

Response to reviewer 3

General comments

Petch et al presented a new method to derive monthly water and energy flow estimates consistent with observed water and energy budgets. The paper is generally well-written, and the topic is highly relevant to the HESS readership. However, I do have some concerns and suggestions:

Thank you for taking the time to review our manuscript. We appreciate all your suggestions and have tried our best to respond to all your comments.

The authors appear to claim that their optimization method works well by evaluating the results with GRACE - a product that was used in the optimization process. Please consider validation/evaluation with an independent product and/or different time periods.

The aim of this paper, and others that have previously used GRACE to constrain the more usual hydrological fluxes, is to bring in a new source of information to bear on what are generally quite poorly known hydrological flux quantities. We have shown that our approach does this more successfully than previous attempts because it takes account of longer-term information contained within GRACE. We have brought information from different products together and made them consistent both with GRACE and with a closed water budget on all timescales. This is the measure of the evaluation. There is not really a more accurate independent data product that we could compare to. See also response 1 to reviewer 2.

The authors aim to present better water and energy data and methods. For the effort to be impactful and meaningful, please share the data and the scripts (the scripts were shared, but I could not find any content in the readme file).

Thanks for pointing out that the scripts were not being shared correctly, we will update the doi in the manuscript. They are available under the following link:

<https://github.com/sammypetch/Water-and-energy-budgets>

Data has been added to a folder named 'Optimised data', which can be found under the same link. This folder contains a .csv file for each of the five basins studied in more detail (Mississippi, Amazon, Congo, Huang He and Amur). Data on additional basins can be made available upon request. The script is also available under the same link.

Since the paper argues that the produced method constitutes an improvement upon current optimisation methods, it would be useful if the evaluation/comparison figures and results section could show a clearer distinction between comparisons with products that are "optimized" datasets and those that are not.

Comparisons with "non-optimised" products is essentially a comparison with the input data. Such as Figure 4 which demonstrates the imbalances present initially. A comparison with other optimised products can be considered the comparison with the other dataset we show, in particular where we demonstrate that other products become inconsistent with GRACE water storage information on longer timescales. We will make this clearer in the text where we discuss Figures 4 and 5, and when assessing the optimisation adjustments.

Since the paper explicitly aims to improve optimization at all time scales (monthly, interannual, trend), it would be useful if the figures and results section could clearly and explicitly show the improvements at each of those time scales.

We indeed aim to bring fluxes into GRACE consistency at all timescales. On a monthly timescale, consistency is shown through monthly budget closure, like other studies. In Figure 4 we aimed to show the impact of the optimisation and demonstrate the improvements from raw observations over different timescales. In Figure 4 (left) we can see strong divergences in the un-optimized storages, particularly the Mississippi and Huang He. For the Mississippi the un-optimized fluxes equate to 5.1 cm excess precipitation each month.

Improvements compared to other optimisation methods are seen primarily over long timescales. The other methods also use monthly constraints to balance the budget, and so, there should be no really “detectable improvement” at this timescale from other optimised products (also response 2 to referee 2). However, because of our longer timescale constraint we can see improvements over interannual to longer periods. In Figure 5 we show the storage implied from ours and other fluxes, to demonstrate this. For example, in the Huang He the CLASS product, despite optimisation, shows a difference to GRACE total water storage anomaly of around 9 cm by 2010, equivalent of a precipitation excess of ~1.28 cm every month. This may be small when considering only monthly fluxes, but over longer periods small imbalances can have a cumulative effect and cause a significant storage divergence.

Specific comments

L53: “is these” should be “in these”.

This technical correction has been made.

L106: Instead of “short and long time scales”, please consider being more precise (e.g., monthly, interannual, long-term trend).

We aimed to be consistent with GRACE on a monthly timescale, as well as in agreement with any interannual and long-term storage trend. We will mention these specific timescales in text.

Other parts of the paper suggest that the aim is to both produce optimized estimates and an optimisation method/methodology. Please include all study aims in this “aim” paragraph.

Yes, we aim to produce a new optimisation method as well as produce new estimates to demonstrate our method. Aims will be updated to state both.

Introduction section: Please consider adding a table providing an overview of optimisation methods. The text already contains a literature review, but it is difficult to gain an overview. Since this paper proposes a methodological advancement, it would be useful to at a glance see in what way this paper presents an advancement.

We hope that our new explanation of aims and objective (see comment 2 from reviewer 2) will help reader gain a clear overview of the advances we have made.

Table 1: “present” is ambiguous, it would be clearer if you simply state the years that were downloaded for use in this study. Also make sure that the capitalisation of the headings are consistent. “Parameter” should be “Variable”, I think. In addition, please consider adding a column

describing the dataset type (e.g., satellite, in-situ measurements etc). For GRACE, should the variable be “water storage anomaly”?

The column containing the period of data availability has been removed and replaced with text to state the years downloaded for study. We have added a new column in the table to describe dataset type. All headings have been Capitalised and ‘Parameter’ has been changed to ‘Variable’. And yes, this should be water storage anomaly! We have corrected this throughout the manuscript

Methods section: Please consider adding an overview figure of the methodological steps. For variable symbols, please consider using single-letter symbols rather than multi-letter symbols.

I appreciate these suggestions to make the methods easier to understand, and we have renamed FIS to S_{fi}. I have attempted to produce an overview figure of the methodological steps, see below. We have found this a useful figure, but not sure if it will be beneficial to the paper.

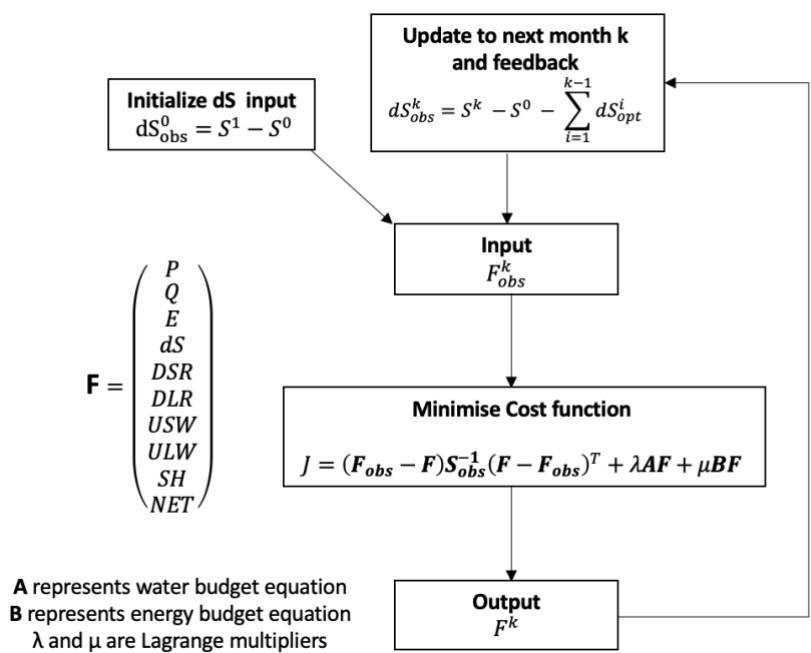


Figure 4 (and elsewhere), please check - “total water storage” or “total water storage anomaly”?

It indeed should read ‘total water storage anomaly’. This has been corrected in all places in text necessary and changed on y axis labels in Figure 4 and 5.

L350 First use of ITCZ, write out.

ITCZ will be written out before first use.

L461 Please consider providing the relative error in the unit of % for Amazon as well.

The error here is 14 % expressed as a percentage of precipitation. We will include this in the manuscript.

L468 Since the imbalances of the Amazon and Amur were explained by the lack of measurements, it seems odd that Congo is presented in this context as the basin with lowest imbalance without

further explanation. Between the lines, the text seems to imply that the lack of measurements is not as much an issue in the Congo, which is not true. If any, the lack of measurements is even a bigger issue in this region. Please consider a revision of the paragraph.

We have now added text to explicitly say that the low imbalance in the Congo is not necessarily because of good coverage to avoid this implication. We have discussed possible explanations such as better observed rainfall due to TRMM, and that low imbalances can occur due to a cancelation of errors, but we cannot know for sure without further investigation. As the main aim of our paper was to present a methodological advancement, we do not go into more detail here.

Sect 5.1. Consider moving relevant parts to the Methods.

A subsection 'Goodness of fit' has been added to the methods and contains relevant parts of section 5.1.

L551. Could the authors also share the optimized results?

Results have now been shared, follow link in response to second comment.

I could not find any content in the readme.md file beside a single row stating "Water-and-energy-budgets". I have attempted to view it both by downloading it and opening it using a text editor, and by previewing it on GitHub. Please check.

This has been checked and should now be accessible from link given in second comment. I will make sure the doi in the manuscript works too.