Review of "An introduction of Three-Dimensional Precipitation Particles Imager (3D-PPI)"

This manuscript describes a new instrument designed to capture the three dimensional structure of snowflakes. The instrument is composed of three high-resolution cameras and one high-speed camera with an LED light source. Based on the technical specifications listed in Table 1 and the example imagery, this instrument appears to be well designed for capturing snowflakes. The manuscript itself is highly detailed, something this reviewer greatly appreciates in an instrument paper, and is well written. That said, I feel some farther analysis and/or discussion is necessary to ensure future users have a complete grasp of the instrument and its data. I debated whether or not my suggestions constituted a major or minor revision; ultimately, I decided to err on the side of caution and list them as major revisions.

General Comments:

1. How robust are the camera alignment and 3D measurements to thermal expansion shifting the cameras (since the cameras are enclosed in a housing, I assume the effects of wind on camera alignment will be negligible)? Adding a brief discussion of how these might affect the measurements would be helpful. Some tests of how much measurement error is produced from slight changes in camera alignment after the calibration could also be illuminating.
2. Given that the sampling volume is so close to the instrument housing, how will wind flow affect the representativeness of the measurements (e.g., increasing or decreasing the collection efficiency of the sampling volume)? While I understand that a full engineering analysis of the wind effects (similar to what was presented in Fig 3 of Newman et al. 2009, https://doi.org/10.1175/2008JTECHA1148.1) may be outside the scope of this paper, some analysis that compares the 3D-PPI to the PARSEVAL with the wind coming from certain directions relative to the camera pointing direction might help give some insight into how well the instrument handles these conditions.
3. Since LEDs rapidly flash to produce light, it would be worth clarifying how the LED interacts with the cameras. Is the 20-microsecond effective exposure time due to the duration of the LED flash being 20 microseconds? Is there some mechanism to ensure that the LED is synchronized with the camera exposures in some way to ensure each frame has consistent illumination (or is the system sufficiently robust that inconsistencies in LED illumination are not a problem)?
4. How are particles at the edge of the field of view handled? I seem to recall reading somewhere in the manuscript that particles touching the edge are ignored (but I can't seem to find where that was now, sorry if I'm mistaken). If the edge particles are discarded, I think the effective sampling volume would need to be a function of particle size (with the sampling volume being smaller for larger particles).
5. Is the tracking software intended to work for rain drops as well as frozen precipitation? It is clear from the manuscript that the instrument is designed for measuring snowflakes, it might be worth noting in section 5.3 whether or not the tracking software is designed to handle any faster falling precipitation.
6. I have some concerns with the tracking algorithm, although it is possible these concerns are due to misunderstanding on my part and/or a need for further clarification in the manuscript.

When first reading over the tracking method, I was somewhat concerned that particle motion wasn't being considered as, in my personal experience, that is the best way to match an existing particle to its new location (although this isn't possible in the first two frames of the particle and some other criteria must be applied). After having studied the description more closely, it sounds like there might be some shape matching going on. I base this on Line 393, where the pixel coordinates of a particle are mentioned. Are these pixel coordinates being used to match the shape of the particle (e.g., the spatial distribution of these pixels relative to some particle centroid is compared between frames via some method)? If so, this warrants more discussion in the manuscript. If not, how are these pixel positions being used (or am I misunderstanding what is meant by pixel coordinates)? Given that the position difference allows for up to 8 m/s of particle motion, I would expect that the other criteria need to be very robust to avoid mismatches.

Specific Comments:

Title: suggest adding "the" before "Three-Dimensional"

Line 16: change "OTT a good agreement" to "OTT have good agreement"

Line 80: add "a" before "field experiment"

Table 1: Thank you for including this table! Having these technical specifications in one place is very useful.

Lines 107 – 111: These numbers don't seem to agree with those in Table 1. Specifically, the telecentric lens pixel size is listed as 3.45 microns in the table and 42 microns in the paragraph. Similarly, the table lists the non-telecentric lens as having a pixel size of 6.9 microns while the text lists 265 microns. It's very possible that these are referring to two different measurements and if that is the case, I encourage the authors to make that clear either in the text or in the table caption.

Lines 177 – 179: the parenthetical "($D_{max}$ is the distance between the two largest points of the particle profile…" could use rewording. Perhaps replacing "largest" with "farthest" would improve the readability?

Line 180: add "the" before "spheres"

Figure 6: Move the first line of the caption to below panel b.

Lines 208 – 210: These sentences could use some clarification. Are these particle centers as seen from a single camera or are these the particle centers from multiple cameras? If these are from the same camera, it might help clarify things to mention that sometimes a single particle will appear as two particles due to being on the edge of the image processing threshold (or whatever reason is appropriate). Just based on the flow of the manuscript, I assume these are for a single camera, but it might help make things clearer to specify that.

Line 224: Are the ceramic spheres the same as the ones used in section 3.2? If yes, perhaps changing the text from "different diameters in section 3.2 were dropped" to "different diameters, as described in section 3.2, were dropped" would make that clear.

Line 227 – 234: The text mentions that the measurements of the smaller spheres tend to be larger than the true size, but the average error of $D_{eq}$ for the small spheres is negative. I may be missing something, but wouldn't a negative error mean the measurements of the small spheres are smaller than their true value? Also, the authors state that this is the average absolute error, which to me implies that it is the mean of the absolute value of the difference between the measured and true $D_{eq}$ and, therefore, should not be negative. I assume the authors are using "absolute" error in contrast with "relative" error. I'm not sure how best to fix this misunderstanding though.

Figure 8: Are these plots for the high-resolution camera or the high-speed camera? It might be helpful to mention which in the caption.

Lines 389 and 401: Line 389 mentions that the frames need to be adjacent to one another (which I interpret to mean that a missing frame is not allowed), but Line 401 mentions that a missing frame is allowed. This seems like a contradiction, but I suspect I'm just misinterpreting the authors' meaning. Some additional clarification in the text might be needed.

Lines 390 – 391: Is the 200 pixel interval purely in the vertical or is that include the horizontal component of the distance as well. If that includes the horizontal distance, it might be worth noting that this means the instrument will have difficulty producing accurate particle fall speeds at high cross-camera-view wind speeds (which isn't a problem, but is good to know for anyone performing an analysis of the data).

Lines 416 – 417: If westward motion is positive, I assume the 3D-PPI was facing towards the south? It might be useful to mention the direction the instrument is facing in the paragraph starting on Line 324 (preferably as a bearing, but a general direction would do if you don't know the exact bearing).

Lines 426 – 428: Are these outliers real or are they a result of mismatches by the tracking algorithm. If they're a result of mismatches, it might be helpful to provide some statistics regarding how prevalent these outlier are (e.g., what percentage of the total sample population or the a reasonable range of percentages of their size bin populations) so the reader can determine if they are sufficiently infrequent to be considered negligible.

Lines 434: Ensure the 41.5 microns per pixel matches what is said in the text (Lines 107 – 111) and in Table 1