NORSAR ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

NORSAR Scientific Report No. 1-85/86

FINAL TECHNICAL SUMMARY

1 April - 30 September 1985

L. B. Loughran (ed.)

Kjeller, December 1985

VII.4 NORESS-NORSAR processing system comparison

As an initial assessment of the NORESS real time event detector, a study has been conducted comparing the NORESS detection file to the seismic bulletin generated from NORSAR data. Such a comparison is of particular interest since the small NORESS array is located in the same geographical area as the large NORSAR array (Fig. VII.4.1). Thus we obtain a measure of how the high-frequency NORESS processing based on densely deployed sensors compares to the NORSAR processing, which utilizes lower signal frequencies and larger intersensor spacing.

The data base for this study covers the six-month period April-September 1985, during which the NORESS experimental detection processor (RONAPP) has been run with a fixed parameter setting (reference subsection VII.3). For the purposes of this evaluation, time intervals when NORESS operation was degraded due to transmission line problems have been deleted, thus the total number of full data days is 138, or approximately 75 per cent of total time.

The NORSAR event list for these 138 days comprises in total 1628 seismic events. All of these have been reviewed and accepted by the analyst, and thus constitutes an excellent reference data base. The NORESS automatic detection list for the same interval contains 14069 entries, and has not been subject to systematic analyst review. From the results of subsection VII.3, it is clear that the large majority of NORESS detections correspond to local and regional phases, which are not reported in the NORSAR bulletin. Thus, the respective numbers of NORSAR-NORESS detections alone give no measure of the relative array detection performance, and it is necessary to match the entries directly against one another in order to obtain a comparison.

The following procedure was applied in matching NORESS detection entries against NORSAR-reported events. For each NORSAR event, the predicted P arrival time at NORESS was calculated based on the NORSAR arrival time and the NORSAR estimated phase velocity and azimuth. If one or more NORESS detections were found within 15 seconds of the predicted time, the time of the earliest such detection was then examined. If this differed less than 3 seconds from the predicted time, a match was automatically declared. If the difference was in the range 3-15 seconds (about 5 per cent of the cases), the NORESS recordings were reviewed in order to determine whether or not they represented the same event (typically, this would be a emergent P phase). In cases where no NORESS entry was found within 15 seconds of predicted time, the event was considered not detected by NORESS.

A total of 1376 of the reference events was thus found to be detected at NORESS, i.e., 84.5 per cent. The NORSAR-reported events are almost exclusively at teleseismic and greater distances, thus this high percentage shows that NORESS has an excellent detection capability for teleseismic and core phases. It might be added that a significant number of the NORESS detections which have no matching NORSAR entry also appear to be of teleseismic origin, and this will be the subject of further study in the future.

Fig. VII.4.2 illustrates the differences in observed and predicted NORESS arrival time for the 1376 common events. In reviewing this figure, it must be kept in mind that the NORSAR arrival times have been refined through analyst review, whereas the NORESS times have been determined automatically. There is on the average a slight positive bias (about 0.5 seconds) in the data, and about 80 per cent of the observed differences are within 1.5 seconds of this average. This indicates that the automatic arrival time definition used in the NORESS processing system works quite well, especially taking into account that the large majority of the events are of low magnitude, and many are characterized by emerging P-waves or multiple phases.

The percentages of NORSAR events detected by NORESS are shown as a function of distance and azimuth (NORSAR estimates) in Figs. VII.4.3 and VII.4.4. Not surprisingly, NORESS detects all of the NORSAR events within 20 degrees distance (as well as many more events not visible on NORSAR recordings). Otherwise, Fig. VII.4.3 shows that the relative NORESS detection performance of P-waves decreases slightly with increasing distance. A noteworthy feature is the high percentage of core phases detected by NORESS; this is primarily due to the predominantly high frequency signals seen from the Kermadec-Fiji Islands region in combination with favorable signal-focusing effects at NORESS for this region.

From Fig. VII.4.4 it is seen that the large majority of NORSAR events are in the azimuth range 0-120 degrees. The NORESS detection percentages are about constant when averaged over 30 degrees azimuth windows. The only exception, the interval 180-210 degrees, comprises very few events, mostly low-frequency earthquakes from the South Atlantic Ridge. Even when taking the uneven distribution of reference events into account, it might be surprising that NORESS does not show higher percentages for the predominantly high frequency signals from Asia (azimuths 0-120 degrees) than for the low frequency signals from North America (azimuths 270-360 degrees). The explanation lies in the signal focusing effects across NORSAR: For high seismicity areas such as the Japan-Kamchatka arc and Hindu Kush, NORSAR benefits from sharp focusing effects at subarrays 02B and 03C, respectively, whereas the NORESS site (06C) is relatively poor in comparison. The fact that the detection percentages remain so high is attributed to the improved gains by the high frequency signal processing at NORESS. The high NORESS detection percentages from North America are due to relatively favorable focusing effects at the NORESS site for this region, which at least partly compensate for the detectability loss caused by low signal frequencies.

For those teleseismic regions that are characterized by both high-frequency signals and favorable signal focusing effects at the NORESS site, the NORESS detection performance appears to be significantly better than that of NORSAR (judging from SNR of common events). For example, Semipalatinsk explosions show 10-14 dB higher SNR for NORESS when comparing the respective array beams. Admittedly, at least part of this difference will be compensated for by the introduction of higher frequency filters at NORSAR, which is now in progress.

The 1376 common NORSAR-NORESS events have also provided a data base for comparing various signal parameter estimates. Fig. VII.4.5 shows the results with respect to azimuth and slowness. The median NORSAR-NORESS difference is 12 degrees (azimuth) and 1.5 s/deg (slowness). It should be noted that the grid used in the automatic f-k analysis of NORESS signals is relatively coarse, and this is likely the reason for some of the differences. Also, at low SNR, the NORESS f-k solution becomes more unreliable because of noise interference, and analyst interaction would be necessary to improve the estimates in such cases. Nevertheless, it appears that NORESS can provide, in most cases, a useful automatic estimate of teleseismic phase velocity and azimuth. The eventual capabilities of the array in this regard cannot be assessed until more detailed regional studies have been conducted.

The differences in estimated dominant signal period for NORSAR and NORESS are illustrated in Fig. VII.4.6. This parameter is measured manually at NORSAR, automatically at NORESS, in both cases on the respective array beam. The NORSAR beam is unfiltered, whereas a variable prefilter is applied at NORESS, and this accounts for some of the differences. However, the most significant factor appears to be the array beam loss at high frequencies at NORSAR, causing the NORSAR period measurement to be biased high in many cases.

In conclusion, this study has shown that the high-frequency signal processing conducted at NORESS provides a teleseismic detection capability which is comparable to that of the much larger aperture NORSAR array. NORESS also gives useful azimuth and phase velocity information for teleseismic events, although its capabilities in this regard are limited by the array aperture. Further studies will be directed toward continued improvements in NORESS automatic processing, and also toward taking advantage of the NORESS experience in improving high-frequency signal processing at NORSAR.

F. Ringdal

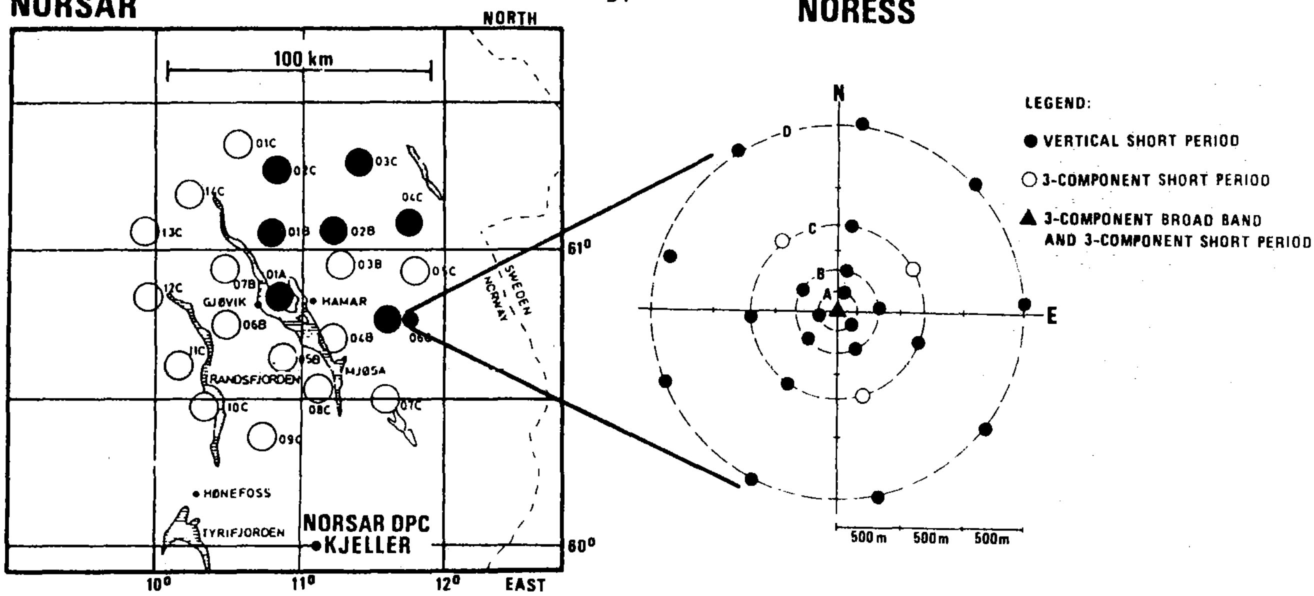


Fig. 1 Map showing the relative geometries of the NORSAR and NORESS array. The current NORSAR SP configuration comprises 7 subarrays (large filled circles), each with SPZ seismometers deployed over an area 10 km in diameter. NORESS comprises 25 SPZ sensors within a 3 km diameter aperture.

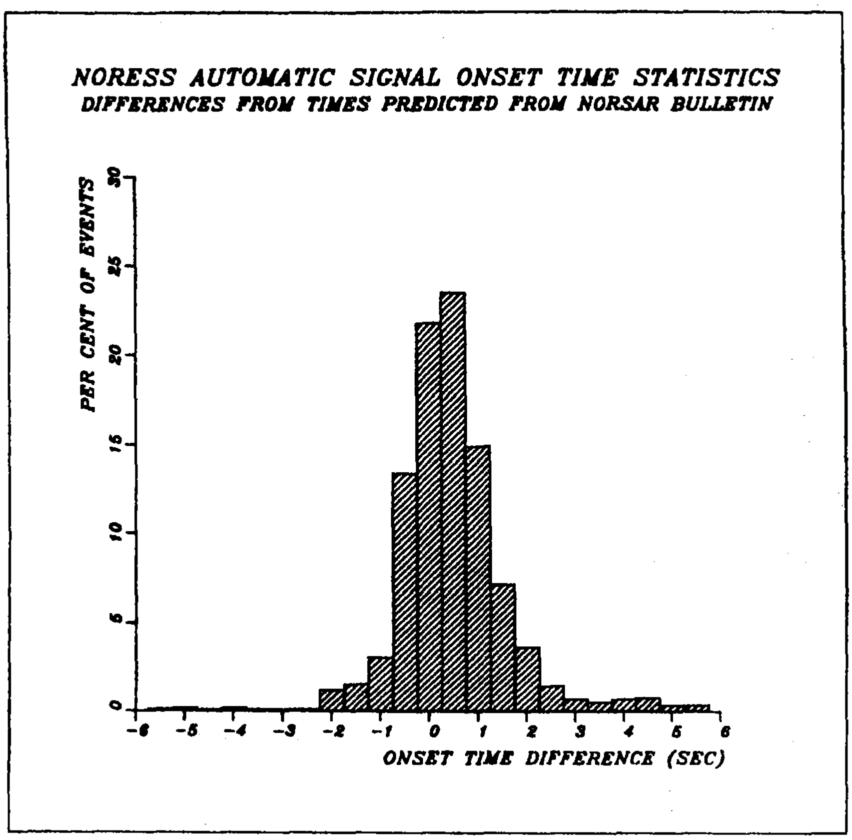
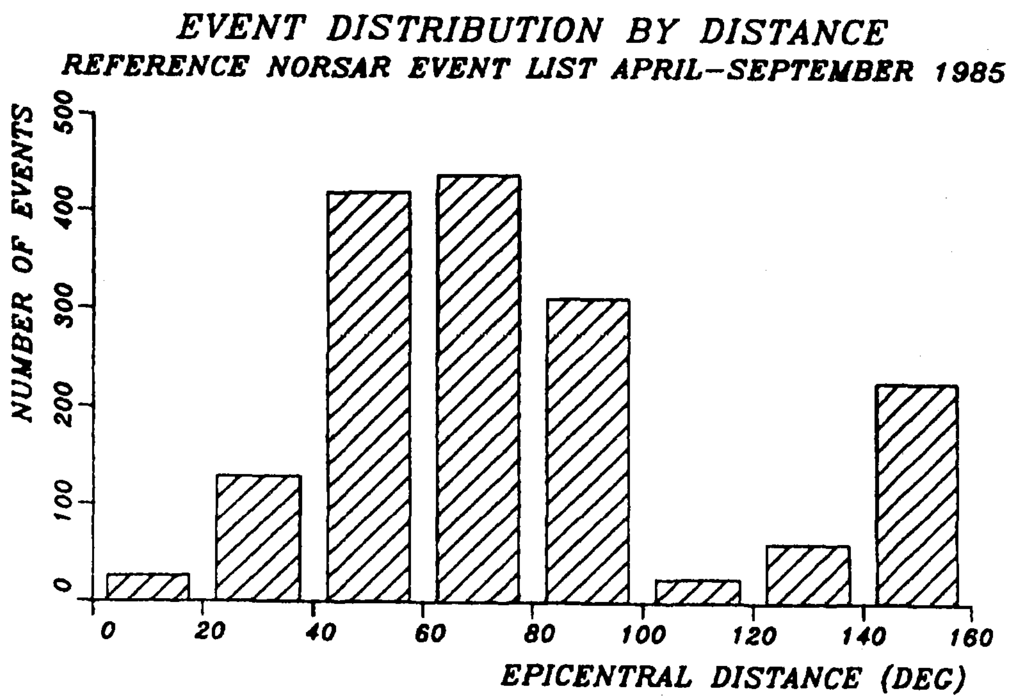


Fig. VII.4.2 Histogram showing the distribution of differences between signal onset times computed for NORESS and predicted onset times based on the NORSAR bulletin. The data base consists of seismic events detected by both systems during April-September 1985.



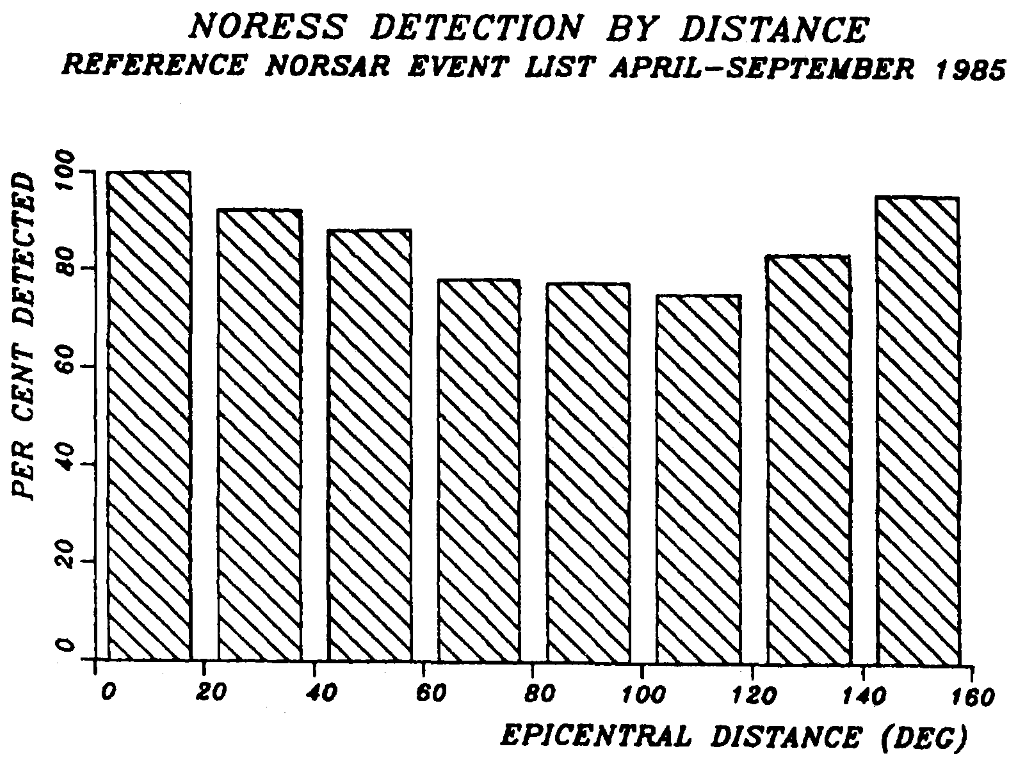
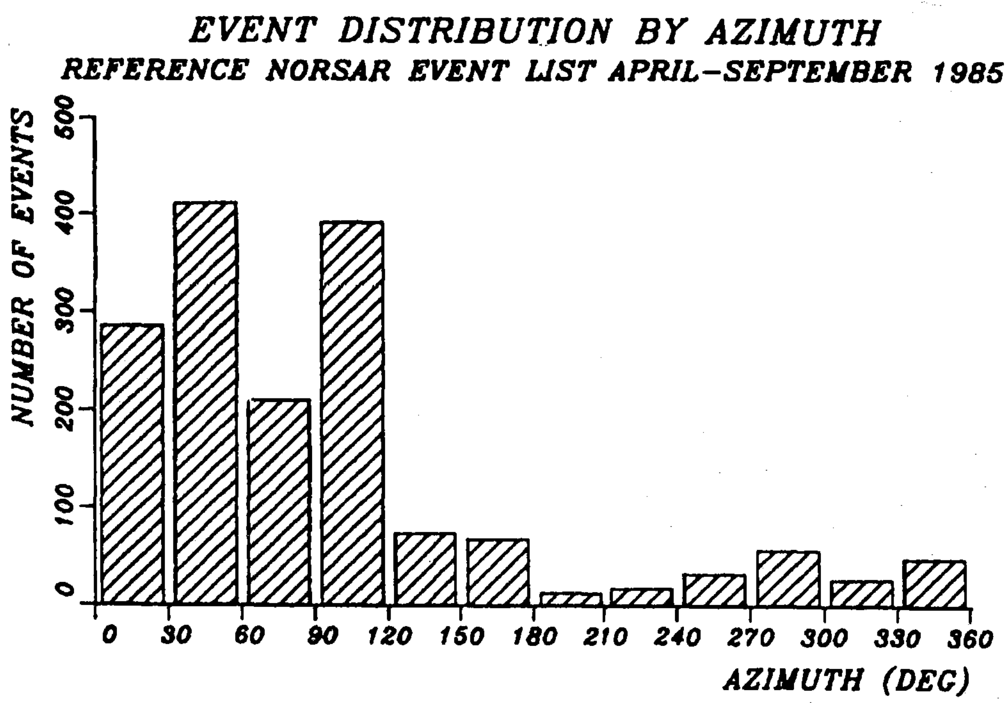


Fig. VII.4.3 Top part of figure shows the distribution by epicentral distance (20 degrees increment) of seismic events reported by NORSAR April-September 1985, during time intervals when NORESS was operational. The bottom part shows percentages of these events detected by NORESS. Note the high NORESS detection percentages at all distances.



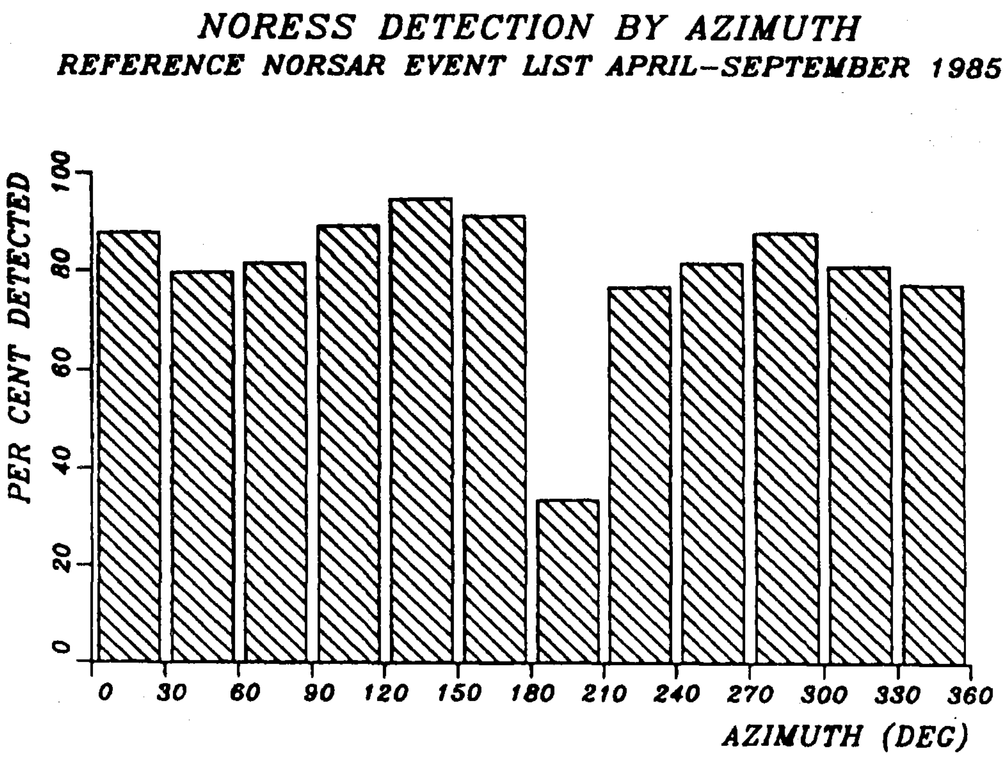
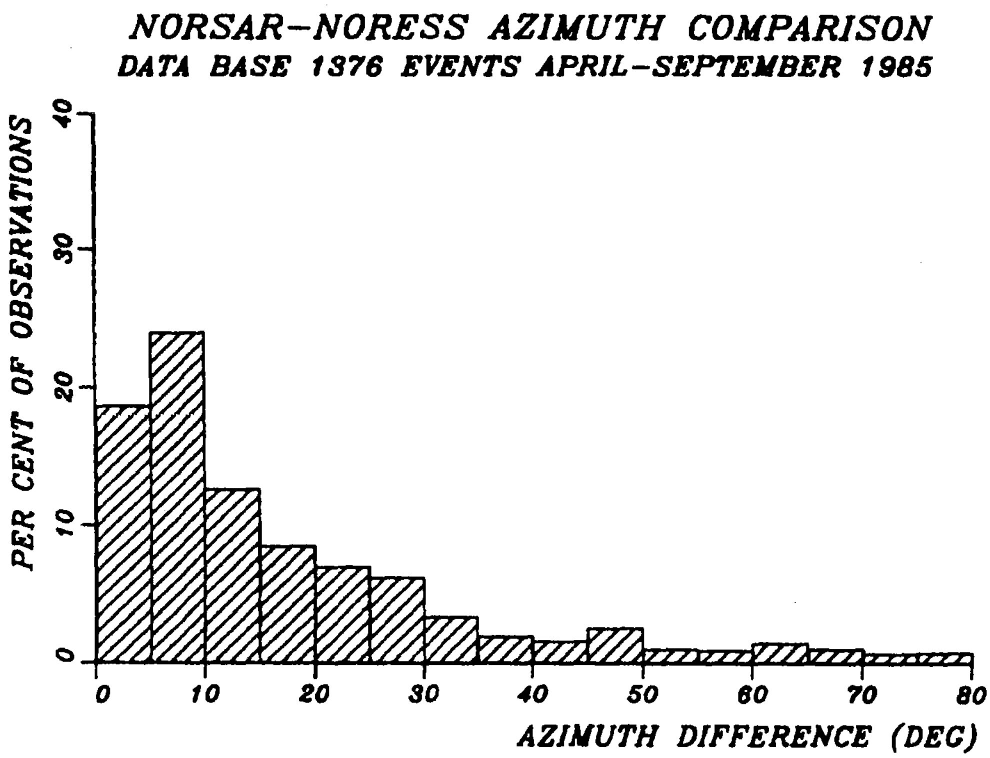


Fig. VII.4.4 Same as Fig. VII.4.3, but with event distribution based on NORSAR azimuth (30 deg increments).



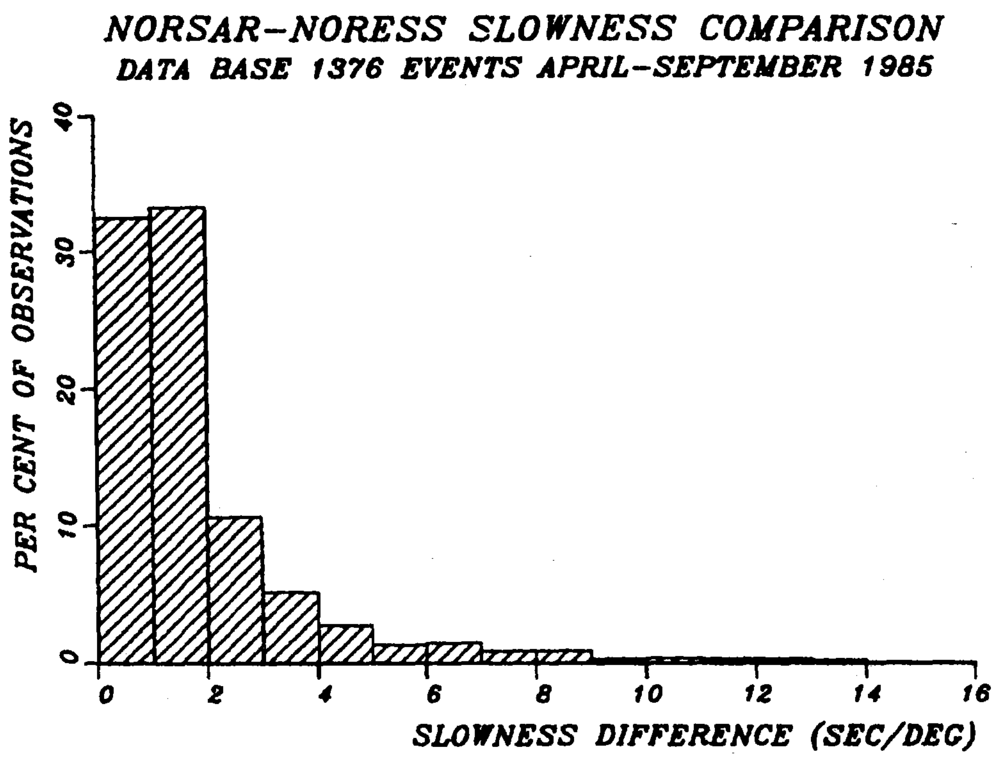


Fig. VII.4.5 Histograms showing differences (absolute values) between NORSAR and NORESS azimuth and slowness estimates for the common events in the data base.

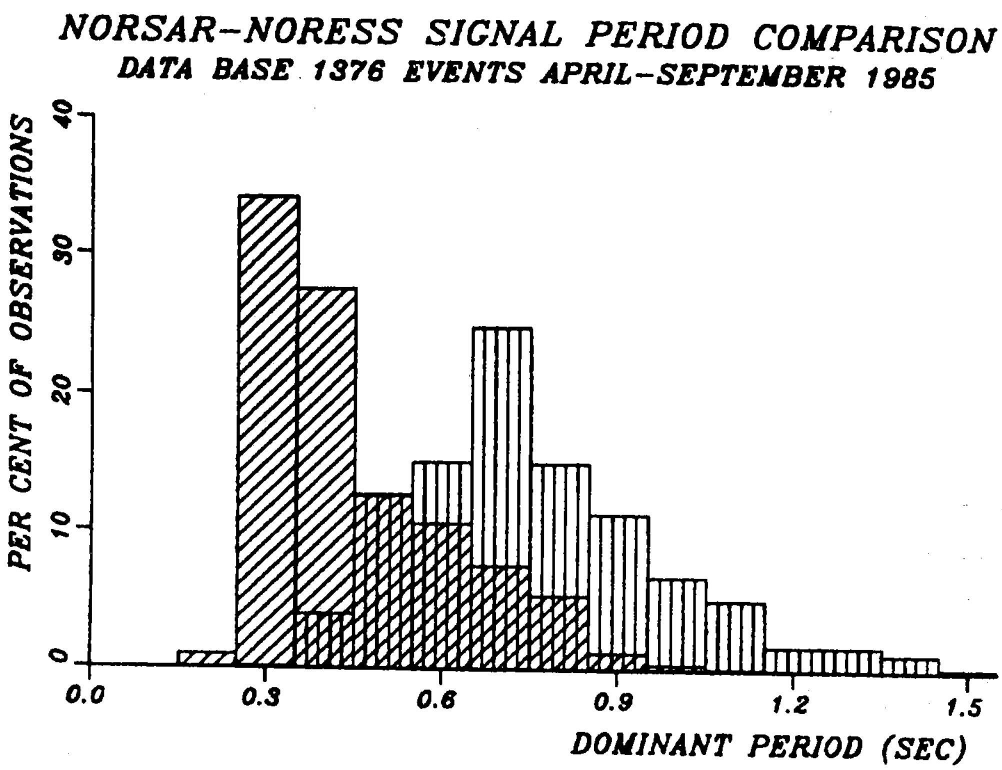


Fig. VII.4.6 Comparison of dominant signal periods estimated by NORSAR and NORESS for common events in the data base. The NORSAR histograms have vertical hatching, vs diagonal hatching for NORESS. Note the significantly lower dominant periods estimated from NORESS data.