The Research Council of Norway (NFR)

NORSAR

NORSAR Scientific Report No. 1-95/96

Semiannual Technical Summary

1 April - 30 September 1995

Kjeller, November 1995

7.6 Magnitude estimation at the IDC — a case study

Introduction

Several recent papers have addressed the shortcomings of the currently available magnitude scales for the purposes of GSETT-3. Harjes (1995) has suggested that a "unified" magnitude scale should be developed for operational use at the IDC. Such a magnitude scale should have the following general characteristics:

- Consistent with current teleseismic m_b
- Applicable to "all" distance ranges
- Computed automatically
- Valid over large magnitude range (at least 2.0-6.5)

The primary purpose would be to develop a "generic" magnitude scale that could be used as a first estimate of m_b. Subsequent refinements would then be possible by introducing station/region-specific correction factors in areas where adequate data are available.

In the NORSAR Semiannual Technical Summary 1 October 94 - 31 March 95 Kværna and Ringdal (1995) described a possible approach to developing a unified magnitude scale, by using the IDC Threshold Monitoring system.

By analyzing selected IDC-reported events in detail, they found that the TM approach offers a consistent, automatically computed data set that is directly applicable to m_b estimation. Since upper limits on all non-detecting stations are provided, the method is easily expandable to include maximum-likelihood magnitude estimates. It was also pointed out that a similar approach can be used to estimate M_S, with upper 90% M_S limits provided automatically for events for which no surface waves are detected.

In this paper we follow up the general question of IDC magnitude estimation by analyzing a recent earthquake sequence in Greece during May-June 1995. This includes comparisons of IDC magnitudes in the Reviewed Event Bulletins to those of NORSAR and NEIC, with special view to network bias, recurrence statistics and detectability.

The Greece earthquake sequence May/June 1995

Several hundred earthquakes from the Greece area were recorded at the NORSAR array during May/June 1995. An example of a 12-hour period from the NORSAR monthly bulletin is given in Fig. 7.6.1. Many of these events were also listed in the IDC Reviewed Event Bulletin, using mostly the arrays in central/northern Europe as key stations in the location procedure. Fig. 7.6.2 shows epicenters for a two-week period as given in the biweekly IDC Performance Reports.

As can be seen from Fig. 7.6.1, the majority of the earthquakes were around $m_b = 4.0$ and lower, thus giving a good basis both for a detectability study and to investigate possible magnitude bias effects. As is well known (e.g., Ringdal, 1976), a network magnitude bias can be expected at low magnitudes unless maximum-likelihood techniques are applied.

Magnitude comparisons

Fig. 7.6.3 compares reported magnitudes from the three sources: NORSAR bulletin, IDC REB and NEIC PDE. The following observations are made:

- From plot a) we note that NORSAR and PDE magnitudes are consistent for the larger events, but there is a significant positive "network bias" in the PDE magnitudes for the smaller events. Once the NORSAR magnitude goes below 4.0, the PDE magnitude stays between 4.0 and 4.5, thus reflecting that only those stations with the highest amplitudes contribute to the average m_b.
- From plot b) we note that there is a bias also in the IDC magnitudes for the smaller events, although this plot has much more scatter than plot a).
- From plot c) we note that IDC magnitudes have a negative bias relative to PDE magnitudes. This is not surprising, and has been documented in many IDC Performance Reports. One possible reason is the dominance of high-frequency arrays in the IDC network. However, the large scatter between IDC and PDE magnitudes is a source of concern, and must be due to other reasons as well. It appears that the automatic algorithm at the IDC for magnitude computation needs significant improvement.

Recurrence statistics

Fig. 7.6.4 shows cumulative recurrence statistics for NORSAR and REB for the Greece sequence. The slope of the NORSAR plot is close to 1.0, whereas the REB slope is much steeper. The tendency of REB recurrence curves to show a slope significantly steeper than 1.0 has been observed in many IDC Performance Reports (see e.g. Fig. 7.6.5), and again we prescribe this to a network bias.

It might be noted that under the assumptions of a normal magnitude distribution and an exponential magnitude-frequency relationship (log N=a b*m), a single station or array will provide an unbiased estimate of the b-value (Ringdal, 1975). On the other hand, the a-value from a single-station or array will be biased due to station bias and station scatter. Therefore the b-value of approximately 1.0 inferred from the NORSAR plot should be close to the "real" b-value for this earthquake sequence. When maximum-likelihood magnitudes are implemented at the IDC, we would thus expect the recurrence slopes to become close to 1.0.

Detectability

Fig. 7.6.6 shows the estimated incremental detectability of the REB using NORSAR as a reference for the area and time period mentioned. Since NORSAR is currently not participating in GSETT-3, it can reasonably be used as an independent reference system for such an estimation. The 90% threshold is close to 4.2, which is in fact quite similar to the estimate inferred from the theoretical capability plots in the IDC Performance Reports. This consistency is encouraging.

F. Ringdal

References

Harjes, H.-P., (1995): Calibrating an IMS at regional distances, *in* Proceedings, CTBT Monitoring Technologies Conference 1995, ARPA, Arlington, VA.

Kværna, T. & F. Ringdal (1995): Magnitude estimation using the IDC Threshold Monitoring System, Semiannual Technical Summary, 1 October 1994 - 31 March 1995, NORSAR Sci. Rep. no. 1-94/95, Kjeller, Norway.

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

Ringdal, F. (1976): Maximum likelihood estimation of seismic magnitude, Bull. Seism. Soc. Am., 66, 789-802.

Jun 8 13:39 1995 norsar.bulletin Page 5

13	May	11.15.23.9	NB2	P	0.8	0.5	10	157	19	11.11.04	43N	21E	3.2	383	YUGOSLAVIA
13	May	11.16.13.5	NB2	P	0.5	0.4	13	123	38	11.09.02	32N	48E	3.7	347	WESTERN IRAN
13	May	11.19.47.1	NB2	P	1.1	0.6	10	158	19	11.15.31	43N	21E	3.3	383	YUGOSLAVIA
13	May	11.30.20.8	NB2	P	0.7	0.6	12	157	25	11.25.00	37N	23E	3.4	368	SOUTHERN GREECE
13	May	11.36.11.1	NB2	P	1.6	0.7	10	145	19	11.31.51	44N	26E	3.4	358	ROMANIA
13	May	11.43.08.1	NB2	P	0.7	0.6	9	140	18	11.39.01	46N	28E	3.2	358	ROMANIA
13	May	11.48.22.1	NB2	P	87.7	0.8	9	157	18	11.44.10	44N	21E	5.1	383	YUGOSLAVIA
13	May	11.57.46.3	NB2	P	0.7	0.5	10	160	21	11.53.09	41N	20E	3.2	391	ALBANIA
13	May	12.00.15.2	NB2	P	0.4	0.5	12	157	24	11.55.03	38N	23E	3.2	364	GREECE
13	May	12.09.28.5	NB2	P	0.8	0.6	22	91	83	11.57.04	5N	97E	3.9	706	NORTHERN SUMATERA
13	May	12.33.00.6	NB2	P	0.9	0.7	9	156	18	12.28.55	44N	21E	3.3	383	NORTHWESTERN BALKAN REGION
13	May	12.55.45.9	NB2	P	0.8	0.6	12	167	24	12.50.35	37N	18E	3.4	399	IONIAN SEA
13	May	13.09.57.5	NB2	P	0.6	0.6	12	159	26	13.04.25	36N	22E	3.5	400	MEDITERRANEAN SEA
13	May	13.36.58.8	NB2	P	0.9	0.5	10	158	19	13.32.43	43N	21E	3.3	383	YUGOSLAVIA
13	May	13.39.09.9	NB2	P	2.3	0.8	20	42	79	13.27.07	31N	141E	4.2	211	SOUTH OF HONSHU, JAPAN
13	May	13.46.41.8	NB2	P	1.1	0.6	10	161	19	13.42.25	43N	19E	3.3	383	NORTHWESTERN BALKAN REGION
13	May	13.54.39.7	NB2	P	0.6	0.6	12	159	26	13.49.07	36N	22E	3.5	400	MEDITERRANEAN SEA
13	May	13.57.50.0	NB2	P	0.8	0.6	9	146	18	13.53.45	45N	25E	3.3	358	ROMANIA
13	May	14.13.47.0	NB2	P	1.5	0.8	10	158	20	14.09.21	42N	21E	3.3	383	YUGOSLAVIA
13	May	14.21.21.2	NB2	P	13.7	0.8	9	157	18	14.17.09	44N	21E	4.3	383	YUGOSLAVIA
13	May	14.24.30.0	NB2	P	0.9	0.6	9	146	18	14.20.21	45N	26E	3.3	358	ROMANIA
13	May	14.30.54.5	NB2	P	1.6	0.6	12	159	26	14.25.21	36N	23E	4.0	400	MEDITERRANEAN SEA
13	May	15.03.15.4	NB2	P	0.7	0.8	10	157	20	14.58.47	42N	22E	3.0	383	NORTHWESTERN BALKAN REGION
13	May	15.09.43.7	NB2	P	1.3	0.7	9	157	18	15.05.31	44N	21E	3.4	383	YUGOSLAVIA
13	May	15.19.42.0	NB2	P	0.7	0.6	10	159	20	15.15.11	42N	21E	3.1	391	ALBANIA
13	May	15.30.33.8	NB2	P	4.7	0.8	10	158	19	15.26.14	43N	21E	3.8	383	NORTHWESTERN BALKAN REGION
13	May	15.34.57.9	NB2	P	3.8	0.7	12	159	28	15.29.10	34N	23E	4.4	400	MEDITERRANEAN SEA
13	May	15.44.02.4	NB2	PKPabc	0.7	0.5	27	22	153	15.23.58	35S	179E	3.7	179	SOUTH OF KERMADEC ISLANDS
13	May	15.57.50.5	NB2	P	0.5	0.6	9	147	17	15.53.54	46N	25E	3.1	358	ROMANIA
13	May	16.09.03.7	NB2	P	0.6	0.6	9	140	18	16.04.53	46N	28E	3.1	358	ROMANIA
13	May	16.19.19.3	NB2	P	0.4	0.5	9	157	18	16.15.09	44N	21E	3.0	383	NORTHWESTERN BALKAN REGION
13	May	16.43.27.0	NB2	P	1.0	0.6	10	158	20	16.39.02	42N	21E	3.3	383	NORTHWESTERN BALKAN REGION
13	May	17.15.46.8	NB2	P	4.1	0.8	10	158	19	17.11.25	43N	21E	3.7	383	NORTHWESTERN BALKAN REGION
13	May	17.54.40.0	NB2	P	0.9	0.6	9	155	18	17.50.35	44N	22E	3.3	383	YUGOSLAVIA
13	May	17.59.46.9	NB2	P	12.1	0.9	10	158	19	17.55.30	43N	21E	4.2	383	NORTHWESTERN BALKAN REGION
13	May	18.10.52.0	NB2	P	35.7	0.8	10	158	19	18.06.35	43N	21E	4.7	383	NORTHWESTERN BALKAN REGION
13	May	18.17.33.8	NB2	P	0.7	0.7	12	159	26	18.12.02	36N	22E	3.5	400	MEDITERRANEAN SEA
13	May	18.30.55.3	NB2	P	0.7	0.6	10	157	19	18.26.36	43N	21E	3.1	383	YUGOSLAVIA
13	May	18.40.30.0	NB2	P	3.2	0.7	12	156	25	18.35.12	38N	24E	4.0	368	SOUTHERN GREECE
13	May	18.44.48.2	NB2	P	0.2	0.4	9	148	17	18.40.51	46N	24E	3.0	358	ROMANIA
13	May	18.51.19.8	NB2	P	4.6	0.7	10	160	19	18.47.03	43N	20E	3.9	383	NORTHWESTERN BALKAN REGION
13	May	18.59.50.1	NB2	P	3.0	0.7	9	156	18	18.55.44	44N	21E	3.8	383	NORTHWESTERN BALKAN REGION
13	May	19.01.52.1	NB2	P	0.9	0.6	12	161	26	18.56.25	36N	21E	3.7	368	SOUTHERN GREECE
13	May	19.05.05.4	NB2	P	6.1	0.7	9	156	18	19.00.59	44N	21E	4.1	383	NORTHWESTERN BALKAN REGION
13	May	19.05.40.2	NB2	P	10.9	0.7	12	160	26	19.00.11	36N	22E	4.7	400	MEDITERRANEAN SEA
13	May	19.34.26.8	NB2	P	0.6	0.6	12	159	26	19.28.55	36N	22E	3.5	400	MEDITERRANEAN SEA
13	May	19.42.03.0	NB2	P	7.6	0.8	10	158	19	19.37.42	43N	21E	4.0	383	NORTHWESTERN BALKAN REGION
13	May	21.07.09.3	NB2	P	2.2	0.7	9	155	18	21.03.08	45N	21E	3.7	383	YUGOSLAVIA
13	May	21.13.32.8	NB2	P	49.8	0.8	24	83	94	21.00.19	0N	109E	6.0	261	KALIMANTAN
13	May	21.40.08.2	NB2	P	0.5	0.6	12	157	26	21.34.43	37N	24E	3.4	368	SOUTHERN GREECE
13	May	21.45.38.8	NB2	P	2.6	0.8	10	159	20	21.41.14	42N	21E	3.5	383	NORTHWESTERN BALKAN REGION
13	May	22.06.13.4	NB2	P	0.5	0.6	9	142	18	22.02.11	46N	27E	3.2	358	ROMANIA
13	May	22.33.49.3	NB2	P	1.6	0.6	9	154	18	22.29.47	45N	22E	3.6	358	ROMANIA
13	May	22.42.32.4	NB2	P	56.9	1.7	9	355	17	22.38.33	78N	4E	4.7	640	GREENLAND SEA
13	May	23.32.48.3	NB2	P	4.5	0.8	9	154	18	23.28.42	44N	22E	3.9	358	ROMANIA
13	May	23.51.50.0	NB2	P	5.7	0.6	9	156	18	23.47.41	44N	21E	4.1	383	NORTHWESTERN BALKAN REGION

Fig. 7.6.1. Excerpts from the NORSAR bulletin for a 12-hour period on 13 May 1995.

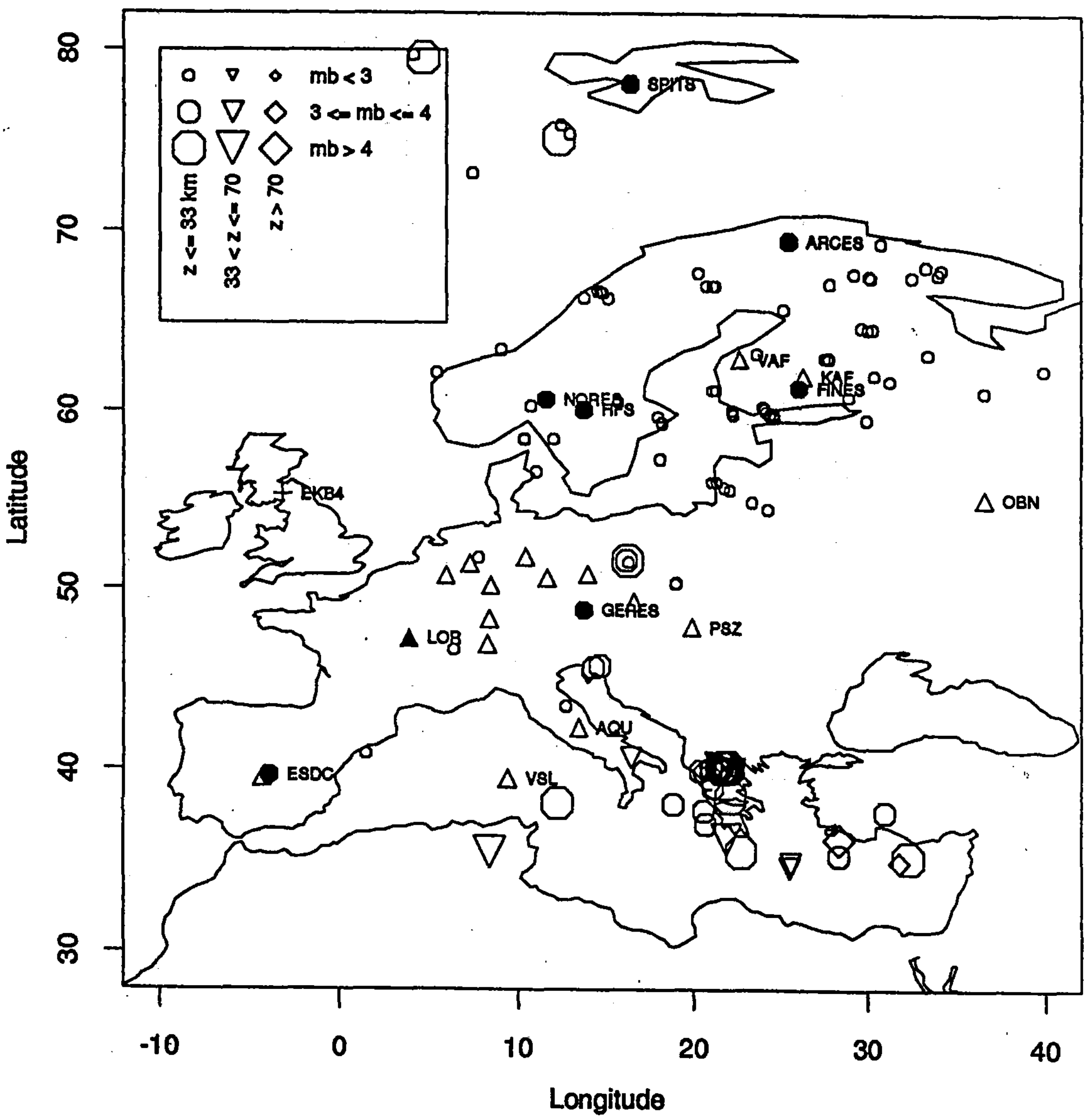


Fig. 7.6.2. REB events in Europe showing the depth and body-wave magnitudes ranges for a two-week period during the Greece sequence. The GSETT-3 stations are indicated as filled circles and triangles. The figure is taken from one of the IDC Performance Reports.

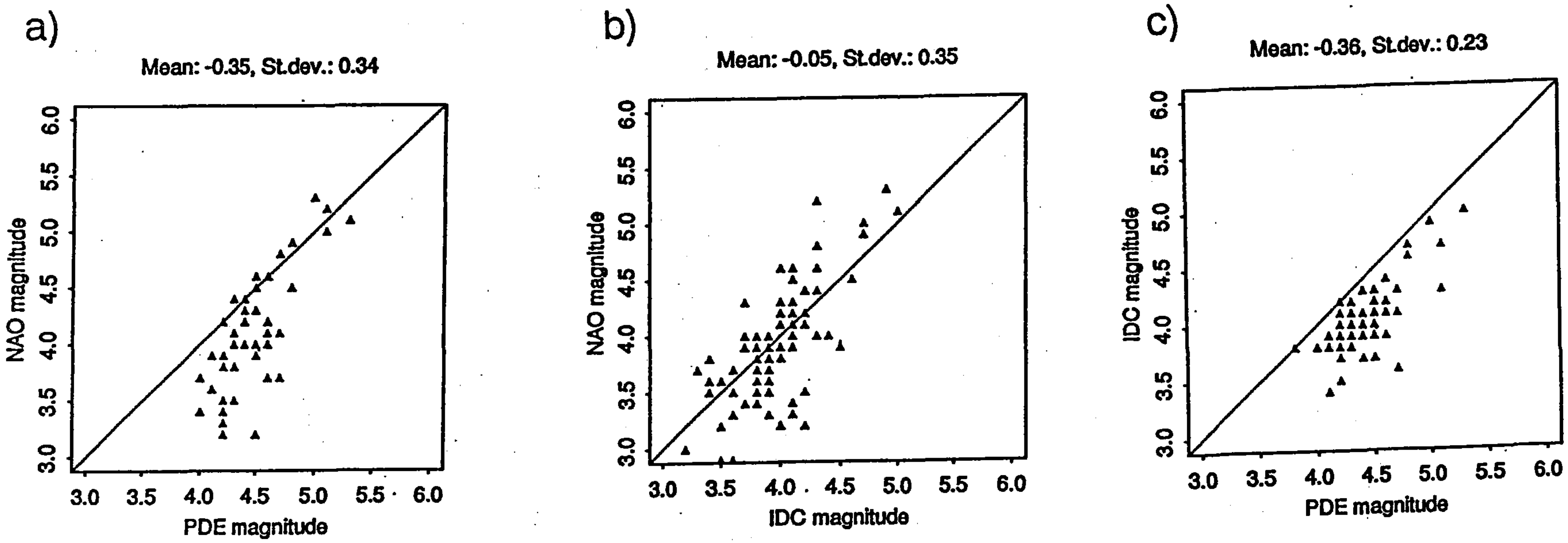
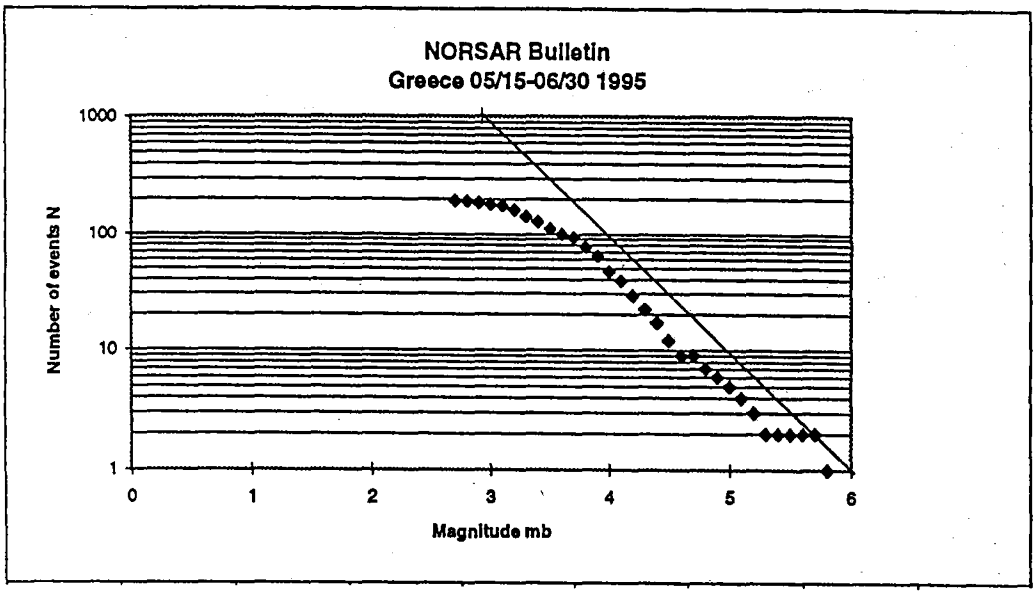


Fig. 7.6.3. Magnitude comparisons for various reporting agencies for the Greece earthquake sequence. Note the network magnitude bias, which is particularly pronounced in figure a) (NORSAR versus PDE magnitudes).

a)



b)

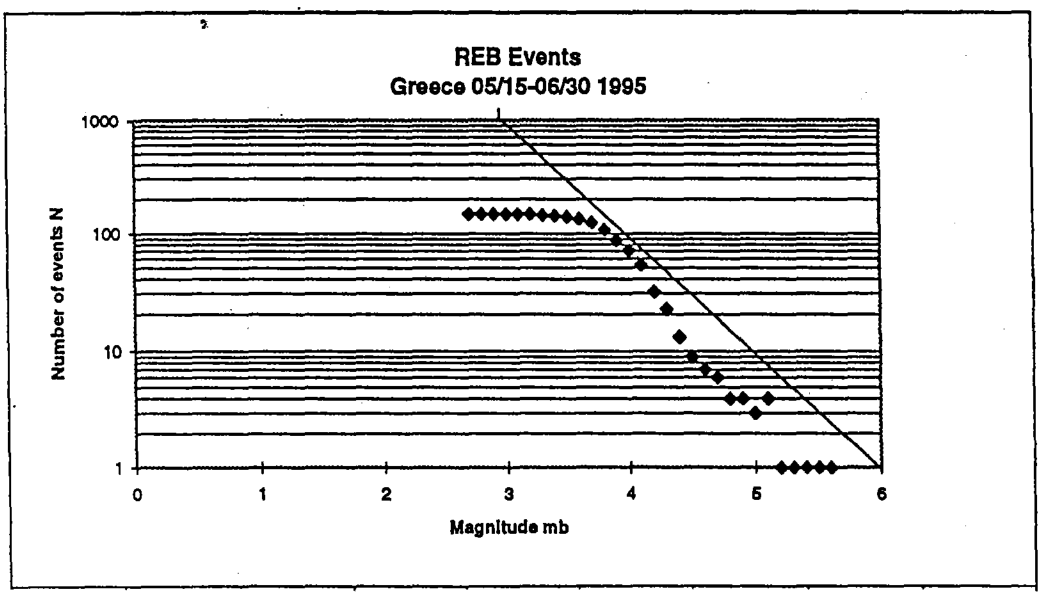


Fig. 7.6.4. Magnitude recurrence statistics for a) NORSAR and b) IDC for six weeks of the Greece earthquake sequence. The straight lines have a slope of 1.0. Note that the NORSAR slope is close to 1.0, whereas the IDC slope appears to be significantly steeper.

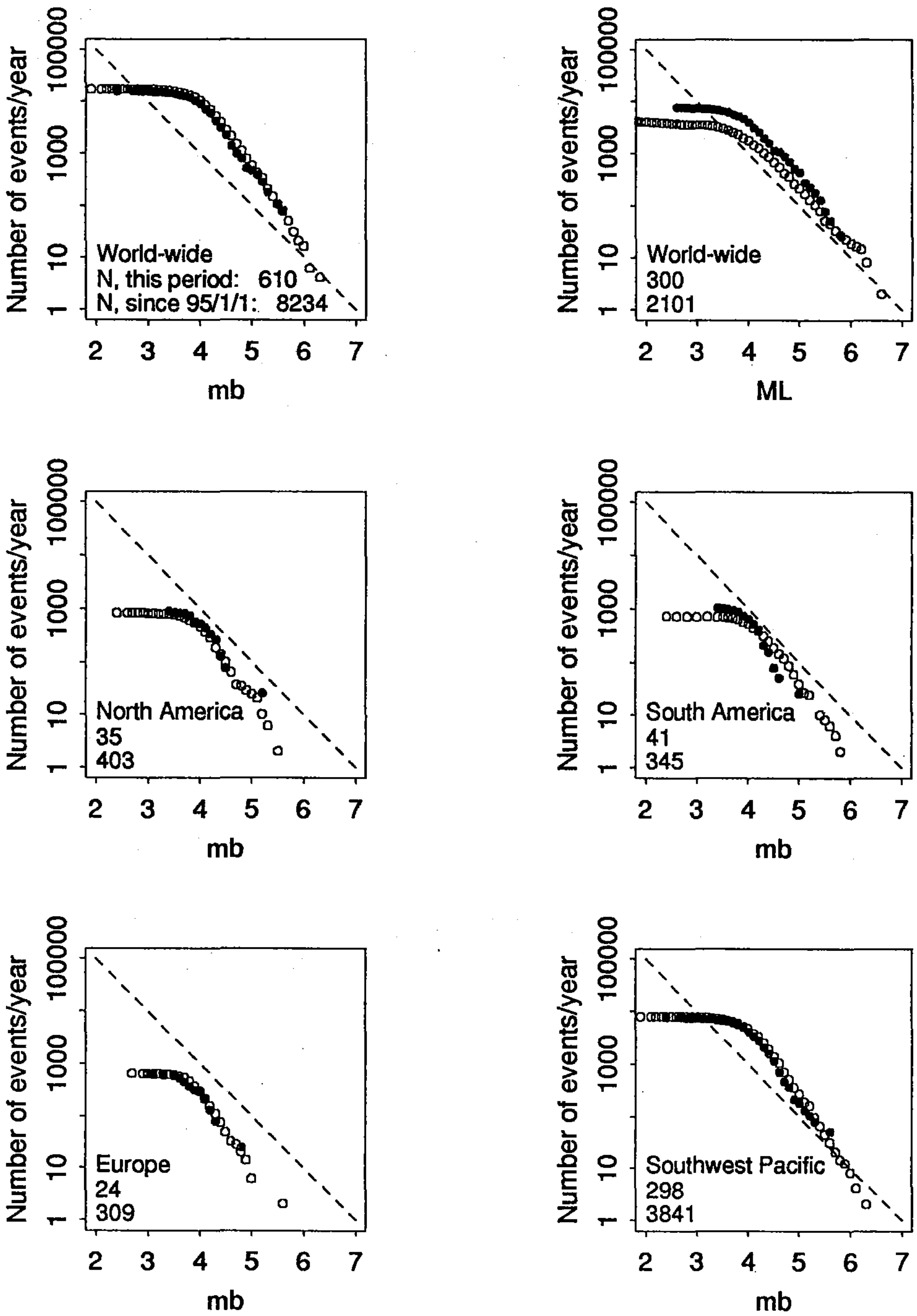


Fig. 7.6.5. Recurrence distribution of body-wave (m_b) and local (ML) magnitudes in the REB for selected regions, as taken from an IDC Performance Report. The stippled lines have a slope of 1.0. Note that the m_b recurrence curves have slopes significantly greater than 1.0 for all regions, which is ascribed to a network m_b estimation bias.

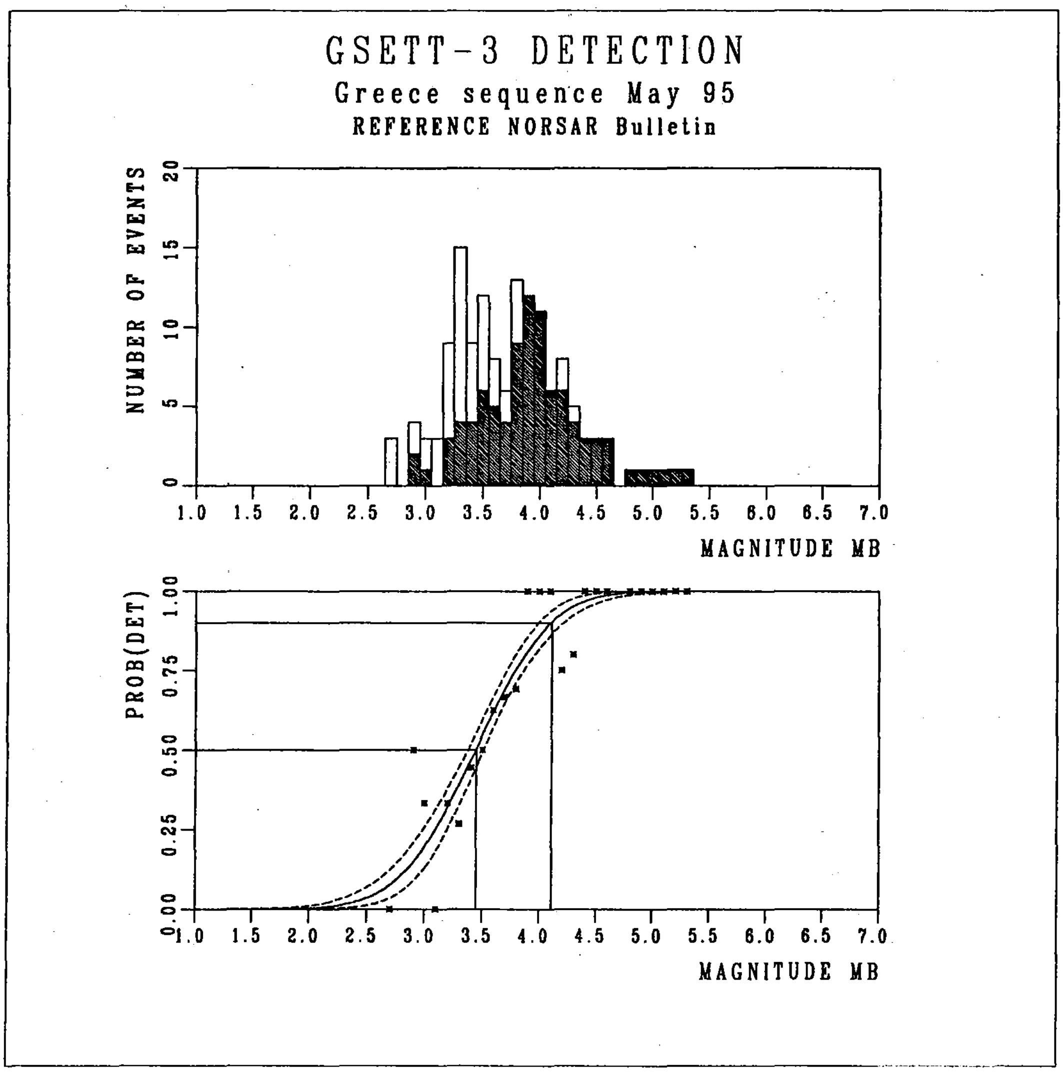


Fig. 7.6.6. Detectability estimate for the IDC REB for the Greece area using the NORSAR bulletin as a reference. The 90% detection threshold is m_b = 4.2, which is close to the theoretical estimate in the IDC Performance Reports.