Discussion link: https://egusphere.copernicus.org/preprints/2025/egusphere-2025-5568/

Review of the Light-weight Observatory Sounding clouds and aerosol, LOONISL a balloon lifted platform for atmospheric aerosol research by Valero et al. (2026)
The interplay between aerosols and clouds in the atmosphere is certainly a topic of great importance and measurements are highly lacking to uncover it. In this paper, Valero et al. (2026) described a set of lightweight instruments mounted on a balloon platform to study aerosol, clouds and trace gases providing a cost-effective approach to address the research questions. Using a set of existing and validated instruments (ECC, POPS) together with other sensors with more questionable scientific performance, the authors show a case study from the BISTUM campaign to demonstrate how the instruments can be used to study cloud-aerosol interactions. However, the study lacks a clear demonstration that the variations between aerosol and cloud concentrations really reflect true atmospheric processes rather than potential instrument artefacts. In addition, the paper does not dive into the many more data that were gathered during these campaigns, which is puzzling. Other measurements presented in this paper (ozone, CO) do not really help the authors in their scientific demonstrations but there are rather listed as quasi-independent measurements. While I believe that the LOONIS platform could indeed be an interesting system to study atmospheric aerosols and clouds, the authors have not provided enough information to demonstrate it. Thus, I do not recommend this paper for publication at this stage and more work is needed. I will provide a more detailed review of this manuscript below.

>We thank the reviewer for the critique to the article.
The manuscript has been revised to address instrument performance and data scope. To distinguish true atmospheric processes from instrument artifacts, the analysis now incorporates laboratory calibrations, extended error evaluation, and a dedicated discussion on sampling limitations.
As the primary objective is a proof of concept, the main text focuses on a single representative case study. This demonstrates the platform's capabilities and establishes a foundation for future studies across different atmospheric conditions.

Ozone and CO measurements are included to demonstrate the platform's multi-sensor capability for simultaneous atmospheric profiling, rather than to directly support the aerosol-cloud interaction analysis. Furthermore, the operational boundaries and uncertainties of less established sensors are explicitly defined and quantified. This provides direct guidance on sensor selection and highlights which instruments should be avoided by groups building similar platforms.

1. The title mistakenly spells aerosol as “aeorsol”

>The title was corrected from 'aeorSol' to 'aeroSol'.

2. The abstract starts with “High-altitude aerosol research” but most of the measurements shown here are in the lower troposphere.

>The phrase "High-altitude aerosol research" has been removed from the abstract to reflect that the presented measurements focus on the lower troposphere. The platform can and will be used for high altitude research.

3. L1: “trace substances”. Can you please clarify this term?

>By 'trace substances', we referred to atmospheric constituents present in extremely low concentrations, specifically focusing on interstitial aerosol particles and trace gases involved in cloud activation and chemical transformation. The term 'trace substances' was removed. The text now reads: '...vertical distribution of atmospheric aerosols.'

4. L10: I do not believe that this paper fully proves the capability of the instruments shown to study cloud-aerosol interactions

>We realize that our original phrasing was too strong and overreached the actual quantitative capabilities demonstrated in this study.

While, for example, our platform successfully captured the qualitative transition of aerosols to cloud droplets (activation) using the combined POPS and UCASS data, we acknowledge that studying complex aerosol-cloud interactions requires rigorous quantitative precision. As we noted in our discussion, the UCASS suffered from severe coincidence errors in dense cloud layers, leading to overestimations of Liquid Water Content.

As demonstrated by similar lightweight UAS payload studies, such as Schön et al. (2024), these cost-effective OPS platforms excel at capturing the vertical profiling and structure of aerosol layers but must be interpreted strictly within the bounds of their physical limitations. Therefore, we have reframed our manuscript to present LOONIS as a proof-of-concept platform that observes qualitative structural evolution.

We have revised the Abstract and the Conclusions.

5. L26: “while aircraft-based measurements provide horizontal transects.” Not always since many aircraft campaigns have used spiral flight patterns to profile the atmosphere

>We have clarified what the strength of balloons are without diminishing the capabilities of airplanes. The text was modified to include spiral flight patterns: 'While aircraft-based research campaigns provide detailed microphysical characterization and excel at providing horizontal transects or spiral profiles across vast regions…' The balloon is doing something that the plane cannot do.

6. L37: Some recent literature reviews are missing such as Dumelié et al. (2024) who showed rapid response capabilities to study volcanic eruptions and wildfires. Dumelié, N., and Coauthors, 2024: Toward Rapid Balloon Experiments for Sudden

Aerosol Injection in the Stratosphere (REAS) by Volcanic Eruptions and Wildfires. Bull. Amer. Meteor. Soc., 105, E105–E120, https://doi.org/10.1175/BAMS-D-22-0086.1.

>The suggested literature has been added to the introduction.

7. L73: The structure of the sentence describing the BISTUM campaign could be improved by separating it into two parts.

>The description of the campaign has changed. The Section 3 is now:

“The first part of the field campaign (BISTUM23) took place in August 2023 at Tailfingen, Albstadt, located in Baden-Württemberg, Germany (48.2576° N, 8.98619° E). This area is predominantly rural, well distanced from major industrial centers which results in a potentially low polluted atmospheric profile compared to densely populated basins (Manisalidis et al., 2020). The launch site was located at 886 m above sea level (ASL). The Albstadt area is a hotspot for thunderstorms because the interaction between wind flowing around the Black Forest and over the Swabian Jura creates a natural trigger point for orographic convection (Kunz et al., 2022).

The second part of the field activities (BISTUM24) took place in June 2024 at Spielberg, located in Hessen, Germany (50.30519° N, 9.25899° E). This area is characterized by its position relative to the industrialized area of the Rhein-Main-region has potential for being affected by airborne pollutants. The launch site was located at 402 m ASL. Thanks to its moderate local background urban pollution convective transport of pollutants could be characterized (Moormann et al., 2025).”

8. Figure1. The rational for placing the instruments in this configuration is not fully explained.

>We have detailed the rationale for the physical configuration in Section 2.2 as well **as** scientific reasons with extra insight in the instruments respective sections.. The basic idea is to have all the instruments balanced with the center of mass as close as possible to the geometric center without the balloon. The mass is distributed symmetrically along the structure. An imbalance could be corrected by moving one of the boxes further or closer to the center, since minor differences between payloads exist. The payload was designed to investigate the coupling between boundary layer emissions and Upper Troposphere/Lower Stratosphere (UTLS) trace matter composition within the constraints of a lightweight balloon platform.

9. Table 1. It is not clear why some instruments are “optional” and others are not.

>The optional instruments are instruments that are not necessary for the payload to work. The current configuration is flexible to allow the removal of some of the instruments without impacting the basic functionality (basic measurement, particle collection, radio communication)

of the system. You could theoretically remove one of the UCASS and replace it with another OPS in the middle of the campaign without changing anything else. We refer to a device as optional if it is not necessary for the platform to operate. For clarification we have now separated the tables into the base platform and the optional sensors that can be attached.

10. Table 2. The FLW-122 Thermal flow device is included with the UCASS to improve the calculation of the concentration based via flow measurements rather than relying on ascent rate derived from GPS data. However, it is not clear to me how the device is further validated for balloon flight applications. Were there pressure tests conducted to further characterize flow measurements of this device relative to other systems?

>Added an explicit reference to the baseline characterization paper in Section 2.2.1. The technical development, laboratory calibration (including wind tunnel and pitot tube validations), and characterization of the thermal flow sensor (TFS) under flight conditions are detailed in Jost et al. (2025).

11. A fundamental aspect of developing a system for atmospheric study is to demonstrate how balloon operations fit in different countries. L92-93 provide very limited information about balloon operation in Europe but the legislation might be different in other countries. Does it mean that the system can only operate in Europe which would limit the science that can be addressed ?

>The system is not restricted to Europe. The 4 kg limit complies with International Civil Aviation Organization (ICAO) global standards for "light" unmanned free balloons. Meeting this baseline standard ensures the platform can operate worldwide without heavy aviation transponders. While local authorities (e.g., FAA in the United States) may require specific air traffic notifications or have slight variations, an exhaustive review of all national legislations is beyond the scope of this manuscript.

We have updated the manuscript to clarify that the design follows ICAO standards to enable international operability, while acknowledging that local regulations apply.

12. L95. The UCASS instrument, to my knowledge" has not been validated for atmospheric measurements. But I also realize that very limited sensors have been used for cloud measurements. Nevertheless, additional efforts are needed to further validate the system, and the installation of a flow meter is probably only one aspect of the problem. While L108-116 describes some comparisons between the UCASS and other sensors for dust, it is not clear how this can be extrapolated to study water or ice clouds.

>The UCASS has been extensively validated for atmospheric aerosol and dust measurements, as documented in the peer-reviewed literature cited in the manuscript (e.g., Smith et al., 2019;

Kezoudi et al., 2021). However, we agree with the reviewer that additional efforts to evaluate and compare under different atmospheric conditions is useful.

13. L124. It is not clear why the author mentioned that the flow sensor is only valid up to 7.5km. Please further explain

>Please refer to Jost et al. 2025 which explains limitations on the use of TFS. The manuscript has been updated in Section 2.2.1 to clarify the environmental threshold causing the 7.5 km limitation.

14. L137. How did the validation of the UCASS were done with theoretical calculations. Why not use traditional aerosols such as PSL to perform the calibration ?

>This was ambiguous phrasing; the validation was not carried out by theoretical calculation, but with the methodology explained in Girdwood et al. (2025). The section now reads:

Between the 2023 and 2024 campaigns, UCASS units were recalibrated to verify optical alignment following mechanical impact during landing. A comprehensive description of this validation, alongside a direct comparison of this method against traditional aerosol calibrations, can be found in Girdwood et al. (2025).

15. POPS paragraph. It is not clear why a refractive index value is introduced here while it is explained that POPS is calibrated with PSL. Please clarify.

>The paragraph detailing the POPS instrument and the data processing has been thoroughly revised to explain the choice of index of refraction assumption, binning scheme and the reprocessing capability offered by the non-commercial version of the software used in the present investigation.

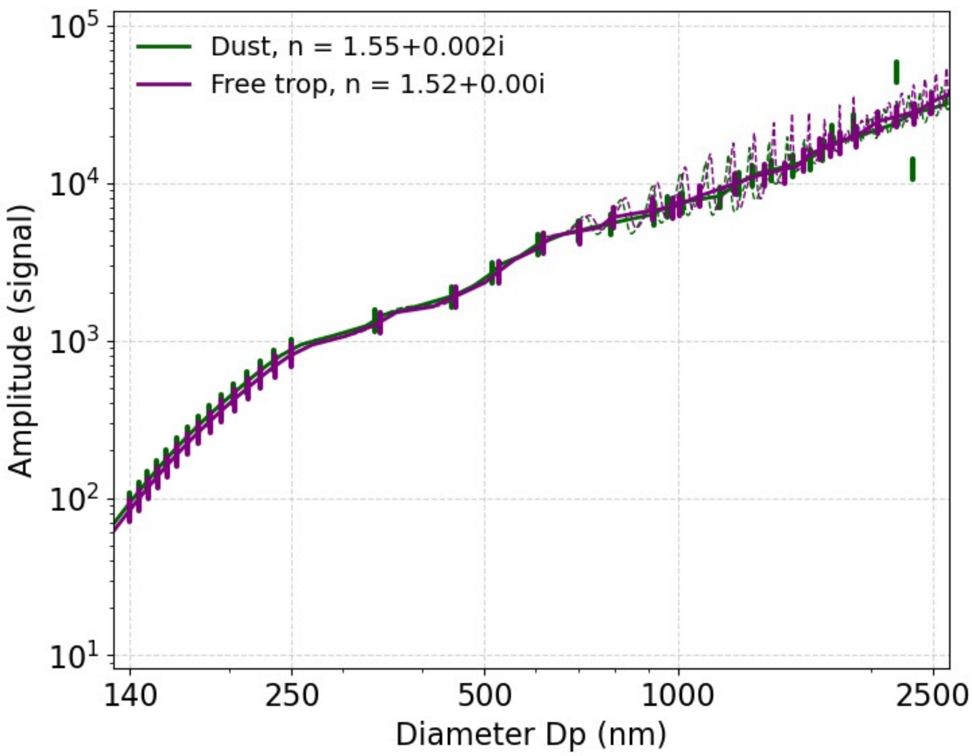
POPS measures the peak amplitude and width of the pulses of scattered light observed as a particles in the sample flow pass through the laser beam in the instrument optical chamber. The POPS used during these flights were running a software version from the NOAA Chemical Sciences Lab that differs from the Handix version commercially available. One of the main differences is that the raw data (amplitude and width) of scattering event interpreted as a particle is recorded on the µSD by default. Although this data is more cumbersome to use, it is more complete than a pre-binned data. Upon retrieval of the instrument the data can then be re-processed potentially using assumptions that can differ from the pre-set configuration. Note that for this platform including an impactor for offline analysis, recovery is of paramount importance for completeness of the atmospheric aerosol picture.

The atm-py package, available online from Hagen Telg's GitHub https://github.com/hagne/atm-py, offers ample python-based code to process the POPS data in various ways. While only a single point calibration is performed in the lab using PSL spheres (usually 508 nm), the POPS response is well known and scales with the PMT gain set during that calibration.
In other words, one only need to know the expected POPS signal from their calibration material (size, IOR) and set the gain where it should be. Hence, when the instrument is operating in condition where one can assume a bulk index of refraction, it is possible to re-process the data

for that particle IOR. POPS being initially developed for stratospheric aerosol measurements, the default has been 1.45+0.00i for sulfates as presented in Todt et al.

A PSL-like sizing is not satisfactory for several reasons. It is certainly not a helpful metric to compare measurements together. Also, the POPS-derived products such as surface area, volume, extinction, and effective radius are all PSL independent although entitled to the assumption used for sizing. Hence, they can provide meaningful constraints for models, and apples-to-apples comparison with satellite retrievals.

For this study, 1.55+0.002i was used when air masses were impacted by dust transport. For the rest of the profiles, instead of 1.45, the new version of the data will use an IOR of 1.52+0.000i for better representation of the European continental background aerosol (Aldhaif et al., 2018). The Mie curves and binning scheme for each IOR are plotted below.



<u>16. L162. What do you mean by “clean environment”, do you have a quantitative number for the presence of aerosols?</u>

>The phrase 'clean environment' has been removed and replaced with specific operational parameters to define the aerosol background. To minimize contamination, TEM grids are prepared and inserted into the impactor housing within a laminar flow clean air bench (Gelaire Twin 30). This system is equipped with a HEPA filter and operates under cleanroom class 3 (VDI 2083) and class 100 (Federal Standard 209 B), which quantitatively limits the maximum ambient particulate matter exposure during sample handling.

17. The section on the impactor does not provide any references. Did you build the system or was it purchased from a private company ? Some references or documents about the impactor should be provided.

>Extra references for the impactor have been provided. This particular design has been used regularly for the past decade and has yielded good results and variations.

18. The alphasense CO-B4 results are not surprising and does not really add much to the study but rather confirm that these systems cannot be used for atmospheric applications. I'm wondering if this section should remain or be included in supplementary materials.

>We agree that in this context these systems cannot be used for atmospheric applications which we have shown during the measurements. We have reduced the section to a short comment, but we would like to provide the information as we think is valuable for the community.

19. L235. SEM/EDX. The paragraph on SEM/EDX is interesting but does not really address some of the important limitations of the technique. Indeed, the technique is highly dependent on the operator and can only be used to detect a part of the aerosol population on the filter which may not be representative of all aerosols present. In addition, the author does not really explain how composition measurements can be used to help with other measurements and correct issues with calibration, especially with OPC measurements.

>We acknowledge the inherent limitations of SEM/EDX (as any other technique) for atmospheric aerosol analysis. References detailing these constraints (e.g., Erikson Hammer et al.) have been added. Determining the chemical composition is necessary to select the appropriate refractive index (e.g., differentiating sulfate from mineral dust). Due to the extent of these modifications, the section has been rewritten.

20. At the end of section 3, the authors have still not fully explained the science objectives for developing LOONIS and the science questions they will address in this paper. There is limited rational to explain how the campaign location was picked up and if the deployment aimed to study convection. We have the impression that the instrument and platform were picked up before looking for science questions and motivations. I believe that the authors need to strengthen the motivation of science for their work.

>We have clarified the original scientific questions in the introduction, for which the payload was purpose-built.

21. L268. The authors mentioned that “This choice allows for a clear characterization of aerosol nucleation processes...”. However, there is no instrument on the platform that allows them to measure freshly nucleated particles (few nm) since POPS starts making measurements at 150nm.

>The term nucleation was ambiguous and we replaced it by referring to cloud droplet activation.

22. L295-L305. This paragraph would be more easily explained if described in a schematic.

>The schematic was created and added to help readers understand the isokinetic/non-isokinetic sampling process that a OPS like this one is exposed to..

23. Figure 5. Why the authors do not show data above 2.5 km

>The main text figures were deliberately restricted to the lowermost 2.5 km to provide a high-resolution, uncompressed view of the most interesting primary boundary layer structure and the specific cloud activation event. We have added the extended vertical profile to the supplementary material. We have also updated the manuscript to explicitly reference this extended profile.

24. L325. Please further explain this sentence. How Schon et al. (2024) noted that the UCASS recorded higher concentrations only in the range 2.12-2.36 micron?

>The range stated in the original draft (2.12–2.36 µm) was a typographical error and has been corrected to 1.52–2.36 µm to accurately reflect the findings of Schön et al. We have revised the manuscript to clarify this specific overcounting of small particles. This direct comparison indicates that the UCASS overestimates the LWC, which is qualitatively in line with the results shown in Schön et al. poiting towards overcounting.

25. Figure 7. Is there a way to derive an error bar for the LWC profiles?

>Error bars have been calculated using Poisson counting statistics and have been added to Figure 7.

26. Figure 8. One of the main conclusions of the paper is related to this figure which seems to indicate that POPS and UCASS are anticorrelated, suggesting that some aerosols may have served as CCN for cloud formation when RH>100%. Why might it be possible, the authors do not really discuss potential artefacts of POPS in cloudy conditions. It is also surprising to see that the upper part of the cloud which undergoes lower RH is also the place where most of the aerosols seem to be depleted. Could the author provide an explanation?

>There are no known POPS artifacts in cloudy conditions. The depletion of aerosols at the upper part of the cloud is entirely consistent with activation of aerosols on the lower levels in the cloud.

27. Figure 10. There is a large bias between the two versions of UCASS. Is there a reason for that?

>This bias is potentially due to sample-to-sample variation, which is not completely corrected for at high relative humidity by a single-point instrument calibration.

28. Ozone analysis is somehow out of the place in this study and should be removed and included in supplementary materials. Otherwise, it would be interesting to discuss how ozone variation between 0-2500 m relates to other variables.

>Both suggestions have been implemented. It is moved to the supplement and nudged in the direction of how the ozone variation intersects with the rest of the measurements of the platform.