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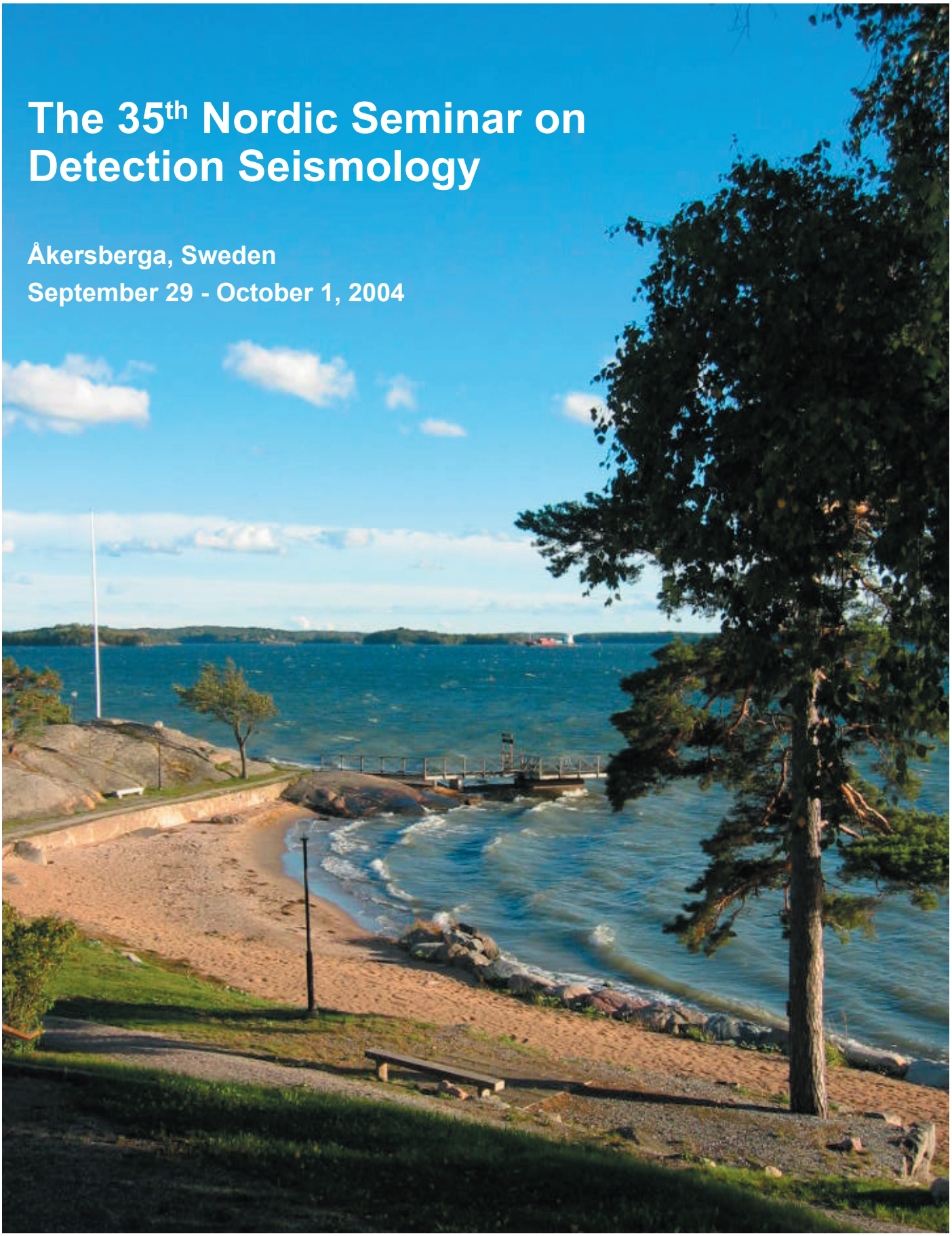
FOI-R--1381--SE
November 2004
ISSN 1650-1942
User Report

The 35th Nordic Seminar on Detection Seismology

Åkersberga, Sweden
September 29 - October 1, 2004



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Systems Technology
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Sweden

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Issuing organization

FOI - Swedish Defence Research Agency
Systems Technology
SE-172 90 Stockholm
Sweden

Report number, ISRN
FOI-R--1381--SE

Report type
User Report

Research area code
NBC Defence and other hazardous substances

Month year
November 2004

Project number
A69011

Customers code

Sub area code
International Security

Author/s (editor/s)

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Organizing committee: Nils-Olov Bergkvist, Leif Persson, Björn Lund, Eva Norrbrand and Anita Kjellvås

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Sponsoring agency

Scientifically and technically responsible

Report title (in translation)

The 35th Nordic Seminar on Detection Seismology

Abstract

This report includes program, list of participants and abstracts for the oral presentations and posters held at the 35th Nordic Seminar on Detection Seismology in Åkersberga, Sweden September 29- October 1, 2004. The seminar was organized in cooperation with Uppsala University and funded partly by the project NDC-seismoacoustics. These seminars have a long tradition and they are organized on a circular schedule among the Nordic countries. The main purpose has been to stimulate Nordic cooperation in the field of seismology originally focused on verification related to the Comprehensive Nuclear-Test-Ban Treaty (CTBT). Today also other topics in general seismology are included in the program. The discussions during the seminar underlined the importance of cooperation between the Nordic countries and the Baltic states in order to improve the monitoring of the Baltic Sea area. The benefit of sharing both parametric and wave form data was pointed out by several participants. On the second day of the seminar a boat trip in the Stockholm archipelago was included in the program and this was much appreciated by the participants. This seminar was attended by 33 participants including one person from Lithuania and one person from the Netherlands. The next seminar in 2005 will be held in Denmark. Greenland was also mentioned as a possible location for the meeting.

Keywords

Seismology, detection, monitoring, nuclear, explosion, earthquake, location, seismicity, network

Further bibliographic information

Language English

ISSN 1650-1942

Pages 48

Price acc. to pricelist

Utgivare

Totalförsvarets Forskningsinstitut - FOI
Systemteknik
172 90 Stockholm

Rapportnummer, ISRN
FOI-R--1381--SE

Klassificering
Användarrapport

Forskningsområde
Skydd mot NBC och andra farliga ämnen

Månad, år
November 2004

Projektnummer
A69011

Verksamhetsgren

Delområde
Internationell säkerhet

Författare/redaktör

Editor: Eva Norrbrand

Organisationskommitté: Nils-Olov Bergkvist, Leif Persson, Björn Lund, Eva Norrbrand och Anita Kjellvås

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Godkänd av
Monica Dahlén

Uppdragsgivare/kundbeteckning

Tekniskt och/eller vetenskapligt ansvarig

Rapportens titel
35:e Nordiska Seminariet om Detektionsseismologi

Sammanfattning

Föreliggande rapport innehåller program, deltagarlista samt sammanfattning till presentationer och posters, som hölls vid det 35:e Nordiska Seminariet i Detektionsseismologi Åkersberga 29 september -1 oktober 2004. Seminariet organiserades i samarbete med Uppsala universitet och det bekostas till del av projektet NDC-Seismoakustik. Dessa seminarier har en lång tradition och de organiseras av de nordiska länderna efter ett cykliskt schema. Det huvudsakliga syftet har varit att främja nordiskt samarbete på seismologiområdet ursprungligen främst med tanke på övervakning av provstoppsavtalet. Efterhand har också andra områden inom mer generell seismologi inkluderats i seminarieprogrammet. Diskussionerna under seminariet underströk betydelsen av ett ökat samarbete med Baltikum för att få en bättre seismologisk övervakning av östersjöområdet. Särskilt pekade man på betydelsen av ett utökat utbyte av både vågformsdata och parameterdata. Seminarieprogrammet inkluderade också en båttur i Stockholms skärgård med middag ombord och detta var mycket uppskattat av deltagarna. I seminariet deltog totalt 33 personer varav en från Litauen och en från Nederländerna. Det Nordiska Detektionsseminariet nästa år kommer att hållas i Danmark eller eventuellt på Grönland.

Nyckelord

Seismologi, detektion, övervakning nukleär, explosion, jordskalv, lokalisering, seismicitet, nätverk

Övriga bibliografiska uppgifter

Språk Engelska

ISSN 1650-1942

Antal sidor 48

Distribution enligt missiv

Pris: enligt prislista

Contents

Wednesday September 29

1200 Registration at Stensnäs kursgård

1230 Lunch

1400 Opening
Nils-Olov Bergkvist

1410 Session I: Seismic Networks and Data Processing
Chairman: Torild van Eck

1410 EC-project MEREDIAN and the Virtual European Broadband Seismic Network (VEBSN)
Torild van Eck, Lucas Calje, Reinoud Sleeman, Bernard Dost

1430 The Swedish National Seismic Network, SNSN
R. Bödvarsson, R. Slunga, B. Lund, S. Olsson, Roland Roberts and A. Tryggvason

1450 Coffee

1520 Virtual Seismic Networks
Reynir Bödvarsson

1540 Bothnian Bay Virtual Seismic Network?
A Quick Look at the Possibilities of Network Cooperation
Jari Kortström

1600 Seismological Monitoring in Lithuania
Andrius Pačėsa
Latvian Seismological investigations
Andrius Pačėsa, Valery Nikulin

1630 Session II: Comprehensive Nuclear-Test-Ban Treaty (CTBT) Related Studies
Chairman: Jan Fyen

1630 Discriminants for Seismic Monitoring
Dan Öberg, Tormod Kvaerna

1650 Iranian Reference Events Recorded at Hagfors Observatory
Ingvar Nedgård

1710 Testing Wireless Intra-station Data Transmission at PS17, (FINES) in Finland
Pasi Lindblom

1730 Spitsbergen Upgrade 2004
Jan Fyen

1830 Dinner

Thursday September 30

0900 **Session II: Comprehensive Nuclear-Test-Ban Treaty (CTBT) Related Studies (Continued)**

0900 The 7th April 2004 FLISA Earthquake – A GT1 Event in Southern Norway
Johannes Schweitzer

0920 **Session III: Seismicity Studies and Seismic Hazard Assessment**
Chairman: Ota Kulhanek

0920 Monitoring and Analysis of Microearthquakes
Michael Roth, Volker Oye and Hilmar Bungum

0940 Temporal Variations of b- and d-values of Mining Induced Seismicity
Leif Persson and Ota Kulhanek

1000 Coffee

1030 To Correlate or Not to Correlate, That's the Question:
On Waiting Time Distributions and a Unified Scaling Law for Earthquakes
M. Lindman K. Jonsdottir, R. Roberts, B. Lund and R. Bödvarsson

1050 Seismicity Ratio with Applied Mechanism and Time-Window Local Earthquake Tomography
R. Bödvarsson and A. Tryggvason

1110 Seismicity in Northwesternmost Sweden
Björn Lund, Ragnar Slunga and Reynir Bödvarsson

1130 Lunch

1240 Ground Motion Simulations and Site Effect Estimation for Istanbul, Turkey
Mathilde Böttger Sörensen, Nelson Pulido, Sylvette Bonnefoy-Claudet and Kuvvet Atakan

1300 **Session IV: General Topics**
Chairman: Gunnar Gudmundsson

1300 The April 14, 2004 Jan Mayen Earthquake
Mathilde Böttger Sörensen, Lars Ottemöller, Jens Havskov, Kuvvet Atakan, Bjarte Hellevang and Rolf Birger Pedersen

1320 The Application of Coda Methodology for the Moment Magnitude Determinations of the Local and Regional Events in Turkey
Tuna Eken, Kevin Mayeda, Abraham Hofstetter, Rengin Gok, Gonca Orgulu and Niyazi Turkelli

1340 Acceleration Modelling of Moderate and Large Earthquakes in Panama
Ronald Arvidsson

1400 Coffee

1430 Session V: Crustal and Lithospheric Studies

Chairman: Roland Roberts

1430 2004 Status of Project Tor

Sören Gregersen and the Tor Working Group

1450 Lithospheric Structure of the Tornquist Zone Resolved by Non-linear P and S Teleseismic tomography Along the Tor Array

Z. Hossein Shomali, Roland G. Roberts and the TOR Working Group

1510 State of Stress in the Fennoscandian Shield

Ronald Arvidsson

1530 Poster Session

Chairman: Marja Uski

ORFEUS and its Data Center

Torild Van Eck, Bernard Dost, Lucas Calje, Reinoud Sleeman and Femke Goutbeek

3D Hybrid Modeling of Local Site Effects in Ataköy Area, Istanbul, Turkey, Due to a Finite-Extent Earthquake Source

Mathilde Böttger Sörensen, Ivo Oprsal, Nelson Pulido, Martin Mai, Kuvvet Atakan

Earthquake and Volcanic Activity in Iceland Monitored by IMO

Gunnar B. Gudmundsson, Steinunn S. Jakobsdottir, Erik Sturkell and Mattew J. Roberts

Re-Assessment of Focal Depth by Using Teleseismic Moment Tensor Inversion

L. Hagos and H. Shomali

Imaging Upper Mantle Discontinuities Using P to S Converted Phases

Sverker Olsson, Roland Roberts, Hossein Shomali

1800-2100 Boat trip in the Stockholm archipelago, dinner on board

Friday October 1st

0900 **Session V: Crustal and Lithospheric Studies (Continued)**

0900 Rock Stress Tensor Estimation and Rock-Water Interaction
Ragnar Slunga

0920 **Session VI: Anniversary Topics**
Chairman: Sören Gregersen

0920 Centennial Anniversary of the Uppsala Seismographic Station
Ota Kulhanek

0940 The Earthquake of 23 October 1904 in the Oslo Fjord Area
J. Schweitzer, F. Pettenati and H. Bungum

1000 Welcome Home
Pasi Lindblom

1020 Coffee

1050 **Any other business**

1130 **Closing Remarks**
Nils-Olov Bergkvist

Seismic Networks and Data Processing
Chairman: Torild van Eck

EC-project MEREDIAN and the Virtual European Broadband Seismic Network (VEBSN)

Torild van Eck, Lucas Calje, Reinoud Sleeman, Bernard Dost

The EC-project MEREDIAN with a consortium of 18 national observatories has successfully coordinated national developments towards a European infrastructure for especially near real-time, waveform data exchange. Currently, more then 400 broadband stations are operating in Europe. A rapidly increasing number of these (116 in September) are contributing to the VEBSN, which provides (near) real-time rapidly available unique data of high quality. Concurrently, broadband waveform data archives at several observatories have been significantly extended and made publicly accessible.

The VEBSN is a concept of real-time European available data coordinated within ORFEUS. It enables observatories (and research institutes) to create relevant virtual networks for improved monitoring, targeted research projects and improved public information. The Orfeus Data Center (ODC) makes the VEBSN data available through. web. ftp and email options, either event oriented or continuous and, for specific purposes, real-time on-line. Additional products such as viewing, rapid locations, magnitudes, moment tensors and noise studies are implemented and/or being developed by the ODC and other institutes within ORFEUS. QuakeExplorer, for example, is a simple stand-alone data-viewing tool developed by Anthony Lomax, which offers a delightful quick insight in the obtained data.

The core of the European (near) real-time data exchange infrastructure is the SeedLink protocol, originally developed by GFZ and further developed and implemented within the MEREDIAN consortium. The wide implementation of SeedLink means that currently it is a de-facto data exchange standard within Europe. This in turn opens up a broad range of possibilities; regional or extended (virtual) national networks, combining mobile networks on-line with permanent station networks, ad-hoc virtual research networks for universities and research institutes. Within the MEREDIAN consortium, for example, a large number of extended regional networks have already been realized.

Consequently, the currently implemented European data exchange infrastructure of the VEBSN offer many new challenging opportunities for earthquake monitoring, research and education in the European-Mediterranean area.

The MEREDIAN (EC-contract EVR1-CT2000-40007) consortium is listed on:

http://orfeus.knmi.nl/meredian

The VEBSN participants (May 2004: 35 institutes/observatories) are listed on:

http://orfeus.knmi.nl/VEBSN

The Swedish National Seismic Network, SNSN

R. Böðvarsson, R. Slunga, B. Lund, S. Olsson, Roland Roberts and A. Tryggvason

Over the last few years, 45 new, permanent, digital, broadband seismological stations have been deployed in Sweden (except for one which is located in Åland), 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. The primary objective of the network is to gain better understanding of the ongoing deformation processes through monitoring of the local microearthquake activity. 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 movements, 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. As a larger data set is gradually acquired, information from these events will be used 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 mantle below the recording stations.

Virtual seismic networks

Reynir Böðvarsson

Detection of earthquakes in areas between seismic networks can be improved by sharing automatic detections between the networks. We are, together with our Danish and Finnish colleagues currently working on development of the Baltic virtual seismic network, utilizing stations in Sweden, Finland and Denmark. The purpose is to increase the operational performance in the area between the national seismic networks. In the near future, we hope to have our colleagues in the Baltic states participating in this network. A similar collaboration between Sweden, Denmark and Norway would be desirable.

Bothnian Bay Virtual Seismic Network ? A quick look at the possibilities of network cooperation

Jari Kortström

Both Finland and Sweden have modern seismic station networks, which can detect, locate and identify seismic events with good accuracy inside the networks. However, the sea areas between countries aren't that well covered. In Bothnian Bay region it could be possible to establish a "Bothnian Bay virtual seismic network", which could locate common events with better accuracy. In this presentation joint parameter data of the two networks were used to test the location capability of such network. Test events were from four locations at Bothnian Bay and Finnish Bay regions. In all sites location accuracy improved by joining the data compared to single network solutions.

Seismological Monitoring in Lithuania

Andrius Pacesa

Latvian Seismological investigations

Andrius Pacesa and Valery Nikulin

Comprehensive Nuclear-Test-Ban Treaty (CTBT) Related Studies

Chairman: Jan Fyen

Discriminants for seismic monitoring

Dan Öberg, Tormod Kvaerna

In this study five discriminants for seismic monitoring are considered. The main objective is to separate recordings with spectral modulation from other recordings. It is known that spectral modulation appears for recordings originating from underwater explosions and ripple fired explosions, which are common in mining. The discriminants are “Maximum cepstral peak”, “P/S ratio”, “Complexity”, “Third moment of frequency”, and “Spectral misfit to earthquake”. A data set consisting of 57 events recorded at Hagfors and ARCES was used to test the discriminants. For this set the discriminants could separate events with and without spectral modulation quite successfully. Especially, “Maximum cepstral peak” and “Spectral misfit to earthquake” worked well.

Iranian reference events recorded at Hagfors observatory

Ingvar Nedgård

Just as it is important to know when a nation has conducted a nuclear explosion it is equally important to confirm when that is not the case. Thirty years ago there was a nuclear explosion conducted almost ones a week. This gave us a god data base of waveforms to compare with new events. Today the number of nuclear tests is few but knowledge of the normal earthquake activity and characteristics are still important. Monitoring underground nuclear explosions by seismic measurements is one way to find out if a request for an on site inspection is necessary. One often used classifier in the identification of seismic signals from earthquakes and explosions is the mb (Ms) classifier. The efficiency of this identification method is down to about 10 kt and it is limited by surface-wave detection and interference. Difference in source dimension and source-time functions for earthquakes and explosions are used in short-period classifiers like spectral ratio and complexity. The most effective way to detect seismic sources at teleseismic distances is to use the vertical component P waves in the frequency band 0.5 – 5 Hz. We have selected reference events with body wave magnitude mb $\geq$ 4.0 from the reviewed earthquake bulletin (REB) of the international data center in Vienna. Waveforms from all Hagfors sensors are saved to MATLAB format. Signals from the GS-13 seismometer at the reference point HFA0 are analysed by the Hilbert-Huang transform (HHT) as they are and after forward-reverse filtering by an elliptic 1.5 – 4 Hz band pass filter of order 12. Most of the 67 events are from the Zagros fault area in the western and the southern part of Iran and a few are from the faults south of the Caspian Sea and in the eastern parts of Iran. The events are from mb magnitude 4.0 – 5.7 and the announced depth is from 0 km down to 96 km.

'Testing Wireless Intra-station Data Transmittion at PS17, (FINES) in Finland'

Pasi Lindblom

Spitsbergen Upgrade 2004

Jan Fyen

The 7 April 2004 FLISA Earthquake – A GT1 Event in Southern Norway

J. Schweitzer

Calibrating the seismic net of the International Monitoring System (IMS) of the CTBTO is a major task for CTBT related research at many institutes. For this calibration work well located seismic events are essential.

On 7 April 2004, a moderately felt magnitude 3.5 earthquake occurred close to Flisa, a small settlement east of the Oslo Graben. This event was observed at numerous seismic stations and arrays in central and northern Europe, in particular the four Fennoscandian IMS arrays observed clear P and S onsets. However, most important is that the event occurred in the vicinity of the NORSAR array (closest epicentral distance less than 20 km) and that P and S onsets could be analyzed from recordings at all 42 sites of the NORSAR array. Array-analysis results together with some PmP and SmS onsets complete the high quality data set of local and near regional observations at the NORSAR array, the Hagfors array and seismic stations in Norway and Sweden. With this huge amount of data the hypocenter of the event can be determined with an uncertainty of about 1 km (99.99 % probability). The inversion of these data gives a hypocenter at 60.55 N and 11.65 E in ca. 22 km depth.

In addition to the main shock with its high quality hypocenter determination, one foreshock and several aftershocks were observed at the NORSAR array and the Hagfors array in Sweden. The application of a master event algorithm was applied to locate these several magnitudes smaller events.

Seismicity Studies and Seismic Hazard Assessment

Chairman: Ota Kulhanek

Monitoring and Analysis of Microearthquakes

Michael Roth, Volker Oye and Hilmar Bungum

Microseismic monitoring has the potential to delineate the internal structure of the subsurface and to investigate its changes over time. We have developed a program for the processing and analysis of miroseismic events and applied it to data recorded with borehole instruments in hydrocarbon reservoirs and 3D seismic arrays in mines. Small-scale networks with source-receiver distances less than a few 100 meters typically record an abundance of events with magnitudes larger than -2 and with corner frequencies above 100 Hz.

Our most comprehensive data set is from the Pyhaesalmi ore mine in Finland that operates an in-mine seismic network of 16 geophones since January 2003. Currently the set contains more than 18000 events (production blasts, rockbursts and spalling) with magnitudes between -1.8 and 1.2. Due to the favorable spatial receiver distribution and the generally good signal-to-noise ratio most of the events can be located automatically with an accuracy less than 10 m. In addition we determined source parameters as seismic moment, corner frequency, radiated energy etc. The data are most valuable not only for hazard mitigation and production optimization, but also for the investigation of source scaling relations. Most existing observations are for magnitudes above 1, and the mining-related microearthquakes extend the range at smaller magnitudes.

In the framework of a project of the International Centre for Geohazards (ICG) we have installed a small network of 6 geophones to monitor seismicity related to the movement of an unstable rock slope. The total volume in motion is about 20-30 million cubic meters, and the annual displacement is about 4 cm. The goal is to assess potential seismic activity related to the movement, to investigate the correlation between seismicity and precipitation, and to identify the the detachment plane.

Temporal variations of b- and d-values of mining induced seismicity

Leif Persson and Ota Kulhanek

Seismic monitoring by local networks in mines provides opportunities of rock mass characterization. The temporal and spatial properties of *b*-values estimated from the frequency-magnitude distribution are frequently used indicator for redistribution of stress. The quantification of events by the linear behaviour of the energy and moment relationship is another dynamic feature useful in mining induced seismicity. Here, we apply these indicators for three different mines. We also discuss the possibilities of forecasting of larger than magnitude one events within the mining area.

To correlate or not to correlate, that's the question: On waiting time distributions and a unified scaling law for earthquakes

M. Lindman, K. Jonsdottir, R. Roberts, B. Lund, R. Bödvarsson

Recently, several studies have been published for defined geogaphical areas where waiting times between successive earthquake events have been used in order to study the temporal and spatial scaling behaviour of earthquakes. The observed waiting time distributions generally show power law behaviour implying power law behaviour even in the real time domain, i.e. Omori-type behaviour, despite the fact that no specific aftershock sequence has been separated for analysis.

Significant deviation from this power law is observed at greater waiting times. Rescaling waiting time distributions from analyses using different magnitude thresholds and geographical areas leads to a "collapse" of the data onto a single curve. This "data collapse" has been (mis)interpreted by some previous authors as evidence that we observe a self-organised critical system and that the position of a change in gradient demarks a change from correlated to uncorrelated behaviour, of great physical significance.

We show that because the data is in practice time-limited, a power law sequence in the real time domain will not produce power law behaviour in the whole of the waiting time domain. This leads to the gradient change in the waiting time distribution. Using realistic simulations of Omori sequences and background seismicity we show that this change of gradient does not, as claimed by some authors, have the physical significance of separating correlated and uncorrelated earthquakes.

We discuss a proposed unified scaling law for earthquakes and present the basic theory and characteristics of distributions in the waiting time domain . The theory is illustrated using numerical simulations and some examples of real data from Iceland. Possible physical explanations for the observed waiting time distributions are discussed.

Seismicity ratio with applied mechanism and Time-window Local Earthquake tomography

R. Böðvarsson, A. Tryggvason

A new algorithm for seismicity analysis has been developed. In this simple algorithm we analyze the seismicity in the SISZ area by looking at the ratio between the number of earthquakes in the compressive and tensile quadrants at any given point in a grid of points covering the SISZ. The purpose was to check if the seismicity pattern could be made more sharp by adding this a priory knowledge of mechanism of the large earthquakes in the area. In the analysis we use data from South Iceland Seismic Zone from 1991 through May 2000. Two major anomalies are found, the strongest located in the vicinity of the June 17th 6.5 earthquake and the the other anomaly in the vicinity of the second 6.5 earthquake. When running the algorithm on various periods between 1991 and 2000 gave similar results already in 1993 although with less pronounced anomaly, particularly around the second event.

In the same area a Local Earthquake tomography has been applied and what we report here are interesting very preliminary results. We think we can observe changes in the seismic velocities which can be related to the two big earthquake of June 2000 in the South Iceland Seismic Zone.

Seismicity in northwesternmost Sweden

Björn Lund, Ragnar Slunga, Reynir Bödvarsson

Since the autumn of 2003, the northernmost section of the Swedish National Seismic Network (SNSN) has gradually entered operation. The section encompasses eight stations, including the old Kiruna station which was refurbished and moved in 1998. The Lannavaara station became operational in June 2004 as the last station in the current upgrade of the northern network.

We will present a preliminary analysis of events recorded in northern Sweden between May 2001 and September 2004. The network has during the time period recorded 96 earthquakes north of 65.5 degree latitude, with magnitudes ranging from below zero to 3.5. Interestingly, much of the seismicity is concetrated in the areas which have seen large scale endglacial faulting, although not necessarly on the actual faults. All events have fault plane solutions and we will show the variability of mechanisms of the events. We will also show very preliminary stress analyzes in areas with sufficient seismicity.

Ground motion simulations and site effect estimation for Istanbul, Turkey

Mathilde Bøttger Sørensen, Nelson Pulido, Sylvette Bonnefoy-Claudet, Kuvvet Atakan

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 performed both on a regular grid and at the recently installed Rapid Response and Early Warning (RREW) recording sites and are based on a M = 7.5 scenario earthquake in the Marmara Sea. The input model is based on a multiasperity source model that involves the combined rupture of the North Anatolian Fault segments beneath the Marmara Sea. We calculate several earthquake scenarios corresponding to different locations of the hypocenter and select the most critical scenario earthquake for the Istanbul region.

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 (i.e. empirical Green's function which uses stochastic element seismogram) of the high frequencies (1.0-10.0 Hz). We apply a high-frequency radiation model which uses a smooth transition from 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.

Local site effects play an important role in the seismic hazard in Istanbul since parts of the city is built on soft sediments. The uneven distribution of damage observed during the 1999 earthquakes already proves the relevance of the local site conditions. The local site effects for the Ataköy area in western Istanbul are estimated using a number of different approaches. H/V spectral ratios are calculated for both recorded microtremor data and modeled noise synthetics, and the standard spectral ratio method is applied to broadband recordings of small earthquakes. In addition, a 3D finite difference scheme is used for modeling site effects based on a local model build from geological, geotechnical and geomorphological data in a separate study. The different approaches in combination give a good insight to the local site effects in the area.

General Topics
Chairman: Gunnar Gudmundsson

The April 14, 2004 Jan Mayen earthquake

Mathilde Bøttger Sørensen , Lars Ottemöller, Jens Havskov, Kuvvet Atakan, Bjarte Hellevang, Rolf Birger Pedersen

On April 14th 2004, a Mb=5.6 earthquake stroke along the Jan Mayen Fracture Zone. The event was located on the north-eastern segment of the fracture zone, offshore the Jan Mayen island. The location of the event falls in an area where the slowly spreading Mohns ridge intersects with the Jan Mayen Fracture Zone. The Norwegian National Seismic Network (NNSN) operates four seismic stations on the Jan Mayen island, which have recorded a large number of aftershocks.

Using data from the NNSN, both recorded locally and on mainland Norway, the event is studied with respect to exact location, magnitude and fault plane solution. Relative locations for the aftershocks are obtained using a master event technique in order to determine the extent and orientation of the fault plane.

The fault plane solution indicates almost pure strike-slip motion and is compatible with the general orientation of the fracture zone. Furthermore there is direct correlation between the location of the event, its early aftershocks and the fault plane solution with the eastern segment of the Koksneset fault as seen from a recent detailed mapping of the bathymetry in the area.

The location of the event is similar to the previous significant earthquake in December 1988 (Mb=5.7).

The application of coda methodology for the moment magnitude determinations of the local and regional events in Turkey

Tuna Eken, Kevin Mayeda, Abraham Hofstetter, Rengin Gok, Gonca Orgulu and Niyazi Turkelli

A recently developed coda magnitude methodology was applied to selected broadband stations in Turkey for the purpose of testing the coda method in a large, laterally complex region. As found in other applications of the method (e.g., Dead-Sea Rift Zone, Western United States, and Italian Alps), coda envelope amplitude measurements result in considerably less variable than distance-corrected direct wave measurements (i.e., Lg and surface waves) by roughly a factor 3-to-4. Despite strong lateral crustal heterogeneity in Turkey, we found that the region could be adequately modeled assuming a simple 1-D, radially symmetric path correction. After calibrating the stations ISP, ISKB, and MALT for local and regional distances, single-station moment-magnitude estimates (Mw) derived from the coda spectra were in excellent agreement with those determined from multi-station waveform modeling inversions, exhibiting a data standard deviation of 0.17. Though the calibration was validated using large events, the results of the calibration will extend Mw estimates to significantly smaller events, which could not otherwise be waveform, modeled. The successful application of the method is remarkable considering the significant lateral complexity in Turkey and the simple assumptions used in the coda method.

Acceleration modeling of moderate and large earthquakes in Panama

R. Arvidsson

Strong motion is affected by distance to the earthquake, local crustal structure, focal mechanism, azimuth to the source. However, the faulting process is also of importance such as development of rupture, i.e., directivity, slip distribution on the fault, extent of fault, rupture velocity. We have modelled these parameters for earthquakes that occurred in three tectonic zones close to the Panama.

Canal. We included in the modeling directivity, distributed slip, discrete faulting, fault depth and expected focal mechanism. The distributed slip is based on previous fault models that we produced from the region of other earthquakes. Such previous examples show that maximum intensities in some cases coincides with areas of high slip on the fault. Our acceleration modeling also gives similar values to the few observations that have been made for moderate to small earthquakes in the range M=5-6.2. The modeling indicates that events located in the Caribbean might cause strong motion in the lower frequency spectra where high frequency Rayleigh waves dominates.

Crustal and Lithospheric Studies
Chairman: Roland Roberts

2004 Status of project Tor

Soren Gregersen and the Tor working group

Across the most significant well-established lithosphere difference in Europe the Tor project was designed to delineate the differences and the shape of the transition across Sweden-Denmark-Germany. The project was named Tor, for Teleseismic Tomography across the Tornquist Zone, which is part of the Baltic Shield edge, and part of the Trans-European Suture Zone (TESZ). The seismograph array covered areas, where extensive seismic crustal studies over the last two decades have identified a terrain boundary between the ancient plates of Baltica and Avalonia, which is almost coincident with the important surface feature, the Tornquist Zone. The Tor project went below this to the deep parts of the lithosphere. It is therefore of great interest that the results of the Tor project indicate a THREE-STEP LITHOSPHERE TRANSITION. The sharp and steep lithosphere edges together make up the very large change in lithosphere from the Proterozoic shield in Scandinavia to the Phanerozoic central Europe. The non-coincidence of (1) sedimentary, (2) crustal, and (3) subcrustal lithosphere edges clearly has great significance for our understanding of the geological evolution of the area. The delineation of the subcrustal structure was greatly helped by our introduction of a display of horizontal gradients of the P-velocity results of the tomographic inversion.

Lithospheric structure of the Tornquist Zone resolved by non-linear P and S teleseismic tomography along the TOR array

Z.Hossein Shomali, Roland G. Roberts and the TOR Working Group

Within Europrobe several projects have had their special emphasis on investigating the subcrustal lithosphere. Project TOR (Teleseismic TOmography TORnquist) is a teleseismic tomography experiment that aims to reveal lithosphere-asthenosphere structures (the differences and the shape of the transition) beneath the Tornquist Zone. The TOR array was designed (July 96-August 97) in a NE-SW direction perpendicular to the geologically very significant Tornquist Zone, which is the most significant well-established lithosphere, difference in Europe. The seismograph array (150 seismic stations) covered areas, where extensive seismic crustal studies over the last two decades have identified a terrain boundary between the ancient plates of Baltica and Avalonia, which is not coincident with the important surface feature, the Tornquist Zone. The effects of crustal structures are investigated by correcting the teleseismic residuals for travel-time variations in the crust based on a 3D crustal model derived from other data. The inversion is carried out for direct teleseismic P and S phases. It was always considered an important goal of the project to make several independent inversions of the tomography data, and compare the results in an attempt to evaluate uniqueness, resolution and accuracy of these inversions. Two different inverse methods (singular value decomposition and a quadratic programming method) are implemented in order to investigate whether or not the lithospheric blocks and major boundaries in the inversion are required by the data or are artefacts of the inversion.

As expected, the derived models show that the relatively old and cold Baltic Shield has higher velocity at depth than the younger lithosphere farther south. The models show two sharp and distinct increases in depth to velocities, which are low, compared to our reference model, as we move from South to North. A sharp and steep subcrustal boundary is found roughly coincident with the southern edge of Sweden. This is below where the edge of the Baltic Shield is usually placed, based on surface geological evidence (the Sorgenfrei-Tornquist Zone). Another less significant transition is recognised more or less beneath the Elbe-lineament. The non-coincidence of (1) sedimentary, (2) crustal, and (3) subcrustal lithosphere edges clearly has great significance for our understanding of the geological evolution of the area.

State of stress in the Fennoscandian shield

Doc Ronald Arvidsson

At the time of early postglacial rebound large earthquakes occurred in northern Fennoscandia, as large as Mw=8.2. These events appear to have fractured the crust as a response to ice withdrawal. We investigate causes limiting the size for these events. Firstly we investigated the fractal properties of both deformation zones in Sweden and for Fennoscandian earthquakes. Our results indicate that the major postglacial earthquakes were limited by the size of older deformation zones. The limitations in length of deformation zones would put an upper limit for the largest earthquakes in the order of the Mw=8.2, Pärvie postglacial earthquake, 8500 yBP. However, size of deformation zones is not a sufficient parameter for causing large earthquakes, we also investigate the strain caused by the receding ice as well as discuss the plate tectonic contribution. In order to further understand the rebound strain we make correlations with current postglacial rebound strains as determined from 3000 daily solutions of GPS data in the BIFROST network.we examine todays stress regime as observed from GPS measurements of the Fennoscandian uplift (Milne et al., 2001). Todays stress contributions are shown to be small from the uplift though in a ten thousand year perspective maybe significant. The plate tectonic contribution in comparison to the extension produced from the uplift shown to be smaller in the center of uplift

Rock stress tensor estimation and rock-water interaction

Ragnar Slunga

Absolute rock stress tensor estimates can be achieved from earthquake fault plane solutions. Conventional stress estimates based on FPS normally only give the orientaions of the principal stresses plus the shape factor relating the intermediate stress to the maximum and minimum principal stress. The complete stress tensor requires two additional constrants. Reasonable additional constraints are given by putting the vertical stress equal to the lithostatic stress and by applying the Coulomb failure criterion. This adds however one additional parameter, the water pressure. Based on rock mechanical observations reasonable estimates can be given for the water pressure. In the upper kilometers of the crust the water pressure is hydrostatic. At greater depths the fractures will close and below that the water pressure will be between hydrostatic and lithostatic. The depth at which the fractures close is about 3 km in basalt. The strength of granite leads to a several times larger closing depth. I present a model relating the water pressure to the smallest compressive principal stress. The model explains the observed smallest depths of microearthquake swarms in Iceland and also results in a general increase in water pressure after immediatly after earthquakes which explains the aftershocks. The model also fits the crustal resistivities observed in Iceland if saline water in fractures is dominating. The model has been applied to a larger earthquake in Iceland and increased stress levels were observed in the hypocentral area before the earthquake.

Anniversary Topics
Chariman: Sören Gregersen

Centennial anniversary of the Uppsala seismographic station

Ota Kulhanek

Instrumental seismology in the Nordic countries started in 1904 with the installation of the Wiechert horizontal-component seismograph in Uppsala. This instrument was in operation without serious interruptions and with practically unchanged characteristics until 1998. About 60.000 Wiechert smoked-paper seismograms were produced, all currently stored in archives of the Geophysical Institute in Uppsala. Wiechert records were systematically analyzed from October 1904 to December 1955 (except for the period June 1905-June 1906) and all relevant information is listed in annual Seismological Bulletins from Uppsala.

A modernization and extension of the seismographic network operated by the Uppsala observatory took place in the 1950´s and 1960´s with an installation of a number of electromagnetic seismometers and photographic-paper recording.

Considerable efforts have been made more recently to establish a modern digital telemetric network. It was put into operation in 1998 and consists currently of 45 stations equipped with Guralp three-component seismometers.

The Earthquake of 23 October 1904 in the Oslo Fjord Area

J. Schweitzer, F. Pettenati, H. Bungum

This year we can celebrate the 100th anniversary the 23 October 1904, Ms 5.7 Oslo Fjord event. The event occurred on a Sunday morning and was felt by people in Southern Fennoscandia, Denmark, Northern Germany and even far as in the Baltic often during their visits of church services.

However, the event was also observed at many seismic stations in Europe. The observation capabilities during these early days of instrumental seismology were of course limited due to low amplification and low time resolution of many seismographs. We collected available bulletin material and even seismogram copies from different sources and tried to locate the earthquake with today's knowledge of travel-time tables and seismic-phase identification. After a careful selection and weighting of published onset times, readings from the seismic stations in Uppsala, Hamburg, Potsdam, Göttingen, Leipzig and Tartu could be used for an instrumental location of the event. The result of the inversion gave with 95% confidence limits:

Source time:	23 Oct 1904, 10:27:10.1 +/- 3.5 s UT
Latitude:	58.80 +/- 0.17 deg North
Longitude:	10.83 +/- 0.42 deg East
Ms:	5.77 (from horizontal component amplitudes in Göttingen)

The depth for this solution was fixed after analysing the macroseismic observations. Therefore the reported intensity data were newly inverted for source location, depth and double couple parameters. The best source solution using the intensity data is so far:

Latitude	58.87 +/- 0.06 deg North
Longitude	10.71 +/- 0.08 deg East
Strike	212 +/- 10 deg
Dip	85 +/- 6 deg
Rake	64 +/- 6 (+/- 180) deg
Depth	28.4 +/- 4 km

'Welcome Home'

Pasi Lindblom

In Finland the first seismic recordings were made 80 years ago on the 2nd of July 1924. As a reminder, Institute of Seismology has got for the very first time in it's history new facilities desinged especially for our own purposes. The meaning of the presentation is to give some good feelings and relaxing moments

Posters

Chairman: Marja Uski

ORFEUS and its Data Center

**Torild van Eck, Bernard Dost, Lucas Calje,
Reinoud Sleeman and Femke Goutbeek**

The Observatories and Research Facilities for EUropean Seismology (ORFEUS) is the European non-profit organization that aims at coordinating and promoting digital, broadband seismology in European-Mediterranean area. Founded in 1987, it has currently an international board of directors representing the 14 corporate founders (countries) funding the foundation, an executive Committee, controlling the daily operations, and a staff, hosted by the Royal Netherlands Meteorological Institute. More then 60 academic and research organizations are currently registered as paying participants representing 29 European countries. The core activities of ORFEUS are: gathering and providing waveform data through its Data Center (ODC) for the scientific community, and European co-ordination through its working groups on station siting, technical support, mobile networks and seismological software. Within the period 2000-2005 ORFEUS coordinates the EC project MEREDIAN (EVR1-CT2000-40007) (18 countries). Within MEREDIAN the Virtual European Broadband Seismic Network (VEBSN) is one of the most successful deliverables. It created a European infrastructure for free rapid waveform data exchange.

Examples of on-going ORFEUS coordinating activities are technical workshops (IRIS-ORFEUS database management, early spring 2005, Trieste; MEREDIAN network coordination, spring 2005, Prague; SeisComP/SeedLink, spring 2005, Prague; broadband installation, 2006, Vienna, Software, 2005/6, place not decided yet) and project applications (upgrading the infrastructure in the Balkans, networking in the Western Mediterranean, and in the Eastern Mediterranean, the European infrastructure for seismological research - NERIES). Also web services, such as the Seismological Software Library, overviews of sensors and data acquisition systems, installed BB stations, technical documentations, manuals, etc are activities pursued within ORFEUS.

ORFEUS and EMSC work closely together under the auspices of the European Seismological Commission (ESC). ORFEUS is also active within the Federation of Digital Seismograph Networks (FDSN) through which it works intensively together with IRIS and its data center on coordinating software development and formatting standards.

3D hybrid modeling of local site effects in Ataköy area, Istanbul, Turkey, due to a finite-extent earthquake source

Mathilde Bøttger Sørensen, Ivo Oprsal, Nelson Pulido, Martin Mai, Kuvvet Atakan

As part of the European project RELIEF (RELiable Information on Earthquake Faulting, EVG1-CT-2002-00069), we investigate the possible effects on the city of Istanbul due to a large earthquake in the Marmara Sea by combining ground motion simulations, local site effect estimation and seismic hazard assessment.

Our target region is the Ataköy area, located between two alluvial systems in western Istanbul, next to the Atatürk airport.

We have constructed a 3D velocity-density model based on geological, geomorphological and geotechnical data from various sources. Bedrock ground motions for a M = 7.5 scenario earthquake are then propagated through our 3D model of the local near surface geology.

Earthquake and volcanic activity in Iceland monitored by IMO

**Gunnar B. Gudmundsson, Steinunn S. Jakobsdóttir,
Erik Sturkell and Matthew J. Roberts**

The Icelandic Meteorological Office (IMO) monitors earthquake and volcanic activity in Iceland using 41 digital seismic stations, 6 volumetric strain meters and 14 continuous GPS stations. The institute provides public information about earthquakes and volcanic eruptions and, if possible, issues hazard warnings to the National Civil Defence Agency, other scientific institutes and the public. Besides operating and maintaining the networks, significant effort goes into analysing and archiving geophysical data for research purposes. The current seismic network is the SIL system, which began automated processing of seismic data in 1991. Since 1991, more than 220,000 earthquakes have been analysed. Nearly 100,000 of these earthquakes occurred in the Hengill-Ölfus area during swarming episodes between 1994 and 1998, which culminated in two Ml~5 earthquakes. In June 2000, two Ms=6.6 earthquakes occurred in the South Iceland Seismic Zone. The first earthquake immediately triggered several Ml~5 on the Reykjanes Peninsula, ~70 km to the west of the source earthquake. Earthquakes of magnitude 5 or greater have also been recorded in the Tjörnes Fracture Zone, beneath the Vatnajökull ice cap and on the Reykjanes Peninsula. Since 1991, two eruptions have occurred at Hekla volcano and two eruptions have occurred beneath Vatnajökull. From 1991 onwards, heightened seismicity has occurred at Eyjafjallajökull volcano; additionally, geodetic measurements revealed uplift of Eyjafjallajökull during the same period. The Katla volcano, located beneath the Mýrdalsjökull ice cap, has shown signs of volcanic unrest since the release of a volcanogenic jökulhlaup from the ice cap in 1999. Seismicity from Katla increased markedly from 2001 onwards. Furthermore, GPS measurements indicate vertical uplift and radial displacement of nunataks on Mýrdalsjökull. These observations have encouraged additional monitoring of ice-surface changes and the hydrology and geochemistry of rivers draining from Mýrdalsjökull in cooperation with other geological institutions in Iceland. Beneath Vatnajökull, the Grímsvötn volcano continues to inflate rapidly, resulting in increased seismicity from the volcano. The aims of the integrated geophysical observations at Mýrdalsjökull and Vatnajökull is to enable accurate forecasts of eruption potential. Using the real-time processing capabilities of the SIL system, it is anticipated that an eruption warning will be issued to the public shortly before either eruption breaks the ice surface.

Re-assessment of focal depth by using teleseismic moment tensor inversion

L. Hagos and H. Shomali

Linear moment tensor inversion was performed by modeling direct P and S waves of teleseismic data. In this study, we present a stepwise inversion procedure that was followed to assess focal depth and model the complexity of an earthquake source. Waveform inversion is done for single point source and a representative focal depth is found to correspond to the minimum misfit between the synthetic and observed seismograms. The measure of the misfit is the ratio of the weighted Residual variance to the weighted data variance (R/D%) which is calculated in the inversion procedure for each step of preferred depth. This procedure is repeated for a given source time function (STF), with its elements being forced to remain positive, by increasing the damping on any element that becomes zero. Estimated source duration, the time for 95% of seismic moment to occur, is also computed at this step. Plots of depth against the computed source duration in this preliminary assessment show an approximation of a linear relationship. A forward modeling is also performed by fixing the moment tensor components and determining the parameters associated with source directivity. A similar approach is used to determine the Rupture velocity and azimuth, that is, corresponding values are found where the misfit is minimum. The last step in this procedure involves fixing the source directivity and improving the fault plane solutions. In this analysis, a 5 km step in depth for a half space and a two layer earth models, are used in all cases. An earthquake with surface wave magnitude of 5.6 which occurred on April 11, 1994 in the Afar depression, is chosen as a test event. 18 Broad band stations with fairly reasonable azimuthal coverage around the event and in the distance range of 30- 90o are selected for our analysis. These numerical experiments are believed to resolve the focal depth and the physical representation of an earthquake.

Imaging Upper Mantle Discontinuities Using P to S Converted Phases

Sverker Olsson, Roland Roberts, Hossein Shomali

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