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7.3 Combining NORSAR and NORESS processing

Introduction

The large aperture NORSAR array started operations in 1970 with 22 subarrays distributed over a diameter of 100 km. On October 1, 1976, the array was reduced to 7 subarrays with aperture about 60 km. Each subarray has 6 short period seismometers and the subarray aperture is about 8 km. During the years 1980-1981, experiments were performed with different subarray geometries to design a smaller array with good detection and location capabilities for local and regional events. As a consequence of this research, the NORESS array was constructed, and it became operational in 1984. The NORESS array has a diameter of 3 km and it is colocated with NORSAR subarray 06C. Figure 7.3.1 shows the geometry of the co-located arrays.

Throughout many years the NORSAR array has shown excellent detection and location capability. The analyst reviewed bulletin for the NORSAR array has been a significant contribution to the seismic community. The NORESS array has also shown very good detection capability for teleseismic events, as well as excellent detection and location capabilty for local and regional events. Moreover, automatic methods work very well for producing a bulletin of local and regional events. (Mykkeltveit and Bungum, 1984).

In this report we will demonstrate how to combine the two different processing techniques used for NORSAR and NORESS to improve the quality of an automatic teleseismic bulletin.

The method for detection of signals is identical for the two arrays. For slowness observations, f/k analysis can be used for the smaller array, due to the high correlation of the signals. For a large aparture array f/k analysis without time corrections does not work, and a beamforming (beampacking) method is used for slowness observation. (See NORSAR Sci. Rep. No 2-93/94).

In automatic detection procedures, many uninteresting signals are usually detected. For the NORESS array, it turns out that the f/k method normally gives apparent velocity values that are lower than Rg phase velocities for such detections, and these detections can therefor be classified as “noise detections”, and do not represent real seismic phases from local, regional or teleseismic events. For the NORSAR array, the automatic method is based on a teleseimic beam deployment, and consequently always gives a resulting teleseismic slowness both for non-seismic disturbances and for local events.

An automatically produced bulletin of teleseismic events by this method is therefore less reliable than a corresponding local/regional automatic procedure using NORESS.

In the report mentioned earlier we discussed additional methods based on the NORSAR array alone to identify local events. In this report we will consider methods where NORESS automatic results are used to try to automatically identify false events in the automatic NORSAR bulletin.

NORESS automatic bulletin

An automatic NORESS bulletin with local and regional events is produced using the "EP_Ronapp" process (Fyen, 1987, 1989). For each event in the NORESS bulletin, we can predict arrivals in the NORSAR array. A simple rule is for each event to pick the first P-phase and the last S-phase arrival time and then define this as a time window. We then extend each end of the window with 20 seconds. For each such time window, we inspect the NORSAR detection list, and mark each phase arrival within the list as a potential local/regional phase.

In addition to definition of local/regional events, the NORESS automatic bulletin identifies teleseismic phase arrivals. A related issue is therefore to investigate the potential for using a NORESS defined teleseismic phase as basis for beamforming of the NORSAR and NORESS array. Another interesting aspect is to try to enhance a NORSAR defined teleseismic location by including NORESS in the process.

Data analysis

For selected data days during the period 4 August - 18 September 1994, we carefully inspected the automatic and reviewed bulletin for the NORSAR array together with the automatic bulletin for the NORESS array.

NORSAR events that the analyst do not include in the reviewed bulletin are routinely classified into the three classes 1) probable local event, 2) clear spike or non-seismic noise on one or more subarrays, and 3) ambigous event with low SNR or secondary teleseismic phase.

By comparing the automatic NORESS bulletin with the automatic NORSAR bulletin, we "masked" all probable local/regional phases, using the simple time window rule defined above. Then we calculated statistics on:

1a) How many NORSAR defined events are correctly masked as probable local?
1b) How many NORSAR defined events are in-correctly masked as probable local?
1c) How many NORSAR defined events that are probably local are not masked?

In addition we looked at NORESS defined teleseismic phases and counted:

2a) How many are connected with NORSAR-defined teleseismic events?
2b) How many are not connected with NORSAR-defined teleseismic events?
2c) How many NORSAR teleseismic events are not connected with NORESS teleseismic phases?

Results

Table 7.3.1 shows the results of the bulletin analysis. We see that 36% of the automatically defined events are accepted as teleseismic events by the analyst. The remaining 64% of the events are either due to triggering from local disturbances within one subarray, or due to bad data conditions (spikes), or due to real local/regional events (but falsely detected as teleseismic by the automatic process).

64% of the local events are correctly identified by this simple masking rule, using the NORESS automatic bulletin. In this analysis we have not counted events where the Lg phase alone has been detected by NORESS. Only events that have been formed by association of a Pn/Pg phase and an Sn/Lg phase at NORESS have been used.

By combining the identified local events and the confirmed teleseismic events, we find that 42% of the NORSAR automatic detetcions are correctly classified. The remaining detections are mostly of low SNR or "spike" detections.

The analysis shows that 64% of the local events falsely reported as teleseismic events by the NORSAR automatic processor, can by masked automatically by inspecting the NORESS automatic bulletin.

Two real teleseismic events are masked out by this method. Both were in the coda of regional events.

75% of the real teleseismic events reported by NORSAR are also confirmed as such by the NORESS array. Thus, by combining NORESS and NORSAR defined teleseismic events, 75% of the NORSAR events can be confirmed automatically.

In addition, NORESS reports a significant number of teleseismic phases that are not detected with the current NORSAR beam deployment. This indicates a significant potential for improvement both by adjusting the NORSAR time delay corrections and by joint NORSAR/NORESS processing.

Conclusions

This study has shown that a clear improvement in the automatic NORSAR processing can be achieved by combining NORSAR and NORESS. By a simple masking algorithm, most of the NORSAR detected local and regional events can be identified as such using NORESS data. Furthermore, NORESS complements NORSAR by giving an "independent" confirmation of the majority of teleseismic phases. Even further improvements might be possible by joint beamforming techniques, although this has not been attempted in this study.

J. Fyen
B. Paulsen

References:

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Fyen, J. (1987): Improvements and modifications, *NORSAR Semiannual Tecnical Summary, 1 Oct 1986 - 31 Mar 1987*, NORSAR Sci. rep. No. 2-86/87, Kjeller, Norway.

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Day # 1994	1A Local Masked	1B Local Error	1C Local NRS miss	2A NRS Tele OK	2B NRS Tele -	2C NB2 Tele	3A NB2 Accepted	3B NB2 Low SNR	3C NB2 False	Number EPX
209										
216	9	1	3	10	2	3	14	7	2	35
219	0	0	0	8	4	2	10	1	1	12
225	0	0	0	9	4	2	11	10	2	23
228	9	0	5	14	3	5	19	1	9	43
234	7	0	5	15	3	1	16	3	8	39
237	0	0	15	6	2	3	9	2	9	35
243	16	0	2	7	3	2	9	1	14	42
253	1	0	0	4	4	3	7	1	8	17
255	9	0	4	11	0	3	14	4	3	34
256	9	0	0	11	3	1	12	5	5	31
257	9	0	3	5	1	0	5	7	10	34
258	0	0	1	5	4	3	8	8	6	23
259	3	0	0	3	2	2	5	14	3	25
260	4	0	0	7	0	3	10	10	3	27
261	1	0	0	8	2	2	10	3	4	18
264	4	0	3	4	6	6	9	4	6	26
265	1	1	5	5	2	3	8	3	13	30
267	2	0	1	5	8	0	5	8	6	22
269	5	0	2	2	3	2	4	7	5	23
Sum	89	2	49	139	56	46	185	99	117	539

1A NORSAR defined events correctly marked as local	64.5%	of local events
1B NORSAR accepted events that are in-correctly marked as probable local	1.1%	of accepted events
1C NORSAR defined events that are probable local, but not marked as such	35.5%	of local events
2A NORESS teleseismic phases connected with NORSAR accepted events	75.1%	of accepted events
2B NORESS teleseismic phases that are not connected with NORSAR accepted events	30.3%	of accepted events
2C NORSAR accepted events not connected with NORESS teleseismic phases	24.9%	of accepted events
3A Total number of NORSAR accepted events	34.3%	of all NORSAR events
3B Number of NORSAR defined events not reported due to low SNR or secondary phases	18.4%	of all NORSAR events
3C Number of false NORSAR defined events due to noisy subarray(s) or spikes	21.7%	of all NORSAR events
Percentage of events that are correctly classified by combining NORESS and NORSAR	42.3%	of all NORSAR events

Table 7.3.1. Results of the bulletin analysis.

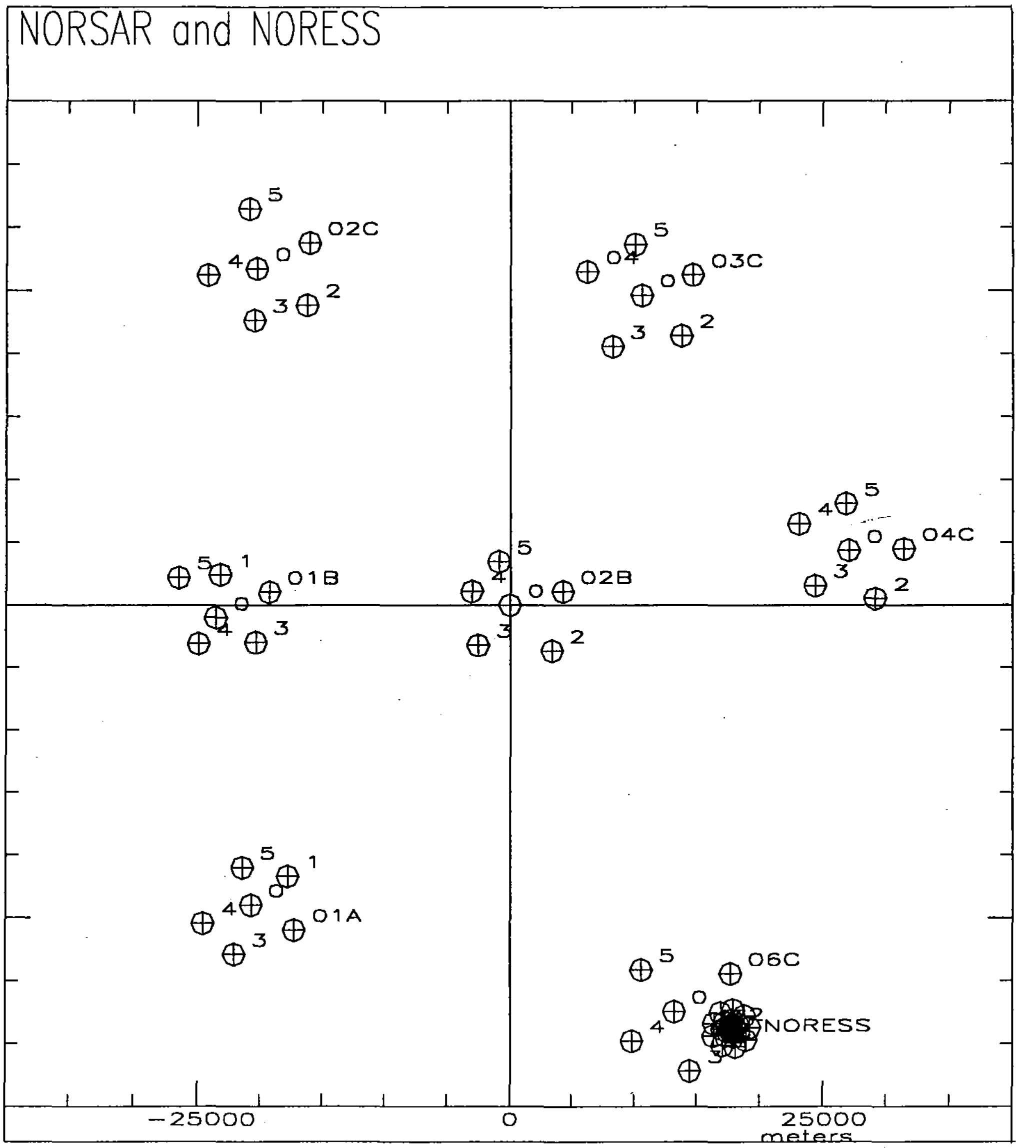

Fig. 7.3.1 The NORSAR and NORESS arrays.