Royal Norwegian Council for Scientific and Industrial Research

EVENT DETECTION AND LOCATION CAPABILITIES AT NORSAR

by

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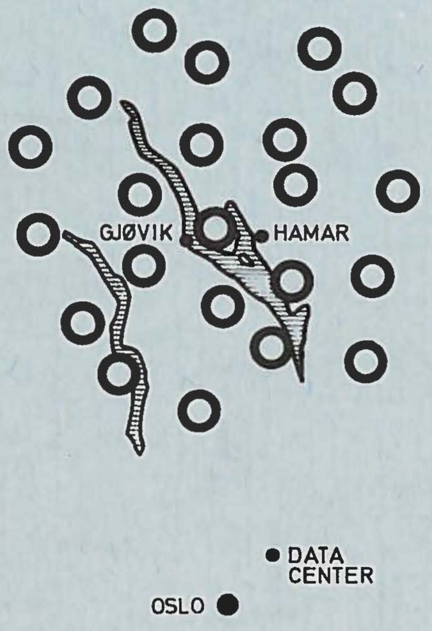

NORWEGIAN SEISMIC ARRAY

NORSAR

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NORWAY

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ABSTRACT

Data published in the NORSAR seismic bulletin between February and June 1972 has been studied in order to find estimates of the detectability and location accuracy at NORSAR. The detectability is calculated from empirical frequency-magnitude distributions, and the 90% cumulative detectability for the teleseismic zone ($30^{o}<\Delta<90^{o}$) has been estimated at m_b4.0, while values for different regions vary from 3.7 to 4.3. These are all NORSAR magnitudes. The magnitude bias between NOAA and NORSAR has been found to be 0.15±0.31 in the teleseismic zone. In this zone, the median location difference between NOAA and NORSAR has been estimated at 160 km, with values for different regions ranging from 130 to 340 km.

INTRODUCTION

The Norwegian Seismic Array came into full operation in the first months of 1971. The array, including the routine data processing, is described in detail by Bungum et al (1971). Fig. 1 shows the essential parts of the data processing system at NORSAR. The Detection Processor first takes care of the recording of all data on magnetic tapes. Then, the NORSAR SP data is processed in real time in search of seismic events, and a queue of detections is created. Some of these detections are later selected for further analysis by the off-line Event Processor, which produces an automatic seismic bulletin. This bulletin is reviewed daily by analysts, and changes are often made before the bulletin can be distributed.

Since 1 May 1971 a reviewed seismic bulletin has been created on a daily basis at NORSAR. This paper is concerned with an evaluation of the data presented in that bulletin, and will be concentrated on the ability of the

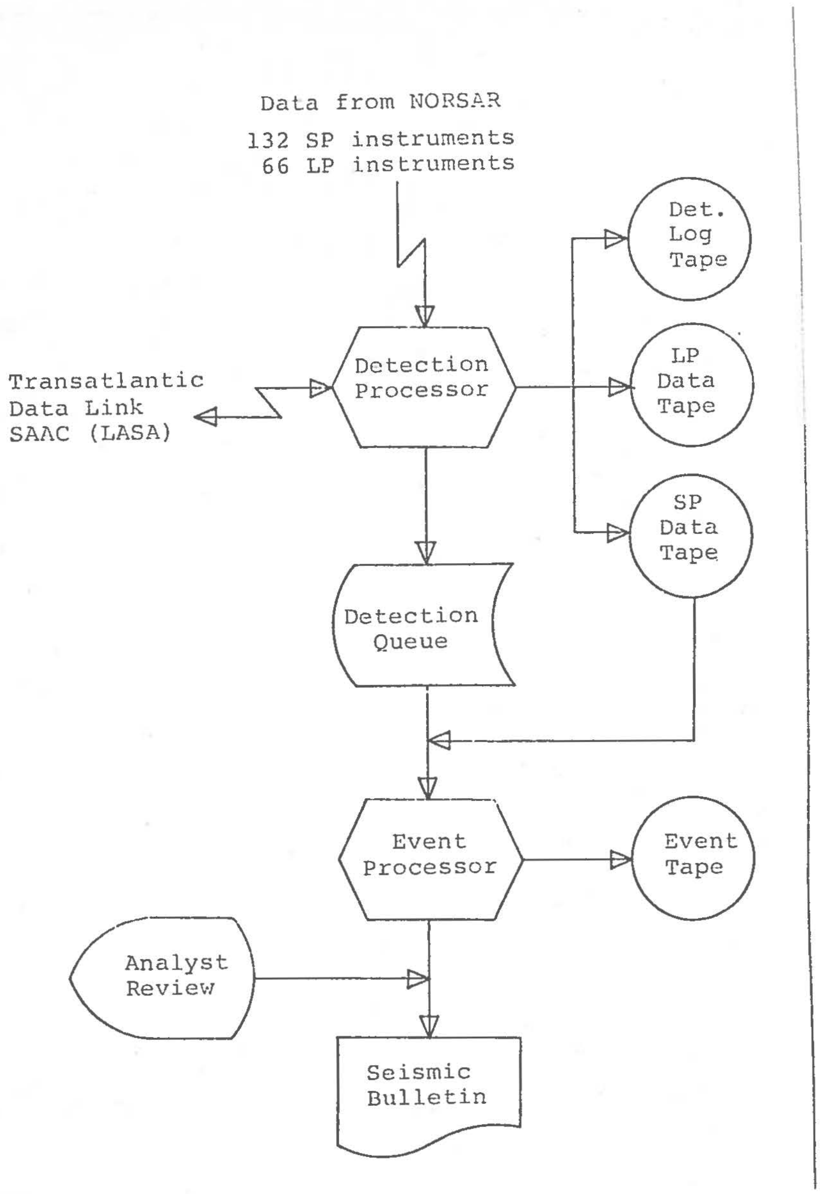

Fig. 1 Schematic view of the NORSAR data processing system.

array to detect and locate seismic events, estimated through a statistical analysis of the data in the seismic bulletin.

DETECTABILITY

Detectability as used in this paper can be defined as the long term operational ability to report, with epicentral information, the occurrence of seismic events. The term detectability is therefore used mainly for notational convenience.

Work continues steadily in order to improve the performance of the array. A number of changes have significantly improved both the detectability and the location accuracy. The main changes are: (1) improved analyst performance, (2) a new array beam deployment as of 14 Dec 1971, (3) on-line filter change from 0.9-3.5 Hz to 1.2-3.2 Hz as of 6 Jan 1972, and (4) new time delay and location corrections as of 27 Jan 1972. The effect of these changes on the detectability can be seen in Table 1, which shows the monthly number of events reported by NORSAR for the time period May 1971 - October 1972. Also given is the number of events reported by NOAA and the number reported by both institutions. The number of reported events is, of course, also dependent upon other factors, first of all time variations in seismicity and long term variations of the noise level.

One of the aims in the analysis work has been to keep the false alarm rate in the seismic bulletin at a low level. This is not possible unless a large number of true detections are left unreported. Some of these could have been included by devoting more time and effort to the analysis, and some could probably be confirmed through a study of the bulletins from other networks.

NUMBER OF EVENTS

Month	NORSAR	NOAA	Common
1971			
May	230	330	122
Jun	264	277	113
Jul	415	591	184
Aug	320	387	136
Sep	334	359	161
Oct	244	381	150
Nov	154	289	90
Dec	280	368	175
1972			
Jan	283	393	168
Feb	379	393	215
Mar	424	354	187
Apr	605	348	225
May	505	395	163
Jun	470		
Jul	547		
Aug	605		
Sep	742		
Oct	496		

TABLE 1

Number of events reported by NORSAR, NOAA and by the two institutions in common.

The number of events N above a given magnitude m, within a certain time period, is generally assumed to follow the relationship

$$\log N = A - b \cdot m$$

both for the entire world and for more limited geographical regions. On this assumption, empirical frequency-magnitude distributions would then make it possible to determine the parameters A and b. Fig. 2 shows such a distribution, both incremental and cumulative, for the

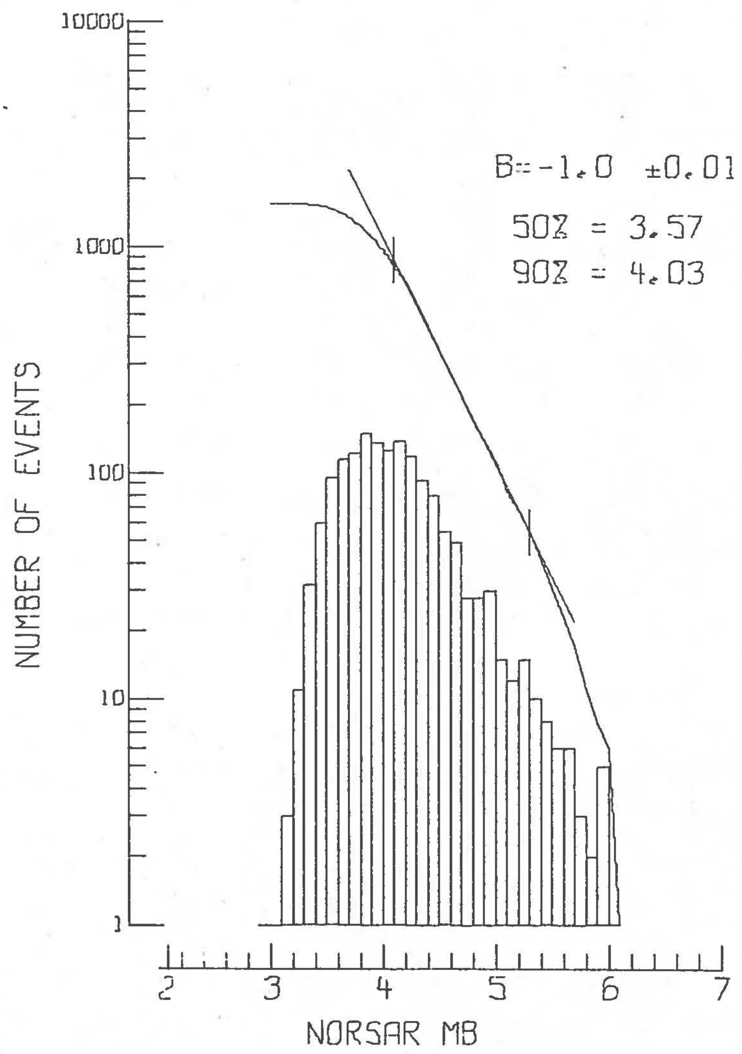

Fig. 2 Interval and cumulative frequency-magnitude distribution for data from Feb-Jun 1972, range 30-90 deg. Straight line is a least squares fit through data within bars.

NORSAR teleseismic zone ($30^{o}<\Delta<90^{o}$). The slope has been estimated by fitting a straight line, in a least squares sense, through the straight part of the cumulative frequency-magnitude curve. Then, the 50% and 90% levels for detectability are determined, based on computation of the assumed number of missed events at any particular magnitude. As Fig. 2 shows, the NORSAR teleseismic data from Feb-June 1972 has a slope of $b = 1.00 \pm 0.01$, and the 50% and 90% detectability levels are m_b 3.6 and 4.0 respectively.

It is important to point out that the magnitudes which are quoted above are all NORSAR estimates. In order to facilitate comparisons with other networks, the relation between NORSAR and NOAA magnitudes has also been investigated. Another point worth noticing is that by presenting data from the entire teleseismic zone, one is combining data with possible different statistical distributions. Therefore, all the results are also presented regionalized, where the regions are defined in distance and azimuth from NORSAR, as given in Table 2.

Region		Regional limits (deg)		Magnitude threshold			Magnitude bias		Location difference		
No	Name	Azimuth	Distance	Events	50%	90%	Events	NOAA-NORSAR	Events	50%	90%
A		0-360	30-90	1555	3.6	4.0	848	0.15±0.31	509	160	510
A1	Atlantic	180-260	30-90	88	3.6	4.3	13	0.45±0.28	11	340	780
A2	N. America	260-340	40-90	114	3.8	4.2	100	0.20±0.33	61	260	810
A3	Aleutians	340-15	30-90	131	3.4	3.9	119	0.17±0.35	57	150	370
A4	Japan	15-70	50-90	738	3.7	4.1	441	0.10±0.29	271	130	530
A5	C. Asia	40-110	30-60	211	3.2	3.7	89	0.20±0.34	43	130	270
A6	Iran	110-180	30-90	262	3.5	3.8	39	0.23±0.29	53	180	520

TABLE 2

Regionalized results for magnitude thresholds (NORSAR m_b), NOAA/NORSAR magnitude bias and NOAA/NORSAR location differences. The data for magnitude thresholds is from Feb-June 1972, except for region A1 with data from May 71-June 72. The data for magnitude bias is all from May 71-June 72, while the data for location differences is from Feb-May 72.

The regionalized results for the magnitude thresholds are all listed in Table 2. As one can see, the 90% detectability level is m_b 4.0 when all teleseismic data is used, while the values for different regions vary from 3.7 in Central Asia to 4.3 on the Mid-Atlantic Ridge. As mentioned above, this cannot be fully evaluated before the possible magnitude bias between NORSAR and some known reference, say NOAA, has been investigated. Fig. 3 shows the NOAA/NORSAR magnitude difference as a function of epicentral

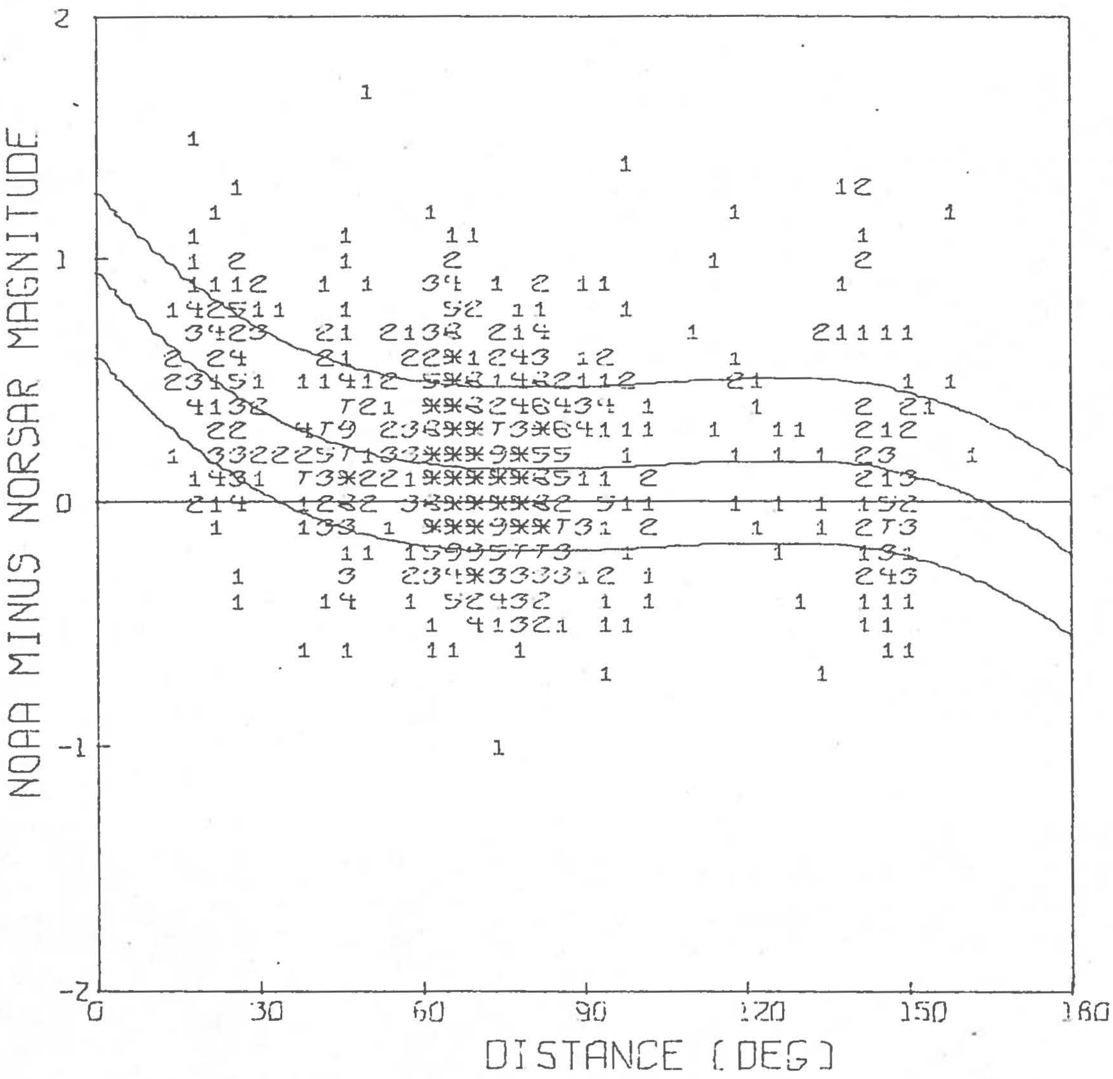

Fig. 3 NOAA/NORSAR magnitude differences vs. epicentral distance for data from May 71-March 72. The curves represent a third degree least squares fit through data, with upper and lower bounds (STD).

distance, where a clear negative bias in the NORSAR data is observed for epicentral distances smaller than 30°. A likely explanation of that bias is the fact that magnitude is measured on the array beam, and more local events have, due to poor coherence across the array, a significant beamforming loss which is not compensated for in the magnitude calculation. As Fig. 3 shows, the scatter in the magnitude data is quite large. Table 2, which gives all the detailed results also for the magnitude bias, shows a bias of 0.15 ± 0.31 for all data within 30°-90°, while the different regions have values ranging from 0.10 in Japan to 0.45 on the Mid-Atlantic Ridge. The scatter in the data is approximately of the same size for all regions.

Now, if one should express the NORSAR magnitude thresholds in terms of some "NOAA equivalent magnitude", one would have to add the bias to the threshold values in Table 2. By doing so, one would get a 90% level of m_b 4.2 for all data within the teleseismic zone, with values for different regions ranging from 3.9 in Central Asia to 4.7 on the Mid-Atlantic Ridge.

It is important to keep in mind when reading Table 2 the special definition of detectability given above. There could easily be a significant difference between the operational and the optimum ability to detect and report events. Another factor of significance is that some of the regions presented in Table 2 so far have not very much data. The regional differences are, however, so large that the trends are quite clear.

One should also notice that the data presented herein is mainly from a time of year when the background noise level is moderate. The noisiest time period so far has been October-December 1971, a period which also shows a minimum in the number of reported events (Table 1). This has been found from an extensive study of the long term short period noise level within the on-line processing frequency band. For the time period January-May 1972, the median noise level within the frequency band 1.2-3.2 Hz has been found to be 1.15 mμ. Some uncertainties apply to the ground motion conversion in this case, while the estimates for the relative variations are more accurate. The 90% level is 2.0 dB above the median and the 10% level is 2.7 dB below, and the long term average can be well approximated by a Gaussian distribution.

LOCATION DIFFERENCES

The location differences between NORSAR and NOAA have also been studied. Since new location corrections were implemented in January 1972, only four months of data were available for investigation. Fig. 4 shows the location differences within the teleseismic zone, incremental and cumulative. From curves like that, the 50% and 90% levels of location differences have been found, and the detailed regionalization results are also given in Table 2. The teleseismic zone shows a median location difference of 160 km, while Japan and Central Asia as the best regions have 130 km and North America as the poorest has 340 km. The expression location difference (and not location error) has been used because the comparison is made between two estimates which both are affected by uncertainties. Since the NOAA standard error of location is in the range of 10-40 km, this clearly becomes significant for regions where Table 2 shows a location difference of about 120 km, as for Japan.

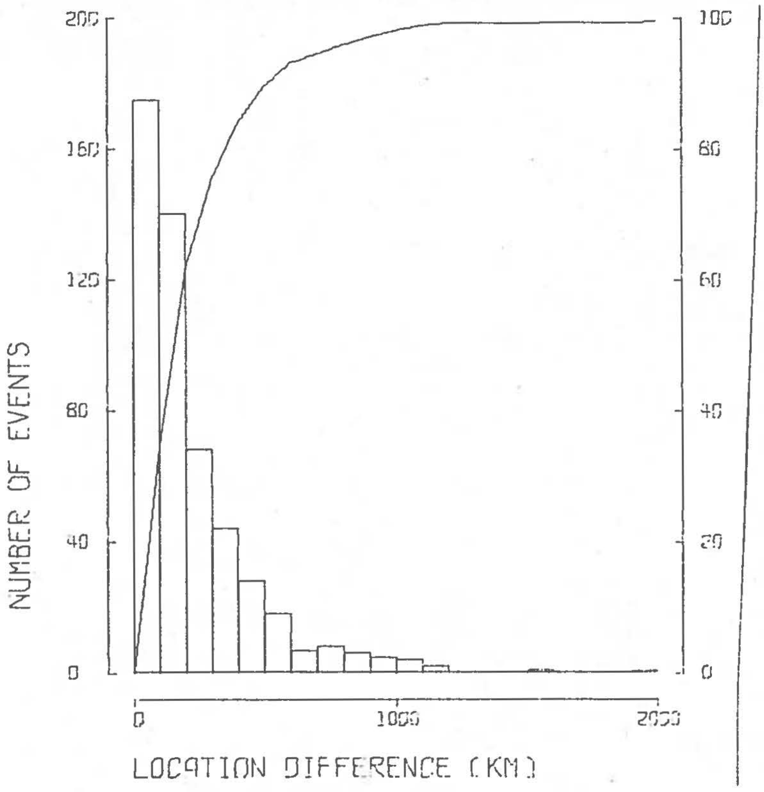

Fig. 4 Interval and cumulative distribution of location differences between NOAA and NORSAR for data from Feb-May 1972, range 30-90 deg.

The regionalized results for the location differences would also here have some uncertainties caused by the limited amount of data. Another factor worth mentioning is that the comparison is made only for events above the NOAA reporting threshold, which for some regions is significantly higher than the NORSAR threshold. One should expect that the location error for small events on an average is somewhat larger, but not much, since the error in most cases would still be within the beam radius, typically 2-3 degrees.

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