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6.1 Seismic event in the eastern Barents Sea, 11 November 2009

6.1.1 Introduction

On 11 November 2009, at 04.18 GMT, signals from a seismic event in the eastern Barents Sea were recorded by seismic stations in the Nordic countries as well as in NW Russia. This part of the Barents Sea has no known history of significant earthquake activity. However, over the past decades, NORSAR has recorded several seismic events at various locations in this region as listed in the NORSAR reviewed regional seismic bulletin. Furthermore, the explosions associated with the Kursk submarine accident in 2000 and a number of explosions in the following years carried out by the Russian Navy have been recorded and are listed in the regional bulletin (see also Kvaerna, 2001).

The area is of interest in nuclear monitoring primarily because of the proximity to the former Soviet nuclear test site at Novaya Zemlya. Mapping the seismicity of the eastern Barents Sea is also important in assessing seismic hazard for production platforms and pipelines in connection with offshore oil and gas fields, such as the large Shtokman field (see Fig. 6.1.1).

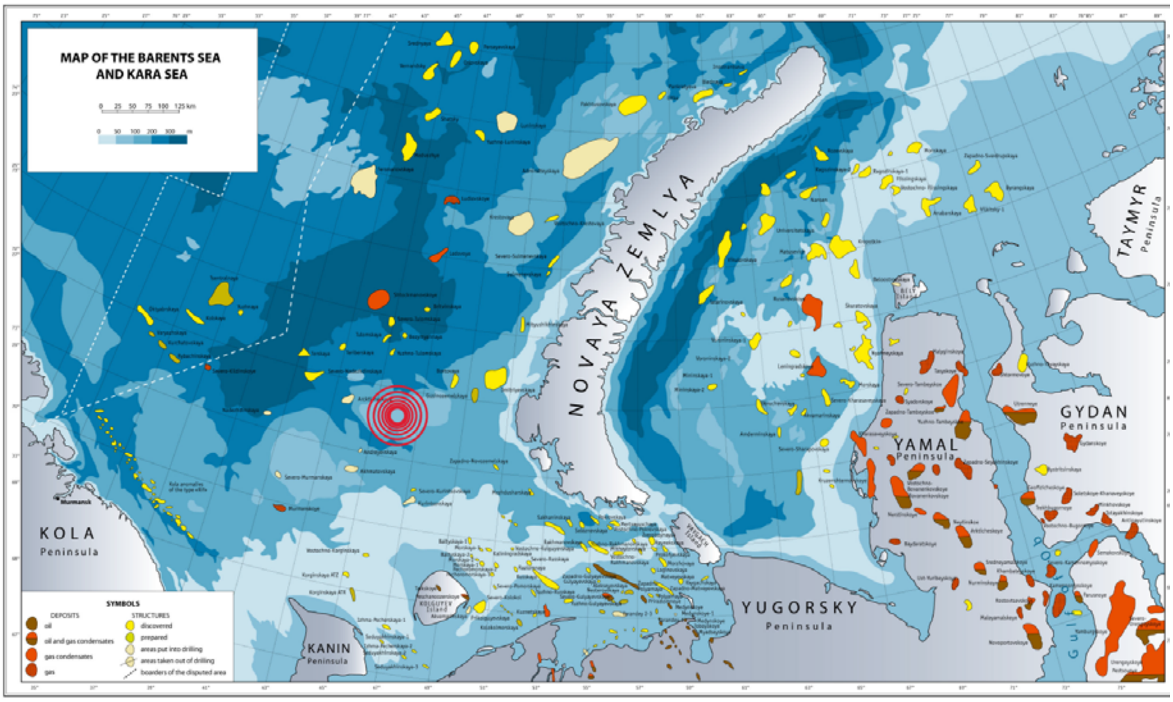


Fig. 6.1.1. Location of the seismic event on 11 November 2009 (red concentric circles). Known hydrocarbon reservoirs are also indicated.

The event parameters as published in the NORSAR bulletin are as follows:

Origin Date/time:	2009/11/11 04:18:21 GMT
Location:	71.58N, 46.09E, Depth 0 (fixed)
Magnitude:	3.2

6.1.2 Observations at ARCES

We have analyzed data from the ARCES array in northern Norway recorded for this event. Fig. 6.1.2 shows filtered recordings (2-16 Hz) of the three-component center seismometer of ARCES. The characteristics of the traces are similar to previous events from this region, with clear Pn and Sn phases, whereas the Pg and Lg phases are not discernible, at least not in this frequency band. We also note that the direction of the event is nearly due east of ARCES, and the consequently the radial component (se) of the Pn-phase is about as strong as the vertical component, while the Sn phase is by far the most prominent on the transverse (sn) component. This is an important confirmation of the advantages of using the transverse component of the seismogram to increase the probability of detecting S-type phases.

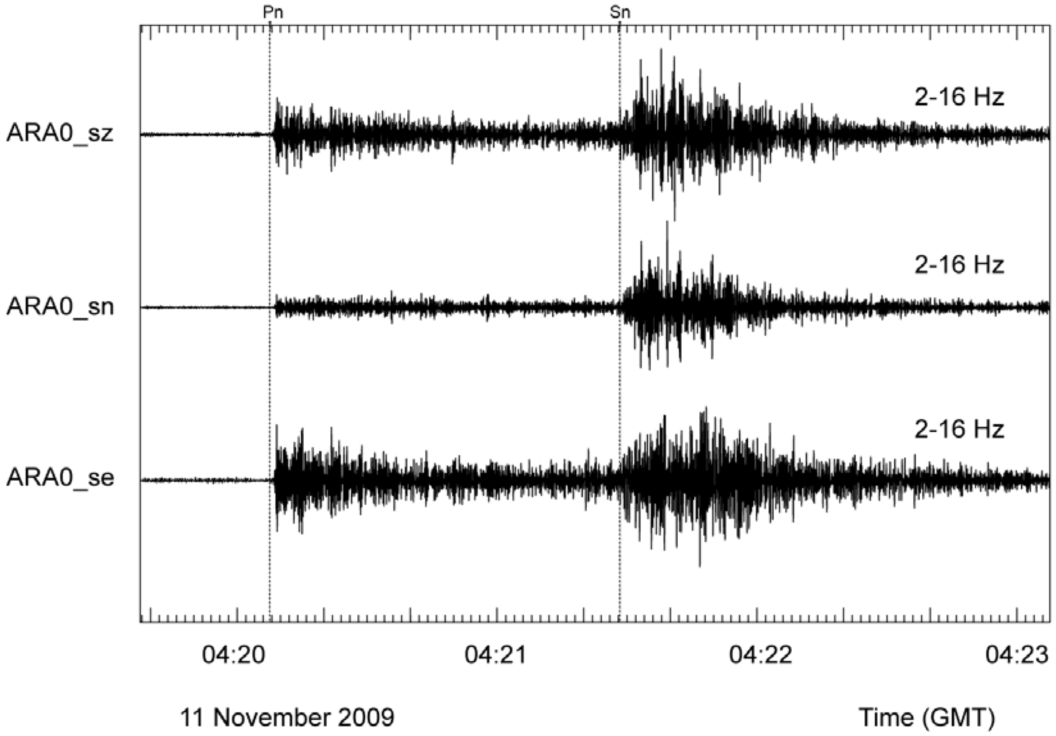


Fig. 6.1.2. Recordings by the three-component center seismometer of the ARCES array of the seismic event in the Barents Sea on 11 November 2009. The traces have been filtered in the 2-16 Hz frequency band.

The event on 11 November 2009 is also important for another reason. As noted by Ringdal et al. (2008), the available high-frequency data at the time of their study did not include recordings of distant events to the east and north-east of the ARCES array, and the high-frequency propagation from the Novaya Zemlya region to ARCES could therefore not be assessed. The present event (at a distance of 800 km) is the first seismic event occurring in the region near Novaya Zemlya after the high-frequency element was installed at ARCES.

We have therefore made a special analysis of the associated ARCES high frequency recordings. Fig. 6.1.3 shows recordings by the ARCES vertical high-frequency element of the event. The recorded trace (bottom) have been filtered in six different frequency bands as indicated on the figure. We note the high SNR for both the Pn and the Sn phases, even in the highest frequency band plotted (20-40 Hz). The Pg and Lg phases are not easily noticed in any of the frequency bands. Fig. 6.1.4 shows spectra of the Pn and Sn phases as well as the noise spectrum. We note again the high-frequency characteristics of the Pn and Sn phases.

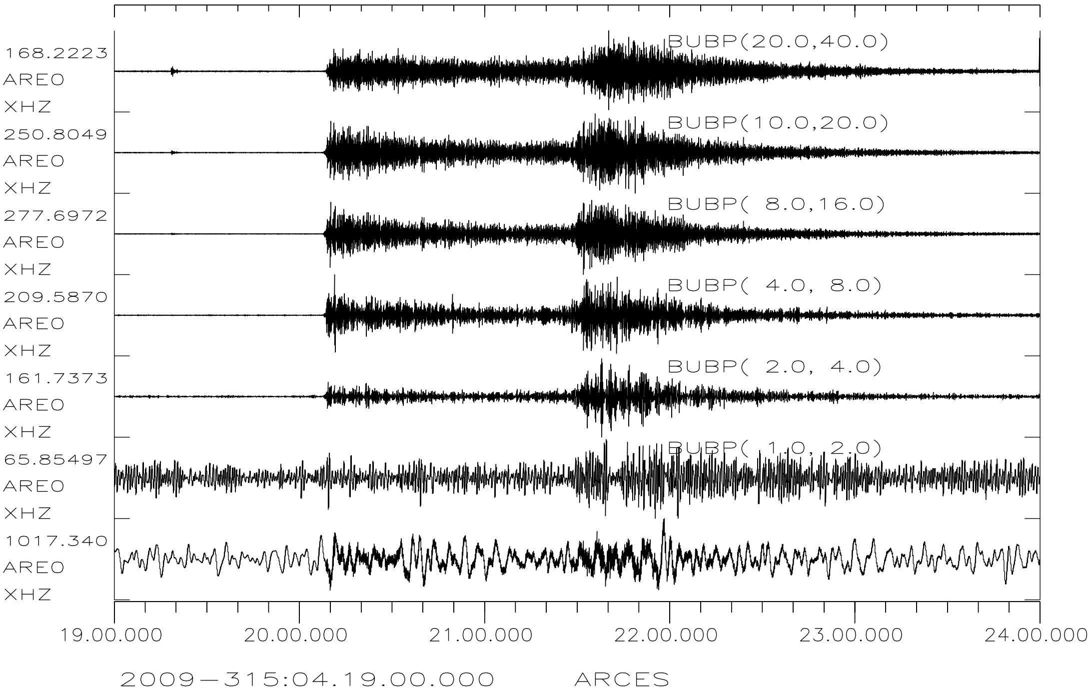


Fig. 6.1.3. Recordings by the ARCES vertical high-frequency element of the seismic event on 11 November 2009. The trace have been filte ed in six different frequency bands as indicated. Note the high SNR for both the Pn and the Sn phases, even in the highest frequency band plotted (20-40 Hz). The Pg and Lg phases are not noticeable in any of the frequency bands.

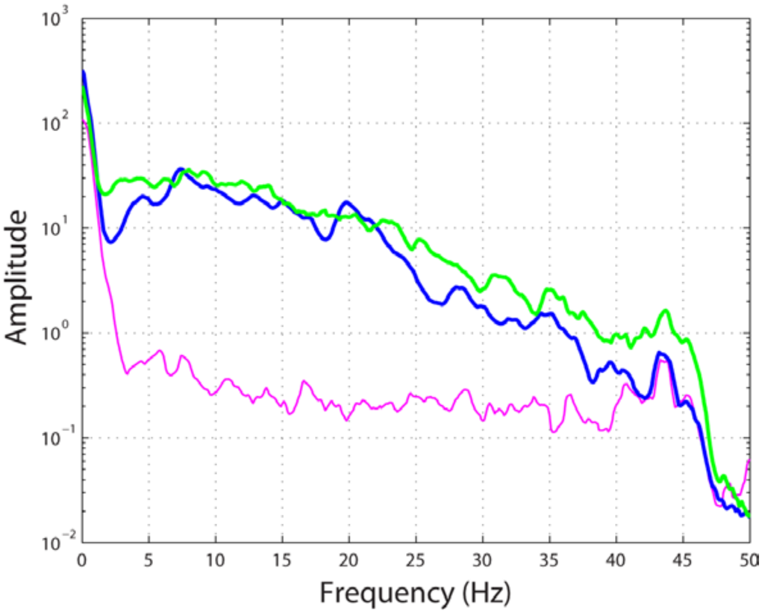


Fig. 6.1.4. Spectra from the ARCES vertical high-frequency element of the Pn (blue) and Sn (green) phases of the 11 November 2009 event. The noise spectrum (magenta) preceding the event is also shown.

6.1.3 Comparison with previous events

After the ARCES high-frequency element was installed, there have been a number of seismic events in or near the mining regions of NW Russia. However, the distance from ARCES to these events are 300 km or less, whereas the epicentral distance of the 11 November 2009 event was as large as 800 km. Nevertheless, it could be of interest to compare the latter event to some of the presumed underwater explosions at about 300 km distance.

One way to make such a comparison is to plot spectrograms as shown in Fig. 6.1.5. Again, a remarkably high signal energy for the Pn and Sn phases is noticeable at high frequencies. Figure 6.1.6 is similar to Fig. 6.1.5, and shows spectrograms from a series of events in the Barents Sea on 19 October 2008. We note that the presumed explosions in 2008 have their dominant energy at much lower frequencies than the event in 2009, even though the latter event is at a much larger distance from ARCES. The spectral scalloping evident in the 2008 plot is typical of many underwater explosions, and is associated with multiple reflections from the bottom and surface of the water.

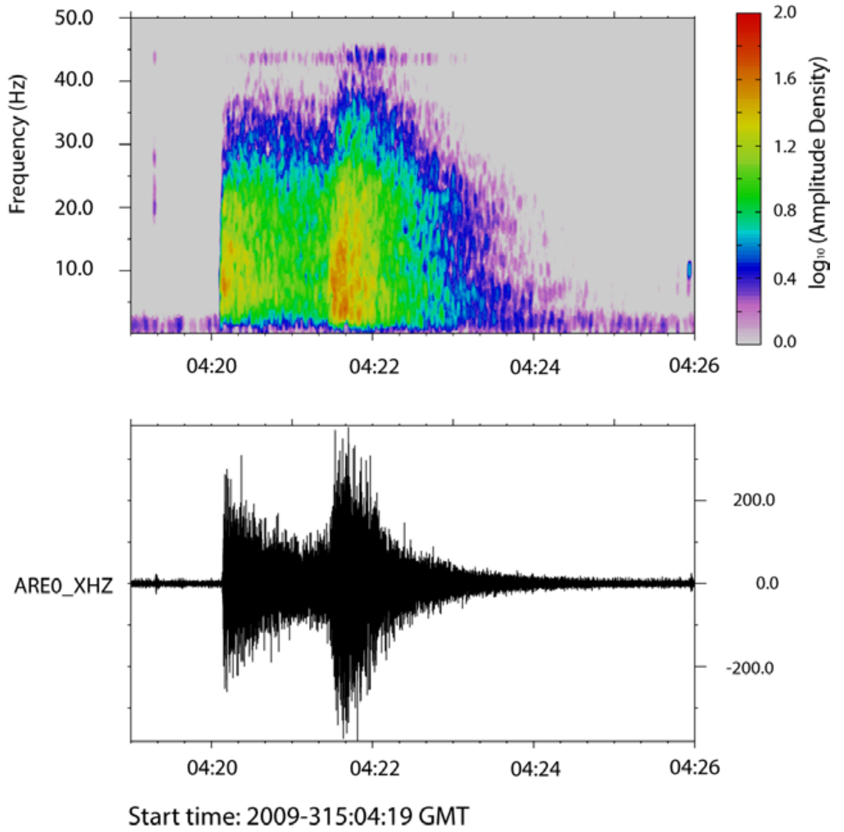


Fig. 6.1.5. Spectrograms from the ARCES vertical high-frequency element of the seismic event on 11 November 2009. The trace have been high-pass filtered at 2.2 Hz. Note the significant energy for both the Pn and the Sn phases, even up to 40 Hz.

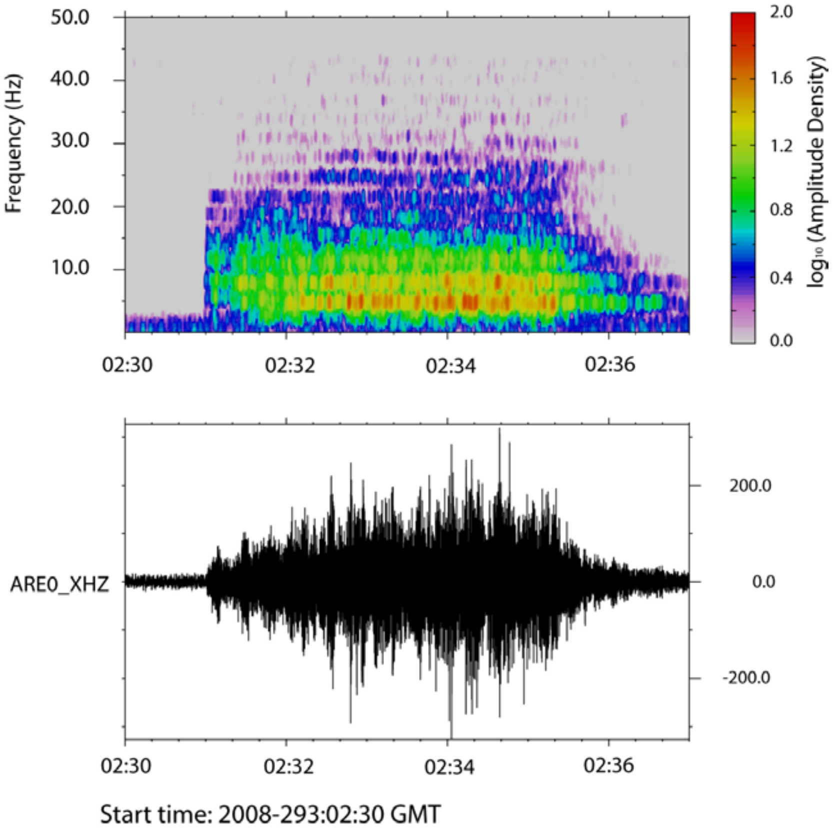
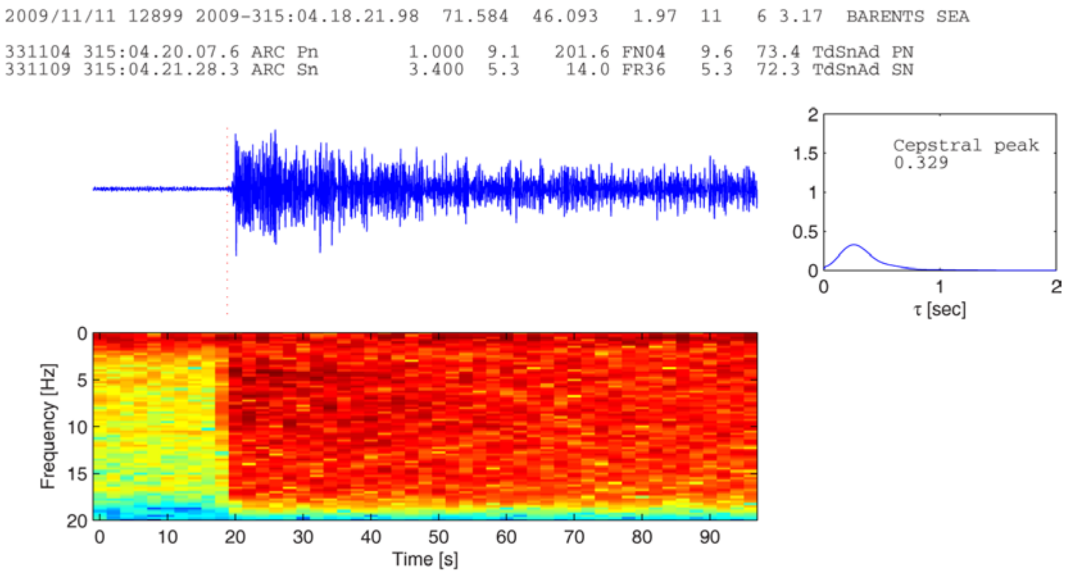


Fig. 6.1.6. Spectrograms from the ARCES vertical high-frequency element of a sequence of co-located presumed underwater explosions near the northern coast of the Kola Peninsula on 19 October 2008. The trace have been high-pass filte ed at 2.2 Hz. Note the significant differences from the plot in Fig. 6.1.5.

6.1.4 Cepstral analysis

We have applied the software described by Öberg et al. (2004) to compare the cepstral peaks associated with various categories of events in the Barents Sea region. We have not used the high-frequency element for this purpose, and consequently we have a number of candidate events. Fig. 6.1.7 and 6.1.8 show the two events described earlier. The cepstral peak is significantly higher for the 2008 event than for the 2009 event. We know from previous studies that cepstral peaks are usually more pronounced for underwater explosions than for earthquakes, although it is difficult to discriminate reliably using this criterion only.

In order to further illustrate the ARCES cepstral analysis, we include some plots of previous presumed earthquakes and explosions in the Barents region. Fig. 6.1.9 shows two known underwater explosions (associated with the Kursk accident) and one presumed underwater explosion, while Fig. 6.1.10 shows two presumed earthquakes. The cepstral peaks are much more prominent for the three explosions than for the two earthquakes.



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2009/11/11 12899 2009-315:04.18.21.98   71.584   46.093    1.97   11    6 3.17   BARENTS SEA

331104 315:04.20.07.6 ARC Pn         1.000  9.1    201.6 FN04    9.6   73.4 TdSnAd PN
331109 315:04.21.28.3 ARC Sn         3.400  5.3     14.0 FR36    5.3   72.3 TdSnAd SN
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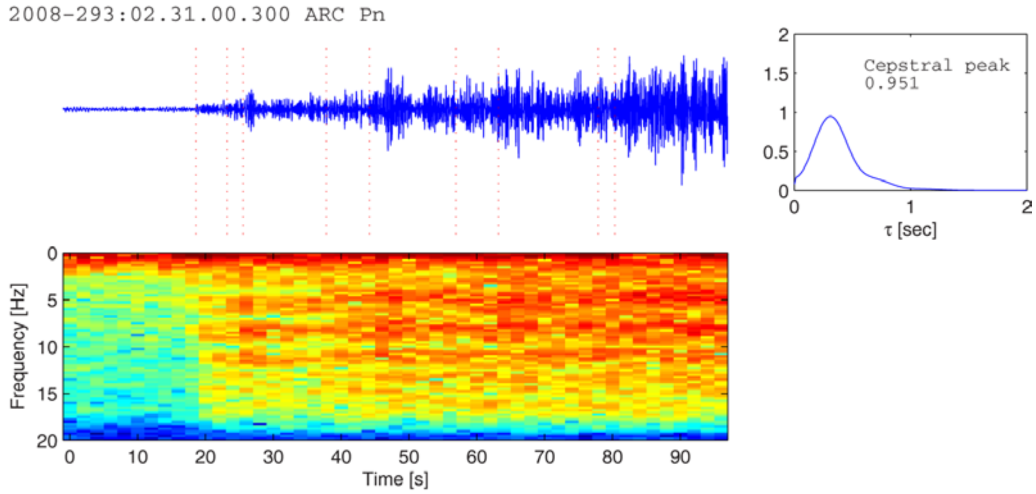
Fig. 6.1.7. Spectrograms from the ARCES vertical central seismometer of the seismic event on 11 November 2009 along with a plot showing the associated cepstral peak.



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2008-293:02.31.00.300 ARC Pn
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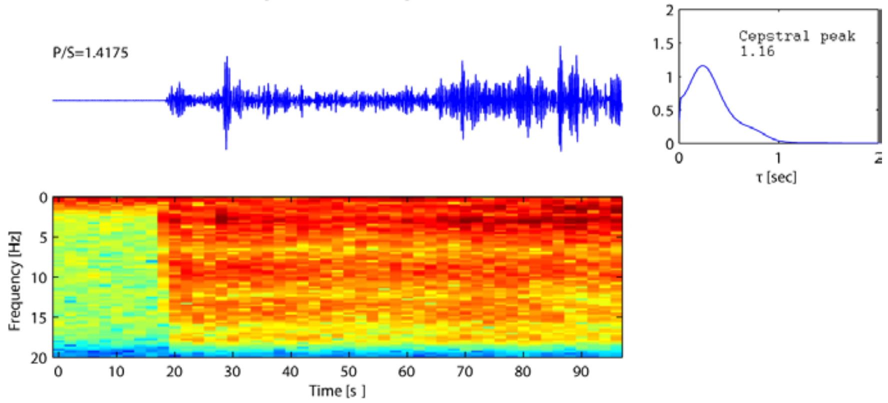
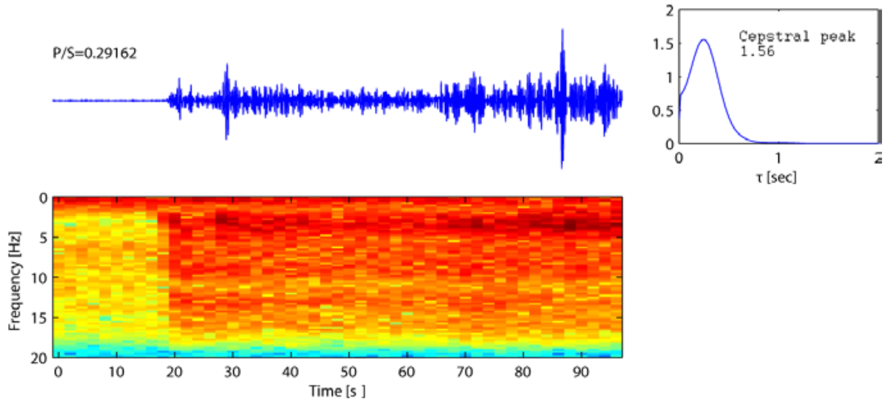
Fig. 6.1.8. Spectrograms from the ARCES vertical central seismometer of a sequence of co-located presumed underwater explosions near the northern coast of the Kola Peninsula on 19 October 2008, along with a plot showing the associated cepstral peak.

The Kursk accident, 12 August 2000, magnitude 3.5



Destruction of the remains of the Kursk, 8 September 2002, magnitude 2.8



Presumed underwater explosion, 21 February 2005, magnitude 2.2

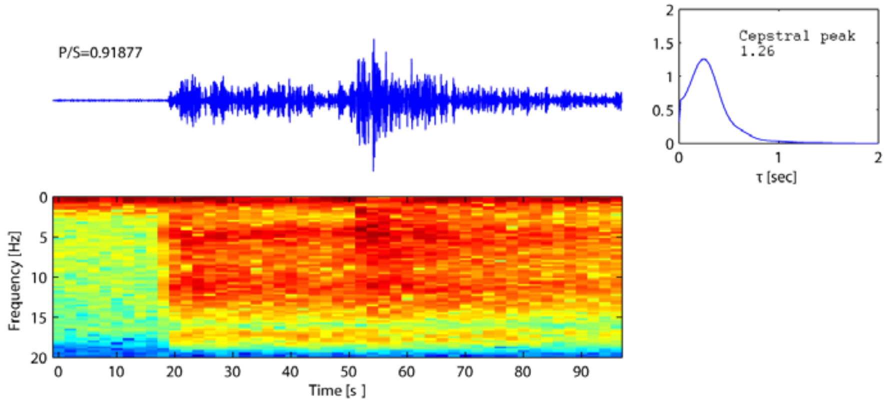
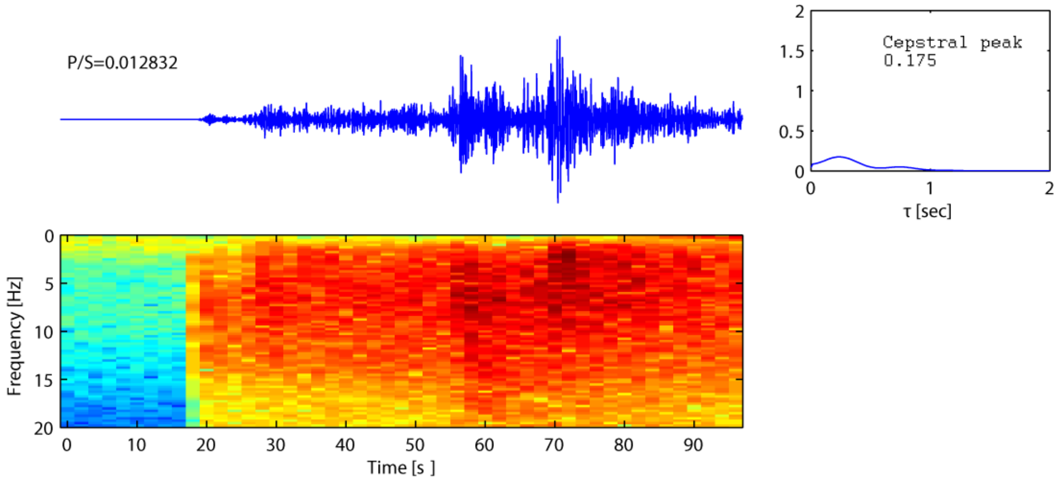


Fig. 6.1.9. Spectrograms from the ARCES vertical central seismometer of three underwater explosions in the Barents Sea, along with plots showing the associated cepstral peaks.

Earthquake on the Kola peninsula, 16 June 1990, magnitude 3.9



Earthquake on the Kola peninsula, 2 September 1998, magnitude 2.6

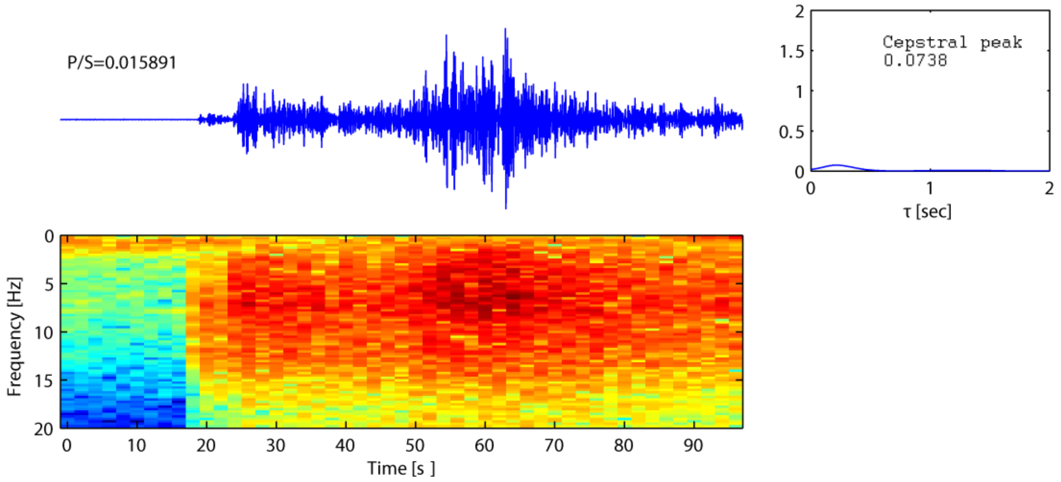


Fig. 6.1.10. Spectrograms from the ARCES vertical central seismometer of two presumed earthquakes located in the northern part of the Kola peninsula, along with plots showing the associated cepstral peaks

6.1.5 Conclusions

Seismic events in the eastern Barents Sea are rare, and the event on 11 November 2009 is therefore of considerable interest. It is the first recorded seismic event in this region since the new high-frequency system was installed at the ARCES array on 23 March 2008. Our analysis of this event confirms the preliminary results of Ringdal et al. (2008) that there is a remarkably efficient propagation from distant events recorded at ARCES at frequencies up to 30 Hz and above.

This result is similar to what has been previously observed at the Spitsbergen array for paths from Novaya Zemlya crossing the Barents Sea. The Spitsbergen studies showed that energy exceeding 20 Hz can be recorded with good signal-to-noise ratio even for small events at epicentral distances as large as 1000 km and we see a similar result in this study, although the event is at a slightly shorter distance (800 km).

As discussed by Ringdal et al. (2008), there are several advantages of high-frequency recordings in a nuclear monitoring context. Although the best filter band for event detection over paths across the Barents region generally appears to be either 4-8 Hz or 8-16 Hz, the most remarkable result shown in our previous as well as the current study is the strong SNR even at the highest frequencies (up to 40 Hz). While such frequencies would not be used for detection purposes, the high frequency data could be very important for signal characterization, as also pointed out by Bowers et. al. (2001) in their paper discussing the level of deterrence to possible CTBT violations in the Novaya Zemlya region provided by data from the Spitsbergen array. In fact, it appears from the present study that similar advantages are provided by the ARCES array. Another example would be to assist in identifying ripple-fired mining explosions or underwater explosions.

As to the source type of the 11 November 2009 event, we are not at this time in a position to give a firm conclusion. The cepstral analysis would indicate that the event is more likely an earthquake than an underwater explosion, but the reliability of the cepstral peak as a discriminant cannot be reliably assessed in this region, due to lack of a sufficient data base.

As more data is accumulated by the ARCES and Spitsbergen high-frequency systems, we may in the future be in a position to carry out a detailed study of the propagation characteristics for additional paths in the region, and make a systematic study of the benefits from combining the high-frequency observations from Spitsbergen and ARCES. This would be expected to contribute to a better understanding of various discriminants for the Barents region. The usefulness of the horizontal components for high-frequency S-phase detection, already demonstrated for the Spitsbergen array, is also an area that needs further study for ARCES.

References

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