3. Modified Betts-Miller-Janjic (BMJ) Scheme

When used to downscale CFSR data over South-east Asia, WRF is found to underestimate the observed precipitation, as given by the Tropical Rainfall Measuring Mission (TRMM) 3B42 version 6 (Huffman et al., 2007), with this excessive rainfall generated mainly by the cumulus scheme, BMJ, originally developed for North America where the environmental conditions are very different from those in the tropics.

The BMJ scheme is modified by making the reference humidity profile more moist (Fonseca et al., 2015). In this scheme the first guess humidity reference profile at each pressure level $p_j$ is prescribed by the lifting condensation level, $p_j + \Delta p_j$ where $\Delta p_j < 0$, of an air parcel with $\theta'_j = \theta_j - \theta_j^0$ (the difference between the air parcel $	heta$ and the air parcel $	heta^0$ has been further cut off). The threshold for condensation $\theta_c$ is piecewise linearly interpolated between the values at the cloud bottom, $\theta_{bb}$, freezing level, $\theta_{fl}$, and cloud top, $\theta_{ct}$, which are in turn parameterized as linear functions of the cloud efficiency $F$:

$$F = \frac{1}{1 + \left(\frac{\theta_{ct} - \theta}{\theta_{ct} - \theta_{bb}}\right)^2}$$

In the default WRF implementation, $F = 0.05$, an empirically determined value continental USA, but in Janjic (1994) $F = 0.6$. A smaller value of $F$ will lead to a more moist reference humidity profile and hence a decrease in the BMJ precipitation. The value of $F$ is decreased from 0.85 to 0.6 and the performance of this modified BMJ scheme is assessed with WRF being run from 1st May 2009 to 1st April 2009 with the first month regarded as spin-up.

Below the precipitation rate (in unit of mmhr$^{-1}$) averaged over June to September (JJAS) 2008 and December to March (DJFM) 2006/2007 for the WRF experiments is shown together with the rainfall rate from TRMM and NCEP CFSR for the two seasons. Also shown is the bias (shading) and the normalized bias contours of ±3.0 (when the absolute value of the normalized bias is ±3.0 the contribution of the bias to the RMS error is less than +−9% and the biases will not be considered significant, see Koh et al. (2012) for more details) with respect to TRMM for each WRF experiment.

It is found that for the whole tropics, and both monsoon seasons, with the modified BMJ scheme most of the rainfall biases are corrected and in some regions the model even gives a better estimate of the observed rainfall than NCEP CFSR.

4. Precipitating Convective Cloud (PCC) Scheme

In WRF subgrid-scale cumulus clouds are radiatively transparent so that the surface temperature remains too warm during rainfall. Recent studies showed cumulus cloud-radiation feedbacks to be important at regional weather and climate scales (Alaïaty et al., 2012) in particular in regions with strong land-sea contrasts such as the Maritime Continent where many of the processes that drive regional climate variability ultimately depend on the accurate simulation of the radiative fields.

A Precipitating Convective Cloud (PCC) scheme, based on the BMJ rainfall, is developed and implemented in the WRF model (Koh et al., 2015). The scheme can be described as follows:

- Following Slingo (1987), the maximum cloud fraction in a column is proportional to the logarithm of the convective precipitation rate at every time-step;
- we assume a top-heavy cloud distribution and compute the cloud condensates based on well-mixed cloudy atmosphere;
- the 1-year experiment (April 2008 – March 2009) is repeated with the PCC scheme. In order to assess the realism of the clouds produced by the model, the WRF clouds are compared to satellite imagery for different regions/seasons. As an example the images below show the clouds for Asia and the West Pacific for a given day in the summer monsoon season. As can be seen, WRF gives a much better representation of the observed cloudiness when the PCC scheme is employed.

The figures below show WRF’s surface net short-wave and long-wave radiation bias (units of Wm$^{-2}$) with respect to that observed by the National Oceanography Centre Southampton Version 2.0 surface flux dataset (NCOSc2; Berry and Kent, 2009) with and without the PCC scheme.

WRF overestimates the surface net short-wave radiation and underestimates the surface net long-wave radiation, suggesting a lack of cloud cover, in particular the absence of shallow cumulus and stratocumulus clouds as the radiation biases are larger in the eastern side of sub-tropical oceans where these clouds are more predominant (Klein and Hartmann, 1993). This is a known problem in WRF. Huang et al. (2013) tested a combination of different physics schemes and found that the model does not properly simulate these clouds.

In the deep tropics, where convective clouds are more prevalent, most of the radiation biases are corrected when the PCC scheme is employed. In fact, over South-east Asia, our region of interest (pink rectangles), the biases in the surface radiation fluxes are very small.

WRF BIASES FOR SURFACE NET RADIATION FLUXES WITH RESPECT TO NCOSc2

WRF WITHOUT THE PCC SCHEME

WRF WITH THE PCC SCHEME

REFERENCES


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