P1.50 LARGE-SCALE ORGANIZATION OF TROPICAL CONVECTION IN TWO-DIMENSIONAL EXPLICIT NUMERICAL SIMULATIONS

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Tropical convection is organized on a wide range of spatial scales, from a cloud system scale (tens of kilometers) up to the scale of the intraseasonal oscillation (thousands of kilometers), e.g., Nakazawa (1988). Despite vigorous research in this area in the last decade, mechanisms behind the observed organization of tropical convection (or, more generally, behind the coupling of tropical convection with the large-scale dynamics) remain ambiguous. This paper illustrates applications of a 2D cloud-resolving model to the problem of large-scale convection organization in the tropics.

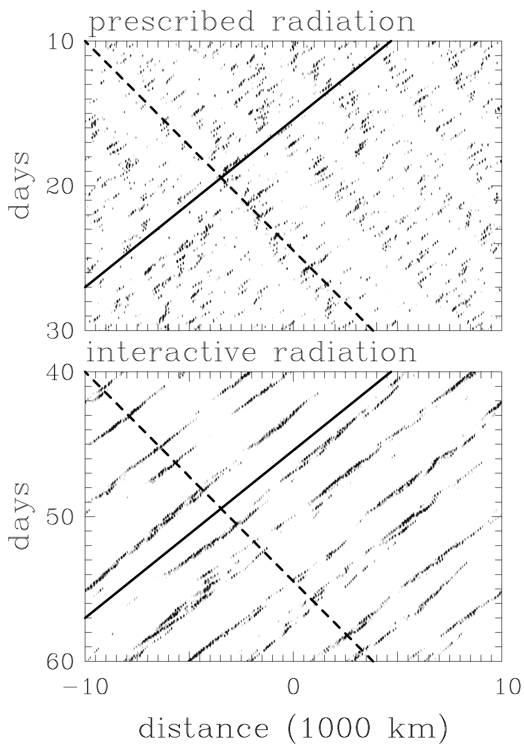

Figure 1: Hovmöller diagram of the surface precipitation rate for the 2D cloud-resolving simulation applying prescribed radiative cooling (upper panel) and interactive radiation transfer model (lower panel). The mean easterly wind and speed of eastward-propagating convectively coupled gravity waves are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

We present results from two-dimensional ($x-z$) cloud-resolving simulations in which a periodic global-scale horizontal domain is used (20,000 km) and a horizontally homogeneous SST of 30°C is assumed. The horizontal (vertical) gridlength is 3.5 km (1/3 km). Radiative processes are either parameterized by applying a horizontally homogeneous radiative tendency (1.5 K day^{-1} across the troposphere; simulation PR) or the longwave and shortwave radiation transfer model is applied (Kiehl et al. 1994, simulation IR). Diurnal cycle of solar radiation is omitted in IR and domain-averaged radiative cooling is adjusted to match

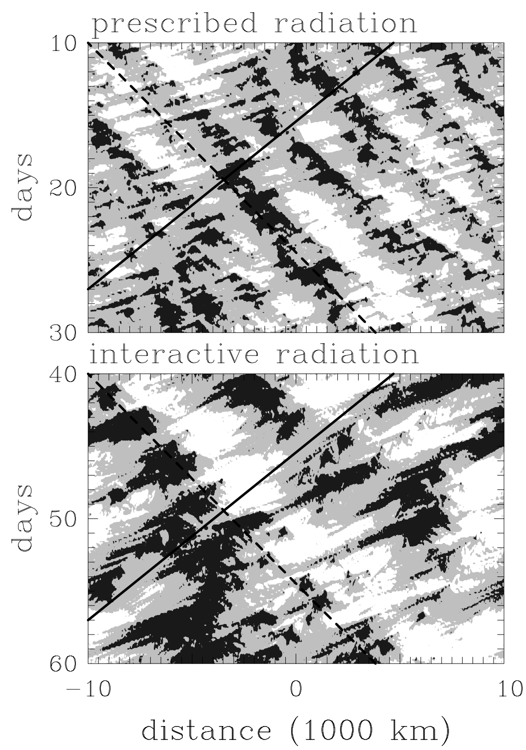

Figure 2: As Fig. 1, but for the potential temperature deviations from the domain average at height of 13 km. The light shading represents perturbations between -1 and 1 K; white and black represent perturbations smaller then -1 K and larger than 1 K, respectively.

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PR. 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).

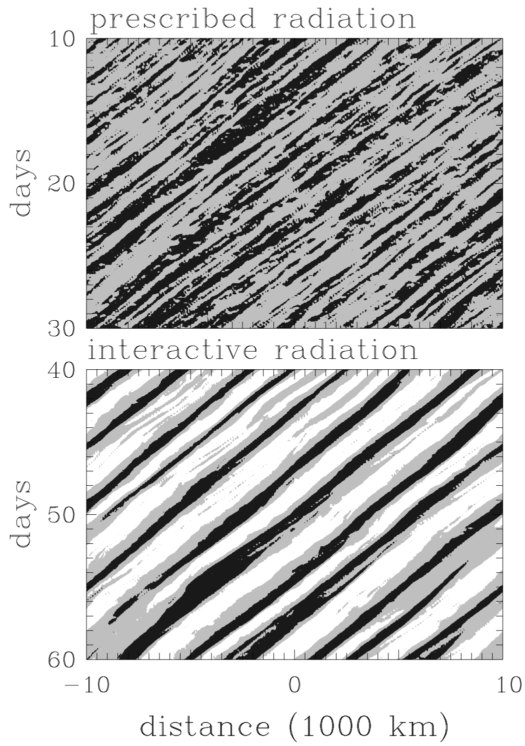

Figure 3: As Fig. 1, but for the precipitable water. The white and black represent precipitable water smaller than 40 and larger than 65 kg m^{-2}, respectively. Gray represents precipitable water between 40 and 65 kg m^{-2}.

Figure 1 shows Hovmöller diagrams of surface precipitation in PR and IR. 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. As discussed in Grabowski and Moncrieff (2001), these envelopes represent large-scale convectively coupled gravity waves, two-dimensional nonrotating analogs of equatorially-trapped Kelvin waves (cf. Wheeler et al. 2000). 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 quite 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 larger in IR.

Figure 3 illustrate spatial distribution of precipitable water (the column-integrate moisture content), in the same format as Figs. 1 and 2. Moisture fluctuations, steered by the mean wind, are relatively small in PR, but are large in IR. The perturbations in IR are a manifestation of a large-scale overturning a few thousand kilometers in scale. This circulation is driven baroclinically by gradients of the radiative cooling between the moist and dry regions. The ascent due to this "large-scale forcing" selects where new convective systems will occur and, in turn, these systems provide moisture to maintain the differential radiative heating. This positive feedback between large-scale radiative processes and moist convection is evidence of a "moisture-radiation instability" hypothesized previously in idealized studies.

REFERENCES

Grabowski, W. W., and M. W. Moncrieff, 2001: Large-scale organization of tropical convection in two-dimensional explicit numerical simulations. *Quart. J. Roy. Met. Soc.*, **127**, 445-468.

Grabowski, W. W., and M. W. Moncrieff, 2002: Large-scale organization of tropical convection in two-dimensional explicit numerical simulations. Part II: Effects of interactive radiation. *Quart. J. Roy. Met. Soc.* (submitted).

Kiehl, J. T., J. J. Hack, and B. P. Briegleb, 1994: The simulated Earth radiation budget of the National Center for Atmospheric Research community climate model CCM2 and comparisons with the Earth Radiation Budget Experiment (ERBE). *J. Geophys. Res.*, **99**, 20,815–20,827.

Nakazawa, T., 1988: Tropical super clusters within intraseasonal variations over the western Pacific. *J. Met. Soc. Japan*, **66**, 823–839.

Wheeler, M., G. N. Kiladis, and P. J. Webster, 2000: Large-scale dynamical fields associated with convectively coupled equatorial waves. *J. Atmos. Sci.* **57**, 613–640.