Response to the comments from Anonymous Referee 2 for the submitted AMT paper: ´Dorff, H. et al. 2021: Horizontal geometry of trade-wind cumuli - aircraft observations from shortwave infrared imager versus radar profiler

We thank the AMT associating editor, Maximilian Maahn, as well as the Anonymous Referee #2, for this enlightening review. Please find below our response to the comments (in *italics*) from the Anonymous Referee #2.

Excellent paper, great summary and illustration of the limitations of 1D transects / chords lengths for characterizing cloud size distributions. Good follow on from Barron (2020) which they cite multiple times. I have only minor comments, detailed below. I have a suggestion which is not necessary for the authors to perform, but I wonder why they did not show at the end a joint-frequency distribution of cloud size and eccentricity? Should we expect some trend in eccentricity with cloud size? Perhaps eliminate figure 9 whose purpose is unclear, and add such a joint-pdf plot? Or leave that for your next work. There are other possible follow-up studies, which just illustrates why this is a good piece of technical foundation.

Response: We cordially thank you for your summarizing feedback of our manuscript and hope that also others enjoyed reading it giving new perspectives for further cloud geometry analysis.

Response to Joint distribution:
Figure 1 illustrates our version following your plot suggestion:

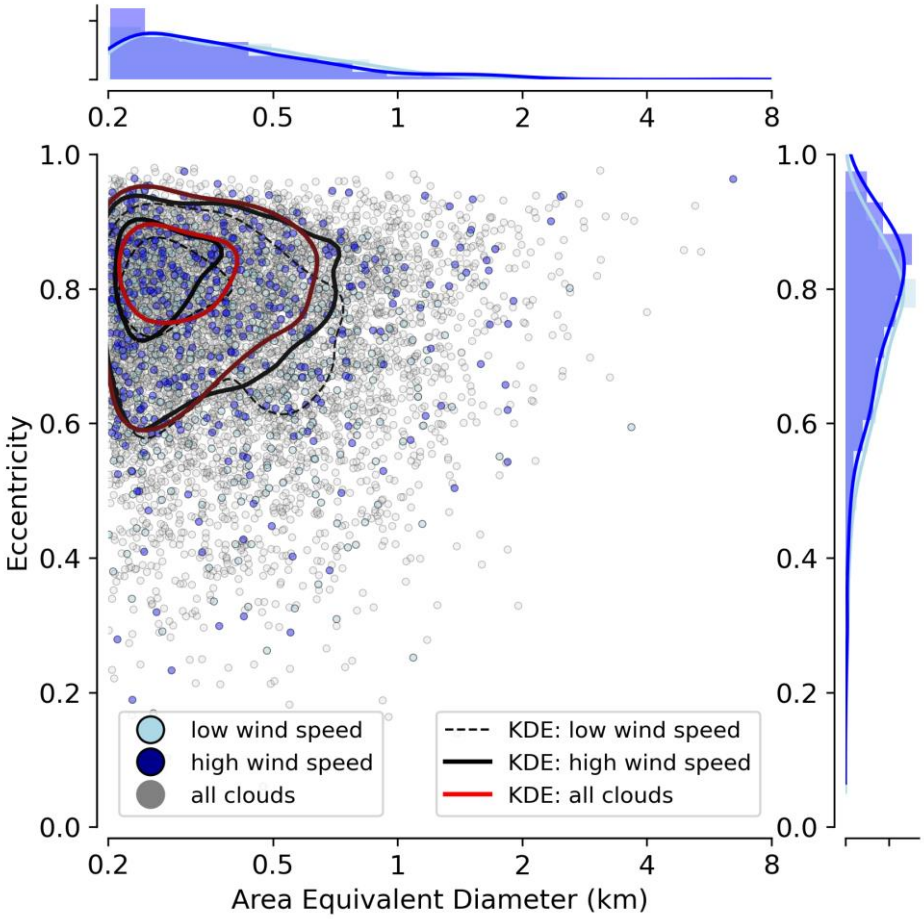

Fig. 1: Joint-frequency distribution of cloud size (referred to area-equivalent diameter) and eccentricity for clouds of RF03 and RF06 with L>200 m and the cloud samples affected by low and high wind speeds. Contour lines in major panel represent three iso-proportions of the kernel density estimate (KDE), distributions for both quantities are given separately at top and right.

First, we really appreciate your suggestion, which is a truly interesting insight on cloud geometry interactions with the wind-field. We inserted the before shown Fig. 1 as Fig. 12 in the manuscript between the discussion of eccentricity and cloud orientation by the normalised radius. Our analysis revealed the following that is now included into the manuscript:

"We hypothesize that larger clouds tilt more into the winds and become even more stretched. For the given clouds of RF03 and RF06, Fig. 12 illustrates the joint-frequency distribution of eccentricity and cloud size also depicting both wind cases. Referring to area-equivalent cloud diameters, the cloud size distributions remain comparable between both wind cases (top panel of Fig. 12) in contrast to an increase of horizontal cloud size and shifts of the scale break with increasing surface wind speed stated in Mieslinger et al. (2019). Inspecting the contours of the joint-frequency distribution, we identify an increase of eccentricity with cloud size especially for higher wind speeds. However, since the sample size strongly decreases for larger clouds as they are rarer and more likely to extend out of the imager FOV, our hypothesis can only be proven by longer observation periods or broader FOV. We thus encourage corresponding studies using e.g. ASTER as in Mieslinger et al. (2019)."

Minor revisions:

Line 25 "limitedly understood" is strange phrasing, consider "only partially understood"
Response: we modified this accordingly.

Line 50 "barely" should be "rarely"
Response: we changed the wording.

Line 72 "precedent" doesn't make sense here, maybe "The conclusions consider the abilities of a prospective flight campaign to answer new research questions."
Response: we amended the sentence.

Line 74 "We consider" change to "we analyze"?
Response: we modified this accordingly.

Line 78 "... in a 2D image."
Response: changed

Line 85 "... the profiling radar enables"
Response: we adapted the grammar

Line 96 Why choose the SWIR band instead of VNIR? Just one short sentence to explain. Something about sun-glint perhaps?
Response: We added the following information to the sentence: "[…] which allows more explicit cloud masking under the presence of sun glint"

Line 127 I wonder if the window freezing issue should be mentioned again at the end in the recommendations.
Response: The instrument provider has solved the issue by adapting the design. A recommendation is no longer necessary.

Line 164 "following aspects" should be "the following aspects"
Response: changed accordingly

Line 174 consider “limited” instead of “dammed” which sounds too much like “damned”
Response: we changed the wording following your suggestion.

Line 183-185 This is a very important and difficult aspect of this analysis, I have experience with this issue. I believe you made the best choice to reduce bias and error of counting a section of a large cloud as a small cloud. However, this does not eliminate bias, but shifts the bias to larger size clouds (which are now systematically undersampled), so that is ideal for this analysis focused on smaller scales, but maybe a note about this should be included in the discussion in the beginning of section 3.4 to warn future users of this analysis technique. The larger clouds are indeed more rare, but will also be undersampled as the cloud length scale approaches the typical image scale.
Response: Indeed both simplifications for larger clouds have pros and cons. This is why we show both simplifications for both coordinate frames, where the mentioned aspects in Sec. 3.2 apply for 2D cloud geometries after coordinate transformation and are not conducted within the along-track coordinate frame. We admit that we stated this distinction a little bit unclearly in the manuscript (which explains your remark for line 315). Therefore, we highlighted the differences at several lines in the manuscript:
First, to underline the relation of Sec 3.2 to only 2D cloud shapes and not along-track cloud sizes, we modified the section title from “Distance based pixels” to “Two-dimensional distance-based pixels”.
Second, we added the following note in Sec. 3.4:
“As long as we remain in the aircraft following coordinate frame, considering along-track cloud lengths, no restriction in cloud cutting as suggested in Sec. 3.2 is performed to include a high amount of clouds. Nonetheless, we only show distributions for lengths up to 10 km, because we are limited by the imager FOV when considering 2D cloud shapes.“
Third, we discuss at the end of section 4.3: “[…] larger clouds may be misinterpreted from the imager if only their edges reach into the imager FOV and artificially enhance the scale break through underestimation. If we completely neglect clouds reaching out of the FOV, we do also produce biases with increasing cloud size (Sec. 3.2).”
In Sec. 4.4, we also remind the reader that only fully detected clouds are now included:
“Hence, we put now emphasis on the misrepresentation of along-track lengths for the effective 2D cloud size of all shallow cumulus clouds fully detected by the imager.”

Line 214 A “scale-break” might also be a sign that a power law is the wrong choice,because, for example, a scatter-plot of frequency vs length scale data on a log-log axis plot that looks like two power-laws with a scale break in between could instead be considered as a single exponential distribution, with the “scale-break” location being the bend in the exponential on a log-log plot. Since 1 function is less complex than 2 functions, the principle of parsimony would suggest considering an exponential distribution instead of a power-law. I don’t expect you to change this for this paper, or change the power-law obsession everyone seems to have, but I do suggest that you consider the exponential instead of a “scale-break” in future work.

Response: We thank you very much for your enlightening comment regarding the complexity of scale-breaks. Indeed, this topic is widely discussed. As mentioned in the answer of RC1, we added some discussions in Sec. 4.3 as follows:

[…] we highlight the ongoing debate of literature about location and artificial or boundary-layer driven origin of scale breaks (Mieslinger et al., 2019). We see that resolution affects the location of the scale breaks in a way that it is missing for airborne observations in hectometre resolution. Although Wood and Field (2011) locates scale breaks above 1 km using hectometre scale spaceborne data, we cannot identify this from the radar curtain samples. On the other hand, larger clouds may be misinterpreted from the imager if only their edges reach into the imager FOV and artificially enhance the scale break through length underestimation. If we completely neglect clouds reaching out of the FOV, we do also produce biases with increasing cloud size (Sec. 3.2). Due to the complexity of scale break origin, some studies, e.g. van Laar et al. (2019), suggest to apply exponential power law fits (Ding et al., 2014) to prevent the scale break by a modified single distribution."

Line 227 Unclear "this prounounces"?
Response: we changed this to "this affects".

Line 276 "contrarily" is not clear, something more like "This affects the distributions in the opposite direction Caption of Figure 5 Remove "exemplary"
Response: We amended the wording as suggested.

Line 315 The point of Figure 9 is unclear... are you trying to show clouds that don't make it into the analysis at all? Maybe draw some lines on Figure 9 to indicate which clouds in that image are included (if any?)
Response: In Sec. 4.3, we rely on the aircraft following coordinate frame and along-track cloud sizes, which do not use the coordinate transformations defined in Sec. 3.2. We admit that this fact should be stated clearer before.

In Sec. 4.3, instead, we can calculate the along-track cloud size independently of any assumptions for e.g. cloud top height which would require profiler data. The length values are unambiguous, at least for the given imager sensitivity. This advantage motivated us to add this section before dealing with 2D cloud shapes in Sec. 4.4 where we then have to consider the bullet points of Sec. 3.2. Neglecting clouds reaching to the FOV edges is here not yet done although we then have the issue of underestimated cloud length (see comments above).

Hence, Fig. 9 just intends to illustrate the aspects described in line 313-317 of the preprint. In order to achieve this more obvious, we included the radar curtain in Fig. 9. In addition, we rephrased the reference to Fig. 9 in a paragraph in order to make the purpose of the visual explanation clearer:

"Clouds exterior of the radar FOV increase the sample non-uniformly which can be seen for an exemplary cloud scene in Fig. 9. When clouds are larger in the along-track axis, they generally tend to be larger in the across-track as well, often reach to across-track edges covering the entire FOV and are embedded in a cluster of numerous small clouds around (Fig. 9). For measurements constrained on a narrow transect, this results in a lower chance of small clouds around to be captured, whereas the largest clouds (at 17:43:15 and 17:44:20 in Fig. 9) are detected anyway, regardless of the resolution. Transferring from 2D to 1D transects thus flattens the distribution."

Line 316 "constraint" should be "constrained" and "This pronounces" doesn't make sense, maybe "This results"
Response: we changed both following your suggestions.

Line 317 “regardless of the resolution”
Response: we corrected this part.

Line 352 Not clear, maybe change to “Using only the radar resolution and statistical methods, e.g., considering circular assumptions (Romps and Vogelmann 2017), or as in Barron et al. (2020), such methods will fail to reproduce the actual double power-laws (not shown). Cloud shapes being rather more elliptical than circular...”
Response: we changed the phrase according to your suggestion.

Line 382 “arises” should be “raises”
Response: we changed the wording accordingly.