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VII.2 Evaluation of NORESS real time processing performance: Case study for 132 Western Norway/North Sea events

The performance of the real time processing of regional events detected and located by the NORESS array is currently being evaluated. For this evaluation it is crucial to be able to compile a data base of events that have been reliably located by another agency. Specifically, one would look for a region with a fair number of seismic events and also well covered by seismic stations. One such region within regional range from NORESS is Western Norway.

During the period April-September 1985 a total of 132 seismic events were detected and located by the RONAPP real time processing package for NORESS data, and also reported by the Western Norway Seismic Network. Fig. VII.2.1 shows the location of the NORESS array, the location of the six stations constituting the network, and the area (hatched) within which the seismic events occurred. These events are typically presumed earthquakes offshore and presumed explosions onshore. The magnitudes are in the range M_L 1.5-3.5, and the epicentral distances relative to NORESS range from 200 to nearly 700 km. 41 of the events were verified through reports as explosions and their locations are known. These explosions occurred at site 1 (3 events), site 2 (36 events) and site 3 (2 events). There is a concentration of events in the coastal area at around 60°N, in addition to the explosion site 2.

Data analysis

The real time processing of NORESS data produces standardized plots which provide the analyst with all essential information on the performance of the automatic event processor. Fig. VII.2.2 gives an example of such plots for one regional event. The location of a regional event results from consecutive detections of

P- and S-type arrivals (identified as P or S according to phase velocity) with a common azimuth. The range is estimated from the travel-time difference between the first P phase (usually Pn) and the strongest phase in the S wavetrain, which is assumed to be Lg, propagating at a constant group velocity of 3.5 km/s. RONAPP utilizes the bearing estimated for the Lg phase in the event location procedure.

Fig. VII.2.3 shows differences bdtween P and Lg azimuths for all events in our data base. The median of the absolute values of these differences is 5 degrees. This is an estimate then of the consistency that should be expected among the azimuths automatically determined for the various phases, for the current choice of processing parameters. Our P and Lg azimuths were compared with those corresponding to the locations by the network. We found that for 47 events the Lg azimuth came closest to the "true" value. For 30 events the P azimuth was the better, and for the remaining 55 events, the P and Lg azimuth deviations from the true values were about the same.

Fig. VII.2.4 shows the differences between the ranges estimated by the NORESS online processing and the ones corresponding to the network solutions. As can be seen from this figure, there is a tendency by the NORESS event location procedure to underestimate the range for events in this region. In addition to the events included in Fig. VII.2.4 there are 35 events in the data base with known location at site 2 (Fig. VII.2.1), for which this range difference is between -10 and -20 km.

Bias sources and location improvements

Both systematic and random errors contribute to the deviations in event locations reported above. The location uncertainty of the network must be considered a random error in this context. The network's average location errors for the explosions with known epicenters are as follows: 30 km for site 1, 10 km for site 2 and 7 km for site 3. For a number of the events in our data base, rather high RMS residuals associated with the network solutions indicate that Lg arrivals may have been mistaken for Sn in reading phase arrivals. This warrants a network relocation experiment for all events in our data base, taking advantage of the regionalization described in section VII.1 of this volume. We think that such a relocation experiment could result in improved network locations.

The frequency-wavenumber analysis leading to an estimate of the arrival azimuth is performed on a finite grid of 41 x 41 points in wavenumber space. This grid size limits the resolution to approximately 3^{o} for the slower phases like Lg and typically 5^{o} for regional P phases. An increase in the number of grid points or a restriction of the frequency-wavenumber analysis to a smaller part of the wavenumber space would increase the resolution power of the azimuth estimator.

The travel time model which is part of the event location algorithm in the RONAPP processing package is based on a uniform Moho depth of 40 km. This is appropriate for a majority of regional propagation paths to NORESS. For the events being studied here, however, a crustal thickness of 30 km in the source region and 35 km at the NORESS array would be adequate. Our location procedure assumes surface sources, while a number of the events in our data base are earthquakes, of unknown but probably intermediate crustal depth. With these changes in our travel time model, the automatically determined ranges would increase by

10 km for surface sources and by 15-20 km for 10-15 km deep earthquakes.

Careful inspection of the NORESS seismograms of our data base resulted in the following observations:

- For 31 events in the distance range 350-500 km we found reason to believe that the Pn phase had gone undetected. For these cases the P phase detected is mostly likely Pg. For most of these events, Pn can be discerned as a weak arrival preceding the much stronger Pg. The time difference is of the order of 3.5-5 sec, corresponding to an underestimation of epicentral distance of the order of 20-30 km. For 28 out of these 31 Pg arrivals, the phase velocity is in the range 6.5-7.5 km/s, which is considered very adequate for this phase. For the three remaining signals, the phase velocity exceed 8 km/s, which would normally be indicative of a Pn arrival. This result indicates a potential of automatically discriminating between Pn and Pg.

- For 9 events, the epicentral range was underestimated by more than 70 km. All of these cases are related to mistaking Sn for Lg, with Sn being the dominant secondary phase or the only secondary phase detected. With proper phase assignments, the ranges for these 9 events would have been correctly determined.

- The main reason for overestimating the range is late detection of the Lg phase.

Corrections along the lines indicated would lead to significant improvements in the range estimation for the Western Norway/North Sea events.

More generally, we think that the experience gained through this case study will result in substantial improvements in the performance of the online processing of regional events recorded on NORESS.

S. Mykkeltveit

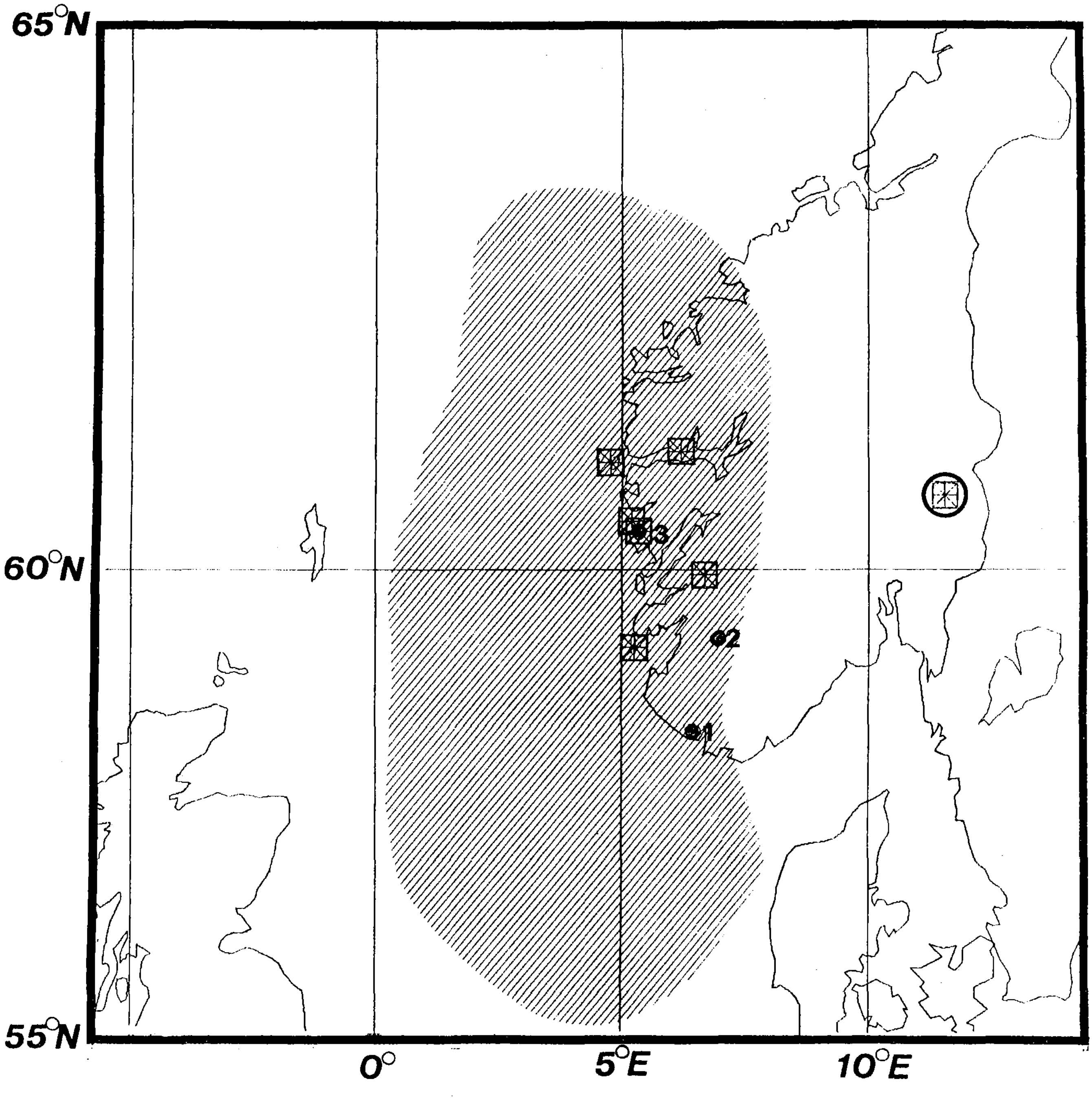

Fig. VII.2.1 Map showing the location of the NORESS array (encircled station symbol), the sixt stations of the Western Norway Seismic Network, the three locations ("1", "2" and "3") for reported explosions, and the source region (hatched) with the 132 seismic events in our data base. The location of some of the offshore earthquakes was constrained also by signals recorded on seismic stations to the west of the source area, i.e., on Shetland and in Scotland.

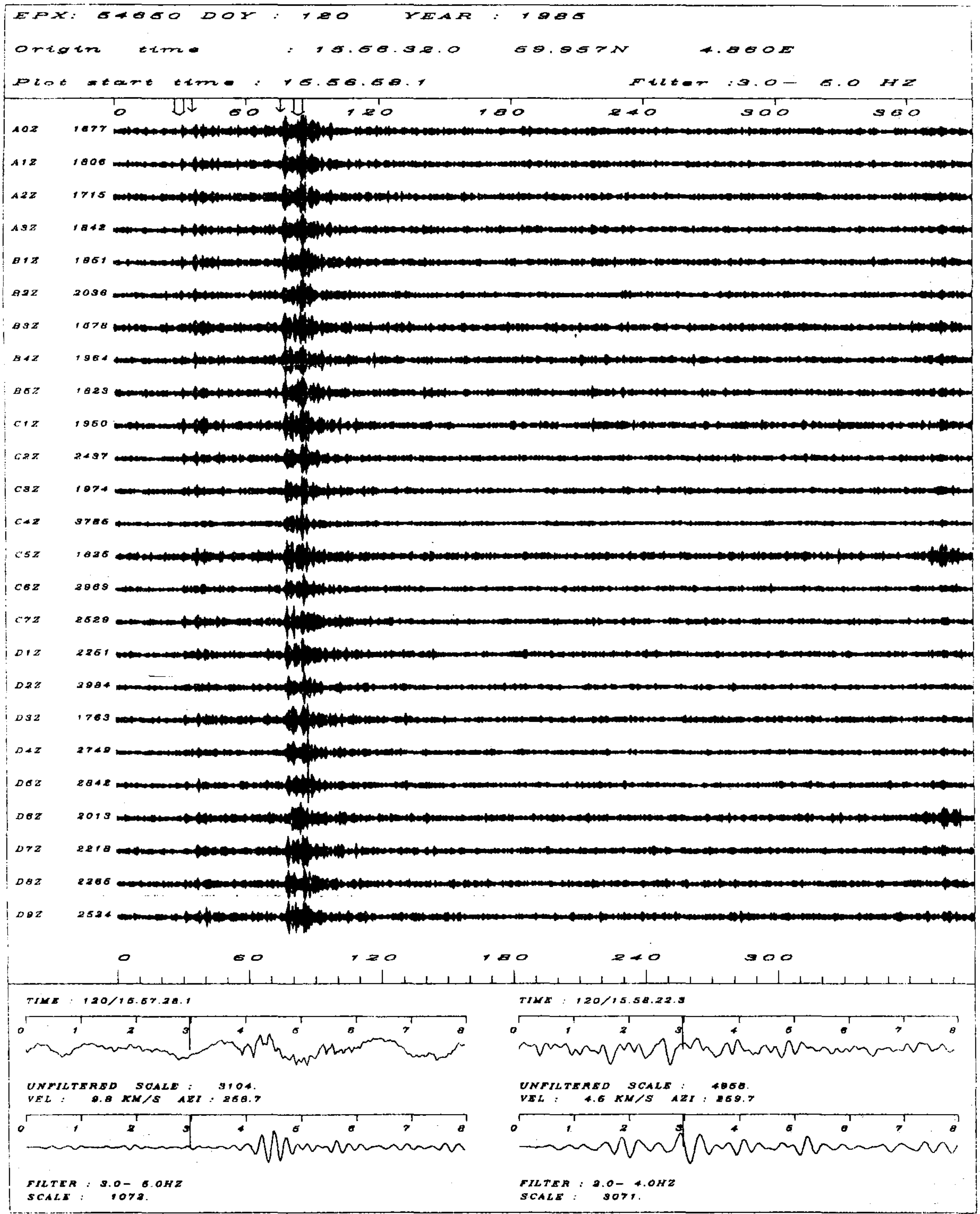

Fig. VII.2.2a Individual NORESS traces for one of the events in our data base. The panel covers 6½ min of bandpass filtered records (3-5 Hz). The four arrows on top of the records indicate detections by the RONAPP real time processing package. The broad arrows correspond to Pn and Lg arrivals, which have been combined to locate the event at the geographical position given on top of the figure. The two additional detections correspond to Pg and Sn arrivals. P and Lg beams are shown in the bottom part of the figure.

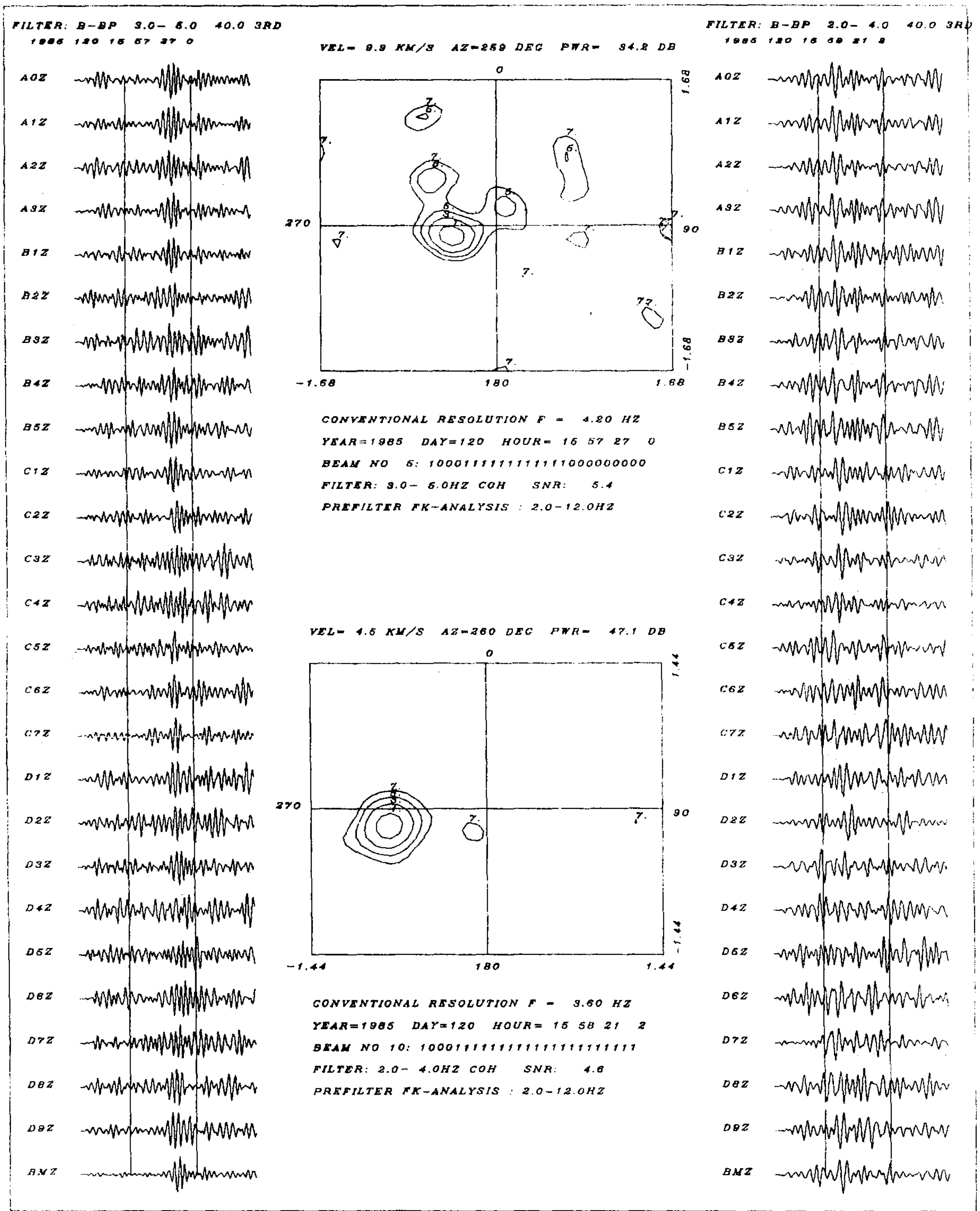

Fig. VII.2.2b NORESS automatic analysis results for the event of Fig. VII.2.2a. The Pn phase (left) and Lg phase (right) are shown for all instruments. Frequency-wavenumber spectra are shown for Pn (top) and Lg (bottom). These spectra are computed for phase identification (P- or S-type arrival according to phase velocity) and estimation of arrival azimuth.

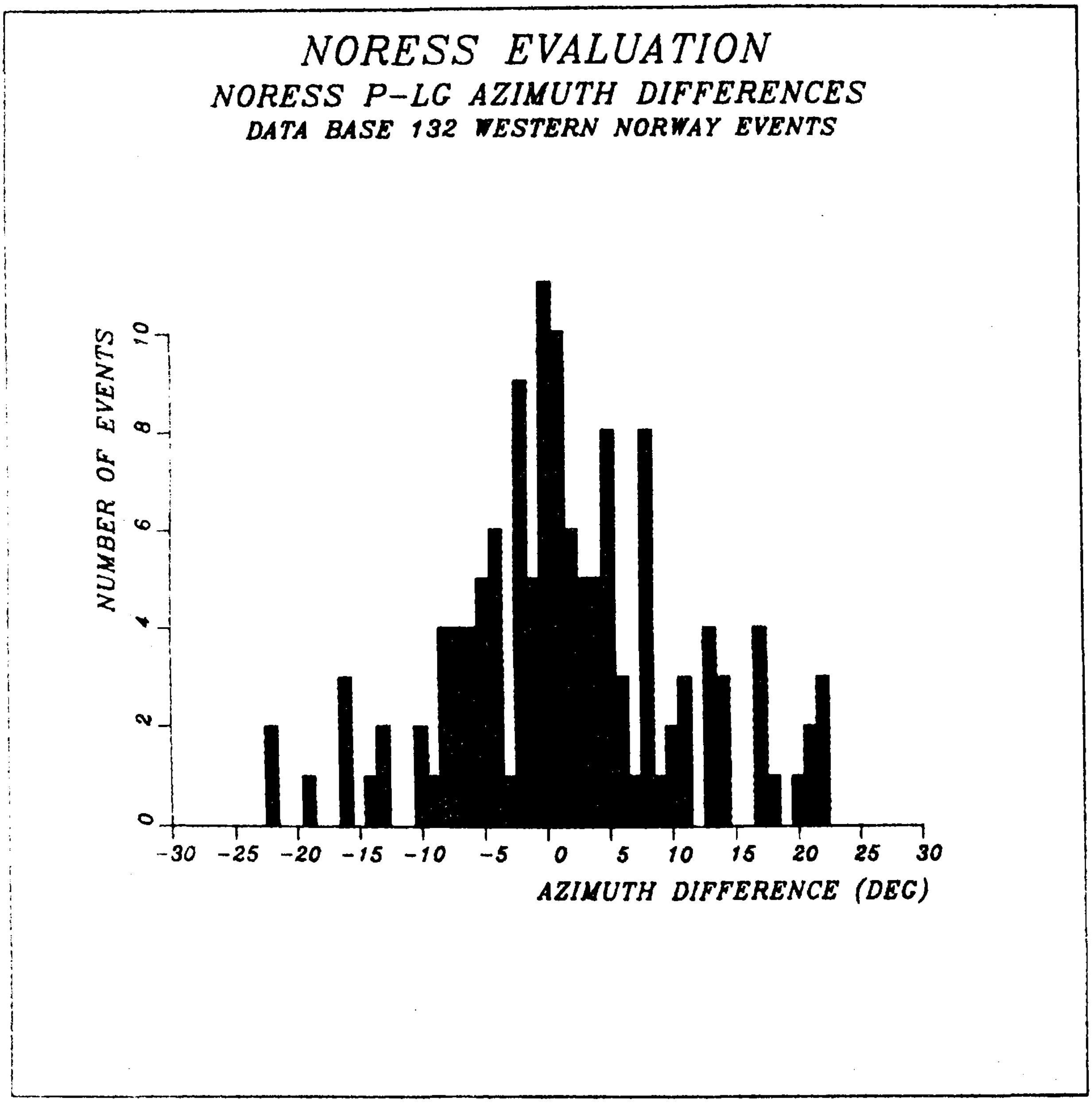

Fig. VII.2.3 The histogram shows the differences between the azimuths automatically estimated for the P and Lg phases by the routine, real time processing of NORESS data, for the 132 events in the data base.

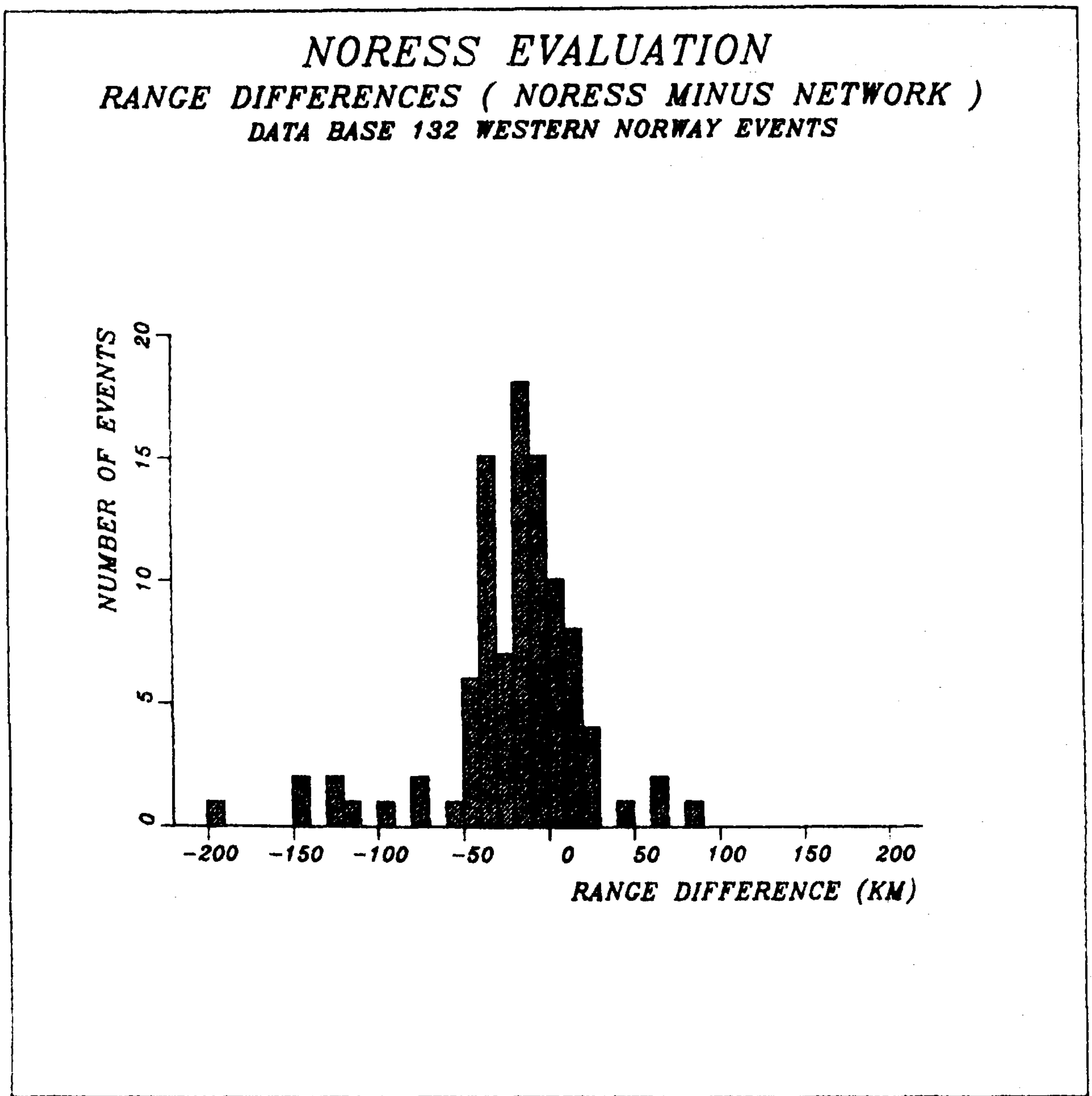

Fig. VII.2.4 The histogram shows the differences between the ranges estimated by the NORESS online processing and the ones corresponding to the network solutions, for the events in our data base. 35 events with known location at site 2 (Fig. VII.2.1), for which this difference was between -10 and -20 km, are not included in the figure.