

Interactive comment on “Estimating long-term groundwater storage and its controlling factors in cold regions” by Soumendra N. Bhanja et al.

Anonymous Referee #1

Received and published: 28 June 2018

General comments

The study presents an interesting use of gravity based remote sensing data (GRACE) for monitoring of groundwater resources in Alberta region and comparing it to available in situ monitoring well data. It is mostly nicely structured and written that the study is easy to follow for the reader. However, there are issues especially concerning the use of the data and the methods that should be revised thoroughly to enhance the quality of the manuscript.

Specific comments:

First main issue is how the in situ data is used. Authors mention in the abstract and in the text that the unconfined and unconfined aquifer monitoring wells are separated

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from the in situ data and different approach for groundwater storage change has been used (equation 1 & 2). This is good as the well reading from confined aquifer compared to unconfined aquifer tell a different information on the aquifer storage. However, this separation of the data does not show in results or in discussion. In addition, this connects to the second issue of the manuscript. You have not given any information where on the studied catchments the wells are situated. As there is no spatial data for the wells or the information how the confined and unconfined aquifers are presented in each catchment, it is rather hard to say how representative the in situ data is for a specific catchment where you have the satellite data calculated and compared.

For example: the basin 7 in situ data and GRACE data do not seem to correlate. You have 15 wells in this catchment, but are these e.g. situated in one aquifer? Are they all unconfined aquifers? The average well data in figure 3 might indicate a strong annual snowmelt impact to the groundwater level in basin 7 average groundwater levels. This would happen in unconfined aquifers in snow dominated region (see comment on snow melt below). With the information given in the manuscript this cannot be confirmed or discussed in detail.

How deep aquifers the wells are monitoring? If the screening zone is for a deeper, confined aquifer, how much a yearly recharge impacts this aquifer? All in all, it would be beneficial to present more in detail how the monitoring wells are presenting the prevailing aquifer conditions in different catchments.

And concerning the methods used: the smallest catchment size (or part of the catchment studied) in this manuscript is Milk basin with 11834 km². In total, the size in three of the catchments is smaller than 20000 km². Is the size of the catchments a problem for the GRACE data methods used or does it cause uncertainty? This issue is previously discussed e.g. in Wishvakarma et al. 2017 for different GRACE approach.

Authors have studied how the precipitation is connected to the GWSA (chapter 3.5). However, role of snow is not discussed in detail. In many northern areas the snow melt

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can be the driving factor for the groundwater storage recharge. Same goes to large areas in Alberta. As during the winter months the precipitation accumulates in snowpack and then usually melts in a short period, it would be more beneficial to compare warm period precipitation and winter time conditions (<0 degree C) separately, or take the snow water equivalent from GLDAS and add this to your analyses. With the straight comparison between monthly precipitation and GWSA a large portion of the yearly hydrological dynamics is missing. Authors have tested different approach in chapter 3.6., but this approach does not takes into account in detail the snow accumulation and snow melt.

Detailed comments:

Use of abbreviations: the text does not follow good order of abbreviations. E.g. in abstract in line 17 you present GWSAobs first time without explanation. And in line 19 has GWsat two times which mixes reader of the abstract. Same continues in text. E.g. in page 2 line 34 GWS is presented first time without explanation.

Page 2, line 20: extra comma

Page 2, line 9, space after point

Page 3, lines 17-18: sentence structure

Page 7: the two equations have a wrong number

Page 7, line 20: repetition from previous sentence

Page 10, line 6: 470 wells were monitored but 157 were used (page 4, lines 13-15) Is Figure 8 is not presented in the text.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2018-185>, 2018.