The value of this study lies, in my opinion, in assessing the feasibility of using TSI images for analysing halo displays to gather information about ice crystal properties. This study is similar to previous studies (e.g. Sassen et al. 2003, Forster et al. 2017), yet holds some valuable contributions since it expands the method to TSI observations, eliminating the need of a sun-tracking camera. However, this work is lacking a discussion comparing the presented method and especially its results to the abovementioned studies. Advantages and limitations of this undoubtedly widely applicable method must be discussed.

Major remarks:

1. As visible in Fig. 5, identifying a 22° halo in TSI images might be challenging (even visually) due to a relatively coarse resolution, stray light, and over-exposed image regions. On the upside, TSI cameras are widely used, hence providing a large dataset from several geographic locations which is very attractive for long-term intercomparison studies.
2. The method used to calculate the 22° halo score has considerable overlap with Forster et al. 2017: features are determined in order to discriminate images containing a 22° halo from images which don't. It would be valuable to discuss the slightly differing choice of these features compared to Forster et al. Please discuss the impact of image resolution/FOV of TSI images on the choice of features. The presented study determines the threshold for labelling the images as "22° halo" and "no 22° halo" manually in contrast to Forster et al., who utilized a machine learning method. Please discuss the merits of the different approach used here.
3. How exactly was the algorithm trained? In order to assess its ability to correctly assign the labels "22° halo" and "no 22° halo" as well as the 4 different sky types, it is common practice to test the trained algorithm against *independent* images, which were excluded from the training data. Please describe how exactly this algorithm was tested.
4. Over-exposed image regions are mentioned several times (e.g. P11, L17). Please discuss their impact on the image classification. How was over-exposure treated in general? How would you assess the influence of over-exposed pixels to the detection of 22° halos?
5. How was ensured that parhelia were not accidentally misclassified as 22° halos at low elevations of the sun?
6. The definition and choice of the four sky types should be explained in the text. Halo displays can form in cirrocumulus and optically thick cirrus clouds as well. It is mentioned several times throughout the manuscript that the sky type classification of the images is used to infer information about the "presence of smooth crystalline habits among the cloud particles" (e.g. P13, L6). To answer that question it would be necessary to differentiate between ice clouds and other sky types including clear sky, as in Sassen et al. 2003 and Forster et al. 2017. Thus, the choice of sky types in this study, seems to be not ideal and aims more at differentiating cloud cover ("clear" vs. "cloudy" vs. "partially cloudy", cf. P11, L4). The definition of "cirrostratus" seems to be limited to optically thin, homogeneous cirrus. However, ice clouds and thus halo displays could also be connected with a "cloudy" as well as "partially cloudy" sky type (cf. P9, L10/11) or

even “clear” for very thin cirrus (cf. P11, L26-29). Please re-assess the choice of sky type classes regarding the interpretation of the results.

7. Finally, “long-term data / image records” is mentioned several times (e.g. P1, L6; P3, L19; P13, L13) and Table 1 refers to multiple datasets spanning up to about 7 years of data. I see this as a potential major advantage of this study. However, the study evaluates only images of one ARM site (Southern Great Plains) from January through April 2018. Please describe only the data that was actually used (cf. Tab. 1 and the statement on P2, L30/31). If the algorithm is applicable to large long-time datasets, why wasn’t this exploited?
8. The introduction could be tailored more towards implications of unknown cirrus optical and microphysical properties, especially ice crystal shape (and orientation), on the Earth’s radiation budget and satellite remote sensing of cirrus clouds. The selection of literature should be revised in this context, with an emphasis on primary literature, especially on the formation and frequency of halo displays (e.g. Minnaert (1937), Tricker (1970), Greenler (1980), Tape (1994), Tape and Moilanen (2006)), as well as ice crystal microphysical properties (e.g. Magono and Lee (1966), Bailey and Hallett (2009)). For example, as a reference for the various ice crystal sizes (P2, L13) and shapes (P2 L20), literature on in situ observations would be more suitable. Delene 2011 and Ewald et al. 2013, for example, don’t seem to be the primary literature to support the statement.

Specific comments on the manuscript:

Introduction

- P2, L16-17: “All of these methods are restricted to a particular time…It is clear that no single method has all the composition information”, please clarify. This statement seems to be inherent of any kind of measurement. What exactly should be pointed out here? How do TSI observations solve this problem?
- P2, L24: “More symmetry in the particle orientations will add additional ice halo features.” Which additional features? Please cite corresponding literature.
- P3, L11: “The fraction of smooth crystals necessary for ice halo appearance is 10% for columns, and 40% for plates (van Diedenhoven, 2014)”. It should be added that these results represent a lower threshold and are based on analysis of scattering phase functions. Therefore, they are not directly applicable to observations of 22° halos in the atmosphere including multiple scattering.
- P3, L12-14: “The consideration of the percentage of cirrus clouds that display optical halo features allows a direct conclusion with respect to the fraction of crystalline habit in the cloud, and, upon further study, about the microphysical conditions in the cloud.” The fraction of hexagonal crystals in cirrus clouds cannot be directly inferred from the frequency of visible halo displays. Beside the single scattering properties, which van Diedenhoven 2014 investigated, multiple scattering has to be considered (cf. Forster et al. 2017).
- P3, L28: “refinement of the algorithm goals” is unclear in this context, please elaborate.

1 TSI images

- P4, L11: Please provide a range for the angular resolution, specifically for the camera (SGP) and time period used in this study.

2 Algorithm

2.1 Goal and Strategy

- P5, L7: What is C_0 ? → Normalization constant? Explanation in L12 should be moved here.

2.2 Image preparations and local sky map (LSM)

- P5, L19: "Some sample steps…" Why not all? Which steps are not shown?
- P5, L26: What is the reason for this the colour balance drift?
- P6, L3: Please specify "from across all TSI records available to the authors". Is this a good reference if the TSI white balance generally drifts? Another possible method would be to calibrate against a white or gray point in the images (e.g. bright cumulus clouds).
- P6, L4: The method how the TSI images were corrected using the scaling factors is not quite clear. It seems like only the blue channel (B) is corrected? How is the normalization of the brightness between 0 and 255 ensured?
- Please define R, G, B. Is this the brightness of the respective color channel?
- P6, L9: "The second step identifies the horizon circle, stretches the visible horizon ellipse…", circle or ellipse? L21 states that the coordinate transformation corrects for deviations from a circle for the 22° halo. And thus also for the horizon?
- P6, L10: "A north-south alignment correction may also have to be applied." Was it applied? If not, the position of the sun and the 22° halo will be shifted. Please discuss.
- P6, L11: "In addition, the horizon is chosen at a zenith angle smaller than 90°, often between 85° and 79°…" How often? Which threshold was used in the other cases? Does it affect the Local Sky Map anyway?
- P6, L19-21: How exactly was the image distortion investigated? Please support this statement by numbers.
- P6, L24: Which "extraneous details" are masked? Please specify.
- P6, L26: What are 40 sky degrees?
- P6, L26: "Units of measurements in the LSM…". Why not simply use pixels? Or zenith and azimuth angles in degrees?
- P6, L28/29: Do you refer to image distortion? "requiring an additional horizontal compression", please explain the procedure. "The algorithm is robust enough to allow this scaling by solar position alone, without loss of efficacy". This should be discussed together with the results.
- Figure 2: Please include a figure showing the LSM as an overlay to the TSI image with 22° halo of Fig. 1 in addition. It would be very helpful to see which portion of the image is actually used for the analysis of the 22° halo when it comes to interpreting the results.

2.3 Computing Sky Type and Halo Properties

2.3.1 Average radial intensity (ARI)

- P7, L5/6: "We found it useful…", as in previous publications (e.g. Forster et al. 2017). It is indeed practical to use the radial brightness distribution since for randomly oriented ice crystals (causing the 22° halo) the scattering phase function varies only along the scattering angle.
- P7, L14/15: move this explanation of the LSM to section 2.2

- P7, L19/20: How does a radial average over 4 pixels affect the visibility of the 22° halo? Is it necessary? Does the angular resolution of 0.4° to 0.7°, as stated in L25, still hold after averaging?
- P7, L3: Please define “a”
- P7, L24: Please indicate the position of the 22° halo in Fig. 3
- P7, L27: What is 15-26 LSM units in degrees? Where is the 22° halo in terms of LSM units? → Could be visible in an additional figure with an overlay of the LSM onto the TSI image with 22° halo of Fig. 1 (as suggested above)

2.3.2 Sky type score (STS)

- P8, L3: Please provide the exact number of images/image segments that were used for training, cf. P10, L22: 44026 images?
- P8, L16: How about introducing the metrics defined in section 2.1 here? In my opinion, the procedure is much easier to understand after the “properties” are explained. In section 2.1 it would be sufficient to explain that a multivariate analysis is performed based on image features/properties. The TSI images are then classified by comparing these features to reference values in a look-up table.
- P8, L17: “continually refined master table” → Please explain this procedure.
- P8, L18/19: As suggested above it would be more convenient for the reader to define Eq. 3 here.
- P8, L19: Please provide the range of values expected for F_{image} (in case of “22° halo” and “no 22° halo”). This might already be interesting to note on P5, L7.
- P8, L25: How was the threshold of 10^{-8} chosen? Is it simply outside of the range of F? What kind of images yield this result? → explained later on P12, L1-3. Should be already mentioned here.
- P8, L29: “taken for the combined sky” → “for all 4 LSM quadrants”?
- P9, L9: Please explain the challenges that can be addressed by the “radial scattering analysis" and how

2.2.3 Ice halo score (IHS)

- P9, L9: The 22° halo is formed by ice crystals in high-level cirrus clouds. So it is visible wherever cirrus clouds are present and not obstructed by low-level water clouds. The sentence as it stands now gives the wrong impression that the 22° halo is overlaid over low-level clouds. Please correct the sentence accordingly.
- P9, L10/11: The fact that 22° halos are present in images classified as CLD and CLR provides more information about the definition of these categories and the selection of criteria rather than about the formation of the 22° halo. Please adjust the formulation of the sentence to avoid misunderstanding.
- P9, L16: “variations in calibration” The image calibration should not vary across the images. The authors probably want to refer to the north-south mis-alignment of the camera and the coarse angular resolution which can pose a problem in identifying exact position of the 22° halo peak.

- P9, L31: According to theory, the 22° halo peak should not be at the "same" location for the red and blue colour channel, but shifted. Is this feature used for the detection of 22° halos?
- P10, L11: Please define "w" here, instead of L15.
- Figure 5: Please provide values for the IHS at the y-axis of the lower panel
- Is the IHS calculated for each quadrant separately? (How) are they combined to classify the image? → info on P10, L22 should be stated here as well as in section 2.3.2.

3 Results for January through April 2018

- P10, L28: The values for C= 10^6 and w=3.5 (w=4 was defined in L15!) should be mentioned earlier, where the respective equations were defined. Eq. 2 should be Eq. 5?
- P10, L19: It is not be surprising that "high halo scores coincide with strong CS signals", however it can be considered a confirmation that the image features used to train the algorithm were reasonably selected.
- P10, L31 through P11, L2: The determination of a "cut-off" or threshold value "to assign an image with a label of halo/no halo" results from training the algorithm. The same way as the threshold of 50% for the sky type. In both cases the threshold is "arbitrary" to some extent, but should be chosen to minimize either false positive or false negative classifications. This is correctly stated later on P11, L19, but should be mentioned earlier.
- Table 5: The difference between "%vis" and "%alg" is not quite clear. It seems that "%vis" provides an assessment of the visual image classification? This might be confusing for the reader. The interesting quantities here are the fraction of correctly and incorrectly classified images by the algorithm, compared to the ground truth (visual classification). Note that IHS > 4000 in the caption, but IHS > 3500 in the text!
- P11, L4: "A small percentage of visual CLD skies trigger a PCL signal, mostly due to inhomogeneities in cloud cover." Please provide a number for the percentage. Does CLD mean completely overcast? Or do the inhomogeneities here correspond to small clear-sky patches?
- P11, L4/5: Please provide a number stating how successful the classification of CLR is.
- P11, L27: If some CLR images were labeled as "22° halo" why is the fraction of halo instances of CLR all sky type 0% in Tab. 5?
- P11, L23-31: The discussion of the challenges of visual classification of TSI images is very interesting, especially for other publications relying on this. As correctly mentioned, additional Lidar observations together with a temperature threshold e.g. from radiosonde data are useful to improve the classification (cf. Sassen et al. 2003 and Forster et al. 2017). Please add the respective citation also on P13, L7-9 and P13, L30.
- P12, L7: Please explain "various dimensions of the record".
- On P10, L22 it was stated that "An image IHS and STS are assigned as the average over all scoring quadrants." How were the results for the individual quadrants obtained in Tab. 6?
- It should be noted that due to the shadow band a "full 22° halo" actually misses its top and bottom.

4 Summary

- P13, L24: 86% vs 85% on P11, L18!

- P13, L27/28: “The algorithm now will be applied to deliver ice halo data for the long-term TSI records accumulated in various geographical locations of ARM sites” Please replace by “In the future, the algorithm will be applied…” to avoid the misunderstanding that this was performed in the present study.

Please consider the following remarks to further improve the quality of the manuscript:
The use of technical terms in the manuscript should be revised. In several instances a more commonly used expression exists, which should be used instead where applicable. For example:

- “Ice halo”, I would suggest using the term “halo display”, which is most commonly used in the literature. Please replace “ice halo” by “22° halo” wherever this specific type of halo display is referred to, e.g. P1, L18 and P12, L10. IHS could be changed to HS22 or simply HS, when it is clear that it is only applied to the 22° halo.
- “look-up table” might be a more commonly use term than “external expandable master table”. It is not clear what “expandable” and “external” means in this context? Most tables are expandable.
- P4, L14: Please explain the “master table” and “seed images”. Try to use technical terms where possible. The term “master table” is more common in the context of databases. Here the term “look-up table” might be a better choice. A more suitable word for “seed images” would be “training images/data”.
- “composition information” (e.g. P2, L17), please specify: does the term refer to microphysical properties, optical properties or cloud phase.
- P1, L14: “standardized”, “calibrations”: Please describe the specific methods rather than using general terms. “Calibrations” → “colour correction” (this seems to be the only calibration performed).
- P3, L9: “radio probes” → “radiosonde measurements”
- P3, L14: Please replace the term “conditions” by a more specific technical term, e.g. “microphysical properties”
- P3, L24: Please specify “photometric data”.
- P3, L29: “effectiveness and types of data” is unclear.
- P4, L5: Please specify “ranges and dates”.
- P2, L21: “Only ice particles with a simple crystal habit can lead to observable symmetric scattering patterns”. Please specify “simple”. Is the message: Ice crystals with a regular hexagonal structure and smooth faces form halo displays?
- P5, L18; P13, L15: “image preparation” → “image processing”.
- P5, L18: Please specify “easy-to-use coordinates”→ spherical coordinates? Please specify “minimal colour calibration”→ “colour/white balance correction”
- P5, L26: “colour drift” → better “colour balance”
- P9, L9: “Partial clearings” → “clear-sky regions”
- P10, L22-26 could be summarized as “the algorithm was trained”.
- Figure 7 basically shows the “training data set”
- P13, L14: “…information on cirrus composition…” → more specific: “…information on the presence of smooth, hexagonal ice crystals in cirrus clouds from observations of 22° halos…”.

Typos and suggestions for improvement:

- P3, L19: “We are introducing an algorithm that will read, standardize, and analyse…” Most algorithms read in data and process it in some way before analysing it. Please be more specific or simply say “We are introducing an algorithm to analyse TSI observations regarding the near-solar sky type,…”
- P3, L25: “halo algorithm” -> please use a more descriptive term. “combined and correlated”, better: “compared”?
- P4, L6: “…the whole sky **from zenith** to horizon.”
- P4, L6: Better: “A sun-tracking shadow band is used to block the sun, which covers a strip of sky from zenith to horizon” (to emphasize that the reason for the shadow band is the sun)
- P4, L8: “JPEG” (acronym for “Joint Photographic Experts Group”)
- P4, L12-13: This seems to be a standard routine and can be omitted.
- P4, L27: “The region is centred at the vector of mean values […] ~~where the vector elements are the mean values of the master set…~~”.
- P5, L21: “…the other **one**…”
- P6, L14: “plain” → “plane”
- P6, L15: “…a coordinate transformation is performed to represent the sky in terms of azimuth and zenith angles.” → “…a coordinate transformation is performed to represent the image pixels in spherical coordinates”
- P6, L24: “adjustments” → “corrections”
- P7, L5: “radius of 22°” → better: “scattering angle of 22°”
- P7, L5/6: “intensity behaviour” → “brightness”.
- P7, L7: “scattering centres” → “scattering particles”. “new to the line-of-sight to the sun” and “in the near-sun sky section” can be omitted for clarity. This statement is true for the whole sky.
- P7, L8: “a very fast initial radial decline…followed by a relatively low gradient” → “exponential decline”
- P7, L10: due to Rayleigh scattering.
- P7, L10/11: the increased forward scattering of larger particles (in this case ice crystals) leads to a decreased gradient of the radial brightness
- P8, L2: Consider starting with the explanation of the properties of I(s). It will make the rest of the section much easier to follow.
- P8, L8: “…gives access **to** the overall brightness…”
- P9, L1: “22:53:00 **UTC**”
- P12, L9: “instance**s”**
- P12, L20: “The closer…, **the** more…”
- P13, L22: “raw image score”→ “STS or IHS”
- P11, L5: “CS and PCL are very successful, but exhibit some difficulties.” → better: “Differentiating between CS and PCL…”?
- P13, L16: “A multivariate analysis of selected LSM properties, as supported by a continually developed master table, allows the assignment…” → “A multivariate analysis of selected LSM features, stored in a look-up table, allows the assignment…”