P2.2-086

Presence of an acoustic signal on seismograms after a man-made event

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INTRODUCTION AND MAIN RESULTS

Powerful quarry explosions generate infrasonic acoustic waves detectable on seismic sensors. These waves appear on seismograms with speeds 0.27–0.33 km/s, slightly below the speed of sound. When the azimuth matches the explosion and the acoustic phase follows the seismic event, it confirms the source is an explosion.

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Introduction

This poster presents a comprehensive seismological analysis of acoustic waves generated by anthropogenic explosions . The study identifies these signals on regional seismograms, estimates their propagation velocities, evaluates the influence of atmospheric conditions, and establishes criteria to distinguish man-made events from natural earthquakes.

Objectives

To conduct a comprehensive seismological analysis of acoustic waves generated by anthropogenic explosions. The study aims to identify these signals on regional seismograms, estimate their propagation velocities, assess environmental influences (e.g., temperature), and establish criteria for distinguishing man-made events from natural earthquakes.

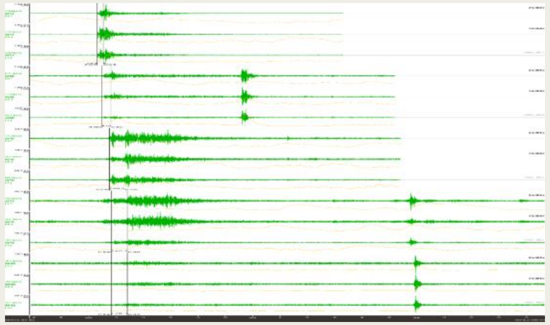
Explosive events, such as quarry blasts, can generate both seismic waves and atmospheric acoustic waves (infrasound). Unlike crustal seismic phases, these acoustic waves propagate through the atmosphere at significantly slower speeds (~330 m/s) and can be detected by sensitive broadband seismic stations. Their analysis provides a reliable criterion for identifying anthropogenic sources and improving event classification.

Methods/Data

- **Seismogram Analysis and Acoustic Phase Identification**

Seismograms from multiple stations show clear P- and S-wave arrivals followed by a delayed low-frequency, low-amplitude signal. This delayed phase corresponds to the atmospheric acoustic wave, typically arriving 60–120 seconds after seismic phases. Measured velocities range between 0.27–0.41 km/s, matching the expected speed of sound under varying atmospheric conditions. At regional distances greater than 10–20 km, the initial explosion-generated shockwave gradually transforms into a standard acoustic wave. This transformation is evident in waveform characteristics and energy decay, confirming its atmospheric origin and supporting its use as a diagnostic feature of anthropogenic explosions.

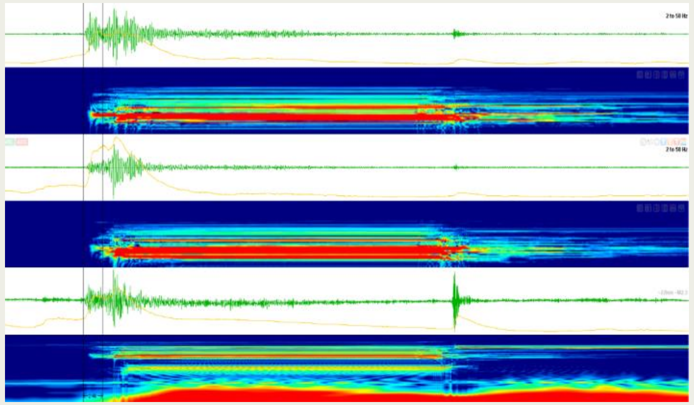
Fig. 1. Multi-station Detection of Acoustic Waves on Seismograms



- **Analysis of Acoustic Wave Spectrograms**

The spectrograms clearly show both the main seismic event and subsequent acoustic wave signatures.
The main seismic signal appears as a high-energy broadband pulse (2–50 Hz) with gradual attenuation, typical of ground-propagated seismic waves.
The acoustic wave is observed a few seconds after the main event, characterized by narrow, high-frequency bands (≈30–50 Hz) and rapid decay.
This temporal delay and spectral pattern confirm the propagation of acoustic energy through the atmosphere following the seismic source.

Fig. 2. Acoustic wave detection on seismograms.



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- **Velocity Calculation Methodology**

After locating the epicenter, three parameters are known: origin time O, distance D (km), and arrival time P. The travel time is calculated as t_P = P – O, and the velocity is:

$$V_p = D/t_P$$

where V_p is in km/s. For example, for D = 31.8 km and t_P = 87 s, $V_p = 0.365$ km/s. Values were corrected for atmospheric conditions and uncertainties

- **Temperature Influence on Acoustic Wave Velocity**

The acoustic wave velocity varies seasonally:
- Winter (0°C): V ≈ 0.27 km/s
- Summer (44°C): V ≈ 0.41 km/s
- These values correspond to:

$$V = \sqrt{\gamma RT/M}$$

Where,
V – speed of sound
γ – adiabatic index (ratio of specific heat at constant pressure) $\gamma = 1.4$
R – universal gas constant, $R = 8.314$ (J/mol·K)
T – absolute temperature of the gas in Kelvin ≈300
M – molar mass of the gas, $M = 0.029$ kg/mol

- **Empirical Regression Model**

A linear regression model was constructed using observed data:

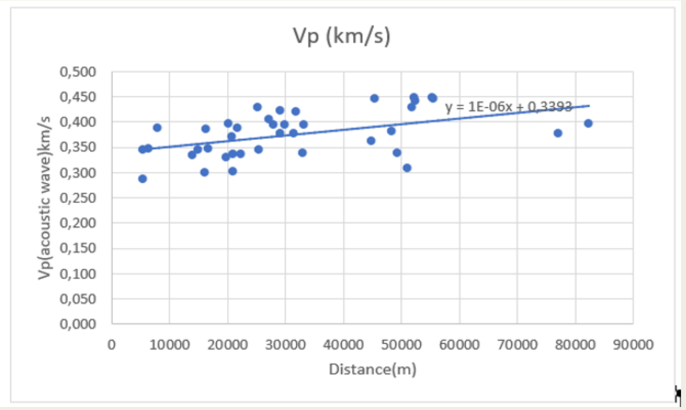
$$V = a \cdot x + b$$

where V is the acoustic wave velocity (km/s), x is the distance (m), $a = 1 \times 10^{-6}$, and $b = 0.3393$.

Interpretation: The model shows a weak positive correlation: greater distance slightly increases velocity, supporting the hypothesis of wave transformation and temperature effects. Additional factors such as air temperature, terrain, and wind may also influence results.

Practical significance: This model supports automated event classification and allows preliminary verification of signal origin using only timing and distance.

Fig.3. Velocity–distance relationship for acoustic waves.



- **Spectral Characteristics**

Spectral analysis using the "Peak Particle Plot" module shows a secondary energy surge coinciding with the arrival of the acoustic phase

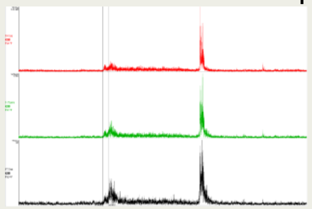


Fig. 4. Peak Particle Plot showing a secondary peak after the main event.

Results

Seismograms from several stations showed a delayed low-amplitude signal after the P- and S-waves, corresponding to an atmospheric acoustic wave. The acoustic phase arrived 60–120 seconds later with velocities of 0.27–0.41 km/s, consistent with the speed of sound in the atmosphere. Spectrograms revealed an additional energy peak in the 30–50 Hz range, confirming its acoustic origin.

Conclusions

Acoustic phases consistently follow explosions with velocities matching the speed of sound. Their distinct delay and spectral features provide reliable criteria to separate blasts from earthquakes, strengthening monitoring systems.