# THE 41st NORDIC SEMINAR

Photo: Rasmus Laursen

# DETECTION SEISMOLOGY

## OCTOBER 6, 13:00
## OCTOBER 8, 12:00

# 2010

GEOLOGICAL INSTITUTE
AARHUS UNIVERSITET
HØEGH GULDBERGS GADE 2
8000 AARHUS C
DENMARK

GEUS

SOLIDUM PETIT IN PROFUNDIS · UNIVERSITAS ARHUSIENSIS

# Program

## Wednesday October 6

12:30 Registration at the AU conference facility

**13:30 Welcome and opening remarks**
Bo Holm Jacobsen
John A. Korstgård, Head of department of Earth Sciences**,** University of Aarhus

13:50 **Keynote lecture**
The mountains of Norway – why and when ?
Søren Bom Nielsen

**14:20 Session I: Seismic Networks and Instruments**
**Chairman: Heidi Soosalu**

14:20 The GreenLand Ice Sheet monitoring Network (GLISN)
T. Dahl-Jensen

14:40 Ongoing and future development of SNSN
Reynir Bödvarsson and Hossein Shomali

15:00 Calibration of seismometers with Lennartz CT-EW1 calibration table
Jari Kortström

15:10 Coffee

15:30 Instrument tests at Stendammen
M. Roth, J. Fyen, P. W. Larsen

15:50 Influence of high-latitude geomagnetic pulsations on recordings of broad-band force-balanced seismic sensors
Elena Kozlovskaya, Alexander Kozlovsky

16:10 **Poster Session – short presentations**

GLISN
Trine Dahl-Jensen

How to deal with sparse macroseismic data?
Reflections on earthquake records and recollections in the Eastern Baltic Shield
P. Mäntyniemi, R. E. Tatevossian and T. N. Tatevossian

Using Contentious Wavelet Transform and Wavelet Packet Denoising for Automatic Earthquake P-Phase Picking
Nasim Karamzadeh, Gholam Javan Doloei, Alireza Moghaddamjoo

Noise levels and detection maps from the Norwegian National Seismic Network
Lars Ottemöller and Berit Marie Storheim

Assessment of active basement faults, capable of producing destructive earthquakes, in Denmark?
S. Gregersen, P. Voss

Moment tensor of the 16 DEC 2008 earthquake in Skåne, Sweden
Jeppe Regel

Depth estimation of the main Haiti earthquake 12 JAN 2010 and selected aftershocks, from travel times of teleseismic pP- and sP-phases observed at the SUMG seismograph, Greenland
Kasper Kofoed Ljungdahl

Parameter sensitivity of ground motion simulations based on hybrid broadband calculations. A case study for İzmir, Turkey
Louise W. Bjerrum, Mathilde B. Sørensen and Kuvvet Atakan

**16:30 Session II: Comprehensive Nuclear-Test-Ban Treaty (CTBT) and ISC related Studies**
**Chairman: Tine B. Larsen**

16:30 The CTBTO Link to the ISC Database
Oriol Gaspà, István Bondár, James Harris and Dmitry Storchak

16:50 The CTBTO/OSI training and exercises, Finland's contribution on these activities
Pasi Lindblom

**17:10 Laboratory Session : Calibration of seismometers**
This session will take place at the seismology laboratory, where we will perform a calibration of different seismometers, with Lennartz CT-EW1 calibration table.

# Thursday October 7

**09:00** **Session II: Comprehensive Nuclear-Test-Ban Treaty (CTBT) and ISC related Studies (continued)**
**Chairman: Tine B. Larsen**

09:00 Detecting the DPRK nuclear test explosion on 25 May 2009 using array-based waveform correlation
Steven J. Gibbons

09:20 Analysis of the IDC Reviewed Event Bulletin for Detection Capability Estimation of the IMS Primary Seismic Stations
T. Kværna and F. Ringdal

09:40 International Seismological Centre (ISC): Mission and Status
Dmitry Storchak, Istvan Bondar, James Harris

10:00 Discussion on accuracy and bias in hypocenterdata and phase arrival readings provided by international databases like ISC and USGS-NEIC
Bo Holm Jacobsen

10:20 Coffee

**10:50** **Session III: Event studies**
**Chairman: Bergthóra S. Thorbjarnardóttir**

10:50 On the earthquakes in the Northern Baltic Shield in the spring of 1626
R. E. Tatevossian, P. Mäntyniemi and T. N. Tatevossian

11:10 Recent major earthquakes in felt Denmark : Skåne DEC 2008 and North Sea FEB 2010
Peter H. Voss

11:30 Lower crustal earthquakes at Askja volcano, Iceland: multi-location melt supply from the mantle within a single volcanic system
Janet Key, Heidi Soosalu, Robert S. White and Steinunn S. Jakobsdóttir

11:50 Glacial earthquakes
Tine B. Larsen, Meredith Nettles, Pedro. Elosegui, the EGGCITE Team, and the SERMI Team

12:10 Lunch at AU conference facility

**13:10 Session IV: Volcano monitoring and eruptions**
**Chairman: Tellervo Hyvönen**

13:10 Monitoring Volcanoes in Iceland
Steinunn Sigríður Jakobsdóttir

13:30 Scenes from the eruptions in Eyjafjallajökull volcano 2010 and related work at the Icelandic Meteorological Office
Hróbjartur Thorsteinsson, Bergthóra S. Thorbjarnardóttir and the IMO staff

**13:50 Session V: Seismic Data Simulations**
**Chairman: Mathilde B. Sørensen**

**13:50 Keynote Lecture**
Factors Controlling Long-Period Deterministic Ground Motion Simulations
Kim Olsen

14:20 Deterministic seismic hazard assessment in Izmir, Turkey
Louise W. Bjerrum, Mathilde B. Sørensen, Torunn Lutro and Kuvvet Atakan

14:50 The earthquake of Feb.27, 2010 Southern Chile (M=8.8): consequences for future large earthquakes in the region
M. Raeesi and K.Atakan

15:10 Coffee

**15:40 Session VI: Seismology - mission and music**
**Chairman: Mathilde B. Sørensen**

15:40 The Mission of the European Seismological Commission
Steinunn Sigríður Jakobsdóttir, President of the European Seismological Commission

16:00 This is Earth speaking!
On using sound transcription of ground vibrations for science and public outreach
Bo Holm Jacobsen

17:53 Guided tour at "Den Gamle By" followed by the Conference Dinner at Møllestuen

# Friday October 8

**09:00 Session VII: Crustal and Lithospheric Studies; Seismic Hazard**
**Chairman: Trine Dahl-Jensen**

09:00 Review of earthquake potential in Denmark: active faults and neotectonics
Søren Gregersen and Peter Voss

09:20 Building the National Early Warning System for Natural Disasters in Finland - LUOVA Project 2008-2010
Kristiina Säntti and Jari Kortström

09:40 Probabilistic tsunami hazard assessment in the Mediterranean Sea
Mathilde B. Sørensen, Matteo Spada, Andrey Babeyko, Stefan Wiemer and Gottfried Grünthal

10:00 Coffee

10:30 Crustal velocity blocks and anisotropy in the central Fennoscandian Shield
T. Hyvönen, A. Korja, T. Tiira, and K. Komminaho

10:50 Upper mantle structure beneath the Southern Scandes Mountains and the Northern Tornquist Zone - results from teleseismic P-wave travel time tomography
Anna Bondo Medhus, Niels Balling and Bo Holm Jacobsen

**11:10 Any other business**
Peter H. Voss

**11:30 Closing Remarks**

# Participants

**ICELAND**

The Icelandic Meteorological Office
Bústaðavegi 9, 150 Reykjavík
Bergthóra S. Thorbjarnardóttir - begga@vedur.is
Steinunn Sigríður Jakobsdóttir - ssj@vedur.is

**FINLAND**

University of Helsinki
Institute of Seismology, Department of Geosciences and Geography
P.O. Box 68, FI-00014 Helsinki
Jari Kortström - jari.kortstrom@helsinki.fi
Pasi Lindblom - pasi.lindblom@helsinki.fi
Päivi Mäntyniemi - paivi.mantyniemi@helsinki.fi
Tellervo Hyvönen - Tellervo.Hyvonen@Helsinki.fi

University of Oulu
Sodankylä Geophysical Observatory, P.O. Box 3000, FI-90014
Elena Kozlovskaya - elena.kozlovskaya@oulu.fi

**NORWAY**

University of Bergen
Department of Earth Science, Allegatan 41, N-5007 Bergen
Kuvvet Atakan - kuvvet.atakan@geo.uib.no
Mathilde B. Sørensen - mathilde.sorensen@geo.uib.no
Louise Wedderkopp Bjerrum - louise.bjerrum@geo.uib.no
Berit Marie Storheim - berit.storheim@geo.uib.no

NORSAR
P.O. Box 53, N-2027 Kjeller
Tormod Kværna – tormod@norsar.no
Steven J. Gibbons - steven@norsar.no
Michael Roth - michael@norsar.no
Berit Paulsen - berit.paulsen@norsar.no

**SWEDEN**

University of Uppsala
Department of Earth Sciences, Villavägen 16, SE-752 36 Uppsala
Reynir Bödvarsson - reynir.bodvarsson@geo.uu.se

**DENMARK**

University of Århus
Høegh-Guldbergs Gade 2, DK - 8000 Århus C
Bo Holm Jakobsen - bo@geo.au.dk
Niels Balling - Niels.Balling@geo.au.dk
Søren Bom Nielsen - sbn@geo.au.dk

Geological Survey of Denmark and Greenland - GEUS
Øster Voldgade 10, 1350 Copenhagen
Hans Peter Rasmussen - hpr@geus.dk
Tine B. Larsen - tbl@geus.dk
Trine Dahl-Jensen – tdj@geus.dk
Tina Hvid – thv@geus.dk
Peter Voss - pv@geus.dk
Søren Gregersen – sg@geus.dk

University of Copenhagen
Niels Bohr Institute
Blegdamsvej 17, 2100 København Ø
Kasper Kofoed Ljungberg – kasperljungdahl@gmail.com

Technical University of Denmark
DTU Kemiteknik, Institut for Kemiteknik, CERE - Center for Energi Ressourcer
Søltofts Plads, Bygning 229, rum 252, 2800 Kgs. Lyngby
Jeppe Regel - jeppe.regel@gmail.com

The Inge Lehmann Archive
Bakkefaldet 10, DK-2840 Holte
Erik Hjortenberg, - erik.hjortenberg@tdcadsl.dk

**ESTONIA**

Geological Survey of Estonia
Department of Mining, Tallinn University of Technology
Heidi Soosalu - h.soosalu@egk.ee

**U.S.A.**

San Diego State University
Department of Geological Sciences, 5500 Campanile Dr.,San Diego, CA 92182-1020
Kim Olsen - kbolsen@sciences.sdsu.edu

**International Seismological Centre (ISC)**

Pipers Lane, Thatcham, Berkshire, RG19 4NS, UK
Oriol Gaspa Rebull - oriol@isc.ac.uk

# Abstracts of talks

# The GreenLand Ice Sheet monitoring Network (GLISN)

T. Dahl-Jensen[1] [invited] , IRIS[2], ETH[3], LDEO-Columbia Univ.[2], GFZ[4], NIPR[5], NORSAR[6], NRC[7], INGV[8], JAMSTEC[5]
[1]GEUS - Geological Survey of Denmark and Greenland; [2]USA; [3]Switserland; [4]Germany; [5]Japan; [6]Norway; [7]Canada; [8]Italy

GLISN is a new, international, broadband seismic capability for Greenland, being installed and implemented through collaboration of USA, Denmark, Switzerland, Germany, Canada, Italy, Japan and Norway. GLISN is a real-time sensor array of over 20 stations to upgrade the scarce network for detecting, locating, and characterizing both tectonic and glacial earthquakes and other cryo-seismic phenomena, and contribute to our understanding of Ice Sheet dynamics. GLISN will provide a powerful tool for detecting change, and will advance new frontiers of research in the underlying geological and geophysical processes affecting the Greenland Ice Sheet. The glacial processes that induce seismic events (internal deformation, sliding at the base, disintegration at the calving front, drainage of supra-glacial lakes) provide a quantitative means for monitoring changes in glacial behaviour over time. Long-term seismic monitoring of the Greenland Ice Sheet will contribute to identifying possible unsuspected mechanisms and metrics relevant to ice sheet collapse, and also detect if the areas of cryo-seismic events change and expand in the coming decades. GLISN will provide a new reference network in and around Greenland for monitoring these phenomena in real-time, and for the broad seismological study of Earth and earthquakes. The GLISN development takes its starting point in the existing stations in and around Greenland operated by members of GLISN. The network will be upgraded and expanded by installing new, telemetered, broadband seismic stations on Greenland's perimeter and ice sheet her ealso with GPS. A virtual network is established where all GLISN data are archived and freely downloaded. In collaboration with GLISN, the Global Centroid Moment Tensor Project will provide a near-real-time catalogue of glacial earthquakes. The development incorporates state-of-the-art broadband seismometers and data acquisition, Iridium and local Internet, power systems capable of autonomous operation throughout the polar year, and stable, well-coupled installations on bedrock and the Ice Sheet.

# Ongoing and future development of SNSN

Reynir Bödvarsson and Hossein Shomali

The Swedish National Seismic Network (**SNSN**) now consists of 62 broad-band high-gain seismological stations. All stations are now transmitting data to Uppsala in real-time. Data from ten stations are now transmitted via Internet to Orfeus and additional stations are through bilateral collaboration made open for Denmark, Finland, and Norway. Until now, the network has mainly been used to locate local earthquakes and evaluation of their source parameters but in the future the network will also be used for location and magnitude estimation of regional and global earthquakes. In this talk we will give an overview of the present status of the network and discuss the ongoing and future development of the **SNSN**.

"**seiscomp3**" has been implemented in **SNSN** since last year. The real-time data are archived in original GCF (via scream) and mini-seed (via seedlink) in continuous mode.

Real-time data are transmitted to **Orfeus** (10 stations), **Denmark** (6 stations), **Finland** (7 stations) and **Norway** (3 stations) via seedlink. We received data also from other international centers e.g. Denmark, Finland, Norway, IRIS and Geofon via seedlink.

Since July 2010, new version of Potsdam SeisComP version 3.0 (2010.256) has been installed. Two versions of seiscomp are run in parallel as following :

**(1)** to locate events in regional and global scales using fine-griding in northern Scandinavia and proportional filtering and trigerring,

**(2)** to locate events in Sweden. Here we used much finer grid (0.25deg), and higher frequency data to trigger small events in order of ML=2.0 (it will be improve even to lower magnitude in future). For events occurred in Sweden, we use modified velocity model for Sweden and the location are done in both linear- and non-linear modes. In any of the above seiscomp3 systems, both location and magnitude are determined.

***<u>We plan in future :</u>***

**(1)** to incorporate 3D-velocity model in the location routine (using non-linear location software, NonLinLoc developed by Lomax),

**(2)** to exchange picks in real-time, between SIL and seiscomp3 servers running in Uppsala,

**(3)** to incorporate during magnitude routine for teleseismic earthquake as a plugin in seiscomp3,

**(4)** to incorporate the spectral amplitude method to determine the fault plane solution as a plugin in seiscomp3,

**(5)** develop our web-server for on-line event location and magnitude estimation for earthquakes in northern Europe.

***We purpose to all participants who use seiscomp3 :***

To exchange the picks in real-time between different data-centers e.g. Sweden, Norway, Denmark, Finland, Iceland. In the current version of location-moduli embed in eiscomp3, now for real-time location only P-phase is used. Thus, real-time picks from different data-centers can improve the location of seismic events in our part of the world significantly. In the revised location-algorithm in seiscomp3, other phases e.g. S-phase can also be used in the location, but the pick information should be provided by other picker than used in current version of seiscomp3. We plan to import e.g. S-picks from our SIL system to seiscomp3.

# Instrument tests at Stendammen

M. Roth, J. Fyen, P. W. Larsen

NORSAR has established a test facility for both seismic and infrasound instruments. The site, named Stendammen, is co-located with the station NC602 in the sub-array NC6 of the large NOA seismic array. The infrastructure consists of a central building with living quarters, an office room, power, internet connection and a spacious nearby concrete subsurface vault. The site is far away from cultural noise and provides a controlled environment for long-term measurement under stable conditions.

In the framework of the modernization of the NOA and ARCES array we currently are testing digitizers and the prototypes of newly developed seismic broadband sensors with hybrid response. We will present the hybrid instrument characteristics, illustrate the site conditions, and provide coherency results.

# Influence of high-latitude geomagnetic pulsations on recordings of broad-band force-balanced seismic sensors

Elena Kozlovskaya[1], Alexander Kozlovsky[1]

[1]Sodankylä Geophysical Observatory, POB 3000, FIN-90014, University of Oulu, Finland

Seismic broad-band sensors with electromagnetic feedback are sensitive to variations of surrounding magnetic field, including variations of geomagnetic field. Usually, the influence of the geomagnetic field on recordings of such seismometers is ignored. It might be justified for seismic observations at middle and low latitudes. The problem is of high importance, however, for observations in polar regions (above 60° magnetic latitude), where magnitudes of natural magnetic disturbances may be two or even three orders larger. In our study we investigated the effect of ultra-low frequency (ULF) magnetic disturbances, known as geomagnetic pulsations, on the STS-2 seismic broadband sensors. The pulsations have their sources and, respectively, maximal amplitudes in the region of the auroral ovals, which surround the magnetic poles in both hemispheres at geomagnetic latitude (MLAT) between 60° and 80°. In our study we analyse the effect of geomagnetic pulsations on recordings of the STS-2 broadband seismometers located in the vicinity of the auroral oval in northern hemisphere. To investigate sensitivity of the STS-2 seismometer to geomagnetic pulsations, we compared the recordings of permanent seismic stations in northern Finland to the data of the magnetometers of the IMAGE network located in the same area. Our results show that temporary variations of magnetic field with periods of 40-150s corresponding to regular Pc4 and irregular Pi2 pulsations are seen very well in recordings of the STS-2 seismometers. Moreover, the shape of Pi2 magnetic disturbances and their periods resemble the waveforms of glacial seismic events from Greenland reported originally by Ekström (2003). Therefore, these pulsations may create a serious problem for monitoring of glacial earthquakes and interpretation of seismic observations in the vicinity of the auroral oval. The problem may be treated, however, if combined analysis of recordings of collocated seismic and magnetic instruments is used.

# The CTBTO Link to the ISC Database

Oriol Gaspà, István Bondár, James Harris and Dmitry Storchak

International Seismological Centre, United Kingdom, oriol@isc.ac.uk

The CTBTO Link to the International Seismological Centre (ISC) Database is an open source collection of interactive tools for manipulating seismological data sets exclusive to National Data Centres. Using a graphical interface and tailored queries for the monitoring community the user has access to a myriad of products including historical seismicity since 1904, Nuclear explosions, Engdahl, van der Hilst and Buland (EHB) bulletins, Ground Truth (GT) events, REB events, frequency magnitude distribution, hypocentral comparison between agencies or seismic stations history information.

**The searches are divided into three main categories: The *Area Based Search (*a spatio-temporal search based on ISC seismicity), the *REB search* (a spatio-temporal search based on REB events*)* and the *Station Search* (a search of seismic stations within a defining distance of an IMS seismic station).**

**The outputs are HTML with a simplified version of the ISC Bulletin showing the most relevant parameters according to the search and access to ISC Bulletin in format IMS1.0 for single or multiple events.**
This is a user friendly interface which we hope will help NDCs to put in context REB events within the historical seismicity.

# The CTBTO/OSI training and exercises

# Finland's contribution on these activities

Pasi Lindblom

Institute of Seismology, University of Helsinki

The primary objective of the Major programme 4, On-Site Inspection, is to make the necessary preparations for the establishment of the OSI regime at the entry into force of the Treaty. The major elements of OSI are inspectors, equipment and the OSI Operational Manual, together with supporting infrastructures.

Since 1998 the OSI division of the preparatory technical secretariat, has organised several training courses and different kinds of exercises for technical and political people, nominated by the State Parties.

This presentation is supposed to give an overview on these activities, also in the past, and tries to highlight those in which Finland and Finns are involved.

# Detecting the DPRK nuclear test explosion on 25 May 2009 using array-based waveform correlation

Steven J. Gibbons
NORSAR, Kjeller, Norway

The Democratic People's Republic of Korea (DPRK) announced on 25 May 2009 that it had conducted its second nuclear test, the first one having taken place on 9 October 2006. As was the case with the first test, the second test was detected and reported by the IDC. We have carried out an experiment taking the 9 October 2006 test as a starting point and running a continuous waveform correlation scheme in order to a) assess the potential for automatically detecting the second nuclear test and b) monitoring the false alarm rate associated with such a detection scheme. Using only data from the Matsushiro array (MJAR), and applying the array-based procedure developed by Gibbons and Ringdal (2006) with a waveform template from the first nuclear test, we found that the second test can be detected readily without a single false alarm during the entire three year period. Moreover, by a scaling procedure, we argue that an explosion many times smaller than the second test would have been detected automatically, with no false alarms, had it taken place at the same site as the second test. We note that this remarkable performance is achieved even though the MJAR array is known to be difficult to process using conventional methods, because of signal incoherency. An important element of the detection procedure for the automatic elimination of false alarms is a post-processing system which performs slowness analysis on the single-channel cross-correlation traces. It is well known that successful correlation detection requires the two sources to be closely spaced (i.e. the detector has a narrow footprint), but there is evidence that array-based correlation covers a larger footprint than the 1/4 wavelength estimated by Geller and Mueller (1980) for single-station correlation. This could be important for a more general application of the method described here, and needs further study.

# Analysis of the IDC Reviewed Event Bulletin for Detection Capability Estimation of the IMS Primary Seismic Stations

T. Kværna and F. Ringdal
NORSAR, Kjeller, Norway (tormod@norsar.no)

We have investigated the IDC Reviewed Event Bulletin (REB) for the time period 1 January 2000 to 15 July 2009 to quantify the event detection capability of individual primary seismic stations of the International Monitoring System (IMS). For a specific target area, we can obtain estimates of the detection threshold of a given station by considering the ensemble of REB reported events in the area, and downscaling each event magnitude with the observed SNR at the station. However, there are some problem areas associated with this procedure such as:

- Possible biases in the REB magnitudes caused by non-detections
- Skewness in the distribution of threshold estimates, also caused by non-detections
- The validity of using the signal-to-noise ratio for downscaling the event magnitude

We address these issues by dividing the events into a binned global grid system and introduce a maximum likelihood estimation procedure to compensate for the presence of non-detections. A major result of this study is a quantification and ranking of the IMS primary seismic stations based on their capability to detect events. For each station, source regions with noticeable signal amplitude focusing effects (bright spots) and defocusing effects can be identified and quantified. We apply this information to calculate updated global detection capability maps for the IMS primary seismic network, both the current capability using existing stations and the projected capability once the network is completed.

Future work will focus on estimating region-specific station corrections and the associated standard deviations and investigate approaches to combining the region-specific station corrections and the detection thresholds in order to provide dynamic checking of the validity of individual phases associated with events defined in the automatic phase association processing at the IDC.

# International Seismological Centre (ISC): Mission and Status

Dmitry Storchak, Istvan Bondar, James Harris

International Seismological Centre, United Kingdom, dmitry@isc.ac.uk

The International Seismological Centre (ISC) is a non-governmental, non-profit making organization supported by 55 research and operational institutions around the world and charged with production of the ISC Bulletin – the definitive summary of world seismicity based on seismic reports from over 120 institutions. Jointly with World Data Center for Seismology (Denver), the ISC runs the International Seismic Station Registry (IR). The ISC provides a number of additional services available from its web-site including the depositary of the IASPEI Reference Event list (GT), EHB & ISS data collections.

The ISC has a substantial development programme that ensures that the ISC data remain an important requirement for geophysical research. This programme includes bringing the ISC edited Bulletin schedule to approximately 15-18 months behind real-time as well continuing collection of preliminary reports from networks days and weeks after event occurrence to make the automatic preliminary ISC Bulletin as comprehensive as possible before the final data become available to the ISC. We aim to modernize the way the ISC computes its hypocentres and magnitudes and to attempt taking some useful measurements from waveforms widely available on-line to improve the accuracy of the ISC Bulletin. We are planning to re-produce the entire ISC Bulletin (1960-2010) by re-computing the ISC hypocenters and magnitudes using ak135 velocity model, identifying and filling the gaps in data, correcting known errors and introducing essential additional bulletin data from research experiments and temporary deployments. The ISC also takes a leading role in compiling the GEM Instrumental Seismic Catalogue (1900-2009).

# On the earthquakes in the Northern Baltic Shield in the spring of 1626

R. E. Tatevossian[1], P. Mäntyniemi[2] and T. N. Tatevossian[1]

[1]Institute of the Physics of the Earth, Russian Academy of Sciences, B. Gruzinskaya 10, Moscow 123242, Russia

[2]Institute of Seismology, Department of Geosciences and Geography, University of Helsinki, POB 68, FI-00014 Helsinki, Finland; email: paivi.mantyniemi@helsinki.fi

This study starts from the earthquakes of 14 May 1626 and 22 June 1626 as given in existing parametric catalogues for the Baltic (Fennoscandian) Shield. The first shock is located in North-western Russia, the second in present-day Finland that was a part of Sweden at the time of interest. A search for previously unknown Russian sources of information is performed, and secondary Swedish sources are replaced by primary ones. The contemporary sources are two Russian chronicles and two Swedish manuscripts not independent of each other. In addition, a later reminiscence is used. The sources are critically analysed and augmented with background information. A new interpretation of one Swedish manuscript is presented. The earthquake dates are analysed. A plausible reason for errors is the different calendars used. A new solution of one earthquake felt in both territories is proposed. The available data are too fragmentary to prove it beyond doubt, but the one-earthquake scenario is feasible in many ways. The tentative epicentre intensity is assessed at 6−7 (EMS), magnitude estimated at 4,7−5,7. The epicentre is located in Russia close to the border between the two territories.

Reference

Tatevossian, R. E., P. Mäntyniemi and T. N. Tatevossian, 2011. On the earthquakes in the Northern Baltic Shield in the spring of 1626, *Natural Hazards*, in press.

# Recent major earthquakes in felt Denmark : Skåne DEC 2008 and North Sea FEB 2010

Peter H. Voss
Geological Survey of Denmark and Greenland

Tremors from the Skåne DEC 2008 and the North Sea FEB 2010 earthquakes were felt across Denmark. The Geological Survey of Denmark and Greenland have collected macroseismic information from both of the earthquakes, resulting in around 4000 and 300 reports, respectively. The preliminary results of the macroseismic surveys are presented for both events. To constrain the depth estimate of the two earthquakes, array measurements including teleseismic pP and sP phases have been modeled for comparison with observed seismic signals, the status of this analysis is presented.
After the North Sea earthquake, 5 small aftershocks occurred in the following weeks, with a preliminary location within 15km of the main event. These aftershocks constitute first documented aftershocks sequence in Denmark. The results from the analysis of the main event and the aftershocks are presented.

# Lower crustal earthquakes at Askja volcano, Iceland: multi-location melt supply from the mantle within a single volcanic system

Janet Key[1], Heidi Soosalu[1,2,3], Robert S. White[1] and Steinunn S. Jakobsdóttir[4]
[1]Bullard Laboratories, University of Cambridge
[2]Geological Survey of Estonia
[3]Department of Mining, Tallinn University of Technology
[4]Icelandic Meteorological Office

The volcanic system of Askja within the north Iceland spreading plate boundary comprises a central volcano with a nested caldera system and a fissure swarm transecting it. Over 1000 lower-crustal earthquakes (13 – 27 km depth) have been recorded at Askja, using local arrays of broadband seismometers. The brittle-ductile boundary in the Askja region is well defined by a sharp lower cut-off of upper-crustal seismicity at depths of 5 – 7 km. The lower-crustal earthquakes are well within the normally aseismic and ductile part of the crust. The events often occur in swarms lasting several minutes, with hypocentres from a single swarm located close to one another. In average, 1.5 events per day are detected, although quiescences up to two weeks have been observed.

Our semi-continuous observations, starting from 2005, outline three distinct and persistent clusters of lower-crustal seismicity. The largest one is located at the northern boundary of the youngest of the nested Askja calderas. This cluster is adjacent to a geodetically proposed magma chamber and extends along the fissure swarm of the Askja volcanic system 10 km to the northeast. The second cluster is located 20 km further to the northeast along the fissure swarm, northwest of Herðubreið table mountain. The third cluster is 10 km east of Askja, north of Vaðalda shield volcano. The dimensions and locations of each of the clusters have not changed since we commenced continuous seismic monitoring in summer 2007. Each cluster has a stable upper cut-off depth, possibly the location of a magma body such as a sill.

Our interpretation is that these earthquakes are caused by magma movements within the lower crust, possibly between sills at different depths. The three spatially separated clusters of events could indicate positions of long term magma supply from the mantle. This suggests that this part of the volcanic rift zone is supplied with melt simultaneously at multiple localities along each segment rather than by lateral melt migration fed from a single input.

# Glacial earthquakes

Tine B. Larsen, Meredith Nettles, Pedro. Elosegui, the EGGCITE Team, and the SERMI Team

Long-period glacial earthquakes occur primarily in Greenland. They appear to be sensitive to climate parameters and could potentially serve as an "early warning" for changes in the dynamics of the Arctic glaciers. However, glacial earthquakes are only useful for this purpose if we understand the mechanisms controlling them.

An international study of Helheim glacier in East Greenland was initiated in 2006 primarily to investigate the source of glacial earthquakes. Interdisciplinary project groups from Denmark, Spain, and the US joined forces to cover a wide range of observables related to glacial earthquakes and glacier dynamics. The study involved seismology, geodesy, glaciology, and climatology.

The seismic waves from the glacial earthquakes are detected at teleseismic distances as well as by regional and local seismographs in Greenland. The higher frequency waves from glacial earthquakes have only reasonable signal to noise ratios at distances less than a few hundred km away, whereas the lower frequencies survive to teleseismic distances. The velocity field of Helheim glacier is measured through three summer field seasons using high-rate GPS measurements directly on the ice. Automatic Weather Stations record a wide range of meteorological parameters for the purpose of looking for correlations between changes in glacier dynamics and changes in melting. Lidar data were collected in 2007 and interpreted jointly with ASTER data. It is difficult to penetrate the highly crevassed part of the glacier with radar, so in order to get a better estimate of the thickness of the ice a gravity profile was measured across Helheim glacier in 2008. Data and results from the projects will be presented.

# Monitoring Volcanoes in Iceland

Steinunn S. Jakobsdóttir,

Project Manager

Warnings and Forecasting

The Icelandic Meteorological Office

The volcanic eruption in Eyjafjallajökull in 2010 had a widespread effect on air traffic in Europe and changed the view on the importance of an evaluation of ash concentration in the air space. There are volcanic eruptions in Iceland about every 5 years. The behaviour of the eruptions and their preparation phases differ from one volcano to another. While Hekla does not show any signs of imminent eruption until about 90 minutes before the onset, Grímsvötn showed increased seismic activity about a year before the eruption in 2004 and the first seismic activity leading to the Eyjafjallajökull eruption was seen 16 years prior to the eruption. Common for all the seismic activity preceding volcanic eruptions in Iceland is that most of the earthquakes are small. With a detection threshold of magnitude ~2 the observed seismicity would in many cases not give clear warnings ahead of the eruptions or at least a much shorter warning period.

# Scenes from the eruptions in Eyjafjallajökull volcano 2010 and related work at the Icelandic Meteorological Office

Hróbjartur Thorsteinsson, Bergthóra S. Thorbjarnardóttir and the IMO staff

Several different aspects of the Icelandic Meteorological Office (IMO) were set in motion during the eruptions in Eyjafjallajökull volcano earlier this year. We will show a short video displaying some of the work done at IMO prior to and during the eruptions. The video was IMO's contribution to a science fair sponsored by the Icelandic Centre for Research which was held this fall.

Figures are shown of earthquake activity and GPS movement related to the eruptions and of water discharge from the eruption site. Pictures and short videos of the erupting volcano and the surrounding area effected are shown, satellite images of ash distribution during the summit eruption and more.

# Factors Controlling Long-Period Deterministic Ground Motion Simulations

Kim Olsen, San Diego State University

Recent large-scale modeling exercises using physics-based simulations have provided useful insight into the factors that control the long-period (less than ~2 Hz) ground motion levels for large earthquakes. Here, I review lessons learned from earthquake scenarios that would affect tens of millions of people: M7.7-8.0 strike-slip events on the southern San Andreas fault, California, M7.0 normal fault scenarios on the Wasatch fault, Utah, and M8.5-9.0 megathrust events in the Cascadia subduction zone, Pacific Northwest region. Path effects can amplify the ground motions significantly. For example, wave-guide channeling effects can generate 10-fold differences in peak ground motions dependent on the epicentral location. The description of the rupture propagation on the fault can also significantly affect the ground motions. For example, complex sources with abrupt changes in direction and speed in the rupture propagation can decrease the wavefield coherency substantially, as compared to simpler source descriptions. As a result, the more complex ruptures can generate long-period ground motions factors of 2-3 smaller than those for simpler source descriptions. In addition, super-shear rupture speeds may cause large-near-fault peak ground motions, while the radiated energy from the Mach wave fronts is propagated to large distances from the fault. Deterministic simulations of dip-slip (normal or reverse) scenarios show that directivity effects can be important for the resulting ground motion distributions. For megathust events, the rise time of the source time functions is a critical but mostly unconstrained parameter controlling the ground motion levels.

# Deterministic seismic hazard assessment in Izmir, Turkey

Louise W. Bjerrum, Mathilde B. Sørensen, Torunn Lutro and Kuvvet Atakan
*Department of Earth Science, University of Bergen, Norway*

From deterministic ground motion simulations peak ground levels and frequency content from an expected earthquake can be estimated. This is valuable information for engineering applications when working with risk mitigation in areas where future destructive earthquakes are expected. We investigate the variability in simulated ground motions due to uncertainty in input parameters adopted in the simulations. We have calculated broadband ground motions on various sites within Izmir, the third largest city of Turkey, and discuss the differences in peak ground motion as well as the dominating frequencies at the different sites. Furthermore, we have conducted a field study from which we have obtained H/V curves from the sites, and we compare the predicted dominating frequencies from the simulations with those measured at the different sites and try to estimate the expected amplification of the seismic waves. We find that the parameters rupture initiation point, rise time, seismic moment, fault depth dip and asperity location have the largest effect on the simulated ground motions. The largest variability in simulated ground motion is found above the fault plane and the standard deviation of peak ground acceleration and velocity exceeds 300 cm/s$^2$ and 30 cm/s, respectively.

# The earthquake of Feb.27, 2010 Southern Chile (M=8.8): consequences for future large earthquakes in the region

M. Raeesi[1] and K.Atakan[1]

[1] Department of Earth Science, University of Bergen, Allégt.41, N-5007 Bergen, Norway

E-mail: raeesi@geo.uib.no; atakan@geo.uib.no

The interseismic deformation in subduction zones between large/great plate interface earthquakes, as it is observed in the changing seismicity patterns, provide important clues, when interpreted together with the a-priori knowledge on the size and the location of asperities. Combined with previously documented earthquake rupture histories on a given segment with detailed slip distribution, these precursory phenomena may help in identifying the areas where future large/great (M>8) earthquakes are likely to occur. Such long term indicators may help in forecasting the large/great earthquakes in sufficiently long time before its occurrence, hence providing opportunities in terms of preparedness and mitigation efforts.

Recently introduced techniques of using gravity anomalies to detect the location and size of the asperities in subduction zones, opens a new way for interpreting the changing seismicity patterns along the entire subduction system including the outer-rise, fore-arc, subducting slab etc. The capacity of this approach has previously been demonstrated through retrospect case studies (Raeesi and Atakan, 2009). In the present work the “trench parallel Bouger anomaly (TPBA)”, and its derivatives are used to identify the location and size of the asperities and later combined with the changes in the seismicity patterns. The earthquake of Feb. 27, 2010 Southern Chile (M=8.8) as well as other earthquakes along the South American subduction zone are studied with respect to the underlying asperity distribution.

Along the Chilean coast, the asperities located between 30.8 to 32.2 degrees S show a clear pattern of earthquake clusters at their rim. These events can be interpreted as preparatory activities for a future large earthquake. The reverse outer-rise earthquakes clustering in a small region of 50×40 $km^2$, strongly indicate that these asperities are in critical condition. Yet another indicator is the normal earthquake of 1997/10/15 (M=7.1) that confirms the down-dip extension due to locking in the up-dip.

There are obviously many other such cases that need to be studied in other subduction zones. A systematic approach is needed looking into the details of the TPBA together with the seismicity of the outer-rise as well as the subducting slab. A set of precursory indicates of deformation can be identified and applied given the main tectonic elements of the subduction system is known a-priory. The knowledge on the occurrence of the previous large earthquakes in such areas is another important dimension which constrains the time perspective.

# This is Earth speaking!
# On using sound transcription of ground vibrations for science and public outreach.

Bo Holm Jacobsen, Department of Earth Sciences, Aarhus University, Denmark, bo@geo.au.dk

Ground motion shows a dramatic range in amplitudes and frequencies, and reflect a number of natural and man-made processes. In science we have come far in analyzing ground motion by numerical and graphical methods. The obvious exposure of ground motion as sound waves in air is not new. Still, the required speedup of the sounds requires some abstraction and explanation if used towards the public, and the numerical transformation of standard seismological data formats to music file formats is not part of the standard inventory in research groups.

This talk will present some examples of earthquake sounds used in public outreach, supplemented by ground motion data supplied by seminar participants. Moreover, I will present some simple software tools based on MATLAB by which it could be straight forward for professionals to produce sound rapidly for the media in the typically hectic situations after earthquakes with public interest.

# Review of earthquake potential in Denmark: active faults and neotectonics

Søren Gregersen and Peter Voss

Geological Survey of Denmark and Greenland, Ostervoldgade 10, DK-1350 Copenhagen K, Denmark, sg@geus.dk.

Whether geologically known faults are active is almost obvious in plate-boundary earthquake zones like California, while an assessment is needed for intraplate zones. The inactive area Denmark must naturally be seen in a regional frame of Scandinavia/northern Europe. And the assessment of faults, which could eventually produce a destructive earthquake, includes long-term evidence from geology of time scales millions and thousands of years, as well as short-term evidence from seismology and geodesy. Special paleoseismology investigations on time-scale a few thousands of years were never made in Denmark. The causes of the release of stresses in earthquakes are important. Lithospheric plate motion is judged to be dominant over uplift/subsidence in Denmark/southern Scandinavia. An evaluation of the earthquake potential in the Danish area is presented with improved background material. Not one of the faults in Denmark on land is found to show potential for destructive earthquakes. The most active areas in the Danish seas are halfway to Norway, to Britain and to Sweden, in the Skagerrak Sea, the North Sea and the Kattegat Sea with only moderate earthquakes up to magnitudes around 6.

# Building the National Early Warning System for Natural Disasters in Finland

# LUOVA Project 2008-2010

Kristiina Säntti[1] and Jari Kortström[2]

[1]Finnish Meteorological Institute
[2]Institute of Seismology, Department of Geosciences and Geography, University of Helsinki

In 2008 the Finnish government initiated a project to build up a national early warning system for natural disasters (Finnish acronym: LUOVA). The project responds to needs to enhance the preparedness against natural disasters that would affect Finnish citizens and cause economical losses. LUOVA warning and information system is jointly developed by the Finnish Meteorological Institute (principal responsibility), Finnish Environment Institute and Institute of Seismology, University of Helsinki (ISUH).

The goals of LUOVA are:

- Clarify and improve distribution of information on natural hazards
- Collect forecasts, analysis and warnings from different disaster information providers
- Uniform structure and format of information
    - One fast information channel between safety authorities
    - 24/7 on-call monitoring, warning and information system
- Compile real-time situation picture to support decision-making of the authorities
- Web portal is developed to alert and inform authorities, citizens and media of natural disasters.

Phenomena covered during the LUOVA pilot 2010 are domestic storms, floods and forest fires and overseas tropical cyclones, tsunamis and earthquakes.

ISUH is responsible for producing early warnings and damage assessments of destructive earthquakes for LUOVA system. The Institute uses the SeisComP 3 software as a main tool for real-time monitoring. Alternative ways of getting automatic alerts of large earthquakes are email services of GEOFON, USGS and EMSC. USGS ShakeMaps are also retrieved automatically for real-time situation picture. All gathered information will be evaluated by 24/7 on-call seismologist before giving out any alerts on the LUOVA portal.

# Probabilistic tsunami hazard assessment in the Mediterranean Sea

Mathilde B. Sørensen[1], Matteo Spada[2], Andrey Babeyko[3], Stefan Wiemer[2] and Gottfried Grünthal[3]

[1]Dept. of Earth Science, University of Bergen, Norway

[2]ETHZ, Institute of Geophysics, Zürich, Switzerland

[3]GFZ German Research Centre for Geosciences, Potsdam, Germany

Estimating the occurrence probability of natural disasters is critical for setting construction standards and, more generally, prioritizing risk mitigation efforts. Tsunami hazard in the Mediterranean region has traditionally been estimated by considering so-called “most credible” scenarios of tsunami impact for limited geographical regions, but little attention has been paid to the probability of any given scenario. In this study, we present the first probabilistic estimate of earthquake generated tsunami hazard for the entire Mediterranean and estimate the annual probability of exceeding a given run-up height at any coastal location in the region. Our PTHA methodology is based on the use of Monte-Carlo simulations and follows probabilistic seismic hazard assessment methodologies closely. The highest hazard is found to be in the Eastern Mediterranean owing to earthquakes along the Hellenic Arc, but most of the Mediterranean coastline is prone to tsunami impact. Our method allows us to identify the main sources of tsunami hazard at any given location, and to investigate the potential for issuing timely tsunami warnings. We find that the probability of a tsunami wave exceeding 1 m somewhere in the Mediterranean in the next 30 years is greater than 95 percent. This underlines the urgent need for a tsunami warning system in the region.

# Crustal velocity blocks and anisotropy in the central Fennoscandian Shield

T. Hyvönen, A. Korja, T. Tiira, and K. Komminaho

Institute of Seismology, University of Helsinki, Helsinki, Finland

The central Fennoscandian Shield has a complex composition as a consequence of its tectonic history. After several crust forming events, progressive thrusting, extensional phases and building up island arcs, the crust is composed of varying size blocks and slanting belts. These blocks and belts can be visualized by seismic tomography method. The tomography data comprises of P-wave and S-wave arrival data from controlled source refraction and reflection experiments, from a passive seismic tomography experiment, and from chemical explosions. Addition of the data from the BABEL sea reflection lines and land stations enabled to include the Gulf of Bothnia to the study area. The number of receivers increased to 2895 and seismic sources to 565 giving 19180 first P-wave and 15146 S-wave crustal travel times. The resulting rays covered larger area and revealed smaller-scale structural blocks than the previous tomography model by Hyvönen et al. (2007).

The distribution of the P- and S-wave velocities, and the velocity ratio, Vp/Vs, varies locally in the whole crust to the depth of 40 km. The anomalous velocity behavior expresses several distinct blocks and belts, which can be associated with the main geological units. The border zone between the Archean and the Proterozoic terranes of the Shield can be distinguished as an upper crustal low velocity zone. The schist belts are associated with velocity minima, Vp/Vs <1.70. Higher velocities, Vp/Vs >1.76, characterize rapakivi granitoid batholiths and the Central Finland Granitoid Complex suggesting hidden mafic blocks in the lower crust.

In the isotropic tomographic velocity models of the crust anisotropic component is embedded in the residual component. Horizontal azimuthal dependency of residual component images the horizontal component of tectonic transport. An azimuthal anisotropy in tomographic model (Tiira et al. 2010a, 2010b) is verified when fast P-wave velocity direction is matched with slow one in the orthogonal direction. The resulting anisotropy directions coincide with transport directions drawn from structural observations.

References

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# Upper mantle structure beneath the Southern Scandes Mountains and the Northern Tornquist Zone - results from teleseismic P-wave travel time tomography

Anna Bondo Medhus, Niels Balling and Bo Holm Jacobsen

Department of Earth Sceinces, University of Aarhus, Denmark (anna.bondo@geo.au.dk)

Improved knowledge of P-wave velocity structure has obvious implications for location and magnitude estimation quality in detection seismology. Likewise, velocity structure is important in the understanding of the dynamics of the upper mantle as well as the timing and mechanisms shaping prensent day topography and near surface geology. Debate persists regarding the geological age of the Scandes Mountains.

We contribute by imaging upper mantle structure beneath southern Scandinavia using teleseismic P-wave travel time tomography (P-tomography). We include data from mobile stations deployed in projects CALAS, CENMOVE, MAGNUS, SCANLIPS and Tor. Permanent stations included are those available from the University of Uppsala, NORSAR and GEUS.

P-wave arrival times generally show differences of up to 1 second across the study area. Upper mantle velocities are relatively high in southern Sweden and southern Norway east of the Oslo Graben. Lower velocities are observed in the Norwegian-Danish Basin southwest of the Sorgenfrei-Tornquist Zone (STZ) and in the southwestern part of Norway. We detect a remarkably sharp lateral velocity gradient which we interpret as the southwestern boundary of thick Baltic Shield lithosphere. Thus, we find the boundary of thick lithosphere to more or less coincide with the STZ in the southeastern part of the study area, extending from southern Sweden into the northern part of Jutland. From here it turns north, passing through the Oslo Graben area to about 60 N then turning northwest, approaching the Norwegian west coast around 65 N.

Thus, as compared to Baltic Shield, upper mantle velocity is significantly reduced beneath deep sedimentary basins of Denmark and northern Germany.

# Abstracts of posters

# How to deal with sparse macroseismic data?

# Reflections on earthquake records and recollections in the Eastern Baltic Shield

P. Mäntyniemi[1], R. E. Tatevossian[2] and T. N. Tatevossian[2]

[1]Institute of Seismology, Department of Geosciences and Geography, University of Helsinki, POB 68, FI-00014 Helsinki, Finland

[2]Institute of the Physics of the Earth, Russian Academy of Sciences, B. Gruzinskaya 10, Moscow 123242, Russia

This contribution discusses the scope of historical earthquake analysis in low-seismicity regions. Examples of non-damaging earthquake reports are given from the Eastern Baltic (Fennoscandian) Shield in North-eastern Europe. The available amount of information about past earthquakes is typically sparse in the region, and cannot be increased through a careful search in archives. An attempt is made to apply the recommended rigorous methodologies of historical seismology developed using ample data to the sparse reports from this part of the world. Attention is paid to the context of reporting, the identity and role of the author, the circumstances of reporting and the chance of verifying the available information by collating the sources. The reliability of oral earthquake recollections is evaluated. An improvement to existing databases using parametric earthquake scenarios is proposed.

# Using Continues Wavelet Transform and Wavelet Packet Denoising for Automatic Earthquake P-phase Picking

Nasim Karamzadeh, Gholam Javan Doloei, Alireza Moghaddamjoo

In this paper we present a new method for automatic earthquake phase picking based on pre-filtering of z-component seismogram with Wavelet Packet (WP) denoising scheme and detection in Continues Wavelet Transform (CWT) coefficients. The proposed method consists of following steps: At the first step WP based prefiltering has been done using bior6.8 mother wavelet. Then, CWT coefficients that have been calculated for a predefined scale are used to produce a Characteristic Function (CF). Afterwards, the first estimation of the P-onset time, $t_I$, is obtained by checking three adaptive thresholds on the CF, these thresholds control energy amplitude and duration of the earthquake signal. Finally, a time window of 10 seconds around $t_I$ is selected and the same procedure is followed by using bior1.3 analyzing wavelet and the final P-phase onset, $t_P$, is calculated and declared.

Performance of the method is evaluated on a database of more than 200 very minor ($2 \leq m_b < 3$) local earthquakes and the P-phases which are determined by the algorithm are compared with the operator P-phase picking existed in the databases. Results indicate the reliable performance of the proposed method. Time difference between the manual and the automatic P-phase arrival time obtained less than 0.2, 0.1 and 0.05 sec for about 98%, 96%, and 86% of the events, respectively. In addition results are compared with an existing well-known method of P-phase picking called Autoregressive Akaike Information Criteria (AR-AIC), which indicates the reliable performance of the proposed method.

This poster was presented by Peter Voss.

# Noise levels and detection maps from the Norwegian National Seismic Network

Lars Ottemöller and Berit Marie Storheim Department of Earth Science, University of Bergen, Bergen, Norway

The Norwegian National Seismic Network, operated by the University of Bergen (UiB) and NORSAR, comprises of both short-period and broadband seismic stations. The total of seismic stations is 39 of which 35 are operated by UiB and 4 by NORSAR. This presentation will show the noise levels at the UoB stations, and illustatres how those compare to detection maps. The noise levels are presented as power spectral density plots, which have become the standard for displaying microseismic noise.

These plots allow for site evaluation, but are also used as tool to identify equipment problems. Based on the recorded earthquake catalogue detection levels were computed, which can help to identify regions where additional stations may be required. Future plans for the network include the installation of additional broadband stations, and completion of the transition to real-time data.

# Assessment of active basement faults, capable of producing destructive earthquakes, in Denmark?

S. Gregersen[1], P. Voss[1]
[1]GEUS, Denmark

Whether geologically known faults are active is obvious in earthquake zones, while an assessment is needed for intraplate non-earthquake zones. The inactive area Denmark must naturally be seen in a regional frame of Scandinavia. And the assessment of faults, which could eventually produce a destructive earthquake, must include long-term evidence from geology of time scales thousands of years, as well as short-term evidence from seismology and geodesy. The medium-term evidence from paleoseismology on time-scale a few thousands of years is non-existent. The assessment must besides the Scandinavian arguments include parallel arguments on other continents of similar structure and of similar global tectonic situation. Comparisons can be made to other earthquake-free intraplate areas like eastern North America. Discussions on the importance of uplift/subsidence in Denmark/southern Scandinavia are once more taken up these years in the lithosphere project DynaQlim, which covers Upper Mantle Dynamics and Quaternary Climate in Cratonic Areas. An evaluation of the earthquake potential in the Danish area is here presented with improved background material. None of the faults in Denmark are found to show potential for destructive earthquakes.

# Moment tensor of the 16 DEC 2008 earthquake in Skåne, Sweden

Jeppe Regel

Technical University of Denmark
DTU Kemiteknik, Institut for Kemiteknik, CERE - Center for Energi Ressourcer
jeppe.regel@gmail.com

By applying the Dreger code; waveform inversion of locally measured seismograms, to the Skåne earthquake on 16th December 2008, solutions for the moment tensor at 20 different hypocentric depths was compute. A local 1D crustal model was used to represent the sub layers of northern Europe. By evaluating the variance between the computed wave and the observed wave, it was estimated that the best solution for the moment tensor was found at a depth of 8 km +-1km. The moment tensor found, show a slightly tipped vertical strike-slip movement with the corresponding compression stress field in the NNW-SSE direction, which is consistent with results found by others. I found that a 1D low resolution crustal model is sufficient to get results but for further studies, better knowledge of the northern European sublevels should be obtained.

# Depth estimation of the main Haiti earthquake 12 JAN 2010 and selected aftershocks, from travel times of teleseismic pP- and sP-phases observed at the SUMG seismograph, Greenland

Kasper Kofoed Ljungdahl
University of Copenhagen, Niels Bohr Institute
Blegdamsvej 17, 2100 København Ø
kasperljungdahl@gmail.com

By using the seismic signal from the SUMG seismograph, manual identification of the pP- and sP depth phases for the Haiti Earthquake of 12th January 2010 and selected aftershocks were possible. The time differences between the pP and sP arrivals were compared with depth-values obtained from the seismic travel calculator TauP. The estimated depths from TauP were then added to the individual seismic signal as an attribute. The observed seismic signals from each earthquake were then finally compared with a synthetic seismogram produced by the Q-seis program in order to evaluate the TauP depth estimation. The synthetic seismograms were very consistent with the expected depths of the observed ones. The Method allowed a depth estimation of totally 13 Earthquakes with the precision of approximately ±1 km to be found. Further enhancement on the project should be added in order to obtain earthquakes depth for aftershock under 5.0 on the Richter scale.

# Parameter sensitivity of ground motion simulations based on hybrid broadband calculations. A case study for İzmir, Turkey

Louise W. Bjerrum, Mathilde B. Sørensen and Kuvvet Atakan
Department of Earth Science, University of Bergen, Norway

İzmir, the third largest city in Turkey, has been destroyed by large earthquakes several times in history, latest in 1778. In this study, we conduct a deterministic seismic hazard assessment for earthquake ruptures along the İzmir fault, striking directly underneath the city. The level and distribution of peak ground motion is highly dependent on the input parameters. The sensitivity of the ground motion to input parameters is therefore investigated in this study. The method adopted is a broad-frequency ground motion simulation technique, where computations are conducted in two frequency bands; low frequencies (0.1-1.0 Hz) using deterministic simulations and high frequencies (1.0-15 Hz) using semi-stochastic simulations. The calculations for each frequency band are done separately, and the resulting ground motions are combined in the time domain. All computations are done for the bedrock site conditions, and possible site effects are therefore not taken into consideration. We calculate 30 earthquake scenarios, dividing the fault into a grid of point sources and assign different source parameters in order to study their effect on the resulting ground motions. The most important parameters in terms of ground shaking level and distribution are the location of the rupture initiation point, rise time, seismic moment and frequency dependent attenuation. The largest variability of strong ground motion is observed close to the asperity and rupture initiation point for frequencies larger than 1 Hz. The ground motion for lower frequencies is primarily controlled by the location of the rupture initiation point, seismic moment, fault depth and rise time. In case of the higher frequencies the ground motions are most sensitive to average applied stress drop, fault depth and seismic moment.

# Seminar history

**Nordic Seminars on Detection Seismology**

This webpage host the program and abstract volumns and for the Nordic Seminars on Detection Seismology. If you have a copy (paper/digital) of a volumn that is not on this page please send it to pv at geus.dk as pdf/word/text or scanned files and it will be added to this list.

| Title | Host | Date | Program | General info | |
|---|---|---|---|---|---|
| 41st Nordic Seminar on Detection Seismology | Aarhus UNI | 2010 October 6-8 | | PDF | |
| 40th Nordic Seminar on Detection Seismology | FOI | 2009 October 14-16 | PDF | | |
| 39th Nordic Seminar on Detection Seismology | NORSAR | 2008 June 4-6 | PDF | | |
| 38th Nordic Seminar on Detection Seismology | Helsinki UNI | 2007 June 13-15 | | WWW | PDF |
| 37th Nordic Seminar on Detection Seismology | VEDUR | 2006 August 21-23 | PDF | WWW | |
| 36th Nordic Seminar on Detection Seismology | GEUS | 2005 June 8-10 | PDF | | |
| 31st Nordic Seminar on Detection Seismology | KMS | 2000 September 27-29 | PDF | | |
| 26th Nordic Seminar on Detection Seismology | KMS | 1995 November 20-22 | PDF | | |

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