Response to the Referees

Dear Editor and Referees,

We sincerely thank the Editor and the Referees for their careful reading of our manuscript and for their constructive comments and suggestions. We have revised the manuscript accordingly and believe that these changes have improved its clarity and quality.

For clarity, the referees' comments are reproduced in **blue**, and our responses are given in **black**.

Below, we address all comments point by point.

Sincerely,
The authors

Response to Anonymous Referee #2

Referee comment The Max Planck CloudKite (MPCK) platform and its MPCK+ instrument package enable high-resolution, low-airspeed airborne observations of cloud microphysics and atmospheric turbulence using a tethered aerostat. This paper is thorough and even painstaking in its rigorous attention to detailed characterization of the system and all component instruments. The authors have achieved what they claim in the closing sentence: "These results establish MPCK platform and MPCK+ as a capable and versatile platform and instrument for probing small-scale processes in clouds and the atmospheric boundary layer, and they provide a solid foundation for future developments."
Key novel advances include:
- Airborne PIV system: Demonstrates a highly novel airborne two-frame 2D Particle Image Velocimetry (PIV) system, enabling direct calculation of instantaneous velocity gradients and turbulence kinetic energy dissipation rates without relying on long spatial averaging via Taylor's frozen-turbulence hypothesis.
- Synchronized co-located Imaging: Combines 2D PIV with a fast 3D digital in-line holography system. The consecutive hologram spacing is less than 1 m. Every fifth hologram coincides with a PIV frame, creating a co-located volume to observe 3D droplet positions/sizes alongside 2D flow fields.
- Tethered aerostat operation: Deploys a 250 m3 HeliKite operating at low true airspeeds (∼10 m/s) to achieve continuous sampling across tens of kilometers, up to 2 km altitude AGL.
- Aerodynamic characterization: Provides systematic wind-tunnel testing and aerodynamic flow corrections while evaluating flight stability across a wide range of conditions.
I recommend the paper be accepted, and suggest the authors take into consideration the following points:

Response: We thank the referee for the positive evaluation of our manuscript and for the valuable comments and suggestions that have helped us improve its clarity and quality.

Referee comment 1 Lines 8, 181, and various other places: I shy away from claims of "first". It's sufficient to point out that the system is novel.

Response: We agree with the referee's suggestion and have revised the wording.

Referee comment 2 Line 29: New single-photon lidar systems can resolve 1-cm scales, so the statement is not precisely correct. The statement is true for typical atmospheric remote sensing systems.

Response: We thank the referee for this clarification. We have revised the wording to acknowledge that the spatial resolution of typical atmospheric remote-sensing systems is insufficient to resolve sub-metre-scale cloud microphysical variability, while avoiding a general statement about all remote-sensing technologies.

Referee comment 3 Line 89: Possibly a grammatical error... delete "developed"?

Response: We thank the referee for pointing this out. We have corrected the grammatical error and revised the wording accordingly.

Referee comment 4 Line 169: The meaning of "key parameters" is vague... be specific.

Response: We have revised the sentence to specify the relevant cloud microphysical and turbulence processes rather than using the vague term "key parameters".

Referee comment 5 Table 1 column labels: MSM82/2 and MSM89 need to be defined in the caption.

Response: We thank the referee for this suggestion. We have updated the caption of Table 1 to clarify that MSM82/2 and MSM89 refer to research cruises conducted aboard the research vessel RV Maria S. Merian.

Referee comment 6 Table 1 acronyms: There are many of them, and they should be defined in the caption, or in the text close to where Table 1 is first cited. Also, it would be very helpful to indicate the subsection numbers where each instrument is discussed in the paper, since the paper is quite long.

Response: We thank the referee for this helpful suggestion. We have revised the caption of Table 1 to define the acronyms used and added a new column indicating the section in which each instrument is described. This should make it easier for readers to navigate the manuscript and locate the relevant instrument descriptions.

Referee comment 7 Table 1 caption: Should it be "GPS weak rollover"?... In any case, I have no idea what it means.

Response: We thank the referee for pointing this out. We were referring to an issue with the GPS receiver that resulted in incorrect date and time information. We have simplified the wording in the table caption to make this clearer.

Referee comment 8 Figure 3 caption: What is meant by "the removed holography and PIV structure"? Do you mean the holography and PIV instrument with the cover removed?

Response: We meant that the holography and PIV modules were removed from the main instrument housing to provide a clearer view of their optical components. We have revised the figure caption accordingly.

Referee comment 9 Line 261: Does the inclusion of a pinhole spatial filer make the system alignment susceptible to vibration? How robust is this approach for spatial filtering?

Response: A pinhole spatial filter can indeed be sensitive to vibrations and misalignment if not properly designed and mechanically secured. However, our implementation has proven robust in practice. Since its initial deployment, the system has been operated over several years and subjected to repeated transportation and field deployments without any observed alignment issues associated with the spatial filter.

Referee comment 10 Line 284: Grammatical error in "In separate study".

Response: We thank the referee for pointing this out. We have corrected the text accordingly.

Referee comment 11 Line 319: Sonic anemometers do not require long spatial averaging... they provide local velocity information. I guess you are referring to the use of a sonic anemometer or similar for calculation of energy dissipation rate. Please clarify.

Response: We thank the referee for pointing out this imprecise wording. We agree that sonic anemometers provide local, high-frequency velocity measurements and do not inherently require spatial averaging. Our intention was to distinguish between point measurements, for which the estimation of statistically converged turbulence quantities generally requires sufficiently long time series, and PIV measurements, which provide spatially resolved velocity fields. We have revised the sentence accordingly to clarify this distinction.

Referee comment 12 Lines 344-345: Unclear what this sentence about pulse separation adjustment means.

Response: The pulse separation Δt_{PIV} is selected to balance two competing requirements. A sufficiently long separation is needed to obtain in-plane particle displacements that are large enough relative to the particle-position uncertainty for reliable velocity estimation. However, increasing the separation also increases the likelihood of particles leaving the laser sheet due to out-of-plane motion, reducing the number of valid particle pairs. The appropriate separation therefore depends on the flight conditions, particularly the true airspeed. Before initiating each PIV recording, the system automatically adjusts Δt_{PIV} based on the mean airspeed measured by the Pitot tube. We have revised the manuscript to explain this trade-off and clarify how the pulse separation is determined in flight.

Referee comment 13 Lines 457 and 460: Parentheses for Schroeder reference are incorrect.

Response: We thank the referee for pointing this out. We have corrected the text accordingly.

Referee comment 14 Line 533: I guess "softer" should be software?

Response: We thank the referee for pointing this out. We have corrected the text accordingly.

Referee comment 15 Page 32: Could the poor performance of the CDP be a result of rain water collecting on the instrument optics? Its windows are designed for higher true air speeds, and you mention that drizzle was present. Please discuss.

Response: We thank the referee for this suggestion. We agree that water droplets or contamination on the FCDP optical windows could have contributed to the observed discrepancy, particularly given the presence of drizzle during the EUREC^{4}A campaign. We cannot rule out this possibility, although no corresponding window contamination was documented during the measurements. However, in subsequent campaigns, including PaCE 2022, the FCDP showed good agreement with the holographic measurements even at lower true airspeeds. This suggests that insufficient airspeed alone is unlikely to explain the discrepancy and that campaign-specific measurement conditions may have played a role. We have revised the discussion to acknowledge possible window contamination and clarify this interpretation.

Referee comment 16 Figure 14: In the figure axis label and earlier in the paper, ε is used for dissipation rate, but in the figure caption and in the surrounding text, ϵ is used. Please be consistent.

Response: We thank the referee for pointing this out. We have corrected the text accordingly to use ε consistently.