41. Sitzung der AG Seismologie
Wildbad–Kreuth
Programm

Dienstag, 15. September 2015

Oral Session I: 14:00–15:30

Wolfgang Friederich:
Eröffnung der Sitzung

Klaus Stammler, M. Dohmann, T. Grasse, M. Hanneken, E. Hinz, I. Göbel, M. Hoffmann, E. Muhire, C. Müller, H. Schlote, U. Stelling, E. Wetzig:
Bericht über das Seismologische Zentralobservatorium der BGR (SZO)

A. Strollo, W. Hanka, J. Saul, F. Tilmann and the GEOFON team :
Recent developments at GEOFON

Manuel Hobiger, Donat Fäh, Christian Scherrer, Clotaire Michel, John Clinton, Carlo Cauzzi, Franz Weber:
Current status of the renewal projet of the Swiss strong motion network (SSMNet)

Tobias Megies, Lion Krischer, Elliott Sales de Andrade, Robert Barsch and the ObsPy Development Team:
ObsPy: A Python Toolbox for Seismology - Introduction, Recent Developments and Future Plans

Oral Session II, Earthquakes, 16:00–18:00

Andreas Barth:
Location and source mechanism of the Karlsruhe earthquake of 24 September 2014

Diehl, T., Singer, J., Hetényi, G., Kissling, E., Clinton, J.:
Along-Strike Differences of the Main Himalayan Thrust and Deformation within the Indian Crust: Insights from Seismicity in Bhutan and its Foreland

Frank Krüger , Galina Kulikova, Angela Landgraf:
Instrumental magnitude constraints for the July, 11, 1889, Chilik earthquake

Plötz, A ., Schmid, F., Schlindwein, V. and Scholz, J. R.:
Seismicity of the segment-8 volcano at the Southwest Indian ridge

T. Dahm, M. Hensch, S. Heimann, S. Cesca:
The seismo-mechanical coupling of caldera subsidence, ring-fault earthquakes and lava flow of the 2014-2015 eruption at Bardabunga volcano, Iceland

Andrea Brüstle, Margarete Vasterling, Bernd Schmidt, Ulrich Wegler:
Seismische Echtzeitüberwachung der Geothermiekraftwerke Insheim und Landau

Nicolai Gestermann:
Nachbebensuche bei der Feldübung IFE14 der CTBTO in Jordanien

Mittwochvormittag, 16. September 2015

Oral Session I, Earth Structure, 9:00–10:30

Max Moorkamp, Bjoern Heincke, Marion Jegen, Richard Hobbs and Alan Roberts:
Improved imaging of the subsurface through joint inversion of seismic, magnetotelluric and gravity data

Antje Schlömer, Wolfram Geissler, Wilfried Jokat, Marion Jegen:
Is there any mantle plume beneath Tristan da Cunha?

M. Reiss, G. Rümpker, F. Tilmann, X. Yuan, E.J. Rindraharisaona:
Seismische Anisotropie des Lithosphären-Asthenosphären-Systems im südlichen Madagaskar

R. Kind, X. Yuan, T. Meier:
Der obere Mantel unter den Alpen und Umgebung aus S Receiver Functions und Tomographie

J. Kummerow, W. Bloch, P. Salazar, P. Wigger, G. Asch & S.A. Shapiro:
High- Resolution Seismicity Image of the North Chilean Forearc

Oral Session II, Earth and Planetary Structure, 11:00-12:30

Judith Confal, Tuna Eken, Frederik Tilmann, Seda-Yolsal Cevikbilen, Yesim Cubuk, Erdinc Saygın, Tuncay Taymaz:
Investigation of Mantle Kinematics beneath Hellenic-Subduction Zone by using Teleseismic Direct Shear Waves

C. Thomas, L. Cobden:
Can we explain the D" reflector with the post-perovskite phase transition?

M. Knapmeyer, Fischer, H.-H., Knollenberg, J., Seidensticker, K.J., Thiel, K., Arnold, W., Faber, C., Möhlmann, D.:
SESAME und MUPUS: ein aktives seismisches Experiment auf dem Kometen 67P Churyumov-Gerasimenko

Alexandra Czeluschke, Martin Knapmeyer:
Neu-Auswertung der Daten des aktiven seismischen Experiments der Apollo 17 Mission

Brigitte Knapmeyer-Endrun and Conny Hammer:
New events identified in Apollo 16 lunar seismic data by Hidden Markov model based event detection and classification

Mittwochnachmittag, 16. September 2015

Poster Session, 14:00-16:00

Gesa Becker, Brigitte Knapmeyer-Endrun:
Moho depth from single-station seismic autocorrelations in preparation of the InSight SEIS installation on Mars

M. Bischoff, J. Fritz, N. Gestermann, T. Plenefisch, E. Wetzig:
Aktuelle Seismizität im Bereich der Erdgasfördergebiete Niedersachsens und Erweiterung des Stationsnetzes

Moritz Fehr:
Lokale Verstärkungseffekte induzierter seismischer Ereignisse im Bereich der norddeutschen Gaslagerstätten

Kasper Fischer:
Ein interaktives Erdbebeninformationssystem basierend auf FDSN Webservice und JavaScript

Florian Fuchs, Götz Bokelmann, Petr Kolinsky, Gidera Gröschl, Maria Theresia Apoloner and the AlpArray Working Group:
AlpArray in Austria and Slovakia: The network and current status

Michael Grund, Alexandra Gassner, Christoph Sens-Schönfelder, Joachim Ritter and Frederik Tilmann:
LITHOS-CAPP: The German contribution to SCANarray

Michael Grund, Joachim Ritter, Manuel Gehrig:
Analyse und Charakterisierung von Bodenerschütterungen während des Tunnelvortriebs für den Stadtbahntunnel Karlsruhe

Björn Heyn, Christine Thomas:
Improving source array processing – Implications for array seismology?

Frederic Klimm, Florian Schmid, Vera Schlindwein:
Local seismicity of the Aurora Vent Field, Gakkel Ridge, Arctic Ocean

Markus Kriegerowski, Simone Cesca:
Western Bohemia earthquake swarm region: Moment tensor inversion and their synthesization

Angelo Pisconti, Edoardo Del Pezzo, Francesca Bianco and Salvatore de Lorenzo:
Seismic Q estimates in Umbria Marche (Central Italy): hints for the retrieval of a new attenuation law for seismic risk

Thomas Plenefisch, Nicolai Gestermann, Monika Bischoff:
Seismicity and stress field in the vicinity of natural gas fields in Northern Germany

Philipp Prasse, Christine Thomas:
Pacific Anisotropy – real or apparent?

Anne-Sophie Reiß, Christine Thomas:
Behaviour of mantle transition zone discontinuities beneath the Indian Ocean from PP precursors

Johannes Salvermoser, Céline Hadziioannou, Simon Stähler:
Structural Monitoring of a Highway Bridge using Passive Noise Recordings from Street Traffic

Felix Schneider, Sofi Esterhazy, Götz Bokelmann, Ilaria Perugia:
Wechselwirkung eines seismischen Wellenfeldes mit Hohlräumen im Untergrund

Sebastian Wehling-Benatelli, Ludger Küperkoch, Wolfgang Friederich:
PyLoT – a tool for consistent manual and automatic processing of seismic data

Stephanie Wollherr, Alice-Agnes Gabriel, Thomas Ullrich, Alexander Breuer, Alexander Heinecke, Sebastian Rettenberger, Heiner Igel, Michael Bader:
The SeisSol software package for large-scale earthquake simulations with complex geometries

Oral session III, Noise Studies, 16:00–18:00

Rafael Abreu, Heiner Igel, Christine Thomas, Ana Ferreira and Jochen Kamm:
Modelling micropolar waves in seismology

Friederike Lott, Mahmoud Al.-Qaryouti, Joachim Ritter, Ulrich Corsmeier:
Seismological and meteorological measurements at the Dead Sea to investigate the impact of wind on seismic signals

Josefine Umlauft, Hortencia Flores-Estrella, Andreas Schmidt, Michael Korn:
Locating mofettes using seismic noise records from small dense arrays and Matched Field Processing Analysis in the NW Bohemia/Vogtland Region, Czech Republic

Klaus Stammler:
Beeinträchtigung von GRF-Stationen durch Windkraftsignale

Tobias Horstmann, Andrea Brüstle, Thomas Spies, Jörg Schlittenhardt, Bernd Schmidt:
Ermittlung oberflächennaher Strukturen bei Unterhaching mit H/V- und Array-Messungen der seismischen Bodenunruhe

Annabel Haendel, Matthias Ohrnberger and Frank Krüger:
Extraction of phase slowness and near-surface Qs between 1-4 Hz from noise crosscorrelations

Mitgliederversammlung, 20:00

Mitgliederversammlung der AG Seismologie

Donnerstag, 17. September 2015

Oral session I, Arrays and Projects, 9:00–10:30

L. Cristiano, T. Meier, F. Krüger, H. Keers, C. Weidle:
P-wave Polarization Analysis at the GRF-Array and the GRSN

Klaus Stammler:
Amplitudendetektor für GRSN

Katrin Hannemann, Frank Krüger, Torsten Dahm:
Analysis of P wave polarization at the ocean bottom

Simon Stähler, Karin Sigloch, Kasra Hosseini, Wayne Crawford, Guilhem Barruol, Mechita Schmidt-Aursch, Maria Tsekhmistrenko, Alessandro Mazzullo:
Preliminary performance report of the RHUM–RUM ocean bottom seismometer network around La Réunion, western Indian Ocean

Lindenfeld, M., Winter, H., Rümpker, G.:
Statusbericht zum Aufbau eines seismischen Kleinarrays am Kleinen Feldberg, Taunus

Oral session II, 11:00-12:00

Gerog Rümpker, Ayoub Kaviani, Frederik Link:
Generalization of the receiver-function stacking method of Zhu & Kanamori (2000) to anisotropic media

Lion Krischer, Martin van Driel, Simon Stähler, Tarje Nissen-Meyer:
Instaseis: instant global seismograms based on a broadband waveform database

Hinweis auf die Mailingliste der AG

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41. Sitzung der AG Seismologie
Wildbad–Kreuth
15.–17. September 2015

Collected Abstracts

Modelling micropolar waves in seismology

Rafael Abreu (1,2), Heiner Igel (3), Christine Thomas (1), Ana Ferreira (4) and Jochen Kamm (1,5)

(1) Institut für Geophysik, Westfälische Wilhelms-Universität Münster, Corrensstraß e 24, D-48149 Münster, Germany.
(2) Instituto Andaluz de Geofisica. Universidad de Granada, Campus de Cartuja s/n, E-18071 Granada, Spain.
(3) Department of Earth and Environmental Sciences, Ludwig-Maximilians-University, 80333 Munich, Germany.
(4) Department of Earth Sciences, University College London, London WC1E 6BT, UK.
(5) Department of Earth Science, Uppsala University, Sweden.

We study 1D seismic wave propagation in micropolar elastic media. Micropolar media is a generalization of classical elastic media, where each particle has intrinsic rotational degrees of freedom (spin). We perform numerical simulations of wave propagation in a 1D micropolar media using three different numerical techniques: Finite-Difference, Pseudospectral and Spectral-Element methods (FDM, PSM and SEM respectively). We find harmonic analytical solutions for different problems configurations. Like in conventional elastic media, the SEM discretization accommodates the free surface condition in a straightforward way and also leads to diagonal mass matrices (in the displacement and spin fields), for which we are able to use explicit time integration schemes. The spin waveform is directly dependent on the micropolar elastic parameters and different spin waveforms are obtained when applying a source time function over the displacement field only. We give a physical interpretation of the micropolar elastic constants and relate them to dispersion properties of the micropolar wave propagation phenomena. The micropolar effect on numerical seismograms has a direct implication with the wave phase, wave amplitudes and arrival times, for which this study presents a different perspective in seismological applications like seismic waveform tomography, induced seismicity and viscoelastic wave propagation, as well as many different areas in seismology.

Location and source mechanism of the Karlsruhe earthquake of 24 September 2014

Andreas Barth, Karlsruher Institut für Technologie (KIT)

41. Sitzung der AG Seismologie, Wildbad Kreuth, 15.-17.09.2015

Abstract

On 24 September 2014 a M_L 2.3 earthquake occurred beneath the urban area of Karlsruhe/Germany, which was felt by only a few people (I_0=III). It was the first seismic event in this area since an intensity VII earthquake in 1948.

I analyse data of 35 permanent and temporary seismometers to localise the event and to determine the focal mechanism to compare it to previous seismicity. Restricting the data to P- and S-phases from 18 nearby stations mainly within the Upper Rhine Graben and optimising the local earth model results in an epicentre in the very Southwest of the city at 48.994°N/8.288°E in a hypocentral depth of 7 km. To calculate the focal mechanism I determine 22 P- and 5 S_H polarities that constrain a stable left-lateral strike-slip focal mechanism with a small thrusting component and nodal planes striking NE-SW and NW-SE.

The new epicentre lies near to the region of the maximum intensity of the I_0=VII earthquake in 1948. Additionally, both focal mechanisms show a NE-SW striking nodal plane that dips to the SE. However, for the 1948 event a normal faulting mechanisms was determined earlier. While the recent event had fault dimensions of some hundreds of meters, the one in 1948 affected a fault plane with some kilometres length. Taking the uncertainty of the macroseismic epicentre in 1948 and the fault dimensions into account, both events might have happened on the same fault plane as part of the Graben parallel flower structure beneath the Upper Rhine Graben, that even might been connected to the seismically active area around Rastatt approximately 20 km further south.

Moho depth from single-station seismic autocorrelations in preparation of the InSight SEIS installation on Mars

Gesa Becker & Brigitte Knapmeyer-Endrun,
Max-Planck-Institute for Solar System Research, Göttingen

The InSight Mission to Mars is scheduled for launch in 2016. It will place a single three component very broad-band seismic sensor and a collocated three component short-period seismometer on the planet's surface. As it is therefore not possible to use data from a seismic network, single-station methods have to be applied. In addition, seismicity on Mars is considered to be less abundant than on Earth, making it all the more important to make the best use of the data available, by also considering the information recorded in between events.

Understanding the interior structure of a planet is of essential importance to learn about its past, present and future. By extracting reflected body waves from stacked autocorrelations of ambient noise, information about the crustal structure can be revealed. Current estimates of the average thickness of the Martian crust are derived from space-born/satellite gravity measurements and topography and require many assumptions, therefore showing great variations in the order of a factor of 2. With the help of seismic data a more accurate estimation of the crustal thickness at the seismic station can be provided, serving as a baseline for gravity modeling and giving a starting point for models of crustal formation. In order to determine the crustal thickness using autocorrelations, various approaches have been applied (Tibuleac & von Seggern 2012; Gorbatov et al. 2013).

In preparation for the data return from Mars, the different approaches were tested on terrestrial datasets from stations of the GRSN network and permanent stations on the Eastern European Craton, which cover a wide range of crustal thicknesses. As a first step the various processing schemes were compared and evaluated. Additionally different parameters, such as time window for the autocorrelations, scaling factor, and dependence on global seismicity were analyzed. One approach, closely following the method used by Groos et al. (2012), was chosen to resolve the depths of the Moho discontinuity for the different stations. The initial results compare well with depths obtained from a European Moho depth map (Grad et al. 2009) and from receiver functions (Knapmeyer-Endrun et al. 2014), making it a promising method to also give insight into the interior of Mars, by using the one available station.

References

Gorbatov, A. et al., 2013. Crustal properties from seismic station autocorrelograms, Geophys. J. Int., v. 192, p. 861-870, doi: 10.1093/gji/ggs064

Grad, M. et al., 2009. The Moho depth map of the European Plate, Geophys. J. Int., v. 176, p. 279-292, doi: 10.1111/j.1365-246X.2008.03919.x

Groos, J.C. et al., 2012. Performance of different processing schemes in seismic noise cross-correlations, Geophys. J. Int., v. 188, p. 498-512, doi: 10.11117j.1365-246X.2011.05288.x

Knapmeyer-Endrun, B. et al., 2014. Moho depth across the Trans-European Suture Zone from P- and S-receiver functions, Geophys. J. Int., v. 197, p. 1048-1075, doi: 10.1093/gjj/ggu035

Tibuleac, I.M. & von Seggern, D., 2012. Crust-mantle boundary reflectors in Nevada from ambient seismic noise autocorrelations, Geophys. J. Int., v. 189, p. 493-500, doi: 10.1111/j.1365-246X.2011.05336x

Aktuelle Seismizität im Bereich der Erdgasfördergebiete Niedersachsens und Erweiterung des Stationsnetzes

M. Bischoff*, J. Fritz*, N. Gestermann**, T. Plenefisch**, E. Wetzig**
*Landesamt für Bergbau, Energie und Geologie (LBEG), **Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)

Die aktuelle seismische Aktivität in Norddeutschland konzentriert sich auf das Gebiet der Erdgasförderung von etwa 400 x 70 km^2 von der Grenze zu den Niederlanden im Westen bis Salzwedel in der Altmark im Osten. Die Erdbeben stehen mit hoher Wahrscheinlichkeit im Zusammenhang mit der Erdgasförderung. Die Indizien hierfür sind erstens die räumliche Nähe zu den produktiven Lagerstätten, während im weiteren Umfeld keine Seismizität beobachtet wird, zweitens die Herdtiefen, die im Tiefenhorizont der Lagerstätten von etwa 5 km liegen. Drittens traten die Ereignisse erst nach dem Beginn der Erdgasproduktion auf. Zudem werden Abschiebungsmechanismen beobachtet, wobei die nordwest-südöstlich orientierten Streichrichtungen recht gut mit den Streichrichtungen der Region, z.B. des Allertal-Lineaments, übereinstimmen. Diese Störungen könnten aufgrund der Abnahme des Porendrucks im Reservoir infolge der Erdgasförderung durch Spannungsveränderungen reaktiviert worden sein.

Seit 1977 wurden insgesamt 60 seismische Ereignisse mit Magnituden (M_L) zwischen 0,5 und 4,5 in der Erdgasförderregion beobachtet. Die Wahrnehmungsschwelle für diese Erdbeben liegt bei etwa M_L 1,9. Erdbeben der Stärke M_L 3,0 werden ehrfahrungsgemäß im Umkreis bis 15 km um das Epizentrum verspürt und sorgen für große öffentliche Aufmerksamkeit. Innerhalb des letzten Jahres ereigneten sich in der Erdgasförderregion sechs Ereignisse oberhalb der Wahrnehmungsschwelle bis M_L 3,1. Das stärkste dieser Erdbeben ereignete sich am 19. Dezember 2014 und wurde etwa 10 km östlich von Cloppenburg im nördlichen Bereich der Erdgaslagerstätte Goldenstedt/Visbek lokalisiert. Das zweitstärkste Beben mit M_L 2,8 ereignete sich vier Monate zuvor ca. 5 km weiter südlich an derselben Lagerstätte. Infolgedessen wuchs das öffentliche Interesse an Hintergrundinformationen zur Seismizität im Raum Cloppenburg. Vier weitere Beben, mit $1{,}9 \leq M_L \leq 2{,}1$ nur geringfügig oberhalb der Wahrnehmungsschwelle, fanden an den Erdgaslagerstätten Hengstlage, Siedenburg/Staffhorst und Rotenburg statt.

Während die seismische Überwachung der Erdgasförderregion östlich der Weser in der Vergangenheit durch lokale Stationsnetze seitens Industrie, Universitäten und Behörden deutlich ausgebaut wurde, war die seismische Überwachung westlich der Weser bislang unzureichend. Im Jahr 2014 wurde mit der Stationserweiterung auch in diesem Bereich durch BGR, LBEG und Universität Münster begonnen. Mittlerweile stehen vier Stationen mit Echtzeit-Datenübertragung zur Verfügung, deren Daten die Lokalisierungsgenauigkeit und Bestimmung der Herdmechanismen verbessern. Während der Niedersächsische Erdbebendienst im LBEG vornehmlich Stationsstandorte im Epizentralgebiet besetzen wird, erweitert die BGR ihr Stationsnetz durch neue Standorte auf den Höhenzügen des südlichen Niedersachsen und nördlichen Nordrhein-Westfalen mit besseren Standortbedingungen. Auf Grund der zu erwartenden höheren Datenqualität sollen diese Stationen auch für Strukturuntersuchungen und zur Erweiterung des deutschen Regionalnetzes (GRSN) etabliert werden.

Seismische Echtzeitüberwachung der Geothermiekraftwerke Insheim und Landau

Andrea Brüstle, LER; Margarete Vasterling, BGR; Bernd Schmidt, LER; Ulrich Wegler, BGR

Im Rahmen des MAGS2-Projekts wird die in MAGS begonnene seismologische Datenerfassung in der Region der beiden Geothermiekraftwerke Landau und Insheim fortgesetzt. Hierfür wird ein lokales seismisches Netzwerk, besteht aus 12-14 Oberflächen-Stationen, von der Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) betrieben. Um die Lokalisierung der Mikroseismizität zu verbessern, wird das Netzwerk durch 3 Bohrloch-Stationen in Tiefen von etwa 100 und 300 m ergänzt. Diese Bohrlochstationen werden vom Landeserdbebendienst Rheinland-Pfalz (LER), z.T. in Kooperation mit industriellen Partnern, betrieben. Die Wellenform-Daten werden in Echtzeit zur BGR übertragen und zusammengeführt. Die Ereignisdetektion erfolgt ebenfalls in Echtzeit mit Hilfe eines bereits im MAGS-Projekt entwickelten Kreuzkorrelations-Detektors, der in SeisComP3 integriert wurde. Durch die geringe Ausdehnung des Netzes von weniger als 20 km und unverfestigte Sedimente innerhalb der Grabenstruktur ist die übliche Bestimmung der Lokalmagnitude nicht möglich und es wird deshalb eine Relativmagnitude aus dem Amplitudenverhältnis der beobachteten zu den größeren Ereignissen mit bekannter Lokalmagnitude bestimmt. Die manuelle Ereignis-Auswertung erfolgt zeitnah am LER und ermöglicht die Abbildung der räumlichen und zeitlichen Entwicklung der Mikroseismizität. Von besonderem Interesse ist dabei die Identifikation des jeweiligen mikroseismisch aktiven Volumens der Standorte Landau und Insheim und die Beobachtung des seismisch inaktiven Gebiets zwischen den beiden Reservoiren. Während der ersten 22 Monate seit dem Beginn von MAGS2 im Oktober 2013 wurden insgesamt 406 Ereignisse automatisch detektiert, die als geothermisch induzierte Ereignisse oder Steinbruchsprengungen klassifiziert wurden. Die manuelle Auswertung ergab, dass 73% der bekannten Ereignisse (Detektionen der BGR und industrieller Betreiber) von Landau und Insheim mit dem Kreuzkorrelations-Detektor identifiziert werden konnten. Ereignisse, die so nicht automatisch detektiert wurden, waren meist zu schwach, um diese in den aufgezeichneten Wellenformdaten mehrerer Seismometer des Stationsnetzes identifizieren zu können. Diese vom MAGS-Detektor nicht gefundenen Mikrobeben konnten daher meistens auch nicht lokalisiert werden. Die ausgewerteten Ereignisse lassen sich eindeutig einem der beiden Reservoire zuordnen, da deren seismischen Wolken deutlich voneinander getrennt sind.

Diese Arbeit ist Teil des Verbundprojekts MAGS2 „Mikroseismische Aktivität geothermischer Systeme – vom Einzelsystem zur großräumigen Nutzung“ (Einzelprojekts EP1). Das Projekt wird durch das Bundesministerium für Wirtschaft und Energie (BMWi) gefördert und vom Projektträger Jülich betreut.

Investigation of Mantle Kinematics beneath Hellenic-Subduction Zone by using Teleseismic Direct Shear Waves

Judith Confal [1,2], Tuna Eken [2], Frederik Tilmann [3,4], Seda-Yolsal Çevikbilen [2], Yeşim Çubuk [2], Erdinç Saygın [5], Tuncay Taymaz [2]

(1) Department of Applied Geosicence, Berlin Technical University, Berlin Germany, judithconfal @gmail.com
(2) Department of Geophysical Engineering, The Faculty of Mines, Istanbul Technical University, Istanbul, Turkey
(3) Deutsches GeoForschungsZentrum GFZ, Potsdam, Germany
(4) Freie Universität, Berlin, Germany
(5) The Australian National University, Research School of Earth Sciences, Canberra, Australia.

Abstract

Direct shear-wave splitting measurements based on the Reference Station Technique in the southern Aegean Sea revealed significant seismic anisotropy. The technique overcomes possible contamination from the source–side anisotropy on direct S-wave signals recorded at a station pair by maximizing the correlation between the seismic traces at reference and target stations after correcting the reference stations for known receiver-side anisotropy and the target stations for arbitrary splitting parameters probed via a grid search. We initially determined receiver-side anisotropy derived from SKS splitting measurements performed at four broadband stations. Following the bootstrap approach, in which only these four stations with well-constrained SKS splitting parameters are used as seeds to determine the splitting parameters of seismic stations of the EGELADOS temporary network in an iterative manner, we obtained splitting parameters at 35 stations with good-quality S-wave signals extracted from 82 teleseismic events. The fast polarization directions (φ) show a general trend of NNE-SSW orientation that ranges from 5.8° to 51.8°. Two stations in the west close to the Hellenic Trench and one in the east show N-S oriented fast polarizations. In the back-arc region three stations exhibit NE-SW orientation. Split time delays (δt) vary between 1.0s and 1.6s. Employing direct S-waves enabled more stable and reliable splitting measurements, with an average of 46 individual measurements. The overall fast polarization variations tend to be similar to those obtained from previous SKS splitting studies in the region but indicate a more consistent pattern. Splitting analyses on direct shear waves resulted in larger split time delays compared to the previous studies, possibly because they travel along a longer path in the same anisotropic structure. Observed differences between direct shear waves-derived (this study) and previous SKS splitting measurements could be due to the fact that S-waves propagate by sampling a broader zone in the upper mantle as well as anisotropy measurements based on insufficient number of individual SKS splitting measurements reported in earlier studies. Very consistent NNE-SSW directed anisotropic directions imply a dominant asthenospheric source due to the mantle flow exerted by the retreat of the African lithosphere along the Hellenic Trench.

NEU-AUSWERTUNG DER DATEN DES AKTIVEN SEISMISCHEN EXPERIMENTES DER APOLLO 17 MISSION.

A. Czeluschke (alexandra.czeluschke@dlr.de)[1], M. Knapmeyer (martin.knapmeyer@dlr.de)[1], J. Oberst (juergen.oberst@dlr.de)[1,2] und I. Haase (isabel.haase@tu-berlin.de)[2], [1]Deutsches Zentrum für Luft- und Raumfahrt (DLR), Inst. für Planetenforschung, Berlin, Germany, [2]Technische Universität Berlin, Institut für Geodäsie und Geoinformationswissenschaften, Deutschland

Einleitung: Die Oberfläche des Mondes ist mit einer Schicht aus Lockermaterial bedeckt. Ständige Meteoriteneinschläge pulverisieren die Oberflächengesteine und lassen so diese Regolith-Schicht entstehen. Die Apollo Missionen hatten unter anderem zum Ziel diese oberflächennahen Strukturen und Schichtungen zu untersuchen, um so die Entstehung und den Aufbau des Erdtrabanten besser zu verstehen.

Während der Apollo 17 Mission, welche im Dezember 1972 auf dem Mond landete, wurde neben vielen anderen Experimenten auch das Lunar Seismic Profiling Experiment (LSPE) durchgeführt. Dabei stellt das LSPE das größte, aktive seismische Experiment dar, welches auf einem anderen Himmelskörper durchgeführt wurde.

2009 startete die Lunar Reconnaissance Orbiter (LRO) Mission. Diese lieferte mit den aufgenommenen Bilddaten die Möglichkeit, die Positionen der von den Apollo Astronauten aufgestellten Instrumente neu zu bestimmen. So konnten durch Kombination aktueller hochauflösender Bilder der Lunar Reconnaissance Orbiter Camera (LROC) (0.25 - 0.5 m/Pixel) mit historischen Apollo Fotoaufnahmen, welche von den Astronauten auf dem Mond aufgenommen wurden, u. a. die Koordinaten der seismischen LSPE-Quellen und -Empfänger neu bestimmt werden [1]. Die aus diesen Positionen abgeleiteten Abstände zwischen Empfänger und Quelle zeigen deutliche Abweichungen (bis zu 40 m) zu den bisher publizierten Werten. Neue Berechnungen der P-Wellengeschwindigkeiten sind Teil dieser Arbeit.

Daten: Die Original-Daten des Apollo 17 LSPE sind über das National Space Science Data Center (NSSDC) der NASA zu beziehen.

Die dort erhältlichen Daten sind restaurierte Apollo-Telemetriepakete, welche auf dem Mond aufgezeichnet und in Echtzeit zur Erde übermittelt wurden. Die Originaldaten wurden von uns in ein für moderne seismische Auswertungen nutzbares Format umgewandelt.

Mit Hilfe der LROC-Bilddaten konnten verbesserte Koordinaten für bisher sechs der acht Sprengladungen, Explosive Package (EP) genannt, bestimmt werden. Diese sechs Explosionen wurden von den vier Geophonen des LSPE-Arrays aufgenommen, somit sind 24 Einzelseismogramme Grundlage unserer Untersuchungen.

Filterung: Seismische Wellen unterliegen auf dem Mond starker Streuung. Die Seismogramme zeichnen sich daher durch emergente Einsätze, das Fehlen deutlicher späterer Einsätze, breite strukturlose Spektren und lange Signalabklingzeiten aus [2][3], welche es schwierig machen, nachfolgende Phaseneinsätze zu identifizieren. Außerdem sind die Seismogramme durch periodische Störsignale des Telemetriesystems überlagert [4], welche wir durch Anwendung eines Wiener Filters unterdrücken. Die gefilterten Seismogramme als Grundlage nutzend, haben wir neue Zeiten für die Ersteinsätze der P-Wellen bestimmt.

Neue Geschwindigkeits-Tiefen-Profile: Die vorhandenen Laufzeiten können durch ein Drei-Schichten-Modell nachgebildet werden. Die P-Wellengeschwindigkeiten liegen bei 285 m/s für die oberste Schicht, 580 m/s für die zweite, darunter liegende Schicht und 1825 m/s für die unterste Schicht bei der Verwendung der neuen, LROC-basierten Empfänger-Quelle-Distanzen. Im Gegensatz dazu liegen die P-Wellengeschwindigkeiten bei Verwendung der früher publizierten Entfernungen bei 495 m/s, 960 m/s, and 4700 m/s [4]. Es ergeben sich signifikante Änderungen in den Schichtdicken. So reduziert sich beim Übergang zu den neuen Abständen die Mächtigkeit der obersten Schicht von 390 m auf 96 m und von 1385 m auf 773 m für die zweite Schicht.

Ausblick: Die oberste Schicht ist mit Daten von vier EPs, aufgenommen durch vier Geophone, sehr gut bestimmt. Wogegen die zweite und dritte Schicht jeweils nur durch einen Schuss, welcher von den vier Geophonen aufgenommen wurde, bestimmt sind. Sobald die noch fehlenden Positionsdaten der letzten zwei EPs und des Impaktes der Lunar Module Aufstiegsstufe bestimmt sind, möchten wir diese Daten in unsere Auswertungen miteinbeziehen. Damit können die Übergänge zwischen den drei Schichten und die Geschwindigkeitsstrukturen unterhalb der Apollo 17 Landestelle noch genauer bestimmt werden.

Danksagung:
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The seismo-mechanical coupling of caldera subsidence, ring-fault earthquakes and lava flow of the 2014-2015 eruption at Bardabunga volcano, Iceland

T. Dahm, M. Hensch, S. Heimann, S. Cesca, et al.

The 2014-2015 collapse of the Bárðarbunga caldera was accompanied by a notable seismic sequence. We determine full moment tensors and relative centroid locations for 77 M > 5 earthquakes, revealing that they cluster beneath the northern and southern caldera rims and can be interpreted by frictional controlled sliding events at segments of the caldera ring fault and additional sub-vertical CLVD sources below, possibly related to the response of the magma reservoir feeding the Bardabunga fissure eruption.

Earthquakes in the northern cluster occur at deeper levels than in the southern cluster, and the temporal evolution differs in both clusters. The cumulative moment release, however, is very regular and scales linearly with the observed caldera subsidence.

We discuss a simple fluid-mechanical collapse-outflow model, which can explain the relation between cumulative moment, caldera subsidence and outflow rate.

Along-Strike Differences of the Main Himalayan Thrust and Deformation within the Indian Crust: Insights from Seismicity in Bhutan and its Foreland

Diehl[1], T., Singer[2], J., Hetényi[1,2], G., Kissling[2], E., Clinton[1], J.

[1] Swiss Seismological Service, ETH Zurich, Switzerland
[2] Institute of Geophysics, ETH Zurich, Switzerland

The seismicity of Bhutan is characterized by the apparent lack of great earthquakes and a significantly lower activity compared to most other parts of the Himalayan arc. Virtually no information on the seismicity and crustal structure of Bhutan exists, although a minimum slip potential of ~5 m is suggested for this section of the Himalaya. To better understand the underlying mechanisms of this anomalously low activity and to relate it with possible along-strike differences in the structure of the orogenic belt, a temporary network with up to 38 broadband seismometers was installed in Bhutan between January 2013 and November 2014.

In this work we present a catalog of local and regional earthquakes detected and located with the GANSSER seismic network complemented by regional stations in India and China. The data was integrated into the powerful SeisComP3 infrastructure of the Swiss Seismological Service, allowing efficient access and processing. State-of-the-art data analysis and earthquake location procedures were applied to derive a high-precision earthquake catalog of Bhutan and surrounding regions. Focal mechanisms from regional moment tensor inversions and first-motion polarities complement the earthquake catalog.

In the vicinity of the Shumar-Kuru Chu Spur in East Bhutan, seismicity forms a moderately dipping structure at about 12 km depth, which we associate with the Main Himalayan Thrust (MHT). North of 27.6°N the dip of the structure steepens, which can be interpreted as a ramp along the MHT. In West Bhutan seismicity occurs at depths of 20 to 40 km and receiver function images indicate that seismicity occurs in the underthrusting Indian crust rather than on the MHT. The highest seismic activity is clustered along the Goalpara Lineament, a dextral NE-SW striking shear zone in southwest Bhutan, which appears to connect to the western edge of the Shillong Plateau in the foreland. Focal depths indicate that this shear zone is located at depths of 20-30 km and therefore in the underthrusting Indian crust.

Lokale Verstärkungseffekte induzierter seismischer Ereignisse im Bereich der norddeutschen Gaslagerstätten

Fallstudie zur Mikrozonierung mittels H/V – und Array-Ambient-Noise-Messungen

M. Fehr

In den vergangenen Jahren konnten im Bereich der norddeutschen Gaslagerstätten zahlreiche seismische Ereignisse mit Magnituden von $M_L > 2.5$ aufgezeichnet werden. Diese wohlmöglich durch die Gasförderung induzierten seismischen Ereignisse waren vereinzelt deutlich an der Oberfläche spürbar. Somit ist das Verständnis über die Auswirkungen solcher Ereignisse an der Oberfläche von großer Bedeutung, wobei die Stärke bzw. Intensität der Bodenbewegung maßgebend durch den lokalen Untergrund bestimmt wird. Daher ist es zur Gefährdungsanalyse möglicher lokaler Standorteffekte unbedingt notwendig, detailliertes Wissen über den oberflächennahen Untergrund zu erlangen.

Im Zuge einer Dissertation in Zusammenarbeit mit dem WEG (Wirtschaftsverband Erdöl- und Erdgasgewinnung e.V.) und der DMT GmbH Co. KG sollen Methoden zur Messung von Bodenunruhen getestet, durchgeführt und weiterentwickelt werden, um daraus quantitative Informationen zur Gefährdungsanalyse ableiten zu können. Ferner sollen Wellenformmodellierungen unterstützend angewandt werden, um potenzielle Verstärkungseffekte genauer verstehen zu können.

Ziel ist eine Mikrozonierung des Untersuchungsgebiets und dabei stellen H/V- und Array-Ambient-Noise-Messungen eine einfache und kostengünstige Alternative gegenüber z.B. aufwendiger Bohrverfahren dar. Diese Messungen erlauben eine nicht-invasive Ermittlung geologischer Untergrundparameter und ermöglichen eine Einschätzung von Gefahrenpotentialen für bereits vorhandene aber auch in Zukunft geplante Infrastrukturen.

Ein interaktives Erdbebeninformationssystem basierend auf FDSN webservice und JavaScript

Kasper D. Fischer
Ruhr-Universität Bochum
Institut für Geologie, Mineralogie und Geophysik
Seismologisches Observatorium

Poster

Der FDSN webservice stellt eine Schnittstelle zur Abfrage von Erdbeben- und Stationsdaten sowie Wellenformdaten über das Internet zur Verfügung. Anfragen werden durch spezielle URLs erstellt und die Ergebnisse werden in Form von XML Daten oder miniSEED Daten bereitgestellt. Damit eignen sich diese besonders gut zur Weiterverarbeitung durch diverse 335Software. Der FDSN webservice wird bereits durch zahlreiche erdbebendienste bereit gestellt (z. B. IRIS, ORFEUS und USGS) und ist Bestandteil der Software Seiscomp3. Im Rahmen der Umstellung der Routineauswertung am Seismologischen Observatorium der Ruhr-Universität Bochum auf das Seiscomp3 System Anfang 2014 wurde ein neues Erdbebeninformationssystem zur Information der Öffentlichkeit entwickelt. Dieses basiert auf dem FDSN webservice und ist mit JavaScript umgesetzt. Das Ergebnis ist eine interaktive Karte sowie Erdbeben- und Stationsliste. Neben einer schnellen Übersicht über aktuelle Ereignisse erlaubt dieses System auch das Abrufen von Detailinformationen zu einzelnen Ereignissen oder zu den genutzten Stationen. Die verwendeten Softwarebibliotheken sowie der entwickelte Code stehen unter Opensource Lizenzen und sind frei verfügbar.

Poster Abstract

AlpArray in Austria and Slovakia: The network and current status

Florian Fuchs, Götz Bokelmann, Petr Kolinsky, Gidera Gröschl, Maria-Theresia Apoloner and the AlpArray Working Group

Department of Meteorology and Geophysics, University of Vienna, Althanstraße 14, UZA 2, 1090 Vienna, Austria

Contact: florian.fuchs@univie.ac.at

AlpArray is an unique European transnational research initiative in which 43 research institutes from 15 countries join their expertise to advance our knowledge about the structure and evolution of the lithosphere beneath the entire Alpine area. In Austria and Slovakia the AlpArray seismic experiment is coordinated by the Department of Meteorology and Geophysics (IMGW) at the University of Vienna.

During spring 2015 the deployment of 46 mobile broadband seismometers (and two permanent stations) commenced and by end of autumn 2015 Austria and western Slovakia will be covered by a dense seismological network with an average station spacing of about 40 kilometers. The mobile network consisting of 30 Reftek 151 60s sensors (provided by IMGW) and 16 broadband sensors from GFZ Potsdam and LMU Munich will complement the permanent Austrian seismic network operated by the Austrian Zentralanstalt für Meteorologie und Geodynamik (ZAMG) that will also install the two permanent stations. AlpArray stations in Austria and Slovakia will continuously record high-quality ground motion data for approximately two to three years. Seismic data will be distributed through the European Integrated Data Archive (EIDA) and shared with the collaborating AlpArray institutes.

Here we present the status of deployment in Austria and Slovakia as of September 2015.

Nachbebensuche bei der Feldübung IFE14 der CTBTO in Jordanien

Nicolai Gestermann

Bundesanstalt für Geowissenschaften und Rohstoffe, Stilleweg 2, 30655 Hannover

Der Kernwaffenteststopp-Vertrag (CTBT – Comprehensive Nuclear-Test-Ban Treaty), der 1996 von der UN-Vollversammlung angenommen wurde, soll Kernwaffentests aller Art verbieten. Er ist allerdings noch nicht in Kraft getreten, da ihn bislang nicht alle Länder unterzeichnet oder ratifiziert haben. Die Überwachungsorganisation CTBTO (CTBT-Organisation) in Wien ist zwar noch provisorisch, baut aber seit 1997 ein weltweites Kontrollnetz auf, welches die Einhaltung des Vertrages künftig überwachen soll, und ist bereits jetzt in der Lage, eine mögliche Vertragsverletzung aufzuspüren.

Falls das Überwachungssystem der CTBTO einen Test nicht zweifelsfrei nachweisen kann, sieht der Vertrag als letztes Verifikationsmittel eine Vor-Ort-Inspektion (OSI - On-site Inspection) in einem Gebiet bis zu einer Größe von 1000 km^2 vor. Im November 2014 wurde von der CTBTO die umfassende Feldübung IFE14 (Integrated Field Exercise 2014) in Jordanien im Küstenstreifen des Toten Meeres durchgeführt. Es war eine simulierte OSI unter möglichst realistischen Bedingungen.

Für die Vor-Ort-Inspektion sind gemäß Vertragstext nur bestimmte Technologien zugelassen. Eines der vertraglich erlaubten Verfahren ist das Monitoring der Seismizität im Inspektionsgebiet zum Nachweis möglicher Nachbeben des Trigger-Ereignisses. Die Nachbeben sollen Hinweise auf den Ort des möglichen Nukleartests liefern.

Die Erfassung der Seismizität im Inspektionsgebiet erfolgte mittels Mini-Arrays mit einer Apertur von etwa 100 m und 4 Elementen. Der Erfolg der Nachbebensuche basiert auf vielen Faktoren. Hierzu gehören z. B. ein geeignetes Design des Stationsnetzes und die Auswahl geeigneter Seismometer-Standorte. Der Aufbau des Stationsnetzes in der gebirgigen Region des Toten Meeres war unter vielen Gesichtspunkten eine Herausforderung. Auf Grund der zeitlichen Limitierung und der begrenzten personellen Ressourcen konnten insgesamt nur 16 der geplanten 35 Stationen in Betrieb genommen werden.

Vorgestellt werden das während der Übung installierte Stationsnetz, Ergebnisse zur Abschätzung der Detektionsfähigkeit sowie eine erste Auswertung der seismischen Daten. Es wurde angestrebt, eine Detektionsfähigkeit von -2.0 (M_L) für das gesamte Inspektionsgebiet zu erreichen, was jedoch nicht vollständig gelang. Die drei kleinen Sprengungen mit Ladungsstärken zwischen 3 und 10 kg TNT-Äquivalent, die zur Kontrolle der Detektionsfähigkeit des Stationsnetztes durchgeführt wurden, konnte das System aber ohne Einschränkung detektieren und lokalisieren.

Analyse und Charakterisierung von Bodenerschütterungen während des Tunnelvortriebs für den Stadtbahntunnel Karlsruhe

Michael Grund[1], Joachim Ritter[1], Manuel Gehrig[2]

[1]KIT, Geophysikalisches Institut, michael.grund@kit.edu, [2]Herrenknecht AG

Im Rahmen der sogenannten Kombilösung entsteht im Untergrund der Karlsruher Innenstadt ein Stadtbahntunnel von knapp 3 km Länge. Dort befinden sich Sande und Kiese der Rheinauen. Nach Inbetriebnahme des Tunnelbohrers im November 2014 wird eine Fertigstellung der annähernd in Ost-West-Richtung verlaufenden Röhre im Herbst 2015 angestrebt. Zur Untersuchung der Bodenerschütterungen durch den Tunnelvortrieb wurden insgesamt sieben Messstationen des KArlsruher BreitBand Arrays (KABBA) in Gebäuden am Campus Süd des Karlsruher Instituts für Technologie (KIT) installiert, welche direkt an die Bohrstrecke angrenzen. Neben sechs in Kellerräumen platzierten Sensoren (5 Breitbandseismometer, 1 Beschleunigungssensor) wurde ein oberflächennahes Bohrloch ausgehoben und mit einem Beschleunigungssensor ausgerüstet. Die kontinuierlichen Aufzeichnungen im Zeitraum November 2014 bis Januar 2015 werden hauptsächlich durch von Straßenbahnen und Baumaschinen verursachte Bodenunruhen dominiert. Die Inbetriebnahme des Tunnelbohrers ist im Zeit- und Frequenzbereich der seismischen Registrierungen sichtbar, allerdings betragen die entsprechenden Amplituden meist weniger als 2 mm/s. Sie liegen somit in ähnlichen Bereichen wie die durch die Straßenbahnen verursachten Erschütterungen. Im gesamten Beobachtungszeitraum wurde an keiner der Messstationen in den Gebäudekellern die Anhaltswerte der DIN 4150 überschritten, welche üblicherweise für mögliche Schädigungen durch Erschütterungen an Gebäuden herangezogen werden (2-5 mm/s). Mit den in unterschiedlichen Distanzen zu dem Tunnelbohrer gemessenen Amplitudenwerten konnten weiterhin Dämpfungsbeziehungen und entsprechende Qualitätsfaktoren bestimmt werden. Diese betragen ca. $30 < Q < 50$ und entsprechen Werten, die in anderen Experimenten für relativ unverfestigte Sande und Kieslagen bestimmt wurden.

LITHOS-CAPP: The German contribution to SCANarray

Michael Grund[1], Alexandra Gassner[2], Christoph Sens-Schönfelder[2], Joachim Ritter[1] and Frederik Tilmann[2]

[1]KIT, Geophysikalisches Institut, michael.grund@kit.edu, [2]GFZ Potsdam

The LITHOS-CAPP project (LITHOspheric Structure of Caledonian, Archaean and Proterozoic Provinces) focuses on crustal and upper mantle structures of Scandinavia in terms of understanding their geodynamical evolution. This project is the German contribution (KIT and GFZ) to the SCANarray field experiment implemented by a consortium including also NORSAR, NGU (both Norway) as well as the Universities of Copenhagen, Oslo, Leicester, Uppsala, Bergen, Aarhus and Oulu. We aim at deeper insights into the development of high topographies at passive continental margins in the absence of recent compressional tectonic settings.

In the fall of 2014, in total 98 broadband stations have been deployed by the project partners covering central and northern Norway and Sweden and the western margin of Finland; 20 broadband seismic stations were provided by the instrument pool of the GFZ. Our project links to former studies which mainly covered the southern regions of Scandinavia (e.g. MAGNUS, SCANLIPS1 & 2 and SVEKALAPKO experiments). Those previous studies examined some unexpected characteristics, in particular an unusually shallow crust-mantle and lithosphere-asthenosphere boundary (LAB) beneath the high-topography Scandes mountain range of western Norway. The lower topography regions of eastern Norway and Sweden, however, reveal a thicker crust which is in contrast to the principles of Airy isostasy. A clear crustal root of the Scandes seems to be absent. Lower seismic velocities than expected for a tectonically stable region have been found for southern Norway with a sharp transition to higher *vp* and *vs* beneath Sweden. To obtain a high-resolution (lithospheric) shear wave model, we will combine tomographic and waveform inversions of shear waves and surface waves with SKS splitting measurements. The contribution of KIT covers S wave tomography and SKS splitting examination. Poor backazimuthal coverage and SKS phases with low SNR will be tackled by the simultaneous inversion of multiple waveforms. GFZ will concentrate on the analysis of surface waves and ambient noise and the subsequent production of 3D models, including both isotropic and anisotropic analyses. The focus is on the variation of crustal and lithospheric structures as well as seismic velocity across the Scandes mountain range and western (Phanerozoic) and eastern (Proterozoic) Scandinavia. (Non)-spatial variation of anisotropic structures across tectonic units may give us a hint at the tectonic formation.

Extraction of phase slowness and near-surface Qs between 1-4 Hz from noise cross-correlations

Annabel Haendel, Matthias Ohrnberger and Frank Krüger
University of Potsdam

Knowledge of the quality factor Qs of near-surface materials is of fundamental interest in various applications. Attenuation can be very strong close to the surface and its effect on seismic wave propagation needs to be taken into account when studying e.g. ground-motion prediction in seismic hazard analysis, seismic sources or in oil and gas exploration.

In recent years, several researchers have studied the retrieval of attenuation coefficients from the cross-correlation of ambient seismic noise. The retrieval of exact amplitude information from noise correlation functions is, in contrast to the extraction of travel times, more difficult because amplitudes are affected by variations of the ambient seismic field in space and time. Zhang & Yang (2013) tried to overcome these difficulties by computing higher order noise correlations (C^3) because the additional correlation step homogenizes the original noise source distribution.

We focus in our study on very small station spacings (<2 km) and high frequencies (1-4 Hz) using data of a small scale array experiment that was carried out in the Euroseistest area in northern Greece in 2011. We compute C^3 correlations between all possible station pairs of the array and estimate phase slowness dispersion curves and frequency dependent Qs for stations located either mainly on weathered rock and or on soft soil. We can show that the C^3 method leads to improved correlation results (higher signal-to-noise ratio and improved time symmetry) compared to simple cross-correlations. The C^3 functions are rotated from the ZNE to the ZRT system and we focus on Love wave arrivals on the T component. Phase slowness is extracted using a slant-stack method. Attenuation is inferred by looking at the relative amplitude decay of the C^3 functions with increasing inter-station distances. Thereby we always select different station combinations relative to changing reference stations. By doing so the error of the obtained Qs estimates can be assessed. We obtain very small Qs (<20) both on weathered rock and soft soil. The low quality factor on rock contradicts previous Qs results from local rock samples obtained in the laboratory but agree on the other hand with the findings of different VSP experiments conducted in rock and hard rock. We argue that our Qs is rather a scattering Q than an intrinsic one. The separation of intrinsic and scattering Qs is subject to future investigation.

Analysis of P wave polarization at the ocean bottom

Katrin Hannemann, Frank Krüger, Torsten Dahm

The particle polarization of an incoming P wave is the result of the interference of the incoming wave itself and the reflected P and SV wave. This polarization is often referred to as the apparent incidence angle to emphasize that it differs from the actual incidence angle of the P wave. The difference of the ocean bottom compared to the free surface lies within the additionally refracted P wave in the water column, which changes the reflection coefficients needed for the calculation of the apparent incidence angle. These coefficients have been calculated by several authors since the beginning of the last century. We recalculated the coefficients and used them to find a relation for the apparent P wave incidence angle at the ocean bottom. After some assumptions, the resulting relation depends on the S velocity and the density of the ocean bottom. Fortunately, the dependence on the S velocity is much stronger, which allows an estimation of a velocity range from the measured apparent incidence angles.

We use (Z,R) receiver functions for our analysis, because of their ability to transform rather complex P wave signals in spike like features, which ease the measurement of the polarization angle. The frequency dependence of the angles is analysed by applying different low pass filters to the receiver functions before the estimation of the apparent incidence angle. The different used frequency bands allow to investigate the velocity structure with depth because of the different penetration of the observed waves. We refer to the resulting curves of apparent S velocity with filter period as apparent S velocity profiles.

Furthermore, we test different synthetic models in order to investigate the resolution of the proposed method. We find that it is possible to detect either an increase or a decrease in velocity with depth. In a next step, we present the results for a low velocity layer at different depth in either the crust or the mantle. The signature of a 50 km thick low velocity layer in the mantle gets smaller the deeper the layer, but is still visible at 100 km depth below sea floor. We also test the influence of the layer thickness on the apparent S velocity profile for a low velocity layer at 30 km below sea floor within the mantle and find that a thickness of several tens of kilometres is necessary for a noticeable influence on the profiles.

Up to now, we performed several tests for a grid search based inversion of real data from an ocean bottom experiment in 2012. The data were collected within the DOCTAR project (Deep OCean Test ARray). We present the results for all available stations and a rough classification of the data as a preparation for the later on inversion. The data can be grouped into two classes with either a one or a two layer crust over mantle.

In summary, the analysis of P wave polarization is a promising tool to enlarge the spectra of seismological techniques for ocean bottom experiments.

Improving source array processing – Implications for array seismology?

Björn Heyn[1], Christine Thomas[1]

[1] *Institut für Geophysik, Westfälische Wilhelms Universität Münster,*

Corrensstr. 24, 48149 Münster, Germany

Email: b_heyn01@uni-muenster.de

Abstract

Previous source array studies revealed difficulties concerning the depth distribution of earthquakes and the coherency of waveforms when dealing with source stacks. To improve the normalization of differing source mechanisms within such a source array, four different methods based on deconvolution and correlation are applied to synthetic data and compared afterwards. The synthetics are calculated for seven different velocity contrasts using the reflectivity method. For identification of the reflection at the D“ layer, the traces are stacked using the fourth root vespagram analysis and a time domain migration. It can be shown that migration is to be preferred due to the possibility of taking into account the varying earthquake depths. Apart from a few very special combinations of all varying parameters, the previously used method of doing a spiking deconvolution with the P-wavelet can be improved by applying a Hilbert transform to the wavelet prior to the deconvolution or by using the iterative deconvolution method developed for receiver functions. Still, the picking of the P-wavelet has a strong influence on the observed polarity of the PdP arrival, while the sensitivity for the different methods varies and thus has to be considered carefully.

Current status of the renewal projet of the Swiss strong motion network (SSMNet)

Manuel Hobiger[1], Donat Fäh[1], Christian Scherrer[1], Clotaire Michel[1], John Clinton[1], Carlo Cauzzi[1], Franz Weber[1]

[1] Swiss Seismological Service (SED), ETH Zurich, Switzerland

In an ongoing project, the Swiss Seismological Service is renewing and expanding its strong motion network. The goals of this enlargement are a better spatial coverage of earthquake-prone regions, a better localization of earthquakes and ultimately the verification and improvement of seismic hazard models.

During the first phase of the project, 30 new stations have been installed between 2009 and 2013, both replacing existing dial-up strong motion stations and installing new stations. In the framework of the ongoing second phase of the project, 70 more stations are planned to be installed by 2019. Until present, 18 of these are already installed; the site selection for the remaining stations is in progress.

The stations of the network are free-field and mainly installed in densely populated urban areas of high seismic risk, but also in more rural areas where relevant earthquakes happened in the past.

The process of the station installation takes several steps for all stations. Once a suitable target area is identified, an H/V survey is combined with geological information and gives a first overview of the expected local site effects. Suitable important public buildings like hospitals, schools or fire departments, which could house a free-field station in the vicinity, are then searched for. In these places, test stations are installed for several days in order to evaluate the local noise level.

Using all available information, the final station location is selected. After the installation of the station, the site is characterized using passive and active seismic methods. Using one or several passive seismic arrays of variable sizes, we measure the Love and Rayleigh wave dispersion curves as well as the Rayleigh wave ellipticity curves using different analysis methods. In some locations with difficult site conditions, we also perform active measurements using MASW.

All results from the measurements are combined and in the end inverted for the shear-wave velocity profile underneath the strong motion station. Using this underground profile, the amplification of the structure can be calculated and compared to the observed empirical amplification, identifying particular site-specific phenomena such as edge-generated surface waves or resonances.

New events identified in Apollo 16 lunar seismic data by Hidden Markov-model based event detection and classification

Brigitte Knapmeyer-Endrun[1] and Conny Hammer[2]

1-Max Planck Institute for Solar System Reseach (MPS), Göttingen
2-Swiss Seismological Service, ETH Zurich

NASA's InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission to Mars will for the first time deploy a seismometer on the surface of the planet in September 2016. The mission does not feature any dedicated orbiter, so continuous data will be relayed to Earth at a reduced rate, and full range data will only be available on request for a couple of days after the original transmission. As no event waveforms from Mars are available prior to the mission, the mission is well suited for the application of an event detection and classification algorithm that can work on single station continuous data with a minimum of a priori information. An algorithm up to that task, based on Hidden Markov models (HMMs), has recently been introduced by Hammer et al. (2012, 2013). Here we test its performance on the only extraterrestrial seismological data that contain confirmed event recordings, the Apollo data, which differ from typical terrestrial seismograms in both signal shape and source process. The baseline for comparison is the Long Period Event Catalog (LPEC, Nakamura et al., 1981).

As the Apollo data were recorded at the dawn of digital seismology, various steps of pre-processing are necessary to extract the seismograms from the binary Exabyte tape files. As many events listed in the LPEC have been found to be invisible or of inferior SNR (Bulow et al., 2005), we graded the events in four classes, the top two of which should definitely be detected by the algorithm. We trained the HMMs on background noise and single event waveforms for the most common event types, i.e. deep moonquakes, impacts, and shallow moonquakes. After several improvements on the draft classifier, including daily noise retraining, the combination of results for different components, and the use of an additional prototype for near impacts, we applied it to approximately three years of Apollo 16 data. We are able to detect 81% of all events of sufficient quality and correctly classify 70%. The false alarm rate is 20%, dominated by false deep moonquake detections, some of which could actually be very small events. For impact, the false alarm rate is 6%, and for shallow moonquakes, zero. We also find that flagging of unknown event types is possible by setting a threshold value below which the noise model is a poor description of the data. Intriguingly, besides being able to classify 50 previously unclassified events, we detect 210 new events not listed in the LPEC. The majority of these events are deep moonquakes, which also show the typical temporal clustering in occurrence times. Newly detected impacts, mainly close events, have occurrence times that correlate with known meteor showers. Thus, new discoveries are still possible with this well-worked data set almost 40 years after the end of transmission of seismic data from the Moon.

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Local seismicity of the Aurora Vent Field, Gakkel Ridge, Arctic Ocean

Frederic Klimm, Florian Schmid, Vera Schlindwein

During Polarstern cruise PS86 to the Arctic Ocean in summer 2014, local earthquake data were acquired in the vicinity of the recently discovered Aurora hydrothermal vent field at the intersection of Gakkel Ridge and Lena Trough over a two weeks period of time. In addition to several seismometers deployed on drifting ice floes, for the first time an OBS was deployed below sea ice cover which is used for determination of magnitudes of the recorded events. In the present study, the data acquired are processed and evaluated. Seismic events which clearly can be identified as earthquakes are located in a one-dimensional, local velocity model created on the base of previous research. A total of 28 well-located earthquakes of 98 identified events can be located with sufficient accuracy for geological interpretation. The main source of location uncertainty results from uncertainties in the thickness of the water layer due to insufficient cover with high resolution bathymetry data. However, quality of the present results is comparable to surveys performed on other ultraslow spreading ridges. Earthquakes preferentially occur at locations of exposed bathymetry. The northern rift flank of the area of investigation follows the strike direction of Gakkel Ridge, whereas the south-eastern flank follows the strike direction of Lena Trough. Seismicity is present at great depths down to 25 km, implying a very cold lithosphere. The hydrothermal vent field and its immediate vicinity is subject to very low rates of seismicity. This is an indicator for Aurora being an established system potentially located in peridotitic crust.

SESAME und MUPUS: ein aktives seismisches Experiment auf dem Kometen 67P/Churyumov-Gerasimenko

M. Knapmeyer [(1)], Fischer, H.-H. [(2)], Knollenberg, J. [(2)], Seidensticker, K.J. [(2)], Thiel, K. [(3)], Arnold, W. [(4)], Faber, C. [(2)], Möhlmann, D. [(2)]

(1) DLR, Germany (martin.knapmeyer@dlr.de) (2) DLR, Germany, (3) Cologne University, Germany (4) Saarland University and Göttingen University, Germany

Im Rahmen der Rosetta-Mission und der Landung von Philae auf dem Kometen 67P/Churyumov-Gerasimenko zeichneten die Akzelerometer des Instruments CASSE die Hammerschläge auf, mit denen die Wärmeflußsonde MUPUS in den Kometenboden getrieben wurde. Dies war das erste aktive seismische Experiment auf einem anderen Himmelskörper seit dem Lunar Seismic Profiling Experiment von Apollo 17 im Jahre 1972. Das Ziel dieses Experiments war die Erkundung der elastischen Parameter und der Struktur des oberflächennahen Materials auf dem Kometen. Es wurde am 14.11.2014 am endgültigen Landeplatz Abydos durchgeführt.

CASSE (Comet Acoustic Surface Sounding Experiment) ist eines von drei Instrumenten im SESAME-Konsortium, und eines von insgesamt zwölf Instrumenten auf Philae. Es besteht aus drei piezoelektrischen Transmittern und drei dreiachsigen Akzelerometern (Brüel & Kjaer 4506 Ortho-Shear, empfindlich für Frequenzen von 1 Hz bis 3.5 kHz), die in den Landefüßen von Philae eingebaut sind. Neben einem einfachen Listening-Modus und einem getriggerten Modus (Schwellwerttrigger und FIFO-Ringspeicher) ist damit auch ein aktives Sounding von Fuß zu Fuß durchgeführt worden.

MUPUS (Multi Purpose Sensor) ist eine Kombination aus einem Wärmeleitfähigkeits- und Wärmeflußexperiment mit einem bodenmechanischen Experiment. Die Wärmeflußsonde besteht dabei aus einem ca. 30 cm langen, mit Temperaturfühlern bestückten Stab (PEN genannt), der in ca. 60 cm Entfernung vom Lander ausgesetzt wurde. An seinem Kopf befindet sich ein Hammermechanismus, in welchem ein auf eine definierte Energie aufgeladener Kondensator über eine Spule entladen wird, die dann wiederum durch ihr Magnetfeld die Hammermasse auf den PEN beschleunigt.

CASSE war am 14.11.2014 von 00:12 UTC bis 02:28 UTC aktiv und nahm 5 Sätze von Zeitreihen im Listening Mode und 14 im getriggerten Modus auf. Die Samplingfrequenz betrug 2 kHz im Listening Modus und 4 kHz im getriggerten Modus. Die Abstände zwischen Quelle und Empfänger betrugen nominell 94 cm, 164 cm und 239 cm, wobei die Wellenwege topographiebedingt länger waren. Insgesamt wurden 19 Hammerschläge registriert, die zu 50 auswertbaren Ersteinsatzzeiten führten.

Die Registrierungen zeigen, daß alle drei Füße von Philae mechanischen Kontakt zum Boden haben. Es gibt allerdings systematische, aber zeitlich variable Unterschiede in der Datenqualität, die vermutlich von kleinen Umlagerungen des Landers in der geringen Schwerkraft herrühren.

Aufgrund des ungeplanten Verlaufs der Landung, welcher dazu geführt hat, daß nur wenig Informationen zur lokalen Topographie des Landeplatzes vorliegen, kann nur ein Mindestwert für die Wellengeschwindigkeit abgeleitet werden. Demnach beträgt die P-Wellengeschwindigkeit oberflächennah mindestens 115 m/s, was mit der mittleren Dichte des Kometen zu einem Axialmodul von mindestens 4 MPa führt.

Western Bohemia earthquake swarm region: Moment tensor inversion and their synthesization

M. KRIEGEROWSKI[1], S. CESCA[2]

[1]University of Potsdam, Institute for Earth and Environmental Sciences; E-mail: kriegero@uni-potsdam.de
[2]Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Department 2.1, D-14473 Potsdam, Germany;
E-mail: simone.cesca@gfz-potsdam.de

Western Bohemia shows frequent earthquake swarm activity occurring within a very confined source region; The majority (80%) of the seismicity nucleates in the area beneath Novy Kostel in the Czech Republic. While most earthquakes are weak, with magnitudes M_L<3.5, few largest events reached magnitudes up to M_L=4.6 in recent years. The seismic activity can hypothetically be related to migrating magmatic fluids or gases of magmatic nature. Both hypothesis are supported by the imaging of a compact and potentially impermeable body at the top of the seismogenic zone. This could act as a sealing layer preventing further migration of uprising fluids. This scenario suggests that fluids gathered beneath the sealing layer could increase the pore pressure and eventually cause fracturing in the seismic swarm focal region.

The origin of the seismic swarms remains debated but further insights can be drawn from the analysis of focal mechanisms of weak events. A semi-automated full waveform based inversion routine is set up to identify moment tensors of recent earthquake swarms. The applied method uses pre-calculated Green's function databases. This allows to invert for numerous moment tensors while keeping time consumption low. A test application of this method to 8 days of data from the 2008 seismig swarm yields more than 400 successfully inverted events with magnitudes down to Ml 0.2.

The retrived source parameters are used as input for a newly developed toolbox, which enables to generate synthetic earthquake swarm catalogs as well as realistic synthetic waveforms.

Instaseis: instant global seismograms based on a broadband waveform database

Lion Krischer (1)
Martin van Driel (2)
Simon Stähler (1, 3)
Tarje Nissen-Meyer (4)

(1) Dept. of Earth Sciences, Ludwig-Maximilians-Universität München, München, Germany
(2) Dept. of Earth Sciences, ETH Zürich, Zürich, Switzerland
(3) Leibniz-Institute for Baltic Sea Research, Warnemünde (IOW), Germany
(4) Dept. of Earth Sciences, University of Oxford, Oxford, UK

Spherical models for planetary bodies represent a widely used characterization of bulk global material properties, which can often explain up to 90% of recorded data. Our novel methodology combines accurate seismic wave propagation with symmetry properties of radiation patterns, reciprocity, and high-order interpolation. **Instaseis (http://www.instaseis.net) delivers a comprehensive waveform database from which arbitrary source-receiver configurations and high-frequency record sections for a given model can be extracted within seconds**. The database thus acts as a once-and-for-all solution to wave propagation in spherically symmetric models. This not only frees users from re-running wave propagation codes, but opens doors to new applications in which vast numbers of parameter variations are desired such as modifications in source properties (moment tensor, source-time function, location), filtering, or background models, e.g. in a framework for probabilistic uncertainty assessment.

Using reciprocity, two simulations with the global wave-propagation solver, *AxiSEM* (Nissen-Meyer et al. 2014, http://www.axisem.info), suffice to generate a complete database of Green's functions: one as a "source" for the vertical, and one for both horizontal components. Storage of the propagating spatio-temporal displacement field at all distances (0-180 degrees) and depths (0-700 *km* for earthquakes) on the actual basis of the spectral-element mesh ensures the same accuracy as for the numerical wave propagation solution upon posteriori interpolation. The ease of computation (10K CPU hours) and tolerable storage requirements (a few TB for 1 *Hz* waveforms) implies that multiple such databases may be computed for several models at high resolution (1 *Hz* for global-Earth synthetics), e.g., continental versus oceanic crust, anisotropic versus isotropic, or various lower-mantle models. Further applications include the efficient generation of reference synthetics for global tomography, wavefields for hybrid 1D-3D methods, and responses to finite-fault sources.

Instaseis offers a user friendly interface written in Python and directly integrates with *ObsPy* (http://obspy.org), it includes a graphical user interface and can run in a client/server configuration via HTTP, such that the databases can be accessed and shared over the internet without the necessity to download large volumes of data. A first example of such a database is being developed and stored at the IRIS DMC (Seattle), to deliver on-demand customizable synthetics.

Instrumental magnitude constraints for the July, 11, 1889, Chilik earthquake

Frank Krüger , Galina Kulikova, Angela Landgraf

Institute of Earth and Environmental Science, University of Potsdam
Karl-Liebknecht-Str. 24/H60, 14476, Potsdam, Germany

A remarkable series of earthquakes with magnitudes above 6.9 occurred in the northern Tien-Shan between 1885 and 1911. The largest event, the Chilik earthquake with an estimated magnitude of 8.3, has occurred on July 11th, 1889. This magnitude is based on sparse macroseismic intensities, obtained by testimonies of witnesses. However, despite several juvenile fault scarps in the epicentral region no through going surface rupture associated with such a large magnitude, has been localized - a puzzling dilemma. Could the intensities, and consequently the magnitude been overestimated? This would have major implications, not only for the understanding of the earthquake series, but also for regional hazard estimates. Fortunately, a fragmentary record from an early Rebeur-Paschwitz seismometer exists for the Chilik event, recorded in Wilhelmshaven (Germany). To constrain the magnitude of this earthquake, we use the late coda waves of this record in comparison with that of recent events from Central Asia, recorded in Germany and transferred to Rebeur-Paschwitz instrument characteristics. Additional constraints come from disturbances of historic magnetograms that exist from the Chilik and the 1911 Chon-Kemin earthquakes. Scaling of these historic records confirm a magnitude about 8 for the 1889 Chilik earthquake, pointing towards a lower crustal contribution to the fault area.

High- Resolution Seismicity Image of the North Chilean Forearc

by J. Kummerow[1], W. Bloch [1], P. Salazar [2], P. Wigger [1], G. Asch [3] & S.A. Shapiro [1]
[1] Freie Universität Berlin, FR Geophysik
[2] Universidad Católica del Norte, Antofagasta
[3] Helmholtz-Zentrum Potsdam Deutsches GeoForschungsZentrum GFZ

Abstract

Several thousands of microearthquakes with $Ml > 0.5$ have been recorded by three recent temporary local seismic networks in the Iquique segment and on the Mejillones Peninsula in the North Chilean subduction zone. The monitoring was complemented by components of the permanent IPOC (Integrated Plate Boundary Observatory Chile) seismic network, providing a great on-shore possibility to study in detail the relatively shallow seismicity of the subducting Nazca slab.

Here, we present an overview of our previous results and ongoing research.
We show precise relocations of the observed seismicity and the Vp/Vs distribution in the study area obtained from differential P and S arrival times. Special focus is given to the clearly identified double seismic zone of the downgoing Nazca slab. One band of seismicity is located at the plate interface. The second one lies $20 - 25\,km$ deeper within the oceanic mantle and can be mapped updip to unusually shallow levels of less than $50\,km$.

Lindenfeld, M., Winter, H., Rümpker, G. (Goethe Universität Frankfurt)

Statusbericht zum Aufbau eines seismischen Kleinarrays am Kleinen Feldberg / Taunus

E-Mail: lindenfeld@geophysik.uni-frankfurt.de

Im Rahmen des BMWi-Projektes FERRY (Seismische Fernüberwachung geothermischer Kraftwerke mittels Arraytechnologien) wurde ein seismisches Array auf dem Gebiet des Taunus Observatoriums am Kleinen Feldberg errichtet. Ziel ist ein den Oberrheingraben überdeckendes und von den Kraftwerksbetreibern unabhängiges seismisches Monitoring zukünftiger geothermischer Anlagen von zentraler Stelle aus. Aufgrund seiner Abgelegenheit bietet dieser Ort gute Voraussetzungen, um auch relativ schwache Beben im Rhein-Main Gebiet detektieren und lokalisieren zu können.

Korrelationsanalysen der Registrierungen eines temporären Arrays, die mithilfe des NORSAR Instituts durchgeführt wurden, zeigten, dass Stationsabstände > 150 m ein optimales Signal/Rausch-Verhältnis beim Beamforming gewährleisten. Das aus diesen Voruntersuchungen abgeleitete permanente Array besitzt eine Apertur von etwa 700 m mit TNS als zentralem Element. Jeweils drei und fünf Stationen befinden sich (näherungsweise) auf zwei konzentrischen Kreisen um die Regionalnetzstation TNS.

Die Bauarbeiten zur Errichtung des Arrays begannen im Herbst 2014 und sind weitgehend abgeschlossen. Die Geräte sind zum Schutz gegen Wetter und Vandalismus in Betonschächten von ca. 1 m Tiefe untergebracht. Die Stromversorgung erfolgte bisher über Akkumulatoren, wird aber zurzeit auf Kabel bzw. Solarunterstützung umgestellt. Die Datenübertragung per LTE-Netz bzw. Kabel wurde an einigen Stationen erfolgreich getestet und wird demnächst an den restlichen Stationen eingeführt. Die Auswertung der Registrierungen (Detektion, FK-Analyse, Beamforming) erfolgt mit der von NORSAR bereitgestellten DPEP-Software.

Wir zeigen Datenbeispiele und Lokalisierungen von Beben im Taunus und im nördlichen Oberrheingraben und vergleichen unsere Ergebnisse mit den Lokalisierungen des SiMoN-Netzes.

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Seismological and meteorological measurements at the Dead Sea to investigate the impact of wind on seismic signals

Authors: Friederike Lott[1]*, Mahmoud Al.-Qaryouti[2], Joachim Ritter[3], Ulrich Corsmeier[1]
* Corresponding author
[1] Karlsruhe Institute of Technology KIT, Institute of Meteorology and Climate Research IMK. Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany
[2] Jordan Seismology Observatory JSO. Ministry of Energy and Mineral Resources. P.O.Box 140027, Amman11814, Jordan
[3] Karlsruhe Institute of Technology KIT, Geophysical Institute GPI. Hertzstraße 16, 76187 Karlsruhe, Germany

The HGF project DESERVE focuses on multiple geoscientific disciplines addressing natural risks such as climate aspects, seismic hazard and hydrology in the environment of the Dead Sea region. Taking advantage of the interdisciplinarity of the project, an experiment on the influence of meteorological parameters on ground motion is realized.
There have been several studies on correlations between seismic noise and wind speed, such as the investigations on storms by Holub et al. (2007, 2009). However, hitherto investigations on the influence of wind on seismological data were secondary results in experiments that were not purpose-built and therefore limited in the comparability of meteorological and seismic data sets.
We designed a target-oriented experiment in the Dead Sea valley. The area provides various distinct local wind systems that are well investigated within the DESERVE project. For the time period from March 2014 to February 2015 we installed 15 three component seismic high frequency and broad band stations at the slope of the Dead Sea valley near Madaba in Jordan. In the vicinity we additionally installed a permanent meteorological station providing three component wind data with 20 Hz sampling.
First results show high signal to noise ratios at the seismological stations and correlations between the amplitude of seismic velocity and wind speed. We investigate the energy in the seismological time series using Fourier and Stockwell transformations and compare it to wind speed and wind direction. The power spectral density of the seismic signals is cross correlated with the wind speed. The instruments for the field experiment were provided by the Geophysical Instrument Pool at GFZ.

Holub, K.; Rušajová, J.; Sandev, M. (2008): *The January 2007 windstorm and its impact on microseisms observed in the Czech Republic.* Meteorologische Zeitschrift, Vol. 17 No. 1, pp. 047-053, doi: 10.1127/0941-2948/2008/0264

Holub, K.; Rušajová, J.; Sandev, M. (2009): *A comparison of the features of windstorm Kyrill and Emma based on seismological and meteorological observations.* Meteorologische Zeitschrift, Vol. 18 No. 6, pp. 607-614, doi: 10.1127/0941-2948/2009/0409

ObsPy: A Python Toolbox for Seismology - Introduction, Recent Developments and Future Plans

Tobias Megies[1], Lion Krischer[1], Elliott Sales de Andrade[2], Robert Barsch[3] and the ObsPy Development Team[4]

1) LMU Munich, Department of Earth and Environmental Sciences, Munich, Germany
2) University of Toronto, Department of Physics, Toronto, Canada
3) EGU Executive Office, Munich, Germany
4) http://docs.obspy.org/credits.html

ObsPy (http://www.obspy.org) is a community-driven, open-source project dedicated to building a bridge for seismology into the scientific Python ecosystem. It offers

a) read and write support for essentially all commonly used waveform, station, and event metadata file formats with a unified interface,
b) integrated access to all large data centers, web services and databases, and
c) a comprehensive signal processing toolbox tuned to the needs of seismologists,

Python, currently the most popular language for teaching introductory computer science courses at top-ranked U.S. departments, is a full-blown programming language with the flexibility of an interactive scripting language. Its extensive standard library and large variety of freely available high quality scientific modules cover most needs in developing scientific processing workflows.

Together with packages like NumPy, SciPy, Matplotlib, IPython, Pandas, lxml, and PyQt, ObsPy enables the construction of complete workflows in Python. These vary from reading locally stored data or requesting data from one or more different data centers through to signal analysis and data processing and on to visualizations in GUI and web applications, output of modified/derived data and the creation of publication-quality figures.

ObsPy enjoys a large world-wide rate of adoption in the community. Applications successfully using it include time-dependent and rotational seismology, big data processing, event relocations, and synthetic studies about attenuation kernels and full-waveform inversions to name a few examples. All functionality is extensively documented and the ObsPy tutorial and gallery give a good impression of the wide range of possible use cases.

We will present the basic features of ObsPy, recent developments and applications, and a roadmap for the near future and discuss the sustainability of our open-source development model.

Improved imaging of the subsurface through joint inversion of seismic, magnetotelluric and gravity data

Max Moorkamp, Bjoern Heincke, Marion Jegen, Richard Hobbs and Alan Roberts

Creating accurate and comprehensive images of the Earth's subsurface is one of the current challenges in geophysical research. Many geophysical methods used for imaging the subsurface are approaching their theoretical limit of resolution given the constraints on feasible measurement locations and time. Thus combining several different techniques in integrated modelling approaches has gained the focus of attention. However, integrating techniques that are sensitive to different physical parameters such as velocity and conductivity poses additional challenges. It requires assumptions on the relationship between them either in terms of structure, i.e. coincident boundaries, or in terms of some sort of direct relationship between the physical parameters.

We will present case studies of joint inversion approaches for marine hydrocarbon exploration that highlight the potential and demonstrate the difficulties of performing joint inversion. We will compare the efficiency of different coupling approaches, investigate the influence and benefit of prior information and assess the additional information that we can obtain. Finally, we will also provide some recipes on how to alleviate the significant computational cost of performing several inversions simultaneously.

Seismic Q estimates in Umbria Marche (Central Italy): hints for the retrieval of a new attenuation law for seismic risk

Angelo Pisconti[1,4], Edoardo Del Pezzo[2,3], Francesca Bianco[2] and Salvatore de Lorenzo[1]

[1]*Dipartimento di Scienze della Terra, Università di Bari 'Aldo Moro', Via Orabona* 4, *I*-70125 *Bari, Italy. E-mail: salvatore.delorenzo@uniba.it*
[2]*Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Napoli Osservatorio Vesuviano, Via Diocleziano* 328, *I*-80124 *Napoli, Italy*
[3]*Instituto Andaluz de Geofisica, Universidad de Granada, Profesor Clavera* 12, *E*-18071 *Granada, Spain*
[4]*Now at: Institut für Geophysik, University of Münster, Corrensstraβe* 24, 48149 *Münster, Germany*

ABSTRACT

In the Umbria–Marche (Central Italy) region an important earthquake sequence occurred in 1997, characterized by nine earthquakes with magnitudes in the range between 5 and 6, that caused important damages and causalities. In our work, we separately estimate intrinsic and scattering Q^{-1} parameters, using the classical multiple lapse time window analysis (MLTWA) approach in the assumption of a half-space model. The results clearly show that the attenuation parameters Q_i^{-1} and Q_s^{-1} are frequency dependent. This estimate is compared with other attenuation studies carried out in the same area, and with all the other MLTWA estimates obtained till now in other tectonic environments in the Earth. The bias introduced by the half-space assumption is investigated through numerical solutions of the energy transport equation in the more realistic assumption of a heterogeneous crust overlying a transparent mantle, with a Moho located at a depth ranging between 35 and 45 km below the surface. The bias introduced by the half-space assumption is significant only at high frequency. We finally show how the attenuation estimates, calculated with different techniques, lead to different peak ground acceleration decay with distance relationships, using the well-known and well proven Boore's method. This last result indicates that care must be used in selecting the correct estimate of the attenuation parameters for seismic risk purposes. We also discuss the reason why MLTWA may be chosen among all the other available techniques, due to its intrinsic stability, to obtain the right attenuation parameters.

Seismicity and stress field in the vicinity of natural gas fields in Northern Germany

Thomas Plenefisch[1], Nicolai Gestermann[1], Monika Bischoff[2]

(1) Bundesanstalt für Geowissenschaften und Rohstoffe, Stilleweg 2, 30655 Hannover
(2) Landesamt für Bergbau, Energie und Geologie, Stilleweg 2, 30655 Hannover

The Northern German basin is a tectonic region of relatively low seismic activity with only singular and weak tectonic events. However, during the last decades seismicity raised in the vicinity of the natural gas fields. Due to the spatial vicinity of the epicenters to the operated gas fields and their appearance starting after the beginning of extraction they are ranked as induced events. The epicenters of these events extend 50 km NS and 400 km EW from the border to the Netherlands in the West to Altmark region in the East.

Altogether, 55 events with M_L 0.5 to 4.5 were detected between 1977 and 2014. Many of them were felt by parts of the inhabitants up to 15 km from the epicenter whereas the strongest one, the magnitude 4.5 event close to the village of Rotenburg on 20th October 2004, was even felt in Hamburg as far as 65 km from the epicenter. Whereas epicenters can be determined with relatively high accuracy, other source parameters, such as focal depths and focal mechanisms, are of lower accuracy. This is mainly caused by the sparse station coverage in the area at least until 2012 and relatively bad signal-to-noise conditions as a result of thick sedimentary layers. Overall, focal depths are found to be rather shallow in the range of 2 to 10 km.

The process of earthquake generation is still not well understood. Trigger mechanisms have not systematically been investigated. We generally assume, that anthropogenic stress changes within the reservoir lead to the reactivation of prominent tectonic faults. The predominant cause for stress variations might be the large pore pressure reduction in the reservoir as a consequence of the gas extraction. Additionally, heterogeneous compaction within the reservoir may influence the variation of the local stress field.

We present focal mechanisms for 8 events with $M_L > 2.8$ under the assumption of a pure double-couple and invert the solutions for the regional stress field. The majority of the focal mechanisms represents normal faulting and exhibits NW-SE oriented nodal planes being in quite good agreement with the strike direction of nearby tectonic faults. For example, the Aller Lineament which marks the southwestern boundary of the natural gas field at Völkersen, might be activated.

In our presentation we also compare the focal mechanisms of the induced events of Northern Germany with mechanisms of the natural gas fields in the Netherlands and with the few mechanisms for the rare tectonic events in Northern Germany and adjacent areas. The stress field calculated on the base of the induced events is compared with stress measurements in boreholes published in the European Stress Map for Northern Germany.

Seismicity of the segment-8 volcano at the Southwest Indian ridge

Plötz, A ., Schmid, F., Schlindwein, V. and Scholz, J. R., AWI Bremerhaven (2015)

Abstract

New oceanic crust is formed at the mid-oceanic ridges (MOR), where the lithospheric plates drift apart. The structure and characteristics of MOR differ with spreading rates being either fast (80-100 mm/a), slow (20-55 mm/a), or ultraslow spreading ridges (< 20 mm/a). In comparison with faster spreading ridges the ultraslow spreading ridges are poorly investigated, their spreading mechanisms and parameters for generating volcanic centres are relatively unknown. Local earthquakes analyses can be used for a better understanding of the thermal and mechanical condition of the lithosphere at MOR.

The Southwest Indian ridge (SWIR) separates the Antarctic and African plates and with a full spreading rate of ~14 mm/a belongs to the ultraslow spreading ridges. The segment-8 volcano (65.60° E, 27.65° S) is located at the north eastern part near the Rodriguez triple junction. We processed nine months of continuous seismic data recorded by a network of eight Ocean Bottom Seismometers (OBS) in this area. After automatic event identification, arrivals of p- and s-phases were hand-picked. Locations of 2972 hypocentres could be calculated using the linear location algorithm HYPOSAT. Furthermore, we used the relative location algorithm hypoDD to improve the standard earthquake location and additional waveform cross-correlation of P-phases to increase the accuracy of phase onset times.

We received a sharp image of seismicity confined to the rift valley with local magnitudes in the range -0.7 up to 3.5. Absolute locations are on average accurate to within 3.5 km including all events. We could identify spatial clusters around the segment-8 volcano with considerable background seismicity through the recording period. Receding from the centre of the volcano, focal depths increase continuously to 17 km, defining the boundary between brittle-ductile behaviour of the lithosphere.
The results show a noticeable zone with a radius of 15 km without any occurrences of earthquakes located beneath the central volcano and deserve special attention. First analyses show that this aseismic zone has a remarkable low-velocity anomaly, which indicates increased temperatures.

Pacific Anisotropy – real or apparent?

By Philipp Prasse and Prof. Dr. Christine Thomas
Westfälische Wilhelms-Universität Münster

Anisotropy of the lowermost mantle beneath the South- to Central Pacific is investigated, using US Array receivers and events located near the Tonga-Fiji subductions. We use three different distance ranges (65°-85°, 90°-110° and >110°) for S-ScS, SKS-S, SKS-Sdiff differential splitting analysis. By utilizing this method we can correct for upper mantle-, source- and receiver side anisotropy and effectively determine shear wave splitting solely caused from the lowermost mantle. Delay times of horizontal (SH) and vertical polarized (SV) shear waves exhibit that predominantly the SV wave is delayed relative to the SH wave by up to 3 seconds. Motivated by the discrepancy of previous pacific studies, which observed $V_{SV} > V_{SH}$ as well as $V_{SV} < V_{SH}$, we test the possibility of isotropic structure causing the observed splitting. Synthetic seismograms, based on various isotropic models, are computed. While layered models do not show consistent splitting, models, which represents the lower most mantle as just a negative gradient in P- and S-wave velocity, results in very clear apparent anisotropy. As a result this study presents a possible alternative way of explaining the structure of the D".

Seismische Anisotropie des Lithosphären-Asthenosphären-Systems im südlichen Madagaskar

M.C. Reiss*[1], G. Rümpker[1], F. Tilmann[2], X. Yuan[2], E.J. Rindraharisaona[2], [3]
[1]Goethe-Universität Frankfurt, Institut für Geowissenschaften, Frankfurt, Deutschland,
[2]Deutsches GeoForschungsZentrum, Potsdam, Deutschland,
[3]Institute and Observatory of Geophysics Antananarivo, Antananarivo, Madagaskar

Madagaskar nimmt eine Schlüsselrolle bei der Entstehung und dem späteren Auseinanderbrechen des Superkontinents Gondwana ein. Zunächst lag es im Zentrum der Panafrikanischen Orogenese infolge der Kollision von Ost- und West-Gondwanaland (~700-650 Ma), bevor sich Madagaskar in mehreren Stufen von Ostafrika und später von der Indischen und der Antarktischen Platte löste. Dieser Prozess war vor etwa 69 Ma abgeschlossen. Madagaskar besteht heute aus verschiedenen tektonischen Einheiten: die östlichen Zweidrittel Madagaskars sind hauptsächlich aus Präkambrischen Gesteinen, das westliche Drittel aus Sedimenten aufgebaut; der Süden ist durch eine Anzahl von N-S bis NW-SO ausgerichteten Scherzonen charakterisiert. Zur Bestimmung der vermuteten komplexen Lithosphären-Asthenosphären-Struktur wurde ein temporäres Netzwerk im Süden Madagaskars installiert, welches aus 25 Breitband- und 25 kurzperiodischen Stationen bestand und zwischen 2012 und 2014 für 2 bzw. 1 Jahr betrieben wurde. Die Breitbandstationen bildeten ein Ost-West Profil, welches verschiedene tektonische Blöcke sowie Hauptscherzonen querte, während die kurzperiodischen Stationen den östlichen Teil des Profils flächenhaft ergänzten.

Zur Untersuchung der seismischen Anisotropie der Kruste und des oberen Mantels bzw. der damit verknüpften dynamischen Prozesse führen wir Splittinganalysen von Kernphasen durch. Dabei können die Polarisationsrichtung und die Verzögerungszeit Hinweise auf die Orientierung und Mächtigkeit anisotroper Schichten geben. Wir verwenden die Phasen von bis zu 22 teleseismischen Events an den temporären Stationen und der Permanentstation VOI des GEOFON-Netzwerks. Zunächst erfolgen Einzeleventanalysen mittels Energieminimierung der transversalen Komponente. Für Stationen, deren Einzeleventanalyse keine signifikante azimutale Abweichung der Polarisationsrichtung zeigt, wird zusätzlich eine Joint-Splittinganalyse durchgeführt. Unsere Ergebnisse zeigen Verzögerungszeiten zwischen 0.4 und 1.5 s. Die schnellen Achsen sind im Zentrum des Profils überwiegend NNW-SSO orientiert, während sie östlich der Ranotsara-Scherzone einem NO-SW Trend folgen. Wir führen eine Wellenfeld-Modellierung durch, um die Einflüsse verschiedener anisotroper Quellregionen zu untersuchen. Die synthetischen Wellenformen werden mittels der Einzeleventanalyse analysiert, um sie mit den beobachteten Splittingparametern zu vergleichen. Unsere Ergebnisse zeigen, dass zuletzt aufgestellte Mantelflussmodelle die relativ stark variierenden Splittingparameter nicht erklären können. Unsere Beobachtungen können am besten durch den Beitrag asthenosphärischer Anisotropie, auf Grund der absoluten Plattenbewegung in Richtung ~50°, in Verbindung mit fossiler Anisotropie in der Lithosphäre mit einer schnellen Achse von -40° erklärt werden. Diese ist gegebenenfalls mit dem Einschub des Antananarivo Blocks in den metasedimentären südlichen Teil Madagaskars während der Pan-Afrikanischen Orogenese verbunden.

Behaviour of mantle transition zone discontinuities beneath the Indian Ocean from PP precursors

Anne-Sophie Reiß[1], Christine Thomas[1]

(1) Institut für Geophysik, Westfälische Wilhelms Universität Münster, Münster, Deutschland

As part of the RHUM-RUM project we investigate the upwelling plume beneath the Piton de la Fournaise volcano. It is one of the most active volcanoes in the world and located on La Réunion Island, around 800 km east of Madagascar in the Indian Ocean. A long-lived underlying mantle plume is suspected to be responsible for the formation of the island. Understanding the depth origin and dimensions of such a mantle plume helps to better understand mantle processes and the heat flux of the Earth. If the plume originates at the core mantle boundary the Earth is cooled down differently compared with an indirect cooling of plumes originating at subduction zones in the upper mantle. In this study we use PP waves, compressional bodywaves that get reflected once at the midpoint between source and receiver. Underside reflections of PP waves off the seismic discontinuities at 410 km and 660 km depth, which mark the upper and lower boundary of the mantle transition zone, are called precursors. They arrive earlier in the signal due to shorter travel paths. In order to investigate the topography of these discontinuities, differential traveltimes between the main phase and the precursor signal are measured. If hotter material intersects the mantle transition zone, the discontinuities at 410 km and 660 km depth are deflected, hence the topography of the mantle transition zone can be an indicator for an upwelling plume. The 410 km discontinuity, which exists due to the phase change of olivine to spinel, should be depressed significantly in the presence of hot upwelling material. Because of the opposite Clapeyron slope of the phase change of ringwoodite to magnesiowuestite and perovskite at 660 km depth, the topography of this discontinuity should be elevated. For this study we analyse over 3000 events with $M_w \geq 5.8$ and bounce points distributed over the entire Indian Ocean. Array seismology methods, such as vespagrams and slowness-backazimuth analysis, are used to enhance the signal-to-noise-ratio and detect and identify precursor signals. Using different source-receiver combinations enables us to get a dense coverage of bounce points of PP waves in the Indian Ocean and especially around La Réunion, also with crossing ray paths. The differential travel times of PP arrivals and their precursors of robust stacks are corrected for crustal and tomographic features and converted into depth values of the seismic discontinuities. In our data, we can detect clear underside reflections off the 410 km discontinuity and also some off the 660 km discontinuity. The preliminary topography of the two discontinuities indicates a thinned mantle transition zone, which we interpret as a large upwelling beneath La Réunion.

Generalization of the receiver-function stacking method of Zhu & Kanamori (2000) to anisotropic media

Georg Rümpker, Ayoub Kaviani, Frederik Link (Goethe University Frankfurt)

The effect of anisotropy on the estimates of crustal thickness *H* and average bulk v_P/v_S-ratio *k* can be significant in the presence of strong seismic anisotropy. Here we extend the stacking approach of Zhu and Kanamori (2000) to include all twenty P-to-S converted phases and their crustal reverberations that are generated in the anisotropic case - instead of only five phases in the isotropic case. The ray-based algorithm of Frederiksen and Bostock (2000) is used to calculate the amplitude and arrival time of each phase. Synthetic tests are performed to investigate the feasibility and robustness of the stacking approach. For simplicity, we assume hexagonal symmetry and a horizontal symmetry axis but more general anisotropy may be considered. The tests reveal that the estimates of *H* and *k* can be significantly affected by the presence of crustal anisotropy. We verify the feasibility of the stacking approach for real data by applying the method to examples from three different tectonic regions. The results show that the anisotropic stacking scheme presented here can provide much better constraints on the estimation of *H* and *k* in comparison to the isotropic stacking. The anisotropic stacking can also help to resolve ambiguities in the determination of *H* and *k* when several maxima of stacked receiver-function amplitudes arise in cases of complex crustal structure. The approach can be generalized further by simultaneously inverting for anisotropic and structural parameters of the crust.

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Structural Monitoring of a Highway Bridge using Passive Noise Recordings from Street Traffic:

Johannes Salvermoser*, Céline Hadziioannou*, Simon Stähler*

*LMU München

Structural damage on bridges presents a hazard to public safety. Due to increased safety norms and the aging of structures built after the second world war, the interest in performing **structural health monitoring** (SHM) is steadily growing.

Different approaches for SHM have been proposed in the last decades to amend well-established but work-intenstive regular visual inspections. Important features we aim to improve for future systems, are temporal resolution, accuracy of detection and minimization of logistical effort. This study contributes to the development of an alternative monitoring system for civil structures, based on passive seismic measurements.

Damage is often indicated by deviations of wave velocity in the medium caused by stress changes, opening cracks or other disturbed scatterer distribution.
Cross-correlations of traffic noise recorded at **geophone** receiver pairs on a **reinforced concrete bridge** were found to be sufficiently stable for comparison and sensitive to velocity changes in the medium. A method which was originally introduced for seismological applications and named Passive Image Interferometry (PII) [Sens-Schönfelder & Wegler, 2006], was used to quantify small velocity fluctuations in the medium and thereby observe structural changes.

The evaluation of more than two months of continuous geophone recordings yielded velocity variations **dv/v in the range of -1.5% to +2.1%** for a temperature range of -23°C to +14°C. The resemblance between the observed velocity fluctuations and the corresponding temperature time series is striking, which is remarkable for two completely independent data sets.
Due to this strong conformity between the measurements, we proceeded with an estimation of a scaling factor between temperatures and wave velocity changes, a **velocity variation rate (VVR) per °C**. In a linear regression approach to adjust temperature values to velocity variations for each 24h-interval consecutively, we calculated the best fitting VVRs.
An average value of **0.064 %/°C** could be identified, which corresponds well to other studies on concrete structures. In the future, we plan on conducting experiments that include real damage scenarios in simulations and laboratory experiments to check the sensitivity of our method to damage induced velocity variations. The ultimate aim is to develop a working automated monitoring system that takes only passive traffic noise as an input.

Is there any mantle plume beneath Tristan da Cunha?

Antje Schlömer [1], Wolfram H. Geissler[1], Wilfried Jokat[1], Marion Jegen[2]

1. Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research
2. Geomar, Helmholtz Centre for Ocean Research Kiel

Tristan da Cunha is a volcanic island in the South Atlantic located very close to the Mid-Atlantic Ridge. Generally, it is accepted to be the location of a mantle plume, which has been active at least since the breakup of Gondwana at 130 Ma, the time when the Paraná/Etendeka flood basalts were emplaced. Furthermore, it is associated with the formation of the Walvis Ridge and the Rio Grande Rise, and therefore it is one of the key examples of a hot spot track linking a flood basalt province to an active ocean island volcano. However, global tomography models are contradicting about the origin of Tristan da Cunha: Whether it is a deep mantle plume or caused by shallow plate tectonics. To gain a better understanding, we deployed 24 broadband ocean-bottom seismometers, 26 ocean-bottom electromagnetic stations and 2 seismological land stations in January 2012 with the German research vessel Maria S. Merian. We acquired continuous seismological data for one year and recovered the instruments in January 2013.

We use cross-correlated travel time residuals of teleseismic earthquakes to perform a finite-frequency tomography to resolve the P wave velocity upper mantle structure beneath the island.
Here we show our preliminary results of the 3-D velocity perturbations in the upper mantle: We do not image a plume-like structure directly beneath the island. Instead we observe a low velocity region in the southwest of our array that might be related to a local mantle upwelling (mantle plume).
Additionally we show the local seismicity in the Tristan da Cunha region.

Wechselwirkung eines seismischen Wellenfeldes mit Hohlräumen im Untergrund

Felix M. Schneider[1)], Sofi Esterhazy [1,2)] , Götz Bokelmann [1)], Ilaria Perugia [2)]

[1)] Institut für Meteorologie und Geophysik, Universität Wien
[2)] Fakultät für Mathematik, Universität Wien

Im Rahmen einer On-Site-Inspection (OSI) ist es die Aufgabe der Comprehensive Nuclear-Test Ban Treaty Oranization (CTBTO) Hohlräume, die durch nukleare Tests entstanden sind, zu detektieren. Mit unserer durch den Wiener Wissenschafts-, Forschungs- und Technologiefonds (WWTF) finanzierten Studie zur Wechselwirkung des seismischen Wellenfeldes mit Hohlräumen im Untergrund, möchten wir dieses Problem grundlegend untersuchen. Ziel ist es, Methoden und Messaufbauten zu entwickeln und vorzuschlagen, welche die Existenz von Hohlräumen belegen können.

Dabei soll herausgefunden werden, welche Art von seismischen Quellen genutzt werden können, um an der Oberfläche Signale der Wechselwirkung von Hohlraum und Wellenfeld als solche zu identifizieren. Dabei ist insbesondere von Interesse welche Quellfrequenzen nötig sind und wie die Auslage, sowie die Empfindlichkeit der seismischen Sensoren zu wählen ist. Ob ein natürliches passives Quellfeld genutzt werden kann oder ein künstlich aktives Quellfeld erzeugt werden muss, ist zunächst offen bzw. Teil der Fragestellung.

Zunächst wird das generische Modell eines sphärischen akustischen Hohlraums in einem elastischen Halb- bzw. Vollraum untersucht. Dabei werden zwei unterschiedliche Ansätze verwendet. Einerseits wird das seismische Wellenfeld numerisch mit Hilfe der Finite Elemente Methode (FEM) simuliert. Dies hat zum Vorteil, dass die Modellierung später vom einfachen generischen Modell zu komplexeren unregelmäßigen Geometrien angepasst werden kann. Andererseits wird eine analytische Lösung des Hohlraums im elastischen Vollraum implementiert. Ziel ist hier, die numerischen Lösungen zu verifizieren, sowie tiefere Einblicke in das Anregungsverhalten des Hohlraums zu bekommen. Eine Idee ist, das resonante Anregung des Hohraums ein charakteristisches frequenzabhängiges Abstrahlverhalten erzeugt, welches als Identifizierung des Hohlraumes dienen kann.

Hier werden erste Ergebnisse der FEM-Modellierung, sowie der analytischen Lösung eines zeitperiodischen seismischen Wellenfeldes in Wechselwirkung mit einem sphärischen akustischen Hohlraum im elastischen Vollraum gezeigt und verglichen.

Preliminary performance report of the RHUM-RUM ocean bottom seismometer network around La Réunion, western Indian Ocean

Simon C. Stähler[1,6], **Karin Sigloch[2,1]**, Kasra Hosseini[1], Wayne C. Crawford[3], Guilhem Barruol[3,4], Mechita C. Schmidt-Aursch[5], Maria Tsekhmistrenko[2,5], Alessandro Mazzullo[4]

1. Dept. of Earth Sciences, Ludwig-Maximilians-Universität München
2. Dept. of Earth Sciences, University of Oxford
3. Institut de Physique du Globe de Paris
4. Laboratoire GéoSciences Réunion, Université de La Réunion
5. Alfred Wegener Institute Bremerhaven
6. IOW Leibniz-Institute for Baltic Sea Research, Warnemünde

RHUM-RUM is a German-French seismological experiment based on the sea floor surrounding the island of La Réunion, western Indian Ocean. Its primary objective is to clarify the presence or absence of a mantle plume beneath the Reunion hotspot.

RHUM-RUM's central component is a 13-month deployment (Oct 2012 to Nov 2013) of 57 broadband ocean bottom seismometers (OBS) and hydrophones over an area of 2000x2000 km^2 surrounding the hotspot. The array contained 48 broadband OBS from the German DEPAS pool and 9 stations from the French INSU pool. It has been the largest deployment of DEPAS and INSU OBS so far, and the first large joint experiment.

We give an overview of station performance and issues encountered, touching on instrument responses, recorder and battery performance, noise characteristics, and data yield. Of the 57 stations, 46 had proper seismometer and 53 proper hydrophone recordings. Out of a installation time of 13x57=741 station-months, 412 months of data were actually realized for the seismometers, and 710 for the hydrophones.

At long periods (>10 s), the DEPAS stations are affected by significantly more noise than the INSU stations, a difference that is most pronounced on the horizontal components and can probably be explained by tilting of the instrument assemblage. The DEPAS sensors are integrated into the OBS frame and buoy assemblage, and would therefore record its motions, caused for example by the action of deep sea currents. However, this integrated setup also makes the DEPAS OBS easier to deploy and recover, especially in large deployments such as this one.

Beeinträchtigung von GRF-Stationen durch Windkraftsignale

K. Stammler,
Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover

Eine im Rahmen eines Verwaltungsgerichtsverfahrens erstellte Studie zu den quantitativen Auswirkungen von Windkraftsignalen auf die Messstationen des GRF-Array zeigt erhebliche diesbezügliche Beeinträchtigungen an einigen Standorten im Frequenzfenster zwischen 1 und 7 Hz. Es wurden systematisch an allen GRF-Standorten über ein Jahr gemittelte Unruhespektren ermittelt und in Abhängigkeit von der lokalen Windstärke aufgetragen. Beim Vergleich von Zeiträumen vor und nach der Installation von Windkraftanlagen zeigt sich erst seit der Installation von Windkraftanlagen eine Windabhängigkeit der Unruhespektren, welche damit als ein Identifikationskriterium verwendet werden kann. Bei Frequenzen in der Nähe von 1 Hz konnten solche Signale aus über 15 km Entfernung nachgewiesen werden. In diesem Frequenzbereich treten inzwischen an allen GRF-Standorten Windkraftsignale auf. Eine Wechselwirkung mit der unter GRF liegenden Sedimentschicht wird vermutet. Bei höheren Frequenzen ist die Reichweite geringer. Der von BGR für ihre Stationen schon länger geforderte Mindestabstand von 5 km für neue Windkraftanlagen ist aus seismologischer Sicht angemessen.

Bericht über das Seismologische Zentralobservatorium der BGR (SZO)

K. Stammler, M. Dohmann, T. Grasse, M. Hanneken, E. Hinz, I. Göbel, M. Hoffmann, E. Muhire, C. Müller, H. Schlote, U. Stelling, E. Wetzig
Bundesanstalt für Geowissenschaften und Rohstoffe (BGR), Hannover

Es wird ein Überblick über die Tätigkeiten am SZO der BGR gegeben. Der Bericht umfasst folgende Themen:

- Durchführung von Testmessungen an möglichen neuen GRSN-Standorten
- Zusammenstellung und Statistiken der vorhandenen Stationen im Archiv der BGR
- Korrektur der Azimuthausrichtung der Horizontalkomponenten an GRF- und weiteren Stationen
- Erfahrungen mit Bohrlochinstrumenten an drei Standorten (GRFO, RETH, GOR1)
- Entwicklungen am Datenzentrum

Can we explain the D'' reflector with the post-perovskite phase transition?

C. Thomas[1], L. Cobden[2].

1Institut für Geophysik, WWU Münster, Münster, Germany.
2Geosciences, University of Utrecht, Utrecht, Germany.

Seismic observations from the lower Earth's mantle indicate a reflector that marks the top of the D' region. Many studies have imaged this reflector in previous years, many of them in high-velocity regions that could be due to slab graveyards, and many interpretations have been published previously. Since the discovery of the post-perovskite phase transition ten years ago, the D' reflector has often been interpreted as the place of the phase transition. Even looking at wave forms, polarities, deeper reflectors and amplitudes of the reflected waves has shown agreement with properties of post-perovskite and the confidence of it as the cause for the D' reflector has been increasing. Here we are looking at several new places and identify D' reflections in P and S-waves: we target especially low velocity regions and places, where we do not expect slab material in the lowermost mantle. We test wave forms, polarities, amplitudes, timing and frequency content of the reflected waves and compare these across many diverse regions in the mantle. It seems that post-perovskite can still explain many observations; however, a large number of assumptions has to be made to explain all observations in all regions simultaneously and leaves the question whether the reflector in D' can always be explained through a phase transition to post-perovskite or whether we have to consider other possibilities.

AG Seismologie 2015

Locating mofettes using seismic noise records from small dense arrays and Matched Field Processing Analysis in the NW Bohemia/Vogtland Region, Czech Republic

Josefine Umlauft, Hortencia Flores-Estrella, Andreas Schmidt, Michael Korn

Institute of Geophysics and Geology, Leipzig University

Talstr. 35, 04103, Leipzig, Germany

Abstract

The NW Bohemia/Vogtland region is characterized by currently ongoing geodynamic processes within the intracontinental lithospheric mantle. This activity results in the occurrence of earthquake swarms as well as CO_2 degassing zones, called mofettes. These two natural phenomena are related to each other since it is considered that fluid flow and fluid-induced effective stress can trigger earthquake swarms. At the Earth's surface they appear spatially separated within the area under investigation, but their connection could be explained by the existence of pathways within the crust that allow efficient and permanent fluid transport. These pathways need to be located and mapped.

With this background we applied the noise source localization method *Matched Field Processing (MFP)* to detect mofettes and investigate their characteristics, considering the CO_2 degassing process as high frequency noise source. We chose different test sites: the Dolní Částkov Borehole, which is an artificial mofette that we used to validate the methods functionality and the South Hartoušov and the North Hartoušov mofette fields, both natural CO_2 degassing areas.

On each site, we measured seismic noise in continuous mode over several hours (7-9 hours), with a sampling frequency of 250 samples per second in multiple campaigns using an array of ~30 stations randomly distributed. Each array covered an area of about 1 ha and consisted of vertical geophones (4,5 Hz) connected to Reftek Texans.

For the *MFP* computation the phase velocity $c(\omega)$ of the study area is required, which we obtained from active seismic experiments with hammer blows as source.

With the *MFP* analysis at the artificial mofette in Dolní Částkov we could relocate the noise source successfully and hence, the method's functionality was confirmed. In the South Hartoušov mofette field, we detected one fundamental noise source, probably a fluid pathway, as well as small *MFP* maxima at the surface that can be related to a dry mofette. We show preliminary results of the North Hartoušov mofette field, a complex degassing field with multiple *MFP* maxima that indicate a diffuse fluid channels in the subsoil.

PyLoT – a tool for consistent manual and automatic processing of seismic data

S. Wehling-Benatelli[1], L. Küperkoch[2], W. Friederich[1]
[1]Ruhr-Universität Bochum, [2]BESTEC GmbH

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The increasing density of seismic surveillance facilities lowers the magnitude of completeness and enlarges the amount of seismic data available on all scales. Thus, automation of processing these data, e.g for monitoring purposes, is of increasing importance in seismology. Seismic phase onset times are physical measurements and hence have errors. Automatic determination of reliable phase onsets and assignment of objective picking uncertainties requires several processing steps and highly consistent, manually acquired reference onset data for testing and tuning. PyLoT is a software package providing a comprehensive toolbox for automatic picking of seismic phase onsets and featuring a GUI driven, platform independent, manual phase identification and picking tool for production of the required reference onset data. The program is designed to follow the suggestion to the determination of consistent phase onsets by Diehl et al. [2012] and therefore produces phase onsets which are fully characterized by non-symmetric in addition to symmetrized picking errors. All phase onset data prepared with PyLoT are ready for location with external seismological software like NonLinLoc and determination of source mechanisms.

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Abstract AG Seismologie; 15.09-17.09.15 (**Poster**)

Titel: **“The SeisSol software package for large-scale earthquake simulations with complex geometries“**

Stephanie Wollherr*, Alice-Agnes Gabriel*, Thomas Ullrich*, Alexander Breuer+, Alexander Heinecke+, Sebastian Rettenberger+, Heiner Igel*, Michael Bader+.

* Department of Earth and Environmental Sciences, Ludwig-Maximilians-Universität, München
+Department of Informatics, Technische Universität, München

We present the recently optimized software package SeisSol for the simulation of realistic earthquakes in three-dimensional complex geometries.
The dynamic earthquake faulting and the subsequent seismic wave propagation is solved simultaneously by a high-order ADER-DG method implemented on unstructured tetrahedral meshes. Quick adaptation of the mesh resolution allows a fine sampling of the cohesive zone on the fault while satisfying the dispersion requirements of wave propagation away from the fault. Enabled by hardware-aware optimization the software reaches now multi-petaflops performance on some of the largest supercomputers worldwide (Breuer et al., ISC 2014). SeisSol further has proven to be highly scalable on current and future HPC infrastructure due to a overlapping OpenMP/ MPI parallelization (Heinecke et al., SC14). The resulting speed-up of a factor of 5-10 allows simulating realistic large-scale scenarios including up to a billion elements and frequencies up to 10 Hz.
To demonstrate the advantages of the scheme we present the simulation of the 1992 Landers earthquake on a complex fault system where rupture transfers between principal faults in terms of jumps and branching. For this scenario we compare the rupture process on the fault with purely elastic material properties of the surrounding material to a simulation using plastic yielding to show the effects of incorporating plastic deformation into SeisSol. Another challenging application regarding mesh generation is the simulation of subduction zone earthquakes including small angles where fault and surface intersect. To better understand the conditions under which such earthquakes may cause devastating tsunamis we present a model for the 2004 Sumatra earthquake. This work highlights the benefits of using modern numerical methods for fundamental earthquake physics and physics-based ground motion modeling.