Understanding rainfall characteristics in climate models and observations

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Summary: Analysis of rainfall variability on a range of space/time scales sheds 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 model parametrisations.

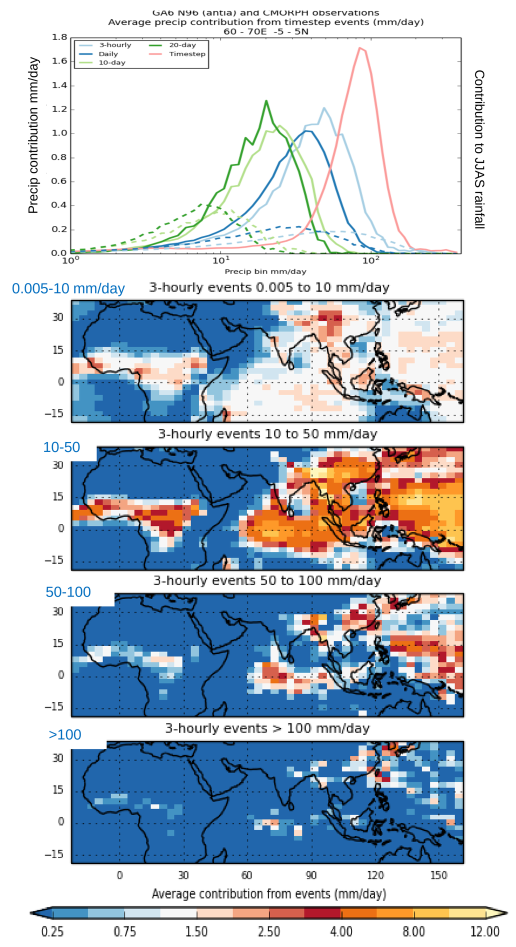
1. Introduction

- Daily averaged rainfall gives the impression that models overestimate light rain in the Tropics *(Stephens et al. (2010) "Dreary state").*
- However, models exhibit a wide range of sub-daily rainfall characteristics.
- Such characteristics can have a significant impact on the regional-scale circulation and water cycle.
- Lack of knowledge or understanding of the spatial and temporal variability in rainfall, in observations and models, can undermine our confidence in projections of the spatial and temporal characteristics of heavy rainfall in a warmer climate.

Analysing Scales of Precipitation (ASoP) diagnostic package

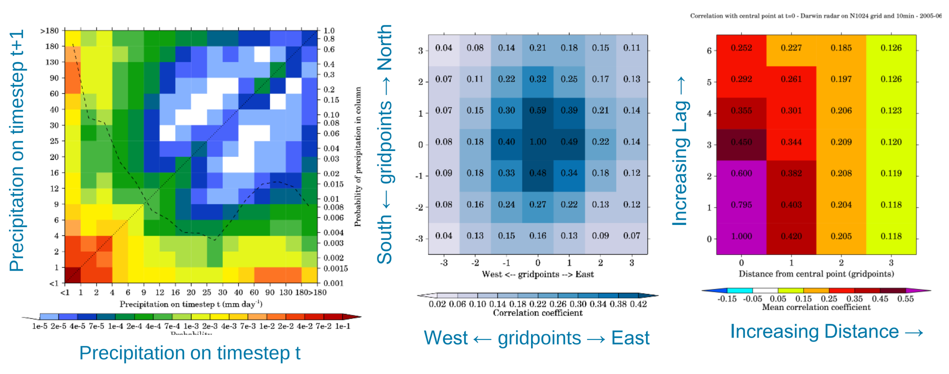
Methods include:

- Two-dimensional PDFs of timescale t and t+1 precipitation.
- De-correlation time for rainfall at various thresholds and at various timescales;
- Spatial autocorrelations of rainfall at various distances and lags;
- Spectral distributions of rainfall intensity and their contribution to total rainfall, calculated for each grid box and applied at a range of time and space scales.



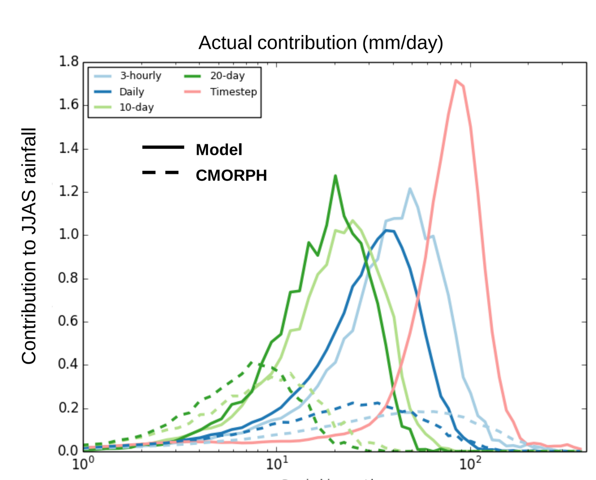
Klingaman et al., doi:10.5194/gmd-10-57-2017;

Martin et al., doi:10.5194/gmd-10-105-2017



2. Rainfall Intensity stratification

We can use the analysis of rainfall intensity distributions at different time resolutions to trace systematic errors through the timescales down to the model timestep.



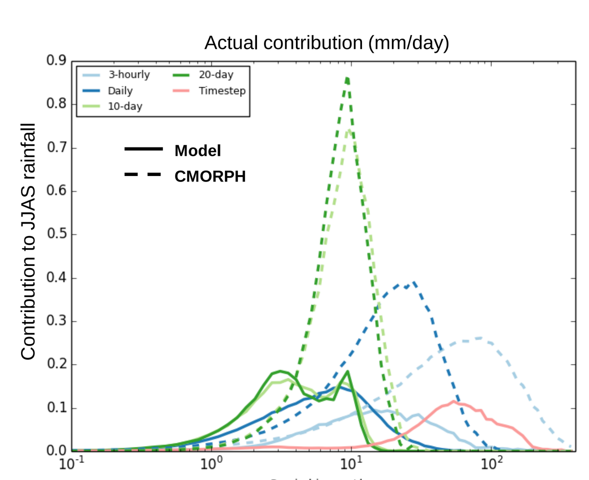
Equatorial Indian Ocean

Distribution of sub-daily and daily rainfall amounts is reasonable, but events are too frequent (not enough dry periods).

This leads to an overestimate in 10-day and 20-day totals.

Too little shift in the distributions to the left with increased averaging period indicates poor intra-seasonal variability.

→ positive bias driven by all timescales



West Africa

Timestep intermittency and poor diurnal cycle bias 3-hourly rainfall amounts to seasonal totals.

This leads to an underestimate in daily, 10-day and 20-day totals.

Very little shift in the distributions to the left with increased averaging period indicates little day to day variability.

→ negative bias driven by sub-daily timescales

- Intensities at the timestep level over ocean are typically ~100 mm/day (NOT light rain!).
- Averaging over time shifts the histogram to the left, indicating intermittency.
- Less shift to the left in model than in observations indicates lack of variability.
- A similar spectral shape to observations, but larger total contributions from each bin to the seasonal mean, indicates errors relating to frequency (too many events, not enough gaps).

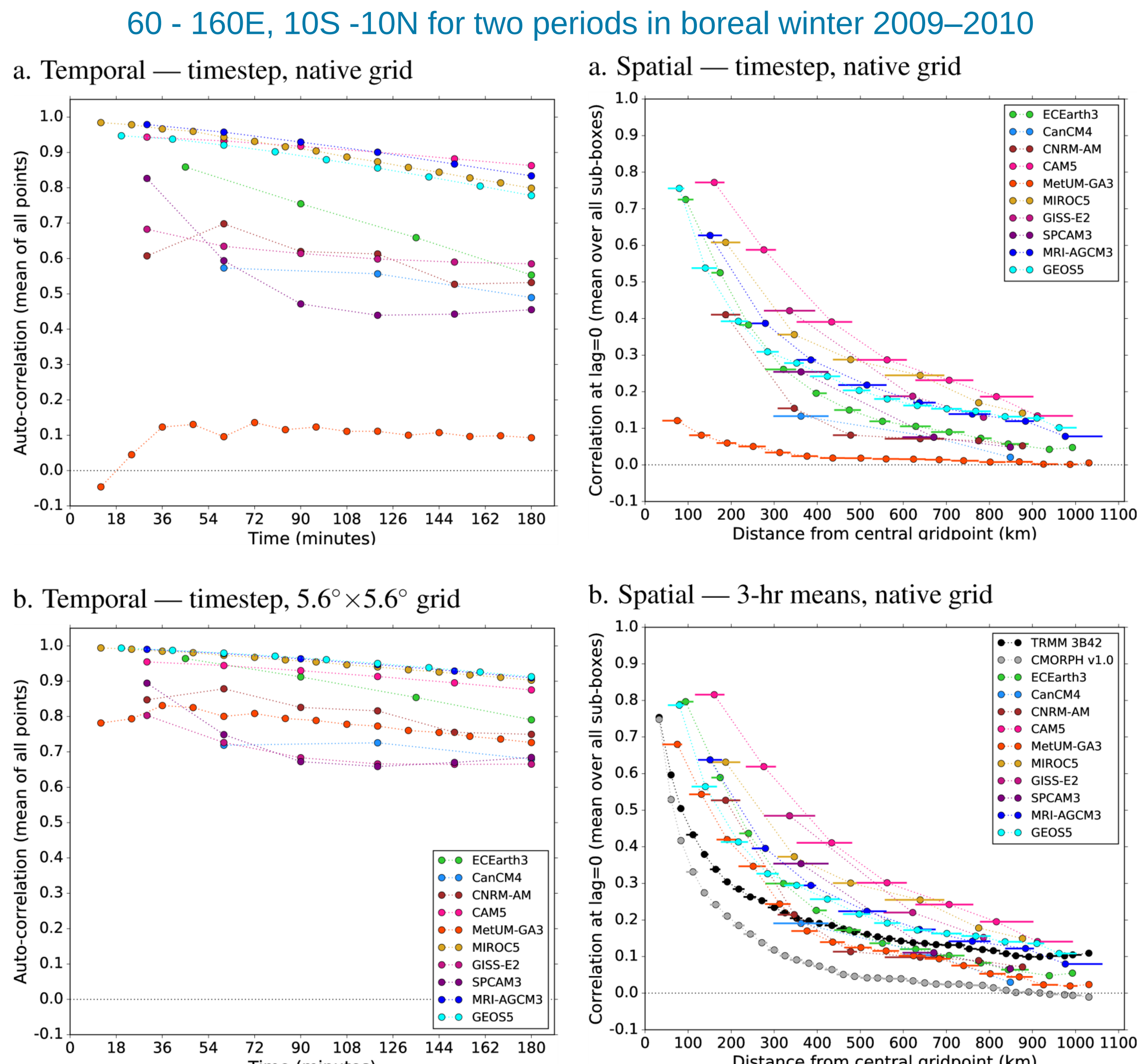
3. Rainfall spatial and temporal coherence

60 - 160E, 10S -10N for two periods in boreal winter 2009–2010

Effects of spatial averaging

- Spatial averaging increases the temporal scale of precipitation in all models.
- It is particularly effective for highly intermittent models.

Spatial averaging over 5.6° x 5.6° chosen as 4 x the resolution of the coarsest models.



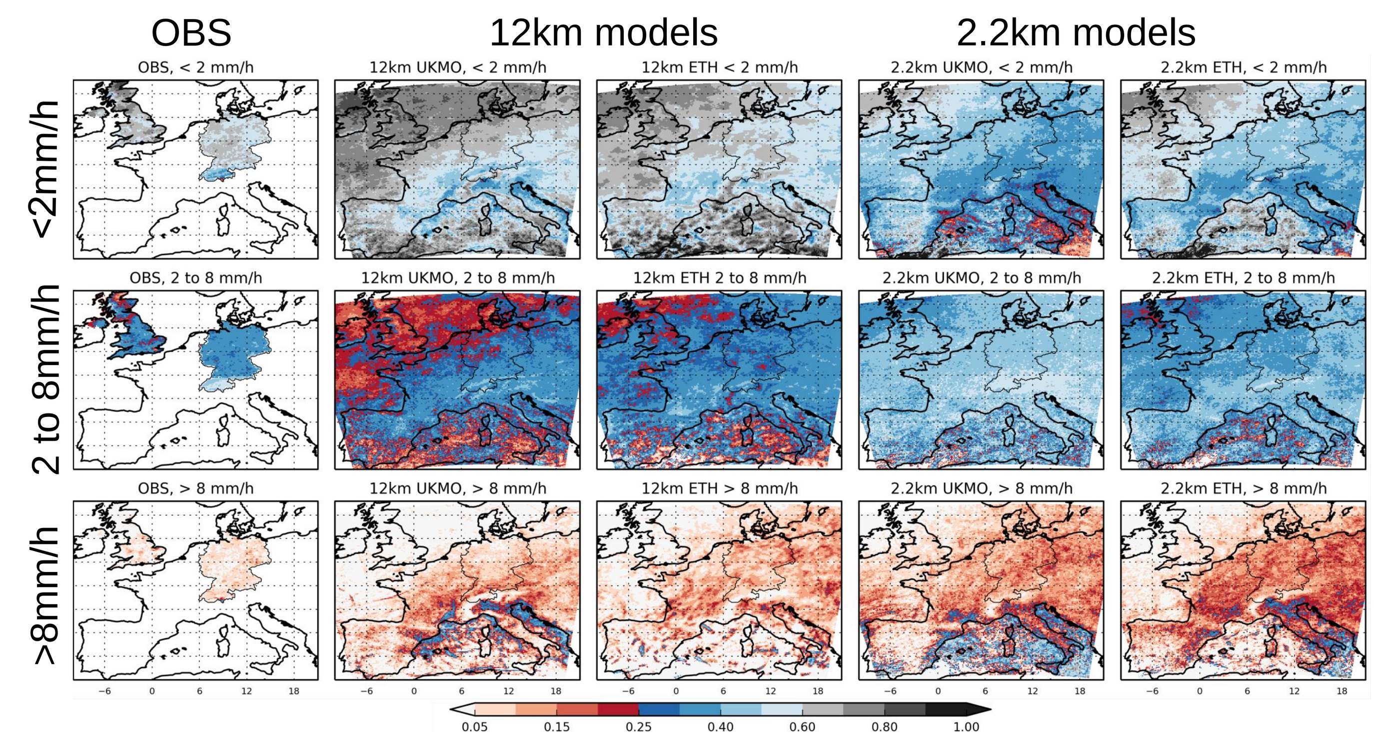
Effects of temporal averaging

- Temporal averaging increases the spatial scale for all models, especially the MetUM.
- All models have greater coherence than TRMM and CMORPH at distances <300 km.
- CMORPH has smaller precipitation features than TRMM.

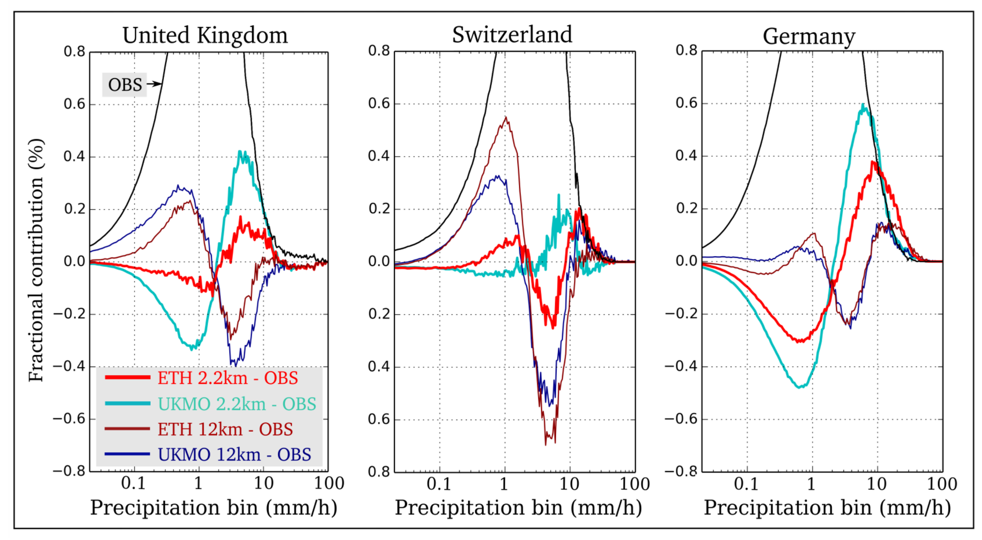
4. European regional models

Evaluation of convection-permitting 2.2km regional models compared to their 12km convection-parameterised counterparts (10 year simulations driven by ERA-interim) by Berthou et al. (2018).

Fractional contributions for different precipitation intervals at every single grid-point (top) and country-by-country spatial pooling with the full spectrum (bottom).

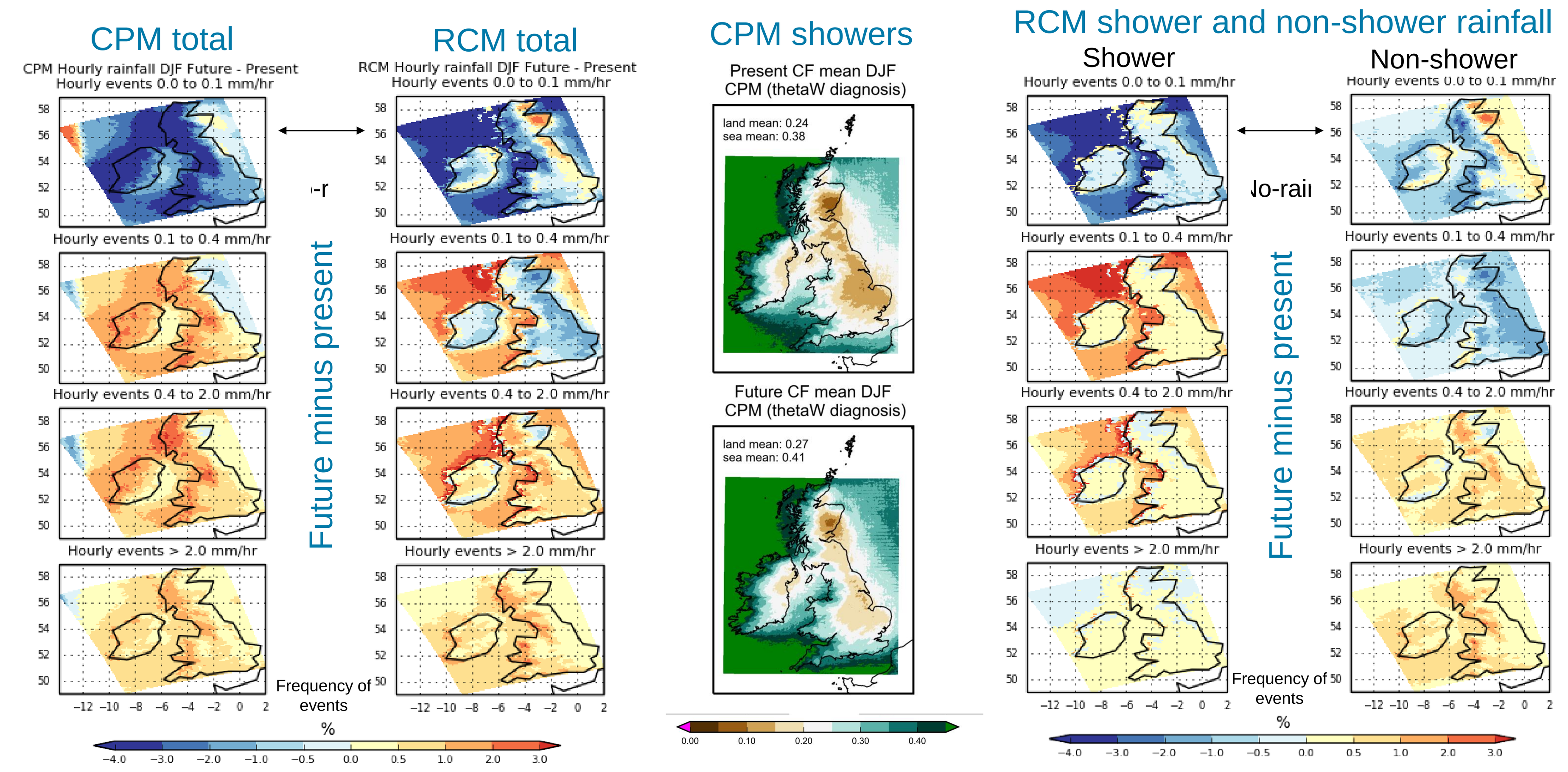


- 12km convection-parameterised models overestimate light (<2mm/h) precipitation and underestimate moderate to high precipitation rates (2 to 8mm/h).
- 2.2km convection-permitting models over-correct this bias and have not enough light precipitation and too much moderate to high precipitation rates. The UKMO model has a worse bias than the ETH-COSMO model.



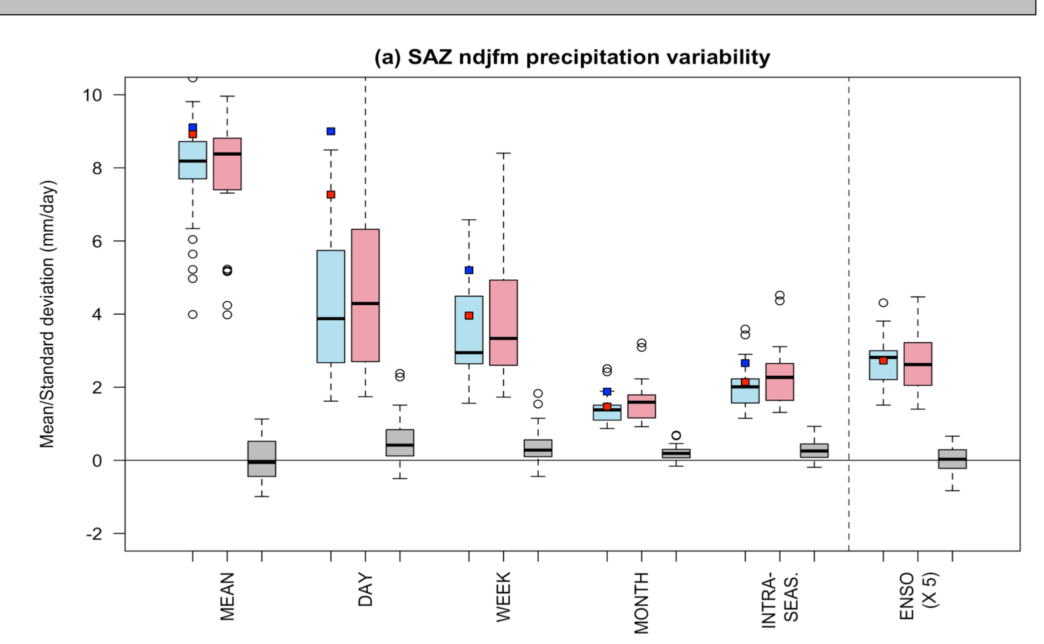
5. UK Climate change projections

Convection-permitting simulations at 2.2 km resolution show greater future increases in UK winter mean rainfall than those from the coarser (12km) driving model (Kendon et al., submitted). Around 60% of the future increase in winter precipitation occurrence over land comes from an increase in convective showers in the 2.2km model, which are most likely triggered over the sea and advected inland with potentially further development. In the 12km model, increases in precipitation occurrence over the sea (which are largely due to an increase in convective showers) do not extend over the land, partly because the convection parametrisation scheme has no direct memory and is thus unable to advect the diagnosed convection over the land.



6. Assessing rainfall variability across timescales

- Time-series of gridded daily precipitation data are detrended, then bandpass filtered at a number of timescales from daily to decadal.
- Variability on each timescale is assessed by taking the standard deviation of each bandpass-filtered time-series.
- Comparison of models against observations, and assessment of projected changes in variability, have so far been carried out for monsoon regions (Brown et al. 2017) and Brazil (Alves et al. submitted).



Southern Amazon region Rainy Season: Observed (blue and red squares) and CMIP5 end of 20th c. (blue boxplots), end of 21st c. (pink boxplots) and change between 20th and 21st c. (grey boxplots), mean precipitation (left column) and s.d. of bandpass filtered time-series (other columns).

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