GENERAL COMMENTS

This manuscript presents an updated version of the H08 GHM that focuses on refining how human water abstractions are modeled at the global scale. Six water sources used for abstraction are focused on here: river flows regulated by large and smaller reservoirs, aqueduct transfers, desalination, renewable and nonrenewable groundwater. Model improvements are largely based on methodologies developed in other studies and results of simulated water fluxes for abstraction are validated against those reported in other peer-reviewed publications. The updated H08 GHM is then used to 1) estimate flows and stocks of natural hydrologic sources and 2) simulate the impact of human water use on natural hydrology both globally and within a subset of major watersheds. This updated model differs from existing GHMs in that no other GHM simultaneously incorporates groundwater recharge, groundwater abstraction, aqueduct transfers, local reservoirs, desalination and return flow/delivery loss into estimates of global water balances. The work presented here represents an important step forward for GHMs.

> Thank you for summarizing the key significance of our work. We appreciate your taking the time to review this paper.

SPECIFIC COMMENTS

[R2-M1] I am happy to see water infrastructure being more explicitly integrated into GHMs beyond reservoir operations. Aqueducts (Section 2.1.3) and desalination (2.1.5) are important components of human water use that need to be considered as they can have profound impacts on water availability at the regional scale. While I recognize that accounting for these types of infrastructure at the global scale is challenging, it seems that assuming “implicit aqueducts” (e.g.,p. 6,lines23-24) exist to meet water demands may lead to significant overestimation of this form of abstraction, especially given the order of water extraction (e.g., river, global reservoir, aqueduct, local reservoir…).

> We have added the following explanation of implicit aqueducts to Section 2.1.3: “As most global hydrological models are grid based, water source is restricted within a grid cell unless aqueducts are present. This condition may result in the production of an artificial gap in water availability in a single basin (i.e., rich in cells with main river channels and poor in neighboring cells without). Implicit aqueducts express the diversion of water in major rivers to surrounding grid cells, reflecting our general

observation that river water is well transferred within a basin, particularly in major river basins in temperate zones. Hence, water availability seldom differs drastically with distance from main river channels."

[R2-M2] Without any rationale for why this order was selected, I would argue that aqueduct transfers would be far less common than abstractions from local reservoirs. Additional justification on why this particular order was used, or why implicit aqueducts would be very common, would provide needed clarity on this.

We hope that our previous response also answers this question. Regarding the order, the present algorithm takes water first from the river within a grid cell, then from the major river in the neighboring grid cell, and finally from local reservoirs. For example, downtown Tokyo takes water from two distant rivers (i.e., the second source shown above). Indeed, water abstraction for major cities is sourced from the main stems of distant major rivers that have stable flow throughout the year. We believe that the assumption that some grid cells chronically depend on the river discharge of nearby grid cells is reasonable.

[R2-M3] What is the benefit of pursuing Option 1 (assuming an imaginary unlimited surface water source) vs. Option 2 (water deficits)? Section 3.4.1 seems to argue that temporal variability does appear in the model and simulates periods where water scarcity exists during which water may be unavailable. From this perspective, it would seem that aligning the model to always have access to an unspecified surface water would diminish this profoundly important problem of scarcity, where deficits are real and serious problems for many, including those irrigating with surface water who may face serious curtailments or crop failures.

Option 1 was needed to keep our simulation aligned with the fundamental precondition of this study, which is that the values reported to the AQUASTAT database are actually withdrawn regularly by every country. The validity of the precondition is not necessarily obvious considering the uncertainties in individual data. Unspecified surface water (USW) was estimated at as much as 700 km^3 yr^{-1} globally which is too large to solely attribute it to the lack in performance of H08.
Option 2 excluded the usage of USW and the volume was turned into water deficit or water scarcity. WeWater deficit is regularly observed in many places of the world, for instance as shown in Fig. 13 in Asian countries in the dry season. Also the global

distribution of USW (Fig. 12) largely overlaps with the reported water stressed regions in some of earlier studies (e.g. Fig 2c of Oki and Kanae, 2006). We speculate that the reality would be in between Options 1 and 2, but making a more specific statement on this subject is difficult due to a lack of data. We revised the related parts in Methods and Results Sections to make our intention clear.

[R2-M4] Many municipal water systems have significant delivery losses (30-60%), particularly in low-income countries due to a lack of funds for infrastructure repair and deliberate vandalization. Even in the USA, many municipal systems report unaccounted for water losses of higher than 10%. While I also do not know of any global inventory of water lost during delivery, there are rough estimates available (e.g., http://siteresources.worldbank.org/INTWSS/Resources/WSS8fin4.pdf) that might warrant a re-examination of the assumption that 0.1 and 0.15 (page 10, lines 6-7) are reasonable estimates for this parameter.

Thank you for this information. Please note that the water use efficiency that we incorporated in this study (the ratio of water consumption to withdrawal) differs from the water transfer efficiency that you mention (the ratio of water delivered to water users to water dispatched from water suppliers). We agree that these delivery losses could be an important part of the water balance in many regions, however it is not possible to directly include these losses in the current model parameterizations. We were not able to directly include your input in the current version of our model, but we will include it in the next version of our model.

TECHNICAL CORRECTIONS

There is a typo on the first line of Section 2.1.7- "fulfil" should be "fulfill"

Thank you; we have made this correction.

Figs 5, 6 and 12 are pretty cramped. Finding a way to make these easier to view would be very helpful. (Maybe this won't be an issue if readers can access a high quality version online at publication).

Thank you. We will try to ensure that quality is maintained during the publication process.

Fig 11 would be even better if there was a nearby or integrated table that reminded readers what each of the three letter codes were. Or, alternately matched pie charts with map areas by a letter (and letters could be tied to region codes in table S2). Right now it's hard to see what matches what section of the map.

Thank you for this suggestion. We have added three-letter regional codes to the map.