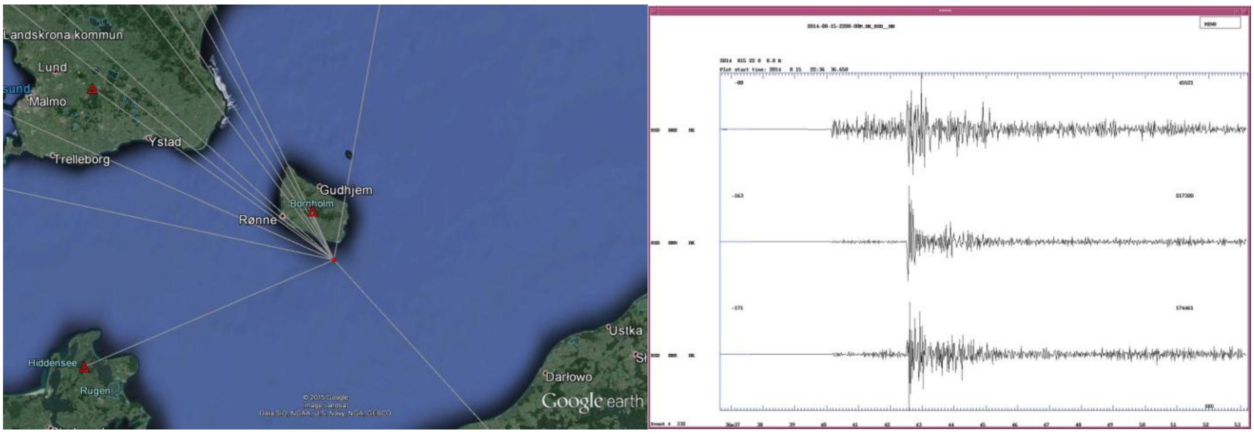
The 46th Nordic Seismology Seminar - SEP 30th to OCT 2nd, 2015 on Bornholm, Denmark

PROGRAM



Epicenter, station locations, raypaths and seismogram of the 15th AUG 2014, 2.6M_L earthquake, located 27km from the venue.

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Erik Hjortenberg

in memoriam

Seismologist Erik Hjortenberg- in memoriam

By S. Gregersen

Erik Hjortenberg was a big city-person in Copenhagen, but developed very early love for the wild and sometimes furious nature of Greenland. During the International Geophysical Year 1957 – 58 he volunteered as a student to set up and take care of a new seismograph station in Station Nord, a military base far north. And sitting there he chose to specialize in seismology in the later part of his studies. After his graduation from University of Copenhagen he chose to study geophysics/seismology in Alberta in Canada for a PH.D. degree, which was not available in the educational system in Denmark at the time. Later he went for expeditions and caretaking of seismographs plus wandering vacations in Greenland. He was employed 1963 – 2000 in seismology in the Geodetic Institute of Denmark, which in 1989 became part of the National Survey and Cadastre of Denmark.

Erik's thesis was on microseisms, also called seismic noise. And Erik stayed in close contact to that theme within seismology. Based on this specialization Erik has been often co-convener and reporter on progress within this theme, and chair or secretary of working groups. Early in his career he wrote a Bibliography of Microseisms, and later he expanded our data on microseisms via 3-component seismograph studies, via NORSAR array studies, and in attempts to characterize and get rid of noise in detection of signals on Greenland seismographs.

Erik was part of the Danish studies of local earthquakes, participating in field work and in a paper on the earthquakes of Denmark following an earlier review by Inge Lehmann. And this leads to mentioning that Erik was always an admirer of Inge Lehmann, never disagreeing with her. This led to his personal inheritance of Inge Lehmann's scientific, handwritten notes, which have only recently been turned over to the national archives of Denmark. Erik was very keen in Nordic seismological cooperation, and close to the end of his career we noted that he had the record of having been present at all the annual Nordic meetings from the beginning. Late in his career he was the Danish representative in the UN talks in Vienna on detection and discrimination seismology.

Erik was the “nicest person on earth” an expression many of you will have heard me say before. He was always ready with advice for me, when I was getting into seismology, and I noticed he did the same to every student or colleague with just a bit of interest. I have never come into his office to talk about something or to ask a favour without getting the best treatment. He seemed to forget his own engagement to be of service to his colleague. Another characteristic about Erik is that he had an extremely good memory for happenings and details years back. He looked weak, but was much stronger than suggested by the looks. He was fond of and good at mountain walking. And you should have tried to follow him on the bicycle on the paths near his home or his summerhouse!

Erik died quietly in a nursing home near his house in Copenhagen on April 25, 2015, at the age of 84.

Søren Gregersen

PRELIMINARY PROGRAM

Wednesday SEP 30

12.30-12.50 Registration at Radisson Blu Fredensborg Hotel

13.15 Opening

13.30 Seminar
Convener: T. Dahl-Jensen

First probabilistic seismic hazard assessment for the Shanxi Rift System, North China. B. Li

Geodynamics arguments around the IASPEI excursion in southern Sweden 2013 on postglacial earthquakes. S. Gregersen

A joint Nordic effort to compile a modern macroseismic map on the strong earthquake of 23rd October 1904. M.B. Sørensen

15.00 Break
Convener: M.B. Sørensen

Seismicity of the Nordland area, Norway. J. Michalek

Focal mechanisms in Nordland, Norway. I. Janutyte

Update on the Burträsk fault seismicity. B. Lund

European Plate Observing System (EPOS): recent developments in Europe and in Norway. K. Atakan

Poster session:
Analysis of waveforms of local earthquakes from the West Bohemia/Vogtland area and from Reykjanes Peninsula – II. A. Boušková
Earthquake Bulletins from Denmark: Processing Procedures and Formats. Rasmussen, H.P
Macroseismic Intensity Maps of Recent Earthquakes Felt in Denmark. S. Gregersen
Earthquake swarms in Greenland. T. B. Larsen

18.00 Dinner at Radisson Blu
19.30-21.00 Workshops:

1. EPOS meeting, Chair: K. Atakan
    a. Who: Participants with an interest in EPOS
    b. Where: the meeting hall
2. Analysts meeting, Chair: B.M. Storheim
    a. Who: Participants with an interest in earthquake data processing
    b. Where: café

Thursday OCT 1
08.30 Seminar
Convener: H. Soosalu

3-D crustal model for Norway. I. Janutyte
Sedimentary thickness from Receiver Function analysis – a simple approach. Case study from North Greenland. T. Dahl-Jensen,

Challenges and problems in cleaning up historical earthquake catalogues – the FENCAT case study, part I, M. Uski

10.00 Break
Convener: K.S. Vogfjörð

Challenges and problems in cleaning up historical earthquake catalogues – the FENCAT case study, part II, H. Soosalu

New advances of the "CTBTO Link to the ISC Database", K. Lentas

stationXMLtool, a new standalone software tool for creating, editing, and extracting metadata from stationXML files. P Schmidt

Investigating the impact of a more advanced method for ground motion modeling in earthquake damage and loss assessment. M.B. Sørensen

12.00 Lunch
13.00-17.30 Bus trip to pit mine and geological sites.
18.00 Conference Dinner at Radisson Blu
19.30-21.00 Bi-lateral networking

Friday OCT 2
08.30 Seminar
Convener: M. Uski

Installation of a Semi Permanent Seismic Station. P. Lindblom

NORSAR field installations - Status 2015. M. Roth

Ulkokalla seismic station – Ground motion measurement on an offshore islet. T. Vuorinen

10.00 Break
Convener: T.B. Larsen

Real-time monitoring of seismicity and deformation during the Bárðarbunga rifting event and associated caldera subsidence, K. Jónsdóttir

With and against seismic noise. L. Ottemöller

Mapping magma movements and fault surfaces in the Bárðarbunga 2014 eruption
Kristín S. Vogfjörð

Acoustic signals recorded on seismic stations in Denmark, P. Voss

11.50 Closing remarks

ABSTRACTS

First probabilistic seismic hazard assessment for the Shanxi Rift System, North China

Bin Li*, Mathilde Bøttger Sørensen and Kuvvet Atakan

Department of Earth Science, University of Bergen, Allégaten 41, N-5007, Bergen, Norway

We present the first probabilistic seismic hazard assessment (PSHA) for the Shanxi Rift System, North China, which has been defined as one of the areas of highest seismic hazard and risk in China in recent decades. We applied a Monte-Carlo based approach to PSHA, based on the most complete earthquake catalog available and a detailed zonation for the region. Both area sources (for M_S <6.0) and fault sources (for M_S ≥6.0) are considered and a synthetic earthquake catalog is generated through Monte-Carlo simulation. A logic-tree is applied to represent the epistemic uncertainty related to attenuation models for the rift system and the whole region of North China. Our results show that nearly the entire rift system faces a significant seismic hazard and associated high seismic risk, as more than 80% of the population and the main economical infrastructure are concentrated in this region. The highest hazard is found in the areas around the north margin of Tianzhen fault and the north segment of Hengshan fault in the north, and in the Linfen basin and the area around Zhongtiaoshan fault in the south of the rift system. Our results are comparable to but a refinement of the results of previous probabilistic seismic hazard studies. Deaggregation of seismic hazard for five large cities in the rift system indicates that the seismic hazard is most contributed by the nearby sources. The results of this study provide a better understanding of the seismic hazard in the Shanxi Rift System and can thereby help guiding earthquake risk mitigation in the future.

Geodynamics arguments around the IASPEI excursion in southern Sweden 2013 on postglacial earthquakes.

Soren Gregersen and Peter Voss
GEUS, Ostervoldgade 10, DK-1350 Copenhagen K, Denmark.

Postglacial uplift is important for stress and strain in Scandinavia. But the World Stress Map project gave convincing evidence, that plate motion is responsible for the dominating stress. The uplift is on the other hand well recorded via geodesy and geology, in time scales of hundreds and thousands of years. Investigations are these years concerned with the stress-strain relationships. Large earthquakes occurred right when the Ice Cap left Scandinavia around 9.000 years ago, but how long did its effects last? This was the topic of the seismology excursion in southern Sweden in connection with the IASPEI meeting in Gothenburg 2013. Claimed palaeo-earthquake sites of younger age were visited. The outcome of the excursion was shortly said: "possibly earthquakes, but not probably". The best possible strain fields from geodesy and geology are found and elaborated on for Denmark and the Kattegat region including south-western Sweden. Some suggested large irregularities are discarded with convincing arguments. We encourage similar evaluations in those areas of Scandinavia, where it has not been done recently?

A joint Nordic effort to compile a modern macroseismic map on the strong earthquake of 23rd October 1904

Päivi Mäntyniemi, Institute of Seismology, Department of Geosciences and Geography, University of Helsinki, Finland
Mathilde B. Sørensen, Department of Earth Sciences, University of Bergen, Norway

The strongest earthquake on the Fennoscandian Peninsula in the 20th century occurred on 23rd October 1904. It was an early instrumental earthquake with a wide area of perceptibility. The macroseismic effects were studied by individual researchers in the affected countries, but there is no modern map available. This initiative attempts to fill the gap.

A modern macroseismic map means that the macroseismic intensities are assessed using original written documentation, unified cross-border criteria and a recent macroseismic scale (European Macroseismic Scale, EMS). The assessments are given as intensity data points (IDPs) that are the basis for estimating macroseismic parameters.

An IDP map shows the geographical distribution of the earthquake effects and all affected localities according to the obtained (uncovered) felt reports. Each IDP contributes to the seismic history of the respective locality. EMS intensities can be used to rank the occurrence and to test the scale. The work also provides information about the social and economic impact of rare occurrences that is needed when assessing future seismicity and seismic hazard of the target region. The presentation gives examples of the ongoing work.

Seismicity of the Nordland area, Norway

Jan Michalek[1], Ilma Janutyte[2], Lars Ottemoeller[1], Conrad Lindholm[2]
[1] University of Bergen, Norway
[2] NORSAR, Kjeller, Norway

The Nordland area (65-70N; 8-18E) is tectonically active part of Norway. Enhanced seismicity may reflect on off-shore subsidence combined with the uplift of landmasses usually attributed to glacial isostatic adjustment (related to Pleistocene unloading). Detailed monitoring of seismic activity in the Nordland area started in 2013 as a part of the NEONOR2 project and information obtained from analysis of earthquakes together with geodetic data should be the key inputs for modeling of deformation and uplift patterns and their mechanisms in the region.
Local/regional network of 26 broad-band stations were deployed which together with the permanent NNSN stations consist 32 stations within span 350 x 200 km. About 330 earthquakes of M>1.0 were recorded between Sep 2013 and Sep 2015 (ca 900 M>-0.4 events). The main aim of the project is to reveal the stress field in that particular region. Therefore the detailed analysis of individual events was performed including precise relative location (using hypoDD program) and space-time migration analysis. The project is ongoing and results are therefore preliminary.

Focal mechanisms in Nordland, Norway

Ilma Janutyte(1), Jan Michalek(2), Conrad Lindholm(1), and Lars Ottemoller(2)

(1) NORSAR, Kjeller, Norway, (2) University of Bergen, Bergen, Norway

This study is a part of the ongoing NEONOR2 project which is carried out in norther Norway. The aim of this work is to define the focal mechanisms for the earthquakes occurring in the Nordland area both on-shore and off-shore. The improved station coverage with 26 temporary seismic stations in the study area in addition to the permanent deployments in Norway and Sweden enables to achieve this task with higher precision compared to the previous studies. To obtain the solutions of the focal mechanisms we use four different programs: FOCMEC, HASH, PINV and FPFIT, which are implemented into the SEISAN program package. As a result, we obtaine the preliminary focal mechanisms for a number of earthquakes in the study area. However, it is not always possible to obtain a stable solution, because many factors contribute to it. In the study we also define the ruling tectonic stresses of east-west direction in the study area.

Update on the Burträsk fault seismicity

Björn Lund and Darina Buhcheva
Department of Earth Sciences
Uppsala University

The area around the Burträsk endglacial fault (EGF), south of the town of Skellefteå in northern Sweden, is not only the most active of the EGFs but also the currently most seismically active region in Sweden. Here we show the preliminary results of the first two years of a temporary deployment of six seismic stations around the Burträsk fault, complementing the permanent stations of the Swedish National Seismic Network (SNSN) in the region. During the two year period December 2012 to December 2014, the local network recorded approximately 1,500 events and is complete to approximately magnitude -0.4. We determine a new velocity model for the region and perform double-difference relocation of the events along the fault. We find that many of the events are aligned along and to the southeast of the fault scarp, in agreement with the previously determined reverse faulting mechanism of the main event. Earthquakes extend past the mapped surface scarp to the northeast in a similar strike direction into the Bay of Bothnia, suggesting that the fault may be longer than the surface scarp indicates. We also find a number of events north of the Burträsk fault, some seemingly related to the Röjnoret EGF but some in a more diffuse area of seismicity. The Burträsk events show a seismically active zone dipping approximately 55 degrees to the southeast, with earthquakes all the way down to 35 km depth. Focal mechanisms are calculated for all events and the highest quality mechanisms are analyzed for faulting style variations and the state of stress. In order to further increase our analysis capability in the area we installed an additional six temporary seismic stations during August 2015 and the new station configuration is presented here.

European Plate Observing System (EPOS): recent developments in Europe and in Norway

Kuvvet Atakan[1] and the EPOS-IP and EPOS-N Teams
[1] Department of Earth Science, University of Bergen
Allégt.41, N-5007 Bergen, Norway
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The main vision of the European Plate Observing System (EPOS) is to address the three basic challenges in Earth Sciences: (i) Unravelling the Earth's deformational processes which are part of the Earth system evolution in time, (ii) Understanding the geohazards and their implications to society, and (iii) Contributing to the safe and sustainable use of georesources. EPOS was first included in the ESFRI Road Map in 2009. Following a Preparatory Phase (EPOS-PP) project with funding from the EC-FP7 program, the EPOS is now starting its implementation phase (EPOS-IP) project in October 2015. Implementation of EPOS is funded through the Horizon2020 program of EC with 18,3 million Euros, where 46 partner institutions from 23 countries will work together for the integration of Solid Earth Science data, data products, services and software coming from the National Research Infrastructures organized through the 10 Thematic Core Services (TCS) defined in EPOS-IP. This integration will provide a wealth of opportunities for new research through a comprehensive e-infrastructure (Integrated Core Services). EPOS services will be open not only for the scientific communities, but also for government authorities, industry as well as general public.

As a part of the Norwegian implementation of the EPOS, a dedicated project, EPOS-Norway (EPOS-N) is recently funded by the Research Council of Norway to provide a seamless integration of the Norwegian Solid Earth Science data, data products, services and software. The goal of EPOS-Norway is to bring all relevant data that maps the physical conditions of the Earth's crust under a unified umbrella that makes data easier accessible, provides an integrated infrastructure that can be used by geoscientists and provide mechanisms for improved use of all available Solid Earth Science data, and initiates and facilitates closer interaction between scientists from different fields. EPOS-Norway aims to implement this goal through: (i) Component-1: Developing a Norwegian EPOS e-infrastructure to integrate the data from the seismological and geodetic networks, as well as the data from the geological and geophysical data repositories, which is in line with European EPOS implementation; (ii) Component-2: Improving the monitoring capacity in the Arctic, including northern Norway and the Arctic islands; (iii) Component-3: Establishing a Solid Earth Science Forum for providing a constant feedback mechanism for improved integration of multidisciplinary data, as well as training of young scientists for future utilization of all available solid Earth observational data through a single e-infrastructure.

3-D crustal model for Norway

Ilma Janutyte[1], Steven J. Gibbons[1], Johannes Schweitzer[1], Lars Ottemoller[2], and Tormod Kvaerna[1]
[1] NORSAR, Kjeller, Norway, [2] University of Bergen, Bergen, Norway

The aim of this work is to develop a new 3-D crustal velocity model for Norway. The work is performed as a part of the Norwegian National Seismic Network (NNSN) and the NEONOR2 projects. We used data from the permanent stations of the NNSN, the permanent seismic arrays operated by NORSAR, the temporary broadband deployment of the NEONOR2 project, and the stations from diverse temporary field deployments in Norway in addition to an extensive database of phase picks made both at NORSAR and at the UiB. The territory of Norway is divided into three parts, and the development of the 3-D velocity model is performed in stages. Firstly, the optimal 1-D velocity models are constructed for the different regions of Norway using the VELEST program, which is implemented into the SEISAN program package. Secondly, the obtained 1-D models are applied as the starting models for full 3-D tomography using the FMTOMO program. As a result, we obtained 3-D models of velocity variations for southern Norway, and territories of Nordland and Finnmark in Norway. The models reveal significant variations of seismic velocities and the Moho depths.

Sedimentary thickness from Receiver Function analysis – a simple approach. Case study from North Greenland

Trine Dahl-Jensen, Peter Voss and Tine B. Larsen
GEUS

Receiver Functions (RF) calculated at seismological stations contain information about changes in the subsurface, and are frequently used to obtain a depth to Moho. For some stations, it is clear from reverberations that there are several layers in the crust, often caused by a thick sedimentary cover of unknown thickness. Our approach is to determine basic information about the sedimentary thickness by forward modelling. We use a very simple model consisting of a sedimentary layer over a crystalline crust, and vary the thickness of the sedimentary. For each forward model, a synthetic RF is calculated, and the RMS difference to the observed data (the stack of all calculated RF) at a station is calculated. With only two variable parameters we can do a comprehensive search of the parameter field, and find the global minimum.

Case study:
A series of stations provide information on the crustal structure of the North Greenland. The thickness of the sediments in the Franklinian Basin is largest to the north where the basin is observed on the offshore. At the coast the thickness is a few km, and further south at the southern verge of observed rocks from the Franklinian basin the thickness is smaller than we can analyse – presumed less than 500m. The depth to Moho thins towards northwest; from typical values for a shield area to half t he thickness at the coast. In the Wandel Sea Strike-Slip Mobile Belt we find a several km thick high velocity sedimentary basin. The thickness of Proterozoic sediments of the Thule Basin can be interpreted in good agreement with earlier geological estimates. Further south, on the NW coast of Greenland we see no indication of a sedimentary basin. The only inland station in this study is situated on 2.5 km thick icesheet. Treating the ice as a sedimentary layer allows the depth to Moho to be estimated in spite of the very strong reverberations from the 2.5 km thick ice layer.

Investigating the impact of a more advanced method for ground motion modeling in earthquake damage and loss assessment

Mathilde B. Sørensen, Dept. of Earth Science, University of Bergen, Norway
Dominik H. Lang, NORSAR, Kjeller, Norway

An important component and input parameter in earthquake damage and loss assessment (often referred to as seismic risk) is the seismic hazard represented in terms of earthquake ground shaking. Although it is well known that rupture kinematics plays an important role for the spatial distribution and characteristics of ground shaking and hence the associated damage, seismic risk studies have traditionally been based on simple models often considering a point/line source in combination with empirical ground motion prediction equations (GMPE). In this study, an alternative approach for earthquake damage and loss assessment is suggested, where the ground shaking is determined through stochastic ground motion simulations. To account for uncertainties in the source parameters for future earthquakes, realistic ranges of input parameter values are defined through calibration with information on ground motion records of past events, and a large number of simulations are performed to cover these ranges. The method is applied to the city of Managua, Nicaragua, which is underlain by several surface-rupturing active faults of various types. Results are presented both in terms of ground shaking and associated damage and loss estimates, and are compared to the results of the traditional GMPE-based approach.

Challenges and problems in cleaning up historical earthquake catalogues – the FENCAT case study

Marja Uski[2,] Heidi Soosalu[3], Kati Oinonen[2], Björn Lund[1]
[1]Department of Earth Sciences, University of Uppsala, [2]Institute of Seismology, University of Helsinki, [3]Geological Survey of Estonia

Historical earthquake catalogues are of utmost importance when estimating seismic hazard and risk for vulnerable constructions, such as nuclear power plants. Particularly for low-seismicity regions, like Nordic countries, every incorrect catalogue entry may bias risk calculations to a noticeable extent. There is also a trade-off between a dataset that stretches as far back in time as possible and a dataset that is reliable.

Cleaning up macroseismic event catalogues is challenging, as source material is of very varying quality. For instance, information may be second-hand, transformed in later citations and translations. Language barriers and unequal accessibility to archives may cause that the most correct notes do not end up as catalogue sources. Even dates – whether being according to an old or a new calendar – or the claimed time of occurrence, may create confusion.

We examine critically the quality of FENCAT, the catalogue of Fennoscandian earthquakes compiled from national and regional catalogues, separate studies and reports. Here we focus on historical records from southern and central Finland and Sweden, NW Russia and Estonia. The ultimate task is to fix up FENCAT as a whole to a consistent and homogeneous dataset.

We have found examples of catalogue entries clearly requiring adjustment or deletion, even though they may have appeared well-established until now. In FENCAT, it tends to be more likely that macroseismic magnitudes are overestimations than underestimations. Mid-winter historical earthquakes are problematic, as many of them rather turn out to be frost-related events. A specifically Swedish feature is the long mining history dating back to Middle Ages. It can be expected that several mining-induced seismic events from obsolete Swedish underground mines have been listed as earthquakes without better knowledge. With our meticulous inquiry of historical events in these study areas, we even have found some bizarre occurrences that have erroneously ended up in the catalogue as earthquakes.

New advances of the "CTBTO Link to the ISC Database"

Kostas Lentas, Dmitry A. Storchak and James Harris
International Seismological Centre (ISC)

The CTBTO (Comprehensive Test-Ban Treaty Organisation) link to the International Seismological Centre (ISC) database is a collection of tools and graphical interfaces for analysing and plotting the datasets maintained by the ISC. The ISC database includes the seismicity of the Earth, mining induced events as well as nuclear and chemical explosions reported by national seismological agencies around the world. The service gives special access to the CTBTO and the national data centres, via simple database queries. Four main search tools are available: (i) the area based search (spatio-temporal search based on the ISC Bulletin), (ii) the Reviewed Event Bulletin based search (spatio-temporal search based on specific events in the REB), (iii) the ground truth (GT) based search (spatio-temporal search based on IASPEI Reference Event list) and (iv) the International Monitoring System (IMS) station based search (historical reporting patterns of seismic stations close to a selected IMS seismic station). The link provides details on seismicity, available moment tensor results, frequency-magnitude distributions, network hypocentre comparisons, individual station data, waveform previews and download request tools, as well as an interactive hypocentre relocation facility using the ISC locator for the events in the REB list.

stationXMLtool, a new standalone software tool for creating, editing, and extracting metadata from stationXML files

Peter Schmidt, Björn Lund, Hossein Shomali
Department of Earth Sciences
Uppsala University

In 2012 the International Federation of Seismological Networks, FDSN, released a new standard for the exchange of metadata, FDSN stationXML.
The release were motivated by various limitations with the former metadata standard, the FDSN dataless SEED format, such as but not limited to, a limited possibility to describe the instrumentation at a specific station/channel (50 character free-format string); network start and end dates, uncertainties in location, elevation, depth, azimuth, dip and frequency; information on local geology; restriction status; time series availability. At SNSN we currently use the dataless format for much of our metadata, but are in the process of migrating to stationXML. However, currently no dedicated software for creating, and maintaining stationXML files exists. Instead anyone wishing to use the stationXML format will have to save he metadata in some other format, e.g. dataless or the inventory XML format of Seiscomp3, and thereafter use a converter between the chosen format and stationXML such as the station-xml converter provided by IRIS. This makes maintaining the metadata in stationXML format a bit of a hassle. That said, in the python programing language the seismology module ObsPy includes a framework for reading stationXML files into a, for the purpose dedicated, class object as well as functions for writing the data back to stationXML files and verifying existing files against the stationXML scheme. The framework is still under development but has already reached a high level of maturity. At SNSN we are therefore at present building upon this framework a tool, the stationXMLtool, dedicated to the creation from scratch, as well as editing and extracting data from existing stationXML files. In its first version this will be a command line tool mainly designed to work on UNIX/Linux but potentially portable to other OS as well. In a later stage we plan to also implement a GUI interface. Here we will present he current status of the first stage of the project which is expected to ready for release to anyone interested in the software later this fall/early winter.

Installation of a Semi Permanent Seismic Station

Pasi Lindblom
Institute of Seismology, University of Helsinki

Nowadays it is quite normal to build up temporary seismic stations for a pre-defined time periods. If these measurements will be carried out over the winter, at least in the Nordic countries there will be some challenges in protecting the instruments against the severe weather. If the stations will be deployed inside of existing buildings or cellars, those installations might include some compromises.
This presentation will show one version of a temporary installation of a seismic station in Finland very recently. The selected site is on an outcrop near a summer cottage, so there is the needed electricity available. The station site is located near the town called Imatra in South East Finland and it is planned to be built up as a permanent station in the summer 2016. The station code will be announced later.
Hopefully this illustrated presentation could give some new ideas to those who are involved to the real seismic work.

NORSAR field installations - Status 2015

M. Roth, J. Fyen, P. W. Larsen, U. Baadshaug, J. M. Christensen
NORSAR, Norway

A significant part of the NORSAR field installations has been modified and upgraded recently.
We changed communication for the NOA array cancelling VSAT as main transmission means and implemented broadband over satellite and cell network communication. The ARCES array is currently in a major recapitalization phase. End of 2014 we replaced all seismic sensors, digitizers and central acquisition system in that ARCES is now a full 3C broadband seismic array. In September 2015 we installed additionally 9 infrasound sensors into the A and B ring of the array. SPITS got a makeover with new digitizers and communication in 2015. The inner sites of the NORES array (A and B ring) were upgraded with 3C broadband sensors as well and we plan to get the 7 sites of the C-ring operational until the end of this year. Our infrasound array IS37 was complemented with a seismometer in the central site.
We will give an overview on the modifications and future plans.

Ulkokalla seismic station – Ground motion measurement on an offshore islet

Tommi Vuorinen and Jari Kortström
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Ulkokalla is an islet located in the Gulf of Bothnia ca. 20 km offshore from Kalajoki. This treeless open sea islet, which is ca. 400 m long and 150 m wide, is the location of semi-permanent seismic station, OBF8. The station operates as part of the Ostrobothnian seismic network (OBF) constructed to monitor and evaluate seismic hazard around the Hanhikivi 1 nuclear power plant.

While Ulkokalla has some permanent structures, including a lighthouse, it has no connection to the power grid or any other permanent power generation systems. The islet also lacks a source of fresh water and an all-weather harbor. Thus, the construction of the seismic station has demanded some unusual solutions. In this presentation the power generation solutions and the set up of the seismic monitoring equipment are briefly discussed.

The quality of the OBF8 seismic data is evaluated through noise measurements and comparisons with mainland OBF-stations. The Finnish Meteorological Institute's weather station, located within several meters of the seismic station, and the open and isolated environment provide a unique opportunity to study the impact of weather to seismic noise. Specifically, the impact of wind to seismic noise for OBF8 is presented.

Real-time monitoring of seismicity and deformation during the Bárðarbunga rifting event and associated caldera subsidence

Kristín Jónsdóttir (1), Benedikt G Ófeigsson (1), Kristín Vogfjörð (1), Matthew Roberts (1), Sara Barsotti (1), Gunnar B. Guðmundsson (1), Martin Hensch (1), Theodór Hervarðsson (1), Bergur H Bergsson (1), Vilhjálmur S. Kjartansson (1), Pálmi Erlendsson (1), Melissa Pfeffer, Hildur María Friðriksdóttir(1), Magnús T. Guðmundsson (2), Freysteinn Sigmundsson (2), Thóra Árnadóttir (2), Michelle Parks (2), Stephanie Dumont (2), Elías R. Heimisson (2), Vala Hjörleifsdóttir (3), Jón Söring (1), Bogi B. Björnsson (1), Sigrún Hreinsdóttir (4), Víðir Reynisson (5), Björn Oddsson (5), The FutureVolc team. and The SIL monitoring group (1)

(1) Icelandic Meteorological Office, Iceland
(2) Nordic Volcanological Center, Institute of Earth Sciences, University of Iceland, Iceland
(3) UNAM, Mexico
(4) GNS Science, New Zealand
(5) The National Commissioner Of The Icelandic Police Department of Civil Protection and Emergency Management

Abstract

We present a monitoring overview of a rifting event and associated caldera subsidence in a glaciated environment during the Bárðarbunga volcanic crisis. Following a slight increase in seismicity and a weak deformation signal, noticed a few months before the unrest by the SIL monitoring team, an intense seismic swarm began in the subglacial Bárðarbunga caldera on August 16 2014. During the following two weeks, a dyke intruded into the crust beneath the Vatnajökull ice cap, propagating 48 km from the caldera to the east-north-east and north of the glacier where an effusive eruption started in Holuhraun. The eruption terminated at the end of February and has become the largest eruption in over 230 years in Iceland. The dyke propagation was episodic with a variable rate and on several occasions low frequency seismic tremor was observed. Four ice cauldrons, manifestations of small subglacial eruptions, were detected. Soon after the swarm began the 7x11 km wide caldera started to subside and subsided in total some 65 meters.

Unrest in subglacial volcanoes always calls for interdisciplinary efforts and teamwork plays a key role for efficient monitoring. Iceland has experienced six subglacial volcanic crises since modern digital monitoring started in the early 90s. With every crisis the monitoring capabilities, data interpretations, communication and information dissemination procedures have improved. The Civil Protection calls for a board of experts and scientists (Civil Protection Science Board, CPSB) to share their knowledge and provide up-to-date information on the current status of the volcano, the relevant hazards and most likely scenarios.

The evolution of the rifting was monitored in real-time by the joint interpretation of seismic and cGPS data. The dyke propagation could be tracked and new, updated models of the dyke volume were presented at the CPSB meetings, often daily. In addition, deformation data and models based on remote sensing were presented, further supporting the interpretations of lateral movements of magma. The rapid evolution of the dyke called for a quick response to install new seismic and GPS stations to improve constraints for the intrusion (seismic locations and deformation). The subsidence of the caldera called for innovative thinking, resulting in a high-rate cGPS instrument together with a strong motion sensor being installed on the ice surface. Moreover, specially designed broadband glacier seismometers have been installed. Surveillance flights were carried out to monitor ice surface changes providing important data on caldera deformation.

Many geophysical data used for the volcano monitoring as well as interpretations have been made accessible to the public. Automated and manually checked earthquake locations were presented on web based maps and were updated every five minutes. In addition cGPS time-series and maps showing GPS deformation vectors together with the color coded temporal evolution of the earthquake sequence were presented and updated regularly on IMO's webpage. Several examples of near-real-time data transfer, analysis and online visualization will be presented.

With and against seismic noise

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Seismic noise is present all the time and everywhere and, therefore, an important consideration when operating seismic stations as well as working with earthquake data. A good knowledge of the expected seismic noise, by developing regional noise models, is important when evaluating the performance of a seismic network or when considering the use of data for research. Instrument performance and vault construction can be evaluated when using noise as a signal and long-term monitoring of noise is a standard tool for data quality control.

We have worked with seismic noise from Norway and Turkey to establish reference noise models and to resolve the temporal and geographical distribution. In Norway, there is a clear seasonal variation of the microseismic peaks correlating with the weather conditions over the North Atlantic. In Turkey, we find very low microseismic peak amplitudes at all sites, but also a shift of the peaks to higher frequencies compared to other regions and a clear geographic difference with respect to the coastal distance.

A side outcome of the noise analysis was the identification of serious instrumental issues on some of the stations in Turkey. We further looked at the effect that vault construction has on the long-period performance of a seismic station. Finally, we found that the general assumption that cultural noise does not contribute to long-period noise is not quite correct.

Mapping magma movements and fault surfaces in the Bárðarbunga 2014 eruption

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Bárðarbunga volcano in the northwest corner of Vantajökull glacier in Iceland had been showing signs of increasing unrest from the year 2006, with seismicity confined to the region northeast of the caldera rim and extending north along the fissure swarm, as well as distributed along the Loki ridge on the southern fissure swarm. In the early hours of August 16 2014 the seismicity suddenly escalated, moved south along the eastern caldera rim and then to the southwest out of the caldera. From there the seismicity took a sharp turn towards northeast and propagated in jerks and leaps over 48 km in the next two weeks. This propagation of seismicity represented lateral magma movement along a segmented dyke from the caldera to Holuhraun, north of the glacier margin, where a 6 month long eruption started at the end of August. During the first three weeks, several episodes of low frequency tremor were observed, signifying magma-ice interaction under the Dyngjujökull glacier. Also during the unrest, the caldera subsided over 60 m and seismicity soared along the caldera rim, with over 80 M>5 events occurring over the first four months.
Relative relocation of microearthquakes during the unrest resolve several details of the dyke intrusion, show an upwelling of magma outside the caldera and discern fault patterns on the caldera rim. Relocations in the dyke resolve 8 main vertical segments of varying length and strike, but more details in the temporal and spatial distribution of seismicity can also be resolved. The tight event distribution in the plane of the dyke suggests that the dyke is rupturing unbroken crust, and focal mechanisms of the individual events in general show nearly horizontal tension axes, near perpendicular to the strike of the dyke segments. Under the southern end of the dyke the relocated events reveal a vertical channel extending down to nearly 20 km depth. This channel was active over several years before the eruption and showed increasing activity up to the time of eruption. This channel, which probably represents upwelling magma may have played a critical role in enabling the magma from Bárðarbunga to escape into the lateral dyke. Relocations on the caldera rim show a more diffuse event distribution, but can image a near vertical fault along the southern rim and a more complicated pattern along the northern rim, where the event distribution extends towards north, outside the caldera ring fault.

Acoustic signals recorded on seismic stations in Denmark

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In 2009 and 2014 fireballs crossed the sky over Denmark, both passed through the atmosphere with sufficient energy to generate supersonic booms that could be recorded on seismic stations operated by GEUS. The shock wave from the 2009 supersonic boom originated over the Baltic Sea east of the island Falster and was registered by two vertical short period (S-13) seismic sensors located 208 metres apart at station LLD. The 2014 shock wave was recorded on a small net of six broad band (STS-2) seismic stations in the northern part of Jutland covering an area of app. 60 km^2. The analysis of the seismograms from these two events is presented together with observations from other sources such as infrasound data and surveillance cameras. The net of seismic stations in northern Jutland has been in operation in 2014 and 2015, during this period several thunder storms has passed the net of seismic stations and generated clear signals in the seismic recordings. Examples of seismograms from these events are presented together with observations from lightning detection systems.

POSTERS

Analysis of waveforms of local earthquakes from the West Bohemia/Vogtland area and from Reykjanes Peninsula - II

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We analyse waveforms of local microearthquakes that occurred at two seismoactive regions: the West Bohemia/Vogtland region in the Czech Republic and the Reykjanes Peninsula region in the SW Iceland. The microearthquakes are monitored by the WEBNET and REYKJANET local networks, respectively, being operated by the WEBNET group of the IG in Prague. The WEBNET network is in operation for more than twenty years. It consists of 22 three-component seismic stations cover the West Bohemia region and monitor the swarm-like seismicity in the magnitude range from -0.5 to 4.2. The REYKJANET network was built up in summer 2013 with the assistance of colleagues from several institutions (IMO, Uppsala University, MIT, Reykjavik University and ISOR) and consists of 10 three-component seismic stations.

The West Bohemia/Vogtland seismic swarm area is situated at the intersection of two main fault systems, Eger Rift trending NE and Mariánské Lázně Fault zone trending NW. In addition, N-S and E-W trending faults are indicated in the region. The main epicentral area in the vicinity of the Nový Kostel village is associated with the N-S trending fault plane. The region is a part of European Variscides with volcanic activity prolonged till Holocene. The area is famous by numerous mineral springs and CO_2 emanations of mantle origin. Observed earthquakes have predominantly strike-slip mechanisms with minimal volumetric changes.

The waveforms recorded at stations of the WEBNET network display pronounced reflected and refracted waves both for P- and S -wave groups and also split S -waves. Additionally, seismic signals show complexities produced by a 3-D crustal structure, the v_P/v_S ratio variability and wave back-azimuth anomalies. The analysis of such high-frequency complex waveforms can improve our knowledge about tectonic structure of the whole geodynamic area. As an example, a detailed study of the S-wave splitting indicates weak and spatially dependent seismic anisotropy in the upper crust. Using ray tracing techniques, analysis of radiation patterns of seismic sources, stacking of seismograms and numerical modelling of waveforms, we determine depth and the topography of the Moho dicontinuity, and identify a prominent shallow crustal discontinuity at depth of 3.5-6.5 km.

Geologically noticeable younger Reykjanes Peninsula shows much higher tectonic as well as volcanic activity. The area is in an extensional regime of the Mid-Atlantic Ridge, with systems of strike-slip faults, close to active volcanoes. Seismic anisotropy and inhomogeneity of the Earth crust are also quite pronounced. The analysis of waveforms of local earthquakes in this area has just started. We study properties of primary as well secondary phases in seismograms, the presence of regular as well irregular seismic waves, and other interesting wave phenomena.

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Earthquake Bulletins from Denmark: Processing Procedures and Formats

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Over time earthquake bulletins from Denmark have been produced in different formats. The purpose of this presentation is to give an overview of the different formats used for these earthquake bulletins and to describe the history and processing procedures behind the bulletins. The Weekly bulletin, unique for Denmark, is presented by example together with the associated telex format and Monthly Bulletin. And the development of the Weekly bulletin is described.

Macroseismic Intensity Maps of Recent Earthquakes Felt in Denmark

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Abstract
With the purpose of scaling the size of historical earthquakes we have made attempts to correlate areas for intensities 3 and 4 independently with magnitudes for recent events. It looks like those areas for earthquakes in Denmark are as large as those in "bedrock Scandinavia" in Finland, Sweden and southern Norway.

Earthquake swarms in Greenland

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Detecting small earthquakes is a challenge in large, sparsely populated regions such as Greenland, where local seismographs are few and far between. Earthquake swarms consisting of tens to hundreds of shallow earthquakes with magnitudes less than 4 occur in Greenland even though it is a tectonically stable, intraplate environment. The enormous distances between events and detecting stations are a challenge in the analysis. The seismograph coverage of Greenland has vastly improved since the international GLISN-project was initiated in 2008, but still it is a common situation to have less than five seismographs located within 1000 km of an event. Some of the larger earthquakes in the swarms, with a magnitude between 3 and 4 are detected by the IMS on the large seismograph arrays located up to 65 degrees away. The analysis of Greenland earthquake swarms is significantly improved by including IMS waveform data as well as SEB phases. The swarm earthquakes have very similar waveforms, so results obtained for the larger events can be used as a priori knowledge for the rest. One of the major challenges is the lack of local velocity models.

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