Reviewer 2.

Dear reviewer, thank you for your contributions, certainly will improve the paper. Here you can find the response to your comments, questions, and suggestions. The paper will be submitted for a careful English editing.

Comment 1.

Here are some questions/comments/input to improve/supply this document:

This paper can be supplemented by a better presentation of the physiographic characteristics of the catchment, presenting, in particular, the specificities and originalities of the forest cover and mostly of the vast "Cuvette Centrale" which plays a decisive role in the exchanges with the atmosphere. This paper needs also to be enriched by a paragraph about the spatiotemporal variations of hydrological regimes inside the Congo basin, with particular attention on the Oubangui catchment. It is well known that the northern part of the basin, impact on the discharge cycle at Brazzaville/Kinshasa gauging station (you can complete with some appropriates references thank the list added).

Reply 1: Thank you for your suggestion. In the article, the section 1.1, dedicated to mentioning some aspects of the region under study is now improved. For this new version, we followed your recommendations. We utilized the references provided to enrich the discussion along the paper. Please read section:

1.1 1.1 Region of Study

The Congo River Basin (CRB) is located in central-equatorial Africa, an important part of the continent containing major rivers and dense forest (Fig. 1). With an approximate area of 3,687,000 km2 (Alsdorf et al., 2016), the basin includes several African countries: the Democratic Republic of the Congo (DRC), the People's Republic of the Congo, the Central African Republic, and parts of Zambia, Angola, Cameroon, and Tanzania (Chishugi, 2008). The Congo River (also known as the Zaire during at one time) is over 4,375 km long, considered to be the fifth longest river in the world, and the second longest in Africa after the Nile River (IBP, 2015). Its discharge shows a composite variability, which is due to the sum of its tributaries (Laraque 2001). With an annual discharge of 5000 m3 s-1 at its mouth, the Oubangui River is the second most important tributary to the Congo River (mean flow 41 000 m3 s-1), after the Kasai River (8000 m3 s-1) (Briquet, 1995).

The CRB comprises the second largest continuous rainforest in the world; covering an area of approximately 1.8 Million km2 the high rate of evaporation is comparable to the oceans is one of the main features of the forests, being extremely important for storing carbon and having an impact on the continental and global climate system mainly through the water cycle (Haensler et al., 2013; Marquant et al., 2015; Wasseige et al. 2015). The basin is composed basically of a central area that contains an immense forest swamp best known as "Cuvette Centrale"; an immense depression at the centre of the basin where sediment accumulation since the Quaternary alluvial deposits rest on thick sediments of continental origin, consisting principally of sands and sandstones (Kadima et al., 2011; Gana and Herbert, 2014) (Fig. 1). Here the spatial distribution of forested wetland types is controlled by topography and also by the time and the intensity of the submersion, making it the most extensive peatland complex in the tropics (Dargie et al., 2017). From a rainfall point of view, because of the topographic barrier around the "Cuvette Centrale", the Congolese central basin functions to a large extent as a closed system of precipitation, on-site evaporation, and precipitation (Robert, 1946; Sorre, 1948). Located in the heart of the dense Congolese equatorial forest is the Lake Telé, an immense elliptical body of water (3 m deep for a surface of 23 km2 and a maximum water storage evaluated to 55x106m3) where hydrological exchanges are almost exclusively vertical with very little lateral contribution from the surrounding swamp (Lareque et al., 1998). Furthermore, the basin contains several large, permanent open water lakes including Lake Tanganyika, the largest of the African rift lakes and the world's second largest by volume and depth (Coulter, 1991; Cohen et al., 1993).

Around the central basin, there is mainly a humid evergreen dense forest and to the north and south mosaics of mixed forest; woody savannahs savannas and savannas (Marquant et al., 2015). The current distributions of different forest types correlate strongly with annual rainfall and particularly with the length and severity of dry seasons (CARPE, 2005). The CRB moist forests are the continent's main forest resource, containing an extraordinary biodiversity (Ilumbe, 2006; SCBD-CAFC, 2009) that brings important economic benefits to approximately 60 million people living in local communities (Hugues, 2011; Marquant et al., 2015). Unfortunately, in the CRB the rate of deforestation varies from one country to another. Overall, the basin had a net deforestation rate of 0.09% between 1990 and 2000, compared with 0.17% between 2000 and 2005 (Tchatchou et al., 2015). In fact, the satellite data show a widespread decline in greenness in the northern Congolese forest over the past decade, which is generally consistent with decreases in rainfall, terrestrial water storage, and other related aspects (Potapov et al., 2012; Zhou et al., 2014; Hua et al., 2016) like hydrological regimes (Laraque et al., 2001; Laraque et al., 2013; Wesselink, 1996).

The air masses originating from three permanent anticyclones located to the north-west (Azores), south-west (St. Helena), and south-east (Mascarene) of the CRB converge along the Intertropical Convergence Zone (ITCZ), which separates the southerly low-level winds from the northerly winds, and the Inter-Oceanic Confluence Zone (IOCZ), *separating the westerly from the easterly winds in the southern part of Africa (Samba and Nganga, 2012). In general two modes of circulation: circulation of Hadley and the Walker circulation control the movement of air masses and the climate in Central Africa, leading to moisture convergence not being uniform in the atmospheric column (Tsalefac et al., 2015, Pokam et al., 2012). Areas which are positively correlated with Congo convection are areas of the ascending arm of the Hadley cell (Matari, 2002), while the east-west oscillation of the Walker circulation cell modulates the moisture advection from the Atlantic Ocean and the upward motion over the CRB (Matari, 2002; Lau and Yang, 2002) .*

The rainfall-generating mechanisms are controlled by a zone of shallow depression systems in the CRB (Samba and Nganga, 2012) as well as north-south ITCZ migration (Samba and Nganga, 2012; Alsdorf et al., 2016) together with Mesoscale Convective Systems (MCS) (Jackson et al., 2009) and the African Easterly Jet along with the typical circulation of the Hadley cell (Nicholson, 2009; Pokam et al., 2012; Haensler et al., 2013).

Comment 2

-Pa. 1 - Lig. 22: change "local evaporation or transpiration" by "local evaporation and/or transpiration"

Reply 2: Thank you. It has been changed.

Comment 3

-Pa. 2 - Lig. 28: change (also known as the Zaire) by (also known as the Zaire during at one time)

Reply 3: Thank you. It has been changed.

Comment 4

-Pa. 3 - Lig. 33: complete "Nevertheless, satellite data show a widespread decline in greenness in the northern Congolese forest over the past decade, which is generally consistent with decreases in rainfall, terrestrial water storage, and other related aspects (Zhou et al., 2014) by,

"Nevertheless, satellite data show a widespread decline in greenness in the northern Congolese forest over the past decade, which is generally consistent with decreases in rainfall, terrestrial water storage, and other related aspects (Zhou et al., 2014, please complete with some others appropriates references in the list added), like hydrological regimes (please complete with some appropriates references in the list added)."

Reply 4: Thank you. Please consider the next paragraph in which we have introduced the new appropriate reference from those provided by you. As figure 1 was changed the previous content of this paragraph too.

"In fact, the satellite data show a widespread decline in greenness in the northern Congolese forest over the past decade, which is generally consistent with decreases in rainfall, terrestrial water storage, and other related aspects (Potapov et al., 2012; Zhou et al., 2014; Hua et al., 2016) like hydrological regimes (Laraque et al., 2001; Laraque et al., 2013; Wesselink, 1996)".

Comment 5

Pa. 6 – "The mean annual discharge of the Congo River is 38617.4 m3 s-1, as calculated from the GRDC monthly streamflow values registered at the Kinshasa-Brazzaville gauging station" here, it is necessary to specify during the 1980-2010 study period). Explain why the choose of this period and what about its representativeness on the entire secular chronic of hydro-pluviometric data?

Reply 5:

We have introduced the next sentences in Material and Methods to explain the selection of the period 1980-2010.

"*The selection of global datasets was decided because of documented gaps in the hydrological information of the CRB (Tshimanga, 2012). However, observational data series are available on the SIEREM website (Boyer et al., 2006) mainly to the north part of the basin. In this work, the analysis covers the period 1980-2010 taking into account the availability of ERA-Interim from 1980 and the river discharge data available at Kinshasa gauge station until 2010".*

"*The mean annual discharge of the Congo River is 38617.4 m3 s-1, as calculated from the GRDC monthly discharge values registered at the Kinshasa gauging station in the period 1980-2010. In the secular chronic of the hydro-pluviometric data (1903-2010) recorded at Brazzaville gauge station, close to Kinshasa and analysed by Lareque et al. (2013), the average flow of the Congo River from 1982 to 1994 is below the annual mean, followed by a period of stability from 1995 to 2010. At long-term results of Mahe et al. (2013) pose that as for the equatorial rivers, the Congo river runoff time series (at the Brazzaville station) follows no long-term trend (here these author refers runoff as discharge) and that the minimum shows a lesser inter-annual variability than that of the average or of the maximum".*

Comment 6:

- pa. 5 lig. 26: You can complete and illustrate your description of the evolution of the global change in the Congo basin, using the different studies and data base about the rainfall and hydrological regime during the last century (see references list added and the SIEREM and ORE-Hybam site) http://www.hydrosciences.fr/sierem/and www.ore-hybam.org

Reply 6:

Thank you for the list of references. Please consider the new changes in section:

3.1 Climatology: Rainfall and runoff over the basin and Congo River discharge

The annual cycle of precipitation over the CRB is depicted in Figure 2. The most notable feature of the monthly patterns is the latitudinal migration of the maximum precipitation throughout the year, which leads to different seasonal patterns over the territory (Bultot, 1971; Chishugi 2008). Based on previous results Mahe (1993) defined four great climatic zones over the Congo Basin: the North (Ubangi River Basin), where the influence of the North African continental air mass is prominent; the South (Kasai River Basin), which is influenced by South African air masses; the eastern and south-eastern parts of the basin (Lualaba River Upper Basin), which are influenced by the humid Indian Ocean air masses; and the Center-West, where the climate is controlled by the Atlantic Ocean. In fact, the evaluation of the impact of rainfall on various sectors and its distribution throughout the annual cycle may be as important as the total annual rainfall (Owiti and Zhu, 2012). During January, February, and March, the southern half receives more precipitation, while April is a transitional month with maximum rainfall in the west-central and northeast parts of the basin. From May to August the rainfall pattern appears homogeneous and reveals that the majority of the average precipitation occurs in the northern part, coinciding with the northward excursion of the ITCZ between February and August (Nicholson and Grist, 2003; Suzuki, 2011). From May to October, the northeast of the CRB receive the highest rainfall, favouring the Oubangui catchment, a right-bank tributary of the Congo River that drains at the Bangui gauge station an area of 488500 km2 (Runge and Nguimalet, 2005). In September the rainfall increases to the south affecting the centre of the basin, with the greatest extension in October. In November, the central and southwestern parts of the CRB receive more rainfall and during December there is also an extension to the southeast. The regime of precipitation over the CRB is clearly differentiated by a latitudinal oscillation of maximum accumulated values, in accordance with several studies reviewed by Alsdorf et al. (2016) and within an interannual variability higher in the north and south than in the central units of the basin (Mahe, 1993).

Monthly average precipitation for the whole basin shows an annual cycle with two maximum peaks during March-April and October-December, with values greater than 4.5 mm day-1, each accounting for 21% and 32.6% of the mean annual rainfall in the CRB, respectively (Fig. 3). During June and July, the average rainfall reaches its lowest level of around 2 mm day-1. This cycle is similar to that described by Washington et al. (2013), who compared the Congo rainfall climatology through several datasets obtained from reanalysis and ensemble models. However, they argued that the maximum rainfall in the basin occurs from March to May and from September to November, while the minimum occurs in June-August. The differences in monthly average precipitation may be due to the areas used; they used a box region over equatorial west Africa while we use the CRB boundaries.

The mean annual cycle of runoff in the CRB (Fig. 3) follows the same annual cycle as rainfall although it is always lower, varying between maximum values of 3.0 and 3.5 mm day-1 during November-March and minimum values below 1.5 mm day-1 during July and August. The long-term distribution of precipitation and runoff over the African continent is almost the same (Siam et al., 2013), but the highest values of runoff are concentrated in the heart of the equatorial forest along the Middle Congo River branch (Alemaw, 2012), with these wetlands receiving the majority of their waters from upland runoff (Lee et al., 2011) and several large rivers draining into the Congo in this middle section; the largest of these is the Ubangi, at the north of the Congo Basin (Harrison et al., 2014). The interannual correlation calculated between the two series (precipitation and runoff) over the CRB is high, r = 0.73 (significant at p<0.05) and r = 0.72 with a one-month lag. Fig. 3 shows that from March onwards the runoff reflects a one-month lag compared with precipitation. In general, in a steady state, the precipitation exceeds the evaporation (or evapotranspiration) over the land and the residual water runs off, resulting therefore in a continental freshwater discharge into the oceans (Dai and Trenberth, 2002). This also occurs in the CRB, where monthly values of precipitation minus the actual evapotranspiration obtained from the GLEAM dataset seem to follow the same annual cycle as precipitation (Fig. 3). In June (P-E) has a negative value, which means that on average there is more evaporation in the basin than precipitation [as in Dai and Trenberth (2002) and Siam et al. (2013)].

The mean annual discharge of the Congo River is 38617.4 m3 s-1, as calculated from the GRDC monthly discharge values registered at the Kinshasa gauging station in the period 1980-2010. In the secular chronic of the hydro-pluviometric data (1903-2010) recorded at Brazzaville gauge station, close to Kinshasa and analysed by Lareque et al. (2013), the average flow of the Congo River from 1982 to 1994 is below the annual mean, followed by a period of stability from 1995 to 2010. At long-term results of Mahe et al. (2013) pose that as for the equatorial rivers, the Congo river runoff time series (at the Brazzaville station) follows no long-term trend (here these author refers runoff as discharge) and that the minimum shows a lesser inter-annual variability than that of the average or of the maximum.

The annual cycle of discharge (which is very similar to the precipitation and runoff) shows climatological maxima during November-December (Fig. 3) with values above 48000 m3/s, while in July and August the minimum is less than 30000 m3/s. Despite this, a difference is seen during March when high precipitation and runoff occur, but the discharge is low. During the next few months the precipitation and runoff decrease while in contrast the discharge increases, reaching a maximum in May. This lag should reflects the time needed for the surface runoff to reach the river mouth but also the groundwater contribution (Dai and Trenberth, 2002, 2008; Marengo, 2005; Rwetabula et al., 2007; Sear et al., 1999), as documented by Materia et al. (2012) using data recorded at Brazzaville station, about 400 km upstream of the river mouth. The direct relationship between precipitation over the basin and the discharge has a correlation of 0.52, which increases to 0.66 for a one-month lag (both statistically significant at p<0.05), confirming the lagged response mentioned earlier. Briquet, (1993) pointed out that a translation of the stability of this hydrological regime is shown by a high (low) frequency of floods occurrence on close dates from one year to the other. Future climate projections (21st century) despite to be uncertain, show a basin average increase in both rainfall and evaporation, but the total increase in rainfall tends to be higher than the increase in evaporation and result in most scenarios the runoff is increasing (Beyene et al., 2013). Nevertheless, for the northern sub-basins of the Oubangui and Sangha Rivers Tshimanga and Hughes (2012) downscaled scenarios in which occur more than 10% decrease in total runoff as a consequence of relatively little increase in rainfall and a consistent increase in potential evapotranspiration.

Comment 7:

In § 3.1and Fig. 2: why do you not used the monthly in situ rainfall data in the Congo Basin available during one century on the link (https://www.researchgate.net/publication/312383745_Monthly_rainfall_gridded_dataset_for_Africa_for_the_period_1970-1979_at_the_half_a_square_degree_interpolation_Inverse_Distance_Weighted). This data base seems more complete that the CRU?

Reply 7:

Thank you very much for this information. This data is available for 10 years and we needed a longest and homogenous dataset over the basin, hence we decided to use the CRU data since is successfully worldwide used.

Comment 8:

Fig. 1: Given its importance in Congo basin’s water balances, I suggest to place the contour of the “Cuvette Centrale”.

Reply 8:

We made a new Figure representing the land use instead of the elevation. In this new figure, we contoured the Cuvette Centrale.

Comment 9:

-Fig. 15: can be enlightened and commented thanks to the study of the evolution of annual and monthly discharges of the more important right bank tributaries like Oubangui and Sangha river (in Laraque et al., 2013). The authors can also find more “field” explanations in someone of the others reference I communicate for them mainly about the special role of the “Cuvette Centrale” partially or totally flooded depending on the hydropluviometric cycle within the Congo Basin.

Reply 9:

Thank you for your advice to improve this analysis. We utilized documentation from your reference list to explain some possible behavior. It is difficult to relate moisture lose over the CRB with interannual variability of the Congo and Oubangui rivers. Our goal is to identify the response of the basin in extreme periods as source or sink of moisture for itself. A deepest analysis must be done at subbasin scale to support a better hydrological reponse linked with the budget of E-P over the basin. However, we hope that the improvements in the explanation have improved this section.

The Oubangui basin in the northeast of the CRB, should have benefited in 1982 due to positive anomalies of **|***(E-P)i10<0***|***, favouring the precipitation in the half north of the CRB. In the Oubangui basin, a decrease in runoff observed everywhere coincides with a decrease in rainfall with a time lag of 3 years, which can be explained by the sponge-like functioning of the drainage basin, where interannual variability is less important for runoff than for the rainfall series (Orange et al., 1997). An important finding of theses authors is that also the maxima and minima of annual rainfall do not completely coincide with the extreme flow events; as occurred in 1982, a severely wet year when positive anomalies of* **|***(E-P)i10<0***|** *over the half north of the basin including the Oubangui basin. According to the results of Orange et al. (1997), it was documented by Laraque et al. (2013) that from 1982 to 2010 the Oubangui remains in the drought phase, as the Congo returns to a phase of stability.*

Comment 10

-Pa. 15- Lig. 26: this sentence “For 1995, the anomalies are negative in the east and north of the basin”, don’t seems to correspond to the Fig 15 (year 1995). I thing necessary to change “east” by “west”.

Reply 10:

Thank you! We have already changed the word.

Comment 11:

-Pa. 15 - Lig. 31: It is not exact to write “river discharge in the basin”, when only the discharges used come from Kinshasa gauging station, because even if this station controls almost all the catchment, its regime is not representative of the spatial variations of the hydrological cycles of every tributaries in this basin. Please consult the references list I give to you.

Reply 11: Our apologize for this mistake. We made it along the entire article. It is now

Others comments:

-Why the authors don't write anything about the Hadley cells and Walker circulation?

Thank you, you are right. We hope the following sentences included in the articles are enough.

"The air masses originating from three permanent anticyclones located to the north-west (Azores), south-west (St. Helena), and south-east (Mascarene) of the CRB converge along the Intertropical Convergence Zone (ITCZ), which separates the southerly low-level winds from the northerly winds, and the Inter-Oceanic Confluence Zone (IOCZ), separating the westerly from the easterly winds in the southern part of Africa (Samba and Nganga, 2012). In general two modes of circulation: circulation of Hadley and the Walker circulation control the movement of air masses and the climate in Central Africa, leading to moisture convergence not being uniform in the atmospheric column (Tsalefac et al., 2015, Pokam et al., 2012). Areas which are positively correlated with Congo convection are areas of the ascending arm of the Hadley cell (Matari, 2002), while the east-west oscillation of the Walker circulation modulates the moisture advection from the Atlantic Ocean and the upward motion over the CRB (Matari, 2002; Lau and Yang, 2002)" .

"The rainfall-generating mechanisms are controlled by a zone of shallow depression systems in the CRB (Samba and Nganga, 2012) as well as north-south ITCZ migration (Samba and Nganga, 2012; Alsdorf et al., 2016) together with Mesoscale Convective Systems (MCS) (Jackson et al., 2009) and the African Easterly Jet along with the typical circulation of the Hadley cell (Nicholson, 2009; Pokam et al., 2012; Haensler et al., 2013)".

"In CEA Hua et al. (2016) documented for April-May-June consistently strong negative anomalies falling since the 1990s, primarily related with SST variations over Indo-Pacific associated with the enhanced and westward extended tropical Walker circulation which is consistent with the weakened ascent over Central Africa associated with the reduced low-level moisture transport".

-In the document, in many cases it is necessary to change runoff by streamflow or river discharge

Reply: Thank you, the word streamflow has been replaced by the correct word in all the paper. It was a mistake to utilize this word since we don´t really use it.

-I don't think the title clearly reflect the contents of the paper, which relates more with the fluxes and exchanges budget of moisture in the atmosphere of Congo basin? But this title could be preserved if the author takes more account of the hydrological characteristics and particularities of this basin, as advised in my comments.

Reply: We understand your suggestion. It is difficult to establish an accurate relationship between the water balance computed for all the CRB and the hydrology characteristics of some differentiated regions or subbasins. Nevertheless, we hope the new changes could preserve the title. We believe that a future analysis performed at sub-bains scales could involves more hydrological issues.