Operation of the

Norwegian National Seismic Network

2012

Supported by

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Prepared by

Department of Earth Science
University of Bergen
Allegaten 41, N-5007 Bergen

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1 Introduction

This annual report describes the operation of the Norwegian National Seismic Network (NNSN) for the year 2012. The University of Bergen (UiB) has the main responsibility to run the NNSN. This report covers operational aspects for all seismic stations operated by the Department of Earth Science at the UiB and includes the financial report.

The network is supported by the oil industry through the Norwegian Oil and Gas Association and UiB.

The seismicity of Norway and surrounding areas is presented in Appendix 1. The seismic arrays operated by NORSAR are covered in Appendix 2 of this report. NORSAR is subcontracted to deliver data of interest to NNSN and also take part in joint data processing.

2 Operation

In Norway, the University of Bergen (UiB) operates 31 of the seismic stations that form the Norwegian National Seismic Network (NNSN). NORSAR operates three seismic arrays, which also include broadband instruments and two single seismometer station (Figure 1). NORSAR provides data from four broadband stations to the NNSN.

There is an ongoing process by UiB to change short period (SP) with broadband (BB) seismometers and to increase the number of stations where data can be transmitted to Bergen in real time. As of today the number of SP, BB stations and stations with real time transmission are listed in Table 1.

Table 1. Overview of UiB seismic stations

	Short Period	Broadband	Real time
Number of stations	11	20 (17 with natural period greater than 100 sec)	28

The operational stability for each station is shown in Table 2. The downtime is computed from the amount of data that are missing from the continuous recordings at UiB. The statistics will also show when a single component is not working. This is done as the goal is to obtain as complete continuous data from all stations as possible. This means that also communication or computing problems at the centre will contribute to the overall downtime. In the case of communication problems, a station may not participate in the earthquake detection process, but the data can be used when it has been transferred. Thus, the statistics given allow us to evaluate the data availability when rerunning the earthquake detection not in real-time.

The data completeness for the majority of the stations is above 95%, except for the following stations:

- FOO: problems with stable powersupply which gave problems with PC and seismometer
- HYA: problems with digitizer
- KMY: problems with digitizer
- KTK: problems with digitizer
- MOR: Problems with seismometer

Table 2. Data completeness in % for 2012 for all stations of the NNSN operated by UiB.

Station	Data completeness %
Askøy (ASK)	99
Bergen (BER)	100
Bjørnøya (BJO)	97
Blåsjø (BLS)	100
Dombås (DOMB)	96
Florø (FOO)	83
Flostrand (FLOS)	Closed Mar 2012
Hammerfest (HAMF)	100
Homborsund (HOMB)	99
Hopen (HOPEN)	96
Høyanger (HYA)	95
Jan Mayen (JMI)	99
Jan Mayen (JNE)	99
Jan Mayen (JNW)	99
Karmøy (KMY)	93
Kautokeino (KTK)	72

Station	Data completeness %
Kings Bay (KBS)	98
Kongsberg (KONO)	98
Konsvik (KONS)	100
Lofoten (LOF)	100
Mo i Rana (MOR8)	70
Molde (MOL)	98
Namsos (NSS)	97
Odda (OOD1)	98
Oslo (OSL)	100
Snartemo (SNART)	100
Stavanger (STAV)	100
Steigen (STEI)	99
Stokkvågen (STOK)	98
Sulen (SUE)	99
Blussuvoll (TBLU)	96
Tromsø (TRO)	100

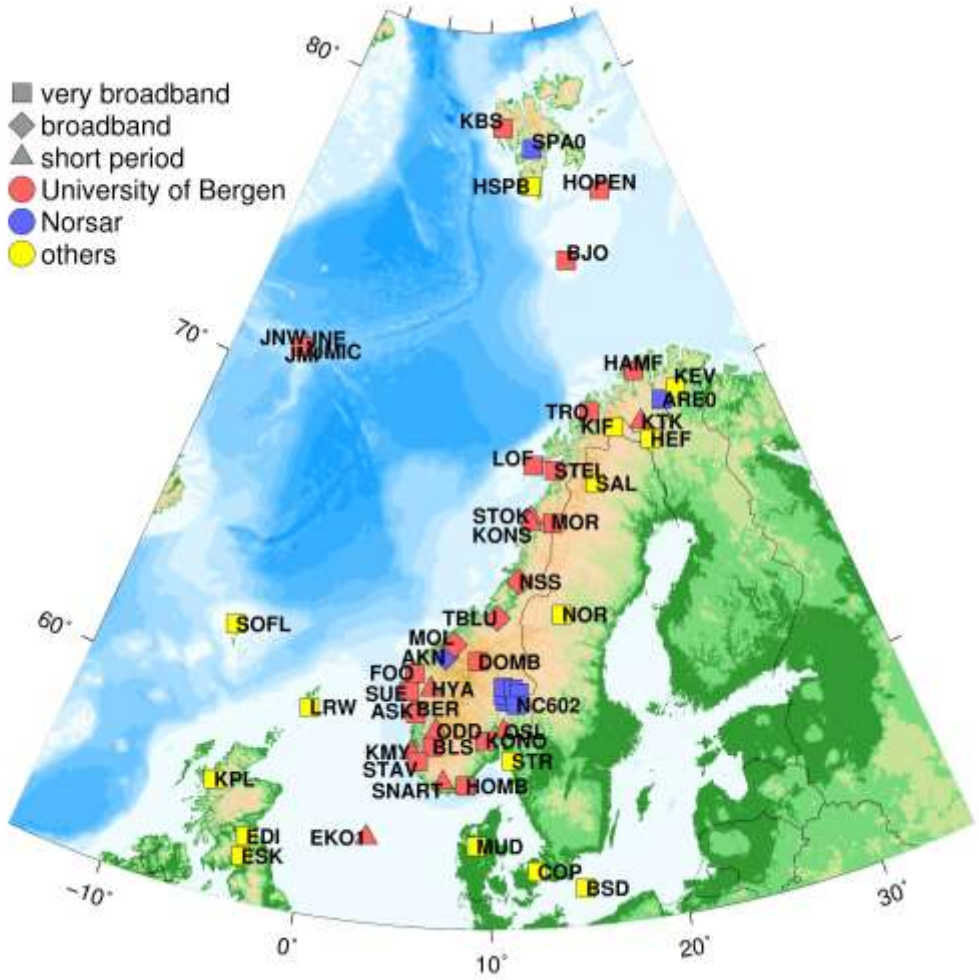

Figure 1. Stations contributing to the Norwegian National Seismic Network (NNSN). UiB operates 32 stations (red) and NORSAR operates the stations marked in blue including the 3 arrays, and stations AKN and JMIC. Data from stations in yellow are received continuously in Bergen, but are operated by neighbouring countries.

3 Field stations and technical service

The technical changes for each seismic station are listed below. It is noted if these changes are carried out by the respective local contact and not by the technical staff of UiB. When a station stops working, tests are made to locate the problem. Sometimes the reason cannot be found and the cause of the problem will be marked as unknown.

Major changes during 2012 were:

JMI station was upgraded with Trillium 120 and Guralp DM24 at the vault. A new cable was installed at NSS between the house and the vault and the digitizer was relocated to the house. STEI was upgraded to a Nanometrics Trillium 120 sensor and Guralp digitizer and new software was installed on the PC.

Ask (ASK)	27.02-07.03.12: Communication down due to broken BB line. No data lost.
Bergen (BER)	20.6.12: Replaced digitizer, same type.
Bjørnøya (BJO1)	No visit or technical changes. 27-30.01.12: Station down. Restarted system. 07-09.03.12: Station down. Restarted system.
Blåsjø (BLS)	No visits or technical changes.
Blussvoll (TBLU)	No visits or technical changes.
Dombås (DOMB)	22.11.12: Communication changed from ADSL to wireless CDMA450 (ICE) communication.
Florø (FOO)	12.08.12: Visit. GPS receiver replaced to Guralp DM24. Seismometer restarted.
Hammerfest (HAMF)	No visits or technical changes.
Homborsund (HOMB)	11.01.12: Station down due to power loss. PC replaced by local operator.
Hopen (HOPEN)	21.09.12: Maintenance of junction box performed remotely having contact with a staff member at Hopen. 16.10.12: New power supply and cable to digitizer was installed by local operator.
Høyanger (HYA)	29.11-17.12.12: Data lost due to broken digitizer. Digitizer replaced by local operator.

Jan Mayen (JMI)	18-28.08.12: Visit. JMI station upgraded with Trillium 120 and Guralp DM24. Digitizer is installed at the vault and serial line modems are used for communication. There is some loss of data on the line, which will be resolved by installing new modems. Short-period vertical component is kept for redundancy. Noise problem with short-period sensor solved.
	03.10.12: Visit. Attempt was made to change modems and install accelerometer. However, due to limited time this has to be done by the local operator.
	22.09-17.12.12: Occasional problems with full disk at the station. Data are transferred, but some might be lost. New disk will be installed.
Karmøy (KMY)	17-19.01.12 Visit. Noise on Z component. The error is due to the cable. The vertical sensor (SS-1) was relocated to the house.
	02-30.11.12: Station down due to broken digitizer.
Kautokeino (KTK)	05.01-16.03.12: Station down due to malfunctioning digitizer and no new digitizer available in Bergen. Digitizer replaced after period of downtime.
	27.04-10.05.12: Station down due to malfunctioning digitizer. Digitizer replaced.
	9-26.06.12: Station down. Digitizer replaced.
Kings Bay (KBS)	No visits or technical changes.
Kongsberg (KONO)	No visits or technical changes.
Konsvik (KONS)	No visits or technical changes.
Lofoten (LOF)	No visits or technical changes.
Mo i Rana (MOR8)	Data noisy due to interference since December 2011. Test was carried out by local operator, guided from Bergen, to establish the cause of the problem which was related to the grounding of the satellite dish.
	06.01.12: Signal improved by giving satellite dish new earth cable.
	12.08.12: Loss of signal from seismometer.
	25.10.12: Visit. New seismometer installed.
Molde (MOL)	No visits or technical changes.

Namsos (NSS)	09-11.01.12: Visit. New cable from sensor to house. Digitizer moved from sensor box to house. Seismometer signal now analog where it was digital over serial line before. GPS moved to new position.
Odda (ODD1)	No visits or technical changes.
Oslo (OSL)	No visits or technical changes.
Snartemo (SNART)	No visits or technical changes.
Stavanger (STAV)	No visits or technical changes.
Steigen (STEI)	08-10.05.12: Visit. Station upgraded to Nanometrics Trillium 120 sensor and Guralp DM24-EAM. PC upgraded with new software
Stokkvågen (STOK)	25.02-02.03.12: Station down due to power loss.
Sulen (SUE)	No visits or technical changes.
Tromsø (TRO)	01.02.12: GPS antenna and Guralp digitizer were replaced by local operator.

4 NNSN plans

The overall purpose of the NNSN is to provide data both for scientific studies, but equally important for the routine observation of earthquakes. This in principle means that broadband seismometers are desired at all sites. However, in areas where additional stations are deployed for local monitoring, short-period seismometers are sufficient. The number of broadband seismometers in the network will be increased to replace existing short period instruments. A general goal for the future development has to be to achieve better standardization in particular with the seismometers and digitizers. The total number of stations for now should remain stable, but it is important to improve the overall network performance.

We now report achievements for 2012, and then give the plans for 2012/13.

4.1 Achievements in 2012

- New station: Several sites were considered in the area around Geilo. A noise site survey was carried out at Skarslia near Ål. Preparations for the installation are being made to complete installation during spring/summer 2013 depending on weather conditions. The vault will be modified from existing stations to

achieve a better performance at long periods by using a larger container to reach greater depth.

- Steigen: The station has been upgraded with broadband seismometer and 24-bit digitizer.
- Jan Mayen: A broadband seismometer was installed at the JMI site. The vertical component shortperiod sensor is kept for redundancy. The setup was also changed by installing the digitizer at the vault and using serial line modems to transmit the signals to the recording system at the base. The data is combined with the other stations and used for detection. In addition, the setup at the base was modified to eliminate all unused electronics. This resulted in removal of noise on the JMI shortperiod instrument that had been a problem for years. An accelerometer has been purchased and shipped to further increase the dynamic range of this station and to avoid clipping during large events.
- Real time data from Ekofisk are now integrated into the NNSN network. The data are received in form of segd data files, and these are converted to a near-realtime data stream using software developed at UiB (based on the Optoplan segd reader). In addition, a segd to miniseed converter was developed that allows to convert and process archived data.
- NNSN website: continue development
  Progress: The menu system and content of the page have been modified to improve access to the information.
- A noise test was done at Gullfaks between September and October, 2012.
- EPOS: An infrastructure proposal was submitted to NFR. This includes for the NNSN funding for 3 offshore stations, 10 new broadband stations and upgrade of 10 existing stations is included.

4.2 Plans for 2012/2013

- Upgrade: Stations OSL, KMY, ODD1 and STOK will be considered for upgrade with Guralp digitizers. (This has been delayed by faulty equipment supplied by the manufacturer and long delivery times).
- Upgrade: Stations OSL and STOK will be considered for installation of a broadband seismometer.
- Planning for upgrade of the two Jan Mayen stations JNE and JNW will begin depending on agreement with Fiskeri og kystdepartementet (FKD).
- Planning and site survey for a new station between Stokkvagen and Steigen.
- Strengthen the collaboration with NORSAR on data processing through technical visits.
- Hopen: The station is to be improved by re-siting and new construction of the vault. The existing STS2 seismometer has to be checked and will temporarily be replaced with a Nanometrics sensor.
- Research and development: This activity will start in 2013 in close collaboration between UiB and NORSAR. The main topics for 2013:
    1. Stress drop distribution
    2. Storfjorden activity
    3. Jan Mayen activity
    4. Earthquake location and velocity models

5. Evaluation of the network

APPENDIX 1

The NORSAR Regional Arrays

The NORSAR Stations and Arrays - 2012

NORSAR is operating the following seismic installations:

- NOA (southern Norway, array, 42 sites, 7 3C broadband sensors and 35 vertical broadband sensors)
- ARCES (Finnmark, array, 25 sites, 1 3C broadband sensor, 4 3C short-period sensor and 21 vertical short-period sensors)
- SPITS (Spitsbergen, array, 9 sites, 6 3C broadband sensors and 3 vertical broadband sensors)
- NORES (Hedmark, array, 25 sites, currently 9 3C short-period sensors)
- JMIC (Jan Mayen, 3C broadband sensor)
- AKN (Møre og Romsdal, 3C broadband sensor)
- TROLL (Antarctica, 3C broadband sensor)

Additionally, NORSAR receives and processes data in realtime from:

- FINES (southern Finland, array, 16 sites, 2 3C broadband sensor, 1 3C short-period sensor and 15 short-period vertical sensors)
- HFS (Hagfors, Sweden, 10 sites, 1 3C broadband sensor and 9 short-period vertical sensors)
- EKA (Eskdalemuir, United Kingdom, 20 sites, 1 3C broadband sensor and 20 short-period vertical sensors)

All NORSAR waveform data and parametric data are openly available and can be accessed through web-interfaces or direct means. The NORSAR webpage www.norsardata.no provides access to general station information, to automatic and reviewed seismic bulletins, to real-time plots of short and long-period data, and to an AutoDRM request form for waveform data retrieval.

The seismic array data are automatically processed and analysed. The fastest near realtime process 'Automatic Alert' is based on single array detection and provides event locations within a few (1-3) minutes delay. The alerts with event and location details are published immediately on http://www.norsardata.no/NDC/ael/eventmap1.html (which is also integrated into the NNSN website). A second automatic process called GBF (generalized beam forming) awaits for automatic phase picks from all arrays and delivers more reliable/accurate results within up to a few hours delay. Automatically processed seismic events with magnitude larger than 2 (or 1.5 if the event is of special interest) are manually analysed and reviewed. In this step all available waveforms (also from single stations) are utilized. Graphical displays and parametric event data and for 'Automatic Alert', 'GBF' and 'Reviewed bulletins' can be found on http://www.norsardata.no/NDC/bulletins/.

NORSAR seismic arrays/stations (NOA, NORES, ARCES, SPITS, JMIC, AKN) and contributing arrays (HFS, FINES, EKA).

1 New developments at NORSAR

The upgrade of the NOA array that commenced in 2011 has been completed in July 2012. The NOA array is now an all-broadband seismic array. It consist of 7 three-component broadband sensors (360 sec -50 Hz) and 35 vertical broadband sensors (120 sec -50 Hz). The sensors have a hybrid instrument response (proportional to velocity for frequencies up to 1/3 Hz, proportional to acceleration from 1/3 to 2 Hz and again proportional to velocity for frequencies 2 to 50 Hz), which allows to monitor weak high-frequency events with high sensitivity as well as large earthquakes without clipping. Data are sampled at 40 Hz and transmitted in real-time to NORSAR via VSAT and landline.

NORSAR entered into an agreement with the United Kingdom National Data Centre, AWE Blacknest, for continuous realtime data access to the seismic array EKA (Eskdalemuir, Scotland). We established data transmission in December 2012 and started in 2013 with routine array processing. The incorporation of the EKA data enhances the detection capability for events in the North Sea and contributes to a higher localization accuracy especially for that region.

2 Systems Recording Performance

All data recorded at NORSAR are continuous. The following table provides a monthly overview on the data availability of the 12 data streams provided by NORSAR to NNSN.

	ARE0	JMIC	NAO01	NB201	NBO00	NC204
Jan	100.00	99.99	100.00	99.99	99.96	100.00
Feb	95.03	99.99	99.98	98.93	99.97	99.98
Mar	100.00	99.86	99.99	100.00	100.00	99.99
Apr	94.22	93.33	99.99	100.00	100.00	99.99
May	100.00	99.94	99.90	100.00	99.98	100.00
Jun	100.00	99.89	99.98	96.11	99.99	99.99
Jul	42.36	99.92	99.97	100.00	99.98	99.97
Aug	100.00	99.81	99.98	99.98	99.99	99.98
Sep	91.15	99.54	99.99	99.79	99.99	99.96
Oct	93.85	99.93	99.43	99.95	99.38	99.96
Nov	99.94	92.50	99.94	99.97	99.89	99.97
Dec	100.00	96.92	97.34	99,99	100.00	99.98

	NC303	NC405	NC602	SPA0	AKN	HFC2
Jan	100.00	100.00	100.00	99.99	98.46	100.00
Feb	96.23	99.99	100.00	99.99	89.28	100.00
Mar	98.29	100.00	98.30	99.99	100.00	99.87
Apr	100.00	100.00	100.00	99.99	100.00	100.00
May	100.00	100.00	100.00	99.96	100.00	100.00
Jun	99.97	99.73	99.88	99.96	100.00	99.58
Jul	99.97	99.98	99.96	99.96	100.00	100.00
Aug	99.98	99.98	99.91	100.00	100.00	100.00
Sep	99.99	99.90	100.00	99.96	100.00	100.00
Oct	99.95	99.86	99.91	99.95	100.00	100.00
Nov	100.00	99.98	100.00	100.00	100.00	100.00
Dec	100.00	99.99	100.00	100.00	100.00	100.00

Table 1. Systems recording performance (in % of data completeness) for the 12 data streams provided from NORSAR to NNSN.

3 Detections

The NORSAR analysis results are based on automatic phase detection and automatic phase associations which produce the automatic bulletin. Based on the automatic bulletin a manual analysis of the data is done, resulting in the reviewed bulletin. The automatic bulletin for northern Europe is created using the Generalized Beam Forming (GBF) method. This bulletin (www.norsardata.no/NDC/bulletins/gbf/) is subsequently screened for local and regional events of interest in Fennoscadia and in Norway, which in turn are reviewed by an analyst. Regional reviewed bulletins from NORSAR are available from 1989 and from 1998 onwards they are directly accessible from via internet (www.norsardata.no/NDC/bulletins/regional/). Table 2 gives a summary of the phase detections and events declared by GBF and the analyst.

	Jan.	Feb.	March	April	May	June
Phase detections	158092	150345	144362	126972	108740	118010

Associated phases	6053	5508	6870	5108	6543	5694
Un-associated phases	152039	144837	137492	121864	102197	112316
Screened GBF events for Fennoscandia/Norway	1208	1157	1245	1065	1207	1305
No. of events defined by the analyst	69	74	81	61	84	47
	July	Aug.	Sep.	October	Nov.	Dec.
Phase detections	132474	157199	170086	177547	130303	153686
Associated phases	7664	10213	9629	9074	6453	6878
Un-associated phases	124810	146986	160457	168473	123850	146808
Screened GBF events for Fennoscandia/Norway	2071	2648	2281	2009	1380	1372
No. of events defined by the analyst	50	53	64	39	39	50

Table 2. Phase detections and event summary.

4 Combined NORSAR-UiB data analyses

Array processing is fundamentally different to single-station processing and there is no straightforward way to merge and commonly process array and single-station waveform data. However, on a higher level parameters like phase arrival readings from array beams and single stations can be combined and be used for event localization. At NORSAR the parameters of analyst-reviewed events are converted into parameter files in Nordic format and forwarded via ftp to UiB on a daily basis. The magnitude threshold has been lowered to about M 1.5 for regional events of potential interest for the NNSN. After transferring the parameter files, the NORSAR analyst logs into the the UiB data base using SEISAN and integrates the events. Integration means to merge NORSAR and UiB events, which may require to repick seismic phases, to include new phase readings, to edit double phase readings and to relocate the seismic event with the new parameters.

5 NORSAR-UiB data streams

All historic and realtime NORSAR data can be downloaded using the well-known automated Data Request Manager (AutoDRM). In addition NORSAR has established a seedlink server (athene.norsar.no) that provides realtime data streams from all NORSAR broadband instruments. UiB is currently receiving 12 three-components streams from stations ARE0 (ARCES array), JMIC, NAO01, NB201 NBO00 NC204, NC303, NC405, NC602 (NORSAR array), SPA0 (SPITS array) , HFC2 (Hagfors array) and AKN which can be integrated into their single-station processing schemes.

6 The use of Norwegian data

Data collected on Norwegian seismic stations are made available through the Internet and is provided on request to interested parties. Therefore it is difficult to get a comprehensive overview on the use and all publication based on Norwegian data. The following reference list shows publications and presentations of NORSAR scientists for the reporting period, based on data of NNSN and NORSAR stations.

6.1 Publications and presentations based on NNSN and NORSAR data

Fyen, J., S. J. Gibbons, T. Kværna, S. Mykkeltveit, F. Ringdal, M. Roth and J. Schweitzer, NORSAR's automatic processing. Joint Scientific Commission meeting AFTAC, Florida 6-8- November 2012

Fyen, J. and M. Roth, 2012. NORSAR history and field installation in text and pictures. Joint Scientific Commission meeting AFTAC, Florida 6-8- November 2012

Gibbons, S. J., F. Ringdal and T. Kværna, 2012 Ratio-to-moving-average seismograms: a strategy for improving correlation detector performance, Geophysical Journal International, Vol. 190, No. 1. (July 2012), pp. 511-521, doi:10.1111/j.1365-246x.2012.05492.x

Gibbons, S. J., 2012. The Applicability of Incoherent Array Processing to IMS Seismic Array Stations. Geophysical Research Abstracts Vol. 14, EGU2012-1366, 2012 EGU General Assembly 2012 http://meetingorganizer.copernicus.org/EGU2012/EGU2012-1366.pdf EGU 2012 oral presentation, Vienna International Center, 25 April 2012

Gibbons, S. J., 2012.The Applicability of Incoherent Array Processing to IMS Seismic Arrays. Pure and Applied Geophysics In Pure and Applied Geophysics (online only 17 October 2012), doi:10.1007/s00024-012-0613-2

Havskov, J, P. Bormann and J. Schweitzer, 2012. Seismic source location. http://ebooks.gfz-potsdam.de/pubman/item/escidoc:43361:4; doi:10.2312/GFZ.NMSOP-2_IS_11.1; 36 pp., escidoc:44031 P. Bormann (ed.) (2012), New Manual of Seismological Observatory Practice 2 (NMSOP-2). 2nd (revised) edition, Potsdam: Deutsches GeoForschungsZentrum GFZ, doi: 10.2312/GFZ.NMSOP-2

Harris, D. B., S. J. Gibbons, A. J. Rodgers and M. E. Pasyanos, 2012. Nuclear Test Ban Treaty Verification: Improving Test Ban Monitoring with Empirical and Model-Based Signal Processing. IEEE Signal Processing Magazine, Vol. 29, No. 3. (May 2012), pp. 57-70, doi:10.1109/msp.2012.2184869

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Knapmeyer-Endrun, B., M. Ohrnberger and J. Schweitzer, 2012. Temporal variability of the noise wavefield at different scales: Influence on H/V and FK results. Noise and Diffuse Wavefields, Extended Abstracts of the Neustadt Workshop, 11 – 14 November 2012, Deutsche Geophysikalische Gesellschaft Mitteilungen, Sonderband IV/2012, 29-30, 2012

Knapmeyer-Endrun, B., M. Ohrnberger and J. Schweitzer, 2012. Temporal variability of the noise wavefield at different scales: Influence on H/V and FK results, Neustadt Workshop "Noise and Diffuse Wavefields", 11. – 14. November 2012

Kværna, T., 2012. Verification-related research at NORSAR. Joint Scientific Commission meeting AFTAC, Florida 6-8- November 2012

Kværna, T., M. Pirli and J. Schweitzer, 2012. Overview of the seismological activities in the Arctic region, including plans for a seismic array on Bear Island. Joint Scientific Commission meeting AFTAC, Florida 6-8- November 2012

Kværna, T. and F. Ringdal, 2012. Analysis of the IDC reviewed event bulletin for detection capability estimation of the IMS seismic stations. Joint Scientific Commission meeting AFTAC, Florida 6-8- November 2012

Kværna, T, S. J. Gibbons, D. B. Harris and D. A. Dodge, 2012. Adapting Pipeline architecture to track developing aftershock sequences and recurrent explosions. Joint Scientific Commission meeting AFTAC, Florida 6-8- November 2012

Pirli, M., J. Schweitzer and B. Paulsen, 2012. A long earthquake series in the European Arctic: challenges and limitations to seismotectonic interpretation, 33rd General Assembly of the European Seismological Commission, Moscow, August 2012

Pirli, M. and J. Schweitzer, 2012. Seismic activity at the region of convergence of the Mohns and Knipovich Ridge, as seen within the International Polar Year 33rd General Assembly of the European Seismological Commission, Moscow, August 2012

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Schweitzer, J., J. Fyen, S. Mykkeltveit, S. J. Gibbons, M. Pirli, D. Kühn and T. Kværna, 2012. Seismic Arrays. http://ebooks.gfz-potsdam.de/pubman/item/escidoc:43213:7; doi:10.2312/GFZ.NMSOP-2_ch9; 80 pp., escidoc:44028 P. Bormann (ed.) (2012), New Manual of Seismological Observatory Practice (NMSOP-2). 2nd (revised) edition, Potsdam: Deutsches GeoForschungsZentrum GFZ, doi: 10.2312/GFZ.NMSOP-2