Correction of cloud optical thickness retrievals from airborne and satellite measurements and its application to cloud tomography

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3D effects (such as escape of light through cloud sides) can cause substantial underestimation of cloud optical thickness (COT) in airborne and satellite retrievals based on 1D radiative transfer computations, such as widely used bispectral (Nakajima-King) technique. We proposed a simple linear correction of the retrieved COT with the renormalization factor $(1 + A)$ dependent on the cloud's aspect ratio A [1]. The latter is an effective measure of how much light can escape through cloud sides, while in plane-parallel computations (corresponding to zero aspect ratio) radiation can leave the cloud only through its top and bottom.

Our assumption was successfully tested using synthetic 3D RT data. The testing cloud dataset consisted of two parts: (1) three LES-generated Cu clouds with aspect ratios close to 1 or 2; and (2) 12-case dataset of simplified box clouds with aspect ratios ranging from 0.5 to 3 and COT ranging from 10 to 50. These clouds were used in 3D RT model to generate radiative fields that were sampled into virtual datasets simulating measurements of the Research Scanning Polarimeter (RSP) flying above the clouds. The RSP's COT retrieval algorithm is a modification of bispectral technique with droplet effective radius taken from polarimetric retrievals, while LUTs based on 1D RT are used to derive COT values from nadir-view total reflectances. Our tests showed that the initial RSP-derived COT values were substantially smaller than the COTs computed basing on LES microphysics, while the renormalization has dramatically improved the RSP's retrieval accuracy.

In order to justify our COT correction proposition we introduced a heuristic ``block model'' of 3D radiative effects and demonstrated that the functional form of the renormalization factor is consistent with the process of radiation escape from cloud sides in an essentially 3D geometry. We also extended the block model to the case of single-layer broken cloud field with radiative interaction between the neighboring clouds. In this case the renormalization factor depends also on the distance between clouds. The latter model was tested on an extensive set of 3D RT simulations.

The proposed renormalization technique was used to improve tomographic retrievals [2] from the real RSP measurements made during NASA's Cloud, Aerosol and Monsoon Processes Philippines Experiment ($CAMP^2Ex$) conducted in the vicinity of the Philippines during the Southwest Monsoon (August–September 2019).

References

[1] Alexandrov, M.D., B. Cairns, C. Emde, and B. van Diedenhoven, 2024: Correction of cloud optical thickness retrievals from nadir reflectances in the presence of 3D radiative effects. Part I: Concept and tests on 3D RT simulations. *Front. Remote Sens.*, *submitted*.

[2] Alexandrov, M.D., C. Emde, B. van Diedenhoven, and B. Cairns, 2021: Application of Radon transform to multi-angle measurements made by the Research Scanning Polarimeter: A new approach to cloud tomography. Part I: Theory and tests on simulated data. *Front. Remote Sens.*, **2**, 791130.

Preferred mode of presentation: Oral