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Discussions

Interactive comment on "Tracer-based analysis of spatial and temporal variation of water sources in a glacierized catchment" *by* D. Penna et al.

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Response to Reviewer #1

Tracer-based analysis of spatial and temporal variation of water sources in a glacierized catchment by Daniele Penna, Michael Engel, Luca Mao, Andrea Dell'Agnese, Giacomo Bertoldi, Francesco Comiti

We thank the reviewer for his/her detailed comments that have helped us to improve the paper. The reviewer's comments are quoted in their entirety and the authors' responses are given directly afterwards.

Comment 1: "The authors present an interesting case study about the spatio-temporal

variation of the most important water sources contributing to runoff and groundwater recharge in a high alpine catchment in the southern European Alps. The study presents a unique and extensive dataset of stable isotopes and EC measurements in the study area. The study has shown that snow, not surprisingly, plays a crucial role for the generation of runoff and groundwater recharge in the mountainous study area. It is well known that there are large uncertainties of snow stable isotopes for the investigation of the water sources in high alpine environments. An enrichment of heavy isotopes due to intermitted melting processes has been reported (Dietermann and Weiler, 2013). Surprisingly, the snow stable isotope data, especially the samples from spring and summer snow patches, show no fractionation signal in the presented study. Is this related to the particular sampling locations (e.g. shading)?"

Response 1: We believe that the snowpack in our study catchment underwent the same progressive seasonal isotopic enrichment during the melting season showed in other studies (e.g., Taylor et al., 2001; Lee et al., 2010; Dietermann and Weiler, 2013). However, our data did not allow for a clear representation of this process mainly because we sampled different snow patches at different elevations and at different locations on various occasions, without sampling several times the same snow patch and "following" the temporal evolution of its isotopic composition. Thus, the spatial variability in isotopic composition of different snow patches (due, for instance, to elevation, microtopography, wind drift and also shading effects as the reviewer suggested) could have masked the progressive isotopic enrichment of the snowmelt samples. The only clue about the possible enrichment of the snow samples could come from the wide variability of the isotopic composition of the snowmelt samples that likely reflects the combined effect of the different elevations where the samples were collected and the progressive seasonal isotopic enrichment that snowpack underwent during the melting process (pag. 4893, L16-18 of the original submission). The fact that the snowmelt samples fell close to the LMWL, and that the slope of the dual isotope relationship was close to 8, does not necessary implies that no fractionation occurred, but suggests that there might have been a high consistency of isotopic fractionation in the dD-d18O relationships at the catchment scale as well as a general consistency and temporal covariation of meltwater isotope values at the catchment scale (Zhou et al., 2014). We added this interpretation and the reference in the revised manuscript.

Zhou, S., Wang, Z., Joswiak, D.R., 2014. From precipitation to runoff: stable isotopic fractionation effect of glacier melting on a catchment scale: catchment-scale isotopic fractionation effect of glacier melting. Hydrol. Process., 28, 3341–3349, doi:10.1002/hyp.9911

Comment 2: "Furthermore, the intercepts of the different snowmelt samples differ from each other. The authors have identified a predominantly oceanic origin of the air masses in the study area. However, it is well known that the Southern Alps can have significant precipitation inputs originating from Mediterranean air masses (e.g. Winter 2013/2014)."

Response 2: We agree with the reviewer that the Southern Alps can be often hit by precipitation originated in the Mediterranean basin. However, the South Tyrol lies in a transition zone between the climate of the Southern Alps (more influenced by the Mediterranean Sea) and that of the Northern Alps (more continental-like with influences from the Atlantic Ocean). The complexity of the topography, with elevations varying between about 50 and 3900 m, allows the coexistence of many different microclimates; in the space of only 100 km both very wet (more than 1500 mm/year) and very dry (less than 500 mm/year) climates are present, making this one of the most heterogeneous areas in Europe with regard to precipitation (Brugnara et al., 2012). In particular, the Vinschgau valley develops from West to East, and is sheltered from the influence of Southern air masses from high mountain ranges (among which is Mt. Ortler, 3905 m a.s.l., the highest peak in the region). Therefore, we believe that the data we collected reflect this microclimatic complexity in precipitation patterns. We added this concept to the revised version of the manuscript.

Brugnara, Y., Brunetti, M., Maugeri, M., Nanni, T., Simolo, C., 2012. High-resolution

analysis of daily precipitation trends in the central Alps over the last century. International Journal of Climatology 32, 1406–1422. doi:10.1002/joc.2363

Comment 3: "I will encourage the authors to discuss the results and the uncertainties of the presented snow stable isotope data in more detail."

Response 3: Please, see response to comment 19.

Comment 4: "The study nicely characterizes the important runoff generation processes in the study area using classical hydrological tracer methods. The study presents no new methods or the identification of unknown processes. The tracer data nicely confirm fundamental process knowledge in alpine environments. The scientific value of the study lie therefore in the characterization of the hydrological runoff generation processes in an insufficient investigated study environment using environmental tracers. The presented sampling approach and the methods used are valid. However, the authors present lot of speculations to explain the hydrological processes from the collected data."

Response 4: We thank the reviewer for recognizing the added value of this work, that is mainly related to the insufficient information that we have about water sources in such rough environments. In the revised version of the manuscript, we reduced the possible speculations and limited our comments only to the results that could be robustly obtained by the analysis of the data collected.

Comment 5: "I kindly invite the authors to recheck the citations and the references list very carefully in the manuscript. I found references not cited in the references list (e.g. Page 4893, Line 1; Page 4894, Line 11; Page 4897, Lines 5 and 12)"

Response 5: Thank you for finding this oversight. We rechecked all references carefully and included the missing ones.

Comment 6: "Furthermore, the structure of the results and discussion section could be reconsidered. I recommend the presented study for publication in HESS after revising the submitted manuscript based on the suggestions of this review."

Response 6: The first draft of this manuscript was organized in two distinct sections, such as "Results" and "Discussion". In the end, we decided to merge the two sections in order to avoid redundancy, and make the manuscript more concise and clearer.

Comment 7: "Page 4884, Line 2: Please introduce Table 1 and Figure 1 together for a better overview of the study area and the locations."

Response 7: Done.

Comment 8: "Page 4884, Line 10: Please provide approximate elevation."

Response 8: Done.

Comment 9: "Page, 4884, Line 23: Most likely it is not appropriate to call a flood event in September a ROS flood. Since those floods are usually characterized by an extensive snow pack all over the catchment area, but a general definition of those floods is lacking. How many snow, and on what elevation was the snow, line prior to this event? Please clarify."

Response 9: We agree, it was a mistake. Even though it snowed a little in the few day prior to the rain event, it cannot be defined as a rain-on-snow event. We changed this in the text.

Comment 10: "Page 4884, Lines 28-29: Please use italic font for vegetation names."

Response 10: Yes, indeed vegetation names are already in Italics.

Comment 11: "Page 4885, Lines 6-11: This section could be shorter."

Response 11: We changed it as follows: "The upper catchment is poorly subjected to human pressureas only sparse cattle and sheep grazing is present up to 2400 m a.s.l.. A small gravel road goes up to around 2220 m a.s.l. and a limited net of tracks crosses the middle and the upper part of the catchment. "

Comment 12: "Page 4886, Line 1: Please shortly mention the uncertainties for a quantification of the peak flows during the floods mentioned before derived from those rating curves."

Response 12: Done.

Comment 13: "Page 4887, Line 7: There is an "a" missing prior to 1 m?"

Response 13: No, the sentence is correct.

Comment 14: "Page 4887, Line 10: Fall 2012, instead of fall 2013 at the end of the sentence?"

Response 14: Yes, thank you, we have corrected it.

Comment 15: "Page 4888, Equation 1: The equation for calculating the deuterium excess is wrong in the manuscript. The proper equation is: d-excess = delta D – 8 * delta 18-O. Please check if the calculations were done with the correct formula."

Response 15: Yes, thanks, it was a slip in the equation (but a serious one!). Fortunately, all calculations were done with the correct formula.

Comment 16: "Page 4889, Line 1: Please mention the different water components (snow, GW and rainfall) for more clarity."

Response 16: Done.

Comment 17: "Page 4891, Lines 1-20: This section could be shorter. The references with the equations are sufficient. The equations in this section could be presented in a table for example."

Response 17: We put the equations of the different LMWLs found by various authors for mountain locations in Northern Italy in a new Table (Table 3), and this way we shortened the section.

Comment 18: "Page 4893, Lines 5-6: The unknown factors could be mentioned in the text."

Response 18: We removed the sentence since it didn't add any relevant information to the paragraph.

Comment 19: "Section 4.3: Please provide a more detailed discussion about the challenges and the uncertainties associated with the sampling of snow stable isotope data. See therefore Dietermann and Weiler (2013), for example."

Response 19: We added a discussion on this in Section 4.3. We decided not to go into much detail on this because otherwise this would make the section (that both reviewers has asked to shorten) even longer.

Comment 20: "Page 4894, Line 12: Year of the citation Cable et al. is wrong in the text or the references list. Please check."

Response 20: The citation in the reference list was correct (2011), the one in the text was not. Corrected.

Comment 21: "Page 4895, Line 17: Section 4.9 does not exist. Probably section 4.8 is the right one."

Response 21: Yes, thanks. Corrected.

Comment 22: "Page 4896, Line 14: Section 4.9 does not exist. Probably section 4.8 is the right one."

Response 22: Yes, thanks. Corrected.

Comment 23: "Section 4.6 would be perfect as an introduction at the beginning of the results section. Section 5 and Section 6 could be merged together, since there are repetitions of concluding remarks."

Response 23: We agree that Section 4.6 would act as an effective introduction to the results about tracer dynamics in the study catchment. However, we believe that the

current position of Section 4.6 provides a very good link with the analysis of the spatial (first) and the temporal (later) dynamics of tracer concentration in stream water and groundwater, described in the next sections. Therefore, we decided to keep the same structure of the paper. However, in the revised version we merged section 5 and section 6, as suggested.

Comment 24: "Section 6: I suggest arranging the conclusions the same way as in the objectives section."

Response 24: Done.

Comment 25: "Page 4904, Line 3: I think the uncertainty of the snowmelt contribution to groundwater recharge is not needed at this point."

Response 25: We believe that it is more correct to report it also here.

Comment 25: "Page 4904, Lines 7-16: From my point of view a paper is a discrete study and therefore this extensive outlook for following studies is not appropriate."

Response 26: We removed this part. The new section 5 is now shorter and more concise.

Comment 27: "Page 4904, Line 24: Is there a "and" missing?"

Response 27: Corrected.

Comment 28: "Page 4905, Line 2: Please check the DOI of this citation."

Response 28: We checked. The DOI looks very strange but it's correct.

Comment 29: "There are some references that are missing in the main text of the manuscript (e.g. Page 4906, Line 4; Page 4906, Line 27, Page 4906, Line 30)."

Response 29: Thank you, removed and corrected.

Comment 30: "Page 4908, Line 1-4: Please check if this paper is already available in HESS"

Response 30: No, at the time of this resubmission the paper is still under review for HESS.

Comment 31: "Page 4914, Table 4: Please check the intercept of stream water (tributaries) and groundwater (negative values?)."

Response 31: We checked, they are correct. The intercept values for tributaries and groundwater are negative. Examples of negative intercepts in the dual-isotope relationship for surface water and groundwater are reported in Andreo et al., 2004; Burns and McDonnell, 1998; Dalai et al., 2002; Kendall and Coplen, 2001; Liu et al., 2008; Ogrinc et al., 2008; Wang et al., 2012;.

Andreo, B., Liñán, C., Carrasco, F., Jiménez de Cisneros, C., Caballero, F., Mudry, J., 2004. Influence of rainfall quantity on the isotopic composition (18O and 2H) of water in mountainous areas. Application for groundwater research in the Yunquera-Nieves karst aquifers (S Spain). Applied Geochemistry 19, 561–574. doi:10.1016/j.apgeochem.2003.08.002 Burns, D.A., McDonnell, JJ, 1998. Effect of a beaver pond on runoff processes: comparison of two headwater catchments. Journal of Hydrology, 205, 248-264 Dalai, T.K., Bhattacharya, S.K., Krishnaswami, S., 2002. Stable isotopes in the source waters of the Yamuna and its tributaries: seasonal and altitudinal variations and relation to major cations. Hydrological Processes 16, 3345–3364. doi:10.1002/hyp.1104 Kendall, C., Coplen, T.B., 2001. Distribution of oxygen-18 and deuterium in river waters across the United States. Hydrological Processes 15, 1363–1393. doi:10.1002/hyp.217 Liu, Y., An, S., Xu, Z., Fan, N., Cui, J., Wang, Z., Liu, S., Pan, J., Lin, G., 2008. Spatio-temporal variation of stable isotopes of river waters, water source identification and water security in the Heishui Valley (China) during the dry-season. Hydrogeology Journal 16, 311–319. doi:10.1007/s10040-007-0260-3 Ogrinc, N., Kanduč, T., Stichler, W., Vreča, P., 2008. Spatial and seasonal variations in δ18O and δD values in the River Sava in Slovenia. Journal of Hydrology 359, 303–312. doi:10.1016/j.jhydrol.2008.07.010 Wang, Y., Chen, Y., Li, W., 2014. Temporal and spatial variation of water stable isotopes (18 O and 2 H) in the Kaidu River basin,

Northwestern China: temporal and spatial variation in stable isotopes of Kaidu River basin. Hydrological Processes 28, 653–661. doi:10.1002/hyp.9622

Comment 32: "Page 4917, Figure 2: For more clarity and to reduce the caption text, the number of samples could be included as "n=65"."

Response 32: Done.

Comment 33: "The caption text of a number of tables and figures could be shorter. The second sentence of Table 5 is not needed, since the computation of the uncertainty is already described in the main text of the manuscript, for example."

Response 33: We shortened the caption of Table 5 as well as the captions of other Figures and Tables.

Comment 34: "Page 4921, Figure 6: The size of the letters in the figure could be bigger in the final version of the manuscript for more clarity."

Response 34: We agree. They appear larger in the original figure, that was clearly printed too small in the HESSD pdf. We'll make sure it will be large enough in the hopefully final accepted paper.

Comment 35: "Page 4923, Figure 8: For more clarity and to reduce the caption text, the number of samples could be included as "n=8"."

Response 35: Done.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 11, 4879, 2014.

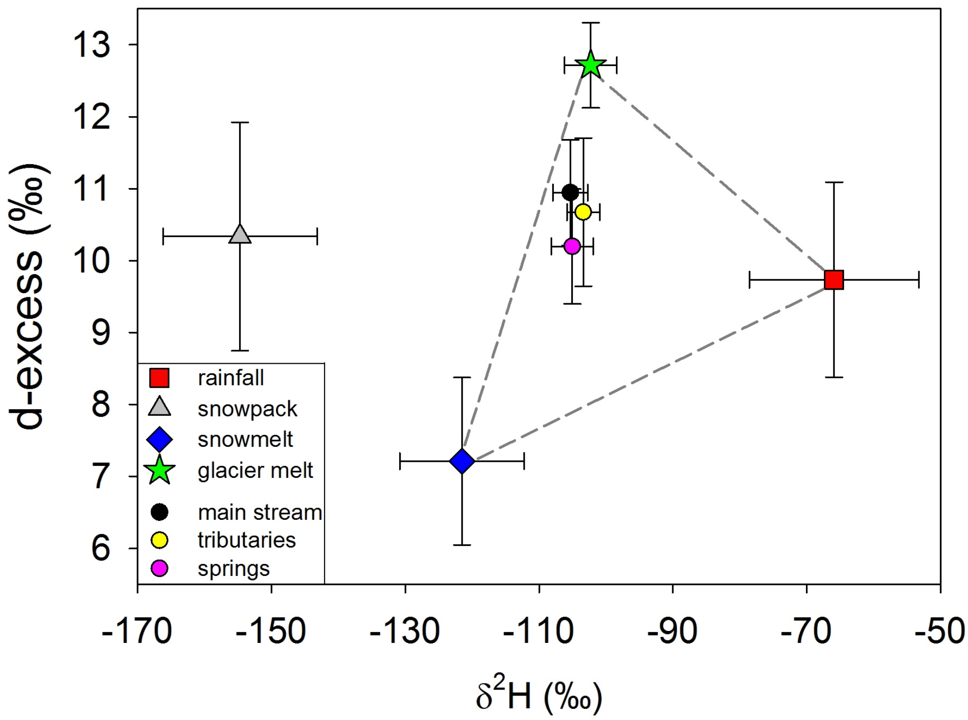

Fig. 1. Fig. 5. Mixing diagram between d2H and d-excess of all average values of samples collected in the Saldur catchment. The error bars represent half of the standard deviation. The d2H and d-excess compos

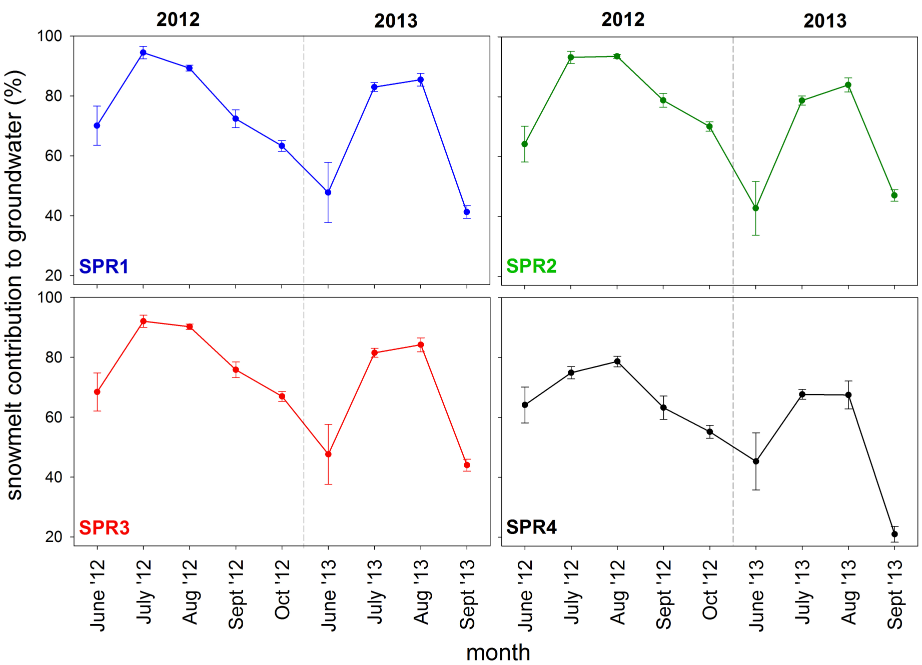

Fig. 2. Fig. 10. Snowmelt contribution to groundwater recharge based on d2H data for different sampling times in 2012 and 2013. The error bars indicate the ± uncertainty at 70%.