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7.5 Processing of Spitsbergen array data

Introduction

The Spitsbergen array is used as an Alpha station in the GSETT-3 experiment currently conducted by the Group of Scientific Experts. This nine-element 1 km aperture array is described in Mykkeltveit et al (1992). Since its installation in 1992, the array has undergone a number of incremental upgrades and improvements with respect to field instrumentation, power supply system and various other aspects concerning the reliability and stability of the field system. The most noteworthy modification in the context of this short communication was the replacement in September of 1994 of the nine vertical S-500 seismometers by Guralp ESP seismometers. At the same time, a broadband three-component seismometer of type Guralp CMG-3T was installed at site B4.

Data from the Spitsbergen array are transmitted continuously to the GSETT-3 International Data Center (IDC) in Arlington, Virginia. At the IDC, the Spitsbergen data are subjected to detection processing, and the results are incorporated in the global network processing at the IDC, which results in a daily Reviewed Event Bulletin (REB) issued 2-3 days after each data day.

In the fall of 1994, it was observed that the processing of Spitsbergen array data both at NORSAR (using the dp/ep processing package) and at the IDC (using the SigPro program module) was non-optimal. The main problems appeared to be associated with the following three categories:

- a large number of false, non-seismic detections
- detections associated with events at very short distance
- poor estimates of the slowness vector, with the f-k analysis resulting in teleseismic type velocities for many local phases.

Fig. 7.5.1 illustrates the problems associated with the latter category above. The figure shows the P-wave azimuth residuals as given in REBs issued during January - March 1995, for the Spitsbergen array as well as for the ARCESS and Hagfors arrays. As expected from the aperture difference between the arrays, these residuals are much larger for the Spitsbergen array than for ARCESS (ARCESS has an aperture of 3 km). The Spitsbergen residuals are, however, also much larger than for the Hagfors array. The aperture of the 5-element Hagfors array is the same as that of the Spitsbergen array. It is thus reasonable to assume that by proper tuning of the post-detection processing of the Spitsbergen data, one would be able to better estimate the slowness vector.

This contribution describes our initial efforts towards improving the processing of Spitsbergen array data to make this array contribute better in the global network context.

Processing results for new recipe

A close examination of the Spitsbergen data showed that many of the false detections appeared to be associated with short data dropouts. The special factor to consider here is the relatively broadband character of the data from the Guralp sensors of the array, which appears to require a different quality control algorithm to handle data dropouts than those used for other array data recorded at NORSAR.

Further, the study of the Spitsbergen array processing revealed that the f-k analysis performance to estimate the slowness vector was not optimal. To avoid leakage of low-frequency noise into the passband used in the f-k analysis, it was found that prefiltering the data in a frequency band adapted to the passband of the detecting beam improved the stability of the slowness estimates. It was also found that the f-k spectrum must be computed out to slowness values of 1 s/km to capture phases with low apparent velocity.

More specifically, we tested a new recipe for the dp/ep Spitsbergen processing against the old recipe, where the new recipe was characterized by the following:

1. Improved data quality control in the detector algorithm to account for data dropouts.
2. New algorithm for prefiltering the data before applying the f-k analysis: If a detection is declared on a beam filtered in the frequency band f_1 - f_2 Hz, then prefilter the data in the passband (f_1 - 0.5) - (f_2 + 0.5) Hz using a 3rd order Butterworth filter with two passes.
3. Extension of the slowness search space out to 1 s/km to accommodate phases with low apparent velocity.

For 27 March 1995 we made a comparison between the output from the old and new recipes for the Spitsbergen array, with results as shown in Tables 7.5.1 and 7.5.2. The improved data quality control reduced the number of detections from 1116 to 966. The tables show the f-k results in terms of phase velocities and f-k quality, respectively. It is seen that the new recipe has greatly reduced the number of detections with assigned high phase velocities. Similarly, the percentage of detections with phase velocities below 2 km/s has increased significantly. The f-k quality (which is a measure of the height of the main peak in the f-k spectrum relative to the second highest peak, and where a value of 1 indicates the most well-defined peak) distribution centers on higher values for the new recipe, which is to be expected since the f-k analysis is generally performed on data prefiltered in a higher band for the new recipe.

Changes in the IDC processing of Spitsbergen data

Based on the above results from the new Spitsbergen processing recipe, recommendations were made to the IDC to make similar changes in SigPro. We have been made aware that the DFX code that will soon replace SigPro has new procedures for improved data quality control, so the revised gap handling in the new NORSAR dp/ep recipe was not part of the recommended changes. Changes in SigPro implemented on 2 June 1995 thus amounted to the following:

- Prefiltering of the data before f-k analysis. The SigPro code can only accommodate two filter bands for this, and it was decided to use the bands 1.5-12.0 Hz and 2.0-12.0 Hz for signals with dominant frequencies below 2 Hz, and equal to or above 2.0 Hz, respectively.
- Extension of the slowness search space out to 1 s/km.

In order to assess the effects of the modifications made to the processing of Spitsbergen data at the IDC on 2 June 1995, SigPro results before and after this date were compared to the results from the new recipe running at NORSAR (since 28 March). Fig. 7.5.2 shows the phase velocities for the Spitsbergen detections at the IDC (top) and at NORSAR (bottom), for a time interval before the change was made in SigPro, and Fig. 7.5.3 provides the same comparison for a time interval following this change. It is evident that the changes made in SigPro have not had the desired effects; there is still a predominance of very high phase velocities. It is noted that the distribution of phase velocities in the NORSAR dp/ep Spitsbergen processing is very similar to that observed for the other arrays, like, e.g., ARCESS.

Similarly, the f-k quality was compared for time intervals before and after the changes in SigPro. As can be seen from Figs. 7.5.4 and 7.5.5, there is a shift in the direction of higher f-k quality values, as expected.

Fig. 7.5.6 shows the P-wave azimuth residuals in the REB for Spitsbergen for a time interval after the changes in SigPro. Even though the number of phases used is fairly limited, it can be seen when comparing with Fig. 7.5.1 that the azimuth residuals have not changed significantly.

Conclusions

We have succeeded in developing some clear improvements in off-line processing of Spitsbergen data, but so far it has not been possible to duplicate these results at the IDC. Our conclusion is that the choices for prefilters before the IDC f-k analysis are too limited, but we also understand that this situation will be rectified with the introduction in the IDC processing of the new DFX code.

Fig. 7.5.7. shows the dominant signal frequencies for the REB Spitsbergen P-wave arrivals for distances exceeding 20 degrees for the period after the SigPro changes (the SigPro changes did not affect these values). It is seen that about 50% of the teleseismic P-wave signals have dominant frequencies of 3 Hz and above, and these signals should consistently have been filtered before f-k with a filter that has a lower cutoff higher than 2 Hz.

The work towards improving the Spitsbergen array processing will thus continue.

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Reference

Mykkeltveit, S., A. Dahle, J. Fyen, T. Kværna, P.W. Larsen, R. Paulsen, F. Ringdal and I. Kuzmin (1992): Extensions of the Northern Europe Regional Array Network — New small-aperture arrays at Apatity, Russia, and on the Arctic island of Spitsbergen. In: Semiannual Tech. Summ. 1 April - 30 September 1992, NORSAR Sci. Rep. No. 1-92/93, Kjeller, Norway.

Velocity interval v km/s	Old recipe No. of detections	New recipe No. of detections
v≤2	7	278
2<v≤3	35	47
3<v≤4	23	149
4<v≤6	43	168
6<v≤8	40	126
8<v≤10	57	79
10<v≤12	42	60
12<v≤14	30	31
14<v≤20	77	22
20<v	762	6
All	**1116**	**966**

Table 7.5.1. The table shows the phase velocities for Spitsbergen array detections for 27 March 1995 as determined by the old and new NORSAR dp/ep recipes, respectively.

f-k quality	Old recipe No. of detections	New recipe No. of detections
1	545	20
2	85	34
3	435	766
4	51	4
All	**1116**	**966**

Table 7.5.2. The table shows the f-k quality for Spitsbergen array detections for 27 March 1995 as determined by the old and new NORSAR dp/ep recipes, respectively.

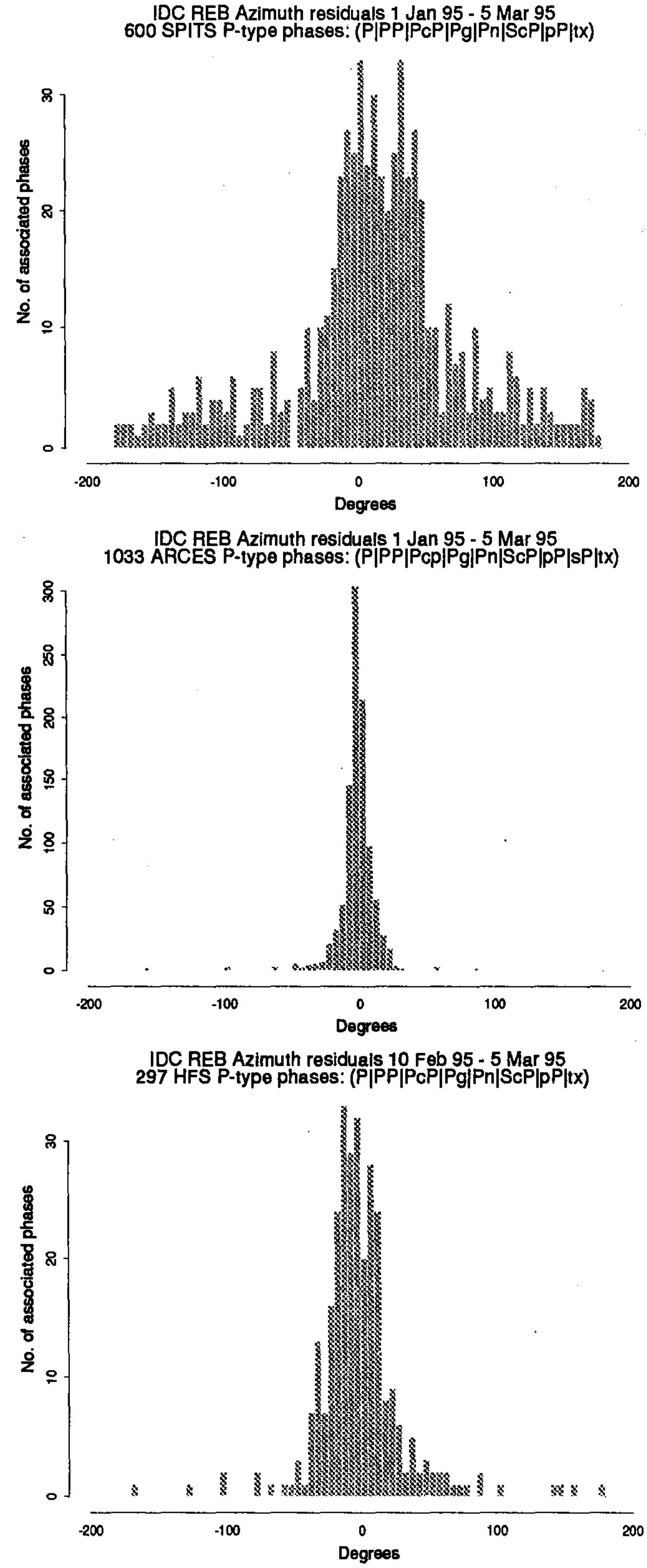
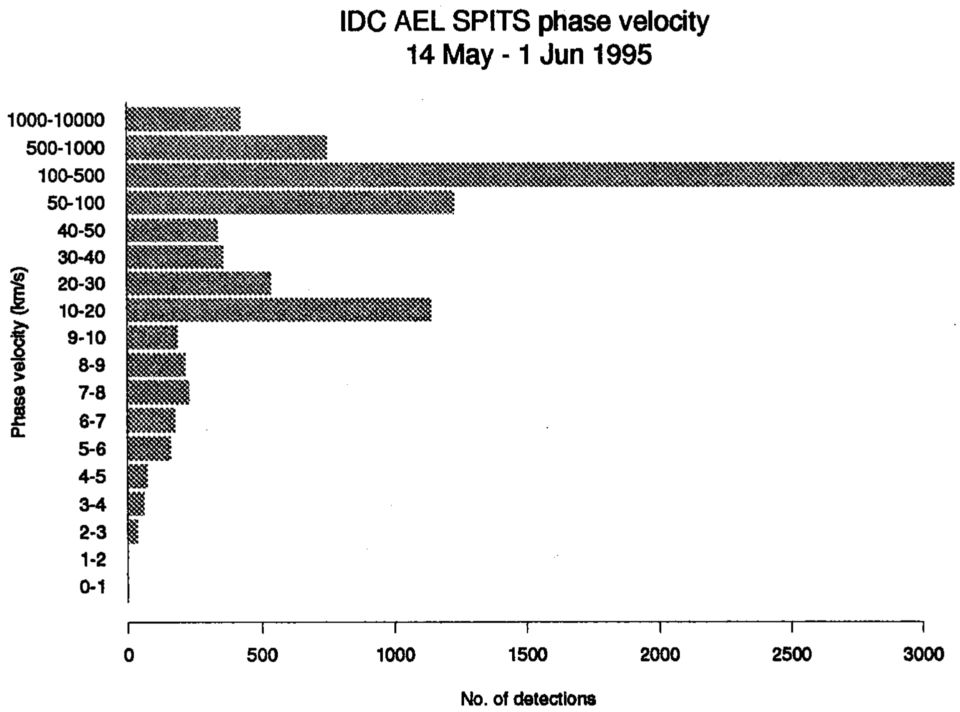


Fig. 7.5.1. P-wave REB azimuth residuals for the Spitsbergen array (top), the ARCESS array (middle) and the Hagfors array (bottom) for the time intervals indicated for each station.



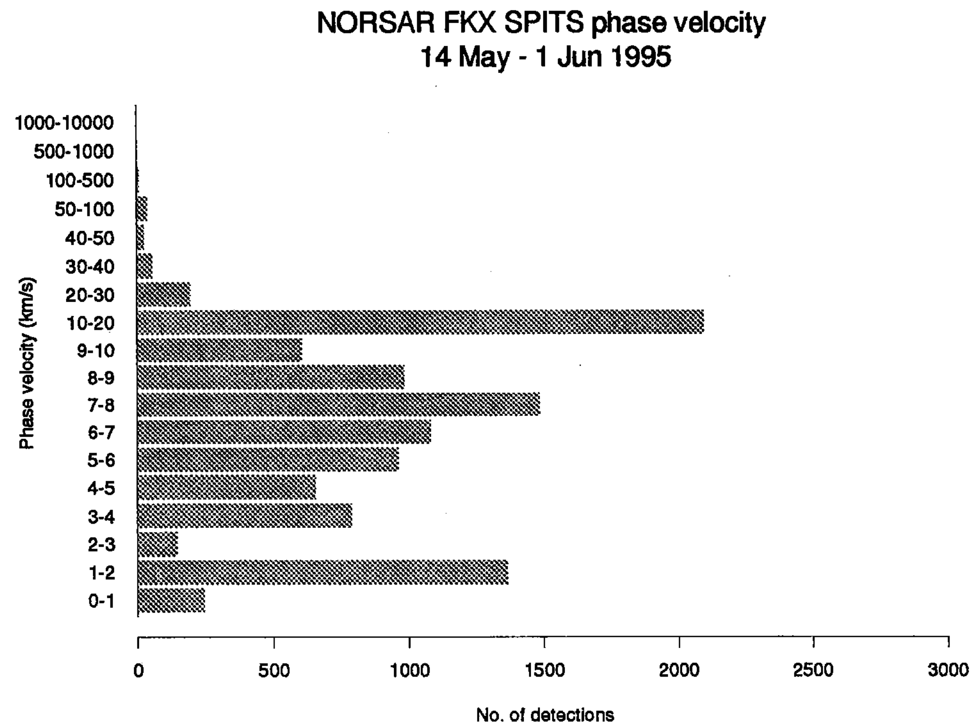
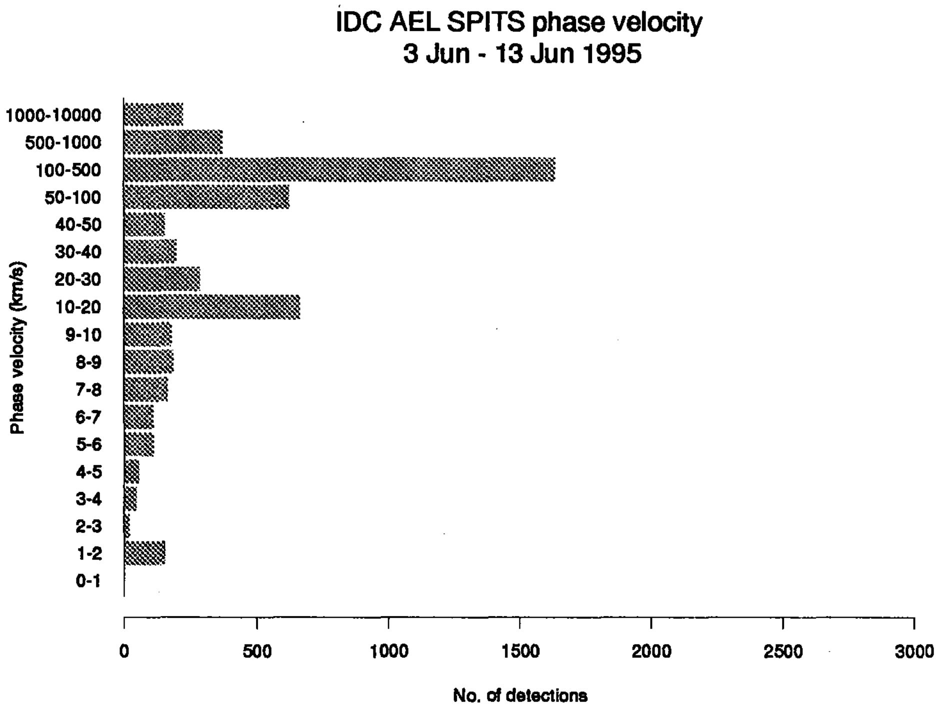


Fig. 7.5.2. Phase velocities for Spitsbergen array detections by SigPro at the IDC (top) and by the dp/ep package at NORSAR (bottom) for a time interval before the modification to the SigPro processing.



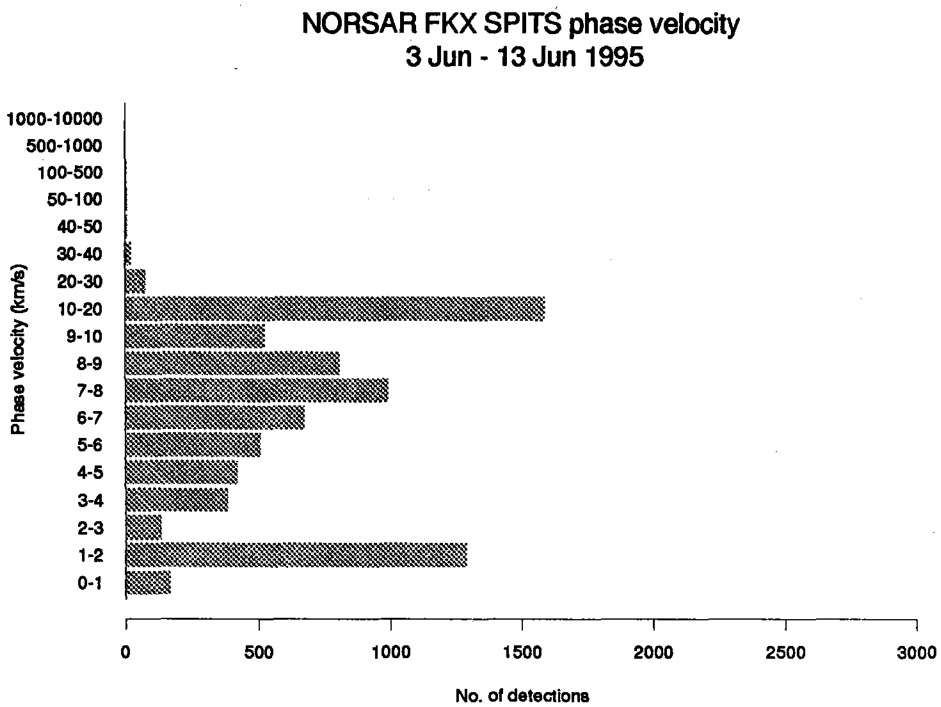


Fig. 7.5.3. Same as for Fig. 7.5.2, but for a time interval after the modification of the SigPro processing.

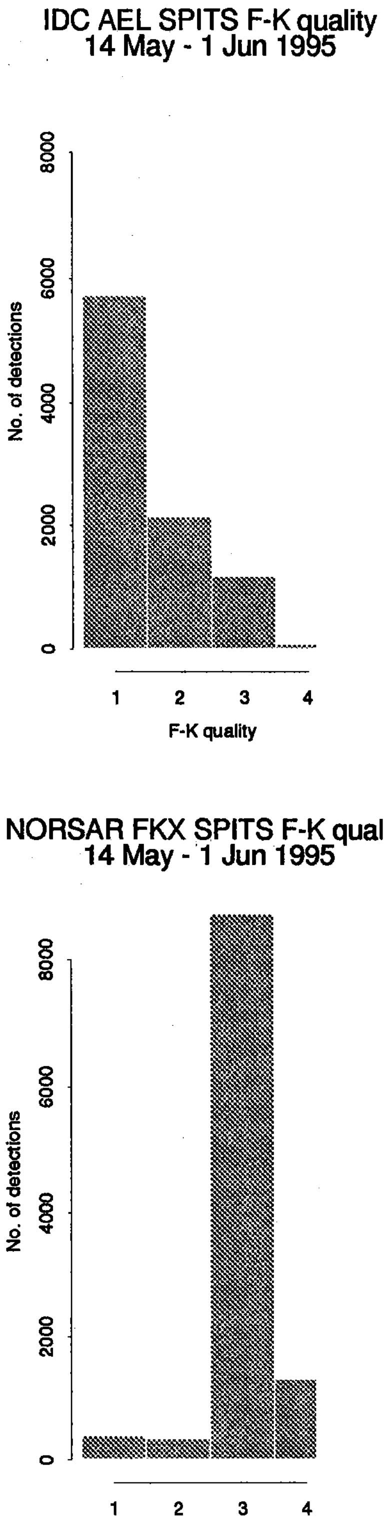
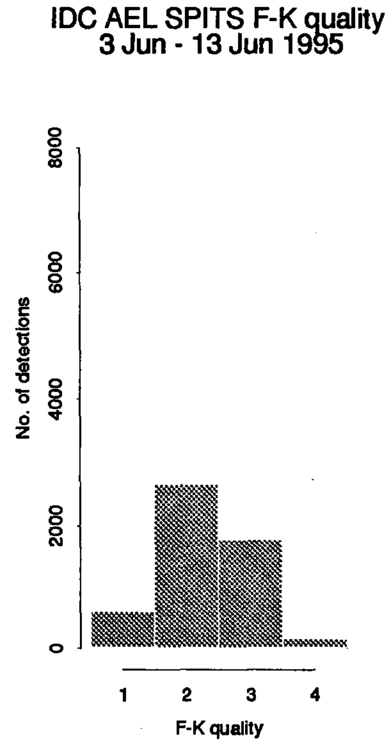


Fig. 7.5.4. f-k quality for Spitsbergen array detections by SigPro at the IDC (top) and by the dp/ep package at NORSAR (bottom) for a time interval before the modification to the SigPro processing.



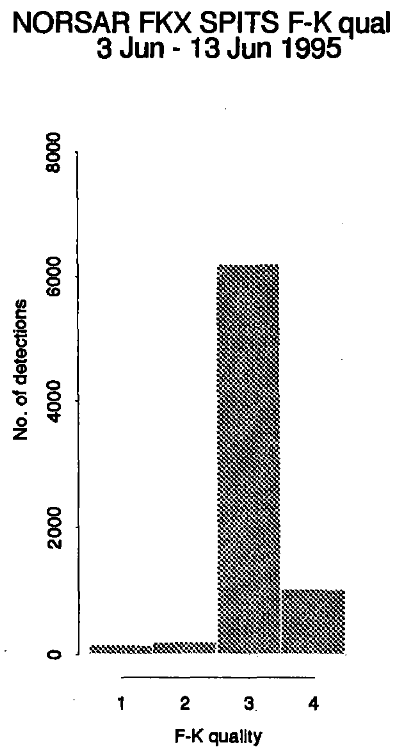


Fig. 7.5.5. Same as for Fig. 7.5.4, but for a time interval after the modification of the SigPro processing.

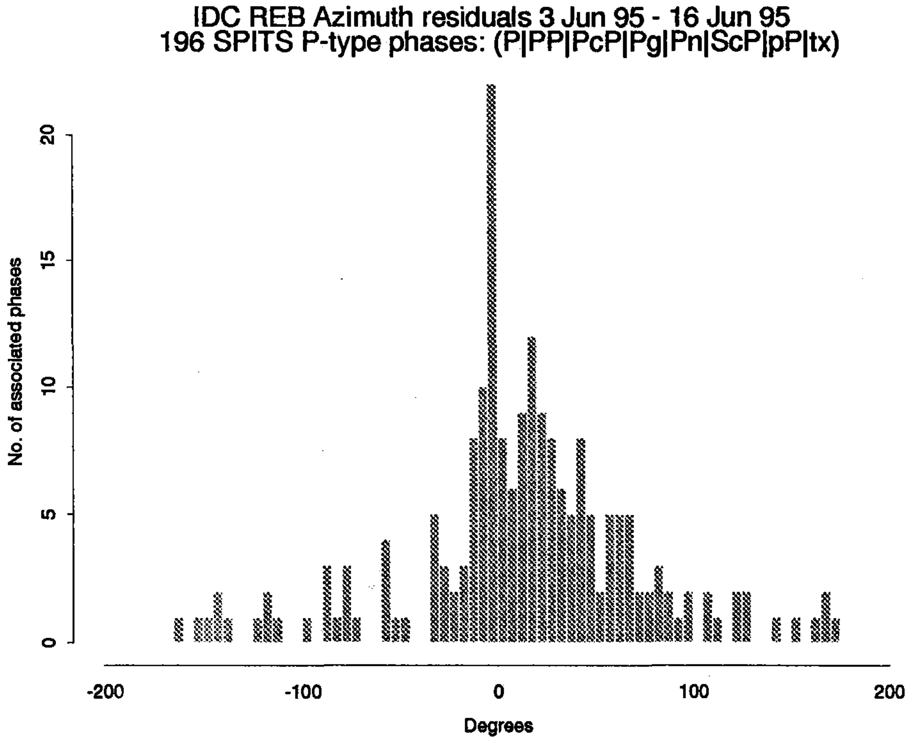


Fig. 7.5.6. P-wave REB azimuth residuals for the Spitsbergen array for a time interval after the modification of the SigPro processing.

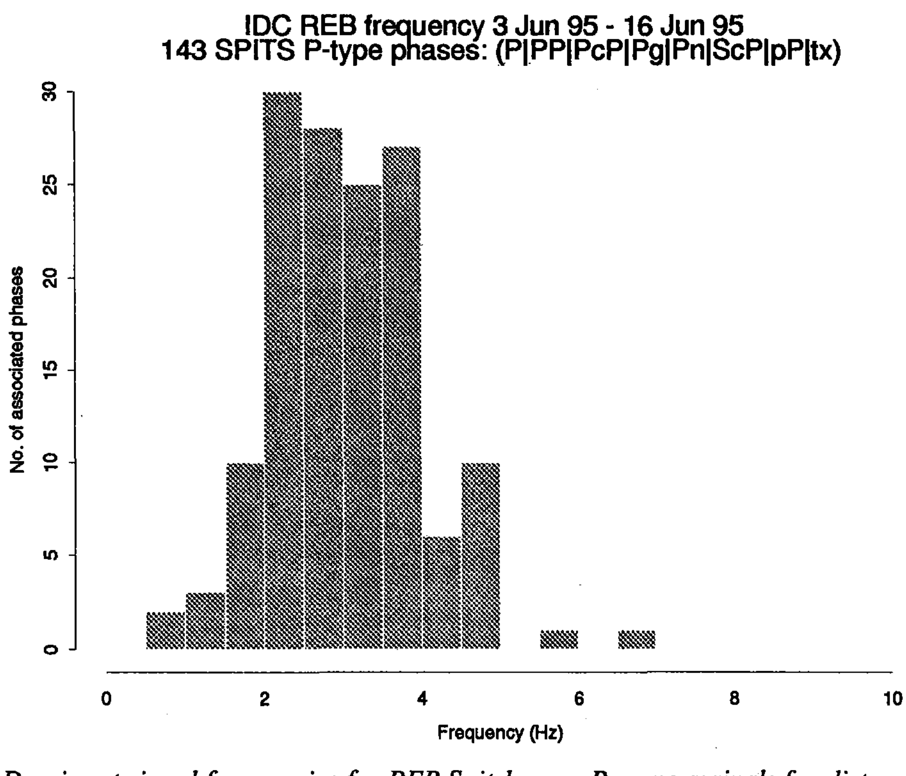


Fig. 7.5.7. Dominant signal frequencies for REB Spitsbergen P-wave arrivals for distances exceeding 20 degrees for a time interval after the modification of SigPro at the IDC.