Review of Article: "Identifying water mass depletion in Northern Iraq observed by GRACE" by G. Mulder et al. (hessd-11-11533-2014)

Summary

This study interprets a temporal gravity change signal observed by the GRACE satellite mission over Iraq using a set of auxiliary data and a hydrological model. Although many studies have addressed similar objectives for other geographic regions, the topic is still of considerable interest, particularly when GRACE data are combined with other remote sensing data types such as altimetry. In general, the presentation of the methodology lacks clarity and I have a number of technical questions/comments, which are listed below. The manuscript will need substantial revision before it can be published in HESS.

Review Comments

1. The overall strategy for this study is not clearly explained. Some people use GRACE data to inform hydrological models in a calibration and/or data assimilation approach (e.g. Milzow et al., 2011). Others compare GRACE data to hydrological model output to check consistency and identify weaknesses in both the GRACE data and the models. What exactly is the purpose here? This should be explained upfront. If the purpose is to inform the model, then it is essential to document model improvement in an independent validation period.

2. GRACE processing: There are basically two ways of processing GRACE data in the literature: Either the level 1 range rate data is inverted for spherical harmonic coefficients or for mass changes on a grid. The second approach is usually termed the MASCON approach (e.g. Rowlands, 2005). The method you present here seems to be a hybrid between the two, in the sense that mascon parameters are fitted to level 2 spherical harmonic coefficients instead of range rate data. I know that GRACE processing is not the focus of this paper, but it would still be nice to explain the pros and cons of doing it this way. For instance, I do not understand if you can retrieve the 6 MASCONS shown in Figure 2 independently of the rest of the planet or if you always have to invert for a global set of mascons? Also, why do the MASCONS have circular shape, why not adapt them to the geometry of the basins of interest as for instance in Krogh et al., 2010?

3. The purpose and basis of the various corrections described on page 11539 are not really clear to me. Why does the contribution of the lakes have to be scaled by ½ and 1/3? How did these numbers come about? Why is the GRACE region extended into the southwestern desert, if this is really not part of the study area of interest? All this needs to be motivated and explained much better.

4. It is stated that the aquifers are karstified, and highly transmissive. Water level and storage variations in such aquifers are generally suppressed because of the high transmissivity and water is effectively drained over short time scales. Lines 4-9 on page

11548 seem to suggest the opposite. It would be nice to discuss if the simulated groundwater storage variations are reasonable given the available hydrogeological knowledge and observations from the region.

5. Throughout the manuscript, language and grammar should be checked and clarity of the wording should be improved, see also details listed below. Please always call the same things by the same names. For example, the manuscript sometimes talks about the "Lesser Zab catchment" and sometimes about the "smaller Dukan area", although, I believe, those two names refer to exactly the same thing.

6. A lot of place names are used in the text, but cannot be found on any of the maps. I think the paper would benefit from a detailed base map that shows and names all places, rivers and lakes referred to in the text.

7. Please explain how the uncertainty bands for the surface water storage and snow storage in fig 8 were derived.

8. Why use snow from GLDAS? Why not run a simple snow accumulation and melt routine on top of the hydrological model? At least that would ensure consistent precipitation input. How exactly is the TRMM product corrected for snow from GLDAS?

9. Very little is said about how the uncertainties of the simulated storages have been determined (fig 9). To me, these uncertainty bounds look very narrow. Can they be justified? For instance, were the errors due to parameter transfer from gauged to ungauged parts of the catchment taken into account? Can these uncertainty estimates be hold up against real observations? It would be nice to see the comparison of simulated and observed hydrographs at least for the single available station…

Details

1. Page 11534, line 11: "Corrected for" should probably be "estimated". Total mass variation should include lakes.

2. Page 11534, line 19: "Depletion of geology"? Please re-word. I guess you refer to natural depletion of groundwater.

3. Page 11535, line 6: Is this predicted decrease due to anthropogenic climate change?

4. Page 11535, line 20: "riparian" should be "upstream".

5. Page 11537 line 9: Please give the version of the TRMM 3B42 product used here. Versions 6 and 7 are quite different in other parts of the world, here too?

6. Page 11537 line 22: Please reword. The lakes influence the GRACE signals.

7. Page 11538 line 9: "dises" should be circles??

8. Page 11542, line 5: "bias-corrected" may be better than "calibrated"

9. It is not unambiguously stated in the text how GRACE and the model are compared (e.g. page 11546, line 23). It is stated that GRACE and the model are compared, while in fact the comparison is between GRACE minus surface water storage and the model.

10. Figure 1: Both maps should have coordinate systems/scale bars and colorbar legends.

11. Figure 2: Needs coordiates/scales

References

Krogh, P.E., Andersen, O.B., Michailovsky, C.I.B., Bauer-Gottwein, P., Rowlands, D.D., Luthcke, S.B., Chinn, D.S., 2010. Evaluating terrestrial water storage variations from regionally constrained GRACE mascon data and hydrological models over Southern Africa – preliminary results. Int. J. Remote Sens. 31, 3899–3912. doi:10.1080/01431161.2010.483483

Milzow, C., Krogh, P.E., Bauer-Gottwein, P., 2011. Combining satellite radar altimetry, SAR surface soil moisture and GRACE total storage changes for hydrological model calibration in a large poorly gauged catchment. Hydrol. Earth Syst. Sci. 15, 1729–1743. doi:10.5194/hess-15-1729-2011

Rowlands, D.D., 2005. Resolving mass flux at high spatial and temporal resolution using GRACE intersatellite measurements. Geophys. Res. Lett. 32, L04310. doi:10.1029/2004GL021908