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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Detecting groundwater discharge dynamics from point to catchment scale in a lowland stream: combining hydraulic and tracer methods" *by* J. B. Poulsen et al.

Anonymous Referee #1

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The manuscript presents a field and modeling study in an agricultural lowland river catchment in Denmark combining different techniques to quantify groundwater-surface water exchange on different spatial scales. Some of the presented techniques are relatively new while others are standard procedures to quantify groundwater-surface water interaction. The work addresses one of the major problems of present day research within this field, the inability to scale locally measured exchange fluxes on catchments and/or vice versa. The presented combination of methods is very useful and promising; so in my opinion the article addresses main scientific questions of HESS and is therefore suitable for publication. In general I regard the manuscript as very well writ-

ten and presented; with respect to groundwater-surface water interaction it is in its quality clearly above the average of submitted contributions. I have therefore only a few remarks on the presentation and the author's conclusions. I listed them in specific comments below. However, since I have some expertise regarding the use of Vertical streambed Temperature Profiles (VTP) I have a more general remark how the authors applied this technique.

General remark on the analysis of VTP's:

The advantage using VTP is that these profiles are easy to measure and to analyze and that spatially distributed measurements are possible. This comes at a cost, because assuming a thermal steady state for the analysis to determine exchange fluxes never is completely correct and thus neither the results of the analysis. The method only allows a relative rough estimate-the error of the analysis remains unknown. To maximize the validity of the method some conditions should be met. In a not exhaustive list I present some publications which summarize experiences, recommendations and limitations of this steady-state solution the authors apply:

1)Schmidt, C., B. Conant, M. Bayer-Raich, and M. Schirmer (2007), Evaluation and field-scale application of an analytical method to quantify groundwater discharge using mapped streambed temperatures, J. Hydrol., 347(3-4), 292–307, doi:10.1016/j.jhydrol.2007.08.022.

2)Anibas, C., J. H. Fleckenstein, N. Volze, K. Buis, R. Verhoeven, P. Meire, and O. Batelaan (2009), Transient or steady-state? Using vertical temperature profiles to quantify groundwater-surface water exchange, Hydrol. Processes, 23(15), 2165–2177, doi:10.1002/hyp.7289.

3)Anibas, C., K. Buis, R. Verhoeven, P. Meire, and O. Batelaan (2011), A simple thermal mapping method for seasonal spatial patterns of groundwater–surface water interaction, J. Hydrol., 397(1-2), 93–104, doi:10.1016/j.jhydrol.2010.11.036.

Comparing the recommendations in these publications with the application of the methodology in your manuscript I have the following remarks:

Page 13108, Line 3: As far as I saw do you use all the measurements at 0, 0.025, 0.05, 0.075, 0.1, 0.15, 0.2, 0.3, 0.4 and 0.5m below the streambed and the groundwater temperature at 5 m depth to solve the analytical equation. Both Schmidt et al. (2007) and Anibas et al. (2011) recommend that for the steady state analysis only temperature measurements below the zone of diurnal temperature oscillations should be used for the analysis. Usually this is the zone between 0.1 and 0.2 m below the streambed. Otherwise the diurnal influences determine the final result. You use all of them-so it would be interesting to see how much your results would change if only the measurements of 0.15, 0.2, 0.3, 0.4 and 0.5m would be used for analysis! The new flux rates might be lower than the presented ones but would be more reliable and realistic.

P 13115, L 15-28 and P 13115-13116, L 29-5: I could imagine that the spatial trend and distribution of fluxes determined with fewer sensors would fit better with the results of the other methods. Regarding the range of the estimated results; I detected another methodological problem with: You measured the VTP beginning of June, hence in spring, a time when transient seasonal influences on the streambed temperatures are still strong (especially given the location in Northern Europe). Anibas et al. (2009) show that the results of a steady state analysis are sensitive to these seasonal transients. So you have to be aware that your presented results most probably overestimate the real fluxes. The methodology itself does not allow quantifying this effect; however you should discuss or recognize this in your manuscript. To conclude, I think that it is not impossible to do the steady-state analysis with your profiles, but it should be clearly stated that it is difficult to get a reliable quantitative estimate with them. Trends and distribution however should be OK.

P 13115, L 24: You state that no downward fluxes were detected. That is good, while anything else would have surprised me! The presented methodology only allows for the quantification of upward fluxes (see Schmidt et al., 2007 and Anibas et al., 2011). The

model can be easily inverted but a stable surface water temperature combined with a varying groundwater temperature does not exist, so in practice only upward fluxes can be calculated. With some experience one can visually analyze the measured temperature profiles, relative straight gradients or discontinuous temperature distributions in depth can indicate loosing locations; such profiles often lead to a bad model fit. Such results should be treated with caution since the error margin can be very big (several 100% or even a different direction in flow). In any case can the steady state analysis be misleading in river sections which are partly gaining and loosing since it will always only result in gaining estimates. Please state and handle this in your manuscript accordingly.

Other Specific Comments:

P 13107, L11: Here you could refer to Figure 2; there all the events are indicated.

P 13123, L 22: Please add a reference for the EU water framework directive like: European Commission: Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy, Official Journal of the European Community, L327, 1–72, 2000.

P 13124, L 7: Must be 'Verhoeven, R.'

General remarks on the Figures:

Figure 1: I would extend the caption for 'Map of the study area in Jutland, Denmark showing the Skjern River catchment and sampling sites'. In the legend above (c) I see a graphical problem with the words 'layout'. Please indicate in the figure, caption and or the text the direction of flow within the Skjern River catchment.

Figure 2: The difference between 'event sampling' and 'campaign' is not properly explained. Please indicate this in the caption and also in the text of the manuscript. Why did you choose these times for the event sampling and campaign?

Figure 3: What do the different colors mean for the contour lines?

Figure 4: As indicated in Fig.1(c) the river section runs almost in east-west direction, starting with 'layout A' on the right hand side. In Fig. 4 however 'Layout A' starts on the left side of the figure and layouts B and C follow towards the right side. For me it would be more logic if Fig. 4 would follow Fig.1(c). Thus Fig. 4 could be mirrored so that 'Layout A' is right and 'Layout C' is left. The same is valid for Fig. 6.

Figure 5: Also here a have a graphical problem with the words 'Layout'. The caption on the vertical axes must be 'Strength. . .'

Figure 6: As in Fig. 4 here I also suggest that the figure is mirrored so that 'station 1' is on the right side and 'station 4' on the left. In (b) 'Station 3 (tributary)' I have a graphical problem.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 13101, 2014.