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7.1 Global event detection performance during GSETT-2

Introduction

During the period 22 April to 9 June 1991, the Conference on Disarmament's Group of Scientific Experts carried out the main phase of its Second Technical Test (GSETT-2) (Reference: CD/1144). A total of 34 countries participated in this test, providing seismic data for 42 consecutive data days from 60 stations distributed around the globe (Fig. 7.1.1). Data were recorded and processed at National Data Centers, and parameters as well as waveform segments were transmitted to four experimental International Data Centers (EIDCs) for further analysis. Results of these analyses were summarized in event bulletins, which were transmitted back to participants from the EIDCs.

An important aspect of the performance evaluation of GSETT-2 is the completeness and quality of the final event bulletin (FEB). This seismological output is closely linked to the actual spatial distribution of seismic stations. For GSETT-2, a very heterogeneous global coverage yielded large regional variations in detection threshold. About one half of the participating stations were situated in and around Europe, consequently a large number of small events were detected, mainly quarry blasts and rock bursts of magnitude 1 to 4. On the other hand, in many areas of the globe where the station distribution was very sparse, only larger earthquakes were detected.

In this paper a preliminary assessment is made of the global event detection capability during GSETT-2. By comparing the FEBs to the bulletins of the National Earthquake Information Center (NEIC), we obtain detection statistics separately for the northern and southern hemisphere. We make no assessment in this paper of the location precision of the GSETT-2 network solutions. In sections 7.2 and 7.3, a more detailed discussion of the GSETT-2 performance in some selected regions is presented.

Method

The method used for detectability estimation has been described by Ringdal (1975), and is briefly summarized as follows:

1. A reference system, independent of the system to be evaluated, is used. Event lists and magnitudes from this reference system are compiled.
2. For each reference event, a comparison is made to see if the system to be evaluated has detected the event.
3. Based on the number of detections/no detections at each magnitude, a maximum likelihood approach is made to estimate a "detection curve" of the form

$$G(m;\mu,\sigma) = \int_{-\infty}^{m} \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{(x-\mu)^2}{2\sigma^2}} dx \quad (1)$$

Here $G(m;\mu,\sigma)$ denotes the incremental probability of detection, given event magnitude m. The detection curve is completely characterized by the parameters μ and σ. The 50 and 90 per cent incremental detection thresholds (μ_{50} and μ_{90}) become:

$$\mu_{50} = \mu \quad (2)$$

$$\mu_{90} = \mu + 1.29 \cdot \sigma \quad (3)$$

It should be noted that while the method assumes that the reference network provides independent event estimates, it is not necessary to have a complete event catalogue in any given magnitude range. Thus the reference events actually selected are assumed to be randomly sampled from the total number of events available, much in the same way as opinion survey polls attempt to address randomly selected subsets of the population. The resulting detectability estimates will be representative for the region considered only to the extent that the reference event set is representative.

When applying the method in practice, it is often desirable to restrict the range of values of σ when maximizing the likelihood function. This is done to reduce the influence of outliers in the data set. In this paper we have restricted σ to the interval 0.10-0.80 m_b units.

Reference network

The reference data base for this study has been the monthly bulletin from the U.S. National Earthquake Information Center (NEIC).

For the main phase of GSETT-2, upon which this analysis is based, the reference NEIC catalogue contained 829 seismic events with an assigned m_b value. The magnitude range was 2.6-6.4.

The criteria used to determine if a given reference event had been detected by the GSETT-2 network was as follows:

- Epicenter difference at most 3.0 degrees
- Origin time difference at most 60 seconds.

These criteria are the same as those used when merging FEB bulletins.

Results

The initial results from the detectability study are presented in Figs. 7.1.2-7.1.4. Each figure is based upon analyst comparison of the reference events with bulletin reports according to the criteria defined above.

Fig. 7.1.2 shows detectability statistics for the entire globe taken together. The 50% and 90% thresholds are estimated at m_b 3.7 and 4.7, respectively. In view of expected regional differences, we will look at the northern and southern hemisphere separately.

Fig. 7.1.3 shows results for the northern hemisphere. The estimated 50% and 90% thresholds are m_b 3.4 and 4.4, respectively. We observe that there is a relatively large range in detectability; thus there are detected events below $m_b = 3.0$, and non-detections as high as $m_b = 5.0$. This is of course due to the large regional variations in GSETT-2 network capability.

It is of interest to discuss in some details a few of the *non-detected* events of relatively large magnitude: Table 7.1.1 lists all NEIC-reported events of $m_b \geq 4.5$ in the northern hemisphere that were not detected according to the criterion given above. The following comments apply:

- Events 2, 4, 8, 9, 14 and 15 were not reported by any EIDC during GSETT-2.
- Events 5, 6, 7 occurred during the W. Caucasus aftershock sequence, and were not reported originally during GSETT-2 due to heavy workload. They were properly reported after reprocessing.
- Events 1, 3, 10, 11, 12, 13 and 16 were reported during GSETT-2, but the FEB location differed too much from the NEIC location to satisfy the "event matching" criterion.

Note that in some cases (1, 3, 13) one EIDC had a solution that was significantly closer to the NEIC solution than the one selected for the FEB.

In at least one case (event 12) it appears that the FEB solution was significantly better than the NEIC solution.

Fig. 7.1.4 shows results for the southern hemisphere. The estimated capabilities are considerably less than for the northern hemisphere, with 50% and 90% thresholds of $m_b = 4.1$ and 5.1, respectively.

Again, it is of interest to discuss some of the largest non-detected events: Table 7.1.2 lists the NEIC-reported events of $m_b \geq 5.0$ in the southern hemisphere that were not detected. The following comments apply:

- Events 1 and 2 were not reported by any EIDC during GSETT-2.
- Events 3, 4, 5, 6, and 7 were reported during GSETT-2, but the FEB location differed too much from the NEIC location to satisfy the "event matching" criterion.

Note that for events 3 and 5, there were EIDCs that had solutions very close to the NEIC solution, but they were not selected for the FEB.

In assessing these results, it must be remembered that "detection threshold" is closely tied to "location accuracy". The more relaxed our location requirements are, the "better" the detection capability will appear to be. Our results here represent what we think is a reasonable compromise for a global network of the type employed in GSETT-2. It would be of great interest to compare these results to theoretical network capability studies under the different assumptions and conditions in the models.

In this study, all magnitudes refer to reported NEIC network m_b values. The question of a possible bias in network m_b estimates has not been addressed here, but would need to be taken into account when comparing the results to theoretical capability studies.

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References

CD/1144 (1992): Report on the Group of Scientific Experts' second technical test (GSETT-2), Conference on Disarmament, Geneva.

Ringdal, F. (1975): On the estimation of seismic detection thresholds, Bull. Seism. Soc. Am., 65, 1631-1642.

No.	FEB	IDC	ORIGIN TIME	LAT	LON	DPT	NOB	MB
1	CSS	USGS	1991-113:08.58.47.700	9.97	-83.26	10	9	4.6
1	STO	STO	1991-113:08.58.48.100	13.14	-86.81	2	9	3.4
2	CSS	USGS	1991-114:19.11.45.700	31.81	104.54	33	10	4.7
3	CSS	USGS	1991-117:14.48.42.400	17.18	-100.30	53	38	4.6
3	STO	STO	1991-117:14.48.41.500	16.76	-103.80	1	11	4.0
4	CSS	USGS	1991-119:00.51.44.800	13.88	-92.59	62	7	4.6
5	CSS	USGS	1991-119:09.59.24.000	42.62	43.40	10	64	4.6
6	CSS	USGS	1991-119:10.19.41.300	42.22	43.59	10	24	4.5
7	CSS	USGS	1991-119:11.10.11.900	42.58	43.90	10	67	4.7
8	CSS	USGS	1991-119:18.28.17.500	51.00	-178.38	33	12	4.7
9	CSS	USGS	1991-122:06.54.14.300	34.80	26.48	20	32	4.6
10	CSS	USGS	1991-130:05.31.04.400	10.04	124.16	84	5	4.6
10	MOS	STO	1991-130:05.31.08.100	10.48	128.52	88	6	3.4
11	CSS	USGS	1991-136:20.31.05.200	17.04	-102.31	33	35	4.6
11	CNB	WAS	1991-136:20.32.10.400	21.23	-102.99	367	13	3.4
12	CSS	USGS	1991-145:18.59.23.200	42.96	147.59	33	6	4.8
12	STO	CNB	1991-145:18.59.47.700	44.33	137.97	11	18	4.1
13	CSS	USGS	1991-146:17.28.01.300	27.05	99.75	33	9	5.0
13	MOS	MOS	1991-146:17.29.22.600	15.91	103.93	16	8	3.7
14	CSS	USGS	1991-147:12.02.25.700	32.92	56.33	33	5	4.6
15	CSS	USGS	1991-148:20.04.50.000	24.65	94.36	142	9	4.7
16	CSS	USGS	1991-152:06.01.48.700	1.65	123.25	10	7	4.7
16	CNB	WAS	1991-152:06.00.21.700	10.58	119.27	0	8	4.1

Table 7.1.1. NEIC-reported events of $m_b \geq 4.5$ in the northern hemisphere not reported in the FEB (using the event matching criteria given in the text). Whenever an FEB event is close to matching one of the NEIC events, it is listed below it.

o.	FEB	IDC	ORIGIN TIME	LAT	LON	DPT	NOB	MB
1	CSS	USGS	1991-112:19.18.43.500	-11.48	166.19	63	13	5.1
2	CSS	USGS	1991-116:05.25.24.800	-5.43	129.73	227	11	5.0
3	CSS	USGS	1991-128:08.51.40.300	-22.04	68.32	10	37	5.1
3	CNB	WAS	1991-128:08.52.43.900	-20.42	69.73	582	16	3.7
4	CSS	USGS	1991-130:23.30.44.500	-37.00	-98.93	10	10	5.1
4	MOS	STO	1991-130:23.31.03.000	-34.47	-96.46	1	6	4.1
5	CSS	SGS	1991-134:19.17.53.800	-57.72	-25.37	52	16	5.1
5	MOS	CNB	1991-134:19.18.26.800	-34.13	-28.39	1	11	4.3
6	CSS	USGS	1991-141:12.43.35.800	-7.25	129.43	58	14	5.0
6	STO	WAS	1991-141:12.43.02.100	-6.52	126.14	0	8	4.2
7	CSS	USGS	1991-153:11.08.11.200	-18.81	-173.17	33	22	5.2
7	STO	STO	1991-153:11.09.17.800	-19.97	-178.43	285	27	4.7

Table 7.1.2. NEIC-reported events of $m_b \geq 5.0$ in the southern hemisphere not reported in the FEB (using the event matching criteria given in the text). Whenever an FEB event is close to matching one of the NEIC events, it is listed below it.

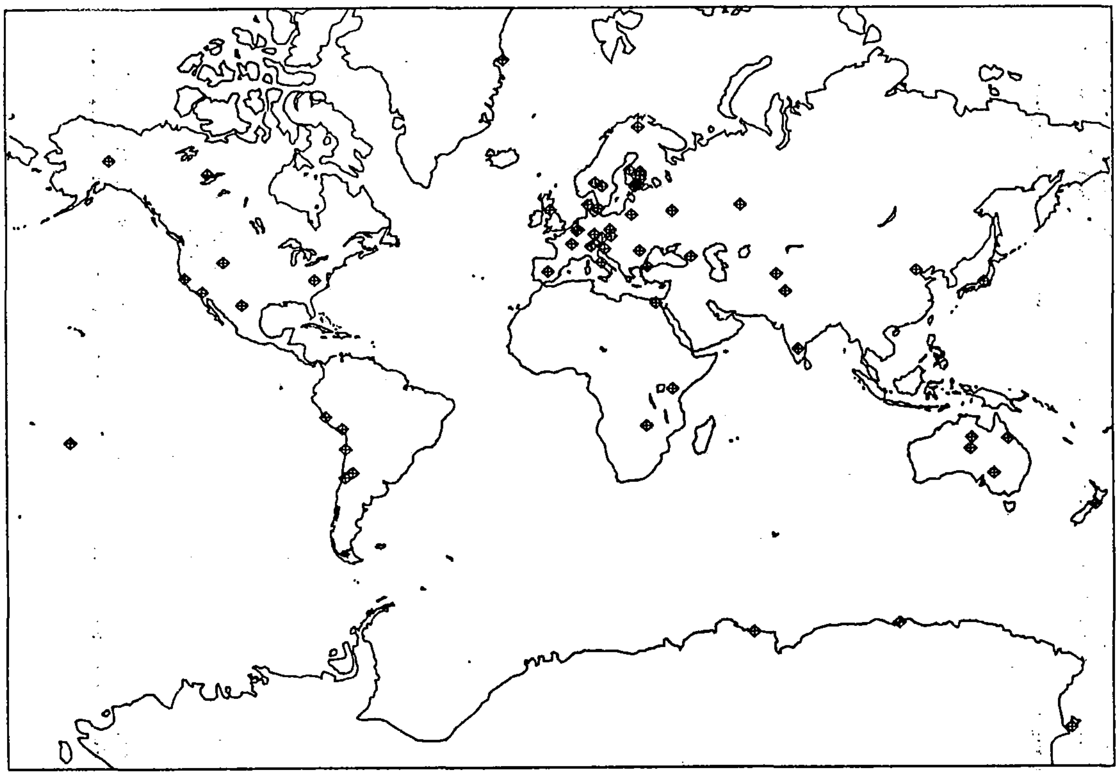

Fig. 7.1.1. Stations participating in the main phase of GSETT-2, April-June 1991 (after CD/1144). Detailed descriptions of station characteristics can be found in Group of Scientific Experts' Sourcebook for International Seismic Data Exchange, CRP/167.

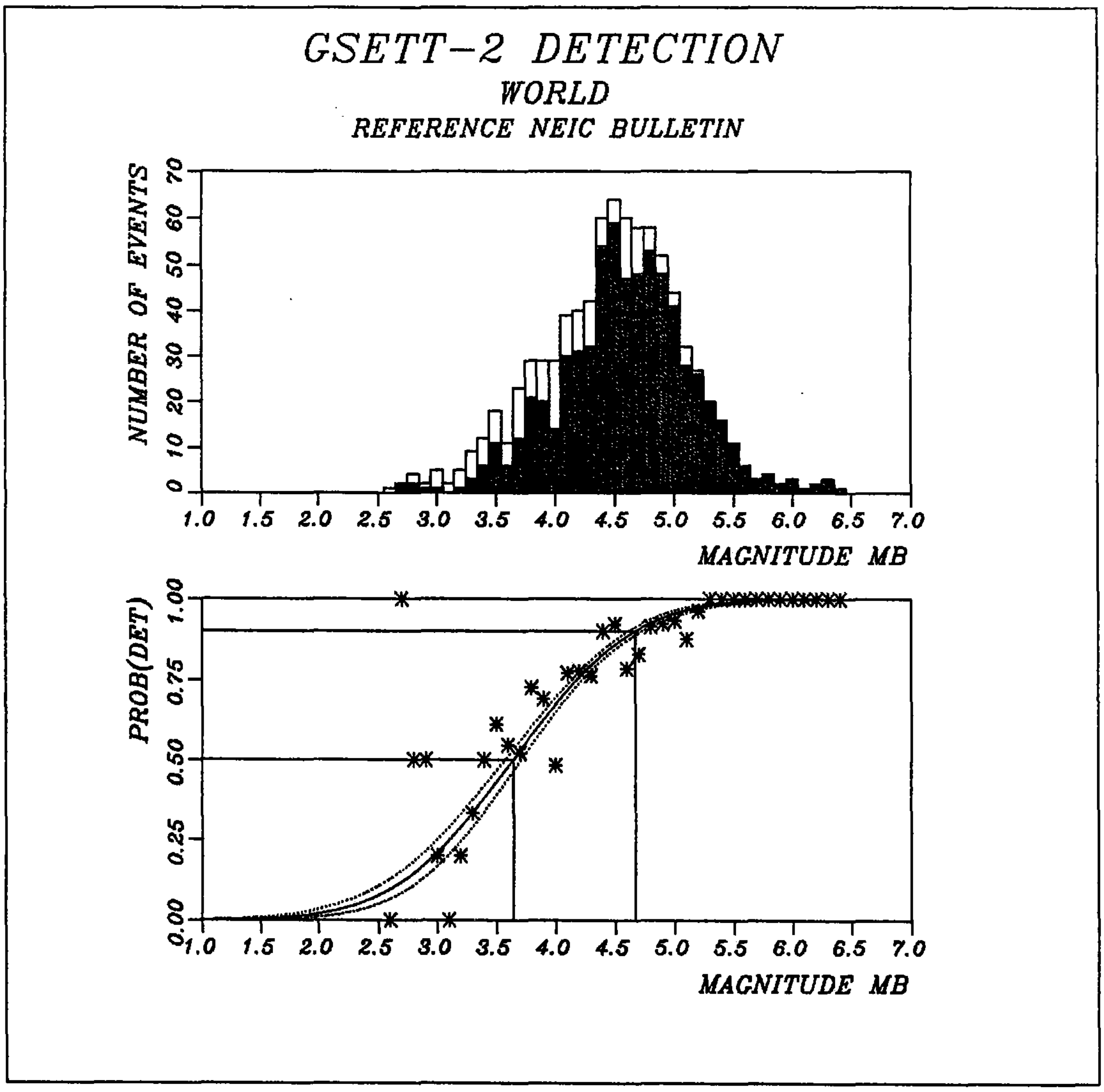

Fig. 7.1.2. Maximum likelihood detectability estimation for the GSETT-2 network, using the NEIC monthly bulletin as a reference. This figure shows statistics for the **entire world.** The upper half shows the reference event set and the number of events actually detected for each magnitude. The lower half shows the maximum likelihood detectability curve and its confidence limits. The actual percentage of detected events at each magnitude is also shown. The criteria for associating FEB events to NEIC events are given in the text.

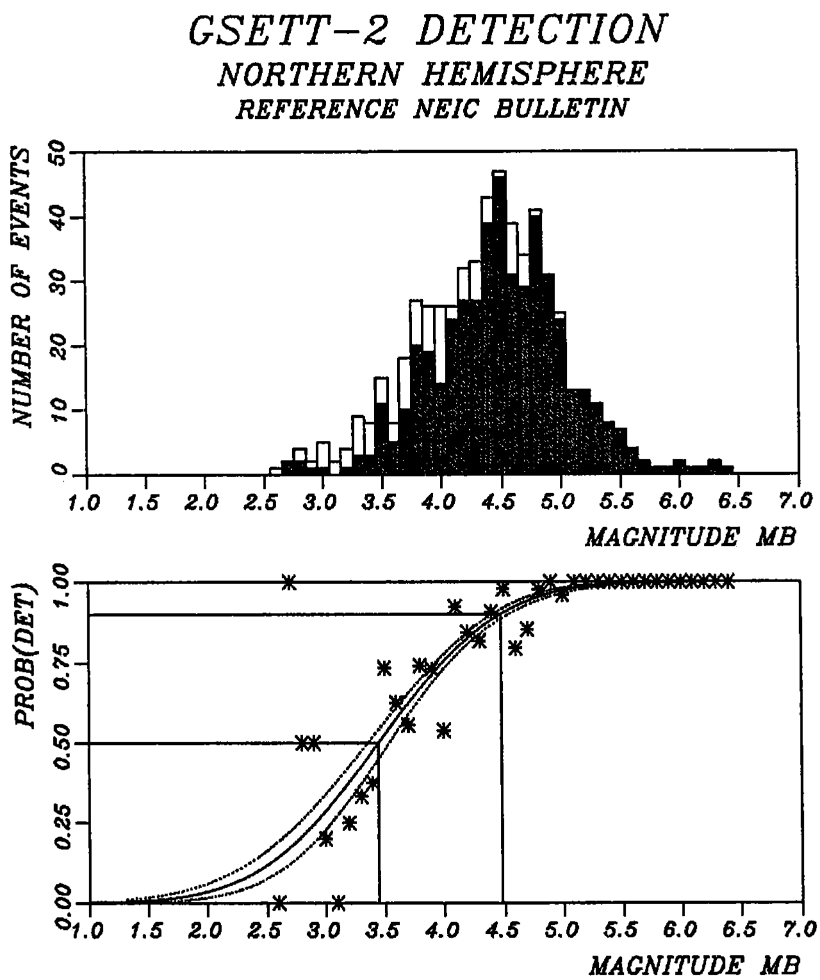

Fig. 7.1.3. Maximum likelihood detectability estimation for the GSETT-2 network, using the NEIC monthly bulletin as a reference. This figure shows statistics for the **northern hemisphere.** The upper half shows the reference event set and the number of events actually detected for each magnitude. The lower half shows the maximum likelihood detectability curve and its confidence limits. The actual percentage of detected events at each magnitude is also shown. The criteria for associating FEB events to NEIC events are given in the text.

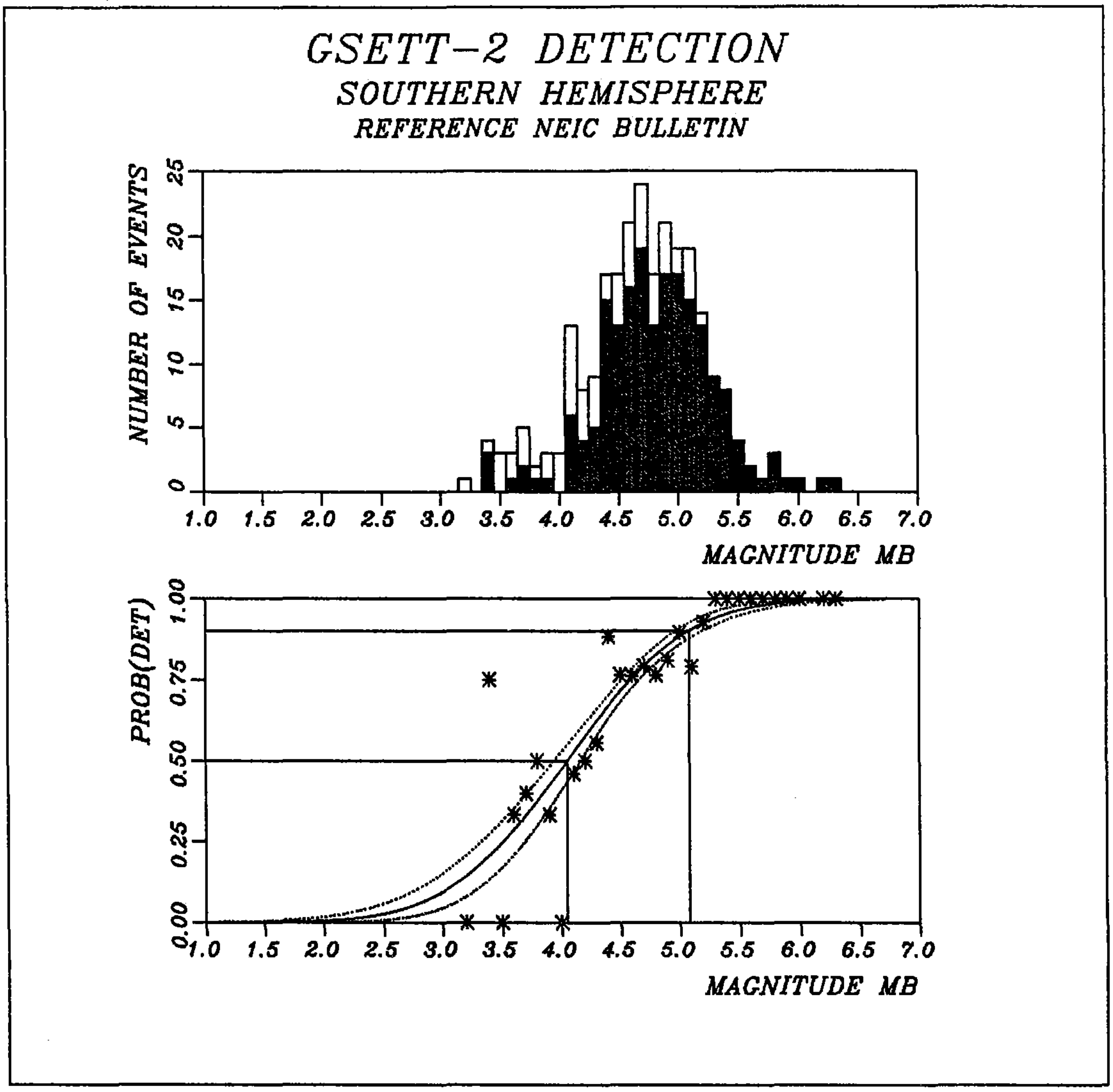

Fig. 7.1.4. Maximum likelihood detectability estimation for the GSETT-2 network, using the NEIC monthly bulletin as a reference. This figure shows statistics for the **southern hemisphere.** The upper half shows the reference event set and the number of events actually detected for each magnitude. The lower half shows the maximum likelihood detectability curve and its confidence limits. The actual percentage of detected events at each magnitude is also shown. The criteria for associating FEB events to NEIC events are given in the text.