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Biogeosciences Discussions

Interactive comment on "Ammonia emissions from cattle urine and dung excreted on pasture"

by J. Laubach et al.

Supplement to: Reply to Anonymous Referee #1

The details of how the mass-budget, or IHF, method was implemented are the same as described and discussed in Laubach and Kelliher (2004).

The parameters required and their relationships are displayed in Fig. 1. There, the measured profile data are shown by black dots, for wind speed *u* (left-hand panel), NH_3 concentration C_N (centre), and the horizontal flux, HF_N (right). The latter is the product of *u* and $C_N - C_b$, where C_b is the background concentration. C_b is marked by a vertical dash-dotted line and is approached by the extrapolated C_N profile at z_b (horizontal dash-dotted line). The wind profile is then extrapolated to the intermediate height $z_{65} = (z_b + z_5)/2$, giving u_{65} (uppermost dot in left-hand panel).

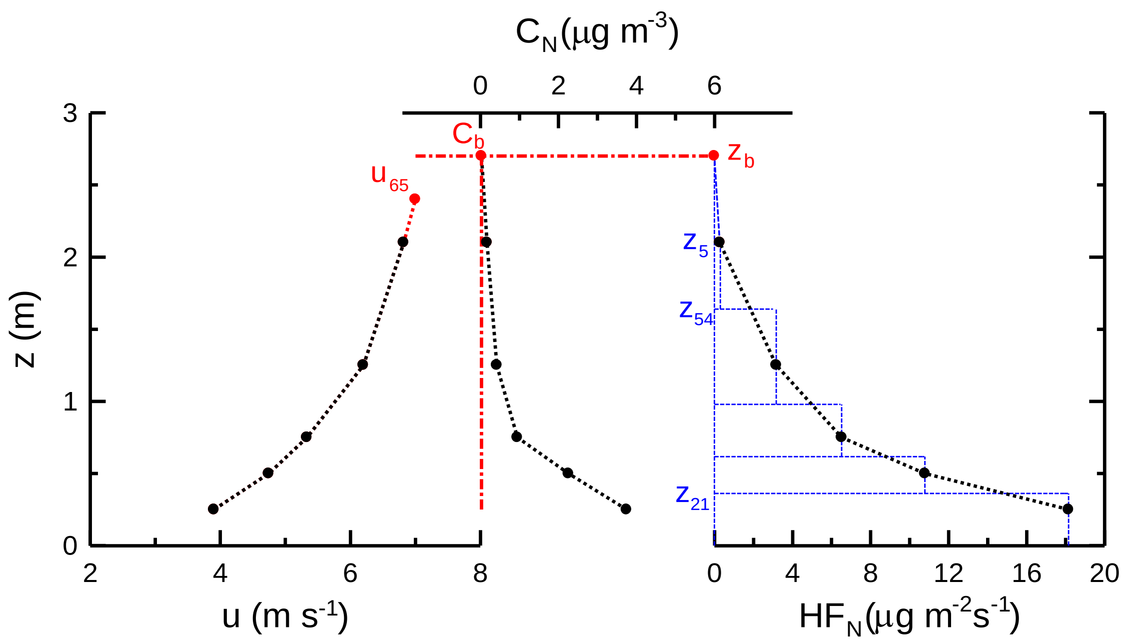

Fig. 1 Example profiles for wind speed, NH_3 concentration, and horizontal flux, HF_N.

The emission rate from the circular area is computed from the integrated horizontal flux (IHF), which is approximated by a summation as follows:

$$\overline{Q_{\mathrm{N}}} = \frac{1}{R_{\max} - R_{\min}} \sum_j \overline{HF_{\mathrm{N},j}}\, \Delta z_j \qquad (1)$$

where R_{max} and R_{min} are the outer and inner radius of the fenced area, respectively (the inner protecting the sampling mast from the cattle). The summation includes 6 terms, 5 of them marked as blue-dashed rectangles ("slabs") in the right-hand panel, between $z = 0$ and z_5. With two exceptions, the boundaries of the rectangular slabs are taken at the intermediate heights $z_{j,j-1}$, which are defined as the logarithmic mid-points between z_j and z_{j-1}, i.e.:

$$z_{j,j-1} = \frac{z_j - z_{j-1}}{\ln(z_j / z_{j-1})} \qquad (2)$$

giving values of 0.36 m, 0.62 m, 0.98 m and 1.64 m for z_{21} to z_{54}, respectively. The exceptions are the bottom boundary of the bottom slab, which is the ground, and the top boundary of the top (fifth) slab, which is z_5.

The sixth term of the summation in Eq. (1) appears in Fig. 1 as the small triangle with base at z_5 and top corner at z_b, representing u_{65} ($C_5 - C_b$) ($z_b - z_5$)/2. This term constitutes the extrapolation of the profiles above z_5 to correct for any amounts of horizontal flux that would otherwise have been missed (Laubach and Kelliher 2004). When C_5 and C_b are indistinguishable, both the fifth and sixth term of the summation vanish. This happened in half of the runs of our experiment, so the uncertainty of the profile shape above z_5 had very minor effect on the estimate of the cumulative NH_3 emissions. By contrast, in the experiment of Beauchamp et al. (1978) the plot radius was much larger and there was significant contribution from the horizontal flux above the top measurement height (ca. 28 %), which they estimated by fitting the profile. Indeed it seems that the need for this extrapolation was the main reason for the profile-fitting, rather than a need for interpolating between the measurement heights.

With respect to such interpolation, the right-hand panel of Fig. 1 demonstrates that the error from replacing the area under the profile by the area of the rectangular slabs is small, because each small triangle missing under a point of measurement height (down to the next-lower intermediate height) is matched by a similar-sized one above the measurement point (up to the next-higher intermediate height). Fig. 1 shows, of course, a "well-behaved" profile, while in practice the profile shape may be more erratic (zig-zaggy). However, the principle of compensating pairs of triangles still applies, for any erratic shape. The largest uncertainty must be assumed for the bottom slab, because the exact shape of the horizontal-flux profile there is poorly known (it cannot grow to infinity at the ground, as a fitting procedure might suggest, because wind speed at the ground is zero).

Given that the error of each horizontal-flux sample is typically 5 to 6 %, and two such measurements are combined at each height (when subtracting background), the uncertainty of the profile integration/summation method would not contribute significantly to the overall error of the integrated profile.

References:

Beauchamp, E. G., Kidd, G. E., and Thurtell, G. W.: Ammonia volatilization from sewage sludge applied to the field, Journal of Environmental Quality, 7, 141-146, 1978.

Laubach, J. and Kelliher, F. M.: Measuring methane emission rates of a dairy cow herd by two micrometeorological techniques, Agricultural and Forest Meteorology, 125, 279-303, 2004.