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A statistical approach to the thermal analysis at fumarole fields using infrared images

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In the last decades, volcanology has evolved significantly, allowing for an improved understanding of volcanic processes preceding, accompanying and following eruptive events. Thermal imaging data, especially when used together with other monitoring techniques (such as seismicity, GPS measurements, and gas emissions), help to determine the nature of volcanic hazards. Between 2013 and 2015, four thermal surveys of the Vulcano Fossa fumarole field have been carried out. The fluid geochemistry of the target area and the time variation of the maximum temperature of the fluids released by the steaming vents have been well defined during the last decades and a great amount of scientific papers discussing interpretative models of the hydrothermal and magmatic systems feeding the fumaroles are available. The sequences of thermal images were recorded from a fixed view point 400 m (38°24.111' N 14°57.721' E), using a handheld infrared camera. The field surveys aimed to define the areal extension of thermal anomalies. The probability plots revealed different populations of data in each survey.
The temperature space variability can be inferred to variable components of heat transport (radiative, convective, conductive) participating in the heat exchange occurring at the ground surface. The variation of shallow permeability of the ground and of the thermal capacity of the exposed surfaces are the main causes of space variability of exposed surfaces.
The enlargement of the exhaling area and/or an increase of thermal anomaly surrounding the main fumarole vents (due to steam heating from the bottom source) can highlight significant increases of thermal release even when the maximum temperature of fumarole fluids falls. It has occurred in the last years in the fumarole in the inner slope, like FA fumarole where t dropped from 700°C in 1993 to the actual 250 °C but at the same time the area of steam emission abruptly changed.
Responding to thermodynamic basic principles the exchange of energy drives each component towards thermal equilibrium. Infrared cameras allow thermal anomalies to be spotted in an instant, but in order to correctly interpret the thermal images great caution should be paid, since retrieved apparent temperatures are affected by a number of factors including emissivity and surface roughness of the object, viewing angle, atmospheric effects, pathlength, effects of sun radiation (reflection and/or heating), presence of volcanic gas, aerosols and air-borne ash along the pathlength, instrumental noise and aberrations, and, particularly for volcanic targets, thermal heterogeneity of the target at the sub-pixel scale. The sum of these influences substantially control the radiation detected by the thermal camera, generally resulting in a significant underestimation of the actual thermodynamic temperature of the target. A statistical methodology was chosen to quantify the thermal anomalies in a steaming ground and it could provide a basis for an indirect temperature monitoring tool in fumarole fields.