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6.4 Towards a Nordic Regional Infrasonic Array Network

6.4.1 Introduction

The International Monitoring System (IMS) currently being established contains an infrasound component consisting of 60 infrasonic arrays distributed globally. As can be observed from Fig. 6.4.1, only one of the stations in this network (IS37 in Karasjok, northern Norway) is located in the European Arctic region. This station has as of today not yet been established, but is in the planning phase. Another infrasound station, IS18 on Greenland, is en operation, but is located too far away to give any significant contribution to the regional monitoring of low-magnitude events in the European Arctic.

An important area of research at NORSAR is to develop methods for joint seismic/infrasonic analysis of events recorded at regional distances. In particular, we wish to apply and evaluate automatic processing techniques for the area comprising northern Fennoscandia and adjacent regions. It is clear that such an approach will require a far denser network of infrasonic arrays than is projected for the IMS.

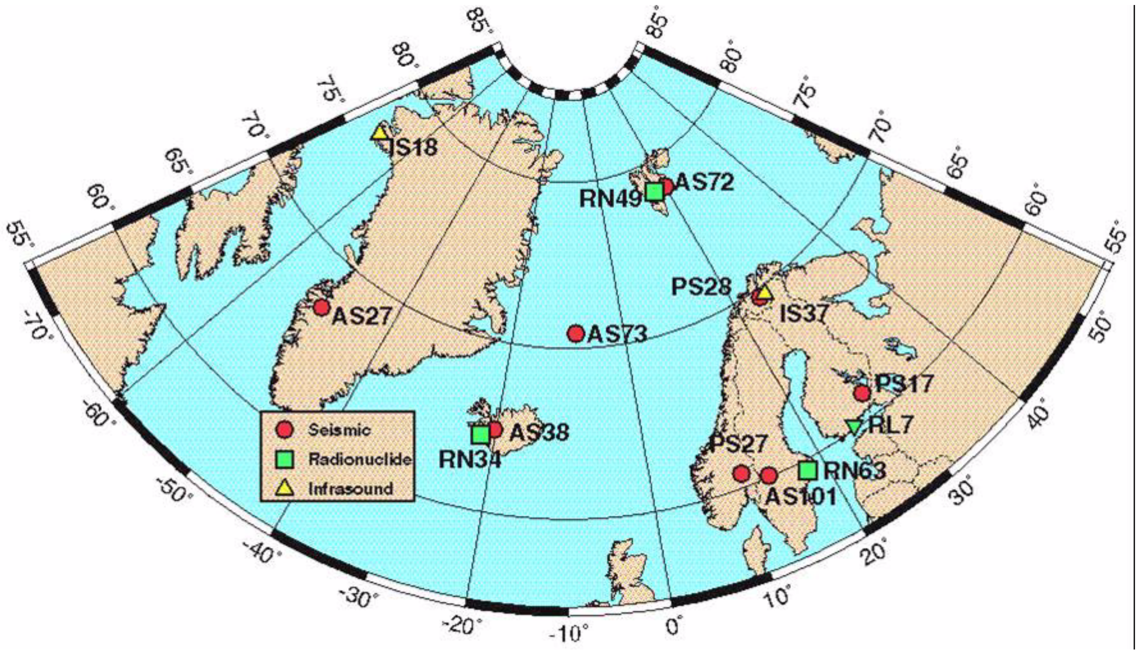

Fig. 6.4.1. Map showing the location of existing and planned IMS stations in the Nordic countries (Norway, Sweden, Finland, Denmark and Iceland). Only two of these stations are infrasonic. The infrasound array IS18 on Greenland is operational, while the infrasound array IS37 in Karasjok, northern Norway, is in the planning phase.

In a number of recent contributions in NORSAR Semiannual Technical Summaries, we have presented infrasonic studies with emphasis on combined seismic-infrasonic observations. The first such study was carried out by Vinogradov and Ringdal (2003), who analyzed seismic and infrasonic signals from a number of mining sites in the Kola Peninsula as well as a site in northern Finland used for ammunition destruction.

In particular, Vinogradov and Ringdal (2003) used data from the Apatity seismic/infrasonic array in their study. The infrasonic component of this array is a small-aperture microbarographic array installed in conjunction with the seismic array near lake Imandra in the Kola Peninsula, with data digitized at the array site and transmitted in real time to a processing center in Apatity. A total of three infrasound sensors are installed in the innermost ring of the array, forming a triangle of approximately 500 m diameter. The sensors are differential microbarographs of model K-304-AM. The frequency working range is 0.01-10Hz, and the sensitivity is 37.5 mV/Pa. The geometry of the combined seismic/infrasound array is shown in Fig. 6.4.2.

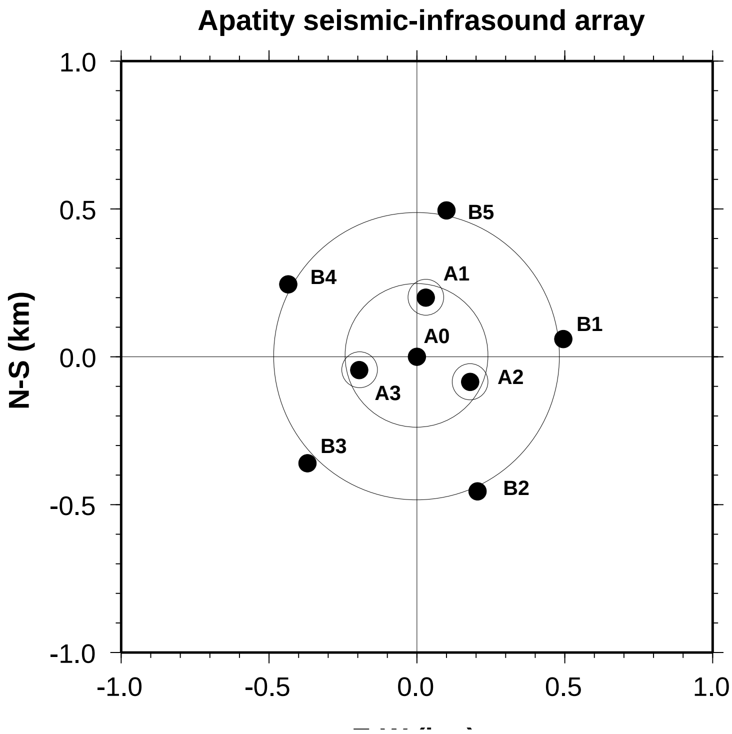

Fig. 6.4.2. Configuration of the Apatity seismic-infrasound array. Seismometers are shown as filled circles, with the location of the three infrasonic sensors (A1, A2 and A3) marked as small circles. The two concentric circles have diameters of 500 m and 1000 m respectively

Although the Apatity array for a long time provided the only infrasonic data available to us, Ringdal and Schweitzer (2005) found that the ARCES seismic array also could be used in infrasonic studies. Although the seismic sensors at ARCES are not by any means as sensitive to sound waves as the microbarographs, they nevertheless provide infrasonic recordings for a number of events at regional distances. The ARCES array (Fig.6.4.3) has the added advantage of comprising as many as 25 sites distributed over an area of 3 km in diameter, and therefore could be used to investigate the spatial characteristics of infrasonic as well as seismic recordings (Ringdal and Gibbons, 2006).

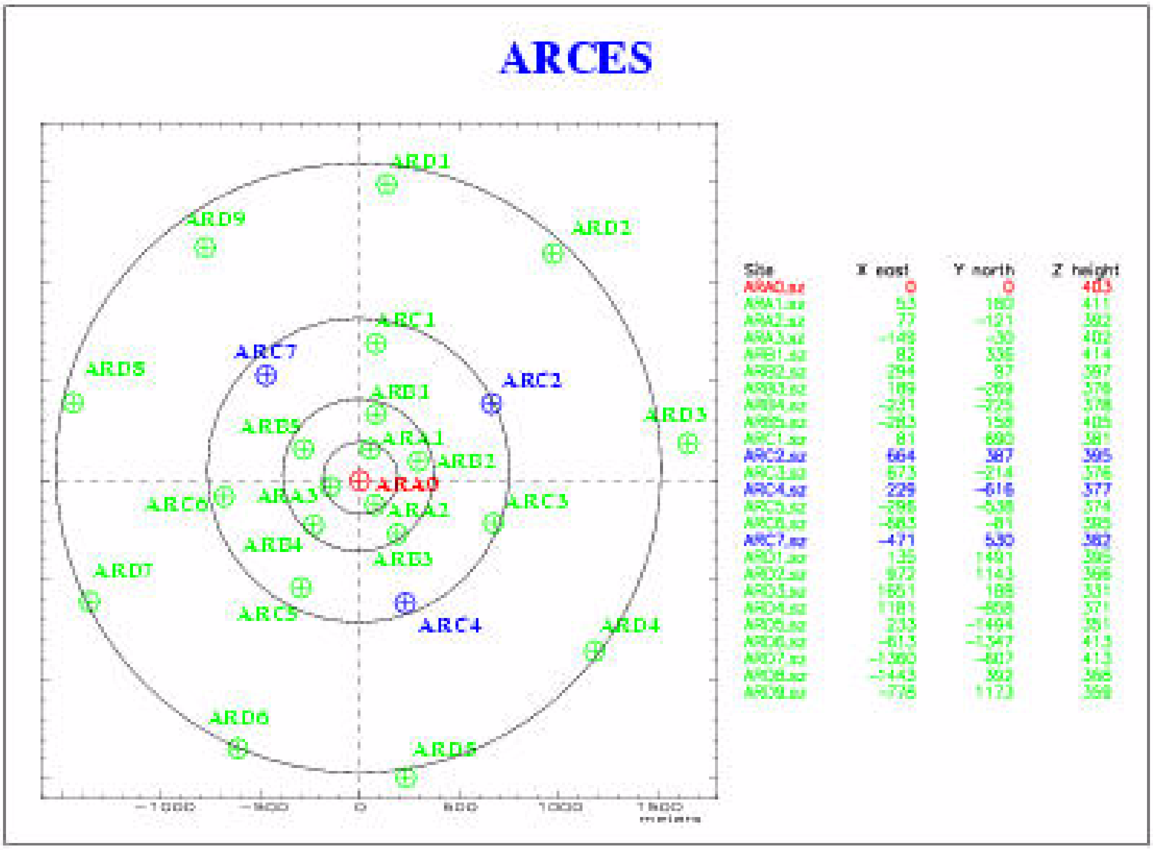

Fig. 6.4.3. ARCES array configuration. The four circles correspond to the A, B, C and D-rings. It turns out that this seismic array is also useful for recording regional infrasonic signals.

6.4.2 The Swedish infrasound network

The Swedish Infrasound Network (Liszka, 2007) has been in operation since the beginning of the 1970s. Operated by the Swedish Institute of Space Physics, the network has until recently comprised four infrasound stations: Kiruna, Jamton, Lycksele and Uppsala. The station in Uppsala was moved to Sodankyla, Finland, during the summer of 2006. The coordinates of these stations are given in Table 6.4.1.

Table 6.4.1 Swedish Infrasound Network

Station	Latitude (N)	Longitude (E)
Kiruna	67.86	20.42
Jamton	65.86	22.51
Lycksele	64.61	18.75
Uppsala	59.85	17.61
Sodankyla	67.42	26.39

Each station consists of a tripartite array of Lidstrom type microphones, with a spacing of 75 meters. Data are digitized at the site and transmitted to a central server. The Swedish Institute of Space Physics makes the recorded data available through the Internet, and also provides software that enables external visitors to locate infrasonic sources and view the recorded time series. Fig. 6.4.4 shows the microphone used in each of the arrays, and the instrument response is shown in Fig. 6.4.5.

Fig. 6.4.4. The Lidstrom infrasonic microphone (After Liszka, 2007).

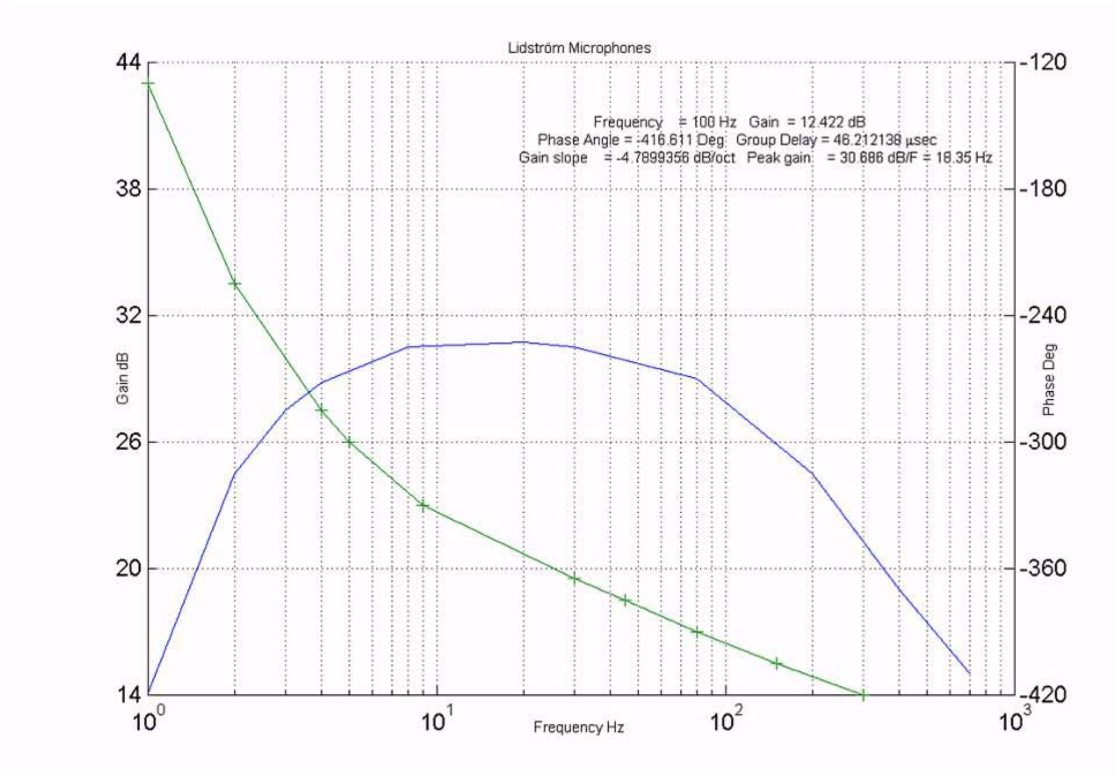

Fig. 6.4.5. The Lidstrom microphone characteristics (After Liszka, 2007).

An important feature of the arrays is the placement of a wind barrier around each microphone. This is in contrast to the spatial filters used at the IMS sites. A schematic picture of a wind barrier is shown in Fig. 6.4.6. It is interesting to note that the use of such wind barriers is now becoming a topic that is creating considerable interest in the international community.

We are grateful to the Swedish Institute of Space Physics for allowing us to use their recorded data in our planned seismic/infrasonic network processing.

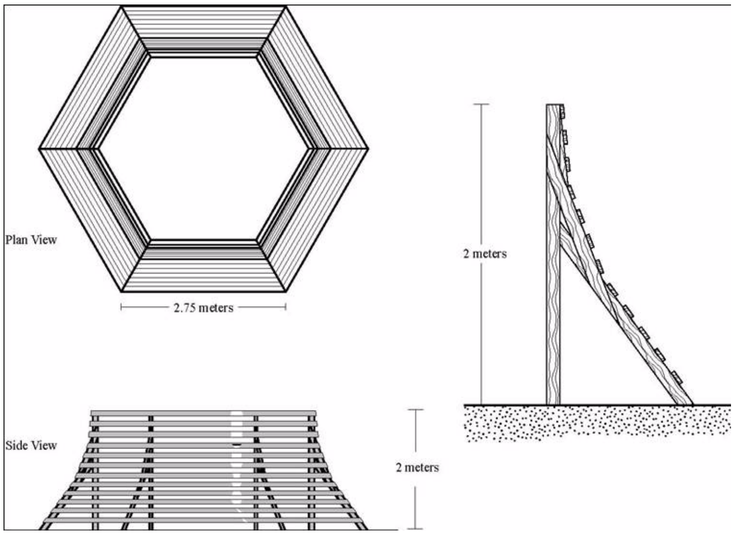

Fig. 6.4.6. A wind barrier of the type used at the recording stations of the Swedish infrasound network (After Liszka, 2007).

6.4.3 Examples of recordings

We present a few examples of infrasonic recordings to illustrate the benefits of the emerging network. We have chosen to use data from the sequence of explosions in NW Russia previously studied by Ringdal and Schweitzer (2005).

Fig. 6.4.7 shows recordings by the four stations in the Swedish network for a two-hour period on 15 March 2005. During this time period, two explosions were carried out, separated in time by approximately 26 minutes. We note that the first explosion shows very strong signals on all four arrays, whereas the second (smaller) explosion is clearly visible on at least two of the arrays.

Fig. 6.4.8 shows a closer view of the Kiruna recordings. Although the signals are clipped due to the limited dynamic range of the digitizer, we have found that reliable azimuths can be easily estimated using either f-k analysis or a cross-correlation technique. The fact that the array is very small does not seem to be a disadvantage at the frequencies of interest for this type of events (2-8 Hz).

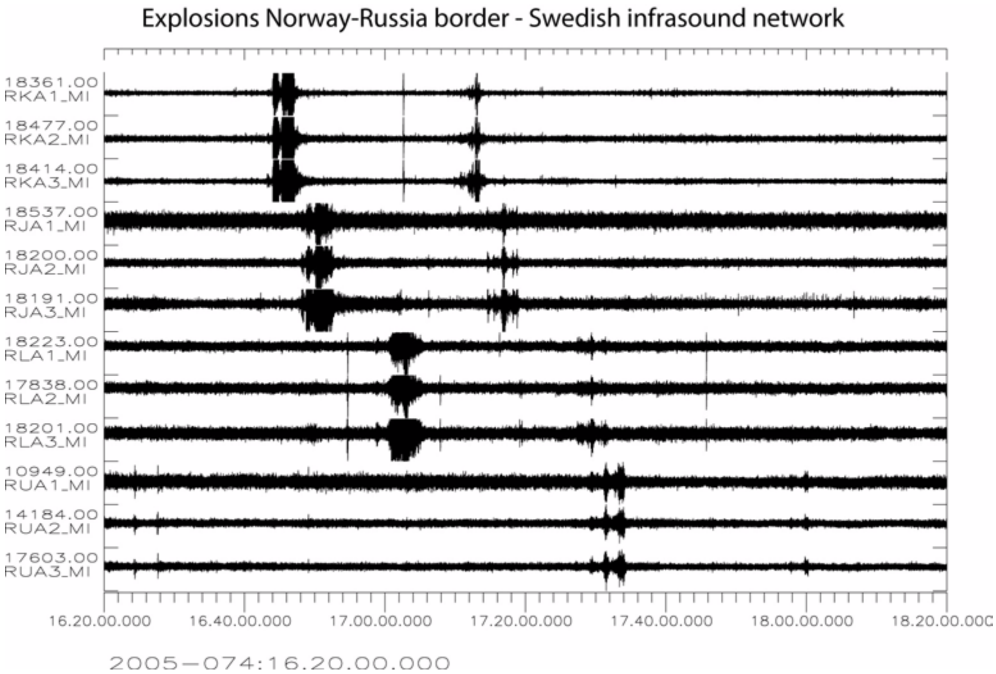

Fig. 6.4.7. Recordings by the Swedish infrasound network of two explosions in NW Russia during 15 March 2005. Three channels for each array are shown. From top to bottom: Kiruna, Jamton, Lycksele, Uppsala.

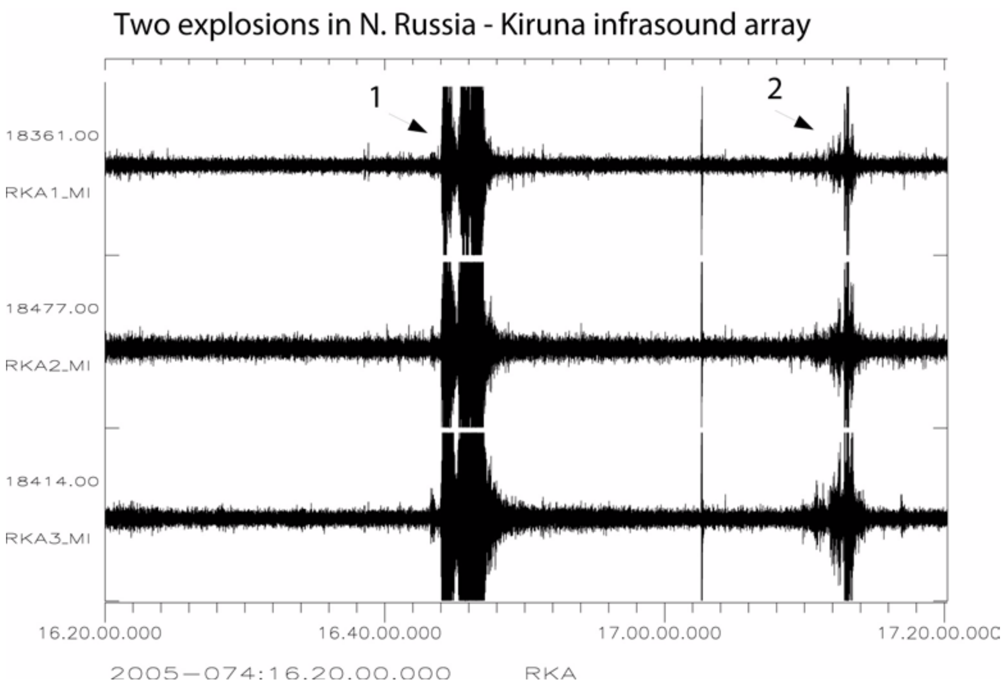

Fig. 6.4.8. Focused view on the two explosions displayed in the preceding figure, showing only the Kiruna station. The onset of the sound waves from the two explosions are marked.

For comparison, the same two explosions, as recorded by the Apatity infrasound array, is shown in Fig. 6.4.9. Here, the dynamic range is much larger, and the true signal can therefore be recorded. It will take time to evaluate the stations in more detail, but it is clear that the Swedish network will provide a valuable addition to the regional seismic/infrasonic monitoring network.

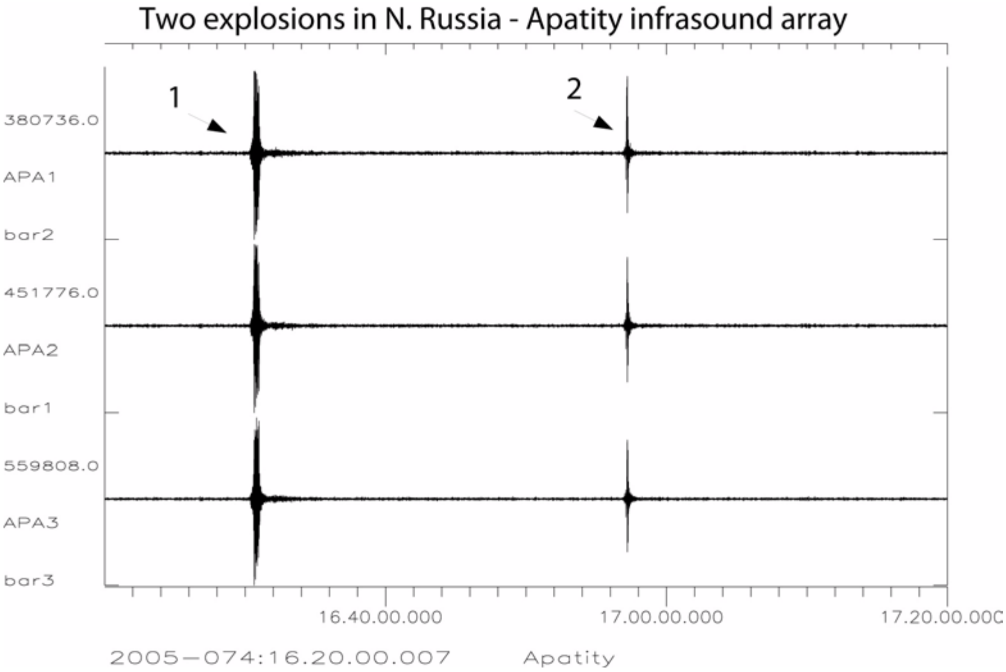

Fig. 6.4.9. The same two explosions as shown in Fig. 6.4.8, but now as recorded by the Apatity infrasound array. See text for details.

Fig. 6.4.10 and 6.4.11 show examples of azimuth estimates for the first of the two explosions using infrasound data recorded by the two arrays (Kiruna and Apatity). In this estimation process we have used the method of Frankel et al. (1991), which comprises pairwise correlations of the individual data channels and a search for maximum energy in the beams formed from time-aligned correlation traces. In both cases (as well as in numerous other cases investigated by us) the azimuth estimates are remarkably accurate. From Fig. 6.4.10 (Kiruna), we note that the azimuth estimate (63.43 degrees) is quite close to the true azimuth (61.87 degrees). The same is also the case for the Apatity estimate (349.56) shown in Figure 6.4.11, which is again close to the true azimuth (348.14).

It is noteworthy that such small arrays are consistently capable of providing reliable azimuths. An especially remarkable observation is that the clipping problem at Kiruna (and also at the other Swedish network stations) has little influence on the quality of the azimuth estimates.

With the inclusion of the Swedish network stations (and the temporary use of ARCES as a substitute infrasound array), we now have available a regional infrasonic array network in northern Europe as shown in Fig. 6.4.12. There are six arrays in this network. When the planned IMS infrasound array near ARCES becomes operational (expected in 2007 or 2008), the quality of this infrasound network will be further improved.

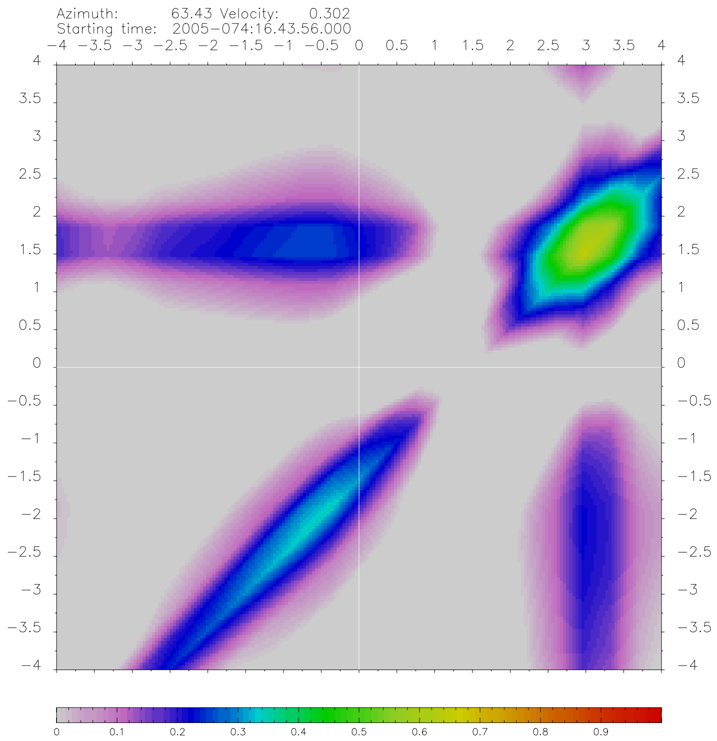

Fig. 6.4.10. Slowness estimate of the Kiruna infrasonic phase for event 1 as shown in Fig. 6.4.8.

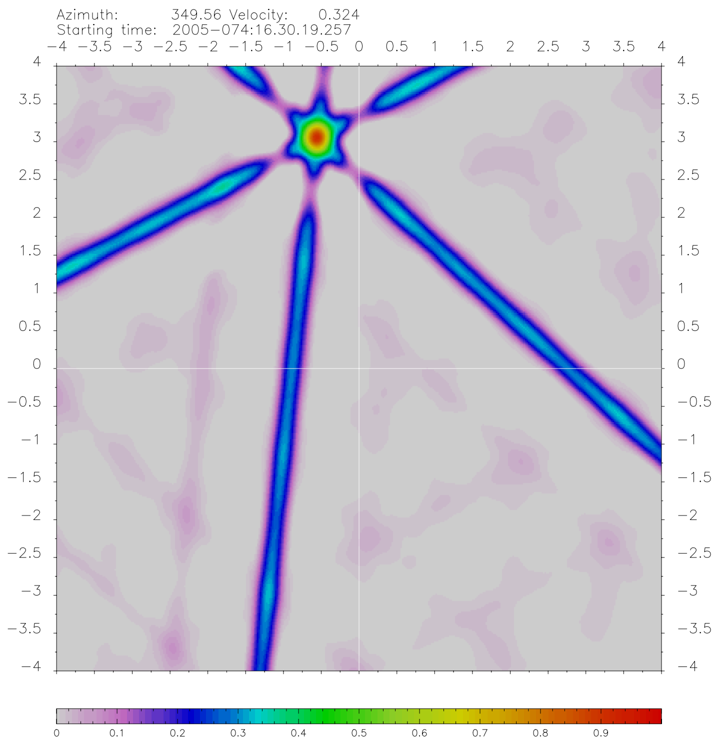

Fig. 6.4.11. Slowness estimate of the Apatity infrasonic phase for event 1 as shown in Fig. 6.4.9.

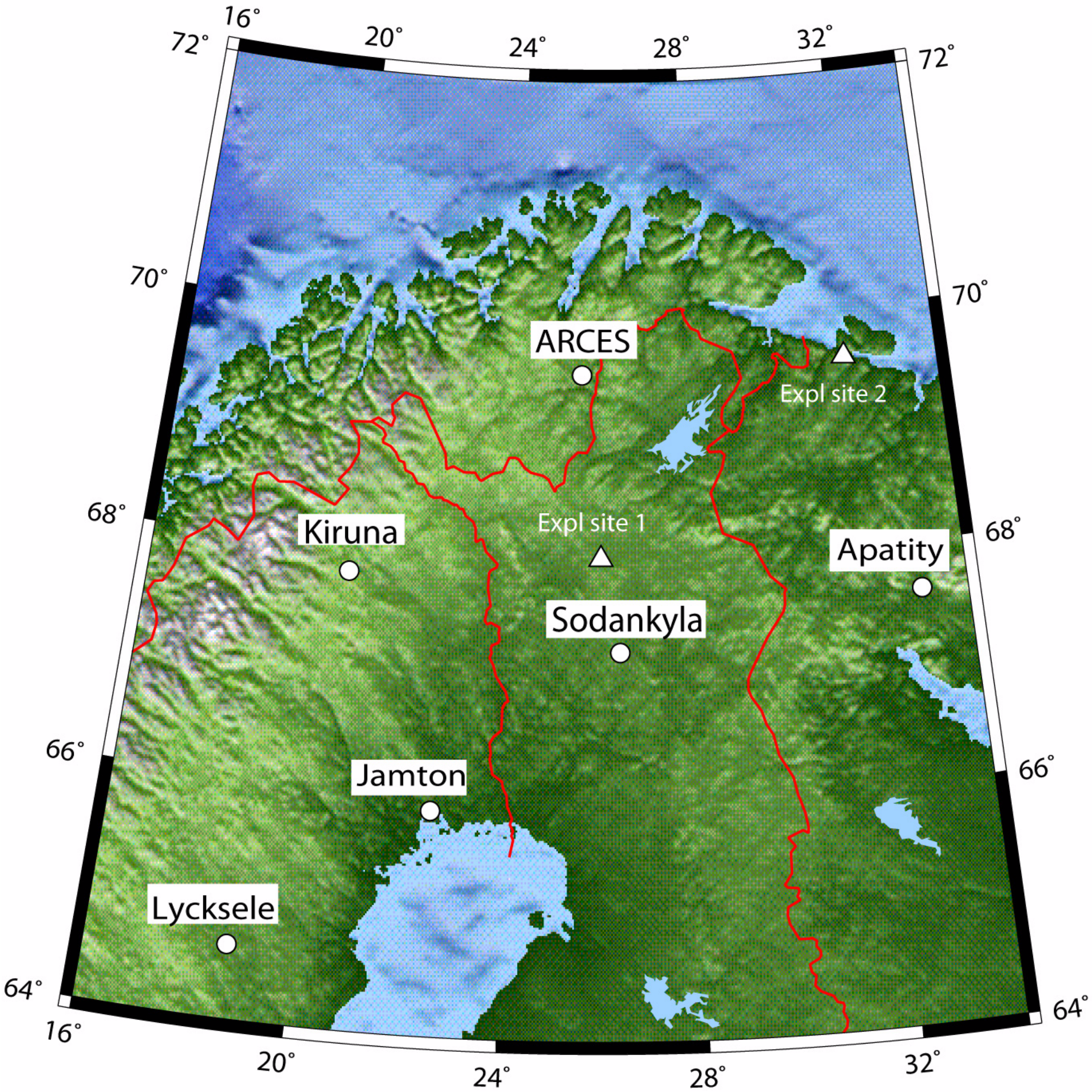

Fig. 6.4.12. Stations in the present Nordic infrasonic array network. Note that the station in Sodankyla, Finland has been moved from Uppsala, Sweden. The two explosion sites in Finland and NW Russia referred to in the text are also marked on the map.

6.4.4 Conclusions

Through the addition of the stations in the Swedish/Finnish infrasonic network, data will be available to allow a much improved joint seismic/infrasonic regional processing at NORSAR. We plan to continue our work on developing automatic phase association techniques for combined seismic and infrasonic phases. We will also follow up our ongoing work on developing two-array and multi-array processing techniques for infrasonic recordings.

Our overall aim is to develop and evaluate a joint seismic/infrasonic bulletin for northern Fennoscandia and adjacent regions. This bulletin would be similar to the automatic seismic bulletin that we are currently providing on the NORSAR Web pages, but it would also contain infrasonic phase associations. Furthermore, we will experimentally attempt to generate an infrasonic event bulletin using only the estimated azimuths and detection times of infrasound phases recorded by stations in the nordic network.

The combined seismic/infrasonic database that we plan to develop in the coming years will be highly valuable for various studies related to obtaining improved accuracy in detecting and characterizing seismic events in the European Arctic region using seismic and infrasonic array recordings at local and regional distances.

Acknowledgements

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