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Temporal and spatial intermittency of sub-daily precipitation in general circulation models

Nicholas Klingaman (1), Gill Martin (2), and Aurel Moise (3)

(1) NCAS-Climate, Dept. of Meteorology, University of Reading, UK (n.p.klingaman@reading.ac.uk), (2) Met Office Hadley Centre, United Kingdom, (3) Centre for Australian Weather and Climate Research (CAWCR), Bureau of Meteorology, Melbourne, Australia

General circulation models often fail to reproduce the observed spatial and temporal distributions of tropical precipitation (e.g. Stephens et al. 2010). The need for improved understanding of how a warming climate may change precipitation variability and extremes has focused model developers' attention on the inability of convection parameterizations to represent the observed range of deep convective processes (e.g. Rossow et al. 2013). As climate-model resolutions increase towards scales previously used for short-term forecasting, the benefits of seamless modelling are being balanced by increasingly apparent deficiencies in convection parameterizations. Under particular scrutiny are the consequences of poorly simulated sub-daily, gridpoint precipitation variability on rainfall distributions at longer (e.g., daily, seasonal, decadal) and larger scales.

We present the behaviour of tropical convection in the MetUM in a hierarchy of global configurations from $\sim$10km to $\sim$100km resolution, and in ten climate models from the "Vertical Structure and Diabatic Processes of the Madden-Julian Oscillation" project. We establish new methods of analysing timestep precipitation that allow comparisons between resolutions and physical parameterizations. We first investigate the relationship between timestep-to-timestep variations of modelled convection at the gridbox scale and its variability on longer and larger scales, and compare simulated and observed rainfall variability. We demonstrate that convection parameterization changes that alter timestep variability (e.g., entrainment and detrainment rates and closure timescales) also affect longer-scale variability. For example, we show that $\sim$100 km configurations exhibit coherent timestep intermittency at large spatial scales, which reduce at finer resolutions and with parameterisation changes that suppress the depth and intensity of convection. Despite a wide variety of timestep behaviour, the models from the "Vertical Structure and Diabatic Processes of the Madden-Julian Oscillation" project become much more consistent with one another, and agree with observations, when timestep, gridpoint rainfall is aggregated to 3-hourly means and a $\sim$500km grid. We hypothesize that these represent the scales at which these models maintain radiative-convective equilibrium.

We next analyse the spatial distribution of rainfall intensity on a range of timescales from $\sim$30 minutes to daily, in models and observations (where possible). This highlights the tendency of some models' convection schemes in some regions to produce intense rainfall on a timestep, interspersed with timesteps of little or no rain, such that daily accumulations can be quite low. This contributes to the "dreary" state of model precipitation (Stephens et al 2010). Our analysis highlights that biases in simulated climatological rainfall arise through a combination of biases in frequency and intensity of timestep rainfall. The magnitude of these contributions varies with timescale and geographic region. Changing physical parameterizations in the MetUM alters this behaviour, with associated adjustments in the climatological rainfall distribution.