Detection of subsurface airflow at Miyakejima and Piton de la Fournaise volcanoes from micro-meteorological and thermal data

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Introduction. The recent discovery of convective subsurface airflow within unsaturated planetary soils [1,2] provides for the first time insights into the atmosphere-soil exchanges within permeable volcanoes. The characteristics of the aerothermal system lying within the unsaturated zone, its occurence in volcanoes on Earth, its ability to transport heat during quiescent periods and the perturbation of this system before eruptions are the key questions we want to address following this discovery. In this study, we present several observations of convective airflow through surface-exposed fractures and permeable soils located at Miyakejima and Piton de la Fournaise (PdF) volcanoes from micrometeorological and thermal data. The measurements were realized in a daily and a seasonal basis.

Subsurface airflow within Miyakejima

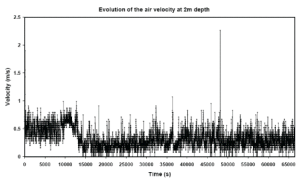


Figure 1. Velocity of the ascending airflow at the center of the fracture (2.5 m depth). The measurements began at 3 p.m. and stopped at 10 a.m. the next day.

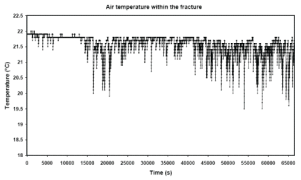


Figure 2. Temperature of the ascending airflow at the center of the fracture (2.5 m depth). The minimum atmospheric temperature was 5 degrees celcius.

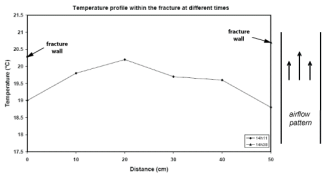


Figure 3. Daytime temperature transect across the fracture aperture at 1m depth measured with 6 thermometers.

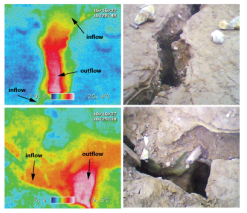


Figure 4. Daytime thermal images at two different locations of the fracture taken at noon. Note the hot and cold regions along the fracture, revealing air outflows and inflows [4].

Winter 2010

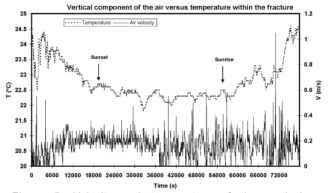


Figure 5. Velocity and temperature of the vertical component of the airflow at 2.5 m depth within the fracture.

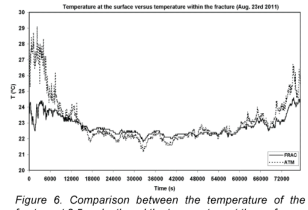
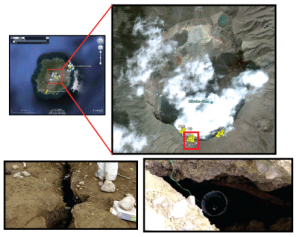


Figure 6. Comparison between the temperature of the fracture at 2.5 m depth and the temperature at the surface.

Summer 2011



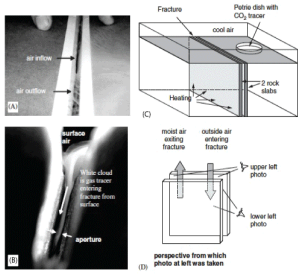


Figure 7. Analog experiment of air convection within parallel slabs [3]. (A) Tracer along the opening of the fracture revealing air inflows and outflows; (B) CO2 gas tracer movement between the slabs; (C) Experimental apparatus; (D) Perpective from which the 2 photos in (A) and (B) were taken.

Subsurface airflow within Piton de la Fournaise

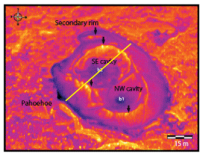


Figure 8. Aerial thermal image of the old inactive Formica Leo cone taken just before sunrise [1]. Hot areas are bright, while cold areas are dark. The temperature contrast between the rim and the crater bottom is 4-5 degrees.

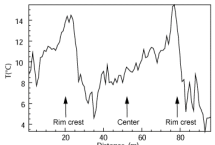


Figure 9. 30 cm-depth temperature profile at the SE crater. The temperature is maximum at the rims, while it is minimum at the center of the crater.

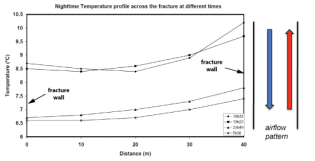


Figure 11. Nighttime temperature transect across the fracture aperture realized with 6 thermometers for 4 different times (austral summer). A hot part is observed at the right wall, which may correspond to air outflow along the walls of the fracture.

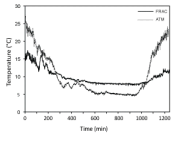


Figure 12. Evolution of the temperature at 2.5 m depth and in the atmosphere at the same location (the measurements began at 2 p.m. until 10 a.m. the next day).

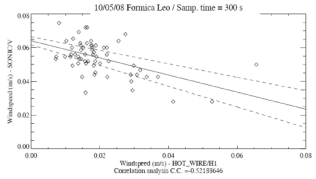
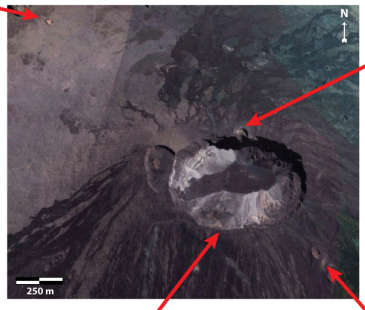


Figure 10. Air velocity experiment above the soil of the bottom of the SE crater using an ultrasonic anemometer. The vertical component is important, while the horizontal one is weak. It proves that air enters the bottom of the cone when there is no wind.



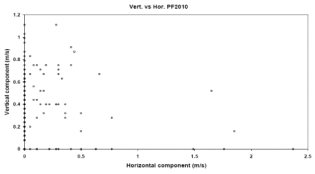
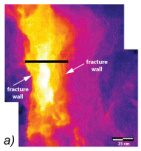
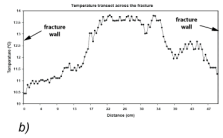


Figure 13. Vertical component of the airflow vs horizontal component at 2.5 m depth at the center of the fracture acquired with two high precision propeller anemometers. The vertical components are several tens of cm/s. The significant horizontal velocity may also suggest a longitudinal component of the convective cell at depth.





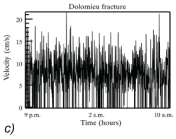
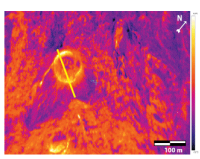


Figure 14. a) Nighttime thermal image of a decameter sized fracture taken just before sunrise in austral winter. b) Temperature profile taken from the thermal image. c) Evolution of the velocity at 2 m depth during the diurnal cycle. The convective pattern is close to the one observed at Miyakejima in winter. The convective pattern is the same than the one observed at the summit of Miyakejima volcano.



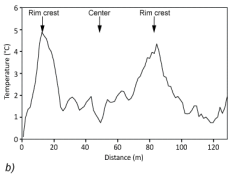


Figure 15 a) Aerial thermal image of the inactive 1966 Maillard cone taken just before sunrise; b) Temperature profile across the cone obtained from the thermal image. As for Formica Leo cone, hot rims and cold bottom are observed. The temperature contrast between the rim and the crater bottom is 4-5 degrees.

Conclusion. A subsurface aerothermal system has been detected within the permeable soils and fractures of Miyakejima and PdF. Further work will be dedicated to the understanding of the hydrodynamic processes as well as the influence of the external parameters (especially pressure) on the convective signal. This discovery may have important implications for the thermal budget of volcanoes, but also for the thermal behavior of the atmospheric bounday layer.

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References. [1] Antoine et al., JVGR (2009); [2] Antoine et al., Icarus (2011); [3] Nachshon et al., 2008