Inverse Methods: a Powerful Tool for Evaluating Aerosol Data, Exemplified on Cases With Relevance for the Atmosphere and the Aerosol Climate Effect

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INTRODUCTION

For a complete description of a given aerosol, more than one parameter is necessary, e.g. parameters concerning size distribution, chemical composition, and particle morphology. On the other hand, most instruments measuring aerosol properties are sensitive mostly to one parameter, but cross-sensitive to others. These cross-sensitivities are often eliminated by assumptions during data evaluation, inducing systematic uncertainties in the results.

The use of assumptions can be reduced by combining the information of several instruments on the same aerosol and using inverse methods for interpretation of the data. The presentation focuses on two application examples of these methods. The first example concerns a size distribution inversion algorithm that combines data from several instruments into one size distribution. The second example deals with an algorithm that retrieves the aerosol asymmetry parameter (with respect to particle scattering) from measurements of the aerosol absorption and spectral scattering and hemispheric backscattering coefficients, thereby providing a set of parameters that completely describes an aerosol with respect to its direct climate effect.

INVERSION OF SIZE DISTRIBUTION FROM SIZE SENSITIVE DATA

If the particle size distribution of an aerosol has to be measured over an extended size range for $D_p <$ 1 µm, especially if high temporal resolution is required (aircraft based measurements of atmospheric aerosol), several measurement principles have to be combined to cover the size range. An algorithm is presented that inverts data from more than one instrument into one consistent particle size distribution without assuming a shape of the size distribution or an initial guess (Fiebig et al., 2005). The propagation of the errors of the input data to the resulting size distribution is calculated using Monte-Carlo-Methods. A prerequisite for applying the algorithm is the careful characterisation of each involved instrument with respect to its transfer function, i.e. the fraction of particles that is registered by the instrument as a function of particle size.

Figure 1 shows an example where the algorithm was applied to data collected on a lab generated soot test aerosol. One size distribution plotted was inverted from data provided by a differential mobility analyser (DMA) scanning the size distribution. The other size distribution was inverted from data of several condensation particle counters (CPCs) with different lower activation threshold diameters. The activation threshold diameter was varied by changing the supersaturation in the CPC and by installing diffusion screens upstream of the CPC.

Other data examples presented will cover aerosols emitted by ship engines collected on a ship engine test rig, and aerosols sampled by aircraft while following an ageing contrail and measuring the effect of contrail ageing on the interstitial aerosol.

RETRIEVAL OF ASYMMETRY PARAMETER FROM MEASURED SPECTRAL OPTICAL PROPERTIES

The second example of an inverse method illustrates how even more complex parameterisations

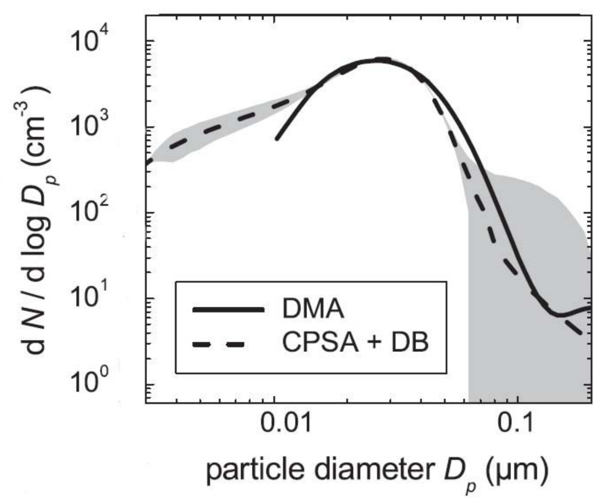

Figure 1: Particle size distributions of lab generated soot aerosol, both obtained with the described size distribution inversion algorithm, once based on DMA data, once based on CPCs, partly equipped with diffusion screens. The uncertainty of the DMA distribution is contained in the line width, the uncertainty of the CPC distribution is shaded in grey (from Fiebig et al., 2005).

of the aerosol microphysical properties can be constrained by combining instruments and applying inverse methods. At the stations of the NOAA ESRL aerosol monitoring network, the particle absorption coefficient at one wavelength and the particle scattering and hemispheric backscattering coefficients at three wavelengths are routinely measured for two size ranges of aerodynamic diameter, $D_{p,aer}$ < 1 µm and $D_{p,aer}$ < 10 µm. From this data, the particle extinction coefficient and the single scattering albedo can be readily calculated. However, for a complete set of optical parameters describing the direct aerosol effect, the asymmetry parameter is missing.

An algorithm was developed that uses the described dataset to constrain a microphysical parameterisation of the aerosol, i.e. the spectral scattering coefficient constrains the particle size distribution, the hemispheric backscattering coefficient constrains the water content, and the absorption coefficient constrains the soot content of the aerosol (Fiebig and Ogren, 2006). From this microphysical parameterisation, the spectral asymmetry parameter is calculated, providing a complete set of optical parameters describing the aerosol direct effect. Figure 2 quantifies the accuracy of the algorithm. For a set of pre-defined test aerosol cases from the literature, the asymmetry was on the one hand calculated directly (x-axis in Figure 2). On the other hand, synthetic data of the instrument set used at the NOAA ESRL stations was generated, used as input for the algorithm, and the asymmetry parameter retrieved (y-axis in Figure2). The retrieved asymmetry parameter agrees with the true one on average within ~1%.

Other examples of more complex applications of inverse methods presented will concern desert dust aerosols sampled during the Saharan Mineral Dust Experiment (SAMUM) that will be conducted in May and June 2006 in Morocco.

CONCLUSIONS

The examples show that inverse methods have the potential to improve the interpretation of aerosol data, minimise the use of assumptions necessary in aerosol data evaluation, and provide a quantification of systematic uncertainties induced by the assumptions remaining in the evaluation. They are a valuable tool in quantifying the aerosol climate effect and may be of interest also in other disciplines of aerosol research.

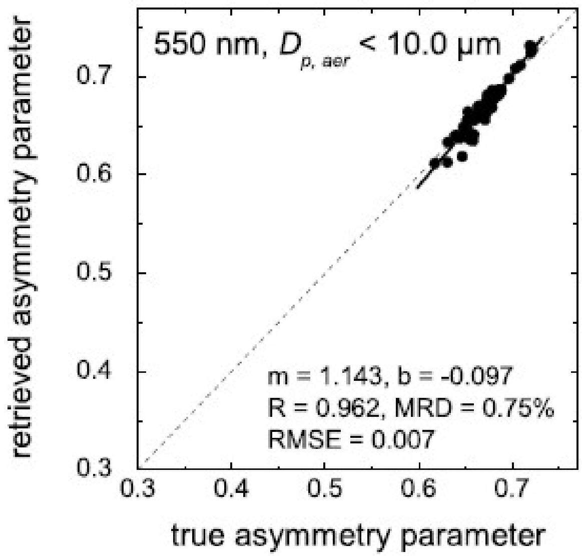

Figure 2: Comparison of true asymmetry parameter and asymmetry parameter retrieved with described algorithm from synthetic data for a set of test aerosol cases from literature (from Fiebig and Ogren, 2006).

Keywords: *atmospheric aerosol, inverse methods, aerosol optical properties*

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