Point-to-point replies to the review report

We would like to thank the editorial support team and the referees for the attention given to our manuscript and for providing a thoughtfully evaluation of our work. Our responses to their comments are provided below and we made the changes accordingly to improve the paper.

For clarity, Referee's comments are shown in bold font and the authors' replies in *italic*.

Referee's comments: *Our reply*

Referee #2 :

This paper presents a synthesis of multiple sources of altimetric water surface height and remotely sensed flood extent over the Congo basin and compares these to in-situ data. The data are then analysed to better understand the spatial variability of surface water hydraulics over the basin. This is a major piece of scholarship that will likely become to the 'go to' reference for such data for many years to come. Altimetric height data show a good fit to ground observations over the Congo, corroborating the findings obtained elsewhere, and are then related to water extent data from the GIEMS-2 product. I think the work will be suitable for publication in HESS with correction of the following issues:

Our Reply: We would like to thank the Reviewer for carefully assessing our work and we appreciate the positive comments. We have taken into consideration all the suggestions made by the Reviewer and it results in an improved manuscript.

I think the paper would benefit from more carefully identifying what we learn as a result of this work that we didn't know before. Whilst assembling and quality controlling the various data sets is a major effort, they are somewhat under-exploited in the present work if I am being honest. I think the paper will be more highly cited if it were to first carefully outline what we currently understand about Congo surface water variability. In the results section and conclusions, the paper should then state where the presented results either corroborate existing knowledge or provide substantial new understanding. There is some attempt at doing this in the paper, but it could be made much more systematic and effective.

Our Reply: Thank you for this important remark. We agree that this paper has two objectives. The first one is to validate/evaluate both datasets (water level and surface water extent) against available in situ observations in the CRB, which can be seen indeed as a first step of quality control. The second objective is to use these datasets to improve our understanding of Congo surface water variability, which represents the main results of the paper. In order to make this structure clearer and highlight the results, we have modified the outline of the paper. It is now:

1. *Introduction*
2. *Study region*
3. *Data and Methods*
   3.1 In situ data
   3.2 Radar altimetry-derived surface water height
   3.3 Multi-satellite derived surface water extent
4. *Validation of satellite surface hydrology datasets and their characteristics in the CRB*

4.1. Validation of altimetry-derived surface water height
4.2. Evaluation of surface water extent characteristics from GIEMS-2

5. *Results: A better understanding on how CRB surface water flows.*
   5.1. Seasonal water travel time through the rivers and sub-basins of CRB
   5.2. Sub-basin contributions to the CRB bimodal hydrological regime.
6. *Conclusion and perspectives*

Moreover, in order to better highlight what is new in our study, we have rearranged some parts of the text. For instance, to introduce part 5.1., we now mention previous studies/results at the beginning of the paragraph (these sentences were previously mentioned after our results): "The water travel time through the rivers and sub-basins of CRB were previously investigated by using observations from a few in situ gauges (Bricquet, 1993). The SWS and SWE dataset enable a similar analysis at the large scale with an extended analysis to the entire CRB."

1. **A lot of the text on GIEMS-2 (e.g. Section 3.3) really just summarises previous work. What is new here is the correlation of GIEMS-2 basin total flood extent time series with various discharge measurements. I think the text on GIEMS-2 could therefore be significantly shortened to only cover the new results presented in this paper.**

Our Reply: We agree with your suggestion and we have shortened Section 3.3. as follow:

"The Global Inundation Extent from Multi-Satellite (GIEMS) captures the global spatial and temporal dynamics of the extent of episodic and seasonal inundation, wetlands, rivers, lakes, and irrigated agriculture at 0.25° x 0.25° resolution at the equator (on an equal area grid, i.e. each pixel covers 773 km^2) (Prigent et al., 2001, 2007, 2020). It is developed from complementary multiple-satellite observations (Prigent et al., 2001, 2007; Papa et al., 2010) and the current data (called GIEMS-2) covers the period from 1992 to 2015 on a monthly basis. For more details on the technique, we refer to Prigent et al. (2007, 2020).
The seasonal and interannual dynamics of the ~25-year surface water extent have been assessed in different environments against multiple variables such as in situ and altimeter-derived water levels in wetlands, lakes, rivers, in situ river discharges, satellite-derived precipitation or total water storage from Gravity Recovery and Climate Experiment (GRACE) (Prigent et al., 2007, 2020; Papa et al., 2008, 2010, 2013). The technique generally underestimates small water bodies comprising less than 10% fractional coverage of equal-area grid cells (i.e., 80 km^2 in 800 km^2 pixels, see Figure 7 of Prigent et al., 2007 for a comparison against high-resolution (100m) Synthetic Aperture Radar images (Hess et al., 2003) over high and low water seasons in the Central Amazon). Note that *large freshwater bodies worldwide such as the Lake Baikal, the Great Lakes, Lake Victoria are masked in GIEMS-2. In the CRB, this is the case for Lake Tanganyika (Prigent et al., 2007). This will impact the total extent of surface water at basin-scale, but not its relative variations, as the extent 280 of Lake Tanganyika itself shows small variations on seasonal and interannual timescales."*

Note that we also took into account this comment when improving the section "Evaluation of surface water extent characteristics from GIEMS-2"(see our answers in the point below).

2. **I also think that a number of the statements about GIEMS-2 cannot be proven based on the research presented in the paper. For example, from line 359 onwards there is a statement that GIEMS-2 exhibits: "very realistic spatial distributions of the major drainage systems, rivers and tributaries (Lualaba, Congo, Ubangui, Kasaï) of CRB.**

The dataset captures well the associated wetlands and inundated areas even in regions with complex floodplains, characterized by extensive flooding in the presence of dense vegetation cover, such as in the Cuvette Centrale". There are two issues with this. First, there are no objective tests in the paper of the accuracy of the GIEMS-2 inundation patterns, so it is impossible to say what is realistic or not: the statements above are a subjective evaluation and not repeatable science. I think that at most you can only say that the GIEMS-2 patterns are plausible. Second, at 0.25 degree resolution I think the above statement overstate the level of detail that can be seen in GIEMS-2. I think these sections of the paper need correction to more accurately reflect what the paper is really able to show.

Our Reply: Thank you for this comment that helps us to correct some of the sentences that overstate our assessment and our interpretation of the level of details using GIEMS-2 dataset over the Congo River Basin. It is indeed important to accurately reflect what we are really able to show.
Here, the assessment of GIEMS-2 is related to two aspects.
Firstly, we comment on the capability of the dataset to spatially depict the inundated regions of CRB. We agree, our analysis is qualitative and subjective as it is difficult to assess GIEMS-2 SWE patterns quantitatively in the Congo River Basin. Therefore, we modified the text accordingly, and reduced the statements to accurately reflect what we are really able to show. The statements as "very realistic", "captures well", "good behavior" are removed. For this part, the text is now:
"Figure 5 shows SWE main patterns over the CRB. Figure 5a and b display, respectively, the mean and the mean annual maximum in the extent of surface water over the 1992-2015 period. Figure 5c shows the variability of SWE, expressed in terms of the standard deviation over the period. Figure 5d provides the average month of SWE annual maximum over the record. The figures show plausible spatial distributions of the major drainage systems, rivers and tributaries (Lualaba, Congo, Ubangui, Kasaï) of CRB. The dataset indeed delineates the main wetlands and inundated areas in the region such as in the Cuvette Centrale, the Bangwelo swamps and the valley that contains several lakes (Upemba). These regions are generally characterized by large maximum inundation extent (Fig. 5b) and variability (Fig. 5c), especially in the Cuvette Centrale and in the Lualaba sub-basin, dominated by the presence of large lakes and seasonal inundated floodplains. The spatial distribution of GIEMS-2 SWE is in agreement with several other estimates of SWE over the CRB (see Fig. 3 and 6 of Fatras et al., 2021), including L-Band SMOS-derived products (SWAF, Surface WAter Fraction, Parrens et al., 2017), Global Surface Water extent dataset (GSW, Pekel et al., 2016), ESA-CCI (European Space Agency-Climate Change Initiative) product and SWAMPS over the 2010–2013 time period. At the basin scale, and in agreement with the results from the altimetry-derived SWH, GIEMS-2 shows that the Cuvette Centrale is flooded at its maximum in October-November (Fig. 5d), while the northern hemisphere part of the basin reaches its maximum in September-October, and the Kasai and southern eastern part in January-February."

Secondly, we assess the seasonality and interannual variation of GIEMS-2 SWE against other independent data related to SWE, such as in situ discharge and water level data. We agree again that it represents indirect evaluations, but they are very important to assess the plausibility of GIEMS-2 SWE variability. We believe all these evaluations, at the basin scale and at the sub-basins scales, are useful so we decide to keep them.

Giving the new structure of the paper and the modifications we made, we believe these sections reflect more accurately the analysis and interpretations we intend to show.

3. The paper would be significantly improved (and citations would be higher) if the data sets were made available to download from a data repository such as Zenodo instead of just saying that the data are "are available upon request to the authors". This would also allow the data sets to have a DOI such that use of the data could be properly tracked by the authors.

Our Reply: We agree. The altimetry data we produce are generally distributed via the Theia-Hydroweb website (http://hydroweb.theia-land.fr/). The SWS dataset over Congo will be soon integrated in this online platform and will be freely available to the community. Likewise, the GIEMS dataset will be soon available on a repository which is still under construction. Meanwhile, for GIEMS-2, we maintain that the data are available upon requests to the authors.
This has been added/modified in the acknowledgments.

4. Line 31. "Shows a good behaviour"? What exactly does this mean when there is no objective and repeatable test of the GIEMS-2 accuracy over the Congo?

Our Reply: You are right. As already mentioned above, we agree that such statement is subjective and therefore we removed it from the abstract.

5. Line 277. "GIEMS-2 uncertainties are quantified to be about 10 %". Could you explain exactly what this uncertainty refers to. I'm assuming it is errors in total inundated area over a large domain, but please could you confirm. Also, what was the ground truth data that was used to calculate this error?

Our Reply: The uncertainty refers to the lack of sensitivity of the radiometer and the retrieval algorithm to detect small water fractions that covers less than 10% in a pixel of ~773 km^2. No ground data were used, but the analysis was based on the comparisons with the International Geosphere-Biosphere Programme (IGBP) DisCover dataset (Figure 4 of Prigent et al., 2007) and high-resolution (100m) Synthetic Aperture Radar images (Hess et al., 2003) over high and low water seasons in the Central Amazon (Figure 7 of Prigent et al. 2007).
We have modified the text to be more accurate: "The approach generally underestimates small water bodies comprising less than 10% fractional coverage of equal-area grid cells (i.e., ~80 km^2 in ~800 km^2 pixels, see for example Figure 7 of Prigent et al., 2007 for a comparison against high-resolution (100m) Synthetic Aperture Radar images (Hess et al., 2003) over high and low water seasons in the Central Amazon)."

3. Line 455. "The satisfactory behaviour of both SWH from radar altimetry and SWE from GIEMS-2". Again, I don't think you can make this statement for GIEMS-2 at this site on the basis of the data you have presented. The data are quite low resolution and their evaluation is only subjective.

Our Reply: We agree and we modified the sentence accordingly: "The evaluation of both SWH from radar altimetry and SWE from GIEMS-2, presented in the previous sections, provides confidence to further analyse the dynamics of surface water and its patterns within the CRB"

4. **The figures would be better as vector files rather than bitmaps.**

Our Reply: Agreed. We convert our figures into vector images for higher quality.

5. The text still needs further a proof read to catch a number of grammatical and typographic errors.

Our Reply: Thank you. We followed your recommendations and we carefully edited the entire text to correct all grammatical and typographic errors.