Comment on hess-2022-279
Anonymous Referee #1

Referee comment on "Hydrological, meteorological and watershed controls on the water balance of thermokarst lakes between Inuvik and Tuktoyaktuk, Northwest Territories, Canada" by Evan J. Wilcox et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2022-279-RC1, 2022

Overview

This manuscript presents a study of thermokarst lakes in the Northern Territories, Canada, investigating hydrological, meteorological, and watershed controls on the lakes' water balance. Twenty-five lakes were sampled five times over the spring-summer season in 2018 and analyzed for stable oxygen and hydrogen isotope ratios. The isotope data were used to calculate the evaporation-to-inflow (E/I) ratio and the isotopic composition of lake source water (δ$I$). Four water balance phases were identified, associated with shifts in meteorological and/or hydrological changes. The E/I and δ$I$ were compared to meteorological and watershed data (e.g., precipitation amount and watershed area to lake area ratio (WA/LA)). Subsequently, the relationship between WA/LA and E/I was used to estimate the average E/I of 7340 lakes in this region, finding that the lakes are not vulnerable to desiccation, and that lakes with smaller WA/LA are likely to be more influenced by increased evaporation in a future warmer climate.

General comments

The manuscript presents an interesting approach to evaluate water balance changes and to estimate E/I, which is relevant for the scope of HESS. The manuscript is well written with an easy-to-follow structure and clear figures. However, there are some issues with the dataset size and associated assumptions that need to be more clearly outlined. I also have some questions concerning the chosen method to infer δ$I$. I have listed my concerns and suggestions for improvement/clarifications below.
Precipitation dataset size: I have some concerns about the small size of the precipitation dataset used for the “isotopic framework”. Are 11 snow samples and 13 rain samples enough to produce a reliable LMWL and estimate δ_P, or would it be better to use a more conservative approach and use the GMWL? How well do the precipitation samples cover the annual range of precipitation isotopic variability in this region? And why not compare your data to GNIP data from Inuvik (from the 1980s)? Justify your approach to use local precipitation data (because they are most representative for the study area and cover the same period as your lake water dataset?). How does the uncertainty related to the precipitation data affect the uncertainty in the δ* and δ_I calculations? Some more information about the precipitation samples would be useful to clarify how well estimated δ_S, δ_R and δ_P are. Were the snow samples collected soon after snowfall, or can the “end of winter snowpack” have experienced post-depositional fractionation processes (e.g., sublimation) before sampling? Were the liquid samples event-based and/or representing all precipitation events from May to September 2018? Have the precipitation isotope data been amount-weighted? Please clarify.

Analytical uncertainty: Are duplicate measurements of every fifth sample enough to determine the analytical uncertainty? In many labs, each sample is injected multiple times (sometimes more than 10 times), the first replicate(s) discarded, and the rest used to calculate an average. How did you deal with drift and memory effects?

Isotope framework: I generally like the approach to present an “isotopic framework”, but some clarifications are needed when comes to presentation of isotope data and the used terminology. One example is the inconsistent use of the delta notation (δ). Some examples of this are on line 44 where δ is missing when introducing water isotope analysis (which is the analysis of the stable isotope ratios δ^{18}O and δ^2H), and ‘δ-δ space’ which should be ‘δ^2H-δ^{18}O space’. There is also a parenthesis missing in equation 1, which should be written: δ_{sample} = (R_{sample}/R_{VSMOW}-1) * 10^{3}. These fundamental things need to be stated correctly. Furthermore, it is not clear when δ_t is referring to δ^{18}O_t and when/if it refers to δ^2H_t as well?

Approach to calculate δ_I: Have you considered using the more recent ‘MWL source implementation’ method by Bowen et al. (2018) to model δ_I values? Using this approach, you supply a MWL equation (you could test the GMWL and your LMWL to see how much difference it makes) and a hypothesized LEL slope with confidence intervals, as well as your lake water δ^2H and δ^{18}O values with uncertainties.

Specific comments

Lines 18-19: Rephrase the sentence starting “WA/LA strongly predicted average lake E/I ratio (R^2 = 0.74)...” to “Lakes with smaller WA/LA tended to have higher E/I ratios (R^2 = 0.74) because they received relatively less inflow. I think “strongly predicted” is an
exaggeration.

Line 40: evaporation-to-inflow ratios. Use this wording throughout the paper (sometimes it says evaporation to inflow, sometimes evaporation/inflow ratio).

Line 44: Change to “In several studies, stable water isotope (δ^{18}O and δ^{2}H) analysis...” and add a couple of references.

Line 60: Explain the concept “snowmelt bypass” here. Now it isn’t explained until in the methods (lines 88-89).

Line 74: Remove “All lakes we selected were either headwater lakes or downstream of lakes that we sampled”, since this information is repeated on lines 76-77.

Line 87: How much did the first day of ice-free season vary between the lakes?

Lines 88-89: Move the definition of snowmelt bypass to the introduction and rephrase it. This sentence does not read well and needs to be clarified.

Line 97: Explain “end-of-winter snow”. Does this mean that you sampled the snow in the end of winter soon after it fell, or that you collected a core of snow accumulating over a longer period? If the latter, how do post-depositional processes impact the isotope values?

Line 98: Are δ_S and δ_R amount-weighted? Change to δ_{Snow} and δ_{Rain} throughout the text to match the terms used in Figure 3 (or change to δ_S and δ_R in the figure).

Line 107: Equation misses parentheses around (R_{sample}/R_{VSMOW} - 1)

Lines 113-114: When introducing the “fundamental linear relationships”, describe the global relationship (i.e., the GMWL) as well. This could also be added to Figure 3.

Line 114: Change ‘δ-δ space’ to ‘δ^{2}H-δ^{18}O space’ (also on line 122).
Line 116: Is $\delta_p$ the average between the two $\delta_s$ and $\delta_r$ values, or the average of the full range of rain and snow values?

Lines 116-122: As it is explained now, it is not clear how the LEL was defined. Looking at Figure 3, the slope of the LEL is different between $\delta_p$ and $\delta_{SSL}$ compared to between $\delta_{SSL}$ and $\delta^*$? It also says that $\delta_{SSL}$ is located along the LEL. Which line is the LEL equation referring to? Why is it not a straight line from $\delta_p$ to $\delta^*$? Please clarify.

Line 122: What does SSL stand for? Add reference for $\delta_{SSL}$ definition.

Lines 126-128: Describe the $\delta_i$ calculation here as well (not only in the appendix).

Line 131: “where $\delta_i$ is the isotope composition of the lake water and $\delta_e$ is the isotope composition of evaporated vapour from the lake (Gonfiantini, 1986)”

Line 136: cumulated rainfall?

Lines 150-151: What do you mean by “data were transformed if the distribution was non-uniform”?

Line 152: Rephrase this sentence (removing the “strong”) and add the $R^2$-value.

Line 170: This is the first time you use $\delta^{18}O_i$. Does $\delta_i$ mentioned throughout the paper refer to $\delta^{2}H_i$ and $\delta^{18}O_i$ collectively, or $\delta^{18}O_i$? Please clarify.

Line 170: “We observed distinct shifts in lake water isotope composition along the LEL...” – This is not easy to read from Figure 3. Do you mean for individual lakes, or the lakes in general? It could be interesting to indicate which lake is which, to be able to compare the different lakes’ responses during P1-P4. This could for example be done (in a supplementary figure?) by giving the lakes different colors, and assign each sampling date a different symbol, and/or by drawing lines between data points from the same lake.

Lines 174 and 180: Remove “very”.


Lines 178 and 184: Change “compositions” to “values”

Lines 193-194: “On September 3, some lakes plotted close to the LMWL, indicating that their waters had experienced negligible amounts of evaporation (Figure 3).” Does this mean that the same lakes plotted on the LEL before, and that the high precipitation amounts during P4 “reset” the lake water to be closer to δ₁ by removing the old evaporation signal?

Line 196: Two thirds of the lakes.

Line 221: Remove “results” before “appears”.

Lines 245 and 246: Change “cooler” to “lower”.

Line 278: Earlier you mention only 5 downstream lakes (e.g., in Table 1). Where did the 6th lake come from (also presented in Figure 5)?

Line 320: evaporation

Line 321: led

Line 329: remove “as high as”

Line 357: Is δₚₛ the value referred to as δₚ in Table A1, or where do you present that value?

Figure 1: Add overview map (e.g., Canada), and add black triangles and red square to legend.

Figure 2: Add reference to meteorological data. Clarify that you show the cumulative precipitation amounts. The sample days are shown by vertical dashed, not dotted lines. Mean daily air temperatures are indicated by horizontal dashed lines.
Figure 3: Please explain all elements in the caption, e.g., that the $\delta_{\text{Snow}}$, $\delta_{\text{Rain}}$ (which are called $\delta_S$ and $\delta_R$ in the text) and $\delta_p$ are averages (it looks like $\delta_{\text{Rain}}$ displays the median, but maybe the average and median are very close?), what the box and whisker plots show, and that the numbers refer to sampling dates. It would also be good to add the GMWL for reference. Which line does the LEL equation refer to? The line between $\delta_p$ and $\delta_{\text{SSL}}$ and the line between $\delta_{\text{SSL}}$ and $\delta^*$ have different slopes. Why? Change color for the snow samples or the May 1 samples, as it is confusing that both are displayed in grey. You could also use different symbols for precipitation samples and lake samples, to make them easier to differentiate.

Figure 4: It says four sampling dates in the caption but should be five. What do you mean by “lake-specific” change in E/I in (c)? Why not also present a panel with the measured $\delta^{18}$O values, to see how much these values differ from $\delta^{18}$O_i?

Figure 6: Are the temperatures and precipitation values in from the year of lake water sampling or the 1980-2020 values? And how were the curves in the three lowermost panels generated? The E/I values at the sampling dates are not the same as presented in Figure 4b? And how were the values between the sampling dates interpolated? Please clarify.

Table 1: Change Polygon Extent to Ice-wedge Polygon Coverage.

Table 2: Clarify in caption that you mean $\delta^{18}$O_i. What do you mean by “adjusted R^2”?

Reference