Volcano Acoustic Monitoring from near and far-field ObServations

VAMOS

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Introduction and motivation

Acoustic monitoring has become a well-established technique to detect explosive volcanic eruptions that can inject ash into the atmosphere, creating hazards for nearby communities and for aircraft flying in the vicinity. The main tasks of infrasound monitoring lie in the detection of signals, in determining the location of their source, and in estimating source parameters such as mass eruption rates. However, each of these aspects of monitoring strongly depends on propagation through the atmosphere and the interaction of the wave-field with the topography. While variations in atmospheric temperature and wind speed gradients can affect the number and magnitude of infrasonic detections, the topography is diffracting the waves thus changing amplitude and frequency content of the signal.

During the last phases of the 67-days-long eruption of the Piton de la Fournaise Volcano, which started on August 2015, the Laboratory of Experimental Geophysics of the University of Firenze, Italy, in collaboration with the Observatoire Volcanologique du Piton de la Fournaise (OVPF) deployed a portable, small aperture, infrasonic array, which allowed to record unprecedented infrasonic data associated with the effusive volcanic activity. The array was installed on the outer rim of the Enclos Foqué, roughly 2.5 km far from the active vent, sited on the southern flank of the Dolomieu cone.

A permanent small aperture infrasonic array is located at the MAIDO Observatory site (~40 Km distant from the eruptive vent) and it proved itself effective to study atmospheric dynamics.

Data collected by these infrasonic sensors at different distances from the eruptive vent give us the opportunity to tackle several issues related to the infrasound propagation and to evaluate potential and limitations of volcano acoustic monitoring at near-regional distances in La Réunion.

Scientific objectives

This project aims to evaluate the possibility and the limitations of the use of the infrasound technology for volcano monitoring in La Réunion.

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As far as we know, the data recorded during the 2015 eruptive activity of the Piton de la Fournaise Volcano (PFV) are amongst the few rare infrasound data-sets reported for this style of basaltic volcanic activity. Moreover the presence of two infrasound arrays, sited at different distances from the vent, represented and unique opportunity to investigate propagation effects for this source.
By comparing the infrasonic records at the two arrays, we have the opportunity to better understand how the local topography and atmospheric conditions affect the propagation of infrasonic signals. Furthermore, the long-term data-set from the permanent MAIDO installation allow an estimation of seasonal variability of noise level at Réunion Island.
Aim of the project is to show that infrasound can be successfully used to locate the source, detect the onset, and track the evolution of the effusive phases as well as to investigate the source dynamics.

Methodology and experimental set-up

The possibility to access the OSU-R facilities, spending one month both at the OVPF and at the MAIDO Observatory (OPAR), allowed us to extend the analysis of the volcano dynamics carried out during the 2015 experimental campaign connecting the expertise of the two local observatories both in the fields of Volcanology and Atmospheric Sciences.

MAIDO observatory provided data recorded by the permanent infrasonic array located at ~40 Km from the source and local atmospheric profiles while the collaboration with the OVPF allowed the integration of the infrasonic near-source observation with other geophysical parameters, such as seismic and ground deformation data recorded by the permanent monitoring network operated by the Observatory.

Since the main goal of the project was to study how topography and atmospheric condition affect the infrasonic signal propagation, we focused on the analysis of the three different phases of activity recorded during 2015 eruption to compare data recorded at the near source array those recorded at MAIDO site. Then, we performed 2D FDTD modelling of the pressure wave propagation in the atmosphere [De-Groot-Hedlin et al., 2011; Lacanna et al., 2014], in order to account for wind effects and atmospheric specification along the whole section, from the source to the MAIDO site. Besides we computed the extension of the shadow zone for propagation of infrasonic waves due the atmospheric conditions and topography of La Réunion Island.

Preliminary results and conclusions

As a first step we performed the analysis of the infrasonic signal recorded during the 2015 eruption by the infrasonic array located 2,5 km far from the eruptive vent (BER site).
Our analysis shows how the infrasonic signals produced during this style of basaltic volcanic

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activity, coupled with the data from the permanent network operated by the OVPF, can be used to provide detailed information on the eruptive source dynamics.

The onset of the eruptive activity is well marked in the infrasonic records from BER (Fig. 1a). However, comparing our data with those recorded at MAIDO permanent array, 38 km far from the eruptive vent, is clearly evident that volcanic activity of PF is not detected at this site (Fig. 1b).

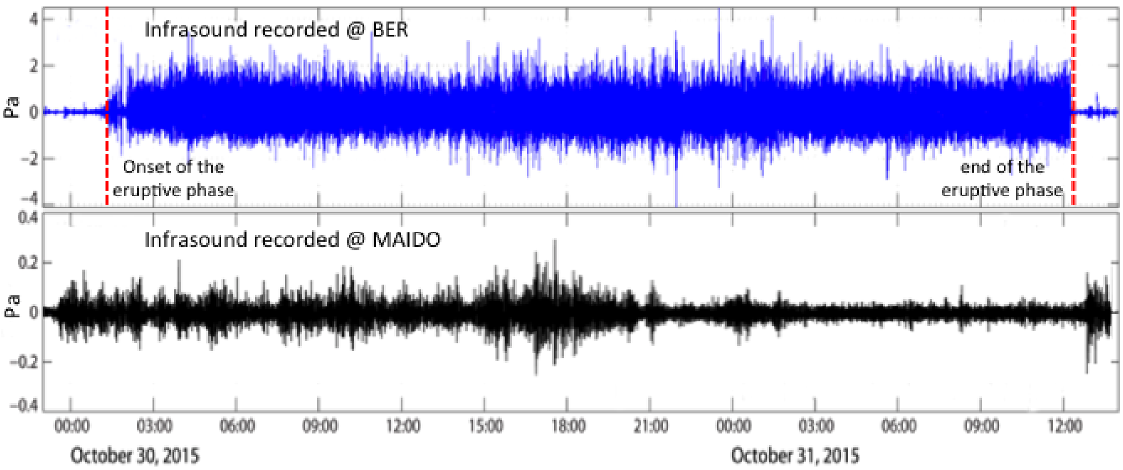
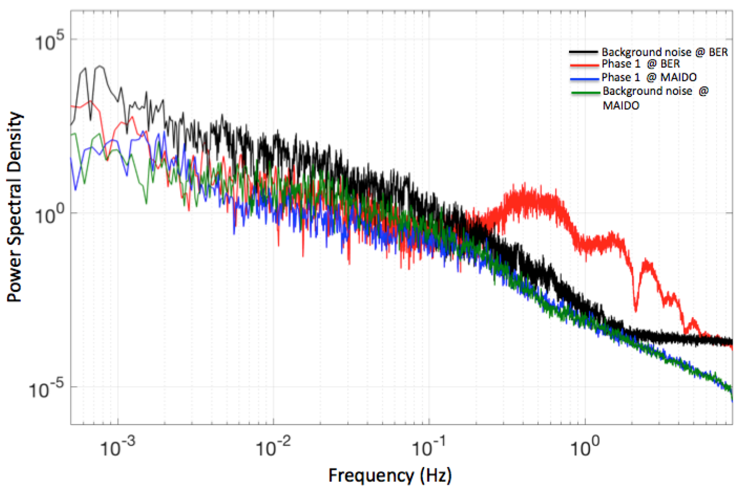


Fig.1 a) infrasonic signal recorded at BER (2.5 km far from the eruptive vent) during the phase 3 (Oct. 30 to Oct. 31) of the 2015 eruption. b) infrasonic signal recorded at MAIDO Observatory (38 km far from the source) during the same period.



This observation is better evidenced from the spectral analysis of the data recorded at the two sites which show a significant spectral enrichment related to the eruptive activity at BER array. Despite the comparable noise level, this behavior is not observed at MAIDO array (Fig. 2).

Fig.2 Spectral content of the signal recorded at BER and MAIDO stations during phase 3 of eruptive activity (red and blue). In

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black and green we report signals recorded during a non-eruptive phase at BER and MAIDO respectively.

In order to explain why the MAIDO array is not able to detect eruptive activity of PF we had to quantitatively evaluate propagation effect using adequate information about topographic and atmospheric structures [Lacanna et al., 2013].

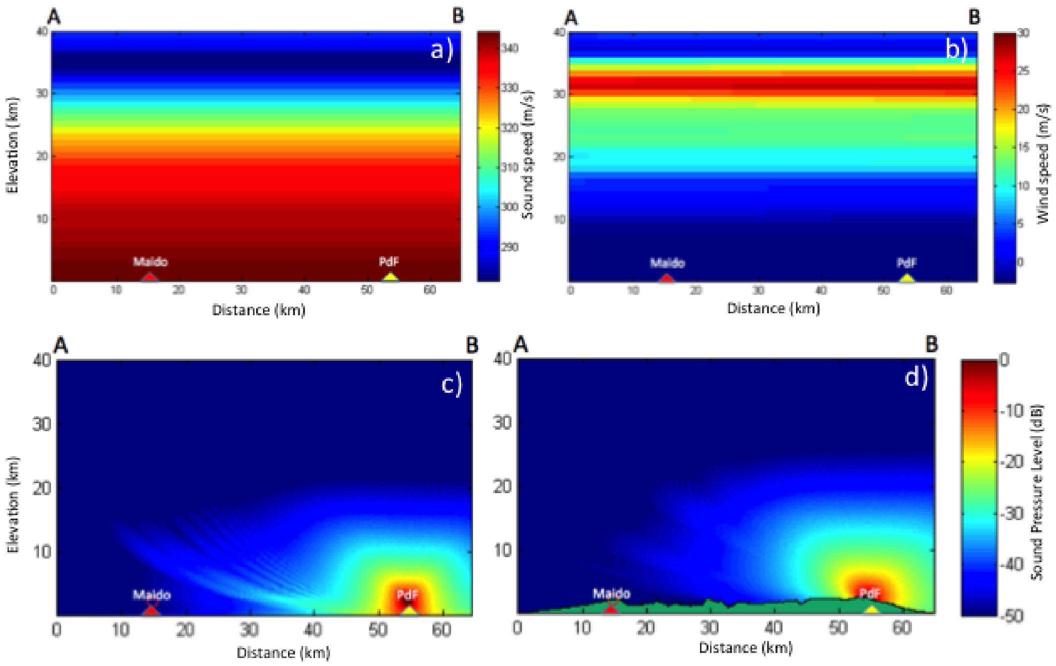

Fig.3 a) Sound speed profile along the section between the two stations. b) Wind speed profile. c-d) Distributions along the section of relative sound pressure level (in decibel) with respect to values at BER without and with topography.

Numerical simulations were performed using a two-dimensional finite difference time domain (2-D FDTD) method (Fig. 3). Effects of atmospheric structure and topography are included in a vertical section along the BER-MAIDO path.

We have compared direct field observations, with results of numerical simulation in order to evaluate the extension of the shadow zone for propagation of acoustic wave in La Réunion. Based on our numerical simulation, atmospheric parameters and topography have proved to strongly control the propagation of infrasound waves for distances larger than 25-30 Km with respect to the source position. According to our observations and modeling, the acoustic waves produced by this style of basaltic activity of PFV cannot be recorded by the MAIDO array. While this conclusion express a limitation for the use of this permanent installation for volcano monitoring, this also means that the infrasound recorded at MAIDO is not affected

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by volcano related signal that may disturb the observation of pure atmospheric dynamics. Besides, our results underline the potential of acoustic monitoring of the volcanic activity and the analysis we carried out could be crucial to correctly evaluate the capabilities of an infrasound array installation as a part of the permanent monitoring network of PFV.

Multidisciplinary approach

The results of this study may have a relevant impact on the enhancing of the local monitoring network in La Réunion both for volcanic and atmospheric purposes.
As an outcome of this study, the possibility of installing a permanent infrasonic array as part of the OVPF monitoring network has been discussed. This could also represent a good opportunity to project cross-domain studies about volcanology and atmospheric sciences and to enhance collaborations between OVPF, OPAR and University of Florence.

Outcome and future studies

Through the synergy between the two OSU-R infrastructures (OVPF and OPAR) and the Laboratory of Experimental Geophysics of the University of Firenze, we will be able to carry out a full analysis of acoustic wave-field produced by this style of volcanic activity and to improve our knowledge on the use of infrasound as monitoring tool at the mid-range distance. Besides, the results will be presented in conferences also as a part of the HORIZON 2020 - ARISE2 design study project and published in international journals.

References

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