Biogeosciences Discussions

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Reply on RC2

Angelica Feurdean

Author comment on "Experimental production of charcoal morphologies to discriminate fuel source and fire type: an example from Siberian taiga" by Angelica Feurdean, Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-1-AC3, 2021

Reviewer 2 General Comments:

Feurdean presents a dataset of experimental charcoal produced from 17 species endemic to boreal Siberian. Using these experimentally produced charcoal, Feurdean makes insights into the reliability and applicability of charcoal morphologies as a proxy of fuel type. Additionally, the author shows how charcoal mass is retained as a function of combustion temperature for these samples.

The manuscript is very interesting and presents a promising dataset for the paleofire field. Its efforts towards proxy calibration of charcoal morphology and morphometry represent a key advance. Its experimental characterization of charcoal produced from several new fuel types and taxa, as well as replication of previous experimental productions of charcoal, make it a useful contribution to the field. Mass retention during charcoal production represents a key gap in our understanding of the source to sink controls of sedimentary charcoal, and this manuscript helps to bridge this gap. Lastly, it improves on some of the methodological approaches of earlier experimental productions of charcoal particles.

However, the manuscript falls short in several ways. Although the bulk of the manuscript is in good order, and the study itself is robust and scientifically sound, the discussion and conclusions are, in my opinion, woefully underdeveloped, especially in light of the novelty of the dataset and approach. In a broader sense, the manuscript fails to fully deliver on the potential conclusions and insights that could be gained from a dataset which is truly brimming with potential. I recommend moderate revision prior to publication and have outlined, in my opinion, the manuscript's primary shortcomings and areas needing improvement below.

R: I want to thank the reviewer for the useful and thoughtful comments, as well as the overall positive response in feeling that this paper was interesting and a useful contribution to the community.

Firstly, it lacks in-depth comparison to prior work, which will surely undermine its impact. For example, several of the taxa tested by the author have also been directly tested in previous experimental studies (e.g., Eriophorum vaginatum in Pereboom et al. (2020), Pinus sylvestris in Crawford and Belcher (2014)), yet there is no discussion of the

similarities and differences of the morphometrics of the charcoal produced from these taxa. Similarly, previous experimental studies have used a variety of techniques (and temperatures) to produce charcoal, but limited comparison is made with these studies and their conclusions. How and why do the values differ and compare between this and other experimental charcoal studies? Although the Discussion focuses on the findings of this study, it does not sufficiently contextualize these findings within those of the published literature. For example, section 4.2 refers to several other studies, but only vaguely compares findings of charcoal particle elongation between these studies. The published aspect ratio data of these experimental studies should be more thoroughly discussed and explored if this is this to have a veritable impact on the field.

R: I am working to extend the comparison of results from this study with others from published literature. The comparisons are also readily visible in the added new Table. As most of the published literature is on the L:W ratio, I have contextualized these findings better.

Secondly, the manuscript does not make actionable conclusions for the paleofire field. Besides a somewhat unconvincing (see specific comments below) description of the potential utility to use charcoal aspect ratios to distinguish fire and fuel types, the manuscript does not provide explicit descriptions of the morphometric values that be used to constrain interpretations of sedimentary charcoal. What is the cut-off for elongation indicative of graminoids? What are the ranges of morphometric values that can be indicative of fuel types? What are the mean values of the aspect ratios of the fuel types that can be distinguished (wood, graminoids, and leaves, as indicated in the Conclusions section)? What is the quantitative relationship between temperature and charcoal mass retention? More specific and worthwhile conclusions need to be made from the dataset. At present, the manuscript is intriguing but does not provide explicit values and tools that can be applied to actual sediment samples, and in turn, inform paleofire interpretations.

R: These are all pertinent questions. I will update the Discussion of the manuscript to further explore and extend on: a) the cut-off for elongation indicative of graminoids? B) the ranges of morphometric values that can be indicative of fuel types? C) the mean values of the aspect ratios of the fuel types that can be distinguished (wood, graminoids, and leaves), and D) the quantitative relationship between temperature and charcoal mass retention. On the other hand, as already stated in the Conclusion, in many cases the overlapping aspect ratios between fuel types make it difficult to come with a clearly defined cut-off value or range values indicative of a specific fuel type.

Lastly, the author should provide the morphometric values derived from the experimental charcoal in Table 1 (or in the supplement) to enable others to more directly compare with this dataset. As it stands, future work will have to estimate values from the figures. To my knowledge, provision of explicit data value ranges is the norm in these types of studies. I strongly suggest the author provide these values to facilitate use of the insights provided by the manuscript.

R: I have prepared a table showing mean values of L:W, Length, and Area in the main paper, and one showing the full range of individual morphometric measurements across all temperatures in the Supplementary Material.

Specific Comments:

L103-104: What was the rationale for this sieve size, given the wide range of sieve sizes used in the paleofire field?

- To get rid of smaller particles but this can anyway be done by automatic selection of grain size. I have added a sentence stating this: The sieving step could be skipped if the size of charcoal particles is detected automatically.

L203-206: Shouldn't this be irrelevant given that the sampled were uniformly dried before combustion?

R: Perhaps. However, with this sentence I wanted to point out that while all other material collected was from alive plants, the trunk wood comes from a dead tree.

L243: Neither of these citations are provided in the references list. The Clark (Clark 1988) and Higuera (Peters and Higuera 2007, Higuera et al. 2007) models of charcoal dispersal do not actually incorporate particle shape. To my knowledge, the model of Vachula and Richter (2018) is the only one to directly test the effect of charcoal particle shape on dispersal distance.

R: Thank you for pointing out this. Indeed, most models assume similar, round particles when simulating the particles' transports. Clark and Peters (2007) made a difference between longer versus rounded particles. They have derived a velocity index, which determined that elongated particles have a lower velocity index and have consequently a longer time of residency into the atmosphere than the rounder one. I have extended this chapter that now reads: '' The shape and density of charcoal particles affect their transport (Clark and Hussey, 1996; Higuera et al., 2014). Models and empirical data generally indicate that the amount of charcoal particle is greatest near the fire source (Clark et al., 1998; Clark and Royall, 1995; Higuera et al., 2007; Peters and Higuera, 2007; Tinner et al., 2006). However, models assume a uniform spherical particle shape and density, when in reality charcoal particles are of different shapes, sizes, and densities. Indeed, recent modelling results show that non-spherical particles have lower settling velocities than spherical particles and produce a spatially more extensive and heterogeneous particle-size distribution pattern (Vacula and Richter, 2018). Specifically, median dispersal distances for spherical and aspherical particles (>150 μm) could be up to 20 km apart (Vacula and Richter 2018). Similarly, Clark and Hussey (1996), derived a velocity index from sedimentary charcoal particles also found that non-spherical particles have lower setting velocities and higher residence time into the atmosphere than the elongated particles.

L248: Aleman et al. did not experimentally produce charcoal particles. The values referred to here were derived from environmental samples. This comparison is not appropriate, in my opinion.

R: Removed from here but added in the new Table dealing with comparisons with published literature.

L297-311: This conflation of fuel type and burn temperature is not convincing. Although the data presented in this paper clearly show the ability to differentiate fuel types, it seems a stretch to suggest that burn temperature might be inferred from fuel type assemblages and charred mass. ***How would this work for an environmental sample?***

How could charred mass be differentiated from total fire activity? Why isn't Figure 2H referred to and discussed in this section? *It should be useful in making these conclusions.*

R: The differentiation of fuel types is not straightforward and cannot be made based on charred mass alone, but by looking at the association between charcoal morphologies and fuel type. For example, if we know (based on charred mass) that Sphagnum preserves as charcoal only after low-temperature burnings, and if we find abundant Sphagnum charcoal morphotypes in the sediments, this could potentially mean that fire temperatures were low, otherwise Sphagnum would not have been preserved and be found as charcoal. Comparison with pollen and plant macrofossils would improve such interpretation. I'm therefore working to extend this aspect in the revised manuscript. Fig2H shows the aspect ratio for fuel mix at a single temperature (300 degrees) and has been used to determine the accuracy of aspect ratio in mix fuel types, as normally occurs in nature.

L359: Where are the morphometric measurement data? How can future researchers actually use these data to better inform their interpretations if they are not provided?

R: In the revised manuscript I will provide a) a new **Table** with median and SD values for all individual species and all temperatures; b) a new **Table** providing comparative results from this study to those from literature, and c) and a new **Table SI**; with full individual measurements at all temperatures.

Figures 2 and 3: The figure captions indicate that the boxplots summarize the median aspect ratios, lengths, and areas of particles for each taxa (i.e., each box plot depicts the median, standard deviation, and range of the median values of the measurements). If I understand correctly, though, these boxplots are actually summarizing the individual measurements. The medians are just one component of the boxplots? This ought to be clarified.

R: I have added this information, the new caption reads: The median aspect ratios of charred particles from (a–d) the individual measurements taxa burned at 250, 300, 350, and 400 °C, respectively, and (e–g) fuel types at burning temperatures.

Technical and typographical corrections:

L14-15: "Graminoids, Sphagnum, and wood"

R: Corrected. This sentence reads: Graminoids, Sphagnum, and wood (trunk) lose the most mass at low burn temperatures, whereas heathland shrub leaves, brown moss, and ferns retain the most mass at high burn temperatures.

L38: End parenthesis is missing from citation.

R: Parenthesis included.

L48: Consider rephrasing. No fires are 'cool'. Consider using more specific fire regime characteristics (e.g., intensity, severity).

R: Rephrased. This sentence reads: This analytical limitation restricts the reconstruction of fuel sources, a crucial factor in determining fire type, i.e., the burning of surface fuels in low or high-intensity fires, or distinguishing between surface and crown fires, which requires greater distinction of fuel types (Courtney-Mustaphi and Pisaric, 2014; Feurdean et al., 2017; Hawthorne et al., 2018).

L71: "paper" singular

R: Done. The paper also discusses the advantages and limitations of laboratory-based burning studies for palaeofire reconstruction.

L85: "tests"

T: Done: This paper builds on previous morphological classifications of charcoal particles and tests the effects of increasing ...

L248: "Mustaphi"

R: Mustaphi and Pisaric (2014) also observed that burning monocotyledons from…

L287-288: "influence"

Done. Fuel arrangements also strongly influence fire propagation.

L292: "cool, surface fueled"

R: Done. Siberian forests burn alternatively as cool, surface fueled by graminoids…

L293: "Anderson"

R: Done, Anderson, 1982

L297-300: Please consider revising this sentence. Its present wording is difficult to decipher.

R: I have removed the sentence *This has a practical importance for determining the ranges of fire severity and frequency that Siberian boreal tree taxa have tolerated in the*

past, and helps to evaluate their potential to adapt to new fire regimes in the future, so that the transition from the theoretic part to the practical application is directly visible. It reads: ''Siberian forests burn alternatively as cool, surface fuelled by graminoids, forbs, ferns, mosses or as hot, high-intensity surface (burning shrubs) and crown fires (Anderson, 1982). Results from this study suggest that the combined use of morphometric and morphological features and charred mass can help distinguish the predominant fuel source. Knowledge of the fuel source may in turn provide clues on fire type, i.e., the combination of fire intensity (temperature) and severity (effect on vegetation). For example, charcoal particles with a higher aspect ratio, typical for graminoids, and dominantly graminoid morphologies that tend to preserve only at a lower temperature, likely indicate a graminoid fuel source, and therefore a cooler, lower-intensity fire (Fig. 5).''

L310: "reveal"

R: Done: The burning experiments also reveal that charred particles …

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