Response to Referee #2

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Dear Dr. David Adams,

Many thanks for your comments and suggestions on the manuscript. We have found your two main critiques to be very timely and useful to improve our study. We hope you'll find the changes made to manuscript satisfactory.

Regarding your two major comments we have made the following changes to the manuscript. First, we included the following in the introduction to motivate the study:

Climate research in recent decades has aimed to reduce uncertainty in climate projections by improving GCMs, but different approaches taken by modelling centres appear to be seemingly disconnected (Jakob, 2014). One approach is to reduce horizontal resolution down to km resolution to rely less on parametrizations and more on physical laws to represent clouds and convection (Palmer and Stevens, 2019). A second approach aims to model Earth System processes to better characterise complex land-atmosphere-ocean biogeochemical cycles that may provide a better constraint on climate sensitivity, a parameter that depends on the carbon cycle (Marotzke et al., 2017; Sellar et al., 2019; Andrews et al., 2019). Finally, recent arguments have also suggested to include stochastic parametrisations of sub-grid processes since this approach has improved seasonal forecasts and may therefore improve climate projections (Palmer, 2019).

To address your second comment regarding perhaps the parametrisations and their role for improved biases, as we mostly see an improvement of the biases in the South American Monsoon with increased resolution we argue that the oceanic component is very relevant, where perhaps the eddy heat flux parametrisations improve as resolution improves.

The results of this study showed that the medium resolution (GC3 N216) simulation improved upon some of the biases of the lower resolution simulations, such as most of the precipitation biases. This improvement in the medium resolution simulation may largely be due to the improved dynamics associated with relying less on model parametrisations and more on physical governing laws. The double-ITCZ problem and the Atlantic ITCZ biases have been shown to be directly affected by the convective scheme. Several parametrised processes associated with the convective scheme have been shown to the treatment of entraintment and moisture-cloud feedbacks (Oueslati and Bellon, 2013; Li and Xie, 2014). The resolution of the ocean sub-model is known to have an impact over the equatorial Atlantic SSTs and the ITCZ biases which are noticeably reduced in the medium resolution simulation (Kuhlbrodt et al., 2018), due to the improvement in the eddy heat flux and the 15associated heat uptake and transport of the ocean. The

improvement in the ITCZ and the associated dynamics also improves the associated circulation biases in the South American Monsoon indicating that the oceanic resolution in these models improve the cross-equatorial transport, SST gradients and the land-sea circulation over the Amazon during austral summer.

1. Specific comments

Line 36 " A bimodal regime characterises the seasonal cycle of precipitation in southern Mexico, Central America and the Caribbean that is typically referred to as Midsummer Drought (MSD)" Perhaps for completeness you can include the more local reference terms for this phenomenon. In Central America it is often called "El Veranillo" and in southern and eastern Mexico "La Canícula". For example a bit more detail on the MSD can be found in these articles, Amador JA et al. 2016, Amador, J.A., et al., (2016), Durán Quesada et al (2017).

We have added the suggested references and more detail to this paragraph:

Line 41 . The complex interplay of moisture transport, evaporation and the dynamics..." When you say evaporation here you should probably clarify if you mean from the sea-surface or from land-surface or both, as terrestrial latent heat fluxes is a difficult quantity to measure and the effects on precipitation are unclear (e.g., moisture recycling).

The manuscript now states:

The complex interplay of SSTs, evaporation and moisture between the East Pacific Ocean and the Caribbean Sea are key for the spatial and temporal characteristics of the MSD (Amador et al., 2006; Herrera et al., 2015; Durán-Quesada et al., 2017; Straffon et al., 2019)

Line 51 "The date of monsoon onset is also region-dependent; in northern South-America convection is observed from early October, whereas convection in southeastern Brazil typically starts in mid- November or later (Marengo et al., 2001; Nieto-Ferreira and Rickenbach, 2011)." You probably want to clarify this. Do you mean deep convection and the associated rainy season? In the Central Amazon region, the rainy season begins late December and lasts until about April. Typically, in October, there may be intense deep convective events in the Central Amazon (see Adams et al 2013), but in terms of convective precipitation, January through April are very rainy (see Machado et al. 2004). How well models actually reproduce the geographic distribution of Amazon Basin rainfall is an important issue, you may want to discuss with a little more detail and citations.

Many thanks for these suggestions, the initial wording was indeed unclear. We hope you like the new wording in the manuscript. Now, when presenting the South American Monsoon:

In the central Amazon and northern South America, convective activity is observed from early October but the main rainy season extends from December to April (Machado et al., 2004; Adams et al., 2013), whereas convection in southeastern Brazil starts in November and peaks in January and February (Marengo et al., 2001; Nieto-Ferreira and Rickenbach, 2011).

Line 69 You should probably clarify what hemisphere you mean here when you say "fall".

Done, we clarified to state "austral fall".

Line 73 "The next efforts to improve climate models include increased horizontal resolution, ..." This drive towards increased horizontal resolution is quite strong, down to the kilometer resolution for GCMs, you should refer to some of the literature I mention in the Major Comments section.

We have addressed this from your major comment.

Line 83 "The study documents the main biases in the simulated climate of UKESM1 and HadGEM3.0 and compares the effect of increased horizontal resolution and Earth System processes on the representation of the AMS climate. The analysis provides a framework for using these climate models in scenario studies, to highlight possible sources of model error that may be corrected and to further understand variability and teleconnections in this region."

Line 98 "GPCP, GPCC and CHIRPS are also used for their longer period, although arguably each of these datasets have shortcomings in either resolution or spatial coverage." You should probably include a few citation of studies that have used these data in similar context for the reader to consider, particularly studies where the shortcomings are discussed.

Reviewer 1 made a similar suggestion. Therefore, now we point to studies that have validated one or several or these datasets in a region of the AMS. However, a study intercomparing the different datasets and validating them against rain gauge data is not know to us. The manuscript now reads:

Some studies have validated one or several of these datasets in the AMS region (e.g. Franchito et al., 2009; Dinku et al., 2010; Trejo et al., 2016).

Line 113 "piControl", I assume you mean pre-industrial, but you should spell it out for the reader.

Done.

Line 190 "Afterwards, the ITCZ migrates northward reaching a peak latitude and mean rainfall at 10N by day 250, or May 30." I think you have made a mistake here, you probably mean early September.

Correct. We corrected this line.

Line 213 Write "Negative ω and low-level moisture biases in the central and East Pacific Ocean ..."

Done.

Line 221 "These are observed as negative zonal wind biases, indicative of significantly weaker upper-level westerlies resulting from the overturning circulation in the Pacific Ocean." This statement is a bit confusing, it sounds as if you are referring to the oceanic circulation within the Pacific Ocean.

This statement has now been removed as the Walker circulation figure has been moved to the Supplementary material and the discussion of the figure in the main paper has been made shorter.

Line 280 Rewrite using commas "The models also show a good representation of the transition from winter to summertime rainfall by representing, with relative skill, the smooth transition from 4 mm day-1 in September to 6 mm day -1 in November and close to 8 mm day -1 in late December."

Done.

Line 290 "these quantities characterise the strength and height of deep convection and the mid-level

moisture." This idea is a little unclear, what you do mean "the mid-level moisture"? Specific humidity has a vertical distribution associated with instability and convection. And OLR for convective cloudiness would be associated with high levels in the atmosphere.

Yes, the wording in this paragraph was unclear. We use the free tropospheric specific humidity values (q at 500 hPa) and the vertical velocity at the same level, as well as OLR. And yes, these are technically different levels in the atmosphere we are looking at, and only a small picture of the vertical characteristics of convection, however, these metrics show interesting differences between model and reanalysis data.

Line 319 Check spelling "althougth"

Done.