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Active structures and thermal state of the Piton de la Fournaise summit revealed by multi-methods high resolution imaging

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Our understanding of dynamic volcanic processes (fluid transfers at depth and eruptions, collapses and sliding, etc.) relies directly on our knowledge of the geometries of magmatic and hydrothermal systems, mechanical heterogeneities and how these structures evolve in time. Imaging the internal structure and temporal dynamics of volcanoes still represents a real challenge to univocally identify the processes that govern their evolution, including eruptive precursors, instabilities phenomena, surface manifestations and their repercussions. It is therefore necessary to more rigorously constrain the geometry and the spatio-temporal dynamics of these structures, and their activation at different depths.

The behaviour of these structural volcanic features strongly depends on physical parameters such as temperature and fluid composition that can be assessed using a range of complementary ground and remote observations. Among these, geophysical methods provide images of the internal structure, which can subsequently be translated in terms of geological structure and evolution. Such constraints are also necessary to provide more realistic numerical models. Recent improvements to the available suite of the instrumentation for volcanological studies, including field geophysics (ground and airborne-Unmanned Aerial Vehicles, UAVs), remote sensing methods and numerical capabilities, allows us to build even more comprehensive analyses of such terrestrial phenomena. In addition, combining several spatial (local and more regional) and temporal scales (one-off studies, time lapse through reiterations, time series) help to better follow the dynamics of the edifices, anticipate eruptive crises and associated hazards.

Here we focus on the highly active and well monitored Piton de la Fournaise laboratory volcano, which is an excellent case study to develop and apply new methodologies in order to address both scientific and societal issues. Amongst the most significant parameters, recent studies have evidenced the potential of magnetic field measurements in imaging thermal anomalies (strong influence of temperature on magnetic measurements) and mechanical heterogeneities (fracturing-alteration at depth). Electrical resistivity is also a powerful tool in volcanic contexts, being very sensitive to fluid contents and particularly well suited to image the shallow structure of a volcanic edifice through, for example, innovative 3D surveys, or more in-depth using magnetotellurics measurements. Based on the analysis of combined recent reiterations of ground magnetic

measurements, UAV magnetic and thermal infrared acquisitions, as well as high resolution electrical resistivity measurements, we focus on the 3D structure and recent evolution of the summit activity at Piton de la Fournaise, using additional constraints such as seismicity and deformation (InSAR inverse modelling).

This study confirms that detecting resistivity and magnetization anomalies, and quantifying their spatiotemporal evolution, can provide powerful tools for imaging volcanic systems at various scales and for providing warning of associated hazards. It also highlights the necessity for 4D monitoring of volcanic edifices using this method to provide greater precision, an important issue that is now made possible using UAV and near real time analyses.

These observational datasets aim to be integrated in open databases distributed through French and European research structures and infrastructures, namely the National Volcanology Observation Service (CNRS-INSU), Epos-France and Data Terra Research Infrastructures, as well as the EPOS VOLC-TCS.

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