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Detection of nuclear explosions by remote regional seismic network

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Abstract

Important issues to monitor nuclear testing are the detection, identification and estimation of nuclear explosion yield. In this study a possibility of detection from point view of nuclear explosions identifying among tectonic earthquakes, using remote, regional *Baltic Virtual Seismic Network* (BAVSEN) from the East Baltic region was verified. Studies have shown that the most effective parameter for these purposes is Ms/Mb magnitude ratio.

Methods and materials

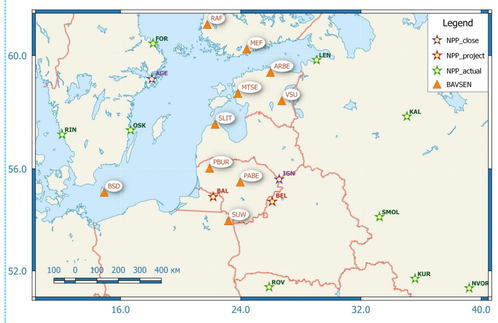

Fig. 1. Baltic Virtual Seismic Network and Nuclear Power Plants in the Baltic area

BAVSEN is part of the GEOFON network (Fig. 1) with center at GFZ Potsdam. It combines 10 seismic broadband stations from Finland, Estonia, Latvia, Lithuania, Poland and Denmark. BAVSEN network has been operational since 2008. BAVSEN seismic network is about 7.0 thousand km away from nuclear explosions epicenters in North Korea and at distance of 6.5 – 9.0 thousand km from tectonic earthquakes hypocenters in Japan and adjacent territory.

BAVSEN network recorded 5 nuclear explosions in North Korea. Only three nuclear explosions were used for analysis. The following parameters were used to identify nuclear explosions: 1) amplitude spectra of P and S waves group; 2) P/S spectral ratios; 3) Ms/Mb magnitude ratio. The first two parameters are based on well-known property of S-wave amplitude exceeding over P-wave amplitude for earthquakes and inverse amplitude ratio for explosions. The parameters of nuclear explosions were compared with tectonic earthquakes of Japan and adjacent territory.

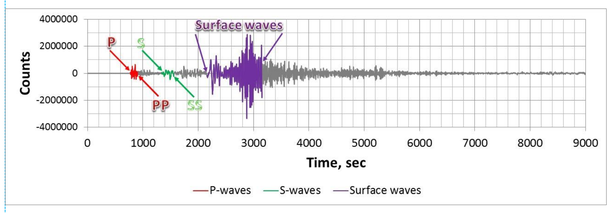

Fig. 2. An example of sampling of seismic waves

Two types of seismic waves (P and S) were used in this study for amplitude spectrums and spectral ratios. Two types seismic waves were used also for estimation of magnitude ratio's: body waves (P-wave) and surface waves (Rayleigh wave's (*Airy* phase ?) T ~ 20 sec). The data used by BAVSEN: 19 values of Ms/Mb magnitude ratios for explosions and only 3 values – for nuclear explosions. Range of earthquakes magnitudes: Ms: 5.7 - 9.0, and Mb: 5.1 - 7.6. Range of explosions magnitudes: Ms: 4.7 - 5.8, and Mb: 5.9 - 6.7. Results of Ms/Mb magnitude ratios by BAVSEN data were compared with similar values of the Aswan seismic network (ASN) data (Kebeasy et al., 1998). 67 values of Ms/Mb magnitude ratios were used according to ASN. Range of earthquakes magnitudes: Ms: 4.1 - 6.9, and Mb: 4.5 - 6.3. The range of explosions magnitudes: Ms: 3.4 - 5.8, and Mb: 5.2 - 6.4. An example of seismic waves sampling is showed Fig. 2.

Results

There is no noticeable difference in amplitude spectra of P and S waves for tectonic earthquakes and nuclear explosions in North Korea. There are almost no differences in P/S spectral ratios for tectonic earthquakes and nuclear explosions in North Korea. The maximum values of spectral ratios are in frequency range of 1 - 2 (3) Hz. The maximum values of spectral ratios vary widely, depending on stations at which these were determined. Width of spectral ratios of Korean nuclear explosions is slightly less than width of spectral ratios for earthquakes (Fig. 4).

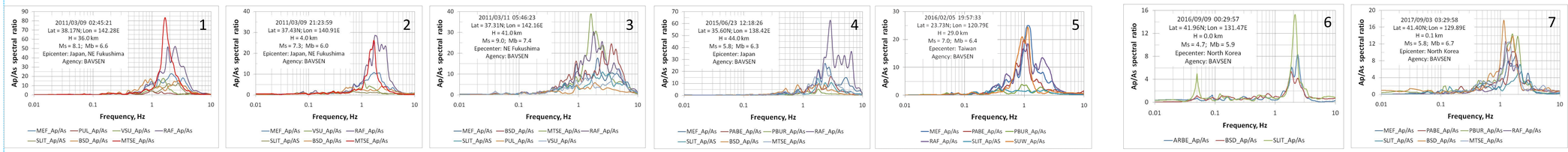

Fig. 4. P/S spectral ratios for tectonic earthquakes (NE Fukushima(1-3), Japan (4), Taiwan(5)) and North Korean nuclear explosions (6, 7)

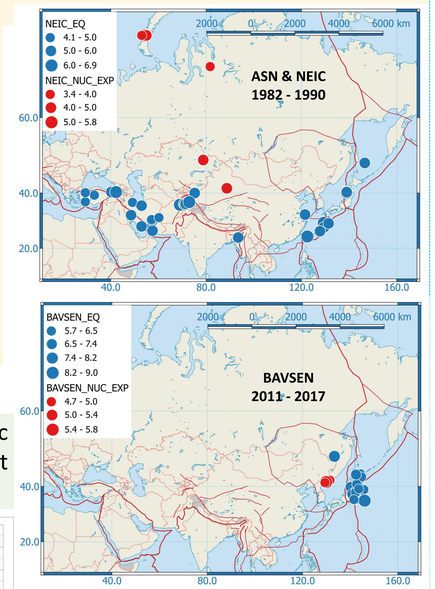

Fig. 3. Earthquakes and nuclear explosions in Korea according to ASN & NEIC and BAVSEN for estimation of relation between Ms and Mb magnitudes

The most effective discriminator for distinguishing explosions from earthquakes is Mb/Ms magnitude ratio . In Fig. 5 shows a comparison of results of BAVSEN seismic network and Aswan seismic network (Kebeasy et al., 1998). Epicenters of earthquakes and nuclear explosions are shown in Fig. 3. In case of the Aswan seismic network, earthquakes were used, epicenters of which are located in Asian large area and nuclear explosions in USSR and China. In case BAVSEN used earthquakes, epicenters of which are located mainly in Japan and near it, and nuclear explosions in North Korea.

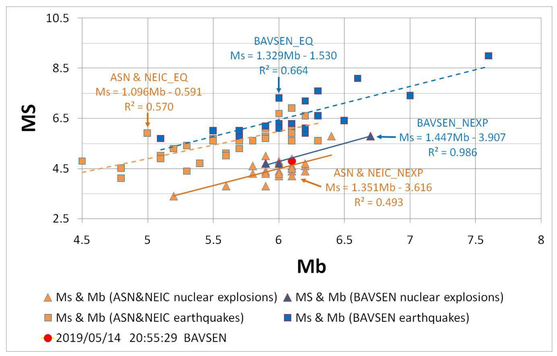

Fig. 5. Correlation between Ms and Mb magnitudes for earthquakes and nuclear explosions

Kebeasy R.M., Amin I.H., Dahy S.A., 1998. Discrimination between natural earthquakes and nuclear explosions using the Aswan Seismic Network. Annali di Geofisica, vol. 42, N 2, 127 – 140.

An example of Ms/Mb ratio of magnitudes ((4.8/6.1)<1) for seismic event of May 14, 2019 (20:55:29), analyzed by BAVSEN data (Fig. 6) and considered as an earthquake is shown in Fig. 5 as red circle. This event get in range of Ms/Mb values typical of North Korean nuclear explosions. In according with analysis results of RRR bulletin data from the JPP38 and the JPX38, presence of Cs-137 was noted within the statistical range (category 3, level 3 – as Typical Anthropogenic). But geographically radionuclide trace is located significantly south of epicenter of the seismic event of May 14, 2019. Such events make sense to carefully analyze.

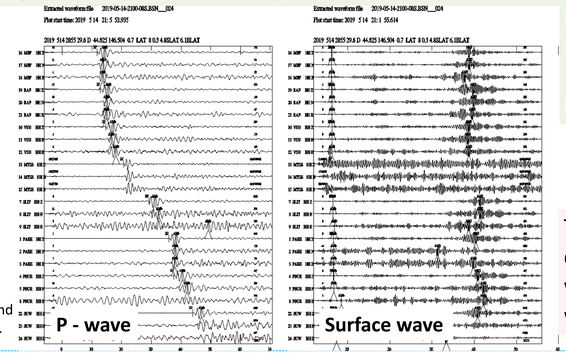

Fig. 6. Seismic event May 14, 2019 P-wave and surface waves

Conclusions and Recommendations

Thus, the Ms/Mb magnitude ratio can to consider as a discriminator for separating earthquakes from nuclear explosions at large distances. The capacity to detection and identify nuclear explosions by means of BAVSEN network would increase in association with IDC products and IMS data. It is advisable to regularly determine the discriminator Ms/Mb for distant seismic events from world's different regions.