Interactive comment on "Droughts and floods over the upper catchment of the Blue Nile and their connections to the timing of El Niño and La Niña Events" by M. A. H. Zaroug et al.

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The following review was written by one of the students of the MSc programme Earth and Environment at Wageningen University. As part of the course Integrated Topics in Earth and Environment, students have to prepare a review of a scientific paper. I supervised this review process, and submit this comment on behalf of the student that produced it. The manuscript by Zaroug et al. was one of the manuscripts that was selected for this exercise. The review is written as an official review in order to comply with the course guidelines , but it should be considered by the authors as a regular comment. I hope that this comment will positively contribute to the review process and that it will help the authors to revise their manuscript for possible publication in HESS.

This article contributes to a major issue in Africa. Millions of people are dependent on the river Nile to which the Blue Nile contributes for approximately 2/3 of the discharge. The authors also clearly show the extreme annual variation that can occur in this part of the world, from 4.7 mm of rain from May to October during the El Niño year 1983 (Eltayeb, 2003), to 216 mm in 24 hours on 4 August of the La Niña year 1988. The authors extent the knowledge on forecasting floods and droughts using El Niño information, a method that has been established over the last few decades. ENSO information has already been proven to be useful in seasonal forecasting (Wang and Eltahir, 1998). An advantage of El Niño is that it has been shown to be generally predictable for two years ahead, using a deterministic model of the coupled ocean-atmosphere system (Cane et al., 1986). "Therefore, the ability to predict flow patterns in rivers will be highly enhanced if a strong relationship between river discharge and ENSO exists, and is quantified" (Amarasekera et al., 1997). The authors contribute to this goal and the article is of relevance for readers of HESS, although I do recommend some minor revisions which could make it even more complete and better understandable for a broader audience. The comments can roughly be divided into four topics which are discussed below.

1 Clarify the importance of El Niño and La Niña timing

The authors indicate very well the importance of forecasting floods and droughts in the catchment of the Blue Nile. But in my opinion the manuscript can be even improved if also the importance and added value of paying attention to starting moment of El Nina and La Niña is better clarified, which is in the end the main objective of the paper. The authors have three main conclusions:

1. An El Niño or La Niña that start in AMJ has the highest risk to result in a flood or drought when it comes to the summer (JJAS), and events that start in ASO or later have the lowest risk.
2. In most cases (4/6) that El Niño was followed by a La Niña there was an (extreme) flood.
3. Of all seasons, the SST anomalies in AMJ are best correlated to the discharge in the summer (JJAS).

The first and the latter conclusion seem to have somewhat overlap. When reading through the results section, the question arises: If a SST anomaly impacts the discharge, does it than really matter whether it is part of the beginning, the middle or the end of an El Niño or La Niña event? Would the AMJ SST anomaly of an El Niño that starts in AMJ have more impact than the AMJ SST anomaly of an El Niño that started earlier and is still going on in AMJ? This way of analyzing, grouping data by starting moment, limits the amount of available data. The largest category, the El Niño's that started in AMJ, only consists of 6 events. Would it not be better to simply take the AMJ anomalies of all years (or only El Nino years) together and correlate them to discharge in the summer (JJAS)? Because than the conclusions about the strength of the relation between an El Niño or La Niña event occurring in (for example) AMJ and the risks for droughts or floods in the summer can be based on more data. Perhaps this is not an option, because an El Niño cannot be regarded as merely an extreme year with above average SST anomalies in the Nino 3.4 area, but really is a change in the weather system (Amarasekera et al., 1997) and therefore cannot be compared to normal years via a linear regression. However, at the end of the article, an analysis like that appeared to be done, correlating SST anomalies for several periods to discharge anomalies, although it hardly receives attention and comes last in the article. Without explanation of the reason for putting a lot of emphasis on the starting moment of El Niño and La Niña events instead of using all available data, I would expect these analyses to come first, showing the impact of SST anomalies in different seasons on the discharge anomalies in that same period. An important conclusion that arises from them, that in this study area only the (Nino 3.4) SST anomalies from May to December have a significant impact on the discharge in the same period, is now lacking in the conclusions. If the chosen analysis method and the added value of assessing El Niño and La Niña starting moments impact is better justified, this would make (the structure of) the article better understandable for a broader audience that is less familiar with the working of the phenomena El Niño and La Niña.

The importance and added value of the starting El Nino and La Nina will be clarified by comparing the correlation of AMJ during the whole years and when El Nino and La Nina start in AMJ.

Eltahir (1996) and Amarasekera et al., (1997) found the correlations between the SST anomalies (MAM) in the Pacific Ocean and the Nile flow at Aswan were -0.36 and -0.37, MAM flow in Aswan is almost equivalent to AMJ flow in Eldiem station. The correlation during AMJ was -0.39 as shown in table 1. This example shows clearly the importance and added value of paying attention to the starting time of El Nino during AMJ. When the correlation calculated in our study and other studies during AMJ of all years it was varying between -0.36 and -0.39. However, when El Nino started in AMJ the percentage increase to 83%, knowing that this percentage was based on 6 events only.

2 Better quantification of results

A general advice for improving the manuscript is to better quantify the results and in that way better communicate strengths of relationships and (un)certainty for future predictions. Results would become clearer if R2 and p-values are given.

Figure 3 indicates the discharge at Eldiem station and using different colours it is simultaneously indicated whether it is a normal, an El Niño or a La Niña period. It supports the statement (although indeed more clearly depicted in Figure 4) that La Niña is associated with above average rainfall/ discharge, but there are also occasions of normal or El Niño periods with high discharge. From the text, the certainty in the relationship between El Niño and drought, or La Niña and flood, is not very clear. Correlations between SST anomalies and discharge anomalies have been performed and the results are given in Figure 8, so a suggestion is to mention those results earlier. Also the plot of SST anomalies against discharge anomalies could be shown. Although this is not new and also shown in the paper of Eltahir (1996) for example, it does show the strength of correlation for this study area, the upper catchment of the Blue Nile.

Another figure where quantification can be helpful is Figure 6. It shows three panels with time series of the SST anomalies in the periods JFM, AMJ and JAS respectively together with a time series of the discharge at Eldiem station in JJAS. Subsequently it is judged by eye that the AMJ series correlates best, while this would be far more easy and precise if a table of R squared values was given, just like Eltahir (1996) and Amarasekere et al. (1997) do. In Figure 7 the time series of rainfall and discharge are plotted simultaneously and the text states that a good correlation is found, but simply quantifying it will already be an improvement . The results of the analysis on the impact of the starting moment of El Niño and La Niña are now shown in a table. Another way to graphically present the results could be a scatterplot with the start month or season of the event on the x-axis and discharge anomaly of JJAS on the y-axis. This might be faster to overview for a reader than a table and depicts the results more quantitative. Horizontal lines can be added indicating the sections normal, drought/ flood and extreme drought/ flood. The results of the analysis are now often given in percentages, which conceals the uncertainty of the small number of observations. The same holds for the analysis about the sequence of an El Nina and La Niña event. It is an interesting result with important implications for water managers when El Niño is quickly followed by La Niña. It should be emphasized, however, that these results are based on a very small sample size. Instead of the probability in percentages, also the number of events should be mentioned.

The coefficient of determination (R^2) and correlation coefficient for the linear fit between Nino 3.4 index in different seasons and the JJAS discharge anomalies at Eldiem station for the period 1965 – 2012 was added and tabulated in table 1. This table was added at the beginning of the discussion:

Table1. The coefficient of determination and correlation for the linear fit between Nino 3.4 index in different seasons and the JJAS discharge anomalies at Eldiem station for the period 1965 – 2012.

	JJAS precipitation	
SST index	R2	Correlation
JFM	0.006	-0.08
AMJ	0.150	-0.39
ASO	0.286	-0.53

We added also the scatter plots for the discharge anomalies at Eldiem station versus Nino 3.4 during JFM, AMJ and ASO, for the period 1965 – 2012 as shown in figure 7.

For figure 7 we calculated also the correlation between the discharge anomalies at Eldiem station and GPCP, CRU and UDEL Rainfall anomalies and over Ethiopian Highlands (35E, 40E, 8N, 13N) during JJAS from 1982 to 2008 as shown in the table below:

Table 5. The correlation between the discharge anomalies at Eldiem station and GPCP, CRU and UDEL Rainfall anomalies and over Ethiopian Highlands (35E, 40E, 8N, 13N) during JJAS from 1982 to 2008.

	GPCP & discharge	CRU & discharge	UDEL & discharge
Correlation	0.64	0.56	0.74

The starting moment of El Niño and La Niña are shown in a table 2 and table 3. In this study we are concentrating on the timing of the start of El Nino and La Nina. The graphical way to present the results by a scatter plot with the start month or season of the event on the x-axis and discharge anomaly of JJAS on the y-axis is not appropriate. The scatter plot shows all the years (figure 7), but we are interested on some seasons during El Nino and La Nina years. The scatter plot can't show also the length of El Nino and La Nina.

The uncertainty of the small number of observations is well indicated now in this study.

3 Clarification of the focus on summer season

The focus in this article is mainly on the discharge summer season (JJAS). In the introduction some reasons for this choice are given: the rainy season in the study area extends approximately from June to September, and other studies that attempted to use oceanic and atmospheric variables in seasonal hydrologic forecasting over East Africa have not focused on June to September rainfall in Ethiopia so far. But when reading the result section, it is not clear why the analysis has not been extended to other seasons or periods as well (ONDJ and FMAM for example), because this seemed a relatively small effort that would make the paper at once more comprehensive and better useful in hydrological forecasting, because it would then contain information on discharge for the entire year instead of only the summer.

Figure 4 does show that discharges are clearly largest in august and that difference between El Niño and La Niña years is larger for august than for June and perhaps also the earlier months, but October might also still have fairly large differences. And why focus only on droughts and floods in the summer, if drought in other seasons which naturally already have lower discharges might have a larger impact. I am not aware of studies showing that droughts and floods are mainly a problem in the summer season, so if that is the reason for the focus on JJAS, than it is advised to add a reference.

In the introduction the authors also refer to Seleshi and Zanke (2004), who reported that June to September rainfall in the Ethiopian highlands is negatively correlated to the equatorial eastern pacific SST. This might also be a reason to focus on the summer, although it is unclear whether or not the SST anomalies also correlate with rainfall in other seasons. In addition, as stated in the introduction, ENSO might be significantly correlated with rainfall variations over the eastern side of the African continent, the signs of the correlations and their phase relative to the seasonal cycle vary from region to region (Camberlin et al., 2001). This is also supported by the findings of Seleshi and Zanke (2004), who showed that warm ENSO episodes (El Niño’s) are not associated with below average rainfall in the rainy season in the semi-arid lowlands of eastern, southern and southwestern Ethiopia, but are only significantly correlated in the Ethiopian highlands. Therefore it would not be superfluous to present relations for different seasons in the upper catchment of the Blue Nile, even if this is also done by other researches in an area nearby. So if the choice to focus on JJAS is based on previous conclusions by other scientist on weak relationships for other seasons than the summer, it is advised to at least indicate this in the article, or even show it with data for the study area itself too, that it yields insignificant results.

Eltahir (1996) found the highest correlations with annual flow of the Nile river not only the for the ENSO index of JJA, but also and even slightly higher for the index of SON and of DJF in the year after the Nile's peak flow. The same was found for the Nile and the Atbara rivers, as shown by Amarasekera et al. (1997). So other seasons than JJAS might also be interesting to pay attention to.

And in the case that a specific season has been chosen to focus on, it is important to clearly state this in results and conclusions. Indicate for example, that when El Niño starts in AMJ, 83% of the cases resulted in a drought in JJAS. Also mention it in captures of figures.

The rainfall in Ethiopian and east Africa is highly variable spatially and temporally. The pattern and the amount of rainfall may change substantially within few kilometers. The correlation with the SSTs may also change dramatically within few kilometers. Ethiopia has three different seasons. But, it is well known that the Blue Nile season is JJAS as shown by the plot of Eldaw et al., (2003). It is not useful to consider NDJ and FMA seasons, because the flow is very small during those seasons as shown in the figure below. The operation and filling of the dams along the Blue Nile depend on JJAS flow.

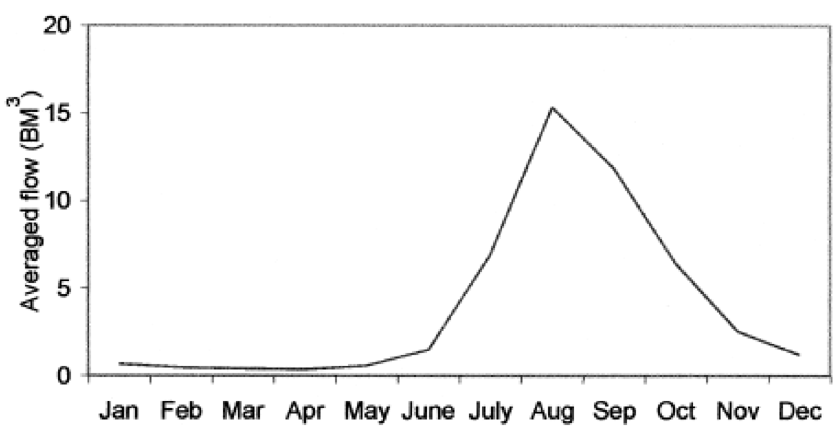

FIG. 1. Mean monthly flows for the Blue Nile River at Eldeim for the period 1913–89.

Eldaw et al., (2003)

Figure 4 showed the largest discharge during August, October will follow the similar receding trend. Almost all the studies in the Blue Nile concentrate on JJAS (this is well known for the Blue Nile).

Seleshi and Zanke (2004), reported that June to September rainfall in the Ethiopian highlands is negatively correlated to the equatorial eastern pacific SST. Some studies divided Ethiopia to regions according to the variability of rainfall seasonality, and used observational dataset to study the impact of the oceanic variables on the rainfall regions in Ethiopian Highlands (Segele and Lamb 2005; Seleshi and Zanke 2004; Gissila et al., 2004). So, some studies concentrate in other seasons in Ethiopia and east Africa when the pattern and rainy season change.

Eltahir (1996) found the highest correlations with annual flow of the Nile river not only for the ENSO index of JJA, but also and even slightly higher for the index of SON and of DJF in the year after the Nile's peak flow. The same was found for the Nile and the Atbara rivers, as shown by Amarasekera et al. (1997). Here it is very important to differentiate between correlating different SST seasons or different rainfall seasons. Both Eltahir (1996) and Amarasekera et al. (1997) correlated the annual flow of the Nile in Aswan with different SST seasons, not with different rainfall seasons.

4 Further exploration of precipitation dataset

The article also presents interesting information on precipitation, yet the authors do not discuss these results in depth. Figure 7 nicely depicts the discharge and the precipitation anomalies for a time series of 26 years, but the three datasets for precipitation differ substantially. What is causing these differences, and which method for rainfall is regarded most reliable for this region? In Figure 8 and 9 show that in the study area two types of precipitation, from the GPCP and UDEL dataset, correlate better with Nino 3.4 SST anomalies than the discharge with SST. The Global Precipitation Climatology Project (GPCP) dataset is a satellite/ gauged-merged rainfall product with a resolution of 2.5_ available from 1979 onwards (Huffman et al., 2011) and the University of Delaware (UDEL) dataset is a global gridded high resolution (0.5_) station (land) dataset available from 1900 onwards. The less good correlated Climate Research Unit (CRU) dataset is a purely gridded gauge product and also has a high resolution of 0.5_. The results and discussion sections explain the same as what can be seen on the graphs, that the correlations are maximum in magnitude in the AMJ through ASO season and that the correlations are higher for precipitation than for discharge except for the CRU dataset. But what does this practically mean? Does this mean that hydrological predictions can be improved if with the SST anomalies first the precipitation is predicted, and only then the translation to discharge is made? This also depends on the strength in the relation between precipitation and discharge, which is currently lacking in the manuscript. Wang and Eltahir (1998) concluded that ENSO information is the only valuable predictor for the long-range forecasts (lead time longer than the hydrological response timescale), but incorporation of the rainfall and river flow information in addition to the ENSO information significantly improves the quality of the medium range forecasts (lead time shorter than the hydrological response timescale). There is thus a potential use for the precipitation dataset in the hydrological forecasting, although this manuscript is probably aiming on long-range forecasts. In the conclusions precipitation is currently not mentioned, while its correlation with SST anomalies is in most cases stronger than for discharge with SST and there might be a potential use for hydrological forecasting.

Figure 7 shows the discharge and the precipitation anomalies, but the three datasets for precipitation differ substantially, because they are produced by different institutes, and they used different methods, dataset, interpolation technique …etc. It is always recommended using several dataset because of the uncertainty in the dataset. It is not easy to tell which method for rainfall is regarded most reliable for this region.

The correlation between the discharge anomalies and the rainfall anomalies is calculated below in table 5:

Table 5. The correlation between the discharge anomalies at Eldiem station and GPCP, CRU and UDEL Rainfall anomalies and over Ethiopian Highlands (35E, 40E, 8N, 13N) during JJAS from 1982 to 2008.

	GPCP & discharge	CRU & discharge	UDEL & discharge

Correlation	0.64	0.56	0.74

The CRU rainfall anomalies which showed the lowest correlation (table 5) with the discharge anomalies at Eldeim station, it showed the highest correlation with Nino 3.4 index during the early seasons (JFM, FMA and MAM), Eldiem station showed the lowest correlation and insignificant correlation during this period. However, during MJJ up to ASO CRU showed the lowest correlation with Nino 3.4, whereas, the other rainfall and discharge dataset showed a higher correlation with Nino 3.4 anomalies. The correlations between GPCP and UDEL rainfall anomalies and Nino 3.4 index are maximum in magnitude in the AMJ through ASO season compare to the Blue Nile flow at Eldiem station. So, the correlations are higher for the precipitation than for the discharge except for the CRU dataset. There is thus a potential use for the precipitation dataset in the hydrological forecasting. So, the ENSO information with the use of precipitation anomalies may improve the hydrological prediction.

5 Detailed comments

Page 10976, line 10: According to the text, Figure 4 depicts monthly precipitation; I believe this should be discharge.

Yes, thanks.

Page 10976, line 16: I think the number 6.813 km3 should be 6.971 km3, otherwise the threshold lines are not symmetric. This is the only case were the number 6.813 is used, in all other cases 6.971 is mentioned as one standard deviation and boundary between flood and extreme flood (or drought and extreme drought when it is minus).

Yes, it is corrected now to 6.971 km^3. Thanks.

Page 10980: Chapter 4 is called ‘conclusions’, but it also contains a brief summary of the introduction and the aim of the paper and therefore could also be called ‘Summary and conclusions’.

It changed now to Summary and conclusion. Thanks.

Page 10985: In the caption of Table 2 I am missing information which is probably the same as for Table 1: "...during JJAS of the same year."

The statement was added to the caption, thanks.

Page 10991: In the caption of Figure 4 the El Niño years are listed; 2994 should be 2004

Yes, it is corrected now. Thanks.

Page 10983: I could not find the article of Trenberth (1997) back in the references

Page 10986: It is a suggestion to add a legend to Table 3 (= end of El Niño, + = start of La Niña)

The legend was added, thanks.

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