Geoscientific Model Development Discussions

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Comment on gmd-2022-59

Anonymous Referee #2

Referee comment on "Water balance model (WBM) v.1.0.0: a scalable gridded global hydrologic model with water-tracking functionality" by Danielle S. Grogan et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2022-59-RC2, 2022

This manuscript presents the UNH Water Balance Model, a hydrology model that has been developed over several decades, but released publicly (open source code) for the first time.

The authors provide a literature review of the model history and evaluate the current model performance against river discharge observations and irrigation water supply requirements. The WBM performs better across North America and Europe in terms of discharge and irrigation water supply, but relatively poorly across Asia and portions of South America.

The manuscript then provides examples of regional simulations including the Indus River watershed as well as the Wyoming headwaters contributing to river flow to the Colorado, Colombia and Mississippi River. This provides an opportunity to demonstrate the novel water component tracking functionality that enables identification of source regions and source stocks for river discharge and irrigation water supply.

The tracking feature appears to be a significant advance in river flow diagnostics and is capable of determining source spatial regions, and source water components (precip, agriculture, groundwater). This should be a valuable tool for land management and government policy makers. Finally, the authors provide an overview of WBM run-time instructions describing the necessary input data and setup scripts to perform a simulation.

This reviewer was impressed with the breadth of the manuscript included 1) a literature performance review, 2) multi-domain simulations with emphasis on the new diagnostic tracking functionality and 3) an overview of a model setup.
This reviewer would have liked much more discussion devoted to WBM performance.

The WBM had a strong high bias in simulating global irrigation water supply as compared to other studies (Table 6). This apparently was caused by a systematic underestimation of discharge for the China/Asia region, but very little discussion (only a mention regarding better parameters are needed) was devoted to this topic. Whereas the authors provided a comparison against similar hydrology models in terms of simulated irrigation supply, no comparison was provided for discharge rates against other models for better context and perhaps lead to a discussion of what model components or parameters are most in need of improvements. This reviewer would have liked more justification or explanation to describe the skill of WBM such that a new user could avoid certain regions or pay special attention to parameters which are poorly constrained. Also an inclusion/reference of a model tutorial would be helpful for new users to begin interacting with the WBM.

Line 66: Very nice explanation of the value of this source component tracking feature in this paragraph.

Line 85: Global models come an out-of-the-box setup of preferred sub-model structures and parameterizations. There is a table devoted to the key default parameters (Table 2), but no discussion of the optimization process that is required for regional simulations, or representation of the range of parameters to make these regional simulations perform well. The authors do present some discussion and results based upon the contribution of uncertainty due to the climate forcing (Figure 3), but missed an opportunity to discuss the contribution of parameter uncertainty in the manuscript.

How modular is WBM in terms of testing particular hypotheses about hydrology and competing methods, etc. ? There is some brief description at the very end of turning flags on/off, but no specifics in how this influences representation of hydrology. Given the source tracking capability it would be interesting to test the impact of certain model assumption/hypotheses.

Model Description:

Line 140: I am assuming the representation of snow is considered single-layer, and does not include multiple layers. Things like snow properties and albedo are not explicitly taken into account. Also insolation and aspect are not considered within the melting term? Care to comment how this might influence your snow source? Has this ever been validated against gridded snow data sets?

Line 200: “Actual evapotranspiration (AET) from naturally vegetated land areas is a function of the PET, soil moisture, and soil properties.”
So rooting depth is not taken into account? What function or purpose is setting the soil moisture pool depth to that of the rooting depth? I assume it’s a single layer soil subsurface then?

Line 210: “While AET from other land cover types (e.g., forest or grassland) can be parameterized and simulated, no published study has yet used this option of WBM. Actual evapotranspiration from other consumptive water uses are described below in Section 2.2.5.”
Are the default parameters provided for forest/grassland types to calculate AET, or does the user have to provide them? If this option has never been used, how does the model treat forest/grassland if run globally – which includes forest and grassland cover?

Line 275: The term “Shallow groundwater pool” is not used in Figure 1. I assume this is the same thing as “groundwater recharge pool”? If so, make sure the terminology is consistent.

Do the grid cells communicate for surface runoff and subsurface discharge or does this get routed directly to river transport model?

The term “unlimited unsustainable groundwater source” seems confusing. Is there a better way to describe this fossil ground water?

Line 550-555: Here you mention spin up time in the context of water source tracking, but I feel this discussion could come much earlier when describing the model dynamics and features themselves.

Table 4: Please define ‘relict’ here.

Because the model is becoming open source, the presumption is to allow for a wider user community. Do you provide a tutorial to familiarize the user with WBM? The authors provide a four-step description towards the end of the manuscript, plus a reference to an instruction manual, but a tutorial would be a great advance.

Model Validation:

Line 620: I recognize this section is devoted to a summary of WBM literature, but it is difficult to evaluate the skill of the model without the context of comparing against other similar hydrology models. There must be some model hydrology intercomparison studies to show here for global river discharge. Certainly Figure 3 might benefit for a comparison against other models.

Line 624: What sort of parameter calibration is performed here? Hand tuning, or more formal DA approaches? Are these parameters available for the user?

Section 3.2.1: Table 2 is good, but a physical definition for the parameters should be stated in the table and not just in text. Perhaps a summary table of parameter values for the literature review manuscripts performed at different regions/resolutions, in addition to the default values.

Line 690: "Above, we reviewed previously-published WBM validations. As none of the prior versions of WBM code have been released open source, it is important to validate the exact model structure in this first open-source release. "
Was there significant mechanistic changes to these pre-release versions? Was adding the tracking capability the only significant difference from this official release version? From Table 7 it seems like you add some new functionality from previous versions: "Added rainfed agriculture, other land cover types, inter-basin transfers, domestic and livestock water demand", but you don't mention that here, and it seems to the reader that the only change is making it open source, when there are some structural changes.

Table 6: Appreciated how the WBM irrigation withdrawal estimate was put in the context of other studies. Would it be possible to construct something similar for global discharge? Especially since the author attributes the high irrigation withdrawal estimate (China) to relatively high discharge rates in the Asia domain, it seems like it would be worthwhile to hone in on discharge biases, and diagnose where and what location these are occurring.

Line 800: "Global discharge is dominated by rain over most of the globe, with snowmelt an important contributor at the poles, and both glacier runoff and unsustainable groundwater important regionally."
"Snowmelt is an important contributor at the poles": That seems like an oversimplification. Seems that Figure 8 shows there is significant snowmelt contributions well down into the northern mid-latitudes especially for mountainous terrain such as the Rocky Mountains and the Himalayas where a larger population rely on snow runoff for irrigation etc. This should be mentioned.

Figure 8: Glacier run-off seems to be unrealistic in the SouthWest and MidWest US where none should be occurring. Glaciers are apparently determined solely by snow input and melting algorithm and not prescribed like land cover types?

Figure 11: Perhaps outline the watershed domain of the Indus river in this figure within the larger figure 10 for better reference and perspective.

Figure 11b: There are no units in this figure. Why is there such a large discontinuity between months 12 and month 1? Why does glacier runoff have such a strong contribution upstream at point A, yet such a small contribution downstream at point B?

4.2 Return flow tracking

Line 867: I feel like this "relict" and "pristine" distinction should be made earlier, because it is used in an earlier table.

Return water diagnostics and source water diagnostics and tracking seem to be some of the most useful components of the system. Would it be easy to port these 'diagnostics' modules to other hydrology models or is it baked into the system?

Figure 12 and 13: Care to comment on why the irrigation return flow waters are so high in the Northern India region? It might help the reader contextualize this diagnostic, and make for interesting discussion of what makes that region so unique.

Figure 14: These plots are interesting and potentially very valuable. Couple questions, in Figure 14b could the color scale be changed to emphasize the 0 to 0.2 discharge fraction? A large part of the watershed domain seems to be the same color of green that is hard to distinguish at all.

Could you not color Wyoming such that the river network can be seen easily? It doesn't seem to be a need to color Wyoming dark blue since it is the headwater region. Also in Figure 14a is this distribution pattern mostly driven by snowmelt? It doesn't look like the distribution is picking up the summer monsoon season where a larger fraction of the water should derive from Arizona and New Mexico. I suppose this depends if the climate forcing captures the SouthWest monsoon.

Model Code development section: Although I do find this section interesting it may be better suited for the appendix, such that the reader can immediately go from the results to the discussion. You have provided steps, and there is access to an instruction manual, but do you also provide a simple user tutorial for a cut down domain and provide the input files so the user can familiarize themselves with the steps?

Discussion:

The tracking capabilities of this model which can attribute discharge source regions, or impact from agriculture on discharge are a great feature and worthy of discussion. The authors refer to the modular nature of the model in order to toggle on/off different features, but they don't provide a test case of this, where for a single experiment, different model structures/assumptions/parameters are switched up to identify the model sensitivity. Just a suggestion.

I was certainly expecting at least more discussion concerning model performance related to river discharge and irrigation water withdrawal as covered in the first part of the manuscript. It was a bit concerning that the WBM was a bit of an outlier when estimating global irrigation water withdrawal, and this was partially attributed by the authors to low discharge rates across China and Asia. Very little to no discussion or explanation was provided for this. The discharge rates seemed to perform relatively well in other regions includes North America, but it was difficult to contextualize given no comparison in performance was provided from other hydrology models.