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Deriving the concentration of airborne ash with a CAS-DPOL instrument: assessing uncertainties introduced by the instrument design

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Explosive volcanic eruptions inject large amounts of gas and particles into the atmosphere resulting in strong impacts on anthropic systems and climate.

Fine ash particles in suspension, even if at low concentrations, are a serious aviation safety hazard.

A key point to predict the dispersion and deposition of volcanic ash is the knowledge of emitted mass and its particle size distribution. Usually the deposit is used to characterize the source but a large uncertainty is present for fine and very fine ash particles which are usually not well preserved. Conversely, satellite observations provide only column-integrated information and are strongly sensitive to cloud conditions above the ash plumes.

Consequently, in situ measurements are fundamental to extend our knowledge on ash clouds, their properties, and interactions over the vertical extent of the atmosphere.

Different in-situ instruments are available covering different particle size ranges using a variety of measurement techniques. Depending on the measurement technique, artefacts due to instrument setup and ambient conditions can strongly modify the measured number concentration and size distribution of the airborne particles. It is fundamental to correct for those effects to quantify the uncertainty associated with the measurement.

Here we evaluate the potential of our optical light-scattering spectrometer CAS-DPOL to detect airborne mineral dust and volcanic ash (in the size range between 0.7μm and 50μm) and to provide a reliable estimation of the mass concentration, investigating the associate uncertainty.

The CAS-DPOL instrument sizes particles by detecting the light scattered off the particle into a defined angle. The associated uncertainty depends on the optical instrument design and on unknown particles characteristics such as shape and material.

Indirect measurements of mass concentrations are statistically reconstructed using the air flow velocity. Therefore, the detected concentration is strongly sensitive to the sample flow and on the mechanical instrument design.

Using a fluid dynamics model coupled with an optical model we analyze the effects of instrument design on the measurement, identify measurement uncertainties and recommend strategies to reduce the uncertainties.

The two main results are that the optical design of the CAS-DPOL aerosol spectrometer can lead to an under-counting bias of up to 40% for larger particles and an over-counting bias of 20%–30% for smaller particles. Secondly, depending on how the instrument is mounted on the plane, the sampling can be subject to a significantly larger size selection bias than typically recognized, especially if the mounting leads to irregular sampling conditions.

To correct both problems a new correction algorithm is described generalizing the results also to other optical particle counters.

Finally, a comparison study is presented showing the effects on mass estimation and radiative forcing for uncorrected and corrected data also stating the resulting uncertainty.