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Reply on RC2

Nataline Simon et al.

Author comment on "Combining passive and active distributed temperature sensing measurements to locate and quantify groundwater discharge variability into a headwater stream" by Nataline Simon et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-293-AC2, 2021

Dear Stefan Ploum,

Thank you for your time and for reviewing our work. We are pleased to read your interest for our study and for the developed approach. Through your comments, it clearly appears that we did not sufficiently manage to highlight the outcomes, the perspectives and the full potential of the described approach.

Thus, with this in mind and following your comments, we propose to revise the manuscript in order to clearly highlight the main objective of this work that is the characterization of groundwater/stream exchanges in headwater catchments. We are aware that for now we highly focus in the manuscript on methodological aspects and detail the interpretation methods. In order to focus more on the characterization of GW/stream exchanges, we propose to make the following revisions of the manuscript:

- In the introduction, we will insist on the importance of quantify groundwater discharge in headwater catchments and on the lack of tools to fully characterize the spatial and the temporal variability of such exchanges.
- All along the manuscript, we will try to shorten the text and especially the section concerning the analysis of the standard deviation of temperature (section 3.1) while better explaining why these methodological points are useful and needed.
- We will also fully rearrange the discussion section, since the current version does not focus enough on the understanding of groundwater discharge processes.

Concerning the discussion section, we propose to reorganize it according to the main outcomes. We will first focus on the detection and the localization of GW discharge areas in order to highlight the usefulness of passive-DTS measurements that can be used to efficiently detect groundwater discharge at high resolution under very long section of FO cable and to monitor temporal variability of discharge. Then, the discussion will focus on the quantification of GW discharge. For this point, we show that passive-DTS measurements are not sufficient since the uncertainties on fluxes estimates are too high (as suggested by the reviewer 1, we will strengthen the question of uncertainties and boundaries conditions). We demonstrate here that conducting active-DTS measurements is a very promising approach to precisely quantify GW discharge into streams. The resolution of estimates is particularly interesting to characterize spatial variabilities at small scale. Such results cannot be achieved with any other methods commonly used in this context. To go further, we will focus on the complementarity of both methods to quantify GW discharge. Indeed, active-DTS measurements also offer the possibility of estimating thermal conductivities of streambed sediments all along the heated section of cable. The estimated values of thermal conductivity can be further used to interpret passive-DTS measurements and considerably reduce the uncertainties of flow estimates. This is also a major result since it highly facilitates the interpretation of passive-DTS measurements allowing the potential quantification of GW discharge at high resolution through long-term monitoring. Classical methods using heat as a passive tracer (either through punctual or distributed measurements) require in general complementary measurements to be interpreted, such as hydraulic gradient measurements for instance (Cucchi et al., 2018), which may be particularly constraining. Moreover, since the spatial resolutions of DTS and of punctual measurements are completely different, it also questions the use of punctual measurements to interpret passive DTS measurements. All these points will be strengthened in the revised manuscript in order to demonstrate the interest of the approach to characterize GW/stream exchanges. These improvements will allow us proposing a complete framework for the use of DTS methods in such contexts.

You also suggest focusing more on contextualizing the presented work by discussing the relationship between spatial distribution of soil/sediment, thermal conductivity, hydraulic properties and implications for the DTS observations. This is a more sensitive point. Indeed, the soil/sediments and their hydraulic properties are roughly described, which makes difficult the comparison with DTS results. Nevertheless, it seems that active-DTS results show the possibility of highlighting small scale heterogeneities which is very promising for future works. Besides the impact of heterogeneities, the correlation between the catchment topography and GW discharges seems demonstrated. In fact, the main driver of groundwater discharge in headwater catchments seems to be the topography. This point is in fact very important for the understanding of headwater catchment and will be therefore more explicitly highlighted as a major conclusion of the paper.

Finally, the question of the spatial heterogeneity could be addressed as a very promising perspective. It should be noted that the role of heterogeneity is limited to small scale variations while large scale variations of GW discharges mainly depend on topography. This point is in good agreement with the fact that the geological properties are similar in the whole watershed. Thus, small scale variations of GW discharges could result from unequal intensities of alteration while the topography would control large scale groundwater response. Note also that the linear deployment of FO cables does not allow discussing the lateral spatial heterogeneity of GW discharge, but this could be achieved through more complex setups, for instance if FO cables are installed ups and downs across the cross-section of the stream.

Once again, we thank you for your comments that should allow highly improving our manuscript. The technical details and text edits you addressed will also be very helpful.

Kind regards,

Nataline Simon & co-authors