Response to Anonymous Referee #1

Comment:

I find the manuscript considerably improved and am happy to recommend that it is published without additional changes.

Previously I stated that I was unconvinced about the validity of performing a global upscaling. While I remain somewhat skeptical, I think that the methods and shortcomings have now been well enough described that readers can make up their own minds in an informed way on how much to trust the global results. On the global scale I believe it would be useful to perform a more rigorous uncertainty analysis, but I understand this is a big task and am content if it is postponed to a future publication.

Reply: We appreciate that the reviewer recognizes the improvement of the revised manuscript. We thank the reviewer for all the insightful and critical comments/suggestions in the review.

Response to Anonymous Referee #2

Comment:

First of all I want to thank the authors for their extensive reply on the concerns and remarks of both reviewers. I think they addressed a lot of issues. I also think the manuscript has improved a lot and also recognized some of the reviewers concerns.
I also noticed that reviewer #1 has a lot of critical and good notes and that the question whether this is the good time to apply this model on a global scale. For what I have seen in this manuscript, the authors did everything to calibrate and validate the model on as much observations they could use. They tried to address the spatial distribution in climate zones, as well as different fertilizer application moments. Additional information to improve their model results are not yet available, so therefore, I think, this lightweight model is useful at a global scale. Like any other model, there are still improvements possible, when useful data or observations are available.

Reply: We thank the reviewer for recognizing the significance of our work. We thank the reviewer for all the constructive suggestions and detailed comments in the review.

Other comments:
I am looking at figure R1-2. There are simulations where the internal time step has been varied between 1 minute and 1 day. I think it is a pity that this figure is not added to the final manuscript (in the Appendix). Could that be done?

Reply: Fig. R1-2 (in Author's response) has been added to Sect.S10 in the Supplementary materials. This is an independent section, and there is an accompanying paragraph discussing the model sensitivity to the temporal resolution.

I also want to make a suggestion (probably not for this version of the model). When I see a lot of peaks which should be reproduced by the model, I always consider to use a dynamic time step method for the Euler method (for example: Adaptive Runge–Kutta methods on https://en.wikipedia.org/wiki/Runge%E2%80%93Kutta_methods). In case a lot of change is happening in the system, small time steps are taken, and when the change is limited, large time steps are taken. The largest time step taken, is dependent on the reporting time (times that the model write results to output files). This avoids missing any kind of peaks and it does not always need more computing time. This is a suggestion.

Reply: We thank the reviewer for pointing out this method/technique. We think this dynamic time-step method can be very useful to address the challenge that higher temporal resolution would require much more computational resources, especially for large-scale simulations. We added this point to the discussion of future work in Sect.S10, together with Fig. R1-2.

The last point from reviewer #1 about the details of the uncertainty estimates. I see that new runs are performed to give more insights in the uncertainty. I appreciate that. But the reviewer is asking to provide more details. I didn't see that in the revised manuscript. I see in the revised manuscript that there are two main aspects of uncertainty: input data and model parameters. I did find the input data. I am missing more information about the basic assumption of the one to four points that are described. There is a conclusion of 33% and 20% uncertainty. But still it is not clear what you assumed and what parameters are changed to reach this conclusion. Can you provide this information?

Reply: We improved Sect.4.3 to clarify the assumptions of the summarised points in the model.

As discussed in the manuscript, systematically quantifying model uncertainty, especially on the global scale, is challenging and difficult because we only have very limited datasets for explicit model-measurement comparisons. The value of 33 % was derived from the comparison with the GRAMINAE experiments, indicating the reduction in the cumulative modelled NH_3 emission to match the measured emission. The value of 20 % came from the multi-site model-measurement. Given that chamber measurements often estimate lower emissions, and global simulations can show both overestimates and underestimates, a rather conservative estimate of 20 % uncertainty is proposed. In contrast to systematic analyses, these two values serve as an approximation or "back-of-the-envelope" calculations for the uncertainty estimation to give readers a useful point of "reference". We have emphasized that "It is worth noting that readers should only interpret the estimates and the uncertainty under the context of modelling" as highlighted during the previous round of review.

I liked the inclusion of the list of parameters needed to be used in this modelling exercise. The question is whether this should be in the main text or in the Appendix. I think the bullet points could be moved to the Appendix. Feel free to keep it or move it.

Reply: We would like to raise a point that high quality measurements are urgently needed and can be valuable for model development and evaluation. Therefore, we would like to have a list of suggested measurements in the main text.