JP4.18 LARGE-SCALE ORGANIZATION OF TROPICAL CONVECTION IN IDEALIZED NUMERICAL SIMULATIONS: IMPACT OF RADIATIVE PROCESSES

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Tropical convection is organized on a wide range of spatial scales, from a cloud scale (a few kilometers) up to the scale of the intraseasonal oscillation (thousands of kilometers). Despite vigorous research in this area in the last decade, mechanisms behind the large-scale organization of tropical convection remain ambiguous. This paper presents results from idealized numerical simulations pertinent to the coupling between moist convection and the large-scale dynamics in the tropics, and to the role of radiative processes in particular.

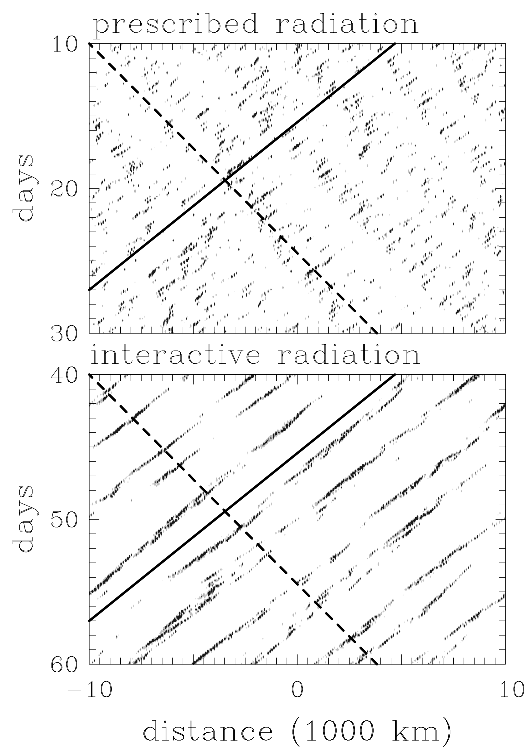

Figure 1: Hovmöller diagrams of the surface precipitation rate for the 2D cloud-resolving simulation applying prescribed radiative cooling (upper panel) and interactive radiation transfer model (lower panel). The mean easterly wind and speed of eastward-propagating convectively coupled gravity waves are shown by solid and dashed lines, respectively.

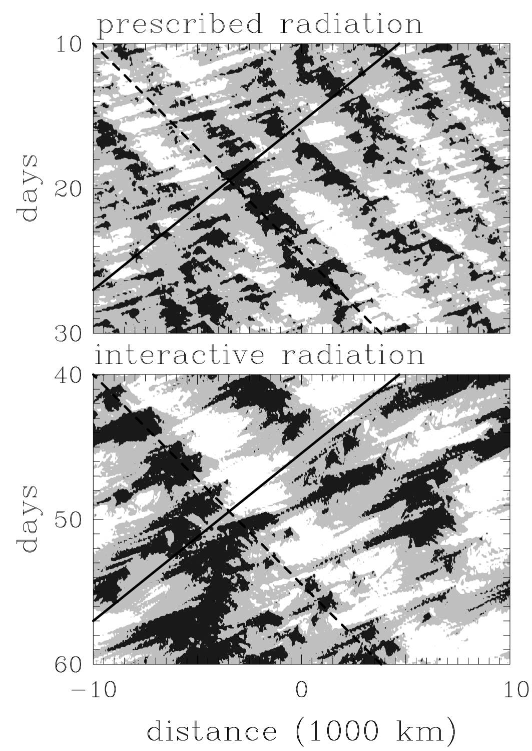

Figure 2: As Fig. 1, but for the potential temperature deviations from the domain average at height of 13 km. The light shading represents perturbations between -1 and 1 K; white and black represent perturbations smaller then -1 K and larger than 1 K, respectively.

Two sets of idealized simulations are presented. In both sets, radiative processes are either parameterized by applying a horizontally homogeneous radiative tendency (1.5 K day^{-1} across the troposphere; simulations PR) or the longwave and shortwave radiation transfer model is applied (Kiehl et al. 1994, simulations IR). The diurnal cycle of solar radiation is omitted in IR and domain-averaged radiative cooling is adjusted to match PR.

The first set considers convective-radiative equilibrium in two-dimensional $(x-z)$ cloud-resolving simulations in which a periodic global-scale horizontal domain is used (20,000 km) and a hor-

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izontally homogeneous SST of 30°C is assumed. The horizontal (vertical) gridlength is 3.5 km (1/3 km). The mean horizontal flow is prescribed as -10 m s^{-1} (i.e., from right to left in the figures) and is maintained using a relaxation term with 1-day time scale. Details of these simulations are discussed in Grabowski and Moncrieff (2001, 2002).

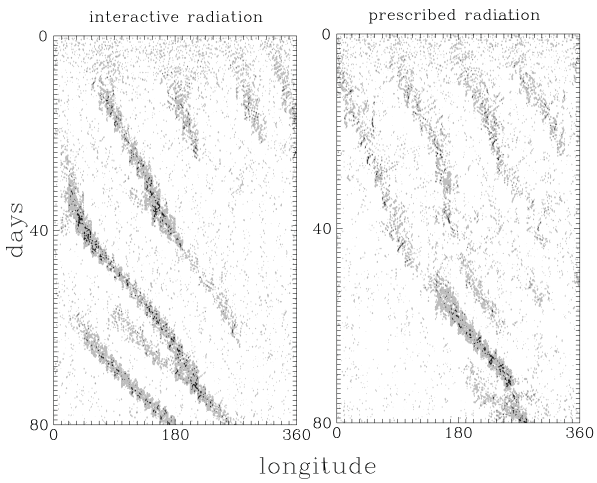

Figure 3: Hovmöller diagrams of the surface precipitation rate at the equator for the CRCP simulations of convective-radiative equilibrium on a constant SST aquaplanet applying prescribed radiative cooling (right panel) and interactive radiative transfer model (left panel).

Figure 1 shows Hovmöller diagrams of surface precipitation in these 2D simulations. In PR, deep convection spontaneously organizes into two primary scales: westward-traveling mesoscale convective systems on a scale of a few hundred kilometers and the eastward-propagating envelopes of convection spanning thousands of kilometers. The envelopes represent large-scale convectively coupled gravity waves, two-dimensional nonrotating analogs of equatorially-trapped Kelvin waves. These waves are identified by the upper-tropospheric temperature perturbations (Fig. 2). The organization in IR, shown in the bottom panel of Fig. 1, seems different at a first glance. Mesoscale convective systems in IR have longer lifetimes and are embedded within zones of precipitation that traverse the entire domain. These zones are steered by the mean flow and are separated by precipitation-free areas 2,000 - 4,000 km in extent. Precipitating systems forming immediately ahead of their antecedents define a spatially coherent pattern of surface precipitation that persists for many days. The large-scale envelopes of enhanced surface precipitation, similar to but not as pronounced as in PR, can also be identified in IR, using the upper-tropospheric temperature perturbations (Fig. 2). However, the horizontal scale of convectively coupled waves is much larger in IR.

The second set of simulations applies a nonhydrostatic general circulation model with Cloud-Resolving Convection Parameterization (CRCP, the "super parameterization"; Grabowski 2001). The cornerstone of CRCP is to use a 2D cloud-resolving model to represent the effects of cloud-scale processes (such as convective motions, precipitation formation and fallout, interaction of clouds with radiative and surface processes) in every column of a large-scale or global model. We consider an idealized problem of convective-radiative equilibrium on a rotating constant-SST (30°C) aquaplanet with the size and rate of rotation of the Earth (as in section 4 of Grabowski 2001). We stress that the radiative transfer in IR applies cloud-scale fields supplied by CRCP and it does not involve any subgridscale representation of cloud structure and overlap.

Large-scale organization of convection in the global CRCP simulations is similar in PR and IR. As Fig. 3 illustrates, large-scale organization of convection inside the equatorial waveguide spontaneously develops in both simulations. As discussed in Grabowski (2001, 2002), such a large-scale organization resembles the Madden-Julian Oscillation, the spectacular example of tropical climate variability on intraseasonal time scales.

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