

Interactive comment on “Biogeochemical model of CO₂ and CH₄ production in anoxic Arctic soil microcosms” by Guoping Tang et al.

Anonymous Referee #3

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Community land model carbon nitrogen (CLM-CN) predominantly represents aerobic decomposition of SOM. In this manuscript, authors propose to include anaerobic processes in this model by integrating new experimental data for redox potential, pH, and temperature parameters from Arctic soils. This manuscript is very thorough. It's amazing to see parameterization of model with experimental data! While this work has some flaws, it is a huge step forward in closing the gap between modeling and experimental data integration. I'm impressed by the author's knowledge of biogeochemical processes in soil and effort to connect real world mechanisms to the modeling results; this is no small feat. It is clear they gave a great deal of thought to their results.

In general, I would recommend the author's provide stronger justification for determining that the most limiting factor for SOM turnover is hydrolysis of macromolecules. This both served as the foundation of this work and is continually provided as an explana-

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tion to observations. While it's tough to cover all possible scenarios in soils, authors should address other potential factors that could drive the rate of SOM turnover and justify why they believe hydrolysis of macromolecules is the most limiting factor.

In the conclusion, I think it would be nice for the author's to add some suggestions for parameters/processes that could be incorporated into this model in the future or specific geochemical measurements that experimentalists should consider collecting during their studies.

—Specific comments—

P3L10-11: "...the hydrolysis and fermentation reactions have been poorly quantified." I'm not sure I follow the point being made here. Is this suggesting that hydrolysis/fermentation of SOM is poorly quantified (in general) or specifically in arctic soils?

P4L28-29: What is a “low-center polygon”? It is frequently referred to the in the text of this article, yet it is unclear to me what it is. This seems like site-specific terminology that may be worth describing. I'm not sure how many readers would know what this is. I'm also assuming the “center” sampling location is a slope since the other two are the “ridge” and “trough”?

P7L28: What do SOM3 and SOM4 represent? LabileDOC, SOM1, SOM2 and the biomass pools were described, but not SOM3 and SOM4. Furthermore, SOM4 isn't included in the fractions listed on P7L29. Is it supposed to be included in this list of fractions? If not, then why is it excluded?

P8L1-2: The turnover time of SOM3 and SOM4 are not listed – these fractions need to be better described or explain why they are excluded.

P8L7-9: Nice explanation for “back of the envelop” biomass estimation

P10L26-27: Are there other potential reasons why the rate of CO₂ would stabilize? Limitation of some other resource? For instance, N? Does this study have evidence to

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support that rate of CO₂ respiration stabilized because of hydrolysis of polymers?

P11L8: parameter Fe3= 0.02 is above the max value in the range of observed values stated on P8L14, can the authors comment on why they might need to increase this value beyond observed values to help the model better match observations for Fe(II)? Do you have any suggestions for some other parameter that should be included or other parameter values that could be altered to help achieve a better model fit, while maintaining values within experimentally observed value range?

P11L11-14: How do these model observations relate to experimental data? Is there any experimental evidence (either from your original work or other soil Fe literature) to support that as Fe3 increases there is a decrease in CH₄ resulting from competition between methanogens and iron reducers? Why wouldn't this also be the case when Fe3 = 0.01?

P11L29-31: This statement contradicts L25-26. L25-26 states as pH increases, CO₂ (aq) increases. L29-31 states as pH increases, CO₂ (aq) decreases. Please provide an explanation.

P12L19: I keep having to look back at what "WEOC" means. I would recommend using some other terminology. Also, this sentence should reference Table 2 not Table 1.

P12L20-22: Is this comparable? The values for rapid CO₂ release in Figure 4 look nearly double or triple the observed values. It appears that CO₂ values for organic center at a LabileDOC = 0.02 fit the experimental data best out of all of these scenarios.

P12L29: "high center polygon trough"? I thought "center" and "trough" were two different sampling sites? Please clarify and be consistent throughout the paper. Same error P13L6.

P13L19-20: I don't follow – how do these studies demonstrate that hydrolysis of macromolecular organics by extracellular enzymes is the rate limiting step? What about bioavailability? Limitation of some other resource?

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P13L24-26: Please rewrite this sentence for clarity.

P13L31: "the model substantially underpredicts..." Please include a figure number.

P14L1: It could also be attributed to populations at that particular site grow more rapidly than the populations at other sites. Hard to say without a T0 measurement... I would tread lightly with this, you don't have strong experimental evidence to support this statement.

P14- first paragraph: The text says the opposite of what is demonstrated in Figure 5. Figure 5 shows the lower initial biomass results in more CH₄, Fe(II), pH increase, etc. Is it possible the figure legend is wrong?

P14L10-12: OK, but if the OM soils are better buffered why are there rapid changes in pH for both the observed and experimental data for OM soils? Figure S6. OM soils appear to have rapid pH changes occur sooner than mineral soils, despite buffering? Please explain.

P16L21: change "enhancing" to "enhances"

P16: Transparent science! Thanks for making your code and data available!

P17: It's unclear what a pH response and temperature response function are. Please better define. What is the reader supposed to take away from this information?

All tables and figures should be able to stand on their own. Improve caption text and add full legends (colors, symbols, and patterns defined in each figure).

-Please format Table 2.

-Figure 2 caption L5 add "as" after "such"

-Figure 5 caption text does not match figure. Legend suggests lowest initial biomass results in highest CH₄. Please make full legend visible (partially covered up).