Editor remark 1:

I found Referee 1's Remark 4 very interesting: "In the same vain, if we imagine that the OM content of soils can change over time in LSM (by coupling it to the carbon cycle). What are the implications in this framework? " In most LSMs with an active carbon or biogeochemical cycle, such as CLM5, the SOM is indeed dynamic due to litter input and decomposition processes. I would appreciate it if the author could provide further details on how to integrate your model framework and equations into such a dynamic model with prognostic SOM. When SOM evolves, the build soil density rho_b would become a prognostic variable, but rho_b is currently a prescribed input for estimating rho_b_om at the same time. Would there be any circulating issue when both rho_b and rho_b_om have to be determined prognositically according to SOM variations? Could the author provide further details in your methods how to adapt your equations in this case?

Response:

Thank you for your interest in my article and for this request for clarification following Reviewer 1's remark on the applicability of this framework to land surface models (LSMs) that would dynamically simulate soil carbon and wish to couple it with this framework. As described in this paper, the framework is not suited to such a configuration, as noted by Reviewer 1. Adapting it to an interactive configuration would be a desirable and interesting follow-up, but it is a research topic in its own right, and I do not have a complete solution at this stage.

Such a development would require, in particular, relaxing the assumption of constant bulk soil density on which the method relies, and I do not have an operational solution to this problem in the present work. This was the primary intent of my response to Reviewer 1. It would also be necessary to conduct rigorous data-based tests to avoid compounding uncertainties from soil carbon cycle schemes and from assumptions about the density of organic matter. Under coupling, the physical effect of soil carbon content can influence vegetation growth, turnover, and mortality, which in turn feeds back on soil carbon. This feedback is slow, but it can lead to unrealistic results if implemented improperly.

I have inserting the following short paragraph at the end of the conclusion that summarizes this position: "*This next step will provide a clear baseline for land-surface physics and a necessary preliminary stage before attempting any more complex prognostic coupling to a dynamic soil carbon scheme, which will in turn deserve specific consideration. The framework proposed in this study, which assumes a time-constant bulk soil density to determine the bulk density of the organic domain, is not, in its current form, directly applicable in LSMs that would couple it with an interactive simulation of the soil carbon cycle. Indeed, attempting to dynamically couple the organic carbon mass simulated by an LSM with our diagnostic relations between* ρ_b*,* $\rho_{b_{om}}$ *and* $f_{v_{om}}$ *raises questions that are outside the scope of this work. On the one hand, if such a coupling were attempted, and in order to avoid any potential circularity, a single structural variable (e.g.* ρ_b *or* $\rho_{b_{om}}$*) should be prognostic, with the other diagnosed using the mixing relations presented here. On the other hand, the desirability of such a coupling can be questioned given the structural and parametric uncertainties of current soil carbon schemes. A tight coupling with soil physics could add uncertainty to the simulated physical state of the land surface and generate undesired feedbacks on the carbon cycle. These* *points should be studied specifically before any coupling is proposed. Nevertheless, by providing a consistent and physically based link between organic and mineral components of the soil, the present framework offers a solid basis for future developments toward more integrated representations of soil processes in land surface models.*”

<u>Editor remark 2:</u>

Referee 2 pointed out several errors in the equations and typos in the text. I also noticed a typo in the revised manuscript. For example, line 696, "a SOC-to-SOM factor of 2" should be "a SOC-to-SOM factor of 1/2". There could be more. Please carefully check through the whole revised manuscript to ensure accuracy in all equations and references in the text.

Response:

Thank you for the careful reading and for pointing out possible typos and inconsistencies. Following your comment and Reviewer 2's observations, I have re-checked the entire revised manuscript, including all equations, symbols, units, and cross-references, and I corrected minor typographical issues where needed.

As context, the sentence and the use of the SOC-to-SOM factor of 2 directly follow Reviewer 1's suggestion (L653): *“Perhaps relevant to indicate that using the SOM/SOC factor of 2 and rho_b_oc of 130 kg/m3, the method of Lawrence & Slater is equivalent to using a rho_b_om of 260 kg/m3. This makes it easier to see the impact of the ‘opposing biases’, and to compare it to the newly proposed method (which gave rho_b_om = 205 kg/m3, 248 kg/m3 and 240 kg/m3 for the 3 lab datasets).”* Regarding the sentence you flagged in the revised version, the SOC-to-SOM conversion factor is intentional and consistent with equation (28), which assumes that SOC represents about half of SOM by mass. Consequently, for order-of-magnitude conversions from SOC to SOM one multiplies SOC by 2; the same scaling applies when interpreting fixed “working” bulk densities assigned to SOC. Under this assumption, a fixed bulk density of organic carbon of 130 kg m-3 is roughly equivalent to a bulk density of organic matter of 260 kg m-3. Because observed SOM bulk densities commonly lie around 200–250 kg m-3, estimating fv_om from SOC by dividing by 130 kg m-3 can yield values that look reasonable, but this arises from compensating errors rather than from a physically sound model, exactly the point raised by Reviewer 1 (remark to L653).

For the avoidance of doubt, the sentence now reads (L686 in the new manuscript): “*In practice, combining a SOC-to-SOM factor close to 2 (equation 28) with a fixed bulk density of organic carbon of 130 kg m^{-3} fixed in previous approaches is equivalent to a bulk density of organic matter of 260 kg m^{-3}, which can be directly compared to the values of 205, 248, and 240 kg m^{-3} obtained for the three laboratory datasets using the present framework. As a result, the predicted $f_{v_{om}}$ may appear reasonable in some cases, but this is due to compensating errors rather than a physically sound model.*”