Institute of Cosmophysical Research and Radio Wave Propagation FEB RAS
Acoustic Research Laboratory

Analysis of geoacoustic emission and electromagnetic radiation signals accompanying earthquake with magnitude M_w = 7.5

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Observation area and earthquake

Geoacoustic pulses and sferics (electrical component) were analyzed during
seismically calm period on **22.03.2020**
seismically active period on **25.03.2020**

- Petropavlovsk-Kamchatskiy
- “Karymshina” site
- Earthquake*

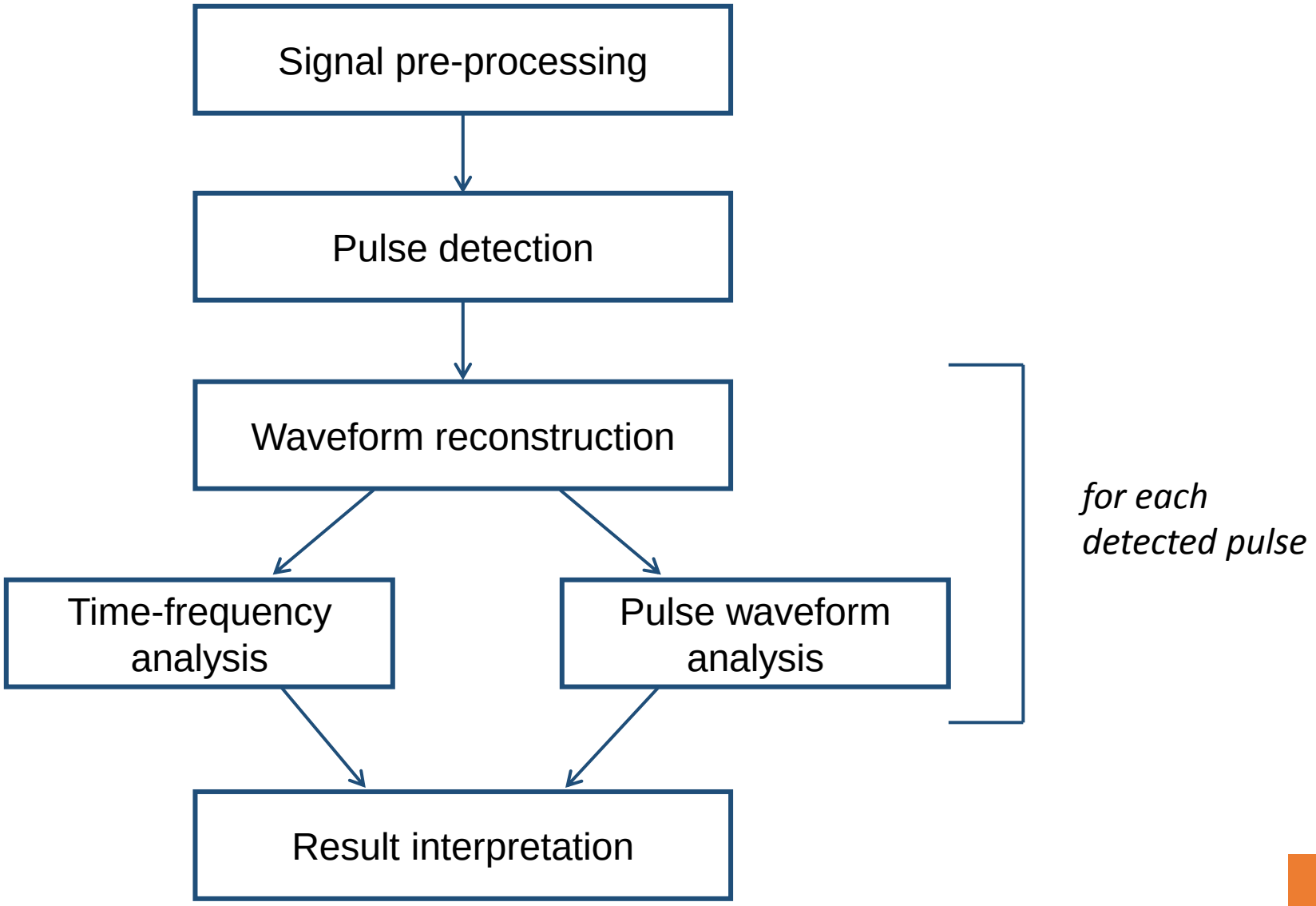
25.03.2020 02:49:21 UTC

48.964° N, 157.696° E

M_w = 7.5, H = 57.8 km, R = 430 km

*NEIC, https://earthquake.usgs.gov/earthquake

Analysis stages



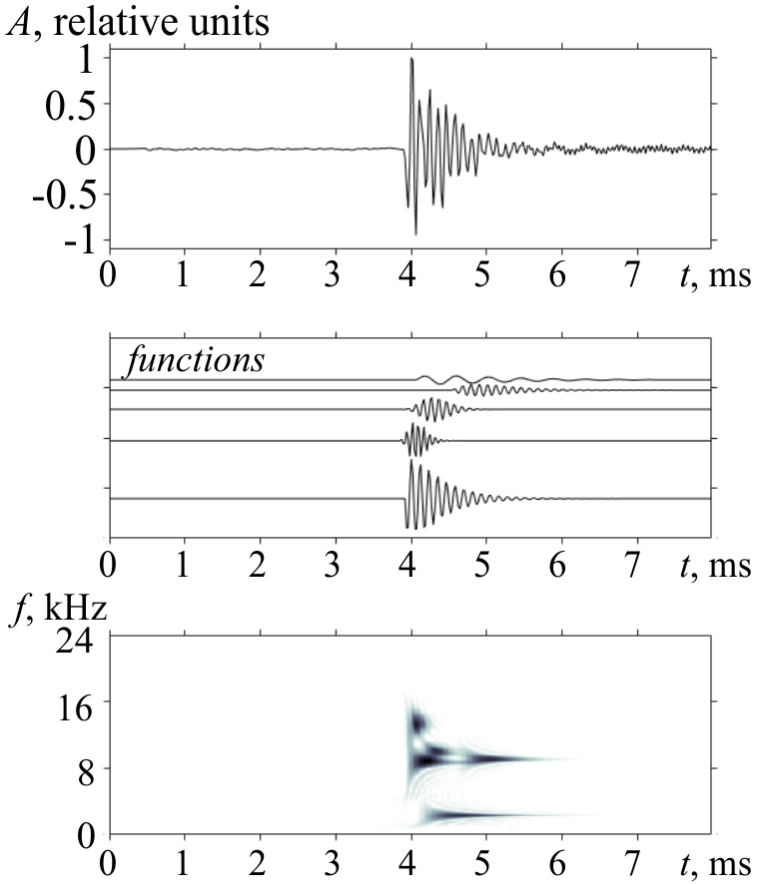
Time-frequency analysis

Adaptive Matching Pursuit *

$$\begin{cases} s(t) = \sum_{m=0}^{N-1} a_m g_m(t) + R_N, \\ \|R_N\| \to min, \\ \|a\|_0 \le \varepsilon. \end{cases}$$

procedure for setting the parameters
\+ ***of the basis function g_m that has***
the greatest correlation with the signal

$s(t)$ is the signal;
$g_m(t)$ are the basis functions;
a_m are the coefficients of decomposition;
N is the size of basis function dictionary;
R_N is the residual;
$\|\cdot\|_0$ is the pseudo-norm (L_0-norm);
ε is the L_0-norm limit.



Geoacoustic pulse sparse approximation

* O. Lukovenkova, Yu. Marapulets, A. Tristanov, A. Kim, Modernization of adaptive matching pursuit method to analyze geophysical signals of pulse nature, E3S Web of Conf., **62**, 02012 (2018)

Waveform analysis

Structural description method *

Descriptive matrix

$$\mathbf{D} = \begin{pmatrix} r_{0,1} & r_{0,2} & \cdots & r_{0,N-1} & r_{0,N} \\ \omega_{0,1} & r_{1,2} & \cdots & r_{1,N-1} & r_{1,N} \\ \omega_{0,2} & \omega_{1,2} & \cdots & r_{2,N-1} & r_{2,N} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ \omega_{0,N-2} & \omega_{1,N-2} & \cdots & r_{N-2,N-1} & r_{N-2,N} \\ \omega_{0,N-1} & \omega_{1,N-1} & \cdots & \omega_{N-2,N-1} & r_{N-1,N} \end{pmatrix}$$

$$r_{i,j} = \begin{cases} 1, & a_i > a_j \\ 0, & a_i \le a_j \end{cases}, \qquad \omega_{i,j} = \begin{cases} 1, & \tau_i > \tau_j \\ 0, & \tau_i \le \tau_j \end{cases},$$

$r_{i,j}$ is the result of comparison of the i-th and j-th extreme amplitudes;

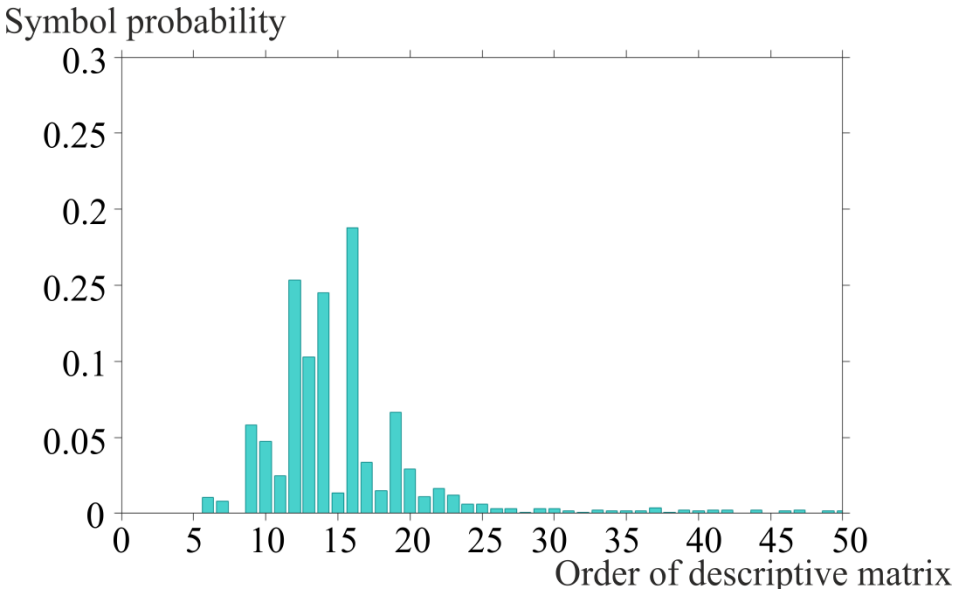
$\omega_{i,j}$ is the result of comparison of the i-th and j-th intervals between the extrema

Pulse classification

The pulses with descriptive matrices that coincide by more than 80% belong to the same class.

Each class is **a symbol**.

A set of symbols forms **a signal alphabet**.



Histogram of signal alphabet

* M.I. Gapeev, Yu.I. Senkevich, O.O. Lukovenkova, A.A. Solodchuk, System approach to identification of geopulses, J. Phys.: Conf. Ser., **1368**, 052034 (2019)

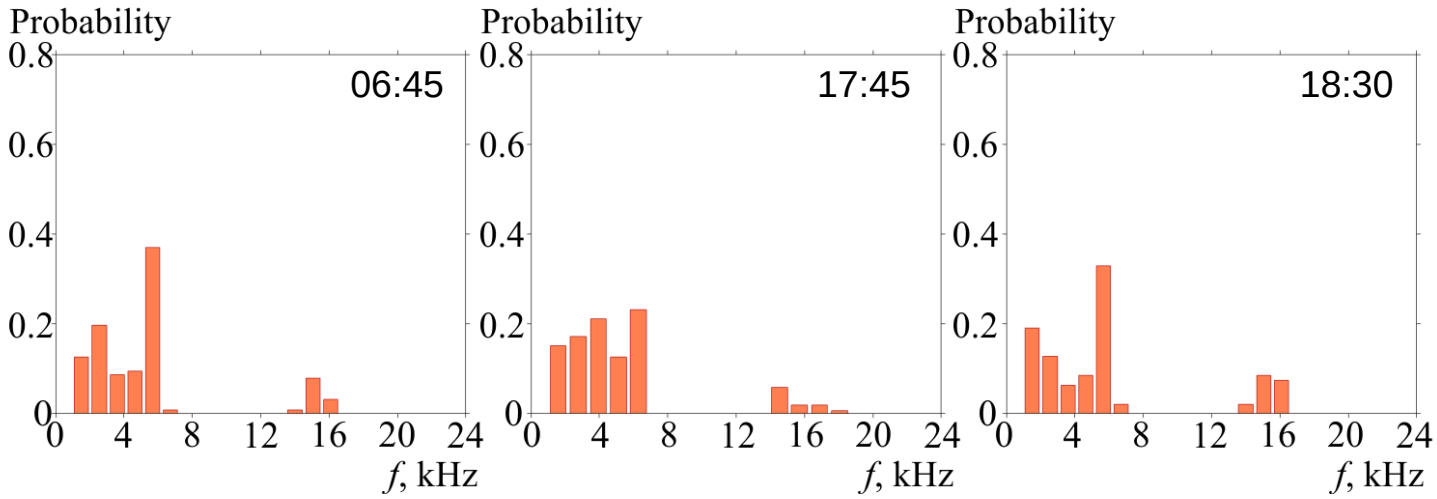
Geoacoustic pulses analysis

Characteristic	Seismically calm period, March 22, 2020	Seismically active period, March 25, 2020
Number of processed records	16	5
Total number of detected pulses	3665	3050
Average number of pulses per 15 minutes	229.06	610
Average maximum pulse amplitude, relative units	0.0146	0.0206
Average pulse duration, ms	5.98	7.47

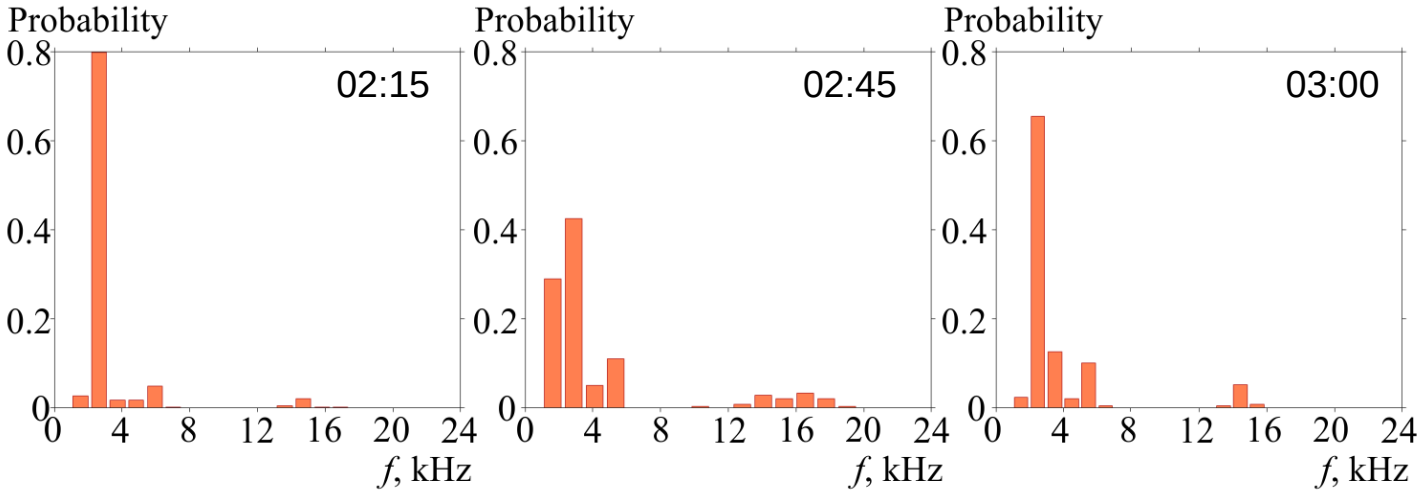
Characteristics of geoacoustic signals

Geoacoustic pulses analysis

March, 22, 2020



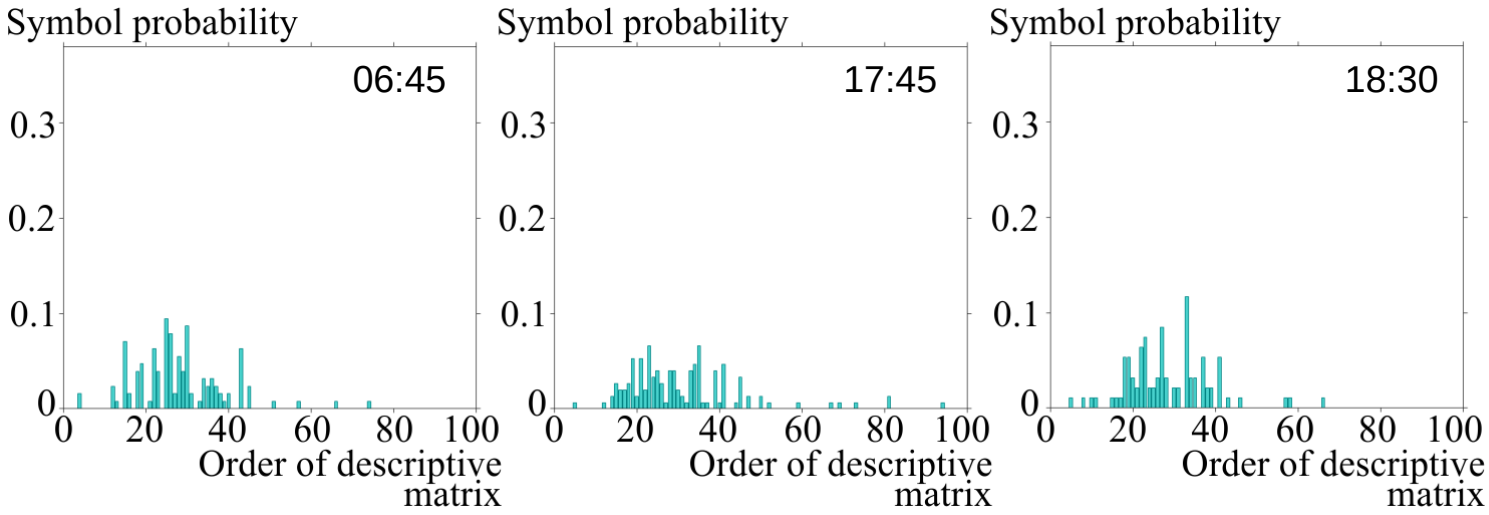
March, 25, 2020



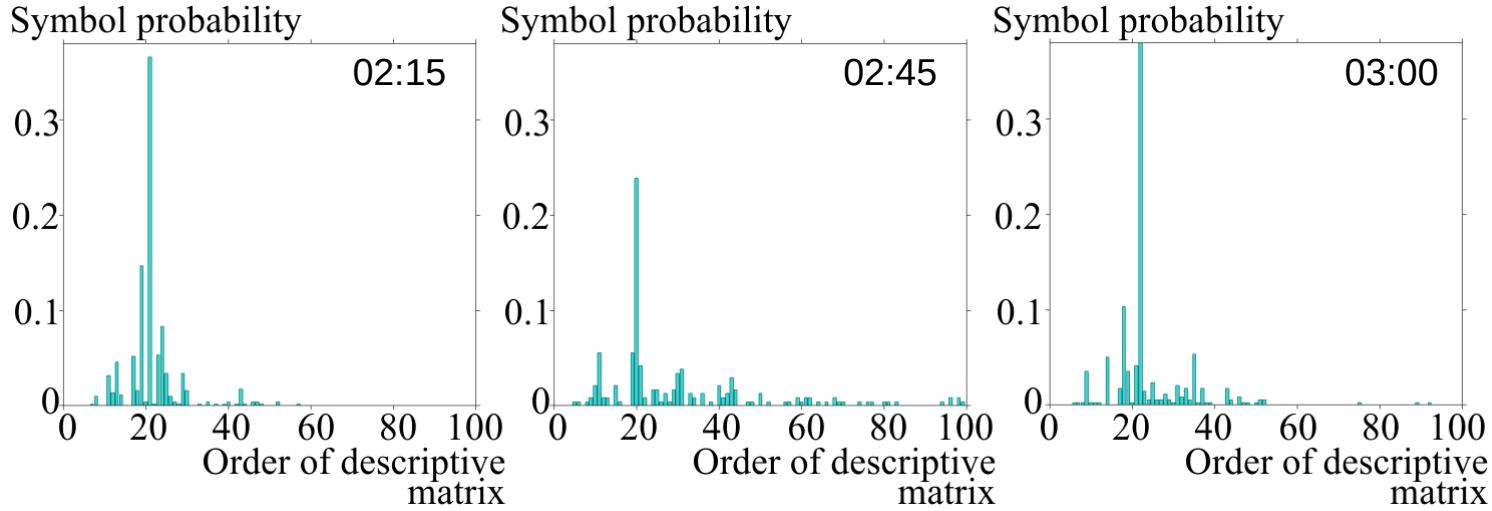
Frequency histograms of first decomposition function for geoacoustic signals

Geoacoustic pulses analysis

March, 22, 2020



March, 25, 2020



Alphabets of geoacoustic signals

Sferics analysis

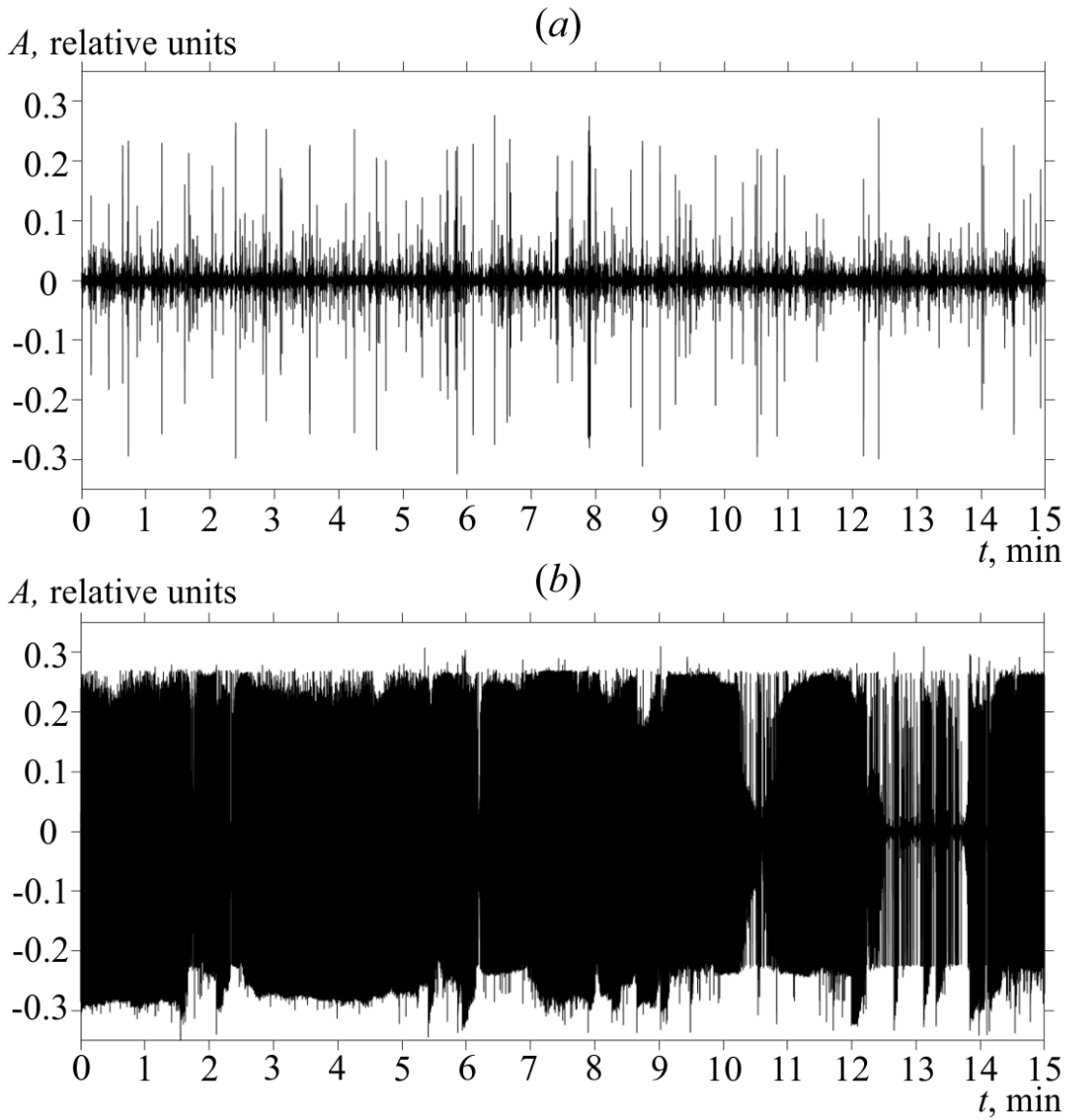
Characteristic	Seismically calm period, March 22, 2020	Seismically active period, March 25, 2020
Number of processed records	17	5
Total number of detected pulses	27436	12074
Average number of pulses per 15 minutes	1613.88	2414.8
Average maximum pulse amplitude, relative units	0.064	0.1503
Average pulse duration, ms	2.9	8.24

Characteristics of sferics

Sferics analysis

March, 22, 2020 06:09

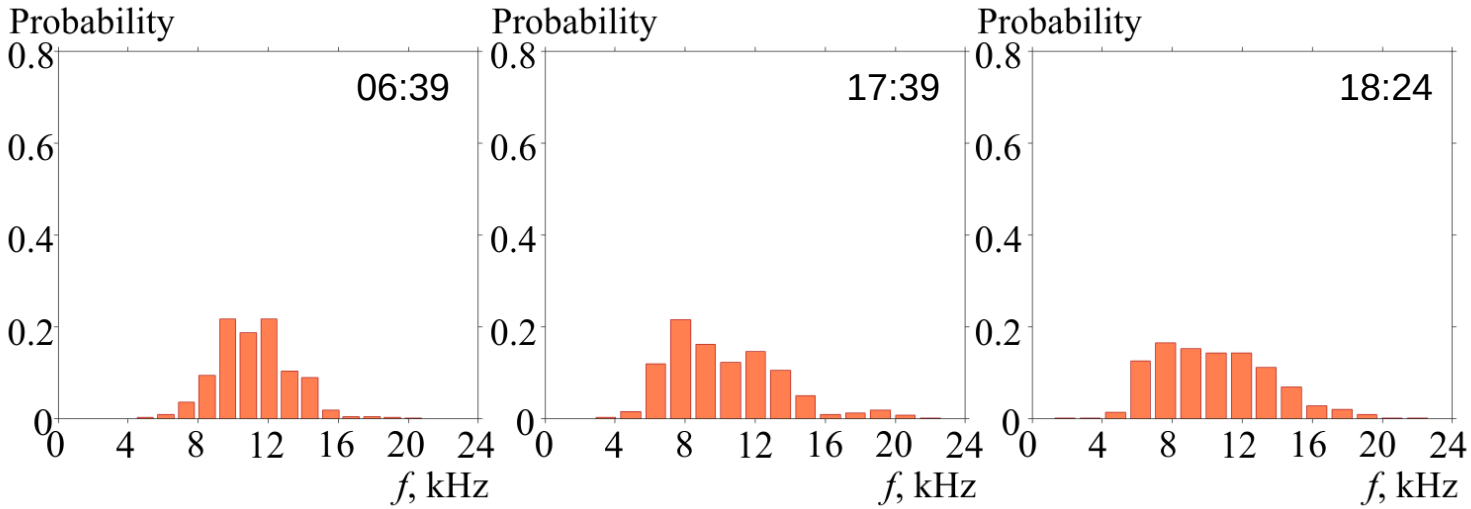
March, 25, 2020 02:24



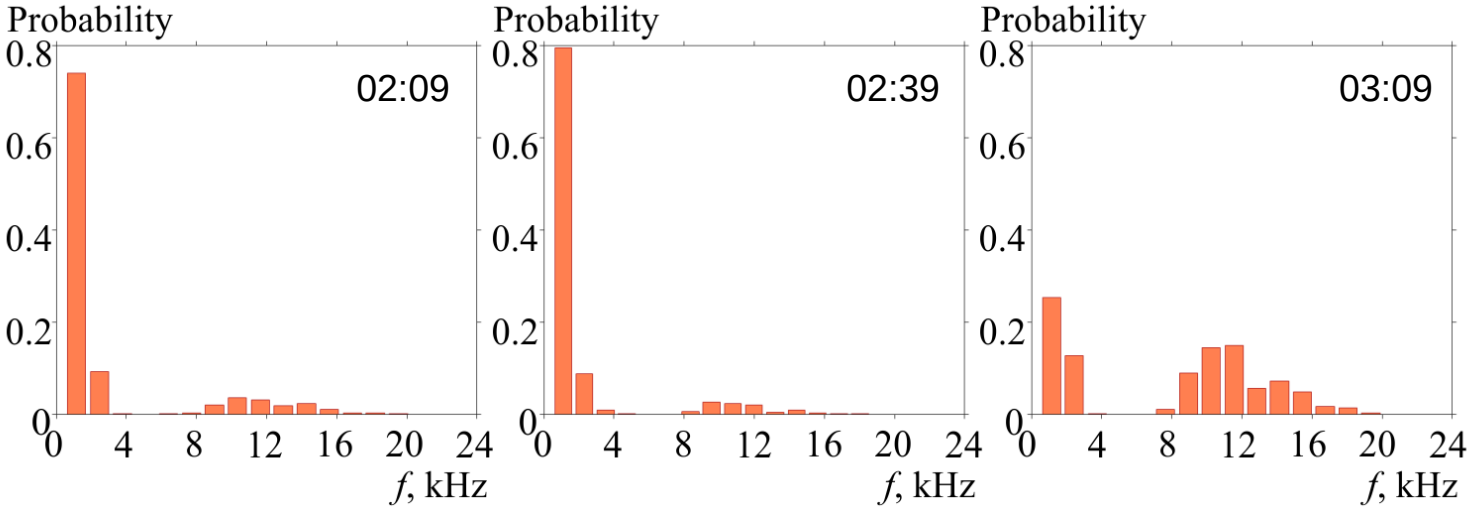
Electromagnetic signals

Sferics analysis

March, 22, 2020



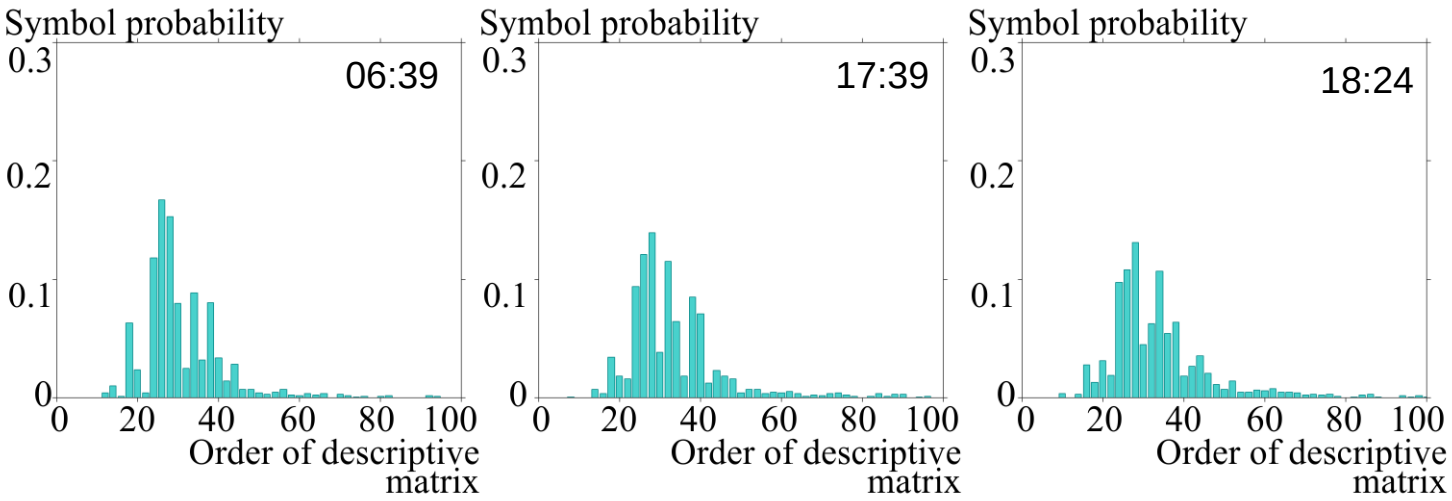
March, 25, 2020



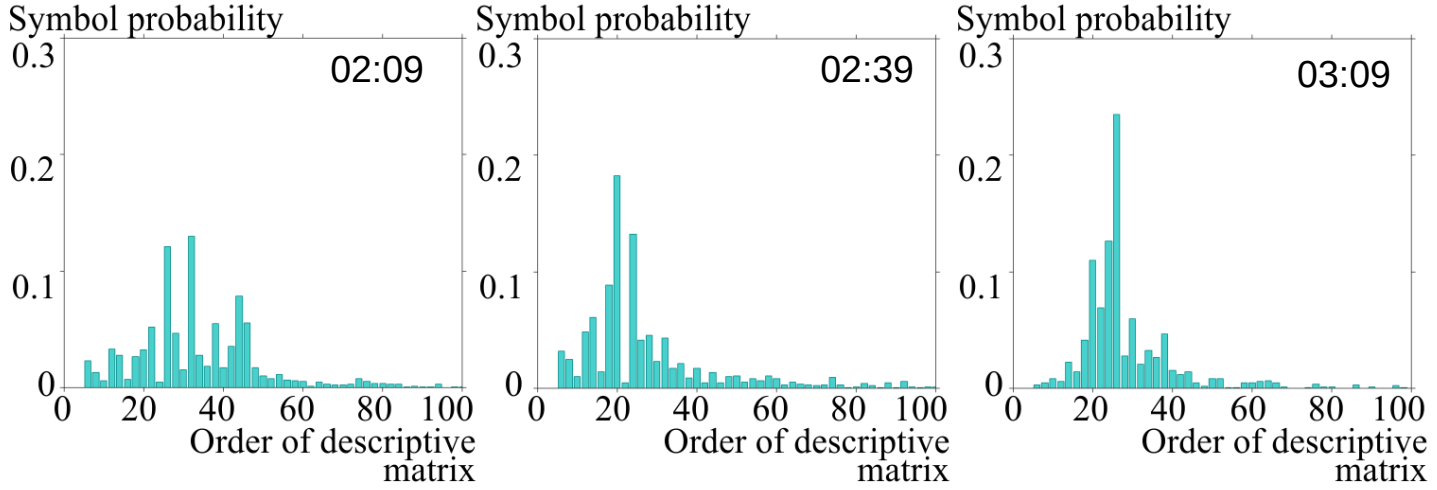
Frequency histograms of first decomposition function for electromagnetic signals

Sferics analysis

March, 22, 2020



March, 25, 2020



Frequency histograms of first decomposition function for electromagnetic signals

Results

It was found that frequency spectra and waveforms of the pulses accompanying the earthquake and pulses registered in the background period differ:

- ✓ The frequencies below 3 kHz are present in spectra of many geoacoustic pulses recorded during the time interval ±30 minutes near the earthquake. More than 20% of the pulses have a similar waveform.
- ✓ Sferics with frequencies below the critical frequency of the Earth–ionosphere waveguide appear in the pre- and post-seismic electromagnetic signals. These sferics are encoded by symbols with descriptive matrices of small orders.

Acknowledgment

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