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Understanding rainfall characteristics in climate models and observations

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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. Under particular scrutiny are the consequences of poorly simulated sub-daily, grid-point precipitation variability on rainfall distributions at longer (e.g., daily, seasonal, decadal) timescales and larger spatial scales. Lack of knowledge or understanding of the spatial and temporal variability in rainfall, in observations and models, hampers model development and can undermine our confidence in projections. A major challenge in advancing our understanding is a lack of comprehensive diagnostics and metrics for analysing the characteristics of both observed and modelled preciptitation across time and space scales.

The ASoP diagnostic package (Analysing Scales of Precipitation; Klingaman et al. 2017; Martin et al., 2017) has been developed and applied to various model and observation datasets over the past few years. ASoP can be applied to data ranging from the gridscale and time-step to regional and sub-monthly averages, and measures the spectrum of precipitation intensity, temporal variability as a function of intensity, and spatial and temporal coherence. When applied to time-step, gridscale tropical precipitation from a range of models, the diagnostics reveal that, far from the "dreary" persistent light rainfall implied by daily mean data, most models produce a broad range of time step intensities that span 1-100 mm/day. Averaging precipitation to a common spatial (km) or temporal (3h) resolution substantially reduces variability among models, demonstrating that averaging hides a wealth of information about intrinsic model behaviour.

ASoP analysis of tropical rainfall variability in MetUM simulations at a range of horizontal resolutions shows that the behaviour of the deep convection parametrization in this model on the native grid and time step is largely independent of the grid-box size and time step length over which it operates. There is also little difference in the rainfall variability on larger/longer spatial/temporal scales. Tropical convection in the model on the native grid/time step is spatially and temporally intermittent, producing very large rainfall amounts interspersed with grid boxes/time steps of little or no rain. Spatial and temporal averaging smoothes out this

intermittency such that, on the km scale, for oceanic regions, the spectra of 3-hourly and daily mean rainfall in the MetUM agree fairly well with those from satellite-derived rainfall estimates, while at 10-day timescales the averages are overestimated, indicating a lack of intra-seasonal variability. Over tropical land the results are more varied, but the model often underestimates the daily mean rainfall (partly as a result of a poor diurnal cycle) but still lacks variability on intra-seasonal timescales. ASoP diagnostics have also been applied to European rainfall (Berthou et al., 2018) and in high-resolution rainfall projections for the United Kingdom (Kendon et al., 2020). Such work is shedding light on how uncertainties in modelling small-/short-scale processes relate to uncertainty in climate change projections of rainfall distribution and variability, with a view to reducing such uncertainty through improved modelling of small-/short-scale processes.