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Long-term gas observations track the early unrest phases of open-vent basaltic volcanoes

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At open-vent basaltic volcanoes, resolving the activity escalation that heralds larger, potentially harmful eruptions is challenged by the persistent mild ordinary activity, which often masks the precursory unrest signals related to heightened magma transport from depth. Gas (SO_2 and CO_2) fluxes at surface are controlled by rate of magma transport and degassing within the magma plumbing system, and thus constitute key parameters to infer deep magma budget and dynamics.

Here, we use several year-long (2014-present) gas observations at Etna and Stromboli volcanoes, in Sicily, to provide new evidence for the utility of long-term instrumental gas monitoring in real-time detecting the early phase of unrest prior eruption, and for characterizing syn-eruptive dynamics. To this aim, we use information from a gas monitoring network of permanent ultraviolet (UV) cameras and automatic Multi-Gas instruments that, combined with geophysical observations, allow characterizing changes in degassing and eruptive dynamics at high temporal/spatial resolution.

Our results show that the paroxysmal (lava fountaining) explosions that periodically interrupted persistent open-vent activity on Etna (during 2014-2020) were accompanied by systematic, repetitive SO_2 emission patterns prior, during, and after eruptions. These allow us identifying the characteristic pre- syn- and post- eruptive degassing regimes, and to establish thresholds in the SO_2 flux record that mark phases of unrest.

On Stromboli, the much improved temporal/spatial resolution of UV cameras allows resolving the escalation of regular strombolian activity, and its concentration toward its North-east crater, that heralds onset of effusive eruptions. During effusive eruption, although magma level drops in the conduit and explosive summit activity ceases, UV camera observations can still detect explosive gas bursts deep in the conduit while no infrasonic activity is detected. Combining the UV camera-derived SO_2 fluxes with CO_2/SO_2 ratio records measured by the Multi-Gas, the CO_2 flux can be

inferred. We find that such CO_2 flux time-series can allow tracking degassing of deeply stored mafic magma months before Stromboli's eruptions. We finally show that remotely sensed gas emission and thermal activity can be combined together to characterize the dynamics of shallow magmatic system prior to and during unrest, ultimately helping to define timing of magma re-charging events driving the eruptions.