

## **Review of acp-2020-861**

Title: "Spatial variability of northern Iberian rainfall stable isotope values: Investigating climatic controls on daily and monthly timescales"

Authors: Moreno et al., 2020.

### **Summary**

This study investigates the isotopic variability in rainfall in the northern Iberian Peninsula at daily and monthly time scales. Several climatic and geographic factors that can help to explain isotope composition are discussed, such as temperature, amount of precipitation, the site elevation, and continental effects. Also, the study aims to link the isotopic variability to air mass pathways (i.e., moisture source effect) using back trajectories and rainfall types (frontal versus convective) based on different weather regimes of precipitation.

Overall, I found the study very interesting and potentially relevant. The study combines isotope measurements in rainfall with a meteorological perspective that can help to explain the isotope variability along a transect of the northern Iberian Peninsula where different weather systems and processes can have an alternating influence on precipitation formation, potentially supporting an improved interpretation of paleoclimate archives in the region. However, I also have a few major concerns that need to be addressed before considering potential publication. In its current state, the storyline of the manuscript is at several places hard to follow, with discussion of results placed in different (sub)sections. In addition, the quality of the text allows for improvements. Please, see for more details general comment #1 and several other specific and technical comments. Another main concern is related to the analysis of the back trajectories that aim to provide an indication of the moisture source / air mass origin and the linkage of this origin to the isotope signals in precipitation. If my understanding is correct, the idea is that moisture pathways from the Atlantic leave a different isotopic imprint than those arriving from the east over the Mediterranean Sea. This analysis, however, seems somehow problematic as for all sites in the study area by far the larger part of trajectories arrive from the west / northwest. In addition, the manuscript states at several occasions that the isotope signals on the western and eastern margins of the Iberian Peninsula are relatively similar. As a consequence, the presented results in section 4.3 appear to be not in line with the stated conclusions derived from this analysis. Please, see for more details general comment #2. My recommendation is to satisfactorily address these two major comments as well as the specific and technical comments, and to resubmit a revised manuscript for consideration of publication.

### **General comments**

#### **1. Organization of the manuscript and writing**

One of the major revisions the article may need is related to the flow and organization of the text. Chapter 4 describes in two sub sections the daily and monthly rainfall isotopic variability, respectively, without that much explanation or interpretation is given. Then, in section 5, called a discussion, while in fact continuing to present results, comes back to subjects that were initially described. As a reader, I felt lost and had difficulty to follow the storyline here. I recommend to reorganize the structure of chapters 4 and 5 into one chapter that presents the results, for example, 4.1 "daily rainfall isotopic variability" (presenting the local water lines), 4.2 "monthly rainfall isotopic variability" (discussing seasonality), and then 4.3 "the geographical controls on rainfall isotopic variability", etc., until section 4.6 "the influence of rainfall types on isotopes". Also, I recommend to discuss the local meteoric water line, currently at two places in the manuscript (lines 244-247 and 281-285) only once in one place, and the same for the analysis on the seasonality, please, see also the specific comments below.

In addition, the quality of the writing may be improved. For example, the excessive use of text in brackets should be avoided when possible. Several examples and other suggestions for improvements of the text are noted under the technical comments.

#### **2. Source regions and backward trajectories**

Although the analysis that addresses the air mass origin associated with the rain events based on the trajectory calculations is very interesting, and is presented in a very interesting and visually illustrative way (Figure 5), it seems that the method is not adequately able to represent the processes the study is aiming for. As the manuscript articulates in lines 399-409, westerly trajectories are dominant, and possibly air mass pathways can undergo moisture uptake in the short time period before arriving over the target areas. However, as the text acknowledges, this process may be well under-represented in this methodology. Therefore, it appears to me that the conclusions, as stated in the abstract “moisture source region (Atlantic versus Mediterranean) also significantly modulate the  $d^{18}O_p$  values” (lines 36-37), the results “These results highlight the importance of moisture source ... .. transect of this study” (lines 420-421), and the conclusions “affected by different moisture sources” (line 521), appear not in line with the presented analysis that shows “... very few episodes associated with other directions (Figure 5). This low, almost negligible, presence of trajectories associated with Mediterranean air mass advections ...”, (lines 399-401). This is once more underlined by the analysis in section 4.4 that shows that Atlantic fronts and backdoor cold fronts have very similar isotopic signals, in contrast to the convective-orographic precipitation. For this reason, I have the impression that the stated conclusions are not in line with the presented results, and that the adopted methodology may not be suitable for its purpose. One thought that came up, and may potentially alleviate the limitation in the methodology, is to limit the time of the backward trajectories to one or two days. This analysis appeared actually to be done (Fig S1), and seems more appropriate and to give more meaningful results, especially for the Borrastre site showing predominantly trajectories from southerly directions that are associated with more enriched precipitation. I would recommend to replace Figure 5 by Figure S1 and limit the analysis to one- or two-day backward trajectories. However, a key point of the study, the easterly advection of moisture from the Mediterranean is not substantially increasing and not showing up in the results. Have the authors considered to use only trajectories from 850 hPa and excluding those from 700 hPa? At which time instances of the rainfall days were the trajectories started? At present, I do unfortunately not have any other suggestions that may lead to a suitable methodology that may serve the purpose of this aspect

## Specific comments

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”?

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?

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.

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.

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.

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

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. 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.”?

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.”?

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 ....”.

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

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.

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

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”.

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

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).

Line 253. This synchronicity is quite remarkable as, according to this study, precipitation 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?

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.

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?

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.

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.

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

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 avoided by choosing another notation, perhaps providing the number of samples between brackets after the  $d^{18}O_p$  values, or simply by removing “n=” in all cells and providing adequate description on top of the columns or in the Table title/caption.

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  $d^{18}O_p$  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?

## Technical comments

Line 32. Please, consider to remove the “;”, and start a new sentence with “Atlantic ...”, and remove “studied”.

Lines 37 and 38. Please, add a comma before “but” and consider to replace “plays a key control” by, for example, “plays a key role” or “exerts a key influence”.

Lines 40, 44, 45 and elsewhere. Please, use a consistent phrasing; “palaeoclimate” or “paleoclimate”.

Line 45. Please, remove the comma after “(e.g., Treble et al., 2005)”.

Line 48. Please, remove the space between “history” and the comma, consider to rephrase the end of the sentence as “meteorological conditions, for example, air temperature and the amount of precipitation (Craig, 1961; Dansgaard, 1964)”.

Line 50. Please, rephrase the end of the sentence as “, and the amount and source of the precipitation”.

Line 52. The authors may consider to replace “mandatory if one wishes” by “essential”.

Line 57. The authors may consider to rewrite “three major precipitation regimes” by “three major weather regimes of precipitation”.

Line 63. The phrase “require further detailed and highly spatially-resolved studies.” reads a little awkward. Please, consider rephrasing, for example, in the direction of “require further detailed studies that account for the high spatial variability of the regions and these processes.”.

Line 67. Please, remove “, for example” and finish the sentence with a period.

Lines 68-69. Please, consider to replace “recovering” by “obtaining” or “covering” and write “at daily time scales”.

Line 73. Please, rephrase “; basically, ...” and start a new sentence with “Atlantic fronts are associated with more negative ...”

Lines 81-82. Please, consider to rewrite the phrase “transect (850-km in straight line)”, for example, by “transect of 850 km”, or “transect of 850 km spherical distance”, and the phrase “typical Atlantic climate to fully Mediterranean sites” by “typical Atlantic to a Mediterranean climate.”

Line 96. Please, write “The Borrastre record”.

Line 108. Please, write “they can cause”.

Lines 113-114. Please, consider to replace “higher” by “enhanced” or “increased”, and “influencing” by “affecting”.

Lines 131-132. The sentence “Also located ... ... occurring mainly in spring and in autumn” reads awkward. Please, rephrase. It may help to start the sentence with “The Molinos site ...”.

Line 134. Please, consider to replace “is influenced by” by “has”.

Line 148. Please, removed the word “Thus, ”

Line 159. Please, replace “that the system was automatic” by, for example “that has an automatic system”.

Line 163. I can’t follow the logic of the sentence “Thus, ... in 2015.”. What does the sentence want to say? Please, rephrase, perhaps by just removing “Thus, ”.

Line 168. Please, remove “daily” after “gauge”.

Line 172. Please, consider to rephrase the sentence, for example as “..., are expressed as  $d^{18}O$  and  $d^2H$  in ...”.

Line 211. “at daily time scales” may read better.

Line 248. Please, write “daily time series”.

Line 261. Please, write “All stations”.

Line 283. Please, rephrase “is made with” as “is based on”.

Line 286. Please, write “allows for an assessment”.

Line 288. Please, rephrase, for example as “show quite similar monthly  $d^{18}O$  values, and typically, more negative ...”.

Line 293 “..., is not what we expected.” Sounds rather colloquial, please, rephrase.

Line 306. Please, consider to rephrase “to explain” as “that can explain”

Lines 320-321. I cannot follow the sentences "... and separated by the Mediterranean Sea. Therefore, the altitude cannot be .... difference between the studied sites.". Do the authors refer here to the difference in isotopic variability in the Alps and the northern Iberian Peninsula, or to the differences between the sites in the northern Iberian Peninsula? What is meant by "separated by the Mediterranean Sea"? Please, clarify and rephrase the text accordingly.

Line 324. Please, rephrase "air mass trajectory" by "air mass origin" or "moisture source region".

Line 328. Is the phrase "at daily and monthly time scales" in the section title needed? Please, consider to omit to shorten the title.

Line 331. Please, consider to replace "or" by "nor", and write "monthly time scales".

Lines 344 and 345. What does the notation "Oviedo+Pindal" and "Mallorca+Barcelona" mean?

Line 333. Please, replace "or" by "nor".

Line 360. It may be more adequate to speak about "origin of moisture for the rainfall".

Lines 374-376. This sentence reads awkward, please, rephrase.

Line 415. Please, consider to replace "more stable" by "similar" or "homogeneous" and add "stations" or "sites" after "the other two".

Line 424. Please, omit the word "whole".

Line 431. Please, omit the word "enter", and "it" at line 434.

Line 435 and elsewhere. Please, write out west and southwest.

Line 484. Please, consider to replace "circumstance" by "process".

Line 491. Please, write "backdoor frontal types".

Line 486. For clarity, the phrase "type of precipitation" may be complemented by ", i.e., convective versus frontal".

Lines 487-488. Please, consider to replace "in separating" by "on".

Line 503. Please, rephrase "the two opposite stations (the westernmost ones and the easternmost ones)", for example in the direction of "the two stations on opposite sides of the Iberian Peninsula" or "the two stations at the far most western and eastern sides of the Iberian Peninsula." or "the two stations at the western and eastern margins of the Iberian Peninsula."

Line 719. Please, consider to replace "the remain ones" by "the remaining samples" and write "with respect to".

Line 725. The caption speaks about "Event"; I thought to understand from the text that the analysis is based on daily samples, not based on rain events?

Line 725-726. The current phrasing of the sentence is unclear. Please, correct, perhaps in the direction of "Note that El Pindal (2006-2009) samples are not represented since they do not overlap with the time period of the other stations."

Figure 4. I assume that the plots show the monthly data from January until December? Perhaps this can be included in the caption, if not in the Figure, for clarity.

Line 743. As a suggestion, “broken” may be replaced by “divided”.

Lines 748-749. The colors and pressure levels in the caption are switched around! Red corresponds to 500 hPa and green to 850 hPa starting points. Please, correct.

Lines 768-769. Please, write “for every station” and “please see Table S2.”

Line 776. The Table does not show numbers in red. Please, correct.

## References

Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, I., Kållberg, P., Köhler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J.-J., Park, B.-K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.-N., and Vitart, F.: The ERA-Interim reanalysis: configuration and performance of the data assimilation system, *Q. J. Roy. Meteor. Soc.*, 137, 553–597, <https://doi.org/10.1002/qj.828>, 2011.

Lee, K.-O., Aemisegger, F., Pfahl, S., Flamant, C., Lacour, J.-L., and Chaboureaud, J.-P.: Contrasting stable water isotope signals from convective and large-scale precipitation phases of a heavy precipitation event in southern Italy during HyMeX IOP 13: a modelling perspective, *Atmos. Chem. Phys.*, 19, 7487–7506, <https://doi.org/10.5194/acp-19-7487-2019>, 2019