

Reviewer #1:

We would like to thank you very much for your helpful and constructive review. We write our responses in blue underneath each of your comments.

Best regards,

Daniel Blank (on behalf of all co-authors)

OVERVIEW

The study investigates the relationship between soil moisture and satellite gravimetry total water storage variations at daily scale and on a global scale. Multiple soil moisture products have been analysed, both for the surface layer and the root zone. The correlation and the time shift among satellite gravimetry total water storage and soil moisture products have been investigated in depth.

GENERAL COMMENTS

The paper is well written and clear. The investigation of daily terrestrial water storage (TWS) variations from GRACE(-FO) has been carried out only in a very limited number of studies and hence their global analysis is surely of interest for the readership of Hydrology and Earth System Sciences. However, I have found some major comments that needs to be addressed carefully.

- MAJOR: In the analysis of different soil moisture products, any disagreement with TWS variations from GRACE is attributed to error in soil moisture product. For instance, when SMOS L4 product has positive time shift with GRACE it is attributed to errors in the algorithm for obtaining root zone soil moisture from SMOS, but it might be an error on GRACE (of course, particularly at daily temporal resolution). Instead of only identifying the area of disagreement, a more detailed discussion should be carried out to shed light on the potential causes for that.

Thank you very much for this comment. Yes, of course it is completely correct that disagreement is not only caused by errors in soil moisture products, but can also be attributed to limitations in the GRACE TWS data set. We will, therefore, extent the discussion of limitations of GRACE, e.g. with respect to the limited temporal and spatial resolution of the TWS data, the noise floor of the daily time series, and the issue of signal separation (full vertically integrated water column including surface water bodies etc.). For this purpose, we will add more information directly in Section 2.1 (description of GRACE data set) and extent the discussion of the results. Nevertheless, we also want to point out that one hypothesis for this study is that the soil moisture products and GRACE TWS do show differences that are not only due to respective errors in both data sets, but that are physically based as the data sets represent different quantities. To explore what we might learn from such differences on hydrological process dynamics is one motivation for this study.

- MAJOR: The investigation with SMAP L4 product should be carried out separately from the other products. SMAP L4 is mostly a modelled product, the contribution of SMAP data is quite limited as highlighted in the analysis for the pixel in India. All satellite soil moisture products are able to identify the irrigation signal, whereas it is not the case for SMAP L4 as it is mostly modelled and it does not include the irrigation component. A paper clearly showing this aspect is going to be published soon. I believe

the analysis with SMAP L4 should be likely removed, or considered completely separately (note that many other modelled products can be considered as well).

While we do agree that for the SMAP L4 data sets it should be clearly stated that they are largely model based and satellite soil moisture is only used for data assimilation, we would very much like to keep them in the study. To assess the information content and possible value of the daily GRACE TWS data, we argue that most might be learned when comparing them to a range of soil moisture products with different signal characteristics. Officially, SMAP L4 is still denoted as a SMAP, i.e., remote sensing, data product. Nevertheless, in the revised manuscript we will stress more strongly, that these data sets are heavily influenced by the data assimilation and thus by the climate data used as input for the land surface model (e.g. precipitation), to leave no doubt that they are not purely based on satellite surface soil moisture observations.

- MINOR: Throughout the paper many acronyms are present without the definition, please add.

Thank you very much for pointing this out! We have added the explanations of all acronyms at their first appearance in the manuscript.

- MODERATE: At line 192 it reads that the linear trend is removed. I believe it would be very interesting to compare the products in terms of their long-term trends. Can the authors add this analysis?

We agree that the analysis of the trends in two different observation types is an interesting investigation on its own, which we would like to leave for a future study. In the present study, we focus on the information content of the daily GRACE TWS data at the sub-yearly and sub-monthly time scale, showing for the first time their signals related to soil moisture dynamics, which we consider to be of sufficient scope for this paper.

In the specific comments I have added several suggestions to improve the manuscript.

SPECIFIC COMMENT (L: line or lines)

L39: Soil moisture can be obtained from microwave but also optical data. If GNSS is mentioned, also optical data should be.

Thank you very much, we will add this to the text.

L53-55: Currently, well established approaches have been exploited for estimating root zone soil moisture from satellite surface soil moisture data. For instance, the operational service under Copernicus providing the Soil Water Index and the EUMETSAT H SAF root-zone soil moisture products. These products should be mentioned and I believe the sentence should be revised.

We will revise the sentence accordingly and add the reference to the mentioned Copernicus data sets.

Figure 2: I would change the text in the legend for “soil moisture”. For instance, “committed area”, or something similar.

We agree that the label „soil moisture“ was not the best choice. We have, therefore, decided to change it to „area suited for analysis“.

L241: These evaluations are valid for the analysed pixel, it should be clear. It seems to read general results.

We will adjust the sentence.

L256: It's not merely extrapolation, there's a physically approach for getting root-zone soil moisture from surface data.

Thank you! Yes, we will correct the sentence to make this more clear.

L260-261: It clearly shows that SMAP L4 is a modelled product not including irrigation, should be considered apart.

Yes, the results corroborate the deficiency of the SMAP L4 product, i.e., that it is mainly driven by precipitation input in the data assimilation framework and thus does not represent the impact of irrigation on soil moisture. Interestingly, with our study this result can not only be backed by purely observation-based near-surface soil moisture products but also by daily TWS observations based on satellite gravimetry.

Figure 3: In the figures the anomalies are shown. It should be clarified in the y-axis labels.

The figure will be adjusted accordingly.

L288: Exactly, GRACE TWS cannot be considered as a reference.

We will make this more clear also in the general discussion of the results (see also our comment above).

L294-295: SMAP L4 does not remove the noise, it is simply a modelled product.

Together with adjusting the text on the SMAP L4 data (as mentioned above), we will also clarify this point.

L329-333: Deficiencies might be due also in GRACE data, right?

As mentioned above, we will extent the discussion of the limitations of the GRACE data and mention here that the deficiencies can be caused by both data products, besides by physically-based differences between the two data types because they do not represent the same hydrological quantities.

Figure 7: It is not readable, please improve.

We will update the figure. Thanks a lot!

Figure 8: In the caption it reads “Data gap between ...” Not clear, please revise.

We will update the caption. Thanks a lot!

L364-365: It seems to me the authors are overselling the results, the correlations in the high-pass filtered signal are very low. Only relatively better with SMAP L4, but it's not a satellite-based product.

We would like to point out that thorough significance testing including the consideration of temporal correlations has been carried out. It revealed significant correlations even for the high-pass filtered time series. Nevertheless, following the reviewer's comment, we will carefully check and eventually adapt the discussion to avoid possible overselling.

Figure 9: The range of the colorbar should be reduced. Otherwise the figure provides little information.

We will update the figure. Thanks a lot!