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Hydrology and Earth System Sciences Discussions

Interactive comment on "Coupled daily streamflow and water temperature modelling in large river basins" *by* M. T. H. van Vliet et al.

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Reviewer 1 (B. Fekete)

We would like to thank Dr. Balázs Fekete for his positive response to our manuscript and his valuable comments. Please find below our responses to his comments.

Reply to Comments:

1) "Perhaps the only concerns I have about the presented water temperature model is how much the reasonable performance is due to the strong seasonality of the temperature. While this question applies to river discharge as well, but discharge hydrographs still have higher frequency signals that could be in par with the seasonal variation. I

wonder, if evaluating the model performance in some sort of deviation terms might be more informative. For instance, one could compute a time series of the temperature difference between the air and the water and test the model performance in reproducing this difference. A mapping of this difference, would be useful information on its own, since it would show, where are the regions where the proposed water temperature modelling is vital."

Reply authors:

We agree that the correlation coefficient is sensitive to the seasonal variation in water temperature. For rivers with a weaker seasonal signal in water temperature we found a lower signal-to-noise ratio and thus a lower correlation coefficient (see P8352, L9-11). However, the other performance coefficients that were selected (BIAS and root mean squared error (RMSE)) quantify model performance in deviation terms. This means that differences are calculated between daily simulated water temperature and daily observed water temperature and these performance coefficients therefore do not reflect effects of the seasonal cycle.

Regarding the reviewer comment on comparison of water and air temperature, we would like to refer to our previous global water temperature study with a nonlinear regression model based on air temperature and river discharge (van Vliet et al., 2011). In this study we show that variability in water temperature is indeed largely explained by air temperature. However, for 87% of the global river stations, the performance of water temperature predictions significantly improved by including discharge as independent variable in addition water temperature, and largest improvements in model performance were found during warm, dry spells. The study described in that paper provided the rational for use of a coupled hydrological-water temperature modelling framework presented in this discussion paper.

2) "NBIAS was not defined in the text and it is not clear what is the difference between BIAS and NBIAS."

Reply authors:

NBIAS is the normalized bias, which was calculated by dividing the bias by the mean observed river discharge (as described on P8347, L17-20).

We slightly changed the sentence to include NBIAS and NRMSE more explicitly: "For river discharge, normalized values of RMSE and BIAS were calculated (NRMSE and NBIAS henceforth) by dividing by the mean observed river discharge values."

3) "Figure 8 show the impact bias of the uncertainties in headwater temperature. While the figure makes sense, but the impact bias as axis label is confusing, since the impact bias here is expressed as percentage, while the BIAS discussed elsewhere was discussed in absolute terms."

Reply authors:

This figure shows the impacts of spatial resolution on propagation of uncertainties in headwater temperature estimates on simulated water temperature along the river course for the Rhine and Meuse. We introduced an overestimation in headwater temperature of +2°C to explore the propagation of this bias. We therefore expressed the impact of bias as percentage of +2°C rather than absolute values, because the absolute bias depends on the selected value of overestimation in the headwater grid cells (+2°C in this case). However, for clarification, we now include a secondary y-axis and show both the relative (percentage) impact of bias and absolute impacts of +2°C bias in headwater temperature. The revised Figure 8 is also shown below.

Reviewer 2

We want to thank the reviewer for his/her positive response to our manuscript and valuable comments. Please find below our responses to the comments.

Reply to Comments:

1) "However, to my opinion there is one problem with this approach: the fact that the

temperature model uses a Direchlet upstream boundary condition, i.e. the so-called headwater stream temperature, which then has to be calibrated, albeit indirectly, as a parameter. This makes the model less suitable for scenario's where upstream water temperature is influenced by changes in groundwater contribution to streamflow as a result of changes in land use, water consumption and climate. This is a pity. And I do not really understand why this approach was chosen. After all, VIC has a full surface energy balance model and hydrology that could be used to provide upstream boundary conditions (both flux and water temperature). Why was this approach not used? Is it because VIC is not accounting well for groundwater discharge? This should be discussed at length in the Discussion part of the paper."

Reply authors:

We agree with the reviewer that alternative methods of estimating headwaters temperatures based on first principles are worth investigating. We also think, as the reviewer suggests, that results from VIC simulations could provide such a solution. In the background work for this study, Yearsley (2012) performed preliminary analyses using headwater temperatures estimated with daily soil temperatures from VIC, which he compared with results based on headwater temperatures with the nonlinear water temperature regression model (Mohseni et al., 1998) for the Salmon River (subbasin of the Columbia). The performance of the RBM model did not improve by using this soil temperature approach of estimating headwater temperature and were not included in the published version. A validation of the performance of the soil temperature simulations from VIC has not yet previously been performed, while an evaluation of the performance of these simulations are relevant for use of soil temperature as input into the RBM model. However, this requires observed data of soil temperature at different depths, which are rather difficult to collect on macro-hydrological scale and should be tested on a smaller scale. Given the experimental nature of the VIC application and the widespread and successful use of the regression model of Mohseni et al. (1998), we believe that the latter approach is appropriate for this study. Finally, while it is true that the errors in estimating the headwaters temperatures are important in the upstream reaches of streams and rivers, these errors decay downstream as atmospheric heat exchange and advected sources dominate (Yearsley, 2012).

We added an explanation of the choice of headwater temperature estimation to section "2.2.3 Estimation of the boundary conditions (headwater temperatures)". We found this section more appropriate to discuss why this approach for headwater temperature estimation was used than the "4 Discussion and conclusions" section at the end of the paper, which was suggested by the reviewer. We included in section 2.3.3(P8344):

"As part of the study described in Yearsley (2012), two methods for headwater temperature estimation were compared for the Salmon River (subbasin of the Columbia). One method uses daily soil temperature from VIC and another method uses a nonlinear water temperature regression model (Mohseni et al., 1998) based on air temperature. Overall, the performance of the RBM model did not improve by using soil temperature to estimate headwater temperature. Given the widespread use of the regression model of Mohseni et al. (1998), we decided to use the latter approach for this study to estimate headwater temperature."

2) "Equations (1a)-(1c): Usually such relationships are used to calculate channel dimensions, not active channel depth. Then, Q is so-called bankfull or channel-forming discharge (estimated as the discharge with a return period of 2-3 years). From this channel depth D and with W can be calculated. Next, from velocity U based on e.g. Manning, method of characteristics or and assumed constant velocity, water depth H = Q/(WU) can be calculated. So, I think that this is a bit awkward way of deriving water depth."

Reply authors:

The relationships in equations 1a-c are based on the work of Leopold and Maddock (1953). These relationships have been used widely to estimate the hydraulic characteristics of streams and rivers, commonly using field measurements. In this study,

given the scale of the problem and the corresponding difficulty in obtaining field measurements, we have used coefficients for the relationships in equations 1a-c based on an analysis by Allen et al. (1994) of a large number of data sets (P8341, L22-24). While the coefficients were estimated for either bank-full discharge, two-year or 2.33 year frequency flows, we have assumed, following Leopold and Maddock (1953), that the relationships hold at all flows. Assuming that the cross-sectional area can be estimated as the product of the width times the depth leads to equation 1c and 2. We agree that the use of Manning's equation would lead to a more elegant approach. However, the use of relations with more coefficients could also introduce uncertainties, because only rather crude parameter estimates for slope and friction factors can be derived on a global scale. A significant data collection is needed to obtain realistic parameter estimates for all stream and river segment which was beyond the scope of this study.

We modified the sentence P8341, L24-26 to better explain the assumption that was made: ".. the assumption was made that these fitted relations can be applied to estimate the hydraulic characteristic of rivers in other regions as well and under different flow conditions."

3) "Title 3.1: not only daily river discharge is simulated and evaluated, but also yearly. So the title is somewhat confusing. Title 3.2: the same goes for temperature."

Reply authors:

In these sections daily simulated streamflow and water temperature series and mean annual cycles in daily streamflow and water temperature are discussed. In addition, we discuss results of the performance coefficients which were calculated using daily simulated and observed series. To emphasize that we tested the performance of the hydrological-water temperature modelling framework on a daily time step we prefer to preserve these titles "3.1 Performance of daily river discharge simulations" and "3.2 Performance of daily water temperature simulations".

4) "Page 8350, line 10: does NBIAS=-0.5 not mean an under-estimation of 50%? This

does not seem accurate."

Reply authors:

Apologies, the value of "-0.5" is incorrect (refers to another basin). The mean value in NBIAS for the Ob River should be "-0.1" (see Table 3). Thank you very much for catching this error.

We have corrected this in P8350, L10: "...NBIAS = -0.1, r = 0.76 for Ob)."

5) "Page 8351, line 23: can it be that the lack of an ice-model is the cause for the too steep a drop of autumn temperature, as ice-formation limits the temperature drop of the water below."

Reply authors:

The overestimation in steepness of the falling limb starts when air and water temperatures are still above 10°C. It is therefore not likely that overestimation in steepness is directly due to a lack of an ice-model. In addition, only a limited number of artic river stations showed this overestimation in steepness of falling limb during autumn. We consider the underestimation in thermal capacity (discharge during summer and autumn) as a more likely reason of this overestimation in steepness of the falling limb for the Lena (see P8351, L24-26).

6) "Line 14 on page 8355: the authors should add here that van these numbers of Beek et al. (2012) pertain to the entire globe, not to a selection of basins. Also, no calibration was used, whereas the regression to estimate the parameters of equation (5) is a form of indirect calibration."

Reply authors:

We changed the sentence to: "van Beek et al. (2012) simulated water temperature on a global scale (without calibration) with mean absolute errors in daily simulations ranging from 1.6°C to 7.6°C, which are comparable or slightly higher than obtained in

our study."

Reference

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Mohseni, O., Stefan, H.G., Erickson, T.R., 1998. A nonlinear regression model for weekly stream temperatures. Water Resources Research, 34(10): 2685-2692.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 8335, 2012.

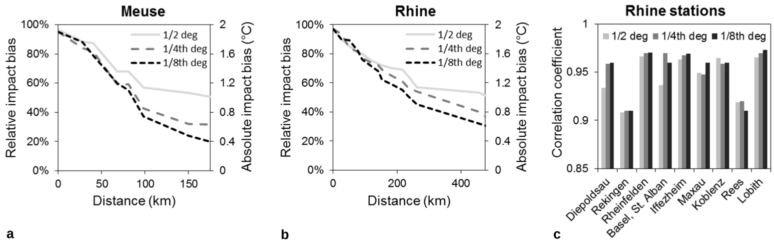

Fig. 1. Figure 8 (revised)