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Inversion techniques on volcanic emissions and the use for quantitative dispersion modeling: The case of Etna eruption on 12 March 2021

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Modeling the dispersion of volcanic particles released during explosive eruptions is crucially dependent on the knowledge of the source term of the eruption 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 particle 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 an 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. The Bayesian formalism allows the algorithm to estimate these characteristics together with the source term itself and thus normalize the inversion problem. This methodology uses source receptor relationships as an input from the FLEXPART (flexible particle dispersion) model 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 12 March 2021, with the volcanic plume being well captured by the lidar measurements of the PANGEA observatory located at Antikythera island in southwest Greece. 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. 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, depending 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 of the dispersed volcanic plumes following the suggested inverse modeling framework would then allow for more effective emergency preparedness for aviation to ensure safety during volcanic eruptions.

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