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VII.6 New results from processing of data recorded at the new ARCESS regional array

The previous NORSAR Semiannual Technical Summary contained a contribution (Mykkeltveit et al, 1987) that described the NORESS-type array installed in northern Norway during the fall of 1987, and also gave some initial results from analysis of data recorded during its first phase of operation. In the present contribution, we report on some additional findings resulting from analysis recorded at ARCESS, which is the name now adopted for this new array.

Analysis of data from the ARCESS High Frequency Seismic Element

The first High Frequency Seismic Element (HFSE) was installed at NORESS in 1985 and has been described by Ringdal (1986a). Another HFSE was installed in ARCESS at the same time as the array was deployed, and we have selected seven events as shown in Fig. VII.6.1 for further analysis using these high frequency recordings. The raw data and bandpass filtered data 30-50 Hz are shown in Figs. VII.6.2 and VII.6.3, respectively, for the vertical component of the HFSE.

As we can see from these figures, there is appreciable energy to beyond 500 km distance in the 30-50 Hz band. However, it is noteworthy that no energy in this band is seen above the background noise for event 7 (M_L = 2.6) at the distance of 714 km.

This behavior is to some degree similar to what was found by Ringdal (1986a) for NORESS, but there are also indications from these seven events that the propagation of high-frequency energy is not quite as efficient around ARCESS as around NORESS. We emphasize, however, that further study is needed before such a conclusion can be reliably established.

Propagation of Rg waves at ARCESS

The 1 Hz surface wave of Rayleigh type, often referred to as Rg, is clearly observed for many events recorded at ARCESS. It is generally known that it takes a shallow source to generate such waves. At NORESS, the Rg phase is never observed for events at distances larger than 70-90 km, irrespective of azimuth. At ARCESS, on the other hand, we have observed clear Rg phases for events located more than 400 km away.

Fig. VII.6.4 shows the Rg phase recorded at the ARCESS high frequency station for an event (no. 4 in Fig. VII.6.1) located at a distance of 349 km. For event no. 3 in Fig. VII.6.1, no Rg waves are observed, even though this is a mining explosion at shorter distance than event no. 4. This shows that the occurrence of Rg is dependent on azimuth. In view of the potential of using Rg in discriminating between shallow and deep sources, this phase will be the subject of further study in our future work.

ARCESS regional P-wave detection capability

An initial assessment of the detection capabilities of ARCESS has been made using the method described by Ringdal (1986b). Adopting the Helsinki seismic bulletin as a reference, we have associated P-phases detected by the on-line procedure with the reported reference events. The time interval processed is essentially January - March 1988, with some events during 1987 also included. The results for a source region comprising mainly the mining areas of western Russia and Finland surrounding the Bothnian Bay are shown in Fig. VII.6.5. This figure gives a histogram of the number of reference events at each magnitude, with the events detected by ARCESS marked specially. The figure further contains a detection probability curve with associated confidence limits, estimated by the maximum likelihood method of Ringdal (1975).

We note that the 90 per cent P-wave detection capability in the region studied (distance range 800-1200 km) is close to $M_L = 2.5$. This can be compared to the NORESS threshold of $M_L = 2.7$ found by Ringdal (1986b) for a similar distance range (700-1400 km). It must be noted here that the reference events were on the average at a slightly greater distance in the case of NORESS, and this may to some extent account for the difference. Nevertheless, we conclude that the new array appears to have a regional detection capability that at least matches that of NORESS.

Regional location capability

The capability of ARCESS to locate seismic events at regional distances has been evaluated and compared to that of NORESS. In addition, we have investigated the joint location capabilities of the two arrays. The data base for this study has comprised a set of seven regional events in October/November 1987, for which we have accurate independent location estimates computed at the University of Helsinki, on the basis of the Fennoscandian network of data.

For the purpose of estimating event location, we have used the program TTAZLOC developed by Bratt and Bache (1988). This program takes into account arrival times, back azimuth estimates and associated uncertainties, and incorporates these data into a generalized-inverse location estimation scheme. TTAZLOC can be applied both to single-array and multiple-array situations, assuming that a sufficient number of phase detections is available.

Table VII.6.1 lists the events in the data base, together with the main results from the data processing. For each event both the network location and the joint two-array location has been listed, as well as the difference (in km) between the two estimates. For comparison purposes, the differences are also given between network location and locations computed on the basis of each individual array.

We note that the joint two-array location procedure produces excellent results, which on the average differ from the network estimates by only 34 km. In contrast, the error in the single-array results are typically more than 100 km. It must be emphasized that six of these events are of very low magnitude (M_L 2.1 to 2.5), and all are at an appreciable distance from both arrays (see Fig. VII.6.6). It is known from earlier NORESS studies that distant regional events are much more difficult to locate accurately than close-in events.

It is noteworthy that the above results have been obtained using arrival times and azimuths estimated automatically using the on-line RONAPP processing system. There is clearly a potential of improvement in using interactive analysis to extract more precise phase arrival times. Also by taking into account regional wave propagation effects, e.g., in a joint epicentral determination scheme, using nearby reference events, it is likely that increased accuracy can be obtained. On this background, the results are quite encouraging.

Conclusions

The initial results from analyzing data from ARCESS show that it fully matches the capabilities of NORESS in terms of regional detection, location and phase identification capabilities. Some significant differences in phase characteristics have been observed between the two arrays, in particular regarding high frequency (>30 Hz) signal propagation and propagation characteristics of the Rg phase. This confirms that optimum multi-array processing will need to take into account regionally based corrections tailored specially to each array. The joint analysis of data from NORESS and ARCESS has been shown to give significantly more precise event location estimates for weak seismic events than each individual array, and a network of such arrays would be expected to provide further improvements.

As the ARCESS array is still in an initial phase of operation, the results presented in this study are based on a limited time interval of recordings. Comprehensive assessments of ARCESS capabilities as well as the joint detection, location and identification potential of the NORESS/ARCESS system will require a much more extensive data base, and will be the subject of further study.

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References

Bratt, S.R. and T.C. Bache (1988): Locating events with a sparse network of regional arrays. Bull. Seism. Soc. Am., 78, 780-798.

Mykkeltveit, S., F. Ringdal, J. Fyen and T. Kværna (1987): Initial results from analysis of data recorded at the new regional array in Finnmark, Norway. Semiannual Technical Summary, 1 Apr - 30 Sep 1987, NORSAR Sci. Rep. No. 1-87/88, Kjeller, Norway.

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Event No.	Origin date, time		Mag. M_L	Network Location (1)		NORESS/ARCESS Joint Location (2)		Location "error" (2) - (1) (km)	Single array location "error" (km)	
				Lat.	Lon.	Lat.	Lon.		NORESS	ARCESS
1	10/31/87	10.09.08	4.2	61.11	4.51	60.84	5.35	54	33	191
2	11/02/87	13.28.00	2.5	61.40	31.60	61.74	31.18	43	277	154
3	11/03/87	22.35.12	2.3	68.37	15.21	68.02	16.56	67	269	125
4	11/06/87	08.25.21	2.1	66.51	14.87	66.45	14.93	8	15	27
5	11/10/87	11.06.58	2.2	59.63	22.36	59.60	22.13	13	93	148
6	11/10/87	12.29.01	2.3	61.50	30.40	61.58	29.80	33	21	84
7	11/13/87	12.15.20	2.3	59.30	27.60	59.35	27.84	15	86	92
							Averages	34	113	117

Table VII.6.1 Comparison of epicentral location estimates from NORESS/ARCESS and the Fennoscandian network (reference to Helsinki bulletin) for a set of seven events. The location accuracy of each individual array is also given. Events 1, 3 and 4 are earthquakes; events 2, 6 and 7 are mining explosions and event 5 is a presumed underwater explosion.

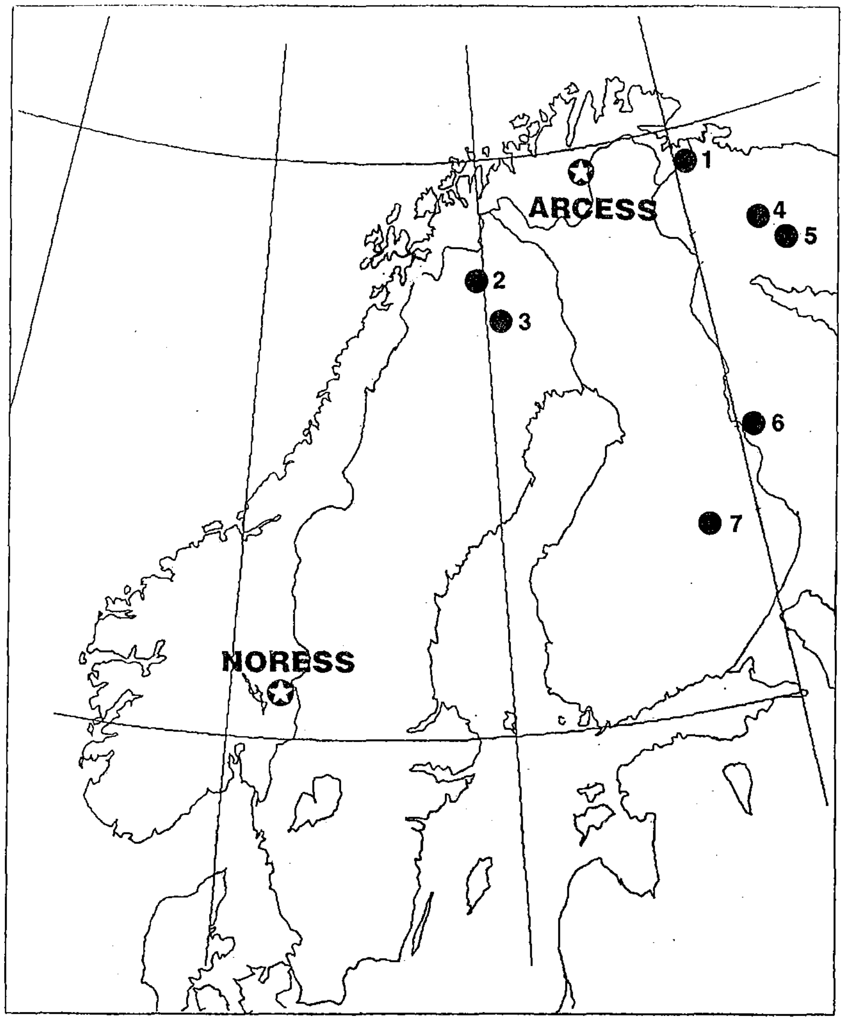
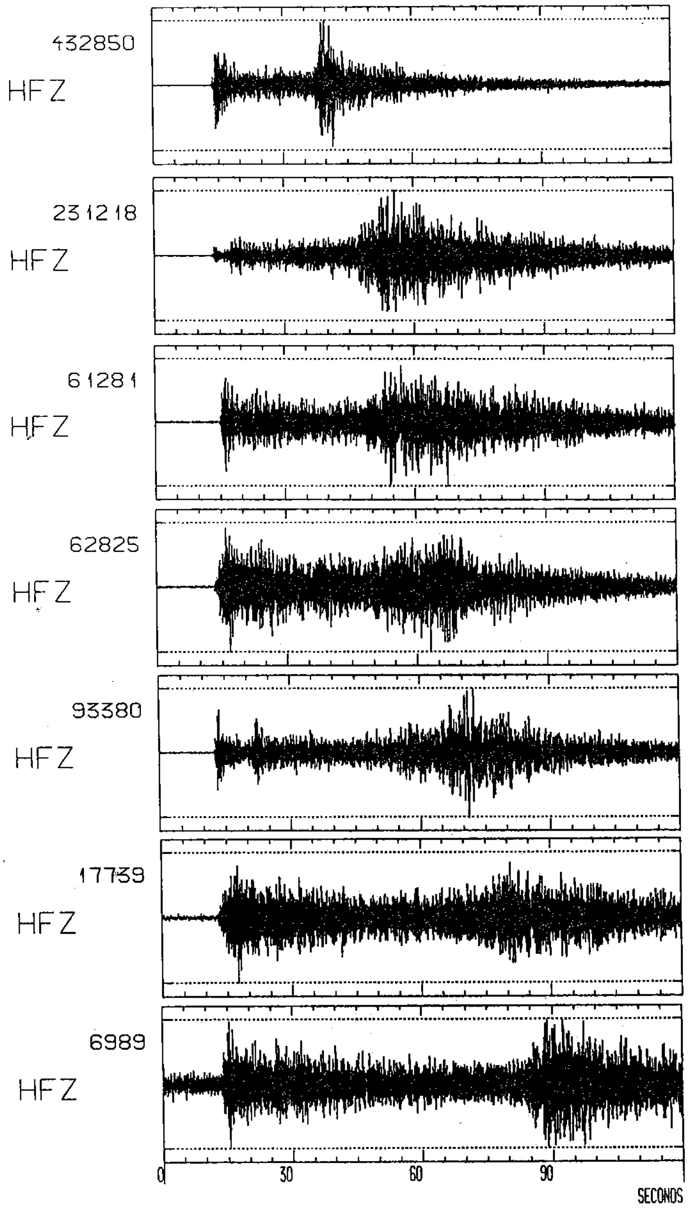


Fig. VII.6.1 The seven events for which ARCESS high frequency data are plotted. The locations of the NORESS and ARCESS arrays are also shown.



Event no.	Distance (km)	Magnitude
1	208	3.1
2	304	3.4
3	339	2.3
4	349	2.5
5	415	2.9
6	584	2.5
7	714	2.6

<u>Fig. VII.6.2</u> Raw data for the HFSE vertical component for the seven events of Fig. VII.6.1.

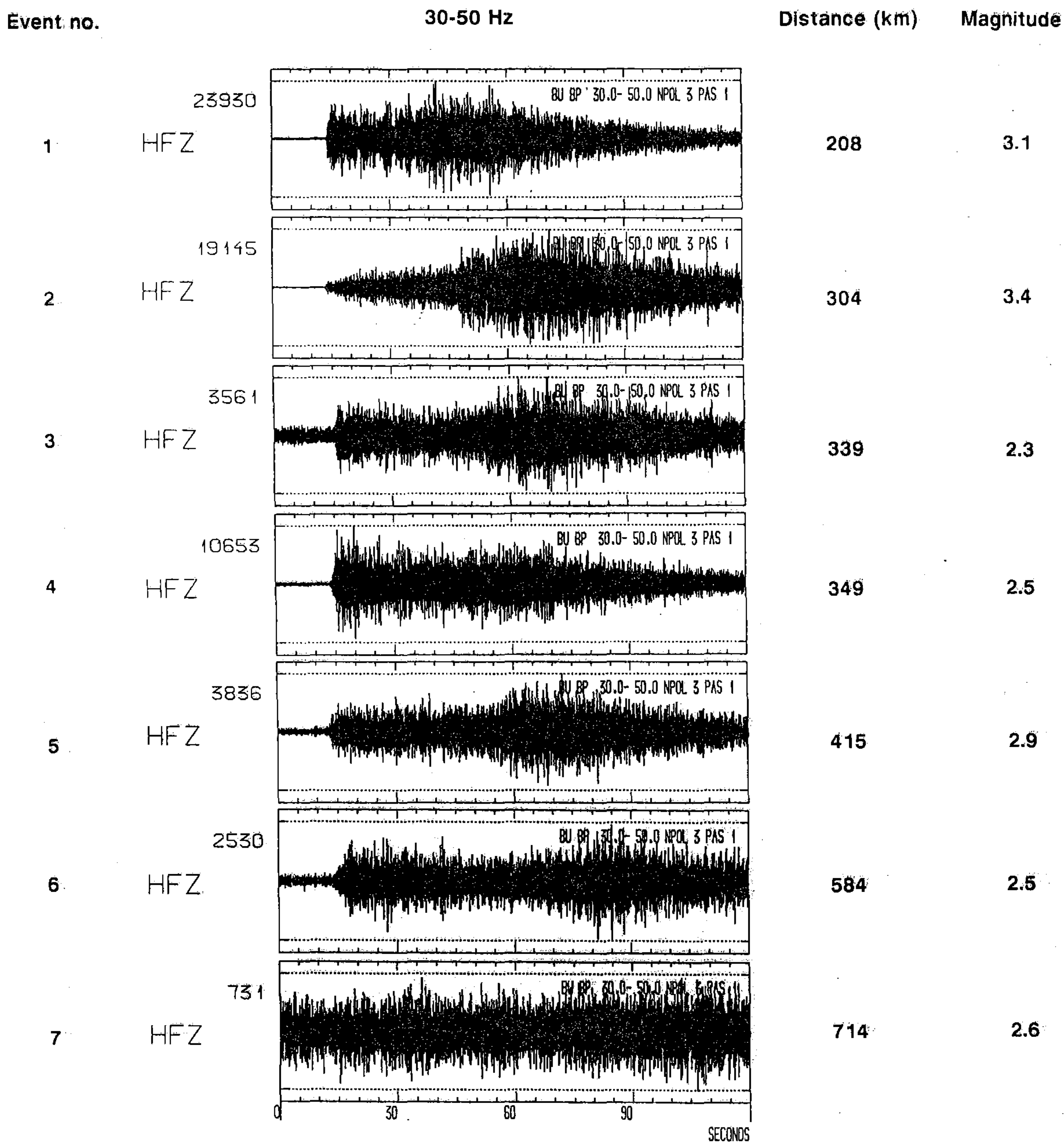


Fig. VII.6.3 Bandpass filtered data 30-50 Hz for the HFSE vertical component for the seven events of Fig. VII.6.1.

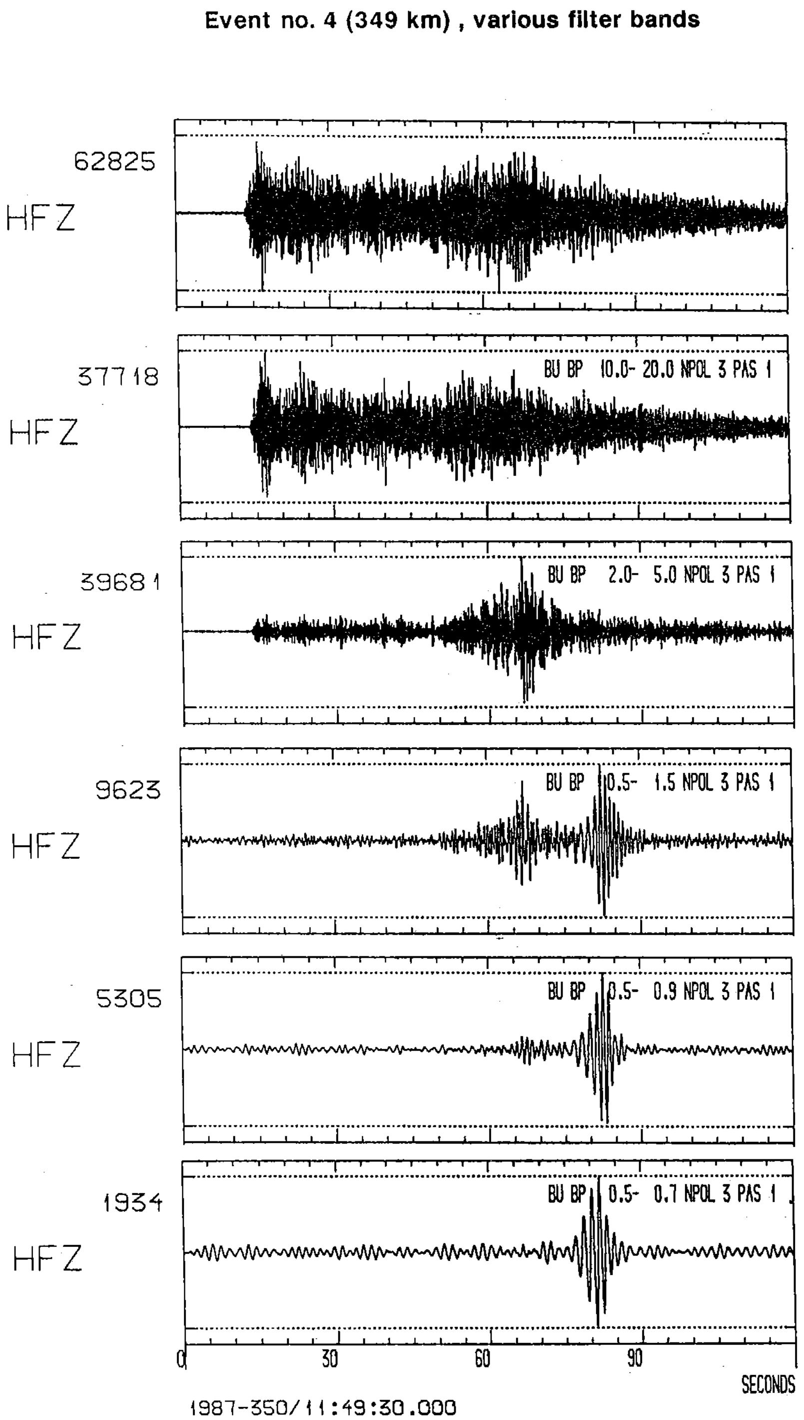
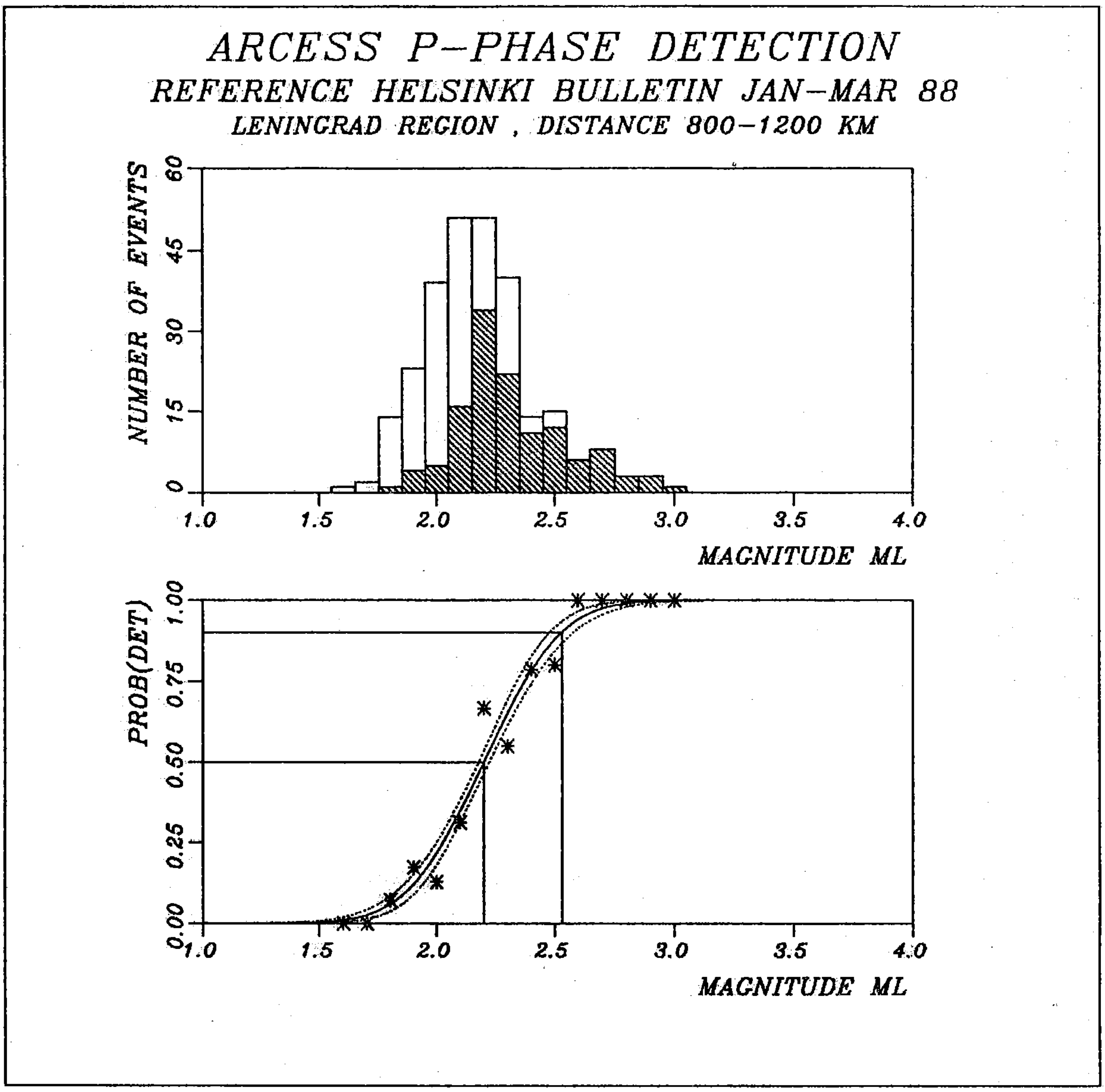


Fig. VII.6.4 The Rg phase for event no. 4 in Fig. VII.6.1 is clearly seen in the three bottom traces.



<u>Fig. VII.6.5</u> P-phase detection statistics for ARCESS for regional events in the distance range 800-1200 km, using the Helsinki bulletin as a reference. The upper part of the figure shows the distribution of events by magnitude with detected events corresponding to the hatched columns. The bottom part of the figure shows the estimated detection probability curve as a function of magnitude, with the observed detection percentages marked as asterisks. The stippled curves mark the 90 per cent confidence limits.

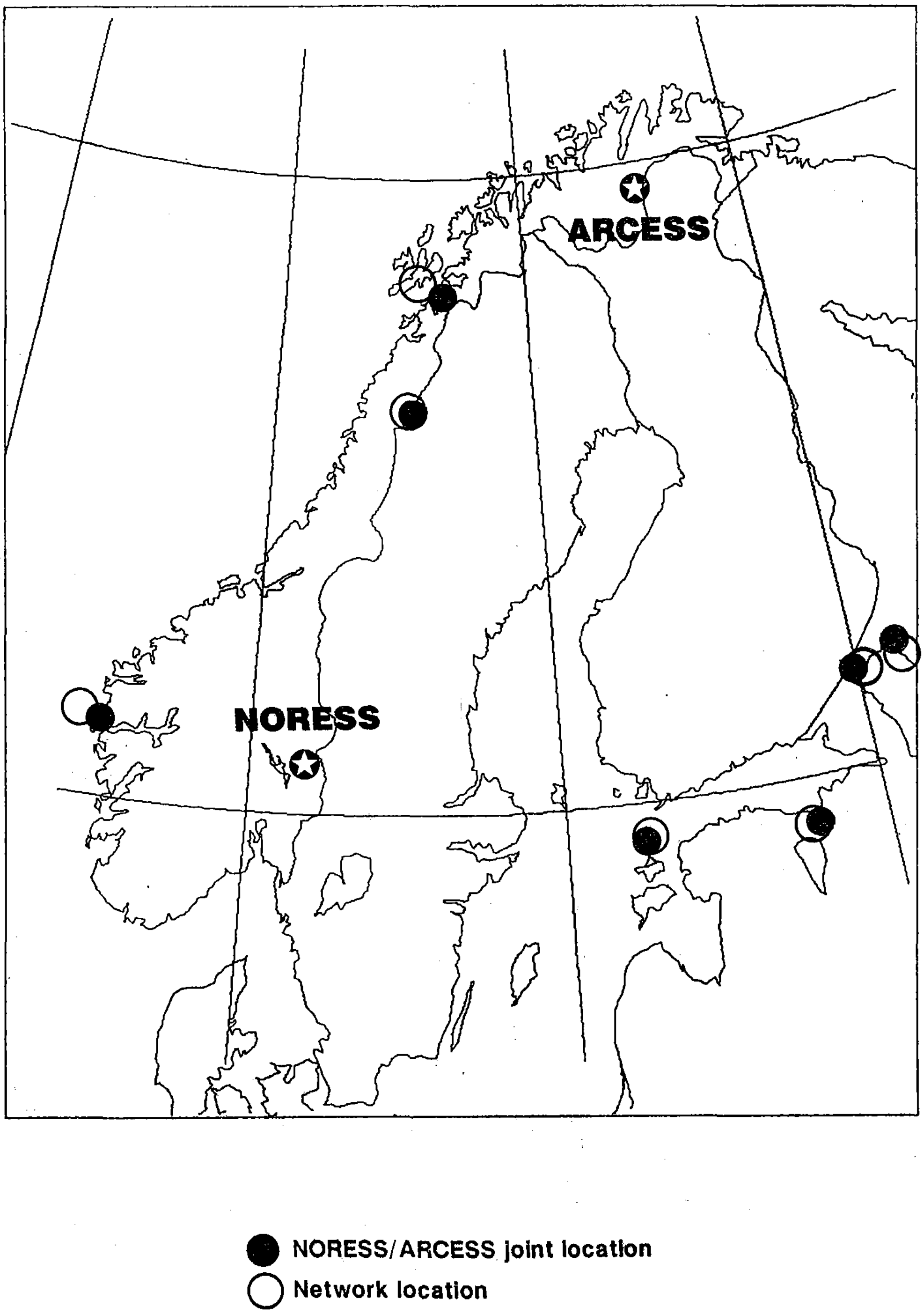


Fig. VII.6.6 Joint two-array location results for the events listed in Table VII.6.1. The open circles are centered at the epicenter locations computed at the University of Helsinki on the basis of Fennoscandian network data, wheras the filled circles are centered at the locations computed from the TTAZLOC program using data from the two arrays (marked on the figure). Note the excellent correspondence of the respective location estimates.