

Review of "Development and Characterization of an Advanced Holographic Instrument for Atmospheric Research"

General Comments The manuscript introduces HOLODROPS and HOLODROPS TRACK, two configurations of a holographic instrument designed for atmospheric research. HOLODROPS provides long term measurements of cloud droplet size distributions, while HOLODROPS TRACK performs short interval 3D particle tracking. The authors also introduce a novel event-based Particle Image Velocimetry (ePIV) system. This ePIV system assesses fluid flow in real time and helps identify optimal measurement windows for the data intensive holographic hardware. The systems were characterized in the laboratory and successfully tested outdoors during a drizzle event.

The development of these new instruments fits very well within the scope of AMT. However, the manuscript requires major revisions in both content and structure before it can be accepted for publication.

Jan Henneberger

Major Revisions

First, the use of event-based cameras is a novel method and needs much more explanation and validation. Please clarify exactly how the event camera translates particle movement into positive and negative events.

Second, a robust discussion of uncertainties is missing. Please define the uncertainty of the size calculations. I strongly recommend repeating the glass bead measurements at larger sizes because the current large discrepancy is unexpected. Furthermore, please discuss the expected errors in particle velocities. This does not need to be a complicated calculation, but a clear estimate of the expected error is necessary.

Third, the comparison of measured particle velocities between HOLODROPS TRACK and the ePIV system is the core of the manuscript and must be expanded. Please compare different averaging intervals to show their influence on the particle speed distribution and any shifts in the mean velocity caused by turbulence. You should also investigate if there is a variation of the mean velocity over time.

Finally, please improve the overall structure and presentation. Be specific with your statements and remove unnecessary repetitions. Ensure consistent naming of the instruments throughout the text. The quality of the plots must also be improved. Please include proper units, axis labels, descriptions of variables, and larger font sizes.

Specific Comments

Introduction: Be more specific with your statements and support them with references. For example, explain why knowing the droplet size distribution helps us understand why some clouds rain. Clarify what you mean by the internal structure of clouds and cite examples where cloud properties varied on a meter scale.

Line 41: Change to "phase of hydrometeors".

Line 45: Consider changing to "scattering or imaging" because a holographic camera does not simply capture the shadow of a particle.

Line 46: Start the paragraph by distinguishing between bulk measurement and single particle instruments. Baumgardner et al. (2011) provides a great overview.

Line 50: Either remove the remote sensing discussion or expand it. Mention Lidar and multi frequency Radar observations and clarify the RADAR acronym.

Line 66: Change to "between ice crystals and droplets".

Line 67: Move this sentence to the previous paragraph.

Line 72: Make the benefits of single droplet versus bulk measurements clearer and describe how holographic cameras combine both.

Line 78: Move this discussion to the next section after introducing holography. Please define "large volume". The main advantage is obtaining a complete droplet size distribution from a single hologram. Also clarify that airflow is necessary for non-holographic methods to avoid resampling a stagnant volume, and they require a precise aspiration speed to calculate concentrations. Holography does not have this limitation.

Line 83: Change "Outlet" to "Inlet".

Line 93: Define "very small scale" and "large number of droplets".

Line 97: Explain why a non-mobile deployment would increase the sample volume.

Table 1: Include columns for resolution, sample volume, and frame rate. Compare the actual instruments rather than the platforms. HoloGondel and HoloBalloon are deployment platforms. The latest version of the holographic imager is described in Ramelli et al. (2020), and a holographic imager optimized for small droplets (smHOLIMO) was developed recently (Fuchs et al., 2025).

Section 1.2.2: Many statements here need precision. The components must be well chosen for all holographic systems regardless of their deployment setting. For wavelength, note that a smaller wavelength increases the detection volume rather than limiting resolution. For energy, emphasize illuminating the entire camera surface without dark edges. For pixel size, note that the detection volume depends strongly on pixel size, so making it too small is not beneficial.

Line 137: This section repeats statements made earlier.

Chapter 2: Add an overview table detailing key parameters like optical resolution, pixel size, number of pixels, detection volume, frame rate, weight, and power consumption for all three instruments. Please also include the specifications of the lens systems used.

Line 180: Based on the two pixel limit described in Section 1.2.2, the optical resolution limit is approximately 6.9 micrometers.

Line 181: Explain why fine resolution limits the possible frame rate of the instrument.

Line 186: State the resolution for a sample volume several meters away from the camera.

Line 216: Provide the weight and power consumption for both the event camera and the high speed camera.

Figure 3: Target 6.5 is resolved but the three bars of target 6.6 at a distance of 125.5 mm cannot be identified.

Line 245: Define the HR and high resolution camera. Make the connection to the HOLODROPS and HOLODROPS-TRACK instruments clear.

Section 3.2: State the uncertainty of the glass bead diameters and the diameters measured by the holographic systems. Adding a table with these results would help. Explain why air turbulence leads to oversizing and why different bead sizes were used for different cameras. Clarify why the 50 micrometer beads had a higher noise level in the high speed camera but not in the high resolution camera.

Figure 4: The histogram labels are too small and the y axis is missing.

Figure 5: The histogram labels are too small.

Line 302: Correct the typo to "location".

Line 309: The camera records holograms and HoloSuite reconstructs the particles. Are "frame" and "hologram" used interchangeably here? Please clarify.

Figure 6: The plot labels are too small. Provide statistics on the accuracy of the measured distance moved.

Line 320: Move these lines to the beginning of the chapter. Clarify if high speed HOLODROPS is the same as HOLODROPS TRACK.

Line 349: This repeats the previous paragraph.

Figure 8: The legend and scaled axes are missing. Explain in the main text how positive and negative events are generated and interpreted.

Line 364: Is it possible to calculate the mean using only frames that contain particles?

Figure 10: Define the unit of velocity. Explain v_x , v_y , and v_z . Ensure consistent instrument naming. Explain the difference between the first and second rows of figures.

Line 385: I expect ePIV to be less sensitive to turbulence since it covers a longer time interval. Please compare a shorter ePIV time interval to the holographic tracking. Showing the evolution of the ePIV velocity distribution over time would be a great way to observe turbulent motion. Finally, explain if the negative mean v_x and v_y velocities in the holographic tracking are a consequence of turbulent motion or if there is another cause.

Supplement: Add missing reference (Line 13), remove double brackets (Line 32), and update the reference format (Line 35).

Figure S1: The right plots appear to show (1 minus Attenuation). Please verify. Make the connection between Figure S1, Figure S2, and the main manuscript clearer.

References

Baumgardner, D., et al. (2011). Airborne instruments to measure atmospheric aerosol particles, clouds and radiation. *Atmospheric Research*, 102.

Fuchs, C., et al. (2025). Putting the spotlight on small cloud droplets with SmHOLIMO a new holographic imager for in situ measurements of clouds. *Atmos. Meas. Tech.*, 18, 2969.

Ramelli, F., et al. (2020). Using a holographic imager on a tethered balloon system for microphysical observations of boundary layer clouds. *Atmos. Meas. Tech.*, 13, 925.