The May 2018 earthquake swarm in Vogtland/NW-Bohemia: Spatiotemporal evolution and focal mechanism determinations

Laura Barth and Thomas Plenefisch

Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, 30655 Hannover, Germany (thomas.plenefisch@bgr.de)

Vogtland/NWBohemia, an area at the border between Germany and Czech Republic, is known as one of the most interesting earthquake swarm regions in Europe. This special type of seismicity is expressed by the accumulation of a huge number of events of similar magnitude and their episodic reoccurrence. During a swarm hundreds or thousands of earthquakes without a distinct main shock occur spatially and temporally clustered.

The most recent swarm of 2018 occurred between the 10th of May and the beginning of September with the main swarm activity in May. With more than 1000 located events and magnitudes up to 3.8 it is one of the most prominent swarms during the last decades. Due to the strength of the swarm and the increased number of stations in the Vogtland/NW-Bohemia region the swarm of 2018 offers various possibilities to investigate the peculiarities of swarms and the special seismotectonic situation of the Vogtland/NW-Bohemia region.

This study concentrates on the spatiotemporal evolution of the swarm and on the determination of earthquake focal mechanisms. Focal mechanisms for all events with magnitudes ML ≥ 3.0 have been calculated. The ensemble of focal mechanism is analysed with respect to variations within the swarm as well as changes with respect to the mechanisms of the former swarms. Most of the focal mechanisms represent strike slip mechanisms with a normal faulting component. The strike direction of one nodal plane (almost NS) reflects the strike of the Marianske Lazne fault zone and parallel striking fault systems. The focal mechanisms are used to invert for the regional stress field which then is compared to the stress field in Central Europe.

Was verursacht die zeitliche Variabilität der Meeresmikroseismik an der Station Helgoland?

D. Becker[1], T. Kruse[2], C. Hadziioannou[1], T. Meier[2]

[1]Universität Hamburg, Institut für Geophysik, [2]Insitut für Geowissenschaften der CAU, Kiel

Die mit der Regionalnetzstation HLG auf der Nordseeinsel Helgoland aufgezeichnete Meeresmikroseismik zeigt im gesamten Frequenzbereich eine starke zeitliche Variabilität der Amplituden wie auch der dominanten Frequenzen. Dies wird sowohl durch den lokalen Wellengang in der Deutschen Bucht wie auch durch entfernte Quellen der Meeresmikroseismik im Nordatlantik verursacht. Während der Frequenzbereich oberhalb von 0.2Hz (die sogenannte lokale Meeresmikroseismik) ganzjährig von Quellen in der Deutschen Bucht dominiert wird, zeigt der klassische Bereich der sekundären Meeresmikroseismik ein komplexeres Verhalten. Im Winter wird er von entfernteren Quellen im Nordatlantik dominiert, zeigt im Sommer während erhöhten Wellengangs in der Deutschen Bucht aber auch einen deutlichen Einfluss des lokalen Seegangs. Zusätzlich werden zu diesen Zeiten ein erhöhtes H/V-Verhältnis der sekundären Meeresmikroseismik und dominanten Ozeanwellenperioden in der Größenordnung von knapp 10 Sekunden beobachtet. Wir interpretieren diese Beobachtung als primäre lokale Meeresmikroseismik, die während des Winters von entfernter sekundärer Meeresmikroseismik überlagert wird.

Bei der Untersuchung von mehrjährigen Zeitreihen beobachtet man zusätzlich zu der jahreszeitlichen Variation der sekundären und primären Meeresmikroseismik im Frequenzbereich der lokalen Meeresmikroseismik spektrale Peaks mit Perioden der Ozeangezeiten. Diese findet man teilweise auch beim H/V-Verhältnis im Frequenzbereich der sekundären Meeresmikroseismik und sie deuten einen Einfluss des augenblicklichen Wasserstandes auf die Erzeugung der lokalen Meeresmikroseismik an. Dabei tritt ein Zeitversatz von 1.5 Stunden zwischen dem Gezeitenhochstand und dem Maximum der beobachteten seismischen Energie auf. Ob dies durch eine Quelle im Westen von Helgoland oder eine andere Ursache zu erklären ist, müssen weitere Untersuchungen zeigen.

Variable spatio-temporal clustering of microseismicity in the Eastern Hellenic Subduction Zone as possible indicator for fluid migration.

Authors: Bocchini, G.M. (1,2), Ruscic, M. (3), Becker, D. (4), Meier, T. (3) van Keken, P. (5)

1. Institute of Geology, Mineralogy and Geophysics, Ruhr-University Bochum, Germany.
2. Institute of Geodynamics, National Observatory of Athens, Germany.
3. Institute of Geosciences, Christian-Albrechts University Kiel, Germany.
4. Institute of Geophysics, University of Hamburg, Germany.
5. Department of Terrestrial Magnetism Carnegie, Institution for Science, United States of America.

Spatio-temporal seismicity clustering suggests that earthquakes do not occur randomly in space, time, and magnitude. Pore fluid pressure changes, as in case of earthquake swarms, and stress changes following a main shock, as in case of aftershock sequences, are known as the main mechanisms causing spatio-temporal clustering of earthquakes. Seismic activity in subduction zones and spatio-temporal seismicity clustering is influenced by the release and migration of fluids in the incoming plate. At shallow depths (<50 km) fluids released by the subducting slab may explain the occurrence of earthquake swarms along and above the interplate seismogenic zone. At intermediate depths (from 50 to 300 km) the mechanisms generating earthquakes are still debated. The hypotheses of dehydration embrittlement, fluid related embrittlement, trasformational faulting, and plastic shear instabilities assume to a different extent the presence of fluids in the source regions.

We investigate the variability of spatio-temporal microseismicity clustering and the occurrence of mutual triggering of events along the subduction interface in south-eastern Aegean as indication for fluid flow along and above the plate interface. The eastern segment of the Hellenic Subduction Zone is well suited for such a study because shallow and intermediate depth microseismicity with completeness magnitude around ML 2.0 has been observed by a dense temporary network during the EGELADOS seismic experiment (Oct. 2005 – Mar. 2007).

We quantify spatial, temporal and spatio-temporal microseismicity clustering from the outer to the inner forearc and at intermediate depths. Since slab depth varies below these regions we can expect varying fluid supply in the overlying crust due to variable pressure-temperature conditions and sediment compaction. Waveform similarity indicates a decreasing of spatially clustered events from the outer (30.2%) and central forearc (34.9%) towards the inner forearc (20.5%) and at intermediate depths (6.9%). The Epidemic-Type-Aftershock-Sequences (ETAS) model, employed to investigate microseismicity temporal clustering, indicates an increase of the percentage of independent events from the outer (32%) and central (46%) forearc, to the inner forearc (93%) and at intermediate depth (93%). Autocorrelation analysis, investigating spatio-temporal clustering, shows the tendency of earthquakes to occur close in space and time in the outer and central forearc, while in the inner forearc, and especially at intermediate depth, earthquakes are more homogeneously and randomly distributed. Thus, spatial, temporal and spatio-temporal analysis show consistent trends indicating that mutual triggering of events is significant in the outer and central forearc, and it is almost absent in the inner forearc and at intermediate depths. We suggest that the different spatio-temporal patterns hint at systematic variations in the presence and migration of fluids on active faults close to failure. No migration of fluids on active faults is observed at intermediate depth.

Neues vom Stromboli

Thomas Braun[1)] und Joachim Wassermann[2)]

[1)] INGV-Arezzo; [2)] LMU-München

Wie bereits von Alexander von Humboldt beschrieben *„... wirft der Stromboli seit Menschengedenken in kurzen Intervallen seine feurigen Lavafontänen zum Himmel, ...Stromboli, ein natürlicher Leuchtturm des Tyrrhenischen Meeres, der schon den griechischen und römischen Seefahrern zur Nachtzeit den Weg wies*“... *„Stromboli, ein natürliches Feldlabor, das nicht nur griechischen und römischen, sondern auch germanischen Seismologen (meist zur Tagzeit) den Weg zur vulkanseismischen Quelle weist*“, würde von Humboldt vielleicht heute hinzufügen. Portable Breitbandseismometer, seismische Arrays, Tiltmeter, Infraschall-Sensoren und neuerdings auch Rotationssensoren wurden oft auf Stromboli ihren ersten Tests unterzogen, bevor sie auch auf anderen Vulkanen installiert wurden.

Zeiten „normaler strombolianischer“ Aktivität wurden 2016 und 2018 von der Uni München dazu genutzt, gemeinsam mit dem INGV und der Firma *BlueSeis* im Kraterbereich Strombolis für mehrere Wochen hochsensible *Fiber Optical Gyroscopes* (FOG), in Kombination mit klassischem Breitband-Seismometern zu installieren. Die resultierenden 6 Komponenten Messungen lassen deutlich Rotationen um alle drei Rotationsachsen, als auch die hervorragende Eigenschaft des FOGs als physikalischer Polarisationsfilter für seismische Wellen erkennen.

Während der letzten Messkampagne 2018 gab es nun auch zufällig die Gelegenheit ein seltenes, akustisch besonders eindrucksvolles Phänomen instrumentell zu beobachten und zu filmen. Dabei handelt es sich um eine plötzlich einsetzende Entgasung, die mehrere Zehner Sekunden lang andauert und – vergleichbar mit einem startenden Düsenjets - einen ohrenbetäubenden Lärm erzeugt, ohne das nur das geringste sichtbare Phänomen an den Kratern zu sehen ist. Während das klassische 3 Komponenten Breitband-Seismometer den „Jets“ ohne besondere Amplitudenzunahmen oder Frequenzänderungen registriert, zeigen die Rotationsspuren deutliche Signale, mit exakt der gleichen Dauer, wie die parallelen Mikrofonaufnahmen des Filmmaterials. Dies ist ein klarer Hinweis für die Einkopplung von Schall in den Boden als *„ground-coupled air waves*“ und dessen Ausbreitung im Boden als Oberflächenwelle.

Gelegentlich wird der anscheinend „regelmäßige“ Auswurf von Lavafetzen, Schlacken und Aschen plötzlich von paroxysmalen Ausbrüchen unterbrochen, wie zuletzt 2003, 2007, sowie ganz aktuell im Juli und August 2019. Im zweiten Teil des Vortrages werden dazu aktuelle Daten und Bilder präsentiert.

Poster session

Microseismicity and active tectonics of the Fonualei Rift and Spreading Center

Cremanns[1], **Schmid**[1], **Kopp**[1,2], **Lange**[1]

[1] GEOMAR Helmoltz Centre for Ocean Research Kiel
[2] Institute of Geosciences, University Kiel

Abstract

The Lau basin is an active back arc system with several spreading centres and microplates rapidly evolving in time. In the northeast basin, we observe a complex setting of a back arc rifting system and a volcanic arc. The Fonualei Rift and Spreading Center (FRSC) is a part of this complex setting, striking northwest and accommodating east-west extension between the Niuafo'ou microplate and the Tonga plate. The volcanic arc strikes northeast-southwest and therefore the offset between the arc and the Fonualei Rift decreases to the south.
The minimal offset between the rift and volcanic arc is 10-15km only. The interplay between the FRSC and the Tofua volcanic arc are not fully understood. Therefore, we deployed a network of 16 ocean bottom seismometers (OBS) across the FRSC which recorded 750 local events within a period of 31 days. The events were located with the NonLinLoc (Non-Linear Location) software package. Furthermore, we determined local and moment magnitudes.
The seismicity catalogue shows an average event rate of 24 events per day. The events are focused beneath the network and in a region south of the network. Especially in the southern region we observe an earthquake swarm with 6 days duration and ~600 events. For the magnitude frequency distribution we determined a b-value for the entire catalogue of 1.05 with a magnitude of completeness of 1.0.
Here, we discuss and present results based on the microseismicity of this ongoing project. In particular, we will relate the seismicity with the bathymetry focusing on the implications on active faulting processes of the region.

The seismic sounds of “plutons”: recent examples of magma reservoir unrest

Dahm[1,2], Cesca[1], Heimann[1], Hensch[3], Rivalta[1]

[1]GFZ German Research Centre for Geosciences, Potsdam, Germany
[2]Institute of Earth Sciences, University of Potsdam, Germany
[3]Geological Survey of Baden-Württemberg, State Seismological Service, Freiburg, Germany

While petrological, gas-isotopical and volcanic tephra studies at volcanoes indicate the existence of voluminous magmatic reservoirs in the lower crust and upper mantle, the detailed seismic mapping of deep reservoir structures is still a challenge. Seismology may contribute by identifying signals related to unrest of such deep magmatic reservoirs. However, such unrest signals are often tiny and their origin is enigmatic.

A review of different types of seismic ‘long-period’ or ‘low-frequency’ signals emitted from deep magmatic reservoirs during unrest indicates systematic features common to specific types of processes, including reservoir and dike resonance, pressurization by magma mingling and mixing, and slow mass movement. We present models to explain such seismic sources, and compare the seismic signatures to recent examples of magma reservoir unrest, including crustal-scale and caldera collapses (Bardarbunga 2014-15, Iceland; Mayotte 2018-19, Comoro Islands) and the possible pressurization of differentiated lower-crust reservoirs (Eifel 2013-2019).

Activity report and achievements of the ICDP-Eger drilling project

Dahm[1,2], Woith[1], Fischer[3], Korn[4], Krüger[2] and the ICDP-Eger Science Team

[1]GFZ German Research Centre for Geosciences, Potsdam, Germany
[2]Institute of Earth Sciences, University of Potsdam, Germany
[3]Charles University of Prague, Czech Republic
[3]Geophysics, University of Leipzig, Germany

Within the ICDP-Eger drilling project we plan to develop one of the most modern and comprehensive laboratories at depth worldwide for the study of the interrelations between the flow of mantle-derived magmatic fluids through the crust and their degassing at the surface, the occurrence and characteristic of crustal earthquake swarms, and the relation to the geo-biosphere. The Eger Rift in the Czech-German border region and the Cheb basin provides an ideal natural laboratory for such a purpose. The general frame of the program has been described in Dahm et al. (2013), ICDP Drillings. In October 2016 the ICDP proposal was accepted for complementing two existing monitoring wells (F1 and F2, <100 m) with five new, distributed, shallow (<400 m) drill holes F3 and S1-S4. Since then, a significant amount of co-funding has been acquired from GFZ, the Czech Ministry of Education, and the DFG.

The F1-F3 drillings together will form a unique facility of three neighboring wells within an active CO_2 mofette, for the continuous recording of fluid composition and fluid flux, as well as intermittent GeoBio fluid sampling. Drilling F3 has by today reached an over-pressurized, CO_2 bearing layer in the crystalline basement and will be completed in September 2019.

Drillings S1-S4 are planned for seismological monitoring to reach a new level of high-frequency, near source observations of earthquake swarms and related phenomena, like seismic noise and tremors generated by fluid movements. Drilling of site S1 (Landwüst), which is the only site located on German territory, was completed in August 2019 to a depth of 402 m and an average inclination of 2.6°. Almost complete coring was achieved, and cores have already been scanned by MSCL measurements in the core storage facility (BGR) in Spandau. Site S2 (Tisova/Kraslice) was drilled in November 2017. The drill hole is accessible to a depth of about 450 m with an inclination of less than 6.4°. Site S3 (Studenec) was completed in December 2018 to a depth of 408 m with an inclination of 9°. Cores are stored at the Czech storage facility in Litometrice. The drilling of S4 is planned in 2020 at one of the recently discovered Maars at the Czech German border region. Sites S1 – S3 will soon be ready for the installation of the seismic equipment.

Instrumentation of the seismic wells will include 8-element geophone chains and a bottom-hole wide-band sensor. The borehole sensors will be complemented at S1 by small-scale surface array of approximately 400 m diameter to obtain truly 3D-array configurations. If possible, broadband surface stations and other sensors will be added to each drill location.

In this presentation we provide information on the status of drillings and sensor installation and provide an overview of the complete monitoring and data handling concept.

Pg and Sg Velocity Models for High-Resolution Seismotectonic Interpretation of Seismicity in Switzerland

Tobias Diehl*, Edi Kissling**, Timothy Lee*

*Swiss Seismological Service, ETH Zurich, 8092, Switzerland
(tobias.diehl@sed.ethz.ch)
**Institute of Geophysics, ETH Zurich, 8092, Switzerland

The seismotectonic interpretation of seismicity and its potential connection with geologically or geophysically mapped faults depends crucially on the accuracy and precision of hypocentre solutions reported in earthquake catalogues. In most cases, changes in the network configuration, analysis techniques (e.g. seismic phase picking) and locations procedures (e.g. seismic velocity models) introduce significant inconsistencies to earthquake catalogues and therefore hamper high-resolution seismotectonic interpretations. In addition, a consistent and realistic estimate of location uncertainties is missing in many catalogues.

In this study, we first demonstrate how ray-distribution and potential errors in velocity models can lead to significant bias in focal-depths estimates. To overcome this bias and other limitations due to the aforementioned inconsistencies included in instrumental earthquake catalogues, we applied an iterative relocation procedure to improve seismic velocity models and hypocentre locations in Switzerland and surrounding regions. The proposed procedure involves tomographic inversions using a dynamic selection of Pg and Sg phases of about 4500 local earthquakes to solve the coupled hypocentre – velocity structure problem in 1D and 3D. Nonlinear location algorithms, combined with a uniform Pg and Sg-phase selection, are used to derive consistent locations and uncertainty estimates for the entire instrumental catalogue of the Swiss Seismological Service (SED). To assess the reliability of the derived uncertainties, the relocated catalogue solutions are compared with high-resolution local studies of induced seismicity in St. Gallen, natural seismicity in the Valais and various quarry blasts. Finally, we demonstrate how the comparison of focal depths with the 3D velocity structure derived from the tomographic inversion can help to constrain host lithologies of upper-crustal seismicity (e.g. sedimentary cover vs. crystalline basement).

Title: **Eruption frequency of Strokkur geyser, Iceland**

Authors: **Eva P. S. Eibl, Sebastian Hainzl, Nele I. K. Vesely, Thomas R. Walter, Philippe Jousset, Gylfi Páll Hersir, Torsten Dahm**

The valley Haukadalur in south Iceland is one of the few places on Earth where jetting eruptions of hot water fountains can be witnessed. Hot spring, furmaroles and geysers are scattered throughout the landscape and one of them is pool geyser Strokkur, where water is ejected up to 30 m high into the air. We have created an eruption interval catalogue that contains 73 466 eruptions from 6/2017-6/2018. Strokkur is characterised by sets of eruptions of different length containing one to six sub-events (multi-tuple eruption). We find that the number of single eruptions to sextuple eruptions exponentially decreased while the mean waiting time after eruptions linearly increased as a function of the number of eruptions in quick succession.

We will (i) present the statistical behaviour of Strokkur geyser with respect to the eruption type, (ii) discuss triggering mechanisms and (iii) the eruptive behaviour which we modelled with a time-predictable onset of eruptions after discharges proportional to the eruption multiplicity.

The Slab Puzzle of the Alpine-Mediterranean Region: evidence from a new high resolution shear wave velocity model of the upper mantle

***Amr El-Sharkawy*[1,2]**, Thomas Meier[1], Sergei Lebedev[3], Mona Hamada[2], Luigia Cristiano[1], and Christian Weidle[1]
[1] *Institute of Geosciences, Christian-Albrechts University, Kiel, Germany*
[2] *National Research Institute of Astronomy and Geophysics, Helwan, Cairo, Egypt*
[3] *Dublin Institute for Advanced Studies, Dublin, Ireland*
contact: amr.elsharkawy@ifg.uni-kiel.de

The Alpine-Mediterranean mobile belt is, tectonically, a highly complicated and active region. Since the early Tertiary, a series of collisions between Gondwana-derived continental microcontinents and Eurasia have shaped the Mediterranean geology due to the closure of the intervening ocean basins. The complex subduction events and associated collisions, resulted in mountain building and plateau formation, magmatism, escape tectonics, lithospheric deformation and opening of back-arc basins. Plenty of studies have attempted to characterize the lithosphere-asthenosphere structure in the Mediterranean, however there are still many controversial issues such as the presence and geometry of slabs and slab fragments e.g. in the Alps, the Dinarides, the Apennines, in the western Mediterranean and beneath Anatolia. In this study, a high- resolution 3-D shear-Rayleigh wave velocity structure of the lithosphere-asthenosphere system beneath the entire Mediterranean including the Alps and the adjacent regions is investigated using new tomographic images obtained from surface wave tomography is presentend. An automated algorithm for inter-station phase- velocity measurements is applied to obtain Rayleigh and Love fundamental mode phase velocities. We utilize a database consisting of ~ 3800 teleseismic earthquakes recorded by ~ 4500 broadband seismic stations provided by IRIS and EIDA in a combination, for the first time, with waveform data from the Egyptian National Seismological Network (ENSN) in order to ensure a good path coverage especially for the eastern Mediterranean. Path average dispersion curves are obtained by averaging the smooth parts of single-event dispersion measurements. We calculate maps of Rayleigh and Love phase velocity for periods between 8 s and 350 s that, in turn, provide a local phase-velocity dispersion curves for each geographical grid node of the map at lateral 30 km inter-knot spacing of 30 km. Each local dispersion curve is inverted individually for 1-D velocity model using a newly implemented Particle Swarm Optimization (PSO) algorithm. The resulting 1-D velocity models are then combined to construct the 3-D velocity model. The obtained model shows significant variations in shear velocities both horizontally and vertically. It reveals slow velocities indicative of shallow asthenosphere beneath Anatolia, the Aegean, the Pannonian Basin, and the Western Mediterranean including Iberia and the Atlas indicating shallow asthenosphere that is correlating very well with the distribution of the Cenozoic volcanism and the surface uplift in this area. In central Anatolia, from 160 km and downward a N-S trending high velocity anomaly in the upper mantle is detected. The eastern Mediterranean from the Herodotus basin in the East reaching the Ionian Sea in the west is dominated by rather thick oceanic lithosphere that is subducting beneath Calabria and in the southern Aegean. Both the Hellenic and Cyprus arcs are clearly imaged with a complicated transition from the Hellenic arc towards the Hellenides and the Dinarides where slab is observed only down to about 150 km depth. The Alpine mantle shows a nearly vertical subducting Eurasian slab in the central Alps, a pronounced change towards the eastern Alps in the region of the Judicaria fault, and a nearly vertically dipping slab in the northern Apennines, whereas a slab window is present in the central Apennines and below about 150 km depth in the northern Dinarides. In the western Mediterranean, the Alboran detached slab is imaged below about 180 km depth along the SE Iberian striking almost parallel the south-west Iberian coastline at depths below 180 km. The Kabylides slab has been imaged clearly beneath north-western Africa with an almost NS-striking detached continuation towards the Tyrrhenian Sea showing a N-S dipping. Based on our results, surface wave tomography can contribute significantly to the imaging of the complex slab geometries and slab segmentations in the Mediterranean.

Keywords: phase velocity, seismic tomography, surface wave inversion, particle swarm optimization, Mediterranean.

Mars vs. Blind Test – erste Receiver Functions für InSight

Brigitte Knapmeyer-Endrun[1], Rakshit Joshi[2], Vedran Lekić[3], Paul Davis[4], Philippe Lognonné[5], Baptiste Pinot[6], John-Robert Scholz[2]

In Vorbereitung der InSight-Mission, deren Breitband-Seismometer SEIS am 2. Februar 2019 den wissenschaftlichen Betrieb auf dem Mars aufgenommen hat, wurde ein Test mit synthetischen Daten durchgeführt, bei dem die Herdlokation und die Krusten- und Mantelstruktur aus der Aufzeichnung eines einzigen Bebens bestimmt werden sollte. Die zur Verfügung gestellten Daten basierten auf Annahmen zum Rauschen sowie zur möglichen Bebengröße und Empfindlichkeit von SEIS. Hierbei zeigten die Ps-receiver functions (RFs), die von verschiedenen Gruppen berechnet wurden, eine gute Übereinstimmung, und konvertierte Phasen und deren Multiple konnten zumindest probeweise direkt in der einzelnen RF-Wellenform identifiziert werden. Die gemeinsame Inversion der RF-Wellenform und der aus dem scheinbaren Auftauchwinkel der P-Welle frequenzabhängig bestimmten scheinbaren S-Wellengeschwindigkeit mit dem Neighbourhood Algorithmus zeigte eine gute Übereinstimmung mit dem wahren Modell (Diskontinuitäten in 9-11 und 49-58 km gegenüber 10 und 54.1 km Tiefe), mit verbleibender Unsicherheit durch die Unsicherheit im Strahlparameter. Sp-RFs konnten aufgrund einer sehr wenig ausgeprägten S-Phase nicht berechnet werden. Das synthetische Ereignis hatte eine Momentenmagnitude von 4.5 und eine Epizentraldistanz von 86.7°.

Auf dem Mars konnten bisher zwei Ereignisse mit klaren P- und S-Wellenzügen registriert werden, die bei 25° bis 30° Herdentfernung Momentenmagnituden zwischen 3 und 4 aufweisen. Die Berechnung von Ps-RFs für das erste Ereignis wird dadurch erschwert, dass ein deutlicher Glitch etwa 15 s nach dem P-Welleneinsatz auftritt, so dass zunächst die Anwendung eines Deglitchingverfahrens nötig ist. Verschiedene Verfahren führen zu unterschiedlichen Amplituden der resultierenden RFs. Die RFs für beide Ereignisse zeigen in den ersten 15 s viele Gemeinsamkeiten, trotz unterschiedlicher Lokation, was darauf hindeutet, dass die beobachteten Phasen tatsächlich Konversionen unterhalb der Station entsprechen und nicht von zufallsverteilten Streukörpern in der Kruste erzeugt werden. Die RFs enthalten keinen Hinweis auf eine dicke Sedimentschicht, in Übereinstimmung mit den Vorhersagen für eine Regolithmächtigkeit von 5-10 m, und eine erste Konversion, die aus einer ähnlichen Tiefe wie im Blind Test Modell zu stammen scheint. Die restliche Wellenform zeigt allerdings deutliche Unterschiede zu den Testdaten, und die Identifikation von Multiplen sowie der Moho-Konversion gestaltet sich anhand von nur zwei RFs schwierig.

[1] bknapmey@uni-koeln.de, Erdbebenstation Bensberg, Universität zu Köln
[2] Max-Planck-Institut für Sonnensystemforschung, Göttingen
[3] University of Maryland, College Park, USA
[4] UCLA, Los Angeles, USA
[5] IPGP, Paris, Frankreich
[6] ISAE-SUPAERO, Toulouse, Frankreich

Assessing areas of potential damage after induced events for legal regulations in Germany

N. Gestermann[1], M. Bischoff[2], T. Plenefisch[1], and Ayk Schindewolf[2]

[1]Federal Institute for Geosciences and Natural Resources (BGR), Germany (nicolai.gestermann@bgr.de)
[2]State Authority for Mining, Energy and Geology (LBEG), Hanover, Germany.

Induced and triggered seismicity in Germany is related to various mining operations such as hydrocarbon extraction, geothermal exploitation and classical mining techniques, i.e. coal and potash mining.

On average, about 14 induced events in Germany per year have magnitudes above 2 and are likely to be felt. After larger events (about three magnitude 3 events per year) small damages to buildings were observed that might have been caused by the ground shakings, e.g. more than 400 damages were claimed after a magnitude 3.1 event at a natural gas field in northern Germany in 2016. This led to public discussions on compensation and to political discussions on improving legal regulations. The possibility of damages caused by mining induced seismic events and difficulties in financial compensation reduced the acceptance of mining projects in the past, e.g. geothermal projects are inhibited.

From the seismological perspective, local measurements of PGV are often rare. Thus, it is difficult to assess the damage potential of the seismic events in detail, especially if intensities are around V (EMS-98). In many cases, a relation between individual damages at buildings and the seismic event is only hardly verifiable. Actually, detailed survey reports could neither prove nor disprove the relation between damages and seismic events in some cases. In conclusion, some of the widely discussed events might have led to small damages.

In case of verified damage due to an induced event, the causative mining company has to pay compensations. In 2016 new legal regulations entered into force. The Federal Mining Act was revised with an improved legal situation for the population by expanding the prima facie evidence on mining activities using boreholes. The new legal regulations define, that damages at buildings are assumed to be caused by the seismic event in the responsibility of the operator of the mining activities, if they occur within a certain area defined by the mining authority (*impact area*, German: “Einwirkungsbereich”).

In 2017, a working group developed a guideline with recommendations on the general procedures and how an impact area should be defined. The guideline determines threshold values for which events impact areas have to be defined and recommends how to specify the *impact area*. The spatial extend of the *impact area* must be based on all available and suited data like peak ground velocities (PGV), macroseismic investigations and other data from empirical investigations or ground motion prediction equations (GMPE).

A brief introduction about the existing legal regulations will be presented and first experiences with the definition of the *impact area* for a few induced seismic events in the area of natural gas extraction in northern Germany with magnitudes between ML 2.9 and 3.6.

E. Gottschämmer[1], A. Nüsse[1], A. Rohnacher[1], K. Drach[1], W. Carter[2], S. De Angelis[2], Y. Lavallee[2], A. Roca[3], P. Castellanos[3], G. Chigna[3], A. Rietbrock[1]

[1] Geophysical Institute, Karlsruhe Institute of Technology, Germany, [2] Department of Earth, Ocean and Ecological Sciences, University of Liverpool, Liverpool, United Kingdom, [3] Instituto Nacional de Sismología, Vulcanología, Meteorología, e Hidrología (INSIVUMEH), Guatemala City, Guatemala

Monitoring volcanoes with seismic instruments has a long tradition. Complementary instrumentation such as infrasound microphones or visual and infrared cameras has recently become more popular as it allows to gain more insight into the underlying physical processes.

Santiaguito volcano (Guatemala) is an active subduction zone volcano and part of the Central American Volcanic Arc. It formed in 1922 within the collapse scar of Santa Maria volcano from Santa Maria's 1902 eruption and is located 11 km south of Quetzaltenango. Santiaguito consists of four volcanic domes aligned from east to west. Present activity is concentrated at El Caliente, the easternmost of the four domes and characterized by small to moderate gas and ash emissions from the central vent and at the eastern flank. We observed substantial dome growth at El Caliente between January 2018 and January 2019. On January 16, 2019, we witnessed an explosion followed by a rockslide at the southern part of the dome leaving a reddish surface visible from INSIVUMEH observatory New OVSAN, 7 km south of El Caliente. This event was accompanied by ash fall at New OVSAN.

To gain a better understanding of dome growth, its collapse, and eruption dynamics, we operate a permanent seismic, infrasound and infrared network at Santiaguito, starting in 2014. Today, the network consists of five permanent stations continuously recording at 75 Hz and 100 Hz, respectively. The seismic data is received in real-time via modem from four of the seismic stations. In January 2019, we deployed an additional temporary network consisting of twelve seismometers and six infrasound sensors. We also installed an infrared camera which records images every second and transmits in real-time.

A comparison of seismic and infrasound data with thermal images allows us to distinguish between explosions from the central part of the vent and those from the eastern flank which can also be discriminated by their frequency content. The comparison also reveals that the actual emission of ash and gas persists much longer than the seismic explosion signal which marks only the opening of the vent. Harmonic tremor signals with up to 20 even and odd overtones can occasionally be observed after explosions and coincide with the emission of hot material. The fundamental frequencies of harmonic tremor range between 0.4 and 0.6 Hz and show clear evidence of frequency gliding. The amplitude of the first harmonic has been used to estimate the source depth of the tremor signals. It shows that the source is located at shallow depths less than 1.5 km. The occurrence of harmonic tremor signals on the infrasound data supports this estimate. Volcano-tectonic earthquakes have been registered at depths between 1 – 2 kilometers less than two kilometers south-west of the active vent.

Geophysikalischer Gerätepool (GIPP) – Statusbericht 2019

Christian Haberland, GFZ Potsdam

Der "Geophysikalische Gerätepool" (“Geophysical Instrument Pool Potsdam”, GIPP) stellt seismische und magnetotellurische Geräte und Sensoren für Projekte von GFZ-Gruppen, Universitäten und anderen Forschungseinrichtungen zur Verfügung. Seit der Inbetriebnahme 1993 hat der GIPP fast 400 geowissenschaftliche Projekte mit Geräten unterstützt (jedes Jahr ca. 30 bis 40). Die Gerätebereitstellung läuft über ein transparentes Antrags- und Evaluierungsverfahren (www.gfz-potsdam.de/gipp). Die Anträge werden durch einen extern besetzten Lenkungsausschuss evaluiert.

In 2018 und 2019 wurden umfangreiche Neuanschaffungen für den GIPP getätigt. Die neuen Rekorder und Sensoren (hauptsächlich Cube Rekorder und Trillium Compact Seismometer) ersetzen alte Geräte. Zusätzlich wurde mit dem Aufbau eines LARGE-N Pools zur Ausstattung von Experimenten mit großen Stationzahlen begonnen (>250 Stationen).

Innerhalb des BMBF-Projekts DeoDataNode wurde eine Datenbank für alle Geräte des GIPP erstellt, in dem die Geräteinformationen (Metadaten; auch Übertragungscharakteristiken der Sensoren) den Nutzern, mit sogenannten “Persistent Identifiers” (PID’s) versehen, zur Verfügung gestellt werden. Diese Datenbank dient der Identifizierung und Referenzierung der Geräte sowie der Informationsbereitstellung (maschinenlesbar; u.a. auch für das GEOFON Archiv).

Eine herausfordernde Aufgabe ist weiterhin die Archivierung der Daten sowie die Pflege der Liste von Publikationen, die mit Geräten des GIPP gewonnen wurden. Gemäß Ausleihregeln sollen die Rohdaten spätestens 4 Jahre nach Abschluss der Feldmessungen frei zur Verfügung gestellt werden.

Im Februar 2019 ist der GIPP, zusammen mit dem Großteil des GFZ-Departments Geophysik, in die Albert-Einstein-Straße 42/46 unweit des alten Standorts in Potsdam umgezogen.

Induced seismicity in the Montney Basin, British Columbia: Stress chatter on a fault/fracture network reactivated by hydraulic fracturing

Rebecca M. Harrington[1], Marco P. Roth[1], Yajing Liu[2], Andres P. Castro[2], Alessandro Verdecchia[1,2], John Onwuemeka[2]

1. Institute of Geology, Mineralogy and Geophysics, Ruhr University Bochum
2. Department of Earth and Planetary Sciences, McGill University

Seismicity related to fluid injection during unconventional oil and gas exploration has increased dramatically in North America in the last decade. In the western Canadian sedimentary basin, high-pressure stimulation during hydraulic fracturing (HF) is linked to the majority of M3+ earthquakes, including several M4+ events in 2018-2019. The vigorous seismic response to injection activity and low historical seismicity rates pose critical questions as to the triggering mechanism(s) and seismic hazard assessment in the affected areas. To monitor seismicity linked to injection, a dense regional seismic network (including McGill and RUB seismic stations, and stations from Natural Resources Canada) has been established since 2017 in Dawson-Septimus, an area of active shale gas development in the southern Montney Play in British Columbia, Canada. Here we present an earthquake source process study using observations from the regional network of earthquakes in a roughly 18-month time span between July 2017—December 2018, including events associated with a M_L 4.5 event on November 30th, 2018, the largest observed so far by the network.

Initial detection and relocation of seismicity between July 2017 and December 2018 resulted in a total of 2298 hypocenters, ~88% of which based on event similarity can be divided to 31 families that spatiotemporally correlate with individual injection stages of HF wells. Relocated groups of events show linear features highlighting inferred conjugate geological structures that suggest a combined control of the regional stress field (with seismicity aligned perpendicular to S_{Hmax}) and the stress field local to HF wells (with seismicity sub-parallel to S_{Hmax}). The observed conjugate structures are consistent with the focal mechanism solutions (FMSs) of nearby M3+ events. Using a multi-station matched-filter (MMF) approach, we detect and further locate an additional 201 events 10 days before and after the M_L 4.5 earthquake on November 30, 2018. The mainshock FMS suggests the rupture occurred on a thrust fault in the basement (~ 4.5 km) dipping approximately 50^o, possibly initiated by pore pressure increase via fast fluid migration along a high-permeability conduit connected to the vicinity of the horizontal wells. Relocated hypocenters of the MMF detections suggest the basement thrust-fault transitions to a near-vertical fracture network in the sediment, where most of the aftershocks are located, and were possibly triggered by Coulomb stress changes from the mainshock. The short (~2 day) delay between injection onset and occurrence of the M_L 4.5 event coupled with the inferred low hydraulic diffusivity of the tight shale injection units are consistent with the interpretation inferred from the seismicity distribution and Coulomb stress calculation.

Clustering and Prediction of Wind Turbine Noise

Site Selection and Introduction of a Clustering Method using Unsupervised Learning

Janis Heuel [1], Wolfgang Friederich [1]
[1] Ruhr-Universität Bochum

Over the last years, the extension of wind turbines (WTs) increased worldwide. Due to negative effects on humans, WTs are often installed in areas with less population density. These areas are also well suited to install seismological stations, e.g. due to less anthropogenic noise. As a consequence, WTs are installed in the same areas as seismological stations. By comparing time series before and after installation of WTs, seismologist noticed a worsening in station quality. This problem lead to a conflict between the wind industry and seismologists. In addition, different interests of both groups might slow the building of new WTs and thus delay the expansion of renewable energy.
The project MISS (Minderung der Störwirkung von Windenergieanlagen auf seismologische Stationen) aims to defuse the conflict by developing reasonable solutions for both sides. This part of the project aims to correct the signal at a seismological station from WT noise, by the development of a database. The database saves pairs of imitated signals at a WT and emitted signals at a seismological station in the vicinity of WTs.
In this study, we present the selection of the site, where we installed several low-cost seismometers (Raspberry Shake 3D) in the vicinity of WTs. Furthermore, we present an idea how to find similar signals at each low-cost seismometer to build the database of signal pairs using unsupervised learning.

Mikroseismizität in Hessen - Die Erdbebenserie bei Bad Schwalbach im Taunus

B. Homuth[1]

[1]Hessisches Landesamt für Naturschutz, Umwelt und Geologie, Wiesbaden, Deutschland

Inhalt

Seit Januar 2018 kommt es in der Nähe von Bad Schwalbach im Taunus an der hessisch-rheinlandpfälzischen Grenze zu einer erhöhten seismischen Aktivität mit einer ungewöhnlich großen Anzahl von Erdbeben. Während der Zeit von Januar bis Dezember 2018 konnten 125 Erdbeben mit Magnituden von M_L = 0,0 bis 2,5 aufgezeichnet werden. Ca. 80 weitere kleine Ereignisse konnten detektiert werden, aufgrund von fehlenden Stationen in der näheren Umgebung jedoch nicht lokalisiert werden. Die Hypozentren innerhalb dieses Erdbebenclusters sind mit zunehmender Tiefe schräg in Südwest-Richtung einfallend ausgerichtet. Sie erstrecken sich über einen Tiefenbereich von 9 bis 19 km mit einer lateralen Ausdehnung von etwa 6 km. Im Vergleich zur Erdbebenserie im Odenwald der Jahre 2014 und 2015 ist die Anzahl der Ereignisse etwas geringer und es fehlt ein klares stärkeres Hauptereignis (mainshock). Ob es sich um eine Erdbebenserie oder mehrere Erdbebenschwärme handelt ist noch nicht abschließend geklärt. Im Unterschied zur Erdbebenserie im Odenwald ist die seismische Aktivität im Taunus auf ein größeres Gebiet verteilt und wird nach Nordosten und Nordwesten durch weitere angrenzende aktive Erdbebenherde fortgesetzt.

Zur Untersuchung der Eigenschaften der Erdbebenaktivität im Taunus wurden Absolut- und Relativlokalisierungen durchgeführt. Zur Bestimmung der Bewegungsrichtungen wurden Herdflächenlösungen anhand von Polaritäten von Ersteinsätzen und Amplitudenverhältnissen von horizontalen und vertikalen Komponenten erstellt. Es konnte ein schrägaufschiebendes Spannungsregime festgestellt werden. Die Ereignisse weisen ähnliche Wellenformen mit sehr hohen Korrelationsfaktoren auf. Eine Besonderheit stellen die für diesen Erdbebenherd typisch auftretenden Signalformen dar, welche durch sehr schnell aneinander gereihte, oft überlappende, Ereignisse charakterisiert werden. Die Ergebnisse dieser Untersuchungen werden dargestellt. Weitergehende Untersuchungen in Bezug auf eine verbesserte Detektion mittels Wellenformkorrelationsdetektoren, verbesserte Herdflächenlösungen und verbesserter Relokalisierung sind für das Jahr 2019 geplant.

Earthquake Source Modeling from GRACE-FO Satellite Gravity, Geodetic and Seismological Observations?

Marius Paul Isken[1,2], Torsten Dahm[1,3], Henriette Sudhaus[2], Sebastian Heimann[1], Rongjiang Wang[1]

[1]GeoForschungsZentrum Potsdam, [2]Christian-Albrechts-Universität zu Kiel, [3]Universität Potsdam

The *Gravity Recovery And Climate Experiment* satellite mission (GRACE, implemented and operated by GFZ, NASA and DLR) was launched in 2002, with the ambition to measure the Earth's gravity field in space and time in high resolution. After 15 years in orbit the twin satellites were decommissioned in October 2017. The mission has been a great success to improve our understanding of mass movements in the hydrosphere, atmosphere and cryosphere. Only a few mass redistributions in the lithosphere were observed, but include spectacular findings of gravity changes induced by the rupture of mega-thrust earthquakes in Indonesia (M_W9.1, 2004), Chile (M_W8.8, 2010) and Japan (Mw9.0, 2011). These observations contributed to a better understanding of the rupture process, the slip distribution at depth, and the post-seismic mass redistribution. Unfortunately, such applications have been limited to earthquakes with magnitudes $M_W > 8.5$ by the sensitivity and resolution of GRACE. The GRACE Follow-On mission (GRACE-FO) was launched in April 2018. The twin satellites of GRACE-FO provide a new optical tracking system to derive gravity changes with highly improved sensitivity and precision. We want to exploit the enhanced information delivered by GRACE-FO and develop new strategies to better use the mission data in solid Earth research. We believe that through the pursued development of new processing and modeling techniques, in combination with space-based surface deformation data and seismological wave forms, the study of processes on a scale of tens of kilometers can be reached in the near future.

Pyrocko - A Versatile Software Framework for Seismology

Sebastian Heimann[1], Marius Kriegerowski[1,2], Marius Paul Isken[1,3], Nima Nooshiri[1], Andreas Steinberg[3,] Henriette Sudhaus[3], Hannes Vasyura-Bathke[2], and Torsten Dahm[1]

[1]GFZ Potsdam, Section 2.1: Physics of Earthquakes and Volcanoes, Potsdam, Germany (sebastian.heimann@gfz-potsdam.de), [2]University of Potsdam, [3] University of Kiel

Pyrocko is an open source seismology toolbox and library, written in the Python programming language. It can be utilized flexibly for a variety of geophysical tasks, like seismological data processing and analysis, modelling of waveforms, InSAR or GPS displacement data, or for seismic source characterization. At its core, Pyrocko is a library and framework providing building blocks for researchers and students wishing to develop their own applications. Pyrocko contains a few standalone applications for everyday seismological practice. These include the Snuffler program, an extensible seismogram browser and workbench, the Cake tool, providing travel-time and ray-path computations for 1D layered earthmodels, Fomosto, a tool to manage pre-calculated Green's function stores, Jackseis, a command-line tool for common waveform archive data manipulations, and Colosseo, a tool to create synthetic earthquake scenarios, serving waveforms and static displacements. This poster gives a glimpse of Pyrocko's features, for more examples and tutorials visit https://pyrocko.org.

Correlating earthquake static stress drop values with fault complexity in the 2016 Amatrice-Norcia earthquake sequence, Central Italy

Kilian B. Kemna[1], Alessandro Verdecchia[1,2], Rebecca M. Harrington[1]

[1] Institute of Geology, Mineralogy and Geophysics, Ruhr University Bochum, 44780 Bochum, Germany

[2] Department of Earth and Planetary Sciences, McGill University, Montreal, Quebec, Canada

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The 2016 Amatrice-Norcia seismic sequence in central Italy activated a system of normal faults in the central Apennines and ruptured the surface along the Monte Vettore normal fault. Due to the complex rupture behavior, including antithetic faults and the proposed reactivation of an old thrust front, the Amatrice-Norcia seismic sequence offers a unique opportunity to study the relationship between fault complexity, surface ruptures, and earthquake source properties.

Here, we focus on the first two months of the Amatrice-Norcia seismic sequence, including the 30 October 2016 M_w 6.5 mainshock near Norcia and more than 30000 aftershocks. Using continuous waveform data from 94 seismic stations with epicentral distances of up to ~100 km, we estimate source parameters of all cataloged earthquakes that exceed specific quality control criteria in a time period ranging from 24 October – 29 November 2016. Displacement spectral corner frequency and seismic moment values are fit using individual earthquake spectra, and corner frequency estimates are refined using spectral ratios. Constrained spectral parameters then provide input for static stress drop estimates based on a circular crack model. Preliminary results suggest the majority of earthquakes have static stress drop values between 1 and 10 MPa and self-similar scaling.

Due to the high quality and quantity of available data, including precise earthquake locations, manually reviewed phase arrivals, and detailed mapping of surface ruptures, the Amatrice-Norcia earthquake sequence represents an opportunity to link earthquake source parameters to geological structures and surface rupture complexity. Preliminary results show correlations between high stress drop values and areas with increasing fault complexity, such as fault intersections at depth (inferred from precise earthquake hypocenters) or the mapped tip of the Monte Vettore normal fault, relative to other fault patches with fewer intersections or mapped surface trace terminations. Future work will examine whether the correlation of stress drop and fault complexity holds using refined stress drop estimates obtained using spectral ratio approaches.

New insights into the structural elements of the upper mantle beneath the contiguous United States from S-to-P converted seismic waves

Rainer Kind[1,2], Walter D. Mooney[3] and Xiaohui Yuan[1]

[1] Deutsches GeoForschungsZentrum GFZ, 14473 Potsdam, Germany

[2] Freie Universität, Berlin, Germany

[3] U.S. Geological Survey, Menlo Park, California, USA

Abstract

The S-receiver function (SRF) technique is an effective tool to study seismic discontinuities in the upper mantle such as the mid-lithospheric discontinuity (MLD) and the lithosphere-asthenosphere boundary (LAB). This technique uses deconvolution and aligns traces along the maximum of the deconvolved SV signal. Both of these steps lead to acausal signals, which may cause interference with real signals from below the Moho. Here we go back to the original formulation of the S-receiver function method and process S-to-P converted waves using S-onset times as the reference time and waveform summation without deconvolution. We apply this "causal" SRF (C-SRF) method to data of the USArray and obtain partially different results in comparison with previous studies using the traditional acausal SRF method. The new method does not confirm the existence of an MLD beneath the cratonic US. The shallow LAB in the western US is, however, confirmed with the new method. The elimination of the MLD signal below the cratonic US reveals lower amplitude but highly significant phases that previously had been overwhelmed by the apparent MLD signals. Along the northern part of the area with data coverage we see relics of Archean or younger north-west directed low-angle subduction below the entire Superior Craton. In the cratonic part of the US we see indications of the cratonic LAB near 200 km depth. In the Gulf Coast of the southern US we image relics of southeast directed shallow subduction, likely of mid-Paleozoic age.

Marsbebenstatistik: Zeitliche Verteilung und seismische Momenten-Rate

Martin Knapmeyer[1], Simon Stähler[2], Maren Böse[2], Tom Pike[3] und das MQS Team der ETH Zürich

Am 02. Februar 2019 wurde mit dem Aussetzen des *Wind and Thermal Shield* die Installation des Seismometer-Experiments SEIS auf dem Mars abgeschlossen. Seitdem wird die Bodenunruhe am Landeplatz von InSight von einem dreikomponentigen Breitband-Seismometer und einem dreikomponentigen kurzperiodischen Seismometer kontinuierlich registriert.

Anhand des Frequenzgehalts werden vier Typen von Seismischen Ereignissen unterschieden:

- Low Frequency: Ereignisse mit Energie bei Frequenzen unterhalb 1 Hz
- High Frequency: Ereignisse mit Energie bei Frequenzen oberhalb 1 Hz
- Broadband: Ereignisse mit Energie sowohl oberhalb als auch unterhalb von 1 Hz
- 2.4 Hz: Ereignisse, welche auf ein schmales Frequenzband um eine kontinuierlich angeregte natürliche Resonanz bei 2.4 Hz beschränkt sind.

Wir untersuchen für jede dieser Gruppen, ob die zeitliche Abfolge der zugehörigen Ereignisse durch einen stationären Poisson-Prozess beschrieben werden kann. Hierzu betrachten wir die kumulative Anzahl von Ereignissen als Funktion der Zeit, die kumulative (*survivor*-) Verteilung der Wartezeiten zwischen Ereignissen, sowie die zeitliche Verteilung dieser Wartezeiten. Bei der Schätzung der Ereignisraten muß die tägliche Variation des durch Wind erzeugten Hintergrundrauschens, welche eine Detektion im Wesentlichen nur abends zuläßt, berücksichtigt werden.

Publizierte Modelle für die seismische Aktivität des Mars schätzen typischerweise zunächst die Rate der jährlichen Momentenfreisetzung, und leiten dann anhand zusätzlicher Annahmen über die Steigung der Größen-Häufigkeits-Verteilung sowie das stärkste mögliche Marsbeben Wiederkehrraten für Ereignisse ab. Wir leiten mit den Verfahren von Knapmeyer et al. (BSSA, 2019, doi: 10.1785/0120180258) aus den Magnituden der beobachteten Ereignisse Schätzungen für die Momentenrate als die fundamentale von diesen Modellen vorhergesagte Größe ab.

[1] martin.knapmeyer@dlr.de, DLR Institut für Planetenforschung, Berlin
[2] Marsquake Service, ETH Zürich
[3] Imperial College, London

InSight: Meilensteine und Missionsstatus, oder: Was bisher geschah

Martin Knapmeyer[1], Brigitte Knapmeyer-Endrun[2]

Wir illustrieren die wichtigsten Meilensteine der NASA-Mission InSight, welche die erste rein geophysikalisch orientierte Marsmission überhaupt ist, und seit den Viking-Missionen zum ersten Mal seit 1976 wieder eine Seismometer zum Mars gebracht hat.

05.05.2018, 11:05 UTC	Start von Vandenberg Air Force Base, Kalifornien
26.11.2018	Landung in Homestead Hollow, Elysium Planitia, Mars
05.-12.12.2018	Lander checkout, erstes "Selfie"
09.12.2018	Kartierung des Arbeitsbereichs auf der Marsoberfläche
17.12.2018	Robotischer Arm greift Seismometer
19.12.2018	Aussetzen des Seismometers
22.12.2018	Robotischer Arm gibt Seismometer frei
26.12.2018	Erste Horizontierung des Seismometers
06.01.2019	Zugentlastung (*Load Shunt Assembly*) des Kabels geöffnet
09.01.2019	SEIS *level low*: herunterfahren auf kürzeste mögliche Beinlänge
26.-28.01.2019	*Load Shunt Assembly* vollständig geöffnet
02.02.2019, 10:19 LMST	*Wind and Thermal Shield* (WTS) ausgesetzt
06.02.2019, 12:10 LMST	Robotischer Arm gibt WTS frei
10.02.2019	Arm greift HP^3
12.02.2019	HP^3 ausgesetzt
22.02.2019	Erstes seismisches Ereignis registriert (S0085a)
28.02.2019	HP^3 Mole beginnt zu hämmern, SEIS zeichnet die Hammerschläge auf
03.06.2019	Erste NASA-Pressemittteilung eines registrierten Ereignisses (S0128a)
28.08.-07.09.2019	Mars in Konjunktion mit der Sonne, keine Datenübertragung möglich

[1] martin.knapmeyer@dlr.de, DLR Institut für Planetenforschung, Berlin
[2] Erdbebenstation Bensberg, Universität zu Köln

Detection and Location Capability of the TIXI seismic array for events in the Laptev Sea Rift Region (Northeast Siberia)

F. Krüger (1), A. Plötz (2) , W. Geissler (2), C. Haberland (3), S. Shibaev (4), B. Baranov (5), N. Tsukanov (5), D. Vollmer (1)

(1) Universität Potsdam, Institut für Geowissenschaften, Potsdam,
(2) Alfred Wegener Institut, Bremerhaven,
(3) Deutsches GeoForschungszentrum, Potsdam,
(4) Yakutsk Branch of Geophysical Survey SB RAS, Yakutsk, Russian Federation,
(5) P.P. Shirshov Institute of Oceanology, Moskau, Russian Federation

We present detection and location results for the first 9 months of data (August 2016 to April 2017) recorded at the temporary TIXI seismic array for events in the Laptev Sea Region in northeastern Siberia. The TIXI array is a 13 element miniarray of 2 km aperture equipped with passive shortperiod seismometers and low power recorders enabling recording during the arctic winter. Data loss was minimal. We used a moving window frequency-wavenumber scheme followed by a threshold detection to find events. The detected events are then classified into small very local events in or within one aperture distance, local and regional seismic events and teleseismic signals by their slowness and frequency characteristics.

We observe several thousands of small very local events especially during the winter months and can relate their occurence to drops in the soil temperature. Several hundred local and regional earthquakes are detected and can be located using a regional velocity model. Local earthquakes form a NNW-SSE striking lineament along the coast line. Regional earthquakes are observed to the NW in the Lena Delta region, to the South and SE in the Buor Kaya Bay and Bulun region and in the Laptev Sea to the NE of the array. We compare the location accuracy using events in the Lena Delta located by the contemporaneously installed LENA delta network. We find some earthquakes at lower crustal/upper mantle level beneath the Buor Khaya Bay, however, event depth determination using a single array is highly model dependent and therefore uncertain.

Definition von Schutzradien um seismologische Messeinrichtungen bei der Errichtung von Windkraftanlagen

Nikolaus Lerbs[1], Toni Zieger[2], Hortencia Flores-Estrella[3], Joachim Ritter[2] und Michael Korn[1]

[1] Universität Leipzig, Institut für Geophysik und Geologie, Talstraße 35, 04103 Leipzig, Deutschland
[2] Karlsruher Institut für Technologie (KIT), Geophysikalisches Institut, Hertzstraße 16, 76187 Karlsruhe, Deutschland
[3] Technische Universität Berlin, Institut für Angewandte Geowissenschaften, Ernst-Reuter-Platz 1, 10587 Berlin, Deutschland

Im Zuge der Energiewende und der damit verbundenen Stromerzeugung durch erneuerbare Energiequellen ist die Zahl der Windkraftanlagen (WKA) und Windparks (WP) in den letzten Jahren deutlich gestiegen. Da WKAs durch die Eigenschwingung des Turmes und die sich bewegenden Rotorblätter Schwingungen erzeugen, die sich als elastische Wellen im Boden ausbreiten und diese von seismischen Stationen registriert werden, beeinflussen sie die Datenqualität dieser Stationen.

Ziel des Projekts ist die Charakterisierung WKA-induzierter seismischer Signale, die durch einzeln stehende WKAs emittiert werden, um Schutzradien um seismologische Stationen definieren zu können. Hierfür wurde eine Messkampagne an einer einzeln stehende WKA bei Pfinztal (Baden-Württemberg) durchgeführt, um die Emission WKA-induzierter seismischer Wellen in Abhängigkeit der Windgeschwindigkeit quantifizieren zu können. Zudem wurde das entfernungsabhängige Amplituden-Abklingverhalten mittels Modellrechnungen für verschiedene geologische Begebenheiten berechnet. Mit Hilfe der ermittelten Emission der WKA-induzierten seismischen Signale und der synthetischen Abklingkurven kann ein Ausbreitungsmodell auf die Distanz berechnet werden. Unterschreiten die Amplituden des Ausbreitungsmodells einen zuvor festgelegten Grenzwert, der für ein maximal tolerierbares Effektivrauschen einer seismologischen Station gilt, ist gewährleistet, dass die Station nicht mehr von WKA-induzierten seismischen Signalen beeinträchtigt ist und somit die Bedingung für einen Schutzradius um eine seismologische Station erfüllt.

Ergebnisse dieser Studie zeigen eindeutig den WKA zuzuordnende Frequenzpeaks zwischen 1-10 Hz, deren Maß an Stärke in Abhängigkeit der Windstärke und in Abhängigkeit der WKA-Leistung stehen. Das synthetische Amplituden-Abklingverhalten mit der Entfernung zeigt eine starke Abhängigkeit bezüglich der Dämpfung der Amplituden sowie eine Dominanz von Oberflächenwellen. Mit Hilfe von Emissionswerten der WKA-induzierten seismischen Wellen und synthetischen Abklingkurven ist ein einfaches und schematisches Bewertungsverfahren zur Definition von individuellen Schutzradien um seismologische Stationen entwickelt worden.

An update on the ISC Bulletin Rebuild project and a new ISC service

Kathrin Lieser, Dmitry Storchak, Lonn Brown, James Harris, Blessing Shumba, Rebecca Verney, Charikleia Gkarlaouni, Burak Sakarya, Domenico Di Giacomo, Kostas Lentas

International Seismological Centre, Thatcham, UK

The Bulletin of the International Seismological Centre (ISC) is widely regarded as the most comprehensive record of the Earth's seismicity, and has been in production for over 55 years. With the support and cooperation of more than 150 agencies worldwide we are able to integrate and combine data from many sources, from global agencies with permanent networks to local temporary deployments. Our position as a not-for-profit and non-governmental entity allows us to create a unique product that is then freely provided to the global community.

This presentation will give an update on the ISC Rebuild project that was introduced in order to further improve the value of the ISC Bulletin. The goal is to bring the earlier period of the Bulletin (1964-2010) into line with more recent years and homogenise our methods across more than four decades of data guaranteeing consistency of locations and error estimates through the entire period. Examples of some of the improvements we are able to make for the older data set include:

- Relocating hypocentres with the latest ISC locator using the ak135 velocity model and all phases from IASPEI Standard Phase List where Jeffreys-Bullen travel time tables with only P phases (and later S phases) were used in the past.
- Recomputing earthquake magnitudes with a new robust procedure using an alpha-trimmed median and a minimum of three stations.
- Introduction and processing of essential additional datasets that had not been available at the time of original ISC Bulletin production.
- Performing quality checks to remove poorly constrained events, duplicate readings in more than one event, bogus events etc.

Last years presentation covered the time period 1964 – 1979. After improving and streamlining our methods on how to review the original ISC Bulletin to produce the Rebuild bulletin, we were able to speed up the analysis substantially and release the next eleven data years. Further, we plan on finishing the entire project by the end of this year. Results from the now publicly available 27 data years (1964-1990) of the Rebuild project as part of the ISC Bulletin will be presented, showing clear improvements to the data set.

The ISC has a lot more to offer for seismologists than the ISC Bulletin. A new product is the ISC Seismological Dataset Repository. It allows individual researchers or groups to submit seismological datasets (e.g. event catalogues or bulletins, velocity models etc.) that they wish to be openly available to the scientific community for a long period of time. This service is also useful for article authors that are required by journals to make the original research data openly available or for authors that wish to store supplementary material to their articles in a more persistent format.

Project KWISS - Characterization of seismic signals produced by wind turbines

F. Limberger[1,2], M. Lindenfeld[2], H. Deckert[1] and G. Rümpker[2]

[1]Institute for Geothermal Resource Management, Mainz, Germany, E-mail: limberger@igem-energie.de
[2]Institute of Geosciences, Goethe-University Frankfurt, Frankfurt am Main, Germany

In the KWISS-project, seismological measurements will be performed and analyzed in the near and far field of a wind farm located in Bavaria. Currently 41 seismic broadband stations are being installed in the region to investigate the spatial and spectral characteristics of the emitted wave field in detail. To define the source signal of a single wind turbine (WT) and the complete wind farm, seismic stations will be installed around the wind farm in distances with maximum 300 m to the WTs for two years. In addition, wave propagation and absorption effects will be analyzed along two profiles up to maximum distances of 10 km. Relevant technical parameters are provided by the wind farm operator, enabling an azimuth- and frequency-dependent correlation of the emitted seismic signals with the operational status of the wind turbine, both in the near and in the far field. Finally, numerical simulations are planned to model the wave propagation in this specific case, but also to investigate the effect of various geological settings on the seismic wave propagation.

First results show clear correlations of the WT rotation rate and power spectral density (PSD) of the seismic signal that is measured directly at a WT, also for frequencies below 1 Hz. When the WT is in operation, PSD increases at distinct frequencies (e.g. 0.3 Hz and 1.1 Hz). Furthermore, the PSD increases at the blade passing frequencies and follow the temporal progress of the WT rotation rate.

The project KWISS is funded by the Federal Ministry for Economic Affairs and Energy and ESWE Innovations- und Klimatschutzfonds.

Did the 2007 Mw7.4 intermediate-depth Martinique earthquake rupture on two orthogonal faults? Evidence of a reactivated subducted ridge-parallel transform fault.

Lindner, Mike[1]; Rietbrock, Andreas[1]; Frietsch, Michael[1]
[1] Geophysikalisches Institut am Karlsruher Institut für Technologie

In the afternoon of November 29, 2007, an earthquake with magnitude Mw 7.4 struck the central islands of the Lesser Antilles Island Arc. The Martinique event, named after the nearest island, is classified as a damaging earthquake causing at least one fatality and leaving several hundred people injured. The event falls, with an approximate source depth of 156 km, into the intermediate-depth range and is part of a larger seismic active cluster at the lower end of the Wadati-Benioff-Zone in the central Caribbean subduction zone. The source mechanism is believed to be of oblique normal faulting within the subducting South America plate in response to the slow distortion of the plate. Yet especially striking is the extremely large non-double-couple component of more than 90%, for which the most plausible explanation is the existence of at least two suitably oriented, non-parallel double-couple subevents. To verify this assumption we perform regional full-waveform moment tensor inversions, using new OBS data acquired by the VOILA project, to identify the mechanisms of 8 events within the deep cluster. Interpretation of the structure and the resulting mechanisms is done in a slab projected coordinate system with converted hypocenter locations relative to the slab surface. We detect mainly normal faulting with a prominent strike parallel to NNE/SSW and a considerable number of normal faulting events striking perpendicular to them. To account for uncertainties in the fault solutions due to horizontal misorientation of the OBS sensors, we conducted analytical tests based on error propagation of the moment tensor elements (Mij) using a random population of 1000 pure double-couple mechanism with a normal distributed misorientation angle. Our study show, that we have to account for an error of up to 5 on the faults parameters and an increased CLVD part of around 8 percent. Considering the error on the fault geometry due to uncertainties in the horizontal orientation, we suggest that the strike of the NW/SE trending fault is related to a subducted transform fault, with the orthogonal fault reactivation of a subducted ridge parallel fault. We also back up those findings by including focal solutions of other sources and by performing a Master event analysis to underline these long-standing features. Our findings show that large intermediate-depth earthquakes, such as the Martinique event, might be related to large heterogeneities in the subducting slab such as transform faults and can rupture on oblique fault planes.

New insights into the nature of the Albstadt Shear Zone, Germany

Mader, S.[1], Reicherter, K.[2], Ritter, J.[1] and the AlpArray Working Group

[1]KIT, Geophysical Institute, Karlsruhe, Germany

[2]RWTH Aachen, Neotectonics and Natural Hazards, Germany

The region around the town of Albstadt, SW Germany, is one of the most seismically active regions in Central Europe. In the last century alone three earthquakes with a magnitude greater than five happened and caused major damage. The ruptures occur along the Albstadt Shear Zone (ASZ), an approx. 20-30 km long, N-S striking fault with left-lateral strike slip. As there is no evidence for surface rupture the nature of the Albstadt Shear Zone can only be studied by its seismicity.

To characterize the ASZ we currently complement the earthquake catalog of the earthquake service of the state of Baden-Württemberg with additional seismic phase onsets. For the latter we use the station network of AlpArray as well as five additional, recently installed seismic stations from the KArlsruhe BroadBand Array. We invert for a new minimum 1D seismic velocity model of the study region. We use this seismic velocity model to relocalize the complemented catalog and to calculate focal mechanisms. All this information is used to determine the potential rupture planes and a possible segmentation of the ASZ. We thank the Landeserdbebendienst in Freiburg for using their data (Az. 4784//18_3303).

Poster:

Seismische Störsignale durch Windenergieanlagen: Evaluierungsmodell für Netzwerkperformance und mögliche (deep learning) Kompensationsmethoden

Tobias Neuffer

Im Rahmen des Forschungsprojekts MISS (Minderung der Störwirkung von Windenergieanlagen auf seismologische Stationen) werden zum einen Untersuchungen durchgeführt, um die Störwirkung von Windenergieanlagen (WEA) auf seismische Stationen detailliert zu analysieren, und zum anderen mögliche Methoden zur Minderung erarbeitet.

Für mögliche Minderungsmaßnahmen wird zunächst die Performance eines virtuellen Messnetzes mit Hilfe von Minimalmagnituden zur Detektion von seismischen Ereignissen für unterschiedliche Entfernungen simuliert. Im Weiteren wird ein Zubau von WEA an unterschiedlichsten Orten modelliert und der Einfluss auf die Netzwerkperformance untersucht. Die Ergebnisse sollen zeigen inwieweit ein Zubau von WEA in der Nähe von unterschiedlichen Messstationen die Detektierbarkeit des Gesamtnetzes für bestimmte Regionen verändert. Außerdem wird mit einer „Seismic Noise“-Karte basierend auf Landnutzungsdaten für NRW gezeigt, wie eine Netzwerkoptimierung zur Steigerung der Performance angegangen werden kann.

Der zweite Schwerpunkt befasst sich mit der Filterung von verrauschten Signalen durch WEA mit Hilfe von Deep-Learning Algorithmen basierend auf der Arbeit von Zhu et al. (2018). Durch eine Vielzahl von seismischen Ereignissen und Langzeitmessungen an WEA konnten Datenbanken erstellt werden, die als Trainingsdatensätze für ein KI-Neuronales Netz genutzt werden konnten. Durch Mustererkennung in Spektrogrammen der seismischen Noise- und Nutzsignalen können die jeweiligen Anteile in verrauschten Testsignalen erkannt und getrennt werden, wodurch ein bereinigtes Signal erzeugt werden kann. Aufgrund der stark harmonischen Anteile und der sehr ähnlichen Charakteristiken der Vibrationen erzeugt durch WEA, kann der Ansatz der Deep Learning Mustererkennung als sehr vielversprechende Kompensationsmethode in diesem Konfliktfeld betrachtet werden.

P-wave travel time tomography of the Alpine upper mantle using AlpArray seismic network data- A preparation for full waveform inversion

Marcel Paffrath[1], Wolfgang Friederich[1] and the AlpArray Working Group

[1]Ruhr-Universität Bochum

Using the extraordinary dense seismic broadband network AlpArray we examine geometry and slab structure of the upper mantle beneath the Alps using a full waveform inversion approach. As the method requires a decent starting model to avoid convergence problems due to cycle skipping, we determined arrivals of P and Pdiff mantle phases of 244 teleseismic events between 2015 and 2018. By combining higher-order-statistics automatic picks and waveform cross correlation, a database of more than 30000 highly accurate automatic P travel times was created. To compute theoretical travel times and later invert for 3D-mantle P-wave speed underneath the Alps, a hybrid approach is chosen where we apply the 3D fast marching method within a 3D box containing the Alpine crust and upper mantle and 1D-ray calculations with the Tau-P method for the rest of the earth. The accurate and highly consistent data residuals relative to the standard Earth model IASP91 enhanced by a 3D crustal model of Diehl et al. (2009) were inverted for a first, preliminary model of the P-wave distribution in the Alpine mantle that can be used for full waveform inversion as well as for first geodynamic models.

DSEBRA: das Deutsche Seismologische Breitbandarray

Antje Schlömer[1], DSEBRA Core-Group

[1] Department für Geo- und Umweltwissenschaften, Ludwig-Maximilian-Universität, 80333 München, Deutschland

Das Deutsche Seismologische Breitbandarray (DSEBRA) umfasst 100 mobile Breitbandstationen, die zur Zeit im Rahmen des europäischen AlpArray Netzwerkes (AASN) im Einsatz sind. Stationen in Deutschland, Österreich und Ungarn wurden mit modernstem seismologischen Equipment ausgestattet und ermöglichen mittels Mobilfunk eine Datenübertragung in Echtzeit. Die Daten bilden die Grundlage für die wissenschaftliche Arbeit innerhalb des deutschen Schwerpunktprogramms MB-4D (SPP 2017, Mountain Building Processes in 4D) und der europäischen Projektpartner des AlpArrays. Ziel des Projektes ist es, die Tiefenstruktur der Alpen aufzulösen, um so Gebirgsbildungsprozesse und deren Bezug zur Oberfläche verstehen zu können. Wir stellen den Status des Netzwerkes vor und beschreiben die Installation und das Equipment der Stationen. Des Weiteren demonstrieren wir die technische sowie qualitative Überwachung des Netzwerkes und erläutern den Datenzugriff.
Vor der Installation wurde das Equipment umfangreichen Tests unterzogen. Daher zeigen wir die Ergebnisse der Seismometerkalibrierung mit Hilfe verschiedener Step-Tables sowie der Huddle-Tests. Außerdem stellen wir Noise-Kurven von Seismometern vor, welche mit unterschiedlichen Abschirmungsmethoden installiert wurden.

InSight mission: removing glitches from SEIS' time series data

John-Robert Scholz[1], Paul Davis[2], Rudolf Widmer-Schnidrig[3], Salma Barkaoui[4], Philippe Lognonné[4], Eléonore Stutzmann[4], Francis Nimmo[5], Guenolé Mainsant[6], Laurent Pou[5], Baptiste Pinot[6], Raphaël F. Garcia[6], Anna Horleston[7], and DPWG

[1] Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany

[2] Department of Earth, Planetary, and Space Sciences, University of California Los Angeles, CA90095, USA

[3] Black Forest Observatory, Stuttgart University, Heubach 206, D-77709 Wolfach, Germany

[4] Université de Paris, Institut de physique du globe de Paris, CNRS, F-75005 Paris, France

[5] Dept. of Earth and Planetary Sciences, University of California Santa Cruz, Santa Cruz, CA 95064, USA

[6] Institut Supérieur de l'Aéronautique et de l'Espace SUPAERO, 10 Avenue Edouard Belin, 31400 Toulouse, France

[7] School of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Road, Bristol BS8 1RJ, UK

InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) is the first planetary mission with a seismometer package, SEIS, since the Apollo missions between 1969 and 1977.

Whilst the SEIS instrument works reliably and within mission specifications, *glitches* are recorded on both SEIS' very broad-band (VBB) and short-period (SP) 3-D sensors. Glitches (Fig. 1) are a particular type of transient instrumental self-noise whose duration is controlled by the transfer function of VBB and SP, respectively. They occur at all times of the day (sol) and span from lowest to highest frequencies in many cases. They may or may not be present on all six seismic components. Glitches affect many of the standard seismological methods and their correction therefore is important.

We have developed three different algorithms to detect and remove glitches. They are based on: (i) the sensors' transfer functions, (ii) a discrete wavelet transform, and (iii) a machine learning algorithm. We present preliminary comparisons across the deglitching methods and discuss their removal success.

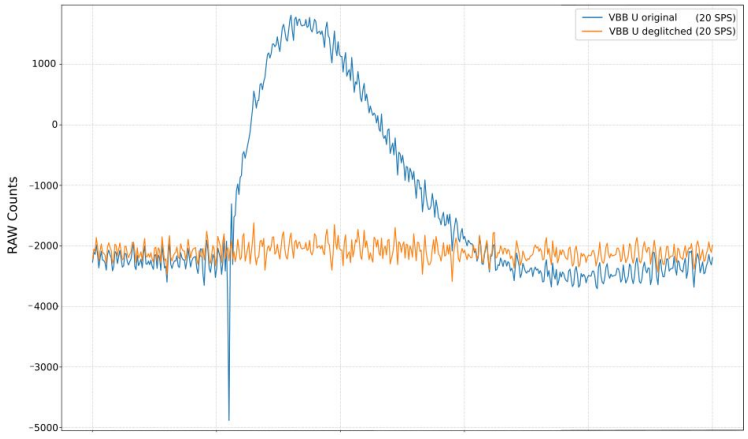

Figure 1:

Example of VBB data in original RAW showing a glitch (blue) and deglitched RAW (orange). Shown removal is based on Discrete Wavelet Transform.

High-resolution imaging of foreshock patterns in microearthquake sequences in Switzerland

Verena Simon, Toni Kraft, Tobias Diehl, and Stefan Wiemer
ETH Zürich, Swiss Seismological Service, Earth Sciences, Zürich, Switzerland (verena.simon@sed.ethz.ch)

How earthquakes initiate is still a largely debated question in earthquake science. In the past several decades, rupture initiation and immediate foreshocks to larger-scale ruptures have been studied intensively in laboratory experiments. For real earthquakes, contrarily, only a small number of high-resolution observations of earthquake nucleation are available until today. These observations are mainly limited to mainshock magnitudes above M4. This limitations may be – at least partly – related to an observational bias caused by the insufficient sensitivity of conventional earthquake catalogs.

To improve this situation, we are working on enhancing the routine SED catalog for selected microearthquake sequences with a matched-filter-based analysis technique that ensures a uniform detection sensitivity and a consistent magnitude estimation over decade-long periods. To better resolve the spatio-temporal behavior of the seismicity, we perform a high-precision relative relocation and a high-resolution statistical analysis of the enhanced catalogs. We show that earthquake nucleation phenomena that are observed on the laboratory scale can also be observed on the microearthquake scale with little instrumental effort.

We present results of our analysis for the earthquake sequence of 2014/15 in the Diemtigtal in the Bernese Oberland, Switzerland. The immediate foreshock sequences to the largest earthquakes (M_L 2.7 – 3.2) of the sequence are linked to a decrease in b-value, a subcritical growth of the immediate foreshock zone and a migration of the immediate foreshocks towards the mainshock hypocenters. We additionally observe repeating earthquake clusters inside the immediate foreshock zone that occur around the latter mainevent hypocenters and may indicate premonitory slow slip in the earthquake nucleation phase.

Imaging the Leipzig-Regensburg-Zone (East Germany) applying moment tensor inversion to low magnitude local earthquakes

Lutz Sonnabend, Sigward Funke, Michael Korn

The Leipzig-Regensburg-Zone (LRZ) is a region of increased seismic activity in eastern Germany. Since the year 2000 the universities of Leipzig and Jena together with Saxon State Office for the Environment, Agriculture and Geology and Thuringian Regional Office for the Environment and Geology established a dense regional seismic network. From this network a comprehensive seismological database has emerged with a magnitude completeness of ML -0.5. The largest observed earthquakes had magnitudes of ML 3.5, although there are records of historical earthquakes near the city of Gera with estimated magnitudes ML 5. In contrast to the NW-SE striking major tectonic features in the region of central Germany, the earthquake distribution of the LRZ is along N-S direction in a 40 km broad strip that is not related to a single major fault. The LRZ could be seen as an extension of the highly seismic active Eger-Rift in the north west of the Chech Republic, but the source characteristics are quite different. It lags the typical earthquake swarms and the sources tend to be deeper.

Moment tensor solutions are well established in global seismology and an optimal tool to better understand source mechanisms. Nevertheless, it is difficult to get stable moment tensor solutions for low magnitude local earthquakes. Our aim is to calculate moment tensor solutions below ML 2.0. In order to get results with good error estimations we use the Grond-package based on the Pyrocko-tool-box developed by Sebastian Heimann (GFZ-Potsdam). This package is based on a bootstrap algorithm to calculate the moment tensor solutions and provides an excellent estimation of the solution errors, but is computationally demanding. So far, we are able to gain stable solutions down to ML 1.4. For the inversion of events below ML 3 it has proven to be advantageous to use not only P- and S-waveforms but also the amplitude spectra as an inversions target. The resulting high quality moment tensor solutions will enable us to perform stress analysis of the area and provide new insights in the earthquake and fault dynamics of the Leipzig-Regensburg-Zone. Therefore it will be useful for improving hazard assessment in this region.

AG Seismologie, 24.-26.9.2019, Rastatt

Bericht über das Seismologische Zentralobservatorium der BGR (SZO)

K. Stammler, M. Dohmann, T. Grasse, M. Hanneken, E. Hinz, M. Hoffmann,
E. Muhire, L. Menke, C. Müller, 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:

- Stand GRSN/GRF, neue Standorte
- Weiterführung der Umbauarbeiten am GERES-Array
- Entwicklungen am Datenzentrum

Body Wave Tomography of the Alpine Region Using AlpArray Data — Automated Picking of P- and S-Phases

Stampa, Johannes

September 9, 2019

Abstract

The AlpArray Project is a european initiative aimed at furthering our understanding of the complicated geological situation in the alpine region and the processes involved in its evolution history. Starting in January 2015 and continuing until June 2020, a dense network comprising more than 300 temporary seismic stations is operated in a joint effort of 24 different institutions. This is complemented by the data gathered by more than 350 permanent stations in the region, as well as further complementary experiments, such as the Eastern Alpine Seismic Investigation, the Central Adriatic Seismic Experiment,the Swath-D and the Ivrea Projects. In this Poster, the preliminary results of automatic determination of the arrivals of P- and S-Phases in this data set are presented. These arrival times will be used for travel time inversion of the upper and lower mantle below the alpine region.

Fundamental Mode Surface Wave Phase and Amplitude Distributions within AlpArray

Tesch, M., Meier, T.

We demonstrate the suitability of large seismic arrays to resolve the frequency dependent fundamental mode surface wave phase, and amplitude fields at an as of yet unprecedeted resolution, by means of a large teleseismic event observed by AlpArray, and its surrounding networks. Our method employs synthetic reference waveforms, for which we determine the set of perturbations required, to arrive at the observed data. This approach serves to reliably separate the desired signal from e.g. higher modes, coda waves, and noise.

The results give a clear impression of the complexity, and distortions present in the wave field, as well as how they evolve over frequency. The observed anomalies are largely not aligned with the propagation direction of the wave front, and are likely explained by scattering / focussing effects induced outside the array, though there exist local disturbances as well, such as discernable reverberations around Mount Etna.

By having access to this precise spatial imaging of phase, and amplitude, it is possible to eliminate assumptions about the shape of the wave field, and derive proper structural information, suppressing the influence that any deformations might take otherwise.

Another look at the treatment of data uncertainty in the presence of outliers

Frederik Tilmann[1], Alexandra Mauerberger[1], Hamzeh Sadeghisorkhani[2]

[1] Deutsches GeoForschungsZentrum Potsdam, 2 Isfahan University of Technology, Isfahan (IUT), Iran

In probabilistic Bayesian inversions, the data uncertainty is a crucial parameter for quantifying the uncertainties and correlations of the resulting model parameters or, in transdimensional approaches, even the complexity of the model. However, in many geophysical inference problems it is poorly known. Therefore, it is common practice to allow the data uncertainty itself to be a parameter to be determined. In a Markov chain Monte Carlo approach, some uncertainty parameter is varied probabilistically in the same way as the physical model parameters through the iterations of the Markov chain. Although in principle any arbitrary uncertainty distribution can be assumed, in the vast majority of published studies usually simple Gaussian distributions are assumed, whose standard deviation is then the unknown parameter to be estimated.

However, in this special case, a simple analytical integration is sufficient to marginalise out this uncertainty parameter, reducing the complexity of the model space without compromising the accuracy of the posterior model probability distribution. This approach works equally well if there are different data classes with unknown errors, without having to introduce a priori weighting between them.

It is well known that the distribution of geophysical measurement errors, although superficially similar to a Gaussian distribution, typically contains more frequent samples along the tail of the distribution, though, commonly described as outliers. In linearised inversions these are often removed in subsequent iterations based on some threshold criterion, but in Markov chain Monte Carlo inversions, this approach is not possible as they rely on the ratio of data probability density functions, which cannot be formed if the number of data points varies between steps of the Markov chain.

The flexibility to define the data error probability distribution in Markov chain Monte Carlo or other direct search methods can be exploited in order to account for this pattern of uncertainties in a natural way, without having to make arbitrary choices regarding residual thresholds or having to remove potential outliers at the outset. In particular, we can regard the data uncertainty distribution as a mixture between a Gaussian distribution, which represent valid measurements with some measurement error, and a uniform distribution, which represents invalid measurements, e.g. due to misidentification of the signal, interfering events, or simply blunders. The relative balance between them is an unknown parameter to be estimated alongside the standard deviation of the Gauss distribution. For each data point, the algorithm can then assign a probability to be an outlier, and the influence of each data point will be downgraded according to its probability to be an outlier. Furthermore, this assignment can change as the Markov-chain Monte Carlo search is exploring different parts of the model space.

The approach is demonstrated with both synthetic and real examples. Applied to a tomographic inversion problem based on automated ambient noise phase dispersion measurements, the resulting model is shown to be much less dependent on the choice of quality control thresholds then inversions based on the Gaussian error assumption, while retaining a similar magnitude and spatial scale of the inferred anomalies. The framework also suggests a weighting scheme in linearised inversions.

Ambient noise tomography in the Pannonian Basin – preliminary results

Máté Timkó (1) Lars Wiesenberg (2), Amr El-Sharkawy (2), Zoltán Wéber (1), Thomas Meier (2)

(1) Kövesligethy Radó Seismological Observatory, MTA CSFK GGI, Budapest, Hungary
(2) Institute of Geosciences, Christian-Albrechts-Universität zu Kiel, Germany

The Pannonian Basin and the surrounding orogens are located in central Europe and are parts of the Alpine–Carpathian orogenic mountain belts. This is a back-arc basin characterized by a thinned lower crust and an updoming mantle. Beneath the basin the Moho discontinuity is not deeper than 30 km and the lithosphere also has smaller thickness ($\sim$ 80 km) than the continental average. Imaging the velocity structure of the crust and upper mantle may help us to understand better the structure and formation of the Pannonian region

We used the data from the permanent stations of the broader Carpathian region together with the AlpArray Network and analysed one year seismic data from 2017. Vertical component noise cross-correlation functions were computed and Rayleigh wave inter-station phase velocity curves were determined using an automated measuring algorithm. Anisotropic phase velocity tomography were carried out for whole Pannonian Basin between the 3 to 40s periods ($\sim$ 5-50 km).

The main features of the retrieved phase-velocity images highly resemble the known geologic and tectonic structure of the area (Moho topography, orogenic belts and the deep basins) and are comparable to recent tomographic models published in the literature.

Title: Ambient Noise Tomography across the Oman Ophiolite

Authors: Lars Wiesenberg[1], Christian Weidle[1], Amr El-Sharkawy[1,2], Thomas Meier[1], Sergei Lebedev[3]

Affiliation: Christian-Albrechts-Universität Kiel[1]; National Research Institute of Astronomy and Geophysics, 11421, Helwan, Cairo, Egypt[2]; Dublin Institute for Advanced Science[3]

The Oman ophiolite is one of the best preserved and studied ophiolites, where oceanic lithosphere was obducted on top of a continent. It covers an area of about 700 x 140 km² but its 3D geometry, as well as the properties of the underlying continental lithosphere are largely unknown. We operated a temporary broadband seismic network with 40 instruments for continuous, passive seismic registration for 27 months, complemented by 18 permanent stations in the study region. Cross-correlation functions (CCFs) are calculated for vertical, radial and transverse components for all station pairs. We then derive phase velocities for Rayleigh- and Love waves in the period range 2 – 40s by phase fitting the CCFs to the Bessel Function and applying an automated picking routine to determine reliable bandwidths in the dispersion measurements. The automation allows for determination of multiple dispersion curves per path, for example by separately measuring causal and acausal components of the Green's function, or by different stacking intervals in the CCFs (e.g. daily, hourly and monthly, annual). This yields additional constraints on uncertainties of the final dispersion curves. Azimuthally anisotropic phase velocity maps are calculated which show velocity anomalies that are very consistent with geological features at the shortest periods (<10s). At longer periods (>15s) the velocity pattern subdivides the study region into a faster eastern and slower northwestern part below the Oman Mountains.

We then invert local dispersion curves to shear wave velocity profiles using a novel implementation of a radially anisotropic, probabilistic inversion. Combination of the obtained 1D models to a 3D model provides the first three-dimensional view of shear wave velocity variations in the Eastern Arabian Plate margin. The model highlights at shallow levels strong lateral velocity contrasts between unconsolidated young sediments south of the Oman Mountains and ophiolite covered areas. Northwest of Jebel Akhdar, high velocities dominate the upper crust while east and south of it, lower velocities prevail at shallow depths. At lower crustal levels, the region subdivides in an eastern part with a presumably shallower Moho (<35km) and a northwestern part where the crust is significantly thicker (>40km).

Title: Structural Analysis of Northern Oman using Receiver Functions

Authors: Lars Wiesenberg[1], Frank Krüger[2], Christian Weidle[1], Thomas Meier[1]

Affiliation: Christian-Albrechts-Universität Kiel[1], University Potsdam[2]

The Oman ophiolite is one of the best preserved and studied ophiolites in the world, however, its 3D geometry and the properties of the underlying Arabian continental margin are largely undetermined. The obduction process occurred around 94-97 million years ago and remnants of the obducted oceanic lithosphere cover today an area of about 700 x 140 km. Due to Major uplift processes around 30 to 40 million years ago the ophiolite is today largely exposed and surrounded by Eocene to Quaternary sediments. We use P- and S- Receiver functions (RFs) to map seismic discontinuities in the continental lithosphere. In addition, we seek for information in the RFs on the thickness of the ophiolite and potentially other upper crustal structures, e.g. the Hawasina sedimentary units. We use data from 58 seismic stations, 40 of which we operated temporarily with continuous passive registration from October 2013 to February 2016 across the Oman mountains and 286 events with magnitude larger than 6 from the dataset for RF analysis.

We apply a semblance based migration to convert RF conversion times to estimates of conversion depth.

The results show clear variations in Moho depth with a decrease from (north-)west to east. This is consistent for both P- and S- Receiver Functions. In addition we see clear indications for variations in LAB depth across the area from S- Receiver Functions and a shallowing towards the continental margin. At higher frequencies we see indications for upper crustal sequences like the Hawasina sediments.