Operation of the

Norwegian National Seismic Network

2011

Supported by

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1 Introduction

This annual report describes the operation of the Norwegian National Seismic Network (NNSN) for the year 2011. 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 Industry Association ("Oljeindustriens Landsforening" (OLF)) 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 32 of the seismic stations that form the Norwegian National Seismic Network (NNSN). NORSAR operates three seismic arrays, which also include broadband instruments and one 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	14	18 (15 with natural period greater than 100 sec)	29

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:

- HYA: problems with digitizer
- KTK: problems with digitizer
- KONO: problem with phone line; however more data available from IRIS
- KONS: communication problems
- NSS: problem with digitizer and cable
- TBLU: station powered down in summer holidays

Table 2. Data completeness in % for 2011 for all stations of the NNSN operated by UiB.

Station	Data completeness %
Askøy (ASK)	98
Bergen (BER)	99
Bjørnøya (BJO)	99
Blåsjø (BLS)	100
Dombås (DOMB)	97
Florø (FOO)	98
Flostrand (FLOS)	Closed Mar 2012
Hammerfest (HAMF)	99
Homborsund (HOMB)	100
Hopen (HOPEN)	96
Høyanger (HYA)	89
Jan Mayen (JMI)	99
Jan Mayen (JNE)	99
Jan Mayen (JNW)	99
Karmøy (KMY)	100
Kautokeino (KTK)	86

Station	Data completeness %
Kings Bay (KBS)	98
Kongsberg (KONO)	93
Konsvik (KONS)	90
Lofoten (LOF)	99
Mo i Rana (MOR8)	34 (almost complete since September)
Molde (MOL)	96
Namsos (NSS)	57
Odda (OOD1)	100
Oslo (OSL)	100
Snartemo (SNART)	99
Stavanger (STAV)	99
Steigen (STEI)	95
Stokkvågen (STOK)	99
Sulen (SUE)	98
Blussuvoll (TBLU)	93
Tromsø (TRO)	100

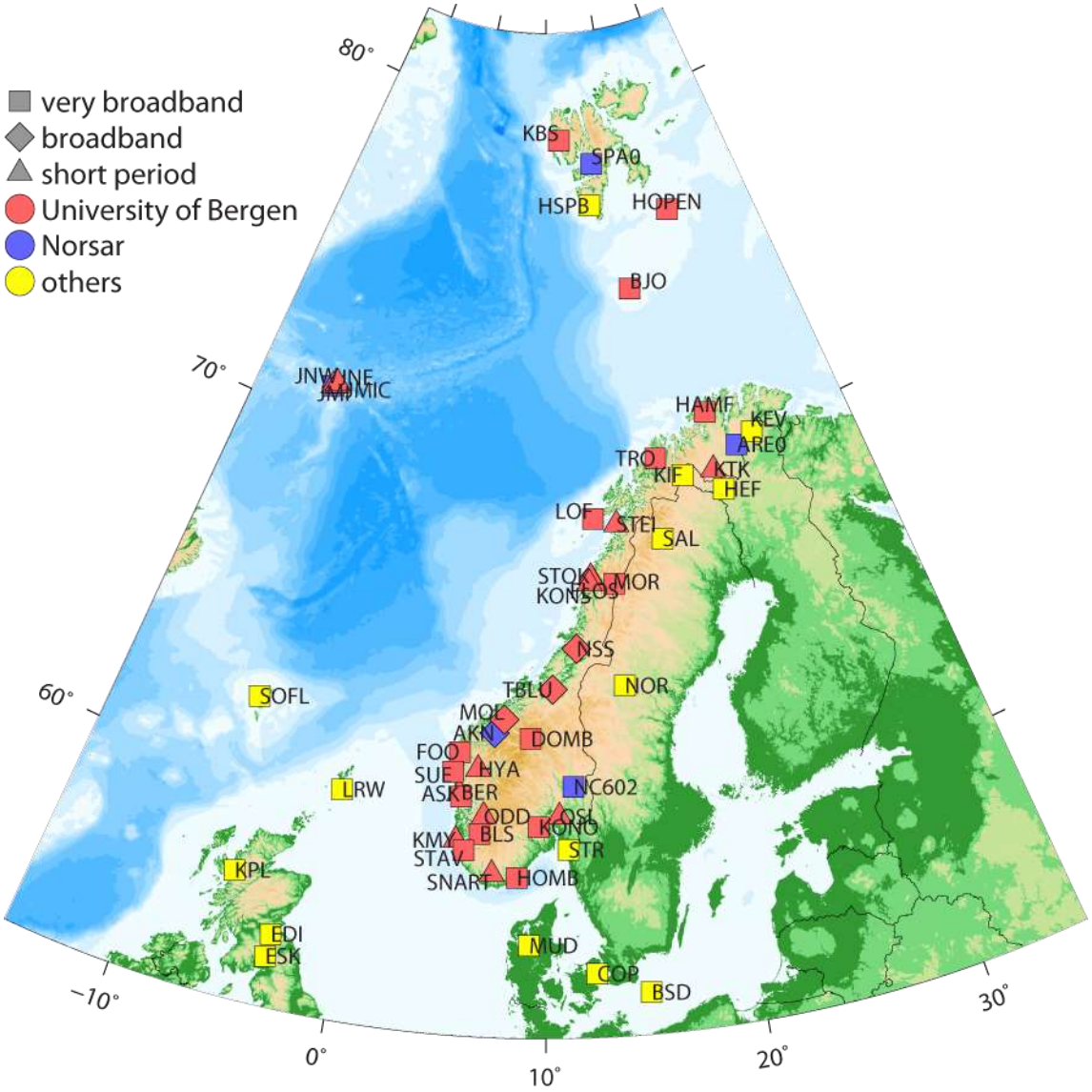

Figure 1. Stations contributing to the Norwegian National Seismic Network (NNSN). UiB operates 32 stations (red) and NORSAR operates the stations marked in blue including the 3 arrays, and station AKN. Data from stations in yellow are received continuously in Bergen, but are operated by neighbouring 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 2011 were:

MOR8 was upgraded to broadband with real-time satellite communication. A new digitizer and Trillium 120 sec broadband seismometer were installed at BJO. The same digitizer type is now also used at HOPEN. STAV was upgraded to Trillium seismometer and Guralp digitiser early in the year. LOF was upgraded to Trillium seismometer and Guralp digitizer.

Ask (ASK)	17.02.11: Visit. A new Guralp Digitizer (model CMG-D2M4-EAM) was installed. Unit is modified, gain has been changed from 3.2µV to 0.8µV. GPS antenna is now G-13788. Modem restarted
	19.04-26.04.11: Station down, reason unknown. Restart by local operator.
Bergen (BER)	18.01.11. New Guralp digitizer (CMG-D2M4-EAM) installed.
Bjørnøya (BJO1)	9.10.11: Visit: The station was upgraded to a Nanometrics Trillium 120PA sensor, industrial PC, new Guralp CGM-EAM Digitizer and Guralp GPS.
Blåsjø (BLS)	No visit or technical changes.
Blussvoll (TBLU)	7.7.11-3.8.11: Station down during school holidays, eventually restarted by local operator.
Dombås (DOMB)	01.02.11: A new digitizer(CMG-D2M4-EAM) was installed by the local operator.
	19.08.11: Station down 31/07/11 16:32 to 19/08/11 06:30 due to thunder storm. A new modem was installed, but station still not ok. Using ICE communication temporarily. This was a temporary solution, and the station was reconnected to ADSL later in the year.
Florø (FOO)	28.02.11: The existing Guralp sensor was replaced with a Trillium 120 sensor.
Flostrand (FLOS)	05.01.11: GMS router for communication was replaced by local operator.

	15:02.11: The station was down from 13.02.2011 to 15.02.2011 due to power loss.
	28.02.11: Station down, possibly problem with cable. The station will not be fixed before the station configuration in the area has been evaluated.
Hammerfest (HAMF)	05.03.11: Local contact checked the GPS
	31.03.11: The defective GPS antenna is replaced by local operator. Timing is now OK again.
Homborsund (HOMB)	No visit or technical changes.
Hopen (HOPEN)	The sensor is drifting and is every second week recentred by the local operator. This explains part of the lack of data where the instrument drifts to the limit.
	Visit: 13.10 2011. Installation of Guralp Digitizer CGM-EAM, Guralp GPS, Industrial PC. The seismometer was turned 90 deg. The Streckeisen STS-2 was not replaced.
Høyanger (HYA)	22.07.11: Station stopped at 14:20 due to thunderstorm. Station down until 23.08.
	05.08.11: New PC installed by local operator and communication is working. However, no data recorded due to problem with digitizer.
	23.08.11: Visit: The existing SARA digitizer was replaced with a Guralp CMG-DM24-EAM.
Jan Mayen (JMI)	No visit or technical changes.
	The bandwidth of the satellite link has been increased, and real-time communication is becoming possible.
Karmøy (KMY)	12.12.11: Digitizer replaced with the same type as before (Sara SR-04) by local operator.
Kautokeino (KTK)	11.07.11: 0650 UTC used SMS for remote restart.
	08.07.11: Station down.
	25.08.11: New PC installed by local operator.
	12.09.11: Earthdata digitizer replaced by the local operator due to noise on E component.
	21.09.11: Visit. New CMG-DM24-EAM digitizer installed.
Kings Bay (KBS)	No visit or technical changes.
Kongsberg	Communication down between 26. September – 14. October 2011 due

(KONO)	to a cable problem outside the mine.
Konsvik (KONS)	Occasional communication problems. No visit or technical changes.
Lofoten (LOF)	09-11.05.11: Station upgraded with a Trillium 120PA sensor, a Guralp CMG-DM24-EAM digitizer and an industrial PC.
Mo i Rana (MOR8)	05.01.11: Station restarted by local operator. Down since 30.11.10. The local operator is not available for periods of time during the winter. 11.05.11: Station down. Cable was destroyed. 20.06.11: Visit. A new sensor and digitizer were installed. The cable was repaired, but the sensor still does not work. 19.07.11: Visit. It was not possible to make the sensor work at the site, so it was temporarily moved. Station is now transferring data in real time using satellite communication. A new site will be constructed. 26.10.11: Visit. A new site has been created closer to the farm. A new 100 meter signal cable for the new site was installed, and the sensor was moved to the new site. 10.12.11: Noise including spikes recorded. 21.12.11: Effort put into pin pointing the source for the noise. In the end the earthing for the satellite head was found to be the reason. Connected to station earth. Removed and given separate ground.
Molde (MOL)	No visit or technical changes.
Namsos (NSS)	07.07.11-26.10.11: Station down due to thunderstorm and lightning. Expected damage to PC and Digitizer. 25.08.11: New PC installed by the local operator. Station still down due to serial line converter or digitizer problem.
Odda (ODD1)	No visit or technical changes.
Oslo (OSL)	No visit or technical changes.
Snartemo (SNART)	05.08-10.08.11: No contact with the station, due to local problems at the phone company.
Stavanger (STAV)	08.02.11: Visit. Installed a new BB sensor, Trillium 120PA, new Guralp digitizer (CMG-DM24) and GPS antenna, a new industrial PC.

Steigen (STEI)	18-29.05.11: Station down due to power loss.
Stokkvågen (STOK)	25.07.11: Thunderstorm and lightning caused communication failure. New modem was installed by the local operator.
Sulen (SUE)	06-08.12.12: Station down due to power loss.
Tromsø (TRO)	No visit or technical changes.

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. Of course 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 2011, and then give the plans for 2012.

4.1 Achievements in 2011

- Mo i Rana: The Mo i Rana station will be upgraded when the satellite link is sufficiently tested.
  Progress: Done. New station completed in October 2011. Trillium 120, CMG-DM24-EAM and satellite communication.
- Lofoten: the station will be upgraded by installing a new digitizer and computer; a broadband seismometer will be installed either at Lofoten or Steigen.
  Progress: Done. The station LOF was upgraded with a Trillium sensor in May 2011.
- Further upgrade: We have received funding from the department for six broadband sensors. Two of these will be used for portable deployment. The other four will be installed on current NNSN stations. The NNSN budget for new investments in 2011 will be used for digitizers.
  Progress: All available broadband sensors are installed. Five stations are being available for temporary deployment.
- New stations: planning for possible stations in the Hardangervidda area and near Bergen will start.
  Progress: The area around Geilo/Ustaoset is of interest due to easy access by train. The local 'kommune' has been contacted and the area is explored to find a good site. Noise tests are planned.

- Stokkvågen network: The network was intended to be temporary at the time of installation. With five years of recordings we will look into changing the configuration of these stations. A possible solution is to keep one of them, but to move one of them to half-way between this area and Steigen. Equipment at Stokkvågen, Steigen and the new station will have to be improved. During 2011, a noise site survey will be made. Progress: No progress has been made. Station FLOS is down, and will be closed at end of 2011.
- Continue with the integration of data from Ekofisk and Statfjord.
  Progress: Sample data from Ekofisk were received, and are evaluated. Real-time data transfer still needs to start. A seismometer was deployed at Statfjord was operating from 23.12.10 in the shaft of STC. However, due to unstable power supply no recordings were made.
- Establish automated routines for event based waveform data extraction from NORSAR for the associated triggers to the NNSN database.
  Progress: Beam data are now available from NORSAR and copied to UiB automatically. The beam data has been looked at in specific cases, but are not yet included in the daily processing routines at UiB.
- Procedures: earthquake response and interaction with NORSAR to be developed.
  Progress: Analyst from NORSAR has visited Bergen twice (February and June). A short document with a task list was prepared.
- NNSN website: continue development
  Progress: The menu system and content of the page is under revision. A first version of the new menu system is available. However, progress is a bit slow.

4.2 Plans for 2012

- New station: The station in the Hardangervidda will be installed. During 2011 search for a site at Hardangervidda started. Contact was made with the local 'kommune' and seven possible locations were identified. Noise testing are planned during May and installation of the new station during summer 2012.
- Upgrade: Stations OSL, KMY, STEI and STOK will be upgraded to a Guralp digitizer.
- Upgrade: Stations OSL and STEI will be considered for installation of a broadband seismometer.
- Ekofisk: Complete the data integration.
- Strengthen the collaboration with NORSAR on data processing through technical visits.
- Jan Mayen: Improve signal quality of the JMI station and install a broadband seismometer.
- NNSN website: continue development.

APPENDIX 1

The NORSAR Regional Arrays

The NORSAR Stations and Arrays - 2011

NORSAR currently operates three seismic arrays (ARCES in Finnmark (25 sites), SPITS on Spitsbergen (9 sites) and NOA in southern Norway (42 sites)) and two broadband stations (JMIC on Jan Mayen and AKN in the county of Møre og Romsdal). The fourth seismic array NORES (25 sites) was hit by lightning in 2002 and was partly refurbished end of 2010. Additionally NORSAR collects data from the FINES array in southern Finland and the HFS array in southern Sweden. The data streams are available in real-time at NORSAR and are subjected to immediate automatic processing and analyses. All waveform and parametric data are openly available and can be accessed through web-interfaces or direct means.

NORSAR seismic stations JMIC and AKN and arrays NOA, ARCES, SPITS and NORES (partly refurbished).

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.

1 New developments at NORSAR

The seismic array NORES close to Løten, Hedmark has been partly refurbished in December 2010 and is being used as an experimental array since then. We installed at the innermost 9 sites (out of 25 sites) of the NORES array 3-component short-period instruments. Data from

the NORES array are crucial for the detection and localization of small seismic events in Southern Norway.

New 3-component broad-band sensors with a hybrid instrument response (360 sec – 50 Hz) have been installed at each of the former broad-band sites of the NOA array (sites NAO01, NB201, NBO00, NC204, NC303, NC405, NC602). For about a 3-months period the new instruments have been running in parallel to the original instruments. End of October 2011 we switched off the original instruments and data forwarding from the new hybrid instruments to NNSN commenced. In spring 2012 we will complete the upgrade of the original one-component short-period sites of NOA with vertical-hybrid broad-band instruments (120 sec - 50 Hz). In the final configuration the NOA array will have 7 three-component and 35 one-component sites.

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	99.66	100.00	100.00	100.00	99.82
Feb	99.99	99.78	100.00	99.99	99.99	99.80
Mar	100.00	100.00	100.00	100.00	99.99	99.85
Apr	100.00	100.00	100.00	100.00	99.99	99.83
May	100.00	97.84	100.00	99.99	100.00	99.79
Jun	100.00	98.72	99.97	96.32	99.99	99.77
Jul	100.00	96.82	99.98	80.11	99.96	99.77
Aug	100.00	99.69	99.97	99.81	99.99	99.66
Sep	99.21	99.97	99.98	99.98	99.99	99.91
Oct	100.00	100.00	99.94	99.99	99.98	99.88
Nov	96.46	100.00	99.94	99.97	99.97	99.71
Dec	100.00	99.61	99.99	99.95	99.99	99.98

	NC303	NC405	NC602	SPA0	AKN	HFC2
Jan	100.00	100.00	100.00	100.00	100.00	100.00
Feb	100.00	99.99	100.00	100.00	99.77	100.00
Mar	100.00	100.00	98.30	100.00	100.00	100.00
Apr	100.00	100.00	100.00	99.94	100.00	100.00
May	100.00	100.00	99.96	100.00	100.00	96.53
Jun	100.00	99.99	99.98	100.00	100.00	98.72
Jul	100.00	99.97	99.99	97.10	100.00	100.00
Aug	95.52	99.97	91.17	99.01	100.00	74.73
Sep	98.89	99.99	99.99	99.99	100.00	99.92
Oct	100.00	100.00	100.00	99.96	99.84	100.00
Nov	98.76	99.98	99.99	100.00	99.99	100.00
Dec	99.98	99.96	100.00	100.00	96.59	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	160379	122100	153146	127385	145738	122652
Associated phases	6726	5008	6867	5315	5797	5012
Un-associated phases	153653	117092	146279	122070	139941	117640
Screened GBF events for Fennoscandia/Norway	1153	883	1234	966	1077	991
No. of events defined by the analyst	94	53	88	57	65	53
	July	Aug.	Sep.	October	Nov.	Dec.
Phase detections	137926	147173	181920	161251	159100	178099
Associated phases	5795	5862	8443	8252	6409	6835
Un-associated phases	132131	141311	173477	152999	152691	171264
Screened GBF events for Fennoscandia/Norway	1157	1205	1892	1910	1436	1423
No. of events defined by the analyst	53	59	41	60	48	59

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

Evers, L. G. and J. Schweitzer, 2011. *A climatology of infrasound detections in northern Norway at the experimental ARCI array*, Journal of Seismology, **15**, (3), 473-486, 2011, doi: 10.1007/s10950-011-9237-8

Fyen, J., 2011. Status of NORSAR's stations in the International Monitoring System POLRES Project Seminar, Longyearbyen, March 2011

Gibbons, S. J., J. Schweitzer, F. Ringdal, T. Kværna, S. Mykkeltveit and B. Paulsen, 2011. Improvements to Seismic Monitoring of the European Arctic Using Three-Component Array Processing at SPITS, Bulletin of the Seismological Society of America, Vol. 101, No. 6. (01 December 2011), pp. 2737-2754, doi:10.1785/0120110109

Gibbons, S. J., J. Schweitzer, F. Ringdal, T. Kværna and S. Mykkeltveit, 2011. Improvements to Seismic Monitoring of the European Arctic Using 3-Component Array Processing at SPITS, CTBTO - Science and Technology Conference, 8-10 June 2011, Hofburg Palace, Vienna, Austria.

Gibbons, S. J., The Infrasonic Wavefield at Regional Distances from Repeating Seismo-Acoustic Events, Seismological Society of America, 2011 Annual Meeting, Memphis, Tennessee, 13-15 April 2011.

Gibbons, S. J., 2011. The infrasonic wavefield at regional distances from repeating seismo-acoustic events, EGU General Assembly 2011, Vienna Austria, April 3-8, 2011

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Kværna, T., F. Ringdal and J. Given, 2011. Application of Detection Probabilities in the IDC Global Phase Association Process, NORSAR Sci. Rep. 2-2011, NORSAR, Kjeller

Kværna, T., 2011. Analysis of the IDC Reviewed Event Bulletin for Detection Capability Estimation of the IMS Primary Seismic Stations, Seminar "Cooperative studies on Spitsbergen", NORSAR, Kjeller, February 2011.

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Kværna, T., F. Ringdal and J. Given, 2011. Application of Detection Probabilities in the IDC Global Phase Association Process, Monitoring Research Review 2011, Tucson, Arizona, September 13-15

Lindblom, E., B. Lund, C. Juhlin, R. Bödvarsson, A. Tryggvason, M. Uski, and T. Kvaerna, 2011. Microearthquake activity on the Pärvie endglacial fault system, northern Sweden, EGU General Assembly 2011, Vienna Austria, April 3-8, 2011

Matoza, R.S., Vergoz, J., Le Pichon, A., Ceranna, L., Green, D. N., Evers, L. G., Ripepe, M., Campus, P., Liszka, L., Kvaerna, T., Kjartansson, E., and Å. Höskuldsson, 2011. Long-range acoustic observations of the Eyjafjallajökull eruption, Iceland, April–May 2010, Geophysical Research Letters, Vol. 38, No. 6. (30 March 2011), L06308, doi:10.1029/2011GL047019

Pirli, M., B. Paulsen and J. Schweitzer, 2011. Late stages of the Storfjorden, Svalbard, aftershock sequence. NORSAR Sci. Rep. 1-2011, NORSAR, Kjeller, Norway, 64-73.

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Pirli, M. and J. Schweitzer, 2011. A year of swarm seismicity on the Mohns - Knipovich Bend. Seminar "Cooperative studies on Spitsbergen", Longyearbyen, March 2011.

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Pirli, M. and J. Schweitzer, 2011. Seismic swarm activity along the spreading zones of the northern Mohns Ridge and the Mohns – Knipovich Bend, as viewed within the International Polar Year. IUGG, Melbourne, Australia, June-July 2011.

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Pirli, M., J. Schweitzer, T. Kværna & The IPY Project Consortium, 2011. A year of seismic swarm activity on the Mohns – Knipovich Ridge Bend Nasjonale Sluttkonferanse for Polaråret, Tromsø, 12. – 13. April 2011

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Roth, M., J. Schweitzer, V. Asming and E. Kremenetskaya, 2011. The new broadband station in Barentsburg, Seminar "Cooperative studies on Spitsbergen", Longyearbyen, March 2011

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