

Anonymous Referee #2

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General comments

The well-written and well-structured manuscript presents an analysis about the impact of the seasonal rainfall distribution on ANPP in the Sahel zone during the period 2001-2015. The authors utilized a gridded dataset of daily precipitation to compute different seasonal rainfall metrics and related these to NDVI SIN (derived from a time series of MOD09Q1) as a proxy for ANPP. The objective of the manuscript is addressed with a sound methodology and the findings of the authors are supported by the results. Overall, the topic is very interesting and relevant, e.g. for the food security and climate change community, and I support the acceptance of the manuscript after minor revisions. In general, I would like the authors to address a few more issues in the discussion/conclusion. First, please discuss the quality of the utilized data products, especially the rainfall dataset, and if this could affect the obtained results. Second, please address the possibility of an adaptation of the vegetation (e.g. change in species composition) to a change in the seasonal rainfall distribution (related to the last paragraph in the summary and conclusion section). Furthermore, I would be interested if the authors tested if there is a relationship (correlation) between the different analysed seasonal rainfall metrics. But this does not need to be part of the paper (it is just curiosity). More specific comments are given below.

We would like to thank the reviewer for the supportive comments and suggestions, which have certainly helped us in improving the manuscript. We have implemented all of the suggestions and we believe that the revised version of the MS is now substantially improved. Below we respond to each of the comment individually.

General comments

First, please discuss the quality of the utilized data products, especially the rainfall dataset, and if this could affect the obtained results.

R1: Thanks. We have adopted reviewer1's suggestion and your comment (L90) and the CHIRPS data were used to replace RFE, We discuss data quality in the beginning of the discussion section of the revised version: (L267-278)

" Uncertainty in the rainfall data is inevitably to have an impact on the extraction of seasonal rainfall metrics which further impacts the relationship between seasonal rainfall metrics and ANPP. Based on improved climatologies systematic bias in the CHIRPS dataset has been removed and the data is considered state-of-the-art within quasi-global, high spatial resolution rainfall datasets (Funk et al., 2015). As this study does not address temporal changes in the seasonal rainfall metrics or \sum NDVI, but merely presents results on the general coupling between rainfall metrics and vegetation productivity, we consider the results to be statistically robust. We conducted a parallel set of analyses based on the RFE-2.0 rainfall product developed by the NOAA Climate Prediction Center (CPC) (Herman et al., 1997), which, like CHIRPS, is also a gauge-satellite blended and the outcome of these analyses yielded nearly similar results as what is presented here. At the same time \sum NDVI derived from MODIS will also be impacted from cloud cover during the growing season, but the use of the Savitzky-Golay filtering algorithm has proven to be an effective way of overcoming residual noise effects in the NDVI time-series (Fensholt et al., 2015). "

Second, please address the possibility of an adaptation of the vegetation (e.g. change in species composition) to a change in the seasonal rainfall distribution (related to the last paragraph in the summary and conclusion section).

R2: This is an excellent point, which is on our to-do-list, however it would require long-term records of field observations of herbaceous species composition to study further – but that would certainly be interesting. We have added the following sentence to this section (L353-356).

“Inter-annual differences in the seasonal distribution of rainfall is known to have an impact on species composition in Sahel (Mbow et al., 2013) and it is likely the herbaceous vegetation is able to adapt to changes seasonal rainfall distribution expressed by a shift in the abundance of species favored by increased heavy rainfall events and longer dry spells.”

Furthermore, I would be interested if the authors tested if there is a relationship (correlation) between the different analysed seasonal rainfall metrics. But this does not need to be part of the paper (it is just curiosity).

R3: The non-parametric Spearman’s rank correlation coefficients between all seasonal rainfall metrics are showed in the below:

	R	Onset	Cessation	RD	SDII	R95sum	CDD
R	1						
Onset	-0.79	1					
Cessation	0.60	-0.45	1				
RD	0.92	-0.83	0.60	1			
SDII	0.69	-0.37	0.32	0.38	1		
R95sum	-0.91	0.82	-0.60	-0.99	-0.35	1	
CDD	-0.82	0.67	-0.33	-0.86	-0.41	0.84	1

Specific comments

Line 12: “number of rainy days, rainfall intensity, number of consecutive dry days and heavy rainfall events” -> please specify that these metrics refer to the rainy season

R4: We changed the text as ‘This study tests the importance of rainfall metrics in the wet season (onset and cessation of the wet season, number of rainy days, rainfall intensity, number of consecutive dry days and heavy rainfall events) on growing season ANPP’ . (L11)

Line 17: Please add a half sentence to shortly explain the meaning of “breakpoints” in this context

R5: Thanks, we have included the following sentence in the abstract: “We analyzed critical breakpoints for all metrics to test if vegetation response to changes in a given rainfall metric surpasses a threshold beyond which vegetation functioning is significantly altered.” (L17-18)

Line 26: remove “KM” from the reference

R6: Sorry for this. It has been changed accordingly. (L28)

Line 29: “wet season which can be highly variable between years” -> the wet season is highly variable in time and space (please add the space component)

R7: Thanks. It has been changed accordingly. (L31)

Line 34: “21st century climate change” -> add “predicted”

R8: Thanks, we have changed it as suggested.

Line 89: Provide a reference/website where to access the RFE-2.0 data

R9: RFE-2 was replaced with CHIRPS, so this paragraph has been deleted. We added the website and reference for CHIRPS.

Line 90: Please provide an explanation why you opted for the RFE-2.0 dataset and not another daily precipitation dataset like CHIRPS (see also comment of M. Marshall)

R10: Since we fully agree that CHIRPS data will be a better choice than RFE, we have followed this suggestion and replaced all the analyses by CHIRPS data.

Line 109: “on day (Pi)” -> Is there something missing, e.g. “on a certain day”?

R11: Thanks. We rephrased this sentence to make it clearer.

Line 122: Provide a reference for the MOD09Q1 product and/or a website where to access the product

R12: Thanks. We have added a “Data availability” section following “Summary and conclusion”. (L358)

Line 128: Please specify if you did the resampling of the NDVI data before or after applying TIMESAT

R13: Thanks. We have rephrased this part a bit to make it clearer. We first calculated the \sum NDVI and then the resampling was done. e.g., The derived small seasonal integral was used as the \sum NDVI. The method is well established and proven to be a reliable proxy for the growing season ANPP in Sahel (Olsson et al., 2005; Rasmus et al., 2013). The \sum NDVI data was then aggregated to the resolution of CHIRPS (0.05 °) using a bilinear resampling method. (L134)

Line 129: Provide a reference for both land cover maps; Specify how the masking was done (i.e., did you mask out water if both LC maps indicate water in a pixel or if at least one of the LC indicate water?)

R14: Thanks for your suggestion. It has now been specified that pixels with water were masked out if one or both of the land cover products indicated the presence of water in a pixel. (L136-137)

Line 133: Please explain why you chose the Pearson's correlation coefficient and not for example the non-parametric Spearman's rank correlation coefficient

R15: We thank the reviewer for this comment. We have used the non-parametric Spearman's rank correlation coefficient in the new version since it measures the monotonic relationship which is a better choice in this study. This has now been corrected in the text. (L141)

Line 134: Please provide the R package name for the GAMs

R16: Thanks. The MGCV package is provided.

Line 135: "Team, 2014" should be "R Team, 2014"

R17: Thanks. It has been corrected accordingly.

Line 138: "individual rainfall variables" -> please use terms consistently, e.g. use "individual seasonal rainfall metrics" here

R18: Thanks for your suggestion; it has been done accordingly throughout the MS.

Line 151f: "The 95th percentile of NDIV SIN [: : :] for a given rainfall amount" -> It is not fully clear how you calculated the potential vegetation productivity: Did you calculate it pixel-wise? Does the "given rainfall amount" represent the mean annual rainfall sum of a pixel? -> please clarify the description of your calculations

R19: Thanks, we have rephrased this sentence (L162-166). We added '*The 95th percentile of $\sum NDVI$ was selected to represent the potential vegetation productivity attainable for a given seasonal rainfall metric (Donohue et al., 2013). Seasonal rainfall metrics were binned according to the dynamic range of the individual metrics and the average 95th percentile of $\sum NDVI$ was calculated for each bin (for onset, cessation and RD bins with an interval of 1 were used; for SDII a bin of 0.3 was applied; for R95sum bin intervals were set to 0.02; finally we used bins 0.5 for CDD)*'.

Line 158: "with a later onset" -> should it not be "with an earlier onset"?

R20: Sorry for this mistake and it has been changed to 'earlier'.

Line 166f: "with a near linear relationship" -> Fig. 4 does not look like a linear relationship

R21: Here we simply want to show the spread of $\sum NDVI$ for each rainfall zone and when considering the different quantiles of the plot, we actually believe that it's correct to present this Fig. 4 relationship as near-linear.

Line 182: "variations in seasonal rainfall distribution" -> Do you mean all seasonal rainfall metrics?

R22: Yes, the term seasonal rainfall distribution was used to indicate seasonal rainfall metrics. To make it clearer, we have now added a few examples "(e.g., onset and R95sum)". (L198)

Line 239: "from where the rather low amount of vegetation loses sensitivity to even more extreme seasonal distribution" -> please reformulate as the phrase is not really clear

R23: Sorry for this. We have rephrased this sentence to: “from where the vegetation loses sensitivity to the impact from an increased frequency of heavy rainfall events” (L258-259)

Line 255: RESTREND approach -> please explain a bit more this approach

R24: Thanks, we have added this part a parenthesis explaining the approach: “regressing Σ NDVI from annual precipitation and subsequently calculating the residuals as the difference between observed Σ NDVI and Σ NDVI as predicted from annual precipitation)” (L285-289)

Line 367f: Some information like publisher are missing for this publication

R25: Sorry for this mistake. It was an IPCC report and we specified this in the L417.

Line 390f: Information about journal volume, issue and pages missing

R26: Sorry for this. The missing information was added. (L441)

Line 400: Some information like publisher are missing for this publication

R27: Added. (L451)

Line 432f: Should be “R Team” instead of “Team, R”; there is twice the year 2014

R28: Sorry for the mistake. Corrected. (L479)

Table 1: Definition of CDD: should it not include “during the wet season” or something

Similar

R29: Thanks. We rephrased the sentence, which now reads: “Maximum number of consecutive days with rainfall <1 mm during wet season”

Figure 1: Here the study area is defined as the area between 100-700 mm annual rainfall. But in the description of the study area on page 4 you define your study area as the area between 100-800 mm annual rainfall -> Please choose one definition and use it consistently throughout the paper

R30: Sorry for this mistake. We used 100-800 mm yr⁻¹ and it has been changed throughout the MS accordingly.

Figure 5: Please provide a parameter and a unit for the color scale in the sub-figures

R31: Thank, we have added ‘Density’ as the title for the color scale.

Figure 6: Maybe provide an r value for each sub-figure as in figure 5

R32: Since there are three variables shown in each sub-figure, we have decided to report the r values in a separate analysis (Figure 7).