THREE-DIMENSIONAL RADIATIVE TRANSFER CONSIDERATIONS IN THE REMOTE SENSING OF CLOUD PROPERTIES

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Passive shortwave remote sensing of cloud properties is shown to be very sensitive to the three-dimensional morphological structure of the cloud field. This results in significant differences between apparent radiative and hydrological cloud properties, affecting the consistent treatment of clouds and cloud-radiative feedback in climate models.

Viewed globally, most cloud types, including cumuliform, stratiform and cirriform clouds, display this sensitivity. A small subset of global clouds appears to be insensitive to three-dimensional radiative transfer effects, and remote sensing of these clouds can be pursued with high confidence using traditional approaches. For the vast majority of remaining global cloud types, however, consideration of three-dimensional radiative transfer must be incorporated into new remote sensing approaches in order to obtain consistent results.

This is illustrated through recent studies of spectral radiance measurements made nearly simultaneously from nine different viewing directions by the Multiangle Imaging SpectroRadiometer (MISR) on the Terra satellite. These multiangle measurements can be analyzed with varying levels of complexity to obtain improved estimates of cloud albedo and cloud optical depth, even for complex cloud cases. For albedo, the issue is mainly in improved angular models, as functions of solar and viewing direction. For optical depth, the issue is partly to remove biases associated with solar zenith angle, and partly to extend the range of retrievable optical depths beyond their traditional saturation values (≈50). Both the optical depths and angular models are further complicated by their dependence on spatial scale.

An elementary analysis makes use of the multiangle redundancy without direct recourse to three-dimensional radiative transfer, directly improving stochastic estimates of albedo and optical depth. Slightly deeper analysis uncovers the limiting degrees of freedom associated, for example, with surface bidirectional effects and upper-level thin cirrus, and provides a first-order input to a more sophisticated analysis that uses fully fledged reconstructions of the three-dimensional scene and compares it against three-dimensional radiative transfer constraints. The main goal of the latter approach is to obtain better estimates of cloud optical depth, both to remove the bias and to extend the retrievable range.