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# NORSAR

ROYAL NORWEGIAN COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

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# SEMIANNUAL
# TECHNICAL SUMMARY
## 1 October 1980—31 March 1981

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## VI.4 Automatic Determination of Arrival Time, Amplitude and Period for Teleseismic Events

In our Semiannual Technical Summary for 1 Oct 79 - 31 Mar 80 we published a chapter on automated arrival time determination for local and regional P and S waves. That approach was based upon computation of signal envelopes, and the procedure has now for some time been included in our routine analysis of data from Stiegler's Gorge Seismic Network. (For other approaches to this problem, see for example Stevenson, 1976; Stewart, 1977; and Anderson, 1978.)

Our work in this area has now been extended to include teleseismic events, and we have here found it necessary to develop a completely new procedure, where also signal amplitude and period are computed. The procedure is as follows:

1. Initial arrival time. Compute STA/LTA on a filtered trace, after defining window lengths for STA and LTA. Declare a detection if P out Q successive STA/LTA values exceed a given threshold. If no detection is obtained, try again with a different (lower) threshold. The end of a detection is declared whenever the criterion fails, and several detections can be obtained for one particular event. The start of the first detection is used as the initial estimate of arrival time.

2. Signal amplitude, initial signal period. Define a window around the initial estimate of arrival time, and search for maximum absolute amplitude within this window. Then find the maximum opposite deflection by searching both ways in time until two zero crossings are observed. This search is done on a time series which has been smoothed by sliding a 5-point interpolation window through the data (using a least squares fit of a 2nd degree curve), and the exact locations of the two peaks are obtained by a similar interpolation. Signal amplitude (zero-peak) is then taken as half the difference between the two extreme deflections, and first estimate of signal period is twice the time difference between the peaks.

3. Refined signal period. Starting at the point of maximum signal amplitude, a number of peaks or troughs are found on each side. This is done by using the 5-point smoothing procedure, combined with certain criteria for defining a peak. The time differences between the peaks are then arranged in increasing order, and a refined estimate of the signal period is defined as twice the average of the median and its two neighboring values. However, if the scatter among these exceeds a certain value, the initial estimate of signal period is used (point 2 above).

4. Refined arrival time. Compute noise RMS from two successive time intervals and use the lowest of the two. Start at the point of maximum absolute amplitude and move forward one peak/trough at a time with the object of finding the first one that belongs to the signal. Any of these criteria can stop the search: i) having moved forward more than a specified distance (presently three full signal periods), ii) the last peak having fallen below a certain level as compared to the RMS noise level, iii) the last peak having fallen below a certain level as compared to the maximum amplitude. When the first peak has been identified in this way, the refined arrival time on the filtered trace is taken as the position of the peak minus one quarter period. The filter phase shift is finally compensated for by calling a subroutine with filter characteristics and signal period as input values, and phase shift in seconds as output.

## Performance

The procedure outlined above has been implemented in the routine NORSAR processing of teleseismic events. The performance has been very good both with respect to arrival time and amplitude/period, even though some work still remains in determining the parameter values.

The performance with respect to arrival time determination is shown in Figs. VI.4.1-2, using 8 events from May 5-7, 1981. The two uppermost traces are unfiltered beams (scaled differently), and the bottom trace is the filtered beam on which the parameter extraction has been done. As seen from the figures all of the events are of intermediate or poor quality, which is where the challenge is in this respect. The two main problems here are

(i) To find a correct initial estimate of arrival time. Even though we have succeeded there for all the examples given, it is evident that there must be a tradeoff between detecting weak precursors and not detecting in the noise preceding the signal. If an incorrect initial estimate is obtained, the procedure will not get on the right track again.

(ii) Once a correct initial arrival time estimate is obtained, to be able to follow an emergent signal into the noise without going too far ahead. We feel that our procedure works quite well in this respect, and good examples here are events 3, 5 and 6 in Figs. VI.4.1-2.

The performance with respect to signal amplitude and period still remains to be numerically evaluated (as compared to analyst decisions), but it is evident that the performance in both cases is very good. The main problem here is to find the right window, where we have used guide lines for $m_b$ computations. It is of course more difficult to estimate signal period than amplitude, and the key to the good performance here is that the period is estimated from the distribution of values obtained over several cycles on the seismogram. In this way we avoid the large errors that can occur if only one cycle is used (superimposed wavelets), and it has so far been very rare that the analyst has measured a signal period differing more than 0.1 sec from the automatic determination.

H. Bungum

## References

Anderson, K.R. (1978): Automatic analysis of microearthquake network data. Geoexploration, 16, 159-175.

Stevenson, P.R. (1976): Microearthquakes at Flathead Lake, Montana: A study using automatic earthquake processing. Bull. Seism. Soc. Am., 66, 61-80.

Stewart, S.W. (1977): Real-time detection and location of local seismic events in Central California. Bull. Seism. Soc. Am., 67, 433-452.

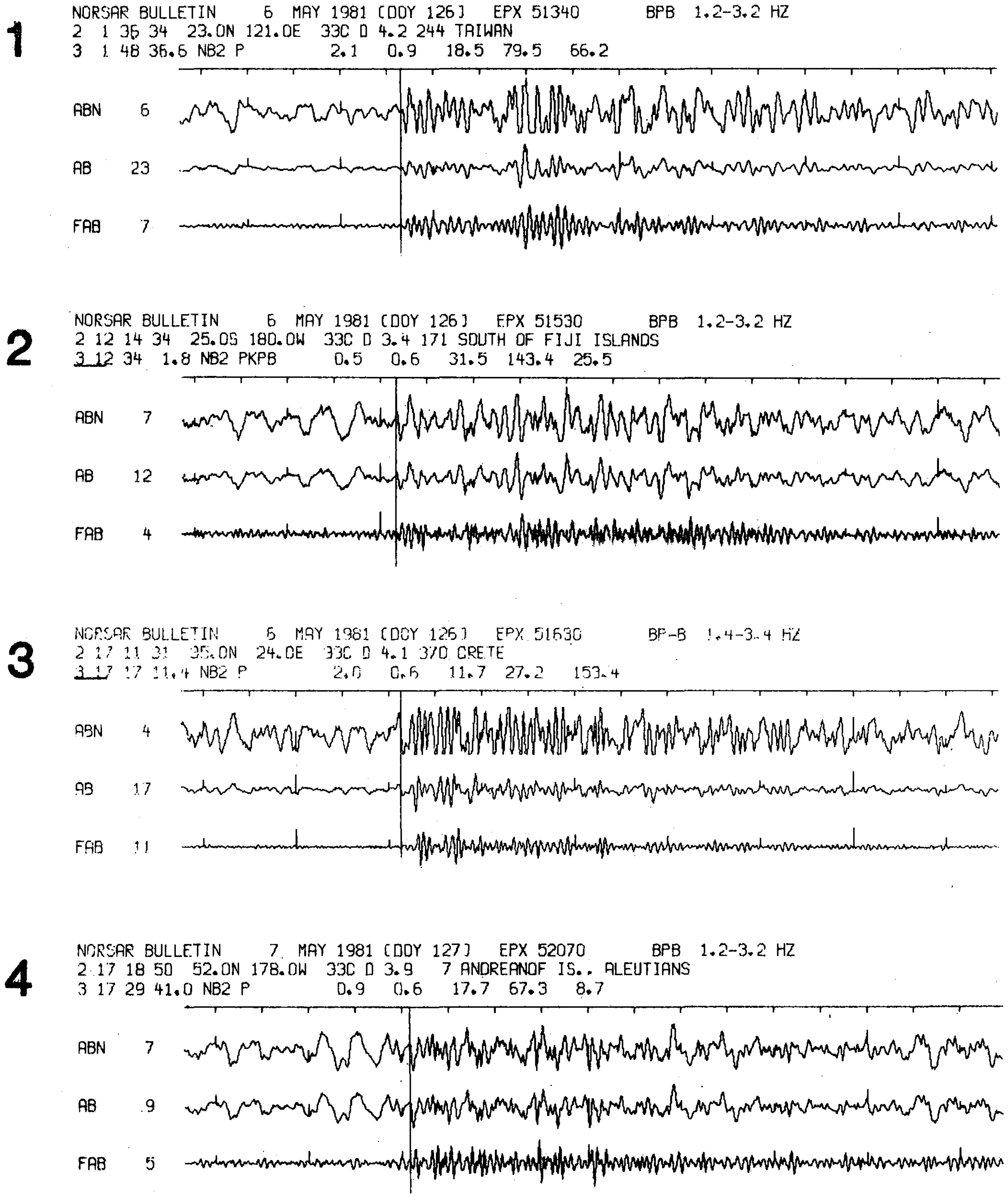

Fig. VI.4.1 Results from the automatic and routine processing of four events at NORSAR, with two unfiltered and a filtered beam for each event, and with the epicentral solution on top. The vertical lines indicate the arrival time determinations.

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NORSAR BULLETIN      5  MAY 1981 [DOY 125]    EPX 51240        BPB  1.2-3.2 HZ
2 19 41 51   32.0S 179.0W  33C D 4.0 179 SOUTH OF KERMADEC ISLANDS
3 20  1 45.9 NB2 PKPB       2.1    0.8    38.0  150.4  30.9
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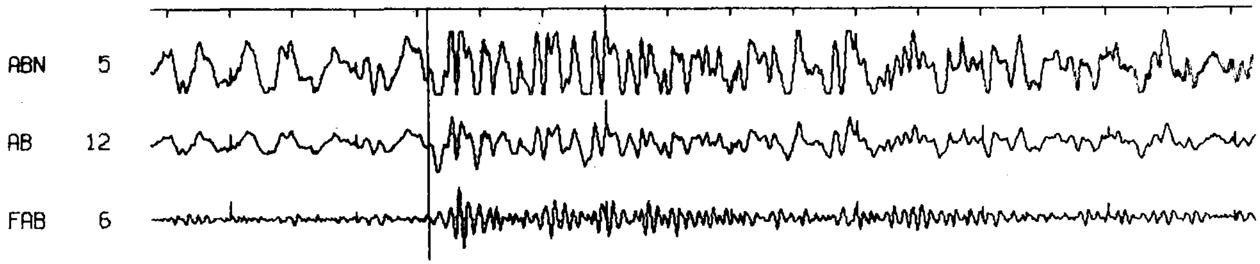

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NORSAR BULLETIN      5  MAY 1981 [DOY 125]    EPX 51260        BP-B  1.4-3.4 HZ
2 20 53 42   46.0N  27.0E   33C D 3.4 358 RUMANIA
3 20 57 43.4 NB2 P           0.9    0.5    8.9    17.6    139.2
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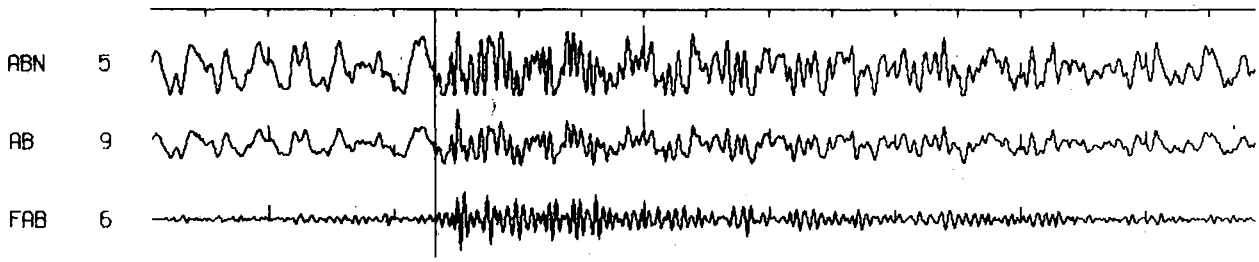

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NORSAR BULLETIN      5  MAY 1981 [DOY 125]    EPX 51270        BP-B  1.4-3.4 HZ
2 21  4 30   32.0N  74.0E   33C D 3.8 711 SOUTHWESTERN KASHMIR
3 21 13 18.2 NB2 P           0.8    0.6    13.8   49.6    96.1
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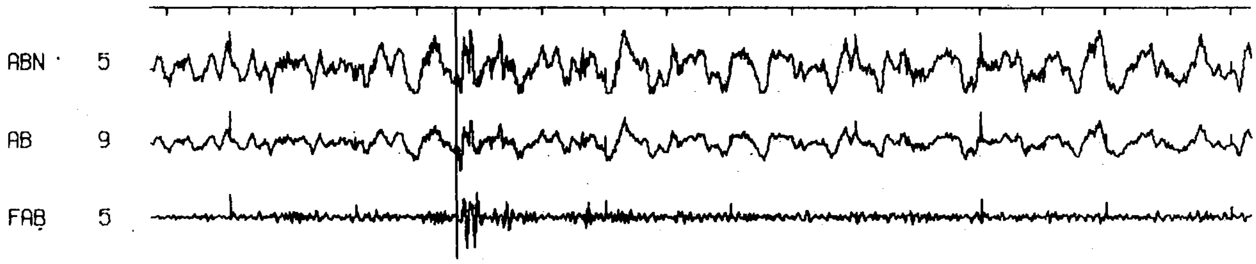

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NORSAR BULLETIN      5  MAY 1981 [DOY 125]    EPX 51280        BP-B  1.4-3.4 HZ
2 21 32 41   83.0N    7.0W   33C D 3.2 641 NORTH OF SVALBARD
3 21 37 39.7 NB2 P           0.6    0.6    10.9   22.7    354.4
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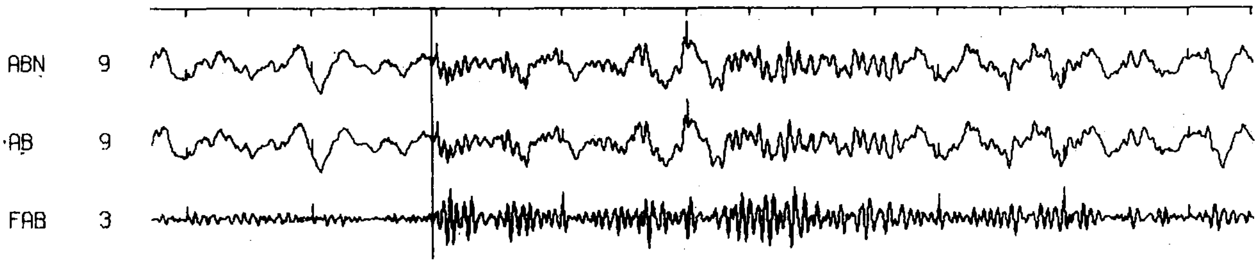

Fig. VI.4.2 Same as for Fig. VI.4.1, but with four new events.