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Atmospheric Measurement Techniques Discussions

Interactive comment on "First correlated measurements of the shape and scattering properties of cloud particles using the new Particle Habit Imaging and Polar Scattering (PHIPS) probe" *by* A. Abdelmonem et al.

Anonymous Referee #3

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Review of "First correlated measurements of the shape and scattering properties of cloud particles using the new Particle Habit Imaging and Polar Scattering (PHIPS) probe" by A. Abdelmonem et al. Submitted for publication in Atmospheric Measurement Techniques Discussions

Recommendation: Should be acceptable for publication following mandatory revision.

This paper presents the design and operating principle of the PHIPS probe which is

meant to measure the 3-d morphology and corresponding optical and microphysical properties of individual cloud particles simultaneously. As there really is no probe in existence right now to measure the 3-d shape of cloud particles, and in that there are many unanswered questions in the relationship between distribution of ice particle shapes and sizes and scattering phase functions, this probe offers exciting possibilities for addressing some relevant and important scientific questions. The paper and instrument seem to be technically sound. The paper is highly relevant for AMTD given its focus on the operating principles, calibration and preliminary results from the PHIPS probe.

The weakest aspect of the paper was the lack of quantitative linkage between the measured ice crystal properties and the derived scattering properties. This should be improved before publication. Further, there should be a better link to some of the key questions in cloud-radiative interaction studies than is present in the current version of the manuscript. I recommend that these points be addressed by the authors before the paper is published. I also am including a couple of other points that the authors might want to consider in their revision of the manuscript.

As written, the paper currently gives a comparison between the measured phase function of a water droplet and one obtained from Mie theory, and between that of a columnar crystal and one derived from a ray tracing algorithm. I would have liked to have seen this analysis extended to additional measurements and to see how the comparison varied according to different aspect ratios. For example, Fu (2007) has examined how scattering properties vary with aspect ratio. In addition, given that one of the main mechanisms by which single-scattering radiative properties are represented in models is through the asymmetry parameter, I would have liked to have seen a comparison of the measured and modeled asymmetry parameters. One main issue in cloud-radiative interaction studies right now is that there are discrepancies between directly measured asymmetry parameters and those that are derived from measured size and shape distributions (Um and McFarquhar 2007). One possible candidate to explain this discrepancy is surface roughness (Yang et al. 2008). Can comparing asymmetry parameters and scattering functions over a series of aspect ratios reveal any additional information about surface roughness? Also, context should be given to this investigation by referencing past studies that have quoted surface roughness as a potential reason for discrepancies between measured and modeled scattering phase function.

The link to current questions in cloud-radiative interaction studies is weak. On page 2886, the authors talk about the use of ice crystal size distributions as input for optical scattering models like Mie theory, and state that the shape assumed in Mie theory is different from actual ice particle habits. Although Mie theory may have been used around 20 years ago to model ice crystal scattering properties, there are ample studies in the last 20 years that have used much more sophisticated methods for computing ice crystal scattering properties. Some such studies should be referenced (Takano and Liou 1995; Yang et al. 2000). Also, one of the big mysteries right now is why we cannot get closure between derived scattering properties (e.g., asymmetry parameter) and those derived from in-situ size/shape distributions using sophisticated libraries of single-scattering properties. Is this a result of surface roughness, inclusion of small ice crystals that are shattered artifacts, inadequate representations of ice crystal shapes that do not well match idealized habit models, etc. ? Referencing some such studies would provide a much better context for the development of this instrument and give the proper perspective for its development.

I think one of the ultimate goals of PHIPS would be for use on an aircraft. With that regards, there are a couple of useful additions that could be made to the manuscript. First, I note from the instrument description and Figure 2 that there is a sampling tube for the instrument. Is there a concern that shattering of large particles on this tube could cause small ice crystals to be swept into the sample volume in much the same way that occurs with other cloud probes (e.g., Field et al. 2003; McFarquhar et al. 2007)? Second, although the instrument may work well in a laboratory, will the response time of the instrument be sufficient to detect particles when operating at the true air speed

of an aircraft (shattering will also become more of an issue with the greater aircraft speeds)? Finally, the authors note the small detection volume for the PHIPS. Hallett (2003) examined the statistical significance of a measured particle size distribution by computing the integration time or distance that an aircraft would need to fly to measure at least 100 particles in each size bin. This could provide an interesting context for stating the sample volume of PHIPSâĂŤto me, this is much easier to understand than the statement that the maximum acquisition rates are 262 KHz and 10Hz for scattering phase functions and images.

Another main issue when calculating scattering properties from measured size/shape distributions is the fact that many ice crystals do not match the shapes of the idealized ice crystals for which libraries of single scattering properties are available (e.g., Yang et al. 2000). In fact, Korolev et al. (2003) found that about 98% of ice crystals measured in arctic clouds were irregular rather than having idealized shapes for which scattering libraries are available (e.g., bullet rosettes, columns, plates, aggregates of columns, dendrites, hollow columns, etc.). A big advantage of PHIPS in such situations is that the scattering phase function will be directly measured. However, I'm not sure how the two views will retrieve the 3-d cloud structure in such cases.

Minor Comments:

Page 2891, line 23. I would say that rosettes are a pristine habit. There are much more complex habits that exist, and these complex habits may dominate in some situations.

Page 2893, line 14, “pass” instead of “path”

Page 2896, line 16, remove “for this purpose”

Page 2898, particle classification. There are far more complex particle classification techniques in existence (e.g., differentiating rosettes, columns, plates, aggregates, etc.). Perhaps provide the context of the classification algorithm being used here.

Figure 3, is this figure needed?

Interactive comment on Atmos. Meas. Tech. Discuss., 4, 2883, 2011.