Response to comment on amt-2023-89 by Anonymous Referee #1

Summary: The authors report on drone-based measurements of hail sizes after an event in Switzerland that produced hail up to ~4 cm in maximum dimension. They describe a new, deep-learning based technique to automatically identify and size hailstones from the drone imagery. The technique is an improvement/extension (or at least a twist) on the methods reported in Soderholm et al. (2020, AMT). A particularly valuable contribution of this paper is the multiple drone missions to observe hailstone melting rates. The content is highly relevant to the hail community and is a timely contribution.

Unfortunately, I was disappointed to find at least 3 examples of plagiarism (see below) from websites in the description of some of the methods. I did not check for further instances, because the journal should have some ability to do so. In my view, plagiarism is a serious offense, and thus I recommend rejection at this time. However, I do find the research to be useful, and I do hope that the authors can rewrite the plagiarized portions of the manuscript in their own words, and address the other comments and suggestions below.

We very much appreciate the feedback by Referee #1 and all the raised comments, that help to improve the manuscript. All Referee comments are shown in black, the authors responses in green text color.

Major Comments:

1. I found at least 3 examples, based on where the style/tone of the writing abruptly changed. The first is on Lines 154-156. The text from the manuscript is as follows:

General answer:

Indeed, there are several instance in the manuscript where the text directly referred to an available source without correct citation. We admit that this should be clearly avoided in a scientific publication and want to thank the reviewers for pointing this out. We now carefully went through the manuscript to identify additional occurrences eventually not mentioned by the reviewers. All occurrences are related to definitions (e.g. an orthophoto, object detection) and specific characteristics of a software (e.g. OpenSFM library) where the text from a very early version of the draft unfortunately remained until submission. We now rephrased all relevant sentences and wrote it in our own words. In addition we directly refer to the relevant resources from with the information is taken.

"An orthomosaic is a photogrammetrically orthorectified image product that has been mosaicked from an image collection, correcting for geometric distortion and color matching the image data to create a seamless mosaic data set."

and from the ArcGIS website (https://pro.arcgis.com/en/pro-app/latest/help/data/imagery/generate-an-orthomosaics-using-the-orthomosaic-wizard.htm#:~:text=An%20orthomosaic%20is%20a%20photogrammetrically,produce%20a%20seamless%20mosaic%20dataset):

"An orthomosaic is a photogrammetrically orthorectified image product mosaicked from an image collection, where the geometric distortion has been corrected and the imagery has been color balanced to produce a seamless mosaic dataset."

The corresponding lines are now adapted and the definition of an orthophoto is now written in our own words.

Line 129-133 in the revised manuscript now reads: "An orthomosaic is defined as a composite of multiple aerial (airborne or space-borne) photos that are previously processed to remove inherent distortions caused by the geometrical properties of the lenses (airborne photos) and the earths curvature (space borne satellite images). Thus, the processed individual pictures and the resulting composed orthomosaic is distortion free and exhibits a true scale that allows to estimate the size of the objects within the photo."

The second is on Lines 168-169. The text from the manuscript:

"The library serves as a processing pipeline for reconstructing camera poses and 3-dimensional scenes from multiple images. Here we make use of some basic modules for SfM: Feature detection, feature matching, minimal solvers."

is largely taken from the github page for this software (https://github.com/mapillary/OpenSfM/blob/main/README.md):

 "OpenSfM is a Structure from Motion library written in Python. The library serves as a processing pipeline for reconstructing camera poses and 3D scenes from multiple images. It consists of basic modules for Structure from Motion (feature detection/matching, minimal solvers) with a focus on building a robust and scalable reconstruction pipeline."

The corresponding lines are now adapted and rephrased in our own words. In addition, we refer to the official github page of this software.

Line 143-145 in the revised manuscript now reads: "The library can be used to reconstruct camera positions and 3-dimensional scenes based on multiple images (mapillary, 2023). Here we make use of the basic modules for SfM: Feature detection, feature matching, minimal solvers."

The third is from Lines 192-193. The text from the manuscript:

"Object detection is a technology related to computer vision and image processing that tries to detect instances of semantic objects of a certain class (e.g. cats, dogs, cars, buildings, etc.) in digital images and videos."

is taken from the following website (https://www.credly.com/skills/image-processing-object-detection#:~:text=Object%20detection%20is%20a%20computer,in%20digital%20images%20and%20videos.):

 "Object detection is a computer technology related to computer vision and image processing that deals with detecting instances of semantic objects of a certain class (such as humans, buildings, or cars) in digital images and videos."

The corresponding lines are now adapted and rephrased in our own words.

Line 165-166 in the revised manuscript now reads: "Object detection is a computational method to automatically identify and locate different objects or semantic classes (e.g. trees, bicycles, faces) within an image or a video."

2. Section 2.1: I appreciate the detailed information and experiences in this section, but it comes across as a little bit "preachy" or reads like pontification. Please take a look at this section and try to trim it down to what is necessary and germane for the main story about the new technique.

We now shortened this section to avoid any "preachy" character related to our experience. In particular, we deleted the paragraph highlighting the dangers associated with chasing thunderstorms and focus on specific technical aspects that are important to collect successfully collect data, which can be analyzed using the proposed methods.

3. How would this motion blur affect the hail size results? This should at least be mentioned here, even if the answer is "not at all" so you do not leave the readers wondering.

Motion blur would lead to small (< 1.5 mm) overestimations of the hail dimensions, as we use camera settings and flight speeds to reduce the motion blur to below one pixel size (1.5 mm).

We will clarify this in Section 2.2:

"A low horizontal flight speed is necessary to reduce the motion blur (Bemis et al., 2014; Soderholm et al., 2020), which is within one image pixel in our case and leads in general to small overestimations (< 1.5mm) of the hail dimensions."

4. Lines 339-340: The authors should make a note here that the aspect ratios reported are probably not the same as measured in other studies (Knight 1986, Shedd et al. 2021), which are the measured maximum and minimum axes of the hailstones. What the drone sees are the projected maximum and minimum axes, based on whichever way the hailstone happens to be laying on the field. If hailstones are perfectly oblate spheroids, you would always capture the maximum dimension but not always the minimum dimension. Because hailstones tend to be ellipsoidal or irregular, this means your axis ratios probably do not correspond to the true stone axis ratios.

Thank you for this important comment on the aspect ratios and your clarifications, which we take partly into our discussions.

In Section 3.1 and the image caption of Fig. 9 (new Fig. 11), we now speak of projected aspect ratios:

"The projected hail aspect ratios indicate that the majority of hailstones have equal axis lengths (Fig. 11(b)) and 75% of the hailstones have projected aspect ratios higher than 0.75."

Further, we added and expanded a paragraph (information moved from introduction) about the aspect ratios within the discussions:

"Hailstones usually have an oblate spheroid shape with mean axis ratios close to 0.8, though they can sometimes have large protuberances (Knight, 1986) and the probability for nonspherical shapes rises with increasing maximum dimension (Shedd et al., 2021). As a consequence the hail aspect

ratio decreases for larger sizes as shown in the various studied data sets (Knight, 1986; Soderholm et al., 2020; Shedd et al., 2021). Figure 6 in Shedd et al. (2021) compares their recent results on the evolution of aspect ratios with maximum hail dimensions from manually measured hailstones to the results of Knight (1986). The slopes of the decreasing aspect ratios are comparable, but the absolute values tend to be lower in the hail data set of Shedd et al. (2021), reflecting possible effects by melting before the measurements were taken. Likewise with hailpads, the shape factor in the image plane can be determined with the aerial drone-based hail photogrammetry, but the estimated aspect ratios (Fig. 11(b)) may differ from in-situ measurements as published in e.g. Knight (1986); Shedd et al. (2021). The hail images show only the projected maximum and minimum axes, which may differ to the true stone axis ratios."

Minor comments/Typos/Grammar issues:

1. Line 24: "asses" should be "assess"

The typo has been corrected.

2. Line 29: I think "alps" should be capitalized? Same in Line 60?

Thanks, we now capitalized all instances of "alps".

3. Line 39: probably more accurate or clearer to say "maximum dimension" instead of "diameter" (the latter connotes a sphere or circle)

In general we now do not use the term "diameter" anymore and rather speak of "dimension" or simply "size".

4. Line 52: no comma after "known"

The comma after "known" is deleted now.

5. Line 53: A more comprehensive and more recent study is by Shedd et al. (2021, JAS) that looks at hailstone shapes; consider comparing the Knight (1986) results to those of Shedd et al. here.

Thank you for mentioning the Shedd et al. (2021) study, which we now included for a brief comparison to Knight (1986) within the discussion section. See also our answer to your previous comment on lines 339-340.

6. Line 54: Soderholm et al. (2020, AMT) also report on the axis ratios, correct?

Yes of course, now in this paragraph within the discussions (see previous comment), we added the citation of Soderholm et al. (2020) as well.

7. Line 56: "decent" is a bit informal, is there a way to quantify what this means?

Now we omit the word decent and reformulated the text passage to:

"That day, the ingredients for long-living and well-organized severe thunderstorms (humid air, high instability and strong wind shear) were in place across Switzerland. An air mass with steep lapse rates was advected from the southwest above a moist low-level air with mean mixing ratios around 12 g kg^{-1}."

The mixing ratio value has been derived from the Payerne sounding at 12UTC.

8. Line 61: what is the lowercase s? Is this South? If so, it might be clearer to spell it out. Update, it happens again in Line 62, so I don't know what this means. Please spell it out.

The "s." should have been the abbreviation of the word "see". E.g. …(see Fig. 1).. etc. There are many more instances of this abbreviation in the manuscript. Now we always write the full word "see".

9. Line 74: "respectively" is used incorrectly here, should read as "at a distance of 770 m and 1470 m, respectively, to the NNE of…"

Thanks, this instance of respectively in line 74 has been corrected.

10. Figure 1, caption: the description in the caption regarding EMLs and "loaded gun" belongs in the text. However, "loaded gun" is a bit colloquial, consider using other terminology. Check on the convention for how to portray units (i.e., m/s or m s^-1, etc.) for AMT. Finally, explain or provide a legend for what the colors mean in the hodograph, and indicate the units (m/s or kts?) for the rings on the hodograph.

Now Figure 1 is revised in the way, that we reduced the number of barbs (Referee #2 comment) and we removed any interpretation from the caption (no use of "loaded-gun" anymore). All units styles should be AMT conform as well. We changed the color for the layers in the hodograph (0, 1, 3, 5, 10 km) and they are defined now in the caption of Fig. 1 . Further the label on the hodograph axis was added and we changed from m/s to kt units. The MetPy software reference has been added and please note there is a slight change in the absolute values for e.g. CAPE, CIN, SRH likely due to the use of a newer version of MetPy.

11. Figure 2: consider enlarging the dots for the hail reports, they are all very small and hard to see.

Thanks for this suggestion, we enlarged the markers for the hail reports (by 20%) and hope the visibility improved. For further adjustments on this Figure 2, please refer to the corresponding comment and answer to Referee #2.

12. Section 2: the first 3 or 4 lines are probably not needed, since they are just telling readers what is coming up. How about just start with the material? Similarly, the second sentence of subsection 2.1 can be removed, it is useless for the narrative of the paper.

Yes you are absolutely right, the first sentences here are not strictly needed. Now we skip these sentences. Also the second sentence of subsection 2.1 is removed now. Please note that substantial language and text editing have taken place here too (Referee #2 comment).

13. Line 106: no comma needed after "found"

Due to substantial language and text editing here, the start of the mentioned sentence with "It was found, …" is different now.

14. Line 113: "Aside the" should be "Aside from the"

Now we write "Aside from the …" in line 99 (revised manuscript).

15. Lines 119-121 are not needed – it is pretty obvious that any field experiment would require good forecasting ahead of time! Just start with "During days with conditions favorable for supercells," or something like that.

We now start the sentence (line 104) as suggested with:

"During days with conditions favorable for supercells, the drone operators…".

16. Line 130 and elsewhere, "hereby" is not the correct word to use here. Please revise.

In the whole manuscript, we do not use the word "hereby" anymore.

17. Line 136: "hail core punch" is too colloquial, please revise.

Section 2.1 has undergone substantial language changes and we do not use the expression "hail core punch" anymore.

18. Line 141: "analyses" should be "analysis"

At the end of Section 2.1 we now write:

"… for an in depth analysis."

19. Lines 142-147: Even though these are important points for storm chasers, I don't think these are appropriate for the manuscript because they aren't relevant for reporting on the technique and results. Please remove.

Like suggested, this paragraph at the end of Section 2.1 (old version) is removed now.

20. Line 206: no comma after "mentioned" (And, if you're writing it in the paper, it seems worthy of mentioning. Best practice is to not include text like "It is worth mentioning" etc. and just cut to the chase with the important points).

Thanks for pointing this out. Substantial language, text editing and reformulations have taken place and now we try to avoid such expressions.

21. Line 231: "tow" should be "two"

Corrected now.

22. Line 241: the brackets usage for quotes here needs to be changed to conform to AMT's convention/guidelines. This occurs throughout the manuscript.

We now avoid these quote signs within brackets («») and write the e.g. run-3 instances in italic font instead. In case it is not AMT confirm yet, it will be corrected during official typesetting.

23. Lines 354-355: This is repeating the finding from the first sentence in the paragraph; combine these two sentences into one and keep them together in the text (otherwise the logic is jumping around).

Yes, we agree that this should be improved. The whole readability in this part of the manuscript should be better now. The second paragraph of Section 3.2 starts with:

"Within all virtual hail sensors only 45 hailstones with a size larger than 30mm are observed and thus only 0.3% (34 out of 10000) of the virtual sensors exhibit an impact of such large hail."

24. Lines 356-367: There are several one-sentence paragraphs here; simply combine them into a coherent paragraph with connecting sentences or words.

Section 3.2 now consists of only 3 paragraphs.

25. Line 377: Does the changing shapes of the larger hailstone agree with the cartoon drawn in Shedd et al. (2021)? In other words, is there evidence that protuberances or lobes melt more rapidly than the rest of the stone, tending to "smooth" the stones?

Here we have to mention, that based on visual observations on site and also the drone images, the hail stones were not showing extensive protuberances with this event. Even if the statement

("protuberances melt more rapidly") seems to be true for the stone 1 (top row in Fig. 11), we are not able to make a statistically profound statement about it yet.

Further we would need to put much more effort into the validation of the mask shapes, if they capture also the small lobes. For future studies this is for sure a very interesting point of investigation.

26. Line 387: No comma needed after "range" (or after "bins" on the next line)

Due to substantial language and text editing here, the wording changed now.

27. Line 389: But, certainly, physics tells us that there should be some dependence on size, right? One can refer to Rasmussen and Heymsfield (1987, JAS), for example.

We agree with the referee that the physics describing the melting of ice particles could be briefly mentioned. We added the following information from the mentioned reference within the Section 4 (Discussion) lines 373-378:

"Other studies by Rasmussen and Pruppacher (1982) and Rasmussen and Heymsfield (1987) have explored the melting of spherical ice particles falling at terminal velocity. They found that the melting rate depends on the initial size of the spheres size and the surroundings, including temperature, humidity, turbulence, and how meltwater is shed. The hailstones in our case are already on the ground, so they experience different environmental conditions compared to when they are falling through the atmosphere. We have not measured these specific conditions for each hailstone, so we cannot make any conclusions about how the melting rate relates to their initial size."

28. Line 394: This is important information that could be included earlier in the text, near the description of the event!

In the introduction following line 60 (revised manuscript version) we include now the on-site observations:

"For this location MESHS indicates a maximum expected severe hail size of 63mm and on-site observations revealed maximum dimensions between 40mm and 50mm."