

Clim. Past Discuss., author comment AC2
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Reply on RC2

Jack Longman et al.

Author comment on "Carbon accumulation rates of Holocene peatlands in central-eastern Europe document the driving role of human impact over the past 4000 years" by Jack Longman et al., Clim. Past Discuss., <https://doi.org/10.5194/cp-2021-65-AC2>, 2021

This study by Longman et al. present a thorough synthesis of long-term Holocene carbon accumulation rates for the Carpathian Mountains, presenting data from eight new peat cores. This is an excellent addition to global peat datasets as records from mountain peatlands and peatlands from Eastern Europe and poorly studied. The Holocene dating resolution for the study sites is very impressive, as is the evaluation of the potential drivers for changes in CAR. The methods and discussion of a complex mix of drivers including anthropogenic impacts and dust inputs are well thought out and clearly presented, both from data-driven hypotheses and explanations from other studies in the region.

We appreciate the reviewer's detailed and helpful comments, and have used them to improve the manuscript. Our responses to the comments are highlighted below in italics.

In general, for clarity, I would recommend that the site information, results, supplementary etc. are presented in the same site order every time, either from North to South or the reverse.

We agree this improves the readability of our work and have adjusted all figures and tables to present sites along a SW to NE transect, in the same manner as Figure 2.

In addition, after reading such a well-presented and convincing "carbon story", I would have preferred the conclusion to end with larger-scale impacts for the future of the regions and further study. Perhaps adding that high-resolution studies of the last millennium or last couple centuries would be useful future studies to evaluate these drivers as well as recent anthropogenic impacts and future trajectories. Finally, the importance of the sites should be highlighted. Yes, it is a small carbon sink on a global scale, but what about the relative % for Romania or the Carpathian Mountain region?

We appreciate these suggestions, and now include a short addition to the conclusion, which highlight how important these environments may be for CE European carbon storage and some possible future research directions.

"Our work indicates the potentially large carbon sink represented by mountainous peatlands in Central-Eastern Europe. To better constrain their importance in the regional carbon cycle, more work is necessary to investigate other carbon sinks in Romania and

Serbia, such as lake sediment, forest soils and lowland peatlands. Work in these environments should help to better understand the size of the current carbon sink, and how it has varied in the past. This would help in determining exactly how important mountain bogs are in the regional carbon balance, and, when combined management and monitoring exercises, may help to mitigate the worst of the impacts of anthropogenic climate change."

Unfortunately, the data necessary to assess exactly how much the carbon sink of bogs in Romania represents as a proportion of total carbon sinks, and so we cannot make a reliable estimate. Future work in the region could make such conclusions possible.

In addition to the above general comments, I have the following minor points to clarify the methods and enhance the discussion, in particular relating to the age-depth models.

Line 19: suggest rephrasing to "in mountainous peatlands"

We have made this change.

Line 49: suggest rephrasing to "on individual scales" to "for individual peatlands" or "on a local scale"

We agree and have made this change.

Line 72: suggest rephrasing to "important carbon sink for the regional carbon budget"

We have rephrased this sentence in light of the other reviewer's comments, so it now reads:

"...constitute an important carbon sink for the overall carbon budget, one which may represent a regionally important carbon stock."

METHODOLOGY

Section 2.1 Refer to Figure 1 and Table 1 here in the text

We have added references to the figure and table here.

Section 2.2: where were the samples for the other cores dated? What sample thickness was dated?

We have included this information in the updated manuscript:

"The majority of samples were taken from 1cm slices of bulk sediment/peat, an approach which has been shown to yield reliable age information (Holmquist et al., 2016)."

And

"Samples from Sureanu (SUR), Zanoaga Rosie (ZNG), MLH and Mohos (MOH) bogs were measured at the HEKAL AMS Laboratory, MTA ATOMKI Institute for Nuclear Research of the Hungarian Academy of Sciences in Debrecen. 5 dates from SUR were analysed by the 14C Centre at Queen's University Belfast (Longman et al., 2017a). Samples from Crveni Potok (CP) were analysed on extracted plant macrofossils at the Poznan Radiocarbon Laboratory (Finsinger et al., 2017)."

Section 2.3: There is a step missing here. To clarify, as with LOI calculations, was the C density calculated as 50% of the organic matter density (as in Turunen et al. 2002 and

others by convention)?

We did indeed follow this methodology, and include the following in the updated manuscript:

"Organic content was converted to carbon density by assuming 50% carbon (c.f. Turunen et al., 2002)."

It might be useful to present figures for the bulk density, C%, ash content for each core in the supplementary material, particularly in light of the focus in the discussion on dust.

We include these figures in the updated supplementary material.

Section 2.4: The time series with changepoint analysis aspect is really interesting!

I suggest that the LORCA and C stock sections be moved to section 2.3 (on Carbon accumulation calculations). There should also be a mention that these rates (CAR, LORCA) are all "apparent" rates, not accounting for decomposition, and not calculated from a net carbon balance.

We have moved this methodology to Section 2.3, and now indicate these rates are all 'apparent':

"As we do not account for decomposition, all rates presented here (e.g. LORCA, RERCA and CAR) are apparent and not calculated from a net carbon balance."

Line 104: Clarify the simple LORCA definition before explaining the calculation. As in the Clymo and Turunen articles cited, LORCA is the cumulative carbon for the core divided by the basal age.

We clarify this in the updated manuscript.

Line 117: The justification for limiting discussion of RERCA is very relevant here – focus on longer term rates! I would suggest adding a methodological justification that the dating resolution for the last ~100 years is limited for the cores presented.

We have updated the manuscript as follows:

"Further, the resolution of radiocarbon dating for the most recent 100 years is too low for meaningful conclusions for a number of the bogs. Therefore, we also quantified the amount of carbon accumulation for the past 1000 years (see Table 2 for all average values), following Gallego-Sala et al. (2018), and focus our discussion on longer-term CAR variability."

Line 135: "averaging multiple records provides" (add "s" to provide)

Change made.

RESULTS

I suggest, for clarity, that the results in the figures, models and tables be presented in the same order as in the methods.

The ordering of the methods is dependent upon location of analyses (e.g. where the radiocarbon and LOI analysis was completed), and so we would rather not use this ordering scheme throughout. Instead, and in agreement with the reviewer's earlier

comment, we now order all figures, model and tables from SW to NE.

Line 170: Suggest using consistent decimals for LORCA and CAR.

We have removed all decimal places here, for simplicity and uniformity.

Line 186: peat bogs (separate the words)

Change made.

DISCUSSION

In addition to mineral inputs from local erosion and deposition, could wind direction and/or exposure be factors to consider? For instance, in peatlands along the Gulf of St Lawrence in Canada had higher LORCA if they were sheltered from cold winter winds (<https://doi.org/10.1177/0959683614540727>), and other peatlands in NE China had increased productivity from mineral inputs from wind-borne dust from the Loess Plateau (<https://doi.org/10.1177/0959683619892661>). Note that, while I do find the anthropogenic driver argument provided by the authors very convincing, these could be additional climatic factors to consider.

These are interesting points, and we now refer the reader to the first study in our updated manuscript, but make it clear that the investigation of these small-scale forces is challenging in a study like ours:

"In addition to general climatic controls, it is also possible that smaller-term fluctuations and local configurations may impact CARs. For example, CARs of some peatlands along the St. Lawrence River in Canada are strongly impacted by the level of sheltering from cold winter winds (Magnan & Garneau, 2014). Such local climatic controls are challenging to evaluate on the scales studied here but may play a role in some of the bogs."

We have added the second reference to our section discussing the impact of dust-related nutrient supply:

"Some previous work also highlighted a range of other drivers behind peat accumulation rates, with mineral dust input listed as the primary driver of peat growth in a Swedish peatland (Kylander et al., 2018), and with fluctuations in supply of dust from the Loess Plateau in China important in controlling local peat development (Pratte et al., 2019)."

Line 210: yes, this is a small global sink and the rapid nature of accumulation is great but perhaps to further value the importance of this sink, could you put it in context in Romania? For ex. Is this more C than in forests? Is it 50% of annual emissions?

This is a good suggestion and so we have added the following to the updated manuscript. We have also changed the unit to megatonnes as it is more sensible for our values:

"It should be noted that this upper estimate is four times the amount of carbon sequestered by forests in Romania per year (2.5 Mt C/yr) (Olofsson et al., 2009), and represents 13% of the yearly Romanian anthropogenic carbon emissions (circa 80 Mt C/yr) (Crippa et al., 2021)."

Line 345-346: Rephrase this passage for clarity. The decomposition is ongoing and recent peat has undergone less decomposition resulting in more "apparent" carbon. It's not clear that it is being preserved or sequestered.

We have adjusted this sentence as suggested.

TABLES

Table 1. I suggest (for clarity) that the authors present the peatlands in Table 1 in the same order as in the map or figures throughout the paper.

We have made this change to Tables 1 & 2, and Figure 3.

It may also be useful to add the coring date and a very general description of peatland type (raised bog, blanket bog, fen) – perhaps split into 2 tables (for example, Table 1: site information; Table 2: peat data), or in the supplementary material if the authors feel this is too much for one in-text table.

We have added this information to Table 1, wherever it was available.

Table 2. Add the units for RERCA

Units added

Table 3. Precipitation seasonality p-value for whole period should be <0.01

Correction made.

SUPPLEMENTARY MATERIAL

First paragraph: Rephrase - Sphagnum stems not stalks

Change made.

Last paragraph: The dates were calibrated using IntCal20 (Calib 8.2?) not IntCal13, as stated in the main text. Indicate here also that the models were generated using the rbacon package (v.?) in R.

Changes made.

Age-depth models: As stated previously, the modelling resolution is very impressive! Below are some small points of clarification, or curiosity on my part.

- Supplementary Figures 1, 4 and 3: indicate in the legends that the bottom of these models is interpolated (e.g. BVU, the bottom-most 14C date is 144 cm yet the model extends to almost 200 cm and the basal peat). The rates calculated for these interpolated sections could bias the results.

We have added the following to each of these legends:

"The base of this model (between the last radiocarbon date and basal peat) is interpolated, and so carbon accumulation rates calculated from these depths should be treated with caution."

- Supplementary Figures 6, 7 and 8: there is no surface input into these models. Were the dates interpolated from the top-most 14C date to the coring date? A brief sentence explaining this could be added to the legend.

We have added the following to the legends of Figures 6 & 7:

"For the uppermost section of peat, the model interpolates between coring date and the first radiocarbon date."

For Supplementary Figure 8, sampling did not include the very uppermost section of peat, with the top date taken from the uppermost sampled peat layer.

- Supplementary Figure 2 (SUR): what is the green calendar date at ~35-40 cm?

This is the first radiocarbon date, coloured green by Bacon as it is younger than 1950 CE.

- Supplementary Figure 6 (ZNG): Do the authors have any thoughts on why the accumulation rate is so low between 1000-8000 cal BP? Perhaps a hiatus in the model would allow for all the dates to be included, if there were a known disturbance such as erosion or a fire.

This is not necessarily a hiatus, but a period of very slow peat growth, a feature observed in all blanket bogs from Semenic Mountain (with BVU showing it in deeper sections, but not presented here). A complete hiatus does not occur- indeed our radiocarbon dating across the period indicates the slow but steady accumulation of peat.

Supplementary Table 1:

- It would be useful to add columns for calibrated dates and modelled dates (and ranges) in addition to the 14C ages presented in the table. If not here in the supplementary material then definitely on Pangaea

We agree and so will include these data in our Pangaea submission.

- There is an error with the depth for the Mlhua core – basal depth is 6730 cm!

Change made- 'depth' and 'age' columns have been switched.

Supplementary Figure 9: Romanian peat bogs (add n to Romanian)

Change made.