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Discussions

Interactive comment on "Climate change impacts on river discharge in West Africa: a review" *by* P. Roudier et al.

P. Roudier et al.

philippe.roudier@jrc.ec.europa.eu

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=> We thank referee #3 for its useful comments which helped us to improve the paper and to submit a new improved version of the manuscript. We answer below to each comment point by point.

Overall Evaluation This paper presents a thoughtful synthesis of a large number of studies that examine potential impacts to major rivers in West Africa. The paper points out that most of the research carried out to-date focuses on the effects due to climate change (via precipitation, temperature, and potential evapotranspiration), while a few also examine the effects of changes in water withdrawals, land-use, and atmospheric CO_2 concentration. The paper pulls together the results from many studies and pro-

vides insight to the state of our understanding of potential changes to West African rivers. Below, I offer a few suggestions to provide additional context for the synthesis and improve the communication of the results and implications. Overall, I think the paper makes a valuable contribution to our understanding of West African hydrology.

=> Thank you.

Specific Suggestions To help orient the readers who may be less familiar with West African rivers, I recommend that the authors include a table with some basic information about the river basins. Specifically, I recommend that they include: river name, mean annual flow, watershed area, river length, mean annual precipitation over the basin, and average aridity index (PET/P). Such information will be especially helpful when interpreting the results that are presented river-by-river. Additionally, I think the discussion of the sensitivity of river discharge to changes in precipitation would be improved if put into the context of some theory. Specifically, Budyko-type curves provide a first-order estimate of river runoff as a function of mean annual precipitation and PET. Using such a curve could provide a theoretical prediction of what the sensitivity of discharge to precipitation might be, and the results from the range of studies (as expressed in figure 6) could then be discussed in reference to that theory. Specifically, the relatively simple curve of Schreiber, 1904, provides a relationship between mean annual runoff (R), precipitation (P), and potential evapotranspiration (PET):$R = P * \exp(-PET/P)$ Using this equation, the sensitivity of runoff to changes in precipitation can then be expressed as $(dR/R)*(P/dP) = 1 + PET/P$ The left-hand-side represents the ratio of the percent change in rainfall relative to the percent change in precipitation – the slope of the lines given in figure 6. Those slopes could then be compared to the term on the right-hand-side and differences or similarities discussed. And, of course, one could use the Budyko curve (1974) or other formulation instead of the equation from Schreiber. This would provide a nice theoretical framework for the interpretation of the variability among the river basins.

=> We added a table (see at the end) describing the parameters suggested by referee #3. However, we do not provide rainfall and PET as we do not have access to PET values over all the basins and as the map provides already a first assessment of the average rainfall for each basin (we added the watershed borders to the map). => We moreover thank referee #3 for his idea of adding Budyko-type curves. This would be indeed a very interesting analysis but we are limited here by the information available in the papers that we reviewed: very few of them give PET and rainfall changes and almost none of them provide the raw values (not changes) of these variables, so unfortunately it is not applicable to this database.

Language and Technical Correctness

Overall, the paper is well written. There are a few places where the use of language could be improved (see some specific examples below). I also offer some comments on how the figures might be enhanced as well.

Figure 5: As I understand it, the goal of this figure is to present the relationship between changes in river discharge to changes in temperature and rainfall. Visually, however, the primary message is a relationship between changes in temperature and changes in rainfall, and only secondarily about discharge. I suggest eliminating this figure and replacing it with one that is similar to figure 6, but which plots change in discharge versus change in temperature. Doing so would reveal the clear dependence of discharge on precipitation and the lack of dependence of discharge on temperature in a more effective way.

=> We followed Referee #3 advice and plot the following figure showing temperature change vs. discharge change (see at the end,fig 1) However, we decided to keep the previous one as its main aim is to compare the effect of temperature and rainfall on runoff, to select the parameter with the largest influence and to study it in the next figure more precisely (fig 6). If we put the suggested figure (below), it is not obvious to demonstrate if a negative runoff change is negative because of the temperature change or because of the rainfall, as rainfall is not shown.

Figure 6: In addition to the general conclusion that runoff is sensitive to rainfall, the authors might wish to quantify (perhaps right on the figure or in a separate table) the sensitivities and their variability among rivers. That would enable the reader to compare among the basins in a quantitative way, and compare those values to the river characteristics (see comment about adding a table) and theory (see comment about Budyko-type curve)

=> Referee #3 is right and this is what we tried to do by adding the linear model for each river, and for the whole distribution. As explained before, it is unfortunately not possible to use Budyko-type curves here but we added a table with the regression equation of each line in order to quantify more precisely the differences among rivers (see at then end).

Figure 7 – I interpret the warm colors to mean a reduction in monthly flow and the greens to indicate an increase; I recommend that it be articulated explicitly in the caption which colors indicate a increase and which a decrease.

=> Referee #3 is right, we modified the figure.

In the abstract and conclusions, I recommend that the phrase “much more” be eliminated – the contrast is between positive and negative, not positive and much more positive.

In section 2.1, line 15 I believe this statement is intended to be about intra-annual variability (not interannual variability). If so, I recommend eliminating the phrase “variations in” and replacing inter annual with intra-annual.

In section 2.3, I recommend separating the first paragraph into two (with the separation coming just before the phrase, “To create the database...”).

=> Corrections made as recommended by referee #3

I also recommend that the first part of that section be expanded a bit to give the reader a clearer sense of the overarching approach – that the studies related to climate are integrating into a database and assessed quantitatively, whereas the works addressing water withdrawals and carbon are treated more as case studies.

=> We modified this section in order to be more precise:

“Note that to be consistent with the other studies dealing only with climate change, we did not put the results including water use and land use changes in the database and thus we did not use them in section 3.1 to 3.3. More precisely, for McCartney et al. (2012) and Murray et al. (2012), we only kept the ‘climate only’ scenario. The other scenarios were used in section 3.4, as case studies.”

Throughout – rather than the phrase “contrasted climatic and hydrological conditions”, I recommend “varying climatic and...”

=> Corrections made as recommended by referee #3

=> References

McCartney, M., Forkuor, G., Sood, A., Amisigo, B., Hattermann, F., and Muthuwatta, L.: The Water Resource Implications of Changing Climate in the Volta River Basin, 2012.

Murray, S. J., Foster, P. N., and Prentice, I. C.: Future global water resources with respect to climate change and water withdrawals as estimated by a dynamic global vegetation model, Journal of Hydrology, 448-449, 14-29, 2012.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 2483, 2014.

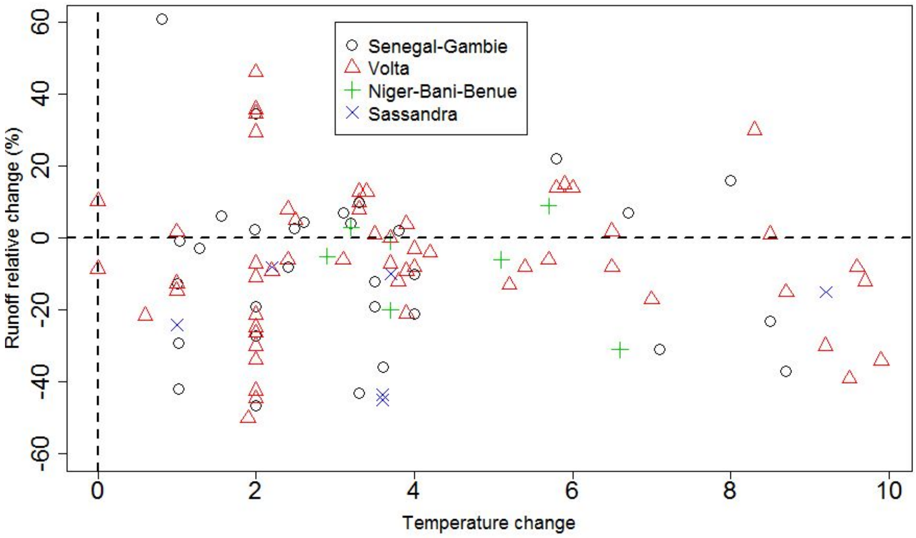

Fig. 1. Relationship between runoff change (y-axis, %) and temperature change (x-axis).

River	Mean annual flow	Catchment area	Length of upstream mainstem (and total length)
Niger (Malanville)	1053 m^3/s	1000000 km^2	2367 km (3478 km)
Senegal (Dagana)	687 m^3/s	268000 km^2	1550 km (1757 km)
Black Volta (Bamboi)	263 m^3/s	134200 km^2	843 km (1355 km)
White Volta (Pwalagu)	125 m^3/s	63350 km^2	555 km (1334 km)
Volta (outlet)	1106 m^3/s	394100 km^2	1245 km
Gambia (Gouloumbou)	149 m^3/s	42000 km^2	451 km (799 km)
Sassandra (Soubre)	331 m^3/s	62000 km^2	-
Bani (Mopti)	1101 m^3/s	281600 km^2	1004 km (3457 km)
Benue (Yola)	22 m^3/s	107000 km^2	431 km (1541 km)

Fig. 2. characteristics of the selected rivers. All values come from the Global Runoff Data Centre (GRDC).

River	Equation	Pearson correlation coefficient
Senegal-Gambie	Runoff change=1.3*rainfall change + 8.0	0.59
Volta	Runoff change=1.6*rainfall change - 10.6	0.77
Niger-Bani-Banue	Runoff change=2.0*rainfall change - 12.6	0.91
Sassandra	Runoff change=2.0*rainfall change + 7.7	0.68
All	Runoff change=1.6*rainfall change - 6.5	0.73

Fig. 3. Regression equation between rainfall change and runoff change, for each of the river.