Referee #1

The manuscript "Hydroclimate and bedrock permeability determine young water fractions in streamflow across the tropical Andes mountains and Amazon floodplain" by E.I. Burt et al. proposes an analysis of the young water fractions in a set of small and mesoscale catchments in an area without or with scarce previous information.

The subject is timely and the area is poorly known, the paper is well structured and written and the figures and tables are adequate.

Nevertheless, the methods are rather outdated because the authors follow the approaches used in the early works when relevant aspects such as the importance of the sampling rate and the dependence of young water fraction on stream discharge were not yet sufficiently described. Some of the more significant papers in this aspect are cited by the authors in the discussion but not taken into account in the methods.

This means that the results obtained in this work are largely suspect to be dependent on the flow regime of the streams and on the moments when the samples were taken respect to the flow regime. The relationships obtained between the young water fractions and the characteristics of the catchments, stated from the title, may therefore be spurious.

In my opinion, the manuscript could be accepted for publication in HESS if the following recommendations are followed.

We thank the reviewer for their feedback. We are pleased that they recognize the timeliness and relevance of our work. Of course, we would have loved to collect higher time resolution data, as used in some recent papers estimating catchment young water fractions and their discharge-dependence — yet such sample collection was precluded by the extremely remote location and challenging conditions at our sample sites, as well as our focus on studying multiple catchments to capture differences between them. These factors are described more below.

We have evaluated discharge-dependence within our dataset, and while not as rich in information as we might have hoped (or might be possible with higher frequency sampling), the results do substantiate our interpretations of systematic differences between the catchments in our study, as described more below. We hope this clarification helps to allay the reviewer's concern that the relationships we identify may be artifacts of the sampling regime.

1) Given the scarce sampling rate and the lack of comparison with the flow regimes, the conclusions of the work should be removed from the title, which should be less conclusive.

We have updated the manuscript title to:
"Isotope-derived young water fractions in streamflow across the tropical Andes mountains and Amazon floodplain"

2) The sampling scheme did not follow strict time intervals so the 'unweighted' young water fractions are not time-weighted but of uncertain significance. Therefore, I strongly recommend to use only the 'volume-weighted' (the usual term is flow-weighted) young water fractions in the text, discussion and conclusions while the unweighted water fractions can be shown in a table just for comparison.

We have changed "volume-weighted" to "flow-weighted" and now use only the flow-weighted Fyw unless explicitly stated otherwise. We still include the unweighted results in Figure 7a and 8d for reference.

3) The dependence of young water fraction on discharge (discharge sensitivity) should be analysed. This dependence has been scarcely investigated but may inform on the behaviour of the catchments and be more robust for catchment comparison, because it might be less dependent on the sampling scheme and more appropriate than the young water fraction in this work. This dependence may be stated for every catchment using the equation (6) in the Gallart et al (2020) paper already cited in the manuscript.

When we first read the Gallart et al (2020) paper, we were excited by the findings and curious to see if we could apply a similar method to our dataset. There were several factors that limited our ability to apply the referenced Equation 6 to our data:

1. Given the remote location of the studied watersheds, as well as the especially challenging field conditions (including high temperature and humidity that rapidly rusts metals and degrades electronics, diverse animals that chew tubing and cables, low sunlight at ground level), it was impossible to employ auto sampling devices. Collecting all samples by hand limited the ability to sample across many quantiles of flow for each stream, especially for these streams which were all > 1km (often more) from any permanent structures.

2. Additionally, given that we were interested in answering questions about how the geomorphic gradient of the Andes mountains to Amazon foreland floodplain influenced the stream young water fraction, we opted for a greater spatial resolution — sampling seven different watersheds — and ultimately sacrificing the high temporal resolution achieved by Gallart et al. (2020) for one watershed.

However, despite these limitations, we still attempted to apply the framework from the Gallart et al. paper early on in our work, to see if it would be useful. For 6 of the 7 studied watersheds, we had enough oxygen isotope data to divide into four quartiles, based on discharge. We then calculated the young water fraction for each of the quartiles of isotope data. The figure below shows the results. We had initially decided not to include these results in our manuscript due to the

high uncertainties. And, with respect to the reviewer's comment, we still maintain that these uncertainties (and our limitation of calculating only across discharge quartiles) make application of Eq. 6 from Gallart et al. difficult.

Yet despite the high margins of error (due to the small number of samples in each quartile), there are some interesting points that emerge from this analysis, worth pointing out in the context of the reviewer's question. Given the interest in discharge-dependency of F_{yw} as expressed by the reviewer, we have also added these plots to panels in Fig. 6, with ample caveats about the large uncertainties.

Key takeaways from this figure include the observation that all the sites (except for 276-SC, most likely due to a small number of sampling points) point to an increase in the stream young water fraction with increasing discharge quartiles — much as expected based on prior work (e.g., Gallart et al., 2020) — albeit with very large uncertainties that preclude unequivocal interpretation or further quantitative analysis of the discharge-dependency. Yet, importantly, the mid-elevation sites (especially Site 1540-SC) have the overall highest F_{yw}, and F_{yw} increases consistently across the quartiles. F_{yw} increases with discharge also for the high Andes sites (3472-SC and 3077-SC), but the values are systematically lower than for the mid-elevation 1540-SC site. Thus, the high overall F_{yw} that we calculate at 1540-SC is not simply an artifact of discharge dependency but holds across all discharge quartiles. This consistency suggests that the differences we observe between catchments are not simply differences in discharge-dependency but rather reflect underlying hydrologic behavior of the catchment. Site 2432-SC has a very high F_{yw} for the highest quartile, which is caused by several storms that had a distinct isotopic influence on the stream oxygen isotope composition. This effect explains the very large range in bootstrapped F_{yw} values in Fig. 7b, and it is worth pointing out that the range in these bootstrapped values implicitly captures the effect shown in the quartile plots (e.g., similar values across the quartile plots will yield tight distributions in the bootstrapped results, and vice versa).

A more detailed explanation of the resampling approach used is recommended

We agreed with this comment and added a thorough explanation of the resampling approach at the end of section 2.2 (Lines 395-400; 440-45).

Finally, the current knowledge shows that "it has been difficult to identify a simple topographic control on young water fractions at the global scale" because of the inadequate and variable sampling schemes and the lack of consideration of flow regimes. Different sampling schemes and periods can give different results (Stockinger et al. 2016 and 2019, Gallart et al., 2020). The authors should propose a final conclusion more adequate to the limited sampling schemes used in their work.

The reviewer raises a fair point. It is not our purpose in this manuscript to assess all the factors that may affect results from prior studies. Yet we do think our

results highlight the potential complexity of catchment transit times in mountainous terrain and have rewritten this sentence to capture that point, as follows:

“Our results emphasize the complexity of the role of mountainous regions in the hydrological cycle, with more factors than topography likely to control young water fractions at the global scale.”

Suggested paper not cited in the manuscript: Stockinger et al. (2019). Time variability and uncertainty in the fraction of young water in a small headwater catchment. Hydrol. Earth Syst. Sci., 23, 4333–4347

We thank the reviewer for drawing our attention to this paper. We have now cited this paper on line 1153.