Comments on "Inclusion of flood diversion canal operation in the H08 hydrological model with a case study from the Chao Phraya River Basin – Part 1: Model development and validation"

Reply to RC1

This paper describes the successful implementation of flood diversion canal operation in H08 for the Chao Phraya River Basin, which accounts for over half of annual average river discharge diversion of the CPRB. This novel implementation is clever, well described, and I find the paper quite enjoyable to read. I only note a few places where this paper may benefit from improved clarity before publication. Below are a few minor comments/questions for the authors.

Thank you very much for your valuable comments regarding the scientific contribution of our work. We highly appreciate your review comments that provided valuable insights for further modifications of our current version.

The detailed point-by-point replies to all the minor comments are given below. Once again thank you for enlightening us with your valuable comments and suggestions.

Minor comments

1. Water diversion during dry season appears to be quite sensitive to the pristine flow simulation used to estimate river and canal carrying capacities. Is it conducted by only including the digitized canal network but excluding direct human influence such as dams, reservoirs and human water use? Are the results then compared with naturalized or raw observed data when computing for NSE (Suppl. S4 L75)?

Thank you very much for your comment. We agree with your point that the water diversion during the dry and wet seasons appears to be quite sensitive to the pristine flow simulation used to estimate river and canal carrying capacities under the generalized scheme. The pristine flow simulation (naturalized simulation in the manuscript; NAT) was conducted by enabling only the land surface hydrology and river routing modules of the H08 model, which does not account for the direct human influences such as dams, reservoirs, and human water use. Further, this "NAT" simulation was compared with the 'naturalized observed discharge' at Nakhon Sawan (C.2 station). The 'naturalized observed discharge' at Nakhon Sawan was reconstructed by following Mateo et al. (2014). This was performed by adding the water stored in the two major dam reservoirs (Bhumibol and Sirikit) with the ‘observed discharge’ at Nakhon Sawan. The ‘naturalized observed discharge’ was adequately reproduced at Nakhon Sawan, with daily and monthly Nash-Sutcliffe efficiency (NSE) values of 75.18% and 86.07%, respectively. Estimating the ‘naturalized observed discharge’ downstream of Nakhon Sawan station must be extremely difficult because of the presence of many unmonitored canals. The transformation of ‘observed discharge’ into the ‘naturalized observed discharge’ and the associated uncertainties are described in detail by Champathong et al. (2020). These explanations were added to section S4.1 of the supplementary material to avoid confusion. Line 76

Mateo, C. M., Hanasaki, N., Komori, D., Tanaka, K., Kiguchi, M., Champathong, A., Sukhapunnaphan, T., Yamazaki, D. and Oki, T.: Assessing the impacts of reservoir operation to floodplain inundation by combining hydrological, reservoir management, and hydrodynamic models, Water Resour. Res., 50(9), 7245–7266, https://doi.org/10.1002/2013WR014845, 2014.

Champathong, A., Hanasaki, H., Kiguchi, M. and Oki, T.: Reconstructing the pristine flow of highly developed rivers – a case study on the Chao Phraya River, Hydrol. Res. Lett., 14(2), 89-96. https://doi.org/10.3178/hrl.14.89, 2020.

> I am wondering why the river canal capacity decreases along the natural river channel between some locations (i.e., C.13 to C.3), even when there are no canals between them (Figure 4). Also, it seems that the capacity values shown in Figure 4 are a mix of simulated Q5 (main river) and observed (canal, Table S1). Is this correct? It would be quite informative if the simulated river/canal carrying capacities are also listed in Table S1.

We would like to clarify that the river and canal carrying capacities shown in Fig. 4 are the observed values in the CPRB. These carrying capacities of the river channel and canals at various locations are solely determined by their cross-sections. Near the Chao Phraya dam (C.13 station), the river channel can hold a maximum discharge of 2840 m^3/s, whereas at Sing Buri (C.3 station) the channel gets narrower and can hold a maximum discharge of 2340 m^3/s. Since these are observed values, the presence or absence of canals does not play any role in the river carrying capacities at these locations. Sincere apologies for the confusion made by us. To avoid further confusion, we have modified the caption of Fig. 4 as well as section 3.2.1 of the manuscript that the values shown in Fig. 4 are observed values. Line 283; Line 306; Line 809

In addition, the simulated river and canal carrying capacities under the regionalized and generalized schemes are also included in Table S1 to provide more clarity. Line 371 (manuscript); Line 9 (supplementary material)

2. While the generalized canal scheme has potential for global applications, a major obstacle is the estimation of retention areas. In this study paddy fields were used as retention area with fixed depth, and this would not be applicable globally. I am curious how the authors would apply this scheme globally, especially when the bathymetry of lakes/ponds are not known and cannot use the 1 m depth assumption.

Thank you very much for your comment. The most important land use for potential retention areas is the low-lying areas along rivers (floodplains) and canals. Historically, such lowland is used for paddy cultivation in warm Asian countries. Being paddy is not the required condition for retention areas. In addition, although the lakes/ponds could be partially filled with water during the wet season, they can also be used as retention areas based on available free space. Under such circumstances, the bathymetry of lakes/ponds may be useful but not essential for estimating potential areas for the retention pond. Indeed, some of them are permanently inundated (i.e., maintained by groundwater flow, etc.) and hence cannot be used as effective retention storage.

For modelling, the geographic locations of possible retention areas (e.g., low-lying areas, lakes, ponds, wetlands, etc.) along with their depth and areal extents available for storage of floodwater specific to each area should be estimated. This information can be extracted from remotely sensed data such as general DEMs (e.g., MERIT DEM), satellite imageries (MODIS/LANDSAT), radar altimetry, as well as from literature although it is strenuous. There are several databases (G-REALM, HYDROWEB, RLH, DAHITI, etc.) from which we can extract the information regarding lakes/ponds. The global application of this scheme that includes the estimation of retention areas is one of the limitations this study currently poses, and we will pursue further research into this area. This explanation was added to the discussion (section 5 of the manuscript) to have more clarity. Line 578

3. Although the authors already did a fantastic job describing the model, I would still like to ask a few questions to make sure I understand the details correctly: In P11L346, “10% of diverted water is supplied to each of the nearby grid cells that was further utilized for irrigation”. Do you mean for each of the 5’ grid that the canal passes, 10% of total diverted

> water is supplied to that grid? So as the diverted water flows along canal to each grid, it first loses 10% of water for water supply, then fully fill that grid's retention capacity before moving to next grid, where this process is repeated until either the water is fully contained in the retention area, or flows out of the basin. Is this correct (I am especially uncertain about the retention filling: P14L441 says "this runoff constitutes a portion of retention pond storage")? If water is only supplied to grids the canal flows to, then the schematic diagram of Figure 2 should perhaps be slightly modified and remove the second arrow of B on the lower left. Also, how is the water balance closed if irrigation demand is less than water supplied to the local grid? And would this "supply to nearby grid" percentage change if the simulation is performed on finer/coarser resolution?

Thank you very much for your comment. The operation of the canal system introduced in this study depends upon the dry and wet seasons. During the dry season, a minimum amount of water is diverted into the canals. Once diverted into the canals, 10% of the diverted water is supplied to each of the 5′×5′ grid cells through which the canal passes as well as to the immediate lateral neighbouring grid cells of the canal. This water is used to meet the irrigation demand. If the demand is less than the water supplied to the local grid, then the surplus water after meeting the demand is further added to the discharge of the corresponding grid cell. This river discharge finally returns to the river channel as shown in Fig. S1a and b and thereby closes the water balance. The remaining diverted water after supply will move to the subsequent downstream grid cells. This process is repeated until the diverted flow is fully depleted or reaches its destination. This supply component is enabled only during the dry season to augment water supply needs. In this study, for simplicity, 10% of diverted water is supplied to each of the nearby grid cells because our primary concern was flood control. Therefore, of course, we should change this fraction of 'supply to near grids' if we are performing the simulation on a finer/coarser resolution. One alternative way to overcome this issue is that we can finalize the 'supply to near grids' based on the water demand in each of the grid cells through which the canal passes as well the in the neighbouring grid cells. In such instances, it can be confirmed that the supplied water will be completely utilized. These explanations were added to the manuscript to avoid confusion regarding the 'supply to near grids' component (section 2.2 and section 5). In addition, Fig. 2 has been slightly modified to clearly portray the water supply to the grid cell through which the canal passes as well as to the immediate lateral neighbouring grid cells. Line 156; Line 190; Line 570; Line 802

During the wet season, either canal carrying capacity, or a minimum amount of flow is diverted to the canals. Once diverted, a portion of the diverted flow drains into the retention areas and then fills to the grid's retention pond capacity before moving to the next grid. This process is repeated along its flow route until flow either diminishes to zero or reaches its destination (either within the basin or out of the basin). The storage of diverted water in retention areas is allowed only during the wet season to supplement flood control. In addition to the diverted water storage during the wet season, the retention areas are modelled in such a way that they receive runoff generated from precipitation in each grid based on their areal fraction during both dry and wet seasons. This runoff constitutes a part of retention pond storage and only the remaining storage capacity is available for the storage of diverted floodwater during the wet season. These explanations were added to the manuscript (section 2.2) to avoid confusion regarding the 'retention storage' component. Line 201

4. What are the similarities between the explicit aqueduct water transfer module and this canal operation module?

Thank you very much for your comment. The earlier aqueduct module of the H08 model was to provide water supply to the grid cells that are farther from the river channel to meet their water demand (agricultural, industrial, and domestic) through structures of canals, pipes, and others. If there is a water demand to meet, the scheme assumes that the water could be transferred until the river flow at the aqueduct origin falls below the environmental flow because the information regarding the aqueduct carrying capacity was not available for most cases (Hanasaki et al., 2018). This aqueduct water transfer scheme transfers water only when the water demand is positive. It does nothing for excess water availability (i.e., floodwater). To overcome this limitation, we introduced the new canal operation scheme. This scheme operates to provide a minimum water supply during the dry season irrespective of the water demand and divert floodwater (subject to a maximum of the canal carrying capacity) during the wet season to reduce flood risk. In both cases, environmental flow is maintained in the river channel. To have a clear differentiation between the aqueduct water transfer scheme and the newly introduced canal operation scheme, more explanations were added regarding the operation of the aqueduct water transfer scheme of the H08 model in the manuscript (section 2.2). Line 121

Hanasaki, N., Yoshikawa, S., Pokhrel, Y. and Kanae, S.: A global hydrological simulation to specify the sources of water used by humans, Hydrol. Earth Syst. Sci., 22(1), 789–817, https://doi.org/10.5194/hess-22-789-2018, 2018.

How do you determine if it is canal or aqueduct based on Google Earth images?

For global applications, recently, Shumilova et al. (2018) prepared a global inventory of 110 water transfer megaprojects (exiting, planned, and proposed) from which the canal origin, destination, route, purpose, type of canal, and carrying capacity can be retrieved. During global applications, such kinds of global inventories can be utilized to get the canal information. Since the H08 model does not consider the hydraulic characteristics of the water conveying structure, it can be assumed as an open channel, pipe, or any other structure if the data on aqueduct type is not available. In a similar fashion, we introduced a generalized scheme that operates with Q_{50} as the canal carrying capacity (with the assumption that the median flow should be diverted under flood conditions) under the limited data availability scenario.

Shumilova, O., Tockner, K., Thieme, M., Koska, A. and Zarfl, C.: Global Water Transfer Megaprojects: A Potential Solution for the Water-Food-Energy Nexus?, Front. Environ. Sci., 6(DEC), 150, https://doi.org/10.3389/fenvs.2018.00150, 2018.

5. Figure S4: Are you using multi-year averaged crop calendar?

Thank you very much for your comment. The authors would like to make clear that the crop calendar is not multi-year averaged. Instead of estimating crop calendar for every single year and generating a multi-year averaged crop calendar, we multi-averaged the variables (air temperature, shortwave downward radiation, evapotranspiration, and potential evapotranspiration) that were used to compute the crop calendar from 1980 to 2004. Then by utilizing these multi-year averaged variables, we estimated a single crop calendar for each of the crops in CPRB. Later, we compared this simulated crop calendar with the observed crop calendar of major crops in Thailand (Fig. S4) and the planting and harvesting dates were fairly captured. In order to avoid confusion, we added this explanation to the Supplementary material (S4.3.1). Line 120