36th NORDIC SEISMOLOGY SEMINAR

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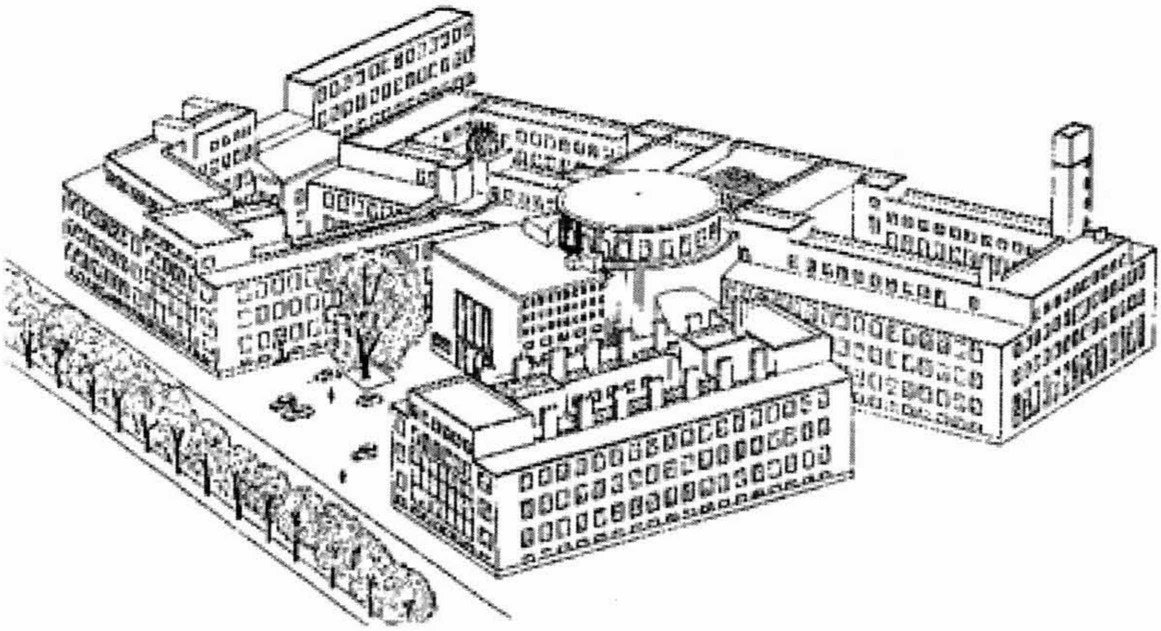

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	11:20 – 11:40	The Grímsvötn eruption in November 2004: Comparison with the Hekla 2000 eruption, Steinunn S. Jakobsdóttir
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	14:10 – 14:30	The Swedish national seismological network – 60 Broad-Band stations, R. Bödvarsson
	14:30 – 14:50	The seismic stations in Denmark and Greenland, T.B. Larsen, P. Voss, S. Gregersen and HP Rasmussen
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	16:15 – 16:40	Departure by boat to seafort Trekroner which lies at the entrance to Copenhagen Harbour.

		The foundation of the seafort was laid in 1786, and it was thanks to Trekroner and 66 cannons and 18 naval vesels, that the British fleet in 1801 was not able to enter Copenhagen Harbour. Nowadays the island is open for visitors.
	16:40 – 17:40 or 18:10	Sightseeing at seafort Trekroner
or	17:40 – 18:00 18:10 – 18:30	Sailing back to the city center (Amaliehaven)
	19:00 – ?	Dinner at Restaurant Rebétiko, Borgergade 134, 1300 Copenhagen K, Phone: 33 91 91 25. Reservation under the name: Søren Gregersen Dinner at participants own expense

Friday, 10 June		
Large-scale structural studies Chair Pekka Heikkinen	09:00 – 09:20	Seismic Heterogeneity in the Crust and Upper Mantle, H. Thybo, L. Nielsen, A. Ross, and A. Pontevivo
	09:20 – 09:40	Test of the Upper Mantle Low Velocity Layer in Siberia with Surface Waves, Antonella Pontevivo and Hans Thybo
	09:40 – 10:00	Rayleigh wave attenuation in Greenland, T. M. Jørgensen, T. B. Larsen, F. Darbyshire, S. Gregersen, P. Voss, O. Gudmundson, W. Hanka, and T. Dahl-Jensen
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Seismic hazard Chair Jens Havskov	10:30 – 10:50	National Seismic Risk Assessment – an Example from Germany (CEDIM), G. Grünthal and R. Wahlström
	10:50 – 11:10	Ground motion simulations for a M=7.5 scenario earthquake in the Marmara Sea and implications for the city of Istanbul, Turkey, M. B. Sørensen, N. Pulido, K. Atakan, A. Ojeda, and M. Erdik
General Chair Jens Havskov	11:10 – 12:00	General discussion and concluding remarks
Lunch	12:00 – 13:30	

1. Crustal Structure along FIRE Deep Seismic Reflection Lines

Annakaisa Korja (1), Pekka Heikkinen (1), & FIRE Working Group.

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The FIRE (Finnish Reflection Experiment) consortium - consisting of the Geological Survey of Finland, and Universities of Helsinki and Oulu, with Russian Spetsgeofizika S.G.E. as a contractor - carried out Vibroseis measurements between 2001 and 2003 in Finland. Four lines with a total length of 2100 km have been measured. The depth penetration of the profiles is 80 km. The reflection lines follow main roads and when possible old deep seismic refraction profiles SVEKA, FENNIA, BALTIC, POLAR).

The FIRE-lines transects the main geological boundaries of the Fennoscandian Shield. FIRE lines 1 and 3 cross the Archaean-Proterozoic boundary zone that was formed when the Paleoproterozoic terranes collided with the rifted Archaean margin. FIRE lines 1-3 cross-cut each other at the Central Finland Granitoid Complex displaying orogenic stacking and collapse structures. FIRE line 2 is the southern continuation of line 1. Line 2 images the Southern Finland Arc Complex. FIRE line 4 is situated in northern Finland. It displays crustal structures associated with Paleoproterozoic rifting of the Archaean Karelian Craton and the following Proterozoic collisions initiating the overthrusting of the northern schist belts and Lapland Granulite Belt.

2. 3D waveform modelling for the Pyhaesalmi ore mine, Finland.

Michael Roth.

NORSAR, Norway.

Over the last 3 years we have collected and processed microseismic events that occurred in the Pyhaesalmi mine, Finland. The data are recorded with an in-mine seismic network and they comprise production blasts and rock bursts. Both source types generate significant shear wave energy. This is not surprising for the rock bursts, because they are supposed to contain a shear failure component. The blasts, however, are expected to radiate mainly compressional waves. In the ideal case of a explosion point source in a homogeneous full space shear waves cannot be generated at all.

Generally, the subsurface is heterogeneous and, more important, the blasts are close to the free surface. The interaction of the explosive source with heterogeneities in the immediate vicinity produces a shear wave component that propagates independently. In addition, there is more shear wave generation due to scattering and wave conversion during the propagation of the regular P- and S-waves resulting in P- and S-wave codas.

In order to investigate these effects we performed 3D finite-difference (FD) computations for the Pyhaesalmi mine model. To this end we used a viscoelastic finite-difference code written by Bohlen (2002, C&G). The code is stable even for very strong material contrasts and it uses the message passing interface (MPI) standard, which allows the implementation on a computer cluster. We considered 3 different models: a) a homogeneous model, b) a model with the host rock and the ore body and c) the complete mine model including the excavated stopes. The models were discretized onto a 2 m grid, and the total model volume was (600 m)^3. The synthetic seismograms for the complete mine model show the same characteristics as the observed seismograms in terms of shear wave generation and scattering.

3. Construction and testing of a 3D seismic velocity model in the greater Barents Sea region

N. Maercklin (1), O. Ritzmann (2), H. Bungum (1+2), J.-I. Faleide (2+1), W. D. Mooney (3), & S. T. Detweiler (3).

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(2) Dept. of Geosciences, University of Oslo, POB 1072 Blindern, N-0316 Oslo, Norway.
(3) U.S. Geological Survey, 345 Middlefield Rd., Menlo Park, California, USA.

We constructed a 3D seismic *P* velocity model for the extended Barents Sea region including Svalbard, Novaya Zemlya, the Kara Sea, and the Kola-Karelia regions. The crustal model is based on a large number of existing 1D and 2D velocity profiles, constrained by geological observations, and the nominal resolution is 50 km. Each grid node is filled with a five-layer crustal model (plus water and ice), and the continuous upper mantle velocity structure is taken from published regional models. Seismic *S* velocities and the density structure shall be included in the near future. The final model also aims to improve seismic monitoring and verification in this region, including improved event locations and event size estimation, and a better understanding of regional seismic wave phases.

Validation of the velocity model includes forward modeling of observed travel times and relocation of seismic events. For this purpose we compiled a set of reference events with known or well-located epicenters, referred to as *Ground Truth* (GT) events. The GT events comprise quarry blasts and announced chemical explosions located mainly in Scandinavia and the Kola Peninsula, nuclear explosions in northwestern Russia and on Novaya Zemlya, and natural earthquakes. With these events we obtain good *Pn* and *Sn* ray coverage in the main target region. Phase arrival times of multiple events at some sites provides estimates on timing errors at some stations.

Here we present the model in terms of regional contour maps and seismic velocity transects. North-south trending transects in the western Barents Sea show Moho depths between 10 and 45 km, with average values around 35 km. Thicknesses of sedimentary layers vary considerably and reach locally more than 10 km. Strongest variations are observed in the west between northern Norway and Svalbard, whereas transects further east exhibit a more simple, layered crustal structure. As the crustal velocity structure in the source or receiver region strongly influences phase arrival times, the detailed 3D model is therefore also important for the monitoring of events at regional distances, where corresponding ray paths run mainly in the upper mantle. Furthermore, there are evidences for significant velocity variations in the mantle of our study region.

4. A teleseismic receiver function study in southern Norway

L. Svenningsen (1), N. Balling (1), B. H. Jacobsen (1), R. Kind (2), & H. Bungum (3).

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At the end of the Cretaceous period the Scandinavian Caledonides and the Scandinavian Peninsula as a whole were eroded to a peneplane. During the Cenozoic, major parts of the peninsula is expected to have been uplifted resulting in a present mean topography of up to 1200 m with summits above 2400 m.
Details of timing and causes of uplift are not known. Suggested uplift mechanisms include asthenospheric diapirs, lithospheric delamination, and crustal underplating.
As a part of the multidisciplinary project *CENMOVE (CENozoic vertical MOVEments in NW Europe)* teleseimic data are collected along two profiles in southern Norway. These profiles cross the two major highlands, Hardangervidda (Lillehammer-Bergen) and Jotunheimen (Lillehammer-Ålesund), respectively. We apply the receiver function method to improve knowledge of lithospheric structures and, in particular, the crust-mantle boundary of the region. This will improve our basis to distinguish between different uplift mechanisms.
The two profiles contain 6 and 11 mobile seismograph stations, respectively, including both shortperiod and broadband seismographs. Station spacings are between 20 and 50 km. Across Hardangervidda, 5 stations were deployed for half a year during the summer of 2001. Across Jotunheimen, 11 stations were deployed from spring 2002 until spring 2004. Results of the receiver function analysis are presented including new information on Moho topography.

5. High velocity structure in the crust of central Denmark from ray-inversion of ESTRID seismic refraction project

Alessandro Sandrin & Hans Thybo.

Geological Institute, University of Copenhagen, Denmark.

The main target of the project is to define the size and shape of a large intrusion in the middle–lower crust in central Jutland. The supposed existence of the intrusion was investigated by Thybo & Schoenharting (1991) and Zhou & Thybo (1996) through analysis of gravity data. The signature of a high density body below the city of Silkeborg is clearly indicated by the gravity data, the upward continuation of which indicates that the anomaly is due to a body that reaches depths >20 km.

To better constrain the shape and size of the intrusion, the ESTRID (Explosion Seismic Transect at a Rift In Denmark) seismic refraction campaign was carried out in May 2004. The main profile strikes approximately W–E (parallel to the elongation axis of the intrusion) for 140 km from the North Sea to the City of Århus. A total of 238 1-component seismographers were deployed at an approximate distance of 600 m. Six shots were detonated at regular distances along the profile: two shots of 500 kg of dynamite in the North Sea and in the Århus bay respectively, and four more shots inland. Additionally, 150 instruments were deployed in a fan geometry (75 instruments for each fan), with centres located at the shot-points at sea.

The data obtained were used for seismic tomography of P-waves, and the preliminary velocity structure was used as a starting model for a travel-time forward modelling and inversion on first and second arrivals (Zelt & Smith 1992). Several phases were noted in the seismic sections for the six shots. The diving waves in the sedimentary succession (P_s) have a cross-over offset at ~20–25 km with the diving waves in the basement (P_g). The P_g shows velocities in the range 6.0–6.8 km/s, increasing with depth. The upper mantle diving/refracted wave (P_n) is identified at extreme offsets and only for a few seismograms, therefore the velocities in the lower crust and the depth to the Moho were investigated using the P_mP (Moho reflected waves).

The velocity structure obtained shows a sedimentary succession with low to intermediate velocities (~2.0–5.8 km/s) to a depth of ~8–9 km. At this depth the velocity increases to >6.2 km/s. This is interpreted as the top the basement. Moreover a high velocity anomaly (>6.8 km/s) is observed at distances of 60–160 km from shot-point 1, with the top at a depth of 11–12 km. This high velocity zone matches the positive anomaly in the gravity data and is therefore interpreted as due to the supposed intrusion. The depth to the Moho varies from ~28 km in the western part of the ESTRID profile to ~32 km in the easternmost part of the profile.

6. Seismic mapping of the Carlsberg Fault, Copenhagen, Denmark

L. Nielsen, H. Thybo & M. I. Jørgensen.

Geological Institute, University of Copenhagen, Denmark.

The Carlsberg Fault is located in a NNW-SSE striking fault system in the border zone between the Danish Basin and the Baltic Shield. Recent, small earthquakes indicate that this area is tectonically active. It has been debated whether the Carlsberg Fault is still active or not.

In this study, we locate the concealed Carlsberg Fault zone along a ~20 km long trace in the Copenhagen city center by seismic refraction, reflection and fan profiling. We supplement our seismic investigations with multi-electrode geoelectrical profiling. The seismic refraction study shows that the Carlsberg Fault zone is a low-velocity zone and marks a change in seismic velocity structure. A normal-incidence reflection seismic section shows a coincident flower structure. We have recorded seismic signals in fan geometries from shots detonated both inside the low-velocity fault zone and up to about 1 km away from the fault zone. The seismic energy was recorded on a total of six receiver arrays (1.5-2.5 km long arcs) across the expected location of the 400-700 m wide fault zone at distances of up to 10 km from the shots. Shots detonated inside the fault zone result in: 1) weak and delayed first arrivals on the receivers located inside the fault zone compared to earlier and stronger first arrivals outside the fault zone; 2) strong guided P- and S-waves as well as surface waves inside the fault zone. The fault zone is a shadow zone to shots detonated outside the fault zone. Finite-difference wavefield modelling supports the interpretations of the fan recordings.

Our fan recording approach facilitates cost-efficient mapping of fault zones in densely urbanized areas where seismic normal-incidence and refraction profiling are not feasible. The geoelectrical measurements show that the fault zone is characterized by low resistivities (< 5 ohmm), indicating that the fault zone is fractured and water-filled. This interpretation is supported by hydrological measurements conducted by others, which show that the Carlsberg Fault zone is highly permeable.

7. Modeling of ground motions and stress transfer caused by the December 26, 2004 Sumatra earthquake

M. B. Sørensen (1), K. Atakan (1), J. Havskov (1), N. Pulido (2), & A. Ojeda (3).

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On December 26th 2004, a devastating earthquake of M=9 occurred offshore Northern Sumatra. Due to the size of this earthquake and the accompanying tsunami wave, disastrous consequences have been observed at several countries around the Indian Ocean with a total death toll of more than 200 000. The tectonics in the region are characterized by the oblique, NNE oriented subduction of the Australian and Indian plates under the Sunda microplate with a rate of 6-6.5 cm/yr. This oblique convergence results in strain partitioning, where the trench perpendicular thrust faulting along the subducting slab accommodates the E-W component of the motion, whereas the N-S component of the motion is probably accommodated by the right-lateral strike slip faulting along the Great Sumatran Fault which passes along the western part of the main Sumatra island parallel to the volcanic chain. Source parameters of the December 26th 2004 event have been used for modelling the resulting ground motions in the nearby affected regions. This will give information about the importance of ground shaking in the total destruction of places like Banda Aceh, Northern Sumatra, Indonesia. The modeling is performed for a multi-asperity finite fault using a hybrid procedure combining deterministic modeling at low frequencies and semi-stochastic modeling at high frequencies. In addition, stress transfer is modeled to estimate the resulting stress distribution and give an insight to the issues of future earthquakes along the neighboring segments of the subducting slab or along strike-slip faults on mainland Sumatra.

8. The threat of tsunamis in Europe caused by earthquakes

G. Grünthal & R. Wahlström.

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A comparison of epicentral maps of large earthquakes in and along the border of the western Eurasian Plate, including the Mediterranean Sea region, shows the advantage of a map based on data compiled, edited and unified (M_w magnitudes) from many regional catalogues and special studies, compared to listings from international seismological centres. There is a long record of deadly tsunamis in above all the Mediterranean region. The by far most usual cause of tsunamis is earthquake rupture underneath the sea, and the study of the occurrence and distribution of large earthquakes in Europe and the Mediterranean indeed has a strong practical motivation. It is pointed to the relevance of high quality earthquake maps, based on more complete and constrained data than in the conventional maps, for tsunami hazard estimations.

9. The Scientific Correspondence between Inge Lehmann and Harold Jeffreys

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The scientific correspondence between Inge Lehmann (1888-1993) and Sir Harold Jeffreys (1891-1989) is preserved in the Inge Lehmann archive in Holte, currently being high resolution scanned at Storia Geofisica Ambiente, Bologna. The letters by Inge Lehmann are either drafts or carbon copies, since Jeffreys´ originals have disappeared. The poster show historic examples of the scientific correspondence between a good observer and a good theoretician.

The poster also show how the idea of a discontinuity surface within the core was proposed by Inge Lehmann in a letter to Harold Jeffreys, May 31, 1932. At the discontinuity surface the velocity increased with depth. She wrote that there is hardly anything to disprove such a surface in present observational data. That was four years before her paper, entitled P´, that proposed the existence of an inner core. Jeffreys answer dated June 4, 1932 was discussed by Bischoff (2004), he describes how her studies of the June 17, 1929, Buller, New Zealand earthquake had made her wonder about P waves at Swerdlowsk and Irkutsk in the shadow zone. Jeffreys thought that diffraction could account for her observations.

Inge Lehmann discovered the inner core, but her model does not consider the question about whether the inner core is solid or fluid, that was done by others much later (e.g. Birch, 1940; Bullen, 1946; Bolt, 1987 and Cao et al., 2005).

Inge Lehmann took part in the creation of the European Seismological Commission in 1951 (with Wilhelm Hiller as president), and in the creation of the International Seismological Centre in 1964. Sir Harold Jeffreys is known for his distinguished work in many branches of geophysics and also in the theory of probability and astronomy.

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10. Resolution of the teleseismic tomographic image of the subcrustal transition at the Tornquist Zone

Peter Voss (1), Søren Gregersen (1), & the TOR Working Group.

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Several studies have shown that a major subcrustal transition zone is found in the area of the Tornquist Zone. In order to study how well this major subcrustal transition zone can be resolved with teleseismic tomography, we present results from inversions of relative P-phase travel times of data from the TOR project. The data consist of 3400 relative P-phase travel times from 48 earthquakes at teleseismic distances observed on 150 seismic stations installed on the 900 km long and 100 km wide TOR array. The result are from a inversion with a standard reference model used as a priori model and a inversion with a hard a priori constraint that only allow two lithospheric plates with a sharp transition in the tomographic image. The results are compared to synthetic inversions. These inversions are a checkerboard test, a vertical transition test and a northeast dipping transition test. In all the inversions the inverse Monte Carlo sampling scheme is used.

11. Depth to Moho in Greenland: Receiver Function Analysis suggest two Proterozoic Blocks in Greenland

Trine Dahl-Jensen (1), Tine B. Larsen (2), Ingo Woelbern (3), Torben Bach (2+4), Winfried Hanka (3), Rainer Kind (3), Søren Gregersen (2), Klaus Mosegaard (5), Peter Voss (2+5), & Olafur Gudmundson (6).

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(6) Danish Lithosphere Centre, Øster Voldgade 10, DK-1350 Copenhagen K, Denmark.

The GLATIS project (Greenland Lithosphere Analysed Teleseismically on the Ice Sheet) with collaborators have operated a total of 16 temporary broadband seismographs for periods from 3 months to two years distributed over much of Greenland from late 1999 to present. The very first results are presented in this paper where receiver function analysis has been used to map the depth to Moho in a large region where crustal thicknesses were previously completely unknown. The results suggest that the Proterozoic part of central Greenland consists of two distinct blocks with different depths to Moho. North of the Archean core in southern Greenland is a zone of very thick Proterozoic crust with an average depth to Moho close to 48 km. Further to the north the Proterozoic crust thins to 37-42 km. We suggest that the boundary between thick and thin crust forms the boundary between the geologically defined Nagssugtoqidian and Rinkian mobile belts, which thus can be viewed as two blocks, based on the large difference in depth to Moho (over 6 km). Depth to Moho on the Archean crust is around 40 km. Four of the stations are placed in the interior of Greenland on the ice sheet, where we find the data quality excellent, but receiver function analyses are complicated by strong converted phases generated at the base of ice sheet, which in some places is more than 3 km thick.

12. An unusual earthquake in central Sjælland, Denmark

Tine B. Larsen (1), Søren Gregersen (1), Vanja Orozova-Bekkevold (2), & Peter Voss (1).

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(2) Danish Transport Research Institute (DTF), Lyngby, Denmark.

On November 6, 2001 at 18:05 UTC a small, ML=2.8 earthquake struck central Sjælland, approximately 60 km from Copenhagen. Despite the modest magnitude, the shaking and loud sounds from the earthquake frightened people over a large area. Minor damage to a few houses was reported. Earthquakes in Denmark are rarely strong enough to be felt, and site responses are only known in very general terms. This particular earthquake resulted in more than 300 useable felt reports. More than half of the observers reported hearing deep humming sounds or a large bang as the earthquake struck. The earthquake was felt widely east of the epicenter, out to a distance of more than 60 km, whereas the earthquake was hardly felt west of the epicenter. The felt area correlates very well with the local geology, where thick sediments west of the epicenter appear to have dampened out the shaking. Several techniques for determining the focal mechanism have been tested, but the data quality is insufficient to yield a reliable result.

13. Advanced array processing at NORSAR: Recent developments and future plans

Frode Ringdal, Tormod Kværna & Steven J. Gibbons.

NORSAR, Norway.

Scientists at NORSAR have for a number of years conducted research to improve seismic monitoring tools at regional distances, with emphasis on the Barents/Kara Sea region, which includes the former Novaya Zemlya test site. The activities comprise development and improvement of detection, location and discrimination algorithms as well as experimental on-line monitoring using tools such as regional Generalized Beamforming (GBF) and Threshold Monitoring (TM). It also includes special studies of mining events in various regions.

This presentation will concentrate on three aspects which are currently being focused upon in NORSAR's research program: 1) Further development of NORSAR's regional on-line processing system for automatic multi-array detection and location, 2) Advanced site-specific one-array processing, using a "spotlighting" technique to achieve optimized event detection and location, and 3) Use of waveform correlation in combination with array processing to achieve an order-of-magnitude improvement in detection capability at sites for which appropriate calibration information is available.

We will provide examples illustrating the potential of the "spotlighting" technique to provide automatic one-array locations comparable to or better than analyst-reviewed network-based locations. We will further present examples on the power of the array-based correlation technique, demonstrating, for example, that waveform correlation could be used to detect the small aftershock (m_b=2.5) following the 16 August 1997 Kara Sea event, not only at the Spitsbergen array (distance 1100 km), but even at the large NORSAR array situated more than 2300 km from the epicenter. We also discuss some other potential applications of this technique, which is currently a major research project at NORSAR.

14. The detection of low magnitude seismic events using array-based waveform correlation

Steven Gibbons.

NORSAR, Norway.

The most effective method of detecting a signal with a known form in noisy data is to correlate the incoming data stream with a waveform template. Such methods have received relatively little attention in the field of detection seismology for the simple reason that the majority of detected signals do not correspond to waveforms which are known a priori. However, waveform correlation provides an exceptionally effective method for the detection of low-magnitude events from sites for which good signals already exist.

For each channel, a running cross-correlation coefficient is calculated by sliding the template waveform along the datastream. If a detected event is truly co-located with the event which generated the master signal, the peaks in the correlation functions for the different seismometer sites will occur simultaneously and beamforming can be applied to increase the likelihood of detection over an array. One remarkable result is that the correlation traces are coherent even when the waveforms themselves are not, meaning that correlation beams can be calculated for large aperture arrays and spare networks. We demonstrate examples in which events up to a magnitude smaller than that detectable using traditional array-processing methods have been detected using the matched filter detector.

15. Increased possibilities to hide nuclear tests in the coda of earthquakes.

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Improvements in earthquake warning algorithms make it easier to hide nuclear weapon tests in earthquake coda. The long term warnings indicate often the place of the next large earthquakes years before. The short term warnings are often giving indications of one or more months before which may be used for hiding a weapon test. The nuclear explosion can be placed in the vicinity of the coming earthquake and may then be fired automaticly by sensors close to the epicenter. Simple methods like mb/Ms may then fail to identify the explosion. This point will be illustrated by a closer look at some Icelandic earthquakes for which the use of microearthquakes has been tested for gaining information of where and when an earthquake will occur. Especially use of the fault plane solutions of the microearthquakes will be discussed. The quality of the earthquake prognoses is expected to improve and already today some countries may have advanced methods that can be used for hiding explosions.

16. Energy Partitioning for Seismic Events near the Coast of Western Norway

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We have addressed the question of how seismic energy is partitioned between P and S waves at regional distances between 20 and 220 km. The database for this study consists of recordings at the stations of the National Norwegian Seismic Network (NNSN) of events from the region offshore Western Norway. For this region we have both natural earthquake activity as well as frequent occurrence of underwater explosions carried out by the Norwegian Navy. The data were provided by the University of Bergen.
For a set of 49 presumed earthquakes and 24 presumed underwater explosions, we measured the S/P ratios in different frequency bands at seven stations of the NNSN (KMY, BLS, ODD, ASK, SUE, HYA and FOO). For both event populations we investigated the effects of epicentral distance and frequency band, as well as individual station effects.
A result from this study is that the mean S/P amplitude ratios for explosions and natural events differ at individual stations and are in general higher for natural events and frequency bands above 3 Hz. However, the distributions of S/P ratios for explosions and natural events overlap in all analyzed frequency bands. Thus, for individual events in our study area, S/P amplitude ratios can assist the discrimination between an explosion or a natural event, but other measures such as spectral analysis should be included in the interpretation.

17. A local seismicity study in Kuusamo, NE Finland

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In a low-seismicity region such as Finland, earthquakes are weak and randomly scattered. Analysis of microearthquakes (magnitude less than 2) recorded by a dense local network can, however, provide reliable data on local stress field and slip pattern as well as on active faults and their geometry.

During the years 2003 and 2004, a temporary network of five three-component stations has been installed at Kuusamo, the most seismically active area in Finland. The Kuusamo region is transected by two major shear zones. The first one is a NE-oriented zone starting from central Finland and continuing to the White Sea and the second one is a NW-SE-striking zone bounded by Näränkävaara, Iivaara and Mustavaara. Earthquake activity seems to cluster at the intersections of these zones. The Kuusamo network, completed with the permanent station at Maaselkä (MSF), is covering the areas of enhanced seismicity. In addition to the research on local seismicity, the recordings of the network will be used in local tomographic studies.

First results of the seismicity survey in Kuusamo are presented.

18. The Grímsvötn eruption in November 2004: Comparison with the Hekla 2000 eruption

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On 1 November 2004 a subglacial eruption started in the Grímsvötn caldera in Vatnajökull. The eruption was predicted in both long term and short term. GPS measurements in June 2004 revealed that the southern caldera rim was uplifted to similar position as prior to the last eruption, in 1998, and seismic activity had increased mid-year 2003. Also, observations of meltwater accumulation in the caldera showed that a flood, or jökulhlaup, was imminent. Two weeks before the eruption the seismic activity increased again. This was interpreted as a precursor to a jökulhlaup or/and an eruption and therefore a notification was given to the national civil defense authorities. Monitoring the evolution of the earthquake activity led to a forecast of a jökulhlaup a day or two before the water reached the outlet from the glacier.

Already in 1953 the Icelandic volcanologist Sigurður Þórarinsson suggested, based on his observations, that pressure release due to jökulhlaup might trigger an eruption. Therefore the first notice about an expected eruption was sent to the aviation authorities a couple of days before the onset of it. At the onset, in the evening of 1 November, the national civil defense authorities, the Oceanic Area Control Center (for aviation), the Volcanic Ash Advisory Center in London and scientists at other institutes were notified that an eruption had started.

The eruption lasted just over 4 days. Even though this was a relatively small eruption the first traces of it were seen some 2 weeks prior to the onset. The situation was very different for the eruptions in the volcano Hekla, where earthquake occurrence started about an hour before the onset. In this presentation the monitoring of Grímsvötn 2004 eruption will be illustrated and it compared to Hekla 2000.

19. Felt reports at large distances of the eartquakes in non-seismic Kaliningrad in West Russia

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The earthquake activity in Northern Europe is generally of magnitude well below 6 and with felt reports from distances up to a few hundred kilometres. The earthquakes of magnitudes 4.4 and 5.0 in the Kaliningrad enclave of West Russia on 21 SEP 2004 were exceptional in an area devoid of seismic activity (Fig. 1). Macroseismic felt observations were collected in all of the nine countries surrounding the Baltic Sea and further away in Norway and Belarus, at exceptionally long distances up to 800 km (Fig. 2). Minor damage occurred in the Kaliningrad enclave and in northern Poland. As far away as in Landskrona in Southern Sweden the town hall was evacuated for a moment. The intensity distribution is very elongated along the geological trend of the Tornquist Zone, along the edge of the Baltic Shield and the East European Platform. This pattern is almost a mirror image of that of the Oslo earthquake in Norway in 1904 (Fig. 3), which was felt as far away as in the Baltic states.

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20. One hundred years of seismic stations in Norway

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The seismograph installed at the Bergen Museum in 1905, marked the initiation of the Norwegian National Seismic Network (NNSN). Since then, there have been several single stations, small local networks and arrays in operation. From 1990, all stations except the NORSAR (Norwegian Seismic Array) arrays, were joined in the national network. The Norwegian oil industry has supported the operation of seismic stations at UiB since 1984. NNSN is today financed by the University of Bergen and the Norwegian Oil Industry Association and the operation takes place at Department of Earth Science, the University of Bergen. The network now has 30 stations, of which 6 are broad band. About 4000 events a year are recorded, the majority of which can be located. The majority of the old data and all new data is available at our web site www.geo.uib.no. The 100 years of operation was celebrated May 12 with a seminar and the opening of an interactive seismology exhibition at the Bergen Museum.

21. Upgrading of The Seismic Stations in Finland: Never Ending Project

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During the last decade instrumentations of the seismic stations in Finland have gone through many levels. Today practically all the stations are equipped with 24-bit digitizers and 3-c broad band seismometers

There is a plan to replace in all of the stations the quite new recording system with a brand new system which will be developed this year by engineer Seppo Nurminen. At the same phase there is an aim to continue to connect almost all our stations to the internet, some of those connected through satellite.

The network in Finland is increasing with two new stations during this year.

22. The Swedish national seismological network - 60 Broad-Band stations

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Over the last few years, 47 new, permanent, digital, broadband seismological stations have been deployed in Sweden, from Lannavara in Lappland in the North to Blekinge in the South. The network operates largely automatically, and is now essentially complete in the Eastern part of the country. Additional 13 stations are under construction and will be set in operation by the end of this year.

The primary objective of this 60 station network is to monitor local seismicity. With the current station spacing of about 100 km, completeness down to magnitude 0 is assured within the network.
This magnitude corresponds to very small moments, for example to a motion of 0.01mm over a fault area with a radius of about 50m. Several hundred Swedish earthquakes are detected every year. Only a few (5 to 10) of these are so large that they are felt by people living close to the epicentre. While Sweden is a low seismicity area, the high sensitivity of the system means that ongoing deformation processes in the crust can be monitored in detail. As a larger data set is gradually acquired, it will also be possible to use information from these events to elucidate structures within the Swedish crust.
In addition, the network records signals from larger distant (teleseismic) earthquakes, and also regional events of sufficient magnitude. These data are analyzed to reveal details of the structure within the crust and upper mantle below the recording stations.

23. The seismic stations in Denmark and Greenland

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The transition to a digital seismograph network in Denmark and Greenland was speeded up in 1999, and today we operate a fully digital broad-band network in both places. The Danmarkshavn station in northern Greenland is still equipped with both an analog and a digital system in order to facilitate phase pickings by local personnel, but this is the last analog system we operate. In connection with our transfer from KMS to GEUS the communication to all of the Danish stations was upgraded to ADSL-connections. This ensures cheap, fast and reliable near-real-time transfer of data from the seismographs to our main server. In Greenland only data from the SFJD and the SUMG seismographs are available in near-real time. The communication to the SFJD seismograph is operated by CTBTO, whereas the temporary SUMG station is run by GFZ. Data from the remaining Greenlandic stations are transferred to Copenhagen via tapes or hard disks. Only 4 out of currently 16 seismographs in Greenland are permanent. The rest are installed in connection with various research projects. Although data access to most of the temporary stations is restricted, use of the data for specific projects is normally possible. Eventually the data will be freely available.

24. Seismology at the BGS: an overview

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The British Geological Survey operates a nationwide network of 145 seismograph stations in the United Kingdom. The network is subdivided into twenty regional sub-networks consisting of a number of remote outstations and a central data acquisition and recording facility. Most of these stations are equipped with short-period seismometers. However, it is planned to upgrade the existing network to broadband sensors with high dynamic range digitisation and real-time communications links. At present, 8 broadband stations are in operation. The talk aims to give an overview of existing monitoring equipment and future upgrade plans, including hardware at the remote sites and processing software. About 200 earthquakes are recorded in the UK per year. The talk will also present issues related to the routine analysis and give an overview of current research topics.

25. Seismic Heterogeneity in the Crust and Upper Mantle

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Pronounced seismic heterogeneity in the interior of the Earth may be detected and imaged with high-resolution seismic data from controlled source seismology with dense station spacing and at high frequency, e.g. from he Russian Peaceful Nuclear Explosion (PNE) data set. Such data holds the potential to focus on details at selected depth intervals. Mantle body waves indicate pronounced heterogeneity at three depth levels; other depth intervals appear transparent at the considered frequency band of 0.5-15 Hz. We model characteristic scale lengths and velocity contrasts by application of 2D Finite Difference simulation of seismic wave propagation.

(1) The *Teleseismic Pn Wave* is identified in the East European. Ryberg et al. (1995) interpret a high-frequency seismic wave, which propagates by scattering from thin, elongated bodies between Moho and ca. 100 km depth. We find that this model cannot explain the low-frequency part of the data. Instead, all features of the teleseismic Pn wave are explained by reverberations in the lower crust of a whispering gallery phase that travels in the uppermost mantle with multiple bounces at the Moho. This model is in agreement with other findings of lower crustal heterogeneity.

(2) *The Mantle Low-Velocity Zone (LVZ)* is a global feature. A characteristic delay at offsets of 800-900 km (8°) in all high-resolution seismic sections shows that the top of the LVZ everywhere is at a depth of 100±20 km. A pronounced coda indicates heterogeneity in the LVZ at characteristic scale lengths of 5-15 by 2-6 km. We interpret that the rocks in the LVZ have a temperature close to the solidus or even may contain small fractions of partial melt. The solidus of mantle rocks is very low (<900°) below a depth of 80-100 km if volatiles are present. We suggest that the rocks are in a totally solid state below the LVZ, this depth being an indicator of the thermal state of the upper mantle.

(3) Significant scattering *from around the top of the Mantle Transition Zone* indicates the presence of highly heterogeneous depth intervals above and below the 410 km discontinuity at a characteristic scale length of 8-20 by 3-8 km. These observations may be explained by either (i) A high percentage of Fe in this part of the mantle (up to Fe# 17%) which affects the phase transformations of the olivine component; (ii) Possible phase changes from pyroxenes to the garnet phase majorite; or (iii) Heterogeneity arising from subducted slabs that have equilibrated around the Transition Zone.

26. Test of the Upper Mantle Low Velocity Layer in Siberia with Surface Waves

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The existence of the upper mantle low velocity layer (LVL) in the depth range of 100-180 km in the Eastern Siberian Craton is tested with surface waves dispersion curves. From the comparison of synthetic data we find that: (1) a pronounced LVL (for example, 80 km thick and 2% velocity reduction) can be distinguished in the ambient noise from a constant velocity model by comparison of the fundamental mode group velocities, whereas a thin LVL (40 km thick) with small velocity contrast (less than 2%) cannot be resolved; (2) the fundamental modes of Love and Rayleigh waves have similar properties; (3) the phase velocity differences are smaller than the standard error and they alone cannot discriminate between the models, whilst the group velocity is in general more sensitive.
Inverting the synthetic dispersion curves by the non-linear Hedgehog inversion method, a pronounced LVL (more than 40 km thick and with a strong velocity contrast of about 5%) is detectable but it is not possible to resolve both velocity and thickness for a thin LVL with a strong velocity contrast. In the inversions of dispersion curves of models with a pronounced LVL, all solutions include a LVL whereas the solution space includes models with and without a LVL for models with a zero or positive gradient velocity-depth structure.
In order to constrain the mantle structure of the Eastern Siberian platform, we invert also real data with travel path across the craton. Almost all solutions include a LVL in the depth range of 80-150 km with a velocity contrast up to 2% to the surrounding intervals. Furthermore, despite low resolution at large depth, a pronounced asthenospheric LVL below a depth of about 225 km is a constant characteristic of the set of solutions. The presence of the LVL in the upper mantle in cratonic areas has already been demonstrated from tomographic inversions or seismic traveltime inversions along the high-resolution PNE seismic data profiles across the Siberian platform, from full-waveform modeling as well as from petrological studies. The present study confirms the existence of a low velocity layer in the upper mantle below a depth of about 100 km in Siberia, although not fully compelling since the LVL needs to be pronounced in order to be unambiguously identified.

27. Rayleigh wave attenuation in Greenland

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Rayleigh wave attenuation in Greenland is studied for the first time. Using a two-station method, apparent values of Q are calculated across Greenland in the period range from 25 to 150 seconds. Data are primarily from the GLATIS project (Greenland Lithosphere Analysed Teleseismically on the Ice Sheet, Dahl-Jensen et al, 2003), using temporary and permanent broadband seismographs in Greenland. 969 seismograms were visually inspected and 163 were selected for further analysis. A clear Rayleigh wave arrival was required, as well as great-circle alignment of events with two stations within a 5 degrees tolerance. Selected data was filtered twice, first to remove instrument responses, and then, with phase-matched filters, to reduce effects of noise and multipathing. Measurements of amplitudes were attempted with both spectral estimation techniques and multiple filter analysis, with the later being the more stable method. The seismograms are filtered with narrow bandpass filters peaked at selected frequencies between 0.005 and 0.04 Hz, and the maximal Rayleigh wave amplitudes are measured. Average interstation values of Q are calculated and linearly inverted. The resulting surface maps of apparent Q are compared with Rayleigh wave velocities from the same region.

28. National Seismic Risk Assessment - an Example from Germany (CEDIM)

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One of the main objectives of the earthquake risk sub-project of CEDIM, the Center for Disaster Management and Risk Reduction Technology, is assessment and mapping of seismic risk for Germany. There are several earthquake prone areas in the country, producing ground shaking intensity up to grade VIII (EMS-98). The seismicity is highest in parts of the Federal States of Baden-Württemberg, Rhineland-Palatinate, North Rhine-Westphalia, Saxony and Thuringia, which all are densely populated, industrialized and have a high concentration of developed infrastructure. This implies a challenge for future disaster preparedness and risk mitigation activities. The seismic risk in Germany represents typical features with a low earthquake occurrence probability, yet potentially high consequences. Therefore, the results of seismic risk analysis are indispensable for planners and decision-makers for preventing possible future seismic disasters. A methodology of seismic risk analysis - including hazard, vulnerability and assets - is described and preliminary results are presented.

29. Ground motion simulations for a M=7.5 scenario earthquake in the Marmara Sea and implications for the city of Istanbul, Turkey

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Following the disastrous earthquakes in Izmit and Düzce along the North Anatolian Fault in 1999, the earthquake hazard in the Istanbul area became a great concern. In this study we simulate the strong-ground motion in the Marmara Sea region with special emphasis in Istanbul. Simulations are based on an earthquake scenario in the Marmara Sea using a multiasperity source model that involves the combined rupture of the North Anatolian fault segments beneath the Marmara Sea. In the simulation of the strong ground motion, we use a hybrid model combining a deterministic simulation of the low frequencies (0.1-1.0 Hz) with a semi-stochastic simulation of the high frequencies (1.0-10.0 Hz) using empirical Green's functions. We apply a high-frequency radiation model which uses a smooth transition between non-spherical to spherical wave radiation as the frequency increases. Computation at each frequency range is performed separately and the total ground motion is combined in the time domain. We calculate several earthquake scenarios corresponding to different hypocenter locations and source parameters and obtain information on the sensitivity of ground motion to these parameters. This will help us to select the most critical scenario earthquake for the Istanbul region. Computations are performed for both a regular grid and for the recording sites of the recently installed Istanbul Earthquake Early Warning and Rapid Response system.

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