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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Data assimilation of GRACE terrestrial water storage estimates into a regional hydrological model of the Rhine River basin" *by* N. Tangdamrongsub et al.

Anonymous Referee #3

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The paper is valuable because addresses how remotely observed regions could benefit from the assimilation of GRACE TWS into hydrological model in order to improve hydrological states.

However, my main concern is related to the description of the assimilation technique. To my knowledge the application of the EnKF technique is quite different from existing GRACE-EnKF (e.g.: Zaitchik et al 2008, Forman et al. 2012, Houborg et al. 2012, Li et al. 2012), therefore I recommend to accurately describe how the EnKF is implemented [I.e. what are the assimilation states, how are background/error covariances calculated, how are increments applied to the model states, what are the assumed

spatial/temporal correlations of model/observations, etc.]. The paper could really benefit from a more detailed description of the EnKF used. I'm herein detailing some of the major comments.

Comment on the calibration vs. non calibration experiment: My first guess when I read the experiment setup was that results will not change much if the parameters were not calibrated but assumed to be the average over the basin. Even if you are using gridded (1deg) GRACE products, the spatial representation of GRACE is much courser than that so I would have guessed that the impact of a detailed (high spatial resolution) calibration of the model parameters does not have a major impact on your results if the spatial average of the parameters are used instead. In my opinion choosing an average of the calibrated parameters as the "non calibrated" case may be too optimistic and not representative of a region with limited observations. I would suggest to add/substitute this case with one where the parameters are not known (e.g. for example maybe just derived from a global land classifications such for example: http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/ or other globally available database)

Comment on the verification methods: The whole section about how/why you choose to scale groundwater insitu observations from piezometric to storage units needs some work. It is not clear to me why if you remove the soil moisture temporal mean from GLDAS you can get \Delta_GW_{in-situ}? Where does the \DeltaSM_{GLDAS} come in in the context of equation (1)? If you remove a constant (average SM) from the GRACE aren't you effectively obtaining the same time series just shifted by a constant value?

Comments on the EnKF technique: The paper could really benefit from a more detailed description of the EnKF used. To my knowledge the application of the EnKF technique is quite different from existing GRACE-EnKF (e.g.: e.g.: Zaitchik et al 2008, Forman et al. 2012, Houborg et al. 2012, Li et al. 2012), therefore I recommend to accurately describe how the EnKF is implemented. I'm listing here my main concerns about the

EnKF method.

Treatment of snow: It is unclear to me what is the need to remove snow from the GRACE observations prior assimilation? Why don't just include it in the assimilation scheme? And include a snow term in the calculation of the modeled TWS?

Actual EnKF scheme: It is assumed that a single observation is acquired in the middle of the month, however GRACE TWS is assumed to "represents the surface mass deviation for that month relative to the baseline average over Jan 2004 to Dec 2009." therefore this has to be considered as an average TWS variation for the entire month. This is effectively the reason why existing GRACE-EnKF techniques used a "two-step" approach (Zaitchik et al. 2008, Forman et al., 2012) where a single month was modeled twice: one time to obtain a "monthly average" observation prediction (from an open-loop simulation of the entire month, and not simply from the TWS modeled at a single day; and a second time to apply the increments computed from the EnKF. Are you also using a two-step approach or a straigforward application of the EnKF (as a real time assimilation scheme)? How would results change if instead the observation was assumed to be taken of the end of the month?

Temporal correlations: Observations are assimilated every 5-days. This is done after the temporally interpolating observations. Isn't this interpolation introducing an implicit temporal correlation across the assimilated observations? The EnKF assumes that each observation is independent from each other but the 5-days temporal interpolation includes temporal correlation. Did the authors consider the effects of their 5-days interpolations in the assimilation scheme? For example, how would results change if instead a different temporal window (lets say daily or every 15 days) is chosen for interpolation? Or how would results change if none interpolation was done after all and perhaps observations were assimilated only at the end of a month?

Spatial correlations of the GRACE observations: I read from http://grace.jpl.nasa.gov/data/gracemonthlymassgridsland/ that "The spatial sam-

pling of all grids is 1 degree in both latitude and longitude (approx. 111 km at the Equator). However, this does not mean that two neighboring grid cells are 'independent' because spatial smoothing has been applied" this means that spatial correlations between neighboring GRACE-TWS pixels should be applied. It seems that the authors did not consider observations spatial correlations in their EnKF, is it correct? If so what is the rationale for not including it?

I fear that untreated spatial/temporal correlations could impact the robustness of this paper conclusion, unless explicitly considering their effects in the assimilation scheme.

Some minor comments/edits:

Figure 2/or add to the text... can the authors add a schematic representation of the model? E.g. it would be useful to understand what exactly upper/lower (UZ/LZ) mean in terms of the actual model physics. In the same figure, of text can the authors described how is soil moisture (SM) defined (e.g. depth? rootzone only? surface+rootzone? etc)

Please avoid the usage of "later" e.g. in section 2 toward the end of the first paragraph.

Can the authors add orographic contours on the Figure 1. Also the text oftentimes refers to the "Alps" region, could you please add this label in Figure 1.

Table 4-5 are very hard to read, maybe can group these by regions identified in Figure 1. Or perhaps help the reader by highlighting which stations improved or not upon the open loop case?

References:

Forman, B. A., Reichle, R. H., & Rodell, M. (2012). Assimilation of terrestrial water storage from GRACE in a snowâĂŘdominated basin. Water Resources Research, 48(1).

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Li, B., Rodell, M., Zaitchik, B. F., Reichle, R. H., Koster, R. D., & van Dam, T. M. (2012). Assimilation of GRACE terrestrial water storage into a land surface model: Evaluation and potential value for drought monitoring in western and central Europe. Journal of Hydrology, 446, 103-115.

Zaitchik, B. F., Rodell, M., & Reichle, R. H. (2008). Assimilation of GRACE terrestrial water storage data into a land surface model: Results for the Mississippi River basin. Journal of Hydrometeorology, 9(3), 535-548.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 11837, 2014.