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Atmospheric Measurement Techniques Discussions

Interactive comment on "Application of infrared remote sensing to constrain in-situ estimates of ice crystal particle size during SPartICus" *by* S. J. Cooper and T. J. Garrett

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This manuscript presents three case studies of comparisons between cirrus ice crystal effective radius (r_e) inferred from a bi-spectral remote sensing technique and r_e determined from in situ cloud probe measurements. I have concerns about the general approach used in this study, as well as the specific presentation of the results and the conclusions drawn.

General comment:

Direct comparison of satellite remote-sensing measurements of clouds is generally

challenging, and such comparison for cirrus clouds is particularly problematic. Aircraft sampling essentially provides a pencil of measurements through the atmosphere. Cirrus clouds are typically very highly structured, both horizontally and vertically. Surface area density and ice water generally vary by orders of magnitude over horizontal distances of just a few km, and effective radius can vary by more than a factor of two over these spatial scales. In agreement with past studies, SPartICus measurements indicate that effective radius often increases systematically with decreasing height in cirrus (Lawson, 2011). This vertical structure is expected due to differential sedimentation speeds of small versus large crystals. An example from tropical anvil cirrus indicated effective radius increasing from $\simeq$30 μm to 80 μm as the sampling aircraft descended from 12 to 9 km (Lawson et al., 2010). Aircraft necessarily provide a very limited view of the vertical variability in cloud microphysical properties, and biases toward the upper or lower parts of cirrus could result in misrepresentation of the vertically averaged cloud properties. Although the comparisons presented in this manuscript focus on moderate optical depth cirrus, this does not imply that the cirrus were necessarily vertically thin nor does it imply a lack of vertical variation in r_e.

The authors state that in the case studies chosen the Learjet was located in relatively homogeneous areas of cloud. However, examination of the MODIS images (Figs 2-4) suggests considerable horizontal inhomogeneity in the cloud fields where the Learjet was sampling. In fact, casual examination of satellite imagery indicates that homogeneous cirrus clouds are a very rare exception. The authors focus on 5-10 minute average values of effective radius, and little or no discussion of variability is included.

Given the unavoidable problems and limitations with comparison of in situ measurements and satellite retrievals of cirrus microphysical properties, it would seem that solid conclusions could only be drawn if a large number of cases were included in the analysis. Unfortunately, that does not seem to be possible here given the limitations of the BTD threshold technique approach and the limited number of satellite/aircraft coincidences.

Specific comments:

1. The focus of the paper seems to be on evaluating effective radii determined from measurements made with the 2D-S probe and from traditional FSSP probes with inlets and no corrections for shattering. However, in the most interesting “intermediate” case, the authors switch over to using CDP measurements instead of FSSP measurements. There is no discussion of why this is done, and the manuscript discussion and conclusions seem to imply that the two probes are equivalent. However, as the authors acknowledge earlier in the manuscript, the CDP has no shroud or inlet and therefore is likely much less susceptible to particle shattering compared to the FSSP. The authors should therefore acknowledge that the “intermediate” case presented has no relevance to the evaluation of effective radii determined from FSSP probes.

2. At the end of the abstract, the authors state “There is no evidence to support that an FSSP-100 with unmodified inlets produces measurements of r_e in cirrus that are strongly biased low, as has been claimed.” They should also acknowledge that the evidence presented here does not convincingly demonstrate that FSSP-100 probes with unmodified inlets do not produce measurements of r_e in cirrus that are strongly biased low. The manuscript only provides one extreme small particle case study and one extreme large particle case study for comparison with the FSSP measurements. The BTD approach only provides a somewhat qualitative comparison (r_e larger or smaller than $\simeq$20 μm). As discussed above, the problems associated with comparisons leave open the possibility that the results are affected by sampling biases in the aircraft measurements.

In agreement with past studies, the results presented here indicate that effective radii determined from FSSP measurements in cirrus are considerably lower than those determined from 2D-S measurements (e.g. Lawson, 2011). The authors acknowledge that the comparisons with the BTD retrievals do not definitively indicate that either is incorrect. Korolev et al. (2011) presented comparisons between measurements made with a standard FSSP and an FSSP with the inlet and shroud removed. The com-

parison indicated that in ice clouds the standard FSSP response was overwhelmingly dominated by shattering artifacts. For a balanced presentation, the authors should acknowledge the results from the (Korolev et al., 2011) study.

3. Table 3 provides values of r_e determined from 2D-S measurements with and without shattering artifacts removed. The values are nearly identical, and the apparent point of showing this is to demonstrate that shattering has negligible impact on determination of effective radii. As discussed above, there is every reason to believe that the shattering problem is much more severe for FSSP probes with a shroud and inlet than for 2D-S probes that are designed to limit the possibility of shattering artifacts reaching the sample volume. The authors should acknowledge that the comparison presented in Table 3 is not relevant for the issue of shattering artifacts in FSSP datasets. A related issue is that accurate measurements of ice concentration are important. Effective radius is an important measure for determining cloud radiative effects, but knowledge of ice concentration is needed for understanding cloud nucleation processes as well as for predicting how the cloud will evolve over time. Even for the 2D-S probe, shattering can significantly affect ice concentration (Lawson, 2011). Note that the relative impact of shattering on 2D-S ice concentrations depends strongly on the concentration of natural small crystals (Jensen et al., 2010).

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