Operation of the

Norwegian National Seismic Network

2010

Supported by

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1 Introduction

This annual report describes the operation of the Norwegian National Seismic Network (NNSN) for the year 2010. 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 two single seismometer station (Figure 1). NORSAR provides data from five 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	**18**	**14**	**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:

- ASK:Communication and power problems caused downtime. Replacement of equipment has fixed the problems.
- KBS: The station was down during maintenance by the USGS.

- SNART: Malfunctioning equipment possibly caused by lightning. The problems occurred during summer which increased the downtime.

Table 2. Data completeness in % for 2010 for all stations of the NNSN operated by UiB.

Station	Data completeness %
Askøy (ASK)	94
Bergen (BER)	100
Bjørnøya (BJO)	99
Blåsjø (BLS)	99
Dombås (DOMB)	99
Espegrend (EGD)	96
Florø (FOO)	99
Flostrand (FLOS)	96
Homborsund (HOMB)	97
Hopen (HOPEN)	98
Høyanger (HYA)	99
Jan Mayen (JMI)	98
Jan Mayen (JNE)	98
Jan Mayen (JNW)	98
Karmøy (KMY)	100
Kautokeino (KTK)	95

Station	Data completeness %
Kings Bay (KBS)	95
Kongsberg (KONO)	99
Konsvik (KONS)	96
Lofoten (LOF)	99
Mo i Rana (MOR8)	97
Molde (MOL)	96
Namsos (NSS)	99
Odda (OOD1)	100
Oslo (OSL)	100
Rundemanen (RUND)	100
Snartemo (SNART)	92
Stavanger (STAV)	99
Steigen (STEI)	97
Stokkvågen (STOK)	99
Sulen (SUE)	97
Blussvoll (TBLU)	95
Tromsø (TRO)	98

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 2010 were:

A new broadband seismic station was installed in Hammerfest (HAMF), the stations Espegrend and Rundemannen were permanently closed, Oslo was upgraded to three components, at Jan Mayen a major upgrade was done installing industrial PC with Linux Seislog and the analog helicorder was stopped. Two stations, Dombås and Blåsjø, were upgraded to broadband stations. Kautokeino is now realtime.

Ask (ASK)

13.01.10: Visit. Modem restarted
23.04.10: Visit. Replaced malfunctioning digitizer
28.07.10: Visit. Communication and power problems
21.10.10: Visit. Replaced malfunctioning digitizer
13.12.10: Visit. ADSL installed

Bjørnøya (BJO1)

No visit or technical changes.

Blåsjø (BLS)

20.05.10: Visit. A Trillium broadband seismometer together with a Guralp DM24 digitizer were installed. An industry standard PC was installed for acquisition.

Blussvoll (TBLU)

28.06.10: Remote restart. Station down between June 19-28th. Problems with power supply.

Dombås (DOMB)

18.09.10: Digitizer was replaced by local operator
26-27.10.10: Visit. A Trillium broadband seismometer together with a Guralp DM24 digitizer were installed.

Espegrend (EGD)

EGD was permanently closed 02.01.10.

Florø (FOO)

11.06.10: Replaced the temporarily installed Trillium sensor with a Guralp sensor.

Flostrand (FLOS)

No visit or technical changes.

Hammerfest (HAMF)

7-11.06.10: visit. New installation of the station. Trillium sensor, Guralp DM24 digitizer, GPS and industrial PC with Seislog for Linux.

Homborsund (HOMB)

No visit or technical changes.

Hopen (HOPEN)

During the summer a cable (left on top of the ground summer 2009) was buried by local operator. The sensor is drifting and is regularly recentered by the local operator.

Høyanger (HYA)

No visit or technical changes.

Jan Mayen (JMI)

28.07-04.08.10: Visit. Installation of Industrial PC with Linux Seislog , Guralp 6 ch. Digitizer, Seedlink/Earthworm/Winston, access to Swarm to enable continuous plotting on screen at JMI. The analog helicorder was stopped. Training course was given.

Karmøy (KMY)
No visit or technical changes.

Kautokeino (KTK)
10-12.08.10: Visit. Installation of industrial PC.
NetCom GPRS. Sikon GSM MINI telecommander.

Kings Bay (KBS)
Visit by USGS: Digitizing and communication equipment replaced.

Kongsberg (KONO)
No visit or technical changes.

Konsvik (KONS)
No visit or technical changes.

Lofoten (LOF)
No visit or technical changes.

Mo i Rana (MOR8)
No visit or technical changes.

Molde (MOL)
No visit or technical changes.

Namsos (NSS)
No visit or technical changes.

Odda (ODD1)
No visit or technical changes.

Oslo (OSL)
19.01.10: New station installed at old site. Installation of three SS-1 Kinemetrics sensors was done by local operator.

Rundemanen (RUND)
Station permantley closed 24.11.2010.

Snartemo (SNART)

New PC was installed by local operator.
A digitizer was installed to replace the existing malfunctioning digitizer.

Stavanger (STAV)

There were network problems with the system during the summer
where it was not possible to contact the local operator. However, the
data was later retrieved.

Steigen (STEI)

No visit or technical changes.

Stokkvågen (STOK)

No visit or technical changes.

Sulen (SUE)

09.06.10: Visit. Recentering sensor. Replaced PC.

Tromsø (TRO)

26.04.10: Industrial PC installed by local operator
01.10.10: Visit. Installation of Guralp digitizer and GPS.

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 2010, and then give the plans for 2011.

4.1 Achievements in 2010

- Complete the installation of the station in Finnmark.
  Progress: Done, station installed in Hammerfest.
- Develop internal procedures for handling public inquiries and urgent processing in case of significant earthquakes in Norway.
  Progress: A phone line was setup at UiB for the public (55 58 26 17). The call will be transferred to staff member on call. This has started as a voluntary activity. Procedures at UiB are written up.

- Develop a joint web-page for NNSN to be in operation by the summer of 2010.
  Progress: A proto type version is online. Feedback on this from Norsar was received, and based on this further improvements are required. The pages were also discussed further and reviewed at UiB. A new web development package will now be used, and the menu system be redone.
- Establish written guidelines for daily routine processing between UiB and Norsar.
  Progress: The UiB analysts visited Norsar in the beginning of 2010. While the routine is working, written guidelines have not been produced yet.
- Establish automated routines for event based waveform data extraction from Norsar for the associated triggers to the NNSN database.
  Progress: NORSAR now produces waveform files with beam data that are automatically uploaded with the parametric data. This is now (2011) being tested.
- Continue upgrade of communication to real-time.
  Progress: 2 systems are at present time not transferring data in real time. Satellite communication is tested for use in MOR to replace the ISDN line. This test is still in progress, but when completed the system will be installed and at the same time the station will be upgraded to broadband seismometer. For the time being, there is no easy solution to obtain real-time data from the system in Jan Mayen. However, it will be desirable to also receive that data in real-time.
- Upgrade two existing stations to broadband seismometers.
  Progress: Blåsjø and Dombås are upgraded to BB seismometers.
- Continue with the integration of data from Ekofisk, and Statfjord.
  Progress: Regarding Ekofisk, contact was made with Optoplan. UiB is waiting for the system installation and access to the data.
  Statfjord: Installation of a Guralp sensor for testing was done in December 2010.
- Install equipment for on-scale recording for large earthquakes on Jan Mayen through broadband seismometer or accelerometer.
  Progress: We have replied to the request by FKD for payment related to the siting and operation of the seismic stations, and are waiting for their response. Getting a response that ignores our case, we have to write again. Until the situation is cleared no firm plans will be made.

4.2 Plans for 2011

- Mo i Rana: The Mo i Rana station will be upgraded when the satellite link is sufficiently tested.
- Lofoten: the station will be upgraded by installing a new digitizer and computer; a broadband seismometer will be installed at Lofoten.
- 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 (planned Bjørnøya, Namsos, Florø). The NNSN budget for new investments in 2011 will be used for digitizers.

- New stations: planning for possible stations in the Hardangervidda area and near Bergen will start.
- 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.
- Continue with the integration of data from Ekofisk and Statfjord.
- Procedures: earthquake response and interaction with NORSAR to be developed.
- NNSN website: continue development

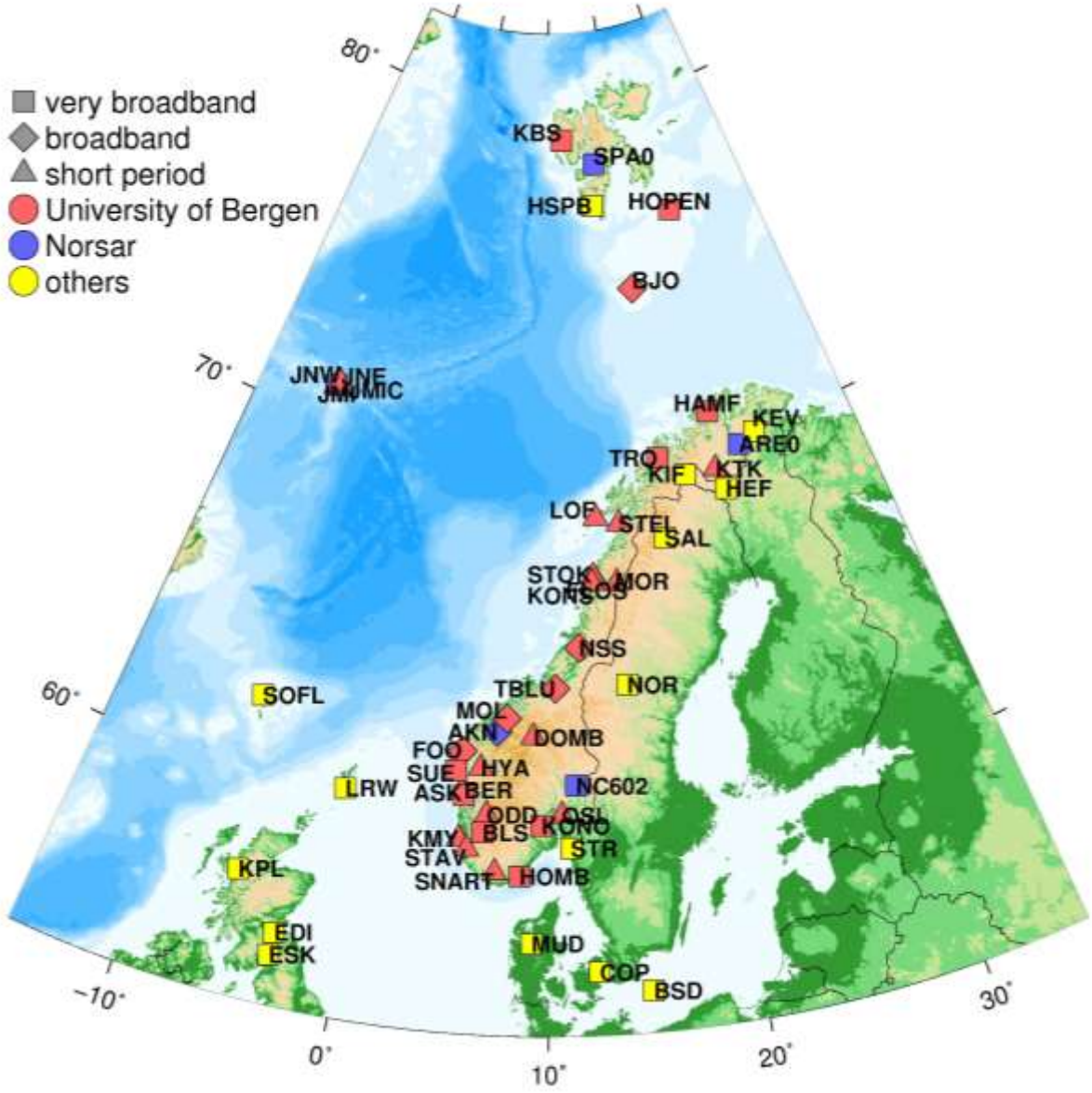

Figure 1. Stations contribution to the Norwegian National Seismic Network (NNSN) database. Stations included in UiB operates the 32 stations (red) and NORSAR operates the stations marked in blue including the 3 arrays. Data from stations marked in yellow are received continuously in Bergen, but are operated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

APPENDIX 1

The NORSAR Regional Arrays

The NORSAR Stations and Arrays

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 is under reconstruction. Additionally NORSAR collects data from the FINES array in southern Finland and the HFS array in southern Sweden. The data streams are available in realtime 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 under reconstruction).

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

In September 2010 NORSAR installed in cooperation with the Kola Regional Seismological Centre a new permanent seismic broadband station in Barentsburg, Spitsbergen. The new station (BRBA) will improve the monitoring capabilityof man-made events (e.g., mining blasts, rock bursts), seismic events related to the moving of glaciers (icequakes, calving) and

regional and teleseismic earthquakes. It will be a significant supplement to the already existing permanent stations in the Svalbard region.

In the framework of the recapitalization of the NORSAR arrays we intend to install new seismic sensors with a hybrid response function. The transfer function of the instruments was designed to be suitable for the ambient noise conditions of our sites and to deliver similar or higher data quality than the existing systems are doing.

More detailed information about the Barentsburg station and the new hybrid instruments can be found in the NORSAR Scientific report 1-2011 (in press). The relevant chapters 6.3 and 6.4 are attached at the end of this document.

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	99.99	100.00	100.00	100.00	100.00	99.89
Feb	100.00	99.99	94.78	100.00	100.00	99.94
Mar	100.00	100.00	99.98	100.00	100.00	99.83
Apr	100.00	99.96	100.00	100.00	99.99	99.93
May	100.00	99.94	100.00	100.00	100.00	99.91
Jun	100.00	98.98	100.00	99.99	99.99	99.88
Jul	99.99	99.25	99.85	99.99	99.99	99.92
Aug	100.00	99.34	100.00	100.00	100.00	99.89
Sep	99.99	99.93	100.00	99.99	99.99	99.89
Oct	96.24	99.95	100.00	100.00	100.00	99.93
Nov	100.00	100.00	99.99	100.00	100.00	99.92
Dec	100.00	99.94	99.99	99.98	100.00	99.91

	NC303	NC405	NC602	SPA0	AKN	HFC2
Jan	100.00	100.00	100.00	99.95	100.00	100.00
Feb	100.00	100.00	100.00	99.99	100.00	100.00
Mar	100.00	100.00	100.00	99.99	100.00	100.00
Apr	100.00	99.99	100.00	96.33	99.99	100.00
May	96.83	100.00	100.00	100.00	100.00	100.00
Jun	100.00	100.00	99.99	99.96	100.00	100.00
Jul	100.00	99.99	100.00	99.91	100.00	100.00
Aug	100.00	100.00	100.00	100.00	100.00	100.00
Sep	100.00	99.99	100.00	99.98	100.00	100.00
Oct	100.00	100.00	100.00	100.00	91.20	100.00
Nov	100.00	100.00	100.00	100.00	99.99	100.00
Dec	100.00	100.00	100.00	99.98	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	147930	147412	152054	137002	137374	118260
Associated phases	4241	5372	5942	5967	5827	5437
Un-associated phases	143689	142040	146112	131035	131547	112823
Screened GBF events for Fennoscandia/Norway	857	985	1132	1010	1045	1082
No. of events defined by the analyst	47	80	76	84	81	89
	July	Aug.	Sep.	October	Nov.	Dec.
Phase detections	138600	165868	162829	157767	181772	170905
Associated phases	6381	7741	8544	7877	7060	5952
Un-associated phases	132219	158127	154285	149890	174712	164953
Screened GBF events for Fennoscandia/Norway	1274	1541	1710	1540	1375	1083
No. of events defined by the analyst	97	99	97	89	77	67

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 AREO (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.