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7.6 Regional detection performance during GSETT-2: Initial results for the Fennoscandian array network

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). 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. 7.6.1). Data were recorded and processed at National Data Centers, and results 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 detection capability during GSETT-2 for Fennoscandia and NW Russia. This is the region that had maybe the best instrumental coverage during the experiment. In particular the regional arrays deployed in this area made significant contributions.

Our results for this region represent in a sense the "best" regional performance during GSETT-2. It is in no way representative for the performance on a global or more extended regional scale. However, it does serve to illustrate the potential capabilities of a monitoring network, assuming that an adequate density and number of high quality, sensitive array stations are deployed.

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

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

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:

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

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

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.

Reference network

The reference data base for this study has been the catalogue of seismic events in northern Europe regularly compiled by the Seismological Institute, University of Helsinki.

The stations used in compiling this catalogue are in almost all cases comprised of the Finnish seismic network single stations. For all practical purposes, the compilation is independent of the regional arrays in Fennoscandia (NORESS, ARCESS, FINESA). The magnitudes quoted in the bulletin are likewise derived independently of the regional arrays, and comprise either duration magnitudes (in most cases) or local magnitudes. These magnitudes are fairly consistent with magnitudes calculated by the Intelligent Monitoring System, while their relationship to teleseismic m_b estimates is at present not well established.

For the month of May 1991, upon which this analysis is based, the reference catalogue contained 321 seismic events in the region bounded by 58°-70°N, 20°-40°E, of which 108 had an assigned magnitude in the range 1.7-2.9.

Results

The initial results from the detectability study are presented in Figs. 7.6.2-7.6.4. Each figure is based upon analyst comparison of the reference events with bulletin reports according to different reporting criteria:

a) One-array detection:

In Fig. 7.6.2, an event is considered detected if it was reported with 2 phases (P and S; or P and Lg) by at least one of the three regional arrays (NORESS, ARCESS, FINESA). In terms of GSETT-2 final event bulletins, this means that the event would either be located as a multi-station event, or listed as an NDC-reported event. We note that the 50 % threshold is close to 1.7, and the 90 % threshold is 2.3 in this case.

b) Two-array detection:

In Fig. 7.6.3, the detection requirement is 2 phases (P and S; or P and Lg) from one array and at least one confirming phase from another array. This added requirement has the effect of increasing the 50 % threshold to 2.1, and the 90 % threshold to 2.4.

c) GSETT-2 reported events:

In Fig. 7.6.4, the GSETT-2 reported events, located by at least one IDC, are shown. (We have not counted as detected events those events whose definition depended upon reportings from the Finnish network stations KAF and VAF, since these two stations were part of the reference network.) The resulting thresholds are similar to those displayed in Fig. 7.6.3 (the two-array case).

Conclusions

The regional evaluation of detection results from GSETT-2 presented here shows that in a region with dense coverage of high-quality array stations as in Fennoscandia, it is possible to detect seismic events at very low magnitudes.

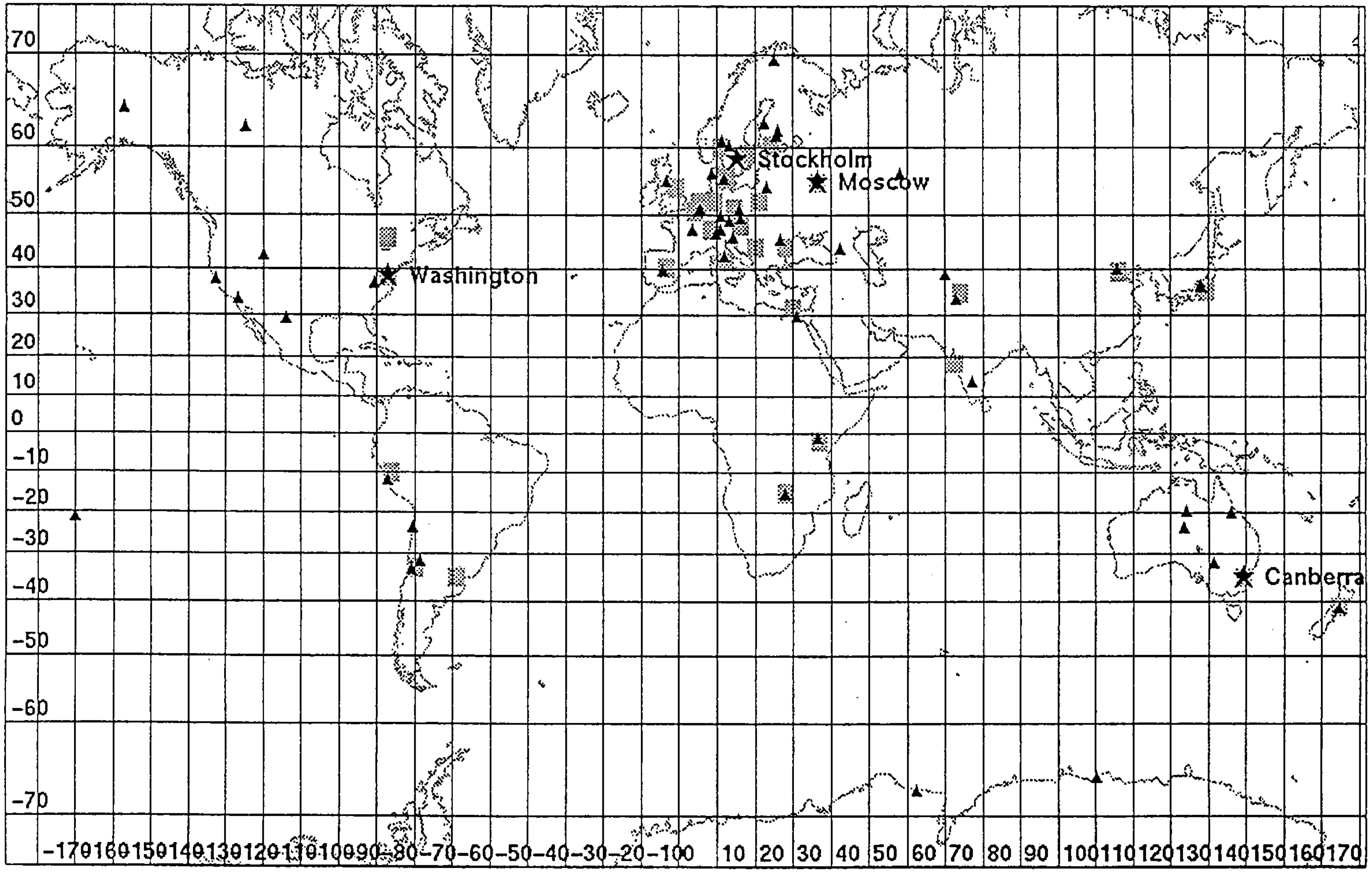
The 90 per cent threshold of around magnitude 2.5 found in this study must of course be considered with the appropriate caution: thus it refers to a regional magnitude scale that currently is not well calibrated in terms of global magnitude. Also, in other geological environments, the wave propagation and array noise suppression characteristics may be different. Therefore, it is not known to which extent such results would be possible to duplicate in other parts of the world.

Further work should be undertaken to evaluate the GSETT-2 detection performance in other regions, in order to gain experience for future studies. It will also be necessary to study event location performance, and evaluate how the detection capability varies as a function of different requirements with regard to event location accuracy.

F. Ringdal

References

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



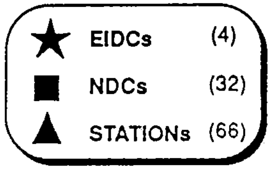


Fig. 7.6.1. EIDCs, NDCs and stations participating in GSETT-2, April -. June 1991 (After GSE/US/68).

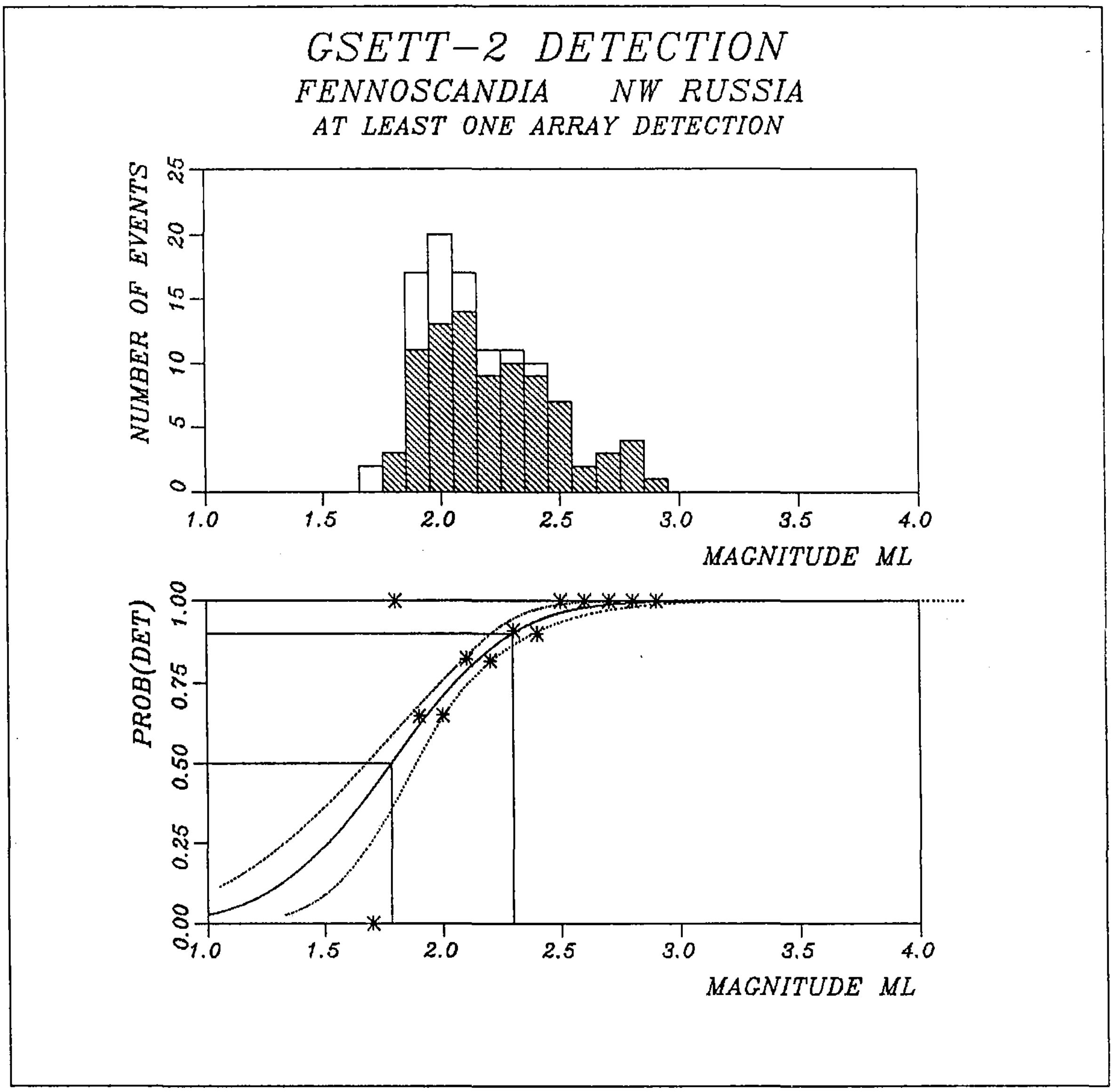


Fig. 7.6.2. Maximum likelihood detectability estimation for Fennoscandia-NW Russia using the Univ. of Helsinki bulletin as a reference. The upper half shows the reference event set and the number of events actually detected for each magnitude. The lower half shows the maximum likelihood detectability curve and its confidence limits. The actual percentage of detected events at each magnitude is also shown. This figure is based upon a one-array detection requirement.

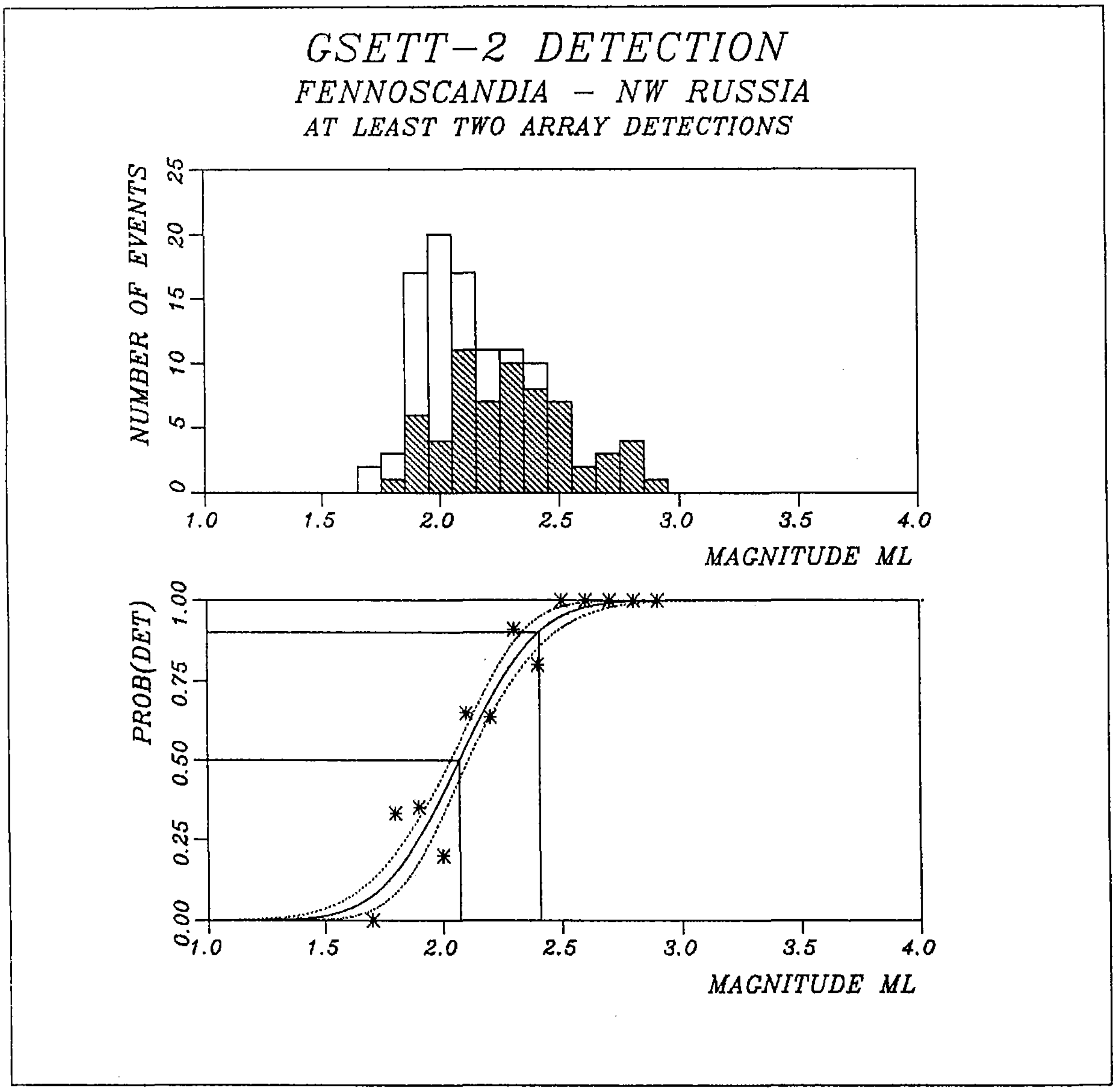


Fig. 7.6.3. Maximum likelihood detectability estimation for Fennoscandia-NW Russia using the Univ. of Helsinki bulletin as a reference. The upper half shows the reference event set and the number of events actually detected for each magnitude. The lower half shows the maximum likelihood detectability curve and its confidence limits. The actual percentage of detected events at each magnitude is also shown. This figure is based upon a two-array detection requirement.

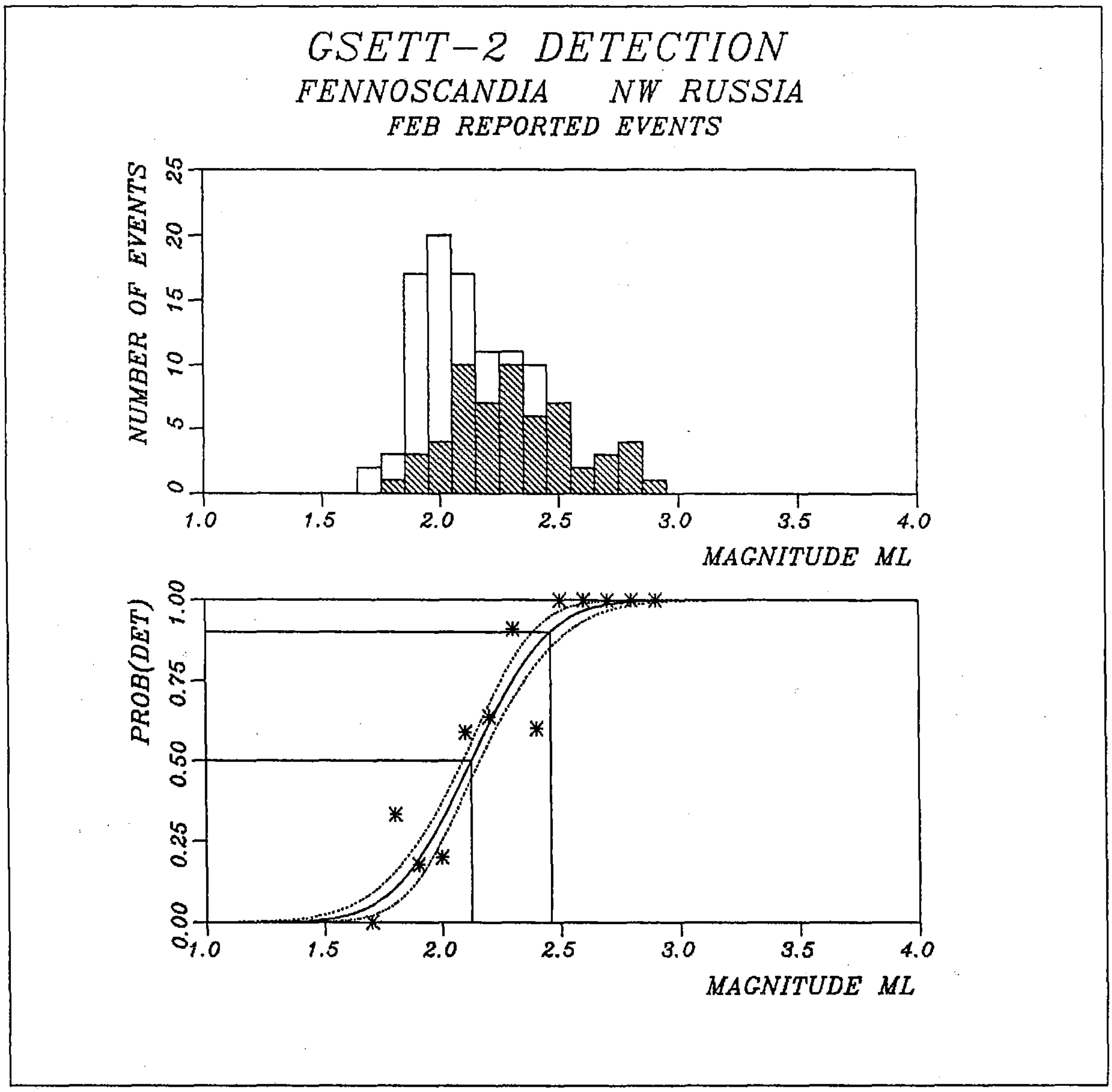


Fig. 7.6.4. Maximum likelihood detectability estimation for Fennoscandia-NW Russia using the Univ. of Helsinki bulletin as a reference. The upper half shows the reference event set and the number of events actually detected for each magnitude. The lower half shows the maximum likelihood detectability curve and its confidence limits. The actual percentage of detected events at each magnitude is also shown. This figure is based upon FEB reported events as discussed in the text.