Biogeosciences Discuss., 6, S930–S939, 2009
www.biogeosciences-discuss.net/6/S930/2009/

Biogeosciences Discussions

Interactive comment on "SURFATM-NH_3: a model combining the surface energy balance and bi-directional exchanges of ammonia applied at the field scale" *by* E. Personne et al.

E. Personne et al.

Received and published: 30 April 2009

We greatly thank both reviewers for their careful reviewing and the detailed and constructive comments. All comments are taken into account in order to delete the errors and to improve the quality and understanding of the study presented here.

Our answer is divided in two parts. First, we propose an organized answer based on the substantive issues, and secondly, we propose a revised paper integrating the suggested improvements by the reviewers.

Small oversights and errors were corrected directly in the revised paper.

From the essence of the comments of the reviewers, it can be proposed an answer divided in four points:

1 Proposal of an approach in order to investigate the origin of the NH3 ground emission.

In order to better represent the ground surface emission, it could be proposed an approach which combines the soil and the litter emission. This approach is represented in Figure R1 and it can be calculated an effective compensation point at the ground surface (χ_{eff}) with the following characteristics.

The effective compensation point (χ_{eff}) of the ground surface is given by: $\chi_{eff} = R_{eq}\left(\frac{\chi_{soil}}{R^{NH3}_{dry\_soil}+R_{litter\_transf}} + \frac{\chi_{litter}}{R_{litt\_int}}\right)$ The equivalent surface resistance (R_{eq}) is given by Equation R2 :

$$R_{eq} = \frac{1}{\frac{1}{R^{NH3}_{dry\_soil}+R_{litter\_transf}} + \frac{1}{R_{litt\_int}}}$$ Equation R2

with: $R_{litt\_transf} = \frac{\tau_{litt}.\Delta_{litt}}{p_{litt}.D^{NH3}} = \frac{\Delta_{litt}}{Q_{litt}.D^{NH3}}$

see `http://www-egc.grignon.inra.fr/sites/1/bg-2008-0168/` FIGURE R1 (in bg-2008-0168.rp.figures.pdf)

In this approach, $R_{litt_transf}$is the NH_3 transfer resistance through the litter with τ_{litt} and p_{litt} respectively the tortuosity and the porosity of the litter. In the revised paper, it is interpreted as a porous medium function Q_{litt} as in Schaap and Bouten (1997). R_{litt_int} is the resistance for the exchanges from the internal phase of the litter tissues and this resistance is controlled by the closed stomata of the dead leaves of the litter.

With this approach, it can be distinguished the soil and litter emission and/or it can be described an efficient emission ground surface.

BGD

6, S930–S939, 2009

Interactive Comment

This approach has been integrated in the model and the results are presented in Figure R2 with the parameterization of the litter resistances (R_{litt_transf} = 380 s m^{-1} with Δ_{litt} = 0.005 m, p_{litt} = 0.9 and τ_{litt} = 1.5 and R_{litt_int} = 5000 s m^{-1}).

This new approach combining the soil and litter exchange, in particular with the expression of an efficient ground surface, allows to integrate the two sources of NH_3.

See `http://www-egc.grignon.inra.fr/sites/1/bg-2008-0168/` (FIGURE R2 in bg-2008-0168.rp.figures.pdf)

The lack of dynamic of the litter resistances leads the ground emission to be only dependant on the evolution of the emission potentials (Γ_{litter} or Γ_{soil}) and surface temperature.

Indeed, as discussed in the revised paper, the soil emission scenario doesn't take into account the adsorption on the mineral phases of soil or organic matter in the first soil centimetres along the path of NH_3 particles (transfer through the dry soil, see Figure R1 here and Figure 1 in the original BGD paper or revised paper). In addition, the pH of the soil water is questioned as the pH of the available water from soil and/or the pH of the solution containing the ammonium (NH_4^+), and the ammonium NH_4^+ also measured in the first ten centimetres of the soil may not be available for volatilization.

In conclusion, the revised paper doesn't propose this new approach which doesn't introduce a real improvement in understanding of the ground emission processes. It is a neat (smart) theoritical solution for the expression of an efficient ground surface but which needs a more detailed description of the ground surface, in particular in the way of a dynamical approach.

Instead, we propose a discussion on the origin of the emission from the ground.

BGD

6, S930–S939, 2009

2 Cuticular deposition

The cuticular deposition can be calculated by the model but it has not been presented in the original paper. The inaccuracy of the original paper for the deposition over the vegetation (distribution between the stomatal absorbtion and the cuticular deposition never presented/discussed) has been corrected in the revised paper.

The proposed scheme of the NH_3 exchange allows to calculate the distribution of the emission or deposition fluxes for each compartments (ground surface, stomata exchange or cuticular deposition).

The partition is summarized in the Figure R3 for each period of the experiment. It can be seen that the cuticular deposition is low during the diurnal period but it is the major deposition fluxes during the night: the stomatal absorption is low due to the stomatal closure and the cuticular deposition increases due to the air humidity which increases during the night. A version of this summary graphic is included in the revised Synthesis of Results and conclusions paper of Sutton et al. (BGD, 6, 1121-1184, 2009) that is resubmitted for BG.

See `http://www-egc.grignon.inra.fr/sites/1/bg-2008-0168/` (FIGURE R3 in bg-2008-0168.rp.figures.pdf)

With the parameterization of the cuticular deposition (Milford et al 2001a), the model takes into account the air humidity as the climatic variable which affects the deposition on the leaf surface. It is a parameterization which has been studied with the aim to propose a simple solution for the leaf surface NH_3 deposition over grassland, in particular with the use of classical meteorological variables at a reference level. With this approach adapted for grassland and air humidity at the reference level, it seems to be not suitable to use the air humidity inside the canopy ($HR_{z0'}$) calculated by the model, even if a more specific approach should improve the results (Burkhardt et al. 2009, Flechard et al 1999), in particular by taking into account the microclimatic environment

BGD

6, S930–S939, 2009

Interactive Comment

inside the cover, what is the probably first improvement which can be proposed.

In fact, the sensitivity to the air humidity has been tested by integration of the air humidity inside the canopy instead of the air humidity at the reference level. The changes due to this transposition are summarized in the Table R1.

Table 1. Relative variation of the mean cuticular flux due to the substitution of the air humidity measured at the reference level (z_{ref}) by air humidity calculated inside the cover level ($z_{0'}$). $F_{cut}(HR_{zref})$, $F_{cut}(HR_{z0'})$ and $F_{tot}(HR_{zref})$ are respectively the cuticular fluxes with the cuticular resistance calculated with the air humidity measured at the level z_{ref}, with the air humidity calculated inside the cover, and the total NH_3 flux calculated over the grassland as reference (right column).

	$\frac{F_{cut}(HR_{z0'})-F_{cut}(HR_{ref})}{F_{cut}(HR_{zref})} \times 100$	$\frac{F_{cut}(HR_{z0'})-F_{cut}(HR_{zref})}{F_{Total}(HR_{zref})} \times 100$
Whole period (22 may – 15 June)	+ 8%	+ 1%
Precut	+ 30%	+ 42%
Post-cut	+ 7%	+ 0.5%
Fertilization	+ 7%	+ 0.5%

On the whole period or with short vegetation, it can be concluded that the sensitivity to the air humidity level is low, in particular if we investigate the influence of the level of the air humidity on the total NH_3 flux in case of high emission. In this situation, the air humidity level doesn't affect the total NH_3 fluxes.

This conclusion is reversed for the period during which the vegetation is dense and with low fluxes. In this situation, each compartment of the model (ground surface, stomata, cuticle) has the same order of magnitude of fluxes: the cuticular deposition becomes important relatively to the total flux.

A more detailed approach could be proposed in a future work.

BGD

6, S930–S939, 2009

3 Comments on the stomatal resistance

The stomatal resistance at the leaf scale was originally developed for wheat (Pleijel et al 2004). The major species of the grassland are grasses and have amphistomatous leaves as the wheat: i- they have the same pattern of responses to the external factors (regulation by the light, the soil water potential, the temperature and the air vapour pressure deficit) and ii- it was reasonable to think that the parameterization for the wheat was also adapted to the grassland because the difference of the parameterization between wheat and potato proposed in Pleijel et al (2004) was pretty low so that it has been proposed a direct transposition of the wheat parameterization to the grassland for the stomatal aperture in a simplified approach. The pretty good results for the energy balance had confirmed this simplification; this first approach seemed suitable.

In the revised paper, we have proposed a new parameterization of the leaf stomatal resistance which is more transposable to other cover types (in particular for future works) and which is specific to the grassland: we propose the approach described by Emberson et al (2000) at the leaf scale and the bulk stomatal resistance at the cover scale is calculated with the approach of Zhou et al (2006) integrating an effective leaf area index which combines the status of the different leaf populations.

The new results presented in the revised paper are almost unchanged from the viewpoint of energy balance and surface temperatures, and the Table R2 shows the comparison between the original parameterization and the results with the parameterization of the paper of Embserson et al (2000).

The stomatal response proposed by Emberson et al (2000) is more generic than before and it will be more adapted to new experiments and applications in future works (for other cover types). The results in the revised paper are very close to the results obtained in the original paper (Personne et al 2009, BGD) which confirms the quality of the parameters in both cases.

Table 2. Coefficients of the linear regressions: model = f(measure) in terms of energy fluxes.

	Original parameterization (Pleijel et al 2004)	Revised paper (Emberson et al 2000)
	Whole period (22 may – 15 June)	
H	y = 0.90 x + 17 (r^2=0.88)	y = 0.90 x + 18 (r^2=0.79)
λE	y = 1.02 x + 6 (r^2=0.87)	y = 1.03 x + 2 (r^2=0.79)
G	y = 0.72 x – 8 (r^2=0.85)	y = 0.85 x – 6 (r^2=0.87)

4 Sensitivity to temperature :

The sensitivity was tested to the choice of surface temperature estimate used in the model Replacing the surface temperatures ($T_{z0'}$ and T_{surf}) by the air temperature at the reference level (*Ta*) substantially altered simulated fluxes, which underlines the importance of the coupling between energy balance model and the pollutant exchange model..

The results with this simulation are presented in Figure R4 with the scenario S2 (litter scenario) as reference. It can be seen that each day, the diurnal NH_3 fluxes are too low and do not represent the diurnal emission. Due to the lack of surface warming with this substitution, the compensation point calculated at the ground level is too low and the emission from the litter level is unable to reproduce the actual amplitude of NH_3 emission during the diurnal peak.

See `http://www-egc.grignon.inra.fr/sites/1/bg-2008-0168/` (FIGURE R4 in bg-2008-0168.rp.figures.pdf).

Knowing that the diurnal mean gap between the air temperature and calculated ground

BGD

6, S930–S939, 2009

surface temperature is 4°C (see Table R3), the coupling between the energy balance model and the pollutant model appears necessary. This difference depended on the period but it can reach up to 8 °C in particular during the period when the vegetation is low-density (just after the cut and before the fertilization).

Table 3. mean difference between the air temperature (*Ta*) and the ground surface temperature (T_{surf}) or the vegetation surface temperature ($T_{z0'}$) for the 3 periods of the experiment (before the cut, after the cut and after the fertilization). The mean diurnal differences are calculated from each time step on the period 05:00 to 19:00.

	($T_{z0'}$-*Ta*) in °C	(T_{surf} –*Ta*) in °C
Whole period (22 may – 15 June)	+ 2.7	+ 4.2
Precut diurnal period (05 :00-19 :00)	+ 1.6	+ 0.2
Post-cut diurnal period (05 :00-19 :00)	+ 5.1	+ 8.0
Fertilization diurnal period (05 :00-19 :00)	+ 2.2	+ 5.2

These results allow also calculation of the mean gap between ground surface temperature and vegetation surface temperature. The mean diurnal gap reaches up 3°C which justifies the use of an energy balance model with two levels (vegetation level and ground surface level): a "big leaf" approach with only one surface temperature could not reproduce this gap between the ground surface and vegetation surface temperature, which is important in the calculation of the compensation points.

BGD

6, S930–S939, 2009

5 REFERENCES

Burkhardt J., Flechard C. R., Gresens F., Mattsson M., Jongejan, P.A.C., Erisman J. W., Weidinger T., Meszaros R., Nemitz E. and Sutton M. A.: Modelling the dynamic chemical interactions of atmospheric ammonia with leaf surface wetness in a managed grassland canopy, Biogeosciences, 6, 67-83, 2009

Emberson, L. D., Simpson, D., Tuovinen, J. -P., Ashmore, M. R., and Cambridge, M. H.: Towards a model of ozone deposition and stomatal uptake avore Europe. EMEP/MSC –W Note 6/2000. Norwegian Meteorological Institute, Oslo, www.emep.int/reports/dnmi_note_6_2000.pdf, 2000.

Flechard, C., Fowler, D., Sutton, M. A., and Cape J. N.: Modelling of ammonia and sulphur dioxide exchange over moorland vegetation, Quart. J. Roy. Meteorol. Soc., 125, 2611-2641, 1999.

Milford, C., Theobald, M. R., Nemitz, E., and Sutton M. A.: Dynamics of ammonia exchange in response to cutting and fertilizing in an intensively-managed grassland, Water Air Soil Pollut, Focus, 1, 167-176, 2001a.

Pleijel, H., Danielsson, H., Ojanperä, K., De Temmerman, L., Högy, P., Badiani, and M., Karlsson, P. E.: Relationships between ozone exposure and yield loss in European wheat and potato –A comparison of concentration- and flux-based exposure indices, Atmos. Environ., 38, 2259-2269, 2004.

Schaap, M. G. and Bouten, W.: Forest floor in a dense Douglas fir stand, J. Hydrol., 193, 97-113, 1997.

Sutton M.A., Nemitz E., Milford C., Campbell C., Erisman J.W., Hensen A., Cellier P., David M., Loubet B., Personne E., Schjoerring J.K., Mattsson M., Dorsey J.R., Gallagher M.W., Horvath L., Weidinger T., Meszaros R., Dämmgen U., Neftel A., Herrmann B., Lehman B.E. Flechard C. and Burkhardt J.: Dynamics of ammonia exchange with

BGD

6, S930–S939, 2009

Interactive Comment

cut grassland: Synthesis of results and conclusions. Biogeosciences Discuss, 6, 1121-1184, 2009b. GRAMINAE special issue, revised submission for Biogeosciences

Interactive comment on Biogeosciences Discuss., 6, 71, 2009.