Biogeosciences Discuss., author comment AC1
https://doi.org/10.5194/bg-2022-47-AC1, 2022

Reply on RC1

Romina Llanos et al.

Author comment on "Recent significant decline of strong carbon peat accumulation rates in tropical Andes related to climate change and glacier retreat" by Romina Llanos et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2022-47-AC1, 2022

In order to be able to respond to each of the reviewer's observations and comments, I will put all of them in "normal" font, and our responses to them in bold italics, to make sure we respond to everything.

GENERAL COMMENTS

Llanos et al. present a record from a sedimentary core from the Apacheta region in the central Peruvian Andes. Four peat cores from high-Andean Distichia cushion-plant peatlands were radiocarbon-dated and C accumulation rates, TOC and C stable isotope composition are presented for the four 29-35 cm long peat cores. Based on the presumption by Skrzypek et al. (2011), who interpreted growing season temperature as a determining factor for $\delta^{13}C$ in a high-Andean Distichia peatland in Peru, the authors reconstruct temperature from both studied peatlands for the period 1970-2015 CE.

The presented research would potentially represent an important contribution of paleodata in a region, where paleoenvironmental data is still very scarce. However, the presentation and interpretation of the data need significant improvement, and currently, the presented research does not represent a sound and elaborate work. Overall presentation, methodological concept, and data interpretation are not ready yet for publication. As the presented research work needs significant improvement on several topics, I do not recommend it for publication in Biogeosciences.

We thank the referee for their positive comments, their detailed review and for the constructive recommendations. We respond thereafter to each of their comments.

SPECIFIC COMMENTS

1. The exact coordinates of the investigated sites are missing. However, the sites can somewhat be located with help of Figure 1. By checking the "sub-catchments", I absolutely do not agree with the presented "sub-catchment" area of 130 km² for APA 1, which is situated in a kar valley of Nevado Portuguesa (aka Chicllarazo or Apacheta) and has no connection to the yellow-shaded area. However, without exact coordinates, this remains unclear.

We thank the referee for this comment and in the new version we have included

the location in the manuscript.

The exact coordinates of the investigated sites are now specified and we detected a mistake in APA1 position on the map figure 1. APA 1 Cores: Lat. -13,35128; Long. -74,65882; APA 2 Cores: Lat. -13,34324; Long. -74,66140.

Now the sub-catchment areas have been recalculated after a supplementary field work (March-April 2022) and indeed APA1 is much smaller since it is not drained by Apacheta River which is located several meters below the peatland. The sub-catchment area of APA1 is only 3.3 Km2 while for APA2, the sub-catchment area, inserted in APA2 one, is 2.14 km2 (please see Figures RC1.1: The sub-catchment area of APA1, and Figure RC1.2: The sub-catchment area of APA2, in SUPPLEMENT).

None of the peatlands studied is located in the valley of Nevado Portuguesa, the location of the APA1 point on the map (figure 1B) was wrong, but it has already been rectified and the coordinates have also been specified in the paper.

2. The "study area" chapter lacks important information. Distichia muscoides is the only plant species mentioned. In the central Peruvian Andes, cushion-plant peatlands are often dominated by Distichia, but accompanied by other species, which - depending on site factors - might dominate specific areas of the peatlands (other cushion-formers like Plantago rigida, Zameioscirpus muticus, Phylloscirpus deserticola or reed grasses like Deyeuxia/Calamagrostis) or grow into the Distichia Further, these peatlands are usually characterized by shallow pools, which form between the cushions (Coronel et al. 2004). No information is given on that, nor on the topography of the peatland, nor on the influence of grazing or other impact by the local population. Further, no information is provided on the possible influence of geothermal springs, which might contribute to the springwater. The presented study did not conduct analysis of the peatlands` spring and surface water (at least pH and conductivity), which is a prerequisite for any peatland study. Noble & McKee (1982) mention geothermal springs for the Nevado Portuguesa area. Can the influence of geothermal water be excluded?

We thank you for these recommendations in order to provide the reader with more information about our study area.

Accompanying species found in the study area will be added.

"In this region, Distichia muscoides Nees & Meyen (Juncaceae) is the predominant cushion peatland species, and it is present on most high-elevation peatlands in the central Peruvian Andes (Schittek et al., 2015), however other plant species are also found, such as Plantago tubulosa, Aciachne pulvinata, Scirpus rigidus, Calamagrostis rigescens, Calamagrostis spp., Hypochaeris sessiliflora, Hypsela reniformis. Distichia cushions are surrounded by little shallow pools (around 50 cm-large)."

We have also included information about the topography and soils of the study area:

"The Apacheta region is characterized by being a mountainous area, with peatlands located in the valleys and sections with gentle slope, at altitudes above 4100 m asl. Edaphologically, the study area is mainly composed of relatively medium texture deep soils developed upon volcanic rocks (porphyritic andesite) from Apacheta formation (Nm-ap_s) (INGEMMET, 2002). In this area, the main economic activities of the local population are agriculture and livestock. Agriculture takes place at lower altitudes than peatlands and grazing of livestock

occurs in the peatland zone, because peatlands provide year-round forage production for grazing native domestic camelids (llama and alpaca) and for livestock species (particularly sheep). Evidence of grazing activity has been observed in the study area although with little visible impact on peatlands."

About the influence of geothermal water on the study area:

We think that the study area is not influenced by geothermal activity. But as mentioned by Noble & McKee (1982), there are thermal springs in the surrounding region. Also, according to the database of INGEMET (National Geological, Mining and Metallurgical Institute) of Peru there are 2 thermal springs:

- Niñobamba (-13,334°; -74,581°; 3670 m asl) which is located more than 7 km downstream from the Apacheta River and 300 m of altitude difference, so it would not have influence in the study zone.

- Licapa (-13,361°, -74,871°, 4100 m asl) located approximately 23 km west of the study area and belongs to another hydrological basin, so the influence of a geothermal spring is ruled out.

About the analysis of the peatlands` spring and surface water, sorry for our negligence. We have measured pH and conductivity and will add this information in the text:

"Between the cushions of APA 1 an APA 2 peatlands we found small and shallow pools of water that are characteristic of this type of ecosystem. The mean pH and conductivity, measured in these pools during the campaign, were 5.93 and 45.4 μS cm^{-1} for APA 1 and 6.01 and 39.2 μS cm^{-1}for APA2, respectively."

2. The authors point out the relation of carbon peat accumulation rates and glacier retreat, since glaciers have been recognized as "the main water source" for high-Andean peatlands. Line 266 says: "The subsequent reduction in peat growth rates could have been due in part to the decrease in the rate of water inflow from nearby glaciers to peatlands after their complete disappearance." In point of fact, I cannot detect glaciers within the upper catchments of both investigated peatland sites. Many peatlands in the tropical Andes are fed by glacial meltwater. However, the majority of high-Andean peatlands is fed by permafrost (Ruthsatz et al. 2020), and water originates from high-elevation cryogenic soils and glaciolithic deposits (Trombotto 2000). This is the case for the two investigated peatlands (as far as I presume from Figure 1 and Google Earth). Therefore, the whole climate change-related argumentation should not solely focus on glaciers, but also on the very important role of permafrost.

Indeed nowadays there is no glacier in the area and, as the temperature is always positive (see MAAT curves) very probably no permafrost exist today. According to Chadbrun et al. (2017), permafrost requires an average annual temperature of less than -2°C. It is not the case in our study area as we can see with the annual temperature data shown in Figure RC1.3 (Mean annual temperature (°C) over the period 1958-2018 of the four pixels of TerraClimate datasets covering the two sub-catchments, in SUPPLEMENT), so the probability of having permafrost at present is low.

The TerraClimate dataset comprises a global dataset based on reanalysis data since 1958, with a 4 km grid size at a monthly time scale. This dataset was validated with the Global Historical Climatology Network using 3,230 stations for temperature (r =0.95; mean absolute error 0.32°C) and 6,102 stations for

precipitation (r =0.90; mean absolute error 9.1%) (Abatzoglou et al., 2018).

The development of permafrost is badly known in the Andes (Trombotto, 2000) and cryogenic soils are formed above 4600m in Peruvian and Bolivian Cordilleras (Trombotto, 2000). So we cannot exclude that permafrost has played some role in the past in supplying groundwaters to the peatlands during period of warming climate. The manuscript have been modified in this sense.

4. For radiocarbon dates, the authors use the SH calibration dataset. Due to a significant influx of Northern Hemisphere air masses and moisture over a substantial part of the continent, especially the tropical central Andes, during the South American Summer Monsoon (SASM), Marsh et al. (2018) recommend using a mixed calibration curve. During the austral spring and summer seasons, the south shift in the ITCZ brings atmospheric CO2 from the Northern Hemisphere to the Andes, which is taken up by the vegetation during the growing season (Schittek et al. 2016). How do the authors explain the use of the SH calibration set?

We thank the referee for this observation and, indeed, as the region rainfall is associated to the South American Monsoon a mixed atmospheric post-bomb 14C curve between Northern and Southern Hemisphere must be used. We recalibrated the age with the most recent curve published by Hua et al. (2021) using the mixed curve recommended for South American Monsoon region (Bomb21SH3). All other data have been recalculated in agreement of this.

The new age models are shown in Figure RC1.4 (in SUPPLEMENT) and are very similar to the old ones.

5. The authors do not pay attention to the effect that bulk peat stable carbon isotopes may reflect the dilution of atmospheric $\delta^{13}CO_2$ and the effects of early stage kinetic fractionation during diagenesis (Esmeijer-Liu et al. 2012) or other factors like dust influx or vegetational changes. For a scientifically sound reconstruction of paleotemperatures, this has to be taken into account.

Esmeijer-Liu et al.(2012) have studied a peat core from Northern Finland and observed an increase of $\partial^{13}C$ toward the top. The linear trend of $\partial^{13}C$ increase is 0.0072 ‰ yr^{-1}, to be compare to the 0.047‰ yr^{-1} (APA1- C5) and 0.044‰ yr^{-1} (APA2- C4) we observed in our cores. The most recent atmospheric $\partial^{13}C$ - CO2 data (Graven et al., 2017) indicate a trend of 0,0078‰ yr^{-1} for the same period, very close to Esmeijer-Liu et al (2012). So, the observed variation in Finland core can be explained by the atmospheric trend alone. However, the authors consider that there is also an effect of $\partial^{13}C$ decrease during the diagenesis of organic matter. Considering the trends value, this effect must be very low compare with the changes we measured. However, the referee is right in remembering this « Suess » effect on atmospheric $\partial^{13}C$ - CO2 and we will integrate it in our calculations.

Distichia remains are observable in great quantity from the top to the base of our cores and there is no evidence of vegetation change during the study period. We did not find any data about recent dust deposition in the region but it will be surprising that dust deposition has decrease in the las decades.

6. A scientifically sound "high-resolution" record concerning the past 50 years would require age control by applying the Pb/Cs dating method rather than applying CaliBomb upon radiocarbon dating for only 3 samples per core.

Dating of peat using ^{210}Pb or ^{137}Cs is a tricky problem, especially in highly porous

peatlands like those dominated by Distichia where lead is likely to move. The roots of Distichia are likely to transport lead to deeper areas (Benavides et al., 2015). Most importantly, however, dating from Distichia peatlands in Colombia (Benavides et al., 2015) has shown very low unsupported lead values, close to the background of supported lead, when the sedimentation rate is very high. Since the sedimentation rates we observe are even stronger we believe that this method could not have been used.

7. The stable isotope measurement method is described in only one sentence. How about the use of calibrated laboratory standards and what is the analytical uncertainty?

The analytical standard used was "High Organic Sediment Standard – OAS" that consists of batch of high organic content sediments standard traceable to IAEA-CH-6, prepared and certified by Elemental Microanalysis Ltd, Okehampton, Devon. The analytical uncertainty is 0.2‰.

line 43: change "High-altitude" into "High-elevation"

We agree.

line 46: "Their most important ecological role..." This sentence should be reworked. First, it should not be evaluated what is the most important ecological role of peatlands. Second, tropical peatlands do not control decomposition processes in the soil!!!

Our sentence is not clear, of course we cannot evaluate the most important ecological role of peatlands. They just have a great potential to accumulate organic carbon due to the slow decomposition rate of the plants that give origin to the peat. We have changed the text.

lines 52-75: The focus should be rather on permafrost than on glaciers as the investigated peatlands seemingly are not fed by glacial meltwater.

See point 3.

line 81: Vegetation is not dominated by Distichia muscoides! (What is meant by "vegetation"??? Peatland? Steppe?). This is only the case for peatland areas with permanent saturation. The cited literature in this paragraph has no relation to the Apacheta region.

Distichia is the dominant plant species in cushion peatlands in this region and, according to Schitteck et al 2015, in the Central Andes as a whole.

line 90: "The climate of the Apacheta peatlands..." I do not agree with this statement. First, it should be "Apacheta region", second, there definitely is a rainy and a dry season, as this area is affected by the South American summer monsoon.

We fully agree, this is what we meant when we wrote about "large seasonal precipitation variability" with a total rainfall of 830 mm with 82% of precipitation during the rainy season from october to march.

line 199: Chimner

We agree.

line 200: *Oxychloe*

We agree.

line 200: *Azorella* is typical for high-Andean steppe vegetation and never grows inside a peatland.

We agree.

line 250: "...which are typically associated with glacial dynamics..." I do not agree. Distichia muscoides is associated to permanent saturation above 4000 m asl. Its distribution is not restricted to the presence of glaciers.

You are right. Tropical glaciers are an important source of water only for peatlands that are close to them, within their watershed. We have changed the text.

line 292: "good relationship" What does that mean? Did you conduct any correlation analysis?

The comparison is only visual, correlation calculation for this kind of data with different dates in each curve is not very possible. We compared the trends for the NCEP data and reconstructed temperature.

Figure 8: The reconstructed air temperatures of the two presented cores, in some parts, differ significantly, although the two coring sites are very close to each other. How do the authors explain this? How about the other two retrieved cores? Is there any results for them?

As we explained, one of the problems is that the $\partial^{13}C$ and thus temperature values are obtained for different dates on the different cores. Another point is that the growth rates are different in the two cores, meaning that each sample does not correspond to the same interval of time. However, it is certain that this cannot explain all the differences between the curves and those other parameters than temperature also influence the $\partial^{13}C$. This is part of the uncertainty on the temperature reconstruction that we consider nevertheless to be the main factor influencing the $\partial^{13}C$.

For the two other cores the sampling interval is too large (~3 cm) for a good temporal resolution.

The following publications are mentioned in the manuscript, but not listed in the references: Salvador et al. 2014, Huaman et al. 2020, Thompson et al. 2006, Kalnay et al. 1996, Hribljan et al. 2015, Hribljan et al. 2016, Drexler et al. 2015, Cooper et al. 2010, Lourencato et al. 2017, Roa-Garcia et al. 2016, Lähteenoja et al. 2013, Hapsari et al. 2017, Craft & Richardson 1993, Tolonen & Turunen 1996, Turunen et al. 2001, Chimner & Cooper 2003, Turunen et al. 2004, Beilman et al. 2009, Van Bellen et al. 2011, Nakatsubo et al. 2014, Chimner et al. 2016, Bao et al. 2010, Mitsch & Gosselink 2007

We have corrected that, thank you.

Please also note the supplement to this comment:
https://bg.copernicus.org/preprints/bg-2022-47/bg-2022-47-AC1-supplement.pdf