Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2017-280-RC1, 2017

Hydrology and Earth System Sciences
Discussions

Interactive comment on "A global hydrological simulation to specify the sources of water used by humans" *by* Naota Hanasaki et al.

Anonymous Referee #1

Received and published: 23 June 2017

General comments:

Hanasaki et al present their effort to enhance the H08 global hydrology model with schemes to attribute water abstraction to different water sources. They detail the functionality of every scheme, explain its impacts in different regions and finally discuss some sources of uncertainty that should be kept in mind. The study is clearly structured and (even though it is quite long) easy to read and follow. The combination of this number of water sources in one model definitely merits the publication of their work. However, there are some points I like to be discussed before the final paper should be accepted:

- The authors validate their model version by comparing its results to TWS anomalies measured with GRACE. They utilize a simulation with naturalized setup (e.g. no human impacts) with a simulation with all human impacts. However, the latter does not only include their improvements but also the river regulation and dam management scheme implemented in H08 earlier. I would claim this two aspects are already explain most of the improvement in the TWS anomaly. If the author do want to demonstrate an improvement due to their recent chances, they instead need to compare to a simulation with the original H08 and its human impacts enabled.
- At several points the authors point out that the water balance is strictly closed. Technically this will be true as, no doubt, the models tracks all water storages and fluxes and no water is generated or vanished which the authors are not aware of. However, the do use unlimited water sources to satisfy the water requirements and, thus, the water balance is actually violated. Please reformulate such statements to avoid misunderstandings. The authors present numbers about how much water for a given sector is extracted from which source. However, such number seem to rely on very arbitrary decisions about the order of water extractions (see specific comment P18L4). As the numbers are presented as important parts of their results, I would want to see a justification why this order of water abstraction (and therefore this numbers) is more valid than any other order. Are there economic reasons for this prioritisation? What about allowing the different sectors to share a commonly used source according to their relative water demand fraction. This would much better reflect the simultaneous use of a source by different sectors.
- In section 3.4.3, the authors discuss different reasons about why the available water is significantly less than the required amount of water. Here, I would ask them to reflect about some maybe related points: why do you actually chose to satisfy the water requirements instead of just diagnosing the missing water. In

this way you would also avoid the water balance violation via return flows. based on the information from the appendix I understand that the water withdrawn for industrial and municipal sector is consumed. However, in reality both sectors produce a large amount of waste water which, after treatment, goes back into the water cycle. Is this somehow accounted for or does your data source explicitly include the consumed water? If not this might be part of the missing water. what about the possibility that the water is not actually missing. You derive the surface water / groundwater water withdrawal ratio from quite large scale data. Thus, the real ratio at grid cell level might be extremely different. For grid cells with either a large groundwater or surface water storage the use of this large scale average might cause a depletion in the surface water (groundwater) storage even though there would be enough water in the groundwater (surface water) storage. To me this seems to be a much larger source of uncertainty than e.g. the model resolution itself.

Considering these points, I'd ask the author to either justify the robustness of their existing results or adapt some of my proposed changes where possible. Of course, some points (like missing surface water / groundwater abstraction ratio on grid scale) cannot be changed but should be discussed in the uncertainty part. Alternatively, the authors could consider publishing their research in a journal like GMD (http://www.geoscientific-model-development.net/) where the focus is rather on the development of new model components and, thus, less changes in the manuscript would be needed.

Specific comments

- P1L24: Do these numbers refer to the simulation or to the GRACE data?
- P3L14: I am confused about the local reservoirs. So the local reservoirs were

already in the model? It does seem strange to write like ...six things were added, but one not/was already there. . . please clarify.

- P5L11: How do you know the total water requirement? Is this computed by your model (if so, how) or based on external data (if so, which dataset)? I see it is explained in the appendix, so just add a link here.
- P6L3: While I agree with your decision to use the country with the larger population, I'd like to know what uncertainty is introduced due to it. Would a different sampling affect your fractions distinctively? How important do you consider the (not represented) spatial variation of this fraction within the national borders?
- P6L11: So you fulfil the groundwater abstraction requirements by take water from an unlimited reservoir. Considering that the extracted water will partly end up as irrigation water, some of it will enter the soil and eventually the renewable groundwater storage. How does this agree with your statement in the abstract, that your water balance is closed at any time. For me it sounds like you (at least potentially) add water to the system and therefore effectively violate the water balance (although you probably technically close it by accounting for this violation).
- P7L14: Why is the water transport via aqueducts considered to be a withdrawal. I'd assume you just move water in the river network from one cell to another. Please rephrase.
- P8L11: What is a storage area of a grid cell?
- P8L22: Considering you remark (P3L14) I am now confused about whether this is the old local reservoir scheme of original H08 or the new one that was not implemented. . .

- P9L12: Does this mean you (simply) define seawater desalination to be equal to the water requirements from municipal and industrial sector? Could you please add an equation as you did for the other sources.
- P9L31: What would water lost through percolation be in you model? I thought you only have one soil layer? What is the storage water percolates from?
- P10L16: I assume you mean you take the water from the origin of an aqueduct that ends in the actual grid cell, right?
- P10L24: Again, using such an unlimited source is a water balance violation.
- P10L26: What do you mean by statistically based OR well validated?
- P11L20: Do you need all of the 8 forcing variables, or just a subset?
- P11L26: From what I read so far, I disagree with this statement. I think you mean that you track all fluxes, sources and sinks and therefore have no unexplained water imbalance in the model, but you can never have a closed water balance while assuming unlimited water reservoirs. Please either reformulated these remarks concerning the water balance or convince me otherwise.
- P11L29: What does it mean with respect to the global reservoirs which are already part of the original H08? Where they active in the NAT simulation as well? Is the difference between NAT and ALL just the use of the new sub-models (thus you can clearly show their effect on the simulation) or is it naturalized vs human-impacted (in which case you would not know whether a given effect comes from the human-impact related processes already being part of the original H08 or from your new processes)? Furthermore, it would be important to know, to what extent unlimited reservoirs contribute to the results.

- P13L17: Or does it rather demonstrate the validity of your irrigation water requirement computation (and not the full model)? Because (as you said yourself) the requirements for other sectors as well as the separation into surface water / groundwater abstraction comes from data.
- P15L22: So also the global reservoirs are only active in the ALL simulation? Which means it is hard to clearly separate the simulation improvement coming from the reservoir operations already being part of H08 and the new source schemes.
- P17L18: Your renewable groundwater storage is rather stable in all six river basins, but the unlimited storage shows a clear trend towards depletion. Looking at equation 4 and 5, I wonder how this can be because I'd expect that first the renewable storage has to run dry (Eq 4) before the unlimited storage is used (Eq 5). Is this an effect of the monthly and/or spatial averaging? Please explain.
- P18L4: Why is this only partly true? If you would withdraw water for irrigation first, probably all water for industrial and municipal sectors would have to come from unsustainable storages. Thus, different numbers for the different sectors do not appear to be results, but rather reflect your computation choice or the amount of water available. As I understand it, the only robust value in those numbers would be the percentage of unsustainable water use (accumulated over all sectors). Please comment on this.
- P19L9: Why 'introducing USW OR taking option 1'? As I understand it, option 1 means introducing the USW.
- P20L2: You mean of volume of the extracted non-renewable groundwater, not the volume of the aquifer itself, right? Please be concise here, because the paragraph sound like the latter.

- P21L17: Is this improvement really due to the six new schemes or rather due to the already existing global reservoirs and dam operations?
- P22L20: I don't see how the economy (maybe apart from desalination part) and environmental aspects are accounted for in H08. From this paragraph I would expect that as a result of H08 simulations you could come up with kind of a cost-benefit analysis for different sources. Thus, this statement seems a bit strong for me. Please be concise about what exactly you can do with this model version.

Technical comments

- Tab S1: Please repeat the header for every table page
- Tab A1: It seems this data could be easily displayed in portrait format. Please only use sideways tables if really necessary.
- All figures: You seem to prefer to use landscape format. However, it makes reading the paper more difficult especially in digital format and is not necessary for all of you figures (e.g. 1,4,7,8 and others). Please use portrait whenever possible.
- P8L12: You describe the general mechanics of your scheme. Better use present tense for such paragraphs.
- P8L23: Please revise this paragraph with regard to duplicates (estimation of extent areas) and unnecessary information (implementation difficult, still we implemented it). Your paper is quite long anyway, thus it should be shortened wherever possible.

- Fig 6: In the enlarged figure there is not much to see thanks to the text. As you refer only to a few selected basins in your results section, please remove the labels from most points and add them only to those you actually discuss.
- Fig 8: Consider shading the ocean area in a light grey for an easier overview. Also both regions are so close together that you could show them in one map.
- Fig 11: This is an awesome figure! You may think about changing the color of the region borders to avoid low visibility for patches where the background color matches the border color. Also it might be worthwhile to add small lines from the region to the circle to avoid any confusion about what belonging to what.
- P18L25: Typo CAN → CNA (same typo in table S2)
- P19L8: This is not an inconsistency but just the difference

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