# Spectral characteristics of the seismic signals used for ADAP (Automatic Detection of Ash Plume) program

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One of the main tasks of the Kamchatka Branch of Geophysical Servey (KBGS) RAS is informing the Russian Ministry for Emergency Situations and the people of Kamchatka region about natural hazards by the basic types of geophysical control systems data in real time. The speed of informing depends from the introduction of automatic signals detection programs, which accompanying such dangerous phenomena as earthquakes, tsunamis, and volcanic eruptions into the surveillance practice. The second task is find a decision of problem from hazard of ash emissions and the interference of ash clouds with aviation communications routes.

The Kamchatka peninsula weather conditions are difficult and do not allows watch for volcanoes by video and satellite data most part of the time. In addition, satellite monitoring cover the entire surface of the Earth, but it has discrete feature and available only with a delay from 30 minutes to a few hours, so they cannot give an information in real time. Video observations ~~is~~ are available in real time, but they has ~~are~~ significant limits: 1) it is possible only in good weather conditions; 2) it is difficult for observers to continuously look into display, and the ash emissions detection programs for video frames does not exist yet.

Since 2000, the Research Laboratory of Seismic and Volcanic Activity (RLSVA) of KBGS collected a large amount of video, photo and visual data of ash emission from Kamchatka active volcanoes and seismic signals accompanying these events.

As a result of study in 2003, an empirical method of ash emission detection and estimation their height (for the example for Shiveluch volcano) was proposed. Time-spectral analysis widely used in that method, which detected the relative increase of the dominant frequency from 1 Hz to 2ï 4 Hz at the beginning of ash emission signal. It allowed to separate such signals from the other accompanying volcanic events. Since 2003, the proposed method has been widely used in real time regime, and often it was the single and the quickest way to estimate the height of the ash plume.

Since 2012, we developed a new method for the detection of ash emissions and calculating their height based on seismic signals. The criterion for the detection of ash emissions is the frequency index that equal to the decimal logarithm of the ratio of the high frequency band of the seismic signal spectrum to the low frequency band. Ash emission detected, when the frequency index falls into a certain numerical range. Comparison video data and calculating data of the height of the ash plume led us to creation of an empirical formula that depends on the frequency index. It has allowed us to develop an algorithm for an automatic program.

Frequency index from seismic signals of ash emissions very similar to the frequency index calculated for tectonic earthquakes. Time intervals with the tectonic earthquakes were removed from the analysis for prevention çfalse alarmsè.

The program calculations gave much less results on height in comparison to observing ash plums in few cases weak seismicity.

The study of this phenomenon gave the following results: 1) spectral analysis of the seismic signal has shown that a characteristic feature of such eruptions is an insignificant increase of amplitudes in the range 0.125 - 0.375 Hz; 2) height of the ash plume is calculate by the empirical formula multiplied by constant ñ3ò for this eruptions. The insignificant amplitudes increasing in the range 0.125 - 0.375 Hz is a criterion for recognizing such eruptions by automatic program.

The upgraded ADAP program shown that the explosive eruptions mainly consist of a different combinations of seismic events with an amplitudes increasing in the range 0.125 - 0.375 Hz and signals with the insignificant increases. The total height of the ash column is the sum of the heights such events.

ADAP (Automatic Detection of Ash Plume) software intended for automatic detection of the seismic signals accompanying ash emission from active volcanoes is designed and introduced in Research Laboratory of Seismic and Volcanic Activity (RLSVA) of KBGS. This software also calculates the height of the ash plume in real time and automatically sends information about detected hazardous ash emissions by e-mail and SMS to duty scientists. It works with seismic signals in real-time from the most active Kamchatka volcanoes (Shiveluch, Klyuchevskoy, Bezymianny, Kizimen, Karymsky and Gorely). The reliability of the program is estimated at 70%.