Review of the manuscript egusphere-2022-22 "Influence of intensive agriculture and geological heterogeneity on the recharge of an arid aquifer system (Saq-Ram, Arabian Peninsula)" by Seraphin P, Gonçalvès J, Hamelin B, Stieglitz T, Deschamps P

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1 General comments

This manuscript describes an interesting analysis of GRACE data to estimate the components of the water budget for the Saq-Ram Aquifer System.

I appreciated the careful analysis of data in order to assess which are the best products of satellite data processing to perform a water budget analysis for a wide, moderately or poorly gauged, basin. I think this is the most important and innovative aspect of the work. The remarks on effects of intensive agriculture and geological heterogeneity are also interesting, but, in my opinion, they are not so deeply considered in the work as to make them the central focus of the title.

The scientific quality of the work is good, but I would suggest to provide further discussion of aspects related to scaling, which is somehow hidden in the work-flow.

The manuscript is generally well written and well organized. Some minor technical comments are listed below.

I think that this manuscript deserves publication on a public repository. With some corrections and/or integration, it could be submitted to a high-quality international scientific journal.

2 Specific comments

1. Lines 87 to 97. The resolution which can be reached with the remote sensing approach should be discussed. Also the extension of the basin which can be properly studied with satellite data should be discussed. For instance, at line 96, it would be useful to explicitly state how large are the mentioned regional aquifers.

2. Line 214. The averaged water demand for agricultural purposes is given with three or four significant digits. I do not think this is physically acceptable, also taking into account the estimates of uncertainties which are explicitly given later for similar quantities.

3. Figure 3. These data deserves further comments. Any remarks about the increasing discrepancies among the products by JPL, CSR and GSFC for TWS, which is clearly apparent after 2012? Which regression is applied to TWS time series? The linear trends for SWS are not very appropriate, as these time series show, at least, a three-phase behavior: great variability from 2002 to 2006; small variations and values close to zero or poorly negative from 2007 to 2018; high variability and positive values after 2019.

4. Sections 4.3 & 4.4. I appreciate this discussion. However, the two sections could be merged in a better way. At the beginning of section 4.3 it is stated that the transit time of water through the vadose zone is about 350 years; taking into account porosity and saturation, the recharge times should be even longer. This immediately rises the concern about the fact that the dynamics of the unsaturated zone and of the aquifer recharge seems to be much slower than the variability of the gravity field. Furthermore, the time series considered here are 20 years long, which is a time interval much shorter than 350 years. At line 541, it is stated that 12 years of GRACE data are required to obtain the long-term average recharge. This seems to be in contrast with the previous comments, doesn't it?

3 Technical comments

1. I recommend to follow as carefully as possible the guidelines by BIPM about the use of SI units and the format with which values of physical quantities are written. In particular, I recommend to use parentheses to avoid confusion. I list here some examples.

(a) A space should be left between the value and the percentage symbol, e.g., 1 %.

(b) Line 81. "3-4%" should be substituted, possibly with "approximately 3.5 %". Similarly, at line 107.

(c) Line 109. "$1.8 \pm 0.3\%$" should be substituted with "(1.8 ± 0.3) %". Similarly, at lines 115, 345, 388, 418, 419, 445, 454, 459, 562.

(d) Lines 187 & 188. "30 and $90 \times 10^6 \mathrm{m}^3\mathrm{yr}^{-1}$" should be substituted, possibly with "$30 \times 10^6\,\mathrm{m}^3 \cdot \mathrm{yr}^{-1}$ and $90\,\mathrm{m}^3 \cdot \mathrm{yr}^{-1}$". Similarly at line 220.

(e) Line 312. "$210 \pm 30 \times 10^6 \mathrm{m}^3\mathrm{yr}^{-1}$" should be substituted with "$(210 \pm 30) \times 10^6\,\mathrm{m}^3 \cdot \mathrm{yr}^{-1}$". Similarly at lines 325, 330, 355, 387, 462, 463, 465, 488, 489, 541, 559 to 561.

2. Line 51. Although Bierkens and Wada (2019) is a review paper, it could be fair to add citations of some of the seminal papers on this subject.

3. Line 54. Since the resolution of GRACE data and of the products used in this work are given in degrees, it would be useful to include the extension of the basin in latitude and longitude. This can be done here or in section 2.1.

4. Lines 151 & 152. A verb is missing in the sentence "The Climatic Research Unit... (over the period 1901-2019)", isn't it?

5. Lines 212, 318; legend of figure 2. "et al." should be substituted with "and McCluskey".

6. Figure 2. Why only one time series is shown with error bars? How is the uncertainty estimated?

7. Lines 231 & 232. Expression "its 2004.0-2009.9 average value" should be substituted, possibly with "its average value from January 2004 to September 2009"

8. Figure 3. For both plots, I could not find an explicit definition of the reference equivalent water thickness, which corresponds to a null value.

9. Lines 264 & 265. "(GLDAS data are available at https://ldas.gsfc.nasa.gov/gldas)" should be moved before, possibly at the end of the first sentence of this paragraph.

10. Line 290. Which polynomial fit is used? I mean, second, third, or higher degree? I do not see ΔGWS in Figure 3.

11. Line 343. In which sense "needed"?