Depolarization Calibration of the Wyoming Cloud Lidar with two fields of view

Decheng Wu¹, Min Deng², Zhiwen Wang², Zhenzhu Wang¹, Bangxin Wang¹,³, Zhiqing Zhong¹, Dong Liu¹, Chenbo Xie¹, Yingjian Wang¹,³

¹Key Laboratory of Atmospheric Optics, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei 230031, China; ²Department of Atmospheric Science, University of Wyoming, Laramie, Wyoming 82071, USA; ³University of Science and Technology of China, Hefei 230026, China.

*Corresponding author: dchwu@aiofm.ac.cn

Abstract: Aerosol and cloud play key roles in the global climate change, and the understanding of their interaction is still low. The microphysical properties of aerosols and cloud droplets are very important for studying aerosol-cloud interaction. The aerosols microphysical properties could be retrieved from multi-wavelength Raman lidar and multi-wavelength high spectrum resolution lidar. The liquid cloud droplet effective size and liquid water content could be retrieved from multi-scattering signal from cloud, which could be measured by using a two field-of view (FOV) lidar with depolarization sensitivity. The depolarization ratios of the liquid cloud droplets measured by lidar related to the multi-scattering from the droplets. Hence, the depolarization calibration is a key step in the retrieval of liquid cloud droplet effective size by using a two FOV lidar. In this paper, the calibration method and result of the Wyoming Cloud Lidar with two FOVs (WCL-2FOV) were described. During the depolarization calibration, three parameters will be determined:

1. The final half-wave plate axis direction \( \theta_0 \). When the half-wave plate axis was rotated to this direction, the linear polarization direction of the transmitted laser is parallel with the p-vector or s-vector of the polarization cube.
2. The gain ratio. The gain ratio represented the difference of the two polarization channels in optical effectivity and electrical gain.
3. The correction of the depolarization induced by the lidar. The optical elements in the lidar will alter the polarization state of the received scattering signal, and it would induce a large over estimate of depolarization from cloud. This impact needed be corrected in the data processing.

A half-wave plate was employed in the laser transmitter to alter the linear polarization direction of the transmitted laser for the depolarization calibration. The depolarization calibration was carried out in fair day, and the atmosphere is quite stable during the calibration. Firstly, rotated the half-wave plate roughly, and found a rough half-wave plate axis direction. Secondly, rotated the half-wave continuously in a step of 1 degree, and recorded the lidar measurements with different half-wave plate axis direction \( \theta \), make sure that the measurements with half-wave plate axis direction of \( \theta_0 \) and \( \theta_0 + 22.5^\circ \) (or \( \theta_0 - 22.5^\circ \)) are implemented. Thirdly, the depolarization ratios at a proper altitude with high signal-to-noise ratio (SNR) were calculated, and a depolarization ratios-\( \theta \) curve could be obtained. The lowest point of depolarization ratios-\( \theta \) curve could be found exactly by fitting the depolarization ratios-\( \theta \) curve, and the \( \theta \) at the lowest point is \( \theta_0 \). By using the fitted depolarization ratios value at \( \theta_0 + 22.5^\circ \) or \( \theta_0 - 22.5^\circ \), the gain ratio would be calculated. Finally, rotated the half-wave plate axis direction to \( \theta_0 \), and measured the depolarization ratio of the molecular in the aerosol-free ozone by using the determined gain ratio. The correction of the depolarization induced by the lidar could be retrieved from the measured molecular depolarization ratio. This depolarization correction also could be retrieved from the depolarization ratio measurement in the small FOV branch at the liquid cloud bottom.