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Variations in the Ratio of Horizontal to Vertical Components (H/V) for the Stations of the NOTSI Network Studied During the Different Seasons

Emil Oynakov* and Irena Aleksandrova

National Institute of Geophysics, Geodesy and Geography-Bulgarian Academy of Sciences, Bulgaria

Abstract

An assessment and analysis of the amplitude-frequency composition of the background microseismic noise and the possible seasonal variations for 11 seismic stations from the network of the National Operating Telemetry System for Seismological Information (NOTSI) are presented. The paper uses the method of the spectral ratio of the horizontal to the vertical component of the microseismic noise (H/V method of Nakamura). Three-component continuous 24-hour seismic records from the 11 seismic stations were used as input. H/V ratio curves were obtained for the four seasons (winter, spring, summer and autumn), characterizing the amplitude-frequency composition of the microseismic fluctuations in the frequency range from 0.5 to 20 Hz. The obtained curves of the H/V ratio are conditionally divided into two groups - stable; and curves with weak seasonal variations. The first group includes the seismic stations VTS1, PSN, PRD, PLD, MMB and KDZ, which have stable amplitude-frequency characteristics of the microseismic signal regardless of the season. In general, the curves of the first group are easy to interpret and represent smooth curves slightly complicated by extremums of relatively small amplitude. The second group includes stations for which the obtained curves of the spectral H/V ratio have significant seasonal variations: KKB, PGB, PLN, SZK, TRAN. The obtained H/V ratio curves have relatively larger changes compared to the first group. The comparison of the location of the seismic stations with the obtained H/V curves shows the dependence of the amplitude-frequency characteristics of the microseismic signal on the local conditions.

Introduction

Researchers of the consequences of strong and catastrophic earthquakes prove that the surface sedimentary layer can significantly increase the amplitudes of surface seismic waves, which can cause further destruction [1,2]. Determining the influence of the geological environment on seismic waves, in this sense, is an important component of the micro-zoning of areas with moderate and high seismic activity.

The most commonly used method of a wide range of developed methods [3-6] for estimating the amplitude-frequency characteristics of the surface layer is the method of H/V spectral relations (Nakamura method).

The aim of the present study is to assess and analyze the amplitude-frequency composition of microseismic oscillations and their possible seasonal variations in the territory of the seismic network NOTSSI (National Operating Telemetry System for Seismological Information (Figure 1)) with the method of spectral relations (H/V).

Method

To estimate the amplitude-frequency composition of the microseismic signal and the possible seasonal variations according to the data from the seismic stations, the method of the spectral relations of the vertical and horizontal components of the microseismic oscillations (H/V Nakamura) was applied. This technique was first proposed by Nogoshi M. and later popularized by Nakamura Y. [7]. The method is effectively used both for determining the fundamental frequencies and for determining the corresponding oscillation amplification. The spectra of microseismic fluctuations and H/V ratios were calculated using the Geopsy program (http://www.geopsy.org/). To avoid accidental errors caused by near and far earthquakes, explosions and man-made noise, time intervals of 24 hours are selected. For these time intervals, several hundred to fifteen hundred time windows (60 s long) were selected in order to avoid accidental noises in the analyzed records. The resulting H/V ratio curves and the corresponding values of the standard deviations were obtained by averaging the individual H/V ratios for all windows. The standard deviations of the H/V curves are calculated from the arithmetic mean of the logarithms of all individual H/V curves for all windows.

Data

24-hour seismic records from five different days for each season were analyzed as follows: winter - from 13 to 17.01.2018; spring - from 13 to 17.04.2018; summer - from 13 to 17.07.2018 and autumn - from 13 to 17.10.2018. Each of the 24 hour records is divided into 60 second windows (from 100 to 1500 windows), out of which are selecting the windows with the lowest level of seismic noise. The H/V spectral ratio curves for each season were obtained after averaging the average curves for each of the 5 days of the given season.

Results

As a result, the H/V curves characterizing the amplitude-frequency composition of the microseismic noise (Figure 2a) were obtained for

*Corresponding Author: Dr. Emil Oynakov, National Institute of Geophysics, Geodesy and Geography-Bulgarian Academy of Sciences, Bulgaria; E-mail: emil.ilievmg@gmail.com
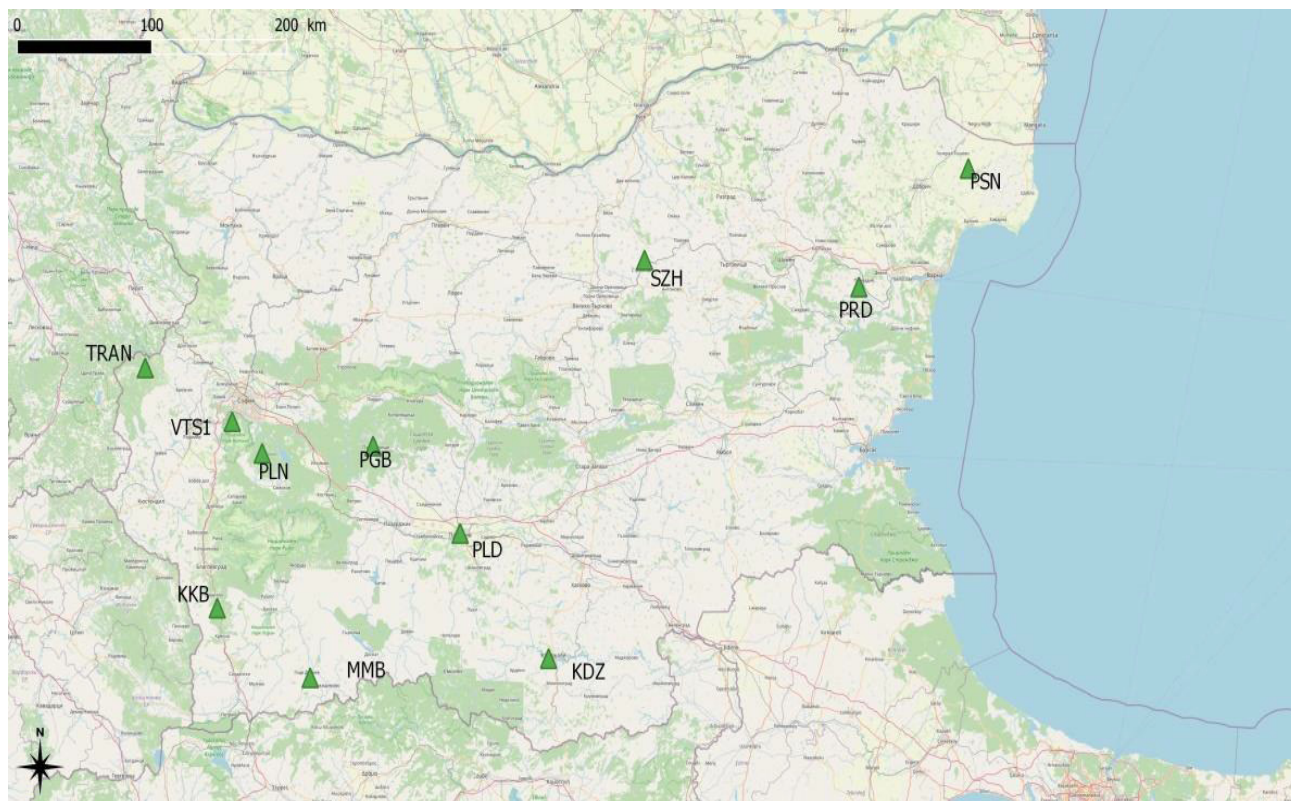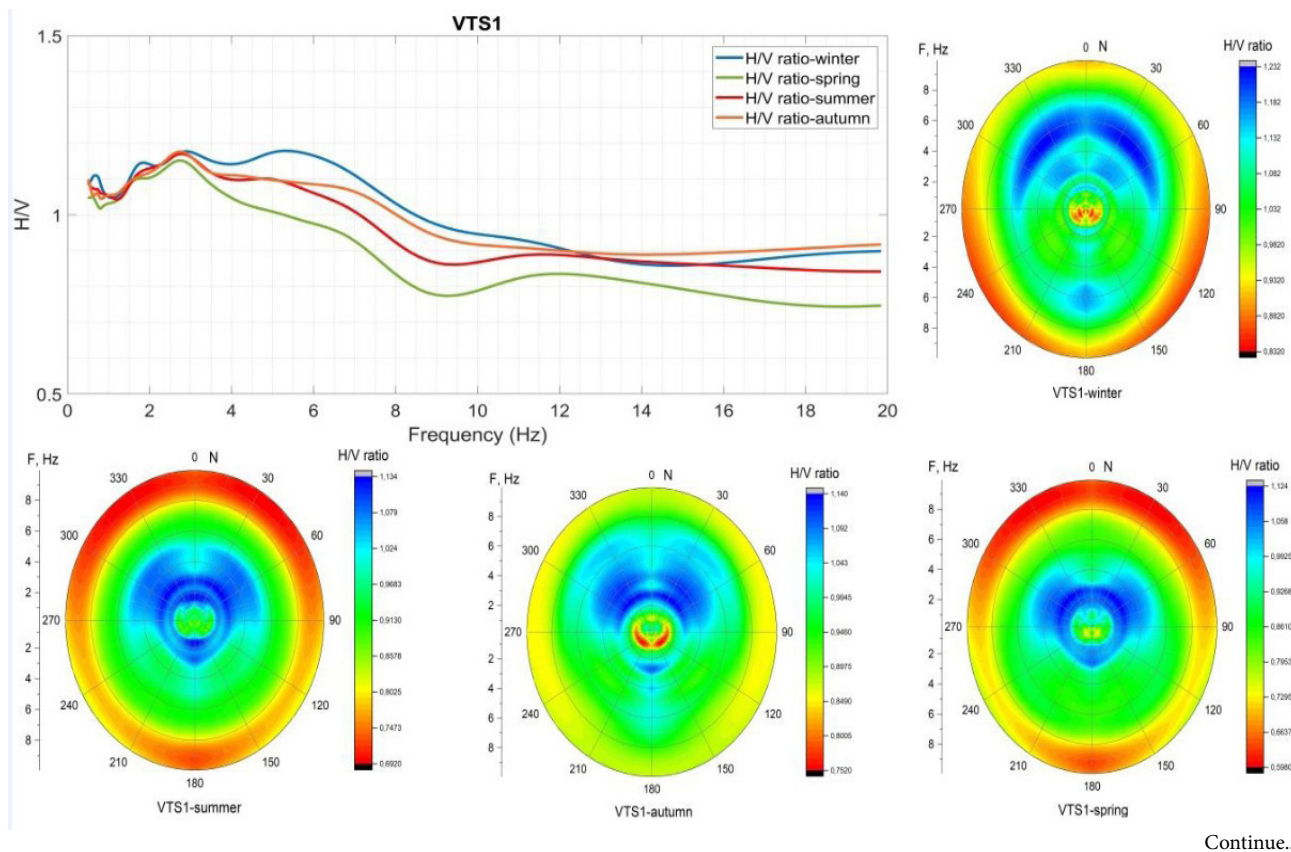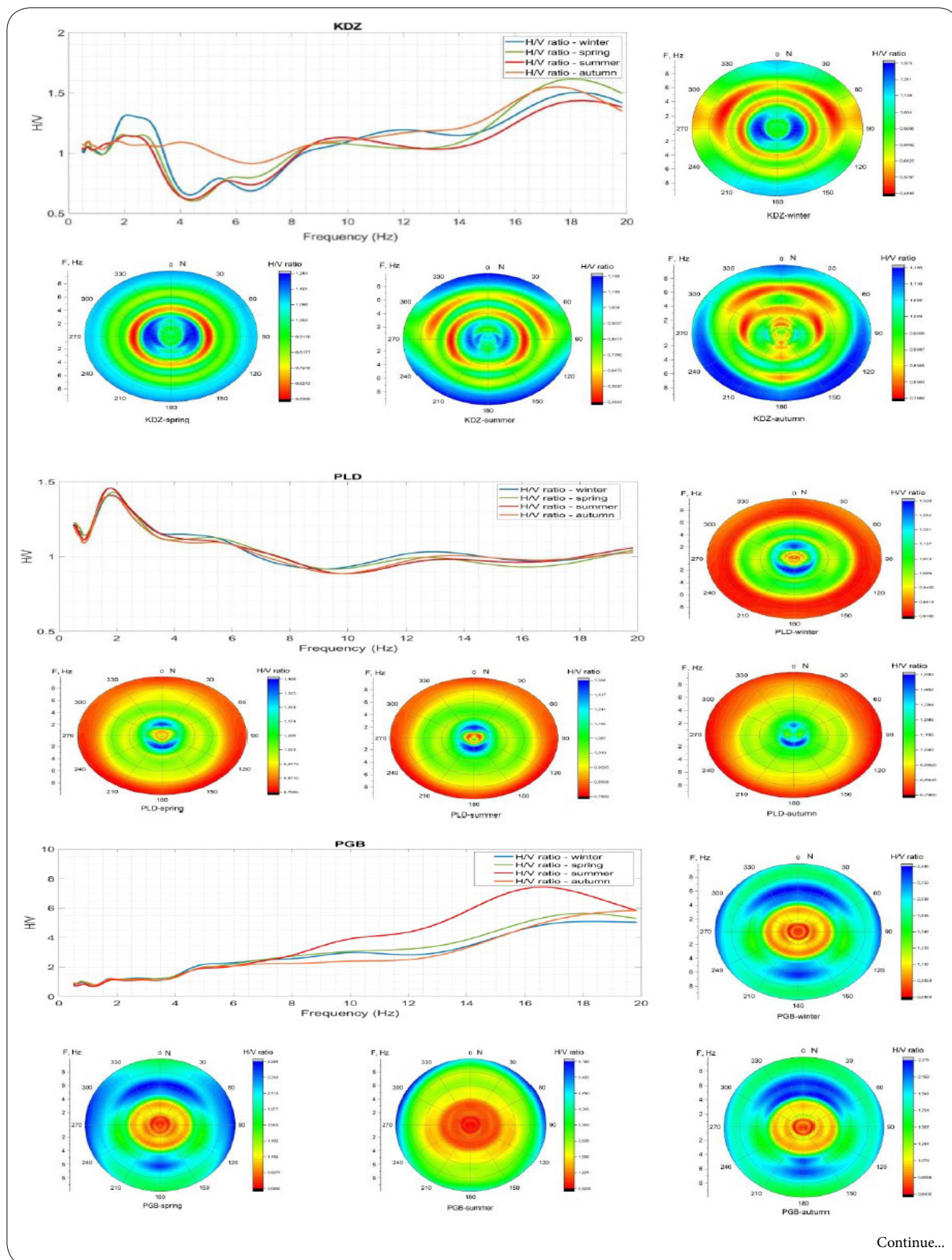
Figure 1: Location of the analyzed seismic stations (▲) from the NOTSSI network.

MMB-winter
MMB-spring
MMB-summer
MMB-autumn
KKB-winter
KKB-spring
KKB-spring
KKB-autumn
PSN-winter
PSN-spring
PSN-summer
PSN-autumn
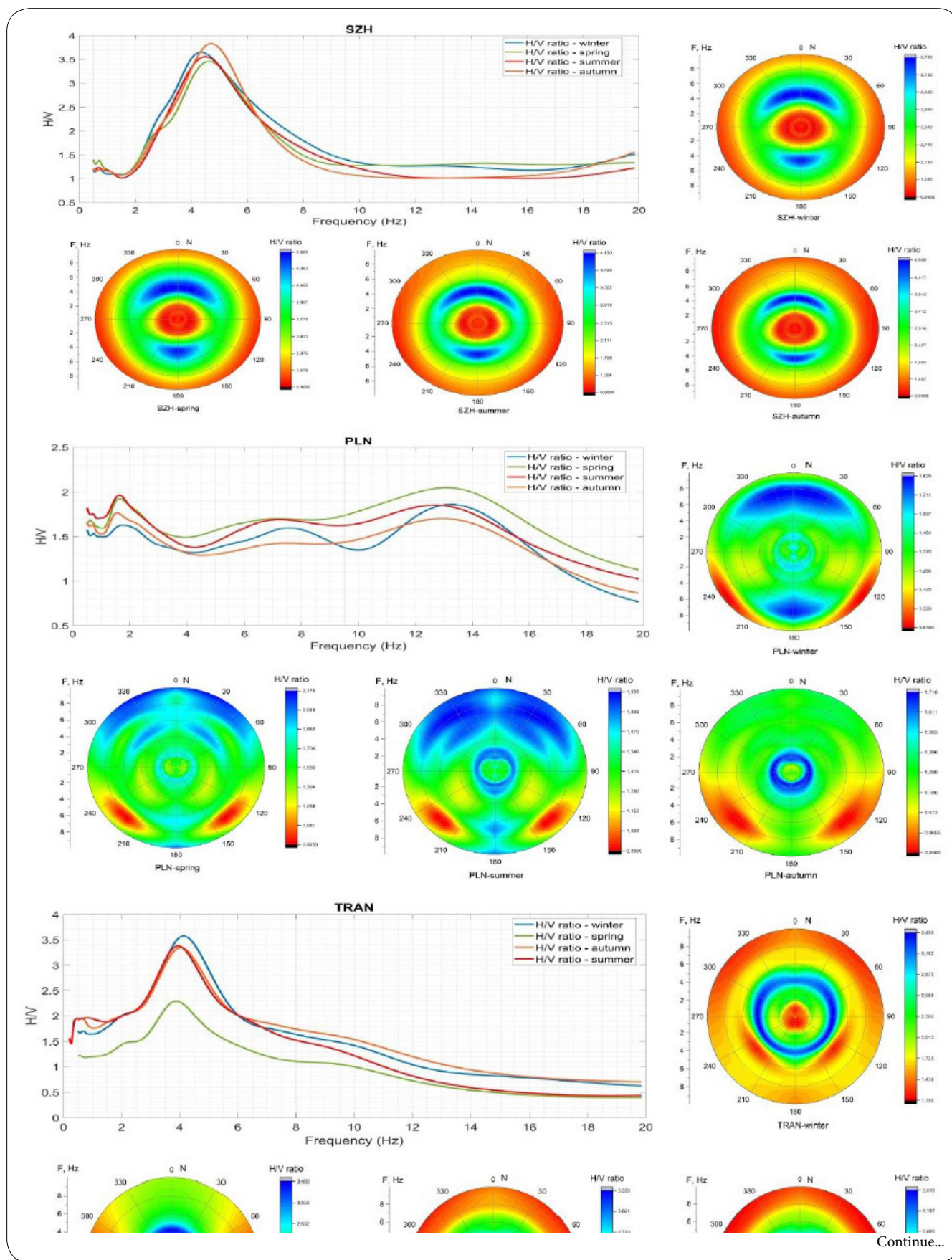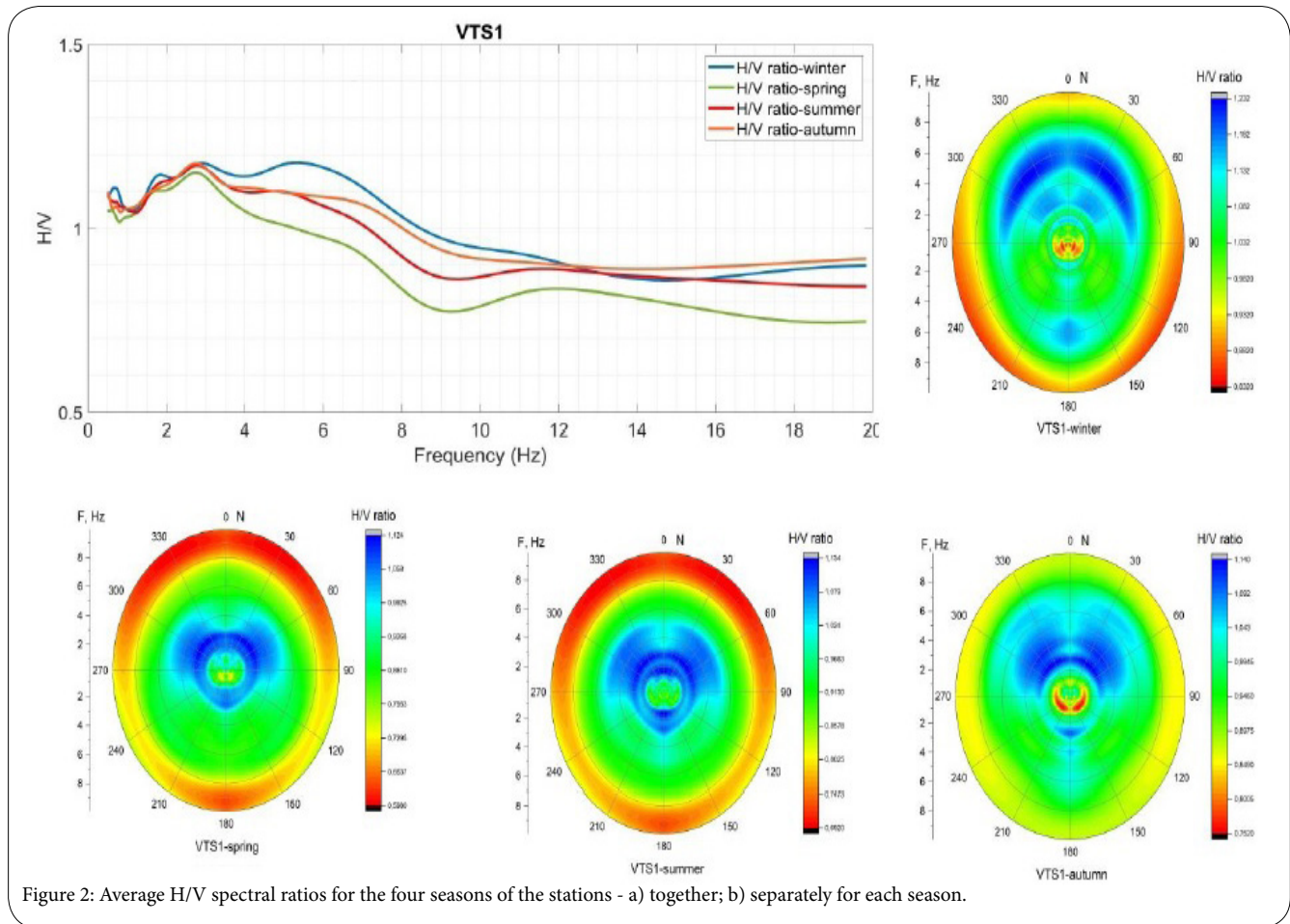
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Figure 2: Average H/V spectral ratios for the four seasons of the stations - a) together; b) separately for each season.

11 seismic stations from the NOTSSI network, for each season (Figure 2b). Taking into account the peculiarities of the recording equipment, the spectral characteristics in the frequency range from 0.5 to 20 Hz have been reliably determined. The criteria developed in the SESAME project were used to verification the reliability of the obtained results (https://www.uni-potsdam.de/sesam/index.php):

1. $f_0 > \dfrac{10}{l_w}$;

2. $n_c(f_0) > 200$;

3. $\sigma_A(f) < 2$ for $0.5 f_0 < f < 2 f_0$, if $f_0 > 0.5 Hz$

where f_0 - frequency of the amplitude peak of H/V; l_W - length of the time window; $n_c = l_w n_w f_0$; n_W - number of windows for the average curve of H/V; $\sigma_A(f)$ - standard deviation of the amplitude $A_{H/V}(f)$; f - current frequency.

According to the type of the obtained curves of the spectral H/V ratio, the studied seismic stations can be divided into two groups. The first group may include the seismic stations VTS1, PSN, PRD, PLD, MMB and KDZ, which have stable amplitude-frequency characteristics of the microseismic signal regardless of the season. In general, the curves of the first group are easy to interpret and represent smooth curves slightly complicated by extremums of relatively small amplitude. For some of the stations (MMB, PRD, VTS1) relatively wide smooth extremes of medium and low (KDZ, PLD) frequencies are observed.

The second group includes stations for which the obtained curves of the spectral H/V ratio have significant seasonal variations: KKB, PGB, PLN, SZK, TRAN. The nature of the seasonal variations for the different stations differs considerably. For a PGB station for the 8-17 Hz frequency range, the H/V curves for the spring and at most for the summer period significantly exceed the levels of the curves for the winter and autumn periods.

In Figure 3 and Figure 4 presents the values of resonant frequency (f_0) and amplification factor ($A_0(f_0)$) for each season.

Conclusion

The level of the curves for the spring, summer and autumn period significantly exceeds the level of the curve for the winter period at frequencies from 0.2 to 8 Hz for the KKB station. For the PLN station, the spring curve exceeds the levels for the other seasons for almost the entire frequency range. The H/V curve for the spring period is significantly lower than the levels for the winter, summer and autumn periods.

The analysis of the spectral H/V ratio for the stations of the second group shows an increase in the amplitudes of the horizontal oscillations relative to the vertical ones in the summer period. This increase may be related to the change in the wave composition of microseisms depending on seasonal and technogenic conditions. In general, the overall increase in the amplitudes of the H/V spectral
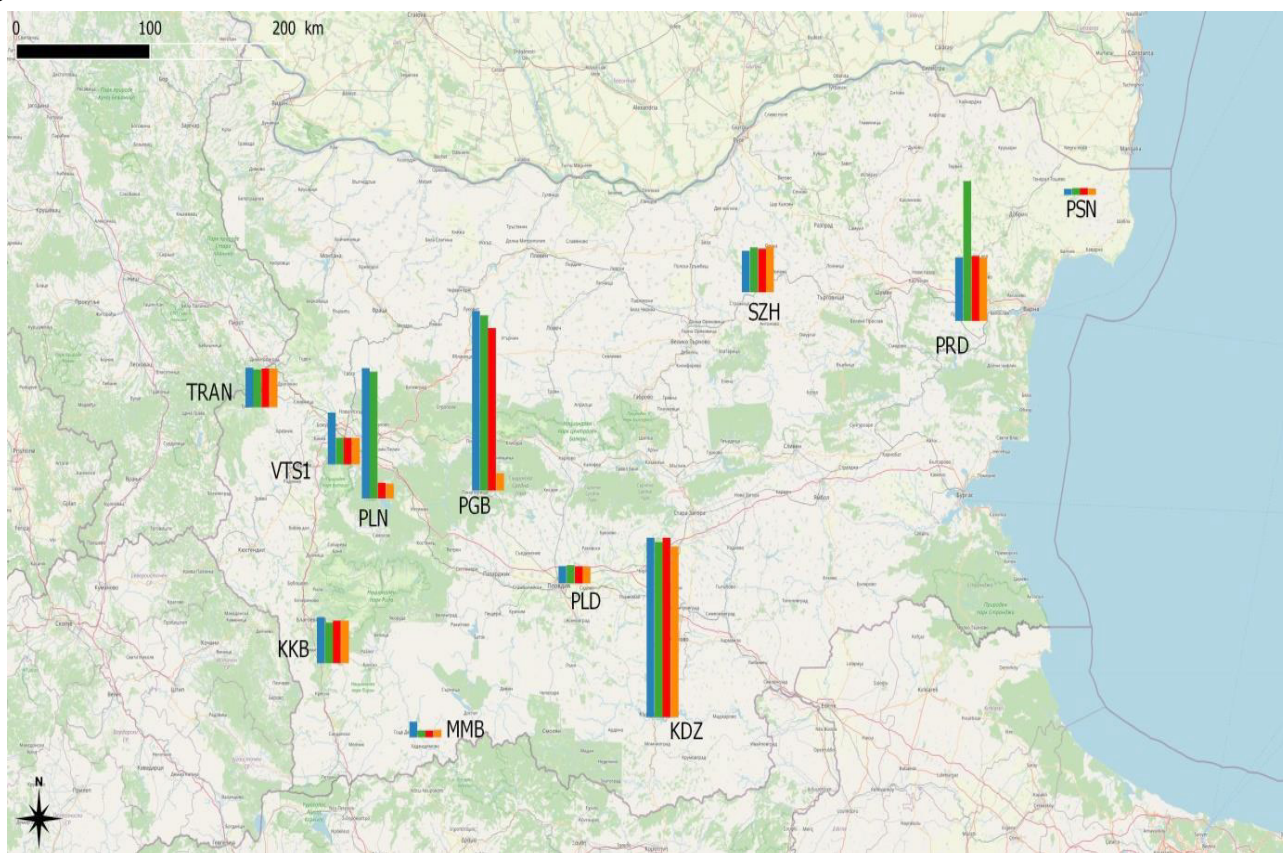
Figure 3: Resonant frequency (f_0) for each season (- winter; - spring; -summer; - autumn)

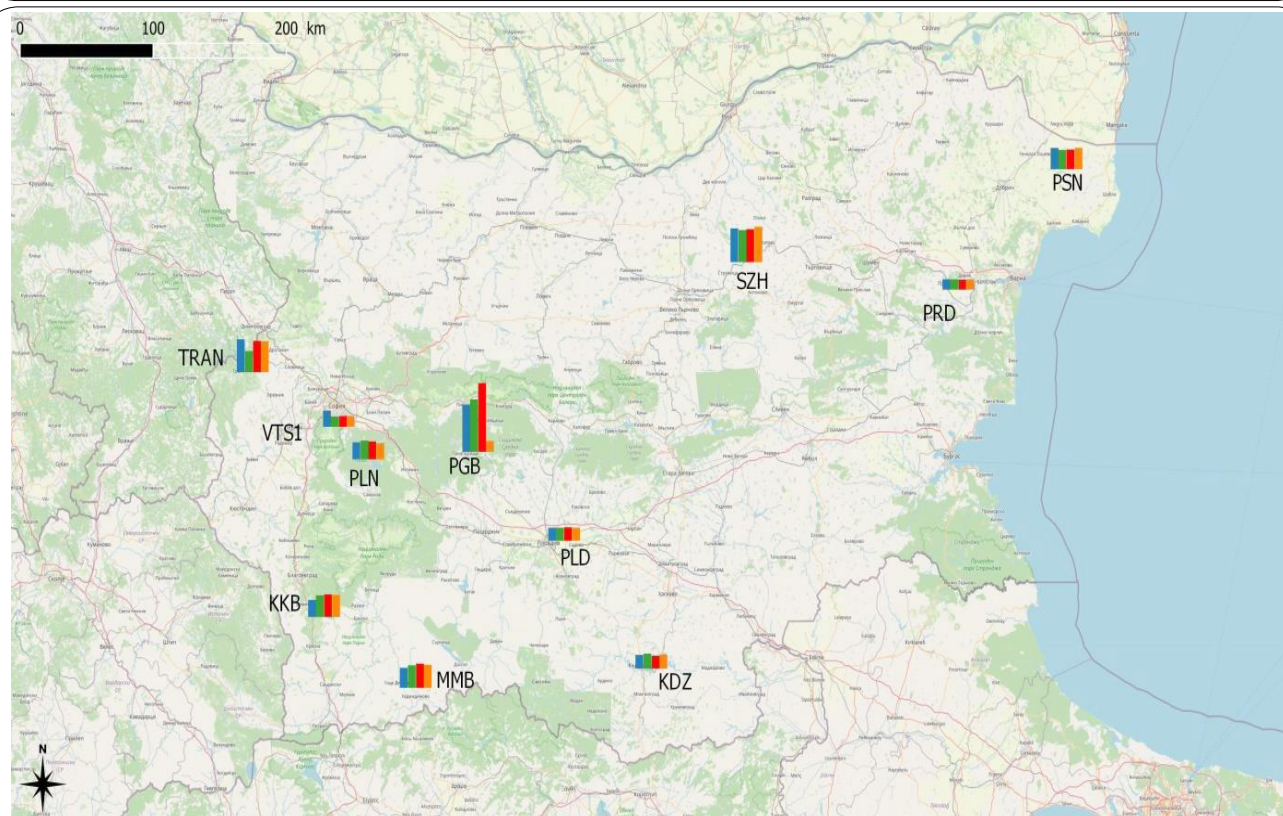Figure 4: Amplification factor A_0 (f_0) for each season (- winter; - spring; -summer; - autumn)

Station code	f_0				$A_0(f_0)$				Correlation coefficients					
	winter	spring	summer	autumn	winter	spring	summer	autumn	winter spring	winter autumn	winter summer	spring summer	summer autumn	spring autumnн
VTS1	5.36	2.75	2.75	2.75	1.78	1.15	1.17	1,18	0.86	0.96	0.94	0.98	0.98	0.94
KDZ	18.43	17.98	18.43	17.54	1.50	1.61	1.43	1.55	0.91	0.67	0.92	0.96	0.66	0.76
PLD	1.81	1.90	1.76	1.76	1.41	1,43	1.46	1.41	0.99	0.99	0.99	0.99	0.99	0.99
PGB	18.43	17.98	16.69	1.81	5.07	5.64	7.42	1.20	0.97	0.98	0.97	0.98	0.95	0.98
MMB	1.64	0.74	0.73	0.76	2.16	2.42	2.60	2.47	0.86	0.90	0.84	0.99	0.89	0.91
KKB	4.74	4.19	4.40	4.40	1.86	2.34	2.43	2.38	0.71	0.69	0.78	0.97	0.98	0.98
PSN	0.67	0.73	0.73	0.71	2.30	2.09	2.14	2.32	0.99	0.99	0.99	0.99	0.99	0.99
SZH	4.29	4.62	4.51	4.74	3.64	3.46	3.56	3.83	0.98	0.98	0.99	0.99	0.99	0.99
PLN	13.37	13.04	1.64	1.56	1.86	2.05	1.96	1.76	0.88	0.86	0.87	0.84	0.97	0.81
TRAN	4.09	3.89	3.99	3.99	3.57	2.29	3.38	3.34	0.98	0.99	0.96	0.98	0.98	0.99
PRD	6.53	14.39	6.69	6.53	1.14	1.13	1.10	1.16	0.96	0.99	0.97	0.97	0.98	0.96

Table1: Estimates of f_0 and $A_0(f_0)$ of the analyzed seismic stations for the different seasons and correlation coefficients between the obtained H/V spectral ratios between the different seasons.

ratio during the spring and summer periods can be explained by the melting of snow and most precipitation compared to other periods [8].

Table 1 presents the calculated resonant frequencies f_0 and the amplitudes of the H/V spectral ratio of these frequencies $A_0(f_0)$ for the individual seasons, as well as the correlation coefficients of the H/V ratio between the different seasons.

Competing Interests

The authors declare that they have no competing interests.

Acknowledgements

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