# Theoretical extension of universal forward and backward Monte Carlo radiative transfer modeling for passive and active polarization observation simulations

**Zhen Wang[a,*], Shengcheng Cui[b], Zhibo Zhang[c], Jun Yang[a], Haiyang Gao[a], and Feng Zhang[d]**

[a]*Key Laboratory for Aerosol–CloudPrecipitation of China Meteorological Administration, School of Atmospheric Physics, Nanjing University of Information Science and Technology, Nanjing 210044, China*

[b]*Key Laboratory of Atmospheric Optics, Anhui Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Hefei 230031, China*

[c]*Physics Department, University of Maryland, Baltimore County, Baltimore, MD 21250, USA*

[d]*School of Atmospheric Sciences, Nanjing University of Information Science and Technology, Nanjing 210044, China*

[*]*Presenting author (intersharp@126.com)*

The theoretical framework of universal forward and backward Monte Carlo radiative transfer modeling in [1] is extended for passive and active polarization observation simulations [2]. It is built upon newly derived forward and backward vector scattering order-dependent integral radiative transfer equations (IRTEs). The unified mathematical formalism not only establishes the design of object-oriented software architecture, but also speeds up software development via the reuse of developed scalar code. The polarization simulations are implemented with the addition of the Stokes vector and the Mueller matrix weight tracing schemes. To improve numerical performance order by order, the extension implementation of hybrid scattering order-dependent variance reduction techniques are given detailedly, with a focus on the formulation of scattering phase matrix truncation on the basis of remodeling vector IRTEs. To enrich polarization simulation features, not only scattering operators but also source vector function and detector response matrix function are formulated in unified mathematical forms for the hierarchies organization of various atmosphere, surface, source and detector classes. The framework was fully implemented in MSCART model. For passive simulation, it not only can handle all 1D and 3D test cases in Phases A and B of the IPRT intercomparison project using forward and backward algorithm, but also simulate polarized radiance in a specified direction at a specified position using backward algorithm. For active simulation, lidar backscatter range-resolved signals can be simulated using forward algorithm. The source package is freely available for research purpose from the corresponding author, with online documentation from https://intersharp.gitlab.io/mscart-docs.

## References

[1] Wang, Z., S. Cui, J. Yang, H. Gao, C. Liu, and Z. Zhang, 2017: A novel hybrid scattering order-dependent variance reduction method for Monte Carlo simulations of radiative transfer in cloudy atmosphere. *J. Quant. Spectrosc. Radiat. Transfer.* **189**, 283–302.

[2] Wang, Z., S. Cui, Z. Zhang, J. Yang, H. Gao, and F. Zhang, 2019: Theoretical extension of universal forward and backward Monte Carlo radiative transfer modeling for passive and active polarization observation simulations (submitted).

Preferred mode of presentation: Oral