5B.3 CHARACTERISTICS OF SIMULATED DEEP CONVECTION IN RADIATIVE-CONVECTIVE EQUILIBRIUM OVER TROPICAL OCEANS

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1 INTRODUCTION

In this paper we report on the results of radiative-convective equilibrium simulations of deep convection over warm oceans using a cumulus ensemble model. Though radiative-convective equilibrium calculations have been analyzed previously by many scientists, the analysis of our simulations focuses on the upward transports of water vapor in the lower half of the modeled troposphere.

2 MODEL

The cumulus ensemble model is three-dimensional. Its horizontal and vertical grid sizes are 1.5 km and 0.75 km, respectively. Its vertical domain is 22.5 km and a sponge layer to absorb gravity waves is employed above 16.5 km. Computations in each instance were done over a domain of 120 km × 120 km. The complete description of the model was given by Zeng (2001).

Radiation is currently treated by a constant cooling rate of 1 K d^{-1} up to 9 km, decreasing linearly to zero at 15 km. As the cooling rate is independent of cloudiness, cloud-radiation interactions do not exist in the model. Turbulence and cloud microphysical processes are computed using the schemes of Klemp and Wilhelmson (1978) with the following changes: The eddy mixing coefficients are 1/3 the values used by Klemp and Wilhelmson and the autoconversion threshold for rain production is set to 0.5 g kg^{-1} rather than 1 g kg^{-1}.

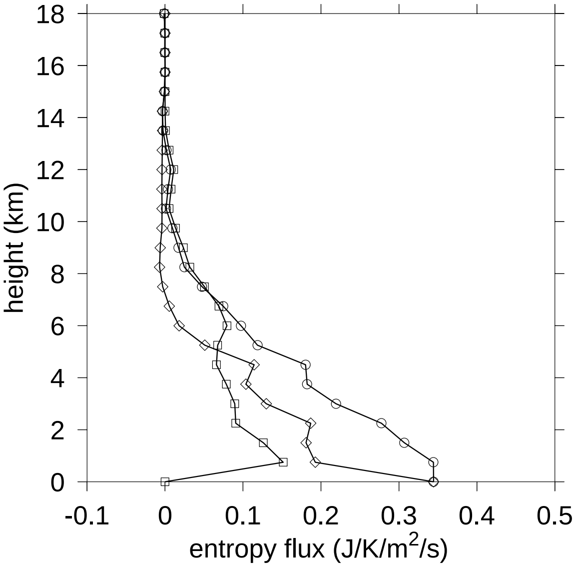

Figure 1: Vertical profile of mean total (circles), eddy (diamonds), and explicit (boxes) moist entropy fluxes for the radiative-convective equilibrium case.

3 ANALYSIS

The model was run to radiative-equilibrium in approximately 60 d. We analyze 11 snapshots of the flow taken at roughly 3 h intervals near the end of the simulation. At the equilibrium stage of this case, moist entropy (or equivalent potential temperature) decreases with height below 6 km and increases with height above this level.

Figure 1 shows the vertical profile of entropy flux averaged over the horizontal domain and the 11 snapshots. The total flux consists of the sum of the eddy and explicit fluxes. The two components are comparable in magnitude for elevations less than 5 km. However, above this al-

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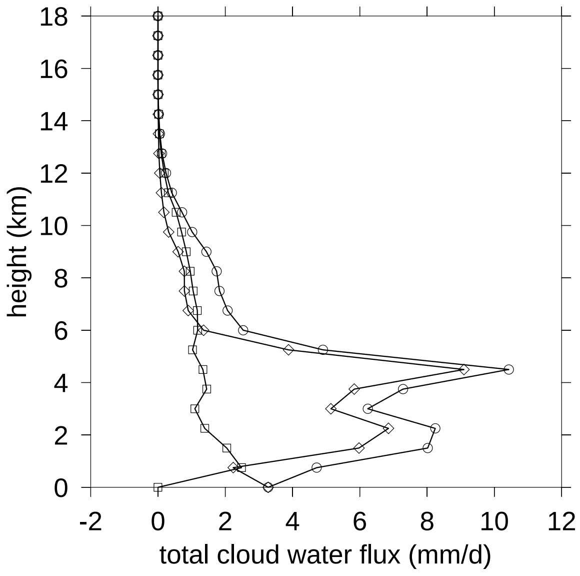

Figure 2: As in figure 1 except fluxes of total cloud water.

titude the explicit flux strongly dominates the vertical transport of entropy. As expected, the total entropy flux decreases monotonically with height, as is needed to balance the imposed radiative cooling.

Figure 2 shows the eddy, explicit, and total vertical fluxes of total cloud water (vapor plus advected condensate). The total flux increases with height at levels where the evaporation of precipitation dominates its formation, and decreases with height at levels where the reverse is true. Thus, below 4 km evaporation generally dominates formation, whereas above this level formation dominates.

Eddy processes play much more of a role for total cloud water than they do for entropy. Below 6 km the eddy transport is about three times the explicit transport, whereas above this level the explicit transport exceeds eddy transport.

The CAPE (convective available potential energy) associated with the mean sounding is about 2050 J kg^{-1}, corresponding to a maximum updraft velocity of 64 m s^{-1} according to parcel dynamics. However, updrafts exceeding a few meters per second are clearly a rarity in this simulation, in spite of the relatively large CAPE. Thus, air contributing to modeled deep convective eddies does not come from the subcloud layer, but from a much deeper layer which has been moistened by eddy transport from the surface. Since these eddies are really surrogates for small-scale, unresolved convection, it suggests that deep convection over the ocean is really a two-step process in which small cumulus clouds moisten a layer several kilometers deep, which then becomes the source region for deep convective cells.

4 CONCLUSION

Simulations of deep convection in radiative-convective equilibrium over tropical oceans reveal that the transport of water vapor in the lower troposphere is dominated by eddy transport rather than explicit transport in the lower half of the troposphere. A scale analysis shows that this result is likely to be typical of coarsely gridded numerical models of convection.

The simulations also show that the vertical velocities in convective updrafts are much less than would be expected based on non-entraining parcel dynamics. This result, which is in agreement with observations of tropical oceanic clouds, is closely related to the highly diffusive behavior of the model at low levels, suggesting that actual transports in the lower troposphere over tropical oceans are dominated by eddies smaller than a kilometer or so in scale.

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5 REFERENCES

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