Dynamics of rain-triggered lahars inferred from infrasound array and time-lapse camera correlation at Volcán de Fuego, Guatemala.

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Abstract

Lahars, or volcanic mudflows, are one of the most devastating natural, volcanic hazards. We present an analysis of several rain-triggered lahar events at Volcán Fuego in Guatemala with an infrasound array and time-lapse camera network deployed along the Las Lajas river channel. While infrasound detects the passage of low frequency sound waves associated with these mudflows, the time-lapse cameras can be used to verify lahar passages and channel responses as these flows move downstream. Twenty-three infrasound microphones and five time-lapse cameras were deployed during the 2021 rainy season (May-October) in the Las Lajas drainage on the southeasterly side of Volcán de Fuego. With the data collected over this field campaign, we hope to quantify flow parameters such as volumes, velocities, and the frequency of these rain-triggered mudflows, as well as characterize flow behaviors in our infrasound signals by correlating data to the time-lapse imagery. This study allows us to identify the occurrence of several lahars, quantify important characteristics, and use a multi-faceted approach to verify and delineate important flow behaviors related to these volcanic hazards.

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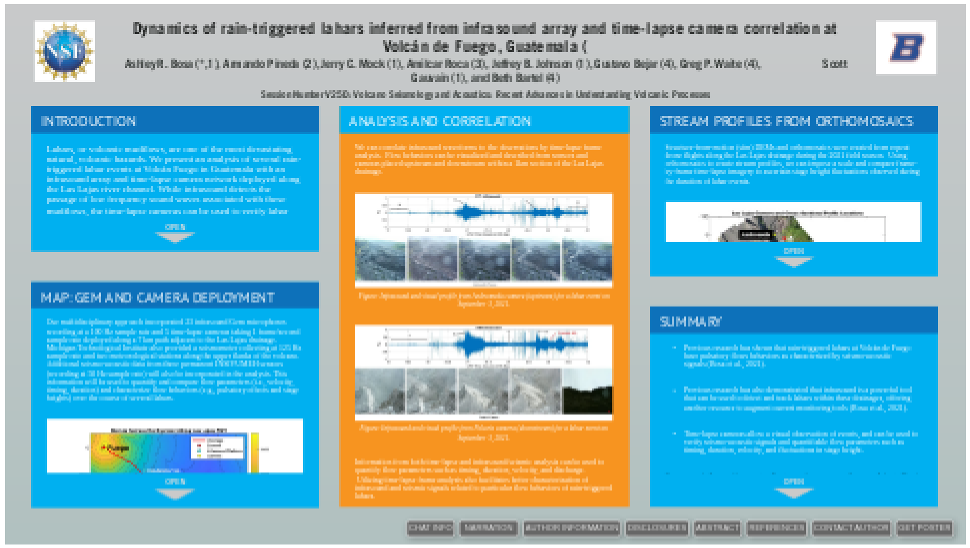

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INTRODUCTION

Lahars, or volcanic mudflows, are one of the most devastating natural, volcanic hazards. We present an analysis of several rain-triggered lahar events at Volcán Fuego in Guatemala with an infrasound array and time-lapse camera network deployed along the Las Lajas river channel. While infrasound detects the passage of low frequency sound waves associated with these mudflows, the time-lapse cameras can be used to verify lahar passages and channel responses as these flows move downstream. Twenty-three infrasound microphones and five time-lapse cameras were deployed during the 2021 rainy season (May-October) in the Las Lajas drainage on the southeasterly side of Volcán de Fuego. With the data collected over this field campaign, we hope to quantify flow parameters such as volumes, velocities, and the frequency of these rain-triggered mudflows, as well as characterize flow behaviors in our infrasound signals by correlating data to the time-lapse imagery. This study allows us to identify the occurrence of several lahars, quantify important characteristics, and use a multi-faceted approach to verify and delineate important flow behaviors related to these volcanic hazards.

MAP: GEM AND CAMERA DEPLOYMENT

Our multidisciplinary approach incorporated 23 infrasound Gem microphones recording at a 100 Hz sample rate and 5 time-lapse cameras taking 1 frame/second sample rate deployed along a 7 km path adjacent to the Las Lajas drainage. Michigan Technological Institute also provided a seismometer collecting at 125 Hz sample rate and two meteorological stations along the upper flanks of the volcano. Additional seismo-acoustic data from three permanent INSIVUMEH sensors (recording at 50 Hz sample rate) will also be incorporated in the analysis. This information will be used to quantify and compare flow parameters (i.e., velocity, timing, duration) and characterize flow behaviors (e.g., pulsatory effects and stage heights) over the course of several lahars.

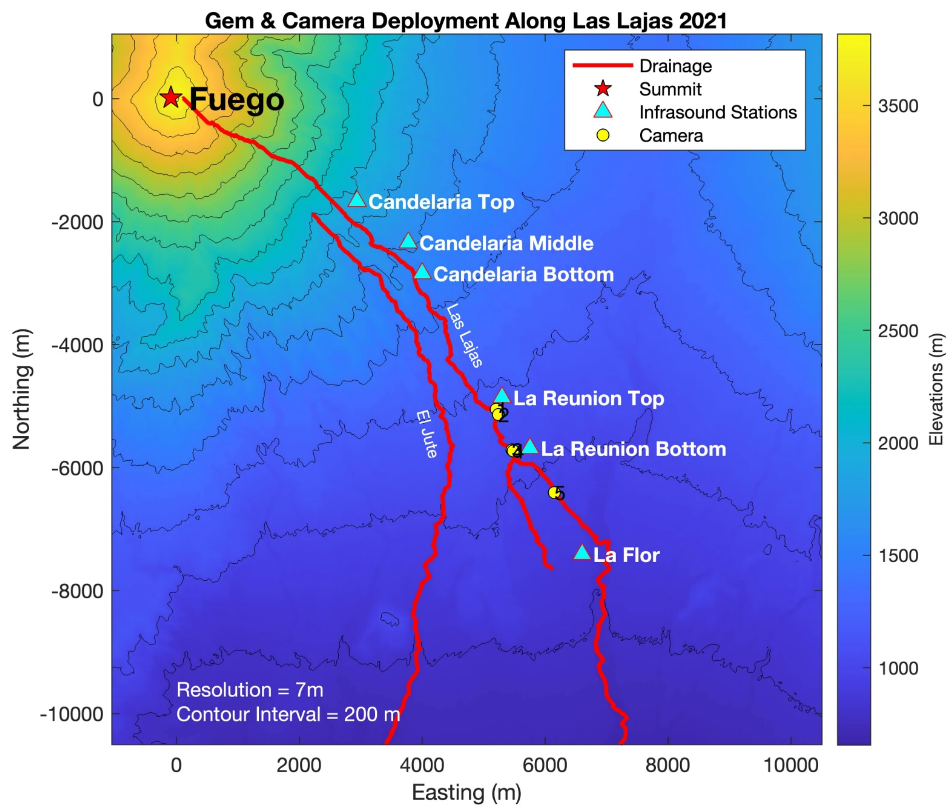
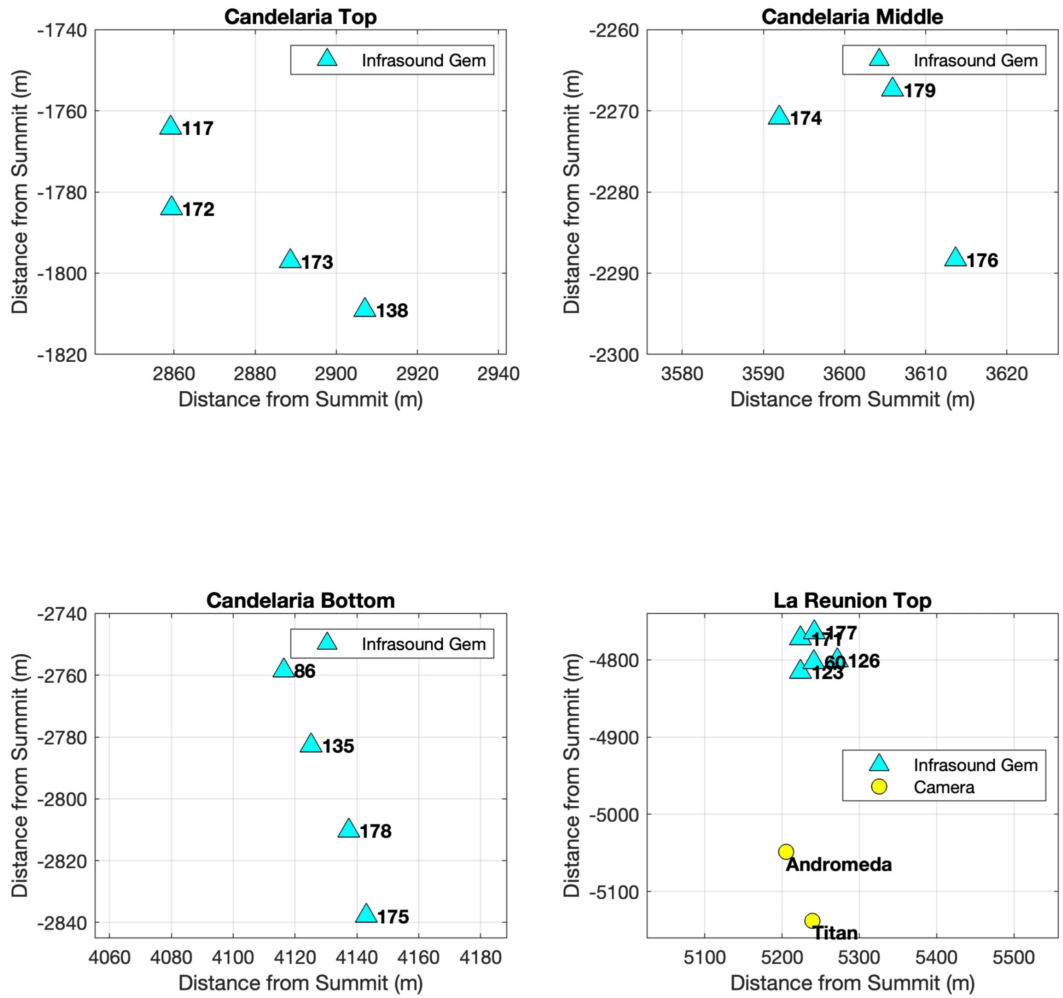


Figure: Infrasound and time-lapse camera deployment sites along the Las Lajas drainage. Drainages derived from a gradient seed on a contoured SPOT7 Digital Elevation Model with the Las Lajas drainage highlighted in red. El Jute drainage is also mapped as it is likely our sensors picked up lahar events from this drainage as well.


Candelaria Top
Infrasound Gem
117
172
173
138
Distance from Summit (m)
Distance from Summit (m)
Candelaria Middle
Infrasound Gem
179
174
176
Distance from Summit (m)
Distance from Summit (m)
Candelaria Bottom
Infrasound Gem
86
135
178
175
Distance from Summit (m)
Distance from Summit (m)
La Reunion Top
177
171
60
126
123
Infrasound Gem
Camera
Andromeda
Titan
Distance from Summit (m)
Distance from Summit (m)

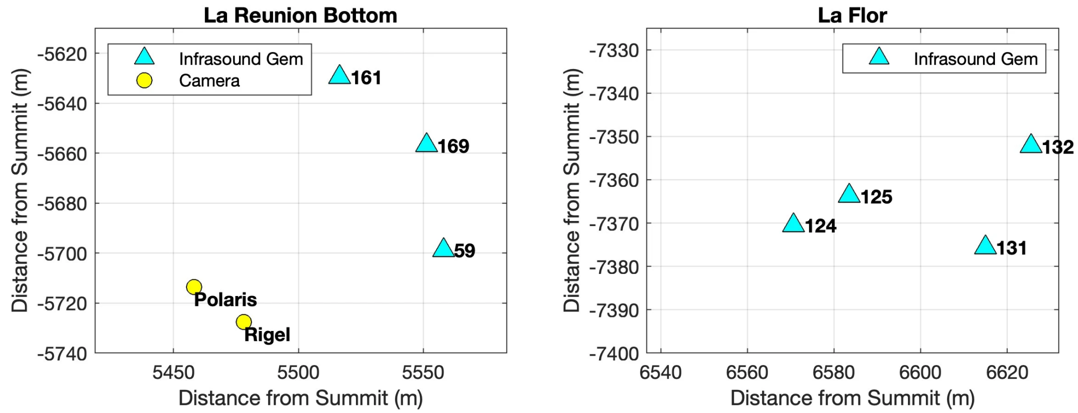


Figure: Panels show the array and camera layouts for each location along the Las Lajas drainage. NB: One camera (Bellatrix) is not displayed, but is located roughly halfway between the La Reunion Bottom and La Flor arrays.

ANALYSIS AND CORRELATION

We can correlate infrasound waveforms to the observations by time-lapse frame analysis. Flow behaviors can be visualized and described from sensors and cameras placed upstream and downstream within a 1km section of the Las Lajas drainage.

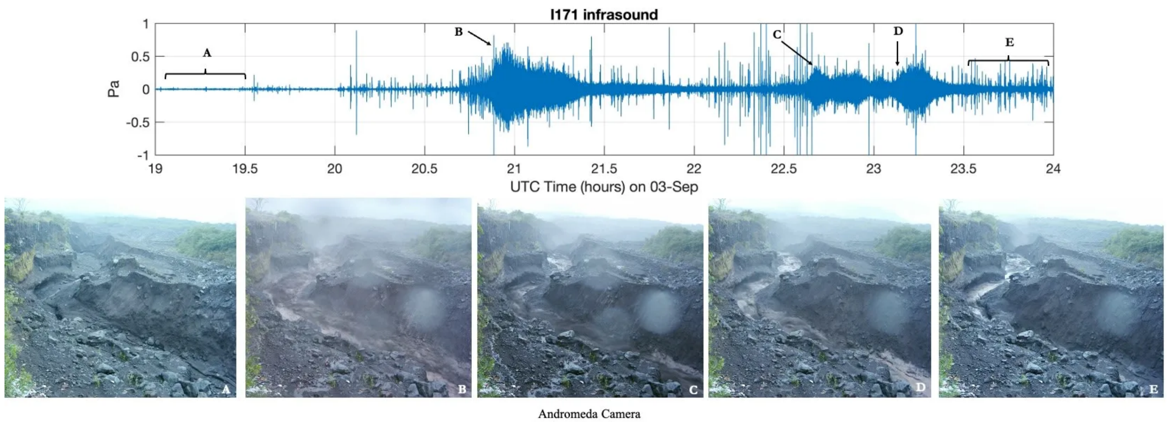


Figure: Infrasound and visual profile from Andromeda camera (upstream) for a lahar event on September 3, 2021.

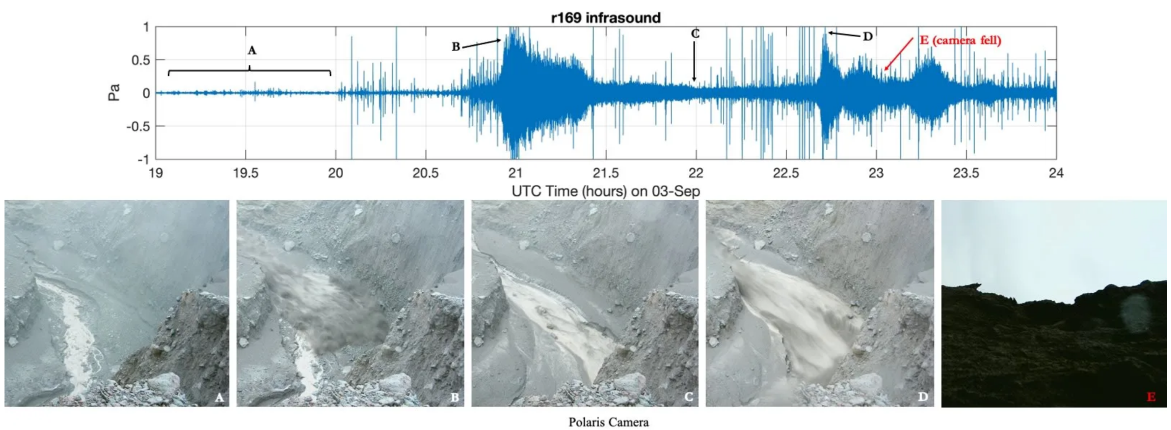


Figure: Infrasound and visual profile from Polaris camera (downstream) for a lahar event on September 3, 2021.

Information from both time-lapse and infrasound/seismic analysis can be used to quantify flow parameters such as timing, duration, velocity, and discharge. Utlizing time-lapse frame analysis also facilitates better characterization of infrasound and seismic signals related to particular flow behaviors of rain-triggered lahars.

STREAM PROFILES FROM ORTHOMOSAICS

Structure-from-motion (sfm) DEMs and orthomosaics were created from repeat drone flights along the Las Lajas drainage during the 2021 field season. Using orthomosaics to create stream profiles, we can impose a scale and compare frame-by-frame time-lapse imagery to ascertain stage height fluctuations observed during the duration of lahar events.

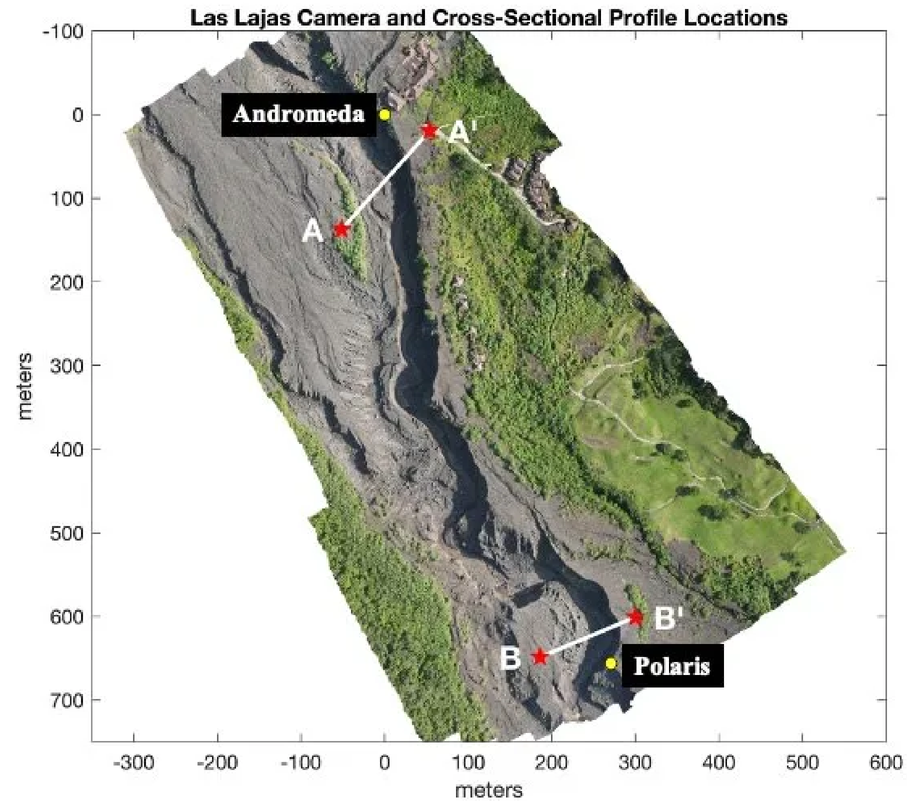
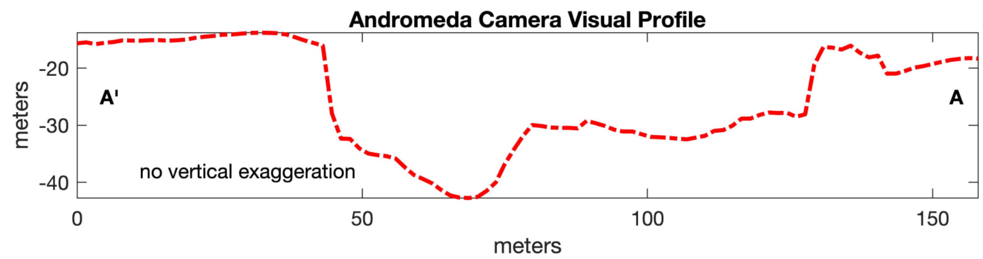


Figure: Camera and stream profile locations. This area covers approximately 1 km flow path distance along the Las Lajas drainage.



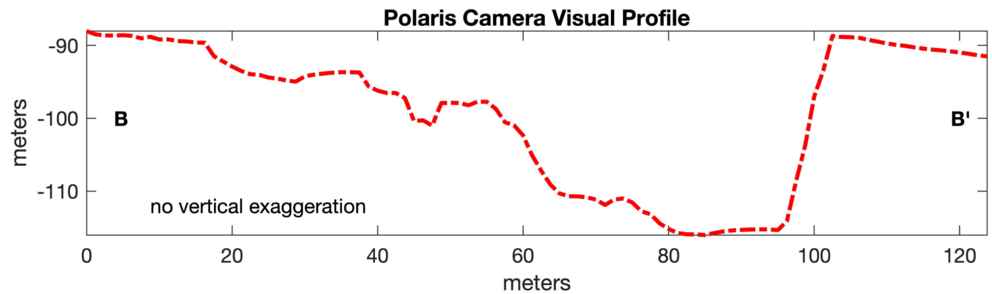


Figure: Visual profiles of the Las Lajas drainage from each camera view. The Andromeda camera faced downstream, while the Polaris camera was faced upstream.

SUMMARY

- Previous research has shown that rain-triggered lahars at Volcán de Fuego have pulsatory flows behaviors as characterized by seismo-acoustic signals (Bosa et al., 2021).

- Previous research has also demonstrated that infrasound is a powerful tool that can be used to detect and track lahars within these drainages, offering another resource to augment current monitoring tools (Bosa et al., 2021).

- Time-lapse cameras allow a visual observation of events, and can be used to verify seismo-acoustic signals and quantifiable flow parameters such as timing, duration, velocity, and fluctuations in stage height.

For more information regarding previous research on pulsing effects of rain-triggered lahars at Volcán de Fuego, please visit:

https://doi.org/10.30909/vol.04.02.239256

DISCLOSURES

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ABSTRACT

Lahars are among the most destructive natural processes at active volcanoes, including at Volcán de Fuego (Guatemala) where the people and property are exposed. Secondary lahars at Fuego (and at other volcanoes) transport large volumes of material and flow at high velocities making them erosive and destructive, capable of depositing material many meters above the flow path. This study's objective is to develop technologies for lahar monitoring of rain-triggered lahars occurring in the Las Lajas drainage on the southeast side of Volcán de Fuego. Our multidisciplinary approach incorporates 23 infrasound Gem microphones, seismometers, meteorological stations, and 5 time-lapse cameras deployed along a 7 km path adjacent to the Las Lajas drainage. Additional seismo-acoustic data from the permanent INSIVUMEH network is incorporated in the analysis. Topographic maps of the Las Lajas drainage are made using structure-from-motion aerial surveys at approximately monthly intervals.

Over the course of the 2021 rainy season (May-October), we maintained sensors and cameras to detect, track and characterize multiple lahar events. These data are used to quantify the frequency of occurrence, the volume and velocity of multiple lahars, as well as confirm infrasound-detections of lahar passages and channel morphological changes (e.g., entrainment of larger material, aggradation, erosion, or shifts in channel geometry). Time-lapse imagery of lahar passage is compared with signal characteristics of the infrasound and seismic data. We observe dynamic flow behavior including events with multiple pulses seen as rising and falling flow stages. This flow behavior is common both in the Las Lajas drainage and in other drainages at Fuego. We also observe and quantify the lahar-induced channel and geomorphological responses, including erosion and bank collapses. Compilation of a catalog of rain-triggered lahar events in Las Lajas over a season permits a dataset amenable to statistical analysis. Our goal is the development of new generation geophysical monitoring tools that will be capable of remote and real-time estimation of flow parameters.

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