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Cover Letter and Responses to Reviewer Comments to accompany the manuscript:
"Unifying soil organic matter formation and persistence frameworks: the MEMS model"

Authors: Andy Robertson, Keith Paustian, Stephen Ogle, Matthew Wallenstein, Emanuele Lugato, and Francesca Cotrufo

Thank you for your correspondence concerning our manuscript and for giving us the opportunity to resubmit a revised version. All comments from the reviewers have been carefully considered and appropriate responses are made below.

Sincerely,

Andy Robertson

Responses to comments from Thomas Wutzler on "Unifying soil organic matter formation and persistence frameworks: the MEMS model" by Andy D. Robertson *et al.*

Reviewer comments in bold and our responses in normal text. Selected new text in the revised manuscript is pasted here in italics. Reference to the manuscript is given as new line number (L).

General comments

All my points have been answered.
The paper should be published.
My comments refer to line numbers in the author response.

Now that I can read Fig. 2, I have a few additional comments.

Fig. 2: I assume that panel mineral soil < 2mm indicates sum of the carbon pools. If this is correct, I suggest to explicitly state this equivalence.

Yes, your assumption is correct. We have now added this level of detail to the figure legend.

L1051-1061:
Figure 2 - Global sensitivity analysis results showing the relative contribution of each parameter to a change in carbon stock of each pool in MEMS v1.0 (leached carbon to deeper soil layers [pool C11] is omitted for clarity) after simulation to steady-state. The two top left panels represent the sum of soil pools (C5, C8, C9 and C10) and organic layer pools (C1, C2, C3, C4 and C6), respectively. Details of each parameter and the abbreviations used can be found in Table 2. The sensitivity analysis was repeated annually for simulation times between 1 and 100 years, every 10 years after that to 400-year simulations and every 100 years after that up to a 1000-year simulation. Results are presented on a log scale in years. The four parameters that were optimized in our analysis (Table S2) are coloured to highlight their importance in the different pools (mid-point of logistic curve where nitrogen content of input influences microbial carbon use efficiency, Nmid, red; maximum decay rate of heavy particulate organic matter, k5, orange; maximum decay rate of mineral-associated organic matter, k9, blue; maximum decay rate of light particulate organic matter, k10, green). A fully colourised version of these results can be in Figure S5.

Fig 2: I did not expect that the rate of the light POM (k10 green) would have such a high importance at centennial times, although the pool is stated to be much smaller than the MAOM pool. How do you explain this? Text at L484 states that its relative contribution diminishes, but I cannot see this from Fig 2.

The light POM pool (C10) can dominate total soil C depending on the system (e.g., evergreen forest in cold sandy climates) – so this pool isn't always smaller than the MAOM. However, the conditions chosen for the sensitivity analysis were median values. In this case, the range of MAOM:POM pool sizes can be seen in that panel of figure 3 and the median is around a 2:1 ratio of MAOM:POM. The high relative sensitivity of total SOM to k10 is likely caused by that single parameter having almost all the influence on the light POM (C10) pool, whereas the MAOM (C9) pool is influenced by a number of different parameters. Overall, the MAOM parameters and light POM parameters do each account for ~45% of total SOM sensitivity, each. At centennial timescales, the relatively sensitivity for k10 impacts on total SOM does drop to around 45% from ~80% (the parameters that influence MAOM saturation take up more of the sensitivity below the green).

L 489: I do not readily understand how Fig. 2 can be interpreted as a depiction of how each pool accumulates over time. Please, either omit or elaborate a bit more.

Yes, this was poorly worded. We have changed the text as per below. Thanks for the suggestion.

L585-587:

Figure 2 can be interpreted as a depiction of how the C pools of MEMS v1.0 are impacted by different parameters as each pool accumulates over time.

L230 Minor issue: It took me some time to understand that the comma after "(pool C8)" introduced a new main clause. I suggest rewording sentence to start with the topic of the section instead of the topic of the former section.

We feel that the current phrasing is more appropriate as it links in directly from the previous section. We understand and appreciate the suggestion though.

L600ff Logical leap: The text argues that Fig 2 shows that short-term parameters influence the immediate dynamics of the MAOM pool. Fig 2 is based on buildup of stocks from zero, where initial dynamics is of course governed by initial input from pools with fast dynamics. Contrary, the statement is very general and you would need to show that this also holds true for a disturbance to developed steady states. I suggest to either omit this point or to demonstrate the statement by a small simulation scenario in a supplementary.

We agree that this assumption is currently untested. Consequently we have altered the text as per below.

L588-592:
Many of the parameters that influence the processes of POM formation and persistence (e.g., LITfrg, Nmid, LCImax, etc.) have relatively high importance (i.e., sensitivity) to changes in total SOM within relatively short time frames (i.e., < 10 years; Figure 2). This may potentially capture the important real-world trend that POM is typically more vulnerable to decomposition with disturbance compared to MAOM (Cambardella and Elliott, 1992). However, disturbance impacts were not evaluated in the inaugural study.