

## RESPONSE LETTER

Prof. Dr. Didier Gastmans  
Environmental Studies Center – São Paulo State University  
Av. 24A, 1515 – Rio Claro (SP) – Brazil

Rio Claro, February 27, 2024.

Dear. Dr. Thijs Heus,

We appreciate all the extensive work on the several revisions provided to improve our manuscript. In this version, we have attended all the minor and major comments provided by a single reviewer. Two faculty members at US-based institutions have reviewed the final English style. The main change in the article relates to the intra-event evaluation, where the results and figures in this section have all been reworked and improved. The figures speak for themselves, and only the main message is presented in the text, avoiding the excessive use of data-rich paragraphs. Sentences were shortened to make this reading more enjoyable. The results section was reduced by at least two pages, aiming for a more concise scientific average. Detailed point-by-point responses to the single referee's comments are presented below.

### Major comments

1.1 Clarify section 2.6 on the sub-cloud evaporation model and use it in the discussion, or remove.

**Response:** As suggested by the reviewer the entire model section was removed.

1.2 Physical meaning of  $\delta_{\text{initial}}$ ,  $\delta_{\text{med}}$  and  $\Delta\delta$ ? Section 2.7

$\Delta\delta$ : can the max and min be anytime in the event? If so, what physical meaning does it have? In addition, how sensitive is it to the duration of the sample collection? e.g. longer duration for sample collection may artificially reduce  $\Delta\delta$ ? And how sensitive is it to the threshold of rain amount that could be used as samples? e.g. if smaller samples are collected at the end of events, they may be more evaporatively enriched?

**Response:** Since the model section was removed,  $\Delta\delta$  is not present in the text anymore.

Same for  $\delta_{\text{med}}$ : what physical meaning does it have? Why not simply using the precipitation-weighted  $\delta$ , as in most studies? I expect that the precipitation-weighted  $\delta$  of the event would be more representative of the large-scale vapor.

**Response:** The weighted average is most used in studies with monthly and daily data. However, we understand your point. Since we were doing an inter-event assessment, the weighted average represents the weight of rainfall, so the processes that become more apparent are ultimately regional. In this context, we have included the weighted average to discuss regional processes, accepting the reviewer's suggestion.

It is assumed at several locations (e.g. l 212, l 351) that  $\delta_{\text{initial}}$  is representative of the large scale vapor. This is not convincing. Usually,  $\delta_{\text{initial}}$  is affected by rainfall evaporation, because the first raindrops often fall with low rain rate and drier conditions, e.g. [Risi et al., 2010, Tremoy et al., 2014].

**Response:** While potential initial evaporation has been discussed in the literature, based on the relatively high RH values over the study area and in the vertical profiles, its effects are most likely minimal. Also, many studies forget that rain does not form under the collection point, so the idea that the evaporation process influences the isotopic composition is more appropriate for this initial condition, the first rain after the formation of the system. In our case, and many others, the rain has already formed and is passing over the collection point. A few kilometers before the rain system arrives, the humidity and temperature begin to change, increasing and decreasing as the rain arrives. The question is: how much of this change in humidity is enough to cause evaporation in a growing or mature convective rain system? I think this would be very difficult to answer without vapor isotope data. In this context, we believe that the initial value represents the mix of regional processes before the arrival of this system at the collection point. This system mixes with local conditions as it passes over the sampling point, resulting in the observed isotopic variation pattern. To better clarify these comments, a specific study would be more appropriate, so we have decided to also remove the  $\delta_{\text{initial}}$  parameter from this version of the article and focus on how local controls produce changes in the isotopic variation pattern of rain.

I advise to use precipitation-weighted  $\delta$  for analysis at the inter-event scale. At the intra-event scale, clarify what  $\Delta\delta$  means or use something more physically relevant.

**Response:** Recommendation accepted, excluding all isotopic parameters ( $\delta_{\text{initial}}$  and  $\Delta\delta$ ) from the previous version and using the weighted average as the main parameter for inter-event analysis.

### 1.3 Description of the results is too lengthy

Section 3.3 is very painful to read. It would help so much the reader to present the results in a more synthetic way. The most interesting part is in the discussion, but when the reader arrives at the discussion, the results section was so long that everything is forgotten. In the results, focus on what is useful to remember to follow the subsequent discussion.

**Response:** We recognize how painful it was to read this section with data-rich paragraphs. The overall section was smoothed and reduced by almost 50%. The reading is more enjoyable now.

## **2 Minor comments**

### Abstract

Reword as: During summer, the  $\delta_{\text{initial}}$  values were lower due to higher rainfall along trajectories from the Amazon forest, whereas during autumn and spring, the  $\delta_{\text{initial}}$  values were higher due to lower amount of rainfall along trajectories from the Atlantic Ocean and Southern Brazil.

**Response:** This phrase was removed.

Meteorological > isotopic?

**Response:** The word was modified.

Modelling > model evaluation

**Response:** The word was modified.

## Introduction

“quick condensation and formation of precipitation with substantial droplets heavy rainfall” - > “large condensation and precipitation rates” (it's more quantitative, and substantial droplets doesn't mean anything).

**Response:** The sentence was modified.

merge paragraph (weather systems)

**Response:** The paragraphs were merged.

de Vries et al 2022 is for squall lines, so it is a convective systems. Other precipitating events have been well studies as well: e.g. mid-latitude cyclones, fronts... e.g.[Barras and Simmonds, 2009, Celle-Jeanton et al., 2004, Aemisegger et al., 2015, Thurnherr and Aemisegger, 2022, Landais et al., 2023, Muller et al., 2015]. They deserve to be cited.

**Response:** The cited articles were not included in the section recommended by the reviewer, which focuses on convective processes and their impact on isotopic composition. Instead, they were added to the subsequent paragraphs that mentioned atmospheric systems studied at high frequency.

remove “and local evaporation effects”, because it is not a weather system

**Response:** The sentence was modified.

this mixes too many different things. Reword as “High-resolution isotope information can provide a better insight into the isotopic variability during the life cycle of rainfall events”.

**Response:** The sentence was modified.

## Data and methods

“Preliminary assessment of local processes” -> “Quantifying the impact of post-condensational Processes”. It's more specific. “Below ... conclusions.”: avoid repetitions: suggestion: “Below-cloud atmospheric conditions are known to affect the rainfall composition through rain-vapor interactions. Since the isotopic composition of near-ground water vapor during the rainfall events was not measured, the framework proposed by Graf et al 2019 cannot be applied here.” And then go on explaining what you do instead.

**Response:** The section 2.6 was deleted.

**Results:** The outline suggested by the reviewer was accepted, and the entire section on intra-event results has been rewritten.

Reword as: “thermal convection over land lead to convective rainfall”

**Response:** The sentence was modified.

## Discussion

“Detailed” > “description”

**Response:** The word was modified.

“were provided by both inter- and intra-events” > “was provided at both inter- and intra-event Scale”

**Response:** The sentence was modified.

“were provided by both inter- and intra-events” -> “was provided at both inter- and intra-event scale

**Response:** The sentence was modified.

“Such... rainfall”. Remove, I don't understand what it means.

**Response:** The sentence was deleted.

“of moist” -> “from moist”

**Response:** The word was modified.

“representing” > “during”

**Response:** The word was modified.

#### Discussion – regional atmospheric controls

“enhanced... processes” > simply “enhanced evapotranspiration”

**Response:** The sentence was modified.

“Now ... its is possible ...” -> “In the extreme case where all the water vapor that is lifted by convection and condenses comes from evapotranspiration, it is possible ...”

**Response:** The sentence was deleted because equation 7 was deleted, too.

About equation 7: “the assumption of isotopic equilibrium may be relevant for the first condensate, but the first condensate is not relevant to represent convective precipitation, which integrates condensation at all altitudes. This is why the calculated values are completely unrealistic for precipitation”.

“I would replace all this calculation with unrealistic assumptions and unrealistic results by simply citing previous studies that have properly investigated the impact of evapotranspiration on the vapor and rainfall composition, e.g. [Salati et al., 1979, Worden et al., 2007, Brown et al., 2008, Levin et al., 2009, Risi et al., 2013, Worden et al., 2021]“.

**Response:** We completely agree with the reviewer. Equation 7 has been removed. The entire explanation has been modified, and all the suggested references have been included.

#### Discussion – Local atmospheric controls

One of the reviewer's main questions was: “Reword to explain that both the vertical structure of rainfall and the humidity impact the local isotopic composition of rain?”

**Response:** To explain how the vertical profile of the rain influences the isotopic composition, we decided further to investigate the radar reflectivity ( $Z$ ) data. To do this, we quantified the  $Z$  values in the vertical profile as described in Methods section 2.5. By quantifying the variation in  $Z$ , we can see that changes in its values illustrate the process of capturing water particles in the raindrop, so that the more it is captured, the higher the concentration

of water in the raindrop and, consequently, the higher the reflectivity. Events with a vertical variation in  $Z$  indicate a change in this droplet formation process. We can see that these changes correspond to large variations in the  $\delta^{18}\text{O}$  values, especially in the  $d$ -excess values. These variations are confirmed by the significant correlations found between  $Z$ ,  $\delta^{18}\text{O}$ , and  $d$ -excess. Regarding the influence of humidity, we believe that more data from the vertical humidity profile measured in situ could help, as, unfortunately, it is not possible to have them; we believe that the influence of humidity on intra-events ends up being minimal because even at  $d$ -excess values of less than 10, the humidity values at the surface were above 90%. For more details on the local meteorological controls, see section 4.2 and Figures 5-8.

### Conclusion

“demonstrating..”: Remove. Grammar problem, and not really true (convection and evapotranspiration may impact the isotopic composition even if these two processes don't interact)

**Response:** The sentence was modified.

“During ... rainfall”-> “Within convective events”; “grammar problem”

**Response:** The sentence was modified.

“The critical ... rainfall”: remove or be more specific. Generally, this study doesn't convincingly argue for the impact of the vertical structure”.

**Response:** The sentence was modified, and the impact of the vertical structure was included.

“certain specific conditions of low humidity of ambient.” -> “low ambient humidity.”

**Response:** The sentence was removed.

“remove. This study did not investigate the conditions of convective rainfall, rather its isotopic composition”.

**Response:** The sentence was removed.

“clarify. You mean that applying linear regressions based on present-day observations for paleoclimate applications should be taken with caution? Is this due to an issue with the time scale? If so reword and clarify.”

**Response:** The sentence was modified.