

## ***Interactive comment on “Observing cirrus halos to constrain in-situ measurements of ice crystal size” by T. J. Garrett et al.***

**T. J. Garrett et al.**

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We thank the reviewer for his perspectives on the paper.

1. The frequent observation of halos by the backseater was a great surprise. I have never seen a 46 degree halo in cirrus, and only very rarely a 22 degree halo during the day. Nonetheless they were seen often in the cirrus measured. The type of cirrus measured was moist synoptic outflow from the Gulf of Mexico, as described at the beginning of Section 3. The reviewer does not describe what sort of arc he thinks is in Figure 5. It could be argued that it is a supralateral arc, but it is not, as the lower portion of the halo was photographed just 9 minutes earlier, and simultaneous supralateral arcs and 22 degree halos don't appear to be possible at these zenith angles. The additional photo will be included the revised

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version. Perhaps the fact that the 46 degree halo does not appear concentric with the inner 22 degree halo is what causes the confusion. This is simply an artifact of angular distortion in the camera, associated with the scattering radiating close to the aircraft but at differing distances from the lens. This is what would be seen most dramatically with a fish-eye lens. Such an effect would not be apparent in normal photographs from the ground, given the halos are effectively at infinity. As another reviewer was troubled by the same thing, this will be elaborated on in the revision.

2. All measurements were in synoptic cirrus, as stated at the beginning of Section 3. The distribution of extinction values was centered around 2 per kilometer in both the halo distributions and the cirrus as a whole (Figure 3).
3. The paper is not fixed on showing the importance of small crystals. It provides an independent evaluation of the instrumentation that measures small crystals. Care was taken to avoid any impression to the contrary. It is true that a 22 degree halo might be associated with large bullet rosettes in principle, and we do not completely exclude it as a possibility. However it was shown in Section 3.3 that this would require an implausibly large physical thickness to provide the scattering intensity observed in Fig. 5, and in fact necessary to overcome the brightness of the blue sky behind it. A much more plausible cloud thickness, one that agreed well with observations, could be inferred from scattering associated with the in situ measurements of small ice crystals.
4. There is only one correct definition of effective radius consistent with the original intent proposed by Hansen and Travis (1974) and Stephens (1978). It is general for all shapes and sizes, and is the one we have used. The effective radius of a bullet rosette with eight hollow bullets would be about one half of the distance from the outer edge of the crystal to the inner edge of the hollowing. The effective radius of a tree is about one half the width of its most common branch size, area-

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- weighted. The equivalent radius is a similar but different parameter that is used out of convenience where we lack direct measurement of the volume to area relationships for individual crystals.
5. It seems that the reviewer has mis-judged the intent of the paper. We do not use the FSSP data to support the halo observations. Rather we use the halo observations to investigate whether the size distribution measurements including the FSSP are consistent - to first order - with the visual observations. Halo observations are unaffected by scattering, hence the intent of the paper. Regardless, multiplying the CIP area by say a factor of six to account for possible over counting by the FSSP would still bring it nowhere close to the CAS areas actually measured.
  6. The phase functions used account for wave effects at small size parameters, as described in the references cited. If they did not, they would not smear the 22 degree halo peak as shown for small values of equivalent radius.
  7. The reviewer is partly incorrect. It is true that a satellite is affected by the light contributions as deep as an optical depth of about 3. However, from Schwarzschild's equation, radiation at those depths is attenuated by the cloud above it, more so than cloud closer to the top. This is basic radiative transfer. Therefore it is still correct to state that ice crystal properties near cloud top matter most to climate.

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