1. Tropical rainfall biases in GCMs

General circulation models (GCMs) have been criticised for failing to represent observed scales of precipitation, particularly in the tropics where simulated rainfall is often said to be too light, too frequent and too persistent (e.g., [1]). However, previous assessments have used temporal or spatially averaged precipitation, which offers little actionable information for model developers, since the physics-dynamics interactions that produce precipitation occur at the native gridscale and timestep. Temporal and/or spatial averaging can change markedly the distribution of precipitation intensities, particularly for models whose convection schemes produce temporally or spatially intermittent precipitation (Fig. 1).

2. Analysing Scales of Precipitation (ASoP)

We introduce a set of diagnostics (ASoP) to compare the spatial and temporal scales of precipitation across GCMs and observations, which can be applied to data ranging from the gridscale and timestep to regional and sub-monthly averages [2]. These diagnostics include:

- Histograms of precipitation intensities (Fig. 1)
- Two-dimensional histograms of precipitation at consecutive timesteps (Fig. 2)
- Contributions of precipitation with distance and temporal lag (Fig. 3)
- Contributions to total precipitation from events within certain intensity ranges (Fig. 4)
- Summary metrics of spatial and temporal coherence (Fig. 5)

3. MetUM timestep intermittency

Application of the ASoP diagnostics to timestep precipitation from MetUM climate and NWP data has found that the convection scheme produces highly intermittent precipitation in space and time, regardless of horizontal resolution [2,3] (Fig. 6). Ongoing research seeks to understand and limit the causes of this intermittency.

4. Effects of spatial and temporal averaging

As shown in Fig. 1, averaging timestep precipitation data to 3-hour means reduces inter-model variability in precipitation intensity spectra. The same effect applies to the spatial and temporal coherence of precipitation (Fig. 7). Models that produce highly intermittent precipitation, such as MetUM, “benefits” more from spatial and/or temporal averaging (Fig. 8).

5. Exploring model rainfall biases

We can use the ASoP diagnostics to examine how sub-daily precipitation intermittency may influence rainfall characteristics at longer timescales (up to ~20 days), in order to shed light on the processes driving model climatological rainfall biases in various regions (Figs. 9).

Summary

- The ASoP diagnostics allow a detailed investigation of spatial and temporal variability in precipitation across scales, in models or observations. Python code to produce all diagnostics shown here, and others, can be downloaded from https://github.com/nick-klingaman/ASoP.
- Attributing climatological biases in regional precipitation to deficiencies in physical parametrisations remains a challenge for model developers. By examining the behaviour of modelled tropical rainfall at a range of spatial and temporal scales, we hope to shed light on how such biases develop.

References