Characterization of the Radiative Properties of Inhomogeneous Clouds

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One of the major sources of uncertainty in climate-based studies is related to clouds and their influence on the radiative transfer. Two broad issues are of relevance to this problem: 1) the influence of clouds on broadband radiative transfer and thus on cloud energetics and 2) the influence of clouds on spectral transfer and thus on remote sensing applications. The work described here addresses key aspects of both these issues.

One of the key issues in parameterizing cloud radiative processes is to account for the sub-grid scale variability. A common approach for incorporating horizontal cloud inhomogeneity in radiative transfer calculations is the use of cloud fraction. We have attempted to determine the limitations of this approach by performing radiative transfer calculations applied to inhomogeneous clouds embedded in two dimensions. For solar radiation, use of cloud fraction leads to non-unique domain averaged albedos exhibiting significant variations.

We have developed new approximate methods to account for the sub-grid scale variability of clouds on the radiative transfer. This approximate method is based on a first order closure technique. Exploiting the translational invariance of the equation of transfer leads to a one-dimensional, plane-parallel-like equation with a modified source term. This approach results in computational speeds exceeding that of the independent pixel approximation and improved accuracy over the latter as determined by numerical solutions of the two-dimensional transfer equation.

A second key issue is in the application of radiance measurements to infer optical properties of clouds. We have examined the effects of horizontal variability on techniques of detecting cirrus clouds and characterizing their radiative properties. Recent inclusion of a strong water vapor absorption channel, centered at 1.38 mm, and many ice/water absorption channels (e.g., 1.64 mm) in one of the future Earth Observing System (EOS) platforms of a moderate-resolution imaging spectroradiometer (MODIS) will enhance our understanding of cirrus clouds.

The aforementioned spectral channels are used in this study to explore the effects uncertainties in cloud microphysical measurements (e.g., particle size distribution) and cloud inhomogeneity exert on the apparent radiative properties, such as spectral reflectance and heating rates. As in Part I of our previous study, which establishes the foundations of the Fourier Riccati method, cloud extinction and scattering functions are characterized by simple spatial variations with approximate microphysics to facilitate our understanding of their radiative properties.

Results of computations suggest that

- Spatial variations in the scattering and extinction functions of clouds play a greater role in determining spectral reflectance than do particle size distributions.
- Spectral reflectances viewed near nadir are least affected by cloud inhomogeneity.
- Cloud inhomogeneity can give rise to spectral heating rates that differ substantially from their plane-parallel averaged equivalents. Because there are no horizontal flux gradients in uniform clouds, it will be difficult to correct for this deficiency.