

Biogeosciences Discuss., author comment AC2  
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## Reply on RC2

Jie Zhang et al.

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Author comment on "Modeling nitrous oxide emissions from agricultural soil incubation experiments using CoupModel" by Jie Zhang et al., Biogeosciences Discuss.,  
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We would like to thank Reviewer 2 for the time and effort that they took to provide useful feedback for our manuscript. The constructive and specific comments help a lot in improving the quality of the manuscript. Please find the response to each comment below.

Reviewer 2 (RC2):

Manuscript "Modeling nitrous oxide emissions from agricultural soil incubation experiments using CoupModel" by Jie Zhang et al.

**RC comment:** Zhang et al. present a study where results from a short term incubation study was used to assess the ability of a process oriented model to simulate N<sub>2</sub>O emissions from soil with the addition of different crop residues and nitrate levels. The paper is generally well written and the topic within the scope of Biogeosciences and presents an interesting discussion and review about challenges of accurately simulating soil N<sub>2</sub>O fluxes. Therefore, I think, that the manuscript should be valuable for other researchers trying to model N<sub>2</sub>O emissions from soils and could be potentially published in Biogeosciences.

**Response:** Thank you for acknowledging our efforts to diagnose the behavior and test the performance of a process model in the realistic scenario for agroecosystems where C and N availabilities suddenly change as observed in a laboratory setup with soil-residue mixtures with corresponding controls.

**RC comment:** However, I agree with the comment by Lorenzo Brilli, that the approach is not really novel and that there is the need to focus more on solutions rather than discussing the limitations.

**Response:** While the methods used in this study are not novel, there are very few papers available to implement a global sensitivity and uncertainty analysis based a complex framework which include the fundamental C and N processes in the soil associated with classical formulas that describe soil physics (e.g., soil water, heat coupled transport, gas diffusion etc.).

With a consistent modeling approach, we evaluated the performance of the model in simulating N<sub>2</sub>O emissions from soil mixed with two contrasting residues, and the results give some directions for future improvements of simulation experiments that could be useful to modelers and for experimental design. It is well-known that heterogeneity at mm-scale in the distribution of moisture as well as labile C and N is critical for N<sub>2</sub>O emissions (Kravchenko et al., 2017; Parkin, 1987), and the results of the present study suggest that residue particles were an important source of N<sub>2</sub>O. The effects of concurrent C and N transformations in organic hotspots can lead to intensive biological activity and process models may require new solutions to describe this. We do believe this model evaluation work has value, even if it was beyond our research goals to investigate specific solutions here. Possible solutions and relevant future work on the heterogeneity issue was briefly discussed line 508-518. **These implications of the study should have been stressed more, and we plan to include a new section in the Discussion about these challenges.**

**RC comment:** In addition, I am not really sure to what extent results from a short term incubation, with sieved and repacked soil cores and limited measurements can be used to calibrate and quantify the uncertainty of a process based model used for simulating N cycling and N<sub>2</sub>O emissions under field conditions. The conditions used in the incubation (sieved, repacked cores, constant temperature and soil moisture) are not typically found in the field and highest N<sub>2</sub>O emissions are often associated with wetting and drying cycles.

**Response:** Thanks for sharing this fair concern which has highlighted the need to discuss the connection between incubation and field conditions. As mentioned also in the response to RC1, the short-term experiment used here for model evaluation represented the period after residue incorporation with an instantaneous input of labile C and N to the soil, the difference between a long-term and a short-term study being whether the incorporation happened at some point during the simulation or initially.

Both field and incubation studies share the same biotic processes, i.e., decomposition, nitrification and denitrification, and in the past model equations have been derived from both types of studies (e.g. DNDC Scientific Basis and Processes, 2017). While models are intended to be used in the field, targeted laboratory experiments are often used to test submodules under controlled conditions (e.g. Grosz et al., 2021; Xing et al., 2011).

The experiment with sieved and repacked soil in cylinders with a change in soil moisture content and temperature compared to previous storage did not show evidence for major disturbances of soil C and N turnover when preincubated for a week under the new conditions before the experiment. In contrast, the residue amendment stimulated biological activity including N<sub>2</sub>O emissions, and this would also be the case under field conditions. We acknowledge that the time course of C and N turnover was probably faster in these incubations than in the field due to the mixing of residues and soil, and this can help explain why in some cases simulations by the model, calibrated to describe field observations, could not capture the dynamics.

We respectfully disagree that high N<sub>2</sub>O emissions are mainly associated with wetting and drying cycles, since many studies have shown that decomposer activity can sustain anaerobic processes and N<sub>2</sub>O production also in well-drained soil (e.g. Duan et al., 2017). Currently the importance of experimental conditions, and the potential for accelerated C and N turnover in organic hotspots is not mentioned until the discussion. **We will expand the Introduction to mention this important context for the modeling of residue decomposition, and will further address the deviations of the laboratory setup from field conditions in the Discussion section.**

**RC comment:** Moreover, sieving the soil will result in the destruction of soil aggregates and lead to increased SOM mineralization. I think that these points need to be better highlighted in the paper and their implications for modelling N<sub>2</sub>O emissions under field conditions discussed.

**Response:** We tend to disagree that sieving to <6 mm is a major disturbance. Petersen and Klug (1994) did not find a significant difference in CO<sub>2</sub> evolution when incubating a similar arable soil after sieving <2 or <4 mm. Also, there was no stimulation of CO<sub>2</sub> emissions from control soil for WW treatments (a minor increase in control soil for red clover treatments was associated with high moisture). Therefore, the decomposition was most likely dominated by the fresh residues.

**RC comment:** LN 25 ff: "For the development of process-based models, we suggest there is a need to address soil heterogeneity, and to revisit current subroutines of moisture response functions." Soil heterogeneity was very much reduced in this experimental set up by sieving and repacking the soil. Can you comment what this implies for field measurements?

**Response:** For the soil environment investigated in the incubation study, the heterogeneity of importance to N<sub>2</sub>O emissions was mainly that associated with residue fragments, since this is where labile C and N were concentrated. In comparison, bulk soil heterogeneity, or the reduction of heterogeneity caused by sieving, was probably much less important. In the experiment, heterogeneity in the distribution of residues was reduced compared to field conditions, since residues were cut and mixed into the soil. However, the residue-soil contact was increased compared to field conditions, and in fact this may have increased the effects of heterogeneity. Although mixing should make the distribution of C and N more similar to the distribution assumed in the model, it may have accelerated residue decomposition and the associated N<sub>2</sub>O emission compared to the field situation.

**RC comment:** Ln 108, to what size was the soil sieved?

**Response:** The soil was sieved to <6 mm (Taghizadeh-Toosi et al., 2021). **We will add the information in the Method section.**

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