EGU24-10708, updated on 20 May 2024
https://doi.org/10.5194/egusphere-egu24-10708
EGU General Assembly 2024

Synergistic Approach to Robustly Reconstruct Eruption Plume Dynamics: Application to Campi Flegrei, Italy

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Explosive volcanic eruptions can inject high quantities of magmatic materials into the atmosphere representing a risk to life and society. To quantify the potential impacts of a future eruption or to forecast what will happen in the next few hours when a volcano is erupting, atmospheric dispersion models are commonly used providing important information for civil protection and other stakeholders. Spatiotemporal distributions of volcanic ash in volcanic plumes are used as an input by a numerical simulation of tephra dispersal and are called eruption source parameters (ESPs). They have been poorly constrained and therefore their variation between models affects volcanic tephra hazard assessment. Since the goodness of ESPs increases with knowledge of the dynamics of eruptive columns, reconstruction of volcanic columns from past eruptions will improve the assessment of volcanic hazards for future eruptions.

In this work we take advantage of recent advances in computational capabilities and modeling in order to robustly reconstruct the dynamics of eruption columns from past eruptions. We do that by applying a synergistic approach between atmospheric dispersion models capable of reproducing the transport of volcanic ash due to atmospheric wind, eruption cloud dynamics models that resolve the ascending and the horizontal spreading of umbrella cloud, and inversion methods able to estimate ESPs using geological data information of tephra deposits.

Specifically, we use the latest version of the ash dispersal model FALL3D that allows us to determine EPSs by inverting field data using the novel GNC (Gaussian with non-negative constants) ensemble-based inversion method, and the eruption cloud dynamics model SK-3D that accurately resolves the turbulence of the volcanic plumes.

As an application, we focus on Campi Flegrei (CF) caldera, in Italy. CF is currently a densely populated area under busy air traffic routes where the monitoring system of the Vesuvius Observatory highlights some variations in the state of the volcanic activity. CF has generated several explosive eruptions in recent geological times, including the ~39 ka Campanian Ignimbrite (CI) super-eruption that is the largest explosive eruption in Europe in the last 200 ka. To reconstruct the CI super-eruption and assess such a huge eruption in CF, we apply our methodology to the geological data associated with this eruption.