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How Volcanic Explosions Interface with Infrastructure: A Brief Analysis of Volcano Infrasound's Influence on Fuego Observatory Near Fuego Volcano, Guatemala

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Abstract

In 2022, roughly 9 kilometers from the summit of the volcano at Fuego Observatory in Guatemala, our team deployed two arrays of low frequency microphones (infrasound sensors) to capture the effects of Fuego Volcano's semi-active period explosions on the observatory building. We hypothesized a discernible differential pressure signal and frequency spectra content between sensors placed inside and outside of the observatory. The peak force exerted on a building by volcano infrasound, depending upon the strength of the explosion and distance from it, may be enough to damage windows or even entire buildings if they are poorly built/kept. This presentation aims to contextualize volcanic explosion emitted infrasound as a potential geophysical hazard capable of harming infrastructure.

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A Brief Analysis of Volcano Infrasound’s Influence on Fuego Observatory near Fuego Volcano, Guatemala

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Background

Volcanoes pose multiple risks in the form of fissures, ash clouds, explosive debris, volcanic mudflows, and lava flows. Volcanoes can also, like the recent 2022 Tonga eruption in the Pacific, explode spectacularly. This presentation aims to contextualize volcanic explosion emitted infrasound as an additional volcanic geophysical hazard capable of potentially harming infrastructure.

Goal

Via infrasound and digital signal processing methods, we sought to measure and interpret the difference in pressure between the inside and outside of Fuego Observatory during volcanic explosions from nearby Fuego Volcano, Guatemala in late August/early September 2022.

Hypotheses

We hypothesized that when measuring the pressure differential inside vs outside Fuego Observatory during volcanic explosions, we would observe a noticeable difference both in pressure and in frequency spectra content between the inside and outside sensors likely due to the scattering and diffraction of pressure waves.

Methods

1 Collected data (sampled at 200 Hz) is windowed into individual explosion events of ~120 second intervals.

2 Verify quality of co-located sensor data (low noise) via cross-correlation methods.

3 Average co-located sensors and compare inside vs outside pressure signals (time-series & power spectra).

4 Keep and filter events with >70% similarity for frequencies between 0.5Hz and 50Hz.

5 Plot and interpret data.

Figure 1: Google Earth (2022)
Outside sensors in red, inside sensors in white; Fuego observatory briefly outlined in yellow (W denotes open window, D denotes closed doors)

Results

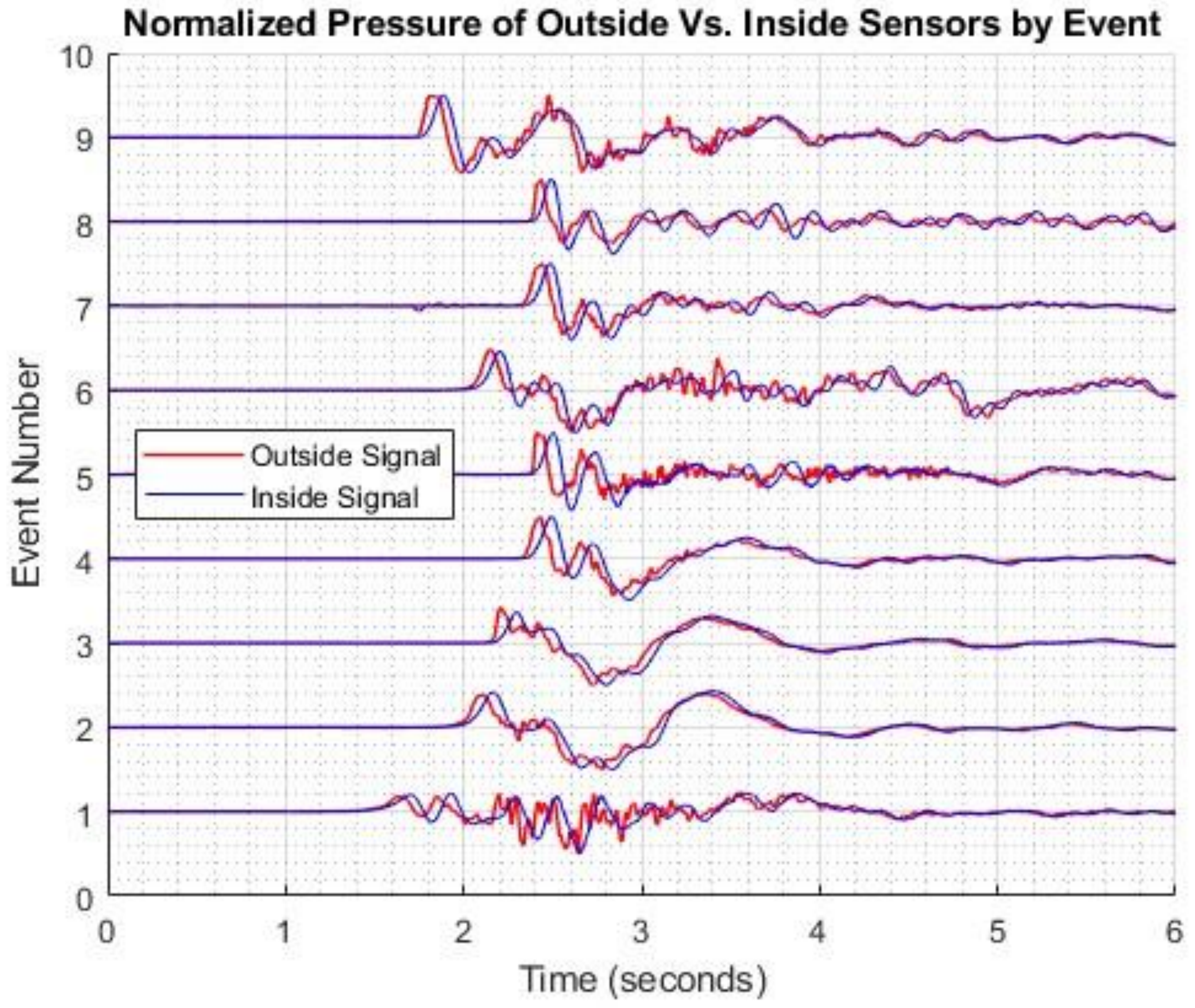
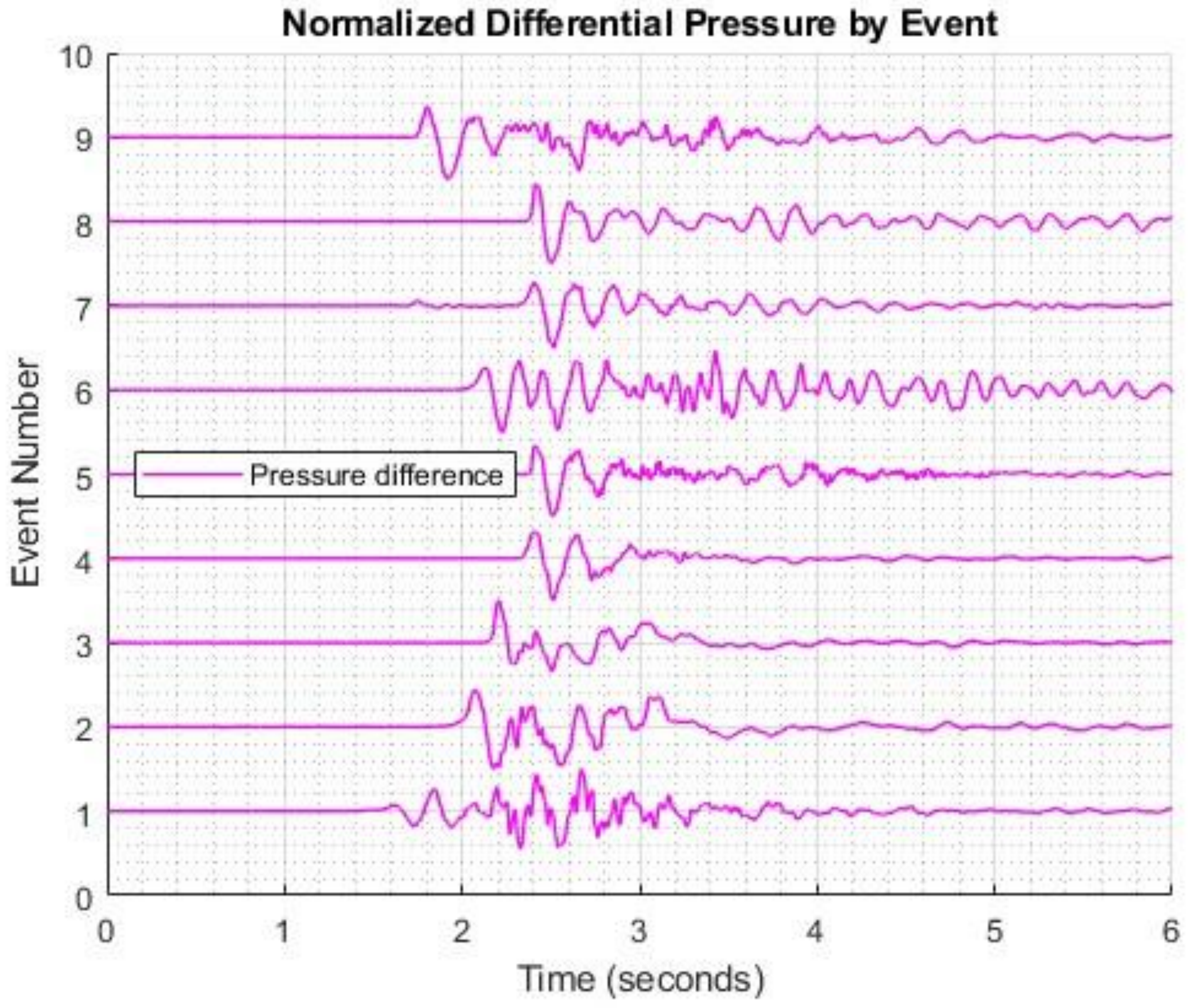
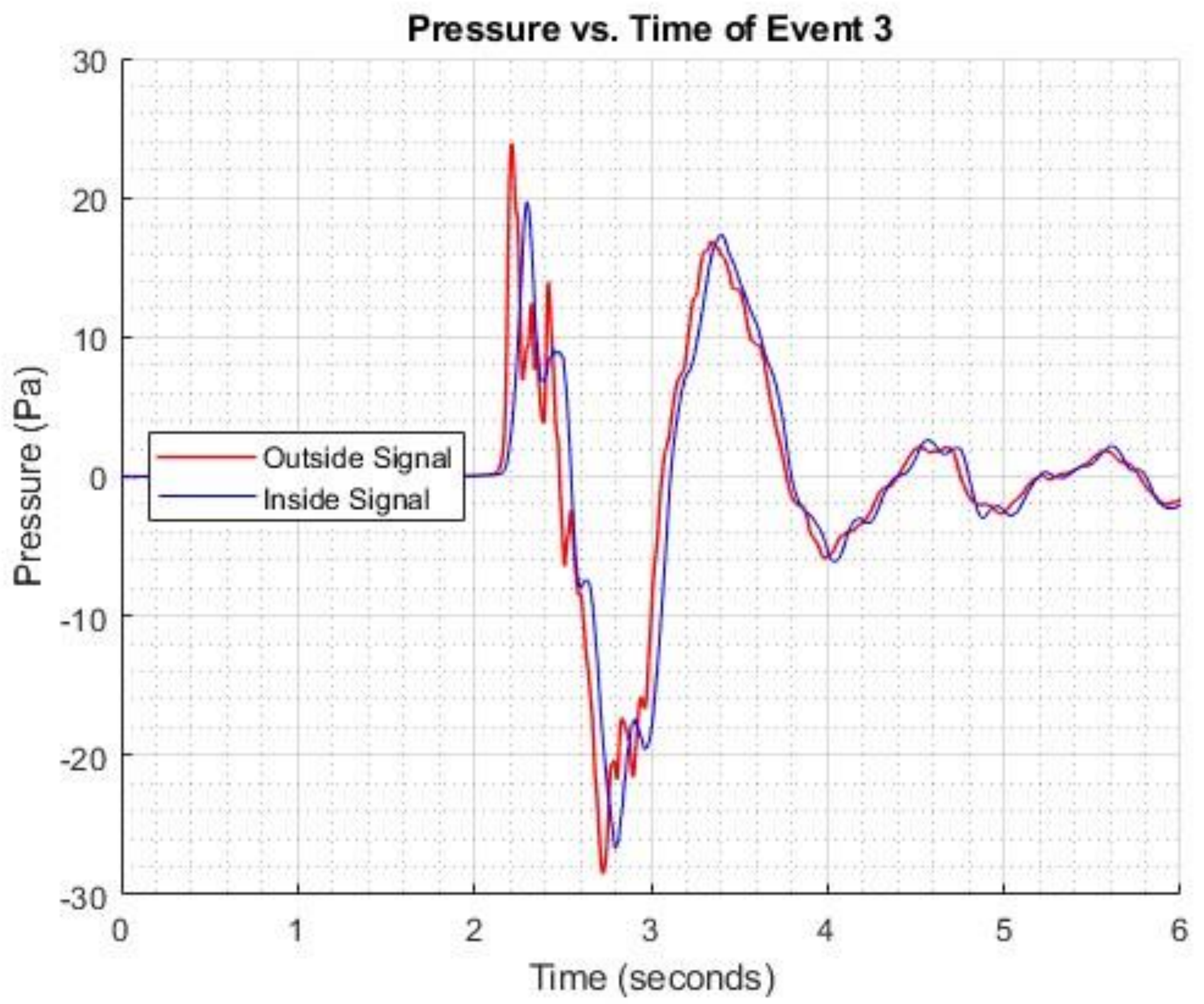


Figure 2 (Above): Plot showing averaged outside signal vs averaged inside signal; plotted zoomed in section of each event of interest with a normalized pressure on the y-axis vs. time, in seconds, on the x-axis. Outside sensor group uses Ch1 & 2 outside while sensor group B uses Ch2 & 3 inside: 4 sensors total; see Figure 1 (Bottom Left).



Event	Peak Pressure (Pa)
9	7.54
8	14.98
7	11.62
6	5.50
5	11.33
4	17.74
3	20.59
2	7.04
1	6.53

Figure 3 (Above): Plot of differential pressure between averaged inside and outside sensors of interest. Y-axis is pressure in pascals, x-axis is time in seconds. Note the peak differential pressure values in the table. Note: for a square meter surface like a window, force exerted on that area can be calculated via P/A = F.



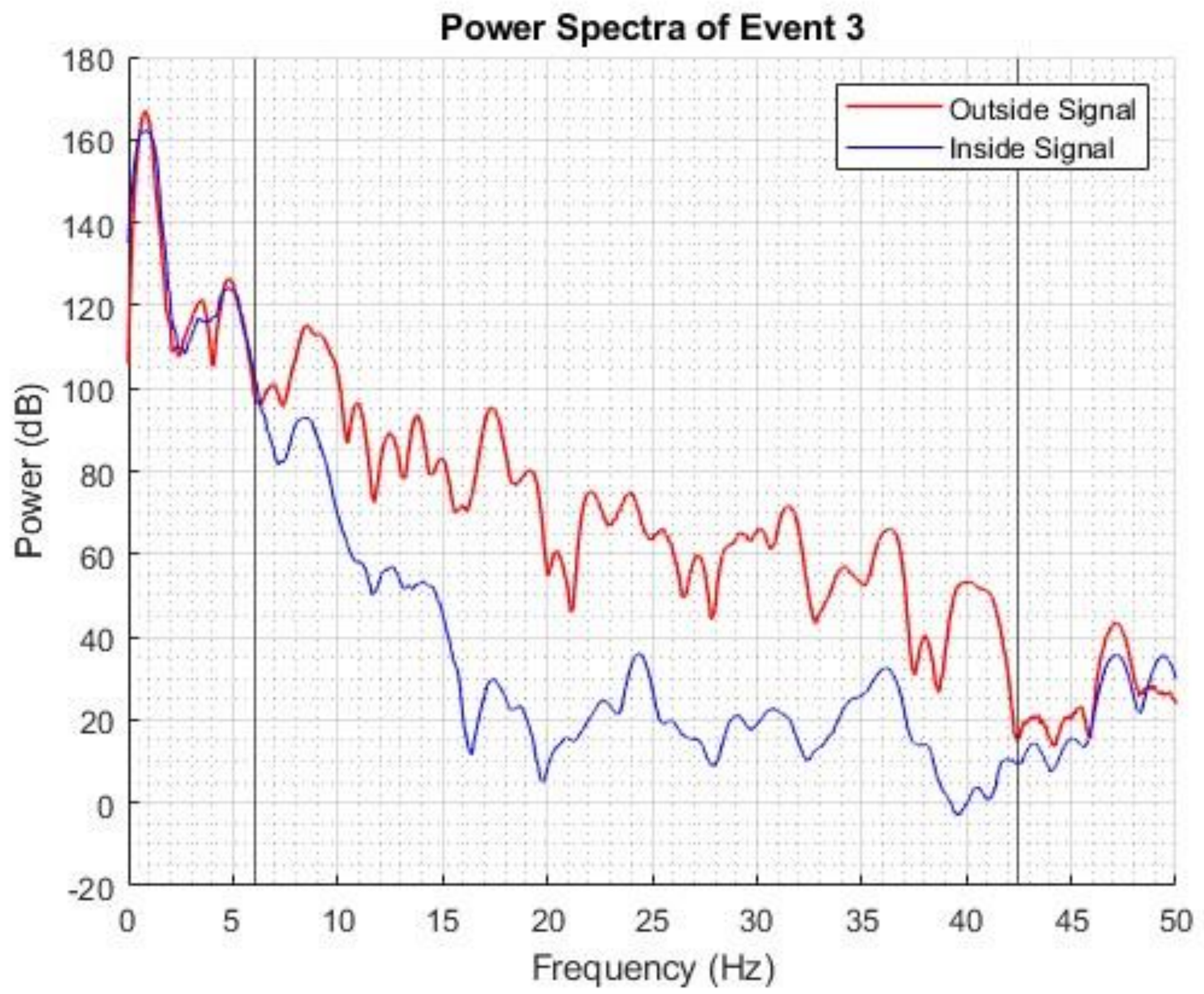


Figure 4: Left) Event 3 Time Series **Right)** Power Spectra of Event 3; Note the vertical lines around 6 and 42 Hz. Inside signal differs greatly between these frequencies.

Key Findings

We observed several consistencies across our events:

- High frequency information is lost as pressure equalizes in the building (Figures 2 & 4)
- Frequency information above ~6Hz diverges between inside and outside sensors up until ~40Hz (Figure 4)
- At ~9km away from the volcano summit, the largest pressure exerted on the building by pressure differences is only ~21 Pascals (Very low)

Importance

Communities and Engineers can use this information to:

1.) Better understand the complex risks that volcanoes pose

2.) Contextualize additional needs that infrastructure near explosive volcanoes might have

Future Work

In this analysis, we are limited by our small, single site and sole use of infrasound. Future work could include:

- Incorporating audible sound in our measurements
- More sites to more accurately determine how building shape influences filtered frequencies
- Modeling pressure vs distance to determine safe zones for infrastructure given a maximum explosion size
- Develop a method to calculate a building’s pressure-based filter response

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