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Statistical estimation of stratospheric particle size distribution by combining optical modelling and lidar scattering measurements

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Abstract. A method for estimating the stratospheric particle size distribution from multiwavelength lidar measurements is presented. It is based on matching measured and model-simulated backscatter coefficients. The lidar backscatter coefficients measured at the three commonly used wavelengths 355, 532 and 1064 nm are compared to a precomputed look-up table of model-calculated values. The optical model assumes that particles are spherical and that their size distribution is unimodal. This inverse problem is not trivial because the optical model is highly non-linear with a strong sensitivity to the size distribution parameters in some cases. The errors in the lidar backscatter coefficients are explicitly taken into account in the estimation. The method takes advantage of the statistical properties of the possible solution cluster to identify the most probable size distribution parameters. In order to discard model-simulated outliers resulting from the strong non-linearity of the model, solutions farther than one standard deviation of the median values of the solution cluster are filtered out, because the most probable solution is expected to be in the densest part of the cluster. Within the filtered solution cluster, the estimation algorithm minimizes a cost function of the misfit between measurements and model simulations.

Two validation cases are presented on Polar Stratospheric Cloud (PSC) events detected above the ALOMAR observatory (69° N – Norway). A first validation is performed against optical particle counter measurements carried out in January 1996. In non-depolarizing regions of the cloud (i.e. spherical particles), the parameters of an unimodal size distribution and those of the optically dominant mode of a bimodal size distribution are quite successfully retrieved, especially for the median radius and the geometrical standard deviation. As expected, the algorithm performs poorly when solid particles drive the backscatter coefficient. A small bias is identified in modelling the refractive index when compared to previous works that inferred PSC type Ib refractive indices. The accuracy of the size distribution retrieval is improved when the refractive index is set to the value inferred in the reference paper.

Our results are then compared to values retrieved with another similar method that does not account for the effect of the measurements errors and the non-linearity of the optical model on the likelihood of the solution. The case considered is a liquid PSC observed over northern Scandinavia on January 2005. An excellent agreement is found between the two methods

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when our algorithm is applied without any statistical filtering of the solution cluster. However, the solution for the geometrical standard deviation appears to be rather unlikely with a value close to unity (σ≈1.04). When our algorithm is applied with solution filtering, a more realistic value of the standard deviation (σ≈1.27) is found. This highlights the importance of taking into account the non linearity of the model together with the lidar errors, when estimating particle size distribution parameters from lidar measurements.

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