SEISMIC CALIBRATION OF THE EUROPEAN ARCTIC

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ABSTRACT

The purpose of this two-year effort, which started on 1 January 1999, is to support the construction of the U.S. Department of Energy (DOE) Comprehensive Nuclear-Test-Ban Treaty Knowledge Base for detecting, locating and identifying seismic events in the area of northern Fennoscandia, the Kola Peninsula, Novaya Zemlya, and the surrounding waters of the Barents and Kara Seas. The main objectives of the effort are to assemble a set of historical seismic observations suitable for characterizing all aspects of seismic wave propagation and seismic sources in this region, to describe the principal seismic phases observed in the seismograms, and to calibrate the region with respect to seismic wave propagation (travel-times and amplitude-distance relations).

The main emphasis during the first year of this contract is on data collection. Waveform data are now being collected for a range of sources in the European Arctic: Nuclear tests at the Novaya Zemlya test site, peaceful nuclear explosions conducted in the area, earthquakes and presumed underwater explosions from 1970 to the present, and representative blasts from mining operations in the Kola Peninsula, northern Norway, Sweden, Finland and adjacent regions of European Russia. Waveform data collected under this effort will be provided in CSS 3.0 format on a set of CD ROMs, with the appropriate metadata included, to DOE through the Lawrence Livermore National Laboratory, to the U.S. Department of Defense through the Center for Monitoring Research and to the U.S. National Data Center.

The project is a collaborative effort between NORSAR and the Kola Regional Seismological Centre (KRSC) of the Russian Academy of Sciences. The main source of data for this project is the historical waveform archives at NORSAR, containing data from the NORSAR teleseismic array and the network of northern European small-aperture arrays. These data will be supplemented with data provided by KRSC for stations AMD and APA in northwestern Russia.

The presentation will provide details on the data being compiled for this project and will summarize the current status of the data collections effort. Representative waveforms for different source types and propagation paths will be shown to illustrative the variability in the characteristics of seismic phases, and some initial results from analysis of the data will be presented.

Key Words: data collection, characterization of seismic phases, seismic calibration

OBJECTIVE

The purpose of this research is to support the construction of the DOE CTBT Knowledge Base for detecting, locating and identifying seismic events in the area of northern Fennoscandia, the Kola Peninsula, Novaya Zemlya, and the surrounding waters of the Barents and Kara Seas. This is done by assembling a set of historical seismic observations suitable for characterizing all aspects of seismic wave propagation and seismic sources in this region, by describing the principal seismic phases observed in the seismograms, and by calibrating the region with respect to seismic wave propagation.

RESEARCH ACCOMPLISHED

The main emphasis during the first year of this contract is on data collection. Waveform data are now being collected for a range of sources in the European Arctic: Nuclear tests at the Novaya Zemlya test site, peaceful nuclear explosions conducted in the area, earthquakes and presumed underwater explosions from 1970 to the present, and representative blasts from mining operations in the Kola Peninsula, northern Norway, Sweden, Finland and adjacent regions of European Russia. We have completed the first phase in generating a list of events for inclusion in this data set, based on systematic searches in regional bulletins covering this area. This work has been carried out in cooperation between NORSAR and the Kola Regional Seismological Centre (KRSC) personnel. The data sources include:

- The bulletin of the International Seismological Centre (ISC)
- The bulletin of the NEIC (USA)
- The IDC Reviewed Event Bulletin
- The NORSAR regional and teleseismic bulletins
- The Kola Regional Seismological Centre regional bulletin

In this work, we have also been able to take advantage of several publications, technical reports, and event lists compiled over the years, containing seismic events for particular sites (like the Novaya Zemlya test sites) or subregions of the European Arctic. The resulting preliminary event list comprises more than 300 seismic events. We will in the next phase of this program go through this list carefully, aiming to extract a subset of about 100 events most relevant to the purposes of the contract.

Table 1 gives an overview of the available digital stations that will form the primary data source for this project. The table specifies the station configuration (array, 3C), its location, the operating organization, and the years during which the station has been in operation.

Station	Station Type	Station Location	Operating Organization	Data Availability (in NORSAR's archives)
NORSAR large-aperture array	Array	60.82˚N 10.83˚E	NORSAR	1971-present
NORESS array	Array	60.73˚N 11.54˚E	NORSAR	1984-present
ARCESS array	Array	69.53˚N 25.51˚E	NORSAR	1987-present
Spitsbergen array	Array	78.18˚N 16.37˚E	NORSAR	1992-present
FINESS array	Array	61.44˚N 26.08˚E	Univ. of Helsinki	1990-present
Apatity array	Array	67.61˚N 32.99˚E	KRSC	1992-present
Amderma array	Array/3C	69.74˚N 61.66˚E	KRSC	1994-present

Table 1. This table gives an overview of available digital stations that will form the primary data source for this project.

We also intend to include some carefully chosen additional digital stations for selected events of special interest. An excellent example is the IRIS station Kevo in Finland. Other potential candidates are KBS in Spitsbergen, EKA in the U.K., and GERESS/Grafenberg in Germany. For all of the stations listed in the table, there are shorter or longer time intervals of system downtime, or degradation of data due to other factors (spikes, channel outages, etc.). Therefore, the years of operation specified in the table must not be taken to mean that data of high quality will be available for every seismic event in this time period. One of the major tasks in the further work will be to analyze the quality of the station recordings for each event and make a selection of a suitable subset accordingly. Given otherwise equal conditions, the event selection will focus upon maximizing the station coverage. In practice, this means that the most recent events are the most important, since this is usually synonymous with having more stations in operation.

Under this contract waveform data in the CSS 3.0 format, with the appropriate metadata information provided in accordance with the specifications given by Carr et al (1998), will be made available on a set of CD-ROMs to DOE through the Lawrence Livermore National Laboratory, to the DOD through the Center for Monitoring Research, and to the U.S. National Data Center. Thus far, a data set of Novaya Zemlya explosions recorded on the large-aperture NORSAR array has been converted from our native format to the CSS 3.0 format, and a CD-ROM containing these data has been distributed.

The data on this CD-ROM comprise all available recordings from 30 explosions on Novaya Zemlya during 1971 - 1990 with ray paths as indicated in Fig. 1. The source-receiver distances are around 20 degrees. The data presented cover all nuclear explosions conducted on Novaya Zemlya during this time interval with the exception of the mb 5.7 explosion on 1978, Sept. 27. The data acquisition systems were out of operation on this date.

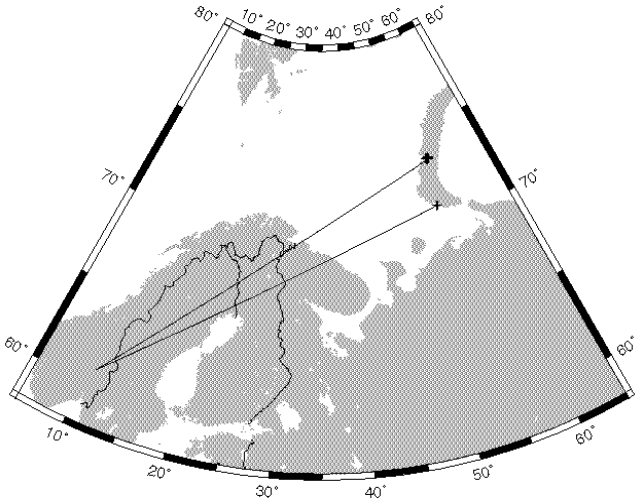

Fig. 1. Ray paths of the data set of Novaya Zemlya explosions during 1971-1990 recorded on the large-aperture NORSAR array.

The data cover a time period of 20 years, in which the instrumentation was largely stable, with the exception that since 1976 some short period channels were equipped with different gain settings and different filter settings over shorter time periods. The data for many of these explosions are saturated for the short period high gain instruments, whereas most of the long period records are recorded on scale. Since 1975 a low gain short period channel has been available, so for all records after that time there is at least one unclipped short period channel available. Figs. 2 to 4 show typical records of events in this data base, and Fig. 5 shows the low gain short period channels for some events recorded during 1975-1979 that have clipped on the other short period channels.

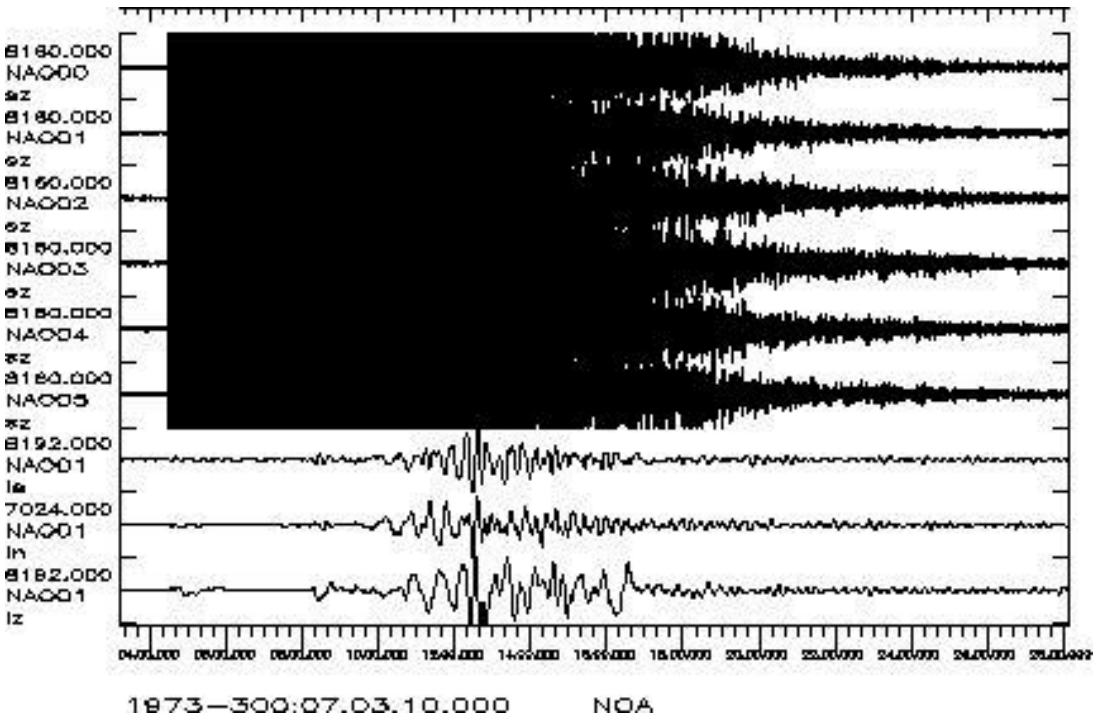

Fig. 2. Data example from the 1973 October 27, magnitude 6.9 explosion with strong clipping of all short period data and slight clipping of long period data

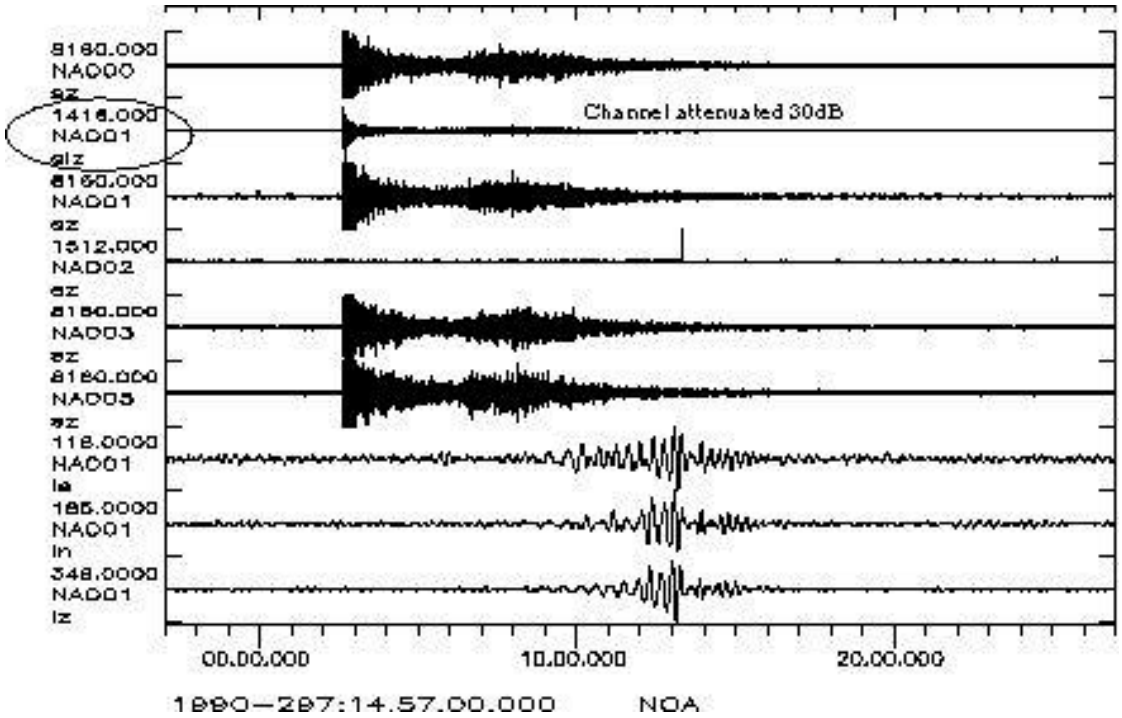

Fig. 3. Data example from the 1990 October 24, magnitude 5.6 explosion with only short period P waves clipped.

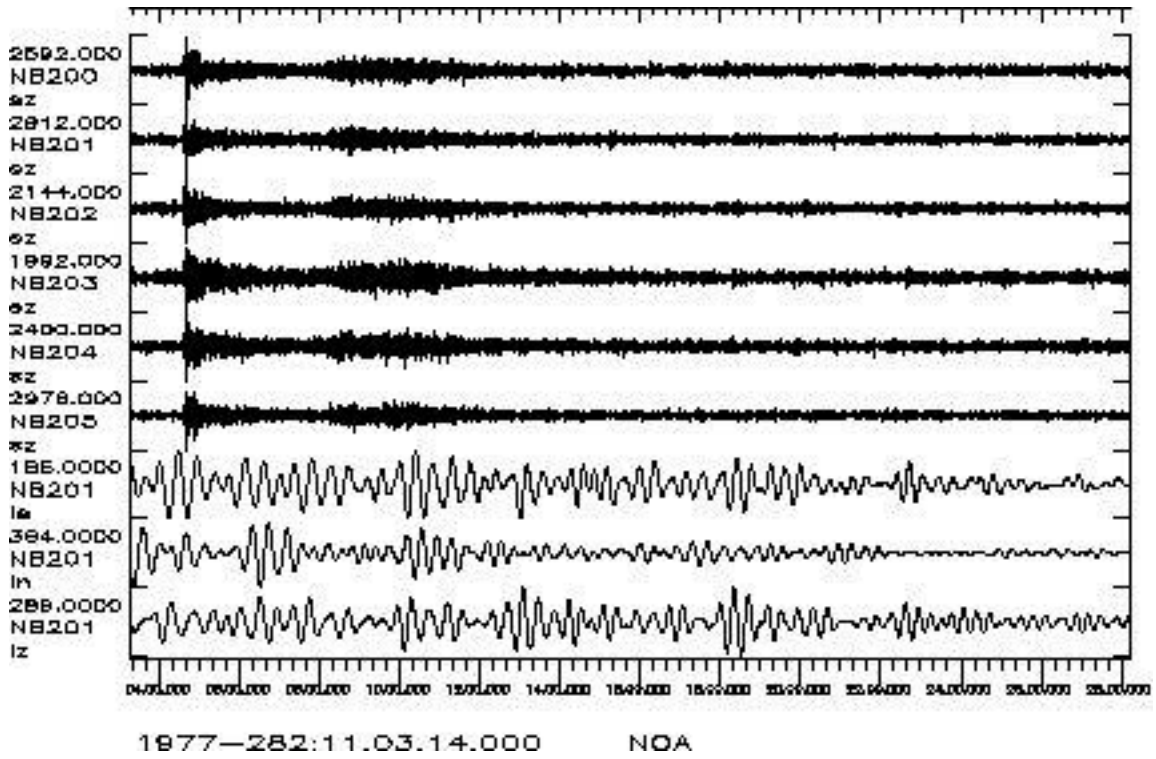

Fig. 4. Data example from the 1977 October 9, magnitude 4.5 explosion with no clipped data.

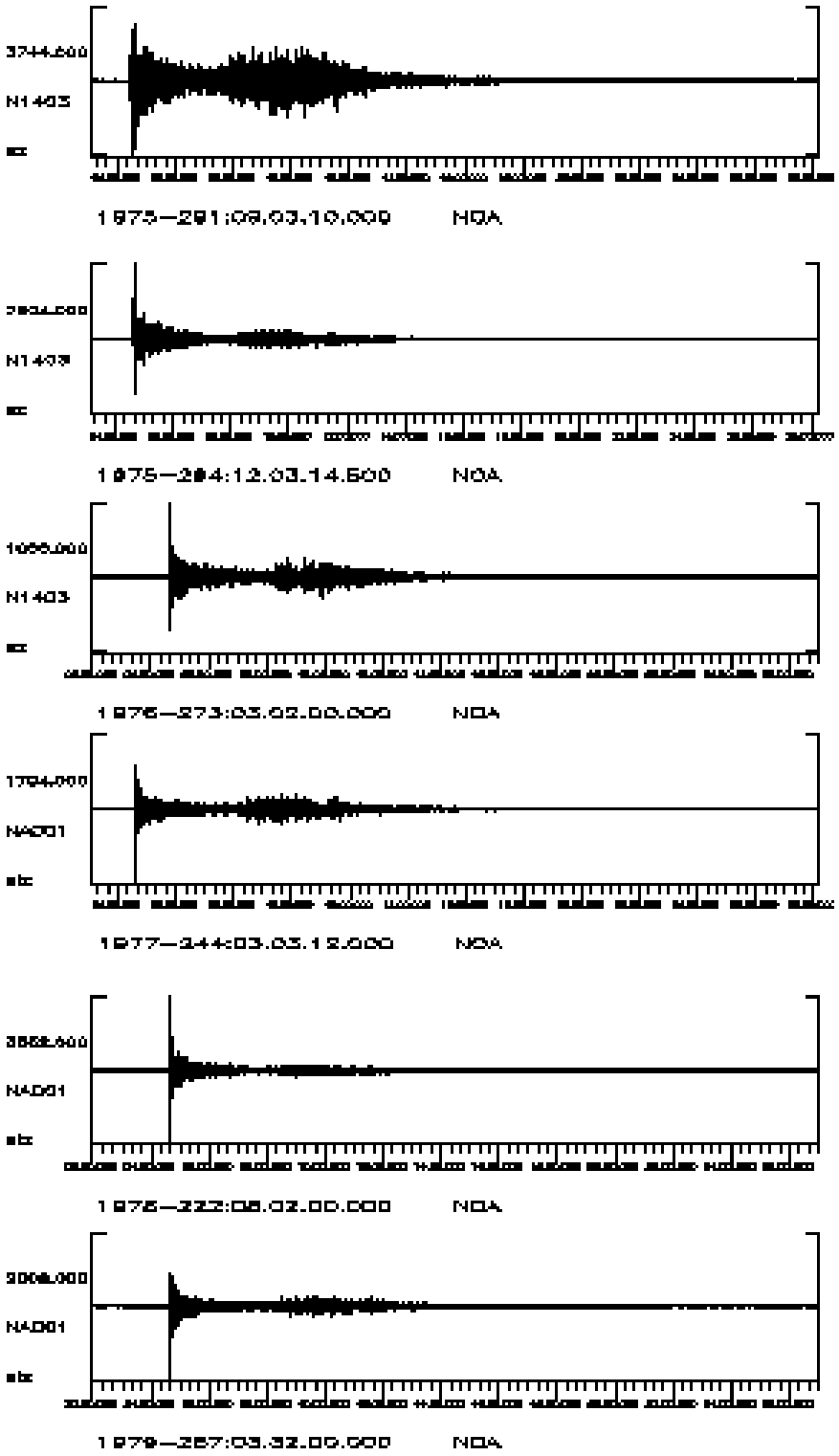

Fig. 5. Data examples of low gain unsaturated short period channels from events where the other short period channels are saturated.

For all data on this CD-ROM, system responses are available in the form of FAP (Frequency-Amplitude-Phase) files. Epicenter information included in the data set is taken from Ringdal (1997).

CONCLUSIONS AND RECOMMENDATIONS

Efforts under this contract so far have resulted in the production of a CD-ROM containing records of Novaya Zemlya explosions recorded on the large-aperture NORSAR array. These data are now available to the research community. For other data, to be made available on CD-ROMs that will appear successively during the course of this two-year effort, we are continuing the extraction of waveforms from our tape library.

The effort will also include analysis of the data in the new data base. This analysis will focus on the following topics:

- Study of the P-to-S amplitude ratio as a function of path, frequency, source type and distance
- Spectrogram analysis of selected presumed underwater explosions and mining explosions at the Kola Peninsula to identify distinguishing characteristics of these events
- Special analysis for a few events with ground truth information using a comprehensive collection of waveform data to include an extended set of stations in the Fennoscandian-northwestern Russia region.

REFERENCES

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