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Hydrology and Earth System Sciences Discussions

Interactive comment on "Storage and transport in cave seepage- and groundwater in a South German karst system" *by* K. Schwarz et al.

K. Schwarz et al.

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COMMENT: In particular, more details about the sampling locations (e.g., depth below land surface) and the sampling times (only during drought periods or some samples soon after heavy rainfall / snowmelt?) must be provided and used for interpreting the results. ANSWER: sampling locations and times will be provided

COMMENT: In addition, results from similar investigations in another spring catchment of same karst area (Gallusquelle catchment) are available and should be compared to the results from this study. ANSWER: Work by Sauter and Geyer will be included in the next version of the manuscript

COMMENT: It is further irritating that several references cited in the text are missing in the references section. While this can easily be corrected, it leaves the impression that

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the manuscript was not prepared with care. ANSWER: Apologies for an incomplete reference list. An explanation (but not an excuse) is that the authors are still getting used to the programme Endnote. In the next version better care will be taken

Specific comments: COMMENT: 1. Abstract, p. 1268, l. 15-19: I think the last two sentences of the abstract, which are very general, are not fully supported by the results. Perhaps they can be replaced by more specific statements (or the discussion in the manuscript can be changed to demonstrate that these general conclusions are valid). ANSWER: These two sentences will be removed or else substantiated by the discussion section

COMMENT 2. Introduction, p. 1268, l. 26 - p. 1269, l. 3: The three compartments defined by Mangin (1974) do not correspond to the conceptual model elsewhere considered in the manuscript. The conceptual model presented here ignores soil and vadose zone, which are several times addressed in the discussion of the results. Thus, a more appropriate conceptual model should be introduced here. ANSWER: We propose an expansion of the Mangin Model that includes soil and vadose zones. This can be done by one or two explanatory sentences below the outline of the 3 compartments by Mangin currently on top of page 1269.

COMMENT 3. Introduction, p. 1269, l. 11-14: 8217;Tracer tests are useful tools particularly for investigation of flow dynamics in karst . . . They were able to reveal information about the fast conduit system.8217; I do not think that the first statement is appropriate; if a tracer is injected before or during a storm event, it may provide information about the dynamics, but this is not very typical. Thus, emphasis should be placed on the second statement. ANSWER: The intention here was to outline the usefulness of stable water isotopes as already present ubiquitous tracers. In order not to deflect from the main topic, we propose to leave out the statement of general tracer tests and begin the paragraph as follows: 8220;In the case of catchment-wide water recharge considerations ubiquetously distributed tracers such as stable isotopes of water can help to assess risks of diffuse pollution. 8220;

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COMMENT: 4. Introduction, p. 1269, l. 14-15: 8217; . . . conduit system. However, the latter usually presents only a small part of the subsurface water balance.8217; Obviously, the conduit system cannot be part of a water balance. The conduit system is a small part of the total subsurface porosity. Alternatively, one could say that direct recharge into the conduit system is a small part of the subsurface water balance. But note that the conduit system probably provides the major contribution to the discharge. ANSWER: Correct. We have dropped the statement about the fast conduit system as suggested in the previous comment.

COMMENT: 5. p. 1272, l. 3-15: Please add the depth below land surface to the description of the sampling locations. If available, you may add further information that might be useful for the data interpretation, e.g., information about the rock porosity (estimate of total porosity, types of porosity, matrix vs. fractures, etc.), the land surface (hill slope, dry valley, doline?), or the soil characteristics (the average soil thickness is mentioned, but are there any differences between the sampling locations?). In addition, you should explain how the sampling times were chosen: Did you try to sample after recharge events; did you prefer drought periods or was there a fixed schedule independent of the hydrologic situation? ANSWER: Lat and long values and if available depth below the sampling locations will be given. However the latter can only be estimated values. Other information about total porosity, fractures and soil characteristica are difficult to obtain. Also sampling times of rain and snowfall were chosen more or less after individual events. In some cases a few minor events were sampled together. Sampling in the caves was not regular and ranged between seval days and dozens of days. However, care was taken to cover various seasons.

COMMENT 6. p. 1274, l. 21-22: 8217; . . . known for fast response to strong precipitation events, however even at this subsurface location no strong seasonality in the O-18 signal was found.8217; Why would you expect a seasonality resulting from fast responses to storm events? It would be rather of interest to see whether there were short-term responses to storm events at this location. Obviously, the study was

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not designed to address this issue, but still the graphs shown in Fig. 3 suggest that short-term responses to storm events were observed. Unfortunately, it is unclear to which sampling location the data belong. Perhaps it would be useful to show the graphs of all locations and to discuss the differences (if there are any). ANSWER: if diffuse recharge dominates within relatively short time spans, a seasonality of the precipitation water and snow could potentially be reflected in the cave drip waters. Initially our hope was to find isotopically marked recharge events (i.e. a summer thunderstorm) in the cave drip water if the flow system was well connected. This could not be found but a weak seasonality in the cave drip wates could be observed and will be shown in the next manuscript version. However, since the amplitudes were small compared to the analytical precision the seasonality found in the caves has to be interpreted with care.

COMMENT 7. p. 1275, l. 10-15: It is quite interesting that you (in agreement with Bauer and Selg, 2006) found that O-18 in spring and cave waters equals the weighted average of O-18 in precipitation. Since recharge occurs preferably in winter and spring one might have expected a shift towards lower values in spring and cave waters. However, a closer look at Fig. 3 reveals that O-18 is low only from November to February and starts to increase above the average already in March. If the recharge period extends beyond March it appears to be reasonable that a precipitation-weighted average is close to the recharge-weighted average. Wouldn8217;t it be possible to calculate a recharge-weighted average? To my knowledge, the geological survey has established a recharge model on a daily basis that could be used for that purpose. ANSWER: the d18O weighted average of the precipitation was weighted by the precipitation amount. However, this was not done on a daily basis but rather based on the precipitation amounts of the water samples collected for stable isotope analyses. To establish a recharge weighted average on a daily basis one would have to also measure the isotopes on a daily basis but the results would likely be very similar. As referee 1 already indicated both the cave drip water and the Blautopf can reach slightly more negative down to 8211; 10.6 permille. In most cases the difference is small but could have been caused by a higher recharge rate during the cold season that is not counteracted

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by evapotranspiration. At any rate these differences are too small to establish proper mass balance calculations.

COMMENTIt is further interesting to compare your results to those by Sauter (1992): On p. 95, Sauter presents a graph showing that O-18 at the Gallusquelle showed a tendency to lower values with decreasing spring dicharges; on p.89 and p. 94, he suggests that this is due to the mobilization of old winter recharge that was stored in lower aquifer zones and only released from storage during low-flow conditions. I wonder whether this is a peculiarity of the Gallusquelle catchment or rather an effect of extreme low-flow conditions. Thus, you may want to speculate about geologic differences between the two catchments and about differences of the hydrologic situations represented by the two time series. ANSWER with an average of 0.5 m3 s-1 the discharge amount at the Gallusquelle is less than the Blautopf discharge (average of 2.5 m3 s-1). This could explain the delayed discharge of stored and isotopically depleted 8220;winter water8221;. Also the Blautopf cave system establishes a relatively large mixing pool where such minor effects might be masked. A reasoning of this sort can be included into the manuscript.

COMMENT A further note: Obviously, the cave seepage water and the spring water sampled are several years old. How far is it justified to compare the O-18 values of today8217;s precipitation with those of these old waters? At least it would be useful to know whether the year under consideration was an average hydrologic year. ANSWER this is a good question and of course it would be desirable to have precipitation and discharge time series covering several years. We can confirm that for the isotope dynamics of the Blautopf precipitation this was insofar a typical year as the cold season precipitation was depleted in 18O and the warm season precipitation enriched. This seasonality is expected to occur in other years as well although smaller or larger amplitudes might be possible.

COMMENT 8. p. 1275, l. 15-18: 8217; . . . similar buffering was found . . . 8217; - is this in spring waters or seepage to caves? Please provide more details. ANSWER

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: in most of the citations quoted caves were sampled directly, although Caballero et al (1996) also collected water from wells to show influences of a different aquifer system in his study area (Nerja southern Spain) and Perrin has sampled spring water samples from a smaller scale (500 m length) karstic network near Basel in Switzerland.

COMMENT 9. p. 1275, l. 29 - p.1276, l. 1: 8217; . . . travel times . . . 8217;. Although it is not possible to calculate exact travel times, rough estimates could be made (e.g., recharge divided by porosity yields an estimate of seepage rate). Very recently, Geyer (2008; Dissertation at the University of Göttingen, Germany) derived some estimates for the Gallusquelle catchment based on the analyzes of tritium data and other environmental isotopes. Obviously, this was not accessible at the time when the manuscript was written, but you might be able to get a copy of it now. ANSWER the work by Geyer will be quoted in the next version of the manuscript. One finding of this work that supports our results is that the spring hydrograph does not reveal the temporal recharge distribution. However focus of our work is more on the mixing in the unsaturated zone directly after the recharge.

COMMENT 10. p. 1276, l. 8-9: 8217; . . . given the thickness of the vadose zone . . . a considerable storage can be assumed for the epikarst.8217; I do not think that there is a straightforward relationship between thickness of the vadose zone and epikarst storage. Please explain your reasoning in more detail or drop this statement. ANSWER: It is true that this relationship is not really substantiated and will be removed.

COMMENT 11. p. 1276, l. 15: This appears to be the hydraulic conductivity of the porous matrix (e.g. measured in a lab experiment). It is not correct and of little help to present this value simply as 8217;average hydraulic conductivities8217;. Measurements at field scale yield much higher values. A detailed discussion of hydraulic conductivities and their scaledependency (referring to the Gallusquelle catchment) is provided by Sauter (1992; available at http://tobias-lib.ub.uni-tuebingen.de/volltexte/2005/2039/) ANSWER: True that one single value is very likely unrepresentative for the study and will be removed.

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COMMENT 12. p. 1276, l. 16-17: 8217;The base flow preferentially enables gravimetrical flow of more easily mobilized water.8217; What exactly is the meaning of this sentence? Perhaps it would be helpful to include in Fig. 5 arrows that illustrate how the conduits receive water under baseflow conditions and after storm events. I guess that under low-flow conditions the porous matrix is increasingly drained (via the fracture system and the conduits), which appears to be in contradiction to your statement. ANSWER: This statement rather refers to the fast conduit system in which presumably capillary forces are minor and negligible. Arrows for different flow scenarios will be added to figure 5.

COMMENT 13. p. 1276, l. 22/23: 8217; . . . heavy precipitation events . . . 8217; - this is one example where it would be helpful if information about the sampling times were provided and if short-term responses apparent in the data were discussed in more detail. ANSWER: Sampling dates will be provided with the data set and figure 3 will be altered to illustrate short term responses.

COMMENT 14. p. 1276, l. 25-30: I would like to add that similar percentages were found by Sauter (1992) in the Gallusquelle spring water. We will include this reference in the manuscript ANSWER: Citations of the work by Sauter will be added to the manuscript

Technical corrections: COMMENT1. Abstract, p. 1268, l. 2: 8217; . . . access waters . . . 8217; probably should read 8217; . . . access to waters . . . 8217;. ANSWER: will be corrected

2. Introduction, p. 1268, l. 23: 8217; . . . 25 Answer: ?

3. References: Einsiedl (2005), Einsiedl and Mayer (2005), Nordhoff (2005), Worthington et al. (2002) are cited in the text but missing in the references section (perhaps others are missing too - I have not checked all the citations). ANSWER: Will be added

COMMENT 4. Caption of Fig. 3: 8217;Tiefenhhle8217; should read 8217;Tiefen-

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höhle8217;. ANSWER: Will be corrected

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