A decade of SO_2 flux and thermal observations at Mount Etna: Insights into magma supply, storage and eruptive activity

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Volcanic gases represent a primary expression of magmatic activity and provide key insights into the state of a volcanic system. Among volcanic gases, sulphur dioxide (SO_2) is widely recognized as a key tracer of shallow degassing dynamics and magma transport within the upper portion of plumbing systems, becoming a valuable tracer of transitions from quiescence to eruptive phases. Here we present an integrated analysis of nearly a decade (2015-2024) of SO_2 flux observations at Mount Etna obtained from a permanent ground-based UV Camera system, combined with satellite-derived thermal fluxes. This long-term dataset allows us to explore the relationship between degassing behaviour and thermal output across different eruptive states.

Using satellite thermal radiance, we identify the Etna's major eruptive phases, which account for more than 90% of the total thermal energy released during the study period. Comparison with the SO_2 flux time series reveals a characteristic escalation pattern associated with these phases: mean fluxes increase from ~1957 t/d during inter-eruptive periods to ~2500 t/d in the pre- and post-eruptive intervals, peaking at ~3800 t/d during eruptive activity. This SO_2 escalation is successfully detected from the employed UV Camera system in 61%, 72% and 72% of the studied pre-, syn-, and post-eruptive periods respectively, with increasing success for larger eruptions.

By converting SO_2 emissions and thermal radiance into magma supply and discharge rates, we further quantify the long-term imbalance between magma input and output at Mont Etna. Our results indicate that, over the investigated decade, only ~28% of the magma supplied to the shallow plumbing system was ultimately erupted, while the remaining ~72% accumulated as excess magma within the

volcanic edifice. This imbalance reflects distinct stages of accumulation and withdrawal, consistent with GNSS (Global Navigation Satellite System) observations from a continuous geodetic network.

Overall, our results demonstrate that the combined analysis of ground-based gas measurements and satellite thermal observations provides a powerful framework for investigating magma transport processes and eruptive dynamics at open-vent volcanoes.