

Design of a Polarimetric Imaging System for Laboratory Small-scale Cloud Droplet Size Distribution Characterization

Zaid Bakri^{a,*}, Claudio Mazzoleni^a, Raymond Shaw^a, and Daniel Miller^{b,c}

^aPhysics Department, Michigan Technological University, 1400 Townsend Dr, Houghton, MI 49931, USA

^bNASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

^cGESTAR-II, University of Maryland, Baltimore, MD, 21228 USA

*Presenting author (zbakri@mtu.edu)

Cloud droplet size distribution (DSD) is a fundamental property that dictates clouds' radiative properties and influences global climate. While satellite and airborne polarimetric measurements of clouds provide crucial DSD information on scales ranging from kilometers down to 100 meters, they often average out critical small-scale inhomogeneities [1-3]. Therefore, there has been a growing demand for measurements at significantly smaller (centimeter) scales, especially for laboratory studies in controlled cloud environments [4-6].

To fill this gap, we are developing a novel polarimetric imaging system for small-scale DSD mapping. The setup employs a polarized camera to measure vertically and horizontally polarized light scattered within a region of the cloudbow angular range ($\sim 139^\circ$ – 145°), chosen for its high sensitivity to droplet effective radius as well as effective variance [7,8]. The retrieval of the DSD is based on Lorenz-Mie Mueller matrix simulations. Our prototype polarimetric imaging system uses two three-wavelength RGB lasers (640 nm, 525 nm, 450 nm) in horizontal and vertical polarization states. The polarized camera is positioned at a fixed scattering angle centered at 142.5° relative to the incident laser beam to measure the polarization of the scattered light. The system is designed to map a $\sim 10 \times 10 \times 1$ cm³ volume of the target cloud, allowing for a spatial resolution of ~ 1 cm and a temporal resolution of less than 1 s. This geometry and the camera's field-of-view result in an angular resolution of approximately 2 degrees per centimeter along the target. Here, we will present the technical details and geometry of our instrument. We will also discuss preliminary results demonstrating the system's ability to distinguish between different DSDs. We will conclude by providing future outlooks for this measurement technique.

References

- [1] Dubovik, O., Li, Z., Mishchenko, M. I., Tanré, D., Karol, Y., Bojkov, B., et al. (2019). Polarimetric remote sensing of atmospheric aerosols: Instruments, methodologies, results, and perspectives. *Journal of Quantitative Spectroscopy and Radiative Transfer*, 224, 474–511. <https://doi.org/10.1016/j.jqsrt.2018.11.024>
- [2] McBride, B. A., Vanderlei Martins, J., Barbosa, H. M. J., Birmingham, W., & Remer, L. A. (2020). Spatial distribution of cloud droplet size properties from Airborne Hyper-Angular Rainbow Polarimeter (AirHARP) measurements. *Atmospheric Measurement Techniques*, 13(4), 1777–1796. <https://doi.org/10.5194/amt-13-1777-2020>
- [3] Pörtge, V., Kölling, T., Weber, A., Volkmer, L., Emde, C., Zinner, T., et al. (2023). High-spatial-resolution retrieval of cloud droplet size distribution from polarized observations of the

- cloudbow. *Atmospheric Measurement Techniques*, 16(3), 645–667. <https://doi.org/10.5194/amt-16-645-2023>
- [4] Allwayin, N., Larsen, M. L., Glienke, S., & Shaw, R. A. (n.d.). *Locally narrow droplet size distributions are ubiquitous in stratocumulus clouds*. Retrieved from <https://www.science.org>
- [5] Yang, F., Meng Sua, Y., Zheng, Z. I., Anderson, J., Fahandezh Sadi, H. I., Min Yeom, J. I., et al. (2025). High-resolution lidar observations of sedimentation-induced size sorting of droplets near a laboratory cloud top. <https://doi.org/10.1073/pnas>
- [6] Shaw, R. A., Ovchinnikov, M., Sedlacek, A. J., Yang, F., Anderson, J., Bakri, Z., et al. (2026). A concept of a convection-cloud chamber to study aerosol-cloud-drizzle interactions. *Bulletin of the American Meteorological Society*. <https://doi.org/10.1175/BAMS-D-25-0113.1>
- [7] Miller, D. J., Zhang, Z., Platnick, S., Ackerman, A. S., Werner, F., Cornet, C., & Knobelspiesse, K. (2018). Comparisons of bispectral and polarimetric retrievals of marine boundary layer cloud microphysics: Case studies using a LES-satellite retrieval simulator. *Atmospheric Measurement Techniques*, 11(6), 3689–3715. <https://doi.org/10.5194/amt-11-3689-2018>
- [8] Hansen, J., Travis, L. D. (1974). Hansen and Travis 1974. *Space Science Reviews*, 16, 527–610. <https://doi.org/https://doi.org/10.1007/BF00168069>

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