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Royal Norwegian Council for Scientific and Industrial Research

PROGRESS REPORT
NORSAR PHASE 3

3rd Quarter 1972

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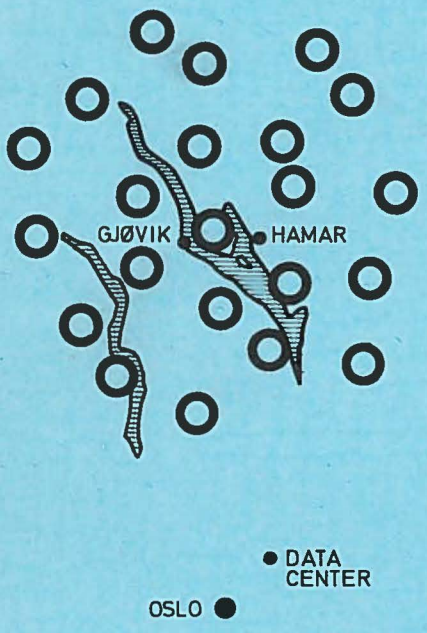
Prepared by E.S. Husebye
(Chief Seismologist)



NORWEGIAN SEISMIC ARRAY

NORSAR

P. O. Box 51. 2007 Kjeller – Norway

NTNF/NORSAR
P.O. Box 51
2007 Kjeller
NORWAY

NORSAR Report No. 37
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1 November 1972

The NORSAR project has been sponsored by the United States of America under the overall direction of the Advanced Research Projects Agency and the technical management of the Electronic Systems Division, Air Force Systems Command.

ARPA Order No. 800 Program Code No. IF10

Name of Contractor	:	Royal Norwegian Council for Scientific and Industrial Research
Date of Contract	:	15 May 1970
Amount of Contract	:	$ 2.051.886
Contract No.	:	F-19628-70-C-0283
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Project Supervisor	:	Robert Major, NTNF
Project Manager	:	Nils Marås
Title of Contract	:	Norwegian Seismic Array (NORSAR)

CONTENTS

I SUMMARY

The report covers the period 1 July - 30 September 1972 which is characterized by improving, estimating and simulating the array detection capability. Plans have been worked out for further centralization of the field maintenance and repair work. The operational performance of the field equipment has been satisfactory also in this reporting period. Computations of seismic noise levels on the long period instruments and short period subarray beams are now performed in the on-line Detection Processor. An average of 21.1 events per day were recorded by the array in the reporting period. Observed and predicted array event detectability in terms of 90 per cent cumulative magnitude threshold gave values of 4.03 and 4.01 units for the teleseismic zone.

II ADMINISTRATION AND ECONOMY

Plans have been worked out for relocating the field maintenance center at Brumunddal, the repair shop and storages at Kjeller into a single facility at Stange near subarray 04B. The moving will take place in Oct/Nov 1972. This centralization of the NORSAR field instrumentation maintenance and repair services is expected to give an annual saving of $2,500 in rental expenses.

Expenditures in the period 1 July - 30 September 1972

1.	Operation & Maintenance		
	1.1 Data Processing Center	$ 86,323	
	1.2 Field Installations	$ 36,351	
	1.3 Data Communications	$ 1,635	$ 121,039
2.	Research and Development		$ 15,426
3.	Administration and Support		$ 17,904
		TOTAL	$ 154,369

III ARRAY MONITORING AND FIELD MAINTENANCE

The performance of both the communication system and the field equipment has been very satisfactory in the reporting period. The preventive field maintenance project initiated

in the previous period is close to completion. Due to vacations, no further developments of the AM system have taken place. The Chief Analyst, O. Steinert, acted as a consultant from 3 August to 26 September during installation of a Danish WWSSN station at Danmarkshavn in north-eastern Greenland.

Array Monitoring (AM)

The NORSAR array monitoring schedules* require a number of tests and controls to be performed on a regular basis. However, due to the small number of disclosed distortions in the field instrumentation and communication links, an investigation of the possibility of modifying the present monitoring schedules is being prepared.

Array Maintenance

Besides normal maintenance, nine seismometers at different subarrays have been replaced as they failed to meet damping ratio and/or natural frequency tolerance limit specifications. The preventive maintenance of subarray vault constructions is completed on another nine subarrays, while three more will be checked this fall. The doors to the CTVs in the A and B rings have been modified to simplify the access. The seismometers listed below have been out of operation for the periods described due to cable breaks:

01A05 from 20-30 September
04B02 from 1-30 September
05B02 from 9-18 August and from 16-30 September
05B04 from 30 August to 30 September
13C04 from 7-9 August.

An FM communication channel transmitting the output from an extra SP seismometer at 05C to NDPC in analog form has

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* O. Steinert: NORSAR AM Operating Plan, NORSAR Tech. Report, 10 Dec 1971.

been implemented. The sensor output is recorded on heat sensitive paper at NDPC using a Helicorder RV-301.

IV COMPUTER CENTER OPERATION - DATA PROCESSING

Programming Efforts

The incoherent beamforming detector was implemented in the on-line DP system 10 July. The initial filter setting has been 1.6-3.2 Hz. Due to the sensitivity of this detector to local explosions and spikes in single sensor channels, it was not feasible to pass the incoherent detections to the Event Processor for further analysis. However, a method for automatically masking those detections which were clearly false alarms, was implemented 17 September and incoherent detections have been processed by EP since this date.

Program development within array monitoring continued in the reporting period, aiming at improving the statistics of the array performance. Computations of seismic noise levels for long period channels and short period subarray beams are performed by the on-line DP as of 1 August. These values are recorded at one minute intervals on the Detection Log Tape. Data cards for the tape library files are now produced by the on-line DP, thus simplifying and improving the tape library service.

Detection Processing

The Detection Processor (DP) was recording on-line for approximately 98% of real time in July, 99% in August and 98% in September. Total down time was thus 32 hours in the third quarter of 1972, most of which was caused by power breaks and hardware failures. No serious problems within the complete on-line system operation were encountered during the reporting period.

Event Processing

The number of detected events in the reporting period has been exceptionally large, namely, 547, 605, and 789 in July, August and September respectively. However, the many event processings resulted in an extraordinary load on the Calcomp plotter, and subsequent delays in the release of the weekly seismic bulletins. An additional plotter has been ordered, and in the meantime all signal amplitudes on the EP plots are scaled down by a factor of 2 in order to reduce the plotter time.

For the purpose of editing a daily bulletin of seismic events, we are developing a program in which the input data is read from the detection log tape. Thus, a daily event list will be available every morning and covering the previous 24 hours, even if the Event Processor (EP) is lagging behind its time schedule.

In the last few months a non-seismologist, but well-trained analyst, has performed the daily review of the EP output, which is the first step in the editing process of the weekly seismic bulletin. The experience here is good, although it is considered preferable to perform routine supervision of the daily analyst work. Extra review assistance is required during peak EP loads which naturally occur when many event are detected. Unfortunately, the same happens when faulty EP operations cause event data to accumulate.

Our contribution to the International Seismological Month project covering the period 20 Feb - 20 Mar 1972 and initiated by Lin. Lab., M.I.T., comprises off-line Dp and EP reruns of those events which were not reported by NORSAR. So far the events in question have been stacked on high rate tapes which are used as input to off-line DP processing. Whenever the event detection test is positive, EP reruns are requested.

V RESEARCH AND DEVELOPMENT

Research and development efforts have been focused on problems relevant to the NORSAR event detection capability as in the previous period. Moreover, a small attempt on multiarray processing is close to completion.

The work on coherent and incoherent beamforming has continued in the reporting period and special attention has been given to amplitude distributions. For example, applying Kolmogorov-Smirnov hypothesis tests on single sensor amplitude observations gave probabilities around 90 per cent for not rejecting a lognormal distribution when this was the true distribution. The subarray beam amplitudes as measured on the Event Processor plots exhibit a distinct pattern for the individual seismic regions. This has been verified by using nonparametrical statistical analysis* like the rank correlation test. The potential of incorporating single sensor amplitude information in the DP and EP systems is under investigation.

A Butterworth bandpass filter is used both during detection and event processing for additional noise suppression. The gain in signal-to-noise ratio (SNR) depends on the shape of the noise spectra, the dominant P-signal frequency and the latter's incremental probability distribution as seen by the NORSAR array. The problem of determining the best-in-average filter is synthesized in the frequency domain, resulting in a recommendation of a lower cut-off filter frequency of around 1.4 Hz.

The NORSAR event detectability is essentially governed by its operational noise level and the array beam deployment. Calculated cumulative probability distributions for noise level fluctuations and signal losses during DP processing, have enabled us to predict the 90 per cent cumulative event detectability for the array. A comparison between observed and predicted array event detectability in terms

* S. Siegel: Nonparametric Statistics. McGraw-Hill, 1956.

of 90 per cent cumulative magnitude threshold for eight teleseismic zones exhibited good similarity as the maximum difference found was 0.18 magnitude units.

The small multiarray data processing experiment is close to completion. The starting point was digitized P-signals from globally distributed WWSS stations. The signal envelopes were used for simulated global array beamforming and velocity filtering processing, and the results obtained were considered satisfactory. Correlation and coherency calculations of envelope similarity gave average values around 0.7-0.9 units. The signal envelopes are relatively long periodic as their spectra peak at frequencies around 0.1 Hz.

VI MISCELLANEOUS

During the reporting period a number of scientists, whose names are listed below, have visited NORSAR Data Processing Center, Kjeller, for special research purposes.

Dr. D.J. Doornbos, Utrecht University, Utrecht, The Netherlands, in the period 1 July - 11 September 1972.

Dr. I. Noponen, Seismological Laboratory, Helsinki, Finland, in the period 1 July - 30 September 1972.

Dr. R.M. Sheppard, Lincoln Laboratory, M.I.T., Cambridge, Mass., U.S.A., in the period 18-30 September 1972.

Dr. H. Ohlendorf, Institute für Geophysik, Der Christian-Albrechts-Universität, Kiel, W. Germany, with a group of 6 students, the 8th of September 1972.

In the reporting period 75 data tapes were sent to SAAC.

K.A. Berteussen, H. Bungum, H. Gjøystdal and E.S. Husebye participated in the 13th General Assembly of the European Seismological Commission in Brasov, Romania, 30 August - 5 September 1972. Altogether the NTNF/NORSAR group gave seven talks, which are listed below:

- K.A. Berteussen and E.S. Husebye: Seismicity in terms of event detection thresholds.
- H. Bungum: Event detection and location capabilities at NORSAR.
- H. Bungum: Array stations as a tool for microseismic research.
- H. Gjøystdal, E.S. Husebye and D. Rieber-Mohn: One-array and two-array location capabilities.
- H. Gjøystdal and E.S. Husebye: Noise suppression problems.
- E.S. Husebye and F. Ringdal: Multiarray processing problems.
- F. Ringdal and E.S. Husebye: Event detection problems using a partially coherent array.

Reports completed in the 3rd Quarter 1972:

H. Bungum: An evaluation of the routine processing of events at NORSAR, Proceedings, Seminar on Seismology and Seismic Arrays, NTNF/NORSAR, 30 September 1972.

H. Gjøystdal, E.S. Husebye and D. Rieber-Mohn: Simulating array event location capabilities, Proceedings, Seminar on Seismology and Seismic Arrays, NTNF/NORSAR, 30 September 1972.

E.S. Husebye: Progress Report, NORSAR Phase 3, 2nd Quarter, NORSAR Technical Report No. 34, 1972.

I. Noponen, E.S. Husebye and D. Rieber-Mohn: Extraction of P wave spectra using the NORSAR array, Proceedings, Seminar on Seismology and Seismic Arrays, NTNF/NORSAR, 30 September 1972.

J. Filson and H. Bungum: Initial Discrimination results from the Norwegian Seismic Array, Proceedings, Seminar on Seismology and Seismic Arrays, NTNF/NORSAR, 30 September 1972.