Comment on gmd-2021-310

Anonymous Referee #2

Referee comment on "Supporting hierarchical soil biogeochemical modeling: version 2 of the Biogeochemical Transport and Reaction model (BeTR-v2)" by Jinyun Tang et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2021-310-RC2, 2021

This paper describes an updated version of the Biogeochemical Transport and Reaction Model (BeTR-v2) including updated algorithms for reactive transport and numerical coupling with vegetation and hydrological processes. Simulations are conducted with the standalone version of the model and compared to analytical benchmarks, and a version of the model coupled to the E3SM Land Model is used to conduct and evaluate global simulations with alternate numerical implementations of soil biogeochemistry and plant-soil coupling. The simulation results compare well with analytical benchmarks. Coupled land model simulations resulted in different carbon, nitrogen, and phosphorus cycle outcomes for the different numerical implementations.

Overall, the manuscript is well written and provides a clear description of the model developments, the simulations that were performed, and the results. There are a few typographical errors and some areas where clarity could be improved.

Page 3, Line 3: I would word this "sharing of common process representations…"

Page 3, Line 19-20: …enable efficient code and knowledge sharING … improvements that have BEEN brought…

Page 4, line 10: SINCE significant code rewriting…

Equation 1: C_g is used in the third right-hand-side term (with D_s), and I think it should the

C^s instead

Page 5, line 18-19: A bit more description of the solver method would be helpful so readers can get a basic understanding without reading a different paper. Also, does the time stepping method account for truncation errors at longer time steps? Is some adaptive time stepping included for cases where the model time step is too long to resolve fast biogeochemical processes (maybe not important in the simulations presented here but potentially important in some applications such as explicit tracking of oxygen concentrations)?

Section 2.4 and Table 1: I had a hard time keeping track of what the differences were between the different simulations. The short descriptions in Table 1 are not very informative because they refer to specific code directories rather than numerical methods, and include several different contrasting numerical approaches described in only one table column. I would suggest adding more columns to the table to clearly differentiate the features of the different implementations. Separate columns could include plant-soil competition solver, plant allocation solver, and parameterization which all varied across different simulations. I would avoid referring to specific code directories where possible and instead refer to the differences in underlying methods, which is more universal. In the text description (page 10), the use of italicized "*ecacnp*" in some places and the names of the implementations (e.g. ELMv1-ECA) in others is confusing and seems specific to this code base rather than a general description of numerical approaches. I would suggest using only one terminology, or else including the "*ecacnp*" terminology in Table 1 so it's easier to keep track of the different terms.

Page 10, line 18-19: "Comparing ELMv1-ECA and ELMv1-ECA" - these are both the same. Should one be different?

Figure 2: There was not an explanation of how column integrated heterotrophic respiration, soil surface CO_2 flux, and CO_2 infiltration rate were calculated and what exactly they represent. I assume the surface flux takes transport of gaseous and dissolved CO_2 into account whereas integrated HR is instantaneous production?

Figure 3: Why was accelerated spinup used here instead of the normal spinup or historical simulation?

Page 18, line 7-8 and Table 2: I would use the PFT names rather than numbers which are not meaningful to readers to are not closely familiar with this land model

Page 18, line 11: "other variables" - Explain which variables

Table 2: Both columns have the same heading "ELMv2-ECA". One should be ELMv1-BeTR-

ECA

Page 19, line 16-18: This sentence feels oddly judgmental. The previous sentence reports better agreement with some benchmarks but there also seems to be worse agreement with others, so it might be more balanced to say that numerical differences can significantly change model outcomes even without changing the underlying differential equations of a model.

Page 21, line 3: Estimates of P dynamics also changed, not just N

Table 3: The units of the numbers are never described and it's not clear whether a higher number means a better or worse fit to the benchmarks.

Page 23, line 12: What is meant specifically by "numerically more robust"?

Page 24, line 2: I don't think there is a basis here to decide whether model parameters are "incorrect" or that a particular numerical coupling is "inappropriate." This study shows that different numerical approaches can yield different results. Without a clear demonstration that one approach or the other fails relative to some benchmarks I don't think it can support a declaration that one is right or wrong. A more balanced wording might be that different numerical approaches can significantly change model behavior and that care should be taken to evaluate whether re-parameterization is necessary following numerical changes. This was clearly demonstrated in this study where the land model needed to be recalibrated following a change to the numerical coupling scheme.