



## ***Interactive comment on “Spatial variability of northern Iberian rainfall stable isotope values: Investigating climatic controls on daily and monthly timescales” by Ana Moreno et al.***

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We appreciate very much the constructive comments by Rev3 which have certainly helped to improve our manuscript. The level of detail of his/her comments is extraordinary and very helpful. Here we comment on some issues related to his/her notes which are of particular importance.

General comments

1) Organization of the manuscript and writing. We appreciate the recommendations from Rev3 to improve the structure of the manuscript (eg. merging chapters 4 and 5)

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Discussion paper

and, accordingly, have modified the organization ending with a Results and Discussion section divided in six subsections. We also avoid repetitions, such as the two previous sections in the text where we talk about meteoric water lines. Some of these ideas are in line with those proposed by Rev2 to shorten the manuscript, so we think the final version is certainly improved and have increased its readability.

2) Source regions and backward trajectories. Rev3 considers insufficient our study of back trajectories to discriminate the moisture source at the study transect. We agree with this argument and it probably represents the largest change we have carried out in this version. In fact, it is true, that most trajectories have an origin in the NW, but they later follow a sometimes quite complicated path with different options of moisture uptake. Therefore, we agree that the study of the trajectories alone is not able to represent the processes we want. Therefore we, first, have replaced Fig. 5 by S1 as Rev3 suggested to obtain our results from trajectories extracted the last 1 or 2 days. Second, we have performed a new analysis to calculate moisture uptake in all events (850hpa trajectories). We use Baldini's method (Baldini et al., 2010) in a more restrictive way (see also Iglesias González, 2019) to identify the locations where moisture uptake processes have been produced during the 48h before the rainfall samples were collected. Taking into account that Iberian Peninsula is surrounded by ocean, together with the fact that most of the rainfall events analyzed in the investigation were produced by frontal systems and convection events (see synoptic analysis), only 850hPa airmass moisture uptake events have been considered as relevant in our new analysis. In addition, while Baldini et al, (2010) considered moisture uptake processes with an increase in 1h of 0.1 gH<sub>2</sub>Ov/kgair as significant, in our analysis we only took into account events where moisture uptake process where higher than 0.25 gH<sub>2</sub>Ov/kgair, so if exists any influence in the rainfall isotopical signal, it would be easier to identify than in other previous studies. With this restricted method, and considering all the events analyzed, more than 3000 moisture uptake events have been identified. These events were analyzed considering seasonal variability and the different locations where the rainfall samples were collected. With this new analysis, we are able to identified changes in the mois-

ture uptake location distribution of the airmasses which produces rainfall events along the Iberian transect. These results are now discussed in detail and represented in a new figure.

Specific comments (Rev3 comments are indicated as RV3)

RV3 Line 2. The title refers to “climate controls” on the variability of isotopic composition in rainfall. The study itself though seems more to be focused on meteorological processes such as moisture pathways and weather regimes/precipitation types of rain days. Perhaps, the authors may consider to use or add another term such as “weather”, “meteorological”, or “atmospheric”?

Good suggestion! We use atmospheric.

RV3 Line 39-40. Perhaps, besides referring to the dataset, this concluding sentence may also refer to the analysis that helps to understand rainfall isotope variability in relation to meteorological / atmospheric processes and geographic influences?

Good suggestion! Change “dataset” by “analyses”.

RV3 Lines 73 and 74. The term “trajectories” is perhaps quite technical for the introduction. Instead, a term that refers to actual physical processes, such as “air mass origins” or “air mass transport” may be more appropriate.

Done

RV3 Lines 80-85. This is a crucial paragraph as it outlines what the intention of the study is, and what it adds to previous studies as outlined in the text above. The thought behind the first sentence “In this paper . . .” is not clear to me. Is the approach, based on multiple stations new and is that the main selling point of the paper? Or is this study presenting a comprehensive analysis based on multiple stations across the Atlantic-Mediterranean transect? In the first case, the authors may write “we introduce a new approach. . .”, and in the latter case, “we present a comprehensive / multiple perspective analysis on daily and monthly . . .”. Also, is it really new that a study considers

multiple stations across a region? If other studies followed such an approach, perhaps for other regions, this may deserve attention in the introduction to provide context for this study, for example by adding a new paragraph. In addition, this paragraph may explicitly refer to the atmospheric processes and geographic factors that influence the isotopic rainfall variability that are addressed in this study to guide the reader's expectations.

We are presenting a comprehensive analyses based on multiple stations, not certainly "a new approach" since there are many studies using multiple stations. Some of those previous references are included now in the introduction. We also added some information about the processes and factors we are going to address in the manuscript.

RV3 Line 87. This section addresses besides the site description and climate also the different weather regimes that bring precipitation over the northern Iberian Peninsula. This may be reflected in the title of the section.

Done.

RV3 Lines 103-104. The phrase "also easterly advections over the Mediterrean Sea" sounds somewhat vague. Please, rewrite, perhaps in the direction of "fronts that approach the Iberian Peninsula from the east (backdoor cold fronts)".

Done

RV3 Lines 119-122. While reading this paragraph I somehow lost the storyline. The first sentence refers to the dominant source regions and seems to follow as a conclusion from the text above, while the next sentence introduces the four different climate zones. The authors may consider to add the first sentence to the paragraph above (or elsewhere), and to start a new paragraph with the second sentence.

Yes, we agree and have removed the first sentence.

RV3 Then, the introduction of the four climate zone regions is hard to follow; It may help rephrase this sentence as, for example, "Below, the seven stations are grouped

into four regions and described in terms of their climatology”. Also, it feels somewhat chaotic to refer at this stage multiple times to Figure 4 while Figures 2 and 3 have not yet been discussed. Is it necessary to include the line “Regional meteorological data are provided in Figure 4A.”?

Done. We have removed references to Fig. 4 that were unnecessary.

RV3 Lines 123-127. Can this paragraph be shortened by saying “The sites of El Pindal and Oviedo...” and removing the sentence on lines 126-127 “Additionally, ... in this study.”?

Done

RV3 Line 197. To what “Meteorological data” is referred? If this is the air temperature and precipitation, please, remove the brackets, and rephrase the sentence to place more emphasis on these meteorological variables, for example, as “Air temperature and precipitation are obtained from the closest meteorological stations over the sampling periods, as indicated in Table 1, to investigate . . . .”

Done

RV3 Line 292. Usually, when referring to the ERA-Interim analysis Dee et al. (2011) is cited.

Done.

RV3 Lines 211-238. In this paragraph I feel quite overwhelmed by the many references to Tables and Figures for which here only the applied methodology is described (e.g., Tables 3, 4, and 5 and Figure 5). I would recommend to only refer explicitly to the Tables and Figures when discussing the scientific results, not when describing the used (statistical) methods.

We partially agree about this. . . but citing tables here is quite necessary to refer to the place where the reader can find the data associated to that analysis. We have kept the

references to Tables and removed those to Figures.

RV3 Lines 223-224. Which reanalysis data are the HYSPLIT simulations using? This should briefly be mentioned, including the resolution of the underlying reanalysis.

Done. We have included this brief sentence: “GDAS (Global Data Assimilation System) have been used in Hysplit simulations with  $0.5^{\circ} \times 0.5^{\circ}$  spatial resolution”.

RV3 Line 226. One should be cautious with referring to the origin of the rainfall using an analysis that is solely based on air parcel trajectories without taking into account the uptake of moisture along its pathways. The part of the sentence may be rephrased in the direction of “to generate a vector representing the mean trajectory of the air mass transport associated with the precipitation”.

Yes, we agree. In this new version, a procedure to consider moisture uptake is included (see general comments above)

RV3 The titles of sections 4.1 and 4.2 may be rephrased as “Daily rainfall isotopic variability” and “Monthly rainfall isotopic variability”.

Done

RV3 Line 245. It may be helpful to refer to a study that presented the Global Meteoric Water Line. More importantly, a reader may expect after these two lines (244-247) an interpretation and discussion of the local meteoric water lines. What do we learn from the analysis? How do these local meteoric water lines compare to other regions? Later on, I realized that lines 281-285 further discuss this subject. The manuscript could benefit to describe this aspect at one place only (see also general comment 1).

We have better organized this section and merged the two places where the meteoric water lines were described. Comparison with other sites in southern France is now included.

RV3 Line 253. This synchronicity is quite remarkable as, according to this study, precip-

itation across the northern Iberian Peninsula is controlled by different weather regimes. May this suggest, along with later findings that show similar isotopic rainfall along the western and eastern coasts, that the elevation and temperature effects dominate the isotopic signatures in precipitation?

We think that this case is quite singular since it represents the influence of an Atlantic front passing over a large region of the IP and affecting our sites in a similar way (high precipitation amount, very negative isotopes). It may be difficult to extrapolate this quite exceptional situation to the whole record and extract general conclusions.

RV3 Lines 261-268. Here I miss again a discussion and interpretation of the results. Simply phrasing the main findings without interpretation leaves the reader guessing what to take away from the text. Later on, I realized that the text from line 286 onwards seems to continue with this analysis. Please, discuss one subjects at one place in the manuscript.

This text was just a presentation of the data since this section was in Result chapter in the previous version of the manuscript. Now we have included the discussion of the data, adding information previously on line 286 onwards.

RV3 Line 315. In fact, when considering the above and following analysis, I get the impression that the elevation and/or temperature effect has the strongest influence on the rainfall isotopic variability (in the order of 2 permil) as compared to all other factors. Or is this too simplistic?

It is true that elevation and temperature are important to explain averaged values (eg. annual means) but not enough to explain daily variability. For that scale, we need to account for the air mass history (moisture origin and moisture uptake, type of rainfall, etc).

RV3 Lines 454-456. Another study that found similar differences in the isotopic signature in precipitation from convective versus stratiform precipitation in the Mediterranean

is Lee et al. (2019). Citing this study may strengthen the text here.

Yes, this paragraph is enriched with new references provided by both Rev2 and Rev3.

RV3 Lines 460-462. The sentence “Backdoor cold fronts . . . . . heavy precipitation and flooding (Llasat et al., 2007)” already appeared in section 2 (lines 107-109) and is thus repetitive. Please, remove the sentence at one of the two locations.

Done. We remove it from the discussion (section 4.6).

RV3 Lines 493-495. I cannot follow the sentence. Please, clarify and correct if necessary. In addition, how are outliers defined in Figure 7?

Following recommendation by Rev2, this last paragraph associating rainfall types with precipitation amount or temperature has been removed since it was rather speculative. We have also simplified Fig. 7 to show only the variation of d18O associated to the three rainfall types

RV3 Tables. Overall, I find the information in the Tables quite overwhelming, and I wonder if the information can be reduced without losing relevant information. For example, the multiple use of “n=” in the cells of Table 2 could be avoid by choosing another notation, perhaps providing the number of samples between brackets after the d18Op values, or simply by removing “n=” in all cells and providing adequate description on top of the columns or in the Table title/caption.

Done. Table 2 is simplified according to these suggestions.

RV3 Lines 223-238. One of the main methodologies of the study is defining the different weather regimes that are linked to the rain events and d18Op values. Upon first reading I missed how these different weather regimes are defined, and realized that lines 231-236 address this method. I would recommend to make this methodology more visible by renaming the title of section 3.4. In addition, more information should be provided on how these different synoptic situations are defined, allowing for potential reproduction of the results. Is this analysis subjective or based on an automated



detection algorithm?

We have changed the title in the method section to make this methodology more visible and provide more information about where to find the criteria (subjective) to define the three different synoptic situations.

We have also changed all the typos and other errors indicated by Rev3 in “Technical comments” thus improving this new version of the manuscript.

#### Cited references

Baldini, L. M., McDermott, F., Baldini, J. U. L., Fischer, M. J., and Möllhoff, M.: An investigation of the controls on Irish precipitation  $\delta^{18}\text{O}$  values on monthly and event timescales, *Clim Dyn*, 35, 977–993, <https://doi.org/10.1007/s00382-010-0774-6>, 2010.

Iglesias González, M. I.: Variabilidad climática del noroeste de la península ibérica durante los últimos 1500 años, descrita por espeleotemas de diversas cuevas del principado de asturias, <http://purl.org/dc/dcmitype/Text>, Universidad de Oviedo, 2019.

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