Inverse modelling of volcanic emissions and their use for quantitative dispersion modeling: the 12th March 2021 Etna's eruption

A. Kampouri[1,2], O. Tichý[3], N. Evangeliou[4], V. Amiridis[1], S. Solomos[1,5], A. Gialitaki[1,6], E. Marinou[1,6], A. Gkikas[1], E. Proestakis[1], S. Scollo[7], L. Merucci[7], L. Mona[8], N. Papagiannopoulos[8] and P. Zanis[2]

[1]IAASARS, National Observatory of Athens, Athens, Greece.
[2]Department of Meteorology and Climatology, Aristotle University of Thessaloniki, Thessaloniki, Greece.
[3]The Czech Academy of Sciences, Institute of Information Theory and Automation, Prague, Czech Republic.
[4] Norwegian Institute for Air Research (NILU), Instituttveien 18, 2007 Kjeller, Norway.
[5]Research Centre for Atmospheric Physics and Climatology, Academy of Athens, Athens, Greece.
[6]Laboratory of Atmospheric Physics, Aristotle University of Thessaloniki, Thessaloniki, Greece.
[7]Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Etneo, Catania, Italy.
[8]Consiglio Nazionale delle Ricerche, Istituto di Metodologie per l'Analisi Ambientale, Potenza, Italy.
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Presenting author email: akampouri@noa.gr

Modeling the dispersion of volcanic particles released during explosive eruptions is crucially dependent on the knowledge of the source term of the eruption that is and the source strength as a function of altitude and time. Forecasting volcanic ash transport is vital for aviation but rather inaccurate for quantitative predictions of the fate of volcanic particles emissions.

Here we demonstrate an inverse modeling framework that couples the output of a Lagrangian dispersion model with remote sensing observations to estimate the emission rates of volcanic particles released from the Etna eruption. We use the LS-APC inversion algorithm (Tichy et al (2020)) where the distance between the model and observations is optimized under the assumption that the source term is either sparse or smooth, while the algorithm alters between these two characteristics. The Bayesian formalism allows the algorithm to estimate these characteristics together with the source term itself and thus regularize the inversion problem. This methodology uses source receptor relationships as an input from the FLEXPART (flexible particle dispersion) model (Brioude et al (2013); Kampouri et al (2021)) constrained by ground-based Lidar measurements and satellite observations of SO_2 and ash emissions.

The case study analyzed here refers to the Etna eruption on 12th March 2021, well captured by the lidar station of the PANGEA observatory located at the Antikythera island in southwest Greece, downwind of the Etna. A dense aerosol layer, suspending in the height range between 7.5 and 12.5 km (19:30 - 21:30 UTC), has been captured by the Polly^{XT} lidar (Fig. 1b). The corresponding, FLEXPART-WRF vertical time-height cross-sections of the volcanic ash concentrations (Fig. 1a) show a similar pattern with respect to the observed volcanic aerosol layer over the PANGEA observatory. For the inversion simulations, we also use data acquired by the Spin-stabilised Enhanced Visible and Infrared Imager (SEVIRI) instrument, mounted on the Meteosat Second Generation (MSG) geostationary satellite. The aforementioned observations serve as a priori source information to estimate the volcanic ash and SO_2 source strength, depended on altitude and time, coupled with the output of the FLEXPART model.

Our results are efficient for real-time application and could supply ash forecasting models with an accurate estimation of the mass rate of very fine ash during explosive eruptions. Improved forecasts would then allow for a more effective emergency preparedness for aviation to ensure safety during volcanic eruptions.

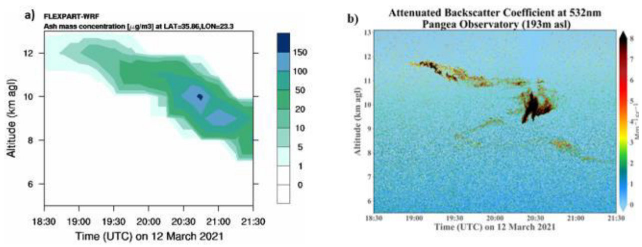

Figure 1. (a) Model vertical cross-sections of volcanic ash and (b) PANGEA-NOA attenuated backscatter coefficient at 532 nm at Antikythera on 12 March 2021.

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