Evaluation of 3D effects in satellite cloud property retrievals using simulated observations

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Due to its simplicity and computational speed, the 1D plane-parallel radiative transfer model enjoys widespread popularity in the satellite remote sensing of cloud properties such as optical thickness and droplet effective radius. The 1D approach reduces natural complexity by treating clouds as horizontally infinite, plane-parallel, homogeneous layers and, thus, ignores 3D effects arising from cloud top structure, side illumination, shadowing, and horizontal photon transport. These simplifications might work well for extensive stratocumulus sheets but are less suitable for broken, heterogeneous cloud fields, where the complex 3D nature of clouds can introduce significant retrieval errors at certain sun/view geometries. This study is a contribution to the long-term community effort of understanding, quantifying, and statistically correcting such 3D retrieval biases. Our two-pronged investigation is based on analyzing actual measurements from existing satellite sensors as well as creating synthetic observations from high-resolution cloud simulations and realistic 3D radiative transfer models.

We will present Multiangle Imaging SpectroRadiometer (MISR) measurements to evaluate the plane-parallel assumption for individual clouds. A simple angular consistency test can be construed from MISR data that compares the measured anisotropy of cloud reflectance with plane-parallel calculations. A cloud scene is deemed plane-parallel by this test if an optical thickness exists for which 1D model reflectances match measurements at all angles within a prescribed relative tolerance. Results will quantify the applicability of the plane-parallel model as a function of cloud type and geographic region.

Next, we will contrast cloud liquid water path estimates from the Advanced Microwave Scanning Radiometer (AMSR-E) and Moderate Resolution Imaging Spectroradiometer (MODIS) instruments, and interpret the observed retrieval differences in light of the prior angular consistency test. The rational behind this comparison is that while 3D errors can strongly bias MODIS optical estimates, they have only negligible effects on AMSR-E microwave estimates.

Finally, we will analyze synthetic MODIS-type cloud retrievals obtained by combining Large Eddy Simulation (LES) cloud fields with the Spherical Harmonic Discrete Ordinate Method (SHDOM) radiative transfer model. The appeal of such an analysis framework is that it allows the rigorous characterization of retrieval errors by comparing simulated observations with the known model truth. Our dataset comprises reflectances of 700 LES scenes at 200 distinct sun/view geometries. We will quantify 3D errors as a function of cloud heterogeneity and solar/view angles, and demonstrate how the results can be used to statistically correct operational 1D satellite retrievals.