Precipitation stable isotopic signatures of tropical cyclones in Metropolitan Manila, Philippines show significant negative isotopic excursions

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Comments of reviewer 1 and authors' reply to every concern:

In the manuscript, the authors attempted to discuss how a 19-month precipitation isotope dataset could be used by government agencies for mitigation and adaptation polices related to typhoons.

Response: This is a misunderstanding of our point, where we proposed that (line 37-40) "There is a clear need for developing a better understanding of tropical cyclone (TC) dynamics and cyclone histories in the context of prediction that may allow government agencies to implement proper mitigation and adaptation policies." We are not suggesting that our dataset is to be directly used by government agencies to base adaptation policies upon. Instead, we are highlighting the scientific significance of our study, that isotopic signals in precipitation can allow us to better understand typhoon dynamics, and inform paleoclimate studies and mitigation measures in the future. We will thus amend this sentence to bring across our point clearer.

The authors also suggested that this study could have possible implications for paleoclimate studies. However, the 19-month dataset is difficult to provide substantial contributions to the hazards related to (1) precipitation processes during typhoon, (2) spatiotemporal isotope characteristics in the region, and (3) paleoclimate studies.

Response: We affirm that our study contributes to our understanding of tropical cyclone hazards in the Philippines, as our in-situ dataset captures information on precipitation isotope signals for normal precipitation events and tropical cyclone events – for an area such as the Philippines, where the studies on typhoon precipitation isotope signals are scant, despite the region being a hotspot for typhoon activities. Being the first study investigating typhoon-related precipitation isotope signals in the Philippines, we are able to learn about how precipitation isotope signals in this region respond to typhoon events with different intensities. In addition, we gain spatiotemporal information of typhoon events through studying the tropical cyclone's position and distance from the sampling station's location, and observing effects of variables such as typhoon distance and intensity on level of precipitation isotopes (e.g figure 4, 5, 6). Furthermore, our 19-month dataset provides modern-day baseline data for investigating typhoon activities in paleoarchives for the Philippines, as well as for paleoarchive data points near our sampling station. As there is yet no precedent dataset or studies that can provide such baseline data for studying tropical cyclones in palaeoarchives

established for the Philippines based on water isotopes, we are convinced that our study is able to make a substantial initial contribution to this area. Kindly refer to the following sections in our paper (lines 71-81, 388-414, 462-465) which discusses our findings' potential for paleoclimate applications.

However, the above topics involve diverse spatial and temporal scales. It is very difficult to justify that the 19-month observations can inform all of them.

Response: We recognize that the observations from our research would be unable to be applied to a spatial range as extensive as the whole of the Philippines. However, our findings are still informative and can be used within a reasonable range in the Philippines, proximate to our sampling station. Also, with reference to our research aims in lines 103-107, the main contribution of our findings is that we are able to capture the influence of spatial distance and progression of tropical cyclones on precipitation isotopic signals at our sampling station. Although the significance of this study is lessened by our single sampling site with a limited data resolution (both spatially and temporally), our findings are nevertheless an initial contribution to such studies which are unprecedented for the Philippines, specifically Metropolitan Manila, and our research aims remain within the capability of our dataset.

In page 7, the authors provide excellent descriptions which summarise what the data could really tell us. The data can only tell us that the precipitation isotope values during typhoons were depleted. However, it is not really something very new.

Response: As outlined in our research aims (lines 103-107), not only is our data able to show that typhoon events result in depleted isotope signals – we were able to study how distance from the typhoon and storm intensity influenced the degree to which the precipitation isotope signals were depleted, for a region where related research is scarce. This is discussed in great detail in the points above. In addition, our data provided interesting findings that may indicate potential for further research in the future (see conclusions line 416 onwards). For instance, we found that strong local convective activities can induce "false signals" where precipitation isotopes are slightly more depleted than average, despite typhoons being distant (lines 316-318, 363-366). Furthermore, our findings indicated that rain-out history and topography may have effects on isotopic signals (lines 290-292, 326-331). Thus, our study provides differentiated findings on the extent to which typhoon variables can affect precipitation isotope signals, and we further discussed potential influences specific to the Philippines region, such as topography, that could influence precipitation isotope signals.

We did not learn anything about typhoon mechanisms apart form that the typhoon rainfalls were clearly depleted of the heavier isotopes. Turning to learning new spatiotemporal signatures of the regions, the daily data set is just not able to capture the typhoon dynamics. In Figure 4, we can see clear that we cannot expect that 3-5 data points for a typhoon event can tell us much about typhoon dynamics.

Response: We reiterate that we have no intention to extensively study typhoon dynamics with our data in this study. Instead, our daily precipitation isotope measurements are suitable for analyzing certain typhoon characteristics, such as typhoon strength, track and rainfall intensity, and how this can have implications for paleoclimate studies in this region. We have also discussed the limitations of our dataset, and provided suggestions for obtaining better sampling frequencies in further studies. As for Figures 4 and 5, it is intended to show the extent of precipitation isotopic response to typhoon events, depending on the typhoon's proximity and rainfall, which is in line with our research aim – to better understand how typhoon events are captured in precipitation isotopes in the Philippines.

Overall, we did not see many substantial results related to typhoon processes here, because of the limitation of the data.

Response: The aim of our study is clearly stated at lines 102-107 and investigated with our dataset ("to understand if there is an isotopic response of precipitation to TC activities in the Philippines, and if so – what signal do we measure and how is it represented spatially. Further, we aim to understand the isotopic variation with distance from the TC track"). Thus, we get a first understanding about typhoon activities with isotopes, as no study has been done there before.

Moreover, the work does not have strong materials related to hazard, although the authors tried to frame the work about hazard mitigation and adaptation policies (Page 2 Ln 40).

Response: We clarify that the intention of our paper is not to frame the work around hazard mitigation and adaptation policies. Rather, we posit that our findings can be used to improve interpretation of results for typhoon paleoclimatology, specifically in the Philippines. Such knowledge has important implications for the prediction of typhoon activities in the study area. Further, we suggest more studies similar to ours should be carried out, to mend the data gap and provide a better picture of the paleohistorical record of typhoons in the Philippines. This in turn can better inform hazard mitigation and adaptation for typhoons in the Philippines.

This paper is more suitable to be a data paper instead of a research paper. Perhaps, the authors should think about submitting this paper to Earth System Science Data (ESSD).

Response: We appreciate the reviewer's kind suggestion regarding the nature of our research paper. Despite the fact that studying typhoon dynamics extensively was not an aim of our paper, we are still confident that our findings can be a contribution of scientific significance, as it provides insight into the influence of typhoon activity on precipitation isotopes in an understudied region. In addition, we also discuss on how other factors such as local convective rainfall and topography may influence precipitation isotope signals. As such, we trust that our contribution is better justified as a research paper rather than a data paper.

Comments of reviewer 2 and authors' reply to every concern:

In this paper, Jackisch et al. use shifts in $\delta^{18}O$ values over a period of 19 months to look for tropical cyclone (TCs) signals in precipitation. This length of records may not be enough for a robust baseline, but still shows some interesting results which can be useful to better understand tropical cyclones in Southeast Asia. Although the use of isotopes to reconstruct TC signals is not new, I believe that research studies like this help reinforce and learn more about patterns and the use of O isotopes in paleotempestology in different regions and at different latitudes. This study also strengthens the fact that we may still be a way from using O isotope depletion as a reliable (or individual) proxy for TCs. I think there may be a slight disconnect between this study and the use of O isotopes in paleotempestology. The authors discuss paleo reconstructions using isotope depletion (eg. Miller et al., 2006; Frappier et al. 2007) but then conclude "Based on our findings we conclude that the location of sample collection needs to be chosen strategically." When reconstructing paleo storms, researchers may not know or have geological evidence of precise movement and path of a TC. Making it potentially difficult to differentiate TCs from other precipitation events. See Oliva et al. (2017) for use of these proxies in plaeotempestology.

Response: Thank you very much for your positive feedback. Your comments are very helpful for improving the quality of our paper. Regarding your general comment, we thank you for highlighting the scientific significance and scientific contribution of our work. We agree with your remark that we may not know the precise path of a TC, but we do not think that our conclusion contradicts this. Such limitation has been included in the revised manuscript with reference to the work of Oliva et al. (2017) and we added the following at line 396: Nevertheless, it is important to consider possible limitations at the study site that arise in paleotempestology, such as sea level change or disruption of sedimentological records through floods or tsunamis. These need to be evaluated when comparing precipitation isotopes related to TCs with other proxy records such as speleothems and coastal deposits and when choosing the study area (Oliva et al., 2017). At line 73 we added the reference of Oliva et al.,2017.

Specific Comments:

Line 43. Ensure this is still true, I believe it is widely accepted that there is likeliness in increase in intensity but not necessarily in frequency. See Woodruff et al. (2013)"At the end of the twenty-first century there will probably be fewer, but stronger, storms globally." Also see IPCC.
Line 52-56 Same as above. Also a graph or figure could be helpful to visualize this.

Response: Thank you, we rephrased the sentence accordingly and changed it to the following two statements at line 42 and 52: Changing climate with associated warming of the surface ocean will likely increase the intensity of tropical cyclones in the future (Emanuel, 2005; Webster and Holland, 2005; Woodruff et al., 2013). Eighty percent of the strongest typhoons making landfall in the Philippines over the last three decades developed during higher than average sea surface temperatures (SST), which supports evidence that TC intensities are projected to rise in the future due to an increase in global temperatures (Guan et al., 2018; Webster and Holland, 2005; Takagi and Esteban, 2016).

Section 2.1. This section does not describe the sampling sites, it describes the Philippines. I am more interested about details of sample locations. Section 2.2 talks about sampling at 14.654◦N, 121.068◦E- Were there any obstructions? Any other potential sources of contamination? Was it on a roof or at ground level? Near other potential sources of water?

Response: Thank you for pointing this out. In the revised manuscript, we have added more specific information at line 133 for readers to get a better understanding of the sampling site: The rain collection station was installed on the rooftop of the Marine Science Institute (14°39'02.5"N, 121°04'08.6"E), which is centrally situated in the campus and surrounded by trees and various green spaces. The rooftop location proved ideal for rainwater collection as it allows unobstructed access to rainwater without any potential sources of contamination.

Line 205. Figure 2 shows that all nine typhoons left distinct, or at least depleted isotope signatures. Why are they not all in the results? The way it is written, it seems like Rammasun and Kalmaegi, along maybe with Hagupit are the only ones to leave such a signature. You hint at the reason at Line 336 but the values should still be presented objectively in the results.

Response: The values are already presented in the result section with reference to figure 2. However, to make it clearer, we have now shown the isotope value in the text for each TC at lines 196, 197, 201 and 202. We have further added the following section at line 202: The other TCs that occurred during the study period and were investigated by us were Mekkhala (Fig.2, point e, -10.77 ‰), Twelve (Fig.2, point g, -7.7 ‰) and Mujigae (Fig. 2, point h, -7.5 ‰).

Line 226. What were the values? 'relatively isotopically enriched' does not mean much.

Response: We have added the values correspondingly at line 226: As the Rammasun storm center tracked towards the northwest and away from Metropolitan Manila, our precipitation samples were relatively isotopically enriched for the following two days, namely -9.12 ‰ on 17 July and -6.26 ‰ on 18 July.

Line 301. I do not think you can consider these outliers, there are more of these values than ones associated to TCs.

Response: This is correct. These outliers are not considered as they are not related to TC activities. We had identified these outliers as produced by convective precipitation events using IMERG satellite data.

Technical Corrections:

General comment. Author should review and ensure the use the units and symbols. For example, the authors use d◦m' at line 115 and dd.ddd◦ at line 132.

Response: Thank you, and we have revised the manuscript and used the d◦m' consistently.

Line 35. A reference here would be helpful to support such a statement.

Response: We have added Cinco et al., 2014 as reference there.

Line 40. "Nine TCs per year made landfall on [...] Philippine waters is 19.4 per year." Consider revising wording, slightly confusing.

Response: We rephrased this sentence as the following: Nine TCs per year made landfall on average between 1951 to 2013 in the Philippines. The number of TCs not making landfall but reaching Philippine waters is substantially higher with 19.4 per year (Cinco et al., 2016).

Line 123. add year of census to population.

Response: We have added the year of census at line 123: 101 million 2017 census

Line 134-137. I suggest removing commercial URLs. It is enough to say the Brand and model.

Response: We have removed commercial URLs at line 134 and 137.

Line 149; 158 URL should be in reference list, not in-text.

Response: We have removed these URLs from the text at line 149 and 158.

Lines 343 -347. I believe you mean r2 (not r), also should all be in presented the same way, not some in-text and some in parentheses. Section 4.4, and in general.

Response: We have made it uniform and now present these values in text and not in parentheses at line 343, 345, 346 and 347.

The discipline of using paleoarchives to reconstruct TC activity is called paleotempestology.

Response: Thank you, we have put more emphasis on this and properly mention paleotempestology several times throughout the text. We have added it at line 79, 396, 402 and 463.

Comments of reviewer 3 and authors' reply to every concern:

In this manuscript, daily measurements of the isotopic composition of precipitation in Manila are presented that have been performed over a period of about 19 months. Events with strong isotopic depletion are linked to passages of tropical cyclones. Unfortunately, in my opinion, the paper is very limited in terms of scientific content (data analysis and interpretation). I have a hard time identifying novel results or conclusions that may merit publication in a peer-reviewed paper. I thus cannot recommend this study for publication in NHESS.

The only conclusion that really follows from the analyses presented in this manuscript is that the precipitation associated with tropical cyclones, in particular those passing relatively close to measurement site, is isotopically more depleted than precipitation from other cloud systems. However, this conclusion is not novel. Already in the late1990ies, Lawrence and others obtained similar results based on more detailed measurements and analyses. I cannot think of any reason why this very general result should be particularly different or noteworthy for TCs in the Philippines. Moreover, this conclusion and the analyses in the manuscript correspond well with the isotopic amount effect (see next point), which has been widely discussed in the literature since Dansgaard's work in the 1960ies.

A characteristic property of tropical precipitation is that larger precipitation amounts are associated with more depleted isotope ratios (amount effect). This is mentioned in passing in the introduction of this manuscript, but not discussed in detail. Nevertheless, it can explain the results presented here: As TCs typically lead to large precipitation amounts, it is to be expected that they are also associated with lower isotope ratios. This is hinted at in the manuscript, but not shown explicitly (e.g., by plotting precipitation amount against isotope ratio). Along the same line, precipitation amount typically declines with distance from the TC center (beyond the eyewall), as does isotopic depletion. As mentioned before, the fact that the results and interpretation do not go beyond this variant of the well-known amount effect strongly compromises the novelty of the study.

A major motivation for the authors appears to come from potential applications of isotope data from proxy archives for paleoclimate reconstructions. However, I don't see how their data could add to the present practice of using tropical data for reconstructions of precipitation amount, based on the amount effect described above. There are many vague statements in the manuscript that, at least for me, are difficult to follow. For example, how could changes in TC intensity, frequency or distance from the proxy site be distinguished from single isotope time series? Why should an isotope time series only represent changes in TC precipitation and not, for instance, changes in the precipitation amount in non-TC time periods? If the idea should be to learn something about such more detailed atmospheric processes (related, e.g., to TCs) by combining proxy records from different locations, then this approach should also be demonstrated with the help of a contemporary study combining data distributed in space, and not just from a single location.

Response: Dear reviewer, we appreciate your feedback regarding our manuscript. We would like to maintain our position that our study provides novel results in the understanding of

typhoons and its effect on precipitation's isotopic composition in the Southeast Asian region. It is true that isotopic depletion related to tropical cyclones has been shown previously in other parts of the world. However, our study is the first of this kind in Southeast Asia, where there is still very limited data available, and provides insight into the magnitude of influence of typhoon events can have on precipitation isotopes.

In your comments, you mentioned the amount effect and how it might explain our data. However, our focus is not on the amount effect, and also we did not intend to investigate it further using our daily isotope measurements affected by typhoon activities. This is because the amount effect is not observed in daily precipitation isotope measurements, but rather on longer timescales such as months and years (please refer to Belgaman et al., 2016; He at al., 2018; Kurita et al., 2009; Marryanna et al., 2017; Permana et al., 2016). We introduced the amount effect (line 85) and provided the explanations for the isotopic depletion related to typhoons observed at our study site (lines 83 to 87). Yet, we believe that our daily precipitation isotope data is helpful for better understanding certain tropical cyclone characteristics in the Philippines, such as its rainfall intensity, strength, distance and track, and this may have implications for future studies in paleotempestology in the region.

To base analyses for other parts of the world such as Southeast Asia using the data from North/South America may result in inaccurate conclusions, as response of precipitation isotopes to typhoons likely varies from region to region because of different climate conditions. Our manuscript presents in-situ data of precipitation isotopes affected by TC activities in the Philippines, providing an important baseline for other studies such as paleotempestological investigations in Southeast Asia. Thus, we believe that our paper would add value to the study of paleotempestology in the Southeast Asian region, which can also help to draw conclusions for prospective mitigation measures in the long run. The results and discussion parts of the manuscript show the capabilities of an isotope time series of 19 months. For instance, we explain how distance (figure 4, figure 5) or TC frequency (figure 2) can be derived from an isotope time series. In addition, further analysis in our manuscript provides insights and caveats in the usage of precipitation isotopes for studies - such as potential "false alarms" for depleted isotope values, resulting from precipitation from other rainfall events rather than TC precipitation (lines 318, 365, 413, 458), as well as opportunity to improve future data quality for such studies by setting up several new stations covering a spatial gradient (line 432). The significance of our study is acknowledged by the second reviewer and the suggested changes have been made by us in order to improve the manuscript (for example presenting all the isotope values in the results or adding more information about the study site in Metropolitan Manila).