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Interactive Comment

Interactive comment on "Centennial black carbon turnover observed in a Russian steppe soil" *by* K. Hammes et al.

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Hammes et al present an extremely unique and valuable dataset on the apparent changes in black carbon (BC) over 100 years in grassland soil of the Russian Steppe. The extraordinary aspect of this study is the analysis of a carefully preserved soil monolith, which was sampled around the time regular grassland fires ceased, ending BC inputs. The analysis of several contemporary profiles suggest that a robust comparison of BC stocks can be undertaken, and implies that approximately 25% of the BC stock was lost over 100 years. Unfortunately, the statistical test used is not valid. Despite this, these results appear to provide valuable confirmation that BC stocks are generally preserved for long periods in soil, but that there is some significant turnover of BC. I raise significant concerns with the turnover calculation used and the conclusions drawn from it, and suggest alternative approaches. In addition, I suggest that the full BPCA dataset be presented or included as supplementary material. Discussion on the apparent transport of BC and on the implications for measuring and monitoring the potential of biochar as C sequestration option should be expanded. My detailed explanation for these recommendations follows.

Equation (1) defines turnover time as a solution to equation(s) described only as 'a one-pool donor controlled model'. Although I can guess, I am not sure quite what this means. I am always concerned when descriptions such as this are made, since researchers in different fields use conflicting terminology to define their mathematics. The underlying model (presumably a differential equation) should be published and terms defined in relation to the model. This would be extremely important if the turnover time calculation made sense as a major finding of this paper, but as I note elsewhere in this review, the assumptions underlying the calculation appear invalid given the and inconsistent with literature. However, I do make the suggestion of performing this calculation for each BPCA, and if this is undertaken, then clarifying the equations solved is most important.

The statistical comparison in this work is not appropriate. The test appears to have been done on horizons, yet horizons are not independent samples. Therefore the assumptions of the statistical test are invalid. A rigorous comparison would require replicate soil profile BC stocks that are representative of the landscape. While it is ideal to have multiple samples from both the historic and contemporary period, I note that it would be reasonable to use contemporary samples to estimate the probability distribution around the single archived sample, and calculate a probability manually. I assume it is too late for the authors to complete this, but I note that such a calculation could be accomplished with perhaps 10 soil cores to 1 m, analyzed as single samples. This would not have been substantially more work than the data presented. Regarding statistics, if anything such as I suggest is undertaken, the rational for using a one-tailed test (presumably that BC inputs ceased and therefore BC stocks could only

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decrease). Further, although complicated, it is possible to use horizon data rather than profile stocks, but when horizon data is utilized, the autocorrelation between horizons must be accounted for. Assuming no statistical approach can be taken, some data on the representativeness and apparent reproducibility of the contemporary soil profiles should be used to replace the statistical comparison at the beginning of the results and discussion, to inform readers of the value of the data.

An fascinating aspect of this work is the apparent downward movement of BC in Figure 3. I strongly recommend more discussion of this interesting result. Several, seemingly testable hypotheses come to mind. In my own work, I have found clear evidence of downward transport, and modeled both the downward transport of colloids and DOM (Baisden et al., 2002; Baisden and Parfitt 2007). This includes California annual grasslands where fire is common, and was once probably more common, as well as New Zealand where fires were introduced by Polynesian and European settlers, and then ceased. The radiocarbon evidence for downward transport was remarkable in these soils with net leaching. In contrast, Torn et al (2002) found no similar radiocarbon evidence for downward in this Chernozem, and it is interesting to consider whether this is due to a lack of net leaching (as evidenced by carbonate accumulation) or the acid treatment used to remove carbonate. A key question is whether the BC appears to have moved as dissolved organic carbon (DOC) or as very fine colloids (with negative charge repelled by soil particles). It seems that a major opportunity for readers to examine or reject certain hypotheses is lost due to the failure to present the suite of BPCAs as a function of depth. In the supplementary material or figures, the results for each BPCA should be presented. Further, given the prominence of the authors in reviews of BC methods, it would really helpful to see carefully considered suggestions on the ability of the BPCA method to examine these transport related questions or whether another BC method may be more appropriate.

In relation to transport, it is also worth noting that Rumpel and others found that BC appears to be preferentially eroded. The potential for water or wind erosion (or lack thereof) should be noted, as it also represents a loss that contributes to turnover and could be important when integrated over 100 years.

As currently presented the turnover time calculation is inappropriate and inconsistent with both the known behavior of black C (Lehmann 2007; references cited on p662 L26) and information presented in Figure 4. Lehmann (2007) has indicated that BC from differing sources vary in their recalcitrance and some BC is partially oxidized over decades following incorporation in soil. Indeed, Figure 4 shows that the less condensed BPCAs show considerable turnover (e.g. BP4CA.) A much more useful interpretation of this valuable data is that approximately 25% of the BC is lost over 100 years, while the remainder appears to have roughly millennial residence times. Such a sensible interpretation is essentially consistent with previous estimates and consistent with the IPCC assessment. While this interpretation is stated or implied, it is not emphasized as it should be, and becomes confused with the turnover time calculation which is emphasized.

The turnover time calculation may have some value, but the limited sensitivity analysis is flawed by not evaluating the potential implications of the black carbon being a heterogeneous pool with two or more residence times. If the residence time calculation is published at all, this deficiency should be carefully dealt with. Since models need to be used but not believed any model-derived turnover time should be accompanied by a clear suggestion of why it has been derived and what its intended use is. For example, a sensible reason to obtain a turnover time is to be able to estimate how much BC is likely to be lost over a 10 year period. From the model proposed in this work, such an estimate can be made from the one-pool model but could be very wrong if in fact 25% of the C was lost in 30 years, and the remainder has a millennial residence time.

Since a main problem with the residence time calculation is that the individual BPCAs appear to show different degradation rates, an interesting alternative would be to attempt to calculate the residence time of each of the BPCAs measured. Such a calculation would be welcome, and would overcome the problem of a calculation inconsistent with both data in the paper and the literature. Such a calculation would also provide much more realistic sensitivity. For example, it may well turn out that the calculated turnover times do not neatly relate to the degree of condensation, and this could be interpreted uncertainty resulting from the methods, analysis, and natural processes and variability.

The authors should more carefully consider the value of this dataset for designing future studies. The ability to examine a 100 year-old monolith in comparison to well-matched contemporary samples is unique opportunity. Unfortunately, we have the problem of n=1 for the archived monolith. Other very old samples do exist. For example, I know of a variety of samples collected by Hilgard in California, but these may be difficult to relocate or resample under similar land cover. More hopefully, there are a great many samples archived in various countries that are on the order of ˜50 years old which often have clearly preserved information and site details. I believe the data presented suggests that other researchers will find it well worth examining archived and contemporary samples spanning a period of 50 or perhaps even 20 years to determine how rapidly different forms of BC appear to be lost.

Overall, this work should attempt to use the unique dataset to make salient comments that can be used in designing emissions trading systems (including a global post-2012 agreement) that are compatible with biochar. Several points seem important. First, it appears that some BC may be lost over timescales of 100 years (and perhaps less). Second, it appears that considerable BC may be transported downward, but not lost from the soil. Since the bulk of BC was transported below 30 cm, the 30 cm accounting depth currently used may be inappropriate. Finally, when this data is combined with other information in the literature, does it support or cast doubt on the suggestion that biochar used as a soil amendments may be a valuable C sequestration opportunity? Based on the data, I conclude that biochar remains a valuable sequestration option and would also ask whether this study contains information relevant to defining sampling intervals and analysis methods that would be appropriate for C monitoring.

I do not include a list of lengthy list of typographical/writing points but do note the following. In figure 4 it is not clear what is plotted. Interpretation in this review assumes the bars are the archived and contemporary soil inventories.

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