Review of the manuscript 'Impact of AMV on rainfall intensity distribution and timing of the West African Monsoon in DCPP-C-like simulations' by Mohino et al.

The authors examine the influence of the Atlantic Multidecadal Variability (AMV) on intraseasonal precipitation characteristics by analyzing a series of model simulations following a commonly used protocol. They analyze the biases shown by the models and estimate the impact of AMV by comparing 10-year averaged AMV+ and AMV- experiments. Models show consistent bias patterns in the summer JAS seasonal total rainfall amounts, number of rainy days and mean rainfall intensity, with an underestimation over the Sahel and an overestimation to the south, especially over the Guinea Coast. The models analyzed show high agreement in the response of West African rainfall to a positive phase of the AMV. This response involves a general increase in JAS seasonal rainfall amounts with higher changes in the southern Sahel, typically close to 10N, and weaker ones to the North. The latter are mainly related to an increase in the number of rainy days due to the enhancement of all types of rainfall events, moderate, heavy and extreme. The stronger changes observed in the southern part of the Sahel are better explained by an increase in the mean intensity of rainfall, as the number of heavy and extreme rainfall events grows, while those for moderate changes little or it even decreases.

We thank the reviewer for her/his careful reading of the manuscript and for the remarks and suggestions. In the following we provide discussion on these comments using red to distinguish our answers from the reviewer’s comments.

Comments:

- introduction: causes of the AMV: please note that AMV variability might also be caused in a model that does not include ocean circulation changes. Please see Clement et al. DOI: 10.1126/science.aab398

Thanks for this remark. We have added the following sentence on this possible mechanism for producing AMV as the second sentence in the second paragraph of the introduction (starting in line 30): “Another possible mechanism, also internal to the climate system, is the response of the upper ocean mixed layer to mid-latitude atmospheric stochastic forcing and subsequent thermal coupling in the tropics (Clement et al. 2015).”

- method: onset and demise of the wet season: 'The daily rainfall anomaly is obtained as the rainfall for each day minus the long-term climatological mean daily rainfall using all available years in the observations and all years and ensemble members in both experiments, AMV+ and AMV-, in the models.' I find this description confusing. I would prefer to rewrite the sentence. Do you mean: The daily rainfall anomaly is obtained as the climatological rainfall for each day minus the annual mean rainfall using ..…

Sorry that the description was confusing. As in Liebmann et al. (2012), onset and demise dates are calculated separately for each year (of each ensemble member, in the case of the simulations), using the actual rainfall value for each day of that year (and ensemble member, in the case of the simulations). The daily rainfall anomaly is then calculated for each day of each year (and ensemble member, in the case of the simulations) as the difference between the actual daily rainfall and the long-term annual mean rainfall, which is defined as the averaged daily rainfall using all days and all years (and ensemble members in the case of the simulations). We have modified two sentences in the paragraph to highlight this detail of the calculation being performed for each year. The sentences in lines 171-174 now read as: “It consists in calculating for each calendar year the dates for the minimum and maximum of the daily cumulative rainfall anomaly which provide the onset and cessation dates, respectively, for the season of that year. The total length of the season is given by the difference between the cessation and onset dates. For the simulations, the calculation is performed separately for each year in each ensemble member. For each day of each year (and of each ensemble member, in the case of the simulations), the daily rainfall anomaly to be cumulated is obtained as the rainfall for that day minus the long-term climatological mean daily rainfall using all available years in the observations and all years and ensemble members in both experiments, AMV+ and AMV-, in the models."

- statistical significance: 'To test whether the change in a given quantity is statistically significant we apply the parametric test for differences of means under independence (Wilks, 2019)' Please describe more precisely what kind of parametric test you have used. I assume you have used a t-test. I am wondering if this test is applicable for extreme values (e.g. Figure 14), because the populations must be normally distributed?

Thank you for your comment. We have indeed used a t-test. To clarify this, we have changed the sentence to: "To test whether the change in a given quantity is statistically significant we apply the parametric t-test for differences of means under independence, assuming a Gaussian distribution for the samples (Wilks, 2019)"

Regarding the concern raised by the reviewer on the use of this t-test for Fig. 14, we note that we are evaluating frequencies (number of days) and not the actual extreme values. The latter would indeed be better fitted with a Generalized Pareto Distribution (Wilks, 2019). The number of days are more normally distributed, even more so because the values we are testing are averages over the 10 years of simulation (we are only assuming each ensemble member as an independent realization and not each year, as explained in lines 187-188 of the manuscript). To show this point further, we have tested for the case of the number of extreme rainy days (Fig. 14) whether the sampling distributions of the 10-year means are inconsistent with a Gaussian distribution using the Kolmogorof-Smirnov goodness of fit test with the variant of having fitted the parameters of the distribution (also known as Lilliefors test, see Wilks 2019). Fig. R1 shows that the Gaussian distribution is in general not inconsistent with the samples of 10-year averages of the extreme rainy days in regions where there is some summer rainfall (typically above 1 mm/day of mean JAS rainfall). This suggests that for most of the areas where significant differences in the number of extreme rainy days between AMV+ and AMV- experiments are shown in Fig. 14 of the manuscript, the assumption of Gaussian distribution used in the t-test is not inconsistent with the distribution of the samples used to evaluate it.

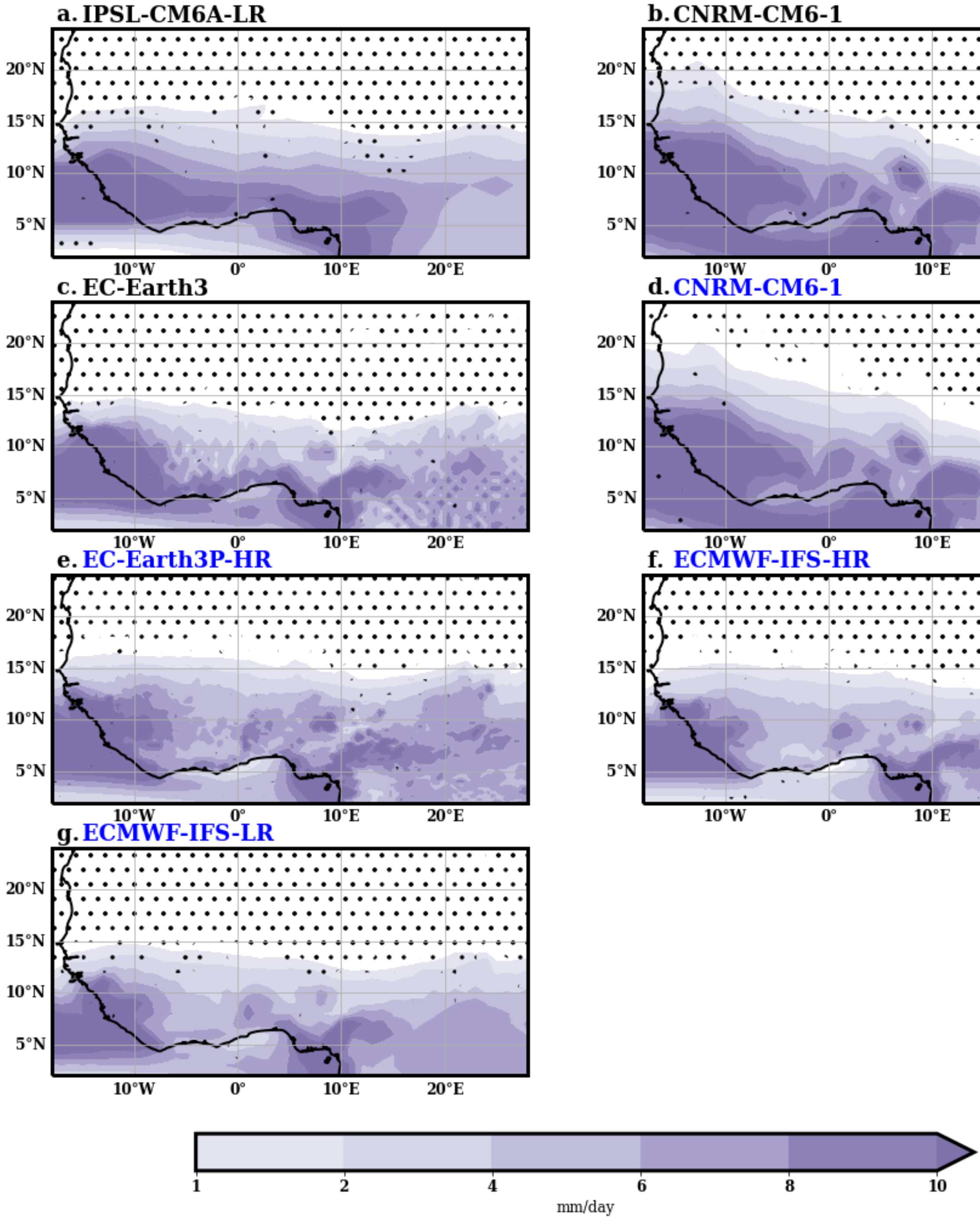

Figure R1: Average JAS rainfall (shaded, mm/day) and regions where the distribution of the samples of 10-year averaged extreme rainy days is inconsistent with a normal distribution (dotted areas) for either the AMV+ and / or the AMV- ensembles. For each grid point, the Lilliefors test has been applied separately for the AMV+ and AMV- ensembles samples of 10-year averaged extreme rainy days. Dots mark where the null hypothesis of normal distribution is rejected at p=0.05 for any of the AMV+ and the AMV- ensembles.

- The color bar (magnitude and units) in some plots might be wrong. I think they do not fit to the caption. Please have a look e.g. at Figure 2 and Figure 5. The caption of Figure 2 says mm/day, but in the figure it says days. I have the impression that also the magnitude of the color-bar is not correct.

Many thanks for this remark. We apologize for these mistakes. We have revised carefully the units and magnitudes in the figures and made the following changes:

* Fig 1: we have added the units for the climatological contours in plots c and d (same units as the corresponding anomalies).

* Fig 2: we have corrected the units in the color bar to “mm/day”. Magnitudes were already right in the former version. The reviewer might have thought magnitudes were wrong because of the values of rainfall biases shown in Fig. 3ab. However, we note that in Fig. 3ab we only plot the averaged biases over the Sahel box (10ºE-10ºW, 10ºN-20ºN). Local values might reach biases as strong as -6 mm/day (for instance the coast of Guinea Bissau in the IPSL-CM6A-LR model). To avoid confusion to the readers, we have changed the sentence in lines 194-197 from “All in all, the models provide too dry conditions over the Sahel ranging from deficits of 0.3 mm/day for the CNRM-CM6-1 model with the DCPP-C protocol to 1.8 mm/day for the EC-Earth3 in DCPP-C and ECMWF-IFS-LR in PRIMAVERA ones, which roughly represent between 8 and 60 % of average rainfall over the Sahel from MSWEP (Fig. 3ab).” to “Averaged over the Sahel box, the models provide too dry conditions ranging from deficits of 0.3 mm/day for the CNRM-CM6-1 model with the DCPP-C protocol to 1.8 mm/day for the EC-Earth3 in DCPP-C and ECMWF-IFS-LR in PRIMAVERA ones, which roughly represent between 8 and 60 % of average rainfall over the Sahel from MSWEP (Fig. 3ab).”

* Fig 5: we have corrected the units in the color bar and in the caption to “mm/day”. We have also corrected the caption for the contours which are the climatological values of the intensity of rainfall and not the number of rainfall days, as it was mistakenly written in the former version.

* Fig 6: we have corrected in the caption the eastern boundary of the westernmost Sahel to 10ºW. When presenting the westernmost Sahel region in the text (line 180) we have expanded the description from “(purple box in Fig. 1cd)” to: “(purple box in Fig. 1cd, taken as the region 17ºW-10ºW, 10ºN-20ºN, after removal of the area west of the line connecting the points 17ºW-12ºN and 15ºW-10ºN).

* Fig 9: we have corrected in the caption the units of the anomalies shaded to mm/day.

- wondering if it might be useful to also compare the precipitation PDFs of the observations and simulations for some key areas.

Following this suggestion, we present in Fig. R2 the PDF of daily precipitation averaged over the Sahel box (10ºW-10ºE, 10ºN-20ºN) for models and observations. Compared to MSWEP, models tend to overestimate (underestimate) the number of days with daily rainfall amounts below (above) 2-3 mm/day averaged over the Sahel. This is particularly problematic for EC-Earth3 model in DCPP-C protocol and the ECMWF-IFS-LR and ECMWF-IFS-HR models in the PRIMAVERA protocol. These model biases are yet beyond our estimate of observational uncertainty: CHIRPS data provides a PDF with a tendency to even higher values of rainfall than MSWEP (Fig. R2h).

The model biases in the PDF of daily rainfall over the Sahel box are consistent with the analysis of the bias in mean rainfall intensity presented in the manuscript: Figs. 3a and 5 already suggested that, beyond the observational uncertainty, models tend to show too weak mean intensity of rainfall over the Sahel, especially for EC-Earth3 model in DCPP-C protocol and the ECMWF-IFS-LR and ECMWF-IFS-HR models in the PRIMAVERA protocol. This is, at the grid point level, when it rains, it tends to rain smaller amounts than in the observations.

Given that the article is already quite long, especially the section on model biases (figures 2 to 6), and that part of the information provided by showing PDFs is conveyed in the analysis of the mean intensity of rainfall, we prefer to leave the PDF analysis out of the manuscript.

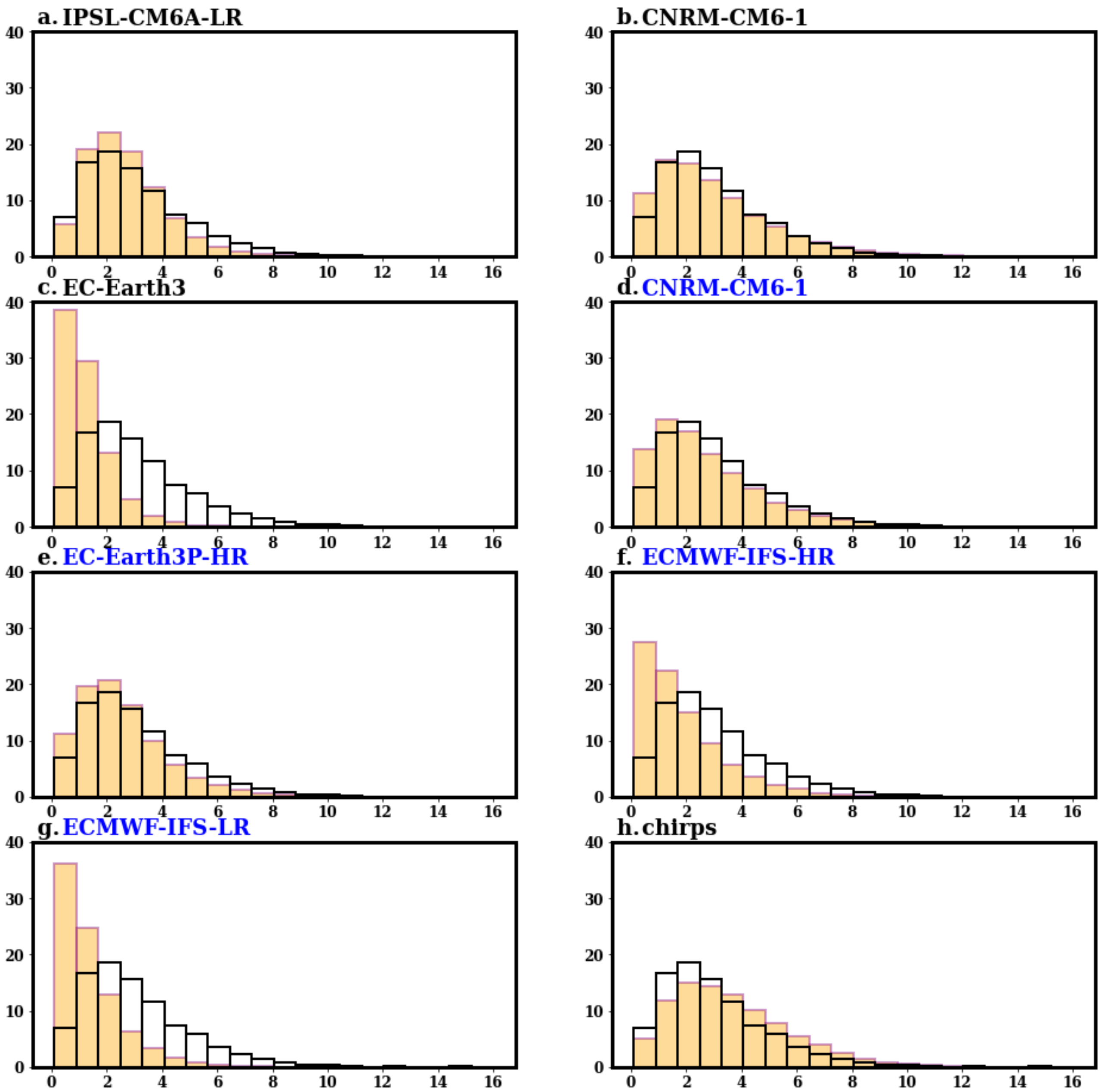

Figure R2: Histograms of daily rainfall in the JAS season averaged over the Sahel box (10ºW-10ºE, 10ºN-20ºN) for the models (orange bars, plots a to g) and MSWEP (black lines in all plots) and CHIRPS (orange bars in plot h). Horizontal axis shows daily rainfall values (mm/day) and vertical axis shows the number of days per JAS season. All days have been used for the calculation (no temporal average has been applied). The simulations following the PRIMAVERA protocol are marked as blue in the model name labels.

Further modifications done to the manuscript:

- We have updated the acknowledgment section to include thanks to the anonymous reviewer and to add an additional source of funding.

References cited:

-Liebmann, B., Blade, I., Kiladis, G. N., Carvalho, L. M. V., Senay, G. B., Allured, D., Leroux, S., and Funk, C.: Seasonality of African Precipitation from 1996 to 2009, Journal of Climate, 25, 4304–4322, https://doi.org/10.1175/JCLI-D-11-00157.1, 2012.

-Wilks, D. S.: Statistical Methods in the Atmospheric Sciences, 4th Edition, Elsevier, Amsterdam, https://doi.org/10.1016/C2017-0-03921-6, 2019.