Reply to Referee #3

In the following please find the corrections and comments to the referee's response. For clarity, the comments of the referee were copied in black and our comments are in blue.

General comments:

The authors present an interesting case study and an extensive dataset about the water cycle dynamics in the developed Schwingbach catchment based on stable isotope data from the water components precipitation, soil water groundwater, and stream water. The presented sampling approach and the methods used are valid so far and described in detail. The observed signatures of the individual components and their interactions are described in detail. The reactions of groundwater and stream water to precipitation events have been already described in an earlier study and this process knowledge is now supported with the stable isotope sampling carried out in the Schwingbach catchment. It seems that groundwater dynamics are dominating the hydrological system of the Schwingbach catchment. The submitted study presents no new methods or the identification of unknown processes. However, substantial stable isotope datasets in developed landscapes are rare and improved process knowledge is important for hydrological modeling and for a better understanding of biogeochemical processes as mentioned in the introduction section of the presented manuscript. It would be an asset for the study to include additional findings about the groundwater dynamics and the process of recharge in the study landscape. The spatially distributed stable isotope soil profiles together with the groundwater signatures would be a perfect dataset. The study is in the scope of the journal and I recommend the presented case study for publication in HESS after revising the submitted manuscript based on the suggestions of the review process.

We thank referee #3 for the valuable comments and technical corrections which helped us to improve the manuscript. All the suggested changes have been included. Find the answers to each comment below.

In general, we improved the quality of the manuscript by including additional statistical analyses (network mapping in combination with a principal component analysis) and a hydrological model for the Vollnkirchener Bach subcatchment. This hydrological model was setup with CMF (Catchment Modelling Framework by Kraft et al. (2011)) and builds on the conceptual model of groundwater-surface water interactions presented by Orlowski et al. (2014). We further estimated mean transit times (MTT) for the Vollnkirchner Bach (sites 13, 18 and 94) and the Schwingbach (sites 11, 19 and 64) using FlowPC (Version 3.1, Małoszewski and Zuber (1996)).

Specific comments:

The introduction section is well written and the relevant processes and fundamentals of stable isotope hydrology for this study are addresses. However, I suggest modifying the structure at one point. There are some research needs (Page 1811, Line 21 – Page 1812, Line 6) mixed with more fundamental background information. Please add a few words about the relevant processes of groundwater-surface water interactions and add some benchmark studies (e.g. Sklash and Farvolden, 1979) in the groundwater part of the introduction section.

We included some benchmark papers on groundwater-surface water interactions in this paragraph of the introduction, which now reads as follows: *"…Unlike the distinct watershed components found in steeper headwater counterparts, lowland areas often exhibit a complex groundwater–surface* *water interaction (Klaus et al., 2015). This interaction between groundwater and surface water remains poorly understood in many catchments throughout the world but process understanding is fundamental to effectively manage the quantity and quality of water resources (Ivkovic, 2009). Sklash and Farvolden (1979) showed very early, that groundwater plays an important role as a generating factor for storm and snowmelt runoff processes. In many catchments, streamflow responds promptly to rainfall inputs but variations in passive tracers such as water isotopes are often strongly damped (Kirchner, 2003). This indicates that storm runoff in these catchments is dominated mostly by "old water" (Buttle, 1994; Neal and Rosier, 1990; Sklash, 1990). However, not all "old water" is the same (Kirchner, 2003). This catchment behaviour was described by Kirchner (2003) as the old water paradox. Thus, there is evidence of complex age dynamics within catchments and that much of the runoff is stored in the catchment for much longer than event water (Rinaldo et al., 2015). Still, some of the physical processes controlling the release of "old water" from catchments are poorly understood, roughly modelled, and the observed data do not suggest a common catchment behaviour (Botter et al., 2010)."*

The reference Garvelmann et al. (2014) is not appropriate on page 1811, Line 13, since no MRT calculations have been conducted in this study.

We deleted this reference here.

The expression "stable isotope components" might be more appropriate at some passages than using "stable isotope pools" (e.g. Page 1814, Line 21).

We changed the expression to "stable isotope components".

Please provide the catchments size and the altitudes at the beginning of the study area section.

We shifted the following paragraph to the beginning of this section: *"The whole Schwingbach catchment encompasses an area of 9.6 km^2, with an altitude range from 233–415 m a.s.l. The Vollnkirchener Bach tributary is about 4.7 km in length and drains a 3.7 km^2 subcatchment area (Fig. 1c), which ranges in elevation from 235–351 m a.s.l."*

Furthemore, I suggest to provide the discharge (additionally) in millimeters to allow a better comparison between the two catchments.

We changed the discharge unit to mm d^{-1}.

How was snow sampled (Page 1817, Line 12)? This is an important information. Solid samples were used in a number of past studies. This is valid for characterising the stable isotope signature of precipitation input. However, Taylor et al. (2001, 2002) have shown that there is a significant difference between the stable isotope signature of solid samples and meltwater samples and they suggest to use meltwater samples in hydrological studies. I suggest to at least shortly discuss this issue in the paper.

We included the following paragraph under the section "Monitoring network and water isotope sampling": *"In winter 2012 to 2013, snow core samples over the entire snow depth of <0.15 m were collected in tightly sealed jars at same sites as open rainfall was sampled. We sampled shortly after snow was fallen because sublimation, recrystallization, partial melting, rainfall on snow, and redistribution by wind can alter the primary isotopic composition of the snowfall (Clark and Fritz,* *1997b). Samples were melted overnight following Kendall and Caldwell (1998), and analysed for their isotopic composition. Open rainfall was collected in self-constructed samplers."*

Including equation 1 (Page 1819, Line 15) is not crucially necessary.

According to the reviewer, we deleted the respective equation.

Can you explain in more detail, why the isotopic signature of stream flow seems be influenced by snowmelt only at site 64?

Unfortunately, our sampling only captured the snowmelt influence at site 64 as well as at groundwater sampling points 27 and 32.

That groundwater is mainly recharged during the winter season well known. During this period the transpiration by vegetation is significantly reduced and water available for recharge. Please include this point in your discussion on groundwater recharge on page 1825.

As recommended by the reviewer we included the following paragraph: *"Generally, less than 5 to 25% of precipitation infiltrates to the groundwater table in temperate climates; the rest is lost to runoff, evaporation from soils and transpiration by vegetation (Clark and Fritz, 1997a). During spring runoff when soils are saturated, temperatures are low, and vegetation is inactive, recharge rates are generally highest. In contrast, recharge is very low during summer when most precipitation is transpired back to the atmosphere (Clark and Fritz, 1997a)."*

Why are the groundwater stable isotope signatures so different? Please explain the statistical differences in more detail. It seems to be related to the different land use forms as you mentioned in the paper. Please provide additional information about this issue. There is probably more potential to explain this issue in combination with the soil profiles.

We performed new statistical analysis and replaced Figure 6 by the results of our new topology interference network map (Kolaczyk, 2014) which is combined with a principal component analysis (Jolliffe, 2002) (now Fig. 9). The network map depicts relationships between surface and groundwater sampling points based on significant correlations ($p<0.05$).

You explain the values observed at piezometer 32 with the influence of snowmelt. Again, why seems the snowmelt signal only influence the values at this location? Please provide more information about this particular site compared to the other piezometer sites.

We included the following information in the discussion section of the groundwater isotopic signatures: *"As shown by Orlowski et al. (2014) piezometer 32 is highly responsive to rainfall-runoff events and groundwater head elevations showed significant correlations with mean daily discharge at this site. Further, effluent conditions and lowest* K_{sat} *values (7–14* $mm \cdot h^{-1}$*) were measured in this stream section (piezometers 32–35) (Orlowski et al., 2014)."*

We further included δ^2H values and groundwater head levels of site 27 in Figure 5 (now Fig. 8). Groundwater isotopic signatures at this site likewise showed snowmelt influenced δ-values in the winter period of 2012 to 2013. Site 32 and 27 were exemplarily selected to show the translocation of snow isotopic signatures to the groundwater in the study area. Additionally, moving averages were plotted through the groundwater and stream water isotope time series (now Fig. 7 and 8).

It would be nice to show the soil moisture values of the soil profiles in section 3.4. Please clearly mention in your discussion of the stable isotope profiles that the study of Garvelmann et al. (2012) was carried out on a hillslope. Therefore the results of the two studies are not directly comparable due to the differing topography of the study areas.

Soil water contents of the spatially distributed soil sampling can be found in Table 2. Soil moisture data for the seasonal soil sampling was included in Figure 9 (now Fig. 6).

We included the following sentence in the section "Spatial variability": *"Soil samples were taken at four consecutive rainless days (1 to 4 November 2011) at altitudes of 235–294 m a.s.l.."*

Moreover, we edited the following sentences: *"Garvelmann et al. (2012) obtained high resolution δ^2H vertical depth profiles of pore water at various points along two fall lines of a pasture hillslope in the southern Black Forest (Germany) by applying the H_2O(liquid)–H_2O(vapor) equilibration laser spectroscopy method. The authors showed that groundwater was flowing through the soil in the riparian zone (downslope profiles) and dominated streamflow during baseflow conditions. Their comparison indicated that the percentage of pore water soil samples with a very similar stream water δ^2H signature is increasing towards the stream channel (Garvelmann et al., 2012). In contrast, we found no relationship between the distance to stream and soil isotopic values in the Vollnkirchener Bach subcatchment over various heights above sea level (235–294 m a.s.l.)."*

I suggest including the information about precipitation and the local meteoric water line in section 3.5 into the description of the precipitation values (section 3.1).

It would also be nice to show the deuterium-18-O plots at the beginning of the results section for an overview of all samples used in the study.

We moved the description about the LMWL and EWLs to the Results section on "Variations of precipitation isotopes and d-excess" as well as the respective Figure.

Technical comments

Page 1812, Line 7-9: Please revise the structure of this sentence.

We rephrased the sentence as follows: *"One way to better understand the relationship between precipitation, stream, soil, and groundwater, is a detailed knowledge about the isotopic composition of the various water sources (surface, subsurface, and groundwater) and their variation in space and time."*

Page 1816, Line 19: was instead of were

Precipitation data is plural. Thus, "were" is correct in this context.

Page 1820, Line 15: ": …rainfall was collected at 15 open field site locations.."

We edited the sentence as recommended by the reviewer.

Page 1820 Line 17-19: Please revise this sentence for more clarity. Which information refers to which citation?

We deleted reference "Gat et al. (2011)" and rephrased the sentence.

Page 1821, Line 28: Schürch, Schurch or Schuerch? Check also in refernces list.

We could not find anything wrong with this reference (Schürch et al., 2003). It was consistently cited throughout the manuscript.

Page 1822, Line 8: Deuterium-excess of what? (Please remove section title or reviose)

We combined all findings on precipitation isotopes (i.e. d-excess and LMWL) under the same section *"Variations of precipitation isotopes and d-excess".*

Page 1824, Line 24: mean transit time

We revised the whole section as follows: *"As described above, MTT calculations did not provide meaningful results. The failure of the MTT estimations is mainly attributed to the little variation in stream water isotopic signatures. Just as in the here presented results, Klaus et al. (2015) had difficulties to apply traditional methods of isotope hydrology (MTT estimation, hydrograph separation) to their dataset due to the lack of temporal isotopic variation in stream water of a forested low-mountainous catchment in South Carolina (USA). Furthermore, stable water isotopes can only be utilised for estimations of younger water (<5 years) (McGuire et al., 2005; Stewart et al., 2010), suggesting that transit times in the Schwingbach catchment are longer than the range used for stable water isotopes."*

Page 1829, Line 24-25: Please revise this sentence for more clarity.

We edited the sentence as follows:

"Isotope compositions of soil water varied seasonally: More depleted soil water was found in the winter and spring (Fig. 9); contrary, soil water was enriched in summer due to evaporation during warmer and drier periods (Darling, 2004)."

Figure 1: Is it possible to include the locations of the stable isotope soil profiles?

We included the locations of the snapshot as well as of the seasonal soil samplings in Figure 1.

Figure 3: There is no dashed line at d=10 (or the quality of the figure was to bad: : :)

The dashed line (d=10) is now a solid black line. We also improved the quality of the figure as well as included monthly d-excess values of GNIP station Koblenz for the same period as the measured data of the Schwingbach catchment (2011 to 2013).

Figure 4+5: Please provide the discharge in mm/day. It would be nice to include the average stable isotope values with a fine solid line for a better comparison.

The discharge unit was changed as recommended. We plotted a moving average through the streamflow as well as through the groundwater isotope time series for Figure 4 (now Fig. 7 and 8). Average stable isotope values were already provided in Table1.

I kindly invite the authors to recheck the citations and the references list very carefully in the manuscript. For example Klaus et al. is from 2015 (please revise throughout the manuscript).

We checked and edited the reference list where necessary.