Progress Report No. 2014-1

for

Norwegian National Seismic Network

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Supported by

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and

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1 Introduction

This annual report describes the operation of the Norwegian National Seismic Network (NNSN) for the first part of 2014. The network is financially supported by the oil industry through the Norwegian Oil and Gas Association and the University of Bergen (UiB). 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.

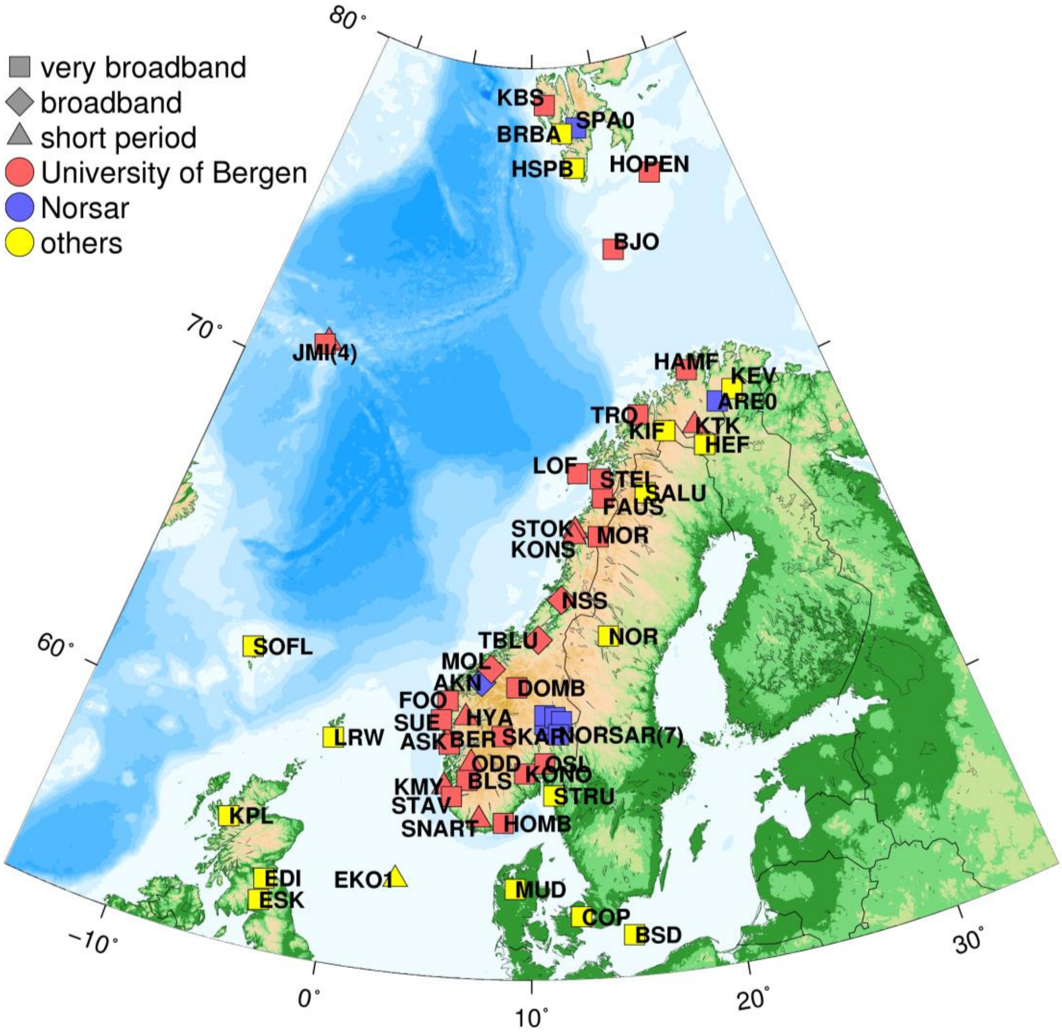

Figure 1. Stations delivering data to the NNSN database.

2 Operation

In Norway, 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 stations (JMIC and AKN) (Figure 1). In total, NORSAR provides data from 12 broadband stations to the NNSN. The station HSPB is operated jointly between NORSAR and the Geophysical Institute, Polish Academy of Sciences, Warsaw, Poland and the stations located in Barentsburg (BRBA and BRBB) are operated jointly between NORSAR and the Kola Regional Seismological Centre of Geophysical Service, Russia. Data from the Danish stations located on the east coast of Greenland are also available and contribute to the location of earthquakes in the Greenland Sea and Norwegian Sea.

The seismicity detected by the network is processed at UiB, but also NORSAR integrates their results in the joint database at UiB. Seismicity maps for the reporting period are shown in Figure 2 and 3.

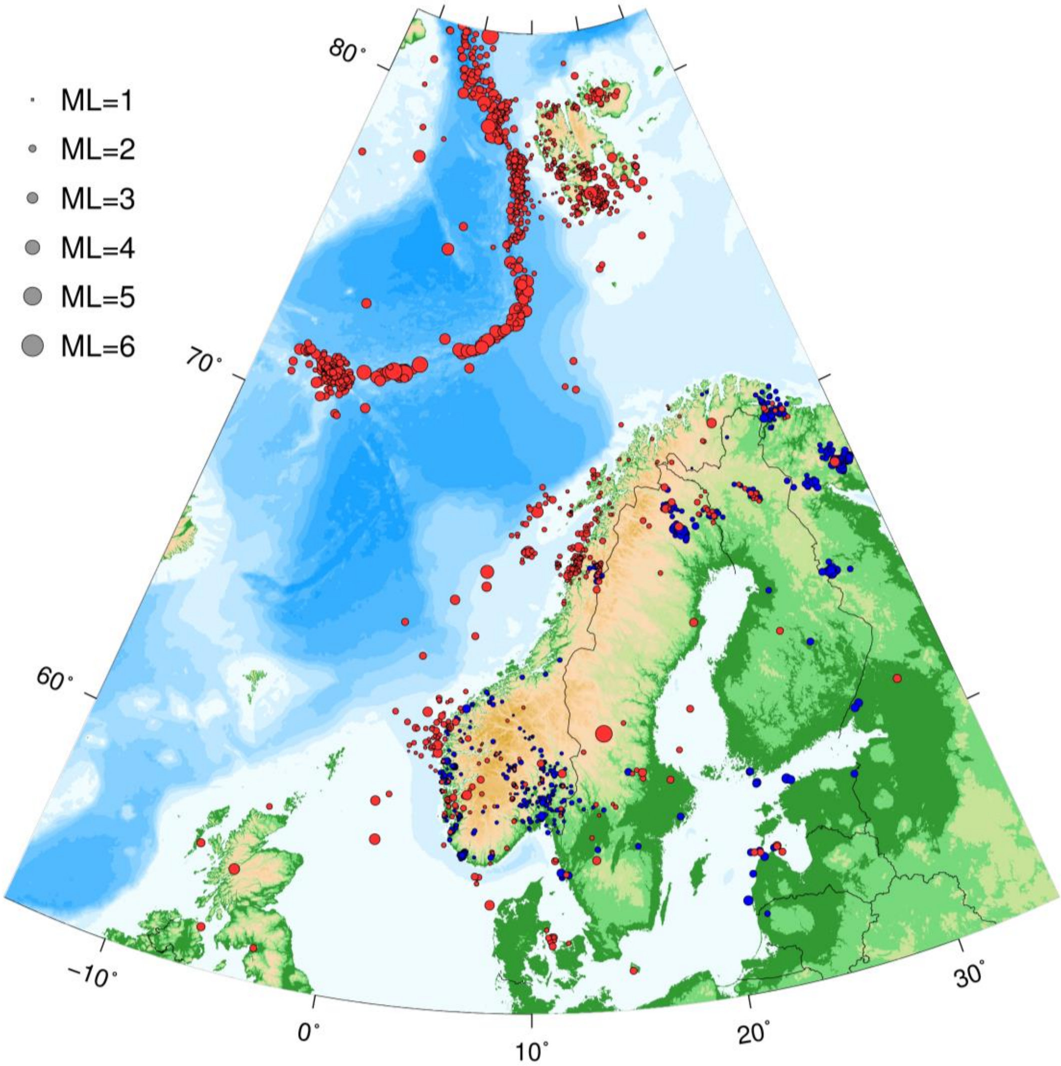

Figure 2. Seismity map showing earthquakes (red) and explosions (blue) for the period January to September, 2014.

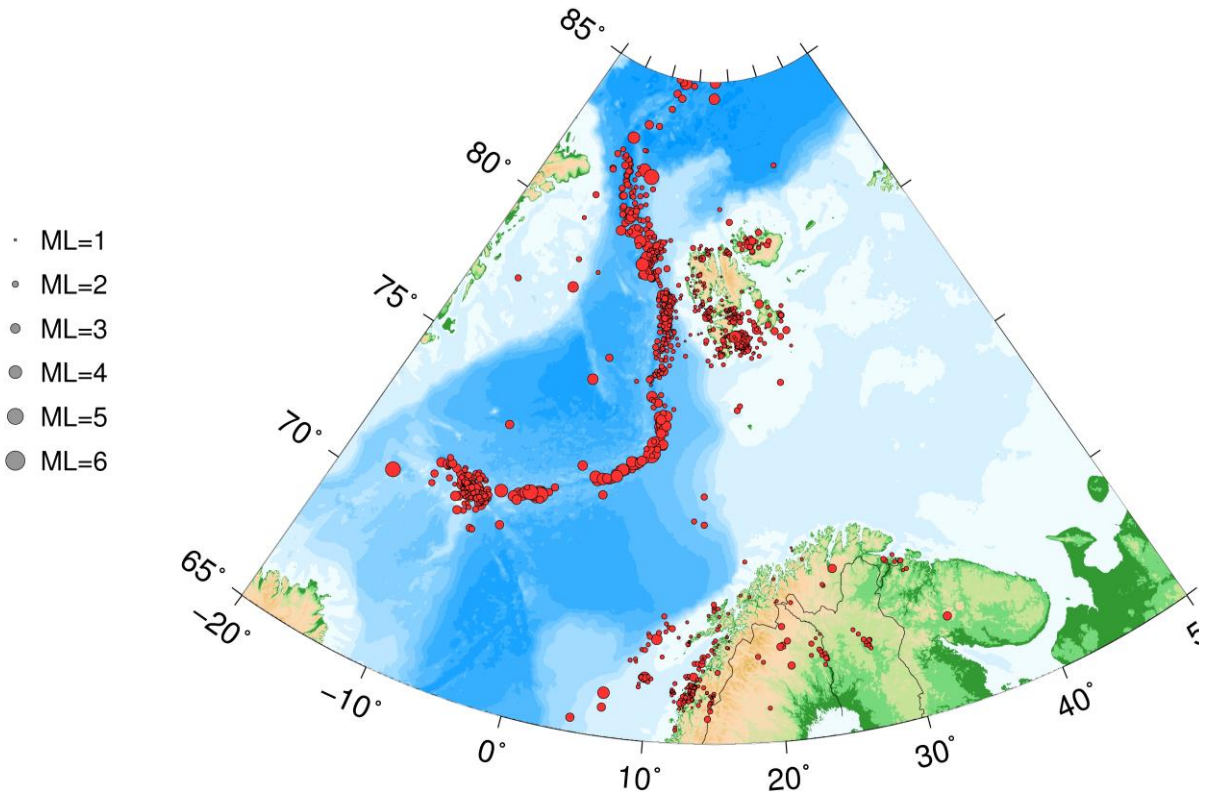

Figure 3. Seismicity in the artic area for the period January to September 2014. Known and probably explosions are excluded.

UiB is in the process of upgrading the NNSN by installing new stations and changing short period (SP) to broadband (BB) seismometers. A further effort is made to install additional high quality digitizers. The current use of seismometers is shown in Figure 1. As of today the numbers 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	22 (19 with natural period greater than 100 sec)	30 (not real time are 2 short period and 1 broadband stations on Jan Mayen)

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, therefore, 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. 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: KTK1, MOR8 and HOMB (see technical service overview for details). The downtime for KTK1 is caused by problems with digitizers at this particular site that has not been resolved yet, and it is expected that downtime for this station will further increase in 2014. The MOR8 and HOMB downtime was due to malfunctioning PCs.

Table 2. Data completeness in % for January to October 2014 for all stations of the NNSN operated by UiB.

Station	Data completeness in %
Askøy (ASK)	99
Bergen (BER)	100
Bjørnøya (BJO)	100
Blåsjø (BLS)	98
Dombås (DOMB)	100
Florø (FOO)	100
Fauske (FAUS)	100
Hammerfest (HAMF)	100
Homborsund (HOMB)	**93**
Hopen (HOPEN)	99
Høyanger (HYA)	100
Jan Mayen (JMI)	99
Jan Mayen (JNE)	99
Jan Mayen (JNW)	99
Karmøy (KMY)	95
Kautokeino (KTK)	**77**

Station	Data completeness in %
Kings Bay (KBS)	99
Kongsberg (KONO)	99
Konsvik (KONS)	96
Lofoten (LOF)	100
Mo i Rana (MOR8)	**85**
Molde (MOL)	98
Namsos (NSS)	98
Odda (OOD1)	99
Oslo (OSL)	99
Skarslia (SKAR)	100
Snartemo (SNART)	97
Stavanger (STAV)	100
Steigen (STEI)	99
Stokkvågen (STOK)	98
Sulen (SUE)	95
Blussvoll (TBLU)	97
Tromsø (TRO)	100

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. The different equipment components can be restarted from Bergen, and this sometimes helps to resolve the issue.

Major changes during this reporting period of 2014 were:

Ask (ASK)	05.09.14: Visit. GPS antenna replaced due to timing problems.
Bergen (BER)	No visit or technical changes.

Bjørnøya (BJO1)	Visit. 23-24.09.14: Maintenance visit. An attempt was made to detect the cause of occasional noise on the vertical component and to plan for the upgrade in 2015.
Blåsjø (BLS)	15.08.14: The UPS was malfunctioning and was disconnected by station contact.
Blussvoll (TBLU)	No visit or technical changes.
Dombås (DOMB)	No visit or technical changes.
Fauske (FAUS)	New station. 20.01.14: Vault constructed. 05.06.14: Visit: Equipment installed 29.06.14: Visit: Station visited to center the seismometer. 19.09.14: Visit: Water ingress checked and considered to be due to condensation. Vault lid to be replaced by concrete lid similar to the one used at SKAR. ICE router replaced
Florø (FOO)	No visit or technical changes.
Hammerfest (HAMF)	No visit or technical changes.
Homborsund (HOMB)	13.05.13: A malfunctioning PC was replaced by the local contact. Data lost between 03.02 – 17.02.2014.
Hopen (HOPEN)	Visit. 22-23.09.14: The existing STS-2 was replaced with a Trillium 120 PA sensor (the STS-2 will be returned to NORSAR). This trip was also an opportunity to plan the station upgrade in 2015.
Høyanger (HYA)	No visit or technical changes.
Jan Mayen (JMI)	No visit or technical changes.
JNE	No visit or technical changes.
JNW	No visit or technical changes.
Karmøy (KMY)	No visit or technical changes.
Kautokeino (KTK)	12.07.14: Station down since 08.07. Digitizer replaced by local operator and the station was restarted. Problem not solved. 20.08.14: Station has been down since 08.07.2014 due to two broken

	digitizers. Digitizers replaced by local operator. All data has been lost. 13.09.14: Digitizer broke down again, station awaiting visit.
Kings Bay (KBS)	No visit or technical changes.
Kongsberg (KONO)	No visit or technical changes.
Konsvik (KONS)	15.08.14: PC replaced by local operator. Station down since 12.08. Data is lost.
Lofoten (LOF)	No visit or technical changes.
Mo i Rana (MOR8)	18.08.14: PC replaced by local operator. Station down since 14.07. Data is lost.
Molde (MOL)	No visit or technical changes.
Namsos (NSS)	No visit or technical changes.
Odda (ODD1)	23.07.14: Visit: GPS antenna replaced due to timing problem. Problem not solved. 22.09.14: Cable to the GPS antenna was replaced by the local operator. The local operator had found that the cable had been damaged by a nesting bird.
Oslo (OSL)	11.04.14: Visit. Upgrade of the station. Mounting a GPS antenna. Change the seismometer from Ranger SS-1 to Trillium 120PA. Change the digitizer from SARA to CMC-DM24S3-EAM.
Skarslia (SKAR)	15.07.14: Visit. Inspection. No changes made.
Snartemo (SNART)	20.05.14: Station maintenance visit. Short period Ranger SS-1 seismometer installed.
Stavanger (STAV)	No visit or technical changes.
Steigen (STEI)	No visit or technical changes.
Stokkvågen (STOK)	No visit or technical changes.
Sulen (SUE)	08:04.14: Because of weak ICE signals, new GSM router installed.

Tromsø (TRO)	No visit or technical changes.

4 Research

4.1 UIB: Noise levels and detection limits

We have computed noise levels for the NNSN stations using data from 2013. From this it is possible to evaluate the performance of the stations. Noise levels result from a combination of the actual background noise, the vault construction and the instrumentation. We also work on establishing the effect that the noise levels have on the different observations we make. Here we are interested to see how the detection levels change for example due to day/night differences and conditions during storms. We also look at the possible decrease in location accuracy during worsening weather conditions. Figure 4 gives an example of those noise level changes during a storm that moves toward the coast and then along it. It is obvious that noise increases both at low and high frequencies. The same is seen at more inland stations, with a smaller increase in noise levels.

Noise at high frequencies (greater than 1Hz) is mostly caused by cultural activity, but also increases due to wind. In the NNSN data we can confirm that wind speeds correlate with the high frequency noise levels. Small local earthquakes have most of their signal energy at these high frequencies and evaluation of this noise allows us to evaluate station performance in terms of detection of small earthquakes. For the cultural noise, we find the expected differences between day and night of up to 14 dB (spectral acceleration power units), which corresponds to more than 0.5 magnitude in detection level difference.

We also see clear expected differences between summer and winter where the long period noise, which is related to wave heights offshore, is significantly higher in the winter by as much as 20dB. This is the frequency range of surface waves, important for the moment tensor inversion of large regional earthquakes as well as ambient noise tomography. When evaluating instrument and vault quality, this is often done by measuring to what low frequencies the background noise can be recovered. In the NNSN, we find that the two recent stations FAUS and SKAR, as well as the Global Seismograph stations KONO and KBS have the best performance. Some of the other broadband stations perform also well, while others are a bit below what is expected. Results from this work can be used to target improvements to the network.

It is planned to look at the link between the residuals in earthquake location with the noise levels as we expect to get on average larger residuals for stations with higher noise levels. This could initially not be confirmed, probably due to the fact that differences between day and night, and summer and winter are of the same order as differences between stations. We will therefore focus on individual stations and see for example significant differences can be found in one season between day and night.

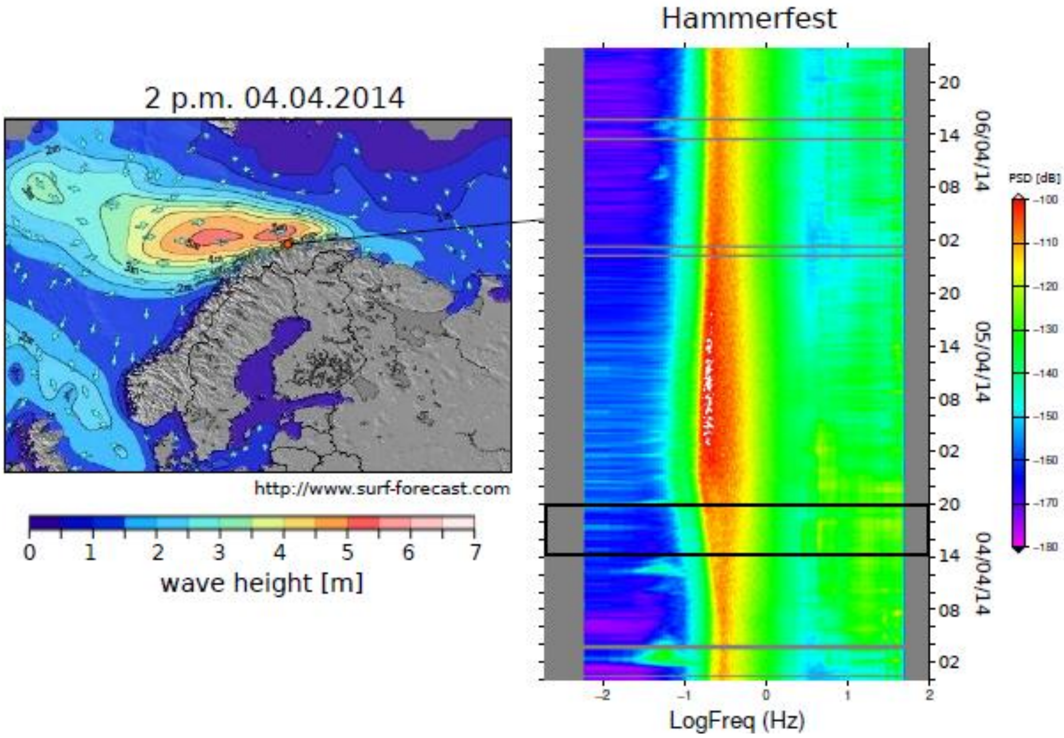

Figure 4. Example of storm affecting the noise levels at the Hammerfest station.

4.2 NORSAR: Progress on the development on a seismic velocity model for Norway (contributed by NORSAR)

One of the research tasks addressed by NORSAR is to develop the 3-D seismic velocity model for Norway. At the moment the study is focused on the southern part of Norway which is 58°-63° N and 3°-13° E (see Figure 5). We have compiled a dataset combining three different bulletins:

1) A selected set of 49 events from UiB catalog with originally more than 10 stations and small time (RMS) residuals. For this data set both the phase picks and phase notations were visually inspected, and if necessary, adjusted. The velocity model used for relocating events was the same which is used by UiB to locate the events in southern Norway.
2) 77 events from the MAGNUS project.
3) 32 events for year 2014 from the NORSAR bulletins.

The total dataset comprises 158 local seismic events recorded at 71 stations within the study area.

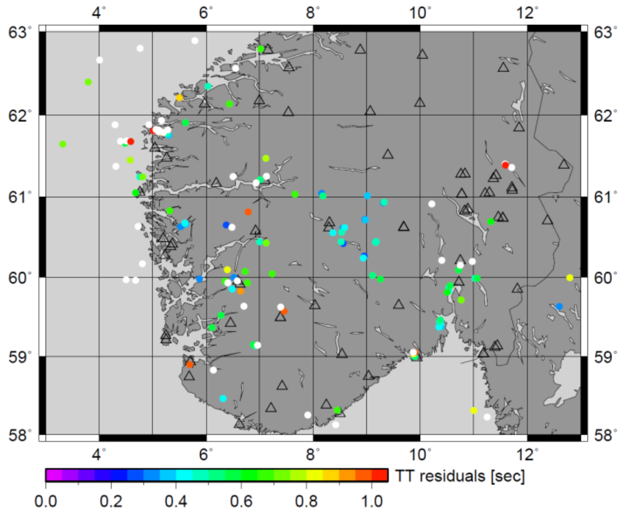

Figure 5. Location of the study area. Triangles mark seismic stations. Circles mark epicenters of seismic events. Colours indicate the RMS time residuals obtained during the VELEST inversion using the velocity model from MAGNUS project (11 layers). White colours indicate time residuals greater than 1 second.

In order to obtain an optimal 1-D velocity model, which will subsequently be used as an input model for developing a 3-D model, we used VELEST program which is implemented into SEISAN package. We have developed two versions of the 1-D model; one with 6 layers (like the UiB model), and one with 11 layers (like the MAGNUS model).

We initially intended to use the SIMULPS code to obtain the 3-D velocity model, but we decided to abandon this program due to complicated nature and clumsiness of the actual code and associated operations. Thus, another program called FMTOMO, which seems to be promising, is now being tested for this purpose.

A similar procedure of developing the 3-D velocity model will be applied for the northern part of Norway. For development of a 3-D velocity model for the offshore areas, we will start out with evaluating the 3-D Regional Seismic Travel-Time (RSTT) model of Myers. The first step in this process is to find reference events having accurate locations. Using the seismological bulletins of the ISC we selected 21 significant earthquakes with magnitudes >4.5 offshore of Norway which have been recorded by many stations at teleseismic distances. The next step will be to compare the RSTT model predictions of these events with the actual observed arrival times at the stations within regional distances (< 15°) from the epicenter.

5 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 will remain mostly stable for now, but it is important to improve the overall network performance.

5.1 Achievements in 2014

- Upgrade: Station OSL was upgraded with a Trillium sensor and Guralp digitizer.
- The new station at Skytli, close to Fauske, was installed during June 2014. The first data recorded June 23rd. The station has been performing well and has very low noise levels.
- At Hopen the STS2 seismometer has been replaced with a Trillium 120 instrument, and construction of new vault was started. The STS2 will be returned back to NORSAR.
- Data from the new NEONOR2 project with temporary deployments in Nordland are available to the NSNN. 17 of the 25 stations are operational with communication and data are transferred to Bergen and processed as part of the daily routines.

5.2 Plans for 2014/2015

- Hopen: The station is to be improved, a new vault has been started by digging and the new vault will be installed in 2015.
- Bjørnøya: A new vault installation will be made.
- Construct a new station on Varanger peninsula (site selection has started in 2014).
- The research and development activity will continue in close collaboration between UiB and NORSAR.
- Strengthen the collaboration with NORSAR on data processing through technical visits. A meeting is scheduled between UiB and NORSAR for December.
- Collaborate with other Scandinavian countries to improve identification of explosions, particulary in Northern Scandinavia. UiB staff will visit University of Helsinki in October or November to discuss the issue of identification of explosions.