Wave Propagation in Volcanoes using a Discontiniuos Galerkin Method

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1. SUMMARY

Seismic wave propagation in volcanic environments presents some challenges in seismology. The wavefield is strongly affected in a volcano by a set of different factors:

1. ***Complex topography revealing as the most important scatter mechanism***.
2. ***Stratigraphy further distorting the wavefield.***
3. ***Magmatic fluids introducing large intrinsic attenuation.***

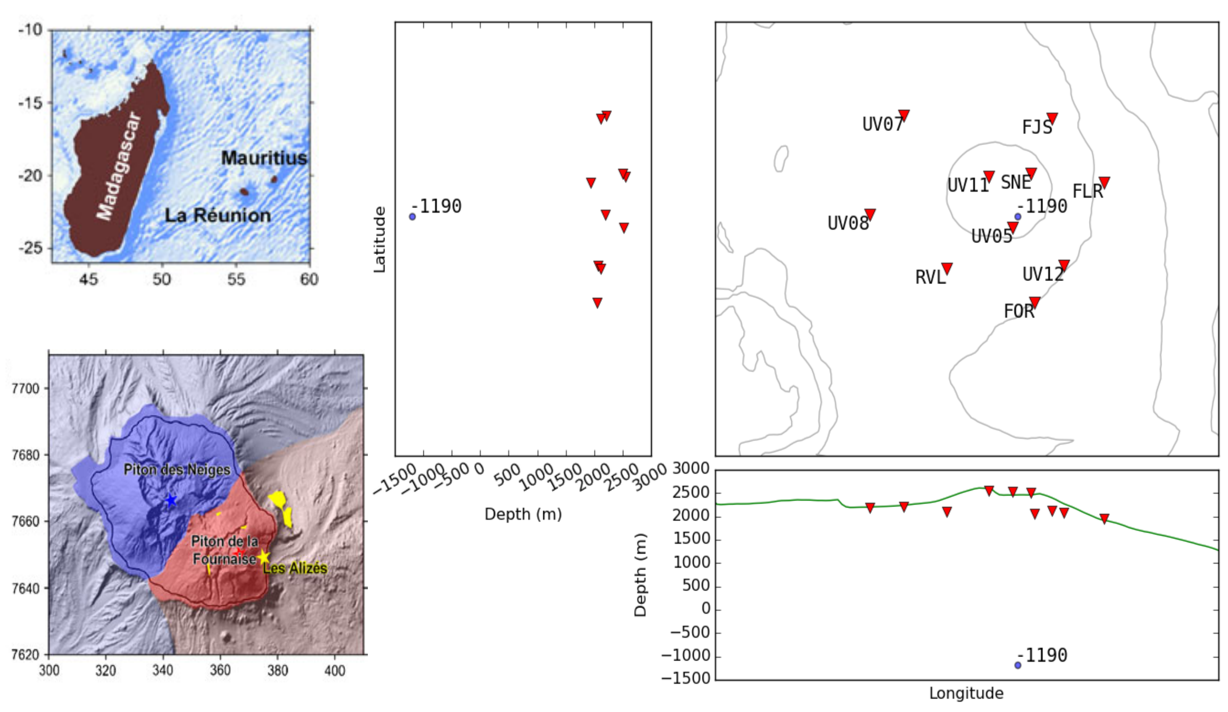
In addition to this, the near-field seismic wavefield can not be ignored and quite often the source mechanism is not well known. This complexity leads to a very diffusive wavefield in which is very difficult to quantify the relative effect of all these factors.

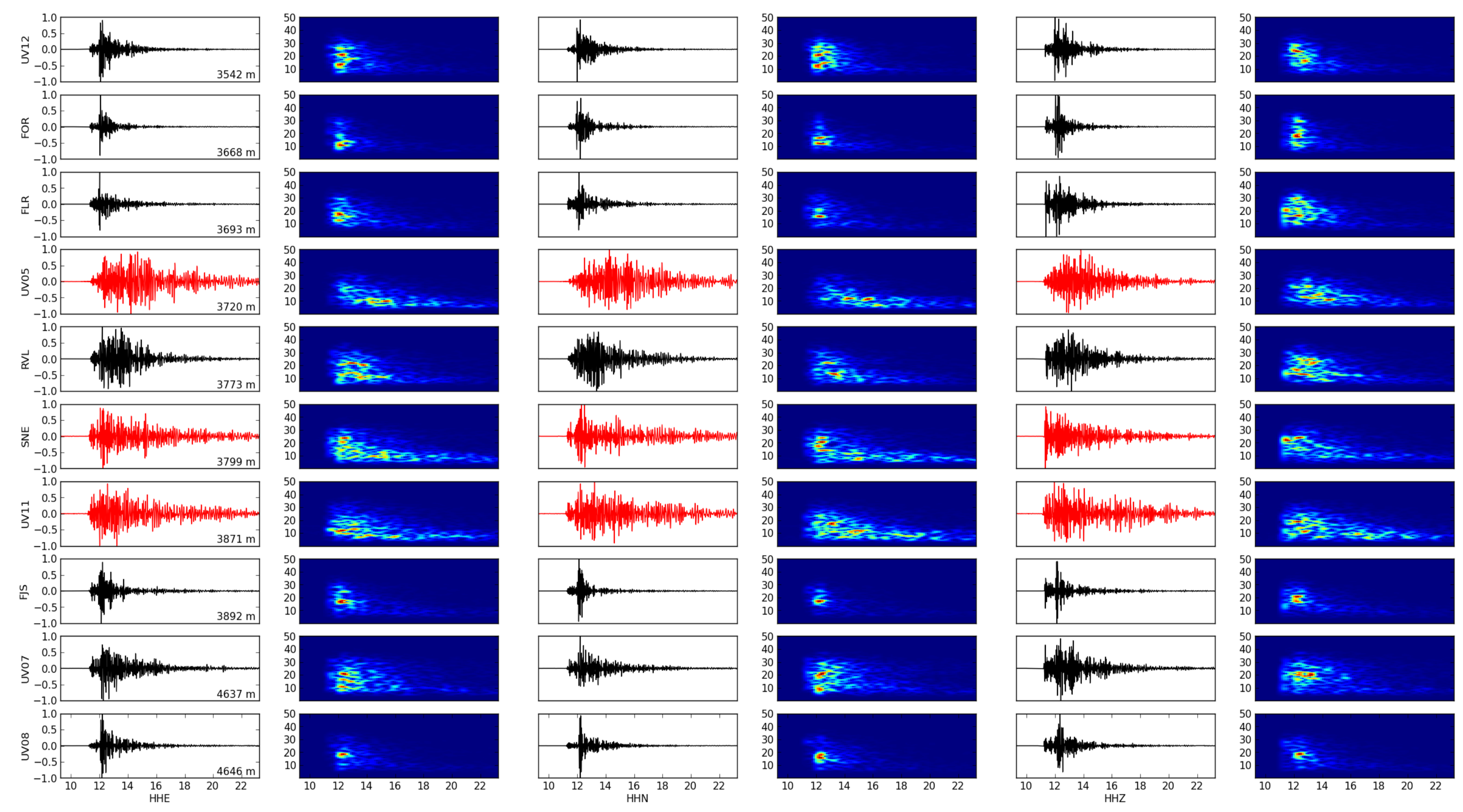
ADER DG emerges as an appropriate numerical method to handle these complexities. Concerning mesh generation algorithms, hexahedral grids have more severe restrictions in meshing efficiently complex geometries than the tetrahedral ones. This crucial difference plays an important role in modelling volcanic wave propagation where steep topographies and inner interfaces must be honoured, especially when we work at high frequencies.

2. SCATTERING PROCESS AT PITON DE LA FOURNAISE

Piton de la Fournaise is a basaltic volcano located on the eastern side of Reunion island, in the Indian Ocean, about 700 km East of Madagascar. It is one of the most active volcanoes in the world with at least 125 eruptions during the last century (30 eruptions since 2000). Since 2009, new broadband seismic stations have been deployed under the framework of the *UnderVolc research project*.

A propagation path effect seems to take place for deep events in this volcano. Seismograms at the stations located right on the summit show a different wavefield compared to those ones that are just nearby around it.

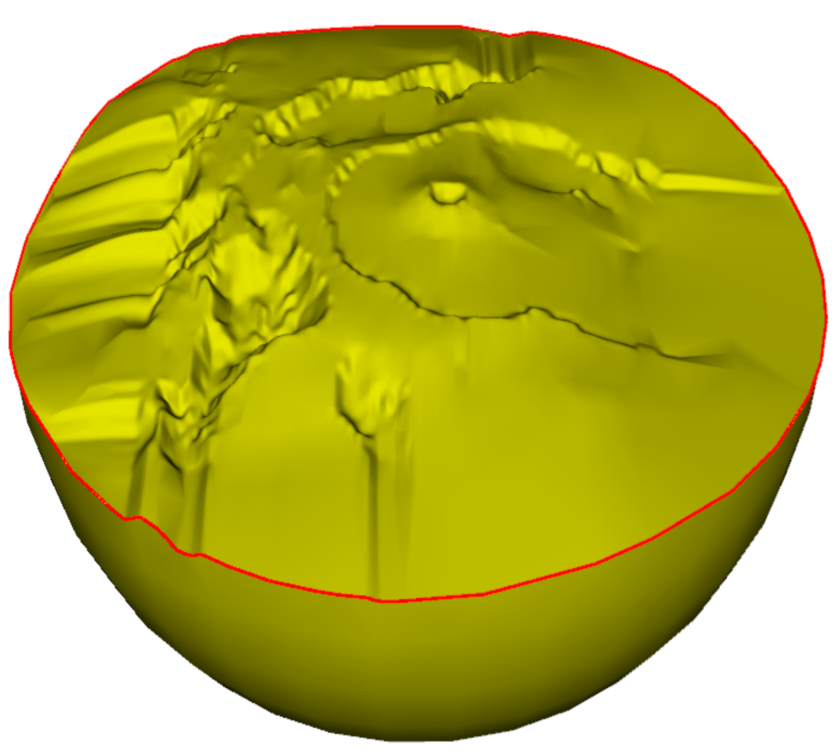




The waveforms of the stations on the summit emulate VT-B events; no distinction between P- and S-wave onset, emergent wave-trains with the main part of the energy shifted to later times, reduction of the maximum amplitude and a considerable lack of the high frequency content.

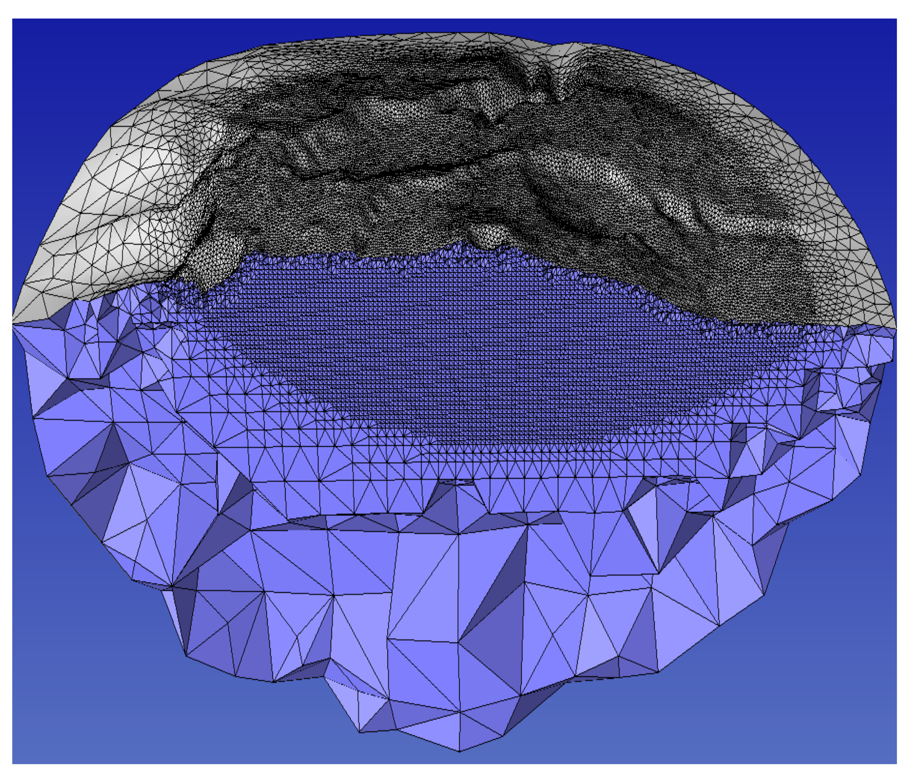
Different factors may explain this path effect; the steep local topography close to the summit, a scattering body which may represent the hydrothermal system and the reservoir located quite shallow, or even some layering extended just on the top of the volcano.

4. CREATING AND MESHING THE GEOMETRY



Starting from a DEM the ***geometry*** is created bottom-up: refers to an approach where one first creates the vertices, connects those to form edges and connects the edges to create faces. In order to avoid boundary reflections we enlarge the geometry applying a Gaussian taper. The intersection of this surface with a sphere finally creates the geometry.

Concerning the ***meshing*** process, in order to delimit a zone where we want to obtain accurate synthetic seismograms we use a refined sphere close to the summit of the volcano (the seismic hypocentre should be included in this region). The size of these elements will determine the highest frequency our simulation can resolved. To avoid numerical noise reflections produced by the coarsening we must fix a low propagation rate value.

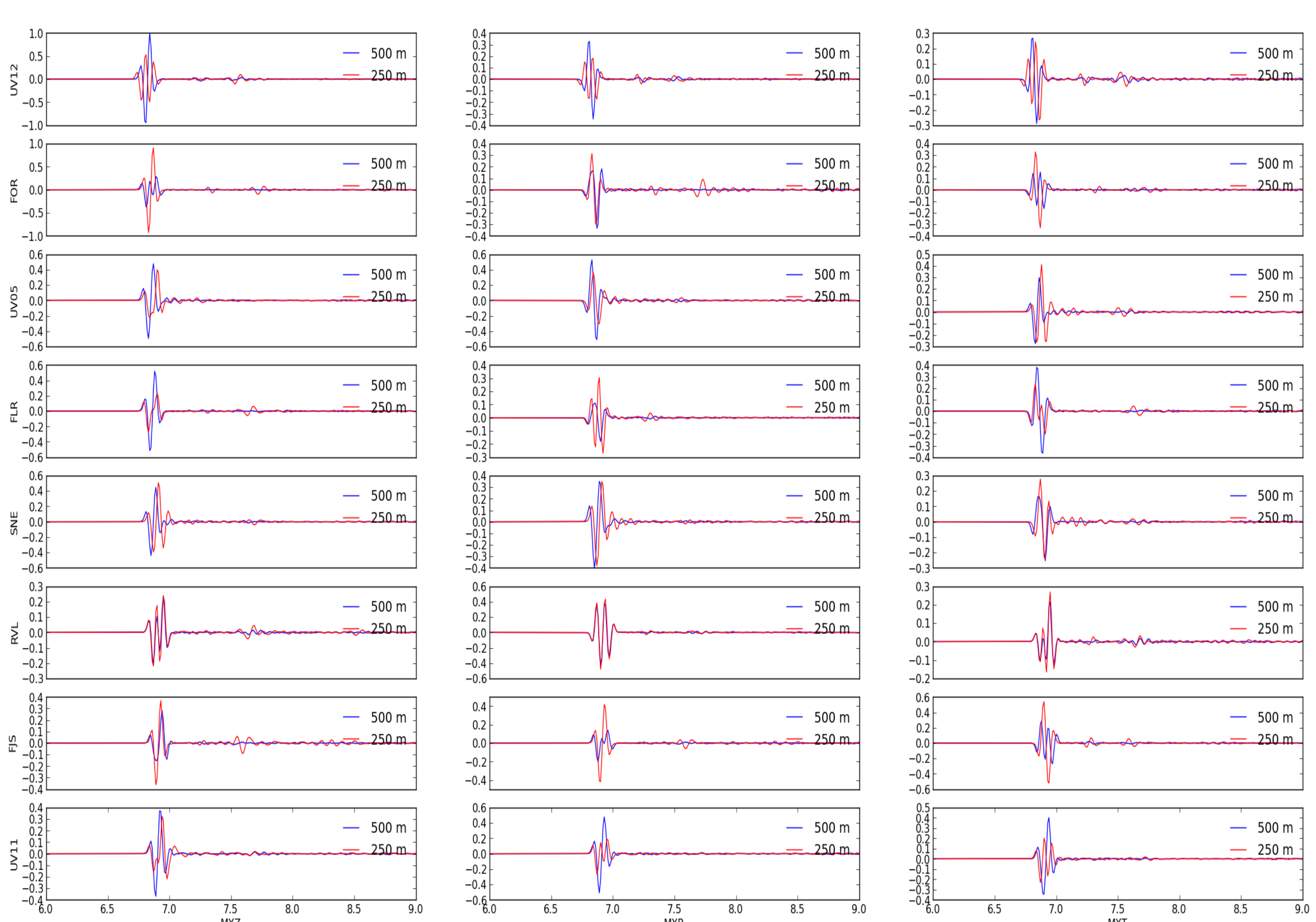


3. ADER-DG METHOD

ADER-DG numerical method reveals as an appropriate one to handle the complex geometries that volcanic wave propagation involves. We mention some of its most important features:

1. *Tetrahedral meshes to approximate complex 3D model geometries.*
2. *Acoustic, elastic, viscoelastic, poroelastic and anisotropic material to approximate realistic geological subsurface properties.*
3. *Arbitrarily high approximation order in time and space to produce reliable and sufficiently accurate synthetic seismograms.*
4. *Explicit local time step algorithm, each element is running its own optimal time step length to reduce computational time*

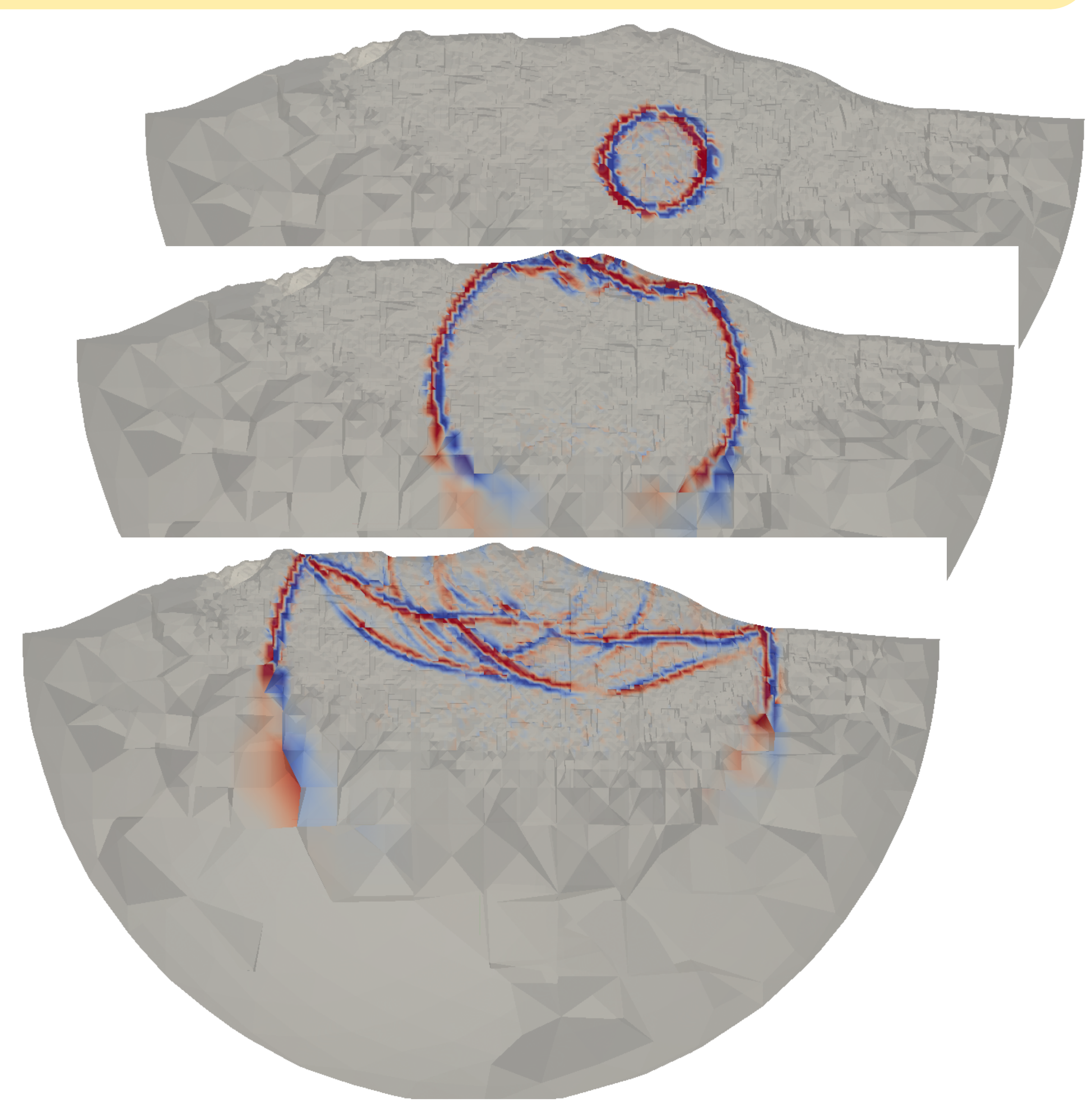
5. WAVE PROPAGATION DEPENDING ON TOPOGRAPHY



We compare two simulations with different topography resolutions (500 m and 250 m), using an event 1190 m bsl and located just below the summit (the same one that section Scattering at Piton de la Fournaise shows). We use an explosive source mechanism. The highest frequency our numerical domain can resolve is 10 Hz.

Some conclusions can be inferred from the seismograms shown on the left: topography does not seem to produce such a drastic effect on the coda (at least working in this frequency/ resolution range), the stations on the summit are not dramatically affected by the local steep topography, increasing the topography resolution modify slightly the seismograms. On the right, we plot the wavefield for the 250 m resolution simulation, it can be observed how the wavefield is significant affected by topography.

These results reveal the importance of including in our model all the complexity that a volcano involves in order to emulate at some point the observed seismograms. In addition to reach higher frequencies, the still ongoing project pretends to incorporate some other scattering mechanisms that may explain the phenomenon already described in Piton de la Fournaise.



ACKNOWLEDGEMENTS

We are grateful to the Observatoire Volcanologique du Piton de La Fournaise (Institut de Physique du Globe de Paris) for avoiding us complete access to the Piton de la Fournaise data.
We thank as well to the computing infrastructure of LRZ (Computer Center for Munich's Universities).