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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Spatially resolved information on karst conduit flow from in-cave dye-tracing" *by* U. Lauber et al.

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We thank the anonymous referee for the very useful and valuable comments that will contribute to improve the manuscript. Most of the referees' remarks will be taken into account. According to her/his specific comments, we will perform the following changes:

General comments:

1. Comment: "The introduction needs a more general overview of methods to describe transport processes in karst systems"

Reply: We will add some more general information about karst hydrogeology and meth-

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ods in karst hydrogeology in order to make the manuscript accessible for more readers.

2. Comment: “Especially in the study site description (but also in the rest of the manuscript) a lot of German names of locations appear that are not relevant for the study itself. For an international audience it might be better to omit some of the German names and to use simple descriptions.”

Reply: Indeed, specific names of locations are generally not relevant for an international audience. Therefore, we try to omit German names as far as possible. However, we will leave at least some the main names in the description of the test site in order to allow comparison with other studies in the test site.

3. Comment: “In the methodology, the analytical part is not described detailed enough. Please provide general structure and equations of the lumped parameter models being used. Please also mention the inherent assumptions of the chosen model structures (constant discharge, geometrical simplifications, etc.).”

Reply: We have not mentioned the details, as the applied models and related assumption are common in karst hydrogeology. However, the reviewer is right, that model details might not be known to all readers of HESS. Therefore, we will add more information to the manuscript and point to references describing the applied method in detail.

4. Comment: “The conclusions need more focus on the relevance of the results in terms of water management but also in terms of future field research.”

Reply: Thanks. We will improve this.

Specific comments:

Page 11312, Line 25: “It might not be known to all readers of HESS why conduits exist in karst systems. Please add one or two sentences about karst evolution.”

Reply: We will add some information about karst evolution and conduits in karst sys-

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tems.

Page 11313, Line 3: “choose another word”

Reply: The manuscript will be proof-read by a native speaker, which will help us to use the right wording.

Page 11313, Line 14: “please provide a more general overview about methods to characterize transport processes in karst systems (eg. environmental tracers, modelling ...)”

Reply: Yes, we will add some more general information about methods to characterize transport processes in karst systems.

Page 11314, Line 16: “Parts of the preceding paragraph are too detailed and may be moved to the study site description or the methodology.”

Reply: We will do so and move some detailed information to the field site description.

Page 11314, Line 22: “comparisons should obviously done in the discussion but I don’t see any point of mentioning them here.”

Reply: We will do so and mention this later.

Page 11315, Line 3: “you mean the recharge area?”

Reply: This will be changed.

Page 11315, Line 9: “please rephrase“

Reply: We are aware about some unclear formulations due to language problems. We will give the manuscript to a native speaker before resubmitting it.

Page 11315, Line 20: “Fig 2 caption: What are "Arges"? If they are caver groups provide a description/reference /link”

Reply: This will be changed.

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Page 11316, Line 3: “was the tracer recovery also close to 100%? If not there could still be some tracer left in the system.”

Reply: Tracer recovery was 52 % and 73 % respectively. The question is, if there could still be some tracer left in the system. However, as the tracer was injected directly into the cave stream, there are no significant storage possibilities within the conduit system under stable flow conditions. BTCs showed that tracer passed the system quickly without large tailing, which would indicate interaction processes with the rock matrix and storage processes. Tracer concentrations had dropped down below detection limit for a period of several days. Therefore, no noteworthy amount of tracer is possibly left in the system.

Page 11316, Line 4 and 7: “town does not appear in map, please indicate or avoid mentioning”

Reply: Thanks, we will improve this.

Page 11316, Line 13: “I guess SP-1 is just before IP-1, please modify arrow in Fig 2 to be clear about that”

Reply: Thanks, we will clarify this.

Page 11316, Line 16: “For which purpose?”

Reply: Charcoal bags were installed at several points in the cave system in order to locate the confluence of the two cave streams. We will add this information in the revised manuscript.

Page 11316, Line 19: “can the flow rate be assumed to stay constant over a whole week?”

Reply: The Reviewer is right: Flow rate cannot be assumed to stay constant. However, discharge was not used to calculate the recovery but for a simple water balance at a key date (see section 4.3 on page 11319 in the manuscript).

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Page 11316, Line 20: “which is the temporal resolution of these observations?”

Reply: The temporal resolution is 4 minutes. We will add this information.

Page 11316, Line 23: “Please provide equations for the calculations for all cases and move the result to results section”

Reply: We will provide the equation for the tortuosity and improve the section.

Page 11316, Line 26: “this is confusing: they were calculated with and without tortuosity (L22) but only the results without tortuosity are mentioned? Please clarify”

Reply: Yes, we did not mention results with tortuosity in the text for reasons of clarity and readability of the text. All results are provided in Table 1.

Page 11317, Line 6: “please provide short description of the model with the governing equations, including also the assumptions that are inherent to the two models (eg constant discharge, geometrical simplifications, etc)”

Reply: Please see our response to Comment 3. We will improve this.

Page 11317, Line 9: “please elaborate in a bit more detail: what do you mean by "multiple pairs of values" and "more robust values"? Some kind of equifinality?”

Reply: We will clarify this in the revised manuscript.

Page 11317, Line 11: “Was an automatic calibration performed? If yes, which algorithm was used?”

Reply: The applied models use an inverse modelling approach for parameter estimation. For calibration, the program uses a Marquardt-Levenberg type weighted nonlinear least-squares optimization approach in order to provide a best fit (van Genuchten et al. 2012).

Page 11317, Line 11: “It is difficult to learn anything from this value because there is no reference whether it is indicating good or bad performance. In addition, this is

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obviously part of the results section“

Reply: Thanks. We will move this to the results section. Furthermore, the wording was wrong and will be corrected: it should read coefficient of determination (R2). Best fit is achieved, when R2 -> 1.

Page 11317, Line 23: “so there might be still some probability that injections 3 and 4 are biased by injections 1 and 2?”

Reply: The reviewers’ remarks are reasonable. By using the same tracer twice in the same test area with only short time period in between, there is general the possibility of overlapping of BTCs. However, the tracer was injected directly into the cave stream and there are no significant storage possibilities for the tracer within the conduit system. BTCs showed that tracer passed the system quickly without large tailing which would indicate interaction processes with the rock matrix and storage processes. Tracer concentrations had dropped down below detection limit for a period of several days. This means, that an overlap can be ruled out in this case.

Page 11317, Line 23: “In the paragraph above RMSE is introduced as measure of performance. In table 1, the coefficient of determination is used instead (but with the same value of .931) - please clarify”

Reply: Please see our response above. The wording will be corrected: it should read coefficient of determination (R2).

Page 11318, Line 14: “The layout of figure 3 has to be improved. (1) all figures in one column have the same time axis -> move them together and show one time axis at the bottom, (2) by introducing a right handed y-axis for IP-2, also the columns can be moved together, (3) that way the figures themselves can be enlarged, (4) using different colours, the point measurements and the continuous measurements can be distinguished much better, (5) the authors may consider adding the most important transport parameters as text to the respective figure (this would facilitate their compar-

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ison).Similar recommendations also apply on Fig."

Reply: Thank you. We will improve the Figures.

Page 11320, Line 4: "I like how this paragraph explains the right half of Fig 5, but please add also some words about the derivation of the dendritic karst network figure on the left, especially the part of the vadose and epiphreatic zones."

Reply: We will do so.

Page 11320, Line 7: "was this found by the charcoal measurements?"

Reply: Yes, the exact location was found by charcoal measurements.

Page 11321, Line 9: "Even though it is already mentioned in Fig 6, please mention also in the text that the gathered information taken in the last ∼20% of the flow distance. Everything what happens in the first 80% is lumped into the information obtained at SP-2. Similarly, this is also true for northern drainage system."

Reply: Thanks, we will do so.

Page 11322, Line 10: "positive or negative?"

Reply: There is a positive increase of dispersion with increasing flow velocity.

Page 11322, Line 18: "this information may be added to the left side of figure 5"

Reply: This will be done.

Page 11323, Line 6: "The calculation of water volumes is not clear to me. Please explain the method in the methodology section. When mentioning the results here, please clarify which results were obtained by this study (and how) and by other studies."

Reply: Indeed, we did not mention the calculation method. We will add this information in the revised manuscript.

Page 11323, Line 10: "mention the charcoal bags: "using charcoal bags along the cave

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flowpaths, the confluence could be located..."”

Reply: We will add this information to the manuscript at an earlier section.

Page 11324, Line 6-9: “Please add some more information similar to this. It is important to relate to the impact of the results on water management in the region. Please also mention that under wet conditions the proportion of water that flows through the conduits can be much higher and that the risk of contamination can increase significantly. In addition, it would also be favourable to add some conclusion about the value of such in-cave experiments -> would you recommend others to do similar?”

Reply: Thanks. We will add some more information in the conclusion. However, we will not address the issue of risk of contamination under high-flow conditions, as this is a complex matter. Higher flow velocities can provoke flushing of potential contaminants and a fast transport to the spring. Related tracer breakthrough exhibits sharp curves and higher maximum concentrations than under low flow conditions (Göppert & Goldscheider, 2008). However, the opposite has also been observed: higher water volumes in the karst system provoke a higher dilution of tracer and therefore lower maximum concentrations under high flow conditions (Pronk et al. 2007, 2009).

Reference: Van Genuchten, M. Th., Šimůnek, J., Leij, F.J., Toride, N., and Šejna, M.: STANMOD: Model use, calibration and validation, Trans. ASABE, 55, 1353-1366, 2012.

Göppert, N., and N. Goldscheider: Solute and Colloid Transport in Karst Conduits under Low- and High-Flow Conditions, Ground Water, 46(1), 61–68, 2008.

Pronk, M., Goldscheider, N., and J. Zopfi: Particle-Size Distribution As Indicator for Fecal Bacteria Contamination of Drinking Water from Karst Springs, Environ. Sci. Technol., 41 (27), 8400–8405, 2007.

Pronk, M., Goldscheider, N., Zopfi, J., and F. Zwahlen: Percolation and Particle Transport in the Unsaturated Zone of a Karst Aquifer, Ground Water, 47(3), 361–369, 2009.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 11311, 2013.