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Discussions

Interactive comment on "Process-based modelling of NH_3 exchange with grazed grasslands" *by* Andrea Móring et al.

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Reviewer's comments on Biogeosciences manuscript bg-2016-555 "Process-based modelling of NH3 exchange with grazed grasslands" by A. Moring et al.

General comments

The paper describes the development, testing, evaluation and sensitivity analysis of a process-based model of NH3 exchange over grazed grassland, applied at the field scale. The 1-D model (GAG_field) is the extension of the recently-developed model of NH3 exchange (GAG_patch, see BG 13, 1837-1861, 2016) for a single urine patch deposited to soil by a grazing animal; NH3 emissions by multiple urine patches are dynamically simulated at the field scale, and their interactions with the surrounding "clean" areas (unaffected by urine) are accounted for using a bi-directional exchange

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Discussion paper

scheme to simulate NH3 recapture by the grassland ecosystem in the near-field.

The paper is generally well written, though with some confusing symbols and turns of phrase in model description, and the model is consistently documented, with adequate referencing to the GAG_patch paper and to the wider literature. The model is evaluated versus field data (gradient-flux measurements from 2 short-term campaigns in Scotland, UK), showing broadly consistent features (emission peaks of similar magnitudes, comparable diurnal fluctuations), although considerable discrepancies remain, which may or may not be explained by large uncertainties in the flux measurements. Notwistanding considerable simplifications in model structure and large uncertainty in model parameters, the model is reasonably successful at simulating net NH3 emissions from grazed grassland, at least for the Scottish dataset tested; it remains to be seen how the model would fare in a different environment (different soil, climate, grazing density, etc).

The model is a welcome development and shows potential for deployment in regional-scale chemical transport models, and thus the paper fits the scope - and should be of interest to readers of -Biogeosciences. However, some key issues and minor flaws need to be addressed first, which may well require the authors to recalculate all tables and figures and provide new, additional model runs, without requiring any major changes in structure, contents or conclusions.

This is especially the case for sections 4.2.1-4.2.3 that deal with model sensitivity to soil physical and chemical parameters and particularly the comparison of sensitivity at field scale compared with patch scale. The main flaw here is that the sensitivity analysis for the patch scale refers to Moring et al. (2016), which used input soil, climate and grazing data from New Zealand, while the field-scale sensitivity uses very different Scottish inputs data (different pH, soil texture, etc). Because sensitivity to a model parameter is (as demonstrated by the authors) hugely dependent on initial/boundary conditions, the very different site characteristics between NZ and UK lead to very different sensitivities, regardless of scale (patch or field). The authors thus have to struggle to adjust input/parameter data in the GAG_patch sensitivity analysis (eg FC, PWP) to 'harmonize' the two datasets, but never actually do so completely because the GAG_patch sensitivity analysis remains a 'hybrid' of NZ and UK data. I recommend a full, new analysis of GAG_patch sensitivity using exclusively Scottish input data, so that the issue of upscaling in sensitivity can be properly addressed.

Specific comments

p2, cN (gN dm-3): is this total N including all N-containing forms, or just urea-N content of urine?

p2, for clarity's sake, please indicate here that Ft is the total net flux over the canopy at patch scale in GAG_patch (while Fnet is the equivalent for field scale in GAG_field)

p5, l10 '...is considered as the only sink term.' Here it would be useful to mention that drainage/leaching of TAN and urea out of the source layer in the case of (heavy) rainfall filling porosity and entrainment of N into deepers soil layers are not considered, and whether, or why, it is reasonable to do so.

p6, l2 '...it would be preferable to neglect the overlap...' : it is not preferable, just easier!

p6, l25, and p7, l12: 10 LSU/ha as 'worst case scenario' is not a valid or representative value for the maximum grazing density in Europe. Intensive and rotational grazing practices can give rise to much higher animal numbers per ha, though for shorter periods of time. See example given in Bell et al., Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-350, 2016, with grazing densities above 20-40 LSU/ha.

p7, l8-9, related to the above : 'As a consequence, the total area of the patches grows in the first eight days, then it remains constant while the animals are on the field'. This is true of extensive grazing, but in intensive management, grazing duration may be just 2-3 days.

p8, l25-29: the terminology Ft vs Fnet vs Fnon is slightly confusing, see e.g. the sentence "...Fnon was derived in the same way as the net NH3 flux (Ft)...", is it possible to use less ambiguous symbols?

p9, l24: related to the above, '...GAG_patch calculates the patch emission (Ft(ti)...': is Ft actually the patch (gross) emission, or the total net flux including exchange with vegetaion? I believe it is the latter, so for clarity's sake please write '...GAG_patch calculates the patch net flux (Ft(ti)...' ?

p9, l1: '...over the non-urine area the dynamic simulation of soil chemistry is not needed...' : it would be needed, to better resolve background exchange fluxes (instead of default /constant Gamma_g values); it's just that we don't have adequate understanding, models and data to do it. Please rephrase.

p9, l17: add '(assuming no overlap)' after '...the area of the field that is not covered by any urine patches.'

p10, l1: 'When calculating Ft(ti) a slight modification is also required...' : a small modification compared with what? with GAG_patch?

p10, l5-6: sentence not clear: why does B=Bmax 'prevent infiltration' ? Do you mean rather that the model formulation cannot account for/simulate infiltration when the B=Bmax situation occurs?

p10, l6: "...prevents infiltration, resulting in no N input to the system and consequently no NH3 emission': surely you don't mean that B=Bmax means no NH3 emission?

p10, l9-10: '...the GAG_patch model modified for the non-urine area...': not very clear what this means?

p10, l11: why was dilution only treated in the first time step in GAG_patch ? And can you please state explicitly on l12 (just before Eq. 11) that dilution is now treated in GAG_field at all time steps and not just at the time of urination ? (if I understand correctly)

p10, l18: which 'second point' , what does this refer to?

p12, l9: the interval 03/09 13-17:00 is not shown anywhere on the figures, thus need not be mentioned here. Please delete.

p12, l11: "...values were assumed to be zero." This is not a reasonable assumption to make, as doing so will necessarily lead, in the model, to the maximum possible net emission (through the maximum possible soil-vegetation-atmsophere gradient). I believe this effect is clearly visible on Figures 8a, 9a, 12a, 13a, where in each case there is a sharp, step-wise, instantaneous increase in modelled flux from large deposition to large emission (step change > +100 ng m-2 s-1) around midday on 27/08, followed by a steep, instantaneous decline one day later around midday on 28/08. The timing of these step changes coincides exactly with the period of missing concentration data, where the authors assume Xa=0, with the strong and immediate effect of boosting net emission b. This is clearly not right. The authors should either: i) start the modelling period at 13:00 on 28/08, or ii) fill this 1-day gap in Xa by assuming Xa equals the mean background concentration in the area at this time of year ($\sim$2-3 μg m-3 according to C. Milford, PhD thesis, The University of Edinburgh, 2004). In either case, all flux figures should be redrawn, and all subsequent sensitivity analyses should be recalculated because the results of this day will affect the total.

This raises another important issue. The measured Xa values were used as inputs to drive the emission and bi-directional exchange models; however, in most cases, the concentrations were measured downwind from the S. field, since the prevailing wind was south-westerly, i.e. the measured Xa values were enhanced with respect to background through the emissions occurring on the S. field, and thus were themselves partly a result of the emission. The concentration gradient across a grazed field may be several μg/m3, as shown by Bell et al., Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-350, 2016. There is thus clearly a problem of recursive logic in using the downwind concentration as input, in such a situation where there is a strong horizontal gradient. There is no easy way out of this issue since the model does not address advection, but at least i) the issue must ne mentioned in the text, and ii) a sensitivity analysis must be run and added to Section 4, in which the model will be run with a range of other Xa values e.g. Xa'= 0.5*Xa, 0.6*Xa, 0.7*Xa etc, or Xa - 0.1μg/m3, Xa - 0.2μg/m3, Xa - 0.3μg/m3, etc... This will likely have the effect of increasing emissions throughout (as already shown by the Xa=0 bias on 27-28/08), and may thus incidently improve the comparison to flux data late August/early September 2002.

p12, l21: related to the above comment: delete the reference to substitution by zero.

p12, l30-33: Gamma_g for the non-affected grassland is a key parameter for the NH3 recapture within the field, and the authors use a value of 3000 based on a comparison of model and measurements early June 2003. It would be useful to see these data as Supplementary Material, together with alternative runs using e.g. Gamma_g = 500, 1000, 5000.

p14, l2 & l12: why must there be a 'conversion', what does it mean to 'convert' SENSnet to SENSpatch? I don't quite see why SENSnet needs to be made 'compatible' with SENSpatch. The sensitivity of Fnet (GAG_field) to model parameters is the sensitivity of Fnet (GAG_field) to model parameters; there is no need for further transformation?

Perhaps the authors need to start this argument on p13, l31 by writing that they wish to compare the model sensitivities of "...Fpatch in the case of the multiple patches simulated within GAG_field and the single urine patch simulated by GAG_patch...", and that in order to do this a mathematical transformation is needed to extract the sensitivity of Fpatch from the overall sensitivity of Fnet. Thus the argument will become clearer.

p15, l8, presumably these scale parameters are the geometric standard deviation (sigma=0.786) and geometric mean (μ=1.154)? The text should say so. Then the start of the next sentence says "The mean of cN ...", I presume but can't be certain that this signifies the arithmetic mean? Again should be clarified.

Equation 21: geometric or arithmetic mean?

p15, l15-16, the mean cN of 11 g dm-3 is the arithmetic mean, and the 'scale parameter' of 2.089 is the geometric mean?

p15, l19: why 30 cN time series (why not 50 or 2000) ?

p16, l2: '...broad accordance with the observations.' Please provide the regression Rˆ2, slope for model vs measurements, as well as RMSE and other such statistics classically used for model evaluation. Was there any filtering of the flux data for periods of low wind speed, strong nocturnal stability or any such quality criteria for flux-gradient measurements ? (it looks as though the flux time series is completely uninterrupted apart from aforementioned periods of AMANDA down time)

p16, l27-28: '...could explain part of the difference between the simulation and measurements on this day (Fig. 8), if the model overestimated the deposition component of the net flux.' The difference could just as well be due to an underestimation of the gross emission from urine patches, there is no telling which; possibly a combination of both.

p16, l29-32 and also section 4.2.4, on the diurnal variations of net emission: is it possible/likely that there is a diurnal variation in urination frequency, with animals being e.g. more actively grazing during day than night, or other temporal urination patterns ? Could this be tested by using e.g. UF(day) = 2*UF(night)? The impact of higher urination frequency during daytime would be compounded by the effect of higher temperatures.

p18, l2: change to "...are between 1-2 orders of magnitude larger than..."

Sections 4.2.1, 4.2.2, 4.2.3: these sections describe the sensitivity of GAG_field to soil physical and chemical parameters, which is very well and fine. However the authors also try to compare this sensitivity to the results obtained for GAG_patch in Moring et al (2016), and claim that the observed differences in sensitivity can be assigned to upscaling. I have a major reservation with this approach, because GAG_patch was run on a dataset from New Zealand in Moring et al 2016. The authors are aware of this limitation because they adjust soil parameters one by one in order to make the two datasets comparable (e.g., very different initial pH values of 6.65 and 4.95, or Theta_urine of 0.18 and 0.3, etc), but as far as I understand they did not go as far as to -re-run GAG_patch and its sensitivity analysis specifically for and using only Scottish data (not just soil inputs, but also weather, stocking density, etc). The comparison of sensitivity for the different scales (patch and field) can only make sense (in terms of the impact of upscaling) if data from the same site are used.

My recommendation therefore is

- either focus on the sensitivity of GAG_field, and leave aside the comparison with GAG_patch results from Moring et al, or at least make it clear that differences cannot be assigned to upscaling

-or re-run the GAG_patch sensitivity analysis using only input data from the Scottish site (forget about GAGpatch results from Moring et al 2016), such that upscaling can be invoked to explain differences for the same soil/weather/grazing conditions In either case the authors would have to re-think/re-draw/re-calculate Tables 3, 4, 5, 6, and rewrite sections 4.2.1 through 4.2.3.

p18, l6-7: '...the main factors that can regulate the governing role of buffering in the evolution of soil pH in the NH3 source layer ... are ... pH(ti) - pH(ti-1) ...' : this turn of phrase is strange, because it is buffering that controls/reglates/modulates the change in pH over a time interval, not the other way around, semantically.

p18, l16, similarly to the above comment, '...These larger changes in soil pH generate a larger buffering effect...' sounds strange; it is the extent of buffering that controls pH change

p20, l20: Fig. 12 does not show a comparison of GAG_field vs measurements

p24, l2-3: 'Over the field scale the response of the NH3 fluxes was extremely strong to the perturbation of these parameters'. This is true, but as pointed out above, it is not adequately demonstrated that this response is stronger at field than at patch scale, because the NZ and UK sites are different.

p24, l27-28: 'The observed sensitivities [of GAG_field] turned out to be much higher than was found in the case of GAG_patch': again, this is misleading because it gives the impression that the only reason for the difference is scale (patch vs field), which is not the case.

Same paragraph: 'The different sensitivities over the two scales can be explained by the different initial soil pH and the different soil physical characteristics': ergo, the difference has nothing to do with scale, but with soil characteristics.

Tables and figures:

Table 2: it seems the model used constant canopy height and LAI over the whole modelling period, this is surprising since cattle will consume grass, so the values should decrease from start to end, which would impact model results. Also, a leaf area index of 1m2 m-2 is very small, there would be hardly anything to eat for 50 cows for a week! I would venture that these values were measured at the end of the grazing period? It might be reasonable to re-run the model with starting LAI and canopy height values of 3 m2 m-2 and 0.2m, respectively, and assume a linear decrease until the end of the period ?

Tables 3,4,5 to be recalculated to show GAG_patch results using fully Scottish input data (soil parameters + weather data + grazing/field data + NH3 concentration data, etc), instead of using GAG_patch sensitivity values from NZ site of Moring et al 2016

Figure 5, bottom line, second cell from right: presumably this is n(tj=n) ?

Figure 6, add scale

Figure 7, the geometric mean value (mu) of 2.089 seems to be abnormally small for this distribution, I would expect the geomean nearer 5-6, close to the median?

Figures 8 through 13 to be redrawn using a non-zero concentration for the missing Xa data on 27-28/08/2002

Figure 8: 'Where the error bars are missing one of the three NH3 concentration denuders were malfunctioning or not registering data at all.' This is slightly misleading, visually, because it is at times when fluxes are most uncertain (calculated from only 2 concentration heights) that there is no indication of uncertainty on the figure... I would suggest to calculate the mean uncertainty from all fluxes from 3-point gradients (mean of red error bars already present on figure), multiply this value by e.g. a factor of 2, and apply to the rest of the points (in a different color) ?

Technical corrections

p4, l9 change 'atmospheric NH3 concentration right above the surface' to 'atmospheric NH3 concentration at thermodynamic equilibrium with the surface'

p9, l16: '... it was treated as a constant...'

p10, l4: change to '...will dilute the incoming urine...'

p10, l28: '...at height z above ground...'

p10, l29: '... the von Karman constant...'

p11, l26: change "as well as" to "and"

p11, l29: '... previous time steps.'

p11, l31: 'hereby"

p12, l3: '...averaged to an hourly...'

p12, l5: '... in the resulting averaged time series...'

p12, l17-18: suggest change to '...the wind direction was from the N. field for 7% and 15% of the time, respectively.'

p13, l12: suggest change 'kept the same' to 'unchanged'

p13, l16 : '...results... ARE compared...'

p13, l19: '...the sensitivity... differS in the case...'

p13, l31: '...and pH(t0) ARE perturbed...'

p14, l3: delete 'to' after 'equals', or write 'is equal to'

p15, l25: Fig.8, not 4 ?

p16, l18: it must be '... not operating until 24/06 13:00...' (not 23/06). 24/06 early afternoon is when the error bars re-appear in Fig.8b, ie back to 3-point vertical gradient?

p16, l19: change to "...suggesting larger uncertainty in the measured dataset."

p16, l22: "...temporal variationS of the NH3 fluxes..."

p22, l16: 'basis' instead of 'base'

p23, l28: '...can be explained by the fact that...'

p24, l9: do you mean rather a low-resolution grid to match the low resolution of the CTM (of the order of a few km^2) ?

p24, l22: change to '...substantially decreased by the simultaneous NH3 deposition to the non-urine area within the field.'

p45, l4, 'The numberS above the plots...'

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