

General comments

The manuscript by Hellsten et al. provides a study into year-long observed variability of ammonia concentrations near three different types of livestock farms in Sweden. The study provides valuable data towards quantifying ammonia emissions from the livestock industry, presenting important concentration measurements close to expected ammonia sources, a relevant scientific question with limited pre-existing results in the current literature. Considering important regulatory decisions, the collected data provides data to not just the scientific community, but also regulatory bodies on the current state of ammonia concentration near agricultural sources of it.

The manuscript is acceptable within the scope of ACP as a measurement report. The measurement setup itself is well considered, and access to spatio-temporal variability, even if on a monthly resolution, is a genuinely valuable contribution. The main findings of the paper, that ammonia concentration has notable seasonal variability and that these emissions are both significant and begin to dilute rapidly with distance are valuable and generally well supported, but the underlying reasoning is sometimes left to a careful reader to reconstruct rather than explicitly presented. However, the manuscript lacks important considerations for confounding variables that may influence the authors' conclusions and lacks robust statistical treatment of its results. At times, the authors attempt to generalize their results to the point where the data from a single farm of each type does not support such generalizations. Finally, the measurement uncertainty and limitations discuss the uncertainties in the measurements themselves, but omits any discussions of uncertainties in the analysis and inference drawn from the results. I have expanded on these in my detailed comments. The language and presentation quality are good, and I only had some minor technical notes on legibility and clarity. I consider the manuscript acceptable for publication in ACP with moderate revisions, particularly in the statistical analysis and treatment of uncertainties.

Specific comments

Line 8: "Furthermore, ammonia contributes to the formation of fine particulate matter ($PM_{2.5}$)"

This should be expanded. Ammonia contributes to both the number and mass concentration of fine particulate matter in important ways. Although this is not the main point in the manuscript, and the manuscript contains no aerosol concentration measurement information, it is nevertheless an important context. Ammonia is known to contribute to both formation of new particles (binary or tertiary formation mechanisms with sulfuric acid) and also increases aerosol mass via condensation onto existing particles. Globally, this secondary effect of ammonia is likely to be the most significant and certainly most long-lasting of its climate effects.

Line 78: "Extended monitoring close to emission sources is therefore needed to identify seasonal trends and to more accurately evaluate the long-term environmental impacts of agricultural NH_3 emissions."

It would be good to explicitly make the connection here as to why measurements close to emission sources are more beneficial over background monitoring of the diffuse background ammonia. I can reconstruct the argument from the text that the environmental effects from short-lived emissions such as ammonia that dry deposit strongly are local in nature. However, for the reader's benefit, it

would be good to state that explicitly. The following paragraph makes this argument somewhat, but it could be linked more explicitly.

Line 94: “Furthermore, as this approach disentangles the impact of different local factors impacting the ambient ammonia concentration in the near vicinity of livestock facilities,”

This argument is difficult to understand as is. How does this approach specifically disentangle the impact of different local factors? Are you claiming that the spatial coverage allows you to determine which specific building or source within the wider farm area is a source of ammonia? I find this claim to be too strong, especially considering that your temporal resolution is one month, and therefore specificity would require extremely compelling evidence to pinpoint such specific sources when source contribution could potentially vary wildly within a single datapoint.

Line 95: “ For each farm, a typical meteorological year (TMY) was constructed to represent climatological conditions to identify the prevailing wind directions.”

With the benefit of hindsight, have you checked that your 12-month period was indeed representative of a typical meteorological year?

Figure 1: Wind roses

Considering all the windroses exhibit very rare northerly winds, I just wish to check that if the wind directions have been averaged, the averaging has been done correctly, that is, separately regarding the sine and cosine components of the wind?

Line 140: Statistical Analysis and Data Assessment

What fraction of the data was removed? Reporting this is important to give the reader an immediate idea of how representative your dataset is. Right now it is difficult to parse how much of spatial or temporal coverage is missing and therefore it is difficult to assess the quality of your inference.

Line 152: “The spatial decrease of ammonia concentrations was analysed by plotting mean NH_3 concentrations against distance from the nearest livestock housing (used as a proxy for emission source distance).”

How good is this as a proxy? As you point out yourself, your source is clearly not a point source, particularly in respect to your spatial resolution. Would it not be better define an approximate center point of your emissions for each farm, mark it on the map, and use that as the point from which you calculate your distance? Alternatively, could you not define each approximate building as a source point and use the median distance from the full set of sources as your distance?

Line 157: “Notably, as a new housing facility was built and put into operation during the measurement period, this altered the actual distance between one measurement site (site 4)”

It is unclear whether this housing facility construction could affect ammonia measurements, nor is it clarified by the authors whether this simply moves an existing ammonia source spatially or whether this introduced an entirely new source point, potentially introducing a breakpoint in the time series as the amount and intensity of sources changed. If the authors insist on retaining the original distances calculated, they should show in the appendix that the change would be meaningless.

Line 173: “Distance from emission sources was the primary factor governing the spatial variation in ammonia concentrations”

How was this determined as the primary factor? Was there a statistical test or a model involved? It is important to state here the method used to determine that the strongest driver or predictor was the distance.

Line 174: “In addition, prevailing wind direction is also important, as sites situated downwind of livestock housing typically exhibit higher concentrations compared with those located upwind or crosswind relative the source (Tang et al., 2005).”

Similar to my previous comment, how was this determined? This is reported as a result, or are you simply pointing to a reference? Your time resolution of one month certainly doesn't make it possible to determine the effect of actual wind direction. Furthermore, as I asked before, have you checked afterwards that the meteorology during your measurement period is comparable to your typical meteorological year? This should be confirmed throughout the manuscript in which you mention the prevailing wind direction.

Figure 3:

Considering that your regression curves for both poultry and pig farms overestimate the mass concentration of ammonia at the smallest distances, have you consider other possible curve fits that would better explain your observations?

Line 211: “This is likely attributable to its location in Skåne, a region characterized by more intensive agriculture, higher livestock densities, and frequent manure application”.

Your background station for the pig farm is in Skåne, yet it shows no difference (around line 183) to your other background station in Västra Götaland. How do you explain this discrepancy with your explanation here?

Line 224: “Ammonia (NH₃) concentrations near livestock housing exhibit high variability,”

In what sense? This should also be described mathematically. You could show how standard deviation changes as a function of distance if you mean high variance. Alternatively, coefficient of variation might be even better. Considering your outliers in Figure 3, this claim is not straightforward to interpret. I realize that with a year of monthly data, the strength of your statistical tests is not the best.

Line 229: “At the pig farm, data from April were excluded from the correlation analysis, as this month exhibited anomalously high concentrations likely attributable to manure spreading activities in the surrounding area”

Why is this considered an anomalous concentration if you specifically can pinpoint even a source rather than a measurement error? Is the argument here that this is due to an elevated regional background? If so, can this be seen at the background station?

Line 230: “Excluding this outlier strengthens the observed relationship between temperature and NH₃ concentrations at the pig farm”

It is not acceptable to exclude an outlier simply to strengthen an observed relationship. See my comment regarding line 229 as to what could be an acceptable reason and how to explain it.

Line 238: “indicating a likely temperature-driven seasonal pattern in ammonia concentrations”

I think this fails to consider other potential factors for these seasonal patterns such as changes in precipitation, mixing in the planetary boundary layer, and surface friction. It would be good for the authors to at least consider how these other confounding variables affect their results. Recent results such as (<https://doi.org/10.1016/j.atmosenv.2025.121525>) underline the effects of precipitation in particular on bird guano. The authors are better placed to answer whether atmospheric precipitation can wet anything relevant at these farms that can increase emissions rates of ammonia.

Line 257: “Poultry farms tend to exhibit more stable NH₃ emissions over time compared to other types of livestock operations, such as dairy or pig farms.”

This needs to be justified, either by numbers or an appropriate reference, either to a figure or table where it is shown or to a literature reference.

Line 275: “This sampler was positioned in an open area approximately 40 meters from the livestock unit door, and the elevated readings may be attributed to its proximity to emission sources and specific local conditions during the sampling period.”

Have you checked whether this is simply due to prevalent wind conditions? I understand that the sampler at site 1, based on the maps provided, was immediately eastward of the farm buildings. It seems obvious to state that proximity is the cause. I think it would be more important to discuss why your site 7, also close to the buildings, does not exhibit high concentrations. Is this because the specific source building is actually much closer to site 1? For this reason, I would recommend to mark specifically the livestock units into the maps so that the reader can have an idea on where the animals are kept, instead of simply being left to guess where the animals are and what the actual expected source buildings are.

Line 282: “On dairy farms, ammonia levels fluctuate seasonally due to changes in livestock housing (indoor vs. pasture), manure handling, and temperature”

It would be good to comment here on whether the seasonal changes here are detectable as spatial changes in your distributed data. Since you actually have a spatially distributed data, it would give much more credibility to this claim if you were able to show that the spatial distribution of ammonia concentration changes. At minimum, a reference to Figure 5c is needed, but adding a spatial plot into the appendix to show a pasture vs. indoor month to give an at a glance view to the reader would be great.

Line 294: “This event likely coincides with field spreading of manure or slurry, which is a known episodic contributor to elevated...”

Did you check with the farmer on whether this spreading of manure or slurry actually occurred?

Line 311: “3.5 Measurement Uncertainties and Limitations”

This chapter addresses important measurement uncertainties and is generally well written. However, the manuscript needs to address also uncertainties and limitations of the study itself. Specifically, the manuscript only considers distance and temperature as the explanatory variables. As I mentioned earlier in my comments, precipitation, atmospheric mixing, and seasonal changes in boundary layer height. The authors also mention that the locations have different surface types, such as flat, hilly or forested. All of these change the surface friction and therefore the vertical mixing at the farms, which can have a significant effect on the measured concentrations, at least in the short term. Also, do your passive samplers measure both gas and particle phase? Increased particle

loading can increased ammonia partitioning to the particle phase. Similarly, using a typical meteorological year does not mean the measurement year was exactly as such. A lack of a weather station at the farms is unfortunate here. I am not asking the authors to do a lot of extra analysis. But these limitations should be addressed in the text.

Technical comments

Line 55: “have difficulties to achieve” should be “have difficulties achieving”

Line 56: Remove the comma after “(IED 2.0)”.

Line 110: “Care was taken to ensure that at least three sites were positioned along the transect of the prevailing wind direction”: I would always use “sampling sites” instead of “sites” because it is easy to confuse farms and sites.

Line 169: “Annual NH₃ concentrations measured at all sites on the three farms are shown in Fig 2.”: This is an awkward sentence. Consider writing “Annual NH₃ concentrations at each farm, separately for each sampling site, are shown in Fig 2.”

Line 212: “more intensive agriculture” should be “more intensive agricultural activities”

Line 227: “are overall correlated”: This is unclear as what to overall correlation means. Consider writing just “are correlated”.

Line 235: “Ireland” should be “Ireland”.

Line 251: “Figure 5 shows that monthly NH₃ concentrations at all measurement sites vary with distance to livestock housing across all three farms.”: This is an unclear sentence. It seems to suggest that the distance to livestock house from a different farm causes variation at another farm.

Line 253: “reflecting more stable background conditions”: More stable background conditions than what? How do you know this, since your only background measurements are tens of kilometers away?

Line 278: “concentration differences at this location”: Do you mean spatial or temporal differences? Clarify.

Line 282: “greater variability”: Variability is imprecise. Do you mean variance?

Line 335: “The measurements further demonstrated that temporal variability is strongly influenced by farm management and meteorological conditions.”: Temporal variability of what? Specify.