

Interactive comment on “Reviews and syntheses: Four Decades of Modeling Methane Cycling in Terrestrial Ecosystems” by X. Xu et al.

Anonymous Referee #4

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This is an excellent and timely review of the current state of process-based methane modeling. While other recent literature on particular methane models typically provide some brief review in the introduction and/or discussion sections, this review paper provides a very useful level of detail for understanding where, how, and why, process-based models of methane differ. As the authors note, these current methane models often poorly reproduce observed patterns, so this is an important reflective manuscript to assess the field before moving forward. That said, I do believe that the manuscript could be improved and clarified before publication. There are several relatively minor terms and phrases that require clarification that are detailed below. On a larger point, I think that it would be helpful to provide more information about representations of CH₄ processes that are included within ESMs, since this is a major suggestion by the authors. They could include basic information on which models are in ESMs in Table

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1, but it would also be helpful to detail plans for future representations.

Within the conclusions of their review, the authors argue that researchers should focus on the development of a fully mechanistic CH₄ model that accounts for all features, and can integrate data on microbial community structure and function. There is always some tradeoff with model complexity and functionality, and I would be more convinced by the authors' conclusions that a more complex mechanistic model should be developed with all components if there was some evidence that this improves simulations over simpler representations. And furthermore, how can the increasing number of plot-to ecosystem-scale measurements of net CH₄ flux be used to constrain such a complex model, except for validation? This type of very complex model would even more so require the aggregation of experimental data on microbial ecophysiology that can be used to parameterize and develop robust uncertainties for these processes, and the authors appropriately note that much of this experimental work is yet to be done. It would be helpful if the authors provided some context for understanding how much data exist to constrain these individual CH₄ processes (a handful of experiments, or potentially hundreds?) and within which ecosystems. Within the section on model-data integration, I also think that it would be useful for the authors to provide more specific detail regarding ways to integrate these different data types (from net CH₄ flux data to process-based experimental data).

Line by line comments follow:

L102-109: I'm confused about the reference number for the percentages: is it the percent of total carbon respiration? Or percent of total methane produced?

L235: You should also consider citing Matthews & Fung (1987) in this history: Matthews, E., and I. Fung (1987), Methane emission from natural wetlands: Global distribution, area, and environmental characteristics of sources, *Global Biogeochem. Cycles*, 1(1), 61–86, doi:10.1029/GB001i001p00061.

Table 1: Since the table is already large, I think that it would be useful to add which

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models are within ESMs (and if so, which ESM) and which models were developed for particular regions/species (rice, Arctic, etc.).

L280-295: I think it would be helpful to add a bit more context for how and why these CH₄ models are added into ESMs. The authors recommend that the third group be the focus to understand potential for reduction into ESM models, but what does it take to reduce a CH₄ model into an ESM?

L315-330: This section is a bit hard to follow with respect to what exactly the differences are here among the models. I think that it would be useful to restructure this with a bit more of an introduction (like the environmental controls section) about the differences among the four distinct classes of substrate representation, with explicit list of the four classes before listing which model is in each class.

L345: I'm not sure what the authors mean by "dramatic bias" caused by a lack of representation, and this should be clarified.

L363: It's hard to follow the many different categories that the authors are creating, and I'm not completely sure which category three refers to as described here.

L370: It would be helpful to provide a bit more context for why Michaelis-Menten representation fails for multi-substrate, multi-consumer networks. Is it purely an equifinality problem?

L398: Unclear what "reported these individual processes" is referring to.

L479: I'm not sure what the "high range" refers to within this context.

L567: Unclear what is meant by "integrative tool" . . . for integrative assessment?

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