Invited Presentation

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CLOUD-RADIATIVE INTERACTIONS IN HIGH-RESOLUTION CLOUD-RESOLVING MODELS

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1. INTRODUCTION

High-resolution, limited-domain models have been employed at several institutions to study the basic nature of the interactions between radiation and cloud systems. These studies have treated deep convection, cirrus, and stratocumulus-topped boundary layers, representing many of the climatologically most significant cloud systems.

2. DEEP CONVECTION

Deep convection and its interactions with radiation are under study using two- and three-dimensional nonhydrostatic models. Horizontal resolutions are typically one to five kilometers with domains up to 800 km in two dimensions and 400 km^2 in three dimensions. The resolutions are chosen to resolve individual deep convective elements. Prognostic equations for microphysical components are coupled with radiative transfer. Radiative forcing of the cloud systems is quite large and closely related to the distribution of microphysical quantities. An illustration is provided in Fig. 1, from a three-dimensional integration of the GFDL cloud-resolving model. Note the significant heating at the base of the anvil region and the cooling at the top of the anvil.

Vertical gradients in radiative heating like those in Fig. 1 can destabilize the stratiform portion of convective systems, and this is one of the primary mechanisms of cloud-radiative interaction that have been proposed. Two other mechanisms are (1) radiative destabilization of the large-scale flow in which cloud systems develop and (2) horizontal gradients in radiative heating and cooling between cloudy and clear areas, resulting in circulations which can feedback on the convective system. Solar and longwave forcing can act through these mechanisms to impose a diurnal cycle on convective systems (Xu and Randall, 1995).

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3. CIRRUS

The role of radiation in cirrus clouds has been studied using two-dimensional, shallow-convection models whose vertical and horizontal domains are around five to ten kilometers with resolutions around 100 meters (Starr and Cox, 1985). Net radiative heating rates are comparable in magnitude with those associated with phase changes, with large compensations between solar and longwave effects.

4. BOUNDARY-LAYER CLOUDS

Radiative interactions involving stratocumulus-topped boundary layers have been studied using large-eddy simulation (Moeng *et al.*, 1995). Domains are typically around two kilometers in the horizontal and vertical with resolutions around ten meters. Complex interactions between entrainment, radiation, and evaporative cooling have been identified. Entrainment decreases radiative cooling as a generator of turbulence (reduced water concentrations associated with reduced cooling and negative buoyancy generation), but entrainment increases evaporative cooling and turbulence. Thus, evaporative cooling acts as a positive feedback on entrainment, while radiative cooling is a negative feedback. The large-scale break-up of stratocumulus with weak surface fluxes and weak shear depends on which feedback dominates.

5. CONCLUSION

These cloud-scale interactions involving radiation have significant implications for atmospheric forcing on longer time and larger space scales. Studies with high-resolution, cloud-resolving models are playing a role in developing parameterizations of these processes for climate models.

REFERENCES

Moeng, C.-H., D.H. Lenschow, and D.A. Randall, 1995: Numerical investigations of the roles of radiative and evaporative feedbacks in stratocumulus entrainment and breakup. *J. Atmos. Sci.*, **16**, 2869-2883.

Starr, D. O'C., and S.K. Cox, 1985: Cirrus clouds. Part I. A cirrus cloud model. *J. Atmos. Sci.*, **42**, 2663-2681.

Xu, K.-M., and D.A. Randall, 1995: Impact of radiative transfer on the macroscopic behavior of cumulus ensembles. Part II. Mechanisms for cloud-radiation interactions. *J. Atmos. Sci.*, **52**, 800-817.

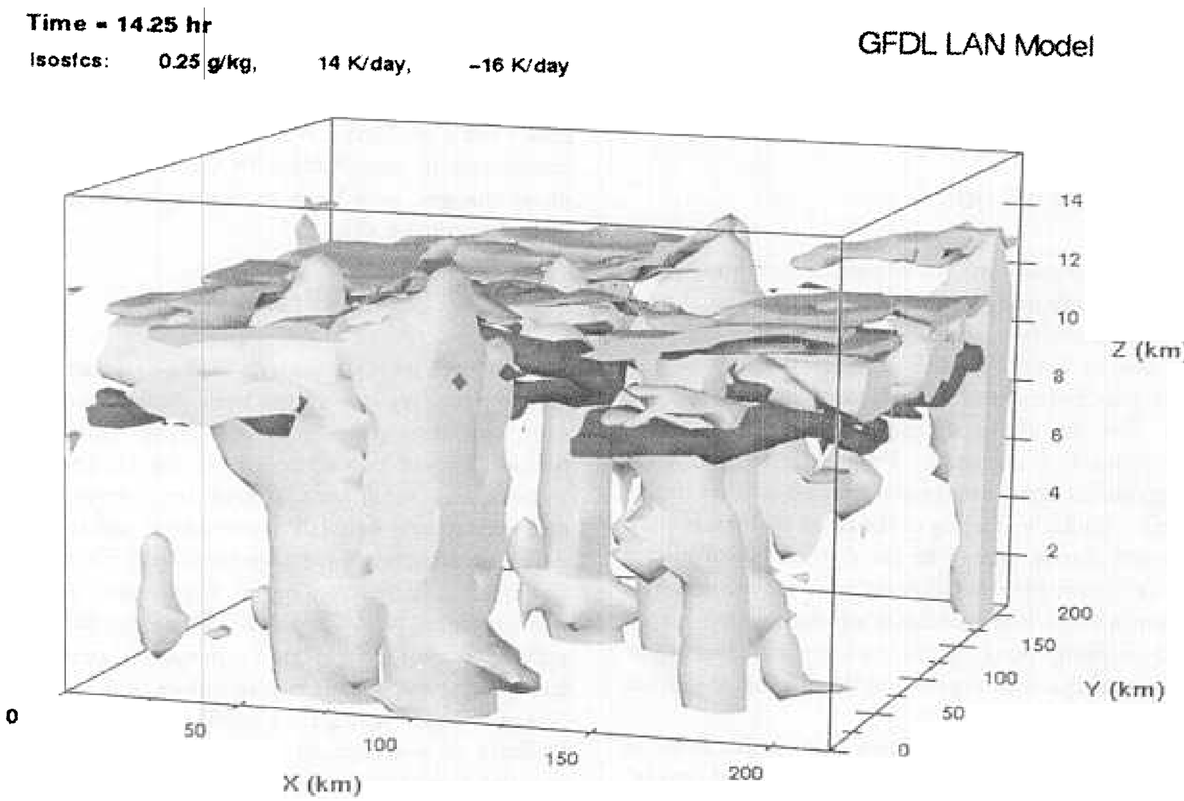

Figure 1. Interactions between microphysical and radiative properties in the three-dimensional GFDL cloud-resolving model. The lightest surface depicts the surface enclosing total condensate mixing ratios greater than .25 g kg^{-1}. The darkest surface encloses radiative heating rates greater than 14 K day^{-1}, and the intermediate surface encloses radiative cooling greater than 16 K day^{-1}. The figure depicts interactions after 14.25 hours in the development of a convective system in a tropical easterly wave.