

## ***Interactive comment on “Water stable isotopes ( $\delta^2\text{H}$ and $\delta^{18}\text{O}$ ) in the Peninsula of Yucatan, Mexico” by Eduardo Cejudo et al.***

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This technical note presents a dataset of stable isotopes in precipitation, groundwater, and lake water in the Yucatan Peninsula (YP), Mexico compiled from published and unpublished information. Using the compiled data the authors defined a regional meteoric water line for the YP and attempt to evaluate the spatial variability of the stable isotopic composition of groundwater in the region. Even though I appreciate the authors' effort, the lack of information regarding the depth of collection of the groundwater samples hampers the usefulness of the dataset and does not allow for an accurate inference of groundwater recharge and flow processes.

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REPLY: thanks to the Referee #2 for all the comments. We would like to begin by saying that this effort represent (to our knowledge) the first attempt to put together most (if not all) of the isotopic data in water in this region, it will be a baseline of this tropical karstic area with scarce data on stable isotopes for water management. The limitation we face would be the same for any researcher who would attempt to make sense of the little data available; yet, the effort has to be done as a starting point in order to build a research program such as the one in the make by the authors for the years to come. This Technical Note is put together for any researcher who may take this database in the future as reference, and then move forward towards a better, deeper analysis using stable water isotopes. Second, we tried not to be conclusive in any way regarding the data and interpretation that we present. The data that we present from the PY is likely all of the available data and we did our best interpreting the number. However, we agree that, due to the limitations of the database, our interpretation might change or it may be confirmed once more data is available. We clearly state where the information gaps are and what is required to fill the void. We agree that we cannot make accurate inference of groundwater recharge and flow processes; thus we did not try to go further. We think that clearly noticing and acknowledging the lack of information is one of the most important motors for research in emergent countries. May this paper be an invitation to the scientific community to research more intensively this important tropical karstic area of the world.

Major issues:

An analysis of the factors influencing the stable isotopic composition of precipitation was not carried out. I am not sure how the authors came to the conclusions in P1L16-19. Supporting such statement would require a thorough investigation of the potential sources and trajectories of moisture contributing to local/regional precipitation (e.g., using Lagrangian back trajectory models) and the estimation of the fractions of convective (and stratiform) precipitation among other types of analyses.

REPLY: We consider that the sentence is not a conclusion as the Referee men-

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tions; rather, we draw the general panorama of the most possible factors influencing the stable isotopic composition of precipitation, based on evidence from regions with similar climatic conditions. The study published by Hu and Dominguez in 2015 (DOI: 10.1175/JHM-D-14-0073.1) tracking sources of moisture in North America, mentioned that both oceanic and terrestrial moisture (i.e. evapotranspiration) are important sources of precipitation. Their work addresses the North American Monsoon; however, we understand that moisture from the Atlantic Ocean have a westward movement, likely depositing precipitation in the YP. We understand and agree with the Referee that “potential sources and trajectories of moisture contributing to local/regional precipitation (e.g., using Lagrangian back trajectory models) and the estimation of the fractions of convective (and stratiform) precipitation among other types of analyses”, would provide depth and certainty to our suggestions. However, we think that such analyses are more on the realm of the atmospheric sciences and are out of the scope of this Technical note. Nonetheless, this keen observation opens up a panorama and an opportunity for us that we have not reflected before. We appreciate the suggestion and we would consider a future contribution dealing with sources and trajectories of moisture and precipitation in the Yucatán Peninsula. Finally, as the referee notes, we do not have enough data for modeling and it will be out of the scope of this Technical note.

The search literature protocol should be described in more detail. In general, the Boolean operators (AND, OR) and other type of operators (e.g., between and within) must be used to connect keywords (e.g., water, isotope, hydrology, etc.) appropriately. A thorough literature review should clearly indicate the used operators and how they were used to connect the search terms. In addition, since the study region is located in a Spanish speaking country, it is likely that valuable information has been published in scientific journals published in that language. Thus, the search should also be done using terms in Spanish and include literature databases that publish literature in that language such as Scielo, Latindex, Redalyc for completeness.

REPLY: Thanks for the suggestion. We have completed literature search in Sci-

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elo and Redalyc as suggested. Latindex is a platform that provides qualitative information about academic journals, print and online; thus, was not useful directly as search engine. Unfortunately, we did not found matches for its addition. Thus, Datamining was conducted using search engines Google Scholar, Scopus, Internet Archive, Web of Science, Scielo, Redalyc and the “Virtual library and Catalogue” at [www.cicy.mx/biblioteca/biblioteca-virtual](http://www.cicy.mx/biblioteca/biblioteca-virtual) using the search terms Isotopes, Water, Yucatan, Campeche and Quintana Roo and their equivalents in Spanish Isótopos, Agua. Boolean operators (AND, OR) were used to connect keywords appropriately. A total of 17 publications were identified with data of the required characteristics and quality (P3 L62-67)

There is an important limitation with the compiled groundwater data. That is, in most of the cases the depth at which those data were obtained is not reported. I checked the Supplementary Material 1 and only 18% out of the 213 groundwater data reported this information and the depth of collection varied largely between 1 and 120 m for the cases in which this was included. The former issue hampers the correct interpretation of the groundwater isotopic data, while the latter indicates that constructing a groundwater isoscape that does not take into account the sampling depth is not meaningful. Unfortunately, these limitations hamper the utility of the compiled dataset for better understanding the groundwater hydrology of the YP in this and future studies.

REPLY: We understand the concern and we realize the complexity of the situation. It is true that we present an isoscape in which few data has a depth of water sampling associated, and those number came from one paper where deep sampling was completed (Sacki et al. 2002). The isoscape previously published by Wassenaar et al (2007) reported groundwater sampled from shallow and unconfined wells, presumably between 5 and 20 m in depth. They do not have certainty of the real depth of all samples since sometimes they collected water from household taps, cisterns, storage tanks and even springs. The expectation was that “all of the water wells sampled were screened in phreatic aquifers”. The same assumption applies here; we produced an isoscape with

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water sampled at phreatic level. We understand the concern that disparity on data “hampers the correct interpretation of the groundwater isotopic data”; so, we amended the isoscape not using the data deeper than 30 m below ground level published by Socki et al. (2002), so the isoscape hereby presented represents mostly phreatic level or depth to screened wells (frequently around 20 m). It is not the ideal scenario for interpreting data, but it is what we can do with what we have on hand, available, and with adequate scientific quality (P3 L81-84 and current Figure 6).

As stated by the editor in the first revision of the manuscript, the basics of isotope hydrology are overemphasized and the value of the compiled data and related inferences are not clear for the reader.

REPLY: As suggested by both referees, we rewrote the Introduction section with less general information about isotopes, narrowing down to what we consider essential information and recent references.

For example, the basics on the factors that influence the temporal variability of the isotopic composition in precipitation is substantially described in lines P4 L108-117, but only a couple of sentences are regarded to the interpretation of the compiled data (P4, L117-119; in addition the reference Li et al. 2015 is missing from the list of references).

REPLY: We consider that our interpretation is not reduced to a couple of sentences, all the paragraph (P4 L112-124) refers to the compiled data. We interpret the data in the PY in the light of other published research, contrasting and comparing them. We present the argumentation in this manner because we outlined the possible scenarios occurring in the area and then stressing those situations most likely occurring based on the reduced data we have, going as far into educated interpretation as possible. We appreciate Referee #2 for noting the missing references. It is now added. Thanks much.

In their response letter to the previous revision by the editor the authors claim that the major finding of their work is the determined RMWL. However, the presented RMWL

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resembles well one previously reported for the study region (P4 L102-103). Thus, I do not find anything novel about this finding.

REPLY: We do not think redundant to provide a RMWL that resembles a local meteoric line representing one location, Playa del Carmen (Quintana Roo, Mexico, 20°35.2', -87°8.04'). Our approach to this apparent dull comparison is that, in this particular case, a local meteoric water line might represent a greater geographical area; yet, having more data makes the RMWL better suited to be the meteoric line. We are not sure if the non-different meteoric lines in this case are just coincidence or are common elsewhere, but we think that when our database contain more information, these meteoric lines will be different. We do not completely agree with the lack of novelty of this finding, it is rather intriguing. We are currently preparing a paper containing an original database that represents the meteoric water line of the PY, including 11 locations distributed in the three states. We can only mention that it has a different slope (lower than 8.1) and an intercept higher than 11.6. Therefore, as abovementioned, this technical note is the starting point of a research program in the make.

The authors mention a supposed altitude effect. Such effect is only apparent (i.e., the stable isotopic composition of rainfall decreasing as altitude increases) because the y-axis of the figure is in reverse order than in the other isotopic plots presented in the manuscript. Even though it is not clear what the data presented in Fig. 4 represent (this must be clearly described in the caption), it is very complicated to argue for a potential altitude effect given the very small range (< 100 m) in elevation among the sampling stations. In addition, I consider that the information presented is not relevant at all for the evaluation of the altitude effect since at some elevations there is a lot of information (6 and 27 m elevation) in comparison to others (a single value at 70 m elevation). I thus suggest the authors to reconsider the statements in P5 L129-133 accordingly.

REPLY: We agree with the comment of referee #2 and greatly thanks for the observation. There is not much we can do with this narrow range of altitud. Referee #1 also mentioned this situation so we have re-arranged our statements so the sentence is

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now as follows “When exploring the altitude effect in a north-to-south cross section, we cannot observe nor suggest a trend of the  $\delta^{18}\text{O}$  at elevations higher than 100 m.a.s.l. because the current isotopic data represents only an area with low relief. Perhaps sampling the longest N-S cross-section, including the highest altitudes in the Peninsula ( $\approx 120$  m in the Ticul range and  $\approx 220$  m in the south), might yield a trend as the one observed in Northern Central America (Lachniet and Patterson 2009)”. (P5 L134-138). In addition, Figure 4 has been eliminated, as it does not contribute substantially to the discussion.

The “retention of the meteoric of isotopic signature in groundwater that suggests fast recharge after precipitation” is argued. Although the aforementioned interpretation of the data could be feasible depending on the hydrogeological characteristics of the groundwater reservoir, I am not sure how the data presented in Fig.5 alone supports this argument. This is because it is not clear when the groundwater samples were collected in comparison to the precipitation ones, and because the characteristics of the groundwater reservoir are not described. A thorough interpretation of the data would require the consideration of hydrogeological characteristics of the aquifer.

REPLY: Both referees coincide in the observation that, with so little data, we cannot be conclusive. We did not express this sentence as a proven fact, we are merely hypothesizing of what this data set suggest and would be required to verify. Certainly, both precipitation and rainfall data were collected simultaneously from May 2007 to April 2008. In this case, we drilled and artesian well, specifically to collect groundwater samples. We have rewritten the paragraph so it is now an observation based on the data we currently have and compared to published research with similar outcomes (P5 L140-154). Even though it is clear that groundwater recharge is influenced by evaporation effects, the geographical location of the monitoring sites for itself (north versus south) cannot explain the differences among the stable isotopic composition of water in the different states of the YP (P5 L141-142). The variability depends on the specific features of each of the monitoring locations (e.g., type and spatial distribution of the

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soil/s, hydrogeological features, presence of open water bodies, etc.). However, since such information is not presented, it is not possible for the authors to explain the observed evaporative effects in the isotopic signal of groundwater across the study region. Because of this, most of their inferences in P5-P6 L144-170 are strongly speculative and are unsubstantiated by the presented data. REPLY: We deeply appreciate referee #2 for providing such an important insight. We now include information regarding soils, geomorphologic features and open water bodies, and relate them to what we consider most likely evaporative effects in the isotopic signal as represented by the proposed evaporation lines (P5 L156- P6 L171).

In open water bodies the lighter water isotopes are preferentially removed during evaporation, so the remaining liquid phase is enriched in the heavier stable isotopes of water ( $\text{O}^{18}$  and D). Thus, the inference of the authors in P6 L173-174 is erroneous. REPLY: We appreciate the observation, we had a typo here, and we meant “less depleted values”. It is now corrected (P7 L209).

The isotopic data presented in the figures is not sufficiently described and discussed (e.g., the GW, lakes, and seawater data in Fig. 1; the  $\text{d}^{18}\text{O}$  versus  $\text{d}$ -excess variability across seasons in Fig. 2; the variability of the stable isotopic data at different elevations in Fig. 3).

REPLY: Thanks for the observation, Referee #1 expressed the same concern. We have included better description in the text of the findings and the results presented in the figures. We assume that referee #2 mentions figures 2 to 4. The GW, lakes, and seawater data is not discussed directly in the RMWL section, for it is only provided there for comparison purposes, and a specific section of groundwater is presented in section 3.2. Regarding the  $\text{d}^{18}\text{O}$  versus  $\text{d}$ -excess variability across seasons, we restrict ourselves to the statements supported by our data (P4 L116-121). We present some educated guesses from L121 to L124 such as convective rains occur more during the dry season, cold front events common from November to March and the wide distribution of  $\text{d}$ -excess in wet season (July to October) once the reader has seen the

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figure. Finally, we have eliminated former Figure 4 (altitudinal effect) as per suggestion of referee #2 “I consider that the information presented is not relevant at all for the evaluation of the altitude effect since at some elevations there is a lot of information (6 and 27 m elevation) in comparison to others (a single value at 70 m elevation)”

Sections 3.3, 3.5 (section 3.4 is missing) and 4 are not directly related to the compiled dataset. Section 3.3 presents a summary of literature findings related to vegetation water uptake and sections 3.5 and 4 read rather like commentaries.

REPLY: We apologize for the mistake in the sub-heading number. In order to attend the observations, we have improved the Introduction and Discussion so we can contrast and compare the finding in the PY with other reports regarding water transpired by plants in karstic aquifers and other ecosystems. We have properly connected all section of the manuscript regarding the integration of water isotopic data for studies of water balances and ecohydrology. Section 3.5 has been re-structured named “Stable isotopes for better groundwater management” before future research (4), addressing how the use of water stable isotopes helps to fill gaps in information regarding sustainable groundwater in karstic areas with large extraction volumes. Thanks for the observation and we expect referee #2 finds satisfactory the modification (Sections 3.4 and 3.5).

Minor issues:

P1 L22-24: Delete as these concepts are widely known by isotope hydrologists. Change completed.

P1 L35: What do you mean by “input parameters”? According to Gat (2005) input parameters is the precipitation, the basic supply for meteoric lines. We have now added precipitation for clarity purposes (P2 L30).

P1 L55: Pore water data is not presented. After Referee #1 suggestion, we change the term for soil water (P2 L54). Soil water is later interpreted as the water used by plants

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for transpiration.

P3 L63: Describe what is the “Virtual library and Catalogue” and why it was included for the literature search. This is the search engine in the library of the Yucatan Center for Scientific Research (CICY). We include it because it has access to thesis and dissertation published at all of the Government research centers and major Universities in Mexico.

P3 L67: Specify that most of the compiled groundwater data did not include information about the sampling depth. Completed P3 L71.

P3 L74: Specify what proportion of the data was interpolated to estimate the  $\delta^2\text{H}$  values. Completed. It represents 7% of the  $\delta^2\text{H}$  data, P3 L78.

P3 L83-86: As mentioned above, I consider that constructing an isoscape without accounting for the depth of collection of the samples does not provide relevant information. I thus suggest to delete this analysis from the manuscript. We have corrected the analysis, including only shallow groundwater (not considering deep samples P3 L82-84). As we mentioned above, previous efforts neither have certainty of the real depth of all samples and the main assumption is that isoscapes are produced with water sampled at phreatic level.

P4 L95: What does “on that matrix” refers to? We wanted to describe the environment or compartment in which the water samples were collected. For example, soil water or groundwater. We have rewritten the sentence “sampling efforts have been focused on that compartment of the hydrosphere” referring to aquifers (P4 L97). Thanks.

Figure 1: The map is confusing. It is not clear whether the text within the map refers to the states or the administrative regions. As the states are often referred to in the manuscript, I would suggest that the states names are shown in the figure instead of the administrative regions. Or even better, to present both with the text in different colors for the states and the administrative regions matching the line colors presented

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in the legend of the figure (red and black) Change completed. State labels included and changes in legend nomenclature.

Figure 2: Specify what the circles of different colors and sizes represent as well as the error bars. This presents data from different water sources published in different studies but those are never discussed in the manuscript. I suggest to describe and discuss all the data presented in the figure or simply not showing it. We think referee #2 is addressing Figure 4. Figure 2 has the legend for all circles and does not have error bars. As it pertains to Figure 4, we agree with the comment as answered above and Figure 4 has been eliminated, as it does not contribute substantially to the discussion.

Figure 4: Describe what the dots of different color and size as well as the error bars represent. Figure 4 has been eliminated.

Technical corrections:

P2 L31: change “d coefficient” by “d-excess” and use the latter consistently in the whole manuscript. Thanks for the correction, referee #1 also mentioned it and the change has been completed (P1 L26), d-excess is used consistently the whole manuscript.

Correct the number of the subsections in section 3 (i.e., there are 2 subsections 3.2). Completed

Figure 2: specify what the solid black line in the plot represents. Solid black lines represents the GMWL, added to the Figure caption.

Figure 5: Delete the word “Groundwater” placed before “isotopic composition. . .”. Specify what the dashed line represents. Changes completed, thanks for the observation. Figure capture has been updated.

Please also note the supplement to this comment:

<https://www.hydrol-earth-syst-sci-discuss.net/hess-2020-16/hess-2020-16-AC3-supplement.pdf>

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2020-16>, 2020.

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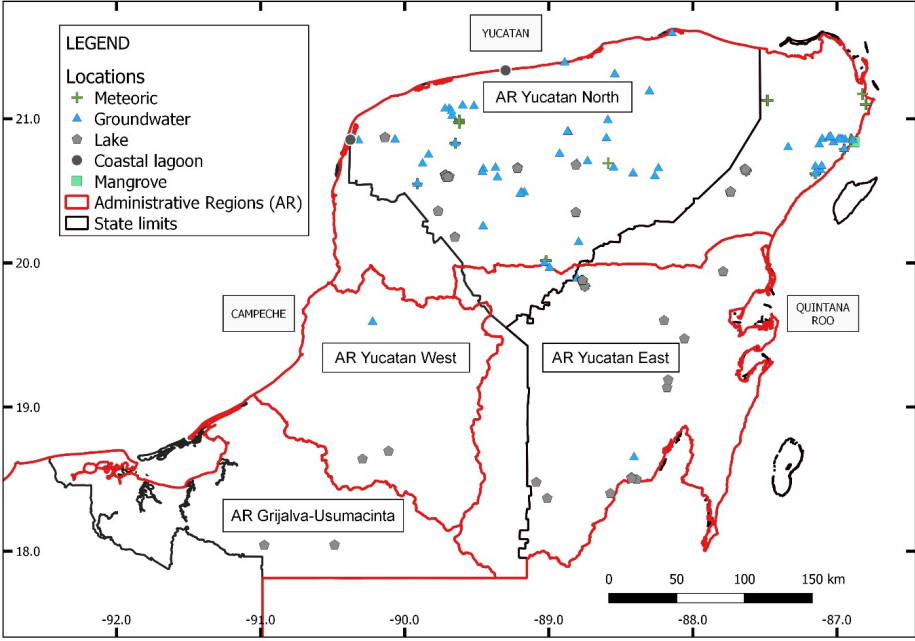


Fig. 1.

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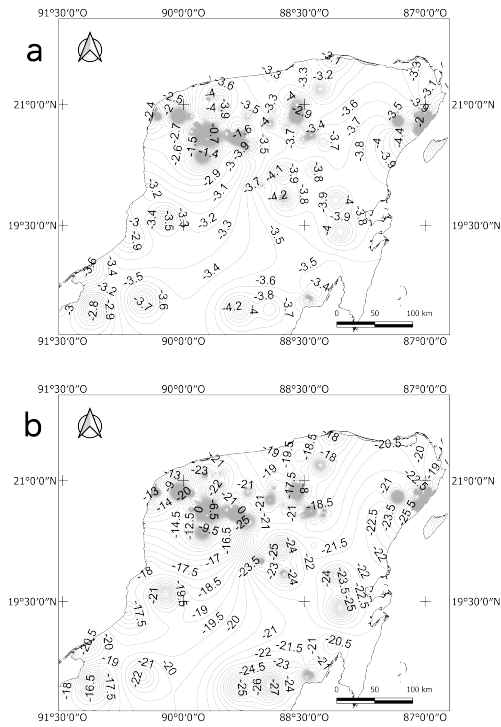


Fig. 2.

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