Development of a Radiative Cloud Parameterization Scheme of Stratocumulus and Stratus Clouds Which Includes the Impact of Cloud Condensation Nucleus on Cloud Albedo

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A three-dimensional (3-D) model for simulating the effect of enhanced cloud condensation nucleus (CCN) concentrations on stratocumulus clouds is presented. Results of two-dimensional (2-D) tests are discussed for a control run and a sensitivity run where CCN spectra were taken to be typical of clean marine conditions or mildly continental air, respectively. For a fivefold increase in initial CCN concentrations, drop concentrations increased about threefold, effective radii (∇_e) decreased by 40%, while liquid water contents show less significant variations. These results are consistent with both observations and expectations. Detailed radiative calculations done on previous runs showed similar microphysical structure.

Several studies have used methods to simultaneously retrieve the effective radius (R_e) and cloud optical depth from multichannel reflectance measurements (Twomey and Cocks 1982, 1989; Curran and Wu 1982; Nakajima et al. 1991). Results from the Regional Atmospheric Modeling System (RAMS) 2-D simulation were used in a preliminary study of the effects of cloud heterogeneities on the remote sensing of marine stratus cloud properties. The microphysical data from a version of the control run and a run with an increased initial CCN concentration were used in a series of 2-D radiative transfer simulations. The upwelling radiances from the cloud fields were computed from the Spherical Harmonic Spatial Grid (SHSG) model described in Evans (1993).

Estimates of R_e and optical depth from the simulated cloud fields were derived by comparing the 2-D model reflectance functions with the reflectance functions obtained from independent pixel (IP) calculations for a range of effective radii and optical depths. The IP-derived estimates of R_e and optical depth were often noticeably different from the actual values of the cloud properties directly calculated from the RAMS simulation, a result which suggests that the effects of cloud geometry are important to consider in the remote sensing of these cloud properties. In particular, the maximum differences in the IP-derived versus actual R_e for the portions of the cloud with an optical depth greater than four ranged from 30% to 50% in both simulations. The domain-mean optical depth was underestimated by nearly 10%, while the maximum differences between the retrieved and actual optical depths were over 20%.

All results are preliminary. More definitive results must await 3-D simulations planned for later this spring.

References

Curran, R. J., and M. L. C. Wu. 1982. Skylab near-infrared observations of clouds indicating supercooled liquid water droplets. *J. Atmos. Sci.* **39**:635-647.

Cunning, J. B. 1986. The Oklahoma-Kansas Preliminary Regional Experiment for STORM Central. *Bull. Am. Met. Soc.* **67**:1478-1486.

Evans, K. F. 1993. Two dimensional radiative transfer in cloudy atmospheres: The spherical harmonic spatial grid method. *J. Atmos. Sci.* **50**:3111-3124.

Nakajima, T., M. D. King, J. D. Spinhirne, and L. F. Radke. 1991. Determination of the optical thickness and effective particle radius of clouds from reflected solar radiation measurements. Part II: Marine stratocumulus observations. *J. Atmos. Sci.* **48**:728-750.

Twomey, S., and T. Cocks. 1982. Spectral reflectance of clouds in the near-infrared: comparisons of measurements and calculations. *J. Meteor. Soc. Japan* **60**:583-592.

Twomey, S., and T. Cocks. 1989. Remote sensing of cloud parameters from spectral reflectance in the near-infrared. *Beitr. Phys. Atmos.* **62**:172-179.