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7.1 Norway's NDC: Experience from the first eighteen months of the full-scale phase of GSETT-3

Background

In order to test its new design ideas for an international seismic monitoring system, the GSE decided in 1993 to embark on its third technical test — GSETT-3. An equally important objective of this test is to furnish the Conference on Disarmament, which started negotiations on a Comprehensive Test Ban Treaty in January of 1994, with timely and relevant technical information.

The Norwegian GSETT-3 National Data Center (NOR_NDC) was established at the NORSAR Data Processing Center (NDPC) at Kjeller in the fall of 1993. Many of the activities at NOR_NDC represent a continuation of work that had been carried out at the NDPC for quite some period of time. Also, most of the infrastructure needed for NOR_NDC was already in place. For example, the dedicated, high-speed link utilized to transmit data to the GSETT-3 IDC in Arlington, Virginia, USA, had already been established in the 1980s in conjunction with the close cooperation in R&D between NORSAR and the CSS (Center for Seismic Studies, later on to become host for the GSETT-3 IDC).

NOR_NDC has evolved gradually over time. Initially, the efforts concentrated on establishing basic NDC functions (in accordance with the NDC requirements defined by the GSE). Later on, the resources available have permitted some voluntary NDC activities that have been encouraged by the GSE (submission of Supplementary data, participation in evaluation efforts, etc.). The Norwegian participation in GSETT-3 (with stations, transmission lines, NDC functions, etc.) has been funded through cooperative programs with the United States and grants from the Norwegian Ministry of Foreign Affairs.

This contribution gives a summary of activities and experience gained at NOR_NDC during the first eighteen months of the full-scale phase of GSETT-3, which started on 1 January 1995.

Norwegian GSETT-3 stations and communications arrangements

From the fall of 1993, Norway has provided continuous data from three GSETT-3 primary array stations: ARCESS, NORESS and Spitsbergen. The location and configurations of these three stations are shown in Fig. 7.1.1. ARCESS and NORESS are 25-element arrays with identical geometries and an aperture of 3 km, whereas the Spitsbergen array has 9 elements within a 1-km aperture. All three stations have a broadband three-component seismometer at the array center.

Data from these three stations are transmitted continuously and in real time to NOR_NDC. The NORESS data transmission uses a dedicated 64 Kbits/s land line, whereas data from the other two arrays are transmitted via satellite links of capacity 64 Kbits/s and 19.2 Kbits/s for the ARCESS and Spitsbergen arrays , respectively.

All data are acquired at NOR_NDC and stored on cyclic disk buffers of length 5-7 days, and are also copied to Exabyte cassettes for permanent archival. The AlphaRead/-Send software (see below) is used to send the data without delay to the GSETT-3 via a dedicated fiber optic link between our NDC and the GSETT-3 IDC in Arlington, Virginia, USA. The capacity of this link was originally 64 Kbits/s, but has been upgraded twice; in July 1994 from 64 Kbits/s to 128 Kbits/s, and in March 1995 to the current speed of 256 Kbits/s.

Uptimes and data availability

Figs. 7.1.2 - 7.1.4 show the monthly uptimes for the three Norwegian GSETT-3 primary stations ARCESS, NORESS and Spitsbergen, respectively. These barplots reflect the percentage of the waveform data that are available in the NOR_NDC tape archives for each of these three stations. The downtimes inferred from these figures thus represent the cumulative effect of field equipment outages, station site to NOR_NDC communication outages and NOR_NDC data acquisition outages. Some of the larger downtimes are due to specific reasons, as follows:

- For ARCESS, the downtimes in June and July of 1995 were mostly caused by announced (by electric company service personnel) and un-announced power cuts at the field site, and the downtime in September 1995 was caused by problems with the satellite transmission hardware at the array site.
- NORESS was down for several days in July 1995 when a severe thunderstorm damaged equipment at the site. There was again a stroke of lightning causing data outage on 18 June 1996.
- The Spitsbergen array was down between 10 and 20 April 1995 when two digitizers were disabled by hardware problems, and again between 20 June 1995 and 3 August 1995 when first an array controller broke and then the windmill which supplies power to the array failed and had to be replaced. The latest problem with SPITS occurred on 10 March 1996 when the battery bank at the site was overcharged by the windmill and exploded, causing severe damage to electronic field equipment. The array remained down throughout June, but resumed normal operation on 1 July 1996, after extensive equipment repair.

Fig. 7.1.5 gives a comparison between the ARCESS data availability as reported by NOR_NDC and the GSETT-3 IDC. Since the ARCESS data are channeled through NOR_NDC, data availability at the IDC would at best be equal to that of NOR_NDC. As can be seen from the figure, the differences in the data availability (with the exception of April 1995) are of the order of 3% and more, and this finding is also representative for the data loss (between NOR_NDC and the IDC) for NORESS and the Spitsbergen array. Some of the reasons for the differences seen in Fig. 7.1.5 are as follows:

- The link between NOR_NDC and the IDC was down for about two days and a half during 25-27 March 1995.
- Due to a disk failure at the IDC, no ARCESS data were recorded at the IDC for a period of about six days in May 1995.

- Some of the discrepancies can be explained by the ways the two data centers report data availability for arrays: NOR_NDC reports an array station to be up and available if at least one channel produces useful data, whereas the IDC uses weights where the reported availability/capability is based on the number of actually operating channels.

Error handling and reporting

To secure reliable forwarding of data to the IDC, procedures have been implemented at the NOR_NDC which, in addition to software systems, include an operator on duty. The operator is responsible for keeping data acquisition and AlphaRead/-Send machines and programs running and for detecting stops and irregularities in data processing and communications. Several alarm systems and interactive tools have been constructed to facilitate these tasks.

During normal office hours, the regular operations personnel rely on alarm display programs with graphical displays running on their workstations; see Fig 7.1.6 (some of the displayed text is in Norwegian, as the programs were tailor-made for internal NOR_NDC use.) At the particular time shown in Fig 7.1.6, the SPITS primary station was down, causing color-changes both in the data acquisition field (svalbard — Norwegian for the Spitsbergen archipelago) and in the AlphaRead/-Send fields.

During unattended operations(with operations personnel being away from their workstations), a problem or an error situation will cause the alarm program to call the pager worn by the operator on duty. If the problem occurs outside office hours, the operator will normally use a home-PC with modem to log in and check the reason for the alarm. The alarm software logs all problems in text files with the time and the reason for the alarm.

When the source of the problem has been identified, the operator will decide whether the problem has affected or will affect the forwarding of waveform data to the IDC. If this is the case, a GSE 2.0 PROBLEM message is written and sent to the IDC (staqc@cdidc.org). The operator will also answer incoming PROBLEM messages to alpha@norsar.no.

Between 1 January 1995 and 30 June 1996, NOR_NDC has sent 65 logged (i.e., with an official NOR_NDC MSG_ID) PROBLEM messages to the IDC. Here follows a summary of the PROB_LOCs (the station where the problem occurred, or the location of the transmit side of a communication link with problems) for the Norwegian GSETT-3 stations, as well as for other stations forwarding their data through NOR_NDC:

SPITS:	18
ARCES:	12
NORES:	9
FINES:	8
GERES:	8
HFS:	5
ESDC:	2
NOR_NDC:	5 (4 about NOR_NDC - IDC link outages, 1 about AC power outage at the NDC)

The sum is larger than 65 as a few messages concerned two or more stations.

Below is an example of a typical message exchange where the IDC staqc (Station Quality Control) personnel have discovered a break in the continuous dataflow from the primary station SPITS. NOR_NDC acknowledges receiving the message by adding a NEW_ENTRY section and then adding another as more information about the problem is available.

```
BEGIN GSE2.0
MSG_TYPE PROBLEM
MSG_ID NOR_960314_004 NOR_NDC
REF_ID NOR_960311_014 NOR_NDC
E-MAIL alpha@norsar.no
PROB_TYPE HARDWARE
PROB_LOC SPITS
AFFECTED_STA SPITS
EFFECTIVE_DATE 1996/03/10
PROBLEM Station Down
ENTRY
 The IDC received only 29% of data from SPITS for 10 Mar 1996.

NEW_ENTRY
 We are aware of the problem. NOR_NDC has not received data from SPITS
 since 1996/03/10 07:00:32. We do not know the reason yet, but will come
 back with another message when we do.

NEW_ENTRY
 Members of our field team yesterday visited the SPITS array site
 to find that the battery bank had exploded due to overcharging.
 The repair will take some time. As work progress, we will keep you
 informed.

STOP
```

The PROB_TYPE- and PROB_LOC-fields were originally entered as UNKNOWN by the IDC, but were filled in by NOR_NDC as the reason for the problem was discovered.

NDC automatic processing

Detection and event processing is performed for all stations for which data are available at NOR_NDC (i.e., also for stations not contributing data to GSETT-3). For the regional arrays, the automatic part of this one-array processing consists of signal processing to detect phases, and event processing with "ronapp" recipes for the EP program to locate seismic events (see Fyen, 1989). The results from these processing steps are routinely reported in the NORSAR Semiannual Technical Summaries, see Section 3.5 in this volume for detailed reports of the last six months. For the NORSAR teleseismic array, data are processed using the Detection and Event Processor, and the results for the last six months are reported in Section 2.3 of this report. Fig. 7.1.7 is a barplot showing the monthly distribution of detections for the various stations for the period January 1995 - June 1996.

It is seen from Fig. 7.1.7 that there are some pronounced seasonal variations in the number of detections, with the higher numbers during the winter. The low number of NORSAR detections during September-November 1995 is due to downtimes related to the array refurbishment effort. Note also the overall high number of detections on the Spitsbergen array.

Fig. 7.1.8 shows the automatically formed single-station events for all stations processed at NOR_NDC. Note the very high number of events automatically formed from the Spitsbergen array data, especially during the winter season.

In addition to the single-station automatic event processing, automatic multi-array processing for event location is performed using the Generalized Beamforming (GBF) method (Ringdal and Kværna, 1989), with phase detection data from the network of regional arrays as input. For the time interval January 1995 - June 1996, GBF automatically located 42,930 events within a geographical window covering central and northern Europe. All the automatic GBF bulletins are available on the World Wide Web at http://www.norsar.no/bulletins/.

NDC data analysis

Events at local and regional distances are manually analyzed using data from the regional arrays. The system used in this work is the Intelligent Monitoring System (see Section 3.6 of this report). The GBF program is used as a pre-processor to the Intelligent Monitoring System, and only phases associated by GBF to events in central and northern Europe are considered. The analysts check the output from this automatic process and select events in accordance with certain criteria (relating to magnitudes and regions of interest) for subsequent manual analysis. The events analyzed in this way comprise the NOR_NDC input to the Nordic Supplementary (Gamma) data, which are compiled by the Finnish NDC and forwarded to the IDC.

For the period January 1995 - June 1996, NOR_NDC submitted 1,087 such supplementary events. These events are shown in Fig 7.1.9. It should be noted that the analysts use data from all the regional arrays available at NOR_NDC, so that in addition to the Norwegian primary stations ARCES, NORES and SPITS, waveforms and detections from HFS (Sweden), FINES (Finland), GERES (Germany) and the Apatity array (Kola peninsula, Russia) are used in this context.

Data from the NORSAR array are analyzed to produce a monthly bulletin of events worldwide. These bulletins contain 5,683 events for the January 1995 - June 1996 time interval. The events are shown in Fig. 7.1.10.

Tools developed

To start operation as a National Data Center, NOR_NDC implemented programs both to forward continuous waveform data to the IDC and to respond to requests for additional data from the IDC and from other NDCs.

The program system used for forwarding of primary data, is the AlphaRead/-Send suite of programs developed at the IDC. AlphaRead reads continuous waveform data from the local NDC recording system (circular diskloops at NOR_NDC) and writes them to LIFO (Last In First Out) buffer files in a system-independent format. These files are read by AlphaSend which sends them to the IDC after a connection has been opened. For a detailed discussion of the Exchange of Continuous Data, see GSE/CRP/243 (1995). To install the AlphaRead/-Send package at NOR_NDC, a small number of low-level subroutines had to be modified to access the diskloop files. After installation, the programs have been running almost un-interrupted and are currently using LIFO buffer files capable of holding 24 hours of data (this number can be increased if deemed necessary.)

For external access to NOR_NDC parameter and waveform data, the Automatic Data Request Manager (AutoDRM; Kradolfer, 1993) retrieved from the Swiss Seismological Service (SED) has been installed. This program accepts email-messages containing formatted requests and returns the requested data by email or through ftp, depending on the amount of data. The AutoDRM version installed at NOR_NDC is 2.8 from November 1995. The data center-specific parts of AutoDRM are localized to a few subroutines and to install the program, only a small number of files had to be modified to read from NOR_NDC diskloops, gap lists and parameter files. Currently, these request types are supported:

- WAVEFORM (only data still on the diskloops, i.e., no data older than 5-6 days. For older data, the archive database at the IDC should be queried)
- CHANNEL (channel information with location, emplacement and seismometer type)
- RESPONSE (instrument response information)
- OUTAGE (outage reports - gap lists)

To request data from NOR_NDC, send an email-message with the following content to autodrm@norsar.no (substitute the appropriate values for MSG_ID and the return email address):

```
BEGIN GSE2.0
MSG_TYPE request
MSG_ID example ANY_NDC
E-MAIL name@my.computer
HELP
STOP
```

The IDC uses a similar AutoDRM program (messages@cdidc.org) which gives access to both the operational (recent) data and the archived waveforms and parameters. Since a number of research projects at NOR_NDC depend on fast and easy access to large amounts of archived waveforms, a program system for semi-automatic requesting and retrieval was developed. The system consists of a collection of UNIX shell-scripts and small FORTRAN programs to automatically request all waveforms associated (following certain criteria) to an event. The program will take an origin identifier (orid - found in IDC bulletins, AELs, REBs, etc.), request a list of phases associated to the origin, compute time intervals to request, and format and send the complete GSE2.0 REQUEST-message to the IDC.

The reply message from the IDC is automatically forwarded into another program which will read the message, decide if it contains a small GSE2.0 WAVEFORM segment which can be unpacked at once or, alternatively, read and execute the necessary ftp-commands to retrieve larger segments. Error conditions (missing waveforms, format errors, etc.) are also handled gracefully.

Contributions to IDC development, evaluation and operation

During the period January 1995 - June 1996, NOR_NDC has, in cooperation with the United States, contributed towards IDC development through software deliveries, as follows:

- NOR_NDC installed a prototype system for Continuous Threshold Monitoring at the IDC in October 1994. An extension of this system to include full GSETT-3 primary network processing was delivered and installed in May 1995. A fully operational version of the system is planned for implementation in the fall of 1996 (see also Section 7.2 of this report).
- In June of 1996, NOR_NDC delivered software for IDC processing of data from the NORSAR teleseismic array in DFX (Detection and Feature Extraction; the software currently used at the IDC to automatically detect and analyze seismic signals), as well as certain DFX extensions to accommodate STA calculations for the Threshold Monitoring system. These deliveries, as well as plans for future deliveries of software to the IDC, are described in some detail in Section 7.2 of this report. One of the future deliveries described in Section 7.2 is an algorithm for improved automatic onset-time estimation. Our initial findings related to this subject are described in Kværna (1995), and further results are reported in Sections 7.3 and 7.8 of this report.

NOR_NDC has participated in the evaluation of several aspects of the IDC operation:

- NOR_NDC participated in the evaluation of the IDC AutoDRM data request manager in May and June 1995 by sending a large number (175 in May and 167 in June) of data requests to the IDC and evaluating the response to these requests in terms of timeliness and completeness. The results of this evaluation are reported in GSE/CRP/262 (1996). NOR_NDC has also participated in testing of the IDC World Wide Web service, as well as in testing of direct IDC database access using SQL.
- A study of the performance of the IDC processing of data from the Spitsbergen array has been conducted by Mykkeltveit et al (1995). The study gave recommendations for certain improvements in the IDC software.
- Magnitude estimation at the IDC has been assessed in a case study by Ringdal (1995) on an earthquake sequence in Greece during May-June 1995.

NOR_NDC has contributed to IDC operations by providing an experienced analyst to the international staff at the IDC. Bernt Kr. Hokland started his work at the IDC on 1 January 1995 and continued his work there through August of 1995.

Other related activities

NOR_NDC is forwarding data to the IDC from GSETT-3 primary stations in several countries. These currently include FINESS (Finland), GERESS (Germany), Hagfors (Sweden) and Sonseca (Spain). In addition, communications for the GSETT-3 auxiliary station at Nilore, Pakistan, are provided through a VSAT satellite link between NOR_NDC and Pakistan's NDC in Nilore. Fig. 7.1.11 shows the locations of these GSETT-3 stations and also indicates the 256 Kbits/s fiber optic link used to transmit these data as well as the Norwegian GSETT-3 data to the IDC.

We have negotiated an agreement with the Norwegian Telecom on the establishment of a VSAT network that enables transmission to the IDC via NOR_NDC of data from stations in Europe, Africa and Asia. So far, data from FINESS, Hagfors, Spitsbergen and the auxiliary station at Nilore, Pakistan, are transmitted to Norway using this VSAT system. The link between NOR_NDC and the IDC has a capacity of 256 Kbits/s, which would permit forwarding data from additional stations to the IDC via NOR_NDC. It has so far been planned that data from an envisged GSETT-3 primary station in Tunisia will be forwarded to the IDC in this manner, and we are also looking into possibilities for routing data from other GSETT-3 primary stations to the IDC via NOR_NDC.

Concluding remarks and future plans

This contribution has summarized activities and experience gained at the Norwegian NDC during the first year and a half of the full-scale phase of the GSETT-3 experiment. The following conclusions can be drawn with respect to current status and directions for future work at NOR_NDC:

- The statistics presented on data availability for the Norwegian GSETT-3 primary stations ARCESS, NORESS and Spitsbergen demonstrate that the goal of 99% data availability at the IDC is not reached. The NOR_NDC data availability exceeds 99% for extended periods of time for these stations, but it is found that a substantial amount of data is lost between the NOR_NDC and the IDC (some of, but not all of this loss is due to discrepancies between the ways the NOR_NDC and the IDC report data availability, as explained earlier). Further work, within available resources, is thus needed to harden those components and processes that most frequently have caused loss of data. More detailed statistics than have been presented in this contribution are available for a study of the reasons for the outages, and this information will be used to assess the value of various possible measures to improve the situation.
- A fairly substantial effort at the NOR_NDC is directed towards processing of the data acquired, for detection and location of events. Besides the obvious value of this in the context of research, IDC evaluation and development, provision of Supplementary data, etc., we think that routine NDC processing is the best means of checking on and ensur-

ing the data quality and integrity. To the extent that the NDCs will be responsible for quality of data from stations on their own territory (as is the case in GSETT-3), NOR_NDC will continue to direct appropriate attention to the data processing task.

- Within available resources, NOR_NDC will continue to contribute to the evaluation and further development of the IDC. Based on our experience over the past couple of years, we believe we are in a good position to pursue several tasks that could lead to improvements in the IDC system.
- NOR_NDC has assisted a number of countries in their efforts towards contributing data to the IDC (see Section 7.5 of this report), and as described in this contribution, several countries send their data to the IDC via NOR_NDC. We intend to pursue these efforts, and we think that the VSAT service offered by the Norwegian Telecom is particularly well suited to solve problems often encountered in ensuring reliable transmission of data from remotely located seismic stations.

In the near future, we will start modifying the Norwegian station participation in GSETT-3 so as to become in agreement with what is now envisaged for the International Monitoring System (IMS) that will be installed to verify compliance with a future CTBT. The NORESS array has been a temporary substitute for the large-aperture NORSAR array, awaiting the completion of a technical refurbishment of this array. This refurbishment program was completed in late 1995, and efforts are now underway to integrate the NORSAR array in the IDC processing, as described earlier. The NORSAR array data will be included in the IDC processing once the processing software developed by NOR_NDC becomes operational at the IDC. The Spitsbergen array will at a suitable time change status from being a primary to becoming an auxiliary station in GSETT-3, in conformity with its status in IMS. Subject to the availability of appropriate funds, we plan to make the seismic station on the Jan Mayen island operational in GSETT-3 by the end of 1996. This station is also in the list of envisaged IMS auxiliary stations.

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U. Baadshaug

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Ringdal, F. (1995): Magnitude estimation at the IDC — a case study. *Seminannual Tech. Summary, 1 April - 30 September 1995*, NORSAR Sci. Rep. No. 1-95/96, Kjeller, Norway.

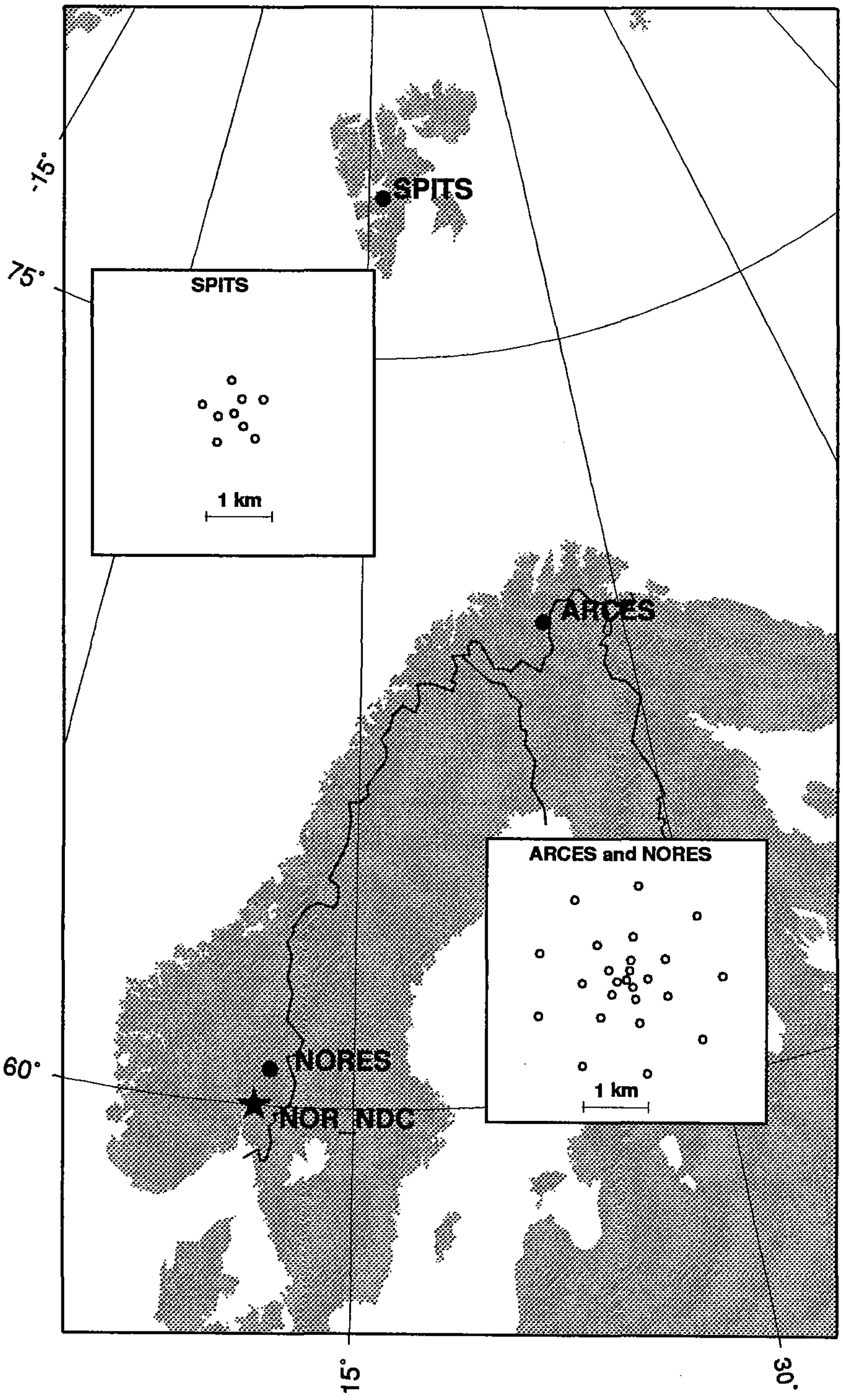

Fig. 7.1.1. The figure shows the locations and configurations of the three Norwegian GSETT-3 primary array stations. The data from these stations are transmitted continuously and in real time to the Norwegian NDC (NOR_NDC) and then on to the GSETT-3 IDC.

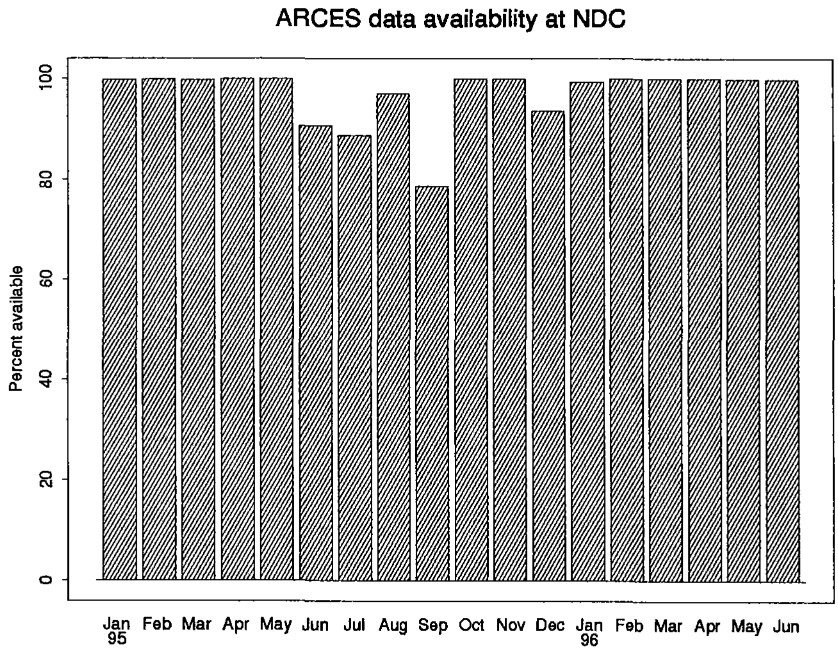

Fig. 7.1.2. The figure shows the monthly uptimes for the ARCESS array for the period January 1995 - June 1996. The barplots reflect the percentage of waveform data from ARCESS that is available in the NOR_NDC tape archives for each month.

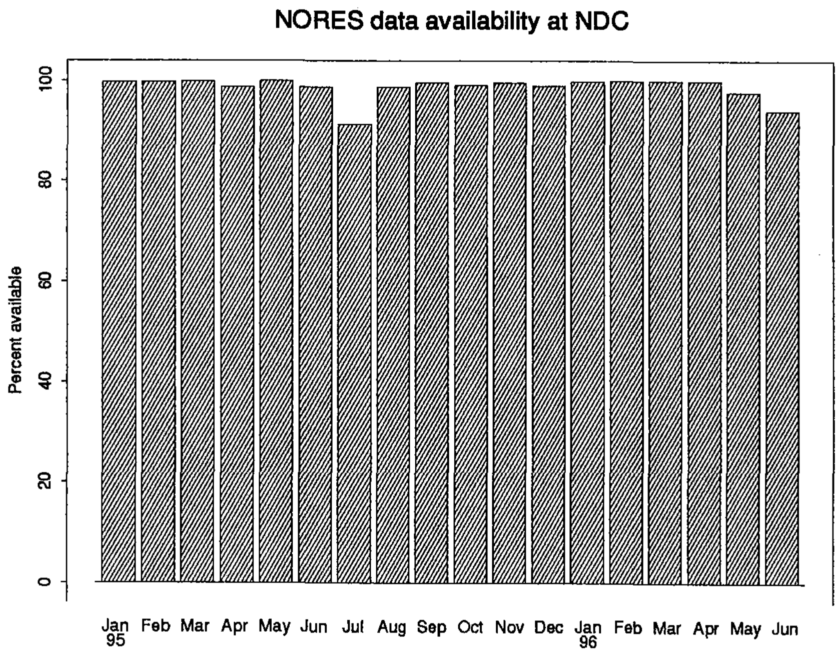

Fig. 7.1.3. The figure shows the monthly uptimes for the NORESS array for the period January 1995 - June 1996. The barplots reflect the percentage of waveform data from NORESS that is available in the NOR_NDC tape archives for each month.

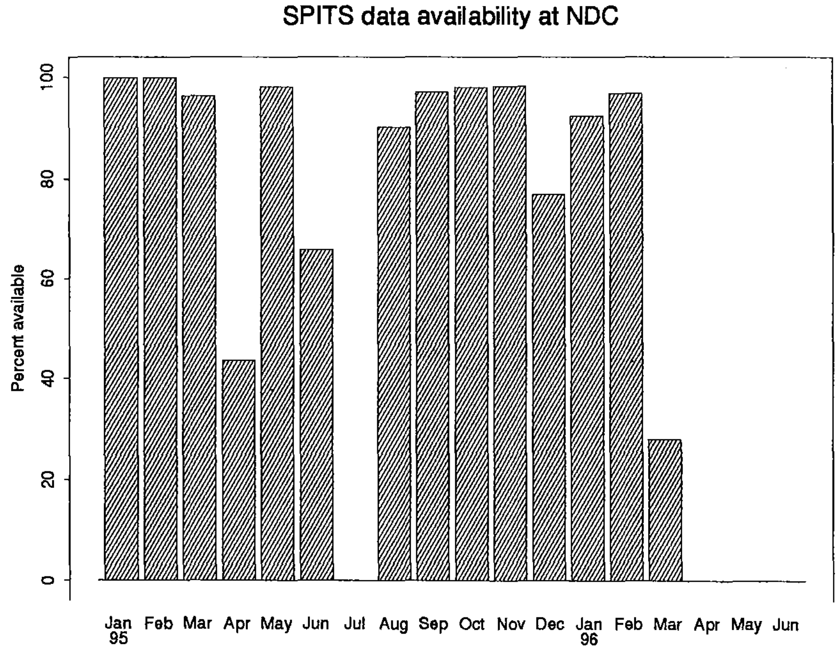

Fig. 7.1.4. The figure shows the monthly uptimes for the Spitsbergen array for the period January 1995 - June 1996. The barplots reflect the percentage of waveform data from the Spitsbergen array that is available in the NOR_NDC tape archives for each month.

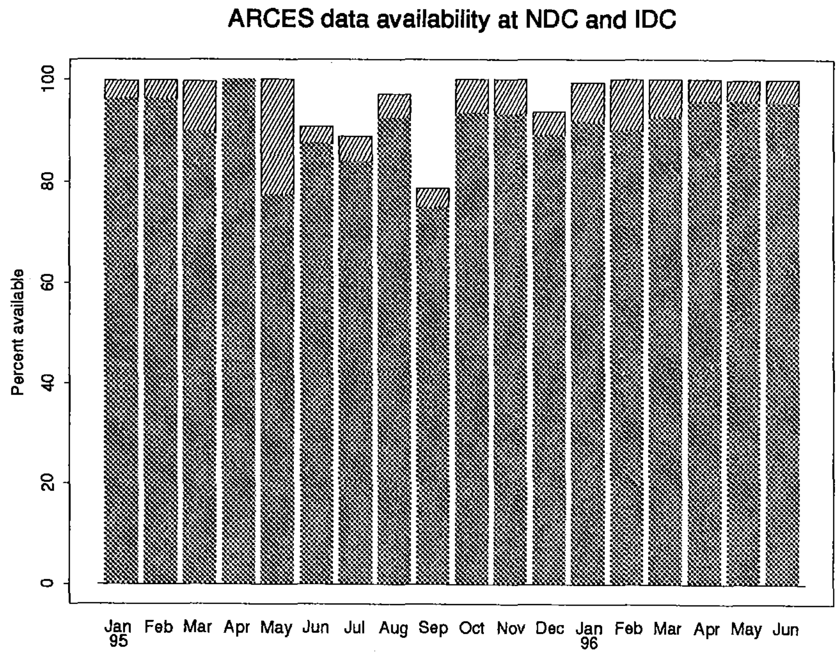

Fig. 7.1.5. The figure shows the monthly availability of ARCESS data in the NOR_NDC and IDC archives, with the higher values representing NOR_NDC data availability, as the ARCESS data are sent to the IDC via the NOR_NDC.

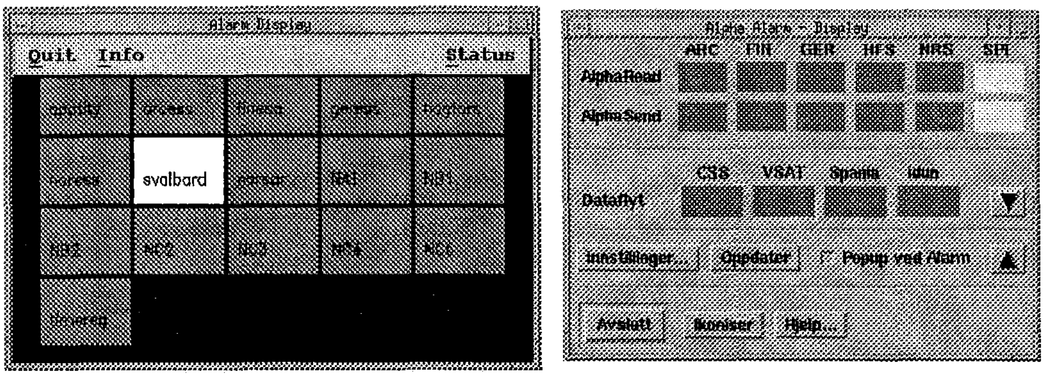

Fig. 7.1.6. The figure shows the graphics of the alarm display program running on the workstations of the operations personnel at the NOR_NDC. See the text for further details.

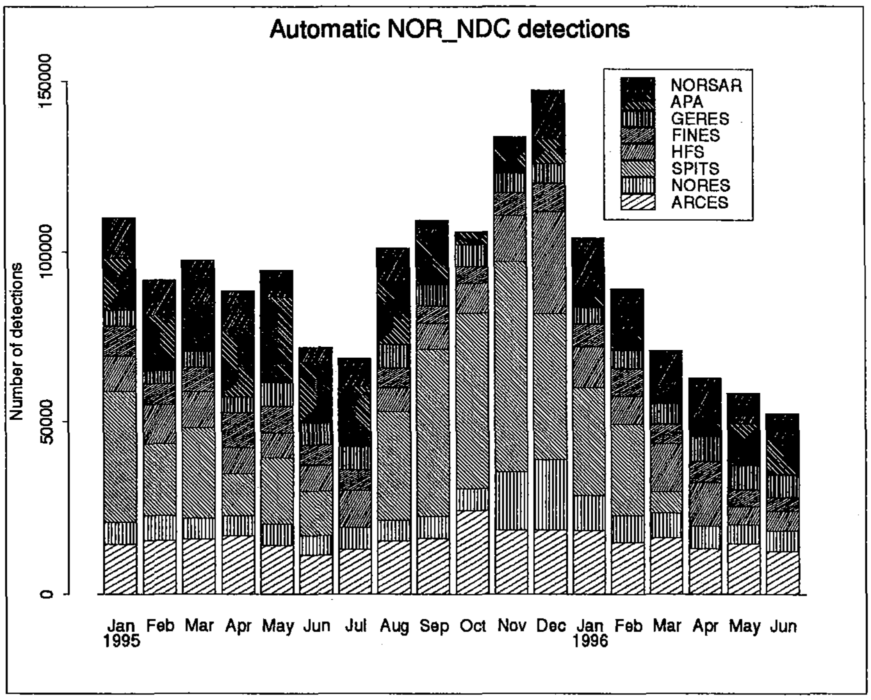

Fig. 7.1.7. The figure shows the number of automatic NOR_NDC detections for the various regional arrays and the NORSAR teleseismic array, for the time interval January 1995 - June 1996.

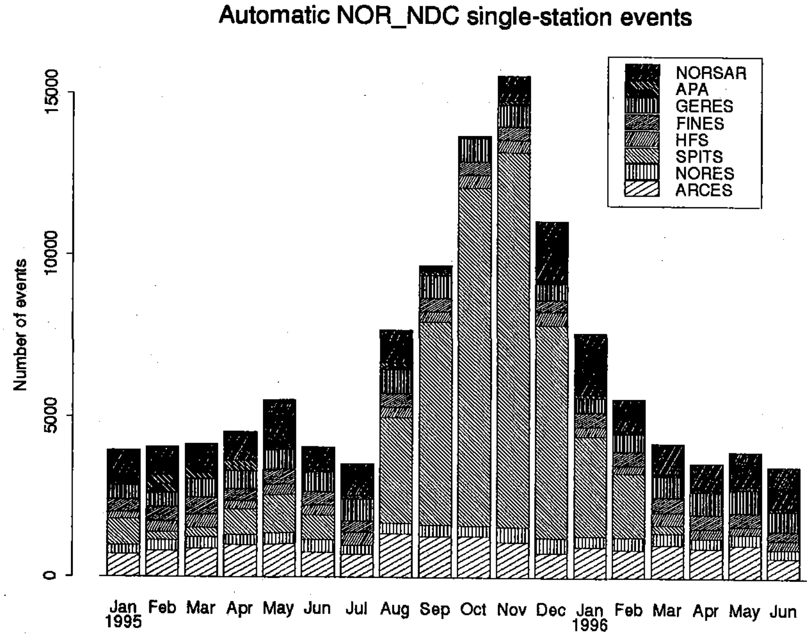

Fig. 7.1.8. The figure shows the number of automatic single-station events formed by the NOR_NDC processing for the various regional arrays and the NORSAR teleseismic array, for the time interval January 1995 - June 1996.

Reviewed Gamma events

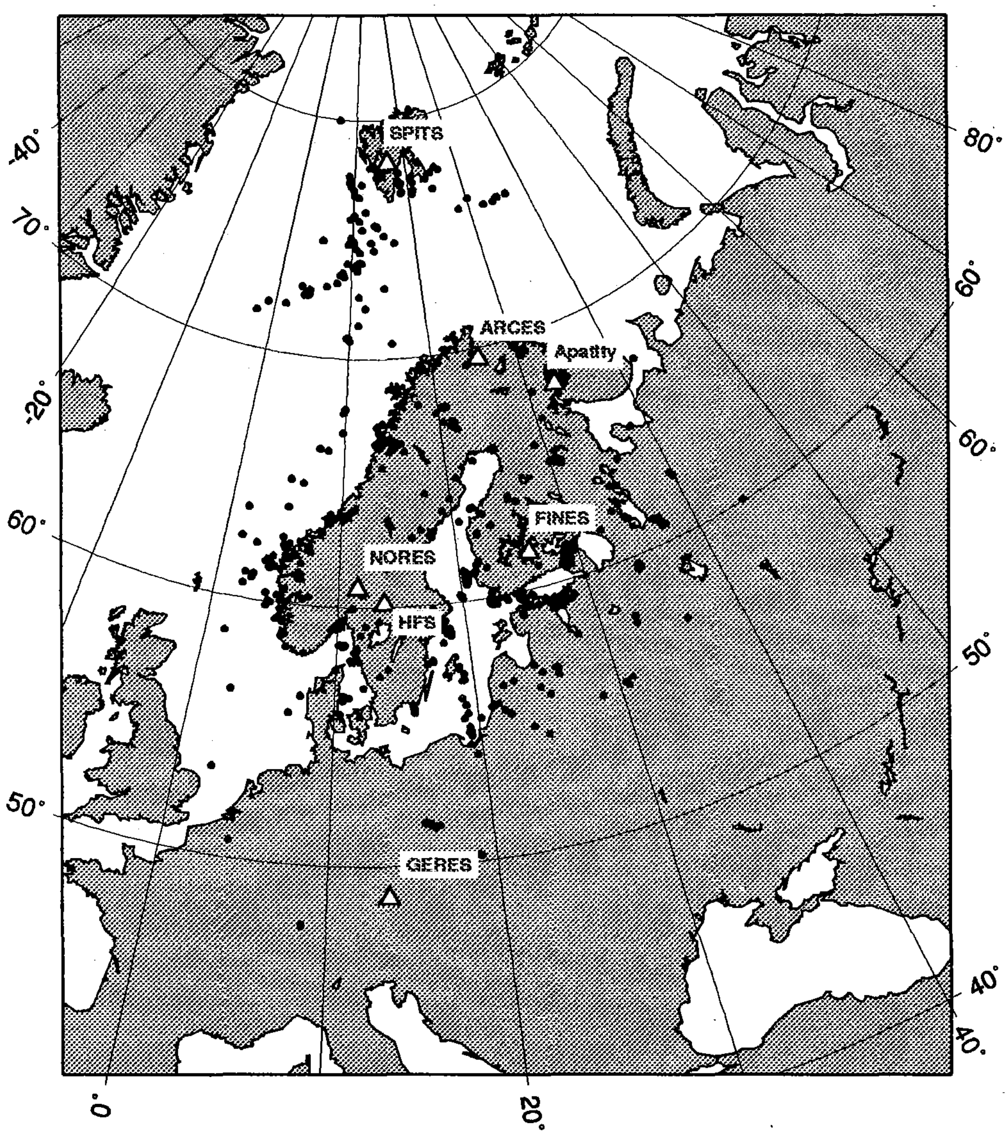

Fig. 7.1.9. The map shows the 1,087 events in and around Norway contributed by NOR_NDC during January 1995 - June 1996 as Supplementary (Gamma) data to the IDC, as part of the Nordic Supplementary data compiled by the Finnish NDC.

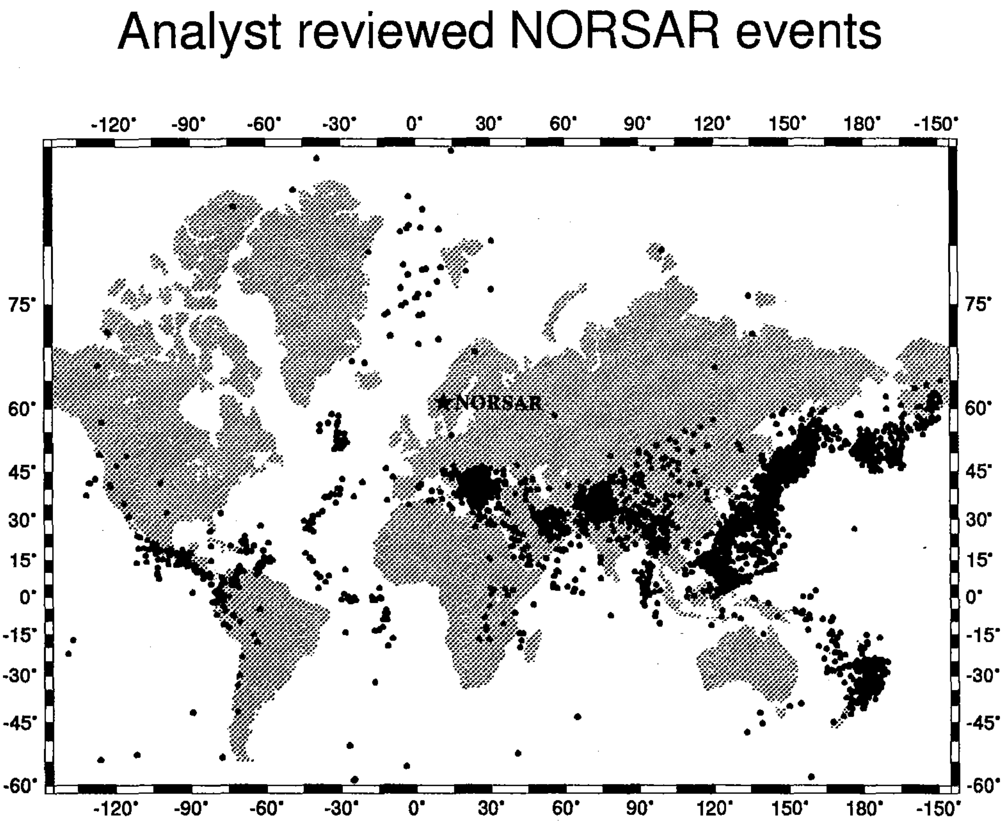

Fig. 7.1.10. The map shows 5,683 events worldwide, analyzed and located from data recorded at the NORSAR teleseismic array during the period January 1995 - June 1996.

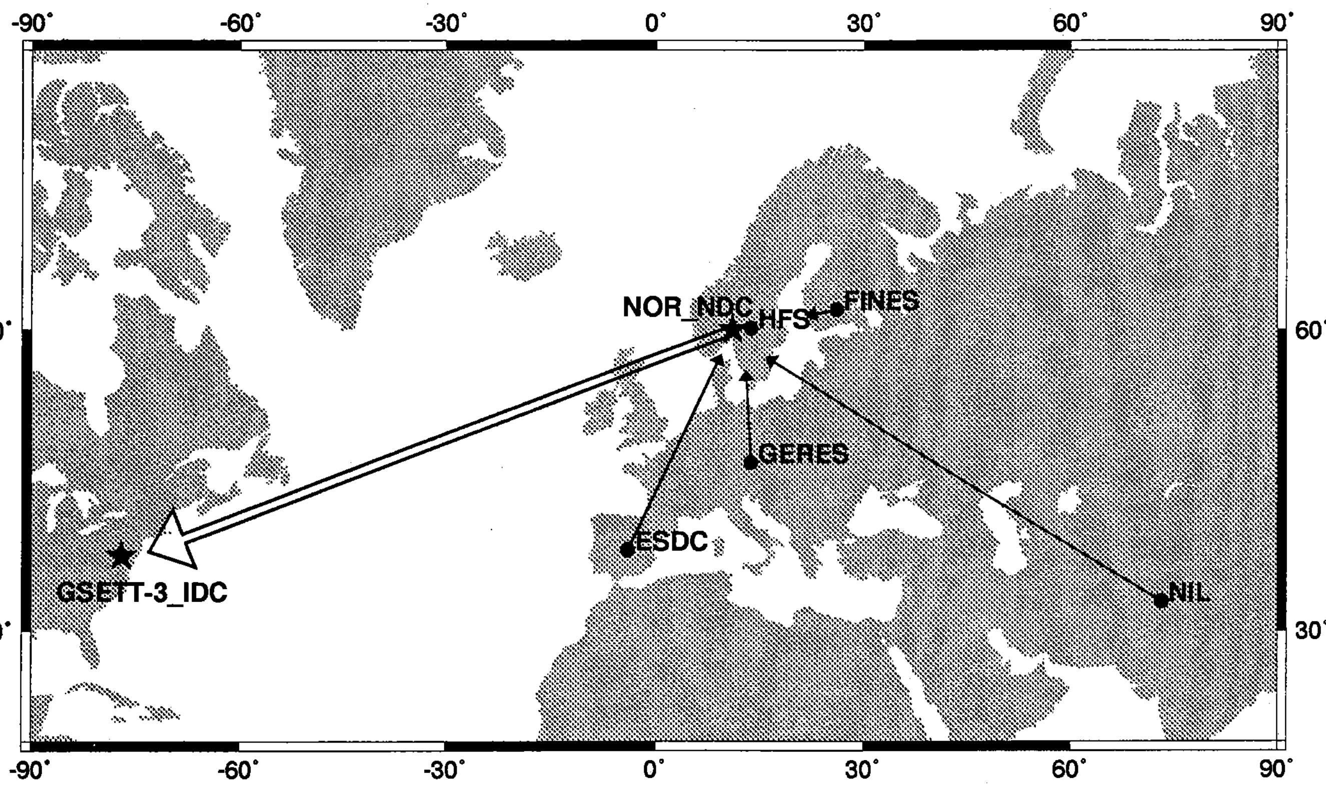

Fig. 7.1.11. The figure shows the locations of GSETT-3 stations outside Norway that use NOR_NDC as a communications node in forwarding the data to the IDC. The high-speed link (256 Kbits/s) between NOR_NDC and the IDC is also indicated.