The dynamics of ammonia bi-directional exchange above agricultural crops

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Abstract

Significant uncertainties exist in ammonia (NH_3) emissions from crop fields, which is relevant for the environmental impact of fertilizers. To better understand NH_3 bi-directional exchange in agricultural ecosystems, we measured NH_3 fluxes above a corn field over two growing seasons. We found that NH_3 volatilization following fertilization was significantly lower than reported in previous studies, revealing our still limited understanding of NH_3 exchange processes. During fully developed corn canopy periods, NH_3 emission and deposition were of similar flux magnitudes than after fertilization, which highlights the importance of the canopy for regulating net NH_3 exchange and its impact on atmospheric reactive nitrogen.

Keywords: ammonia emissions, flux measurements, bi-directional exchange, fertilizer application

1. Motivation

A major source of NH_3 to the atmosphere are emissions from synthetic fertilizer applications on agricultural fields, while their quantification is critical to propose effective NH_3 control and mitigation strategies. However, to date large uncertainties in their magnitude exist. This is in part due to challenges in measuring NH_3 fluxes and systematic differences between emission factor quantification methods. Consequently, our understanding of processes that control the exchange of ammonia within the soil-canopy-atmosphere interface is still limited.

2. Experiment

We investigated the dynamics of NH_3 exchange above a corn field in Eastern Canada, over two consecutive growing seasons in 2017 and 2018. Net ecosystem scale fluxes were measured using the eddy covariance technique together with a quantum cascade laser spectroscopy analyser. For technical details see Moravek et al. (2019).

A few days before seeding in May, the field was fertilized by broadcast incorporation of 155 kg ha^{-1} urea fertilizer. Physical and chemical soil and plant parameters were obtained to characterize NH_3 exchange with a compensation point model (Nemitz et al., 2001), while model adaptations and new parameterizations were tested.

3. Results & Discussion

3.1 NH_3 emissions after fertilizer application

In 2017, we found that NH_3 was emitted a few days after fertilizer application. The peak emission flux of about 600 ng m^{-2} s^{-1} occurred following a precipitation event (>10 mm) promoting urea fertilizer hydrolysis and subsequent NH_3 volatilization. Cumulative NH_3 emissions were <0.1% of the applied fertilizer-N, which is significantly lower than previously reported (e.g. Drury et al., 2017). In 2018, NH_3 emissions were even lower, probably attributed to different meteorological conditions, 2017 being particular wet and 2018 much drier.

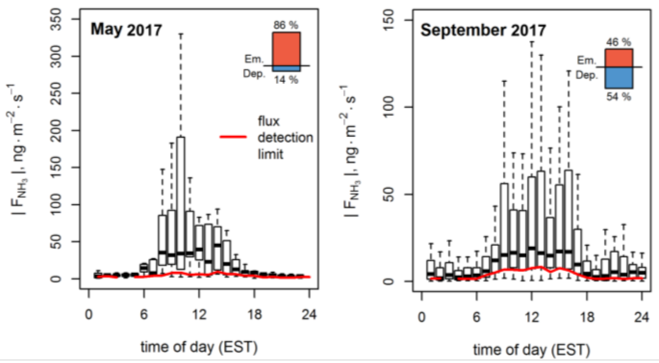

Fig. 1. Diurnal box plot statistics of NH_3 fluxes for May (bare soil) and September (fully developed canopy) in 2017 as presented in Moravek et al. (2019). Values represent absolute fluxes, while the percentage distribution between emission and deposition is displayed.

3.2. Bi-directional exchange with crop canopy

When the corn canopy was fully developed, measured fluxes showed net emission and deposition periods, typically ranging between ±300 ng m^{-2} s^{-1}. The model analysis revealed that soil exchange was limited and that fluxes were governed by stomatal and non-stomatal leaf pathways. Night time emission fluxes exhibit that NH_3 cuticular exchange is bi-directional as suggested in previous studies (Schrader et al., 2016), however, which has not been shown to this extent in field measurements before.

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