

## Reply on RC2

A brief introduction to the revision of the manuscript (MS) as follows:

In the revised MS, the reviewers' comments were fully incorporated into the text accordingly. The text of the MS was revised by us: i) providing more details of the original model and the modifications; ii) reorganizing and rewriting the Abstract, Results and Discussion sections; iii) the sensitivity analysis for the parameters of the improved model was added. Furthermore, we recompiled the Supplementary materials by adding Table S1 and S2 to present the equations and symbols of the regulatory factors affecting  $\text{NH}_3$  volatilization from uplands in the original and modified CNMM-DNDC.

### Referee #2:

*The authors describe an update to the CNMM-DNDC model to improve ammonia emission simulations. First, they performed a calibration and parameterization across upland agriculture sites. Second, they added a new algorithm to simulate ammonia emissions from rice paddy fields with flood irrigation. Finally, the authors conduct a sensitivity study to analyze the contributions to ammonia emissions over a variety of environmental factors (including atmospheric conditions, soil properties, and management of irrigation and fertilizer).*

*The manuscript is novel in that it brings a new management practice, flood irrigation, into a biogeochemistry model for calculation of ammonia emissions. This is a valuable addition to the field and should be considered in future models because of the differences in volatilization from management practices. I think the paper is well written and interesting and fits in the Biogeosciences scope. However, the paper could benefit from some additional clarification before it is ready for publication.*

>> Thanks. We revised the MS strictly according to reviewers' comments as follows.

### General comments:

*Line 47-50: Might also want to mention efforts in ESMs such as Riddick et al., 2016 and Vira et al., 2020.*

>> Revised. Please see changes in Lines 56-57.

*Line 63: "dose and application methods..." The type of fertilizer used (e.g., manure vs. synthetic fertilizer) will also have an effect on volatilization of  $\text{NH}_3$ .*

>> Revised. Please see the change in Line 71.

*Line 102-104: The algorithms were already in the model, my understanding from reading the manuscript is they calibrated and parameterized the model further. However, this is never fully explained in the text under the materials and methods section.*

>> Revised. The calibration and parameterization of the regulating factors except  $f_{\text{depth}}$  and  $f_{\text{Tstep}}$  were adopted from Dubache et al. (2019) and Li et al. (2019). Please see changes in Lines 189-190.

In the revised MS, the zero-intercept linear regression was applied for the calibration of  $f_{\text{depth}}$  and  $f_{\text{Tstep}}$ . Please see changes in Lines 200-210. In Fig. S2, we provided the calibration of  $f_{\text{Tstep}}$  as an instance.

*Materials and methods section, I suggest organizing this differently. The authors start with a description of the sites, but I think it would be better after the model description, but this is optional*

>> Fully agreed and revised. Please see changes in the subsections 2.1 and 2.2.

*Line 155: What regional scale simulations were performed?*

>> Revised. The objective of this study was aimed at modifying the CNMM-DNDC and evaluating the performance of the modified model at the site scale. The regional scale simulation was not tested and will be continued in the future. Therefore, we only conducted the site scale simulations in the MS and we rephrased the sentences to clarify. Please see changes in Lines 170-171.

*Section 2.2.2:*

*The authors indicate recalibration and parameterization, but don't indicate how this was done or which components were included in the process.*

*Line 267-272: As noted previously, can the authors provide a description of the method used to calibrate the model? More explanation is needed for the process used to calibrate parameters.*

>> Revised. The calibration and parameterization of the regulating factors except  $f_{\text{depth}}$  and  $f_{\text{Tstep}}$  were adopted from Dubache et al. (2019) and Li et al. (2019). Please see changes in Lines 189-190. In the revised MS, the zero-intercept linear regression was applied for the calibration of  $f_{\text{depth}}$  and  $f_{\text{Tstep}}$ . Please see changes in Lines 199-210. In Fig. S2, we provided the calibration of  $f_{\text{Tstep}}$  as an instance.

*Were  $\text{NH}_3$  emissions calculated differently from different fertilizer applications (e.g., manure vs. synthetic fertilizer or urea vs. ABC) or was only synthetic fertilizer applied at the sites?*

>> Revised. Different fertilizers (e.g., urea, ABC and other synthetic fertilizers) were simulated separately in CNMM-DNDC model. Please see changes in Lines 174-180.

*In fact, since the authors don't introduce the original model, it is difficult to understand the significance of the modifications to upland volatilization. Perhaps the authors can expand this section or include a supplement that provides more detail on the original and modified algorithms. Also, how the  $f$  values are calculated is also*

*missing in the documentation.*

*For eq 1, how does the depth of the fertilizer application play a role in the  $\text{NH}_3$  flux?*

>> Revised accordingly. We introduced the original CNMM-DNDC model in simulating  $\text{NH}_3$  volatilization from uplands, described in Lines 174-180. Meanwhile, Table S1 and S2 were added to present the equations and symbols for the simulation of  $\text{NH}_3$  volatilization from uplands in the original and modified CNMM-DNDC. Please see changes in the Supplementary materials.

*Because there isn't a good introduction to the initial model, I am left to wonder about the role the parameters play in the emissions process and how sensitive the model is to parameter modification. This would be another good opportunity for a sensitivity analysis. Also, are the final parameter values used for all the sites or are they site/environment specific. Perhaps include a table of the parameters changed and their initial and final values would help.*

>> Revised. The sensitivity analysis for the parameters of the improved model was added. Please see changes in Fig. 8 and subsection 2.4.

*Section 2.4: I think it would also be interesting to look at a sensitivity of the model parameters as well. This would provide an indication of which parameters have the largest influence in the model simulations of emissions and which parameters are*

>> Revised. The sensitivity analysis for the parameters of the improved model was added. Please see changes in Fig. 8 and subsection 2.4.

Section 4:

*The section begins with discussion of the factors affecting emissions and moves into why the model performs poorly for certain conditions. Perhaps split into two sections or separate in different paragraphs.*

*Section 4.2 begins by unnecessarily repeating methods (line 473-483), and again discusses model limitations rather than influences on emissions as the section heading suggests.*

*I suggest a separate section for model limitations or changing the header of 4.1 and 4.2.*

>> Fully agreed and revised. We reorganized the Discussion section and rephrased the titles and the contents as well to make them more readable. Please see changes in the Discussion section.

*Section 4.4 reads more like a conclusion than the actual conclusion in the paper.*

>> Fully agreed and revised. We rewrote this section, which currently it is Section 4.3 in the revised MS. Please see changes in Lines 673-720.

*The conclusion feels like more of an abstract and repeats methodology.*

>> Agreed and revised. We rewrote the Conclusion section. Please see changes in the Conclusion section.

*Data availability: Providing model output is useful but does not allow duplication of this effort. A suggestion would be to provide the actual model used by the authors.*

>> **Revised.** The code and executive program of the modified model can be obtained from <http://doi.org/10.6084/m9.figshare.19388756>. Please see the additional description in Lines 757-758.

**Technical comments:**

*Line 16-18 (and elsewhere): "...evaluated and modified using NH<sub>3</sub> volatilization observations from 44 and 19 fertilizer application events in cultivated upland areas and paddy rice fields in China, respectively." The wording is slightly confusing. I suggest "evaluated and modified using NH<sub>3</sub> volatilization observations from fertilizer application events in 44 cultivated upland areas and 19 paddy rice fields in China."*

>> **Response.** The NH<sub>3</sub> volatilization observations from 44 and 19 fertilizer application events used in the MS were collected from 6 upland sites, 4 paddy rice sites and 1 site with upland and paddy rice area. Placing the numbers of 44 and 19 in front of fertilizer application events were more accurate. Therefore, we retained the expression of '44 and 19 fertilizer application events' instead of 44 cultivated upland areas and 19 paddy rice fields.

*Section 2.1: The authors should reference Table S6 when discussing the upland sites.*

>> **Corrected.** The citation was added in Line 308.

*Line 451: is missing a space between placement and 5.*

>> **Corrected.** Please see the change in Line 556.

*Text is awkward, particularly Line 452-454.*

>> **Agreed.** We rewrote the mentioned sentences and shortened other long sentences throughout the MS. Please see changes in Lines 557-559 and Lines 143-146.

*Section 4.3 is missing; the titles jump from 4.2 to 4.4*

>> **Corrected.** Please see changes in Line 673.

**References:**

*Riddick, S., Ward, D., Hess, P., Mahowald, N., Massad, R., and Holland, E.: Estimate of changes in agricultural terrestrial nitrogen pathways and ammonia emissions from 1850 to present in the Community Earth System Model, Biogeosciences, 13, 3397–3426, <https://doi.org/10.5194/bg-13-3397-2016>, 2016.*

*Vira, J., Hess, P., Melkonian, J., and Wieder, W. R.: An improved mechanistic model for ammonia volatilization in Earth system models: Flow of Agricultural Nitrogen version 2 (FANv2), Geosci. Model Dev., 13, 4459–4490, <https://doi.org/10.5194/gmd-13-4459-2020>, 2020.*

>> **Revised.** The above two references on CESM were added in the reference

section and cited in the text. Please see changes in Lines 56-57, Lines 909-911 and Lines 930-932.