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7.2 Threshold monitoring of Novaya Zemlya: A scaling experiment

Introduction

In the previous NORSAR Semiannual Technical Summary, Kværna and Ringdal (1990) presented results from a one-week experiment in continuously monitoring the Northern Novaya Zemlya test site. Data from the three regional arrays NORESS, ARCESS, FINESA were used to calculate the thresholds, using the method of Ringdal and Kværna (1989). The location of these three arrays relative to the test site is shown in Fig. 7.2.1.

In that one-week study, it was found that the test site could be consistently monitored at a very low magnitude level (typically $m_b = 2.5$). In fact, every single occurrence of the threshold exceeding $m_b = 2.5$ could be explained as resulting from an interfering event signal either from teleseismic or regional distance.

While these results are very encouraging, there is clearly much work remaining to be done before the concept of threshold monitoring is sufficiently well understood. In this paper, we attempt to illuminate the concept further by describing a simple experiment, involving down-scaling of recorded signal traces of the 24 October 1990 explosion at Novaya Zemlya and simulating what might have been observed on the threshold traces if such a down-scaled event had in fact occurred.

Scaling of the 24 October 1990 explosion

The explosion of 24 October 1990 had a world-wide $m_b = 5.6$. Recorded array traces of this event are shown in Fig. 7.2.2, where also the P-wave SNR (STA/LTA) on each filtered array beam is indicated. Our scaling procedure consisted simply of dividing each trace by a factor of 1000 and adding these down-scaled traces to actually observed recordings at various points in time.

Two examples of such "down-scaled" signals superpositioned on noise are shown in Fig. 7.2.3 and 7.2.4. The first of these figures covers a "low noise" interval (local night time), whereas the second figure corresponds to "high noise" (local day time). In the first case, the P phase is readily seen on all three arrays, and the S phase at ARCESS is also prominent. In the second case, the phases are far less clear, although the ARCESS P and S still have good SNR.

Before proceeding, we pause briefly to note that a down-scaling by a factor of 1000 in effect reduces the event m_b by 3 orders of magnitude. In this sense, the down-scaled event corresponds to $m_b = 2.6$. We have not attempted to apply any source scaling law for signal frequency, partly in order to maintain simplicity. Furthermore, such scaling laws, while certainly important, are not sufficiently well known to apply with any degree of confidence.

Moreover, it should be noted that any shift toward higher signal frequencies, as would be a natural consequence of applying frequency scaling, would only tend to improve the signal-to-noise ratios of these high-frequency arrays. Thus, our procedure can be considered as conservative with respect to estimating detection capability.

Simulation of threshold monitoring

Turning now to the actual data, we selected a typical 24-hour time period (day 104/1991), and added the down-scaled signal at hourly intervals in order to get a picture of the effect under different noise conditions. A total of 24 identical signals were thus added at different times.

Fig. 7.2.5 shows the "actual" threshold trace (day 104) for Novaya Zemlya, developed exactly as described in detail by Kværna and Ringdal (1990) for the one-week monitoring experiment. We note that there is only one peak significantly exceeding $m_b = 2.5$; this corresponds to a large teleseismic earthquake ($m_b = 6.0$) from the Ryuku Islands.

Fig. 7.2.6 shows the resulting trace for that same day after adding the down-scaled signals and recomputing the threshold trace. We note that all of the 24 occurrences stand out clearly on the plot. Thus, if an explosion of $m_b = 2.6$ had indeed occurred at Novaya Zemlya that day, and assuming that the scaling is representative, there would have been clear indications on the threshold trace of such an explosion.

Discussion

We emphasize that this study is only intended to give an illustration of the potential of the threshold monitoring method, and that clearly more data and additional analysis is required to assess the situation in more detail. With our procedure of scaling by a constant factor in amplitude, we have, for example, not considered signal variance, which might contribute to a greater variability in the size of the amplitude peak, although the effect is not expected to be very significant.

An interesting observation is the way in which threshold monitoring complements the traditional detection/location type monitoring: Let us for a moment assume that an $m_b = 2.6$ explosion had in fact occurred at Novaya Zemlya, and that the resulting signals were similar to the scaled-down signals used here. It might well be that such an explosion would *not* have been detected and located by the regional array network. In fact, during daytime noise conditions (Fig. 7.2.4) there would very likely have been only one or two confident phase detections (Pn and possibly Sn at ARCESS), and this is not sufficient to locate in the traditional network sense.

Nevertheless, as seen in this paper, such an explosion would have been clearly indicated on the network threshold trace. It would not have been possible to explain this peak as resulting from some "different" event (as was always the case for such peaks in the Kværna and Ringdal (1990) study). Thus, a peak of this type would be a prime candidate for further detailed off-line analysis, possibly implying efforts to acquire additional data in order to further elucidate the nature of the event.

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References

Kværna, T. and F. Ringdal (1990): Continuous threshold monitoring of the Novaya Zemlya test site, *Semiannual Tech. Summary, 1 Apr - 30 Sep 1990*, NORSAR Sci. Rep. 1-90/91, Kjeller, Norway.

Ringdal, F. and T. Kværna (1989): A multichannel processing approach to real time network detection, phase association and threshold monitoring, *Bull. Seism. Soc. Am.*, Vol. 79, 1927–1940.

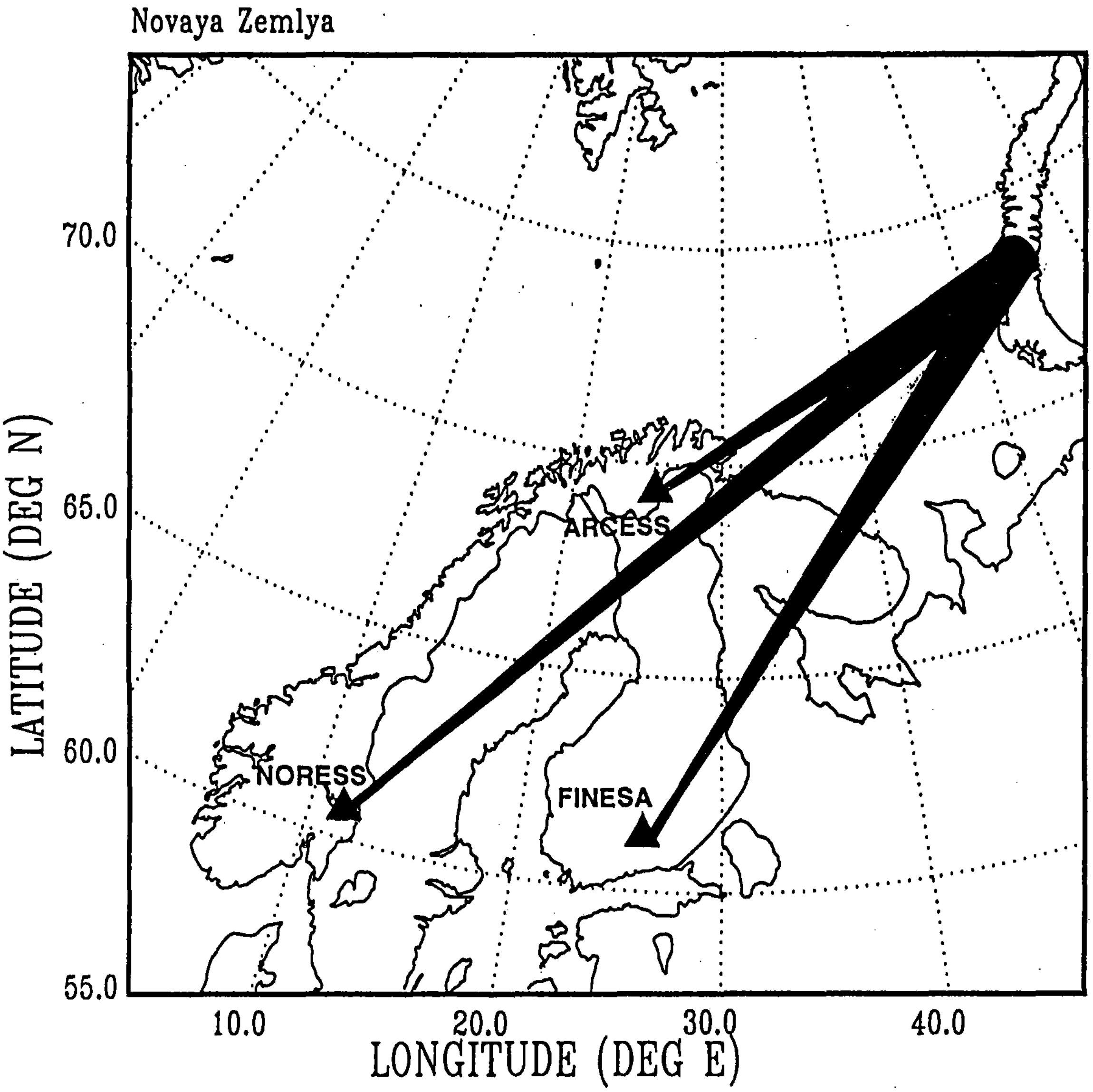

Fig. 7.2.1. Location of the target area (Novaya Zemlya) for the threshold monitoring experiment. The locations of the three arrays NORESS (Δ = 2280 km), ARCESS (Δ = 1110 km) and FINESA (Δ = 1780 km) are indicated.

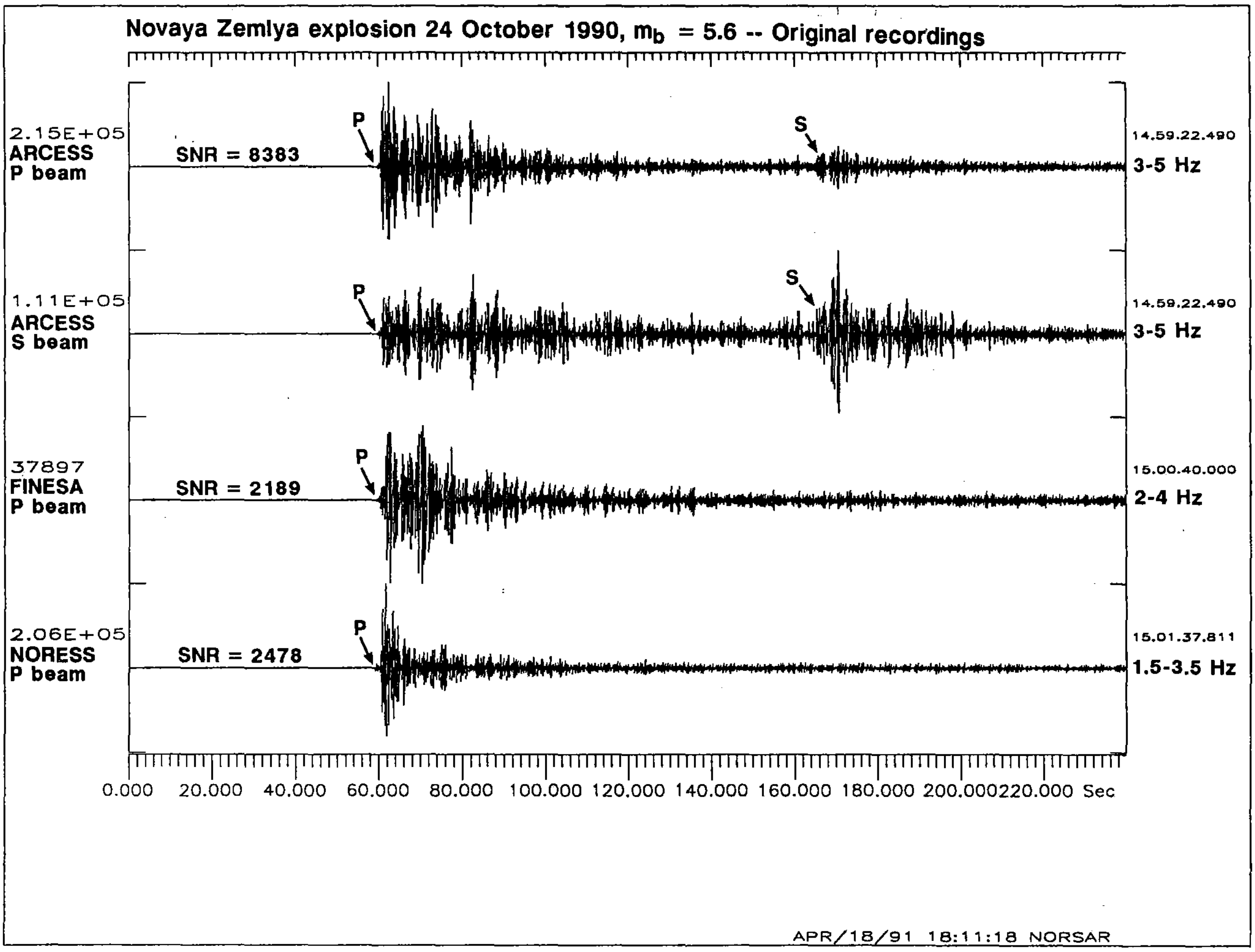

Fig. 7.2.2. P- and S-wave recordings (filtered array beams) at ARCESS, FINESA and NORESS for the Novaya Zemlya nuclear explosion of 24 October 1990. The SNRs of the detecting P-beams are also given.

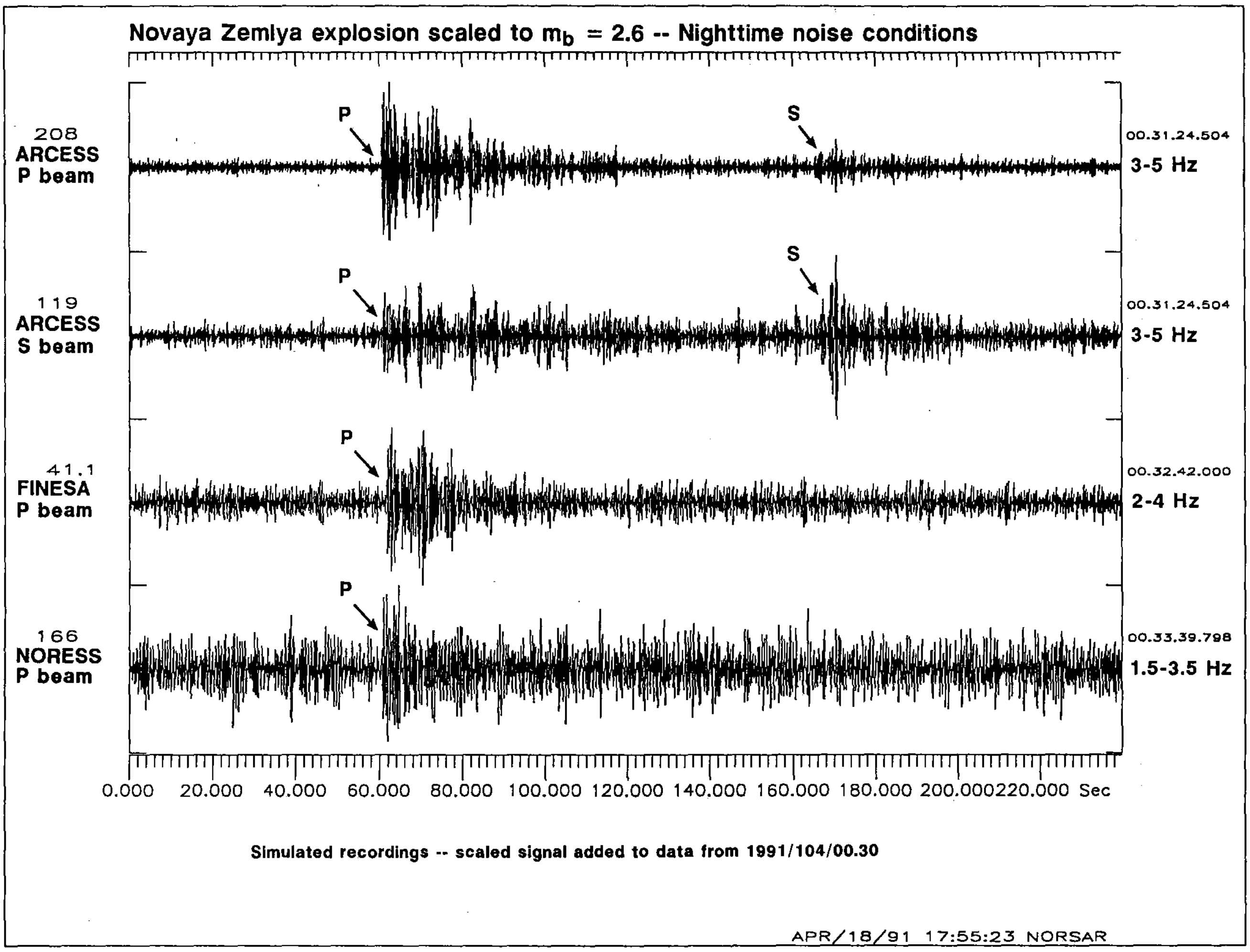

Fig. 7.2.3. "Down-scaled" signals from the Novaya Zemlya nuclear explosion of 24 October 1990 superimposed on noise during a "low noise" interval. The origin time of the simulated "event" is 1991/101/00.30.00.

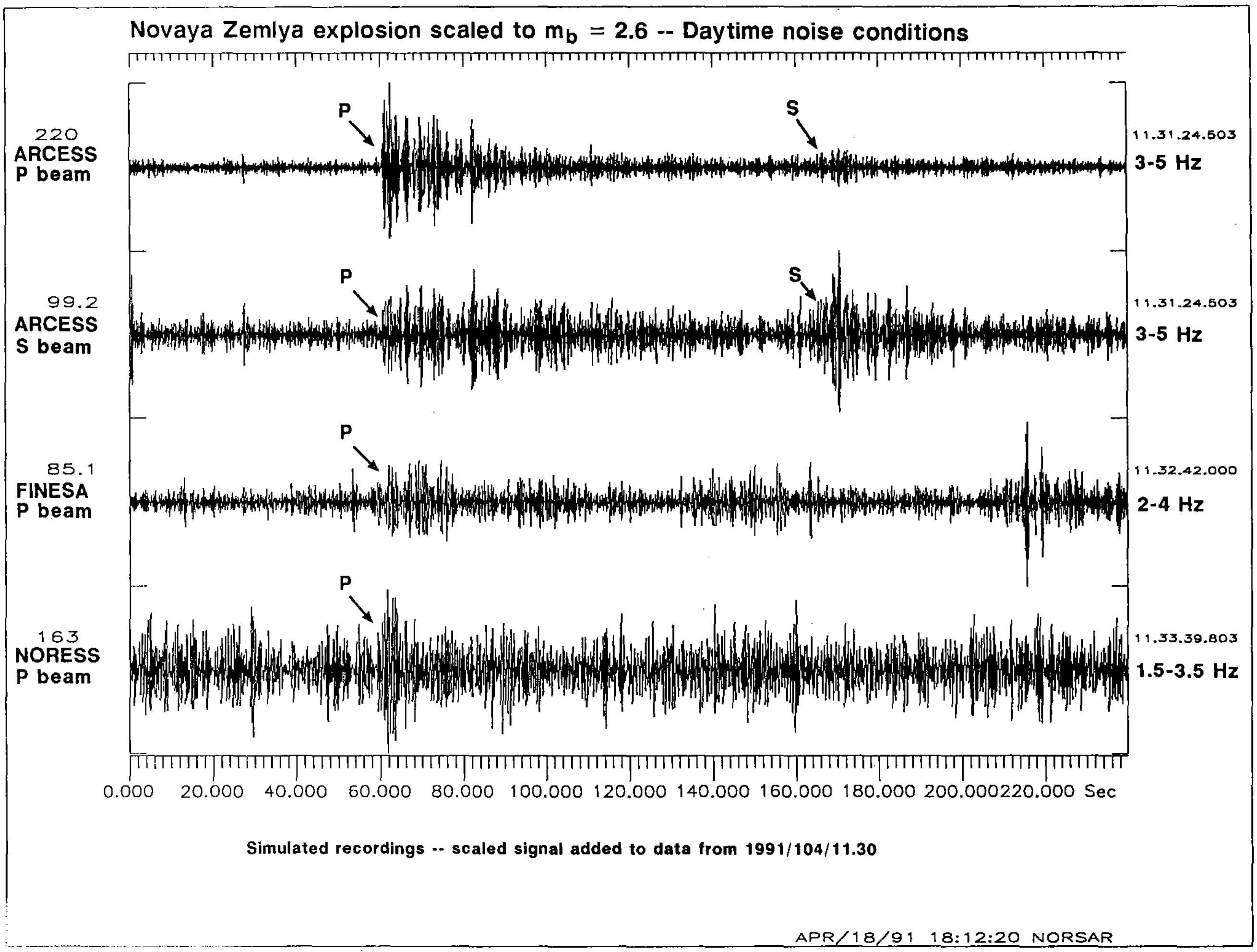

Fig. 7.2.4. Same as Fig. 7.2.3, but for a "high noise" interval. The origin time of the simulated "event" is 1991/101/11.30.00.

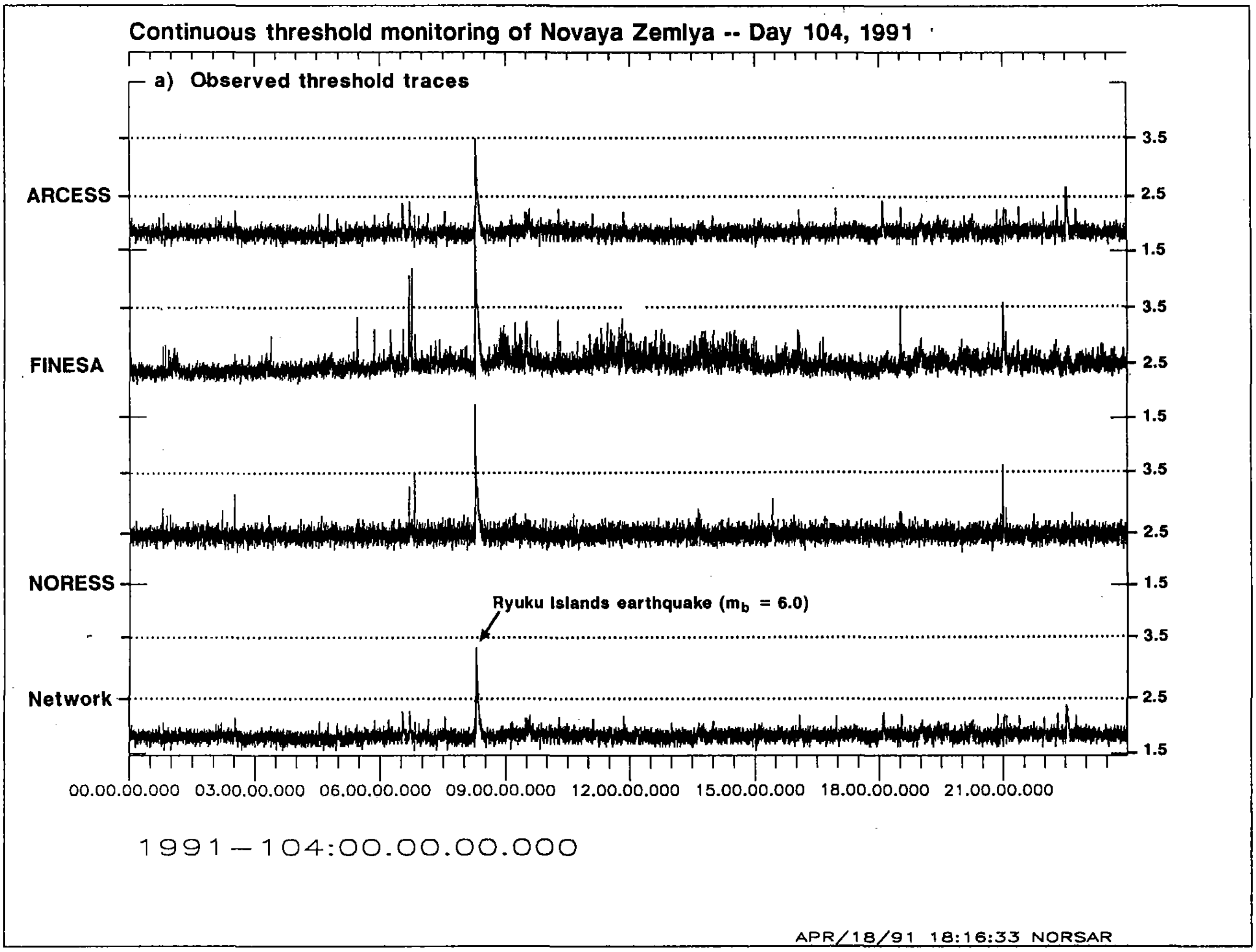

Fig. 7.2.5. Threshold monitoring of the Novaya Zemlya test site for day 1991/104 (14 April 1991). The top three traces represent thresholds (upper 90 per cent magnitude limits) obtained from each of the three arrays (ARCESS, FINESA, NORESS), whereas the bottom trace shows the combined network thresholds. Note that for the network trace there is only one magnitude peak exceeding 2.5.

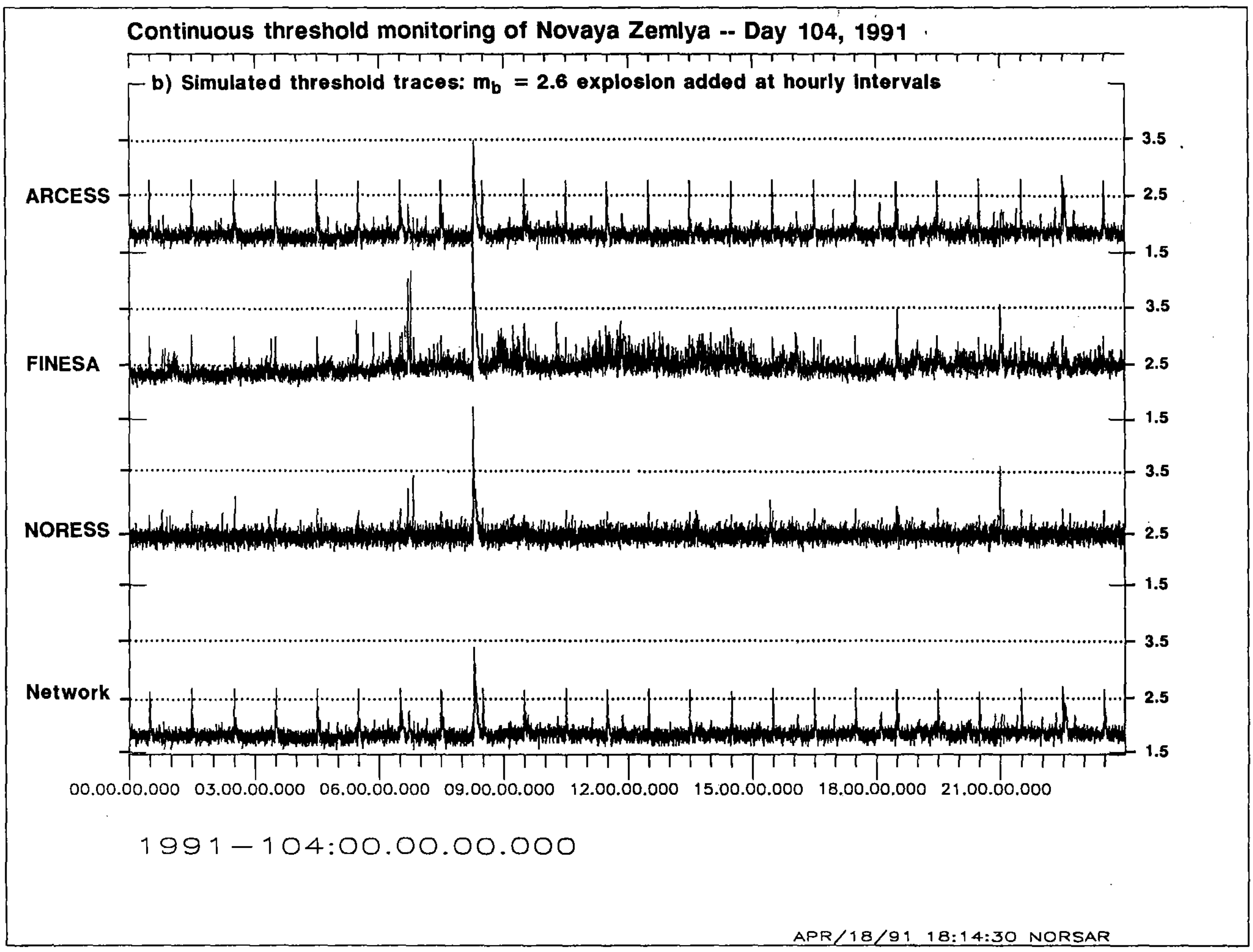

Fig. 7.2.6. Same as Fig. 7.2.5, but with down-scaled signals superimposed on the data at hourly intervals. Note that all occurrences of the simulated $m_b = 2.6$ events clearly stand out on the combined network trace.