Operation of the

Norwegian National Seismic Network

2009

Supported by

University of Bergen

and

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1 Introduction

This annual report describes the operation of the Norwegian National Seismic Network (NNSN) for the year 2009. 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 33 of the seismic stations that form the Norwegian National Seismic Network (NNSN). NORSAR operates 3 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	22	11	27

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 downtime for the majority of stations is below 5%. Larger down time were observed for the following stations:

- Florø: The station was stopped in March due to construction work in the area. The station was reinstalled in December.
- Hopen: The station was down for several months due to extreme climatic conditions. Water had frozen in the aluminium box containing the sensor and combined with low summer temperature. The problem was fixed in October.

- Kings Bay and Kongsberg: The downtime reflects the change of component codes and a missed adjustment in the UiB acquisition system. It does not reflect actual station downtime.
- Konsvik: PC break down caused data loss.
- Oslo: The station was closed in February due to building work at the site and reinstalled in August.
- Sulen: Various technical, communication and software problems caused the large downtime.
- Tromsø: One of the three channels was down for a time period, which is counted as downtime. In addition, one months data is missing from the continuous archive.

Table 2. Downtime in % for 2009 for all stations of the NNSN operated by UiB.

Station	Downtime in %
Askøy (ASK)	0
Bergen (BER)	0
Bjørnøya (BJO)	1.5
Blåsjø (BLS)	0.5
Dombås (DOMB)	1.5
Espegrend (EGD)	0
Florø (FOO)	69
Flostrand (FLOS)	1
Homborsund (HOMB)	0
Hopen (HOPEN)	64
Høyanger (HYA)	6
Jan Mayen (JMI)	0
Jan Mayen (JNE)	0
Jan Mayen (JNW)	0
Karmøy (KMY)	1
Kautokeino (KTK)	1.5

Station	Downtime in %
Kings Bay (KBS)	4
Kongsberg (KONO)	6.5
Konsvik (KONS)	22
Lofoten (LOF)	1.5
Mo i Rana (MOR8)	3
Molde (MOL)	2
Namsos (NSS)	2.5
Odda (OOD1)	3
Oslo (OSL)	60
Rundemanen (RUND)	0.5
Snartemo (SNART)	6
Stavanger (STAV)	5
Steigen (STEI)	0.5
Stokkvågen (STOK)	0
Sulen (SUE)	35
Blussvoll (TBLU)	0
Tromsø (TRO)	12

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 2009 were: station Espegrend was closed, Oslo and Askøy were upgraded to three components, broadband sensors were installed at Florø and Sulen, and stations Blåsjø, Namsos and Høyanger are now realtime.

Bjørnøya (BJO1)

04.02.09. The local operator has replaced the PC with a new industrial PC (Windows).
04.10.09. Visit. Repaired damaged cable to GPS and installed

new GPS. Removed corrosion on sensor.

Blussvoll (TBLU)

No visit or technical changes.

Blåsjø (BLS)

22.06.09. Communication changed from ISDN to a fibre optic solution 'Altiboks' => realtime data transfer to Bergen.

Dombås (DOMB)

No visit or technical changes.

Florø (FOO)

19.03.09. Station stopped due to construction work in the area. All equipment was dismantled.
10-11.08.09. Visit. A new aluminium box was installed to replace the old and a cable was pulled through a cable duct from the site to the recording room.
01-02.12.09. Reinstallation of the station. The following was installed: Guralp CMG-40T seismograph, industrial PC with Linux Seislog, Power supply, Guralp Digitizer, GPS, ADSL modem and lightning protection. It was not possible to level the sensor.
15.12.09. Visit. The malfunctioning Guralp CMG-40T was replaced with a Nanometrics Trillium sensor.

Flostrand (FLOS)

04.06.09. Local operator installed industrial PC with Seislog for Linux.
06.06.09 – 11.06.09. Seedlink problem. Data lost.

Homborsund (HOMB)

22-23.04.09. Visit. Attempt to recenter mass. Not successful.
08.12.09. Visit. Recentering of mass now ok.

Hopen (HOPEN)

01.01.09-31.06.09. The station was not working. No action could be taken to fix problems since the ground was frozen. The box containing the sensor had filled with water and then frozen. The ice inside the box was melted in August using an electric oven, and the sensor sent to Bergen. Inspection of the sensor showed that it was ok.
06.10.09. Visit. Reinstallation of the Streckeisen STS-2. A new cable from site to house was installed so the sensor can be recentred from the house. This option is now used regularly.

Høyanger (HYA)

15.01.09. Visit. Industrial PC with Linux, new digitizer and GPS antenna installed.
03.06.09. Visit. Guralp digitizer was replaced with Sara SR04.
26.08.09. Visit. ISDN communication replaced with GSM

communication (Sarian ER4110). Station is now realtime.

Jan Mayen (JMI)

No visit or technical changes.

Karmøy (KMY)

08.08.09. Local operator installed GPS antenna.
19.08.09. Visit. Digitizer replaced with new Sara SR04. PC replaced with industrial PC running Linux. New realtime communication (ICE) set up.

Kautokeino (KTK)

02.06.09. Visit by Finnish technician.
BB sensor replaced by three SS-1 sensors after being part of data acquisition by University of Oulu.
30.09.09. Local operator (re)installed damping resistors 3.9 KOhm. He also inspected the alum. box with the sensors.

Kings Bay (KBS)

No visit or technical changes.

Kongsberg (KONO)

29.03.09. Station down, unknown reason.
29.04.09 – 05.05.09. Problem with ADSL connection, data lost.
10-16.09.09. Station upgrade done by USGS. Recording and communication equipment were replaced.

Konsvik (KONS)

03.03.09. PC down since 31.12.08. Data lost.
01.04.09. Industrial PC installed by local operator.
20.05.09 – 04.06.09. Defect GSM router
03.06.09. Communication down since 20.05.09. No data lost.

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)

06.02.09. The PC has been replaced with a new industrial PC running Linux and data is recorded in real time.
20.03.09. The station is now connected via ADSL.

Odda (ODD1)

25.08-03.09.09. Data lost due to power cut.

03.09.09. Visit. Replaced broken ADSL-modem and installed new industrial PC also running Seislog Linux. Removed Cisco router and tele commander. Data is recorded in real time.
16.12.09. Local operator has replaced the digitizer to change the sampling rate from 50 Hz to 100 Hz.

Oslo (OSL)

08.09. A broken cable at the department (UiO) was repaired.
23.10.09. A three component seismometer and Sara digitizer were installed. In addition, an industrial PC with Linux Seislog were installed.

Rundemanen (RUND)

No visit or technical changes.

Snartemo (SNART)

06.01.09. Restart by local operator. Down 1 day
06.04.09. Installed industrial PC with Seislog for Linux
26.06.09. New industrial PC installed after heavy lightning. Station down between 19-25.06.09.
24.07.09. Problem with ADSL modem. Local operator.
04.08.09. Problem with ADSL modem. Local operator.
07.08.09. New ADSL modem and lightning protection installed by local operator.

Stavanger (STAV)

No visit or technical changes.

Steigen (STEI)

19.06.09. The local operator has replaced the PC with an industrial PC running Seislog Linux.

Stokkvågen (STOK)

04.06.09. Local operator installed industrial PC with Seislog for Linux.

Sulen (SUE)

10.03.09. Visit. Industrial PC with Seislog for Linux, Guralp CMG-DM24 S6 digitizer, Guralp GPS were installed. 3.9K Damping resistance installed on ch. 1-3
02.04.09. Visit. Trillium sensor installed. Acceleration sensor removed. ADSL communication replaced ISDN.
29.04.09. Visit. Installed new digitizer, GPS and cable to GPS
04.04.09 – 06.05.09. Seislog problem. Spikes in data => data lost.

Tromsø (TRO)

17.09.09. Local operator replaced digitizer with a new ED 2400 digitizer.
18.11.2009. local operator recentered BB sensor at 0920 GMT

WNN network: Bergen (BER), Espegrend (EGD), Ask (ASK), Rundemanen(RUND)

10.12.09. ASK. The analog line was replaced by ICE. 2 SS-1 sensors (horizontal) were installed in the alumin. box. The station is now a 3 component station. An Earthdata digitizer, PC, power supply and new realtime communication (ice), were installed.
31.12.09. EGD was closed permanently as the station only provided low quality vertical component data, and the analog phone was expensive.

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 2009, and then give the plans for 2010.

4.1 Achievements in 2009

♦ UiB

- Install a new broadband station in Finmark.
    - Progress: Visit has been made to find a new location in the area around Hammerfest and also in the Nordkapp area. Noise tests have been made at the two sites. Due to limited technical resources the planned preliminary installation of the station before the end of 2009 had to be cancelled. Plans for installation are now made for week 18. The new stations will be located in Hammerfest.
- Karmøy KMY will get new equipment, mobile phone solution will be tested
  - Progress: Done. The station is from 19th august running with an ICE/CDMA mobile phone connection.
- Mo i Rana (MOR) will get new equipment, mobile phone solution will be tested.
  - Progress: Not done. Scheduled to be done during spring 2010.
- Test mobile phone solution for the following stations: Høyanger (HYA), Blåsjø (BLS), Kautokeino (KTK), Karmøy (KMY), Mo i Rana (MOR)
  -Progress: HYA is updated to GSM
  BLS has a fibre optic connection
  KTK no changes
  KMY has an ICE/CMDA connection
  MOR no changes
- Minor upgrade on several stations.
- ADSL has been installed at Sulen (SUE) and Namsos (NSS)
- The GSM connection to KONS and FLOS used to be unstable. A new configuration has improved the communication stability.

♦ NORSAR

- Develop the prototype of an event detection system to be integrated with NNSN
  - Progress: Automatic detections are provided by NORSAR and integrated with the NNSN detections by UiB. NORSAR further plans to also provide the corresponding waveform data, this work is still in progress.

- Improve joint processing.

♦ NORSAR-NNSN joint analysis work

The NORSAR analyst is, on a weekly basis, merging the NORSAR local recordings into the NNSN database. A SEISAN training course was given at NORSAR by Lars Ottemöller in December 2009 and the UiB analysists visited NORSAR in January 2010.

♦ Other

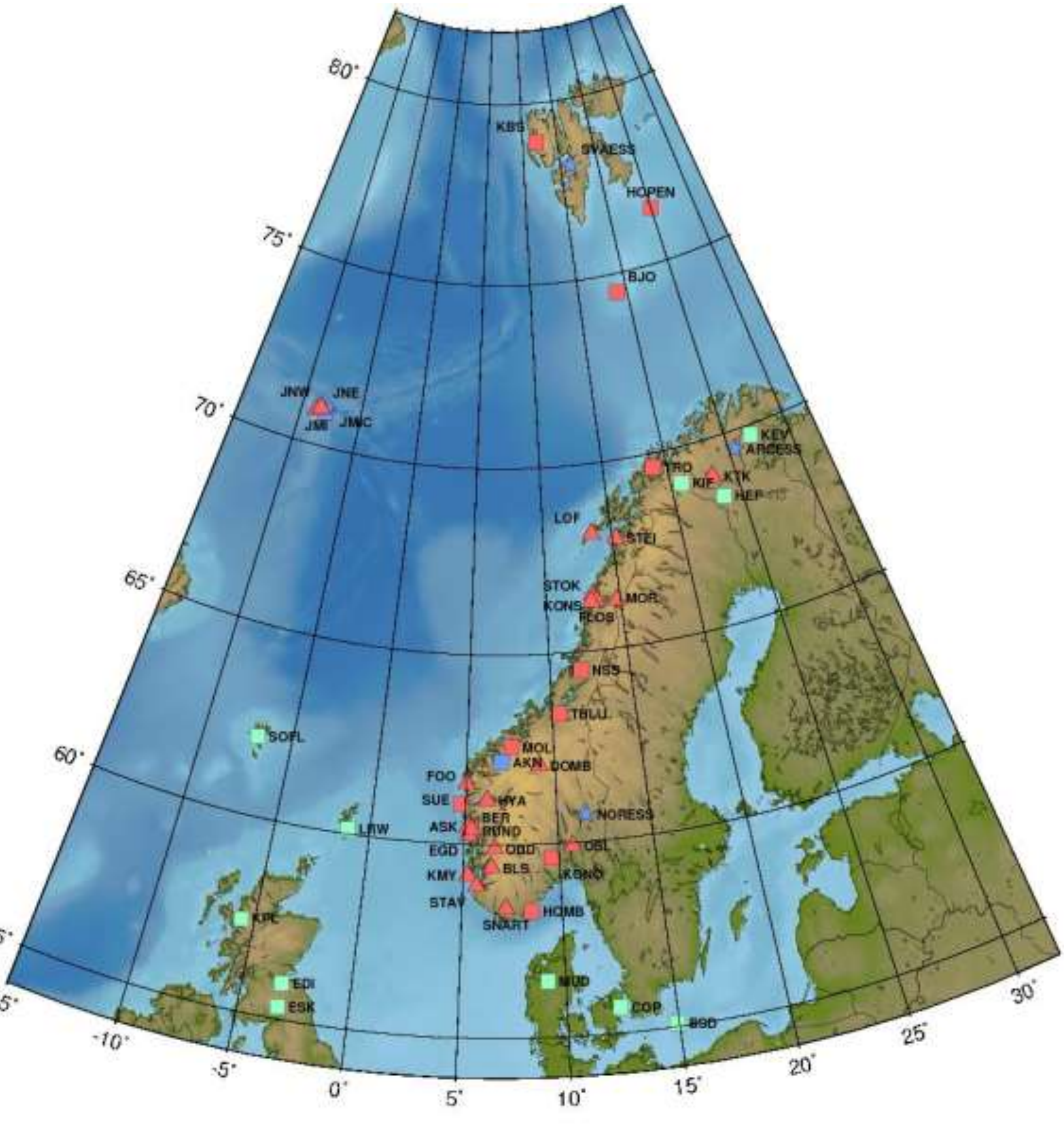
- **Develop joint web pages**: The details of this were discussed by UiB and NORSAR. A prototype of this page has been developed by UiB.
- **Offshore stations**: There is an ongoing effort to connect sensors from Ekofisk and plans to install a new sensor at Statfjord. A noise test at Statfjord was planned for the autumn 2009, but is delayed to spring 2010 before deciding whether the data quality justifies the investment.
- **Accelerometers**: At the previous steering committee it was discussed if it would help to install accelerometer stations. This was to be discussed by Lars Ottemöller and Michael Roth. Summary of these discussions:

  At the recent NNSN meeting in Bergen in October 2009 a discussion was started on whether accelerometers should be added to the network. The argument behind this would be to ensure on-scale recordings from potentially large earthquakes. Such instruments could either be added to the existing stations with little additional operational costs, or one could deploy them at new sites. New sites would imply higher costs since the additional stations need maintenance and basic communication has to be set up (even for non-continuous monitoring it is advisable to check the readiness and state-of-health of the stations regularly). The present strategy is to upgrade the NNSN by replacing short-period with modern broadband seismometers. The sensitivity of the broadband sensor/digitizer system can be selected adequately in order to reduce the probability of saturation due to large earthquakes. As the coverage of Norway with seismic stations is intermediate, and large earthquakes are rare, chances of actual saturation are low. It may, therefore, be advisable to concentrate on the broadband upgrade and possible completion of individual existing broadband stations with accelerometers.

4.2 Plans for 2010

- Complete the installation of the station in Finnmark.
- Develop internal procedures for handling public inquiries and urgent processing in case of significant earthquakes in Norway.
- Develop a joint web-page for NNSN to be in operation by the summer of 2010.
- Establish written guidelines for daily routine processing between UiB and Norsar.
- Establish automated routines for event based waveform data extraction from Norsar for the associated triggers to the NNSN database.
- Continue upgrade of communication to real-time.
- Upgrade two existing stations to broadband seismometers.
- Continue with the integration of data from Ekofisk, and Statfjord.
- Install equipment for on-scale recording for large earthquakes on Jan Mayen through broadband seismometer or accelerometer.

Figure 1. Stations contribution to the NNSN database. Symbols: Triangles:Short period sensors, Stars: Arrays, Squares: Broad band sensors. Coulors: red: Stations operated by UiB, Blue, Stations operated by NORSAR, green: British, Danish and Finnish stations transmitting in real time.



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 station AKN

The 3-component broadband station AKN was installed in October 2009 at the unstable rock slope at Åknes, Møre og Romsdal. The station serves two purposes: i) the monitoring of local seismicity associated with the movement of the rock slope and ii) the monitoring of regional and global seismicity. The station was ordered and financed by Aknes/Tafjord Beredskap IKS, and will be maintained by NORSAR. The sensor is a Guralp ESPC seismometer with a bandwith from 60 s to 100 Hz. Data are recorded contineously with a sampling rate of 200 Hz and transferred in real-time via radio link to NORSAR. The station is fully integrated into NORSAR’s station network, the Norwegian National Seismic Network, and the Virtual European Broadband Seismograph Station Network (VEBSN, Orfeus).

New broadband station AKN at Åknes, Møre og Romsdal (High-resolution aerial photo of the Åknes slope).

View of the seismometer location from bunker'Ormebolet'(~150 m distance) that provides communication and power.

AKN seismometer pit with Guralp CMG-ESPC sensor, data acquisition system CMG-DM24S6DCM (black box)and communication/power box (grey box).

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. Except for AKN, which was started up in October 2009 and SPA0, all other stations have an annual completeness close to 100%.

	ARE0	JMIC	NAO01	NB201	NBO00	NC204
Jan	100.00	99.76	100.00	100.00	100.00	99.68
Feb	100.00	100.00	94.78	99.18	100.00	99.70
Mar	100.00	99.98	99.98	100.00	100.00	99.79
Apr	100.00	99.91	100.00	100.00	100.00	99.63
May	100.00	99.70	100.00	100.00	100.00	99.73
Jun	100.00	99.96	100.00	97.93	100.00	99.78
Jul	100.00	99.96	99.85	99.86	99.86	99.51
Aug	100.00	99.98	100.00	100.00	100.00	99.80
Sep	100.00	99.90	100.00	100.00	100.00	99.74
Oct	100.00	99.99	100.00	100.00	100.00	99.91
Nov	100.00	100.00	99.99	100.00	100.00	99.93
Dec	99.97	99.99	99.99	99.99	99.99	99.89

	NC303	NC405	NC602	SPA0	AKN	HFC2
Jan	100.00	100.00	100.00	100.00	0.00	99.98
Feb	100.00	100.00	100.00	98.66	0.00	99.98
Mar	100.00	100.00	99.99	100.00	0.00	99.96
Apr	100.00	100.00	100.00	63.09	0.00	99.97
May	100.00	100.00	100.00	100.00	0.00	99.95
Jun	96.60	100.00	98.98	100.00	0.00	99.97
Jul	99.86	99.86	99.86	100.00	0.00	99.86
Aug	100.00	99.99	100.00	98.79	0.00	99.97
Sep	100.00	100.00	100.00	100.00	0.00	99.95
Oct	100.00	100.00	100.00	100.00	3.23	99.99
Nov	100.00	100.00	100.00	96.52	99.91	100.00
Dec	100.00	99.99	99.99	99.99	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	247632	230346	249580	136937	149413	132819
Associated phases	11089	11714	14393	8101	7392	5605
Un-associated phases	149851	135860	153505	134850	150721	136191

Screened GBF events for Fennoscandia/Norway	2619	2531	3203	1725	1268	1096
No. of events defined by the analyst	67	61	74	68	110	94
	July	Aug.	Sep.	October	Nov.	Dec.
Phase detections	126546	164949	177069	168350	171859	145566
Associated phases	4895	6603	8263	7041	7109	4922
Un-associated phases	121651	158346	168806	161309	164750	140644
Screened GBF events for Fennoscandia/Norway	959	1320	1625	1436	1621	971
No. of events defined by the analyst	76	69	103	97	96	65

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-NNSN 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. In 2009 NORSAR added the data streams of station AKN and the broadband station HFC2 of the Hagfors array. 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.