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Atmospheric Measurement Techniques Discussions

Interactive comment on "Analysis Algorithm for Sky Type and Ice Halo Recognition in All-Sky Images" *by* Sylke Boyd et al.

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Author's Response to Comments by Reviewer 1 The authors would like to thank reviewer 1 for the thorough and helpful comments to our manuscript "Analysis Algorithm for Sky Type and Ice Halo Recognition in All-Sky Images". We have incorporated many of the suggestions. The paper has improved significantly thanks to the thorough attention to detail given by reviewer 1. We are much obliged, and extend our gratitude. Below, we outline the details on changes made to the manuscript in response to the comments.

General: The introduction is missing one important motivation for detecting halos. One main reason why detection of halos is relevant is that the pristine crystals that produce

them have scattering phase functions with less pronounced backscattering than those of the amorphous or roughened crystals that do not produce halos (Yang et al 2015). As crystal roughness or distortion increase, their phase functions are characterized by decreasing halo features (van Diedenhoven 2014) and decreasing asymmetry parameters (van Diedenhoven et al. 2014; Yang et al 2015). Ice particle surface roughening has a significant influence on the global cloud radiative effect (Yi et al. 2013). Some text along these lines, with the relevant references needs to be included in the introduction.

This is a very good point to make, thank you! Text was inserted in the Introduction to address this concern (page 2, lines 25 to 35) "As shown in theoretical studies (van Diedenhoven, 2014; Yang et al., 2015), halos form in particular if the ice crystals exhibit smooth surfaces. In that case, the forward scattered intensity is much more pronounced as in cases of rough surfaces, even if a crystal habit is present. If many of the ice particles are amorphous in nature, or did not form under conditions of crystal growth- for example by freezing from super-cooled droplets, or by riming – the forward scattering pattern will be weaker, and similar to what we see for liquid droplets: a white scattering disk surrounding the sun, but no halo. In turn, roughness and asymmetry of ice crystals influence the magnitude of backscattered solar radiation, thus influencing the radiative effect of cirrus clouds (van Diedenhoven, 2016). If the particles in the cirroform cloud are very small, e.g. a few microns (Sassen, 1991), diffraction will lead to a corona. Hence, we believe that a systematic observation of the optical scattering properties adds information to our data on cirrus composition and cirrus radiative properties."

Page 2, lines 7 and 11: Replace Knobelspiesse et al., 2015 with Waliser et al. (2009).

Reference to Waliser et al. (2009) was added in line 7. The reference to Knobelspiesse et al, 2015. had already been changed after the editor's request. In line 11, we replaced the reference to Knobelspiesse et al., 2015 with the suggested reference.

Page 2, line 12: Here it is stated that "Cloud particle sizes can range from 0.1 microns

to a few millimetres (Cziczo and Froyd, 2014)." I think few microns to a few millimetres (or even centimeters) is more realistic. Also, I suggest to replace the reference with Heymsfield et al. (2013).

Correction to "few microns to even centimeter sizes" was incorporated, and a reference to Heymsfield et al (2013) was added. The Cziczo and Froyd article is a review paper, reviewing particle size distributions from various measurements.

Page 2, line 12: Replace the reference to Delene, 2011 with Heymsfield et al. (2013) Correction was incorporated.

Line 15: add Hong et al. (2016) to the reference on lidar/radar. Reference was reviewed and added.

Line 20: I suggest to replace all references here with Bailey and Hallet (2009); Baran (2009) and Yang et al (2015).

The references in line 20 have been corrected as suggested.

Line 21: It is not very clear what is meant with "observable symmetric scattering patterns", but it seems that "halo displays" may be more appropriate. Also note in the sentence that smooth crystal surfaces are needed for halos. Please add references to Um and McFarquhar (2015) and van Diedenhoven (2014)

The sentence has been rephrased to "Only ice particles with a simple crystal habit and smooth surfaces can lead to halo displays", and the suggested references have been added.

Line 24: In reference to the "additional ice halo features" cite the book of Tape and Moilanen (2006).

The citation was inserted.

Line 26: Add "forward" before "scattering"

The word was added to the sentence.

On line 27, discussing the corona, refer to Sassen (1991). Also a more realistic size for corona producing ice crystals is "a few microns".

The wording was changed according to the suggestion. The proposed reference was inserted.

Line 31: The presentation at the Gordon Research Conference on Radiation and Climate in 2015 cannot be considered a published result, so please remove the reference. In any case, I thought this sentence was very confusing as I thought this was referencing to the results presented in this paper. I suggest to remove this part.

The sentence and reference was removed.

Line 32: The reference to Seefeldner is incorrect and should be Forster et al. 2017.

The previous change removed this reference.

Section 1 Page 4: line 14: I suggest to replace "start the master table" with "train the algorithm", as the master table is not introduced yet.

(now line 10) The correction was inserted.

Section 2.1 Page 5, line 12: A value for pre-factor C0 is given, but the X is not defined yet. I suggest to give a value for C0 later.

We replaced the sentence with "The pre-factor C0 in Eqn.(6) is chosen later to place the values for F into a convenient number range." Renumbering the equations resulted in the shift in Eqn number.

Page 5: equation 3: Do the absolute values of the elements in x need to be similar so they are weighted equally? Please explain in the text.

We inserted the following sentence in the hope this would clarify the issue: "For the image properties we chose in STS and IHS computation, the elements of Ximage lie

within one order of magnitude of each other. Hence, no weighing became necessary for this application." Renumbering the equations moved former Eqn (3) to Eqn (6).

Section 2.2 Page 5;, line 26: What are the units for BGR? Is that one byte?

The color values in the jpg have no defined unit, but scale with the receive intensity of the light. We hope to have clarified this by inserting the following statement: "Every pixel in a TSI image exhibits a value between 0 and 255 for each of the three colour channels blue (B), green (G), and red (R). The colour values represent the intensity of the colour channel registered for the particular pixel, varying between 0 (no intensity) and 255 (brightest possible)."

Page 6: line 13: Add "to" between "and" and "then".

Correction was applied.

Page 6 (and elsewhere): Use equation numbers for each equation and expressions throughout the paper.

We renumbered the equations, and included all of them.

Page 6: line 5, what is "B" here? In the previous it references to Blue, but the expression is used for all colors. Please clarify in the text.

Equation (8) was modified to include the tinting procedure as done for every color channel in each pixel.

Page 6: line 7: Remove the brackets and make the text explaining alpha into a proper sentence.

We included this correction: "The coefficient ïĄą regulates the strength of the tinting such that ïĄą=0 leads to no tint, and ïĄą=1 produces an image of a single colour." (now page 6, line 13/14)

Figure 2: Define RAI, TL, TR, BL, BR in caption.

The caption was modified to include "The LSM is divided into four quadrants, named according to their position as TR – top right, BR – bottom right, BL – bottom left, and TL – top left. The RAI is the Radial Analysis Interval for which STS and IHS properties are evaluated."

Section 2.3 Page 7: line 6: What are the units of I(s)?

We added the following sentence to the text: "The term intensity refers to the colour values of any of the colour channels, and varies between 0 and 255."

Page 7: line 12: Replace "A cloudy sky" with "An overcast sky".

Now page 7, line 20: the correction has been made.

Page 7: line 19: Use italics for "s"

This has been corrected after the editorial request, perhaps. I am not sure what it refers to? Figure 3 (and 6): Please add proper x-axis labels. There is an "s" in the corner. Please spell out "radial distance" and place in the center. I also suggest to add the labels to the bottom of the bottom figures and add a dotted line indicating the zero deviation. The suggested changes to the figures have been implemented.

Page 8: line 11: replace CLR with "clear".

Correction was included, now on line 21.

Page 8: line 16: It is noted that the "mechanism described in section 2.1" is used. Be explicit about the properties discussed here are inserted in X? Also, I suggest to provide the value of C0 here.

We hope that the following modification explains the process better (now page 8 lines 27 to 33): "We are using the mechanism described in section Error! Reference source not found., Eqns (1) through (6). The continually refined master table defines a mean value vector M, see Eqn (2), and inverse covariance matrix ïĄŞ-1, see Eqn (4), for each sky type. The mean values for M are given in Error! Reference source not found.,

together with their standard deviations for the training set of images. As a new image is processed, its STS property vector X, Eqn (1), is computed for each sky quadrant. Subsequently, a score is computed for each sky type using Eqn. (6). A value of 105 was used for C0 which places a rough separator of order 1 between images that match closely a particular sky type, and those which do not."

Figure 4: Please add y-axis labels. AST in the caption should be ASD.

Corrections were made as suggested.

Figure 5: Black arrows are used to match the images to the timeline, but these arrows are not visible on the black indicating CS. I propose pointing the arrows of the top images to the top of the timeline plot, so that they are visible.

The adjustments to the figure have been made as suggested, and an error in the caption was corrected.

Page 9: line 30: It is mentioned that "if a radial sequence is found in one colour channel, it should be found in the same locations in all colour channels". Should the angular difference between colors of the halo not be taken into account? The red part of the halo is closer to the sun.

There are multiple factors that influence the inability of the algorithm to resolve the color channels. The first is the small size of the TSI images. Even under good lighting conditions, the angular resolution is limited to 0.3ïĆř, particularly near the horizon. When the perspective distortion is removed, a further reduction in resolution is introduced, again particularly affecting near-horizon solar positions at zenith angles above 45ïĆř. That affects the majority of images. The third influence lies in uncertainties in the solar position. Even though a series of calibrations can address any minor misalignments in North-south line, zenith position, mirror-camera alignment, shadow strip position etc, they are manually assigned, and introduce another uncertainty that affects the fine-angle resolution. The wording was changed to "Lastly, a radial sequence should be

consistent across all three colour channels,. . ." to avoid potential confusion.

Section 3 Page 11, line 23: Some caution is rightfully raised about the visual classification. Somemore information on the method would be helpful to include in the text (here or above at the start of section 3). For example, who was doing the classifications? Is that one person, all of the authors, other people? Also, my guess is that the person (or persons?) evaluating the images are not doing this blindly, so they might already be biased towards the classification of the algorithm.

The training of the algorithm is a give-and-take, with the goal to maximize agreement. Visual inspection is not perfect, and neither is the algorithm. We modified page 11, lines 8 through 19 to try to address some of the reviewer's concerns: "For each of the 31 days of March, an observer assigned sky classifications to segments of the day by inspecting the day series as an animation. This can easily be done by using an image viewer and continuously scrolling through the series. Then, the day would be subjected to the algorithm. The sections of the record in which visual and algorithm differed were inspected again, at which point either the visual assessment was adjusted, or the misclassified images were included in the Master table in order to train the algorithm toward better recognition. Adjustment to visual classifications often occurred at the fringes of a transition. For example, when a sky transitions from cirrostratus to altostratus to stratus, the transitions are not sharp. The observer sets an image as the point in which the sky moved from CS to CLD, but the criteria in the algorithm would still indicate CS. This can affect up to a hundred images at transition times, which then were reclassified. On the other hand, if a clearly visible halo was missed by the algorithm, this would be a case for adding new property lines to the Master table in order to capture the particular conditions. After each change in the Master table, the algorithm would be repeated, and recalibrations to the visual record, as well as to the Master table itself were made. The process was repeated several times until no more gains in accuracy were observed. These adjustments were done by SB."

Page 13, line 3-4: For clarity add "in Table 6" after the "second set of numbers". I

suggest to remove the part ", which may be a little easier to interpret".

The text has been adjusted accordingly, now page 13, line 29.

Page 13: It might be good to discuss the results somewhat more in comparison to Forster et al. 2017.

Absolutely. Since submitting this paper, long-year analyses of the TSI record have been undertaken, which show some really interesting seasonal variations in the halo appearances in CS skies. We find maximum halo fraction in CS of 20-25% of all CS skies in March and April, consistently through several years of records. We presented that on a poster at the AMS which can be found online if there is interest. This will give a much better basis for comparison than the four-month record included in this paper. We included some more language on page 13 lines 22 to 25 and 30 to address this concern. "in particular with respect to assessments of variation of smooth versus rough crystals. Forster et al (Forster et al., 2017) discuss that the necessary fraction of smooth crystals for a halo appearance lies between 10% and 40%. The authors observe a 22ïČř halo for 25% of all cirrus clouds for a 2.5-year photographic record taken in Munich, Germany." And "This is certainly consistent with the observations of Forster et al (Forster et al., 2017)."

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2018-401/amt-2018-401-AC1-supplement.pdf

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