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Local magnetic anomalies in rugged volcanic terrain hamper a reliable recording of the Earth's magnetic field in lavas

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Lavas are regarded to be excellent recorders of the ambient magnetic field at the time of their cooling; their magnetization is therefore often interpreted as a reliable representation of the Earth's magnetic field. These interpretations are the bases of our understanding of both the long- and short-term behavior of the Earth's magnetic field. Paleomagnetic measurements on samples from recent lava flows for which the paleofield is known, however, often considerably deviate from the direct observations of the paleofield. Mt. Etna lavas are arguably the most notorious example, with several studies done by different research groups systematically reporting deviations up to $\pm 15^{\circ}$ in direction, and paleointensities are generally underestimated by up to 30%. Over the past decades the causes of these deviations were sought in rock-magnetic properties of the samples, or in alterations induced by the paleointensity experiments.

Here we assess the influence of local magnetic anomalies caused by the magnetization of underlying flows on the ambient magnetic field that a new lava would record. To this end we developed a new device to rapidly measure local magnetic anomalies with unsurpassed accuracy and ease of use (contribution EGU2019-4343), and used it to directly measure the ambient magnetic field just above (20-180 cm) present flows of Mt. Etna. We measured deviations up to $\pm 15^{\circ}$ in direction, and the intensity of the paleofield is generally lower than the current reference field. Our observations are therefore in good agreement with the results of the paleomagnetic experiments on Mt. Etna lavas, and we conclude that local magnetic anomalies arising from underlying flows are a satisfying explanation for the puzzling paleomagnetic results often reported for Mt. Etna.

To further assess the influence of local magnetic anomalies in volcanic terrain –also for less rugged flows– we modelled the magnetic anomalies on Mt. Etna using a finite element potential field model based on a high-resolution digital elevation model of the flows we mapped. We used the known magnetization of the rocks as input, and we were able to broadly reconstruct our field-measurements. We then used our model to determine local magnetic anomalies above a variety of flow geometries, including smoother flows often associated with hot-spot volcanism. It is reassuring that only the rather specific rugged terrain typical to Mt. Etna, with gullies in the order of tens of meters wide and deep, produce the considerable geomagnetic anomalies observed. Nevertheless, the influence of local geomagnetic anomalies on paleomagnetic studies in rugged volcanic terrain is not to be underestimated.