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SELF-AGGREGATION AND LARGE-SCALE CONTROL OF TROPICAL DEEP CONVECTION

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1. INTRODUCTION

Tropical deep convection is observed to be organized on scales from a few tens of kilometers to hundreds and even thousands of kilometers. From satellite and radar observations, we often see the grouping of individual convective cells into cloud clusters, or mesoscale convective systems(MCSs) with horizontal scale of 100km or more, and grouping of individual cloud clusters or MCSs into 'superclusters' with horizontal scale up to 1000km or more (Mapes and Houze 1993, Nakazawa 1988). The mechanism responsible for the grouping or superclustering is not well understood. In particular, Is superclustering a spontaneous self-aggregation of convection, or does it require preexisting large-scale circulations and/or horizontal boundary inhomogeneity? Here, 'self-aggregation' refers to convective organization that would spontaneously develop with horizontally homogeneous boundary conditions and forcing. We use the nonhydrostatic version of PSU/NCAR Mesoscale Model (MM5) to address this question.

2. MODEL DESCRIPTION AND EXPERIMENTS

A general description of the nonhydrostatic version of PSU/NCAR mesoscale model (MM5) can be found in Grell et al. (1994). We run the model at 15 km resolution over a domain 2250 by 1350 km across with doubly periodic boundary conditions. This resolution allows the model to crudely resolve mesoscale convective organization, while reaching the lengthscales of superclustering. Convective cores are parameterized using the Kain-Fritsch scheme. Ice-phase processes are allowed when temperature is below 0^{o}C, where cloud water is treated as cloud ice and rain is treated as snow (Dudhia 1989). Simulations are over the equatorial open ocean with a fixed SST. No rotation effect is included.

The model is forced by prescribed 'large-scale forcing', expressed as advective tendencies of temperature and moisture uniformly distributed over the domain. Due to the lack of sufficiently accurate observational measurements of winds and pressure gradients, momentum forcing is imposed by using nudging terms to relax domain-averaged winds to prescribed reference wind profiles.

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In this paper, we present a set of experiments under different initial conditions and reference wind profiles.

The base experiment (EX1) was initiated with uniform temperature and moisture sounding coming from domain-averages of ECMWF data analysis on the date of December 21, 1992 at 00UTC. This sounding has an average CAPE (Convective Available Potential Energy) of 740 J Kg^{-1}. Initially, a uniform easterly zonal wind of 5 m s^{-1} is prescribed throughout troposphere and meridional wind is zero. Random temperature perturbations (<0.5 K) are applied to the lowest 1km of model levels at the first time step to trigger convection. The 'large-scale forcing' is based on the 24 hour average of a MM5 simulation (Chen 1996) of TOGA-COARE convective system on December 21. The reference wind profile is taken from the sounding on December 21 and fixed in the course of integration. It displays weak low-level wind shear. Experiment 2 has the same setup except imposing strong wind-speed profile with strong shear. Experiment 3 is initiated with horizontally varying initial condition from the inner domain of Chen's simulation (Chen 1996). The rest of parameters are the same as EX1. Table 1 summarizes the three experiments. All experiments are integrated for 4 days.

Table 1: Experiment design

	Initial Condition	Reference Wind
EX 1	Uniform	weak wind and shear
EX 2	Uniform	strong wind and shear
EX 3	Varying	weak wind and shear

3. MODEL RESULTS

In the base experiment, convection does not start until after 8 hours. Then it appears in the form of randomly distributed cumulus throughout the 4-day integration. The individual convective systems occupy no more than 10 grid points (150km) in dimension at their mature stages. Although we see evidence of formation of

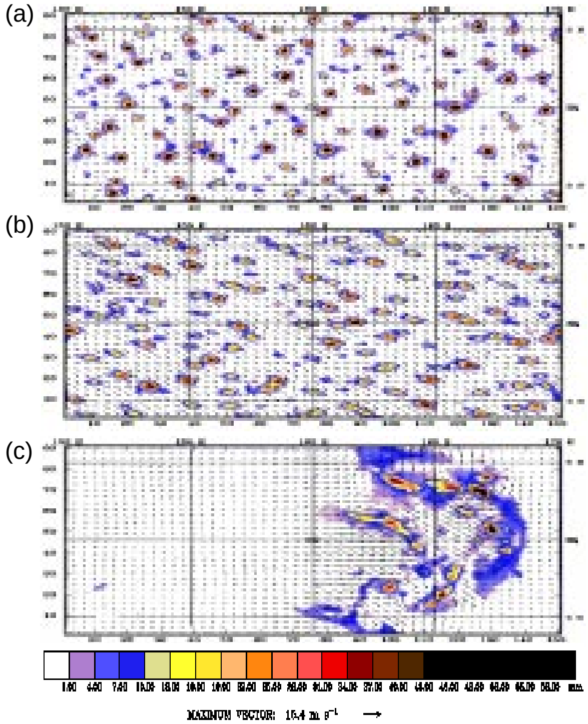

Fig. 1. Horizontal maps of hourly rainfall at Hour 12 for (a) EX1 (b) EX2 and (c) EX3. Superimposed are horizontal wind vectors at the lowest model level (σ = 0.995).

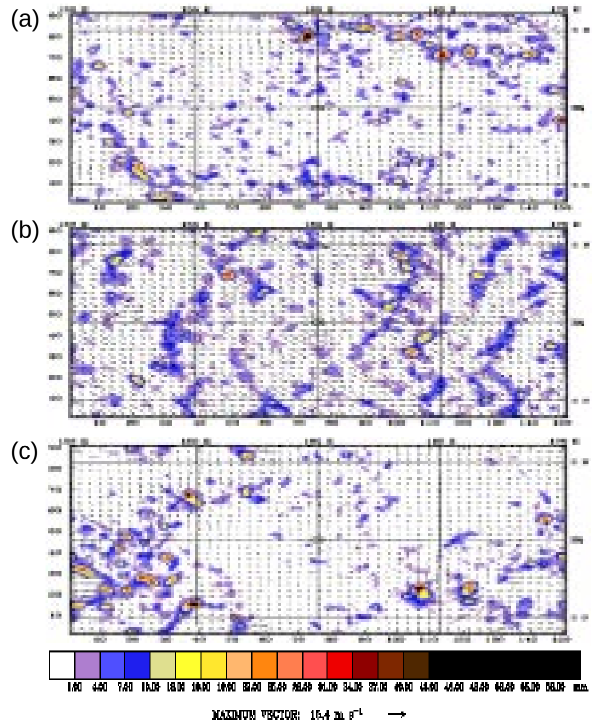

Fig. 2. Same as Fig. 1. except at Hour 92.

new cells at the edge of cold pools generated by previous convection, no organization of cloud clusters is found in this weak-shear environment. Snapshots of hourly surface rainfall at hour 12 and 92 are displayed in Fig. 1a and 2a. When stronger low-level wind and vertical wind shear are imposed on the average wind profile, the simulated organization evolves from random isolated convection (Fig. 1b) to more linear cloud bands (Fig. 2b). However, we have not seen individual convective systems grouping into one greater than 300km in diameter in the above two experiments.

In EX3, convection first initiates near the high surface θ_e area and spreads out, occupying an area more than 300km in each direction during its development (Fig. 1c). Such convective organization is similar to superclusters observed during TOGA-COARE. But it dissipates after 24 hours. Convective organization becomes indistinguishable from results in previous experiments (Fig. 2c).

4. SUMMARY AND DISCUSSION

We have not found evidence of self-aggregation of convection in our simulations that could explain the superclustering of tropical convection. Random distributed convection does not evolve into organized cloud clusters of dimension greater than 300km when uniform ‘large-scale forcing’ is imposed. Strong surface fluxes along with strong vertical wind shear help form linear convective organization but does not seem to help form superclusters.

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