Combining four dimensional variational data assimilation and particle filtering for estimating volcanic ash emissions

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Estimating volcanic ash emissions is a very challenging task due to limited monitoring capacities of the ash plume and nonlinear processes in the atmosphere, which renders application of source strength and injection height estimations difficult. Most models, which estimate volcanic ash emissions, make strong simplifications of the dispersion of volcanic ash and corresponding atmospheric processes.

The objective of this work is to estimate volcanic ash emissions and simulate the ensuing dispersion applying a full chemistry transport model in a hybrid approach by using its adjoint as well as an ensemble of model runs to quantify forecast uncertainties. Therefore, the four dimensional variational data assimilation version of the EURAD-IM chemistry transport model is extended to include a Sequential Importance Resampling Smoother (SIRS), introducing novel weighting and resampling strategies. In the main SIRS step the ensemble members exchange high rated emission patterns while rejecting emission patterns with low value for the forecast. The emission profiles of the ensemble members are perturbed afterwards to guarantee different emissions for all ensemble members.

First identical twin experiments show the ability of the system to estimate the temporal and vertical distribution of volcanic ash emissions. The 4D-var data assimilation algorithm of the new system additionally provides quantitative emission estimation.