (Interactive Gravity and Magnetic Application System) has been around for more than 30 years, initially developed on a mainframe and then transferred to the first DOS PCs, before it was adapted to Linux in the ’90s and finally implemented as a cross-platform Java application with GUI called IGMAS+. The software has proven to be very fast, accurate and the GUI has been adapted for usability, once a model is established. Since 2019 IGMAS+ is maintained and developed in the Helmholtz Centre Potsdam – GFZ German Research Centre by the staff of Section 4.5 – Basin Modelling and ID2 – eScience Centre.

The core of IGMAS+ applies an analytical solution of the volume integral for the gravity and magnetic effect of a homogeneous body. It is based on the reduction of the three-folded integral to an integral over the bounding polyhedrons that are formed by triangles. Later the algorithm has been extended to cover all elements of the gravity tensor as well and the optimized storage enables fast least-squares inversion of densities and changes to the model geometry and this flexibility makes geometry changes easy. Because of the triangular model structure of model interfaces, IGMAS can handle complex, structures (multi-Z surfaces) like the overhangs of salt domes and variable densities due to voxelization.

To account for the curvature of the Earth, we use spherical geometries. This is particularly important for geophysical investigations at global scales. Therefore IGMAS+ is capable to handle models from big-scale to regional and small-scale models (meters) used in Applied Geophysics.

The model technique is user-friendly because it is highly interactive and operates in real-time by means of hardware-accelerated parallel calculations. Modelling is constrained by seismic and structural input from independent data sources and is essential toward a true integration of 3D thermal modelling.

We demonstrate the flexibility of the software by modelling structures of the South American and European lithosphere.

NM/ML Numerische Modellierung, bildgebende Verfahren und maschinelles Lernen: e-Poster
NM/ML-02

Simulation of Seismic Wave Propagation in Porous Rocks Considering the Exploration and the Monitoring of Geological Reservoirs

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Abstract
Modelling the propagation of seismic waves in porous media gets more and more popular in the seismological community since it is an important but challenging task in the field of computational seismology. The fluid content of, for example, reservoir rocks or soils, and the interaction between the fluid and the rock or between different immiscible fluids has to be taken into account to accurately describe seismic wave propagation through such porous media. Often, numerical models are based on the elastic wave equation and some might include artificially introduced attenuation. This simplifies the problem but only approximates the true physics involved. Hence, the results are also simplified and could lack accuracy or miss phenomena in some applications.
The aim of the conducted work was the consistent derivation of a theory for seismic wave propagation in porous media saturated by two immiscible fluids and the accompanying numerical solution for the derived wave equation. The theory is based on Biot's theory of poroelasticity. Starting from the basic conservation equations (energy, momentum, etc.) and generally accepted laws, the theory was derived using a macroscopic approach which demands that the wavelength is significantly larger than the size of the heterogeneities in the medium due to the size of the grains and pores or due to effects on the mesoscopic scale. This condition is usually fulfilled for seismic waves since the typical wavelength of seismic waves is in the order of 10 m to 10 km. Fluid flow is described by a Darcy type flow law and interactions between the fluids by means of capillary pressure curve models. In addition, consistent boundary conditions on interfaces between poroelastic media and elastic or acoustic media are derived from this poroelastic theory itself.
The nodal discontinuous Galerkin method is used for the numerical modelling. The poroelastic solver is integrated into the 1D and 2D codes of the larger software package NEXD that uses the nodal discontinuous Galerkin method to solve wave equations. The implementation has been verified using symmetry tests and the method of exact solutions.
This work has potential for applications in various scientific fields like, for example, exploration and monitoring of hydrocarbon or geothermal reservoirs as well as CO2 storage sites.

NEXD: A Software Package for Seismic Wave Simulation in Complex Geological Media – New Developments

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Abstract
NEXD is an open source software package for the simulation of seismic waves in complex geological media. This includes elastic, viscoelastic, porous and fractured media with complex geometries. For the computation of the wave fields, the nodal discontinuous Galerkin approach (NDG) is used. The NDG approach combines unstructured tetrahedral meshes with an element-wise, high-order spatial interpolation of the wave field based on Lagrange polynomials. NEXD offers capabilities for modeling wave propagation in one-, two- and three-dimensional settings of very different spatial scale with little logistical overhead. It allows the import of external triangular (2D) and tetrahedral (3D) meshes provided by independent meshing software and can be run in a parallel computing environment. The computation of adjoint wavefields and an interface for the computation of waveform sensitivity kernels are offered. The method is verified by means of symmetry tests and the method of exact solutions. The capabilities of NEXD are demonstrated through, for example, a 2D synthetic survey of a geological carbon storage site. The most recent developments have been the inclusion of porous media in 2D and the inversion capabilities to the latest release versions of the 2D and 3D codes as well as the release of the 1D code. NEXD is available on GitHub: https://github.com/seismology-RUB.

NM/ML Numerische Modellierung, bildgebende Verfahren und maschinelles Lernen: e-Poster
NM/ML-04

TRIPLE - Ice Data Hub, Model-based Mission Support and Forefield Reconnaissance System

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Abstract

The ocean worlds of our Solar System, like Saturn's moon Enceladus and Jupiter's moon Europa are covered with ice. Recently, these icy moons gained further scientific interest, as they are attributed some potential to sustain or host extraterrestrial life in a subglacial ocean. The investigation of these moons will also help to understand the evolution of the Solar System. The in-situ exploration of these moons requires novel technological solutions as well as intelligent data acquisition and interpretation tools.

In 2020, the DLR Space Administration started the TRIPLE project (Technologies for Rapid Ice Penetration and subglacial Lake Exploration) which develops an integrated concept for a melting probe that launches an autonomous underwater vehicle (nanoAUV) into a scientifically interesting water reservoir and an AstroBioLab for in-situ analysis. These three components build up the TRIPLE system. As part of a second project stage, it is envisioned to build the TRIPLE system and test it in Antarctica in 2026. In this contribution, we are going to present the general concept of TRIPLE with a focus on the geophysically most relevant aspects.

To navigate the melting probe through the ice, a forefield reconnaissance system (TRIPLE-FRS) based on combined radar and sonar techniques is designed. This will include radar antennas directly integrated into the melting head combined with a pulse amplifier and a piezoelectric acoustic transducer just behind the melting head. In addition, an in-situ permittivity sensor will be implemented to account for the ice structure dependent propagation speed of electromagnetic waves. With this system, obstacles as well as the ice-water interface at the bottom of the icy shell could be detected.

To deliver key parameters such as transit time and overall energy requirement, a virtual test bed for strategic mission planning is currently under development. This consists of the Ice Data Hub that combines available data from Earth or any other planetary body – measured or taken from the literature – and allows display, interpretation and export of data, as well as trajectory models for the melting probe. We develop high-fidelity thermal contact models for the phase change as well as macroscopic trajectory models that consider the thermodynamic melting process and the convective loss of heat via the melt-water flow.

Using Machine Learning for Antarctic Geothermal Heat Flow Prediction

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Abstract
We established a new Geothermal Heat Flow (GHF) model for Antarctica by using a machine learning approach. GHF is substantially related to the geodynamic setting of the plates, and global geophysical and geological data sets can provide information for remote regions like Antarctica, where only sparse direct measurements exist. We applied a Gradient Boosted Regression Tree algorithm in order to build an optimal prediction model relating GHF to the observables.
Employed data sets are reviewed for their reliability and quality in polar regions and we emphasize the need for adding reasonable data to the algorithm. The validity of our approach is indicated by predictions for Australia, where an extensive database of GHF measurements exists. Our new estimated GHF map exhibits rather moderate values compared to previous models, ranging from 35 to 156 mWm^{-2}, and shows visible connections to the conjugate margins in Australia, Africa, and India.
Enhanced knowledge of regional geology in Antarctica would significantly improve GHF predictions. By combining gravity and magnetic data in a joint inversion approach information on the crustal structure can be inferred and possible geological features might become evident. Our aim is to refine constraints on the geothermal structure of Antarctica, which is needed for studies on ice sheet modeling and sea-level rise predictions.

NM/ML Numerische Modellierung, bildgebende Verfahren und maschinelles Lernen: e-Poster
NM/ML-06

Workflow for filling large-scale data gaps based on geostatistical simulation and uncertain constraints with an application to EMAG2 data over Africa

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Abstract
Many applications, e.g. Curie-depth estimation based on magnetic field data, rely on a large scale, high resolution airborne data compilations. This kind of data may show large data gaps in some regions with not enough data in the needed quality or even no data at all. Filling these gaps by simple interpolation approaches or with data from other sources (e.g. satellite data) often leads to changes in the frequency spectrum (frequency gaps) compared to areas with measured data. In these regions, applications like the previously mentioned Curie-depth estimation cannot be applied consistently.
To avoid these frequency gaps and to additionally provide a valid uncertainty quantification for the infill data, we present a workflow to fill the data gaps by geostatistical simulation, either based on Kriging or Multipoint-geostatistics (MPS). To reduce the variability of the simulation realizations, we introduce additional constraining data points inside the data gaps for the simulation. These constraining data points come from another available data set (e.g. satellite data) and are varied for each simulation realization within their uncertainties.
We apply this workflow to data gaps in EMAG2 data over Africa. The constraining data points are taken from a recent satellite magnetic model (LCS-1). Based on this infill data, Curie-depth estimations are conducted for the gap regions and are compared to other infill approaches and to areas with measured data.

NM/ML Numerische Modellierung, bildgebende Verfahren und maschinelles Lernen: e-Poster
NM/ML-07

Interpretation geoelektrischer Sondierungsdaten mittels neuronaler Netze

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Abstract
Neuronale Netze orientieren sich am Aufbau und der Arbeitsweise eines Gehirns. Ein neuronales Netz ist eine nichtlineare mathematische Struktur, die auf bestimmte Aufgaben trainiert werden kann. Dieser Trainingsprozess ist zwar mit einem relativ großen Rechenaufwand verbunden. Sobald dieser abgeschlossen ist, kann ein neuronales Netz allerdings über eine einfache Abfolge von Matrixmultiplikation die Aufgaben lösen, auf die es zuvor trainiert wurde. Da diese Matrixmultiplikation mit einem minimalen Rechenaufwand verbunden ist, ist dieses Verfahren sehr schnell.
Bei der Interpretation geoelektrischer Messdaten besteht die Aufgabe darin ein Modell zu finden, das zu den Messdaten passt. In der Regel werden dazu Inversionsverfahren benutzt, also numerische mathematische Verfahren, deren Rechenaufwand sowohl mit der Anzahl der Messdaten als auch mit der Anzahl der Modellparameter schnell anwächst. Vor allem für die Anpassung von mehrdimensionalen Modellen an große Messdatensätze ergeben sich so hohe Laufzeiten. Es liegt daher nahe, für diesen Fall über den Einsatz neuronaler Netze nachzudenken, um den Rechenaufwand für die Datenauswertung zu reduzieren.
Hier stellen wir die Ergebnisse einer ersten Annäherung an die Nutzung neuronaler Netze zur Auswertung geoelektrischer Sondierungsdaten vor. Dazu wurden sowohl eindimensionale n-Schichtfälle behandelt als auch einfache zweidimensionale Modelle. Der Trainingsprozess wird über eine Vielzahl synthetischer Messdaten vorgenommen, welche für vorgegebene spezifische Leitfähigkeiten und Schichtdicken, erstellt wurden. Dem in dieser Weise trainierten Netzwerk gelingt es dann unabhängig erzeugte Datensätze erfolgreich auszuwerten, d.h. die Anzahl der im Untergrund vorhandenen Schichten zu rekonstruieren sowie deren Dicken und spezifischen Widerstände, innerhalb einer gewissen Fehlertoleranz, abzuschätzen. Die Laufzeiten dieser Auswertung liegen erwartungsgemäß weit unter denen einer vergleichbaren konventionellen Inversion.

NM/ML Numerische Modellierung, bildgebende Verfahren und maschinelles Lernen: Oral presentation (by invitation only)

NM/ML Numerische Modellierung, bildgebende Verfahren und maschinelles Lernen: Oral presentation (by invitation only)
V5-8

Estimating Seismic Moment Tensors based on Bayesian Machine Learning

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Abstract
Estimating fast earthquakes' source mechanism is essential for near real time hazard assessments, which are based on shakemaps and further downstream analysis such as physics based aftershock probability calculations. The model and data uncertainties associated to the estimated source mechanism are also crucial. We propose a Machine Learning (ML) algorithm trained on normalized synthetic waveforms for estimating the full moment tensor of earthquakes almost instantaneously with associated source parameter uncertainties.
A prior assumption is an appropriate location of the earthquakes along with its associated uncertainties. Here, this is obtained by already established Machine learning based algorithms, where the training data set is computed by forward calculations of synthetic waveforms based on Green's functions calculated for a specified 1-D velocity model using the Pyrocko software package. The labels, the information associated to the data, are the moment tensor components, described with only five unique parameters. For predefined locations in an area of interest we train a full independent Bayesian Convolutional Neural Network (BNN). With variational inference the weights of the network are not scalar but represent a distribution of weights for the activation of neurons. Each evaluation of input data into our BNN yields therefore to a set of predictions with associated probabilities. This allows us to evaluate an ensemble of possible source mechanisms for each evaluation of input waveform data.
As a test set, we trained our models for an area south of the Coso geothermal field in California for a fixed set of broadband stations at maximum 150 km distance. We validate our approach with a subset of earthquakes from the Ridgecrest 2019-2020 sequence. For this data set we compare the results of the estimates of our ML based approach with independently determined focal mechanism and moment tensors. Overall, we benchmark our approach with data unseen during the training process and show its capabilities for generating similar source mechanism estimations as independent studies within only a few seconds processing time per earthquake. We finally apply the method to seismic data of a research network monitoring the area around two south-German geothermal power plants. Our approach demonstrates the potential of Machine Learning for being implemented in operational frameworks for fast earthquake source mechanism estimation with associated uncertainties.

AG

Angewandte Geophysik

AG Angewandte Geophysik: e-Poster

AG Angewandte Geophysik: e-Poster
AG-1

Joint structural and joint petrophysical full waveform inversion of shallow seismic and multi-offset GPR data

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Abstract
Surface based shallow seismic and multi-offset ground penetrating radar (GPR) are standard geophysical methods to explore the shallow critical zone of our earth. In recent years full waveform inversion (FWI) of either seismic or GPR data could improve the resolution of the corresponding material parameter models significantly especially in comparison with travel time based reconstructions.

In this work we study for the first time the joint FWI of shallow seismic and multi-offset GPR data both acquired at the earth surface. By means of synthetic reconstructions tests we compare the performance of joint structural inversion (JSI) and joint petrophysical inversion (JPI). In JSI cross-gradient are used to force structural similarity between seismic and GPR multi-parameter models. In the JPI three coupling strategies are investigated (a) the Gassmann equation, (b) the Archie equation, and (c) the complex refractive index model. These relations connect the seismic and GPR model parameters through the common petrophysical parameters, namely porosity and saturation. The synthetic reconstructions tests reveal that the JSI gains only little improvement compared to the individual FWI of seismic and GPR data. The JPI, however, allows a more reliable reconstruction of seismic and GPR model parameters compared to the individual FWI. Furthermore, the deduced petrophysical parameters porosity and saturation can be estimated more reliably by joint FWI if the underlying petrophysical relations are known.

AG Angewandte Geophysik: e-Poster
AG-2

Focused methane migration formed pipe structures in permeable sandstones: Insights from UAV-based digital outcrop analysis in Varna, Bulgaria

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Abstract
Focused fluid flow shapes the evolution of marine sedimentary basins by transferring fluids and pressure across geological formations. Vertical fluid conduits may form where localised overpressure breaches a cap rock (permeability barrier) and thereby transports overpressured fluids towards shallower reservoirs or the surface. Here, we study field outcrops of an Eocene fluid flow system at Pobiti Kamani and Beloslav Quarry (~15 km West of Varna, Bulgaria), where large carbonate-cemented conduits formed in highly permeable, unconsolidated, marine sands of the northern Tethys Margin. Using an uncrewed aerial vehicle with an RGB sensor camera we produced ortho-rectified image mosaics, digital elevation models, and point clouds of the two km-scale outcrop areas. Based on these data, geological field observations, and petrological analysis of rock/core samples, we mapped and analysed fractures and vertical fluid conduits with centimetre accuracy. Our results show that both outcrops comprise several hundred carbonate-cemented fluid conduits (pipes), oriented perpendicular to bedding, and at least seven bedding-parallel carbonate interbeds which differ from the hosting sand formation only by their increased amount of cementation. From these observations, we conclude that carbonate precipitation likely initiated around areas of focused fluid flow, where methane entered the formation from the underlying fractured subsurface. These first carbonates formed the outer walls of the pipes and continued to grow inward leading to self-sustaining and self-reinforcing focused fluid flow. Our results, supported by literature-based carbon and oxygen isotope analyses of the carbonates, indicate that ambient seawater and advected fresh/brackish water were involved in the carbonate precipitation by microbial methane oxidation. We propose that similar structures may also form in modern settings where focused fluid flow advects fluids into overlying sand-dominated formations, which has wide implications for our understanding of how focusing of fluids works in sedimentary basins with broad consequences for the migration of water, oil, and gas.

AG Angewandte Geophysik: e-Poster
AG-3

Dipolinversion mit Komponentengradienten in der Aeromagnetik

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Abstract
In der Aeromagnetik werden zur Kampfmitteldetektion Multikopter eingesetzt, um belastete Flächen schnell und mit hoher Auflösung zu kartieren. Dabei wurden bisher hauptsächlich einzelne Totalfeldsensoren oder Fluxgate-Magnetometer verwendet, bei denen nur das Totalfeld ausgewertet wurde. Das im Rahmen dieses Projektes verwendete System besteht aus zwei dreikomponentigen Fluxgate Sensoren, einer inertialen Messeinheit (IMU) sowie einer GPS-Antenne. Die IMU erlaubt dabei, die Magnetfeldvektoren in das geographische Koordinatensystem zu projizieren und die Positionen der einzelnen Sensoren relativ zur GPS-Antenne zu bestimmen. Mit diesem Messsystem werden neben dem Totalfeld auch die Differenzen der Magnetfeldkomponenten zwischen den Sensoren ausgewertet.
Die Sensoren werden in einem horizontalen Abstand von 50 cm an einem frei beweglichen, T-förmigen Ausleger unter dem Multikopter befestigt. Das Gesamtgewicht des Systems beträgt etwa 5 kg bei einer Flugzeit von 15 Minuten.
Für die Inversion verwenden wir ein Dipol-Modell, das die Magnetfelddaten an den Sensorpositionen berechnet. Da bei unbekannten Störkörpern eine Differenzierung von induzierter und remanenter Magnetisierung nicht möglich ist, werden neben der Position der Störkörper deren magnetische Momente vektoriell bestimmt. Die Anzahl der angepassten Dipole und deren Startpositionen können beliebig gewählt werden. Neben dem Totalfeld können die Differenzen der Totalfelder sowie der Magnetfeldkomponenten zwischen den Sensoren zur Auswertung herangezogen werden.
Um die Genauigkeit des Gesamtsystems zu untersuchen, haben wir mehrere Flüge über ein mit genau vermessenen Nd-Magneten ausgelegtes Testfeld durchgeführt. Das Testfeld umfasst eine Fläche von 100 x 20 m, aufgeteilt in vier Abschnitte mit unterschiedlichen Anomaliekonfigurationen. Für eine optimale Abdeckung und zum Vergleich der Flugrichtungen wurde die Fläche längs und quer mit einer Sensorhöhe von 1,5 m überflogen. Die Analyse der Inversionsergebnisse zeigt, dass bei Verwendung der Komponentengradienten auch überlappende Anomalien voneinander getrennt und aufgelöst werden können. Die mittleren Fehler der Positionen liegen bei 5 cm. Das magnetische Moment kann bis auf 0,35 Am^2 genau bestimmt werden, wobei die Fehler in Deklination und Inklination bei 4° bzw. 2° liegen.

AG Angewandte Geophysik: e-Poster
AG-4

Severe meteorological events in Jena, Thuringia: observations on the seismological footprint at the geodynamic Observatory Moxa

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Abstract
Atmospheric processes, such as severe meteorological storm events, have a strong relevance to climate change and to everyday life safety aspects regarding stability of buildings, forest damage or aviation safety. Due to the coupling effects between the atmosphere and the Earth surface, these processes influence also the ground motion. The aim of this work is to improve the understanding of this interaction trough the analysis of ambient seismic noise records and its correlation with atmospheric pressure, wind velocity, wind direction and gravimetric variations, during strong meteorological events.
Ambient seismic noise is assumed to be permanently present; it is generated by numerous sources that are spatially distributed that act in a discreet or in a continuous way. These sources can be either of natural or anthropogenic origin. Some major natural sources are related to the oceanic micro seismic activity and to atmospheric processes; while the anthropogenic sources include all artificially generated seismic signals related to traffic or industry. Furthermore, the seismic noise field can be characterized as high-frequency (> 1 Hz) and low-frequency (< 1 Hz); the high-frequency seismic noise is strongly dominated by local sources due to anthropogenic activity, while the low-frequency noise is mainly dominated by natural sources.
In this study we analyze the seismic noise field generated by severe meteorological events and therefore focus our analysis on the low-frequency band (< 1 Hz). This kind of meteorological events are usually accompanied by strong wind and atmospheric pressure fluctuations, which can be observed and characterized on the seismological footprint. We show our preliminar results for three storm events that moved across Northern Europe: Kyrill (2007), Xavier (2017) and Frederike (2018). We use meteorological and seismological data recorded at Moxa Observatory of the Friedrich Schiller University in Jena, Thuringia.

AG Angewandte Geophysik: e-Poster
AG-5

Can DAS on dark fibers contribute to active exploration in urban settings ? - First results of a case study in Potsdam, Germany

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Abstract
The de-carbonization strategy of the city of Potsdam, Germany, incorporates the utilization of its geothermal potential. As a first step of developing a deep geothermal project for district heating, an urban seismic exploration campaign of the *Stadtwerke Potsdam* took place in December 2020 in the city centre of Potsdam. Since urban measurements are often difficult to setup and a low-footprint alternative is sought for, we supplemented the contractor-performed Vibroseis survey along three profiles by distributed acoustic sensing (DAS). In close cooperation with the municipal utilities, we interrogated a 21 km-long dark telecommunication fibre whose trajectory followed the seismic lines as close as possible. This was accompanied by a network of 15 three-component geophones for further control and research.
In this contribution we present the data set, the approach for geo-referencing the fibre, and first results regarding DAS recording capabilities of vibroseismic signals in an urban environment. Following the paradigm that the high density of telecommunication networks in urban areas may facilitate the exploration of the often insufficiently known local geology, we strive to further shed light on the possibilities of their employment for urban exploration. In this respect we aim at tackling the question of the accuracy of fibre localization, recording sensitivity and range of active stimulation.

Detecting ground motion in Schleswig-Holstein from radar satellite data

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Abstract
The near-surface geology of northern Germany is characterized by glacial deposits, deformed by rising Permian and Upper Triassic salt structures. Ground motions potentially associated with salt tectonic processes are very slow and are superimposed by signals of e.g. hydrological and anthropogenic sources. To measure them requires the detection of motion rates in the range of a few millimeters per year with sufficient spatial coverage. For large areas little is known about the rates and the characteristics of ground motions, even though they directly affect anthropogenic infrastructure and could have an impact on the future use of the underground for storage purposes or the exploitation of geothermal energy.

To measure ground motion, we use radar interferometric time series data provided by the German Aerospace Center and the Federal Institute for Geosciences and Natural Resources' Ground motion service. These data are based on Synthetic Aperture Radar images acquired by ESA's ERS and Sentinel satellites. Time-series analyses are possible for temporally stable backscattering objects (persistent scatterers) on the ground. Generally, this results in spatially dense observations over built-up areas and sparse observations over rural areas.

We use a set of geostatistical methods to analyze these time series data. We detect signals of large-scale surface-deforming processes such as the subsidence of the marshes. We see small-scale signals like the swelling of Permian anhydrite at the Segeberger "Kalkberg". And we can observe subsidence processes over the historic town of Lübeck.

Our work extends the area of application of the PS-InSAR technique from areas with high motion rates to regions with particularly low motion rates. We discuss methods that can be used to link ERS data to the Sentinel-1 data, in particular, to separate long-term motion processes from short-term effects. We are working on techniques that shall help to decompose different signal sources. Finally, we aim to prepare a set of tools, that can be used by the community.

AG Angewandte Geophysik: Oral presentation (by invitation only)
V1-5

Cavity Detection at Mt. Erzberg with elastic Full-waveform Inversion

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Abstract
The detection, and mapping, of subsurface cavities is an important task, primarily because the potential collapse of a cavity poses a hazard to infrastructure and residents.
In this study we investigate the potential for the seismic detection of a man-made tunnel in hard rock. We compare results obtained through elastic full waveform inversion (FWI) of synthetic and real data collected over an abandoned mining tunnel at Mt. Erzberg roughly 4 m wide and presumably at around 25 m depth. The profile is 128 m long, and we used 75 3-component receivers and a seismic gun. A background P-wave velocity model for FWI was obtained from travel-time tomography (TTT). Because of the large depth-to-size ratio of the tunnel, TTT does not show any sign of the tunnel.
To study the expected seismic signature from the cavity, we insert a cavity into the TTT model, and we compare synthetic data in the TTT model with and without the cavity. Significant time shifts are present in the P-wave time window between 200 and 350 Hz and in the surface-time window between 160 and 300 Hz for offsets greater than 71 m.
Based on these specifications a targeted inversion of synthetic and measured data is conducted, separately inverting the most significant P-wave and surface-wave time-frequency-offset windows. For the S-wave model, we assume a Poisson body, and the density is computed from Gardner's relation.
The synthetic inversion results show a good and reliable reconstruction of the cavity in nearly all inversion approaches and parameters. However, the inversion of the observed data does not show a cavity at the suspected area, presumably due to low signal-to-noise ratio at high frequencies. However, inverting the whole data set and frequency content shows an S-wave velocity and significant density reduction at the position of the cavity.

AG Angewandte Geophysik: Oral presentation (by invitation only)
V1-6

Multiscale and -disciplinary Investigation of the Fracture Network in the Odenwald Crystalline Complex, Germany

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Abstract
In the Upper Rhine Graben region, the crystalline basement constitutes an attractive target for deep geothermal projects due to the favourable temperatures and high potential as fractured and faulted reservoir system. The crystalline units are also promising sites for heat-storage via medium-deep borehole thermal heat exchangers. Hydraulically active fault zones are the targets of main interest, as they exhibit increased permeabilities and thus allow economic flow rates in geothermal wells. However, the characterization of these fault systems is challenging due to the locally more than 5 km thick sedimentary cover, and the low number of boreholes as well as seismic profiles reaching the basement. Within the Interreg NWE DGE-ROLLOUT Project, the aim is therefore to approach the architecture of crystalline reservoirs by investigating outcrop analogues from the adjacent Odenwald Crystalline Complex, which are representative for the geological structure and composition of the northern Upper Rhine Graben basement. Reservoir-scale outcrops are mainly located in active and abandoned quarries, where the fracture pattern and density are strongly influenced by nearby fault zones. Key insights into the 3-dimensional fracture network properties are obtained from high-resolution LiDAR scans, which will be the data basis for a detailed structural model. Besides, selected sections across the mapped fault-zones will be characterized through a combination of gravimetric, geoelectric and scintillometric measurements. These field profiles will be integrated with a regional aeromagnetic survey to map geological units and in particular fault zones signals as well as with lineament analysis results from high-resolution digital elevation models. The compilation of the mentioned methods will result in a comprehensive dataset on structural, petrophysical and mechanical properties of crystalline reservoirs in the Upper Rhine Graben region. This large multi-disciplinary dataset will allow a better understanding of the fracture and fault network architecture and thus a reduction of uncertainties and risks associated with deep geothermal drillings and heat-storage prospects. It will furthermore serve as the basis for realistic simulations of heat transport processes in the fractured basement.

AG Angewandte Geophysik: Oral presentation (by invitation only)
V1-7

Zielgerichtete Kombination geophysikalischer und hydrogeologischer Methoden zur Erkundung ausgedehnter feinkörniger Talfüllungen

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Abstract
Sedimentäre Strukturen können die Fließ- und Transportpfade des Grundwassers in feinkörnigen Talfüllungen stark beeinflussen. Sie müssen daher gezielt untersucht werden, um die Fließpfade und das Abbaupotenzial von Schadstoffeinträgen zu bestimmen. Gängige oberflächengeophysikalische Methoden können diese Strukturen zwar eingrenzen, sind jedoch vor allem in feinkörnigen Lockersedimenten in Eindringtiefe und Auflösung stark limitiert. Bohrlochgeophysikalische Messungen, Sondierungen und Bohrkernuntersuchungen ermöglichen zwar vertikal hochauflösende in-situ Messungen, sind jedoch aufwendig und lösen keine Strukturen auf, die zwischen den Ansatzpunkten liegen.
Wir präsentieren daher am Beispiel des Ammertals bei Tübingen eine Kombination aus großflächigen geophysikalischen Messungen und hochauflösenden Sondierungen. Damit werden hydrogeologisch relevante Teilbereiche und Strukturen im 5 km² großen Auengebiet der Ammer zunächst abgegrenzt und anschließend an repräsentativen Ansatzpunkten untersucht. Beispielhaft untersuchen wir sowohl eine tiefe Rinnenstruktur und ihren Einfluss auf die regionale Wasserbilanz (ein möglicher bevorzugter Fließpfad), als auch Torflagen mit hohem Gehalt organischen Kohlenstoffs und ihren Einfluss auf die auenweite Hydrochemie (potenziell biogeochemisch aktive Zonen mit erhöhtem Stoffumsatz). Eine 2-D geoelektrische Tomographie und Profilmessungen erfassten zunächst die Ausdehnung der Rinnenstruktur. Ihre hydrogeologischen Eigenschaften ließen sich anschließend mithilfe von direct-push HPT-Sondierungen sowie Gamma-logs und hydraulischen Tests in temporären Messstellen gezielt bestimmen. Die Torflagen hingegen wurden durch auenweite Gamma-logs und gezielte direct-push Sondierungen hochauflösend erfasst. Dabei ließen sich die relevanten Zonen mit hohem Anteil an organischem Kohlenstoff vor allem durch in-situ Messungen der Sedimentfarbe gut abgrenzen.
Die Kombination der unterschiedlichen geophysikalischen und hydrogeologischen Methoden erweist sich dabei als effizienter Ansatz, um sedimentäre Strukturen aufzufinden und gezielt zu untersuchen. Dabei richtet sich die Wahl und Kombination der Methoden nach den erwarteten Strukturen, den standort-spezifischen Bedingungen und der individuellen fachlichen Fragestellung. Auf diese Weise lassen sich relevante Teilbereiche auch an großflächigen Standorten sinnvoll eingrenzen, um arbeitsintensive in-situ Methoden und Kernbohrungen auf die repräsentativen Ansatzpunkte zu beschränken.

SE

Seismik

SE Seismik: e-Poster

SE Seismik: e-Poster
SE-01

3D seismic imaging of the Alpine Fault and the glacial valley at Whataroa, New Zealand

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Abstract
The Alpine Fault at the West Coast of the South Island (New Zealand) is a major plate boundary that is expected to rupture in the next 50 years, likely as a magnitude 8 earthquake. The Deep Fault Drilling Project (DFDP) aimed to deliver insight into the geological structure of this fault zone and its evolution by drilling and sampling the Alpine Fault at depth. Here we present results from a seismic survey around the DFDP-2 drill site in the Whataroa Valley where the drillhole almost reached the fault plane. This unique 3D seismic survey includes several 2D lines and a 3D array at the surface as well as borehole recordings.
Despite the challenging conditions for seismic imaging within a glacial valley filled with sediments and steeply dipping valley flanks, several structures related to the valley itself as well as the tectonic fault system are imaged by prestack depth migration approaches.
Within the glacial valley, particularly steep valley flanks are imaged directly and correlate well with results from the P-wave velocity model obtained by first arrival travel-time tomography. Additionally, a glacially over-deepened trough with nearly horizontally layered sediments is identified about 0.5 km south of the DFDP-2B borehole.
With regard to the expected Alpine fault zone, a set of several reflectors dipping 40-56° to the southeast are identified in a ~600 m wide zone between depths of 0.2 and 1.2 km that is interpreted to be the minimum extent of the damage zone. Different approaches image one distinct reflector dipping at 40°, which is interpreted to be the main Alpine Fault reflector. This reflector is only ~100 m ahead from the lower end of the borehole. At shallower depths (z<0.5 km), additional reflectors are identified as fault segments and generally have steeper dips up to 56°. About 1 km south of the drill site, a major fault is identified at a depth of 0.1-0.5 km that might be caused by the regional tectonics interacting with local valley structures. A good correlation is observed among the separate seismic data sets and with geological results such as the borehole stratigraphy and the expected surface trace of the fault.
In conclusion, several structural details of the fault zone and its environment are seismically imaged and show the complexity of the Alpine Fault at the Whataroa Valley. Thus, a detailed seismic characterization clarifies the subsurface structures, which is crucial to understand the transpressive fault's tectonic processes.

SE Seismik: e-Poster
SE-02

Reprocessing of the hessian DEKORP seismic profiles

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Abstract
As part of the German continental seismic reflection program (Deutsches Kontinentales Reflexionsseismisches Programm, DEKORP), three large seismic traverses (with the sub-profiles: DEKORP'84-2S and '86-2N; DEKORP'88-9N; DEKORP'90-3A and '90-3B) were measured in the state of Hesse in Germany. The main research topic of DEKORP were deep seismic studies to investigate the lithospheric structure beneath Germany. Thus, for acquisition, strong sources were used to image in these depths, resulting in an excellent S/N ratio, but the main focus was not on the uppermost kilometres. From today's perspective, however, this depth range is of great interest for a wide range of possible technical applications (including medium-deep and deep geothermal projects). The DEKORP profiles cover approx. 450 km in the state of Hesse and mostly cross areas where only insufficient geological data exist (i.e. only few deep boreholes). In order to close or reduce these knowledge gaps, these DEKORP lines were reprocessed in 2019/20.
The focus of the reprocessing was on improving the resolution / mapping of geological structures down to a depth of 6 km (approx. 3 s TWT) to describe the prolongation of faults and geological structures in more detail than in previous studies. Nevertheless, deeper structures were also reinterpreted and compared to previous interpretations. The results were directly incorporated into the new geological 3D model of the state of Hesse, developed by the Technical University of Darmstadt (Hessen3D 2.0, BMWi-FKZ: 0325944).
In order to achieve these goals and in view of the fact that today's processing methods have improved considerably compared to the 1990‘s, a state-of-the-art reprocessing was applied for all DEKORP profiles traversing the state of Hesse. In comparison to the original processing, additional processing steps like CRS instead of CDP stacking, turning-ray tomography and prestack depth migration were carried out.
For the Rhine Graben profile DEKORP’88-9N, additional attribute analyses (RMS amplitude, instantaneous frequency and phase, Q-factor and others) were carried out in order to examine their potential to gain additional knowledge for 2D crustal seismics. For the profiles DEKORP’90-3A and ’90-3B, in addition to the main lines, also a number of short cross profiles were recorded in order to obtain information on possible out-of-plane reflections.
We present exemplary results of the reprocessing as well as initial geological reinterpretations.

SE Seismik: e-Poster
SE-03

Diffraction imaging and depth-velocity inversion with 3D P-Cable seismic data

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Abstract
Most established methods for the estimation of subsurface velocity models rely on the measurements of reflected or diving waves and therefore require data with sufficiently large source-receiver offsets. For seismic data that lacks these offsets, such as vintage data, low-fold academic data or near zero-offset P-Cable data, these methods fail. Building on recent studies, we apply a workflow that exploits the diffracted wavefield for depth-velocity-model building. This workflow consists of three principal steps: (1) revealing the diffracted wavefield by modeling and adaptively subtracting reflections from the raw data, (2) characterizing the diffractions with physically meaningful wavefront attributes, (3) estimating depth-velocity models with wavefront tomography. We propose a hybrid 2D/3D approach, in which we apply the well-established and automated 2D workflow to numerous inlines of a high-resolution 3D P-Cable dataset acquired near Ritter Island, a small volcanic island located north-east of New Guinea known for a catastrophic flank collapse in 1888. We use the obtained set of parallel 2D velocity models to interpolate a 3D velocity model for the whole data cube, thus overcoming possible issues such as varying data quality in inline and crossline direction and the high computational cost of 3D data analysis. Even though the 2D workflow may suffer from out-of-plane effects, we obtain a smooth 3D velocity model that is consistent with the data.

SE Seismik: e-Poster
SE-04

Die Form und Füllung des glazial-übertieften Basadingen-Beckens, abgeleitet aus hochauflösenden reflexionsseismichen Messungen

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Abstract
Übertiefte Täler in den Alpen ermöglichen uns glaziale Sedimentation und somit einen Teil der quartären Klimageschichte zu verstehen. Reflexionsseimsik kann dabei verwendet werden, um punktuelle Bohrlochdaten in die Fläche zu projizieren oder eine potentielle Bohrlokation vorzuerkunden. Im Rahmen des ICDP-Projekts ‚Drilling Overdeepened Alpine Valleys' (DOVE) sollen eine Reihe von Bohrungen in alpinen, glazial-übertieften Tälern abgeteuft werden. Eine der Bohrungen soll 2021 in einem übertieften Tal des Rheingletschers bei Basadingen, nahe der deutsch-schweizerischen Grenze abgeteuft werden.
In Zusammenarbeit mit der ETH Zürich, wurden zwei Profile im Abstand von ca. 500 m annähernd senkrecht zum Talverlauf aufgenommen. Das erste Profil ist 1246 m lang und bestand aus einer festen Auslage von 624 Geophonen. Das zweite Profil ist 1120 m lang und wurde mit 200 3-Komponenten-Geophonen im roll-along-Verfahren aufgenommen. Für beide Profile wurde bei jedem zweiten Geophon (zwei Meter Geophonabstand) mit einem hydraulischen 4-t Vibrator ein linearer 12-s-Sweep von 20-240 Hz angeregt. Beide seismischen Profile bilden ein asymmetrisches, übertieftes Becken mit ca. 260 m Tiefe ab, wobei der tiefste Bereich nur einen kleinen Teil des breiteren Hauptbeckens einnimmt. Die Auffüllung ist durch mindestens drei Diskordanzen, deutlichen Onlaps und Erosionshorizonten zwischen den Sedimenteinheiten gekennzeichnet. Wir interpretieren die Talfüllung als das Produkt eines hochdynamischen, sedimentären Systems. Der untere Teil, innerhalb des tiefsten Bereichs des Beckens, ist mit chaotisch abgelagerten Sedimenten gefüllt. Der Teil oberhalb einer Diskordanz enthält steil einfallende Reflektoren, die wahrscheinlich 20-30 m mächtige, progradierende Mäanderbanken einer glazial-fluviatilen Umgebung darstellen. Unterhalb des tiefsten Bereichs des Beckens sehen wir Versätze in Reflektoren, die auf Verwerfungen in der Tertiären Molasse hinweisen und mit bekannten Verwerfungen an der Oberfläche korrelieren. Wir vermuten, dass die Verwerfungen das Gestein geschwächt und somit die verstärkte Erosion an dieser Stelle gefördert haben.

SE Seismik: e-Poster
SE-05

Seismic tomography at the scale of a underground rock laboratory in anisotropic host rock

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Abstract
For the seismic characterization of claystone formations around the Mont Terri Rock Laboratory, a subsurface acquisition system developed at the German Research Centre for Geosciences (GFZ) was used, which was successfully applied in rock salt and crystalline. To test the applicability in claystone formations a pilot survey was carried out in January 2019, comprising several niches and galleries of the underground rock laboratory (URL) Mont Terri. The aim of this study is to investigate the anisotropic character of claystone formations and to evaluate the applicability of the acquisition system in a relative sparse geometrical setup for tomographic imaging.

We used rock anchors, which are inserted 2 m into the tunnel walls, equipped with 3-component geophones, which always have the same orientation and therefore are suitable for repeat measurements. Various sources were used for the pilot survey, but for this study only data recorded with the pneumatic impact source were analysed. Since several sources were tested during the pilot survey, only a few shot points were recorded for the pneumatic impact source. Therefore the azimuthal coverage for anisotropic characterization is missing data, but for a first impression an elliptical fit can be computed to evaluate the average seismic P- and S-wave velocity anisotropy for the shaly (AvP=30%, AvS=17%) and carbonate-rich sandy facies (AvP=20%, AvS=30%) of the Opalinus Clay.

For tomographic imaging we used simulr16, which has the feature to set each anisotropic parameter independently for each grid node, which allows us to compute a more accurate isotropic velocity model, as for a uniform anisotropy. Because of the sparse acquisition geometry we decided for a more realistic initial model. Therefore we used velocities from other publications and simulated the excavation damage zone with a gaussian kernel filter.
To study the influence of the anisotropy, we computed a (anisotropic) velocity model without any adjustments by the anisotropic parameters as reference for the (isotropic) velocity model, which takes the anisotropy into account.

In the tomographic results the layer boundary between shaly and carbonate-rich sandy facies can be reconstructed well. Initial tomographic inversion results assuming isotropic conditions show a strong influence of anisotropy, since the P-wave velocities are dependent on the propagation direction of ray paths.

SE Seismik: e-Poster
SE-06

Performance test of seismic sources in clay

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Abstract
Since clay formations are heterogeneous and anisotropic, their seismic characterization at the meso scale is challenging. To investigate the applicability of the GFZ underground acquisition system (Borm & Giese 2003) for characterization and monitoring in clay, we carried out a seismic survey in the Mont Terri Underground Rock Laboratory (URL). Our source comparison aims to evaluate (1) the performance of the seismic sources in clay and (2) their suitability for clay characterization and imaging.

The pilot experiment using impact and vibroseis sources demonstrates their successful application in Opalinus clay. The impact source generates signals with high signal-to-noise ratios and strong lower frequencies. In contrast the vibroseis source has more control of the frequency generation and is able to excite higher frequencies than the impact source. Despite the high attenuation of the Opalinus clay, we observe signals with a penetration depth up to at least 65 m for both sources.

In addition to the performance test, we performed travel time analyses and the resulting average P- and S-wave velocities show a clear azimuthal dependence with fast velocities parallel to bedding strike. The different facies of the Opalinus clay are characterized by distinct average velocities: The carbonate-rich sandy (v_{Pmax} = 4000 m/s, v_{Smax} = 2050 m/s) and the sandy facies (v_{Pmax} = 3720 m/s, v_{Smax} = 1840 m/s) have faster velocities than the shaly facies (v_{Pmax} = 3220 m/s, v_{Smax} = 1480 m/s) which is stronger anisotropic (AvP = 23%, AvS = 32%) than the sandy facies (AvP = 9%, AvS = 12%). Our findings are in good agreement with seismic velocities and anisotropy determined by Schuster et al. (2017), Popp & Salzer (2007) and Siegesmund et al. (2014).

The sparse acquisition geometry was not optimal for reflection imaging of the geological conditions around the URL. However, later arriving shear wave reflections could be extracted from the impact data. A 3D migration focuses these reflections at a distance of ~50 m at the transition from the lower sandy facies to the upper shaly facies.

In general, both sources are well suited for underground exploration in Opalinus clay, e.g. transmission experiments and reflection imaging. Considering the wavefield characteristics of both sources, the impact source is recommended for large offset applications whereas the vibroseis source is particularly suitable for high-resolution applications at near offsets.

SE Seismik: e-Poster
SE-07

Constructing and validating a large-scale velocity-model for the North German Basin in Schleswig-Holstein and Hamburg – A part of the joint project TUNB

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Abstract
As a result of the joint project ‘Subsurface Potentials for Storage and Economic Use in the North German Basin’ (German acronym: TUNB) the Geological Surveys of Northern Germany and the Federal Institute for Geosciences and Natural Resources (BGR) finalized a coherent geological 3D-model of the deep subsurface of the North German Basin in early 2021. The model consists of 13 major base surfaces from Oligocene to Zechstein, fault surfaces and hull surfaces of salt diapirs. In the north-western part it is based on the datasets of the Tectonic Atlas of NW-Germany (GTA) along with well and seismic data from the hydrocarbon industry.

Additionally to modelling the onshore part of Schleswig-Holstein and Hamburg and insuring cross-border consistency to the neighbouring federal states, the Geological Survey of Schleswig-Holstein (LLUR) reconstructed a 3D-large-scale velocity-model based on previous work from Jaritz et al. (1991). Their velocity approach was developed within the GTA-project and is based on sonic-log and check-shot-velocities. It assumes a linear velocity increase, which is calculated from specific global gradients for different major lithostratigraphic layers and laterally varying starting-velocities.

To validate the constructed 3D-velocity-model, its velocities were compared to velocities measured at boreholes by oil and gas companies. In general, a good agreement was found between modelled and measured data (deviation < 5%), in which the average velocities seemed to resemble the check-shot data more accurately than the interval velocities the sonic-log-measurements.
In distinct locations, the velocity-model was used to convert the newly constructed TUNB-horizons from the depth- to the time-domain in order to compare them to seismic sections. Whereas overall a good agreement between horizons and seismic reflectors was found, differences were identified especially in structural complex areas. Whether these can be attributed to earlier interpretations from the GTA, the modelling of the horizons or insufficiencies in the velocity-model has yet to be determined.

A follow-up project to the TUNB-project is anticipated to start in early summer 2021. The goal of the project is to derive a consistent velocity model over large parts of the North German Basin. Main challenges will be integrating available borehole and seismic data into existing velocity-modelling approaches with a special focus on establishing cross border consistency to eastern federal states.

SE Seismik: e-Poster
SE-08

Neubearbeitung und strukturelle Interpretation der reflexionsseismischen Datensätze DEKORP 1-Laacher See 1987

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Abstract
Das Vulkanzentrum Laacher See in der Osteifel zählt zusammen mit der Westeifel zu den jüngsten Vulkangebieten Mitteleuropas. Der letzte große Ausbruch des Laacher See Vulkans (VEI = 6) fand vor nur etwa 12900 Jahren statt. Obgleich die petrologischen Untersuchungen der geförderten Ablagerungen eine große, residuale Magmakammer zwischen 4 und 6 km Tiefe eingrenzen, gibt es bisher keine klaren Hinweise auf Lage und Ort des Laacher See Oberkrusten-Reservoirs aus Geophysik und Seismik. Allerdings werden in den letzten Jahren immer wieder niederfrequente Tiefherdbeben unter dem Laacher See registriert, die darauf hindeuten, dass noch magmatische Fluide aus dem Obermantel in die Kruste aufsteigen können. Daher kann auch in Zukunft mit Vulkanausbrüchen in dieser Region gerechnet werden. Kenntnisse über den strukturellen Aufbau und die mögliche Lage und Ausdehnung der residualen Magmakammer des letzten Ausbruchs sind daher von erheblicher Bedeutung.
Die Auswertung seismischer Messungen im Raum des Laacher Sees mit Bearbeitungsstand der 80er Jahre hatte es nicht ermöglicht, Struktureinheiten oder gar Magmakammern in der Erdkruste nachzuweisen. Im Rahmen der aktuellen Masterarbeit wurden nun die alten Datensätze aus der DEKORP 1 Messkampagne Laacher See 1987 mit modernen Prozessierungsmethoden neu bearbeitet und die daraus resultierenden Ergebnisse strukturell interpretiert. Im Fokus stand ein mögliches 2D-Abbild des Laacher See Caldera-Ringkomplexes zusammen mit Hinweisen auf das erkaltete Magmareservoir des letzten Ausbruchs.
Obgleich die Akquisitionsparameter für DEKORP 1-Laacher See einer anderen Schwerpunktsetzung folgten, liefern Abbild und Auflösung der nun vorliegenden Bearbeitung einen deutlichen Erkenntnisgewinn in Bezug auf die strukturelle Situation dieser Region. Die Tiefenlage der Kruste-Mantel-Grenze kann mit ca. 34 km angegeben werden. Die gestapelten und migrierten Sektionen zeigen einen komplexen Krustenaufbau von der Moho bis an die Oberfläche. Die neue Prozessierung identifiziert eine mögliche Ringstörung oder Intrusion am nordöstlichen Ende des Profils, die mit ca. 7 km eine deutlich größere Ausdehnung hätte als morphologisch erschlossen (ca. 2 km). Die Tiefenlage eines potenziellen Magmareservoirs am unteren Ende der Ringstruktur wird nicht zweifelsfrei aufgelöst. Obgleich die Ergebnisse mehrdeutig sind, wird ein vulkano-tektonisches Modell als Anregung für zukünftige Untersuchungen im Rahmen eines geplanten DFG-Schwerpunktprogramms diskutiert.

SE Seismik: e-Poster
SE-09

Cavity detection by 2D shear wave full waveform inversion - field data application at a monumental burial mound in Bergama, Turkey

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Abstract
The localization of cavities and loose zones remains a challenge for geophysical methods. The physical differences between soil and cavity allow in theory their resolution by different methods. Seismic measurements are especially suited due to their comparably high resolution at larger depth. Full waveform inversion (FWI) uses the whole wavefield to extract physical parameters such as velocity and density and allows variations below the wavelength of the signals to be resolved.
We test the ability of FWI to detect voids using a field dataset at a monumental burial mound in Bergama, Turkey. A known but inaccessible tunnel system from an old excavation in the early 20th century serves as a test example for the method. The dataset consists of 240 SH receivers with 0.5 m spacing traversing the mound's summit above the tunnel system which lies in approximately 30 m depth. 68 shot points with 1 - 4 m spacing are employed along the profile.
For the FWI, a workflow focusing on the reflections is used, i.e., a sequential fitting of frequency filtered field data in combination with time and offset-windows using the Global Correlation Norm as objective function. For a more accurate quantification of seismic velocities in the low-velocity zone, an AGC-normalized L2 norm is used in an additional substage. Very low shear-wave velocities <50 m/s are obtained in the area of the tunnels with a dome of low shear-wave velocities above, suggesting an at least partial cave-in of the tunnel system. Depth, extent and shear wave velocity distribution can be validated by the tunnel system documentation and by a cross section.

SE Seismik: e-Poster
SE-10

Cyclic Depositional Processes on a Mixed System in Northern Campos Basin, SE Brazil

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Abstract
A new mixed turbidite-contourite system is described in the northern Campos Basin, southeastern Brazilian margin. This system is developed in a middle slope setting and was formed through non-synchronous interaction between the turbidity current and a contour current in the same stratigraphic interval (Miocene). Different depositional cycles were accounted based on their diagnostic seismic features. Seismic attributes, seismic facies, and isochron maps were used to identify alternating cycles of downslope and alongslope processes in the study area, along with the intermediate stage with features from both processes (mixed system). The depositional processes resulted from alongslope current activity can be distinguished from the downslope current activity, based on the acoustic characteristics (root-mean-square (RMS) amplitude), internal architecture, and external geometry pattern. While alongslope currents deposits consist of mainly low RMS amplitude values clinoforms with an alongslope trend; the downslope gravity deposits present high-amplitude or chaotic seismic facies, usually higher values of RMS amplitude, channel or channel-lobe features, erosive surfaces, and a basinward depositional trend. In this study, five seismic units are described and later associated with their dominant type of current. Based on the main depositional diagnostic features, it was possible to determine which were the dominant processes that controlled the sedimentation by indicating periods where the margin was mostly submitted to sediment transfer from continent to the basin and periods where the oceanic currents prevailed by redistributing sediments along the isobaths and replacing the axis of downslope transfer conduits. Important information on the paleocurrents' direction was also made based on the final deposits display (e.g. terraces, sediment waves, paleochannels), a northward-flowing bottom current was assumed. Research on alternating dominant processes and mixed depositional systems may provide a better understanding of deep-water depositional processes. Because these processes do not always fit previous depositional models that are mainly described for synchronous systems, new insights on cyclic non-synchronous mixed systems can improve our understanding of how mixed systems are organized through time and space. Setting new models on cyclic deposits and intermediate stages can have a future economic impact on potential hydrocarbon reservoir architecture.

SE Seismik: e-Poster
SE-11

Full Waveform Sonic Log imaging and its application to a dataset from the Ludvika/Blötberget mining area (Sweden).

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Abstract
The exploration of mineral deposits plays a significant role in making mineral resources available for the EU economy. Surface seismic investigations of mineral deposits can provide high-resolution images of the subsurface from which the exact location and dimension of such deposits can be derived. Nevertheless, information on the small-scale structure of the ore body is limited to the resolution of the surface seismic method and therefore the internal composition of the ore body often remains unresolved.
Borehole geophysical studies can address this issue and deliver high-resolution information of various parameters along the borehole trajectory, e.g. sonic logs can be used to derive a velocity profile from first arrival travel times. Here, we present a concept of using the complete seismic wavefield from Full Waveform Sonic Logs (FWSL) to obtain a high-resolution seismic depth image and resolve the internal small-scale structure and composition of an ore body. We analyzed an FWSL dataset from the Blötberget mining area (Sweden) acquired in 2015. The direct wave was suppressed using an averaging filter technique. Further signal processing was kept to a minimum and the dataset was limited to the traces containing reflections from the ore body. We applied Kirchhoff prestack depth migration using constant velocities derived from a combination of the sonic log and the analysis of reflected arrivals. Reflected P-waves as well as reflected guided wave arrivals were used in this approach.
Internal structures of the ore body with thicknesses on the order of 0.5 m could be derived from integrative interpretation and categorization of the obtained seismic images. Furthermore, possible fault zones crossing the borehole have been imaged that are crucial for planning of mining operations and studies on the origin of the deposit. Calculation of synthetic seismograms using a wedge model and using realistic parameters for the sonic log frequency and formation velocity showed that it is possible to resolve layers with thicknesses on the order of 0.2 m, which gives the method significant advantages over surface seismics in terms of resolution. The workflow shows a cost-effective way to derive an internal model of the ore body with low computational effort. The approach complements 3D surface seismic data and VSP data with even increased resolution and for that reason contributes to the characterization of the deposit and its geological setting.

SE Seismik: e-Poster
SE-12

Vintage crustal-scale seismic profiling data made available for future applications: DEKORP 1984 – 1999

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Abstract
The German continental seismic reflection program DEKORP (DEutsches KOntinentales Reflexionsseismisches Programm) was carried out in the years between 1984 and 1999. The aim of DEKORP was to investigate the deep crustal structure of Germany with high-resolution near-vertical incidence (mostly vibro)seismic acquisition, supplemented by wide-angle seismic and other target-oriented piggy-back experiments, all complemented by optimized methods of data processing and interpretation. The DEKORP project was an equivalent to many other deep-seismic programs world-wide such as COCORP, BIRPS, LITHOPROBE, ECORS, CROP, BELCORP, IBERSEIS and others.

The resulting DEKORP database consists of approximately 40 crustal-scale 2D-seismic reflection lines covering a total of ca. 4 700 km and one 3D-seismic survey covering ca. 400 km², recorded in close connection with the German Continental Deep Drilling Program (KTB). Nowadays, re-recording of these seismic traverses in the same extent and quality would often not be possible anymore due to increased acquisition costs and tightened permission requirements. Therefore these datasets provide unique and deep insights into the subsurface below Germany covering the earth’s crust from the surface to the upper mantle.

Currently, many of the original raw data are still stored on old storage media and in formats, which can only be read by special devices, programs and experts. To prevent the final loss of this valuable geoscientific treasure an initiative at GFZ transcripts all relevant DEKORP data to modern formats and media.

Over the last few years the demand for DEKORP data continuously increased. Several academic institutions and commercial companies reprocess and/or reinterpret these data, which lead to significant improvements in the quality of the results. Fields of applications are geothermal development, hazard analysis, hydrocarbon/shale gas exploration, underground gas storage, tunnel construction, disposal of nuclear waste and more.

To simplify the data access for the scientific as well as for the commercial geo-community, a well-structured provision and utilisation concept is being developed. The concept includes so-called data publications with DOIs, a defined license model and automised retrieval for each of the surveys providing raw data, processed data, meta data, related links and more. The plan aims to have all relevant DEKORP datasets compiled and prepared for access via web interface till 2022.

Über die Anwendbarkeit einer 2D SH Wellenforminversion zur hochauflösenden Abbildung von heterogenen 3D Untergrundstrukturen

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Abstract
In den letzten Jahren hat sich die seismische Full Waveform Inversion (FWI) zur Charakterisierung von Untergrundstrukturen im Bereich der Ingenieurgeophysik, Archäogeophysik und seismischen Kohlenwasserstoffexploration etabliert. Dabei beschränken sich viele Anwendungen auf die Verwendung einer 2D Approximation der Grundgleichungen zur Beschreibung der seismischen Wellenausbreitung, selbst wenn die Geologie des Untergrundes eine 3D Beschreibung des Mediums erfordert.

In dieser Arbeit soll die Anwendbarkeit einer 2D SH FWI zur Auflösung von heterogenen 3D Untergrundstrukturen untersucht werden. Im Rahmen des ANGUS-II Projekts wurde eine potentielle Störungszone östlich des Großen Plöner Sees in Schleswig-Holstein untersucht. Eine an der Oberfläche deutlich sichtbare Abbruchkante und signifikante Variationen der Topographie deuten auf eine tektonische Struktur hin. Im Rahmen von zwei umfangreichen Messkampagnen der CAU Kiel im Jahr 2017/2018 wurden vier sich kreuzende seismische SH-Profile in der unmittelbaren Umgebung der Abbruchkante gemessen.

Die unabhängige FWI der seismischen SH-Profile nach dem Scherwellengeschwindigkeits- und Dichtemodell enthüllt komplexe, heterogene, gescherte und verworfene Untergrundstrukturen in unmittelbarer Nähe der Abbruchkante. Trotz der Heterogenität des Untergrundes und der vereinfachten 2D Vorwärtsmodellierung finden sich an den Schnittstellen der Profile ähnliche Strukturen. Im Bereich der Abbruchkante lassen sich nach SW einfallende Schichten identifizieren. Eine Verlängerung der Abbruchkante auf die seismischen Profile korreliert mit Niedriggeschwindigkeitsanomalien in den Vs-Modellen. Die FWI-Dichtemodelle zeigen eine Korrelation mit Bohrlochdichtelogs.

Das Projekt ANGUS-II wird gefördert durch das Bundesministerium für Wirtschaft und Energie (Förderkennzeichen 03ET6122A).

SE Seismik: e-Poster
SE-14

Charakterisierung einer Störungszone im Bereich der Eckernförder Bucht mittels NIP-Wellentomographie und akustischer 2D Wellenforminversion

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Abstract
Im Rahmen des ANGUS-II Projektes sollte ein tektonisches Störungssystem im Bereich der Eckernförder Bucht (Schleswig-Holstein) mit Hilfe einer akustischen 2D Full Waveform Inversion (FWI) untersucht werden. Datengrundlage ist ein ca. 2 km langes Profil, welches im Frühjahr 2019 am Strand der Eckernförder Bucht gemessen wurde. Dabei besteht die Akquisitionsgeometrie aus 81 Schusspunkten, an denen seismische Wellen mit einem vertikalen Fallgewicht angeregt und von 205 Vertikalgeophonen aufgezeichnet wurde.

Der Schlüssel zur erfolgreichen Anwendung einer hochauflösenden FWI ist ein Startmodell, welches den langwelligen Anteil des aufgezeichneten Wellenfeldes möglichst gut beschreiben kann. Aufgrund der geringen Offsets können nur reflektierte Wellen für die Bestimmung dieses Modells genutzt werden. Im Gegensatz zur klassischen CMP- verwenden wir die Common-Reflection Surface (CRS) Analyse. Die aus der CRS Analyse abgeleiteten Stapel-Parameter bilden die Grundlage für einen reflexionsseismischen Tomographieansatz (NIP-Wellentomographie) mit dem sich ein langwelliges P-Wellengeschwindigkeitsmodell des Untergrundes bestimmen lässt.

Durch die Kombination aus CRS-Stack, NIP-Wellentomographie und seismischer FWI lässt sich ein komplex gestörter Untergrund im Bereich der Eckernförder Bucht hochauflösend abbilden.

Danksagung:
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Das Projekt ANGUS-II wird gefördert durch das Bundesministerium für Wirtschaft und Energie (Förderkennzeichen 03ET6122A).

SE Seismik: e-Poster
SE-16

Ermittlung der Einflüsse des flachen lokalen Untergrunds auf seismische Wellenausbreitung mittels Auswertung von 3D-Seismik Daten

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Abstract
Für die Mikrozonierung des lokalen (Stations-) Untergrunds existieren eine Reihe verschiedener Verfahren, welche meist sehr aufwendig sind und umfangreiche Messungen vor Ort erfordern, vor allem, wenn die Bestimmung kleinräumiger Strukturunterschiede vorgenommen werden soll. So können Unterschiede in der lokalen Verstärkung durch den Vergleich der Registrierung von Fernbeben erfolgen, durch eine Auswertung des seismischen Noise aus Horizontal- und Vertikalspektren (H/V-Methode) oder durch die Kreuzkorrelation diffuser Wellenfelder. Auch kann der Aufbau des lokalen Stationsuntergrundes direkt durch Bohrungen oder passive Arraymessungen und kleinskalige aktive Refraktionsmessungen ermittelt werden. Diese Ansätze verhindern jedoch sehr oft aus praktischen und finanziellen Gründen eine großflächige Auswertung. Hier wird nun ein Ansatz vorgestellt, eine solche Mikrozonierung beispielhaft basierend auf den Daten einer im Süden Münchens durchgeführten 3D-Seismik zu erstellen. Hierfür wird ein Verfahren verwendet, welches die aufgetretenen Amplituden an der Geophonlokationen basierend auf der jeweiligen Schusspunktentfernung ermittelt und korrigiert, sowie gleichzeitig Einflüsse durch eine mögliche unterschiedliche Kopplung der Geophone an den Untergrund quantifiziert. Jede Geophonlokation wird durch eine Vielzahl von Quelllokationen angeregt und somit können die Ergebnisse statistisch interpretiert werden. Dies bedeutet, dass neben der Angabe einer frequenzabhängigen Verstärkung des Untergrundes gleichzeitig auch die Angabe darüber möglich ist, mit welcher statistischen Sicherheit diese Verstärkung ermittelt werden konnte. Hierdurch können oberflächennahe Verstärkungskarten für das gesamte Messgebiet der 3D-Seismik erstellt werden. Weder Annahmen über den Aufbau des lokalen Untergrundes, noch über die Verteilung der seismischen Geschwindigkeiten gehen in diese Berechnung ein, da sie direkt aus Messwerten bestimmt werden, die jeweils an diesem Ort selbst gemessen wurden. Letztendlich können diese Ergebnisse verwendet werden, die durch punktuelle Messungen (Array, aktive Refraktionsseismik, Rotationssensor) ermittelten Verstärkungsfaktoren zu verifizieren und so eine flächige Mikrozonierung des Messgebiets zu erhalten.

SE Seismik: e-Poster
SE-15

Anisotropic velocity models for (3D) seismic imaging of the Lower Seve Nappe in Jämtland, Sweden

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Abstract
Strong anisotropy of seismic velocity in the Earth crust poses serious challenges for seismic imaging. Where in situ seismic properties are not available the anisotropy can be determined from independent surface and borehole seismic profiles. This is well established for dense, long-offset reflection seismic data. However, it is unknown how applicable this approach is for sparse seismic reflection data with low fold and short offsets. Here, we show that anisotropy parameters can be determined from a sparse 3D data set at the COSC-1 borehole site in the Swedish Caledonides and that the results agree well with the seismic anisotropic parameters determined on core samples from laboratory measurements. Applying these anisotropy parameters during 3D seismic processing significantly improves the seismic imaging of the high amplitude reflections especially in the lower part of the borehole. Strong reflectors in the resulting seismic data align well with the borehole-derived lithology. Our results aid the interpretation and extrapolation of the seismic stratigraphy of the Lower Seve Nappe.

SE Seismik: Oral presentation (by invitation only)

SE Seismik: Oral presentation (by invitation only)
V3-1

Random-objective waveform inversion of shallow-seismic wavefield

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Abstract
Full-waveform inversion (FWI) is becoming a popular geophysical technique to characterize the physical properties of subsurface models on a broad range of scales. There are several problems that FWI faces, such as high computational cost, high ill-posedness, and lack of uncertainty information. We developed a random-objective waveform inversion (ROWI) method to address these problems. In ROWI, we build multi-objective functions and use a stochastic gradient descent algorithm for optimization. Three different measure functions: the least-squares waveform misfit, the f-k spectra misfit, and the envelope misfit, are used in the multi-objective functions to account for the properties of the shallow-seismic wavefield. The combination of every single shot and every single measure function formulates one of the multi-objective functions independently. This multi-objective framework reduces the ill-posedness of the inverse problem. Additionally, we can estimate the uncertainty information of the model parameters by analyzing the distribution of Pareto optimal solutions in the model space. In the optimization, we randomly choose and treat only one of the multi-objective functions per iteration. Therefore, we avoid using redundant data during the iteration to improve computational efficiency.
We applied ROWI to a 3D 9-component field shallow-seismic example acquired in Rheinstetten, Germany, to demonstrate the robustness and efficiency of ROWI in reconstructing the near-surface model. The distribution of Pareto optimal solutions in the model space provides uncertainty information for the reconstructed model parameters. The reliability of the reconstructed model is verified by multiple 2D ground-penetrating radar profiles.

SE Seismik: Oral presentation (by invitation only)
V3-2

Combination of 3D Borehole Radar and Underground Reflection Seismic - A Case Study for In-Mine Exploration

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Abstract
Within the scope of the SIT4ME research project, a hybrid method consisting of underground reflection seismic and 3D borehole radar investigations was applied to investigate the surroundings of a mine gallery in the Asse II mine (Germany). The Asse II mine is a former salt mine located 70 km southeast of Hannover in Lower Saxony, Germany at the western end of a NW-SE extending salt dome structure including anticlinal uplifted Mesozoic sediments of the western hercynian basin. Between 1967 and 1978, the federal institute for radioactive waste disposal (BGE) used the mine as a deep geological repository for low-level and intermediate-level radioactive waste. In the course of the “Act for the Acceleration of the Recovery of Radioactive Waste and the Closure of the Asse II Mine”, the BGE plans to retrieve all waste material stored by constructing a new shaft in direct proximity to the former emplacement chambers beyond the limits of the local salt dome structure. Hence, the objectives of this study comprised the localization of the salt dome limits, the verification of known geological structures and the discovery of unknown geological conditions. Thus, seismic measurements were performed in a 140 m long gallery section of the Asse II mine, located 15 m ahead of the local gallery face. Within this section, 35 three-component geophone probes were installed in vertical boreholes (gallery floor) with an inline spacing of 4 m. Hammer strikes were carried out at every geophone and source position to generate the seismic signals. The 3D borehole radar survey was performed with two different frequencies, 250 MHz and 50 MHz in an approximately 300 m long exploration drilling positioned at the gallery face of the target gallery. After editing, processing and evaluating both datasets, it became clear that the results of the measurements provide different, but complementary outputs. Both techniques helped to identify several structures of the local salt dome. The 3D borehole radar investigations applying the 50 MHz signal resolved several structures in up to 300 m distance to the borehole. These structures include mine workings, internal salt structures and geological interfaces. In contrary, the 250 MHz probe helped to detect structures in the direct vicinity of the borehole. The seismic measurement helped to extract 24 seismic reflectors, which display both, geological interfaces within the salt dome and the desired limits of the salt dome.

SE Seismik: Oral presentation (by invitation only)
V3-3

Scherwellenseismik als Werkzeug zur Lokalisierung erdfallgefährdeter Gebiete in Schleswig-Holstein

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Abstract
Sowohl plötzliche als auch kontinuierliche Absenkungen des Erdreichs stellen insbesondere im urbanen Raum ein Georisiko für die Bevölkerung und Infrastruktur dar. In Schleswig-Holstein treten solche ‚Erdfälle' und Subrosionssenken an Salzstockhochlagen auf; lösungsfähiges Material wird aus den aufgestiegenen Salzstöcken des Perms herausgelöst, wodurch Massendefizite im oberflächennahen Untergrund entstehen; gravitativ angetriebene Bewegungen des Hangenden führen anschließend zu langsamen aber auch plötzlichen Absenkungen der Erdoberfläche.
Bereits seit vielen Jahrzehnten sind diverse Erdfälle auf den Salzstrukturen Elmshorn und Quickborn bekannt. Die dazu gesammelte geologische Datenbasis wurden unlängst unterstützt durch scherwellenseismische Profilnetze, die in Verbindung mit den geologischen Informationen dazu beitragen, hochauflösend den räumlichen Verlauf der Salzstrukturen und aufliegenden Sedimente zu klären und subrosionsgefährdete Bereiche genauer zu identifizieren. Die Profilnetze wurden mit einem Elvis-Scherwellenvibrator (Quellsignal: 20-160 Hz Sweep) und einem Landstreamer erzeugt. Mit einem Schussabstand von 2-4 m und einem Geophonabstand von 1 m wurden hochauflösende Stapelsektionen mit einem halben Metern CMP-Abstand generiert. Es zeigt sich, dass die Scherwellenmethodik geeignet ist, die lateral heterogene Oberfläche der Salzstruktur (Hutgestein-Oberfläche) und die Feinstruktur der hangenden Sedimente abzubilden. Starke topographische Variationen in der Hutgestein-Oberfläche sowie eine stark heterogene Lithologie sowohl des Hutgesteins als auch der hangenden Sedimente treten über kurze laterale Ausdehnungen kleiner 100 m auf und bekräftigen die Notwendigkeit eines engmaschigen Profilnetzes.
Am Beispielgebiet Marienhöhe in Quickborn werden weiterführende Detailanalysen sowohl der strukturellen Integrität der Schichtabfolge als auch der Scherwellengeschwindigkeit gezeigt. Mittels Erweiterung der reflexionsseismischen Auswertungen um VSP-Analyse und Wellenforminversion ist es möglich, seismische Geschwindigkeiten und Geschwindigkeitsinversionen präziser abzubilden. Die Ergebnisse belegen das strukturelle Aussagepotenzial der Scherwellenseismik für die Untersuchung subrosionsgefährdeter Gebiete sowie das weiterführende Potenzial der Methodik zur Verbesserung des Verständnisses für Subrosionsprozesse.

SO

Seismologie

SO Seismologie: e-Poster

SO Seismologie: e-Poster
SO1-01

Das Zollernalb-Erdbeben vom 1. Dezember 2020: Makroseismik und Herdparameter

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Abstract
Auf der Zollernalb, Baden-Württemberg, ereignete sich nördlich von Albstadt am 1. Dezember 2020 in einer Tiefe von ca. 7 km ein Erdbeben zwischen Jungingen und Burladingen mit einer Lokalmagnitude von ML = 3,9. Es war damit das stärkste Ereignis in der Region seit dem Erdbeben bei Albstadt-Ebingen (ML = 4,4) im Jahr 2003. Die Seismizität ist hier geprägt von der sogenannten Albstadt-Scherzone, einer NS-streichenden Zone verstärkter Aktivität und dem NW-SE-streichenden Hohenzollerngraben. Seit dem Beginn des 20. Jahrhunderts ereigneten sich regelmäßig Erdbeben, die von der Bevölkerung verspürt werden konnten und zum Teil auch Sachschäden verursachten. So erreichten die stärksten Erdbeben (1911, 1943, 1978) maximale Intensitäten von bis zu VIII (EMS).

Das Erdbeben vom 1. Dezember 2020 wurde in weiten Teilen Baden-Württembergs und vereinzelt auch darüber hinaus verspürt. Alleine beim Landeserdbebendienst Baden-Württemberg (LED) am Regierungspräsidium Freiburg gingen über 6000 Wahrnehmungsmeldungen aus der Bevölkerung aus ganz Baden-Württembergs ein. Es gab aber auch Wahrnehmungsmeldungen aus Bayern, dem Elsass und der nördlichen Schweiz. Das Erdbeben erreichte eine maximale Intensität von V (EMS) in der Herdregion. Auffällig sind die zahlreichen deutlichen Wahrnehmungen mit Intensitäten von III oder IV aus dem etwa in 40 km nördlichen gelegenden Stuttgarter Raum. Auch scheint die Stärke der Auswirkungen des Erdbebens nach Osten hin schneller abzunehmen als nach Westen. Diese Verteilung wurde auch bei anderen Erdbeben der Region beobachtet. Eine Ausnahme bildet dabei Ulm, wo das Erdbeben deutlicher als in der Umgebung verspürt worden ist. Mit den gemessenen Beschleunigungen (PGA-Werte) lässt sich dies nicht ohne Weiteres erklären.

Herdflächenlösung und Relativlokalisierung tragen zum weiteren Verständnis des Ereignisses bei.

SO Seismologie: e-Poster
SO1-11

The seismological signature of cyclonic storms through the ears of a sensor array.

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Abstract
Under certain conditions, ocean surface gravity waves (SGW) interact with the seafloor underneath to trigger relatively faint but measurable seismic waves known as ocean microseisms. Cyclonic storms (*e.g.* hurricanes, typhoons) wandering over the ocean are major (non-stationary) sources of the former, thus opening the possibility of tracking and studying cyclones by means of their corresponding microseims.

For this purpose, we identified storm-related microseisms hidden in the ambient seismic wavefield via array processing. Polarization beamforming, a robust and well-known technique is implemented. The analyses hinge on surface waves (Love and Rayleigh) which, in contrast to P-waves, are stronger but only constrain direction of arrival (without source remoteness). We use a few land-based virtual seismic arrays surrounding the North Atlantic to investigate the signatures of major hurricanes in the microseismic band (0.05-0.16 Hz), in a joint attempt to continuously triangulate their tracks.

Our findings show that storm microseisms are intermittently excited with modulated amplitude at localized oceanic regions, particularly over the shallow continental shelves and slopes, having maximum amplitudes virtually independent of storm category. In most cases no detection was possible over deep oceanic regions, nor at distant arrays. Additionally, the rear quadrants and trailing swells of the cyclone provide the optimum SGW spectrum for the generation of microseisms, often shifted more than 500 km off the "eye".

As a result of the aforementioned and added to the strong attenuation of storm microseisms, the inversion of tracks or physical properties of storms using a few far-field arrays is discontinuous in most cases, being reliable only if benchmark atmospheric and/or oceanic data is available for comparison.

Even if challenging due to the complexity of the coupled phenomena responsible for microseisms, the inversion of site properties, such as bathymetric parameters (*e.g.* depth, seabed geomorphology), near-bottom geology or SGW spectrum might be possible if storms are treated as natural sources in time-lapse ambient noise investigations. This will likely require near-field (land and underwater) observations using optimal arrays or dense, widespread sensor networks. Improved detection and understanding of ocean microseisms carries a great potential to contribute to mechanically coupled atmosphere-ocean-earth models.

SO Seismologie: e-Poster
SO1-02

Anwendung des Ausschlusskriteriums „Seismische Aktivität“ bei der Suche und Auswahl eines Standortes für ein Endlager für hochradioaktive Abfälle in Deutschland

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Abstract
Im Standortauswahlgesetz wird in § 22 zum Ausschlusskriterium „Seismische Aktivität“ ausgeführt, dass ein Gebiet nicht als Endlagerstandort geeignet ist, wenn die örtliche seismische Gefährdung größer als in Erdbebenzone 1 nach DIN EN 1998-1/NA:2011-01 ist. Diese Norm wird in Kürze durch eine Aktualisierung ersetzt, die dem Stand von Wissenschaft und Technik entspricht. Der Entwurf hierzu, E DIN EN 1998-1/NA:2018-10, enthält keine Zuordnungen in Erdbebenzonen mehr, sondern weist die seismische Gefährdung räumlich kontinuierlich aus.
Die Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) hat im Auftrag der Bundesgesellschaft für Endlagerung einen Vorschlag zur Anwendung dieses Ausschlusskriteriums unter Verwendung von E DIN EN 1998-1/NA:2018-10 erarbeitet. Die BGR schlägt vor, als Grenzwert zur Anwendung des Ausschlusskriteriums den Wert der spektralen Antwortbeschleunigung im Plateaubereich von 1,8 ms^{-2} in E DIN EN 1998-1/NA:2018-10 zu verwenden. Dieser Wert entspricht der makroseismischen Intensität 7, für den die seismische Gefährdung größer als in Erdbebenzone 1 nach DIN EN 1998-1/NA:2011-01 ist. Für Gebiete, in denen dieser Wert überschritten wird, gilt das Ausschlusskriterium als erfüllt.
Grundsätzlich ist das Ausschlusskriterium „Seismische Aktivität“ im Standortauswahlgesetz jedoch wenig geeignet, um die Erdbebengefährdung eines Standortes für ein Endlager für hochradioaktive Abfälle zu ermitteln. Der Bewertungszeitraum für die Sicherheit des Endlagers beträgt eine Million Jahre und unterscheidet sich erheblich vom Betrachtungszeitraum von 50 Jahren der Norm DIN EN 1998-1/NA. Die Intensität bzw. die Beschleunigung gilt für die Erdoberfläche; die Endlagerung hochradioaktiver Abfälle soll jedoch in tiefen geologischen Formationen erfolgen. Neben der Gefährdung aufgrund von seismischen Bodenbewegungen als Bewertungsmaßstab des Ausschlusskriteriums hat eine andere Art der Gefährdung durch Erdbeben für Endlager in tiefen geologischen Formationen eine größere Bedeutung, nämlich bruchartige Verschiebungen im Endlagerbereich. Das Ausschlusskriterium „Seismische Aktivität“ bezieht sich im Unterschied zu allen anderen Ausschlusskriterien in Standortauswahlgesetz § 22 nicht auf ein wissenschaftlich formuliertes Merkmal, sondern auf eine Norm, deren Bemessungsgrößen aufgrund eines Kompromisses zwischen Sicherheitsbetrachtungen und wirtschaftlichen Überlegungen wie erhöhten Baukosten festgelegt wurden.

SO Seismologie: e-Poster
SO1-03

Seismotectonic regions in Germany based on a new concept

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Abstract
Seismotectonic regions are a basic input in seismic hazard assessment. Several seismotectonic zonations for Germany have been proposed in the past. We have developed a new regionalization based on the definition in the German Nuclear Safety Standard: “A seismotectonic unit is a region for which uniformity is assumed regarding seismic activity, geological structure and development and, in particular, regarding neotectonic conditions”. Our new concept aims for transparent implementation of geological criteria, which we initially analyze separately from seismicity. We strive for a better documentation and justification of the geological elements used to delimit seismotectonic regions, based on an analysis of the geological evolution in six time slices from the Permian (300 Ma) to the Present. The time slices are separated by marked changes in the tectonic regime and associated with the development of new fault systems or reactivation of existing ones. The present-day fault network comprises faults from all time slices. For each time slice, a subset of active faults has been extracted based on geological evidence for fault activity at that time. Uncertainties of these age assignments are documented. The fault subsets delimit regions of different strain intensity. The superposition of strain intensity distributions across all time slices identifies regions affected by polyphase deformation and regions nearly undeformed over geological time, potentially indicating areas of increased or reduced present-day seismic hazard.
Our new zonation consists of fewer regions than earlier ones. The geological zonation correlates well with recent seismicity in areas of Cenozoic rifting and reasonably well with less frequent earthquakes in a belt affected by Mesozoic extension and contraction. However, a few stronger earthquake cluster in regions of low geological strain. The most prominent earthquake clusters (Swabian Jura, Vogtland / NW Bohemia) also defy a simple correlation with known geological structures.

SO Seismologie: e-Poster
SO1-04

Risikoanalyse eines Erdbebenszenarios für die Stadt Köln und die Niederrheinische Bucht

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Abstract
Wenngleich die Niederrheinische Bucht im europäischen Vergleich nur eine moderate seismische Gefährdung aufweist, so ist sie doch innerhalb Deutschlands eines der Gebiete, in dem Erdbeben verhältnismäßig häufig auftreten. Diese Studie quantifiziert die Auswirkungen eines Szenario-Erdbebens am Erftsprung südwestlich von Köln mit einer Momentenmagnitude von 6,5. In der Niederrheinischen Bucht liegen mächtige Schichten von quartären Sedimenten mit starken Impedanzkontrasten in der Tiefe vor; dies hat einen signifikanten Einfluss auf die Dauer und die Stärke der Bodenbewegung bei einem Erdben. Basierend auf einem neuen harmonisierten und räumlich hoch aufgelösten 3D Modell des Untergrunds wird mit Hilfe unterschiedlicher Modellierungsansätze (random vibration Theorie, physikalische Modellierung) die Stärke und die räumliche Verteilung der Bodenbewegung in der gesamten Niederrheinischen Bucht berechnet und in makroseismische Intensität überführt. Entsprechende Schadensberechnungen werden dann auf Basis der Schadensstufen der Europäischen Makroseismischen Skala (EMS-98) für Wohngebäude und Gebäude mit gemischter Wohn- und Gewerbenutzung in der Stadt Köln durchgeführt. Ergebnisse der Schadensberechnungen werden in Form der Anzahl der Gebäude, die den einzelnen EMS-98-Intensitätsstufen ausgesetzt sind, und der Wahrscheinlichkeiten, dass die entsprechenden Wohngebäude diesen Schadensgrad erleiden, dargestellt. Die Ergebnisse zeigen, dass bei einem solchen Beben, welches sich etwa alle 1000 Jahre ereignet, ein erhebliches Risiko für die Stadt Köln besteht.

SO Seismologie: e-Poster
SO1-07

Robust finite earthquake source models from the combination of geodetic and seismic data

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Abstract
Large and shallow crustal earthquakes reveal characteristics of tectonic faults, often by causing considerable damage. Many of them can be studied by using geodetic data, e.g. InSAR data, as well as local to global seismological data. InSAR data provide co-seismic static surface displacements at high spatial resolution that are proportional to the moment and characteristic for the source location, geometry and dimension. Far-field seismic waves carry information about the time-dependent moment release during the rupture. Both datasets are sensitive to the source mechanism. In combination, the weaknesses of each individual data set can potentially be compensated, while information is accumulated.

We have developed methods that enable a strictly quantitative combination of near-field InSAR data and seismic waveforms for kinematic earthquake source modeling. We represent the earthquake with a finite rupture plane of rectangular shape and uniform slip, or a number of planes to allow for segmented faulting if required by the data. Within wide parameter ranges, we estimate the location, dimension and orientation of the rupture plane and the amount and direction of slip. Furthermore, we estimate the nucleation point and the average rupture velocity. The incorporation of Bayesian Bootstrap allows us to rigorously propagate data errors into ensembles of models, representing the model uncertainty.

We apply our methods in a standardized and semi-automated way to about half a dozen instrumentally recorded crustal earthquakes with Mw 6-7 from different tectonic regimes around the globe. We discuss to which extent our use of open global data helps to robustly constrain the faulting and hazard-relevant rupture characteristics. For some examples we compare our results with independent teleseismic multi-array backprojection. These finite but still rather simple source models are highly robust and appear to well reproduce the locations of seismic energy excitation up to 1.5Hz in synthetic-data backprojection. Potentially, source ensembles can be used for informed rupture and ground motion simulations.
We investigate how the data combination benefits for future robust source catalogs that provide a high degree of source complexity.

The presented methods are published open access and open source as part of the Pyrocko software project (pyrocko.org).

SO Seismologie: e-Poster
SO1-09

Characterisation of seismic events using time-reverse imaging

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Abstract
In addition to stable and accurate hypocenters of seismic events, the characterisation of events is crucial for the investigation of seismicity in the context of geothermal reservoirs, CO2-sequestration and other geotechnical applications. Since the origin and nature of the seismicity in such cases is still under investigation, tools should rely on as few a priori assumptions about the sources as possible. Here, an approach is presented to determine the time-dependent moment tensor and origin time in addition to commonly derived hypocenter locations of seismic events using time-reverse imaging (TRI). The full six component moment tensor is derived and may be used to display for example focal mechanisms. The workflow consists of determining the location of potential sources, discriminating artificial and true source locations and obtaining the time-dependent moment tensors by recording the stress components at the derived source locations. Since TRI does not rely on the identification of seismic phases but on the simulation of the time-reversed wavefield through an adequate velocity model, no assumptions about the source location or the type of source mechanism is made. TRI is less affected by low signal-to-noise ratios and is thus promising for noisier sites and quasi-simultaneous events. However, a sufficient number of seismic stations are needed to accurately sample the wavefield spatially. The proposed workflow is demonstrated by locating and characterising microseismic events in the geothermal field of Los Humeros, Mexico. Although higher levels of noise are present and only a one-dimensional velocity model is available at this time, selected events could be located and characterised.

SO Seismologie: e-Poster
SO1-10

A study of thermoelastic effects in seismic monuments and their signature in low-frequency seismic data collected on Earth and on Mars.

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Abstract
The NASA mission InSight to Mars observed a number of Phobos transits which resulted in a transient tilt of the VBB broad-band seismometer (Stähler et al., GRL, 2020). Triggered by these eclipse events which each last at most 30 seconds we conducted experiments at BFO to corroborate the interpretation that the seismometer tilts result
from changes in illumination and subsequent thermoelastic ground deformations.

While both the VBB on Mars and observatory grade terrestrial seismometers are furbished with extensive thermal shielding it is not a priori clear how a change in outside irradiation can lead to a seismometer tilt within only 5 to 10 seconds, as observed on Mars.

Our experimental setup consists of a 100 Watt incandescent light bulb with which we illuminate piers with thermally shielded seismometers in the BFO mine. By placing a bulb directly on the concrete pier and switching on the bulb for only 1 minute at each location we have mapped out the tilt response as a function of the bulb location. To first order the seismometer tilts away from the bulb location and the degree of tilting decays with distance away from the bulb.

While the skin depth for a heat pulse of 30s is only 2 mm for concrete and less than 0.5 mm for Martian regolith this thin surface layer is still elastically coupled to the volume below and if the surface layer expands (light bulb experiments) or contracts (Phobos transit) the volume below must follow based on Hooke's law.

We find that only pier instruments show a clear response to illumination events while sensors installed in 160 cm deep post holes show almost no reaction. Our experiments also lead us to suggest that to further improve low-frequency horizontal component seismic recordings it may be beneficial to thermally isolate not only the sensors but also the pier on which they are installed.

Finite element calculations are planned to simulate these experiments and to further confirm the interpretation.

SO Seismologie: e-Poster
SO1-04

Architecture of the crust and lithosphere beneath the Semail Ophiolite from ambient noise tomography and Receiver Functions: insights on the tectonic evolution of the eastern Arabian Plate

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Abstract
The Semail Ophiolite is the world‘s largest and best exposed oceanic lithosphere on land and a primary reference site for studies of creation of oceanic lithosphere, initiation of subduction, geodynamic models of obduction, subduction and exhumation of continental rocks during obduction. Five decades of geological mapping, structural, petrological and geochronological research provide a robust understanding of the geodynamic evolution of the shallow continental crust in northern Oman and how the late Cretaceous obduction process largely shaped the present-day landscape. Yet, prior to obduction, other first-order tectonic processes have left their imprint in the lithosphere, in particular the Neoproterozoic accretion of Arabia and Permian breakup of Pangea. Due to the scarcity of deep structure imaging below the ophiolite, the presence and significance of inherited structures for the obduction process remain unclear.
We discuss a new 3-D anisotropic shear wave velocity model of the crust below northern Oman derived from ambient noise tomography and Receiver Function analysis which allows to resolve some key unknowns in geodynamics of eastern Arabia: (1) Several NE-trending structural boundaries in the middle and lower crust are attributed to the Pan-African orogeny and align with first-order lateral changes in surface geology and topography. (2) The well-known Semail Gap Fault Zone is an upper crustal feature whereas two other deep crustal faults are newly identified. (3) Permian rifting occurred on both eastern and northern margins but large-scale mafic intrusions and/or underplating occurred only in the east. (4) While obduction is inherently lithospheric by nature, its effects are mostly observed at shallow crustal depths, and lateral variations in its geometry and dynamics can be explained by effects on pre-existing Pan-African and Permian structures. (5) Continental subduction and exhumation during late Cretaceous obduction may be the cause for crustal thickening below today‘s topography. (6) Thinning of the continental lithosphere below northern Oman in late Eocene times – possibly related to thermal effects of the incipient Afar mantle plume - provides a plausible mechanism for the broad emergence of the Oman Mountains and in particular the Jabal Akhdar Dome. Uplift might thus be unrelated to compressional tectonics during Arabia-Eurasia convergence as previously believed.

SO Seismologie: e-Poster
SO1-05

Die ungewöhnliche Intraplattenrotation in Deutschland und ihre mögliche Rolle zur Quantifizierung der seismischen Gefährdungszonen

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Abstract
Eine zentrale Frage der seismischen Gefährdungsanalyse ist es zu verstehen, wo und wie häufig Intraplatten Schadensbeben auftreten können. Mit kontinuierlichen, satellitengestützen Entfernungsmessungen (GNSS und SAPOS Sationen) über Jahrzehnte und hochentwickelten Prozessierungsmethoden lassen sich heutzutage horizontale Geschwindigkeiten der Erdoberfläche kleiner als 0.2 mm/a auflösen. Damit kann mit räumlich dichten Messnetzen die Deformation nicht nur an Plattengrenzen, sondern auch innerhalb einer Platte quantifiziert und mit der aktuellen Seismizität verglichen werden. Deformationen innerhalb einer Platte können z.B. mit Prozessen im Erdmantel, einer diffusen oder zonalen Scherung entlang struktureller Schwächzonen oder mit der Rotation starrer Krustenblöcke zusammenhängen.

Wir leiten erstmals dichte, hochpräzise Netzwerklösungen an 323 GNSS-Stationen in Deutschland und angrenzenden Gebieten ab und kombinieren diese mit Geschwindigkeitslösungen benachbarter Länder. Lokale und regionale Hebungsgebiete betragen bis zu ~2 mm/a und korrelieren mit der Kollisionszone der Alpen und dem quartären/tertiären Vulkanismus in Deutschland. Zusätzlich werden Hebungsregionen unbekannter Ursache im Ostdeutschen Becken detektiert. Auffällig ist die Rotationsbewegung des gesamten westdeutschen Blocks nördlich der Alpen, mit Winkelgeschwindigkeiten von ~0.7±0.3 mas/a. Die Flankenbreiche des Blocks werden durch NS gerichtete Scherzonen mit Deformationsraten von bis zu 10^{-8} 1/a charakterisiert. Die Intraplatten Rotation könnte am nördlichen und südlichen Ende des Blocks kinematisch angetrieben und durch laterale Variationen in der mitteleuropäischen Lithosphäre beeinflußt werden. Die Zone erniedrigter Geschwindigkeiten im Mantel zwischen Rheingraben und Harz und der Mantle Plume unter der Eifel könnte eine aktive Rolle spielen.

Die auffälligste Scherzone hat eine Erstreckung in NS Richtung von mehr als 900 km von Kufstein bis an die Ostsee und zeigt auch in fluviativen Entwässergungsystemen Auffälligkeiten. Allerdings fehlen in der Scherzone historische Erdbeben, und dort wo sie ausgeprägt sind wie zwischen Leipzig und dem Vogtland, ist der Richtungssinn der Herdlösung entgegen dem Richtungssinn der Scherdeformationsrate. Umgekehrt liegen Gürtel mit hoher Seismizität teilweise in Regionen mit geringer Deformationsrate. Eine solche Nicht-Korrelation ist vollkommen unerwartet und bedarf der Erläuterung.

SO Seismologie: e-Poster
SO1-08

Slip-deficit estimation with a 3D fault model of the North Anatolian Fault by using InSAR time series

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Abstract
Crustal earthquakes are events of sudden stress release through rock failure, for example as a consequence of continuous and long-term stress buildup at tectonic faults that eventually exceeds the strength of rock. Before failure, under increasing stress at a fault, the surrounding crust is slowly deforming. The amount and pattern of crustal deformation carries information about location and potential magnitude of future earthquakes.
Time series of space-borne interferometric Synthetic Aperture Radar (InSAR) data can be used to precisely measure the surface motion, which corresponds to the crustal deformation, in the radar line-of-sight. These observations open the opportunity to study fault loading in terms of location, size of locked parts at faults and their slip deficit. Here we study the North Anatolian Fault (NAF), a major right-lateral strike-slip fault zone of about 1500 km length in the north of Turkey and we create its first large-scale 3D finite-fault model based on InSAR data.

We use the InSAR time series of data recorded by ESA's Envisat SAR satellite between 2002 and 2010 (Hussain et al. 2018, Walters et al. In 2014). We represent the fault with several vertical, planar fault segments that trace the NAF with reasonable resolution. The medium model is a layered half space with a viscoelastic lower crust and mantle. We use the plate motion difference calculated through an Euler pole to set up a back-slip finite-fault model. We then optimize the back-slip as the slip deficit, the width and the depth of the locked fault zone at each segment to achieve a good fit to the measured surface motion.
We find shallow locking depths and small slip deficits in the eastern and westernmost regions of the NAF, while the central part shows both deeper locking depths and larger slip deficits for the observation period. The trends of both parameters are in an overall agreement to earlier studies. There, InSAR-time series data have been used to calculate slip deficits at the North Anatolian fault with 2D models and/or assuming a homogeneous and purely elastic medium. Local modeled differences therefore might be connected to differences in the modeling approaches but also remain subject to further investigations and discussions.

Our model provides a very suitable basis for future time-dependent modeling of the slip deficit at the NAF that includes also more recent InSAR time series based on data from the Sentinel-1 radar satellite mission of ESA.

SO Seismologie: e-Poster
SO2-02

Leveraging coherent wave field analysis and deep learning in fiber-optic seismology

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Abstract

Fiber-optic cables form an integral part of modern telecommunications infrastructure and are ubiquitous in particular in regions where dedicated seismic instrumentation is traditionally sparse or lacking entirely. Fiber-optic seismology promises to enable affordable and time-extended observations of earth and environmental processes at an unprecedented temporal and spatial resolution. The method's unique potential for combined large-N and large-T observations implies intriguing opportunities but also significant challenges in terms of data storage, data handling and computation.

Our goal is to enable real-time data enhancement, rapid signal detection and wave field characterization without the need for time-demanding user interaction. We therefore combine coherent wave field analysis, an optics-inspired processing framework developed in controlled-source seismology, with state-of-the-art deep convolutional neural network (CNN) architectures commonly used in visual perception. While conventional deep learning strategies have to rely on manually labeled or purely synthetic training datasets, coherent wave field analysis labels field data based on physical principles and enables large-scale and purely data-driven training of the CNN models. The shear amount of data already recorded in various settings makes artificial data generation by numerical modeling superfluous – a task that is often constrained by incomplete knowledge of the embedding medium and an insufficient description of processes at or close to the surface, which are challenging to capture in integrated simulations.

Applications to extensive field datasets acquired with dark-fiber infrastructure at a geothermal field in SW Iceland and in a town at the flank of Mt Etna, Italy, reveal that the suggested framework generalizes well across different observational scales and environments, and sheds new light on the origin of a broad range of physically distinct wave fields that can be sensed with fiber-optic technology. Owing to the real-time applicability with affordable computing infrastructure, our analysis lends itself well to rapid on-the-fly data enhancement, wave field separation and compression strategies, thereby promising to have a positive impact on the full processing chain currently in use in fiber-optic seismology.

SO Seismologie: e-Poster
SO1-12

Source locations of microseisms in the North Atlantic from Matched Field Processing using full Green's Functions.

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Abstract
Precise knowledge of the sources of seismic noise is fundamental to our understanding of the ambient seismic field and its generation mechanisms. Two approaches to locating such sources exist currently. One is based on minimizing the misfit between estimated Green's functions from cross-correlation of seismic noise and synthetically computed correlation functions. This approach is computationally expensive and not yet widely adopted. The other, more common approach is Beamforming, where a beam is computed by shifting waveforms in time corresponding to the slowness of a potentially arriving wave front. Beamforming allows fast computations, but is limited to the plane-wave assumption and sources outside of the array.

Matched Field Processing (MFP) is Beamforming in the spatial domain. By probing potential source locations directly, it allows for arbitrary wave propagation in the medium as well as sources inside of arrays. MFP has been successfully applied at local scale using a constant velocity for travel-time estimation, sufficient at that scale. At regional scale, travel times can be estimated from phase velocity maps, which are not yet available globally at microseism frequencies.

To expand MFP’s applicability to new regions and larger scales, we replace the replica vectors that contain only travel-time information with full synthetic Green's functions. This allows to capture the full complexity of wave propagation by including relative amplitude information between receivers and multiple phases. We apply the method to continuous recordings of stations surrounding the North Atlantic and locate seismic sources in the primary and secondary microseism band, using pre-computed databases of Green's functions for computational efficiency. The framework we introduce here can easily be adapted to a laterally homogeneous Earth once such Green’s function databases become available, hopefully in the near future.

SO Seismologie: e-Poster
SO1-15

Regional probabilistic seismic hazard assessment in Bangladesh

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Abstract
This presentation summarizes input data, procedures and results of probabilistic seismic hazard assessment (PSHA) in Bangladesh in the framework of the project 'Geo information for Urban Planning and Adaptation to Climate Change'. It is a cooperation of the Geological Survey of Bangladesh (GSB) and the Federal Institute for Geosciences and Natural Resources (BGR) of Germany. The main aim of the project is to provide city planners with "Ground Suitability Maps", which display different geo-factors. Seismic hazard is one of the geo-factors that contributes to these maps. For the derivation of "Ground Suitability Maps", the influence of the local underground conditions will be taken into account additionally. A major part of Bangladesh is located in earthquake prone regions due to active tectonics. The Indian plate moves north-eastward towards the Eurasian plate at a velocity of about 6 cm/year. This motion leads to thrusting to the north (Himalaya) and to subduction to the east together with strike-slip mechanism. The thrusting and subduction processes have caused large historical earthquakes even inside Bangladesh (e.g. 1885 Bengal Earthquake M7 and 1918 Srimangal Earthquake M7.6). Therefore, it is crucial to assess seismic hazard in urban planning in Bangladesh. The input databases were compiled from the literature, reviewed and evaluated in this study. These are earthquake catalog, the distribution of active faults and ground motion prediction equations. The most consistent and reliable databases were selected to be used in PSHA. The data of the earthquake catalog were declustered to eliminate the duplicated events, aftershocks and foreshocks. The spatial distribution of areal seismic sources was characterized using the distributions of earthquakes in the catalog and active faults. The completeness analysis of the earthquake catalog was performed and Gutenberg-Richter magnitude recurrence distribution was derived for each seismic source. The results of PSHA are presented in the form of peak ground acceleration (PGA) maps with 10% and 2% exceedance probabilities in 50 years. As usual in regional PSHA, the results are compiled assuming bedrock as underground condition (so-called engineering bedrock with shear velocity of V_{s30}≥760 m/s). The northern and eastern parts of Bangladesh show the highest seismic hazard with PGA around 0.4 g with 10% exceedance probability in 50 years. This observation was expected because of the active tectonics in these parts.

SO Seismologie: e-Poster
SO1-05

Seismizität im Omangebirge

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Abstract
Am östlichen Kontinentalrand der arabischen Platte befindet sich das Omangebirge mit einer Topographie von bis zu 3000m, welche ab dem späten Eozän in die heutige Form herausgehoben wurde. Das Gebirge ist zu weiten Teilen von dem bekannten Oman Ophioliten bedeckt, dem größten zusammenhängenden Fragment ozeanischer Lithosphäre an Land.
Auf der eigentlich als seismisch inaktiv geltenden Arabischen Platte wurden in der Vergangenheit im Bereich des Omangebirges durchaus, vorwiegend kleinere Erdbeben registriert. Somit stellt sich die Frage nach der Seismizität im Omangebirge und dem damit zusammenhängenden Spannungszustand in dieser Region. Hierfür wurden erstmals die Daten eines dichten temporären Seismometernetzes ausgewertet und mit den Daten des permanenten seismischen Netzes im Oman verglichen. Zunächst konnten Lokalisierungen zwischen dem permanenten und dem dichten temporären Netz abgeglichen werden. Es zeigt sich, dass das permanente Netz seismische Ereignisse im Omangebirge hinreichend generell gut erfasst und lokalisiert, sodass der seit 2003 bestehende Erdbebenkatalog eine zuverlässige Quelle darstellt, wobei aber mit dem temporären Netz die Grenzmagnitude zur Detektion von Events von 2,2 auf 2,0 Mw gesenkt werden konnte.
Um die Seismizität im Omangebirge besser zu verstehen, wurden zu den zwischen 2013 und 2016 mit dem temporären Netz lokalisierten und als tektonisch eingestuften Ereignissen erstmals für die Region Herdflächenmechanismen anhand der Polaritäten der P-Wellenersteinsätze bestimmt. Die Momentenmagnituden der untersuchten Beben lagen zwischen 1,7 und 3,3 und es konnten für 14 Ereignisse Herdflächen bestimmt werden. Ereignisse auf der Musandam-Halbinsel zeigen vorwiegend Transpression, während im zentralen Omangebirge vorwiegend Transtension vorherrscht.
Des Weiteren wurde eine Spannungsinversion durchgeführt. Diese ist trotz der geringen Anzahl an Events recht stabil und zeigt vor allem, dass die Hauptspannungsrichtung von Nordost nach Südwest gerichtet ist. Im Norden dominiert möglicherweise der Einfluss der kontinentalen Kollision zwischen Arabien und Eurasien das Spannungsfeld. Im zentralen und östlichen Bereich des Omangebirges scheinen die maximale Horizontal- und Vertikalspannung annähernd gleich gewichtet, was auf ein Vorherrschen von Extension in Nordwest-Südost Richtung hindeuten könnte.

SO Seismologie: e-Poster
SO1-13

Can we measure shallow groundwater content with urban seismic noise?

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Abstract
Nowadays, most detailed information about groundwater is acquired by wells that show a limited insight in time and especially space. Therefore, it would be interesting to monitor groundwater by continuously measuring seismic velocity changes in the subsurface.
In this study, we investigate the sensitivity of seismic waves to ground moisture changes in the uppermost layers of soil. Shallow soil is affected by environmental influences like temperature, rainfall or drought, which in turn changes the seismic velocity in the subsurface. To monitor velocity changes, Passive Image Interferometry is commonly applied. It makes use of calculating the Noise Correlation Functions (NCF) between two stations to represent a virtual source-receiver setting. Subsequently, velocity changes are measured on the coda waves, often using vertical components and oceanic seismic noise (<1 Hz).
In this study, 3-component seismometers are placed in the urban area of Hamburg, alongside meteorological and soil sensors. This setting enables to measure the high-frequent (>1 Hz) surface waves from cultural noise, which penetrate shallow soil. The NCFs are calculated for all component pairs in order to differentiate between Love and Rayleigh waves. Relative seismic velocity changes are retrieved using the stretching method.
The aim of this work is to determine whether both temperature and water content have a significant influence on velocity. Comparing seasonal relative velocity changes to environmental changes shows a positive correlation between velocity and temperature and a negative correlation between velocity and water content. Moreover, Love waves show a higher relative velocity change than Rayleigh waves. During winter months, low temperatures and high water content result in low velocities with the latter having a higher influence. An exception are freezing events, which cause relative velocity increase twice as high as seasonal changes. During the dry summer of 2018, the water content was constantly low. The correlation between temperature and velocity was higher than in winter months. Thus, both temperature and water content need to be regarded to extract information from the seismic wavefield.
As a conclusion, considering both types of surface waves separately provides useful information about subsurface temperature and water content. Using sensitivity kernels and temperature and water content models can help to quantify the contribution of both processes to velocity changes.

SO Seismologie: e-Poster
SO1-01

Imaging Surface Wave Phase and Amplitude Wave-Fields with AlpArray and Neighboring European Networks

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Abstract
The modern-day coverage and availability of broad-band stations in the greater Alpine area offered by AlpArray, Swath-D and the European seismological networks allows for imaging seismic wave-fields at yet unprecedented resolution. In the AlpArray area and in Italy, the distance of any point to the nearest station is less than 30km, resulting in an average inter-station distance of about 45km. With a much denser deployment in a smaller region of the Alps (320km in length and 140km wide), the Swath-D network possesses an average inter-station distance of about 15km.

We leverage this dense distribution of more than 1500 individual stations to compute the spatial phase and amplitude fields of teleseismic fundamental mode surface waves for multiple events. Wave-field parameters are determined by correlation with synthetic reference wave-forms in order to isolate the fundamental mode signal and to diminish the influence of noise, higher modes, coda waves, or adjacent events on our measurement. The measurements as well as examples of phase and amplitude distributions are shown and discussed.

Particularly the importance of taking amplitudes into account when evaluating surface wave signals becomes apparent, as the dynamic contributions to the eikonal phase velocity are significant. Both heterogeneities in- and outside of the observed region can lead to considerable deformations of the wave-fronts, an effect which needs to be corrected when assessing structural information.

SO Seismologie: e-Poster
SO1-09

Wind Turbine Noise Reduction from Seismological Data

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Abstract
Over the last years, installations of wind turbines (WTs) increased worldwide. Owing to negative effects on humans, WTs are often installed in areas with low population density. Because of low anthropogenic noise, these areas are also well suited for sites of seismological stations. As a consequence, WTs are often installed in the same areas as seismological stations. By comparing the noise in recorded data before and after installation of WTs, seismologists noticed a substantial worsening of station quality leading to conflicts between the operators of WTs and earthquake services.

In this study, we compare different techniques to reduce or eliminate the disturbing signal from WTs at seismological stations. For this purpose, we selected a seismological station that shows a significant correlation between the power spectral density and the hourly windspeed measurements. Usually, spectral filtering is used to suppress noise in seismic data processing. However, this approach is not effective when noise and signal have overlapping frequency bands which is the case for WT noise. As a first method, we applied the continuous wavelet transform on our data to obtain a time scale representation. From this representation, we estimated a noise threshold function either from noise before the theoretical P-arrival (pre-noise) or using a noise signal from the past with similar ground velocity conditions at the surrounding WTs. Therefore, we installed low cost seismometers at the surrounding WTs to find similar signals at each WT. From these similar signals, we obtain a noise model at the seismological station, which is used to estimate the threshold function. As a second method, we used a denoising autoencoder (DAE) that learns mapping functions to distinguish between noise and signal.

In our tests, the threshold function performs well when the event is visible in the raw or spectral filtered data, but it fails when WT noise dominates and the event is hidden. In these cases, the DAE removes the WT noise from the data. However, the DAE must be trained with typical noise samples and high signal to-noise ratio events to distinguish between signal and interfering noise. Using the threshold function and pre-noise can be applied immediately on real-time data and has a low computational cost. Using a noise model from our prerecorded database at the seismological station does not improve the result and it is more time consuming to find similar conditionsat the WTs.

SO Seismologie: e-Poster
SO2-01

Determination of non-linear OBS clock drift by means of noise cross-correlations

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Abstract
In the framework of the BRAVOSEIS project, eight broadband ocean-bottom seismometers (OBS) were deployed in the Bransfield Strait, Antarctica. The internal clocks of the data loggers were synchronised with a GPS signal before deployment. After the recovery 13 months later, the time difference (skew) between the OBS clocks and GPS was measured. Due to a malfunction of some data loggers, only four stations revealed a skew value. Furthermore, the clock drift turned out to be non-linear, so not only the total clock drift, but also the shape of the drift curves has to be determined for all stations.

The evaluation of OBS clock drift by noise cross-correlations was described by Hannemann et al. (2013). We expanded this method for non-linear drift. Two onshore stations with GPS-controlled data loggers could be used, one temporary station of the BRAVOSEIS network and one permanent station of the Antarctic Argentinean Italian Network. Cross-correlations of long-period noise (9-100 s) were calculated, stacked and filtered in pairs between OBS and land stations. This resulted in one trace per day. The first of these traces was correlated with all other traces to determine the daily offset. A polynomial was fitted to the offset data to obtain a smooth function for the time correction.

The quality of the cross-correlations between OBS and onshore stations varied widely. The four OBS in the northern part of the Bransfield Basin yielded excellent results, but the quality of the cross-correlations was not sufficient to determine the clock drift of the four southern stations precisely. Therefore, we corrected the data of the northern stations for clock drift and used them as a base for cross-correlations with the southern stations. One station suffered from a technical fault of the seismometer after five months; in this case, we correlated the hydrophone data with the vertical component of the neighbouring OBS station. Another station failed to synchronize the internal clock before deployment, here we used nearby airgun shots from a seismic survey to estimate the initial time.

Noise cross-correlations have so far been used to calculate linear clock drifts within OBS networks. A combination of careful filtering, usage of data from nearby onshore stations and calculation of polynomial fits can expand this method for non-linear drifts.

SO Seismologie: e-Poster
SO2-03

An automatized XKS-splitting procedure for large data sets: Extension package for SplitRacer and application to the USArray

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Abstract
Recent technological advances have led to community wide use of large-scale seismic experiments which produce seismic data on previously impossible scales. Standard processing procedures thus require automatization to facilitate a fast and objective analysis of the data. Among these, XKS-splitting is an important tool to derive first insights into the Earth's deformation regimes at depth by studying seismic anisotropy. Most often, shear-wave splitting is interpreted to represent crystallographic preferred orientation (CPO) of mantle minerals like olivine as dominating feature and can thus be used as a proxy of mantle flow processes, while shear-wave splitting is also sensitive to shape-preferred orientation due to partial melt or cracks. Here, we introduce an addition to the MATLAB-based (MATLAB 2020) SplitRacer tool box (Reiss & Rümpker 2017) which automatizes the entire XKS-splitting procedure. This is achieved by the automatization of 1) choosing a time window based on spectral analyses and 2) categorization of results based on three different XKS-splitting methods (energy minimization, rotation correlation and splitting intensity). This provides effective and objective results for splitting as well as null-measurement results. This extension allows to use SplitRacer without a graphical interface and introduces a bootstrapping statistics as error estimate of the single layer joint splitting method. The procedures are designed to allow a fast and objective analysis of a vast amount of data, as produced by recent seismic deployments (e.g. USArray, AlpArray). We test this automatization by applying the analysis to the USArray data set, which has approximately 1900 stations and between two to fifteen years of data. We can reproduce the results of former studies with the automatic analysis and provide a catalogue of shear wave splitting measurements for all stations of the network including the current deployment in Alaska/Western Canada.

SO Seismologie: e-Poster
SO1-06

Investigation of mantle flow pattern beneath the Iranian plateau and Zagros by seismic anisotropy

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Abstract
In this study we use an unprecedented data set of seismic waveforms from a network of 245 seismic stations to examine the mantle flow pattern and lithospheric deformation over the entire region of the Iranian Plateau and Zagros by investigation of seismic anisotropy. We also examine the correlation between the pattern of seismic anisotropy, plate motion velocities and surface strain fields using geodetic data.
Previous investigation of seismic anisotropy indicates the presence of a simple mantle flow regime beneath the Turkish-Anatolian Plateau and Arabian Plate. Numerical modeling suggests that this simple flow can be a component of a large-scale global mantle flow associated with the African superplume, which plays a key role in the geodynamic framework of the Arabia-Eurasia continental collision zone. However, the extent and impact of the flow pattern farther east beneath the Iranian Plateau and Zagros remains unclear. While the relatively smoothly varying lithospheric thickness beneath the Anatolian Plateau and Arabian Plate allows progress of a simple mantle flow, the variable lithospheric thickness across the Iranian Plateau and Zagros is expected to impose additional boundary conditions on the mantle flow field.
Our study reveals a complex pattern of seismic anisotropy that implies a similarly complex mantle flow field. The pattern of seismic anisotropy suggests that the regional simple mantle flow beneath the Arabian Platform and eastern Turkey deflects as a circular flow around the thick Zagros lithosphere. This circular flow merges into a toroidal component beneath the NW Zagros that is likely an indicator of a lateral discontinuity in the lithosphere. Our examination also suggests that the main lithospheric deformation in the Zagros occurs as an axial shortening across the belt, whereas in the eastern Alborz and Kopeh-Dagh a belt-parallel horizontal lithospheric deformation plays a major role.

SO Seismologie: e-Poster
SO1-10

Array-Detektion am Helgoland-Array (HELGA)

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Abstract
Auf der Nordseeinsel Helgoland betreibt die CAU Kiel seit 1959 eine seismologische Station. Die seit 2001 digital ausgestattete Station wurde 2017 um ein Multiparameter-Array erweitert. Das sog. Helgoland-Array (HELGA) auf Helgoland und der Nebeninsel Düne besteht aus sechs Seismometern und umfasst auch Mikrobarometer, Tiltmeter und Gravimeter. Speziell mit den Seismometern bieten sich neue Möglichkeiten zur Überwachung der Seismizität im Bereich der südöstlichen Nordsee und der angrenzenden Küstenregionen.

Mittels Beamforming werden aus den kontinuierlichen Wellenformdaten ebenfalls kontinuierliche Zeitreihen der Beampower, des Backazimuths und der horizontalen Slowness berechnet. Ein STA/LTA Detektor auf der Beampower-Spur liefert eine Vielzahl von Detektionen, wobei aufgrund lokaler Störsignale an einzelnen Stationen zunächst unerwünscht viele Fehldetektionen auftreten. Um die Backazimuth und Slowness Spuren für den Detektor nutzbar zu machen, wird aus beiden Spuren eine charakteristische Funktion berechnet, welche die zeitliche Stabilität dieser Parameter über aufeinanderfolgende Zeitfenster abbildet. Mit Hilfe dieser charaktistischen Funktionen gelingt zum einen eine deutliche Reduktion von Fehldetektionen, zum anderen werden auch Ereignisse detektiert, deren Beampower zwar gering ist, Backazimuth und Slowness aber eine eindeutige Wellenausbreitung über das Array abbilden.

Im ersten Schritt wurden die Programme der Array-Analyse anhand von Referenzereignissen kalibriert. In Zukunft sollen die Daten des Helgoland-Arrays mithilfe dieser Methoden auch in Nahe-Echtzeit ausgewertet werden.

SO Seismologie: e-Poster
SO2-04

High frequency array observations of December 2020 swarm at surface and borehole stations at ICDP Eger Rift site Landwüst (Vogtland)

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Abstract
Within the ICDP project “Drilling the Eger Rift”, we focus on the German-Czech border region West Bohemia/ Vogtland which is known for its earthquake swarms. These swarms are clusters of small magnitude (ML<4) earthquakes which are supposed to be linked to the rise of mantle fluids. We aim to improve the seismological observation of these small magnitude earthquakes and related processes especially in the high frequency band above 100 Hz by installing three dense small aperture 3D arrays. Each array will consist of a 400 m deep vertical array borehole installation and a small aperture (400 m) surface array.
The drill site S1 in Landwüst and its surroundings serve as pilot site for the first installation. The borehole chain consists of eight 3-component 10 Hz geophones and the continous recordings are sampled with 1000 Hz. In parallel, twelve surface stations are installed which are equiped with 4.5 Hz geophones. The data were recorded with 400 Hz sampling rate at most locations, but at some selected stations we additionally record data with 1000 Hz sampling rate being the desired sampling rate for the final array configuration. Due to the high sampling rates and the high frequency content of the recorded earthquake signals, local site conditions may lead to non-coherent recordings for different parts of the array which have a major influence on the overall array performance. However, preliminary results from broad band frequency wave number analysis (5-180 Hz) in a moving time window (0.2 s) with first test installation data also indicate that the coherency across the array site is still high enough to clearly identify P and S waves from local earthquakes.
In December 2020, an earthquake swarm started with two activity clusters in Nový Kostel (Czech Republic) and Oelsnitz (Germany). This swarm was recorded by both borehole and surface stations in Landwüst. Preliminary results show that more than 14000 events can be identified at the borehole stations and that about 70-80% of these events are also observed at the surface array. For small earthquakes, mainly the S wave can be identified, but also impulsive P waves are clearly visible at the surface stations. These high frequency waves (up to 230 Hz at the surface and up to 300 Hz in the borehole) show a good coherency across the array. We present recordings from selected events to analyse frequency content and coherency across the 3D array.

SO Seismologie: e-Poster
SO1-14

Coupling Spectral decomposition results with hybrid ground-motion simulations: Application to Rhine Graben area

Razafindrakoto, Hoby[1], Cotton, Fabrice[1, 2], Bindi, Dino[1], Pilz, Marco[1], Graves, Robert[3]
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Abstract
While recordings of strong ground-motion in Moderate-Central Europe is lacking, large databases weak motions records are now available. These records have been extensively used in the past few years to evaluate critical seismic parameters such as anelastic attenuation, stress drop, and site effects through spectral decomposition methods (separation of site-source-propagation). We take advantage of these spectral-decomposition results and the advancement in physics-based broadband ground-motion simulations methods to better predict the high frequency part of large earthquakes ground-shaking In Germany.

This study presents the results of embedding such spectral-decomposition results (Bindi et al., 2019) with a modified version of the Graves-Pitarka (GP) hybrid ground-motion simulation methodology implemented on the Southern California Earthquake Center Broadband Platform. The simulation results were assessed using ground motion recordings from the last 20 years largest earthquakes of the Rhine graben area. They are also compared with simulations from the unmodified GP approach and ground-motion predictive equations. We found that in general, the modification in the high frequency part (e.g., incorporation of compressional waves) was necessary to improve the fit with observations. Our findings also validate the fact that parameters from the spectral decomposition are giving well-calibrated time-histories (in terms of frequency and amplitude) when used as input parameters of the broadband simulations. For the blind simulation of future earthquakes, instead of using event-specific stress-drops, we use the average stress-drops taken from the distribution of the stress drops derived from spectral decomposition. Hence, the findings in this study support the incorporation of scenario-based ground motion simulations for use in the characterization of seismic hazard and other engineering applications in the Rhine graben. Following the validation, we could confidently use the approach to generate time histories for hazard and risk analyses and to complement data for large earthquakes.

SO Seismologie: e-Poster
SO2-05

Nutzung von statistischen Momenten höherer Ordnung zur automatischen Detektion von Erdbebenphasen

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Abstract
Für die automatische Detektion von Erdbebenphasen in seismologischen Daten haben sich STA/LTA-Picker bewährt. In dieser Arbeit stellen wir einen alternativen Ansatz vor, der die statistischen Eigenschaften des aufgezeichneten Signals nutzt. Dafür wird die Verteilungsfunktion der gemessenen Amplituden in einem gleitenden Zeitfenster über zentrale Momente beschrieben. Insbesondere das zentrale Moment 4. Ordnung, die Wölbung oder Kurtosis, ist sensitiv gegenüber Abweichungen von der Normalverteilung. Da die Kurtosis zunimmt, sobald das Zeitfenster den Beginn einer Erdbebenphase beinhaltet, scheint sie für die Detektion von seismischen Signalen geeignet zu sein. In Kombination mit einer Polarisationsanalyse lassen sich die getriggerten Ereignisse automatisch den Einsätzen von P- und S-Wellen zuordnen. Der Polarisationsanalyse liegt ein Optimierungsproblem zugrunde, das aus der Dreikomponentenaufzeichnung der Verschiebung für ein gegebenes Zeitfenster die Richtung einer linear polarisierten Welle ermittelt, die das Verschiebungssignal am besten erklärt. Grundsätzlich wird davon ausgegangen, dass eine eintreffende Welle am Beobachtungsort relativ steil auftaucht. Entsprechend wird ein Winkel des Verschiebungsvektors gegenüber der Vertikalen zwischen 0° und 45° als P-Welle und ein Winkel zwischen 45° und 90° als S-Welle gedeutet.
Der konventionelle STA/LTA-Picker und der Kurtosis-Picker wurden zusammen mit der Polarisationsanalyse hinsichtlich ihrer Zuverlässigkeit bei der Detektion und Zuordnung von Erdbebenphasen getestet. Als Vergleichsdatensatz diente die manuelle Auswertung des seismologischen Observatoriums der TU Bergakademie Freiberg in Berggießhübel mit der Registrierung an der zugehörigen Regionalnetzstation BRG.
In den untersuchten Fällen lassen sich mit dem Kurtosis-Picker mehr Einsätze als mit dem STA/LTA-Picker automatisch detektieren. Der Vergleich der Triggerzeiten mit der manuellen Auswertung zeigt, dass beide Trigger die Ereignisse später als ihre manuell bestimmte Einsatzzeit erkennen. Tendenziell liegen die Triggerzeiten des Kurtosis-Pickers aber näher an den manuell bestimmten Einsatzzeiten. Die Zuordnung der detektierten Einsätze zu P- und S-Phasen funktioniert für teleseismische Ereignisse zuverlässig. Dagegen scheint die Zuordnung für Krustenphasen von Nahbeben und Steinbruchsprengungen nicht immer perfekt zu funktionieren.

SO Seismologie: e-Poster
SO1-08

Analysis of frequency-dependent amplitude decay of seismic emissions from wind turbines

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Abstract
In the framework of the KWISS-project, we deployed 19 seismic stations along a 9-km profile in the vicinity of a wind park in Uettingen/Bavaria in order to determine spectral characteristics and amplitude decays of wind-turbine induced seismic signals in the far field.
Average PSD spectra were calculated from 10 min time segments extracted from a continuous data set of 6 months. In the frequency range between 1 Hz and 10 Hz, we identified 7 distinct peaks whose amplitudes correlate with the rotation speed of the wind turbines. These peaks can be observed to at least 4 km distance, lower frequencies even up to the end of the profile. At distances between 300 m and 4 km the PSD amplitude decay can be described by a power law with exponent b. The measured b-values exhibit an almost perfect linear frequency dependence and range from b = -0.4 at 1.14 Hz to b = -3.9 at 7.6 Hz. However, from a theoretical point of view, the observed frequency dependence of b is difficult to explain if we consider geometrical spreading and anelastic absorption as the only factors that determine the amplitude decay. In particular, at frequencies below 3 Hz, the observed b-values are systematically lower than the theoretical ones, which means that the observed amplitude decrease is weaker than theoretically predicted. We discuss possible factors that may explain this discrepancy. By application of the analytical “phase-shift-elimination-method” we show that the wave field superposition of 3 wind turbines (corresponding to the windfarm in Uettingen) leads to the observed amplitude decay.
The project KWISS is funded by the Federal Ministry for Economic Affairs and Energy and by ESWE Innovations- und Klimaschutzfonds.

SO Seismologie: e-Poster
SO2-06

Spektrale Untersuchung von Schwarmereignissen an Bohrloch- und Oberflächenstationen am Standort Landwüst (Vogtland), ICDP Projekt Drilling the Eger Rift

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Abstract
Die Region Westböhmen/Vogtland an der deutsch-tschechischen Grenze ist durch geodynamische Aktivität in Form von Mineralquellen, neotektonischer Krustenbewegung, CO_2-Entgasungen und periodisch wiederkehrenden Erdbebenschwärmen gekennzeichnet. Mit dem ICDP Projekt „Drilling the Eger Rift“ sollen in der Region u.a. Untersuchungen zu Fluidbewegungen in der Erdkruste und den damit zusammenhängenden Erdbebenaktivitäten durchgeführt werden.

Im Rahmen dieses Projektes wurde nahe der deutsch-tschechischen Grenzen am Standort Landwüst eine ca. 400 m tiefe Bohrung abgeteuft und kreisförmig um die Bohrung herum ein Oberflächenarray mit 12 Stationen (4,5 Hz 3-Komponenten Geophone) aufgebaut. Im Bohrloch wurde eine Bohrlochkette bestehend aus acht 3-Komponenten 10 Hz Geophonen und einem Glasfaserkabel (Distributed Acoustic Sensing System) installiert. Die Daten werden mit einer Samplingrate von 400 Hz bzw. 1.000 Hz (seit November 2020) aufgezeichnet. Durch die Bohrlochinstallation soll die Detektion von sehr schwachen Erdbeben verbessert und insbesondere der Frequenzbereich oberhalb von 100 Hz messtechnisch erfasst werden.

Wir vergleichen die Frequenzspektren und Signal-zu-Rausch-Verhältnisse (Signal-to-Noise Ratio, kurz SNR) von P-Wellen von lokalen Ereignissen im Schwarmherdgebiet um Nový Kostel, aufgezeichnet an den Oberflächen- und Bohrlochsensoren im Frequenzbereich von 200 Hz bis 500 Hz.

Im ersten Halbjahr 2020 wurden mehr als 200 lokale Erdbeben im Magnitudenbereich von -0.6 bis 1 aufgezeichnet (400 Hz Daten). Die Analyse des SNR zeigt eine Verbesserung mit der Tiefe. An den zwei obersten Stationen ist der Trend gegenläufig und als Arbeitshypothese untersuchen wir den Einfluss einer zwischen 90 und 170 m durchbohrten Störungszone, damit verbundene Impedanzunterschiede des Mediums und Unterschiede des Wellenfeldcharakters der Bodenunruhe in verschiedenen Bohrlochtiefen. Die Amplitudenspektren der P-Wellen zeigen in der Tiefe eine deutlich erhöhte Bandbreite bis zur Eckfrequenz des Antialiasfilters (~160 Hz). Seit November 2020 erfolgt die Datenakquisition mit 1.000 Hz an den Bohrlochstationen und einer Oberflächenstation. Zum Jahreswechsel 2020/2021 wurde damit ein Erdbebenschwarm mit mehr als 14.000 Ereignissen mit Maximalmagnituden bis 2.6 M_L in 10 bis 15 km Herdentfernung erfolgreich registriert und zurzeit analysiert.

SO Seismologie: e-Poster
SO1-07

Induced micro seismicity due to raising mine water level in former coal mines in the eastern Ruhr area (Germany)

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Abstract
FloodRisk is an interdisciplinary project focusing on the effects of mine water level rise in abandoned coal mine regions in Germany. Such effects are heterogeneous ground uplift, stress changes due to the change in pore pressure and the reactivation of potential faults. One of the most directly measurable effects is certainly the induced micro seismicity. It is known from previous studies that the flooding of old mines can lead to a renewed increase level in induced micro seismicity in these regions.
In this study the relationship between mine water rise, fluid-induced stress changes and induced seismicity in the Haus Aden dewatering area in the eastern Ruhr area (Germany) will be investigated in more detail.
For this purpose, we operate a network of currently 21 short period seismic stations in the region of the former "Bergwerk Ost" colliery, which had the highest seismicity rate in the Ruhr area during active underground coal mining. This network is still to be expanded to cover the entire water drainage area, about 30 Raspberry Shake sensors are waiting for the possibility of installation.
Nevertheless, the existing network registered almost 1000 induced micro seismic events in a magnitude range from -0.7 up to 2.6 M_{Lv}. Many of these events are spatially clustered and some show quite high waveform similarity. This allows relative localisation and can increase the accuracy of the location. The depth location of the earthquakes, within the limits of localisation accuracy, agrees very well with the distribution of seismicity at the time of active mining. The spatial distribution so far seems to be limited by a large inactive transverse fault in the west. It needs to be clarified what influence this fault has on the propagation of mine water in the underground.
The measured temporal trend of the mine water level, after pumps were shut down in mid-2019, shows a strong correlation with the temporal evolution of the observed micro seismicity. In the first months after the pumps are switched off, the water levels at the observation points rise only slowly and isolated microseismic events occur again. In November 2019, the rise in water levels doubled and at the same time, the strongest induced event in the measurement period was recorded with a magnitude of 2.6 M_{Lv}. In the following months, the seismicity rate ranged from 8 to 34 events above 0.5 M_{Lv} per month, some of which were felt.

SO Seismologie: e-Poster
SO1-02

Basin inversion in the Ligurian Sea revealed by local seismicity

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Abstract
The Alpine orogen and the Apennine system are part of the complex tectonic setting in the Mediterranean Sea caused by the convergence between Africa and Eurasia. Between 30 Ma and 15 Ma the Calabrian subduction retreated in a southeast direction pulling Corsica and Sardinia away from the Eurasian landmass. In this extensional setting, the Ligurian Sea was formed as a back-arc basin. The rifting jumped 15 Ma ago in the Tyrrhenian Sea leaving Corsica and Sardinia in a stable position relative to Eurasia.

Within the framework of the AlpArray research initiative a long-term seismological experiment was conducted in the Ligurian Sea to investigate the lithospheric structure and the seismicity in the Ligurian basin. The passive seismic network consisted of 29 broad-band ocean bottom stations from Germany and France. It was in operation between June 2017 and February 2018.

Two seismicity clusters occurred in the centre of the Ligurian Basin. The 18 earthquakes are located in the lower crust and in the upper-most mantle at depths between 10 km and 16 km. Re-location was performed only using picks from the OBS in the centre of the Ligurian Sea to avoid artifacts from the complex 3D velocity structure of the basin. Moho-refractions Pn and Sn have apparent velocities of 8.2 km/s and 4.7 km/s. The low Vp-Vs-ratio of 1.72 indicates a more brittle behaviour of the mantle material. Fault plane solutions were determined for four events using also the data of land stations in southern France, Corsica, Sardinia and northern Italy. The focal mechanisms are thrust faulting. Fault planes strike in a NE-SW direction, coinciding with the alignment of the events and the direction of the basin axis.

We interprete the two earthquake clusters related to the inversion of the Ligurian Basin where the basin's centre is under compression and stresses are taken up by reactivated faults in the crust and uppermost mantle. The compressional forces could be caused by the convergence of Africa and Europe. In general, observations of earthquakes in continental mantle lithosphere are rare and they reveal on the one hand a strengthening of the crust and uppermost mantle during rifting and on the other hand they support the interpretation that rifting failed in the northern Ligurian Basin.

SO Seismologie: e-Poster
SO1-03

New Small Aperture Broadband Arrays in the European Arctic

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Abstract
As part of the EPOS-Norway infrastructure project, NORSAR received funding from the Research Council of Norway for a new regional seismic array on Bjørnøya (Bear Island) in the European Arctic.

After a long planning phase, a six-element broadband array was installed by NORSAR staff in August 2019 and has been providing data to NORSAR in near real-time since then. Due to several logistical and administrative constraints the 6-element array has an aperture of only 300 m. All sites are equipped with MBB-2 sensors and Earth Data EDR-209 digitizers that are installed in near-surface vaults. Data are automatically copied to the Norwegian node of the European Integrated Data Archive (EIDA) and are openly available.

Due to environmental restrictions less than the planned 9 array sites could be installed on Bjørnøya and the non-used instruments are now available to extend the broadband station Hornsund, Southern Spitsbergen, to another small aperture broadband array, also with 6 sites. The array installation had to be postponed because of the ongoing pandemic and is now planned for the Arctic summer 2021.

This talk will report on planning and installation of the arrays and on the first analysis results from the Bjørnøya array (BEAR) data. We will try to answer the following questions: How is the array performance of the new station? What are the noise conditions on Bjørnøya? How are the seismic monitoring capabilities in the region changing? How are data from this new installation complementing data from the seismic arrays (ARCES, SPITS and Apatity) already installed in the European Arctic when feeding them in the GBF algorithm?

SO Seismologie: e-Poster
SO2-07

How strong lateral heterogeneities affect the azimuthal anisotropy measured with the Eikonal tomography method – an example from the AlpArray network

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Abstract
The Eikonal tomography method as proposed by Lin et al. (2009) can be used to retrieve the phase-velocity field and the azimuthal anisotropy from ambient-noise measurements with relatively low computational effort. We test the method using both synthetic models and a 2 year dataset from the AlpArray seismic experiment. In most of the mapped region, where velocity variations are moderate (within 10%), the anisotropic field is reliably recovered. However, strong velocity heterogeneities, as observed in the sedimentary basins north and south of the Alps, can introduce significant artifacts. These can be understood in terms of the dynamic phase velocity (Wielandt, 1993) due to wave interference. Also, the impossibility to reconstruct the very complex shape of the travel-time field by the given seismic station distribution causes a bias in the mapped anisotropy. By comparison to the synthetic test results, the regions most affected by the bias are removed from the final maps. In the remaining areas, the azimuthal anisotropy is interpreted in terms of the tectonic processes that shaped the Alpine region. In the northern Alpine foreland, we observe a fast axis orientation parallel to the Alpine arc at lower crustal and uppermost mantle depths. Such a pattern is also seen with SKS splitting measurements. In the central Alps, we find a 3-layer structure of anisotropy, variable but mostly arc-parallel in the upper crust, arc-perpendicular at mid-to-lower crustal depths and, in particular, in the lower crustal root and again arc-parallel in the uppermost mantle. In contrast, in the eastern Alps, the pattern is more consistently E-W oriented which we relate to the eastward extrusion.

SO Seismologie: e-Poster
SO2-08

Automatic Picking of Teleseismic P- and S-Phases using an Autoregressive Prediction Approach

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Abstract
In the recent decade, the amount of available seismological broadband data has increased steeply. Picking later arriving phases such as S-phases is difficult, and there are few manual picks available for these phases. Data sets of manual picks can also be problematic, since phase arrival picks are sensitive to the parameters of the filtering, which are often unknown, and the individual picking behavior of the analysts. However, accurate arrival times, especially for these phases, could be used to greatly improve the accuracy of velocity models obtained from seismic tomography. This necessitates the adoption of automatic techniques for determining teleseismic phase arrival times consistently over a large data set.
In this work, a robust automatic picking algorithm based on autoregressive prediction is examined with regards to its accuracy. For this, a series of tests were carried out, using synthetic waveforms as well as real data in conjunction with manual picks obtained from the reviewed ISC-catalog.
Picking errors are estimated by comparing the automatic picks with manual picks, automatic picks at the neighboring stations as well as statistical meth- ods. The quality evaluations suggest potential of using these automatically determined phase arrival times for a travel time tomography.

SO Seismologie: e-Poster
SO1-06

Robust, an Earthquake Early Warning System in the Lower Rhine Embayment, Germany

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Abstract
The Lower Rhine Embayment in western Germany is one of the most important areas of earthquake recurrence north of the Alps, facing a moderate level of seismic hazard in the European context but a significant level of risk due to a large number of important industrial infrastructures. In this context, an early warning system, meaning an early detection of an event whose unfolding may result in damage and loss is of high importance. The project ROBUST aims at designing a user-oriented hybrid earthquake early warning and rapid response system in cooperation with the Geologischer Dienst NRW, where regional seismic monitoring is combined with smart, on-site sensors, resulting in the implementation of decentralized early warning procedures.

One of the research areas of this project deals with finding an optimal regional seismic network arrangement. With the optimally compacted network, strong ground movements can be detected as quickly and as reliably as possible. In this work an optimization approach is used in order to densify the existing sparse network through the installation of additional decentralized measuring stations. A comparison of the best network designs is performed and will be presented in the meeting.

SO Seismologie: e-Poster
SO2-09

Improving seismic deployments using Borehole, Posthole- and SlimPosthole sensors

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Abstract
It is understood that seismic monitoring arrays using surface vaults and shallow cased holes will be limited in seismic resolution as compared to well constructed boreholes in the same locations. The earlier limitations from sensors quality, size, availability, performance, reliability and cost have been improved. Significant improvements to the sensitivity of a network, depending on location, can be achieved with inexpensive cased holes by careful considerations of the signal to noise required in the bandwidth of interest and applying the fabled Goldilocks concept of “just right” for the depth needed to achieve those signal levels. There are ample studies published that reinforce this concept and local water well drillers in most towns capable of these types of installations for reasonable costs. These best practice techniques and noise studies of depth of emplacement can be used as guides for applying this sensor emplacement technique for improving and refurbishing present arrays and building new arrays.

SO Seismologie: Oral presentation (by invitation only)

SO Seismologie: Oral presentation (by invitation only)
V5-3

Seismische VSP Tomographie am ICDP Bohrloch S1 in Landwüst, Vogtland

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Abstract
Ziel des ICDP Projekts "Drilling the Eger Rift" ist die Erforschung geodynamischer Prozesse in WestBöhmen/Vogtland. Die Region ist für wiederkehrende Schwarmbeben im Zusammenhang mit Mantelfluiden und CO2 Entgasungen bekannt. Der letzte Bebenschwarm fand Ende Dezember 2020 statt. Im Rahmen des Projekts wurden drei Bohrlöcher zur Installation von 3D seismischen Arrays abgeteuft. Das Bohrloch S1 ist ca. 1.5 km südlich von Landwüst (Vogtland) entfernt und besitzt eine Teufe von 402 m. Das 3D-Array besteht aus einer Bohrlochkette mit 8 HG-7 10 Hz 3-Komponenten Geophonen, einem Distributed Acoustic Sensing System (Glasfaserkabel) sowie aus einem semipermanenten Oberflächenarray mit 12 PE-6/B 4.5 Hz 3-Komponenten Geophonen und einer Apertur von 400 m um das Bohrloch.

Während des Bohrprozesses wurde eine bisher geologisch nicht erfasste Störungszone in einer Tiefe von ca. 100-160 m identifiziert. Zur genaueren Charakterisierung des Untergrunds sind im Januar und November 2020 VSP (vertical seismic profiling) Experimente durchgeführt worden. Ziel ist die Charakterisierung der Störungszone und die Berechnung einer seismischen Tomographie. Das resultierende Geschwindigkeitsmodell wird zudem für die folgenden Analysen, z.B. für die Lokalisierung der Fluidkanäle in der Region benötigt. Während des ersten Experiments wurden neben den Bohrlochsensoren 40 PE-6/B 4.5 Hz 3-Komponenten Geophone als Oberflächenarray (Gesamtapertur ca. 580 m) installiert. Die Abtastrate betrug 400 Hz. Für das zweite VSP Experiment wurden die Daten von den Bohrlochsensoren, dem Glasfaserkabel und dem semi-permanenten Oberflächenarray registriert. Die Abtastrate betrug 400 Hz (Oberflächenarray) bzw. 1000 Hz (Bohrlochsensoren). Als Quelle kam bei beiden Experimenten ein SDD 6600 Fallgewicht (Gewicht 340 kg) zum Einsatz, das an 66 bzw. 54 Quellpunkten mit einem Abstand von je 10 m angeregt wurde.

Zur Berechnung der seismischen Tomographie sind die Ersteinsätze der Fallgewichtsquellen genutzt worden. Das Ergebnis der Tomographie des ersten Experiments zeigt eine NW-SE einfallende Zone verringerter Geschwindigkeit, die das Bohrloch bei ca. 90-170 m schneidet. Diese Geschwindigkeitsanomalie könnte sich durch die Störungszone oder durch den Wechsel der Lithologie von Muskovitphyllit zu Schluffphyllit und einer damit verbundenen Schwächezone erklären lassen. Diese Tomographie wird nun mit dem 3D-Datensatz des zweiten VSP Experiments erweitert mit dem Ziel, eine verbesserte Auflösung zu erhalten.

SO Seismologie: Oral presentation (by invitation only)
V5-4

Source location and evolution of the 26 s microseism from 3-C beamforming

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Abstract
The distribution of ambient noise sources affects the outcome of ambient-noise based methods. Better constraints on location and behaviour of noise sources will help us understand the processes driving them and improve our applications of ambient noise. One of the most enigmatic noise sources is the 26 s microseism. This very monochromatic source was identified in the 1960’s and is believed to be generated continuously from a fixed location in the Gulf of Guinea. The source mechanism of this signal is still unknown.

We investigate the origin and physical mechanisms responsible for the 26 s microseism using data from permanent broadband stations in Germany, France and Algeria and temporary arrays in Morocco, Cameroon and Botswana for spectral analysis and 3-C beamforming. We find that the source exhibits strong temporal variation in spectral amplitude and is not always detectable, but occasionally it is so strong that it can be detected on stations all around the world. Such "burst" events can last for a couple of hours to a couple of days. For 2004, 2006, 2011, 2013 and 2016, the spectral peak was detected on stations globally about 30 percent of the time. Our beamforming analysis confirms that the energy is coming from the Gulf of Guinea, as shown in previous studies, and that the direction is temporally stable. Whenever the signal is detectable, both Love and Rayleigh waves are generated.

We discover a spectral glide effect associated with the bursts, that so far has not been reported in the literature. The spectral glides last for about two days and are observed on stations globally. Very long period tremors and gliding tremors are also observed on volcanoes as Kilauea in Hawaii and Ambrym in Vanuatu, suggesting that the origin of the 26 s tremor is also volcanic.

SO Seismologie: Oral presentation (by invitation only)
V1-05

Seismic signals can help to improve the early-warning of subglacial floods

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Abstract
Glacier runoff and melt from volcanic and geothermal activity accumulates in glacier dammed lakes in glaciated areas around the world. These lakes eventually drain, creating hazardous subglacial floods that either melt channels (slowly rising discharge curves) or lift the ice sheet (fast rising discharge curves). These floods are usually only confirmed after they exit the glacier and reach local river systems, which can be many tens of kilometres from the flood source. Once in the river systems, they travel rapidly to populated areas. Such delayed detection represents a potentially lethal shortcoming in early-warning.
I will demonstrate how to advance early-warning potential of fast rising floods through the analysis of four such floods in a glaciated region of Iceland. By comparing exceptional multidisciplinary hydrological, GPS and seismic ground vibration (tremor) data, we show that array analysis of seismic tremor can be used for early location and tracking of the subglacial flood front. Furthermore, the timing and size of the impending flood can be estimated, prior to it entering the river system. Advanced warnings of between 20 to 34 hours are achieved for large (peak discharge of more than 3000 m3/s) to small floods (peak discharges from 210 to 380 m3/s), respectively.

SO Seismologie: Oral presentation (by invitation only)
V5-5

Entwicklung einer Mikrozonierungskarte für das Stadtgebiet München unter Verwendung von 6-Komponenten und Array Messungen

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Abstract
Ziel einer Mikrozonierung ist die Ermittlung der S-Wellen Geschwindigkeitsstruktur des flachen Untergrundes, um lokale Erdbebeneinwirkungen abzuschätzen und mögliche Erdbebenschäden eingrenzen zu können. Dies ist vor allem in urbanen Gebieten von großer Bedeutung. Ein neues Geothermie-Projekt in der Münchner Innenstadt erhöht das Risiko für induzierte Seismizität und macht eine genauere Erforschung des Untergrundes notwendig. Bisher erprobte Methoden zeigen jedoch verschiedene Nachteile entweder im theoretischen Verständnis oder in der praktischen Umsetzung. Um Mikrozonierung besonders in Großstädten zu vereinfachen, wird eine neue Methode verwendet, die sechs-Komponenten Messungen (drei Rotations- und drei Translationskomponenten) mit traditionellen H/V Spektralverhältnissen kombiniert. Des Weiteren wurden Array Messungen durchgeführt, um die Ergebnisse mit erprobten Methoden, wie FK-Analyse und SPAC, vergleichen zu können. Sowohl aus den sechs-Komponenten Daten als auch aus den Array Daten konnten Love- und Rayleigh-Wellen Dispersionskurven abgeschätzt und für die lokalen P- und S-Wellen Geschwindigkeitsprofile invertiert werden. Ein Vergleich dieser Geschwindigkeitsmodelle mit der durch Bohrdaten bekannten Lithologie zeigt eine positive Korrelation. Dies ermöglicht die Verschneidung der Geschwindigkeitsprofile mit dem lithologischen 3D Modell von München (GeoPot, TU München) und somit die Interpolation der Geschwindigkeitsdaten auf die Fläche. Dadurch erhalten wir eine vollständige Mikrozonierungskarte für das Stadtgebiet München.

SO Seismologie: Oral presentation (by invitation only)
V5-6

Seismic radiation from wind turbines: observations and modeling of frequency-dependent amplitude decays

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Abstract
As part of the project KWISS*, we determine spectral characteristics and amplitude decays of wind turbine induced seismic signals in the far field of a small wind farm (WF) close to Uettingen/Germany. Average power spectral densities (PSD) are calculated from 10 min time segments extracted from continuous data sets of 19 seismic stations that recorded signals along an 8 km profile, starting from the WF, for up to 6 months. We identify 7 distinct peaks in the frequency range between 1 Hz and 8 Hz that can be observed to at least 4 km distance. The signal amplitudes are decreasing with distance to the wind turbines (WTs), showing stronger decay with increasing signal frequency. In a further step, the seismic radiation and amplitude decays are modeled using an analytical approach which approximates the seismic surface wave field. Since we observe temporally varying phase shifts between seismograms recorded directly at the base of the individual wind turbines, source signal phase information is necessarily included in the modeling approach. Taking this into account, we show that phase shifts between source signals have significant effects on the seismic radiation pattern and amplitude decays. Therefore, we apply a phase-shift-elimination-method to handle the challenge of choosing representative source characteristics as an input for the modeling. To optimize the fit of modeled and observed amplitude decay curves, we perform a grid search to constrain the two model parameters, the seismic shear wave velocity and quality factor. The comparison of modeled and observed amplitude decays at the 7 prominent peak frequencies shows very good agreement and allows to derive a two-layer model, which provides information about local geological properties. The developed approach is suitable to model the amplitude decays not only observed in this project but also for any WF with arbitrary geometry and yields a more general understanding of seismic radiation of multiple WTs, including the significant effects of source signal phases.

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SO Seismologie: Oral presentation (by invitation only)
V5-1

Teleseismic P-wave travel time tomography of the Alpine upper mantle using AlpArray seismic network data

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Abstract
We perform a teleseismic P-wave travel time tomography to examine geometry and slab structure of the upper mantle beneath the Alpine orogen. Vertical component data of the extraordinary dense seismic network AlpArray are used which were recorded at over 600 temporary and permanent broadband stations deployed by 24 different European institutions in the greater Alpine region, reaching from the Massif Central to the Pannonian Basin and from the Po plain to the river Main. Mantle phases of 370 teleseismic events between 2015 and 2019 of magnitude 5.5 and higher are evaluated automatically for direct and core diffracted P arrivals using a combination of higher-order statistics picking algorithms and signal cross correlation. The resulting database contains over 170.000 highly accurate absolute P picks.
For predicting P-wave travel times we consider a large computational box encompassing the Alpine region up to a depth of 600 km within which we allow 3D-variations of P-wave velocity. To account for influences of the strongly heterogeneous crust that cannot be resolved with teleseismic data, we integrate a complex three-dimensional crustal model directly into our model. Outside the box we assume a spherically symmetric earth and apply the Tau-P method to calculate travel times and ray paths. These are injected at the boundaries of the regional box and continued using the fast marching method (Rawlinson et al. 2005). We only invert for differences in P-wave velocities inside the box, where velocity is discretized with a spacing of about 25x25x15 km. The misfit reduction reaches values of over 80%.
The resulting model shows several steeply dipping high velocity anomalies following the Alpine arc. The most prominent structure stretches from the western Alps into the Apennines mountain range reaching depths of over 500 km. Two further anomalies of high complexity extending down to a depth of 300 km are located below the central and eastern Alps, both being detached from the lithosphere and separated by a clear gap. The central anomaly shows mainly southwards dipping, whereas the eastern anomaly is mainly dipping to the northeast. Our new results can benefit from the superior resolution capabilities of the dense AlpArray seismic network, compared to previous studies, providing more accurate insights into depth extent, dip angle and directions. We perform various general, as well as purpose-built resolution tests, to verify the resolution capabilities of our setup.

SO Seismologie: Oral presentation (by invitation only)
V5-2

Current research in earthquake seismology at the University of Bergen: Monitoring, imaging and modeling of ridge, continent, and subduction zone seismicity

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Abstract
The earthquake seismology group at the University of Bergen (UiB) is involved in routine monitoring of seismic activity, distributing seismic data, and conducting research in topics that range from swarm seismicity in Norway to global seismic imaging. Hosted by UiB, the Norwegian National Seismic Network is responsible for seismic monitoring, relying on a network of 40 distributed seismic stations and Norsar's seismic arrays. The network is undergoing constant upgrades in terms of new stations (esp. in the North), improved sensor vaults, and standardized data archiving and data quality management. In 2019, the new UiB-Norsar EIDA data distribution node started operation. The open data archive is growing with our efforts to further standardize old seismic data, convert and validate response information, and provide data quality metrics based on the EIDA and IRIS MUSTANG systems. In Norway, earthquake activity that is subject of our research occurs in a range of distinct settings: in swarms of small intraplate events in N. Norway, along the passive margin offshore Central Norway, in old continental rifts offshore S. Norway, in moderate intraplate sequences on Svalbard, and in large plate boundary events along the oceanic ridge and transform faults. In a current project, we are using a temporary deployment in Nordland to investigate the cause of swarms and intraplate seismicity which are likely due to ridge push, sediment loading, glacial isostatic adjustment and fluid migration. While this type of seismicity is covered well by the local networks, the most active seismic structures covered by the permanent Norwegian networks are located far offshore. To improve the detection and location of related earthquakes, we are working on sensitive template-matching. But we are also looking beyond Norway in our research activities: Motivated by outcrops of pseudotachylites just outside Bergen, we are investigating the drivers of intermediate-depth seismicity in current subduction zones such as in Greece. Using a range of seismic methods, we recently found that intermediate-depth earthquakes are intimately connected to the migration of fluid through the subducting crust and mantle wedge. These conclusions would not have been possible without high-resolution receiver function imaging that is being further developed at UiB: Recent advances include a 3-D Kirchhoff-based migration technique and the PyGLImER toolbox for global imaging with Ps and Sp receiver functions.

SO Seismologie: Oral presentation (by invitation only)
V5-7

Automated wave type classification and isolation using strain and rotation recordings

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Abstract
A complete observation of the elastic deformation caused by the passing of a seismic wave would require the measurement of all nine components of the spatial gradient tensor of the wavefield. Direct measurements of strain and rotation (corresponding to the symmetric and anti-symmetric parts of the wavefield gradient tensor) are now becoming more and more common thanks to the recent rapid emergence of distributed acoustic sensing (DAS) technologies and dedicated rotational seismometers.

Unlike ground displacement recordings obtained by conventional seismometers, certain gradient measurements provide direct information on the recorded wave type (e.g., due to the lack of rotational motions in P-waves). We show that the wave type selectivity of strain and rotation recordings can be used to automatically classify wave modes and subsequently isolate them from the recordings. This can be achieved locally, without the need for extended seismometer arrays. The proposed algorithm is an extension of conventional single-station polarization analysis techniques, taking into account the additional observables obtained from strain and rotation recordings. Since the proposed algorithm is computationally expensive, we additionally discuss potential methods that enable an efficient classification and isolation of wave types for large data volumes, applicable for example to ambient noise recordings (e.g., to extract body waves by interferometry) or exploration scale seismic data.

SO Seismologie: Oral presentation (by invitation only)
PV-3

Listening to ambient seismic noise: what can it tell us about the Earth?

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Abstract
The ambient seismic wave field carries information about the sources that excited it, and about the material that it passed through. By recording and carefully analyzing the seismic 'noise', we can learn many things about the Earth. For example, the most prominent seismic noise comes from interactions between ocean waves and the solid earth. Therefore, it carries the imprint of storms, of weather over the oceans and seas, and even of the tides.
The seismic noise field also carries the imprint of earth structure, and changes therein. I will show that useful signals can be extracted from ambient noise, which can then be used to monitor material changes with high temporal resolution.
Over the past decade, the use of seismic noise has found its way into applications across temporal and spatial scales. I will give an overview of current applications as well as a quick peek into future developments.

SO Seismologie: Oral presentation (by invitation only)
PV-4

Satellite InSAR: from opportunistic science to routine monitoring.

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Abstract
In the past decade, a new generation of radar satellites have revolutionised our ability to measure Earth's surface deformation globally and with unprecedented resolution. By combining data from several InSAR satellites, daily monitoring of ground motion is now possible, whether that be the deformation caused by an earthquake, the evolution of the magmatic system during a volcanic crisis, or the failure of an embankment. InSAR shows precisely which faults slipped during an earthquake; and we have learnt that earthquakes often occur in unexpected locations and that fault ruptures can be surprisingly complex. By capturing the details of aseismic motion, we can place constraints on the frictional properties of faults and the rheology of the crust and mantle. Ongoing improvements in satellite technology have caused a dramatic rise in the number of volcanoes known to be deforming, providing the first detailed information on the spatial and temporal characteristics of volcanic deformation and contributing to a multidisciplinary paradigm shift in our conceptual understanding of magmatic systems. The next 10 years will likely see InSAR analysed alongside other satellite and ground based observations and machine learning algorithms to provide critical tools to help us live our lives safely and without disruption on our dynamic, unstable and dangerous planet.

SO Seismologie: Oral presentation (by invitation only)
V1-2

Large Scale Geomechanical Modelling of Hydrocarbon Production Effects: A Case Study for the Groningen Gas Field

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Abstract
Earthquakes caused by industrial fluid operations, such as hydrocarbon production, wastewater disposal, hydraulic fracturing and CO2 storage, have become a widely discussed topic in recent years. On the one hand, this is due to the potential of these earthquakes to cause damage to people, environment and infrastructure. On the other hand, the seismicity controlling processes remain controversial. Even though it is understood that fluid injection- and production provoke pressure- and stress changes in the subsurface that eventually may destabilise critically stressed, pre-existing faults, various details are still debated. For seismic hazard assessment and risk mitigation, reservoir simulation as well as optimal reservoir development, detectable surface signatures such as subsidence and spatio-temporal signatures of fluid-induced (micro-)seismicity carry valuable information.

In this work, we perform numerical modelling of fluid extraction to explain observed surface subsidence and pressure depletion of the Groningen gas field. We implement different models to take an initial pressure condition into account. This allowed us to analyse and determine the parameters that influence the subsurface pressure state and critical stress changes. Eventually, we compare numerical model results to observed features at the Groningen gas field and calculate failure criterion stress changes.

We demonstrate that the initial pressure condition that we take into account carries important information on the Biot-Willis coefficient, on the elastic parameters and on the possibility of a sub-hydrostatic in situ pore fluid pressure (underpressured subsurface). The obtained pressure solutions generally represent the observed pressure depletion of the Groningen gas field quite well, but underestimate the observed surface subsidence. Regarding failure criterion stress changes, our models suggest fault stabilisation within the reservoir and destabilisation at larger horizontal distance from the target formation. This contradicts the observation that the focal depths typically lie within the reservoir in Groningen. Thus, this model outcome should be in the focus of future research since most of the earthquakes actually occur within the gas reservoir.

UI/ZP

Umwelt- und Ingenieurgeophysik, Zerstörungsfreie Prüfung

UI/ZP Umwelt- und Ingenieurgeophysik, Zerstörungsfreie Prüfung: e-Poster

UI/ZP Umwelt- und Ingenieurgeophysik, Zerstörungsfreie Prüfung: e-Poster
UI/ZP-01

Kontinuierliche Überwachung von Temperaturfeldern mit Bohrloch-Geoelektrik und Georadar - erste Ergebnisse von Modellversuchen am idealisierten Sandkörper "GeoModel-Kiel"

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Abstract
Die Energiespeicherung in oberflächennahen und tieferen Gesteinsschichten steht im Fokus des Forschungsvorhabens ANGUS II ("Auswirkungen der Nutzung des geologischen Untergrundes als thermischer, elektrischer oder stofflicher Speicher"). Sie nimmt bei einem stetig wachsenden Anteil der erneuerbaren Energien an der Gesamtversorgung eine Schlüsselrolle ein, um eine stabile Energiebereitstellung zu gewährleisten. Eine Möglichkeit ist dabei die Speicherung von Wärme im Untergrund. An einem künstlich angelegten und idealisierten Sandkörper, dem "GeoModel-Kiel", werden an der Christian-Albrechts-Universität zu Kiel seit 2019 geothermische Versuche durchgeführt, um die praktische Umsetzung dieser Art von Energiespeicherung zu erproben. Als Wärmequelle dienen zunächst eine, später fünf symmetrisch um die Mitte des Sandkörpers angeordnete Wärme-Sonden mit einem geschlossenen Wasserkreislauf. Während der ersten Versuchsphasen befindet sich der Sandkörper in einem trockenen Zustand, bevor er im Sommer 2019 wassergesättigt wird. Auf Grundlage von Testmessungen vor Beginn der ersten Wärme-Experimente wird ein geophysikalisches Monitoring-Konzept erstellt, mithilfe dessen die Änderungen des Temperaturfeldes überwacht werden sollen. Es beinhaltet dreidimensionale Bohrloch-Geoelektrik-Messungen mit vier im "GeoModel-Kiel" installierten Bohrloch-Sonden. Das geoelektrische Monitoring wird durch Georadar-Messungen ergänzt. Diese werden in Form von Transmissions- und Reflexions-Messungen mit verschiedenen Mess-Geometrien durchgeführt (Bohrloch-Bohrloch, Bohrloch-Oberfläche etc.). Es zeigt sich, dass sich die Auswirkungen verschiedener Heiz-, Kühl- und Wassersättigungsphasen in den Ergebnissen der geophysikalischen Messungen widerspiegeln. Sowohl die qualitativen als auch die quantitativen Änderungen der elektrischen und elektromagnetischen Parameter entsprechen dabei weitestgehend den Erwartungen. Verschiedene Effekte wie z.B. eine Erhöhung der Einspeise-Temperatur oder die schnellere Aufheizung im wassergesättigten Zustand können gut beobachtet werden. Desweiteren können durch das Monitoring unerwartete Ereignisse, beispielsweise eine Leckage an einer Wärme-Sonde, frühzeitig detektiert werden. Gegenstand zukünftiger Untersuchungen wird die Trennung der Auswirkungen von Temperatur- und Bodenfeuchte-Schwankungen auf die Ergebnisse der Geoelektrik- und Georadar-Messungen sein.

Geophysikalische Untersuchungen an mittelalterlichen Malereien in der St. Petri zu Schleswig (S-H) mit Georadar und Thermographie

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Abstract
Die Erhaltung von kulturell bedeutsamen Gebäuden ist aufgrund der Vielfalt historischer Baumaterialien, der komplexen Baugeschichte und Schadensbilder eine Herausforderung. Sie ist in der Regel mit einem hohen finanziellen Aufwand verbunden. Die zerstörungsfreie Prüfung kann dabei helfen, Erhaltungsmaßnahmen zu planen, zu optimieren und zu überwachen.
Dieser Beitrag zeigt die Ergebnisse einer zerstörungsfreien Prüfung der Feuchteverteilung am St. Petri Dom in Schleswig mittels Thermographie und Georadarmessungen.
Diese Methoden sind Standardverfahren in der Ingenieurgeologie und im Bauwesen. Im Bereich der Denkmalpflege ist die Anwendung und vor allem die Kombination dieser Methoden jedoch noch nicht etabliert.
Der Dom beherbergt im Schwahl (Kreuzgang) Wandmalereien aus dem 14. Jhd.. Sie sind durch Gipseinlagerungen und einen Shellac-Überzug z.T. großflächig beschädigt. Im Rahmen eines DBU-Projekts wurden sie in den Jahren 2017-2019 konserviert und restauriert. Um die Materialeigenschaften eines Gewölbeaschnittes (Joch) im sogenannten Schwahl (Kreuzgang) während der Instandsetzung quantifizieren zu können, wurden begleitend Thermographie (aktiv/passiv) und Georadarmessungen vorgenommen.
Durch Wiederholungsmessungen im Abstand von mehreren Monaten konnte die Wirksamkeit des Einsatzes verschiedener Lösungsmittel zur Beseitigung des Shelllac sowie der Gipseinlagerungen bewertet werden. In der passiven Thermographie zeigt sich zudem, dass unterhalb einer abdichtenden Horizontalsperre in ca. 30 cm Höhe ein erhöhter Feuchtegehalt vorliegt. Die in diesem Bereich aufgenommenen Radargramme bestätigen, dass in den Bereichen mit erhöhter Feuchtigkeit eine deutliche Änderung der Reflexionsamplituden und eine höhere Dämpfung vorhanden sind.

Porositätsbestimmung und Verdichtungsnachweis von Bergbaukippen mittels SIP

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Abstract
Die Überwachung geotechnischer Prozesse wie z.B. die Verdichtung von Baugrund oder die Stabilisierung bergbaubedingter Kippen mittels raumerfassender und nichtinvasiver Verfahren ist von hohem Interesse als Alternative bzw. Ergänzung zu punktförmigen Verfahren und daher Bestandteil der aktuellen, in diesem Fall vom BMWi geförderten Forschung.
Die Porosität bzw. deren Änderung infolge Verdichtung gilt dabei als der wichtigste zu untersuchende Parameter. Zunächst bietet sich die elektrische Leitfähigkeit als Materialparameter gut an, um die Porosität mit der Archie-Gleichung zu bestimmen. Bei schluffigen bzw. heterogenen Sedimenten müssen jedoch infolge der größeren inneren Oberfläche auch elektrische Grenzflächeneffekte berücksichtigt werden. Für die Porositätsbestimmung liefern daher Messungen der komplexen elektrischen Leitfähigkeit bzw. der Spektral Induzierten Polarisation (SIP) belastbarere Ergebnisse.
Es wurden umfangreiche Labormessungen der komplexen elektrischen Leitfähigkeit an stufenweise verdichteten, setzungsfließgefährdeten Sanden im Frequenzbereich von 10 mHz bis ca.1 kHz durchgeführt. Der nachgewiesene kausale Zusammenhang zwischen Porosität bzw. Verdichtung und komplexer elektrischer Leitfähigkeit wird als Modellansatz mit einer einfachen empirischen Formel beschrieben.
Für die Anwendung im Feldmaßstab unter Nutzung der Multielektroden-SIP-Technik wurde die direkte Inversion der Porositätsverteilung durch die im Rahmen dieses Projektes entstandene Weiterentwicklung der Inversionstoolbox BERT genutzt. Bei der entwickelten petrophysikalischen Inversion wird die Modellvorstellung in den iterativen Inversionsschritt integriert, d.h., die Modellparameter der Inversion sind die Porositätswerte des Untergrundmodells. Es konnte an zwei Sanierungsobjekten anhand von SIP-Messungen vor und nach einer Bodenverdichtung erfolgreich nachgewiesen werden, dass das Verfahren zur großräumigen und erschütterungsfreien Kontrolle von Verdichtungsmaßnahmen in setzungsfließgefährdeten Bergbaukippen als effiziente Alternative zu kostenintensiven punktförmigen Probenahmen einsetzbar ist.

19th September: a date marked by earthquakes in Mexico City

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Abstract
In Mexico City, September 19th is a remembrance date of what the combination of large magnitude earthquakes with extreme soft sediments and bad constructions can cause. On the 19th September 1985, an interplate event (Mw 8,0; depth = 20 km; epicentral distance near 350 km) caused more than 10,000 casualties and about 190 buildings suffered partial or total collapse. Exactly 30 years later the 19th September 2017, and short after a macroearthquake drill, a Mw 7,1 intraslab earthquake hit Mexico City at 13:40 hours (local time). The seismological records of the 2017 event (depth = 57 km; epicentral distance near 114 km from the city) showed that the ground motion in frequencies between 0.4 and 1 Hz was anomalously large, and it was reported as the second most destructive earthquake in Mexico City, just after the 1985 event, with 369 casualties.

After the 1985 earthquake, the knowledge about the soil conditions in Mexico City resulted in a zonation that divides the subsoil in three zones: the lakebed zone: formed by of 30–80 m deposit of highly compressible, high-water content clay; the hill zone, characterized by a surface layer of lava flows and volcanic tuffs; and the transition zone, composed of alluvial sandy and silty layers with occasional intervals of clay layers. Shear-wave velocities in the upper 30 m of the three zones are 50–100, 750, and 250 m/s, respectively. This zonation is also included on the construction regulations for Mexico City. Unfortunately, because of a lack of information, corruption and sometimes poverty, constructions are sometimes built following no regulation at all.

In this work we show the damage distribution in the south part of Mexico City, due to the 19.09.2017 event, where most of the extreme damage happened. This distribution had not been seen after interplate earthquakes, which can be explained by the closeness, the back azimuth the frequency content and the magnitude of this event, but also because of the city growth to areas that ~60 years ago were still part of a lake with the characteristic soft clay layers from Mexico Basin.

Seismic resonance vulnerability assessment on buildings with different typologies: The case of Guadalajara, Mexico

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Abstract

Structural collapses can occur as a result of a dynamic amplification of either, the building´s seismic response or the ground shaking by local site effects; one of the reasons is a resonance effect due to the proximity of the structural elastic fundamental period T_E and the soil fundamental period T_S. We evaluate the vulnerability to resonance effects in Guadalajara, México, in a four-step schema: 1) we define structural systems in the building environment of western Guadalajara, in terms of their construction materials and structural components; 2) we estimate T_E with different equations, to obtain a representative value in elastic conditions for each structural system; 3) estimation of T_S from shallow velocity profiles, obtained with surface wave analysis; and 4) evaluation of the resonance vulnerability by the analysis of the ratio between T_E and T_S.

We observe that the larger the soil fundamental period, the higher the resonance vulnerability for buildings with height between 17 and 39 m. For the sites with a low T_S, the most vulnerable buildings will be those with a height between 2 and 9 m. These results can be a helpful tool for disaster prevention, by avoiding the construction of buildings with certain heights and structural characteristics that would result in a dangerous proximity between T_E and T_S.

UI/ZP Umwelt- und Ingenieurgeophysik, Zerstörungsfreie Prüfung: e-Poster
UI/ZP-02

Optimierung von Methoden zur Standortcharakterisierung anhand passiver seismischer Messungen am Beispiel der Weserterrassen bei Hameln

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Abstract
Passive seismische Messungen des Umgebungsrauschens sind effektive und nicht-invasive Methoden, um die Struktur des lokalen Untergrunds und mögliche Verstärkungen seismischer Bodenbewegungen zu ermitteln. Liegt beispielsweise Lockersediment auf Festgestein auf, so kann dies bei seismischen Ereignissen eine verstärkende Wirkung auf die seismische Beanspruchung darüberliegender Gebäude haben.
Um einen ersten Überblick über den Standort zu bekommen, wird mithilfe von Einzelstationsmessungen die Fundamentalfrequenz, mit welcher der Untergrund schwingt, ermittelt (H/V-Kurven). Liegt diese in einem ähnlichen Bereich wie die Resonanzfrequenzen von Gebäuden (ca. 1 - 10 Hz) wirkt dies verstärkend, sodass auch seismische Ereignisse mit geringer Magnitude eine erhöhte Einwirkung in Bezug auf Fühlbarkeit und Schäden zur Folge haben. Des Weiteren werden zur Erstellung eines Geschwindigkeit-Tiefen-Profils mehrere Stationen zu einem Array kombiniert. Aus den gemessenen Daten werden mittels einer hochauflösenden Frequenz-Wellenzahl-Analyse (hrFK) und einer räumlichen Autokorrelation (SPAC) Dispersionskurven ermittelt, welche die Phasengeschwindigkeiten von Oberflächenwellen in Abhängigkeit der Frequenz angeben. Die resultierenden Dispersionskurven werden am Ende invertiert, um das Geschwindigkeits-Tiefen-Profil für den lokalen Untergrund zu erhalten.
Insgesamt wurden an den Flussterrassen der Weser drei Array-Messungen an unterschiedlichen Standorten, sowie mehrere H/V-Messungen durchgeführt. Ziel ist es, eine bestmögliche Strategie sowohl für die Vorgehensweise bei den Messungen, als auch für die Auswertung der Daten zu entwickeln und eine bessere Eingrenzung der Tiefenprofile der S-Wellengeschwindigkeiten zu erreichen. So wurde bei der Auswertung der Daten unter anderem eine Trennung in Love- und Rayleigh-Wellen vorgenommen, um die Geschwindigkeitsprofile besser bestimmen zu können. In Zukunft sind zudem Tests mit Variationen der Array-Geometrien geplant, um zukünftige Messungen hinsichtlich Logistik, Messdauer und Personaleinsatz zu optimieren.

Monitoring Reinforced Concrete Structures with Coda Waves - The Influence of Temperature on Ultrasound Velocity Changes Calculated with Coda Wave Interferometry

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Abstract
Monitoring of reinforced concrete structures to ensure their stability and increase their service-life is a crucial element of a modern infrastructural concept. With classical methods of non-destructive testing and inspection, repeated measurements under comparable conditions are difficult to conduct. Therefore, DFG research unit FOR 2825 CoDA researches the assessment of concrete damage using ultrasound coda wave interferometry and embedded sensors. Embedding the sensors into the monitoring target reduces human and non-human factors influencing repeatability. Using Coda Wave Interferometry (CWI), small velocity changes in the material can be detected by comparison of repeated measurements. The technique is sensitive to damaging changes like cracking as well as to reversible influences like material temperature. The understanding of these different influences on the signal is crucial for the analysis of long-term monitoring data to make an educated assessment of the structure and its integrity. With several laboratory experiments in a climate chamber and a long-term experiment recording an annual cycle in a large model on an outdoor test site in Horstwalde close to Berlin, we try to understand the influence of temperature on the CWI results. The results show that the velocity change calculated by CWI does closely follow the trend of concrete temperature. After one year of data recording with the large model being exposed to environmental variations only, the calculated velocity change resembles the annual temperature curve. The data shows a linear dependency between velocity and temperature change in a range of -0.03 percent per °K to -0.06 percent per °K - regardless of specimen size. An approach to remove temperature influence from the yearly cycle recorded in the large-scale experiment using this linear relation is unable to remove high-frequency variations - especially daily influences. Low-pass filtering the data can eliminate these variations while preserving permanent shifts caused by damages. Although we have shown that the influence of temperature on long term monitoring can be removed to a significant extent, there is still an influence of environmental changes remaining in the data. Possible nonlinear effects and influences not related to temperature need to be investigated in the future.

UI/ZP Umwelt- und Ingenieurgeophysik, Zerstörungsfreie Prüfung: e-Poster
UI/ZP-06

Untersuchung der hydraulischen Konnektivität in heterogenen Lockergesteinsaquiferen mittels SIP

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Abstract
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.
Da ein enger Zusammenhang zwischen hydraulischen Eigenschaften poröser Gesteine und deren komplexen elektrischen Eigenschaften besteht, wird untersucht, ob die geoelektrische Erkundungsmethode der Spektralen Induzierten Polarisation (SIP) zu diesem Zweck eingesetzt werden kann.
Mit dem Ziel eine Methode zu entwickeln, die Rückschlüsse auf die hydraulische Konnektivität verschieden dimensionierter Szenarien erlaubt, wird experimentell und numerisch die Nachweisbarkeit von Heterogenitäten der Kornmatrix in den Messdaten der SIP untersucht.
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 Abschnitte für verschiedene Sande mit unterschiedlichen elektrischen und hydraulischen Eigenschaften unterteilt. In dem Modell können gespannte Grundwasserverhältnisse erzeugt und Messungen im homogenen, linearen elektrischen Feld unternommen werden. Zudem kann es in paralleler Richtung zum elektrischen Feld hydraulisch durchströmt werden. Beginnend mit homogenen Packungen wird der Grad der Heterogenität des Modellkörpers schrittweise erhöht und die Wirkung auf die Spektren des komplexen elektrischen Widerstandes analysiert.

UI/ZP Umwelt- und Ingenieurgeophysik, Zerstörungsfreie Prüfung: e-Poster
UI/ZP-09

Feuchtemessungen an Fußböden mit Radar und Neutronensonde - Ein Vergleich von Labor und Praxis

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Abstract
Nach Auftreten eines Feuchteschadens in Fußbodenaufbauten sind sowohl die zeitnahe Feststellung als auch Eingrenzung betroffener Bereiche von besonderer Bedeutung. So können erforderliche Renovierungsmaßnahmen effizient geplant und mögliche Folgeschäden vermieden werden. Zur messtechnischen Beantwortung dieser Fragestellungen werden bereits seit vielen Jahren Neutronensonden eingesetzt, welche allerdings keine Tiefenzuordnung des schadensträchtigen Flüssigwassers zulassen. Hierzu müssen mit hohem zeitlichem und finanziellem Aufwand zerstörende Sondierungsbohrungen vorgenommen werden, welche zukünftig durch den parallelen Einsatz des Radarverfahrens vermieden werden könnten.
In systematischen Laborstudien wurden gängige Feuchteschäden an häufig anzutreffenden Fußbodenaufbauten simuliert und deren Einfluss auf das Messsignal untersucht. Hierbei kamen Zement- und Anhydritestriche, sowie die Dämmmaterialen Styropor, Styrodur, Glaswolle und Perlite-Schüttung mit variierenden Schichtdicken zum Einsatz, um die vielfältigen Konfigurationen der Praxis abzubilden. Für den gewonnenen Datensatz konnten geeignete Signalmerkmale extrahiert werden, welche mithilfe multivariater Datenauswertung eine Klassifizierung des vorliegenden Schadenfalls zulassen.
Zum Ende des Forschungsvorhabens steht besonders die Anwendbarkeit der entwickelten Methoden für die Praxis im Fokus. Hierzu wurden Messungen an realen Schadensfällen durchgeführt und deren Ergebnisse mit den Laboruntersuchungen verglichen. Hierbei stellten sich variierende Schichtdicken, sowie vorkommende Fußbodenheizungen und Armierungsgitter als mögliche Fehlerquellen für eine vollständig automatisierte Auswertung heraus.

Seismic investigation of the Critical Zone in Santa Gracia National Park, Chile using controlled-source generated Rayleigh waves

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Abstract
The EarthShape project aims to understand the interaction between the geological and biological process in developing the Earth's' surface. These interactions, however, are not limited to the surface itself but also extend into the subsurface, especially in the critical zone where intact bedrocks transform into the regolith. In the near-surface investigation, the seismic method is often used as an imaging technique in which we can relate the petrophysical properties of the subsurface to the degree of rock weathering. The Chilean National Park in Santa Gracia provides an interesting case study where the rocks are exposed to an arid climate with a small weathering degree to the rocks. In this research, we imaged the weathering structure in Chilean Santa Gracia National park by using active source generated Rayleigh wave. We analyzed the dispersive property of Rayleigh waves and extracted the Rayleigh wave's group velocity dispersion curves from the recorded traces. The obtained dispersion curves were then inverted using Bayesian inversion with minimum prior information of the subsurface model. From the collection of the 1D shear wave velocity model, we then produced a pseudo-2D model of the shear wave velocity. The pseudo-2D model provides another perspective on how we interpret the Critical Zone. Using these results, we produce a conceptual model of the weathering structure in Santa Gracia National Park, which can be used as critical information in understanding the subsurface geological and biological interaction.

Abschätzung der Wasserretentionsfunktion und der kapillarbasierten ungesättigten hydraulischen Leitfähigkeit durch NMR unter Verwendung kreis- und dreieckförmiger Kapillarmodelle

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Abstract

Geophysikalische Anwendungen der Kernspinresonanz (nuclear magnetic resonance, NMR) werden zur Abschätzung der Porengrößenverteilungen (pore size distribution, PSD) von Gesteinen und Sedimenten eingesetzt. Dies wird üblicherweise durch empirische Kalibrierung mit Hilfe von Daten zum Verhältnis Porenoberflächen/Porenvolumen des Materials realisiert. Ein neuartiges Joint-Inversionskonzept für NMR-Relaxationsdaten liefert die PSD eines Materials mit einem Minimum an Zusatzinformation und benötigt lediglich das NMR-Signal einer gesättigten Probe und mindestens ein weiteres bei Teilsättigung und bekanntem Porendruck. Das neue Inversionskonzept simuliert, als Teil des Vorwärtsoperators, den Entsättigungsprozess und benutzt dabei physikalisch-hydraulisch plausible Grundkonzepte. Als Porenmodell werden Kapillarbündel vorausgesetzt, wobei der Querschnitt der Kapillaren entweder kreisförmig oder dreieckig sein kann.

In unserer Studie untersuchen wir das Potential dieser NMR-Joint-Inversion zur Bestimmung der Wasserretentionsfunktion (WRF) und der kapillarbasierten hydraulischen Leitfähigkeit (K_{cap}) als Funktionen der Sättigung für verschiedene Sande. Es stellt sich heraus, dass die Winkligkeit (angularity) des Kapillarquerschnitts keinen signifikanten Einfluss auf die Abschätzung der WRF hat. Die K_{cap} –Abnahme mit zunehmender Entsättigung wird jedoch stärker beschleunigt, je spitzwinkliger der Kapillarquerschnitt ist. Unsere Studie zeigt, dass die WRF für Sandproben unter sog. fast diffusion Bedingungen zuverlässig vorhergesagt wird. Die K_{cap}-Abschätzungen sind ebenfalls plausibel, neigen aber zu einer systematischen Überschätzung, wofür wir die Tortuosität als Hauptgrund identifiziert haben. Da NMR-Relaxationsdaten im Allgemeinen keine Informationen über die Tortuosität liefern, bleibt ein plausibles Tortuositätsmodell eine Frage der klassischen Kalibrierung.

Eine Weiterentwicklung des Ansatzes wird daher zusätzliche Tortuositätsmessungen berücksichtigen müssen, z. B. durch elektrische Widerstandsmessungen und/oder Gradientenfeld-NMR. Außerdem werden wir in unseren zukünftigen Arbeiten auch Relaxationsmechanismen außerhalb des fast diffusion Regimes als Teil des Vorwärtsoperators realisieren, um die Anwendbarkeit für grobporige Sedimente und Böden zu verbessern. Für feinkörnige Materialien mit hohen Ton- und Schluffanteilen wird dagegen der Einfluss an der Porenwand adsorbierter Wasseranteile in Betracht gezogen werden müssen.

Zerstörungsfreie Untersuchung von Stahlfaserbewehrung in Beton mittels Computertomographie, Spektral Induzierter Polarisation und Ultraschalltransmission

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Abstract
Stahlfaserbeton (FRC) ist ein zementgebundener Hochleistungswerkstoff, der in vielen Bereichen des Bauwesens breite Anwendung gefunden hat, insbesondere dort, wo hohe Zugfestigkeit, strukturelle Integrität und innovatives Design gewünscht sind. Zu den großen Vorteilen dieses Materials gehören seine geringe Anfälligkeit für Rissbildung, seine Undurchlässigkeit für aggressive Substanzen (z. B. Enteisungsmittel) und die reduzierten Anforderungen an zusätzlich eingebettete Stahlbewehrung. Tatsächlich ist es je nach Form eines FRC-Bauteils auch möglich, die klassischen Bewehrungsstäbe komplett durch Stahlfasern zu ersetzen. Auf diese Weise lassen sich erhebliche Mengen an Beton einsparen, der logistische und ökologische Fußabdruck reduzieren und gleichzeitig gewinnen Ingenieure und Designer ein hohes Maß an Flexibilität bei der Schaffung schlanker und leichter Strukturen.
Die strukturelle Integrität hängt, wie fast alle der oben genannten Eigenschaften von FRC, in hohem Maße vom tatsächlichen Gehalt an Fasern und deren räumlicher Orientierung ab. Stahlfasern können sich sogar nachteilig auswirken, wenn sie ungünstig verteilt oder orientiert sind. Solche ungünstigen herstellungsbedingten Faserorientierungen und -verteilungen können z. B. ein unerwünschtes anisotropes Materialverhalten verursachen. Für einen sicheren Einsatz von FRC in der Zukunft müssen zuverlässige zerstörungsfreie Methoden gefunden werden, um die Orientierung und räumliche Verteilung der Fasern im erhärteten Beton zu beurteilen.
In diesem Beitrag stellen wir einen Multimethodenansatz vor, der sich auf Ultraschalltransmissions- (US) und Spektral Induzierter Impedanz (SIP) sowie Röntgen-Computertomografie (CT) stützt. Wir haben eine Reihe von Proben mit bekannten Fasergehalten und -orientierungen in verschiedenen Größen hergestellt und versucht, charakteristische Signalmerkmale zu identifizieren. Aufgrund des hohen Kontrasts zwischen der Röntgenschwächung von Stahlfasern und Beton ist die Faserdetektion mittels CT relativ einfach und das Verfahren kann als Referenzmethode verwendet werden. Vielversprechende Korrelationen konnten darüber hinaus zwischen SIP-Signalmerkmalen und Faserorientierung erkannt werden, gleichzeitig beobachteten wir leichte Verschiebungen in den Ultraschallfrequenzspektren in Abhängigkeit von der Faserorientierung innerhalb unserer Proben. Die Übertragbarkeit der Ergebnisse auf in-situ Untersuchungen großformatiger Probekörper wird in einem nächsten Schritt untersucht.

Delamination Detection on a Concrete Bridge Deck Using Fast Scanning Impact Echo

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Abstract
In this large-scale field study we use a prototype impact-echo scanner to detect delaminations on a concrete bridge deck surveying in total over 17,000 m^2. Delaminated bridge sections are known from manual sounding and coring. A large-scale damage assessment is necessary to identify the need of repair work. Based on first results, two lanes of the bridge are repaired and in subsequent tests the bonding of fresh and old concrete is examined. It shows that delaminations found on the bridge deck surface are unevenly distributed with more defects on the southbound lanes. This indicates constructional problems during the concrete placement. The developed scanner excites stress waves by dropping steel solenoids on the surface and recording the impact-echo frequency by air-coupled microphone arrays. It is pushed at a speed of 600 m/h, hitting the surface 300 times per square meter. The recorded data is preprocessed on site with an automated delamination detection threshold implemented. Found delaminations are transferred to a bridge map to allow an overall damage assessment.

UI/ZP Umwelt- und Ingenieurgeophysik, Zerstörungsfreie Prüfung: Oral presentation (by invitation only)

UI/ZP Umwelt- und Ingenieurgeophysik, Zerstörungsfreie Prüfung: Oral presentation (by invitation only)
V1-1

Machbarkeitsstudie eines seismischen cross-hole Monitorings vor, während und nach einem Methaneintragsversuch auf der Feldskala

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Abstract

Der Erfolg unserer anstehenden Energiewende hängt maßgeblich von zuverlässigen Speichermedien ab. Die Power-to-Gas Technologie nutzt dabei z. B. auch unterirdische Erdgasspeicher. Doch obwohl der geologische Untergrund durch den Menschen schon lange Zeit intensiv genutzt wird und ein exzellentes Speicherpotential bietet, gibt es zur Risikoabschätzung für Auswirkungen auf oberflächennahe Grundwasserleiter kaum bewährte Monitoringmethoden. Variationen in den Messskalen von Mikrometer bis Kilometer (z. B. Frequenzbandbreite, innere Beschädigung von Bohrkernen, Datenerhebungs- und Verarbeitungsartefakte) erschweren das Hochskalieren und Miniaturisieren experimenteller Erkenntnisse und machen die Validierung von Laboruntersuchungen auf der Feldskala unerlässlich. Um diese Forschungslücke zu schließen haben wir einen mehrtägigen Gaseintragsversuch in einem oberflächennahen quartären Aquifer unter kontrollierten Feldbedingungen hinsichtlich Wirkung auf, Interaktion mit und Abhängigkeit von petrophysikalischen Parametern durchgeführt. Dabei dienen die seismische Geschwindigkeit und Amplitude auf Grund ihrer Empfindlichkeit gegenüber der Sättigung in der Gesteinsmatrix als Proxies für Aquifereigenschaften und sollen auf ihre Eignung für das Gasmonitoring geprüft werden. Der kontrollierte Eintrag über drei Injektionslanzen fand auf einer Tiefe von 17 m statt.
Das seismische cross-hole Experiment, bestehend aus einem Quellbohrloch (QB) und zwei Empfängerbohrlöchern (EB) entlang einer Geraden, wurde quer zu den Injektionslanzen aufgebaut. Der zwischen QB und EB1 eingerichtete relativ große Abstand, gegenüber dem Abstand zwischen EB1 und EB2, erlaubt eine quellsignalunabhängige Interpretation seismischer Attribute. Weiterhin profitiert der Messaufbau von seinen Sensitivitäten in Bezug auf Porosität-, Dichte- und Tongehaltsänderungen, und ist dabei komplett frei von Oberflächenrauschen. Unsere Beobachtungen zeigen eine signifikante seismische Geschwindigkeitsabnahme nach der Gasinjektion. Die Detektion der eingetragenen Methangasphase in den oberen 20 m des Untergrundes konnte mit unserer Methode erfolgreich umgesetzt werden.

VU

Vulkanologie

VU Vulkanologie: e-Poster

VU Vulkanologie: e-Poster
VU-1

Identification and interpretation of seismic short-duration events inside the Kolumbo submarine volcano in the Southern Aegean

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Abstract
Kolumbo represents one of the most hazardous, currently active, volcanoes in the eastern Mediterranean. Its last eruption in 1650 AD was associated with a vast explosion, causing a tsunami of regionally devastating impact. The eruption was also associated with the voluminous and rapid release of toxic gases asphyxiating humans and animals on the nearby Islands. Earthquake records from the recent decades document on-going unrest beneath the volcano. Several active hydrothermal vent sites and bacterial mats are present at the crater floor, concentrated near the northern crater wall. The vents emit mainly CO_2, leading to the accumulation of acidic waters in the crater. Accordingly, one of the main volcanic hazards associated with Kolumbo is that rapid overturning of waters in the crater may release harmful amounts of toxic gases. Monitoring the hydrothermal processes inside the Kolumbo crater will provide an important contribution to the understanding and evaluation of this and other volcanic hazards.
In October 2019, we deployed an ocean bottom seismometer and hydrophone (OBS/H) inside the Kolumbo crater. During the four days of passive recording we identified about 100 so-called short duration seismic events, which were only present on the seismometer channels, but absent on the hydrophone channels. The events have durations of less than one second with dominant frequencies between 5 to 30 Hz. Most of the events represent well-polarized seismic phases, which enables us to determine their azimuth incidence angles at the OBS/H. The azimuth angles of all events in the largest cluster coincide with the azimuth angle between the station and the field of hydrothermal vents and bacterial mats inside the crater. This coincidence suggests that the origin of the short duration events is associated with the sub-seafloor migration of fluids or the fluid discharge process at the crater floor. In fact, short-duration events of similar characteristics, recorded by OBS/H, were previously attributed to sub-seafloor fluid migration and the discharge of fluids at the seafloor. Our analyses indicate that seismic monitoring of submarine volcanoes should include the detection and analysis of short duration events, which may act as a tool to characterize volcanogenic geohazard monitoring.

The 2019 Eruption Dynamics and Morphology at Ebeko Volcano Monitored by geophysical instrument networks and remote sensing

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Abstract
Vulcanian explosions are hazardous and are often spontaneous and direct observations are therefore challenging. Ebeko is an active volcano on Paramushir Island, northern Kuril Islands, showing characteristic Vulcanian-type activity. In 2019, we started a comprehensive survey using a combination of field station records and repeated unoccupied aircraft system (UAS) surveys to describe the geomorphological features of the edifice and its evolution during ongoing activity. Seismic data revealed the activity of the volcano and were complemented by monitoring cameras, showing a mean explosion interval of 34 min. Digital terrain data generated from UAS quadcopter photographs allowed for the identification of the dimensions of the craters, a structural architecture and the tephra deposition at cm-scale resolution. The UAS was equipped with a thermal camera, which in combination with the terrain data, allowed it to identify fumaroles, volcano-tectonic structures and vents and generate a catalog of 282 thermal spots. The data provide details on a nested crater complex, aligned NNE-SSW, erupting on the northern rim of the former North Crater. Our catalog of thermal spots also follows a similar alignment on the edifice-scale and is also affected by topography on a local scale. This paper provides rare observations at Ebeko volcano and shows details on its Vulcanian eruption style, highlighting the relevance of structural and morphologic control for the geometry of craters and tephra fallout as well as for structurally controlled geothermal activity.

VU Vulkanologie: e-Poster
VU-3

Classifying infrasound signals at Mount Etna using pattern recognition techniques

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Abstract
The ongoing activity of Mount Etna and the proximity to the nearby population requires constant monitoring. Infrasound recordings play an important role in volcanic observation because explosive activity near or above ground as well as shallow tremor processes are easier to identify with airborne sound waves than with seismic waves that are significantly scattered and refracted in the volcanic edifice. However, infrasound signals are often blurred by noise, in case of Mount Etna, mostly wind induced noise. manual distinction of noisy data from real volcanogenic signals brings along a considerable effort and requires expert knowledge. At Mount Etna five summit craters are currently known with fluctuating levels of activity. This leads to a wide variety of infrasound signal patterns interfered by changing noise levels. In order to distinguish waveforms of noise from signals of volcanic origin we apply unsupervised pattern recognition techniques. We show that by extracting features from the amplitude spectrum different infrasound regimes can be distinguished with Self-Organizing maps (SOMs). This technique provides an option to color-code the results for an intuitive interpretation and allows even for a more detailed recognition of transitional activity regimes. We create a reference data set from multiple months of infrasound waveforms to include as many activity regimes as possible to train the SOM. This enables a fast classification of new data.

VU Vulkanologie: e-Poster
VU-4

Monitoring of ground deformation at Sakurajima volcano using Sentinel-1 InSAR time-series

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Abstract
Surface displacements recorded in volcanically active regions are often driven by magmatic, hydrothermal or tectonic processes. Measuring the deformation experienced by the ground as a result of these processes allows to constrain the changing volcanic conditions and to infer quantitative estimates of the subsurface magmatic storage, thus increasing the knowledge of volcanic hazards for the closest local population. Interferometric synthetic aperture radar (InSAR) has proven to be an useful tool to observe ground deformation in volcanically active areas like the Sakurajima volcano, southern Japan, one of the most active volcanoes worldwide. Its current activity is characterized by degassing and almost daily explosive eruptions. We performed an InSAR time series analysis to identify and characterize time-dependent ground deformation using Sentinel-1 data from early 2019 to late 2020. During this period several large explosions with plume heights between 3000 m and 5000 m occurred. We found evidence of uplift prior to and subsidence after major explosions, which we interpret as pressurization processes. These results may contribute to the discussion about the open/closed nature of the volcanic system of Sakurajima.

VU Vulkanologie: e-Poster
VU-5

Inferring a shallow degassing model for Villarrica Volcano from seismic explosion signals and SO_2 flux

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Abstract
Villarrica is a basaltic volcano with an active lava lake in South Central Chile.
The lava lake displays a variety of degassing styles from gentle seething to more violent Strombolian explosions. This activity is accompanied by sequences of transient seismic waveforms suggesting the presence of discrete gas bubbles in the upper magma column. Gas bubbles flow through liquid-filled pipes according to distinct patterns depending on viscosity of the liquid and volumetric gas flow rate. Laboratory experiments indicate that these regimes are characterized by distinct frequency distributions of bubble sizes and spacings. By assuming that these parameters are reflected by the magnitude of the transients and the time between them, we compared their statistical distributions to infer a flow regime for the shallow conduit of Villarrica. The approximately log-normal distributions indicate a sustained slug flow regime in which the gas ascends in trains of conduit-wide gas slugs. The event catalog for our analysis contained about 20,000 events and was generated from 12 days of seismic data from March 2012 acquired by a dense local network. A well-known problem in earthquake statistics is the incompleteness of event catalogs towards low magnitudes due to decreasing detectability in the ambient noise. We estimated the actual distribution of magnitudes by using a Monte Carlo simulation of the event detection based on the statistical properties of the observed seismic noise. The unknown source depth and mechanism introduce further ambiguity regarding the distributions. Nevertheless, we hope to refine the degassing model by taking into account degassing rates, magma properties and more detailed analysis of the nature of the seismic events.

VU Vulkanologie: Oral presentation (by invitation only)

VU Vulkanologie: Oral presentation (by invitation only)
V1-04

A Multidisciplinary approach to constrain the dynamics of the Altiplano-Puna magmatic system

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Abstract
Continuous Interferometric Synthetic Aperture Radar (InSAR) monitoring (> 25 years) has revealed a concentric surface deformation pattern centered around the summit of Uturuncu volcano above the Altiplano-Puna magma body (APMB) in the central Andes. For the past decades, several numerical studies have successfully reproduced this pattern with models of varying complexity. However, the temperature- and strain rate-dependent visco-elasto-plastic rheology of rocks, the buoyancy of magma, the effects of modelling in 3D as well as the shape of the magma body have often been simplified or neglected.

Here, we use a joint interpretation of seismic imaging, gravity anomalies and InSAR surface deformation data to constrain location, 3D shape and density of the magma body. With the help of the thermomechanical stokes code LaMEM, scaling law analysis, the neighborhood algorithm and bayesian inference, we estimate the uncertainties associated with the geometry of the mid-crustal magma body and identify the most important parameters that control the dynamics of the system.

We find that the density contrast between the APMB and the surrounding host rock must be in the range of 90 to 130 kg/m3 (2 sigma) to satisfy both tomography and Bouguer data. Based on that and the chemistry of eruption products, we estimate the melt content of the APMB to be on the order of 15 - 22 %. We also present a 3D model that can reproduce the observed surface deformation self-consistently by buoyancy driven magma transport without the need for additional pressure sources. The flow pattern is controlled by a central rise at the top of the APMB whose geometry can be constrained with the help of the thermomechanical code while gravity anomalies help to constrain the deeper parts of the magma body. Scaling law analysis shows that the rheology of the upper crust and the magma mush as well as the density contrast between the two are the most important parameters in the system and need to be constrained for a better understanding of the subsurface processes.

DGG-SEG

DGG-SEG Workshop ”Scientific Drilling”

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

An Integrated Approach For Drillstring Vibration Mitigation Combined With Bit Selection Roadmap And Soft Torque Rotary System For Improving Drilling Performance And Downhole Tools Life

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Abstract
Drilling performance is significantly suppressed due to excessive drillstring vibration and wrong bit selection, resulting in decrease in rate of penetration (ROP), expedite drillstring fatigue and potential downhole tools failure.
This presentation addresses an integrated digitalized approach in planning and execution phase where field witness of high drillstring vibration, wellbore instability and tool failure. PETRONAS Wells drilled between 2010-2020 are studied for non-productive time (NPT) and invisible lost time (ILT) related to Drill bit failure and drillstring vibration. Classification of root causes as well as recognized field area related to NPT/ILT categorized to mode of failure and vibration. ROP is often captured by many drilling companies to evaluate the drilling efficiency as it directly related to the footage cost. To date, no reliable model exists that can qualitatively compare historical bit runs However, an adapted Digitalized Bit Benchmarking (DBB) during planning stage developed to capture not only bit performance but also overall section performance to address root cause of field and corrective action. DBB is an independent, operator driven, simplified performance approach for development and appraisal wells targeted not only to identify the fit-for-purpose bit in the section but also opportunities with drill bits providers on performance deal trials. Apart from the existing standard mitigation guidelines in the operators' perspective, this presentation also compares vibration mitigation tools' and latest generation cutters capabilities from various drilling service providers to develop fit for purpose tools for monitoring and corrective actions. Vibrations resulting from various lithology are studied so that additional precaution is adopted when drilling through critical lithology where severe vibration is anticipated during planning stage. Digitalized Drilling Parameters boundary developed in planning phase along with anticipated problem decision chart helps during drilling execution. Proven track record from the implementation of Soft Torque System has shown from 150 to 40% decline in drillstring vibration severity level.
In conclusion, Digitalized Drilling solution application in planning as well as execution phase not only increases overall performance by controlling drillstring vibration but also improving ROP and Downhole tools life.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

High-performance sediment coring for the 100 m depth range: Hipercorig

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Abstract

The recovery of continuous, unconsolidated sediments is a key operational prerequisite for many paleo-climate and environmental studies. Gravity driven or manual, simple coring tools are commonly limited to depths of 10 to barely 20 m. Objectives beyond this penetration limit require deployment of rather cost intensive mining drilling equipment. In order to bridge the gap between these coring options we have developed the Hipercorig.

Hipercorig is a mobile coring instrument designed to reach at least 100 m coring depths on land and in waters of up to 200 m depth. The device has been tested on deep perialpine lakes, recovered successfully hitherto unidentified pre-Holocene deposits and will be deployed on Lake Hallstatt in Austria in 2021. The coring technique is based on a dynamic piston coring system directly powered by a hydraulic down-the-hole hammer that is driven environmentally friendly by water. Offshore, the coring system is kept in place through Kevlar ropes by a coring rig based on a modular barge that carries the casing connector machinery, winches, and anchoring systems as well as a power and hydraulic generator. The crucial advantage of Hipercorig is the high-frequency hammer directly striking on top of the coring barrel, allowing to penetrate hard layers such as glacial till, volcanic ash, sands and gravels, and that the whole system is modular and mobilized in only four standard 20-foot-containers. The core recovery rate of the tool is about 90% in the sediments we have tested so far meaning to ensure flawless coverage double coring and core splicing may be required. However, geophysical downhole logging is possible to complement potential core losses and, in addition, to register continuously and in situ petrophysical properties along the borehole walls.

This contribution will provide technical information, initial scientific results as well as availability and operational costs to the scientific community.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

Challenges of core-log-seismic integration in metamorphic rocks: A case study for the ICDP drilling project COSC-1, Sweden

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Abstract
Driven by significant economic benefits, the hydrocarbon industry developed sophisticated methods for the integration of geophysical and geochemical measurements with direct core observations. However, these techniques were developed primarily for sedimentary settings and have been applied only seldom in metamorphic settings. One outstanding example for comprehensive geophysical and borehole data integration is the COSC-1 borehole in the central Scandinavian Caledonides. It was drilled in 2014 and resulted in an extensive dataset to shed light on deformation during continental collision. Our study combines data from downhole logging and zero-offset vertical seismic profiling at COSC-1, with 2D and 3D seismic measurements to provide constraints on the spatial lithological and textural configuration of the Seve Nappe Complex. We show that there are powerful tools to distinguish between mafic and felsic lithologies in log-core correlation but that metamorphic settings bear special challenges for core-log-seismic integration. In contrast to sedimentary basins, reflections in the Seve Nappe Complex are not as distinct but we can link several of them to magmatic intrusions, which have been metamorphically overprinted. Their setting indicates that the Seve Nappe Complex consists of the remnants of a volcanic continental margin. It appears that in spite of the metamorphic overprint around 417+/-9 Ma, the original configuration of the volcanic passive margin is partly preserved in the Seve Nappe Complex and it thus outlasted continent-continent collision including the nappe emplacement. Integration of borehole and three-dimensional geophysical data reveals lithological changes that can then be extrapolated in three dimensions to arrive at a better understanding of the composition and geometry at mid-crustal levels. Furthermore, our results suggest that mid-crustal reflectivity at COSC-1 is primarily a function of pre-orogenic lithological variations which has to be considered when deciphering mountain building processes.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

New downhole logging instruments for adverse borehole conditions

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Abstract
Borehole measurements deliver substantial geophysical and geochemical data in scientific drilling projects. They are mostly carried out very successfully by methods of wireline logging. However, there is a significant number of projects in which downhole conditions adverse to wireline logging do occur that make a sonde deployment on a cable risky, extremely difficult and therefore very time-consuming or even impossible. The most common adversities are partially blocked boreholes and borehole paths that deviate strongly from vertical. For already more than 20 years various so-called Logging While tripping (LWT) techniques without the need for a logging cable are applied by the logging service industry but this method has hardly been used in scientific drilling although it enables logging in unstable boreholes such as in lacustrine sediment drilling projects.
We established a cable-free memory logging system for drill string deployed geophysical borehole measurements. This modular memory logging system can be deployed in the standard wireline-core-drilling diameters of HQ and PQ. The battery-powered, autonomous sondes record profiles of natural GR spectrum, sonic velocity, magnetic susceptibility, electric resistivity, temperature, and borehole inclination while they are pulled out together with the drill string. Since a precise depth measurement carried out in the drill rig is just as important as the actual geophysical downhole measurements we developed two independent depth measuring devices providing high accuracy of less than 0.1 m deviation from comparable wireline depth. This contribution will provide results of first measurements with the memory logging sondes and show the efficiency of the depth measurement systems

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

A Virtual Core-Log-Seismic Integration Centre in Germany

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Abstract
The goal of core-log-seismic integration is to glean new scientific understanding from diverse datasets that span the millimeter to kilometer scale. Germany plays an important role in international scientific drilling, with major core curation and data management centres, as well as broad expertise in seismic data acquisition, borehole logging and sediment core investigations. Springboarding from this solid foundation, we propose to establish a virtual Core-Log-Seismic Integration Research Centre to act as a nucleus for conceiving and running research projects that harvest the untapped potential of hundreds of scientific boreholes. We envisage that scientists from Germany, in collaboration with key international partners, should work closely together and provide the critical mass and long-term expertise to sustain the research centre. We see this an ideal way to foster collaboration within Germany and globally.
In this presentation we will describe this new initiative and provide some examples of on-going and developing research projects that are underpinned by core-log-seismic integration methods. The examples will include investigations into submarine landslide processes (offshore New Zealand), gas hydrate formation (offshore Taiwan) and continental collision (onshore Sweden).

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

Spectral Gamma Borehole Logging Applied to Predict Tephra Layers in Lacustrine Deposits: An Example from Lake Chalco, Central Mexico

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Abstract
Lacustrine sediments are archives of past environmental conditions. In recent decades, multinational ICDP efforts have conducted lake drilling projects to encode the potential of paleoclimate signals. Gamma-ray spectroscopy is a particularly useful tool as it is non-destructive, fast, and affordable even in cased boreholes. Gamma radiation can be used to identify elemental isotopes in the geological record, which is used for stratigraphic correlation and paleoclimatic investigations.
However, some lake sediments contain tephra layers with specific gamma-ray signatures, presenting a challenge for extracting the primary signals caused by environmental and climatic agents. Here, we use the sediments of Lake Chalco in central Mexico to propose a protocol to identify tephra layers embedded in other sediments using high-resolution spectral gamma-ray spectroscopy. This facilitates dividing the overall sediment column into representative horizons of tephra and non-tephra.
Among the upper 300 m of the lake deposit, our index detected 363 tephra layers, while 388 total tephra layers (≥1 mm in thickness) were reported from the core description of the same borehole, predicting 92% of tephra layers documented in the lake deposits from core descriptions. We suggest that not only the strength of the gamma-ray signal but also the composition of its constituent energy channels can be used to detect embedded tephra layers.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

Overcoming Well Integrity Challenges Associated with Existing Plugged and Abandoned (P&A) & Injection Wells in Offshore Depleted Gas Field for CO_2 Storage

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Abstract
Oil and gas industry is committed towards net zero carbon emission because consequences of climate change could be catastrophic unless responded very soon. One way of reducing CO_2 emissions is to inject it in a depleted reservoir buried underground. This greenhouse gas reduction technique significantly reduces CO_2 released to atmosphere. Three major depleted gas fields, in Central Luconia located offshore Sarawak, have been identified as a possible CO_2 storage site based on their favorable geological characteristics needed to ensure long-term security for CO_2 storage. In order to develop these fields as CO_2 storage sites, long-term integrity of wells drilled in these gas fields must be ascertained to ensure CO2 containment for decades/centuries into the future.

The existing plugged and abandoned (P&A) were drilled 45 years ago and new CO_2 injection wells to be drilled should be designed to withstand downhole conditions having >50%vol CO_2 and CO_2/H_2O mixture. The reservoir pressure and temperature conditions may have further degraded the material strength and elevate the corrosion rate. Geo-mechanic challenges such as field subsidence of 23ft in 25years and faults need to study and considered into modelling. Understanding all the uncertainties that may have affected cement-casing bond, such as quality of cement behind casing, subsidence effect, corrosion rate, etc., is the first step towards well integrity evaluation. Secondly, proper quantification of all the uncertainties involved needs to be done that may affect our long-term underground storage objective of CO_2. High-risk existing P&A wells to be re-entered to restore the well integrity and to reduce future leakage that may happen. Initial steps involved are locating the subsea P&A wells and then monitoring them at the seabed for any indication of bubbling or leakage. Gaining a well control of existing P&A wells is discussed as the wellhead was removed and casings were cut below mudline.
The presentation also outlines the challenges and requirement to design a fit-for-purpose CO_2 injection wells for an offshore CO_2 storage flagship project in South-East Asia. Risk and mitigation approach along with cutting-edge monitoring technologies for potential CO_2 leakage/seepage in the marine environment are elaborated to ensure that the integrity is maintained, and CO_2 is contained underground for years to come.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

Overcoming Subsurface Wellbore Instability Caused Due to Backreaming in an Inclined Wells

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Abstract
After drilling a hole section safe pull out of Bottom Hole Assembly (BHA) and good hole condition to run and cement liner/casing every operator determined but in an unavoidable encounter of Backreaming which required pumping/rotating/pulling drillstring backwards to come of hole due to different reasons. Backreaming takes lot of time to condition the hole in addition to risk of high Cutting or/and Caving's generation result high Equivalent Circulating Density (ECD) has a potential to cause pack off and wellbore instability which result a stuck pipe or hole collapse incident, Micro-dogleg created during Backreaming provide crooked hole affect well placement and logging quality, and ledges trouble to run smooth casing/liner to bottom.

The presentation emphasis on case studies of PETRONAS where medium to hard Backreaming were encounter in numbers of wells. The mitigations, best practices, Mud/BHA design and other strategies has been discussed to overcome and reduce the no of Backreaming issues in future which will help the wellbore quality more reliable in getting good resolution of logging data will minimize Micro-dogleg, ledges created during hard Backreaming process.

It is intended that this presentation serve as a useful reference and starting point for engineers working to improve hole condition and Backreaming i.e. achieve best composite timing for the drilling section.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

First insights into analyses of geophysical data of Prees-2 borehole (England) as part of the ICDP JET-Project

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Abstract
In autumn 2020, an approx. 650 m deep core was drilled at Prees in Shropshire, England, as part of the ICDP project JET (Integrated Understanding of the Early Jurassic Earth System and Timescale). The main objective of the project is to obtain and characterize a complete and continuous sedimentary archive of the 25 million years of the Early Jurassic. The Early Jurassic period (200-175 million years) was a period of extreme environmental change: Rapid transitions from cold or ice ages to super-greenhouse events have been documented, including global changes in sea level and organic carbon distribution, as well as mass extinctions and large-scale isotope anomalies.
Knowledge of this part of the Earth's history is still incomplete, but relevant, as it can serve as an analogue for present and future environmental changes. It is expected that the project will provide a "master record" for an integrated stratigraphy (bio-, cyclo-, chemo- and magnetostratigraphy) of this period, which will also be useful for Earth system modeling. In addition, the project will allow the reconstruction of the local and global palaeoenvironment and the driving mechanisms and feedbacks responsible for environmental changes in the Early Jurassic.
The analysis of geophysical borehole measurements contributes to interpretations with respect to the lithological characterization of sediments and their boundaries, the determination of paleoclimatic history, the description of sedimentary facies and sedimentary cycles, identification of compaction and the development of an increased understanding of neotectonics and recent tectonics in the investigated area.
First preliminary results of these borehole measurements include a lithological classification which is based on a cluster analysis of solely physical data. Furthermore, core-log integration has been carried out and a first attempt towards astrochronology has been made.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

Ocean – ice sheet interaction in West Antarctica: First results from core-log seismic integration in the Amundsen Sea Sector

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Abstract
Throughout past decades, the West Antarctic Ice Sheet (WAIS) reacted increasingly sensitive to ocean and atmospheric forcing resulting in increased ice shelf thinning, accelerated ice flow and grounding line retreat. Its future stability therefore remains to be a critical unknown in global climate projections. In order to evaluate the threat of a potential future partial or full WAIS disintegration, reliable information on past ice sheet dynamics and its interaction with oceanic processes is essential for calibrating and improving such future projections, particularly for periods in earth's past that were warmer than present and thus may serve as analogues for projected future scenarios. However, information on past ice sheet dynamics and interaction with ocean circulation processes in the Amundsen Sea sector, a key area for understanding past and present WAIS stability, are scarce. During the International Ocean Discovery Program (IODP) Expedition 379, sediment cores covering those critical periods were recovered at two sites on the Amundsen Sea continental rise. Those nearly continuous late Miocene-Pleistocene records are located on a seismic network allowing for a regional horizon correlation and seismic sequence characterization by applying core-log seismic integration. The sediment records provide insight into a large sediment drift and further enable comparison to other Amundsen and Bellingshausen Sea drift bodies by seismic correlation. The results of the core-log seismic integration with synthetic seismogram calculation are used to correlate key seismic horizons, e.g. prominent boundaries between Miocene and Pliocene, mid-Pliocene as well as Pliocene and Pleistocene. They may further allow statements about variations in sediment deposition and transport activity related to past ice sheet dynamics.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

Seismic site surveys at ICDP drill sites: examples from COSC-1 (Sweden) and DFDP-2 (New Zealand)

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Abstract
Seismic site surveys are not only helpful to define drill locations but are crucial to characterize the geological setting of the drill site. This is of great importance to link findings from the drilling to regional structures on different scales. Here, we present results from seismic site surveys at the ICDP drill sites COSC (Sweden) and DFDP (New Zealand). At both sites, comprehensive seismic surveys were performed and included surface 2D lines and 3D arrays around the borehole as well as multi-azimuthal walkaway VSP recordings in the borehole. In general, we first derived detailed velocity models by first-arrival travel-time tomography, in the case of COSC including anisotropy. Afterwards, data processing and pre-stack depth migration (PSDM) approaches were applied to obtain seismic images of the subsurface around and below the borehole.

The COSC (Collisional Orogeny in the Scandinavian Caledonides) project focuses on the Caledonian orogen. Two boreholes were drilled and fully cored. At the COSC-1 drill location, we were able to image the internal small-scale structures of the Seve Nappe Complex, provided missing links in the deeper parts to existing regional scale 2D seismic profiles and characterized the seismic anisotropy of the drilled units. The latter significantly improved the imaging results through the usage of an anisotropic velocity model in the PSDM workflow.

The DFDP (Deep Fault Drilling Project Alpine Fault) project aims to deliver insight into the geological structure of the Alpine Fault zone, a major plate boundary which is late in its earthquake cycle. Despite the challenging conditions for seismic data acquisition and imaging within a glacial valley filled with sediments and steeply dipping valley flanks, several structures related to the valley itself as well as to the fault system were imaged. With the help of PSDM methods, we were able to directly image Alpine Fault related reflectors constituting a ~600 m wide damage zone. Structural details of the fault zone show the complexity of the shallow (<5 km) Alpine Fault at the drill site within the Whataroa Valley.

In total, our results proof the importance of comprehensive seismic site surveys to understand complex environments and tectonic settings. At best, surface 2D lines and 3D arrays are combined with borehole (VSP) recordings to gain the maximum information about the geological setting of the borehole.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

Age-depth models derived from borehole logging and seismic data on the example of the sedimentological evolution of Lake Ohrid (North Macedonia/Albania) over the last one million years

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Abstract
To understand the sedimentological history in lake basins, a robust age-depth model is essential. Usually, such models are created based on core material using an integrated geoscientific approach, including biostratigraphy, magnetostratigraphy and radiometric dating. However, suitable core material is not always available and other less direct methods have to be applied. Part of this study is to construct age-depth models based on integrating downhole logging and seismic survey data. The possibilities of this method are shown exemplarily by the data from Lake Ohrid (North Macedonia/Albania). Logging data was acquired during an International Continental Scientific Drilling Program campaign in 2013 and seismic data is from pre-site surveys conducted in 2007 and 2008 (e.g. Lindhorst et al. 2015; Wagner et al. 2014)
Firstly, we interpret seismic data and correlate downhole logging data from three sites to the LR04 benthic stack (Lisiecki and Raymo, 2005). The resulting age-depth models are crosschecked using cyclostratigraphic methods (Meyers' timeOptTemplate method (2015, 2019)).
In a second step, we construct an artificial lithology log based on the physical properties of the sediments and integrate it into the age-depth models. This allows an initial interpretation of the sedimentological history of the three investigated sites.
This approach has the potential to improve future drilling projects by delivering age-depth models and description of sediment properties before core opening or in case, no (suitable) core material is available.

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DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

The Proposed Rock Valley Earthquake/Explosion Direct Comparison Experiment

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Abstract

The proposed Source Physics Experiment (SPE) Phase III: Rock Valley Direct Comparison (RV-DC) experiment will be the first-ever direct evaluation of co-located earthquake and chemical explosion sources recorded at the same seismic stations. We propose to drill to the hypocenter of one of the series of shallow (< 2 km) earthquakes that occurred in 1993 in Rock Valley in southern Nevada, United States. The largest of these was a left-lateral M3.7 earthquake with a dozen events greater than M2 in the sequence. The plan is to detonate a chemical explosion at the same location, depth, and source media properties as the earthquake. The recently completed SPE Phase I (2010-2016) and Phase II (2017-2019) improved our understanding of seismo-acoustic explosion phenomena and developed numerical simulation capability with validation data. These data were generated by subsurface chemical explosions in two different and highly contrasting geologies: wet granite and dry alluvium at depths down to 87 m and 385 m, respectively. The differences between the seismic signals from these two geologies are profound and were not well represented by existing models before SPE was executed. In addition, during SPE natural background earthquakes were recorded and compared with the chemical explosions allowing the evaluation of techniques used to distinguish between them. Because earthquakes usually occur at deeper depths and in different media than the explosions, uncertainties remain in how those parameters play into the observed differences.

The RV-DC will provide key data for testing models now being developed from SPE and used to build new physics-based techniques for use in worldwide underground nuclear test monitoring. In addition, the RV-DC experiment will provide a rare direct sample of an earthquake source region, allowing the determination of fault properties and shedding new light on the physics of earthquakes.

We are working on improving the hypocenter location of one of the large Rock Valley earthquakes as the drilling target. For purposes of providing sufficient volume at depth for the chemical explosive, we will investigate drilling a large diameter borehole. To characterize the location, we want to core and sample the Rock Valley fault properties at depth (e.g., temperature, stress, fault rock characteristics). We plan to draw on recent experiences drilling other active faults such as the San Andreas in California, Chi Chi in Taiwan, and Tohoku offshore of Japan.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

Zero offset VSP survey at the Alpine Fault (New Zealand) using a fibre-optic cable

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Abstract

An extended 3D vertical seismic profiling (VSP) survey was carried out at the DFDP-2B drillsite on the South Island of New Zealand as part of the Deep Fault Drilling (DFDP) Project. One of the main goals is the improvement of the geological model around the Alpine fault system. Additionally, the unique option to directly compare two measurement systems is used: conventional three-component borehole geophones and a heterodyne Distributed Vibration Sensing system (hDVS), which utilizes the optical fibre in the borehole as a receiver chain.

P-wave velocities are derived from first-break picks and compared to sonic log data. Afterwards, a separation of up- and downgoing wavefields is carried out. Seismic processing aims to improve the data quality before further analysis and includes FK-filtering and deconvolution. The obtained results are used for Kirchhoff prestack depth migration and to create a corridor stack. The prestack seismic image and the corridor stack both show reflections that correlate well with known geological boundaries.

Selected reflection events were depth migrated individually. Three distinct reflections are likely caused by fault related features. A detailed comparison to prestack depth migrated images obtained from surface seismic receivers supports this hypothesis.

In conclusion, the hDVS dataset is well suited for seismic imaging. The identified reflectors complement and consolidate the previous imaging results from surface seismic datasets.

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Recent developments for geophysical and geotechnical borehole data acquisition and their application with the MARUM-MeBo sea bed drilling technology

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Abstract
Sea bed drilling technology can provide a valuable complement to the services of classical drill ships, especially for shallow drillings up to 200 mbsf and when working in remote areas difficult to access. The sea bed drill rigs MARUM-MeBo70 for drilling down to more than 70 m and MARUM-MeBo200 for a drilling depth of up to 200 m are developed and operated by the MARUM Center for Marine Environmental Sciences at the University of Bremen since 2004 (Freudenthal and Wefer, 2013).
The recovery of core samples typically is the major goal of scientific drilling campaigns with the MeBo. We use wireline core barrels suitable for both soft sediment and hard rock rotary drilling. In addition, the drilled hole itself can be used for scientific data acquisition. Memory borehole logging tools including Spectrum Gamma Ray (SGR), Dual Induction, Magnetic Susceptibility and Acoustic (P-wave velocity) are used for logging the geophysical properties within the borehole and the adjacent formation. Furthermore, we have developed a temperature probe that can be pushed into the base of the borehole for measuring bottom hole temperatures. We also have developed a 15cm^2 Cone Penetration Testing probe (CPT) for the use with MeBo. This probe is pushed into the base of the borehole for in-situ measurements of the geotechnical characteristics of the formation.
In this presentation we explain the deployment mode of these tools for acquiring in-situ data and show examples from MeBo drilling campaigns where core drilling and different methods of in-situ data acquisition within the drilled formations were combined.

References:
Freudenthal, T and Wefer, G (2013) Geoscientific Instrumentation, Methods and Data Systems, 2(2). 329-337. doi:10.5194/gi-2-329-2013

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Investigating Submarine Slope Failures with Geophysical Data, Scientific Drilling, Laboratory Experiments, and Numerical Modeling

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Abstract
Slope failures in ocean basins represent some of the largest slope failures on Earth, occur on very low-angle slopes, can create deadly tsunamis, and can damage infrastructure. While important geologically and societally, we are still working on our understanding the linkages between how slope evolution and fluid flow precondition a slope for failure, how triggers influence the type and extent of failure, and how failures evolve after initiation. Increasing our basic understanding will help us better constrain what influences recurrence interval, location of failures, and their geohazard potential. Scientific drilling, including site characterization, analysis of cores and log data, and experiments and models, provide necessary data in the marine environment to improve our knowledge of these dynamic and important slope failures. In this presentation, I will summarize the current state of the art for interrogating slope failures and modeling their dynamics through geophysical data, core analyses, laboratory experiments, and numerical models. The presentation will focus on two detailed studies in the Gulf of Mexico, offshore USA and in the Hikurangi margin, offshore New Zealand. These two examples are shown because of the extensive data available and because of theie differing dynamics. The Gulf of Mexico has evidence of instantaneous failures that are interpreted to include fluid-like failures and brittle failures linked to different triggering mechanisms. The Hikurangi margin example has evidence of creep-like behavior as well as instantaneous failure. After summarizing how these studies have advanced our knowledge of slope failure dynamics, I will introduce needs from drilling, sampling, and experiments to further expand our knowledge on slope failures and their geohazard potential.

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Fault zone Drilling and Monitoring: A key Science Theme for ICDP and Recent Results from the ICDP-GONAF Observatory

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Abstract
The principal solid earth geohazards are earthquakes, volcanoes, and mass movements. These hazards occur on very different time and space scales. They strongly depend on local geological conditions, making each one of them challenging to assess and forecast. Deciphering their underlying causes and physical processes is of utmost relevance to understand the full chain from hazard to risk. Key questions and challenges demanding our immediate attention include: What are the drivers initiating and controlling earthquakes, volcanic eruptions and mass movements such as landslides? How do we distinguish faults, volcanoes and potential landslides that present an immediate threat from those with low hazard? How do we build a better quantitative understanding of physical processes, allowing us to provide advanced warning time to mitigate the risks associated with geohazards?
Fault-zone drilling and monitoring provides the only means to access the depths where the energy of earthquakes is stored and released. It has been a centerpiece of the International Continental scientific Drilling Program (ICDP) since its foundation in 1996. Consequently, it is a key science theme of the new ICDP Science Plan released in 2020.
In this talk I review the state of the art in fault zone drilling and monitoring and provide an outlook on the related scientific and logistical challenges. As a case study I will focus on the recently implemented ICDP-driven downhole observatory GONAF (Geophysical Observatory at the North Anatolian Fault). GONAF aims at monitoring the eastern Marmara section of the fault that is late in its seismic cycle and collocated with the Istanbul metropolitan region. There, near-fault monitoring along large portions of the offshore fault section is challenging. Recent results from borehole-based multi-sensor deployments allow to observe distinct slow-slip transients detected by borehole strainmeters that occur in conjunction with local moderate (M>4) earthquakes. Furthermore, lower magnitude-detection thresholds now allow identifying systematic preparation processes leading to M>4 mainshocks as well as extended aftershock sequences complementing postseismic slow slip. These observations show that further reducing the observational gap and broadening the signal frequency bandwidth allows to decipher deformation processes that previously remained undetected, now providing means for improved seismic hazard and risk models for the Istanbul metropolitan region.

DGG-SEG Workshop "Scientific Drilling": Oral presentation (by invitation only)

Drilling experiences in active tectonic environments and across platforms

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Abstract
This talk will give an overview of the experiences of working on the different scientific ocean drilling platforms as well as a focus on results from a recent Mission Specific Platform expedition in the active Corinth Rift in Greece. The current IODP program supports expeditions on Chikyu (with riser drilling capabilities and the ability to drill in deep water), the Joides Resolution, and Mission Specific Platforms (with specific platforms contracted to undertake work where the other platforms cannot gain access or drill). Each platform can have advantages or disadvantages over the other, but in many cases the nature of the science and location dictates which platform is used. I will explain some of the differences between the platforms and expeditions, from my own experiences.
IODP Expedition 381 used the geotechnical vessel Fugro Synergy to drill in the active continental Corinth Rift in central Greece. The Corinth Rift is one of the most active rifts worldwide and a key example of the early rift phase without significant magmatism. This is one of the most seismically active regions of Europe and the rift experiences some of the highest rates of extension worldwide. Drilling at 3 sites took place in 2017 with a small science party on board and only initial and ephemeral analysis conducted. The full science party (34 people) conducted the full description and analysis of core and log data at Marum/University of Bremen in 2018 for 1 month. Primary objectives are to use the high temporal resolution cored and logged record integrated with a high spatial resolution seismic network to resolve in unprecedented detail the structural evolution of the rift and the relative roles and interactions between tectonics and climate on sedimentary and surface processes in an active rift. The new sedimentary record represents the longest and highest resolution stratigraphic record for an early phase rift and an unusual record of basin environmental response to sea level change and fluctuating isolation-connectedness. Some of the preliminary results will be presented.

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Drilling to magma – a journey to the unknown

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Abstract
The science of volcanoes has enormously progressed in monitoring and modeling volcanic systems as well as simulating several aspects of their complex dynamics. Still, we have never observed magma in place, and all we know about it comes from indirect measurements, theoretical models, and large speculation. Notwithstanding our highly sophisticated resources, and in spite of the relevance of understanding magma dynamics and predicting the evolution of magmatic systems, our current knowledge is only partly based on evidence, and a number of aspects with first order impacts on volcanic hazard assessments as well as heat flow and geothermal system dynamics, are still poorly or not known.
The KMT (Krafla Magma Testbed) consortium aims at directly reaching magma at 2.1 km depth below the surface of the Krafla caldera, Iceland, a depth at which it was incidentally hit by Landsvirkjun while drilling in search of geothermal fluids. Surprisingly, none of the abundant geophysical prospecting in the area had suggested the existence of molten rock at such a depth. Missing to recognize the presence of shallow magma seriously alarms for other high risk situations, e.g., Campi Flegrei caldera hosting part of the city of Naples. Similarly surprising, the thermal gradient region above the magma, and the sparse samples that were brought to surface by the drilling fluids, poorly match the dominant hypotheses on the physics and chemistry close to the margins of a buried magma body.
Missing direct observations clearly translates into largely uncertain or possibly wrong understanding. The short-term objective of KMT is that of realizing the first-ever direct observations, measurements and sampling across the rock-magma transition. That is expected to heavily impact our understanding with implications that span from more evidence-based modeling of volcanic unrests and provision of short-term volcanic forecasts, to understanding the mass and heat flow from magma to rocks and into geothermal circulation systems. Over the longer term, KMT aims at establishing the first permanent magma observatory in the world represented by a series of wells open inside and around buried magma, where to develop the third millennium capacities in observing, monitoring, experimenting, and modeling volcanoes and geothermal system dynamics. KMT is fully endorsed by the Icelandic Government and currently rising interest by governments while expanding participation by academies and industries.

Autorenverzeichnis

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