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Reply on RC2

Efrain Noa-Yarasca et al.

Author comment on "An improved model of shade-affected stream temperature in Soil & Water Assessment Tool" by Efrain Noa-Yarasca et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2022-116-AC4, 2022

Response to comments and suggestions from the third reviewer: RC2: 'Comment on hess-2022-116', Anonymous Referee #2, 16 Sep 2022

Q23

The introduction is well done, but I think more citations are needed to back up sentences and arguments…

Citations were added to the introduction, including on the lines mentioned (Lines 47 – 60).

Q24

I am not sure what the authors mean by "restriction of the watershed hydrological process" on lines 58-59.

The mentioned sentence (Line 68 in the revised manuscript) was modified by:

"Although statistical models may yield reliable outcomes with few parameters and simple equations (Benyahya et al., 2007; Mohseni & Stefan, 1999), they often do not take into account the right physical structures that characterize the hydrological process and do not take into account the proper interaction of the hydrological process variables (Boyd & Kasper, 2003; Kim & Chapra, 1997)"

Q25

It may be beneficial for the reader to understand the importance of stream temperature for the DMW. What are the major aquatic species in the DMW that might be influenced by higher stream temperatures? Have there been any fish kills, etc. in the past? I realize that this is a more of a model development paper but including this information will also help understand the application.

The following sentences were included/added to the article:

In line 37: "For example, in the summer of 2015, the Oregon Department of Fish and Wildlife estimated an approximately 55% reduction in the sockeye salmon population along the lower Columbia River stretch due to stream temperature rising to 24.5 °C

(Nguyen, 2021; Sherwood, 2015). Over the past 70 years, the abundance of species such as Coho salmon has shown a drastic decline in California, with similar but less drastic trends in Oregon, due to various factors including elevated stream temperatures (NMFS, 2012, 2014)."

In line 42: "In the local area, Winter Steelhead, Coho Salmon, and resident Cutthroat Trout are among the primary inhabitants of the Dairy McKay watershed streams, whose population is declining due to a variety of water quality factors, including water temperature (CWL, 2019; Hennings, 2014; ODA, 2018). In this regard, the Oregon Plan identified salmon health as a crucial indicator of the ecosystem (Hawksworth, 1999; ODEQ, 2001, 2008, 2010). Additionally, in this area, declines in ecosystem structure and function have also been linked to declines in salmon numbers(Hennings, 2014; ODA, 2018)."

Q26

I am not sure what "…overlying as far as possible on 12-digit HUC boundaries…"

HUC stands for Hydrologic Unit Code, which is the US hierarchical watershed classification system. This sentence was clarified in the article by (line 174):

"…overlying as far as possible on 12-digit HUC (Hydrologic Unit Code) boundaries from DMW, which is the US hierarchical watershed classification system."

Q27

Did the authors examine the influence of tile drainage on stream temperature?

Tile drainage has not been part of the of the study. However, the approach presented in this study can also be used to assess the effects of tile drainage on stream temperature. Tile drainage directly influences lateral flow and groundwater which are variables within the Ficklin et al. temperature model that was also improved in this work.

Q28

Include the Forest Grove weather station on Figure 1.

It was added to Figure 1 as suggested.

Q29

The calibration and validation procedure for streamflow and stream temperature described the Results and Discussion should be part of the Methods section, as these are not results. Additionally, the streamflow was calibrated using SWAT-CUP, but how was the stream temperature calibrated? Manually?

Settings for model calibration were moved to the methodology section as "Model Calibration Setup" (section 2.5) (Line 295). However, the calibration results, which also include the evaluation of the shade factor, were kept in the results section (Line 331 and 337).

Regarding the stream temperature calibration, in line 304, the following sentences were included/added in the section 2.5 "Model Calibration Setup"

"The calibration was accomplished by an iterative procedure that was systematized in Python code following the steps shown in table S4 and S5 in section S6 in the

Supplement. The Python code to iteratively run SWAT, the input data, required SWAT files, and the modified SWAT model (in Fortran) may be found in the Zenodo repository repository at https://doi.org/10.5281/zenodo.6301709 (Noa-Yarasca, 2022)."

Q30

Remove the word "In" at the beginning of the sentence on line 178.

It was removed as recommended (Line 213 in the revised manuscript).

Q31

…how did the authors implement a 30m buffer around the stream when individual HRU types might be distributed throughout the subbasin? If this is indeed the case, did the different riparian scenarios influence the hydrologic results?

Riparian vegetation shade and shade factor were calculated independently of the HRUs in a separate GIS environment from the SWAT model. The pre-computed shade factor values were set up as a table that was read by the SWAT model code that was modified for this study. Two new modules were implemented in the SWAT model code to calculate the water temperature following the approach proposed in this work.

The supplement S2 "Shade Factor Calculation", accompanying the article, shows details and equations to compute the shade factor.

All the modified codes, input data, and the code of the modified SWAT model are available in the Zenodo repository at https://doi.org/10.5281/zenodo.6301709 (Noa-Yarasca, 2022).

Q32

PBIAS should be defined

In line 311, the section 2.6 "Model Calibration Evaluation" that includes PBIAS definition was added to the article.

Q33

Section 3.2.1. Why would the shade factor in winter be greater than in the summer? More explanation on this would be beneficial.

Because of declination angle changes, the solar angle is lower in winter than in summer, resulting in greater projection on the stream and, as a result, more shadow on the stream. This may be the reason why winter shade factor is greater than summer shade factor. When considering vegetation that doesn't keep its leaves throughout the four seasons of the year, this could vary.

Note that this work considered conifers as riparian vegetation, which are common in the DMW Oregon. The majority of these conifers are evergreen, which means they retain most of their leaves all year.

More details on the variation of SF during the year and during the day can be found in the supplement S4 "Shade Factor Temporal Variation" accompanying the article.

Q34

This is minor, but the C1 and C2 parameters discussed in the Results are presented as c1 and c2 in the methods.

They were changed as recommended. They are all now C_1 and C_2. (Line 260, 261, 308, 309, 310, and 360)

Q35

I would consider using mean absolute error (MAE) in addition to NSE for stream temperature calibration

MAE was defined in line 325 and MAE values included/added to the Table 1 "Calibration Coefficients for the Linear, Original Ficklin et al., and Modified Ficklin et al. Stream Temperature Model"

Q36

In Figure 3A it seems that the modified model (and probably the Ficklin model too) has issues with simulating the stream temperature during the winter. I was wondering if the authors could comment on this.

Although the calibration of the modified stream temperature model achieved encouraging results throughout the year, during the winter the gap between observed and simulated values is notable compared to other periods. As mentioned in the section "**Model limitations and uncertainties"** (Line 492), the model outcomes may be affected by unknowns related to input data, model structure, and model parameters, which may be amplified in the winter. In relation to riparian vegetation, for example, the density of the leaves, which we assumed to be constant, could be playing a role in the model. A lower density of leaves in winter would allow the passage of more solar radiation than a dense canopy that could increase the stream temperature. The energy balance of water during the winter months may also be significantly influenced by additional factors or variables, including hyporheic flow, heat from winter precipitation, heat from bottom friction in winter flows, and others. It is recommended that future research take these aspects into account.

In this regard, in line 365, the following sentences were included in section 3.2.2 "calibration"

"Although the calibration achieved encouraging evaluation coefficients, the gap between observed and simulated values during the winter at the upstream control point (sub-basin #31) is notable compared to other periods. In this period and zone, the stream temperature may be influenced by additional factors or variables that have not been considered in this study. These factors can be, for example, canopy density changes in winter, hyporheic flow, heat from winter precipitation, bottom friction heat in winter flows, and others. Future research is recommended to take these aspects into account."

References:

Benyahya, L., Caissie, D., St-Hilaire, A., Ouarda, T. B. M. J., & Bobée, B. (2007). A Review of Statistical Water Temperature Models. *Canadian Water Resources Journal*, *32*(3), 179–192. https://doi.org/10.4296/cwrj3203179

Boyd, M., & Kasper, B. (2003). *Analytical Methods for Dynamic Open Channel Heat and Mass Transfer: Methodology for the Heat Source Model Version 7.0*. http://www.deq.state.or.us/wq/TMDLs/tools.htm

CWL. (2019). *TUALATIN RIVER, TOTAL MAXIMUM DAILY LOAD Implementaion Plan City of West Linn , Oregon City of West Linn* (Issue August 2003).

Hawksworth, J. (1999). *Dairy-McKay Watershed Analysis*. https://www.blm.gov/or/districts/salem/plans/files/watershed_analyses/sdo_dairy_mckay_wa/sdo_dairy_mckay_wachap_1.pdf

Hennings, R. B. (2014). *Stream Temperature Management in the Tualatin Watershed : Is it Improving Salmonid Habitat ?* [Portland State University]. https://pdxscholar.library.pdx.edu/geog_masterpapers/8

Kim, K., & Chapra, S. (1997). Temperature model for highly transient shallow streams. *Journal of Hydraulic Engineering*, *123*(1), 30–40. https://ascelibrary.org/doi/abs/10.1061/(ASCE)0733-9429(1997)123:1(30)

Mohseni, O., & Stefan, H. G. (1999). Stream temperature/air temperature relationship: A physical interpretation. *Journal of Hydrology*, *218*(3–4), 128–141. https://doi.org/10.1016/S0022-1694(99)00034-7

Nguyen, D. (2021). *Warming rivers in US West killing fish, imperiling industry*. AP NEWS. https://apnews.com/article/business-environment-and-nature-fish-climate-change-5c85e86a2ba18171ca55d5de8f89dea3

NMFS. (2012). *Recovery plan for the evolutionarily significant unit of Central California Coast Coho salmon. Volume 1*.

NMFS. (2014). *Final recovery plan for the Southern Oregon/Northern California Coast evolutionarily significant unit of Coho salmon (Oncorhynchus kisutch)*.

Noa-Yarasca, E. (2022). *Data on An Improved Model of Shade-affected Stream Temperature in Soil & Water Assessment Tool* (https://doi.org/10.5281/zenodo.6301709). zenodo.org.

ODA. (2018). *Tualatin River Watershed Agricultural Water Quality Management Area Plan*. www.oregon.gov/ODA/programs/NaturalResources/Pages/Default.aspx

ODEQ. (2001). *Tualatin subbasin Total Maximum Daily Load (TMDL)* (Issue August).

ODEQ. (2008). *Temperature Water Quality Standard Implementation – A DEQ Internal Management Directive*.

ODEQ. (2010). *Cost Estimate to Restore Riparian Forest Buffers and Improve Stream Habitat in the Willamette Basin, Oregon*. https://www.co.benton.or.us/sites/default/files/fileattachments/community_development/page/2516/willametteripcost030310.pdf

Sherwood, C. (2015). *Thousands of salmon die in hotter-than-usual Northwest rivers*. Reuters. https://www.reuters.com/article/us-usa-oregon-salmon/thousands-of-salmon-die-in-hotter-than-usual-northwest-rivers-idUSKCN0Q203P20150728

Please also note the supplement to this comment:
https://hess.copernicus.org/preprints/hess-2022-116/hess-2022-116-AC4-supplement.pdf