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6.2 Infrasound signals from recent rocket launches in the White Sea

6.2.1 Event on 15 July 2009

International news media reported in July 2009 on an unsuccessful launch of the new Russian intercontinental Bulava missile. The missile was launched from a submarine in the White Sea on 15 July. Figure 6.2.1 below shows an excerpt from the internet publication Aviation Week on 17 July, where it is stated that the technical problems resulted in a self-destruction of the missile at the initial stage of the flight.

AVIATION WEEK

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By Alexey Komarov
Moscow

The 11th test flight of an R-30 Bulava (SS-NX-30) solid-propellant ballistic missile, from the Borey-class flagship submarine Yury Dolgoruky in the White Sea on July 15 resulted in self-destruction of the missile at an initial stage of flight.

According to the Russian Defense Ministry statement the first stage of the missile malfunctioned and the weapon self-destructed. Special investigation commission has already established to find the failure cause, a ministry representative told reporters.

It was the sixth failure for the Bulava. After previous unsuccessful launch on December 2008 tests were suspended until the origin of malfunction had been determined. Officials from the investigation committee blamed low-quality components as a major source of problems.

Earlier this year, Deputy Defense Minister Vladimir Popovkin said the ministry expects to complete trials by the end of 2009. Consequently, more than four missiles were planned to be built and tested this year, with the missiles put into service almost immediately.

The Yury Dolgoruky, a Typhoon submarine in NATO classification, is designed to carry up to 16 Bulavas and is also undergoing trials. Another two subs of the class, Alexander Nevsky and Vladimir Monomach, are being constructed at the Severodvinsk Shipyard. Military experts believe up to 40% of Russia's defense budget for this year was allocated for Bulavas and submarine construction and tests.

Meanwhile, Russian firings of the in-service Sineva missile were successful. One of the Sineva launches used a flattened trajectory according to the government press agency Novosti. Sineva firings were carried out from Delta IV-class boats.

Photo: Russian Federation MoD

The McGraw-Hill Companies

Fig. 6.2.1 Excerpt from the internet publication Aviation Week on 17 July 2009

Infrasound signals associated with this rocket launch were recorded at NORSAR's infrasound station at ARCES and the four stations in Sweden and Finland operated by the Swedish Institute of Space Physics (IRF). Figure 6.2.2 shows clear observations at all stations in the time period 17:55 - 18:25 UTC in 15 July 2009. The pattern of signal pulses are quite similar among the different stations.

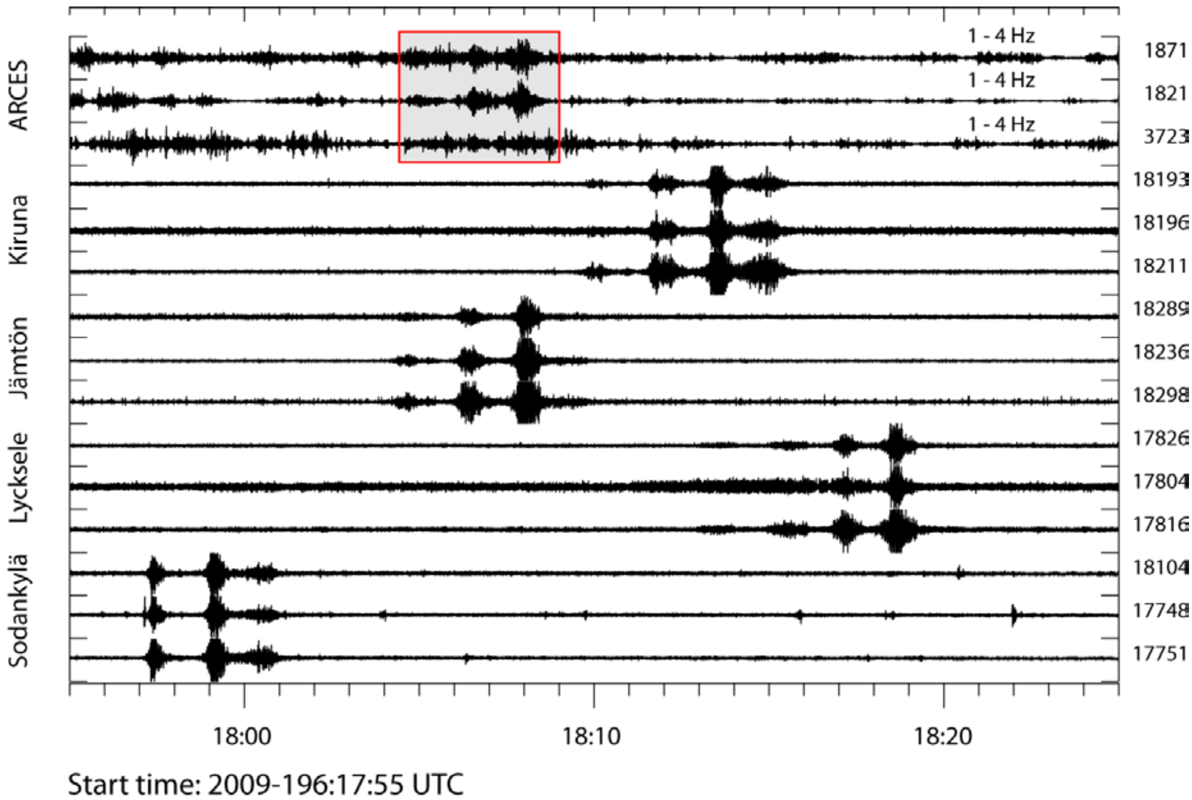

Fig. 6.2.2 Infrasound signals observed in the time period 17:55 to 18:25 UTC on 15 July 2009 at infrasound stations in Norway (ARCES), Sweden (Kiruna, Jämtön and Lycksele) and Finland (Sodankylä). The red rectangle indicates the time period with signals at the ARCES infrasound sensors. The locations of the infrasound sensors are shown in Figure 6.2.4.

Figure 6.2.3 shows azimuthal vespagrams for the different stations for a 10-minute interval centered around the main signal energy. The vespagrams provide information about changes in back-azimuths as a function of time. As seen from Figure 6.2.3, the back-azimuths are relatively constant within the wavetrains of each station. The directional estimates from the different stations are given in Table 6.2.1. We have applied these for location of the event, which we found to be in the White Sea (see Figure 6.2.4). NORSAR's event location has the coordinates:

65.92^{o}N 36.81^{o}E

We have been provided location estimates from Prof. L. Liszka of IRF based on analysis of the two largest signal pulses observed at the 4 stations operated by IRF. These are:

65.77^{o}N 36.89^{o}E
65.69^{o}N 37.08^{o}E

The approximate origin time of the event is estimated to 17:30 UTC.

The strong signal pulses at each station most likely correspond to different stratospheric arrivals. However, both the take-off of the missile and the self-destruction may have lead to the generation of distinct signal pulses at different times, but we are unable to resolve this from our data.

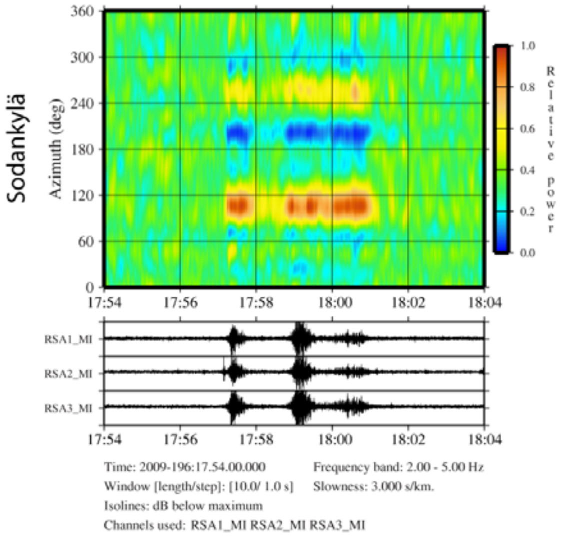

Fig. 6.2.3. Waveforms and vespagrams for a 10-minute segment around the infrasound signals from the event in the White Sea in 15 July 2009. The most energetic areas in the vespagrams (red) indicate the back-azimuth of the arriving signals. The secondary maxima are caused by side-lopes of the recording arrays. A constant sound velocity of 333 m/s is used in the calculation of the vespagrams.

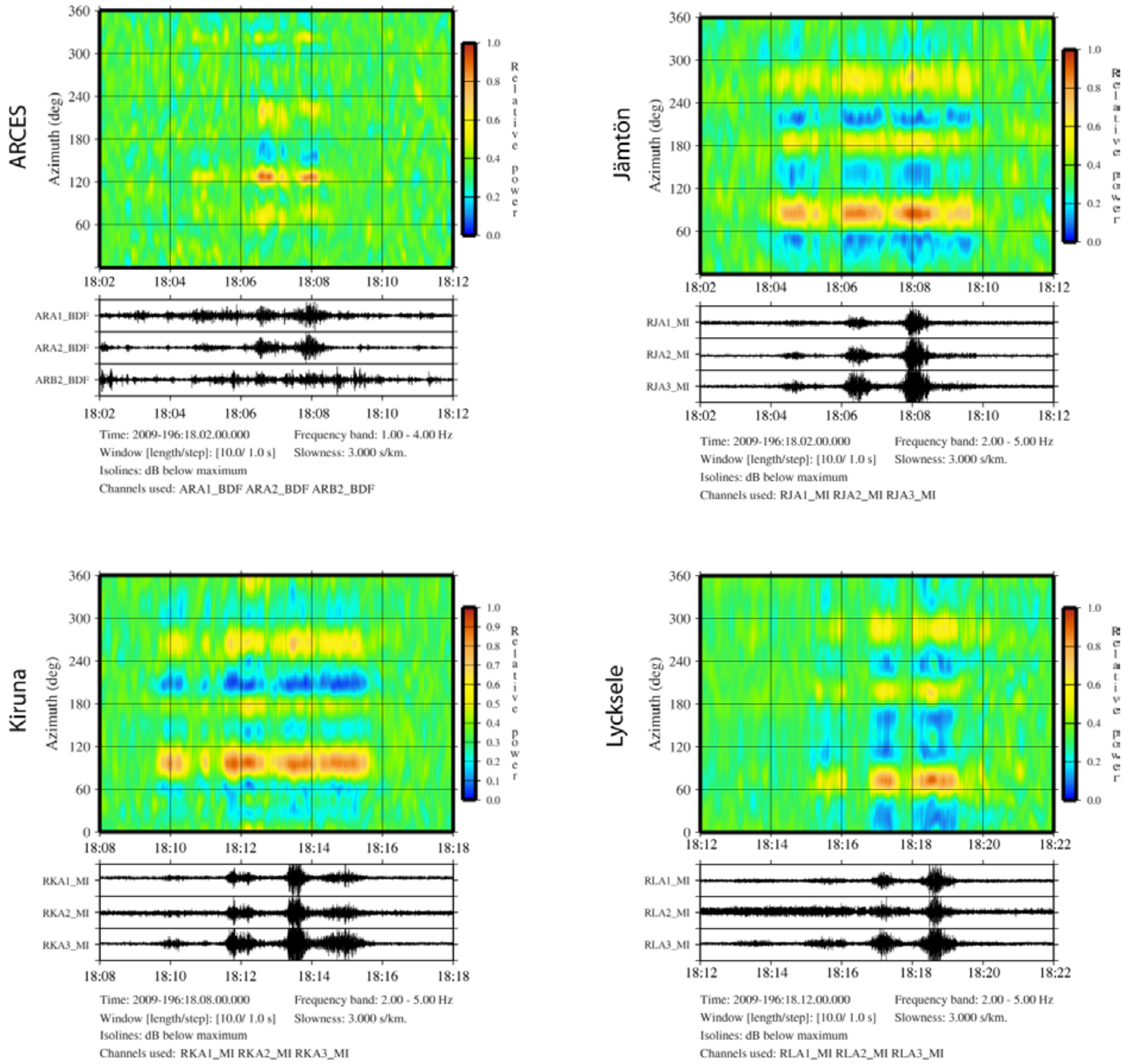

Table 6.2.1. Distances and back-azimuths to the event located in the White Sea on 15 July 2009. The event location estimate is 65.92^{o}N, 36.81^{o}E

Station	Latitude (N)	Longitude (E)	Distance (km)	Back-azimuth (^{o})
Sodankylä	67.42	26.39	489	105.5
ARCES	69.54	25.51	624	126.3
Jämtön	65.86	22.51	651	83.5
Kiruna	67.86	20.42	747	95.3
Lycksele	64.61	18.75	853	73.5

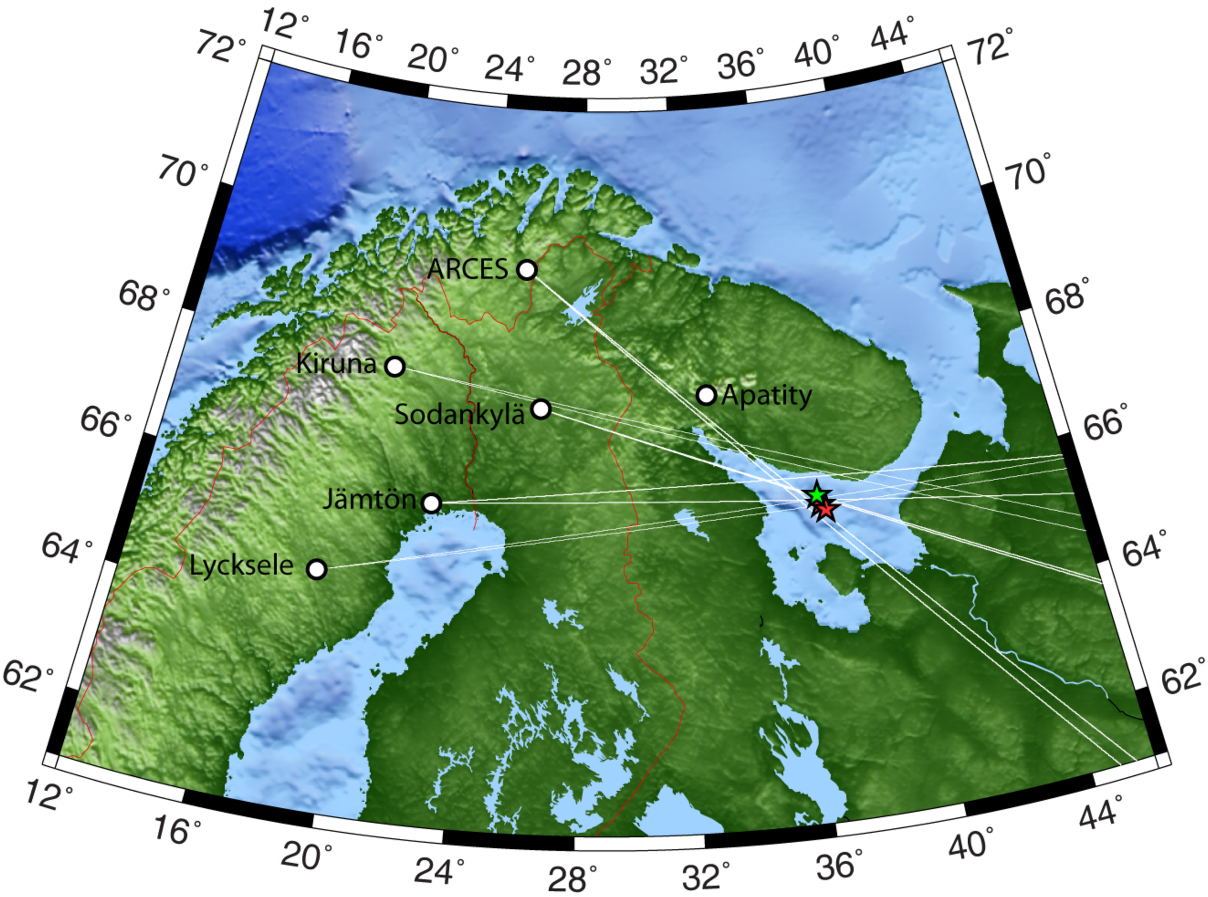

Fig. 6.2.4 Map of infrasound stations in Norway, Sweden, Finland and NW Russia. The station in Apatity was out of operation on 15 July 2009. The white great-circles show estimated back-azimuths from the different stations. Our location is shown by a green star. The red stars show locations provided by Prof. L. Liszka of the Swedish Institute of Space Physics.

6.2.2 Event on 9 December 2009

Around 6:50 UTC on 9 December 2009, strange light phenomena were observed in northern Norway. Figure 6.2.5 shows a photograph taken near Tromsø.

Fig. 6.2.5 Photograph take near Tromsø, northern Norway, of the light phenomena observed around 6:50 UTC on 9 December 2009. The picture is copied from the web page of the newspaper Nordlys at the internet address http://www.nordlys.no/nyheter/bildeserier/article4750399.ece?start=6

These observations caused a lot of attention in the news media, and after a while it became evident that the phenomena were caused by another failure of a Russian Bulava missile. According to the Russian Defence Ministry there was an engine failure in the third stage of the flight that caused the problem. According to recent information provided by the Norwegian Ministry of Defence, they believe that the missile exploded at an altitude between 100 and 300 km above the Novaya Zemlya region, and that the missile was launched from a submarine in the north-eastern part of the White Sea.

Infrasound signals believed to originate from this rocket launch were observed at ARCES as well as at the infrasound station in Apatity on the Kola peninsula. No infrasound signals were found at the stations of the IRF network.

Figure 6.2.6 shows infrasound observations at the ARCES array. From f-k analysis we estimate a back azimuth of about 117^o for this signal (see Figure 6.2.7).

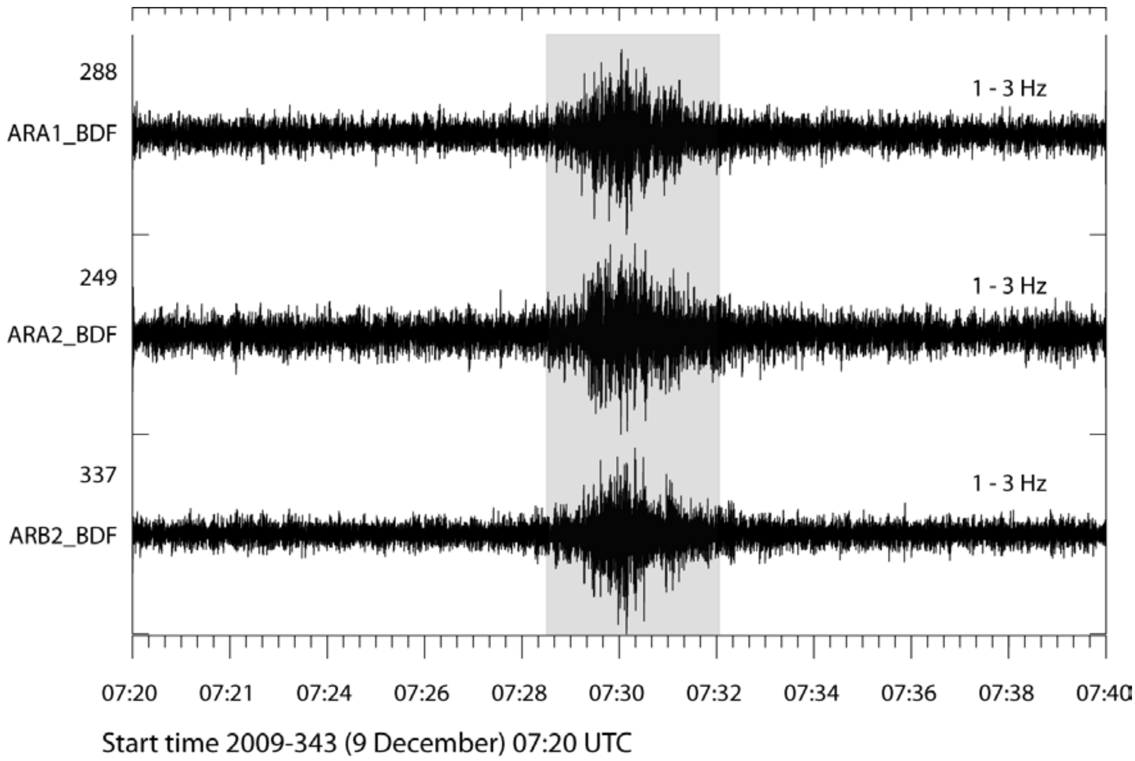

Fig. 6.2.6. Observations at the ARCES infrasound station on 9 December 2009 at about 07:30 UTC. The data are bandpass filtered between 1 and 3 Hz.

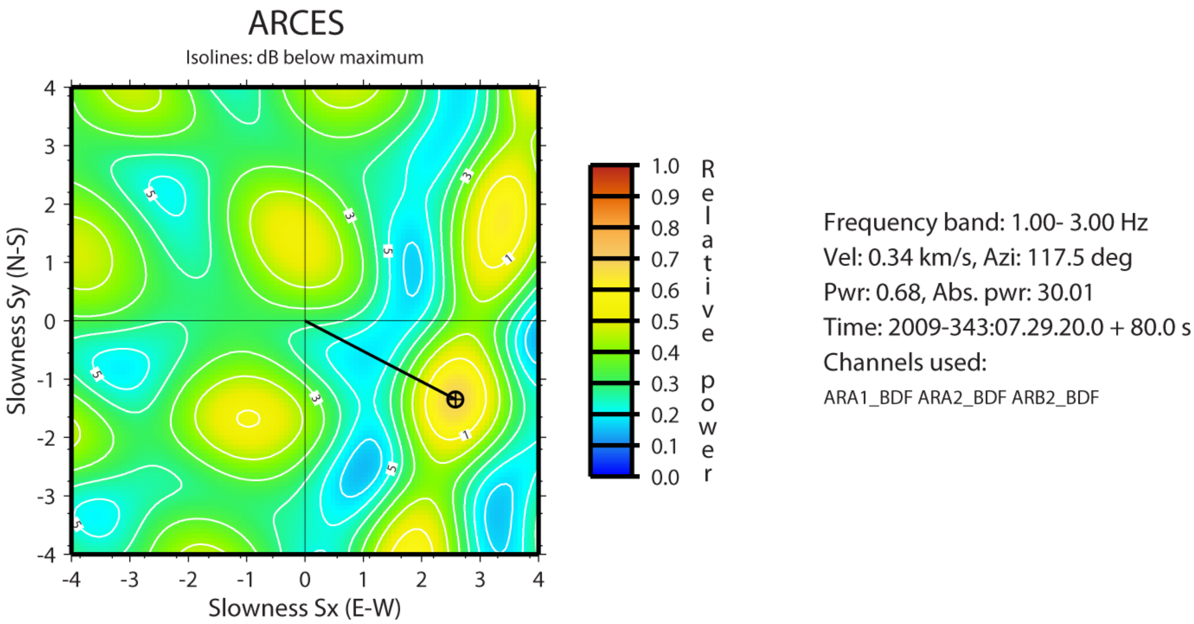

Fig. 6.2.7 F-k analysis of the ARCES infrasound signal shown within the grey-shaded area of Figure 6.2.6.

Clear signals were also observed at the Apatity array (see Figure 6.2.8), but unfortunately only two infrasound sensors were operating at this time. Standard f-k estimation could thus not be performed for back-azimuth estimation. However, by assuming a standard propagation velocity across the array (333 m/s) an azimuthal vespagram could be computed. With only two available sensors, this vespagram exhibit a mirrored image with two maxima (see Figure 6.2.9), and we have to select one of these. As we expect this signal to be associated with the Bulava missile, we selected the lowermost maximum having a back-azimuth ranging between 120 and 130 degrees.

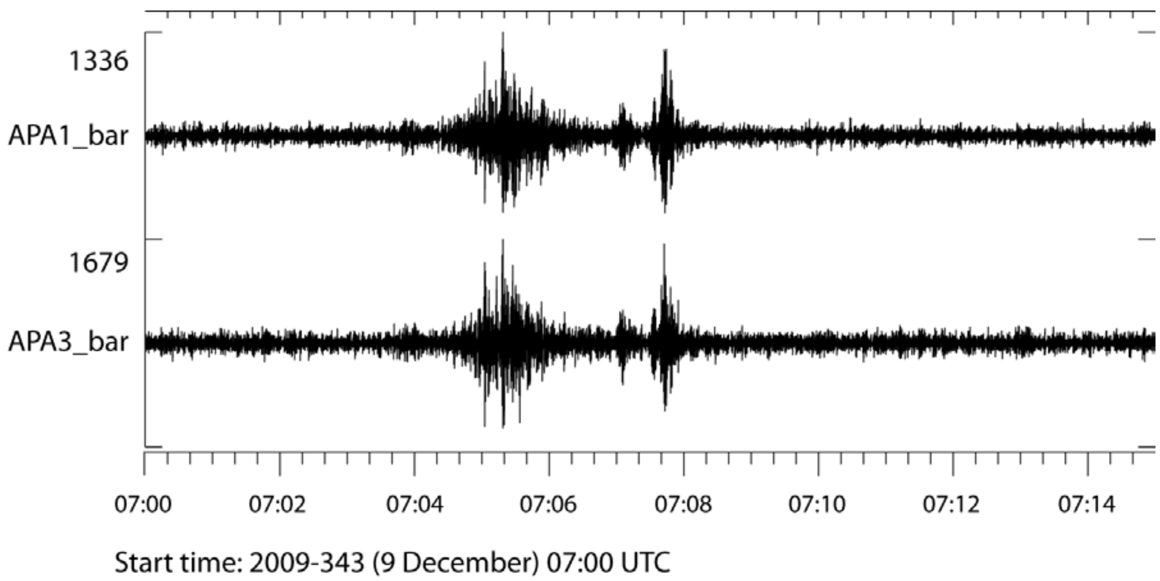

Fig. 6.2.8 Observations at the Apatity infrasound station on 9 December 2009. The signal energy arrives between 07:04 and 07:08 UTC.

Tracing the intersection between the estimated back-azimuths at the ARCES and Apatity infrasound stations, we indicate in Figure 6.2.10 a source region for the infrasound signal. The distances to the Apatity and ARCES stations are approximately 360 km and 730 km, respectively. Applying a standard celerity of 0.29 km/s for stratospheric arrivals we obtain a time difference of about 22 minutes between the Apatity and ARCES infrasound arrivals, which is approximately what we observe at the two stations (see Figures 6.2.6 and 6.2.8). The estimated origin time of the event is in the time interval 06:45 - 06.48 UTC, and the event is most likely associated with the launch of the Bulava missile from the submarine. We do not believe that the infrasound signals are associated with the explosion causing the light phenomena shown in Figure 6.2.5

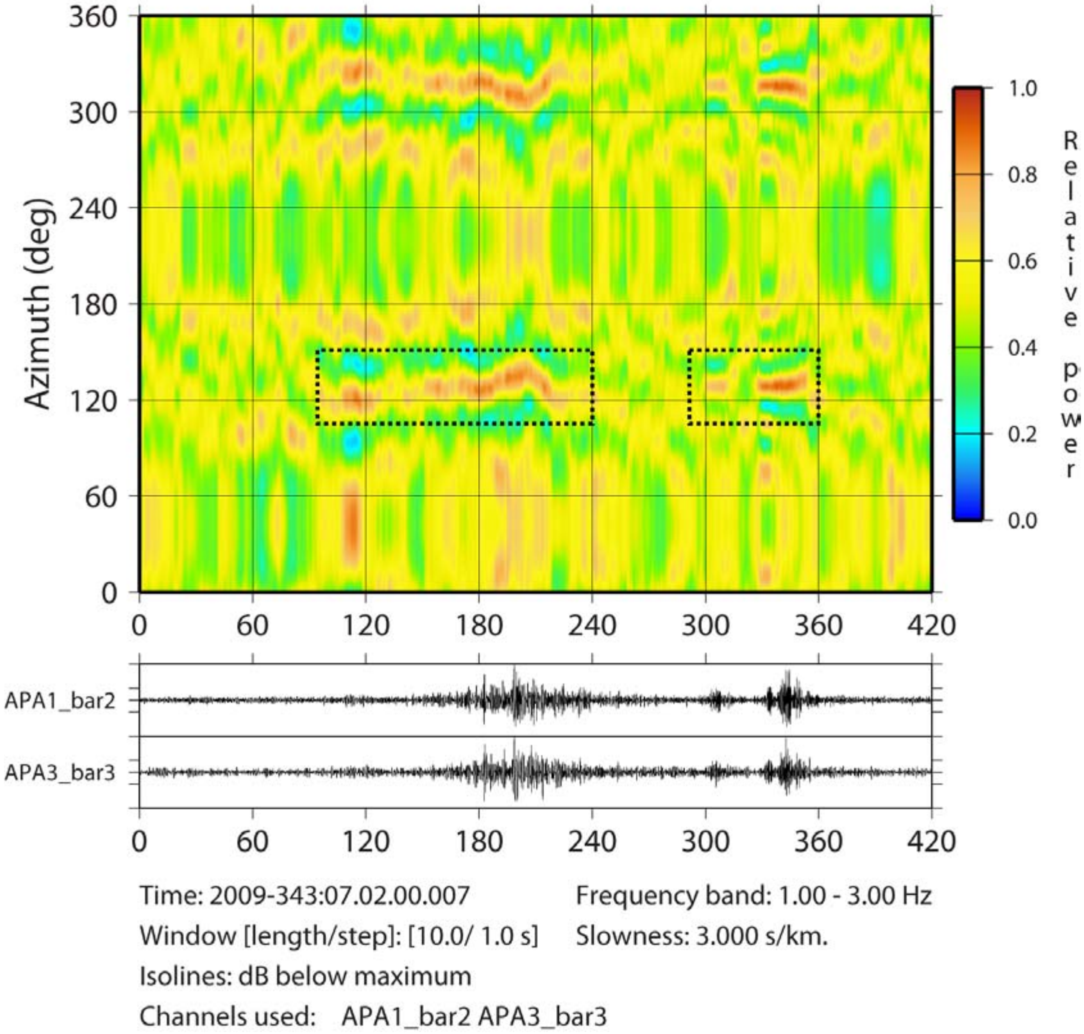

Fig. 6.2.9 Azimuthal vespagram using the two operational Apatity infrasound sensors for the time period 07:02 - 07:09 on 9 December 2009. A standard sound propagation velocity of 333 m/s was applied. The selected vespagram maxima are indicated by dotted rectangles, and these show variation in back-azimuths ranging between 120 and 130 degrees.

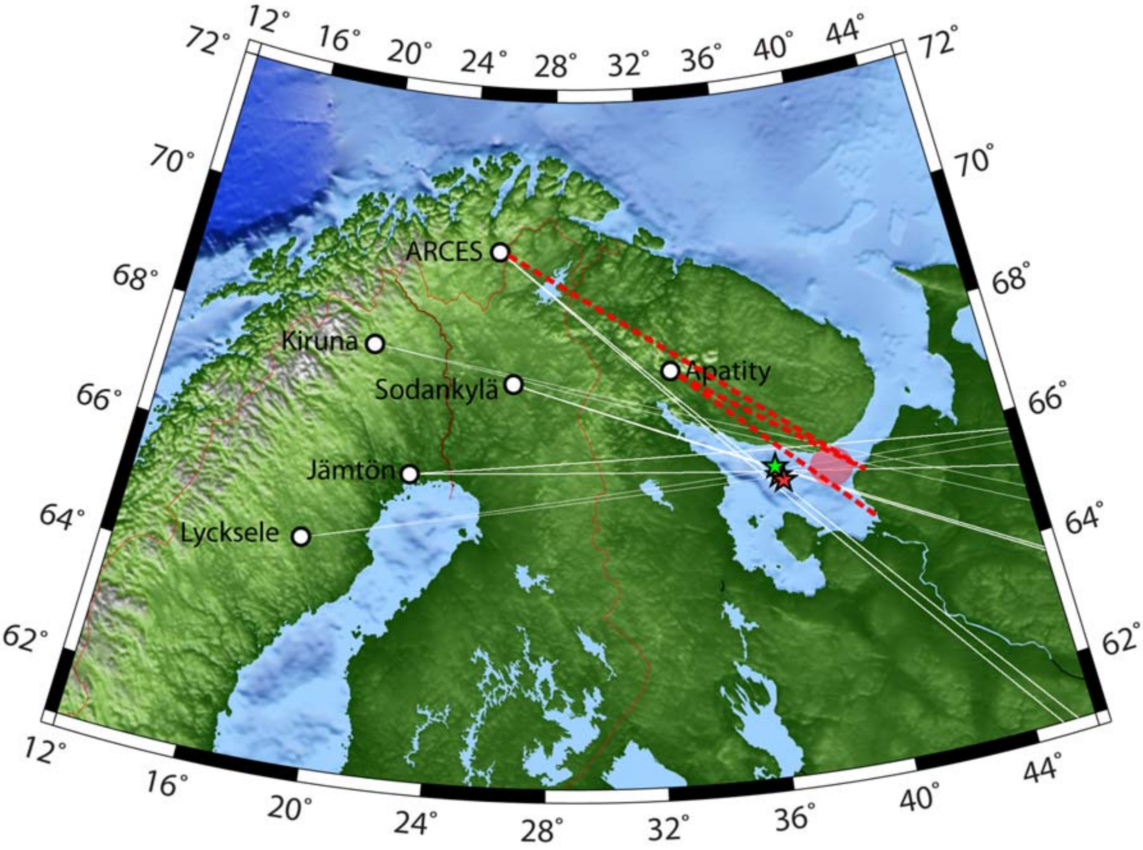

Fig. 6.2.10 The dashed red lines show estimated back-azimuths from the ARCES and Apatity infrasound arrays for the 9 December 2009 event. The approximate source region of this event is indicated by the red ellipse.
For comparison, the red and green stars show the estimated locations of the 15 July 2009 event. See caption of Figure 6.2.4 for details.

Acknowledgements

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Tormod Kværna