We thank the reviewer for the thorough evaluation of our manuscript and for the many constructive comments and suggestions. We have carefully considered all points raised and will be revised the manuscript where we believe the suggested changes improve its clarity, scientific rigor, and accessibility. In a few cases, we respectfully maintain our original approach where the suggested additions would extend beyond the primary scope of this methodological study. Detailed point-by-point responses are provided below.

General Comments

1. Confidence in emission rate quantification: Although the measurement setup successfully captured the expected diurnal cycle (higher emissions during daytime), it remains unclear how confident the authors are in the absolute emission rates derived from their measurements. The quantification performance of the QCL-based system is not explicitly validated against a known reference. Therefore, I recommend that the authors either (I) design an experimental verification of the system against a controlled, known ammonia loss, or (II) explicitly state in the manuscript that the reported values represent measurement-based quantifications rather than true emission rates, acknowledging this limitation.

We agree that absolute validation of field-scale NH_3 flux measurements is an important challenge. However, the objective of the present study was not the calibration of a controlled emission source, but the field evaluation of a QCL-based photoacoustic aerodynamic gradient system under realistic agricultural conditions.

In micrometeorological approaches such as the aerodynamic gradient method, fluxes are not measured directly but are derived from measured concentration gradients and turbulence parameters using Monin–Obukhov similarity theory. Consequently, the resulting fluxes should be interpreted as measurement-based flux estimates obtained within the established AGM framework.

A direct validation against a controlled NH_3 source was beyond the scope of the present field campaign and is rarely feasible for field-scale micrometeorological studies. Instead, confidence in the reported fluxes is supported by (i) calibration of the NH_3 analyzer, (ii) co-located inlet comparison experiments demonstrating negligible systematic bias and a random uncertainty of approximately ±2 ppb, (iii) sensitivity analysis using a large ensemble of stability functions, and (iv) consistency of the obtained emission magnitudes and temporal patterns with previously published NH_3 volatilization studies.

2. Inclusion of uncertainty ranges: It would be highly beneficial to include uncertainty ranges for all quantified nitrogen loss values throughout the manuscript, including the abstract. This would greatly improve the interpretability and reliability of the reported results.

The revised manuscript will include this additional uncertainty estimate, and the corresponding information will also be added to the Abstract.

"The cumulative NH_3 loss was estimated as 1.21 kg N ha^{-1}. Based on instrumental uncertainty (±2 ppb) and literature-reported uncertainty ranges of MOST-based aerodynamic gradient flux calculations, the overall uncertainty is estimated to be approximately ±25%, corresponding to ±0.30 kg N ha^{-1}."

3. Indirect climate impact: The authors should briefly mention the indirect but important pathway by which ammonia volatilization contributes to global warming, namely through the subsequent formation of nitrous oxide (N_2O), a potent greenhouse gas with a global warming potential approximately 273 times that of CO_2 over a 100-year horizon.

This addition will be incorporated into the revised manuscript.

"Volatilized NH_3 may also contribute indirectly to climate change as part of the nitrogen cascade, since redeposited reactive nitrogen can subsequently undergo nitrification and denitrification, leading to N_2O formation."

4. Financial loss context: Quantifying the financial loss associated with fertilizer nitrogen volatilization would be highly valuable for readers from both scientific and applied agricultural backgrounds. Expressing the nitrogen loss in economic terms (e.g., USD or EUR per hectare) would strengthen the practical relevance of the study.

While the economic implications of fertilizer nitrogen losses are certainly important, the focus of the present study is on measurement methodology and flux quantification rather than agronomic or economic assessment. We therefore consider a detailed financial evaluation to be outside the scope of the manuscript.

5. Operational range of the measurement system: The study reports a nitrogen loss of 4% due to volatilization under the specific experimental conditions. However, it is well established that this loss ratio can be substantially higher depending on farming practices, soil properties, climate, and fertilizer type. It would be valuable for the authors to discuss the measurable range of the QCL system, specifically, what is the lowest and highest ammonia volatilization rate that the system can reliably quantify?

In principle, the system does not have a meaningful upper limit in terms of fertilizer nitrogen loss fraction. Even substantially larger losses, theoretically approaching 100% of the applied nitrogen, could be quantified.

The lower quantification limit is more difficult to define because it depends on several factors, including ambient NH_3 concentration, concentration-gradient magnitude, atmospheric turbulence, and averaging time. In practice, the critical parameter is not the absolute NH_3 concentration but the detectability of the vertical concentration gradient used in the aerodynamic gradient calculations.

Based on the instrumental uncertainty (±2 ppb inter-channel uncertainty) and the estimated overall uncertainty of approximately ±0.30 kg N ha^{-1} for the cumulative loss, seasonal NH_3 losses below roughly 0.3–0.5 kg N ha^{-1} would become increasingly difficult to distinguish from measurement uncertainty. We will clarify this point in the revised manuscript.

Detailed Comments

L33: Uncertainty ranges are missing here. Please include a summary uncertainty analysis and report the range for all key quantifications (e.g., cumulative nitrogen loss, mean emission rates).

Please see our response to Point 2 for details of the uncertainty estimation procedure.

L62: In this paragraph, the authors could briefly discuss the indirect influence of ammonia volatilization on global warming via nitrous oxide formation. Additionally, consider adding a separate paragraph or extending the existing text to address the financial loss associated with nitrogen volatilization, preferably expressed in monetary terms per hectare, while acknowledging the key parameters that influence this loss (e.g., fertilizer price, application rate, soil conditions).

Please see our responses to Points 3 and 4 for details regarding the indirect climate impact of NH_3 emissions and the financial implications of nitrogen volatilization.

L119: How would the performance of the system be affected under conditions of low soil clay content? Such soils typically exhibit higher ammonia volatilization rates due to reduced cation exchange capacity. Does the system maintain the same sensitivity and reliability under higher ambient ammonia concentrations?

Soil clay content may indeed influence NH_3 volatilization through its effects on ammonium retention, cation exchange capacity, and related soil chemical processes. However, these factors affect the magnitude of the NH_3 emission rather than the operating principle of the measurement system itself.

The QCL-photoacoustic analyzer measures atmospheric NH_3 mixing ratios and is therefore not directly dependent on soil texture or clay content. Higher emissions from coarse-textured soils would primarily result in higher ambient NH_3 concentrations and concentration gradients. Within the calibrated operating range of the analyzer, the sensitivity and reliability of the measurement system remain unchanged. Consequently, we do not expect reduced system performance under low-clay soils, provided that NH_3 concentrations remain within the linear measurement range of the instrument.

The present study was not designed to investigate the effect of soil texture on NH_3 emissions.

L123: The study applied 30 kg N ha^{-1} as a single fertilization event. However, as noted by Adalibieke et al. (2023) and others, typical annual nitrogen application rates can be substantially higher, often reaching 200–300 kg N ha^{-1} for high-demand crops. A key question arises: if the application rate were increased to, say, 300 kg N ha^{-1}, resulting in much higher ambient ammonia mixing ratios, would the current measurement system still perform reliably? Please discuss the dynamic range of the instrument and its suitability for measuring elevated ammonia concentrations.

As noted in our response to Point 5, the system does not have a practical upper limit with respect to NH_3 volatilization rates under field conditions. In principle, substantially larger NH_3 losses than those observed in the present study, including scenarios associated with much higher fertilizer *application rates, could be quantified provided that the resulting NH_3 concentrations remain within the calibrated operating range of the analyzer.*

L208: I would like to see an experimental validation of the system's performance against a controlled, known ammonia loss (e.g., in a laboratory chamber or a field release experiment). If such validation was not performed, please state this clearly as a limitation and, if possible, outline a proposed validation approach for future work.

Please see our response to Comment 1. As discussed above, a controlled NH_3 release validation experiment was beyond the scope of the present field study and was therefore not performed.

L435: Please translate the reported nitrogen loss (1.21 kg N ha^{-1}, 4.0% of applied N) into a financial loss, using current fertilizer prices. If appropriate, include this economic estimate in the abstract. Additionally, the measured 4% loss falls on the lower side of typical volatilization ranges reported in the literature, See other studies, e.g. Sommer et al. (2004). Please discuss whether the system would function properly under conditions that promote higher volatilization losses (e.g., 15–30%) and whether any saturation or non-linearity effects are expected.

Please see our response to Point 4 regarding the economic implications of nitrogen volatilization. As discussed above, we consider a detailed economic assessment to be outside the scope of the present methodological study. Regarding the performance of the measurement system under higher volatilization rates, please see our response to Point 5.

Figure 1: Consider converting the x-axis from "half-hourly time steps (1–48)" to a more intuitive representation, such as "Hour of day (UTC)" or local time. Additionally, if possible, add additional panels showing other key measured parameters that influence volatilization (e.g., soil temperature, wind speed, relative humidity) to facilitate direct comparison with the diurnal flux pattern.

We agree that the original half-hourly index (1–48) is less intuitive for readers than a direct time representation. Therefore, the x-axis will be changed to time of day (UTC) in the revised figure.

Regarding the inclusion of additional environmental variables, we agree that soil temperature, wind speed, relative humidity, and other meteorological parameters may provide useful context. However, the primary purpose of Figure 1 is to illustrate the diurnal behaviour of NH_3 fluxes together with the concentration gradients and turbulent transfer coefficients directly involved in the aerodynamic gradient calculations. Including multiple additional variables would substantially increase the complexity of the figure and reduce its readability. Therefore, we have retained the original figure structure.