Response to Reviewers

Air quality observations onboard commercial and targeted Zeppelin flights in Germany - a platform for high-resolution trace-gas and aerosol measurements within the planetary boundary layer

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Referee comments are in **black** and authors responses are in **blue**. Lines refer to

Reviewer 2

Tillmann et al. provide an overview of the utilization of a new Zeppelin research platform equipped with instrumentation for air quality studies. They provide some examples of the unique sampling strategies that can be provided with such a platform (i.e. details of the vertical structure of the boundary layer) and the use of the platform to evaluate an emissions inventory.

Generally I think that what is presented is well done. Since the paper is submitted to AMT, I was expecting some more details on the evaluation of the data quality from the different instruments onboard. As far as I can tell, the measurements presented are only from the MIRO instrument. I think it would be appropriate to have a section discussing the data quality from the less expensive chemical sensors, and comment on their utility for the future. Was the intention of integrating them along with the MIRO to evaluate them, or was it to possibly rely on those only in the future for this or other platforms?

On the MIRO side, not all of the chemical measurements were discussed. I think it would be good to comment on the SO2 and NH3 data quality, since these are important for air quality studies and the use of a single instrument capable of providing all of those measurement would be really of wide interest. As the manuscript is though, we don't know if those measurements were deemed to be of sufficient quality for air quality research.

I think that it may be appropriate for a revised version of the paper to be published in AMT, but think that first the sections that deal with the instrumentation should be expanded a bit to:

Provide some comments on the observed data quality or issues from the MIRO, for example how much did the zeros drift?

Expand the data discussion to comment at least on the SO2 and NH3 measurement and compare the measurements between MIRO and the sensors.

We thank the reviewer for the helpful comments and positive feedback. We agree that more information on the electrochemical sensors and MIRO would add value to this paper. As mentioned to reviewer 1 the performance of the low-cost sensors and their optimization are the subject of a different paper we are currently writing and plan to also submit in AMT. Nevertheless, we now include more information on this in the main text which includes the following:

"Furthermore, the potential of the ECSs to measure nitrogen oxides is shown in Figure S3. On average, ECS NOx data are higher by 20% compared to the MIRO for concentrations above 15 ppbv which is the

limit of detection for NOx measured by ECS. This makes the ECSs ideal for the identification of high NOx emission sources during the Zeppelin flights but limited in determining NOx variability at low-NOx environments. Calibrations, sensitivity analysis, and associated uncertainties of the ECSs measurements will be further discussed in a separate publication and are not the focus of this work. In the following, all measured pollutant concentrations are acquired from the MIRO instrument."

Comments on the observed data quality and issues from the MIRO are dealt with in a previous paper, which has now been included as a reference in chapter 2.2:

"We deployed a MIRO MGA^{10}-GP multi-compound gas analyzer, a newly available commercial instrument (MIRO Analytical AG, Wallisellen, Switzerland). The analyzer measures ten trace gases NO, NO_2, O_3, SO_2, CO, CO_2, CH_4, H_2O, NH_3, N_2O with a time resolution of 1s and precisions (1σ) as summarized in Table 2. The stated precisions were determined by Allan-Werle-Variance (Werle et al., 1993). A detailed description of the measurement principle and the instrument's data processing can be found elsewhere (Liu et al., 2018, Hundt et al., 2018)."

Regarding the performance of MIRO in measuring SO_2, NH_3, and H_2O we now include a more detailed discussion on the instrument capabilities in the main text. Given that the MIRO inlet was not optimized for the detection of these compounds these are not further used throughout the manuscript but we rather highlight the potential of a revised setup to measure these compounds in the future.

"The sample inlet line connected to the MIRO consisted of an unheated 8 m long PFA (perfluoroalkoxy alkane) tube with an internal diameter of 4 mm. The sample air was drawn from the inlet located at the hatch box below the Zeppelin cabin at a flow rate of 1.2 lpm resulting in a residence time of around 5 s.

The performance of the MIRO with its sampling line to measure sticky molecules including NH_3 and H_2O was further examined by laboratory measurements which mimicked the conditions during the Zeppelin flights. Fast changes of pollutant concentrations were applied to determine the response times (t_{90}) of the measurement system, which were 240 s and 9 s for NH_3 and H_2O, respectively (see Figure S1). This highlights the future need for a heated sampling line in order to provide quality assured data, especially for NH_3. We therefore omit NH_3 from further discussion. For H_2O and less sticky molecules response times below 9 s result in a spatial horizontal resolution of < 150 m considering a horizontal Zeppelin flight speed of 60 km/h and a vertical resolution of < 15 m for a vertical speed of 1.7 m/s. This provides the upper limits of the spatial resolution of pollutant concentration but is sufficient for the analysis included in this work. Finally, the instrument detection limit for SO_2 is 1.7 ppb i.e., 4.9 µg/m³ (1 σ) and the expected SO_2 concentrations in European urban areas are mostly below 5 µg/m³ (Henschel et al., 2013). Therefore, SO_2 measurements are omitted from further discussions within this paper."