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A novel approach for monitoring hydrothermal systems by continuous magnetotelluric observations

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Understanding the behavior and the evolution of hydrothermal systems is of great interest for both scientific and commercial purposes, such as volcanic hazard assessment and geothermal energy exploitation. To this aim, a novel approach based on continuous magnetotelluric (MT) data is proposed for characterizing and monitoring hydrothermal systems. The use of such an exploration method has a double advance: it allows i) to monitor time variations of the electrical resistivity distribution in the underground, closely related to changes in the physical state of the hydrothermal system, ii) to investigate different depth ranges (from few hundred meters to hundreds of kilometers) without the aid of artificial sources, as the energy for the magnetotelluric technique is from natural electromagnetic source of external origin.
In order to test the effectiveness of the proposed approach, a sensitivity analysis has been performed by simulating different evolution scenarios of a hydrothermal system and calculating the MT response at different time intervals corresponding to different stages of the system dynamics. The study proved to be essential for understanding the degree of sensitivity of the MT method to changes of the hydrothermal system with reference to its possible temporal evolutions. Indeed, the results of tests carried out for a hydrothermal system in an active volcanic area, show that if the variations of the system are exclusively determined by an increase in the rate of the fluid flow emitted by the hydrothermal source, the variations of the parameters that affect the resistivity (i.e. gas saturation and temperature) are too slow to be appreciated through continuous MT observations within a time period useful for monitoring purposes. This result, if confirmed also for other types of systems currently under study, would provide important indications for the monitoring of hydrothermal systems of active volcanoes. In fact, it suggests that the geophysical methods based on resistivity measurements are not able to detect an increase in the rate of the fluid flow from the source in a relatively short time. On the contrary, if the variations of the hydrothermal system are determined by changes in the permeability distribution of the system, caused, for example, by an increase in pressure or flow of fluids emitted by the source and/or by a variation of their physico-chemical properties, significant variations in the gas saturation distribution are observed over a period ranging from three months to a year and a half, which give rise to variations in the resistivity values that can be appreciated through MT observations in the same time interval. This result is of considerable interest, as it proves the usefulness of the MT method in identifying possible changes in the hydraulic parameters of the hydrothermal system, likely related to changes in its dynamics.