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The physical-optics method using different diffraction equations: comparison of numerical results

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At present, the problem of light scattering by ice crystals of cirrus clouds is solved either in the geometrical optics approximation or by solving the Maxwell equations. On the one hand, there the different methods such as FDTD, DDA, and T-matrix are used. Unfortunately, state-of-the-art computing resources allow them to effectively obtain the solution of Maxwell's equations only for small particles with a typical size less than, say, 30 microns. On the other hand, the solution of this problem obtained in the framework of geometrical optics approximations contains a singularity in the backscattering direction that makes the lidar signal interpretation very difficult. This singularity is the result of neglecting the wave nature of light, specifically, the diffraction effect. The necessity to take the diffraction effects into account led to the creation of the physical optics approximation, but there are several ways to take this effect into account. Thus, for example in [1] Jackson writes down the convenient vectorial diffraction Smythe formula that is applicable to both perpendicular and slope screens. Another way is to use the conventional Kirchhoff approximation.

The talk provides a detailed comparison of these options of taking the diffraction effects into account. The results have been checked by the reciprocity principle. It has been shown that for the case of a plane-parallel beam diffraction on a perpendicular screen all these formulae lead to practically the same result at small diffraction angles. It has been found out that for the case of diffraction on a slope screen the vectorial diffraction Smythe formula leads to significant violation of the reciprocity principle. At the same time the vectorial diffraction Smythe formula with our modification and the Kirchhoff approximation give practically equal results. These formulae give different results only for scattering angles close to 90°.

In this talk the software implementation of the physical optics method developed by the authors is presented as an open-source free software. The implementation is based on the beam-splitting algorithm and is capable to use all three formulae to take the diffraction into account. The code of the algorithm is written in C++ as a library that facilitates the inclusion of the physical optics approximation into a third-party program.

[1] J. D. Jackson, Classical Electrodynamics, 3rd Edition. New York: Wiley; 1998.