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6.3 The Ural Mountains Event on 24 December 2012

6.3.1 Introduction

NORSAR, the Kola Regional Seismological Centre (KRSC, Apatity, Russia) and the Institute of Ecological Problems of the North, Ural Branch of the Russian Academy of Sciences (IEPN UB RAS, Arkhangelsk, Russia) have recently signed a cooperative agreement on scientific cooperation in seismology and infrasound research. Within this agreement we have shared data segments from a newly established seismic station in Amderma (AMD^2), northwest Russia deployed by IEPN UB RAS in November 2011 (see Fig. 6.3.1).

During the time period 1993-1999 another seismic station in Amderma (AMD^1) was operated by KRSC at a slightly different location (see Fig. 6.3.2). During this time period, the AMD^1 station recorded a number of interesting events in the Novaya Zemlya - northwest Russia region, among them the well-known events in the Kara Sea on 16 August 1997 (Kremenetskaya and Asming, 1998; Ringdal et al., 2002; Gibbons and Ringdal, 2006; Schweitzer and Kennett, 2002, 2007).

As seen from Fig. 6.3.1, NORSAR's regional monitoring system of regional arrays has for the time period 1990-2013 detected only a small number of events in the Barents/Kara Sea region. An even smaller number of events from this low-seismicity area are reported in the ISC bulletin. However, because of the large hydrocarbon exploration activity in the region and its proximity to the former Novaya Zemlya nuclear test site, seismic events occurring in the area are of high interest to the seismological community.

The newly established station AMD^2, consisting of a Güralp CMG-40-T-1 seismometer and a Geosig GSR-24 digitizer sampling at 50 Hz, is expected to contribute significantly to improving the seismic event monitoring of this region. The station is installed at the premises of the Hydrometeorological Center on a concrete pedestal in a former bomb shelter.

The m_b 3.8 event on 24 December 2012 in the Ural Mountains was one of the first larger events within regional distances recorded at this station. The event was located approximately 100 km south of the city of Vorkuta, on the territory of the Republic of Komi. Location and magnitude estimates of this events reported by different agencies are given in Table 6.3.1.

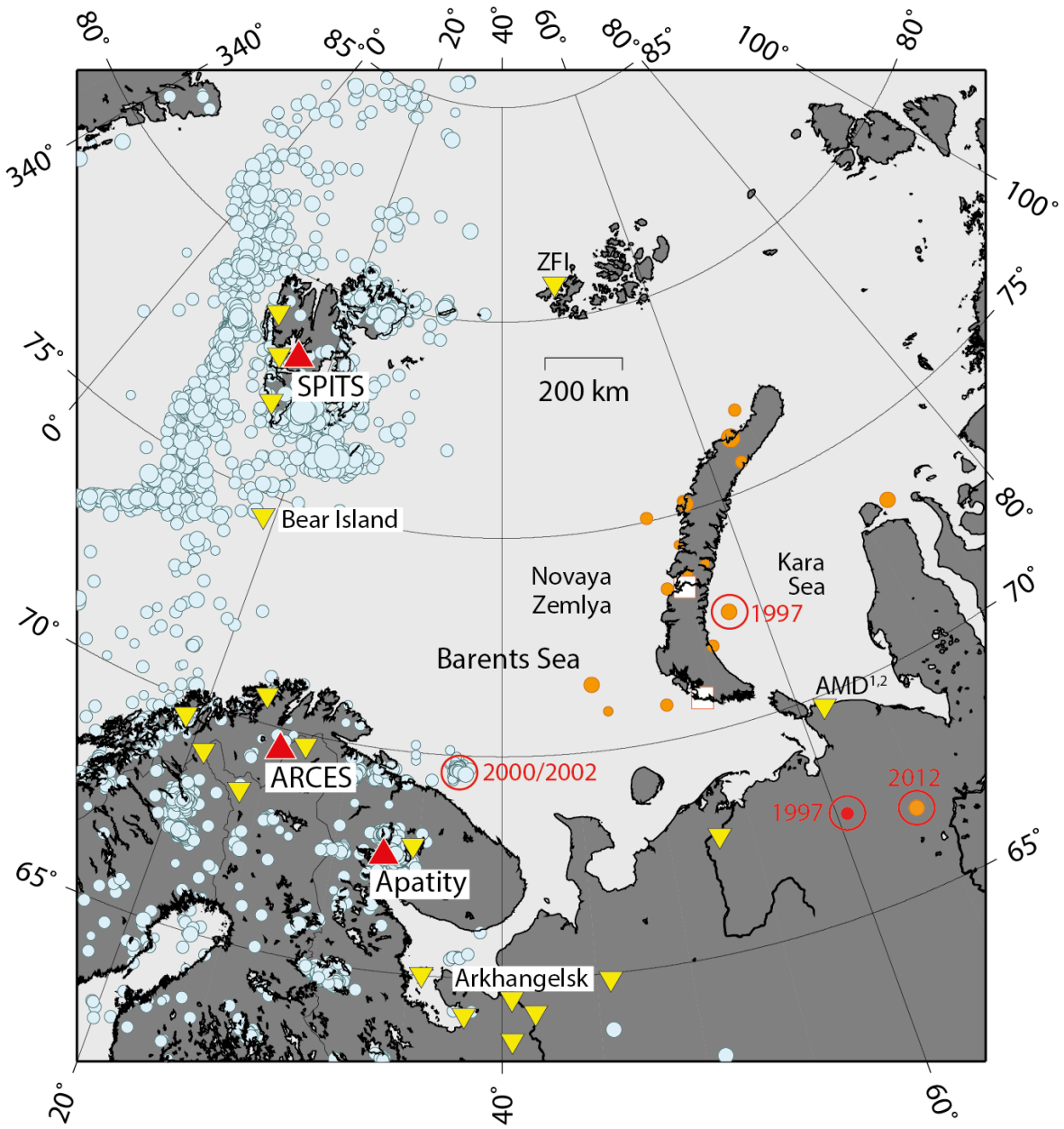

Fig. 6.3.1 The map shows locations of seismic events (orange dots) in and near Novaya Zemlya that have been detected by the NORSAR regional monitoring system since the Soviet moratorium on nuclear explosions began in 1990. Many of these events have not been reported by any other agency. The blue dots represent other seismic events (mostly earthquakes and mining explosions) that have occurred in the region during the same time interval. Key seismic arrays (red triangles) and three-component stations (yellow triangles) in northern Norway, Finland and northwest Russia are also shown on the map. Events analyzed in this study are highlighted by red circles and the year in which they occurred. The 1997 event located south of Amderma (AMD), marked by a red symbol, was detected at that station only. The former nuclear test sites at Novaya Zemlya are marked with white squares.

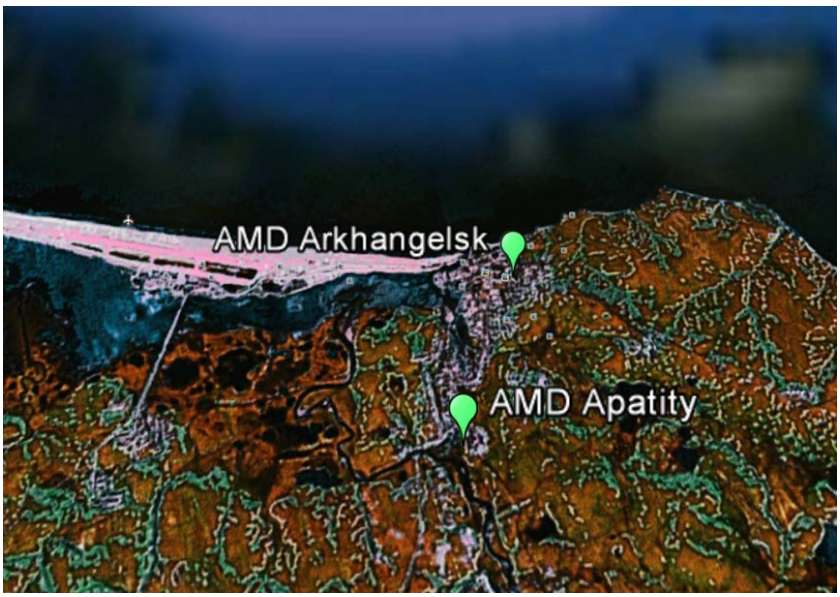

Fig. 6.3.2
Locations of the two seismic stations deployed in Amderma, northwest Russia, by KRSC, Apatity (AMD[1], 1993-1999) and IEPN UB RAS, Arkhangelsk (AMD[2], November 2011 ->). The distance between the two stations is about 2 km.

Agency	Origin Time	Lat	Lon	Depth	Mag
Alert Survey GS RAS [www.ceme.gsras.ru]	06:22:39.9	66.52	63.77	20	m_b=4.0
ISC / IDC [www.isc.ac.uk]	06:22:36.8	66.81	64.40	0f	m_b=3.8
ORFEUS [www.seismicportal.eu]	06:22:34.0	66.94	64.49	2	m_b=3.9
Arkhangelsk seismic network	06:22:39.1	66.47	64.73	10	M_L=3.8
NORSAR [www.norsardata.no]	06:22:39.1	66.94	63.95	0f	m_b=4.5

Table 6.3.1 Location and magnitude estimates of the 24 December 2012 Ural Mountains event reported by different agencies.

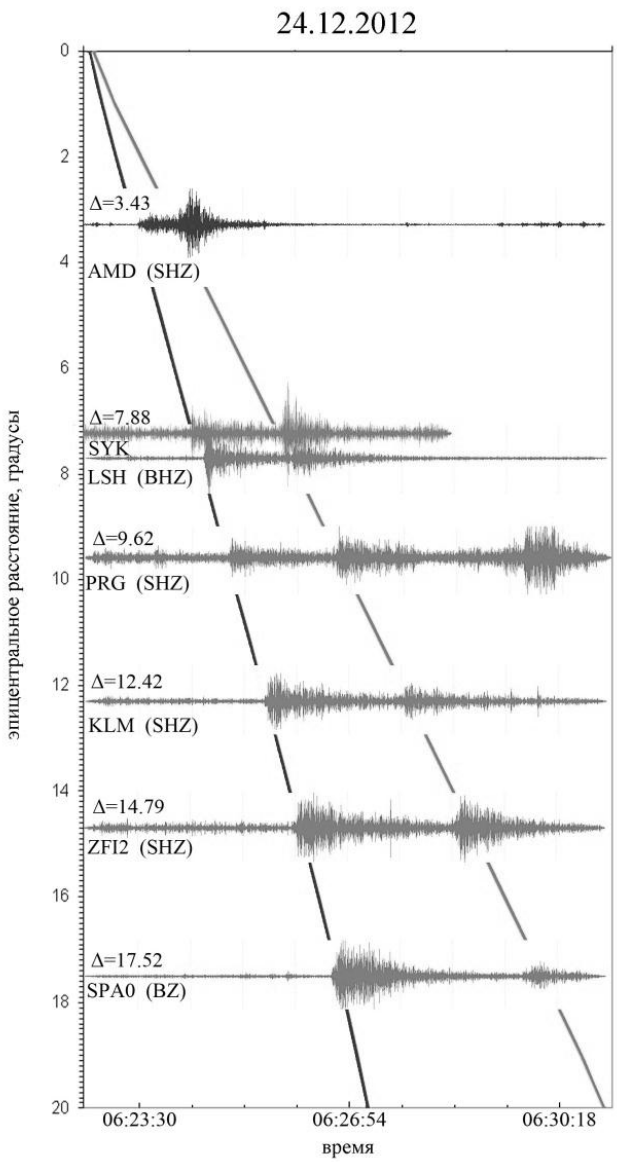

Fig. 6.3.3
Seismogram section of the 24 December 2012 Ural Mountains event as observed at seismic stations on mainland Russia (Arkhangelsk network + Syktyvkar (SYK)), Franz Josef Land (ZFI2) and Spitsbergen (SPA0). The vertical distance axis is given in degrees.

In order to assess the data quality and performance of the new AMD[2] station, we compare the characteristics of the 24 December 2012 event with events recorded at the previous AMD[1] station, operated by KRSC. In addition, we compare the Amderma recordings with ARCES recordings of underwater explosions associated with the Kursk accident in year 2000 and the demolishing of the Kursk wreckage in 2002. The list of events and corresponding recording stations are given in Table 6.3.2.

Date	Origin Time	Lat.	Lon.	Mag.	Station	Dist. (km)	Back-azimuth	Event type
2012/12/24	06:22:37	66.8	64.4	3.8	AMD[2]	347	160	Most likely earthquake
1997/08/16	02:11:00	72.43	57.57	3.5	AMD[1]	334	336	Most likely earthquake
1997/01/31	04:23:53	67.3	60.7	2.5	AMD[1]	275	189	Most likely mine blast
2000/08/12	07:30:42	69.59	37.41	3.5	ARCES	463	84	Underwater explosion
2002/09/08	17:16:28	69.59	37.41	2.8	ARCES	463	84	Underwater explosion

Table 6.3.2 List of analyzed events and the corresponding recording stations. Station AMD[2] is operated by IEPN UB RAS, Arkhangelsk, Russia. Station AM1[2] was operated by KRSC, Apatity, Russia.

6.3.2 Seismograms and spectra

We show in Fig. 6.3.4 seismograms and ground velocity spectra of the 24 December 2012 event recorded at the new AMD[2] station. The spectra of the P-phase (red) and the S-phase (green) are calculated from the vertical component trace, whereas the blue-colored S-phase spectrum is calculated from the horizontally rotated transverse component. A 30 second time window, starting at the phase arrival time is used as the basis for spectral estimation. The noise spectrum (black) is estimated from the vertical component channel using a 30 second time window preceding the P-phase. For comparison we show the noise spectrum preceding the P-phase from the 16 August 1997 event in the Kara Sea, observed at the previous AMD[1] station operated by KRSC, Apatity.

We notice from the seismograms of Fig. 6.3.4 that both the S-phase and the P-coda amplitudes are about a factor of two larger on the horizontal components as compared with the vertical component. The P-coda energy increases gradually on all components during the first 20 seconds after the P onset. From the spectra we observe that the amplitude of the S-phase, as observed on the transverse horizontal component, is more than a factor 10 larger than for the P-phase, observed on the vertical component, for the wide frequency band 0.8 – 8 Hz. We also observe that the previous AMD[1] station had a significantly lower noise level at high frequencies at the time of the 16 August 1997 Kara Sea event as compared with the noise observed at the new AMD[2] station of 24 December 2012. The AMD[1] station was located at a relatively quiet place in an abandoned mine. For frequencies below 3 Hz, the situation is opposite, and the new AMD[2] station shows the lowest noise level. This may be explained by microseisms caused by ocean waves in the open, ice-free Barents and Kara Seas during the Arctic summer.

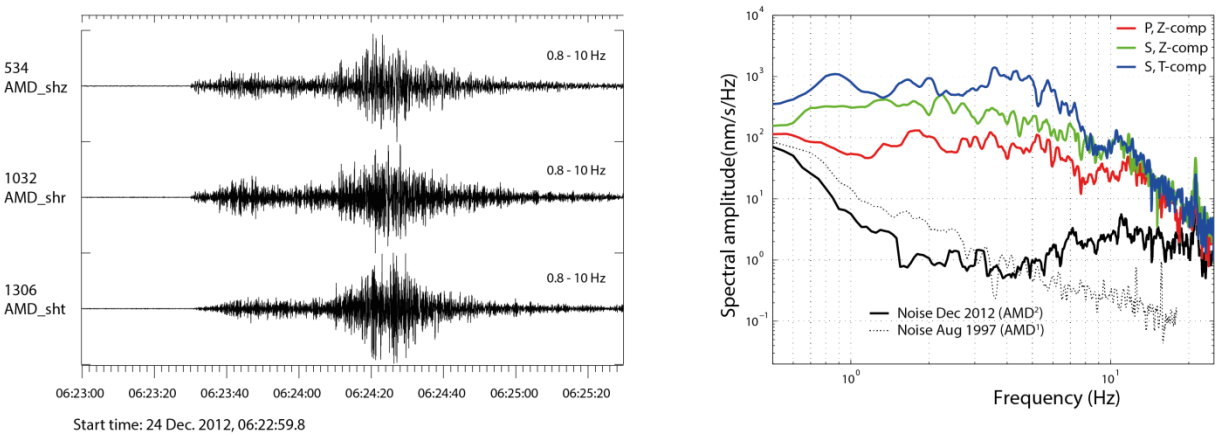

Fig. 6.3.4 The left-hand panel shows recordings at the new AMD[2] station (operated by IEPN UB RAS) of the event on 24 December 2012. The station-event distance is estimated at 347 km. The upper trace shows the vertical component, whereas the two lower traces show the rotated horizontal components (radial and transverse). The data are bandpass filtered between 0.8 and 10 Hz. The right-hand panel shows noise, P- and S-phase ground velocity spectra. The black dotted line shows the noise spectrum preceding the P-phase from 1997 Kara Sea event, observed at the AMD[1] station operated by KRSC.

Fig. 6.3.5 shows waveforms and spectra from the 16 August 1997 event in Kara Sea recorded at the AMD[1] station operated by KRSC. The analysis conducted by Schweitzer and Kennett (2002, 2007) suggested that this was an earthquake located in the middle crust. Different from the 24 December 2012 event, we see a rather impulsive S-arrival at the transverse component, and a larger fraction of the energy at higher frequencies.

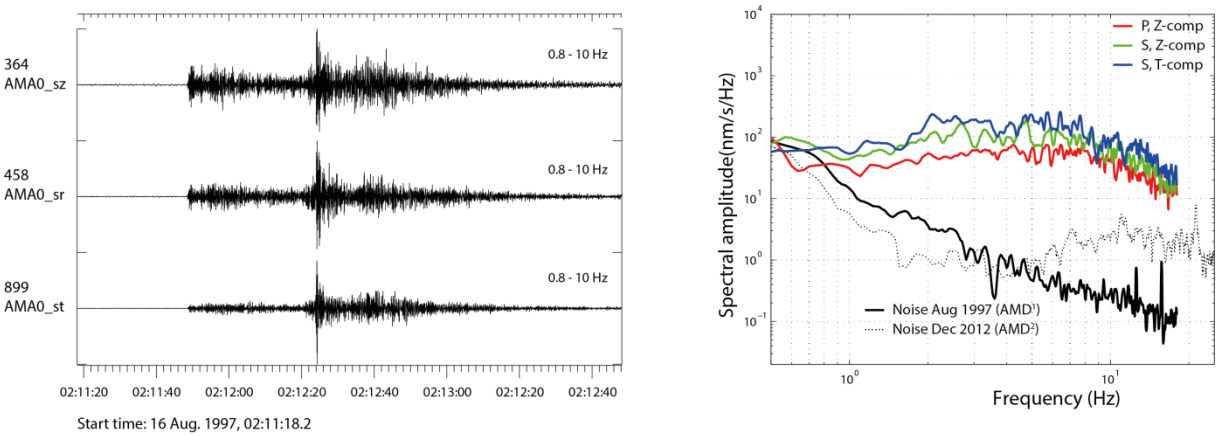

Fig. 6.3.5 The left-hand panel shows recordings at the AMD[1] station (operated by KRSC) of the Kara Sea event on 16 August 1997. The station-event distance is estimated at 334 km. See Fig. 6.3.4 for details. In this case the black dotted line shows the noise spectrum preceding the P-phase from 24 December 2012, observed at the AMD[2] station operated by IEPN UB RAS.

The spectral amplitude of the S-phase, as observed on the transverse horizontal component, is between a factor 3 and 4 larger than for the P-phase, observed on the vertical component, for the wide frequency band 1 – 8 Hz.

Waveforms and spectra from an event located about 275 km to the south of the Amderma station, which occurred on 31 January 1997, are shown in Fig. 6.3.6. Analysis of several years of AMD[1] data conducted by KRSC scientists has shown that the source region where this event occurred is characterized by large mining activity and numerous events, most likely mine blasts, occurring during working hours. The event on 31 January 1997 falls within this category. Different from the events shown in Figs. 6.3.4 and 6.3.5 we observe relatively small differences between the amplitudes of the P- and S-phases, and a relatively strong drop-off of energy at high frequencies. However, the event does not show any significant spectral scalloping which is sometimes associated with ripple-fired mine blasts and underwater explosions. We observe also in this case lower long-period noise levels during the Arctic winter (Jan 1997) as compared with the Arctic summer (Aug 1997), most likely caused by the variability of the strength of the microseisms due to frozen/unfrozen Arctic oceans.

Figs. 6.3.7 and 6.3.8 show ARCES waveforms and velocity spectra for the underwater explosions associated with the Kursk accident in year 2000 and the demolishing of the Kursk wreckage in 2002. The event-station distance is estimated at 463 km (see Table 6.3.2). For both events we observe significant spectral scalloping, and different from the 1997 Kara Sea event observed at AMD[1], there is no dominance of the S-phase energy on the horizontal transverse component.

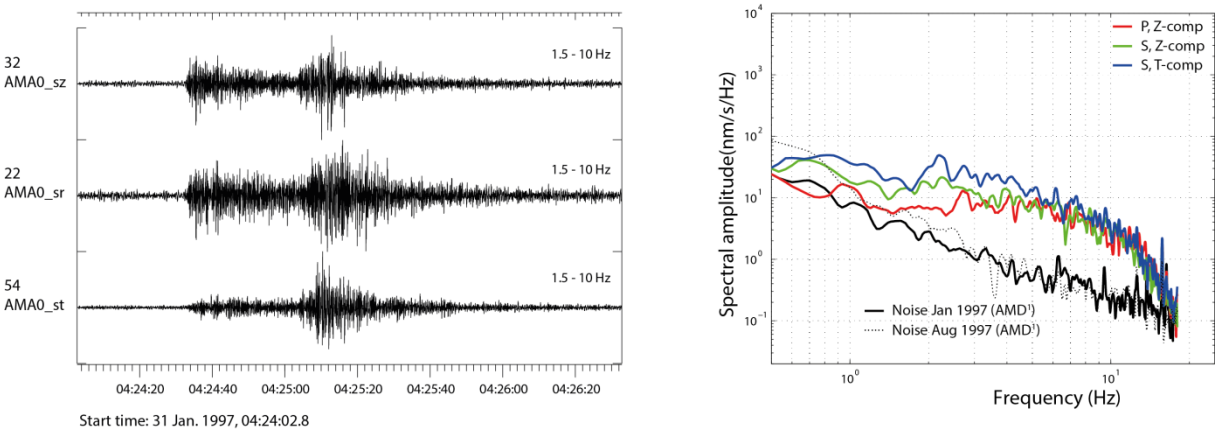

Fig. 6.3.6 The left-hand panel shows recordings at the AMD[1] station (operated by KRSC) of a presumed mine blast in the Vorkuta region on 31 January 1997. The station-event distance is estimated at 275 km. See Fig. 6.3.4 for details. The black dotted line shows the noise spectrum preceding the P-phase from 16 August 1997 Kara Sea event, observed at the same station.

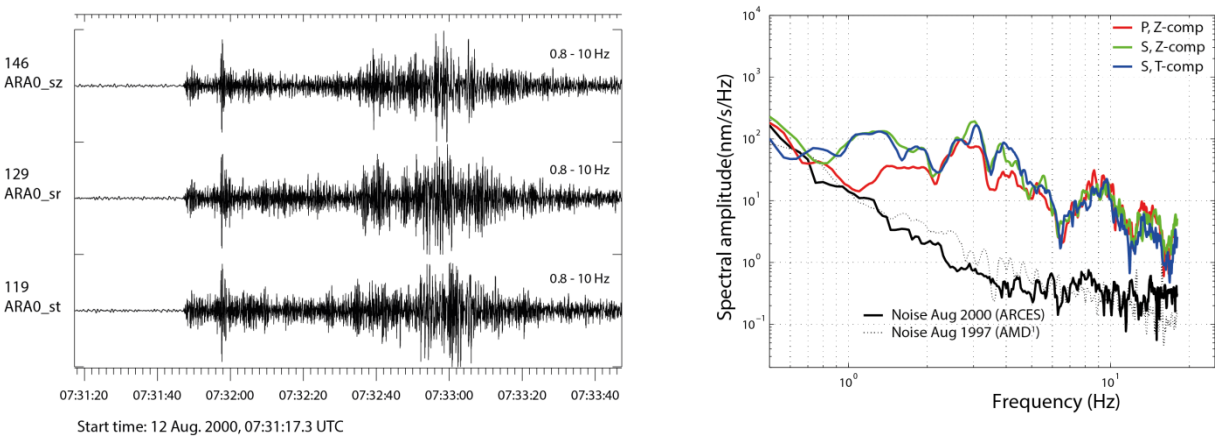

Fig. 6.3.7 The left-hand panel shows recordings at the center element of the ARCES array of the underwater explosion associated with the Kursk accident on 12 August 2000. The station-event distance is estimated at 463 km. See Fig. 6.3.4 for details. The black dotted line shows the noise spectrum preceding the P-phase from 16 August 1997 Kara Sea event, observed at AMD[1], and we notice good correspondence between the ARCES and AMD[1] noise levels.

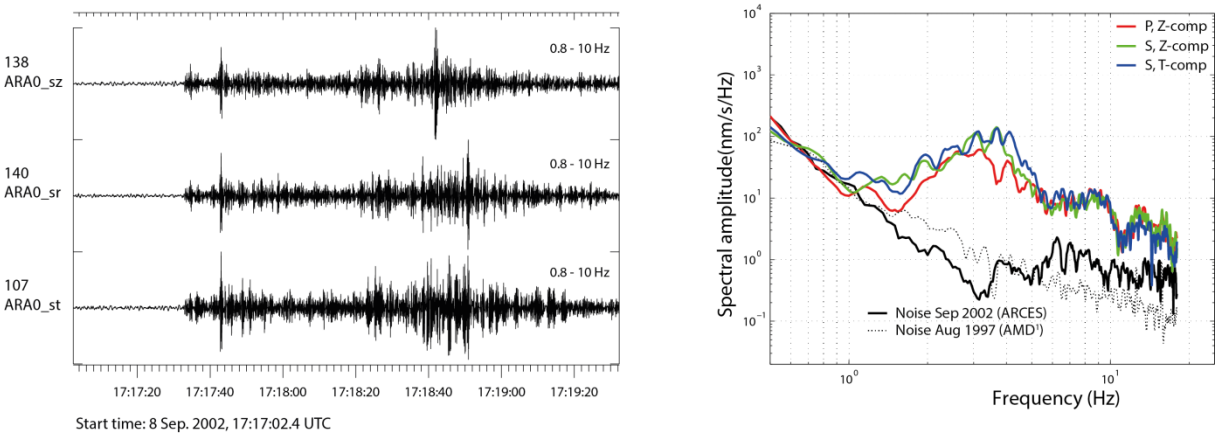

Fig. 6.3.8 The left-hand panel shows recordings at the center element of the ARCES array of the underwater explosion associated with the demolishing of the Kursk wreckage on 9 September 2002. The station-event distance is estimated at 463 km. See Fig. 6.3.4 for details. The black dotted line shows the noise spectrum preceding the P-phase from 16 August 1997 Kara Sea event, observed at AMD[1].

6.3.3 Summary

The new station in Amderma (AMD[2]) operated by the Institute of Ecological Problems of the North, Ural Branch of the Russian Academy of Sciences (IEPN UB RAS, Arkhangelsk, Russia) provided high signal-to-noise ratio recordings of the 24 December 2012 m_b 3.8 event in the north Ural Mountains region. For the time interval investigated (24 December 2012), AMD[2] shows lower background noise levels at frequencies below 3 Hz as compared with the examples shown for the previously operated AMD[1] station (January and August 1997). This may be explained by microseisms caused by ocean waves in the open, ice-free Barents and Kara Seas during the Arctic summer. For frequencies above 3

Hz, higher noise levels are observed for AMD[2], indicating anthropogenic noise sources in the vicinity of the station.

The observation of a very large S/P ratio, the largest S-phases found on the horizontal components, and the long-duration and energetic P- and S-codas suggest that site effects may influence the quality of the observations. Without a detailed study of site effects at the AMD[2] station, it is difficult to derive any firm conclusion regarding the characteristics of the 24 December 2012 event, but the large S/P ratio points in the direction of the event being an earthquake. The event is located in an area with no known mining activity and very low natural seismicity.

Acknowledgements

Data from the former station AMD[1] in Amderma were provided by the Kola Branch of the Geophysical Survey of the Russian Academy of Sciences (KB GS RAS), also denoted the Kola Regional Seismological Centre (KRSC, Apatity, Russia). Data from the new station in AMD[2] in Amderma were provided by the Institute of Ecological Problems of the North, Ural Branch of the Russian Academy of Sciences (IEPN UB RAS, Arkhangelsk, Russia).

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