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Interactive Comment

Interactive comment on "Identifying residence times and streamflow generation processes using δ^{18}O and δ^{2}H in meso-scale catchments in the Abay/Upper Blue Nile, Ethiopia" *by* S. Tekleab et al.

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Reply to reviewer #2 comment

Identifying residence times and streamflow generation processes using δ18O and δ2H in meso-scale catchments in the Abay/Upper Blue Nile, Ethiopia First of all we would like to thank the reviewer for his/her constructive comments and suggestions for improving the manuscript, particularly to revitalize the manuscript in its relevance, readability, style and technical corrections.

General comment: This paper presents baseline information about residence times and stream flow generation processes in two catchments of the upper Nile River. The analysis is conducted based on water samples taken between 2008-2011 of precipitation, stramflow, and spring water. The paper lacks proper discussion of the results and statistical analysis, In addition very little is mentioned about physical processes. The paper will benefit from separating the results and discussion sections. There is no mention about the advantage of using both d18O and d2H. Would the findings change if they only had one set of samples? If so maybe the paper could be shorter by eliminating one of them. Even though it is true that regional studies are little the manuscript would benefit from contextualization with other meso-scale studies in other continents. Finally the paper should be revised for grammatical and spelling mistakes which in many cases prevent the reader from understanding the content.

Reply: We thank the reviewer for his/her critical comments and suggestions to improve the manuscript. Accordingly the results are properly presented in the results section and discussed afterwards in the discussion section of the revised manuscript. Moreover, the results of our study are now compared with results of similar meso-scale catchments in different regions. The overall readability, style, and grammar are improved and spelling mistakes are corrected. Specific comments: (page number are indicate before line numbers)

Introduction

Comment;1. 35 lines 5-15: There are many more studies that are relevant and could be cited. The authors should focus on studies that have been conducted in catchments of similar size. In addition the authors should find papers in which the altitudinal, amount, and continental effects on isotopic composition have been explored.

Reply: We thank the reviewer for the comments and suggestions. Based on the suggestion new reverences are cited in the revised version of the manuscript in the introduction section and discussion part of the mean residence estimation under section

4.5.

Comment: 2. 35 line 19: should it be affected instead of effected?

Reply: The word effected is replaced by affected

Comment: 3. 36 line 2: A reference is missing here.

Reply: The paragraph is now rephrased and appropriate references are given.

Comment: 4. 36 lines 3-8: This sentence is very hard to follow.

Reply: We thank the reviewer for the suggestion. The sentences are now rewritten in the revised manuscript.

Study Area and data sources

Comment: 5. 37 line 13-14: This sentence is hard to read.

Reply: The sentence is now rewritten in the revised manuscript.

Comment: 6. 37 line 14-16: Either all scientific names are given or none.

Reply: The scientific name is removed in the revised manuscript.

Comment: 7. 37 Line 17: Study should be plural (studies).

Reply: We have corrected and replaced study with studies.

Comment: 8. 37 16-23: It would be helpful if the authors include information about what the natural vegetation cover used to be.

Reply: We thank the reviewer for the suggestion. In both catchments hardly any natural vegetation can be found. According to the study of Teferi et al, (2013) in the Jedeb catchment, the human interventions for agricultural expansion had been started before 1950s. Nowadays cultivated land for agricultural purpose cover more than 70% of the catchment and the rest land cover is allocated to grazing, plantation forest and other land cover types. Moreover, according to their study, the natural forest in the Jedeb catchment that remained unchanged over the past 52 years accounted for only 2.2 km2 (∼1% of the landscape).

Comment: 9. 38 Line 4-6: the dates are wrong can't be from 2009 to 2001.

Reply: Now the date is corrected to 2009-2011.

Comment: 10. 38 line 7-12: wording is confusing.

Reply: The sentence is now clearly written.

Comment: 11. 38 line 18: it should be evapotranspiration instead of evaporation.

Reply: The word evaporation is replaced by total evaporation. Savenije (2004) argue that total evaporation is all forms of water changes from liquid to vapor, i.e. soil and open water evaporation plus transpiration and interception evaporation. This is often termed total evaporation.

Comment: 12. 38 line 18: Please provide some information about the Hagreaves method (i.e. input data, basic assumptions, etc).

Reply: We have elaborated the Hargreaves method in the revised manuscript. The method was selected due to the fact that other meteorological data (e.g. humidity, solar radiation, and wind speed etc) in the catchments are scarce and only temperature data was available for our case. Thus it limits the possibility to use different methods for the computation of potential total evaporation. However, the Penman-Monteith method, which has been applied successfully in different parts of the world, was compared with other methods and is accepted as the preferred method for computing potential evapotranspiration from meteorological data (Allen, et al., 1998; Zhao et al., 2005). The Hargreaves model was recommended for the computation of potential evapotranspiration, if only the maximum and minimum air temperatures are available (Allen et al., 1998). Hargreaves and Allen (2003) also reported that the results computing the monthly potential evaporation estimates obtained using Hargreaves method were satisfactory.

Methodology

Comment: 13. 39 line 5-7: This sentence is confusing?

Reply: The sentence is now clearly described in the revised manuscript.

Comment: 14. 39 line 15: A one sentence paragraph is inappropriate.

Reply: We agree on the comment and the paragraph is now included in to the preceding paragraph.

Comment: 15. 39 Line 21-22: I don't think it is necessary to give the equation.

Reply: The equation is ignored in the revised manuscript.

Results and discussion

Comment: 16. 44 Line 4: This section cites figure 3 in which all sources (precipitation, streamflow and spring water are shown. This figure has a lot of information that is not discussed in the paragraph. The paragraph could contrast different sources and cite also Table 3.

Reply: Detail discussion about figure 3 is given in the revised manuscript under section 4.1.

Comment: 17. 44 Line 20: Have you tested if the differences between Yewla and Fana Choke are statistically significant?

Reply: We thank the reviewer for the comment. In the revised manuscript Wilcoxon Signed Rank statistical Test is applied for Yewla and Fana Choke isotopic composition to test their differences statistically. To determine the difference between the isotopic values Wilcoxon Signed Rank statistical Test is applied. The test results show that the difference in the isotopic values at the two locations are statistically significant ($p=0.020$) evaluated at 95% confidence level.

Comment: 18. 45 Line 2: Why the use of "nevertheless"?

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Reply: We ignored the word nevertheless in the sentence.

Comment: 19. 45 line 8-9: Very difficult to read.

Reply: The sentence is now improved in the revised manuscript under section 4.2.1.

Comment: 20. 45 Line 12: Please explain the scatter in figures 5, 6, and 7.

Reply: The scatter points in figure 5, 6, and 7 show that the isotopic composition for different effects (e.g. amount, altitude, and temperature) have moderate effect in terms of the amount (R2 varies from 0.38-0.68), and low regression coefficient for the altitude effect (R2 varies from 0.26-0.39) and (R2 varies from 0.18-0.58) for the temperature effect.

Comment: 21. 45 line 16: please add p-values.

Reply: The p values are included in the revised manuscript.

Comment: 22. 46 line 5-11: Please address the high degree of variability (standard deviation) presented in Table 3. Reply: The high degree of variability is addressed in the revised version of the manuscript.

Comment: 23. 46 Line 12-29: Please add some statistical test to determine if the differences are significant.

Reply: We thank the reviewer for the comment. To determine the difference between the isotopic values at Yewla and Fine Choke a Wilcoxon Signed Rank statistical Test is applied. The test results show that the difference in the isotopic values at the two locations are statistically significant (p=0.020) evaluated at 95% confidence level.

Comment: 24. 47 Line 2: Cite Table 3.

Reply: Table 3 is now cited in the revised manuscript under section 4.2.2.

Comment: 25. 47 Line 7-8: The explanation given for similarities between Debre Markos and Rob Gebeya spring water signatures seems week. Elevation at these

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sampling locations is not considerably different than the elevation at Yewla.

Reply: We agree on the reviewer comment that the elevation difference between Yewla spring and Debre Markos spring is only about 84 m. However, as depicted by the isotope signals, the spring waters at Rob Gebey and Debre Markos seems to have similar pattern over the sampling period. Indeed we have tried to see their common recharge area from the plot of elevation versus isotopes signature of precipitation during the recharge period (i.e long rainy season) shown in figure 1. From the figure the recharge area elevation from the figure for Debre Markos and Rob Gebeya seems located at elevation between 2500-3000. Moreover, as depicted in the figure the isotope signature for Yewla spring exhibit less negative values might suggest the recharge area is starts at the lower part of the catchment. Therefore, it is likely that (Yewla spring found on lower portion of the Jedeb catchment might have different recharge area) and we speculate that Debre Markos and Rob Gebeya springs have a common recharge area in the highlands.

Comment: 26. 49 Line 7 Cite Table 3.

Reply: Table 3 is now cited in the revised manuscript.

Comment: 27. 49 lines 8-17 very difficult to follow. I think the results need to be presented first and then discussed relevant literature. In addition it is hard to understand what the authors mean by “reveal the variation in catchment storage” (line 15) by just citing a figure. More explanation is needed.

Reply: We thank the reviewer for the comment. More explanations are given and the entire paragraph has been rephrased in the revised manuscript.

Comment: 28. 49 Please elaborate on the water balance findings (Line 15-17).

Reply: The results of the annual water balance study (from the plot of annual evaporation ratio to aridity index in a Budyko (1974) curve) show that Chemoga catchment has a higher evaporation ratio than the Jedeb catchment.. Consequently, even though the

Chemoga catchment has a larger catchment area (358 km2) the discharge amount is lower than in the Jedeb catchment (296 km2). Furthermore, the water balance study indicate more surface runoff generation in these catchments, which is in line with the results of the seasonal hydrograph separation, which showed the highest event runoff component using stable isotope data.

Comment: 29. 49 Line 18: Figure 11 does not present d2H. Explain exactly what do you mean by damped.

Reply: We have made corrections in the text. The isotope composition of the input signal (precipitation) in the catchment and the streamflow output signal describe the age of water in the catchment using the fitted Sine wave regression method. The meaning of damped response of the output signal is that the isotope signature exhibit less variation i.e. decreases in standard deviation and amplitude, and lagged as compared to the input signal. This damped behavior in the Jedeb catchment indicates a relatively older age of groundwater than that of the Chemoga catchment.

Comment: 30. 50 Line 1-2. Please avoid single-sentence paragraphs.

Reply: The paragraph is now restructured in the revised manuscript.

Comment: 31. 51 line 19-22: This sentence is too long and confusing.

Reply: The sentences are rephrased in the revised manuscript.

Comment: 32. 51-52 The Uncertainty analysis section is poorly written and would benefit from some graphic display of results.

Reply: The section of the uncertainty analysis is rewritten in the revised manuscript.

Comment: 33. 52 Line 15-17: Discuss the strength of the fits presented in Figure 13. Is the methodology appropriate? What would the uncertainties in the estimated MRT of 4 and 6 months be?

Reply: The strength of the fit explaining the observed output isotope signal is moderate

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as it is shown by the coefficient of determination (R2 varies from 0.47 to 0.66). The method is appropriate, for the short record length and coarse frequency of spatial and temporal tracer sampling, which is typical for our case. Indeed the method gives an indicative first approximation estimate of mean residence times (Soulsby et al., 2000; Rodgers et al., 2005). Definitely, the estimated mean residence times have many uncertainties stem from different sources. For instance, the coarse spatial and temporal variation of isotope composition, and the steady state assumption of the mean residence time distribution could be mentioned.

Comment: 34. 53 Line 9-11: One sentences paragraph should be eliminated. Also comparison with other studies should be included.

Reply: The paragraph is now joined with the previous paragraph. Comparisons with results of similar meso-scale catchments are now included in the revised manuscript under section 4.5.

Conclusions

Comment: 35. Elaborate on the weakness of the short term sampling and resolution.

Reply: Short term sampling and resolution have a weakness to describe well the consistent travel time distribution of the water molecules entering in to the catchment at different time. Moreover, coarse resolution sampling might miss the dynamics of the travel time distribution and hence give a first order estimation of the mean residence time (Rodgers et al. 2005).

Tables

Comment: 36. Table 1: Should it be evapotranspiration instead of evaporation?

Reply: The word evaporation is replaced with total evaporation.

Comment: 37. Table 3: How are the mean values derived? (i.e. how many samples were considered)?

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Reply: The mean values were derived at each sampling location based on the number of samples analyzed in each month. The minimum and maximum number of samples used for the statistical representation was 10 and 31 respectively. The monthly amount weighted isotopic composition for precipitation and volume weighted for discharge have been used to derive the statistical parameters provided in Table 3.

Figures

Comment: 38. Figure 1: Some rivers appear disconnected.

Reply: Figure 1 is now corrected.

Comment: 39. Figure 3: Defined LMWL and GMWL in the legend or caption. This figure has a lot of information. I suggest more careful description within the text (Page 44, lines 5-12).

Reply: More explanation about the meteoric lines is given in the revised manuscript. Moreover the LMWL and GMWL are described in the caption.

Comment: 40. Figure 4: Why some of the markers for d18O are missing error bars? Please explain both in the text and figure caption.

Reply: The reason for missing markers of error bars for d18O is definitely due to the limited sample size for the particular months to meet the computation for the different quartiles. The reason is now clearly described in the revised manuscript.

Comment: 41. Figure 5: Please add p-values of R2.

Reply: The 'p' values are now included.

Comment: 42. Figure 6: I suggest using colors here because it is hard to understand. The caption needs to be reworded.

Reply: Figure 6 is corrected and the caption is now reworded in the revised manuscript.

Comment: 43. Figure 10: It is difficult to interpret. Please add land marks (i.e. ocean names,Countries names, etc.).

Reply: Figure 10 is now corrected.

Comment: 44. Figure 13: what does "A" stands for? There is no mention in the text of neither the R2 nor of these "A" values.

Reply: A, which is the amplitude and the R2, coefficient of determination is now described in the revised manuscript under figure caption.

References:

Allen, R. G., Pereira, L. S., Raes, D., and Smith, M.: Crop Evapotranpiration: Guildlines for computing crop water requirements, FAO Irrigation and Drainage Paper No 56. Food and Agriculture Organization, Land and Water. Rome, Italy, 1998.

Budyko, M.I.: Climate and life. Academic, New York, 1974.

Hargreaves, G. H., and Allen, R. G.: History and Evaluation of Hargreaves Evapotranspiration Equation. Journal of Irrigation and Drainage Engineering, 129 (1), 53-63, 2003.

Rodgers, P, Soulsby, C., Waldron, S., and Tetzlaff, D.: Using stable isotope tracers to access hydrological flow paths, residence times and landscape influences in a nested meso-scale catchment, Hydrol. Earth Syst. Sci., 9: 139–155, 2005.

Savenije, H.H.G, (2004). The importance of interception and why we should delete the term evapotranspiration from our vocabulary. Hydrological Processes, 18(8), 1507-1511.

Soulsby, C, Malcolm, R, Helliwell, R, Ferrier, R.C., and Jenkins, A.: Isotope hydrology of the Allt a' Mharcaidh catchment, Cairngorms, Scotland: implications for hydrological pathways and residence times, Hydrol. Processes., 14: 747–762, 2000.

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Zhao, C., Nan, Z., and Cheng, G.: Evaluating Methods of Estimating and Modeling Spatial Distribution of Evapotranspiration in the Middle Heihe River Basin, China. American Journal of Environmental Sciences, 1 (4), 278-285, 2005.

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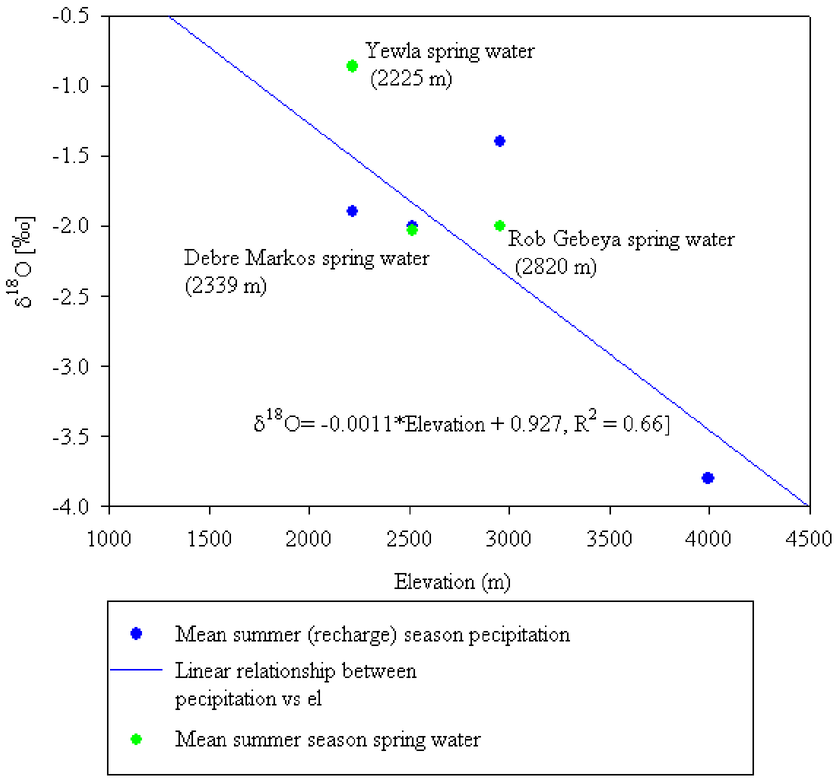

Fig.1 Weighted mean d18O of precipitation vs altitude showing the mean recharge elevations.

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