Hydrology and
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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.

Anonymous Referee #2

Received and published: 11 July 2017

This study combines GRACE's least-squares normal equations of L1B data and results from a hydrological model to improve soil moisture and groundwater estimates. It highlights the importance of the full error variance-covariance information of GRACE data on optimally integrating observations and model estimates. The GRACE-combined approach shows better agreements with in-situ groundwater and soil moisture observations at basin and inter-annual time scales.

This is a well-written article with interesting results. However, I find the methodology is ambiguous. This study claimed the use of raw GRACE L1B data in combination of model outputs. However, the gridded L3 data from GRGS solutions were also used in

the calculation together with the normal equations of GRACE that were obtained from the ITSG-Grace2016 products. Also, the normal equations and gridded TWS were from different centres. Why not using ITSG derived TWS products to be consistent? The validation of soil moisture and groundwater estimates is not sufficient enough to support the conclusion of the article. Overall, this study is valuable for the community. I recommend it for publication after addressing my following concerns.

Line 152: Equation 9 is the most important equation in this study, but some of the information is provided in the later section 3. Also the model covariance matrix is provided in section 4.2. Authors might consider making the method section clearer and reduce some unnecessary equations.

Line 170: Basically, the paper claimed "the use of intersatellite tracking data", but the data was the normal matrix N and vector c obtained from the ITSG-Grace 2016 as well as the gravity field coefficient from GOCO05s solution. No Level 1B data was actually used directly in this study, so I wonder whether the title is appropriate.

Line 195: The GRGS gridded TWS products were used in Equation 9 to work out the TWS values outside Australia. The L3 GRGS products derived from the Earth's geopotential coefficients up to degree and order 80, while ITSG data used in the study were up to 90. Why not using the ITSG TWS data? Can the ITSG normal equation represent the uncertainty in L3 GRGS products?

Line 210: The gridded GRGS data was resampled to 0.5 degree spatially, but the normal equation only contains the information to degree 90. How did you deal with the different spatial scale in the error variance-covariance matrix?

Line 231: depth between 0.022 m not cm

Line 256: The sensitivity study of the model parameters is an important process but not necessary to show in the paper. Author may consider removing table 2.

Line 298: Did you do the CDF matching for few years and validate the results for the rest

of time period? Or did you match all the time series and validate the same time period? If so, your estimates and observations are not independent. The CDF matching may discard important signals of the observations. Since only correlation was calculated, CDF matching is not necessary.

Line 301: The variability of soil moisture inside a basin is quite high. The average of basin and monthly soil moisture can smooth out lot of signals. Since your output is $0.5°$ x $0.5°$ gridded products, why not validate at this scale instead of basin scale? Can you show some validation with in-situ measurements?

Line 307: The groundwater estimates were only validated for two states using the state average. It should be possible to validate all the states over Australia or at basin scale to be consistent with other results. Two states are not sufficient to support the improvement in groundwater storage estimates over Australia.

Line 320: Is that only one value of specific yield per state was used to convert the groundwater level to storage? Will it be more appropriate to use different specific yields for different locations and calculate the average?

Line 468: The difference between model and GC approach for soil moisture is marginal here for basin monthly average. Can you show some time series examples of GC results and AMSR-E retrievals?

Line 482: In Table 4, the trend of GC approach is about one third of in-situ measurements for Queensland. What causes such big difference?

Line 491: It will be interesting to see the groundwater storage change in Murray-Darling Basin after the GC approach compared with in-situ measurements, during the big drought and big wet period.

Line 502: This section investigates the mass variation in the past 13 years based on the GC approach. Figure 8 is a quite good demonstration of the mass variation at different layers of water storage. The top and root-zone soil moisture show quite different

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trends. The root-zone soil moisture has similar trends with TWS and groundwater for most of the basins. It will be better to have some validation of root-zone soil moisture estimates and more sufficient groundwater storage estimates to support the analysis in this section.

Line 579: 0.39 is App1 and 0.42 is App2? So the trend calculating from GRACE subtracting modeled soil moisture is the same with modeled groundwater trend (in Table 4). The NS value for App1 is 0.46, which is less than the CABLE model without GRACE? For Victoria, the NS value of App2 is 0.3 less than CABLE model without GRACE too. With the assimilation of GRACE in App2, the correlation is degraded. It seems model itself without GRACE is better compared to App1 or App2. Still, for only two states validation results, it's hard to demonstrate that GC approach works better due to the error information. It could be your model uncertainty is better estimated using the ensembles as explained in Section 4.2. When you do the App1 and App2, did you also used 7 precipitation dataset as the same as the GC approach? Please clarify.

Line 587: The future work in this section is interesting but no results were provided. Author may consider removing this section completely or providing the results in this paper together with the GC approach.

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