# Capturing the Daily Rain Cycle in the Tropics

Rainfall over the Indonesian region has a pronounced diurnal signature. One test of how well moist convection is represented in models is how well the diurnal rainfall cycle is simulated in this region. In typical atmospheric circulation models, the rainfall over the Maritime Continent peaks too early in the day and the daily range in rainfall rate varies too much, a deficiency that applies over most of the land in the tropics. These difficulties may, at least partly, have to do with the way shallow convection is represented in the models. Shallow cumulus clouds in the morning take moisture from the atmospheric boundary layer at the sea surface and moisten the free atmosphere. This sets the stage for deep convection later in the day.

An adequate representation of shallow convection would seem necessary for capturing the daily rainfall cycle. The strength of shallow convection is largely determined by the rate at which air is mixed from the surrounding environment into clouds as they rise and dilute the original air in the cloud (a process called 'fractional entrainment') and the rate at which they transfer moist air inside a cloud to the air outside (called 'fractional detrainment'). In general circulation model parameterizations, these two processes have been assumed to occur at fixed rates, and the effect of altering these rates on the simulated daily rainfall cycle has not been studied.

At the IPRC, **Yuqing Wang, Kevin Hamilton**, and doctoral student **Li Zhou** have studied how increases in the mixing and diluting rates affect the simulation of the daily rainfall cycle in the Maritime Continent region. They used the IPRC Regional Climate Model with a 0.5°-longitude–latitude grid and 28 vertical levels. The model was run under 3 different conditions for the January 1–March 31 period in 1998, with initial and boundary conditions from ERA-40 reanalysis updated every 6 hours and from Reynolds sea surface temperature updated every week. In the first run, all default parameters in the mass-flux cumulus parameterization scheme were used; in the second run, the mixing and diluting rates were doubled for deep convection; in the third run, the rates for shallow convection were increased 6.7-fold, to a value similar to values inferred from large-eddy simulations for shallow convection.

To obtain a local average daily cycle of the hourly rainfall rate for each model configuration, the hourly rainfall rates were averaged at each grid point and across the 3-month period. The results were then compared with similar TRMM 3G68 rainfall data averaged over January–March from 1998 to 2004. Since the simulations covered only the 3-month period in 1998, comparisons with the 7-year TRMM observations are not straightforward; nevertheless, the TRMM observation provides a reference for assessing the adequacy of the simulated daily rainfall cycle in the region.

As in previous observational studies, the rainfall over land areas in the TRMM data peaks anywhere from late afternoon to midnight (Figure 1a) depending upon the region, and then shifts to the ocean in the late evening to early morning hours. Over the open ocean there is no consistent peak rainfall time and no consistent migration. The hourly rainfall amount during the daily cycle varies quite a bit over land, but little over the ocean (Figure 2a).

The integration with the default parameters simulates an unrealistic rainfall pattern, but one that is typical of most current atmospheric models: rainfall peaks over most of the land areas about 2–4 hours too early and over the ocean, usually during early to mid-morning (Figure 1b); the rainfall rate varies too much over land and coastal areas, and the proportion of large-scale to stratiform rainfall is too small (not shown).

Doubling the mixing and diluting rates for deep convection delays the peak rainfall by about 1–2 hours over most of the land areas and in some of the coastal regions, but otherwise the rainfall pattern does not become more realistic (Figure 2c).

Increasing the rates for shallow convection, though, improves the simulation in nearly all aspects. It brings peak rainfall times closer to observations over both the Maritime Continent and the oceans and simulates the peak rainfall shift to offshore during late evening and early morning hours (Figure 1d). Rainfall over the western Pacific warm pool region, moreover, shifts mainly westward, consistent with the generally westward propagating mid-sized convective systems observed in this region. The simulation produces a realistic daily amplitude in rainfall rate over land (Figure 2d), though it does underestimate the amplitude over the ocean. The shallow convection experiment also produces a more realistic proportion of large-scale stratiform rainfall (not shown).

Analyses of the shallow convection experiment show the reason for the improvements: increasing the mixing and diluting rates slows the destabilizing effect of shallow convection and vertical turbulent mixing in the boundary layer and slows the moistening of the middle troposphere. All this prolongs the onset of deep convection, delaying and reducing convective rainfall during daytime over land while increasing large-scale, longer-lasting rainfall. The change also increases the day-to-day variability in rainfall amount, something that has been difficult to achieve in many general circulation models.

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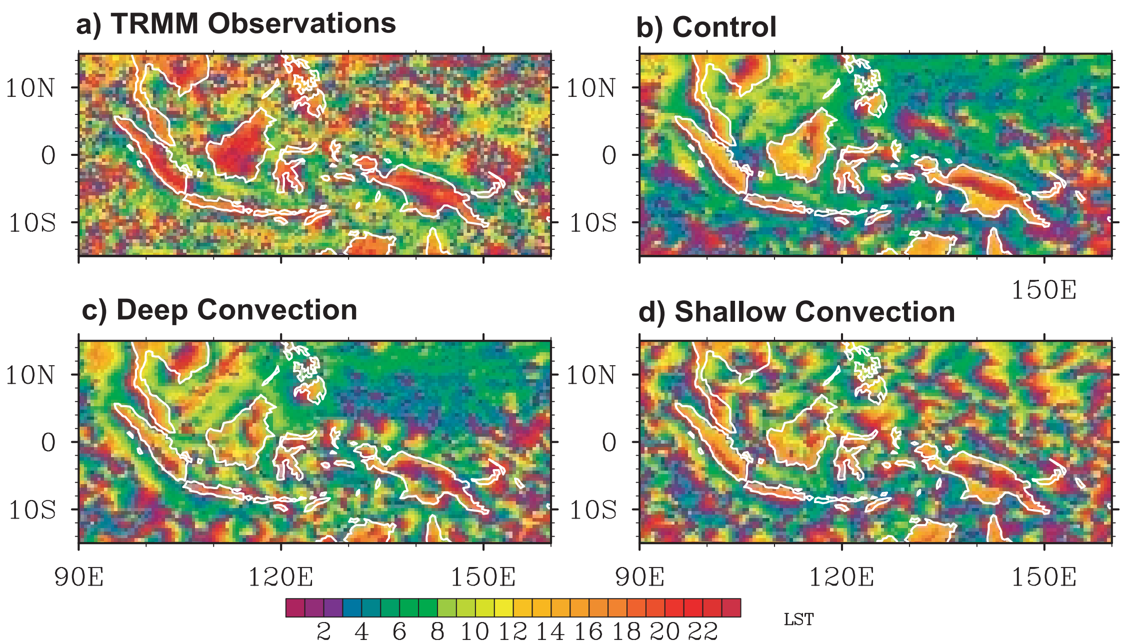


**Figure 1.** The local time of day (see color bar) of composite peak diurnal rainfall rates from (**a**) 7 years of TRMM 3G68 products, and from the 3-month model simulations under (**b**) control, (**c**) deep convection, and (**d**) shallow convection modifications.

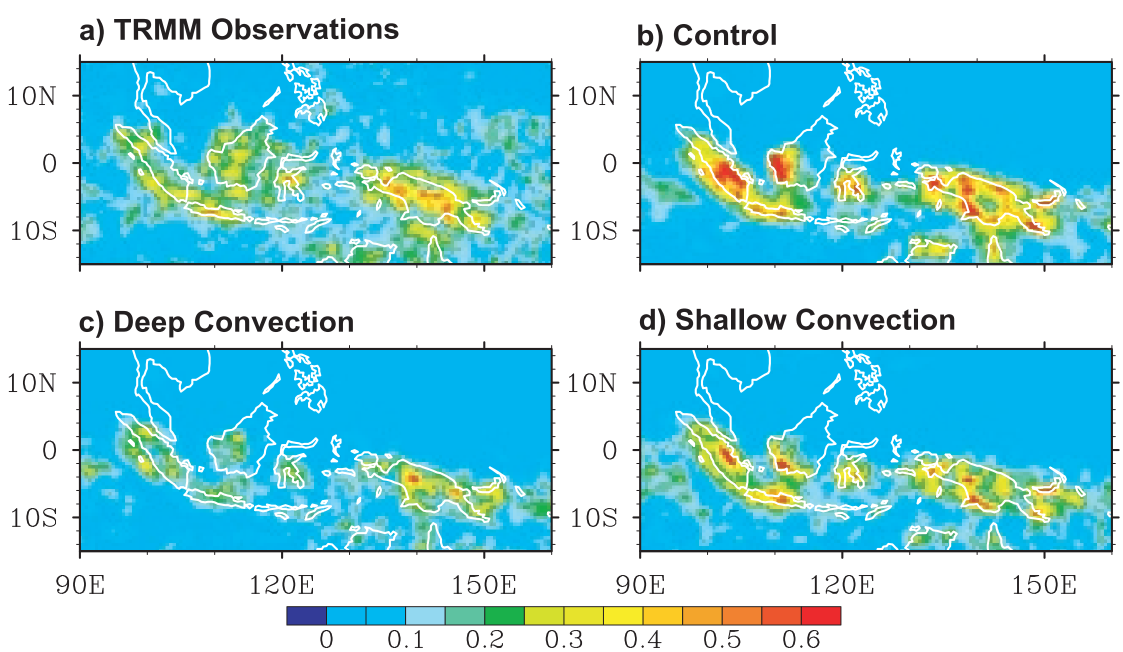


**Figure 2.** The daily amplitude of the rainfall rate in mm/hr from (**a**) 7 years of TRMM 3G68 products, and from the 3-month model simulations under (**b**) control, (**c**) deep convection, and (**d**) shallow convection modifications.