DETECTION OF ISM EVENTS WITH THE YELLOWKNIFE ARRAY

by

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1. Introduction

In January 1972 a group of seismologists from several countries met in Cambridge, Massachusetts, to discuss problems related to the seismic detection and identification of underground nuclear tests. During this meeting it was proposed to conduct a cooperative experiment to establish the capabilities of existing seismic instrumentation for monitoring worldwide seismic activity. The period 20 February 1972 to 19 March 1972 was selected for the experiment, which became known as the International Seismic Month, or ISM. Lincoln Laboratories agreed to act as data center and clearinghouse and consequently published a sequence of Technical Summaries on the results of their statistical analyses of the reported data.

The Division of Seismology and Geothermal Studies was one of the most (if not the most) active contributors of data to the international effort. Partial results of our standard network contributions were written up by Basham, Shannon and Weichert (1973) and by Weichert (1975-b), who concentrated on the contributions and performance of the Yellowknife array (YKA). The most succinct outside evaluation of the YKA was considered to be the tabular detection statistics given by Lacoss, Needham and Julian (1974). In their Table II, reproduced in this report as Table II, they list YKA in second place in terms of reported events. Column 6, added by me, shows that the YKA false alarm rate was by far the lowest of all the important arrays.

In a recent publication, Needham (1975) investigated the detection capability of a subset of stations that contributed to ISM and found that a much smaller number of stations, i.e, 32 stations as compared to the almost 200 stations reporting to ISM, could generate essentially the same event list. Although YKA is included in the 32-station subset, it is disturbing to find the "final station probability" of YKA in Needham's Table 2, also reproduced in this report as Table 2, with 0.583 as one of the lowest of the more important arrays and stations. This apparent inconsistency between Tables 2 and II has led to further study of the YKA detection lists and the results are documented in this report.

2. YKA Event Lists

For an understanding of the following, the procedures followed in processing the YKA data for the ISM must be described. Initially, one pass over the data was made with the old array processing program in free search mode, and the event detections were reported to the Lincoln Laboratory Group. After receiving the first preliminary event list from the ISM data center, a second pass over our data tapes was made, searching only over a few minutes near the ETA's of ISM list events that were not detected during our first pass. This selective search and playback was done with filter settings different from pass I, usually 1 to 4 Hz, instead of 0.5 to 2 Hz. Events confirmed, or newly detected, were also submitted to the ISM data center. This constitutes 'rereading' in the terminology of Lacoss et al. (1974) and of Needham (1975).

A year later, after the CANSAM programs had been written and were running on the PDP11 in Ottawa, the ISM data were once more searched with the new system in order to test its performance, and to compare the newly developed logarithmic sum detector (Weichert 1975-a) with the conventional linear sum detector. When referring to the ISM-CANSAM detections, I shall specifically mean the log-detected events, since the linear detector was used only for about 16 days.

3. YKA Detection for $4.6 \leq m_b < 4.7$

Needham (1975) selected the interval m_b 4.6-4.7 for his station detection statistics because this happens to be closest to the 90% detection probability for his network of stations. It is perhaps unfortunate that he has chosen this interval, since YKA detection seemed to be particularly bad near this magnitude, as indicated by Figure 1, although Needham had certainly no intention of minimizing the YKA contribution. I should point out that the background events in Figure 1 taken from Weichert (1975-b) are worldwide ISM events as given by a non-final bulletin and that the plotted CANSAM detections are also world-wide. Figure 1 has, therefore, no direct bearing on Needham's statistics in Table II, which is restricted to events at less than 90° epicentral distance.

Table 1 lists the 38 ISM events in the magnitude range 4.6-4.7 found in the final ISM Bulletin (Lacoss et al., 1974). Out of these, only 20 events are at less than 90° epicentral distance from Yellowknife, not 24 as indicated in Table 2. In our free-search pass I, we detected

15 of these 20 events, and confirmed another 2. Since Needham includes reread events where available (c.f. the starred footnote "Reread Stations"), I must include the 2 pass II events in column 6, and the "Final Station Probability", column 7, comes to 0.85, not 0.583. It is interesting to consider the reasons for missing events: one event was missed because of tape problems; the other two were at near distances, 23° to 26°, in California and Unimak, where high sensitivity networks exist. Conceivably, the magnitude of these events is over-estimated; on the other hand, crustal complexities lead to poor detection at such short distances, which are therefore not normally considered 'Third Zone'.

The final point of interest is the CANSAM detection of these events. Both, the California and Unimak events, were detected, while only one pass II event was missed, and a second event, no. 640, was not resolved automatically from the coda of the previous event because the system was still in trigger status. Thus the "reread" detection probability for CANSAM is 0.90 in the 4.6-4.7 interval.

4. CANSAM Detection at Less Than 90° Epicentral Distance

For future reference, I have produced an updated version of the already published Figure 1. This is shown in Figure 2, and contains only the ISM events at less than 90° distance from Yellowknife. The YKA detection must here not be understood in the sense of Needham, i.e., events confirmed by rereading are not included, giving a total of 18 events. It is clear that the YKA detection probability sinks below 90% around m_b 4.3, and only below m_b 4.0 does it dip below 70%.

5. Conclusion

The low "Final Station Probability" for YKA in Needham's (1975) Table 2 is an unfortunate accident. In fact, YKA's real performance is better indicated by its position in second place in this Table 2, by Table II in Lacoss et al. (1974), and by Figure 2 of this report. In the interval $4.6 \le m_b < 4.7$, Needham's probability should be 0.85 for the actual YKA contributions. Had CANSAM been running at that time, the automatic probability would have been 0.90, and 0.95 with rereading. In all cases, a loss of 0.05 was due to system malfunction, which is close to the average downtime percentage during 1974.

REFERENCES

Basham, P.W., W. Shannon and D.H. Weichert, (1973). Notes on Canadian Seismograph Station contributions to the ISM Detection Capability, Technical Memorandum 73/3, June 1973, EPB, DEMR, Ottawa.

Lacoss, R.T., R.E. Needham and B.R. Julian (1974). International Seismic Month Event List, Technical Note 1974-4, Lincoln Laboratories, MIT.

Needham, R.E. (1975). Detection capability of a 32-station network, Technical Note 1975-42, Lincoln Laboratories, MIT.

Weichert, D.H. (1975-a). Logarithmic beamforming for suppression of false alarms in seismic detection, Geophys. Res. Lett., 2, No. 4, p. 121.

Weichert, D.H. (1975-b). The role of medium aperture arrays: the Yellowknife system, in Exploitation of Seismograph Networks, K.G. Beauchamp, ed., NATO Adv. Study Inst., Series E, No. 11, 167-195.

TABLE 1.

ISM Events in Magnitude Range $4.6 \leq m_b < 4.7$

ISM no.	Date	Time	Location	ΔYKA (deg.)	Detection in Pass:			Remarks
2	20-2-72	01 08 32	-40.06, 45.98	154.7	I	C		C=CANSAM
16	20	04 30 42	20.83, 120.19	86.4	I	C	<	90°
30	20	10 04 15	18.18, -95.16	46.3	I	C	<	
43	20	14 10 11	-21.52, 69.41	102.6	II	C		
76	21	06 32 07	-8.41, 158.99	95.7	I	C		
100	21	23 42 13	-11.25, 166.27	94.9	I	C		
147	23	11 36 01	51.86, 171.96	39.0	I	C	<	
165	23	23 13 42	35.60, 53.17	81.8	I	C	<	
191	24	15 56 49	36.39, -121.14	26.4	I	C	<	
192	24	16 05 01	-8.66, 150.00	100.1	-	-		
204	25	01 49 02	46.84, -27.69	48.7	I	C	<	
250	26	18 55 51	24.50, 102.46	88.4	II	C	<	
294	28	12 07 03	-37.56, 179.51	112.8	-	-		Tape out
341	29	09 50 08	33.56, 139.37	67.6	II	C	<	
402	01-3	03 51 52	11.37, -62.33	63.1	I	C	<	
444	02	03 16 09	-1.98, 99.65	114.5	-	-		
468	02	12 10 37	20.63, 122.44	85.8	I	C	<	10 sec late C:16 sec early
520	03	23 50 04	40.18, -125.23	23.2	-	C	<	California
529	04	04 00 07	40.07, 79.09	77.2	I	C	<	
640	07	14 01 21	14.50, -94.05	50.1	I		<	30 sec late in trigger status
656	08	01 50 33	14.79, -93.65	49.9	I	C	<	
672	08	15 23 00	54.53, -162.75	25.8	-	C	<	Unimak
682	08	21 49 15	27.97, 56.55	89.6	I	C	<	
693	09	11 48 37	53.17, -166.87	28.6	I	C	<	
700	09	19 45 08	21.20, 142.35	77.3	I	C	<	
716	10	02 22 38	33.39, 140.78	67.2	I	C	<	
718	10	02 57 53	-7.86, 156.47	96.4	I	C		
732	10	13 56 26	-10.80, 161.61	96.6	II	C		
735	10	15 53 30	-24.12, 178.05	101.3	-	-		
760	11	15 54 59	-15.22, -174.76	90.5	II?	-		
814	13	19 59 18	-5.61, 128.56	107.1	-	-		
834	14	08 06 50	-22.76, 171.58	102.8	-	-		
838	14	11 07 30	38.64, 141.59	62.4	-		<	tape problem computer out
849	15	03 56 11	-18.52, -178.26	94.8	-	-		
962	18	15 39 09	-19.75, -177.68	95.7	-	-		
963	18	17 29 14	0.96, -18.24	92.1	II	-		
980	19	05 27 26	-5.33, 152.67	96.0	I	C		
987	19	12 28 50	-32.06, 179.37	107.9	-	-		

TABLE 2**

Station Detection Statistics

Station	1 No. Events $4.6 \leq M_b < 4.7$ $\Delta < 90^{o}$	2 Reported To USGS	3 USGS Station Probability	4 Reported To ISM	5 ISM Station Probability	6 This Experiment	7 Final Station Probability
LAO	16	11	0.688	15*	0.939	15*	0.939
YKA	24	0	0.000	14*	0.583	14*	0.583
UBO	17	12	0.706	12	0.706	12†	0.706
NAO	21	15	0.714	19*	0.905	19*	0.905
HFS	22	9	0.409	14*	0.636	14*	0.636
MBC	20	7	0.350	15*	0.750	15*	0.750
KBL	21	11	0.524	13*	0.619	13*	0.619
ASP	27	19	0.704	19	0.704	19†	0.704
MAT	32	10	0.313	10	0.313	23*	0.719
COL	30	15	0.500	15	0.500	23*	0.767
CHG	27	0	0.000	13*	0.481	20*	0.741
PNS	8	1	0.125	1	0.125	1†	0.125
CTA	29	17	0.586	17	0.586	17†	0.586
BLC	18	5	0.279	9*	0.500	9†	0.500
NUR	20	10	0.500	10	0.500	13*	0.650
TUC	17	4	0.235	4	0.235	10*	0.588
BC	17	2	0.119	10*	0.588	10*	0.588
GBA	20	8	0.400	8	0.400	8†	0.400
SPA	16	9	0.563	9	0.563	15*	0.938
PMG	28	10	0.357	10	0.357	16*	0.571
KIC	10	5	0.500	5	0.500	5†	0.500
CLL	21	6	0.286	6	0.286	6†	0.286
SSF	16	4	0.250	4	0.250	4†	0.250'
BDF	8	3	0.375	3	0.375	3†	0.375
BNG	9	5	0.556	5	0.556	5†	0.556'
QUE	21	6	0.273	6	0.273	12	0.571
SHI	17	1	0.059	1	0.059	9*	0.591
BAG	31	6	0.194	6	0.194	14*	0.452
BUL	9	2	0.222	2	0.222	8*	0.899
AFI	31	5	0.161	5	0.161	9*	0.290
EZN	17	1	0.059	1	0.059	1†	0.059
SHL	25	2	0.080	2	0.080	17*	0.680
MAX	32		0.347		0.436		0.563
P^{o} SJ							0.665 Stations†

* Reread Stations
† Film Chips Not Available at Lincoln Laboratory for Rereading
** from Needham (1975)

Table 2**

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*Reread Stations

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**from Needham (1975)

TABLE II*

STATION	LOCATION	DISTINCT INPUT PICKS	ASSOCIATED PICKS	ASSOCIATED EVENTS	far**
LAO	Montana	3881	1358	734	.81
YKA	N.W. Terr. Canada	634	509	500	.21
UBO	Utah	1082	480	466	.57
NAO	Norway	2297	582	426	.81
HFS	Sweden	502	355	341	.32
MBC	N.W. Terr. Canada	442	332	331	.25
KBL	Afghanistan	983	298	291	
ASP	N. Terr. Australia	535	281	281	
MAT	Honshu, Japan	544	255	252	
COL	Alaska	318	231	228	
CHG	Thailand	892	256	222	
PNS	Bolivia	390	173	173	
CTA	Queensland, Australia	304	172	171	
BLC	N.W. Terr. Canada	196	167	166	
NUR	Finland	215	166	162	
TUC	Arizona	177	152	150	
FBC	N.W. Terr. Canada	166	147	147	
GBA	India	268	144	144	
SPA	South Pole	192	141	141	
PMG	New Guinea	236	125	125	
KIC	Ivory Coast	227	114	112	
CLL	E. Germany	237	109	107	
SSF	France	123	103	100	
BDF	Brazil	272	101	101	
BNG	Cen. African Rep.	209	99	99	
QUE	Pakistan	141	99	99	
SHI	Iran	185	79	78	
BAG	Philippine Is.	84	69	68	
BUL	S. Africa	118	68	66	
AFI	Samoa	166	56	56	
EZN	Turkey	144	55	55	
SHL	India	114	52	52	

* from Lacoss, Needham and Julian (1974)

** far = false alarm rate, = 1-column 5/column 3.

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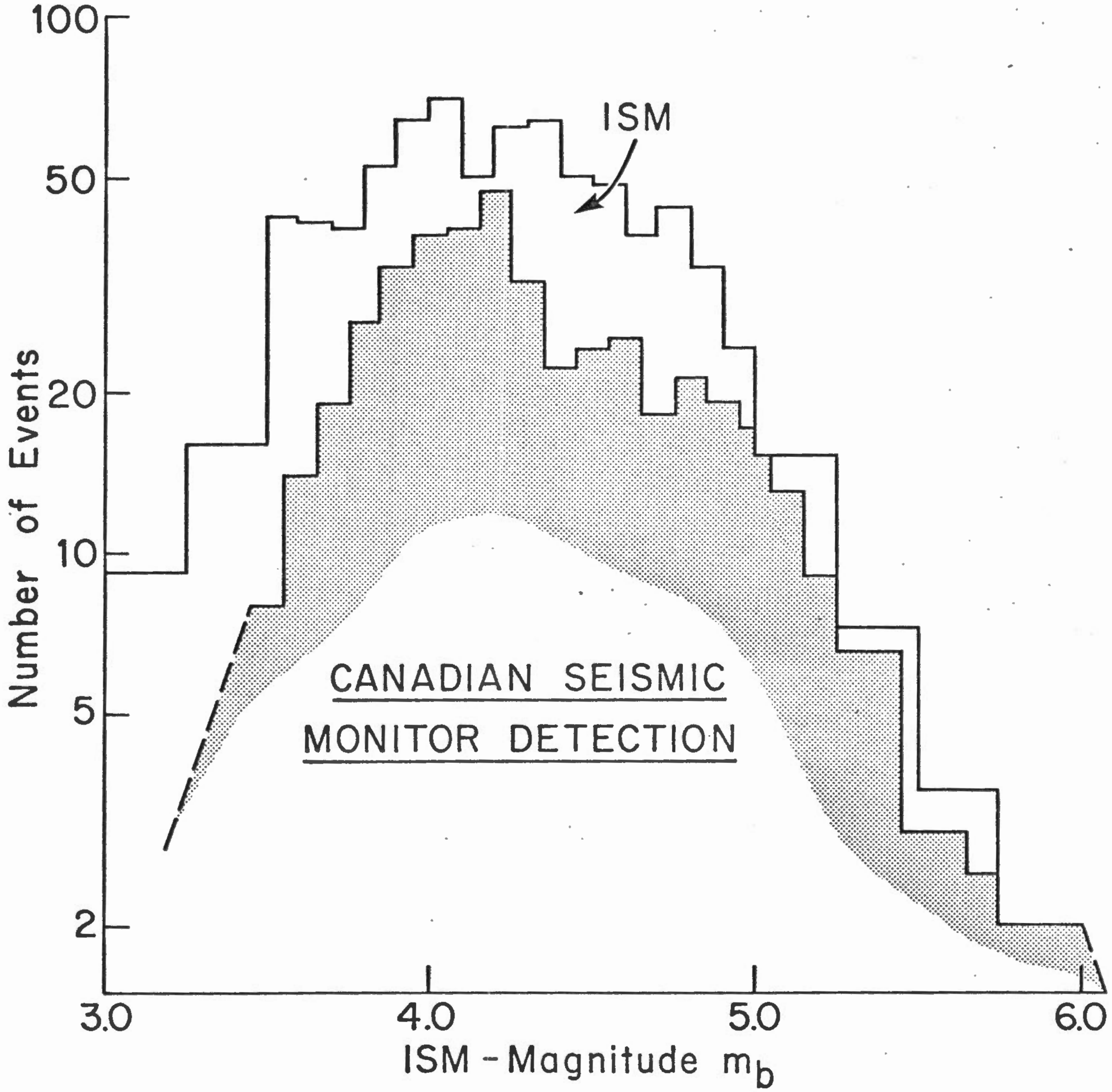

Figure 1. Canadian Seismic Monitor detections of world-wide ISM events, based on an interim ISM Bulletin.

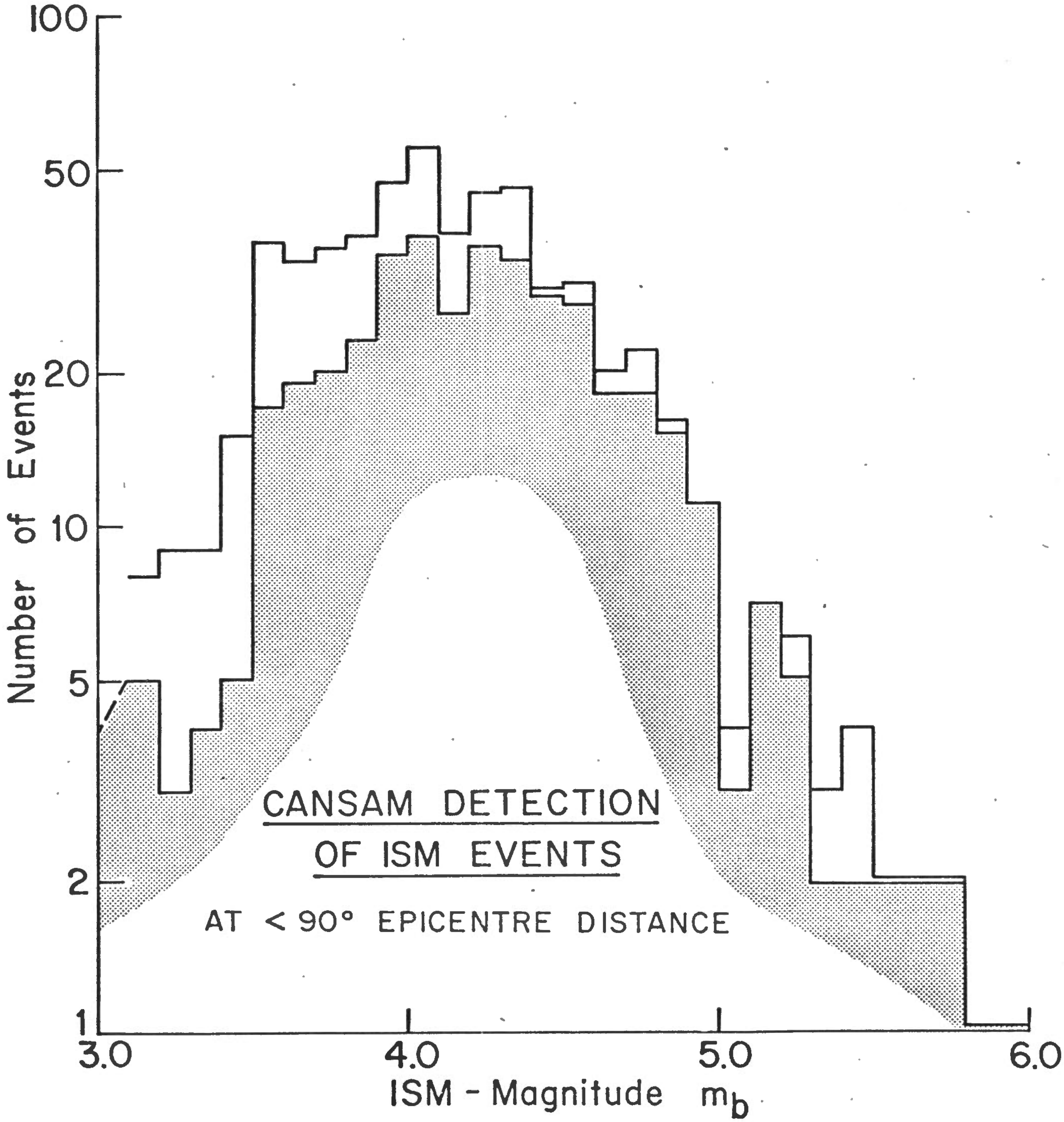

Figure 2. Automatic detection of ISM events by CANSAM system. ISM Background is also $< 90^{\circ}$ from YKA