**Hydrology and
Earth System
Sciences**

Discussions

Interactive comment on "On the use of GRACE intersatellite tracking data for improved estimation of soil moisture and groundwater in Australia" *by* Natthachet Tangdamrongsub et al.

Natthachet Tangdamrongsub et al.

natthachet.tangdamrongsub@newcastle.edu.au

We would like to acknowledge the insightful comments and suggestions provided by reviewer 3. We will consider the reviewer's suggestions in our revised manuscript. Followings are the responses (R) based on the comments:

L15-L16–> This is not true that "there is no covariance matrix for L2 products". After filtering and conversion to TWS, this error can be propagated, which is addressed e.g., in DOI:10.1007/s10712-014-9309-8. L48 repeats the same claim!

R1: Review is correct that the covariance matrix is available for L2 product. However,

C1

the gridded product (Level 3, not L2 product) is discussed here. This is clearly written in L13-L16 of the submitted manuscript: ". . . from the high level products (e.g., land grid). The gridded data products are subjected to several drawbacks such as signal attenuation and/or distortion caused by ad hoc posteriori filters, and a lack of error covariance information." For clarity, we will include the additional information in the revised manuscript as follows: ". . . from the high level products (e.g., land grid from the Level 3 product). The gridded data products . . ."

L16-L17: The consequence is undesired alteration of ... data and its statistical property. It is not clear what this means. Are you suggesting that all other published papers are wrong!?

R2: We mean that the post-processing process of GRACE data might lead to the undesired alteration of the signal and its statistical property. To avoid the confusion, we will modify the statement in the revised manuscript as follows: "The post-processing process of GRACE data might lead to the undesired alteration of the signal and its statistical property"

L21-L22–> This is not clear which approach has been used.

R3: The approach used in this study is the least-squares combination. This is clearly mentioned in the earlier sentence (L19-L22): "The approach combines the GRACE's least-squares normal equation (full error variance-covariance information) of L1B data with the results from the Community Atmosphere Land Exchange (CABLE) model to improve soil moisture and groundwater estimates."

L61-L64–> Inversion techniques for signal separation have been applied, which consider errors in GRACE and complementary data used for signal separation. DOI:10.1016/j.jog.2012.03.001; DOI:10.1016/j.jog.2011.02.003; DOI:10.1007/s10712-016-9403-1

R4: We thank reviewer for the suggested literature. We will include them in the revised

C2

manuscript as follows: "Several signal separation techniques have been developed, which considered the errors in GRACE and complementary data in the signal separation process (Rietbroek et al., 2012; Schmeer et al., 2012; Forootan et al., 2017). However, the GRACE uncertainty is commonly derived empirically not necessarily reflecting the true GRACE error characteristics. Similar issue is seen in the data assimilation application (e.g., Zaitchik et al., 2008; Tangdamrongsub et al., 2015; Tian et al., 2017)."

The Methodology section needs to be specified, please add appendices to clearly how the equations are built. I cannot figure out how the normal equation is formulated, whether it includes KBRR and any orbital information? L120–> Please describe how the matrix A is derived and what are the entries. Similarly L128-L130 are unclear.

R5: In this study, the normal equation from the ITSG-2016 is used, and the description of the data can be found in the data webpage (https://www.tugraz.at/institute/ifg/downloads/gravity-field-models/itsg-grace2016). As the derivation of the normal equation is not the focus of this study, we do not discuss it further but refer to the description in the data webpage and references therein (this is stated clearly in Sect. 3.1). The element of the matrix A is mainly the partial derivative of the variational equation respect to the orbital information and gravitational coefficients. The variational equation include both orbital information and various kinds of L1B data including KBR data.

The accuracy of recovery has not been justified, which is essential for any scientific appliction to show that the accuracy of software is comparable with official products. Please include comparisons with the official ITSG2016 monthly solutions.

R6: The objective of this study is to combine GRACE normal equation with land surface model result to improve the estimated SM and GWS, and do not independently resolve the GRACE solution. This is stated clearly in the introduction lines $80 - 82$ in the submitted manuscript: "The approach optimally combines the GRACE's least-squares

normal equations with CABLE to improve \DeltaSM and \DeltaGWS estimates."

Therefore, the accuracy of the estimated result is only compared with the model-only result (please see Fig. 6). The accuracy of our TWS estimate can reach < 2 cm, which is in line with the GRACE accuracy of $\sim$ 2 cm globally (Wahr et al., 2006).

Furthermore, the official ITSG2016 solution is the unconstraint gravity field. Deriving TWS from the unconstraint SHC requires filtering, which might lead to the alteration of the GRACE signal. Comparing the GC result with the filtered GRACE data might lead to misinterpretation of the GC performance. Therefore, we do not compare our GC result with the ITSG2016 solution. Instead, we compare the GC result with the independent GRACE-derived TWS product such as the GRGS and Mascon that do not require further post-processing.

Results of the inversion might be compared with those that assimilate GRACE into hydrological models to improve the surface/sub-surface storage compartments. Recent studies over Australia include: DOI:10.1002/2016WR019641; DOI:10.1016/j.advwatres.2017.07.001

R7: We thank for the reviewer suggestion. However, the suggested literature were not published when this manuscript is finalized/under reviewed. We will consider the reviewer suggestion in our future work.

References

Forootan, E., Safari, A., Mostafaie, A., Schumacher, M., Delavar, M., and Awange, J. L.: Large-Scale Total Water Storage and Water Flux Changes over the Arid and Semiarid Parts of the Middle East from GRACE and Reanalysis Products, Surv. Geophys., 38:591-615, doi:10.1007/s10712-016-9403-1, 2017.

Rietbroek, R., Fritsche, M., Brunnabend, S.-E., Daras, I., Kusche, J., Schröter, J., Flechtner, F., and Dietrich, R.: Global surface mass from a new combination of GRACE, modelled OBP and reprocessed GPS data, J. Geodyn., 59 - 60:64 - 71,

doi:10.1016/j.jog.2011.02.003, 2012.

Schmeer, M., Schmidt, M., Boschb, W., and Seitz, F.: Separation of mass signals within GRACE monthly gravity field models by means of empirical orthogonal functions, J. Geodyn., 59 - 60:124 - 132, doi:10.1016/j.jog.2012.03.001, 2012.

C5