Improved rainfall and cloud-radiation interaction with Betts-Miller-Janjic cumulus scheme in the tropics

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When the Weather Research and Forecasting (WRF) model is used to dynamically downscale the Climate Forecast System Reanalysis (CFSR) over the Indo-Pacific region, Betts-Miller-Janjic (BMJ) cumulus scheme produces excessive rainfall. The precipitation is not very sensitive to changes in the cloud efficiency but varies greatly in response to modifications of the temperature and humidity reference profiles. After experimentation with all parameters in the scheme, it was found that a one-parameter adjustment in the scheme that yields a more moist humidity reference profile is sufficient and physically necessary to lead a better estimate of the observed precipitation measured by the Tropical Rainfall Measuring Mission (TRMM) 3B42 dataset for the global tropics.

The BMJ scheme does not parameterize the cloud water or ice mixing ratio in deep convection, meaning that cloud-radiation interaction is non-existent when BMJ is used to parameterize deep convection. We invented a two-parameter Precipitating Convective Cloud (PCC) to complement convective adjustment schemes like the BMJ. The two parameters control the total column cloud mass and the level of maximum cloud fraction and were calibrated using surface short- and long-wave radiative flux observations. Two main assumptions were made: the vertical cloud profiles follow a top-heavy Poisson distribution, not unlike observed clouds, and the convective cloud mass per unit water vapour mass in cloudy air is invariant within a column due to efficient vertical mixing. The performance of the scheme was evaluated in a 1-year run and WRF is found to give a much better representation of the observed cloudiness with smaller biases in the surface radiation fields with respect to observations and reanalysis.