Retrieval of Aerosol Properties from Multiwavelength Raman Lidar Data Based on Maximum Likelihood Estimation

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The retrieval of aerosol properties, such as particle size distribution (PSD) and complex refractive index m (m=n-i*k), from extinction (α) and backscattering (β) data of multiwavelength (MW) Raman lidars was widely studied in recent 2 decades with applicable algorithms proposed. Since a lidar retrieval system is probably underdetermined, tens of thousands of solutions with fitting errors less than measurement uncertainty are derived by these algorithms, and special effort should be paid to identify the physically reasonable solution space. In this study, we retrieve the PSD and m from MW Raman lidar data with maximum likelihood estimation (MLE). Firstly, a set of inversion windows constraining the particle size range are set up and a unique solution of PSD and m is retrieved with MLE for each inversion window. Then, the solutions meeting certain selection criteria are selected and averaged as the final solution. There are several highlights in this method: 1) m is retrieved together with PSD by non-linear fitting, which largely reduces the number of individual solutions; 2) the underdetermination are solved by adding smoothness constraints on PSD and a priori estimate of m; 3) the positiveness of all retrieval parameters is guaranteed by logarithmic transformation; 4) the uncertainty of the retrieved parameters can be assessed by considering the propagation of the measurement errors in the iteration process, which provides novel insights into error analysis.

So far, numerical simulations have been conducted, in which synthetic optical data generated by monomodal and bimodal log-normal size distributions with different n's (varying from 1.4 to 1.6) and k's (varying from 0.001 to 0.02) are inverted. For 80% of all the simulated cases, the retrieval biases of particle volume concentration, effective radius and n are less than ±22%, ±24% and ±0.04, respectively. We found k is the hardest to be retrieved and a reliable a priori constrain is needed to ensure its retrieval accuracy. Simulations are being carried out to analyze the influences of measurement errors on both the averaged solution and individual solutions corresponding to different inversion windows.

We applied our new algorithm to the Californian smoke layers over North of France detected by LILAS, a high-performance MW Raman-Polarization-Fluorescent lidar subject to the ATOLL (Atmospheric Observatory of liLLe) platform. Satisfying results were derived. The optical data were fitted with an error of 20%. We are integrating the algorithm into the AUSTRAL (AUtomated Server for the TReatment of Atmospheric Lidars) processing framework to more efficiently evaluate the code with real lidar data and finally implement automatic retrievals. As the principle of MLE makes it a flexible and generalized retrieval algorithm, future steps will incorporate more lidar-measured quantities such as 3 depolarization ratios and different scattering models. Besides, fluorescent information by LILAS can also be considered as extra constraints on aerosol types to improve the retrieval.