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AMMONIA EMISSION MEASUREMENTS OF AN INTENSIVELY GRAZED PASTURE

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ABSTRACT: The quantification of ammonia (NH_3) emissions at ambient air conditions is still a challenge and emission factors for ammonia have therefore a large uncertainty. We present first results of a pasture experiment carried out in western Switzerland in 2016. During the measurement campaign, the pasture was grazed by 24 dairy cows in an intensive rotational management. NH_3 concentrations were measured with line-integrating open-path instruments. The NH_3 emission fluxes were calculated by applying a backward Lagrangian Stochastic dispersion model (bLS) to the difference of paired concentration measurements upwind and downwind of a grazed sub-plot. The instruments were able to retrieve small horizontal concentration differences (as small as 0.5 µg NH_3 m^{-3}) and the resulting fluxes were within a range of 0 to 3 µg N-NH_3 m^{-2} s^{-1}. We found, that the fluxes decreased to values below 0.5 µg N-NH_3 m^{-2} s^{-1} typically within 48 hours. First flux evaluation showed, that rain events during the grazing period had a major effect on the cumulative emissions.

Keywords: NH_3, emission, flux measurements, pasture, grazing, bLS, micrometeoro-logical methods

INTRODUCTION: Agricultural livestock production is the main source of air pollution by ammonia. Grazing is one efficient mitigation option to reduce NH_3. However NH_3 emission experiments over grazed pastures are rare and the available studies reported a large range of emissions factors (2.7 to 25.7% of excreted urine nitrogen (N); Bussink, 1992, Laubach et al., 2013). Many of the studies used manual applied urine and measured the emissions with chamber or wind tunnel methods. These techniques might lead to questionable results due to the altering of the environment and the high heterogeneity of the emissions. Sintermann et al. (2016) showed that line integrated ammonia concentrations can be quantified using open-path MiniDOAS systems. They also suggested that paired systems together with a dispersion model can be used to estimate emissions of a grazed system. This might lead to a better characterization of the emissions compared to previous methods. Häni et al. (this issue) already estimated successfully the emissions of an artificial source. In the present experiment we examined the ability of the MiniDOAS systems to measure NH_3 concentrations and estimate the emissions of a rotational grazing system over a full grazing season.

1. MATERIAL AND METHODS:

1.1. Experimental site: The study site was located in the Pre-Alps of Switzerland at the research farm Agroscope Posieux in the canton of Fribourg. The experiment was conducted at a 5.5-ha-pasture and the cows were managed in a rotational grazing system. Usually twice a day the cows were brought to the nearby barn for milking. The whole pasture was divided into two separate systems (north and south) where each system was divided into 11 paddocks resulting in a rotation period of about 20 days, depending on the grass condition. The herd for each system consisted of 12 dairy cows. The rotation was managed synchronously on both systems and the main measurement campaign took place between May 2016 and October 2016. Monitoring of dung and urine patches on the paddock allowed for the quantification of excreted nitrogen (see also Ammann et al. (this issue).

1.2. Meteorological measurements: For the characterization of turbulent mixing the 3-dimensional wind velocity (u,v,w) and air temperature was measured at 10 Hz using an ultra-sonic anemometer-thermometer (HS-50, Gill Instruments Ltd., UK) mounted at 2 m above ground. Each system (north and south) was equipped with one of those anemometers. Further weather parameters (e.g. global radiation, precipitation) were measured with a standard automated weather station (Campell Scientific Ltd., UK) installed at the northern field.

1.3. Ammonia measurements: Line-integrated ammonia concentrations were measured using four MiniDOAS systems as specified in Sintermann et al. (2016). These open-path instruments make use of the differential optical absorption in the UV range. Two MiniDOAS systems (namely S5 and S2) were installed at the northern field and two instruments (S1 and S6) on the southern field, respectively. All instruments were installed at a height of about 1.3 m. Each MiniDOAS pair (e.g. S5 and S2) was separated by a horizontal distance of about 30 m which allowed for concentration measurements upwind and downwind of the paddock in between. The single light path between the sensor and the reflector for the individual devices had a length of 30 to 35 m. The instruments reported NH_3 concentration at a temporal resolution of one minute. The one minute data were averaged to 30-minute values for further processing.

1. 4. Emission calculation: We used an open source R-version of the bLS dispersion model (bLSmodelR, Häni, 2016; based on Flesch et al., 2004) to relate the measured 30-minute concentration difference to the unknown source strength E of the emitting paddocks (see Eq. 1). The dispersion coefficient D was determined based on the simulated movement of many thousand fluid particles released at the sensor line positions and tracked backwards in time till their eventual touchdown on the specified source area.

(1) $$E = \frac{C_{Downwind} - C_{Upwind}}{D} \quad (1)$$

The bLS program uses wind and turbulence information measured by the sonic anemometer. In order to calculate a concentration footprint for each 30-minute period, we used averaged data of the wind direction, the standard deviations of the wind components, the friction velocity and values representing the surface roughness.

2. RESULTS AND DISCUSSION:

2.1. Concentration results: Due to different problems (power supply, software issues…) the MiniDOAS systems were not running continuously during the grazing period. At the northern field, simultaneous concentration measurements of both systems could be achieved for five management rotations, at the southern field for four management rotations. Figure 1 shows an example of concentration measurements at the northern field during grazing (grey shaded area) and a few days afterwards of the sub-plot in between the MiniDOAS instruments. The concentration measurements yielded values between close to zero and more than 80 µg NH_3 m^{-3}. Depending on wind and atmospheric stability, the concentrations showed a strong temporal variation. The highest concentrations were usually observed during low wind conditions, which prevented an efficient mixing of the boundary layer. During periods with well-developed turbulence and favorable wind direction (no advection from the farm buildings) the horizontal concentration difference between paired MiniDOAS instruments was generally highest shortly after the cows left the monitored paddock with values up to 10 µg NH_3 m^{-3}. Typically the concentration difference decreased significantly within the first 48 hours to values less than 10-20 % in relation to the maximum measured concentration difference. Throughout the measurement campaign, the MiniDOAS instruments showed a high accuracy in the measurements. Concentration differences down to values of about 0.5 µg NH_3 m^{-3} could be detected with sufficient precision.

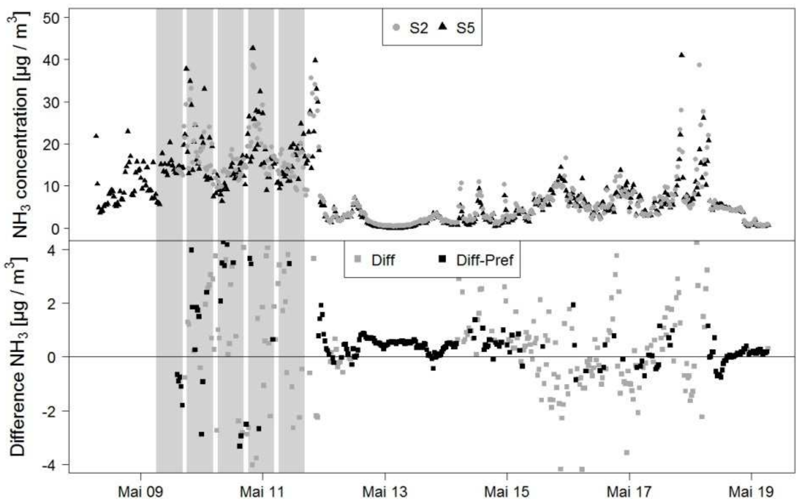

Figure 12. Measured ammonia concentration (top panel) of the MiniDOAS systems S2 and S5. The black dots of the bottom panel show the concentration differences during favorable wind conditions whereas the grey dots show all other differences. Favorable wind conditions exclude the wind sectors with potential advection from farm buildings as well as cases with no or only very little turbulence. The grey shaded areas indicate the time period when cows were grazing on the monitored paddock and the short interrupts indicate the milking periods.

2.2. Emission results: Ammonia advection from nearby farm buildings can lead to severe errors regarding the quantified emissions. Therefore we excluded time periods from further processing with potential advection from the farm buildings. Based on the derived concentration differences and the simulated dispersion coefficients (see Eq. 1) the emissions for the individual 30-minute periods were calculated. Cumulative emissions were estimated by applying a combination of polynomial and linear regressions to the measured data points in order to account for missing or excluded data. Depending on the weather and turbulence conditions the highest emissions were observed at the end of the grazing period. The maximum fluxes observed during the grazing periods were in the range of 1.0 to 3.5 µg N-NH_3 m^{-2} s^{-1}. Rain events during the grazing period significantly reduced the emissions and subsequently resulted in less cumulative emissions. Typical accumulated emissions after 5 days were in the order of 200 to 350 µg N-NH_3, depending on weather conditions and the time the cows spend on the paddock.

3. CONCLUSION: During a field campaign in western Switzerland in 2016 we tested the performance of the open–path MiniDOAS instruments to estimate NH_3 emissions of a grazing system. We found that the instruments worked very well and that they reported stable and plausible NH_3 concentration measurements throughout the field campaign. The emissions were calculated using the measured concentration differences upwind and downwind of the emitting paddock and the dispersion coefficient modeled by bLS. As expected, the highest emissions were observed at the end of the grazing period. These emissions dropped to very low values usually within the first 48 hours after. Rain events during the grazing period resulted in decreased cumulative emissions after 5 days.

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REFERENCES:

Ammann, C., Voglmeier, K., Häni, C., Jocher, M., 2017. Quantification of small scale nitrous oxide emissions and comparison with field-scale emissions of a rotational grazing system. This issue

Bussink D.W., 1992. Ammonia volatilization from grassland receiving nitrogen fertilizer and grazed by dairy cattle. Fertilizer Research, 33, 257-265

Flesch T.K., Wilson J.D., Harper L.A., Crenna B.P., Sharpe R.R., 2004. Deducing Ground-to-Air Emissions from Observed Trace Gas Concentrations: A Field Trial. J. Appl. Meteorol., 43(3), 487–502.

Häni, C.: bLSmodelR - An atmospheric dispersion model in R. R package version 2.4.1. URL: http://www.agrammon.ch/documents-to-download/blsmodelr/, last access: 21 April 2017.

Häni, C., Voglmeier, K., Jocher, M., Ammann, C., Neftel, A., Kupper, T.,2017. Evaluation of backward Lagrangian Stochastic dispersion modelling for NH3: Including a dry deposition Algorithm. This issue

Laubach J., Taghizadeh-Toosib A., Gibbs S.J., Sherlock R.R., Kelliher F.M., Grover S.P.P., 2013. Ammonia emissions from cattle urine and dung excreted on pasture. Biogeosciences, 10, 327–338

Sintermann J., Dietrich K., Häni C., Bell M., Jocher M., Neftel A., 2016. A miniDOAS instrument optimised for ammonia field measurements. Atmos. Meas. Tech., 9(6), 2721–2734.

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This event constituted an opportunity to present the latest scientific advances from research on gas and dust emissions in animal agriculture and contributed to providing information that industry and governments need in order to achieve cost-effective gas and dust mitigation outcomes.

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- **Modeling**
- **Mitigation strategies**
- **Inventories/Environmental assessment**

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