UPPSALA UNIVERSITET

FOI

The 50th Nordic Seminar in Seismology
14th – 16th of October in Uppsala

Abstracts for orals and posters

Monday

Seismic networks and monitoring

13:40 – 14:00
Michael Roth: New developments at the Swedish National Seismic Network

M. Roth, B. Lund and the SNSN team
Uppsala University

The Swedish National Seismic Network consists of close to 70 permanent broadband stations spanning the latitude range from 55.5 to 68.5. All stations are recording at 100 samples per second and are sending continuous data in real-time to our centre at University Uppsala. In the current year we have completed the groundwork for a new station ('bog') northeast of Stockholm, and its operation will commence at the end of October. We have integrated data streams from the Hagfors array into our processing in order to replace our station at Uddeholm, which suffers of increased ambient cultural noise. We are progressing to migrate our decentralized automatic processing system (SIL) into a centralized version (MSIL). This will decrease computational load at the field stations, and it allows us to upgrade station computer software as well as hardware. Parallel to the SIL/MSIL processing routines we have implemented and configured Seiscomp and Earthworm software for automatic event location. Both systems provide relative robust and consistent event parameters, and we are considering ways to merge results from all automatic systems in order to decrease the workload for analyst review.

14:00 – 14:20
Christian Weidle: Recent developments in seismic network densification in Northern Germany

C. Weidle[1], T. Meier[1], A. Omlin[2], E. Wetzig[3], K. Obst[4]

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Northern Germany is a seismically weakly active zone with an overall low exposure to seismic hazard. Despite this, earthquakes with magnitudes above 3 of natural and anthropogenic origin have repeatedly occurred in the last decades both on- and offshore and have been widely felt by the population. A high detection threshold for seismic events is a result of sparse instrumentation in the North German Basin (NGB) and limits our understanding of present seismotectonics and the state of stress in the known fault zones in the area.

The extension and formation of the NGB included the deposition of a thick Upper Permian salt layer that was mobilized in response to repeated tectonic events. In several places, salt domes that have pinched the surface and uplifted chalk cliffs along the Baltic Sea coast are evidence that – despite the present seismic quiescence – tectonic forces are at play that might cause larger earthquakes. Another potential source area for larger earthquakes is the nearby Sorgenfrei-Tornquist Zone at the southwestern edge of the Baltic Shield. On the one hand, it is a known large-scale intercontinental fault system, however, its associated smaller scale faults and their present activity are not well known. In the Quartenary layer of northern Germany, neotectonic deformation is interpreted in various places to have originated from earthquakes and related processes in (post)glacial times. Therefore, the occurrence of larger earthquakes than presently observed can not be ruled out, particularly because the overall state of stress on the existing fault systems in the area is largely unknown.

As a consequence of the low seismic hazard and low occurrence of earthquakes in the region, earthquake monitoring has been pursued with accordingly low priority in the past. Generally unfavorable observational conditions in the NGB are also a limiting factor for seismic monitoring. It is no surprise then that the magnitude of completeness for seismic events in the back catalogue of northern Germany is estimated to be on the order of 2.3 in Schleswig-Holstein and close to 3 in Mecklenburg-Western Pomerania. To reduce the magnitude of completeness and improve our understanding of potentially active fault systems, we seek to densify the observational network from interstation distances of previously >150km to <50km.

In a multi-institutional collaboration, we have since 2014 been able to increase the number of permanent broadband stations in Schleswig-Holstein from previously two to five where all data is freely available through the EIDA node at the BGR in Hannover. In addition, we currently operate two small-scale seismic arrays in Schleswig-Holstein to monitor areas of potentially active salt tectonics around Bad Segeberg and on the island of Helgoland. Data particularly from the latter will also form an important dataset to investigate properties of oceanic microseim in the North Sea.

Recently we have started with seismometer deployments in Mecklenburg-Western Pomerania where we are currently investigating potential sites for a permanent expansion of the seismic network with a first priority along the Baltic Sea coast. Besides improving seismic monitoring in northern Germany, the extension of the seismic network should also provide useful data for our neighbors around the southwestern Baltic sea.

14:20 – 14:40
Leif Persson: Calibration of the ML scale for the Hagfors station

L. Persson and C. Hellesen

FOI

Seismic monitoring of explosions at regional distances is an important task for FOI. For yield estimation, a local magnitude scale ML is necessary to establish for the Hagfors station. The analysis is based on comparison between events at regional distances in Scandinavia. The calibration is based on comparison with the ML scale of NORSAR.

15:10 – 15:30
Peter Voss: The seismological service of Denmark and the Nordic cooperation

P.H. Voss

GEUS

This presentation consist of two parts, in the first part an introduction to the seismological service of Denmark is given, with a focus on the history of the service and the Nordic cooperation. It includes the early years of Dr. Inge Lehmann, the first seismographs, the nuclear test ban, a missing seismic array, nuclear power, hardware and software cooperation and the Nordic-European link. Topics for future opportunities to continue the fruitful Nordic cooperation are given. The second part includes an overview of the recent developments in the seismological group at GEUS and other news; new temporary stations on Zealand and in Central West Greenland, Distributed *Acoustic* Sensor (*DAS*) data, a fireball in Greenland, CTBTO link to SEISAN, OBS hydrophone data, location using 3D models and in the theater: Inge Lehmann.

15:30 – 15:50

Carl Hellesen: Seismic and infrasound measurements from the SHIELD explosion

Carl Hellesen[1], Erik Johansson[2], Tormod Kvaerna[3], Peje Nilsson[4], Leif KG Persson[1], Fredrik Rutqvist[4]

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During the SHIELD test explosion, seismic and infra-sound measurements were made with the aim to obtain fully controlled ground truth data for determining the location and yield of large explosions in Scandinavia. An explosion above ground, such as SHIELD, can be seen as a seismic source where a fraction of the released energy is directed down in the earth's crust. For this reason, the coupling to the ground is generally much weaker when compared with well coupled underground explosions, such as historical nuclear tests. We therefore use the combination of seismic and infra-sound measurements to obtain a better estimate of the yield. We also compare the results obtained from the SHIELD test with a series of smaller test explosions performed at the same shooting range (Älvdalen) as well as quarry blasts in Sweden where the ground truth data are also readily available.

Tuesday

50th anniversary session

09:00 – 09:30
Ola Dahlman: Nordic cooperation a forerunner to international work on CTBT verification.

O. Dahlman

International scientific cooperation has been of key importance to develop and implement the CTBT verification regime. The cooperation among the Nordic countries was one of the very first steps and an important forerunner to a broader and more focused cooperation within the frame of the Conference on Disarmament. This presentation will reflect on this historical development and also on the role of science and scientists in support of global security.

09:30 – 10:00
Svein Mykkeltveit: Reflecting on 50 years of Nordic Seismology Seminars, from the perspective of the nuclear test ban

S. Mykkeltveit

NORSAR

The Nordic Seminar on Detection Seismology - later the Nordic Seismology Seminar - has since the beginning in 1969 been an important venue for seismologists from the Nordic countries to come together annually to discuss issues of common interest. This presentation will concentrate on developments within the area of detection seismology, or seismological verification of a nuclear test ban, both from a technical and a diplomatic/political perspective, as seen through cooperation and efforts within the Nordic countries, and as frequently reported on at these seminars. The emphasis will be on the 1980s and the1990s, which were decades with a large amount of work in our countries to contribute to the technical basis for test ban negotiations, and later to the implementation of the CTBT verification regime.

10:00 – 10:30
Leif Persson: Some pictures from 50 years of seismology at FOA/FOI

L. Persson

FOI

Espoo Finland 1992

11:00 – 11:30
Tormod Kvaerna: Some seismic observational highlights 1969-2019; nuclear tests, other man-made events, and earthquakes

T. Kvaerna

NORSAR

Being located within the stable Eurasian plate, seismic stations in our region are generally good for observing seismic events occurring in Europe and Asia. The Hagfors- and the NORSAR arrays, established 50 years ago, demonstrated unique capabilities for detecting underground nuclear tests in the former Soviet Union and China. Over the years, new deployments and upgrades of station networks and arrays have strongly enhanced monitoring of small seismic events in the Nordic and neighboring regions. With emphasis on monitoring of nuclear testing activities, we will in this talk present a suite of interesting seismic observations and analyses made over the last five decades.

Åkersberga Sweden 2004

11:30 – 12:00
Hilmar Bungum: Some reflections on 50+ years in seismological science

H. Bungum

NORSAR

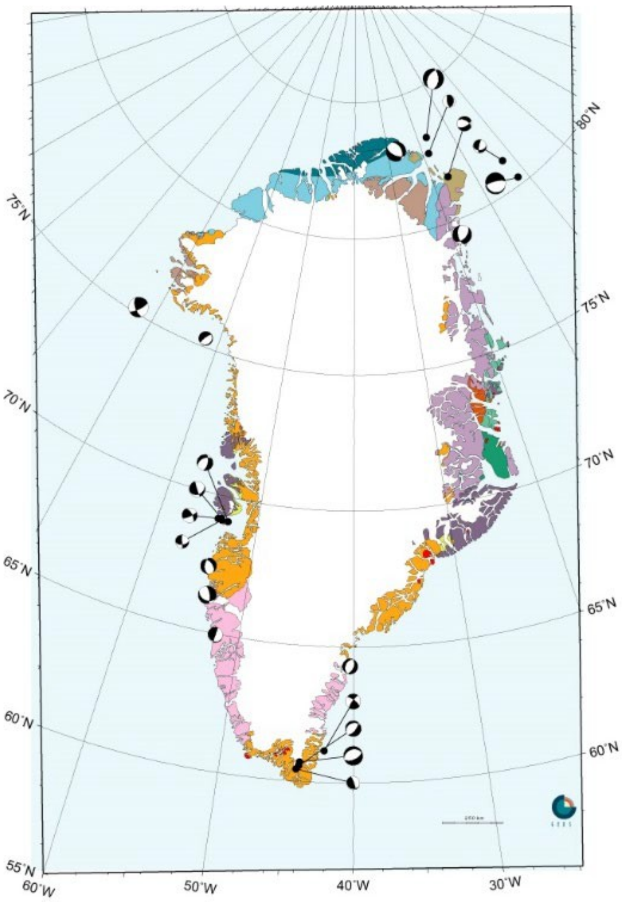
In this presentation I will review briefly my earlier relation to the Nordic Seismological Seminar over 50 years and also some of the work I have done during this time. However, first of all I will be discussing some issues related to seismic hazard for sensitive installations, such as nuclear power plants and waste depositories, which has been an increasingly central subject for me over the last two decades. The widely used SSHAC methodology for such studies has been developed by the U.S. Nuclear Regulatory Commission since the late 1980s, and gradually refined since then. The main SSHAC goal is to identify the complete set of data, models, and methods proposed by the larger technical community that are relevant to the hazard analysis (evaluation), and to apply these in a way that represents the centre, body, and range of technically defensible interpretations (integration). Finally I will discuss briefly some issues related to seismic hazard estimation in low-seismicity regions.

Natural and induced seismicity, and structure

13:30 – 13:50
Trine Dahl Jensen: Focal mechanisms in Greenland and Baffin

T. Dahl-Jensen, P. Voss and T. B. Larsen

GEUS



Initiated by a series of earthquakes in Central West Greenland, and as part of the INTAROS project, focal mechanisms for Greenland and Baffin Bay are presented.

During the first weeks of April, 2016, the little village of Qeqertarsuaq on the south coast of Disko Island, West Greenland, experienced a large number of earthquakes. A large (for the region) Mb 4.7 event was recorded internationally, preceded by six smaller events in the hours before the larger event. A massive aftershock series followed during the following weeks with more than 150 events, two of which were Mb 4.5. The majority of the earthquakes occurred within an area of 50 x 50 km just south of Disko Island. The location of the main event suggests a source depth in the upper crust. Sparse coverage of seismic profiles in the region show faults in the upper crust that have been active in recent geological time. Focal mechanisms for the larger earthquakes are compared with focal mechanisms for Baffin Bay between Greenland and Canada.

In addition, the DNK database for Greenland has been searched for earthquakes with sufficient data allowing for calculation of focal mechanisms, resulting in a number of new results to be added.

13:50 – 14:10
Kristín Jónsdóttir: Earthquake "activities" in North Iceland: The triennial workshop NORTHQUAKE: Seismic swarms in the Tjörnes fracture zone and the Húsavik earthquake exercise

K. Jónsdóttir[1], G. B. Guðmundsson[1], L- Passarelli[2], S. Jónsson[2], A. Ruiz Angulo[1], F. Rodrigo Rodriguez[3], H. Grímsdóttir[1] & Monitoring team at IMO[1]

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The Tjörnes fracture zone (TFZ) in North Iceland is one of the two seismically most active areas in Iceland with on average 4000 earthquakes detected annually since 1993 by the regional seismic network operated by the Icelandic Meteorological Office. Although most of the seismicity occurs off the north coast and the seismic network has only one island seismic station (on Grímsey), the seismic network does an impressive job of detecting small earthquakes (down to magnitude -0.5) and locating their epicentre. The TFZ, essentially a transform zone between the northern volcanic zone of Iceland and the Mid-Atlantic Ridge north of Iceland, has two major transform segments with distinctly different characteristics; the more active Grímsey Oblique Rift (GOR) located to the north includes seismic processes that seem to be of both volcanic and tectonic origin while the Húsavík-Flatey Fault (HFF) to the south near the coast has events mostly occurring along a well-developed transform fault system. In addition, diffuse seismicity occurs between the two transform structures and to the south of the HFF. Overall, the TFZ seismicity is dominated by energetic seismic swarms that take place every 2-3 years in both the GOR and the HFF, swarms that are without a clear mainshock and include thousands of earthquakes occurring over days to weeks.

There is significant earthquake hazard in North Iceland where earthquakes of magnitude 6-7 can occur. First-hand accounts and a variety of data of the earthquakes near Kópasker village in 1976 (M6.3), in Skagafjörður in 1963 (M7) and near Dalvík in 1934 (M6.3) provide information about what we can expect in the coming decades. Over 40 years have passed since the last major earthquake in 1976, which is the longest period without a major event in the area for almost 200 years.

In order to address the status of knowledge of the TFZ a triennial workshop (Northquake) was held for the third time in May this year in Húsavík. Workshop topics included earthquake geology and tectonics, current earthquake activity, earthquake hazard and risk, and multicomponent earthquake monitoring. Response to a hypothetical earthquake scenario in the region was exercised prior to the workshop. The main players of the exercise were: The Civil Protection in Reykjavík and in N-Iceland (responsible for planning police response), the Icelandic Meteorological Office (responsible for regional earthquake monitoring), the Natural Catastrophe Insurance of Iceland and the Icelandic Road and Coastal Administration. The scenario was a major earthquake on the HFF, with the aim to imitate the intensity of the earthquakes in 1755 and 1872. Cascading hazards observed during past major earthquakes, such as tsunamis, rock falls and landslides, were also included in the exercise and added complexities to the needed response.

We will present an overview of the latest seismic activity in the TFZ along with some lessons learned at the Northquake workshop and from the Húsavík earthquake exercise.

Iceland, 1991

14:10 – 14:30

Alex Hobé: The tomographic baseline: a benefit of permanent seismic networks

A. Hobé[1], O. Gudmundsson[1], A. Tryggvason[1], SIL seismological group[2]

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Permanent seismic networks provide multiple benefits for society and geophysicists. Often designed mainly for detection and location of local events, the network data can be used to study teleseismic events as well as tremor data and noise. Catalogue data may also be used for structural studies on different scales, e.g using Local Earthquake Tomography (LET). Temporary campaigns for LET may provide increased spatial resolution. However, comparison of the results of such campaigns is often hindered by differences in raypath coverage (due to varying earthquake and station distribution), regularization, and measurement errors between the campaigns. The study of temporal variations of seismic velocities (which reflect changes in state variables of the crust) is emerging as a new field of study. Permanent seismic catalogues are attractive for such studies due to the long time periods spanned by these recordings. The same obstacles involved in comparing results between temporal deployments are inherent in models derived from network data from different time periods. As long as there are no changes to the permanent network (i.e. addition or decommissioning of stations) the main source of error may often be the variability of the seismicity. Using 15 years of data from the permanent SIL network on the Reykjanes Peninsula in Iceland, we show a baseline study focusing on the Krýsuv.k area. The main purpose is to investigate if there is enough evidence to support the hypothesis of velocity changes with time over the null-hypothesis (no such changes). The recurrence of a characteristic seismicity distribution in this area is a benefit here as it reduces differences due to raypath geometry. The effect of variations in the seismicity (and station) distribution are quantified using synthetic tests. We additionally explore the possibility of jointly inverting data from different time periods as a means to obtain models that contain a minimum change between these periods. The results of this study will be used as a baseline for comparison in a future study using denser networks in the same area with temporal changes in the network geometry.

14:30 – 14:50
Ólafur Guðmundsson: Locating volcanic tremor with network data

O. Gudmundsson

Department of Earth Sciences, Uppsala University, Sweden

Tremor is continuous shaking of the ground, often with an emergent onset. Therefore, measurement of absolute timing of concrete waves and consequently the location of the source is difficult. In the absence of multiple dense arrays we can attempt to use the amplitude decay of the tremor within a monitoring network (Battaglia & Aki, 2003) or indirect measurements of differential time based on correlations within the network to locate the tremor source. Both require knowledge about the velocity structure within the network.
A common setting for tremor observations is at volcanoes, often associated with eruption. We call this collectively volcanic tremor, although the nature of volcanic tremor is quite varied (Konstantinuou & Schlindwein, 2003). The velocity structure around volcanoes tends to be complex.

We present analysis of volcanic tremor at Katla and Eyjafjallajokull volcanoes in Iceland, where amplitude behavior was complex (Sgattoni et al., 2017) and the power radiation pattern of the tremor source demonstrably varied with time and could therefore not have been uniform at all times (Benediktsdo’ttir, 2019). Furthermore, attenuation structure is apparently not uniform. This complicates the tremor source location based on amplitude data.

We also outline a series of methods based on back-projected differential-time information in correlations within the monitoring networks at Katla and Eyjafjallajokull. First, we demonstrate that noise in the correlograms is signal generated and presumably caused by scattering. We then propose a double correlation method to suppress the signal-generated noise (Li et al. 2017a) and a method based on products of back-projected correlograms to further suppress the noise (Li et al. 2017b). Finally, we introduce a probabilistic method, where each correlation trace is first transformed into likelihood based on Bayes’ theorem and characterization of the noise distribution, then back projected with appropriate scaling and convolved with a kernel to account for the uncertainty of the back projection. The joint spatial likelihood distribution of tremor-source location is then the product of all individual back projections upon the assumption of independence (Li & Gudmundsson, submitted to Geophys. Res. Lett.).

This probabilistic method has the advantage of providing a location estimate as well as a measure of its uncertainty. We demonstrate with synthetic tests that an uncertainty estimate of 0.5 km can be realistic for sources within a seven-station network of 20 km aperture for sources internal to the network.

Battaglia, J. & K. Aki, 2003. Location of seismic events and eruptive fissures on the Piton de la Fournaise volcano using seismic amplitudes,]. Geophys. Res. 108(88), 2364, doi:10.1029/200218002193.
Konstantinou, K.I. & V. Schlindvein, 2003. Nature, wave-field properties and source mechanism of volcanic tremor: a review,]. Volcano]. Geotherm. Res. 119(1-4), 161-187.
Sgattoni, G., O. Gudmundsson, P. Einarsson, F. Lucchi, K.L. Li, H. Sadeghisorkhani, R. Roberts & A. Tryggvason, 2017. The 2011 unrest at Katla volcano: characterization and interpretation of the tremor sources,]. Volc. Geoth. Res. 338, 63-78.
Benediktsdéttir, A., O. Gudmundsson & Bryndis Brandsdéttir, Volcanic tremor of the 2010 Eyjafjallajaekull eruption, in Benediktsdéttir, A., 2019. Propagating rifts at the northern Mid-Atlantic Ridge and South Iceland: a Geophysical Study, PhD thesis, University ofIceland.
Li, K.L., G. Sgattoni, H. Sadeghisorkhani, R. Roberts & O. Gudmundsson, 2017a. A double correlation tremor-location method, Geophys.]. Int. 208(2), 1231-1236.
Li, K.L, H. Sadeghisorkhani, G. Sgattoni, O. Gudmundsson & R. Roberts, 2017b. Locating tremor using stacked products of correlations, Geophys. Res. Lett. 44(7), 3156-3164.
Li, K.L. & O. Gudmundsson, 2 019. A probabilistic tremor location method, submitted to Geophys. Res. Lett.

15:20 – 15:40
Björn Lund: Triggering of intraplate seismicity by variations in glacier loading

B. Lund[1], P. Schmidt[1], J.-O, Näslund[2]

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[2]Swedish Nuclear Fuel and Waste Management Co. (SKB)

The occurrence of very large intraplate earthquakes in northern Fennoscandia at the end of the Weichselian glaciation is commonly attributed to the triggering effect of glacially induced stresses. The load of the ice sheet inducedsignificant horizontal as well as vertical stresses in the crust and during deglaciation the relaxation rate of the vertical stress was much higher than that of the horizontal stresses. The increasing differential stress, in combination with an appropriate background stress field, may have triggered the earthquakes. In addition, the long residence time of the ice sheet may have prevented release of accumulating tectonic strain. Here we will use glacial isostatic adjustment modelling to derive the stress evolution during a glacial cycle, using a reconstruction of the Weichselian ice sheet and a few appropriate Earth models. We then apply a frictionally based procedure to infer how the interaction of glacially induced stresses, the background stress field and tectonic stress accumulation affect earthquake productivity during and soon after the glaciation.

15:40 – 16:00
Tommi Vuorinen: Monitoring an Enhanced Geothermal System in Downtown Helsinki

T. Vuorinen, G. Hillers, P. Mäntyniemi, M. Uski, K. Oinonen, J. Kortström

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In June and July 2018 St1 Deep Heat Oy (ST1DH) performed hydraulic stimulation between 6 km and 7 km depth beneath the Aalto University campus, in Otaniemi, Espoo, Finland, to establish an Enhanced Geothermal System (EGS) doublet for district heating. The remarkable depth of the stimulation can be attributed to the shallow geothermal gradient intrinsic to the geologically stable Fennoscandian shield. The Institute of Seismology, University of Helsinki (ISUH) monitored the stimulation stage using a network of surface seismic stations and geophones.

The EGS-site is located near the center of Greater Helsinki in Southern Finland; a region that has low natural seismicity and shallow to non-existent sedimentary cover. Many sensitive installations and other infrastructure are situated within few kilometers of the site. These provide unique challenges, requirements but also opportunities for the seismic monitoring of the project.

We present the various seismic networks that were used in monitoring the site, as well as the induced seismicity that was observed during and after the stimulation. We will also briefly discuss the public response to the induced seismicity with focus on the largest event. For background, the natural seismicity of Southern Finland is briefly covered, as well as the so-called Traffic Light System (TLS) that was used during the stimulation to manage the induced seismicity.

16:00 – 16:20
Kati Oinonen: Information and recommendations for the Finninsh Ministry of the Environment about geothermal energy

K. Oinonen and M. Uski

Institute of Seismology, University of Helsinki

In 2017 a private Finnish energy company St1 started to construct deep geothermal heating plant in Espoo, capital area of Finland. The plan was to drill a 6.1 km deep well, to stimulate bedrock by injecting water with high pressure, and then to drill a second well to the direction of the opened up water flow channels. The (first) stimulation was conducted during summer 2018 and at the moment the company is drilling the second well.

At the beginning of the project the authorities had no clear knowledge of the process and the Finnish legislation did not either recognize the production of deep geothermal energy. Therefore, the Finninsh Ministry of the Environment asked the Institute of Seismology, University of Helsinki and the Geological Survey of Finland to prepare a report as a background for future regulatory work on geothermal power plants and their environmental impacts. The report was published in May 2019 and it will be translated into Swedish and English later on.

The report is based on experience gained during the planning and first stimulation of the St1 site and literature review on legislation and guidelines for geothermal energy facilities in other countries. It gives information on different types of deep geothermal systems, their environmental aspects and seismic risks. It also recommends how different plant techniques should be monitored. In the presentation we will show some of the results and recommendations.

Wednesday

EPOS

09:00 – 09:30
Kuvvet Atakan: European Plate Observing System (EPOS): a Sustainable Research Infrastructure in Solid Earth Science

K. Atakan[1] and the EPOS Consortium[2]

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[2] EPOS Consortium: www.epos-eu.org

The *European Plate Observing System* (EPOS) aims to create a pan-European infrastructure for solid Earth science to support a safe and sustainable society (Horison2020 – InfraDev Programme – EPOS-IP Project no. 676564). The main vision of the European Plate Observing System (EPOS) is to address the three basic challenges in Earth Science: (i) unravelling the Earth's deformational processes which are part of the Earth system evolution in time, (ii) understanding geo-hazards and their implications to society, and (iii) contributing to the safe and sustainable use of geo-resources. The mission of EPOS is to monitor and understand the dynamic and complex Earth system by relying on new e-science opportunities and integrating diverse and advanced Research Infrastructures for solid Earth science.

A large number of Data, Data products, Software and Services (DDSS) are already implemented (in total 186) provided by the 10 Thematic Core Services (TCS) covering the entire spectrum of Solid Earth Science. Integration of these elements with the Integrated Core Services - Central Hub (ICS-C) is already developed as a prototype which is being constantly improved to meet the user requirements. The ICS-C will go into operational phase in 2020 and is hosted jointly by the three Geological Surveys of UK (BGS), France (BRGM) and Denmark (GEUS). Validation of the services started with an internal verification through Technical Readiness Assessment (TRA) and followed by the external validation by an international expert panel.

In parallel with the technical implementation of EPOS ICS-C, there has been considerable effort put in legal, governance and financial aspects of the EPOS services. All 10 Thematic Core Services (TCS) have developed their internal consortia and have identified the related service providers that are legal bodies committed to provide these services through contractual relations with EPOS. In order to provide a sustainable organizational structure for EPOS, the official EPOS-ERIC (EPOS – European Research Infrastructure Consortium: A legal body under the jurisdiction of the European Parliament) is now established and launched in November 2018 in Rome, Italy by the European Commission. Italy was selected after a competitive call and INGV in Rome is now the hosting institution for EPOS-ERIC. In

total, 12 countries have signed the membership for EPOS-ERIC as founding members. Several more countries are in the process of preparing for membership.
Recently, the European Commission through the H2020 InfraDev Programme, has awarded EPOS with a three-year project for the EPOS Sustainability Phase (EPOS-SP). EPOS-SP will start early in Jan/Dec 2020 and aims to attract new member states, as well as new thematic core services (TCS). Currently, the tsunami research and the earthquake engineering communities are interested in becoming TCSs. EPOS-SP will focus on developing sustainable services during the transition from the implementation phase (EPOS-IP) to the operational phase (EPOS-OP).

09:30 – 09:50
Tor Langeland - EPOS-Norway Portal

T. Langeland[1], O. D. Lampe[1], G. Fonnes[1], K. Atakan[2], J. Michalek[2], X. Wang[2], C. Rønnevik[2], T. Utheim[2], K. Tellefsen[2]

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[2]University of Bergen (UIB), Norway

The European Plate Observing System (EPOS) is a European project about building a pan-European infrastructure for accessing solid Earth science data. Implementation phase of the EPOS project (EPOS-IP – EU Horison2020 – InfraDev Programme – Project no. 676564) started in 2015. The EPOS-Norway project (EPOS-N; RCN-Infrastructure Programme - Project no. 245763) is a Norwegian project funded by National Research Council and is closely linked to the EPOS-IP project. The aim of the Norwegian EPOS e-infrastructure is to integrate data from the seismological and geodetic networks, as well as the data from the geological and geophysical data repositories. In this abstract, we present ongoing work on development of the Norwegian web portal for accessing the data.

The EPOS-N Portal is implemented by adapting Enlighten-web, a server-client program developed by NORCE in several projects, among them EPOS-Norway. Enlighten-web facilitates interactive visual analysis of large multidimensional data sets, and supports interactive mapping of millions of points. The Enlighten-web client runs inside a web browser. The user can create layouts consisting of one or more plots or views. Supported plot types are table views, scatter plots, line plots and map views. For the map views the CESIUM is applied. Multiple scatter plots can be mapped on top of these map views.

An important element in the Enlighten-web functionality is brushing and linking, which is useful for exploring complex data sets to discover correlations and interesting properties hidden in the data. Brushing refers to interactively selecting a subset of the data using the mouse e.g. to dynamically alter a bounding box. Linking involves two or more views on the same data sets, showing different attributes. The views are linked to each other, so that highlighting a subset in one view automatically leads to the corresponding subsets being highlighted in the linked views. If the updates in the linked plots are close to real-time while brushing, the user can perceive complex trends in the data by seeing how the selections in the linked plots vary depending on changes in the brushed subset. This interactivity, especially for large data sets, requires GPU acceleration of the graphics rendering. In Enlighten-web, this is realized by using WebGL.

For metadata handling, the EPOS-N Portal will access an external database compatible with the EPOS-IP project. Metadata can e.g. specify data sources, services, ownership, license information and data policy. Bar charts can be used for faceted search in metadata, e.g. search by categories. EPOS-N Portal can access remote datasets via web services. Relevant web services include FDSNWS for seismological data, GLASS for GNSS and OGC services for geological and geophysical data (e.g. WMS – Web Map Services). Standalone datasets are available through preloaded data files. Users can also simply add another WMS server or upload their own dataset for visualization.

Enlighten–web will also be adapted as a pilot ICS-D (Distributed Integrated Core Services) for visualization. The ICS-C (Central Integrated Core Services) is the entry point for users for accessing the e-Infrastructure under establishment in the EPOS IP project. ICS-C will let users create and manage workflows that usually include accessing data and services located in the EPOS Thematic Core Services (TCS). The ICS-C and TCSs will be extended with additional computing facilities through the ICS-D concept.

09:50 – 10:10
Toni Veikkolainen: Developing Finnish online services in seismology

T. Veikkolainen, T. Vuorinen, J. Kortström, T. Luhta

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The operational staff of Institute of Seismology has during this year put remarkable effort to the development of online services. Currently, the general website of the institute is administrated via Drupal content management system and is available at https://www.helsinki.fi/fi/seismologian-instituutti. General news and information about research and seismicity is delivered via this site. Certain services, such as seismic bulletins and earthquake search tool, remain on a separate server outside this system. In addition, Institute of Seismology maintains four Twitter accounts:

- Finquakes (automatic earthquake information in English)
- Seismofin (general news in English)

- Maanjaristykset (automatic earthquake information in Finnish)
- Seismologit (general news in Finnish)

The content of Finquakes and Maanjaristykset accounts is generated via server-side Python scripts, which use tweepy module Python and read the contents of XML files generated by LUOVA managers. The management is active 24/7 and usually earthquake information is delivered to the account within two hours of the earthquake. Besides global earthquake data, the service publishes announcements of Finnish earthquakes, which have at least local interest. Due to the low level of natural seismicity in Finland, all Finnish cases of magnitude 1.0 or greater are taken into account. These usually make news, at least in local context. Seismofin and Seismologit accounts are updated manually during office hours and our aim is to publish at least one tweet per week. Subjects of tweets include, but are not limited to notable explosions and other seismicity beyond natural phenomena, scientific articles, conference trips and other work-related travel, and maintenance of Finnish seismic infrastructure. Most recent tweets are also visible on the general site of the institute.

The automatic earthquake information derives from the National disaster warning system LUOVA. An online map illustrates earthquakes registered by the system (http://www.seismo.helsinki.fi/EQ-search/earthquakemap.php) during the last week. This map is now published in English, yet a Finnish version is available as well. In general, earthquakes in the map are at least of magnitude 4.0. Circle sizes describe the magnitude, while circle colors depend on the event time, flowing from red (fresh) via yellow (two days old) to green (almost a week ago). Numeric information about location, magnitude, time and depth can be read from respective info windows. The Finnish version also includes Finnish location descriptions modified from the traditional Flinn-Engdahl scheme.

The FENCAT earthquake search tool (http://www.seismo.helsinki.fi/EQs/query.php) allows the user to search the North European earthquake catalogue for instrumental and macroseismic events. Both preliminary data and final bulletin data are available, yet these are clearly distinguished by colors. The user may easily change the search location and include various conditions to the query. Results can be viewed on the map and list generated by server-side scripts, and download as CSV file is also possible. This tool, as well as the LUOVA map, were previously run using Google Maps. In general, we aim at transfer of our all map services from Google Maps to Leaflet / Open Street Map or other possible platforms due to changes in pricing policy of Google, and also due to our desire to advance the use of open-source software.

10:40 – 11:00 Annakaisa Korja: The Nordic Research Infrastructure Hub proposal

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Åkersberga 2004

POSTERS

Frederic Wagner: Seismic migration and stack based event detection: a test study for the Swedish National Seismic Network

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In times of rapidly growing computational resources previously inefficient detection algorithms may become suitable for real-time earthquake monitoring. In an effort improve the detection statistics for the SNSN a recently developed earthquake detection algorithm (Wagner et al., 2017) based on the methodology of seismic migration (or back-propagation) and stacking is tested for its applicability on a regional scale and in a near real-time monitoring environment to complement existing detection routines.

The method consists of back-propagation of seismogram attributes, e.g. a short-term long-term average ratio (STA/LTA), from a subset of seismic stations using traveltime look up tables followed by stacking of the time-shifted time series for hypothetical hypocentres in a three dimensional grid. Peaks in the gridded stack are detected as potential hypocentres and a seismic event is declared if a series of criteria are met.

The algorithm was initially developed for a dense local seismic network in Hengill, Iceland, primarily observing swarm activity (natural and induced). Applying the algorithm on a regional scale to a sparser network such as the SNSN with different types of seismic events and varying seismicity poses new challenges for proper tuning. This presentation focuses on the tuning of the algorithm in terms of detection parameters and selection criteria as well as a direct comparison with the the currently running SIL system for a finite period of archived data (not real-time).

Gintare Andriuskeviciene: State of Seismological observation and monitoring in Lithuania

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The territory of Lithuania comprises a part of the Baltic sedimentary basin situated in the western part of the East European Craton that is characterised by low seismic activity - the historical sources since 1616 to 1964 record only a few tens of weak or moderate earthquakes (Pačėsa et al., 2005, Lazauskienė et al., 2012). The eastern Baltic region is more seismically active comparing with the more “inland” aseismic territories of the craton. Several tens (~ 40) of earthquakes of intensities of VI-VII (MSK-64 scale) and local magnitudes up to M_L = 5 are recorded in the Baltic region and neighbouring since 1616. The strongest instrumentally registered earthquakes are Ossmussare (Estonia) earthquake of 1976 (with maximal magnitude up to M_L = 4,75) and the Kaliningrad (Russia) earthquakes of 2004 of magnitudes, respectively, M_L = 4.75 and M_L = 5.0 (M_w = 5.2). The other more significant earthquakes in the region are: February 22, 1821, Kokneses (Estonia), M_L = 4.5; December 28, 1908, Gudogai (Belarus), M_L = 4.5; December 29, 1908, Madona (Latvia); M_L = 4.5 (Boborikin et al., 1993). All the mentioned earthquakes within the same Baltic sedimentary basin in the same tectonic setting show the recent seismic activity of the Baltic region.

The first instrumental seismological observations in Lithuania started in 1970 as Vilnius seismic station was founded. Three analog long period (T=25 s) and three short period (T=1.5 s) seismometers were installed in the territory of Institute of Physics at outskirts of Vilnius. 450 distant and regional seismic events were reported in the seismic bulletin of Vilnius seismic station since 1991 to 1995. Distances from the epicentres to Vilnius station were calculated and reported in the bulletin. No local events were registered in Vilnius seismic station (Pačėsa, 2005).

The first comprehensive study of seismic activity of Lithuania was carried out in 1988 as a part of re-examination of safety of Ignalina Nuclear Power Plant (INPP). Seismic Alarm System (SAS) and complementary Seismic Monitoring System (SMS) were installed in the INPP in 1999. The SAS was designed to issue alarm when damaging seismic wave approaches the INPP, while the SMS was designed to collect data of local seismicity and dynamic behaviour of structures of the INPP (Pačėsa, 2005).

Lithuanian Geological Survey (LGT) implements national seismological monitoring since 1999 and since 2001 has access to CTBTO IDC data. LGS seismological network consists of two broadband seismic stations PBUR and PABE, which are connected to GEOFON network and four short period seismic stations (IIGN, IDID, IZAR, ISAL), which in 2018 were took over from the decommissioned Ignalina NPP.

In LGT all acquired seismological data are analysed, catalogued and overviewed in monthly and yearly bulletins. In 2018, 2077 seismic events were identified, 947 of them were teleseismic events (epicenters located more than 2200 km away), 92 regional (epicenters located more than 800 km away) and 1038 local (epicenters located with 800 km events).

Gunnar Eggertsson: Identifying P and S phases using supervised learning algorithms

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In order to identify P and S phases on a station specific basis, and thereby ease the subsequent phase association process, we apply two types of supervised learning algorithms; logistic regression and multilayer perceptron (MLP, an artificial neural network), to data from the Swedish National Seismic Network. A similar approach was used successfully on Icelandic data (Bödvarsson et al., 1996). As input data we use station specific parametric information on detected phases which have been identified as P or S and associated to seismic events by manual inspection. The parametric data include onset time, duration, signal and noise amplitudes, three-component analysis (coherency and apparent velocity) and references to previous and next phases. We implement both algorithms using the Keras deep learning library in Python and evaluate the results in terms of accuracy, precision and recall. We find that both the logistic regression and MLP algorithms perform very well, with an accuracy of above 90% for 62 out of 64 stations, and that the MLP is consistently better than the logistic regression at 96% accuracy for 62 of 64 stations, with the two remaining at above 90%. Similarly the MLP perform better than logistic regression for precision and recall. Our data set includes varying numbers of labeled phases for each station, from more than 40,000 down to only about 2,000. In addition, on average more than 80% of the data are P phases. We therefore test the identification algorithms on under-sampled data sets with balanced numbers of P and S phases and find that accuracy numbers stay similar but that precision decreases slightly and recall increases, i.e. higher proportion of actual S phases become correctly identified (example of precision-recall trade-off).

Jan Michálek: EPOS-Norway – Integration of Norwegian geoscientific data into a common e-infrastucture

Jan Michálek

University of Bergen

The European Plate Observing System (EPOS) is a European project about building a pan-European infrastructure for accessing solid Earth science data. Implementation phase of the EPOS project (EPOS-IP – EU Horison2020 – InfraDev Programme – Project no. 676564) started in 2015. The EPOS-Norway project (EPOS-N; RCN-Infrastructure Programme - Project no. 245763) is a Norwegian project funded by National Research Council and is closely linked to the EPOS-IP project. The aims of EPOS-N project are divided into four work packages where one of them is about integrating Norwegian geoscientific data into an e-infrastructure. The other three work packages are: management of the project, improving the geoscientific monitoring in the Arctic and establishing Solid Earth Science Forum to communicate the progress within the geoscientific community and also providing feedback to the development group of the e-infrastructure.

Among the six EPOS-N project partners, five institutions are actively participating and providing data in the EPOS-N project – University of Bergen (UIB), University of Oslo (UIO), Norwegian Mapping Authority (NMA), Geological Survey of Norway (NGU) and NORSAR. The data which are about to be integrated are divided into categories according to the thematic fields – seismology, geodesy, geological maps and geophysical data. Before the data will be integrated into the e-infrastructure their formats need to follow the international standards which were already developed by the communities of geoscientists around the world. Metadata are stored in Granularity Database tool (developed in EPOS-IP) and therefore easily accessible by other tools. For now, there are 33 Data, Data Products, Software and Services (DDSS) described in EPOS-N list.

We present the Norwegian approach of integration of the geoscientific data into the e-infrastructure, closely following the EPOS-IP project development. The sixth partner in the project – NORCE Norwegian Research Centre AS is specialized in visualizations of data and developing the EPOS-N Portal. It is web-based graphical user interface adopting Enlighten-web software which allows users to visualize and analyze cross discipline data. Expert users can launch the visualization software through a web based programming interface (Jupyter Notebook) for processing of the data. The seismological waveform data (provided by UIB and NORSAR) will be available through an EIDA system, seismological data products (receiver functions, earthquake catalogues, macroseismic observations) as individual datasets or through a web service, GNSS data (provided by NMA) through the GLASS framework (web service) and geological and geophysical (magnetic, gravity anomaly) maps (provided by NGU) as WMS web services. Integration of some specific geophysical data is still under discussion, such as georeferenced cross-sections which are of interest especially for visualization with other geoscientific data.

Constant user feedback is achieved through dedicated workshops. Various use cases are defined by users and have been tested in these workshops. Collected feedback is being used for further development and improvements of the software.

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Nicolai Rinds: Installation of broadband seismometers for risk evaluation related to landslide and subsequent flooding in Greenland

T. Dahl-Jensen, T. B. Larsen, P. H. Voss, N. Rinds

Geological Survey of Denmark and Greenland – GEUS

After a June 17th 2017 tsunami generating landslide in Central West Greenland, several approaches have been initiated in order to address future risk of serious flooding of settlements in Greenland caused by landslides. As part of the risk evaluation three new broadband seismometers were installed in Central West Greenland August 2019 to improve the detection of seismic events that could be caused by landslides. Three new stations were installed in Qeqertarsuaq (GDH), Niaqornat (NIAQ) and Saqqaq (SAQQ). In addition, the broadband station in Uummannaq (UMMG) was relocated to Saattut (SAATT) due to high ambient noise levels in Uummannaq. In this presentation we report on the new installations, provide data examples and show the resulting noise levels at the four sites. All four sites are equipped with broadband seismometers and dataloggers from the DanSeis instrument pool. Data are transmitted in real time to the seismological datacenter at GEUS, from where they are made available, free and openly.

Peter H. Voss: The HIKE project - an overview

P.H. Voss[1], T.B Larsen[1] and The HIKE team

[1]Geological Survey of Denmark and Greenland – GEUS

The HIKE (Hazard and Impact Knowledge for Europe) project aims to support research and assessments of induced hazards and impacts that are related to the exploitation of subsurface resources and capacities throughout Europe. These goals will be achieved through development, demonstration and implementation of harmonized subsurface data sets and methodologies, investigation of applied use cases, and facilitation of knowledge shared between geological surveys and stakeholders. This presentation gives an overview of the project and in-depth information on the work lead by GEUS regarding; advanced localization of seismicity events in Europe, assessment of induced surface displacements, novel methods for reservoir sealing assessment and seismicity and safety in storage is provided. HIKE is part of the action: Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe (GeoERA), see https://geoera.eu/. This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731166.

Samar Amini: Directivity analysis of the 2017 Hojedk triplet in Kerman, Eastern Iran

Samar Amini, Roland Roberts, Björn Lund

Uppsala Univeristy, Sweden

Using an Empirical Green's function (EGF) approach, deconvolution, and data from local-to-regional distances we analyzed the rupture propagation directivity of three mainshocks (Ml 6.0 - 6.1) and six of the largest aftershocks (Ml 5.0 – 5.5) in the 2017 Kerman seismic sequence, Iran. The EGF procedure was based on data from smaller events (Ml 4.0 – 4.8). Deconvolution applied separately to P and S phases. For the P-wave analysis, deconvolution was used to calculate relative source-time functions, and azimuthal variations in rupture duration were examined. In the S-wave analysis, we investigated along strike rupture directivity by evaluating azimuthal variation of the amplitude spectra. The S-wave spectral deconvolution was also used to estimate the rupture directivity of the largest aftershocks. Two of the mainshocks and four of the aftershocks clearly showed rupture propagation from the south-east towards the north-west. The other mainshock and one of the aftershocks suggested an almost bilateral rupture propagation, and one aftershock showed rupture directivity to the southeast. It seems that the rupture propagation direction in the area is generally to the north-west and the events with different propagation directions are located within the ends of the faulting area. The general rupture propagation direction in the area might be affected by the regional tectonic state of a restraining bend.

Tuija Luhta: Development of daily seismic analysis at the Institute of Seismology, University of Helsinki

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Daily seismic analysis at the Institute of Seismology has come far from its early days of analysing teleseismic events, and receiving and sending data recorded on paper or magnetic tapes. With the development of methods and automation of the analysis process, we have been able to use less resources to daily analysis and more to research and societal duties. In the 1980's, one third of the Institute's staff was involved with the daily analysis. Today, we have one full-time analyst. At the same time, the amount of detected seismic events has been growing rapidly. 1985 the Finnish seismic network recorded about 3200 local and regional seismic events, of which 59 were interpreted as probable earthquakes. 2018 the corresponding numbers, based on the preliminary bulletins, were 19431 and 421.

During the last two decades, the daily analysis has changed from manual analysis of all events to checking of automatic detections. Manual analysis is done only for earthquakes or otherwise exceptionally interesting events. Since 2017 we have developed a new way to archive analysis data, NorDB database. NorDB itself is a PostgreSQL database with Python API for easy access, and StationTool PyQT5 application for maintaining the database. NorDB is tailored to store nordic format seismic data. Data can be exported also in QuakeML format.

This year we've been developing Norlyst application, a tool to do daily analysis in connection with the database. With Norlyst, checking the automatically detected and indentified events will be easier and faster than previously. Currently all the events are checked in Geotool. In the future, only the events requiring manual work will be opened in Geotool. Norlyst also makes storing metadata related to the events easy, facilitating future use of data.

Zeinab Jeddi: Temporary Ocean Bottom Seismographs in the Arctic

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University of Bergen

Natural disasters, e.g. landslides or earthquakes among others, are likely to increase together with the expected changes in the climatic conditions in the Arctic. Accordingly, studying the temporal variations of the Arctic seismicity is required.

Eu-funded INTAROS project (Integrated Arctic Observation System) is expected to contribute with innovative solutions to fill some of the critical gaps in the in situ observing network in the Arctic. Many datasets are currently available for the area through national and international monitoring networks, however there is a big gap still in the oceanic part. To improve the existing catalog and fill part of the large observational gap in the offshore regions of the Arctic, Ocean Bottom Seismographs (OBS) were deployed in 3 different regions: 1) Mohn's Ridge, 2) North of Knipovich Ridge and 3) Storfjorden.

The improvement of the monitoring coverage will provide a new dataset which will enable us to lower the earthquake detection threshold in the study area. Here, we will focus on the results from Loki's Castle hydrothermal field which is located on the Mohn's ultra-slow spreading ridge. The observed microseismic activity of the vent field is barely recorded by permanent network, since the closest land seismic station to the Loki's Castle is in ~345 km distance. Preliminary processes from the OBS deployed on the north Knipovich Ridge is also presented.