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On the implementation of the discrete ordinate method with small-angle approximation for a pseudo-spherical atmosphere

D. Efremenko, A. Doicu, D. Loyola, and T. Trautmann

Remote Sensing Technology Institute, German Aerospace Center, Oberpfaffenhofen, Wessling, Germany (Dmitry.Efremenko@dlr.de)

Numerical problems appear when solving the radiative transfer equation for systems with strong anisotropic scattering. To avoid oscillations in the solution a large number of discrete ordinates is required. As a consequence, the computing time increases considerably with $O(N^3)$, where N is the number of discrete ordinates. The performance can be improved partially by the delta-M method of Wiscombe [1], but this approach distorts the initial boundary problem and can lead to errors in small viewing angles. The efficiency of the discrete ordinate method with small-angle approximation for analyzing systems containing clouds and coarsest fraction of aerosol has been demonstrated by Budak and Korkin [2].

In this work we extend the plan-parallel version of the discrete ordinate method with small-angle approximation, as described in [2], to a pseudo-spherical atmosphere. The conventional pseudo-spherical technique relies on the separation of the total radiance into the direct solar beam and the diffuse radiance [3];the direct solar radiance is treated in a spherical geometry, while the diffuse radiance is computed in a plane-parallel geometry. Taking into account that in the discrete ordinate method with small-angle approximation, the radiance is separated into an 'anisotropic' and a smooth part, and that the direct solar beam is already included into anisotropic part, we introduce a pseudo-spherical correction by substracting the direct solar beam in a plane-parallel geometry and adding it in a pseudo-spherical geometry.

In our simulations we considered a scenario which is typically for the UV/UIS instruments like GOME-2: a spectral interval between 315 nm and 335 nm, and an inhomogeneous atmosphere containing a cloud layer with an asymmetry parameter of 0.9. The numerical results evidenced that the differences between the pseudo-spherical and the plan-parallel models are of about 10 % for an incident angle of 80 degrees, 1 % for 65 degrees and less than 0.3 % for 50 degrees. In addition to these simulations, we compared two version of the discrete ordinate method, namely the discrete ordinate methods with matrix exponential (DOME) [4] and the small-angle approximation. The numerical analysis revealed that the small-angle approximation yields results of acceptable accuracy (of about 1%) for a significantly lower number of discrete ordinates.

References

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