A FAST HYBRID (3D/1D) MODEL FOR THERMAL RADIATIVE TRANSFER IN CIRRUS VIA SUCCESSIVE ORDERS OF SCATTERING

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Cirrus clouds are relevant components of the Earth's climate and radiation budget, but their role is still poorly understood. Many satellites are currently dedicated to cloud observation to retrieve their properties. Concerning cirrus clouds, Thermal InfraRed (TIR) retrieval techniques have demonstrated better accuracy than Visible/Near InfraRed (VNIR) and ShortWave-InfraRed (SWIR) reflectance channels techniques as long as the cirrus is optically thin with small ice crystals. However, current global operational algorithms assume that cloudy pixels are horizontally homogeneous (Plane Parallel and Homogeneous Approximation (PPHA)) and independent (Independent Pixel Approximation (IPA)). The impact of these approximations on ice cloud retrievals needs to be understood and, as far as possible, corrected. To better understand the effects of cloud heterogeneity on TOA thermal radiative quantities and potentially correct cloud parameter retrievals, 3D RT simulations are essential. They allow us to model the impact of cloud heterogeneity on cloud scattering for given microphysical/optical properties, conditional that these properties are realistic. However, full 3D RT calculations are generally very time consuming, particularly in Monte Carlo simulations.

The aim of this paper is to better understand the contribution of the different orders of scattering in the TIR atmospheric window, as has already been done in the solar spectrum. We focus our attention on the contributions of successive orders of scattering inside a heterogeneous cirrus cloud, with different scattering properties, for two of the three channels of the Imaging Infrared Radiometer on CALIPSO at 8.65 μm and 12.05 μm. Realistic 3-D cirri are modeled with the 3DCLOUD code, and top-of-atmosphere radiances are simulated by the 3-D Monte Carlo radiative transfer (RT) algorithm 3DMCPOL. Differences between 3D and 1D RT are discussed in terms of contribution of the successive orders of cloud scattering to the total radiance observed at TOA. We present a hybrid model (FATTIRE-C), based on exact 3D direct emission and 1D first scattering order in each homogenized column, followed by an empirical adjustment linearly dependent on the optical thickness to radically accelerate the 3D RT computations. We anticipate that a future deterministic implementation of the hybrid model will be fast enough to process multiangle thermal imagery in a practical tomographic reconstruction of 3-D cirrus fields.

Keywords: 3D thermal infrared radiative transfer, Monte Carlo, Cirrus

