A Polarimetric Multiple Scattering Lidar Model Based on Poisson Distribution

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For a given probing wavelength, the lidar signal is a function of the aerosol size distribution, of the cloud range, of the cloud optical depth and of the lidar Field-of-View (FoV). Multiple Scattering (MS) is always present in lidar measurements, even for very small optical depths. The higher the optical depth, the higher the MS contribution to the signal. It is one of the causes of depolarization of the lidar signal for water clouds. Its effects can be reduced by restricting the lidar FoV to values close to the laser beam divergence. Often considered as a nuisance, its exploitation can lead to information on cloud micro-physic such as estimation of droplets size and better estimation of the extinction coefficient.
In addition to Monte Carlo (MC) simulations, several models have been developed to simulate the MS contribution to the lidar signal. A good review of the different models prior to 2005 can be found in Ref. [1]. Since then, important research papers have been published that have led to better exploitation of MS especially from space lidar data. A good review is presented in Ref. [2].
These researches rely on mathematical modelling of MS effects. Given the nature of the problem, modeling MS becomes quickly complicated. In this paper, we present a relatively simple model based on Poisson statistics and the equivalent-medium theorem. Poisson statistics are used to determine the scattering order of photons at a given optical depth. The model takes into account the droplet effective size and the lidar FoV. Mie scattering phase functions are used and convoluted to reproduce forward MS orders up to 10. Since the equivalent-medium theorem is used, a single backscattering is considered. In addition, the calculations are also done with modeling the forward scattering Mie function as the summation of 2 gaussians and the backscattering depolarization parameter as a function of the forward scattering diffraction peak width.
The model is referred to as *Multiple Scattering Poisson* (MSP) Lidar model. The model is applied to two standard models of cumulus clouds and on moderate radiation fog. The contribution of the different scattering orders to the MS lidar signal and to the depolarization of the signal is compared to MC simulations. Good agreement is demonstrated for the total lidar signal and for the depolarization of the signal for FoVs of 1 mrad and 12 mrad.

1. Bissonnette, L. R., “Lidar and multiple scattering,” in: Lidar rangeresolved optical remote sensing of the atmosphere, edited by: C. Weitkamp, Springer series in optical sciences, 102, ISBN0387400753, 456 pp., 2005

2. Jimenez, C., Ansmann, A., Engelmann, R., Donovan, D., Malinka, A., Schmidt, J., Seifert, P., and Wandinger, U., “ The dual-field-of-view polarization lidar technique: a new concept in monitoring aerosol effects in liquid-water clouds – theoretical framework,” Atmos. Chem. Phys., 20, 15247–15263, 2020