Regularizing Software for Aerosol Particles

Authors : Christine Böckmann, Julia Rosemann

Abstract : We present an inversion algorithm that is used in the European Aerosol Lidar Network for the inversion of data collected with multi-wavelength Raman lidar. These instruments measure backscatter coefficients at 355, 532, and 1064 nm, and extinction coefficients at 355 and 532 nm. The algorithm is based on manually controlled inversion of optical data which allows for detailed sensitivity studies and thus provides us with comparably high quality of the derived data products. The algorithm allows us to derive particle effective radius, volume, surface-area concentration with comparably high confidence. The retrieval of the real and imaginary parts of the complex refractive index still is a challenge in view of the accuracy required for these parameters in climate change studies in which light-absorption needs to be known with high accuracy. Single-scattering albedo (SSA) can be computed from the retrieve microphysical parameters and allows us to categorize aerosols into high and low absorbing aerosols. From mathematical point of view the algorithm is based on the concept of using truncated singular value decomposition as regularization method. This method was adapted to work for the retrieval of the particle size distribution function (PSD) and is called hybrid regularization technique since it is using a triple of regularization parameters. The inversion of an ill-posed problem, such as the retrieval of the PSD, is always a challenging task because very small measurement errors will be amplified most often hugely during the solution process unless an appropriate regularization method is used. Even using a regularization method is difficult since appropriate regularization parameters have to be determined. Therefore, in a next stage of our work we decided to use two regularization techniques in parallel for comparison purpose. The second method is an iterative regularization method based on Pade iteration. Here, the number of iteration steps serves as the regularization parameter. We successfully developed a semi-automated software for spherical particles which is able to run even on a parallel processor machine. From a mathematical point of view, it is also very important (as selection criteria for an appropriate regularization method) to investigate the degree of ill-posedness of the problem which we found is a moderate ill-posedness. We computed the optical data from mono-modal logarithmic PSD and investigated particles of spherical shape in our simulations. We considered particle radii as large as 6 nm which does not only cover the size range of particles in the fine-mode fraction of naturally occurring PSD but also covers a part of the coarse-mode fraction of PSD. We considered errors of 15% in the simulation studies. For the SSA, 100% of all cases achieve relative errors below 12%. In more detail, 87% of all cases for 355 nm and 88% of all cases for 532 nm are well below 6%. With respect to the absolute error for non- and weak-absorbing particles with real parts 1.5 and 1.6 in all modes the accuracy limit +/- 0.03 is achieved. In sum, 70% of all cases stay below +/-0.03 which is sufficient for climate change studies.

Keywords : aerosol particles, inverse problem, microphysical particle properties, regularization
Conference Title : ICMSSC 2016 : International Conference on Mathematics, Statistics and Scientific Computing
Conference Location : Kuala Lumpur, Malaysia
Conference Dates : February 11-12, 2016