How well are we able to close the water budget at the global scale?, F. Lehmann, B. D. Vishwakarma, J. Bamber

Reply to referee 1

We thank the reviewer for his/her time in reading our manuscript. A detailed reply to the comments made can be found below.

1) Pages 8 and 9: The author mentioned that they applied the method of Long et al. (2014b) to estimate TWSC. However, the formula of Long et al. (2014b) shown below was different from that used in this manuscript. Please double check.

This was a referencing error; the reference should have been Long et al. (2014a).

2) Page 9: It was stated that time-series of P, ET, and R also needed to be time-filtered by equation 3. In my opinion, P, ET, and R are fluxes, while TWS is a state variable. For one given month, P represents the total precipitation that occurs in that month. The use of equation 2 was likely due to that GRACE provides noisy monthly TWSA. It is kind of difficult for me to understand time-filtered P, ET and R. Please clarify.

TWS is indeed a state variable that describes the amount of water at a certain time t. The difference between two months can be written as the integral of the accumulation rate $A(t) = P(t) - ET(t) - R(t)$,

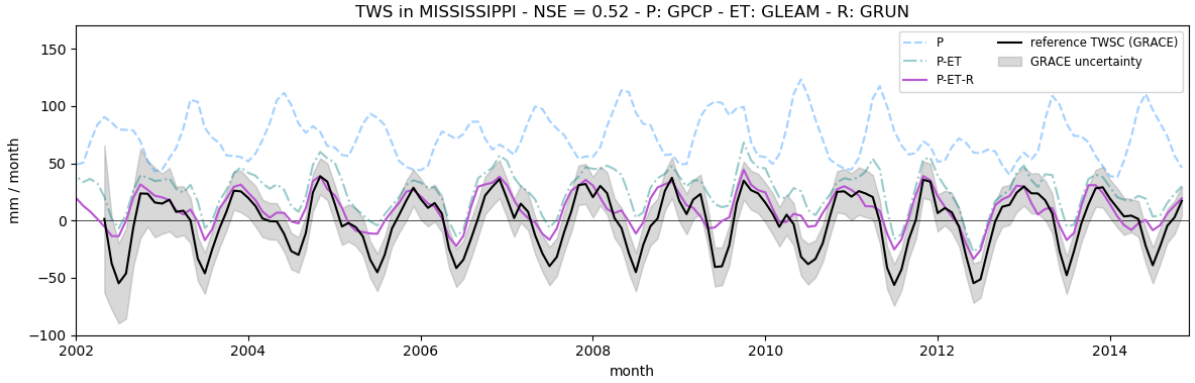
$$TWS(t+1) - TWS(t-1) = \int_{t-1}^{t+1} A(\tau) d\tau$$

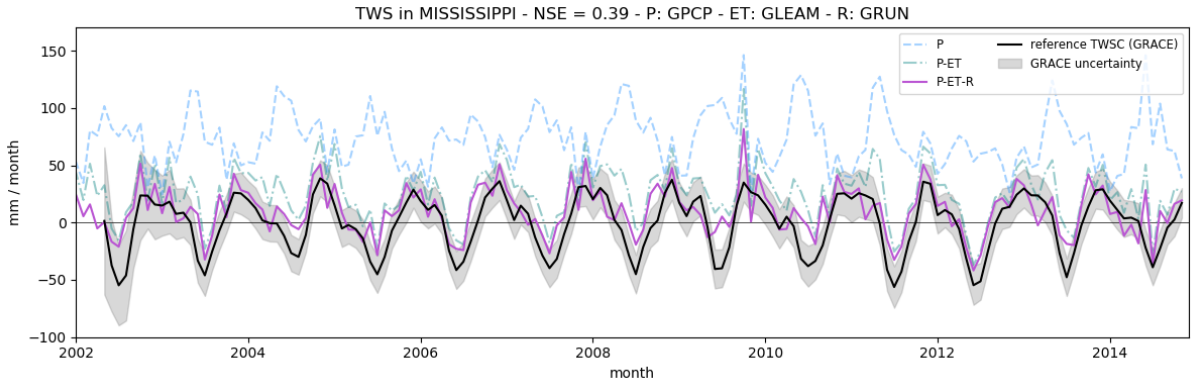
The integral can be either approximated by the value at its center, in which case the equation becomes $TWS(t+1) - TWS(t-1) = A(t) * \big(t+1-(t-1)\big) \approx 2\Delta t \times A(t)$
However, it is known that an integral is better approximated using the trapezoidal rule, which gives

$$TWS(t+1) - TWS(t-1) = \frac{\Delta t}{2}\big(A(t-1) + A(t)\big) + \frac{\Delta t}{2}\big(A(t) + A(t+1)\big)$$

The last formula corresponds to the time filter described in equation (3). On the one hand, the filter smooths slightly the time-series, which removes some high-frequency variations and may lead to optimistic results. On the other, annual peaks are reduced, which may create some underestimation. [Landerer et al., 2010] found that the imbalance error was higher when not using the time filtering, which also reflects our findings.

Below is an example of the water budget closure in the Mississippi basin with (top figure) and without (bottom figure) time filtering.





3) It was concluded that TWS changes reconstructed from the water balance equation (P-ET-R) were more accurate than the long-term and monthly mean of GRACE time series in the corresponding basins. Was the GRACE-TWSC used as benchmark data in the manuscript? If so, I was confused by the conclusion that P-ET-R was more accurate than GRACE-TWSC. I may not understand it. Could the author explain it more?

GRACE TWSC was used as benchmark data but there might have been a misunderstanding. The conclusion that P-ET-R was more accurate than GRACE TWSC refers only to the long-term or annual mean. This comes from the interpretation of the NSE and cyclostationary NSE. They indicate that in a situation where TWSC would be unknown, it would be better to approximate it with P-ET-R rather than using the mean of TWSC over the period when it was known.

4) Figure A12: "The top line of represents precipitations datasets." I did not get it.

We apologize for this typo, a word was indeed missing making the sentence unintelligible.

5) Page 24: "However, version 2.2 of this LSM, which assimilates GRACE data, performed poorly compared to its previous versions." There was an explanation: "Since this dataset assimilates GRACE measurements and was validated against GRDC observations, this may reflect overfitting of runoff that is better constrained than evapotranspiration, therefore leading to unrealistic ET values." Could the author explain it more? Generally, the following seems more easy to understand: when runoff became more accurate, ET would be improved accordingly.

We realized that our interpretation was maybe too superficial. Therefore, we deleted our explanation and instead suggested that this remains an open question for the community.

6) Typo mistakes:
Pages 1, 21 and 23: The "Catchment Land Surface Model" was supposed to be CLSM as the abbreviation had appeared earlier.
It has been corrected.

"Fig. 2" and "Figure 2" were both used in the manuscript. Please unify the expression.
Referring to the journal guidelines, it is advised to use Figure 2 when starting a sentence and Fig. 2 within a sentence.