HESS-2014-195

What causes cooling water temperature gradients in forested stream reaches?

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Dear Professor Cloke,

Please find attached our revised manuscript and a list below of revisions we have made to address the Reviewers' comments.

1. We have included a citation to work that demonstrated instantaneous longitudinal cooling gradients in an un-forested reach with significant hyporheic exchange (i.e. Westhoff et al., 2011). We have also cited Roth et al. (2010) who demonstrated the effects of riparian vegetation scenarios on water temperature metrics using an energy exchange model incorporating flow routing.
2. A description of bed heat flux and how it was measured is provided under the subheading '*Micrometeorological measurements*' in section '*4.4.2 Data Collection*'.
3. The equation for net radiation has been split into short- and longwave components in section '*3.3.2 Net radiation*' and also in section '*3.4.3 Lagrangian water temperature model*'.
4. We removed the description of the equation for latent heat flux as a 'Penman-type' equation in section '*3.3.3 Latent and sensible heat fluxes*'.
5. We recalculated the flow-routing in terms of space (x) and updated the way in which we identified the validation data. Consequently, we updated our methods in section '*3.4.2 Flow routing model*'.
6. We recalculated the stream temperature modelling and updated our methods in section '*3.4.4 Lagrangian water temperature model*' and Figure 6.
7. We have stated explicitly in section '*3.4.4 Lagrangian water temperature model*' that unsmoothed energy flux data were used for numerical modelling.
8. We have clarified our text regarding the Generalised Additive Modelling (GAM) in section '*3.4.1 Statistical models*'.
9. We have stated in section '*3.4.1 Statistical models*' that net energy flux for the GAMs was calculated from the sum of scaled radiative flux (see Section 4.4.3), and turbulent and bed heat fluxes calculated from hydrometeorological observations scaled by linear interpolation between the two nearest AWSs
10. We have updated Objective 1 in section '*1 Introduction*' so that it is clear we quantified instantaneous longitudinal gradients.
11. We updated the text in section '*3.2.2 Hydrology and stream geometry*' to state that good correspondence was observed between measured velocities and discharges and those measured at Littlemill scaled by catchment area.
12. We updated section '*3.2.1 Stream temperature measurements*' to state the accuracy of the micro-loggers and thermistors.
13. We have stated that we measured incoming solar radiation, as opposed to solar radiation, in section '*3.2.3 Micrometeorological measurements*'.

14. We have stated total rainfall during the study period in section '*4.1 Prevailing meteorological conditions*'.
15. We have corrected our spelling of 'reac h' in section '*4.4 Modelled spatio-temporal water temperature dynamics*'.
16. We have included a description in section '*3.3.2 Net radiation*' of how the threshold value was selected for converting hemispherical photographs to binary images.
17. We have conducted a sensitivity analysis on the only user-defined, site-specific parameter in the model i.e. the threshold used for converting hemispherical photographs to binary images. Our methods are described in section '*3.3.4 Sensitivity analysis*'. We have included the results of the sensitivity analysis on Figure 6 alongside the modelled results from using the optimum threshold for image conversion. The results of the sensitivity analysis are presented in section '*4.4 Modelled spatio-temporal water temperature patterns*'.
18. We have provided quantitative evaluations of the water temperature model in section '*4.4. Modelled spatio-temporal water temperature patterns*' and in Tables 1 and 2.
19. We have added a discussion of the limitations of our methods in section '*5.3 Limitations*'. We have placed particular emphasis on the limitations associated with representing turbulent fluxes at high spatial resolution, not measuring spatially distributed potential hyporheic exchange, and not conducting sensitivity analyses on the parameters used when calculating the turbulent fluxes.
20. We have revised the title to read '*What causes cooling water temperature gradients in a forested stream reach*?'
21. We have stated explicitly in the '*Abstract*' and in section '*3.1 Experimental design*' that we took 211 (as opposed to > 200) hemispherical photographs within the reach.
22. We have amended our incorrect spelling of 'Storey' to 'Story'.
23. We have removed the redundant word 'predominantly' from section '*1. Introduction*'.
24. We have amended the incorrect labelling of AWS_{Open} on Figure 1 and added forest cover to the map.
25. We have added panel f to Figure 2, which includes plots of water temperature at AWS_{Open} and AWS_{FDS} and instantaneous differences in water temperature between the two sites. We refer to this panel in section '*4.2 Observed spatio-temporal water temperature patterns*'.
26. We have added Figure 3, which demonstrates the magnitude of instantaneous water temperature gradients within the reach throughout the monitoring period.
27. We have replaced panels 3a and 3c-d (numbered as such in our original submission, now Figure 4) with Figure 4a, which is a 'heat-plot' of water temperatures throughout the study period.
28. We have overlain the example hemispherical images in Figure 4 (original submission, now Figure 5) with the grid overlay applied by Gap Light Analyser.
29. We have replaced panels 5a-c (original submission, now Figure 6) with Figure 6b, a 'heat-plot' of net energy throughout the reach and study period.

30. We have updated Figure 6 (original submission, now Figure 7) after changing the model structure and we have included the results of the sensitivity analysis on the image threshold value.
31. We have removed panel a from Figure 7 (original submission, now Figure 8).
32. We have provided details of the radiation model validation.

We think the revised manuscript deals with all the key issues raised by the Reviewers and consider that the study is a strong contribution in an emerging research field. We hope that you and the Reviewers will be content that we have responded adequately to the comments and that the manuscript may be accepted for publication in *Hydrology and Earth System Sciences*.

Sincerely,
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