

Review of Abdelmonem et al. 2016

This article describes a unique new instrument that may be of significant interest to the atmospheric science community. The fundamental operation of this instrument is unchanged from the proven PHIPS instrument described in great detail in Abdelmonem et al. 2011, so I have little doubt that the design is sound. Given the comprehensive nature of the earlier AMT article with excellent instrument descriptions, theory, laboratory calibration data and cloud chamber data, this manuscript seems incomplete. Section 5 should be strengthened with the addition of significantly more laboratory data to verify the operation of the new instrument. I believe that this manuscript would also be enhanced by combining the results from field deployments (presumably to be included in part II).

As my expertise is not in aircraft flow characteristics of instruments or computational fluid dynamics, I will reserve any comments on section 4. I believe that the comments of Darrel Baumgardner in this area are sufficient. I will split my review into general comments on the remaining sections, followed by specific comments.

General Comments

Section 1: Introduction

There is a concerted effort in this section to describe a host of other aircraft deployed particle probes. This divergence is distracting because the PHIPS instrument is fundamentally different from forward scattering probes (FSSP, CDP, FCDP, SID), Optical array probes (2DC, 2DS, CIP, HVPS, etc.), and holographic imagers (HOLODEC). A discussion of these other probes is only relevant if a data inter comparison is to be presented in this article.

The PHIPS instrument is most similar to a combination of a Polar Nephelometer and a Cloud Particle Imager (CPI) so comparisons should be made to these instruments only. The PHIPS presents unique advantages by combining both of these instruments in one package, but the limitations compared to individual instruments should also be highlighted. The foremost of these is the very slow sampling rate for the imager, which may not be problematic in a cloud chamber but might limit sampling statistics for high speed aircraft sampling. Issues like these would best be addressed with inter comparison of aircraft flight data for co-located CPI, Polar-Nephelometer and PHIPS instruments.

Section 2: Basic Instrument Concept

This section is fine, but personally I find a schematic figure describing the features PHIPS (like Figure 1 of Abdelmonem et al. 2011) much easier to understand than the current Figure 1 in this manuscript.

Section 3: Basic Instrument Concept

Overall the description of the instrument components is reasonable. In the Imager section (3.1.2) the magnification of the camera is stated to be variable from 1.4-9.0, I would like to know what typical operating resolutions are. How big is the Field of View for a dual image of particles at various magnifications? These questions are answered for the earlier PHIPS instrument in section 2.1 of the Abdelmonem et al. 2011 article but are neglected here. The differences between the Cloud chamber and aircraft PHIPS instruments might be slight, but considering that new optical components (lenses and mirrors) are used in the PHIPS aircraft instrument it would be good to address the FOV and resolution for the imaging system again.

Section 5: Modeling of the Instrument Response and Detection Range for the Scattering Optics

Omission of any particle images is somewhat troubling. I am disappointed that no laboratory data is presented here for the imaging system. It should be fairly trivial to show images of the glass beads passing through the sample volume (as was done in Figure 4 of the 2011 PHIPS article). Images of the monodispersed particles would help to demonstrate the focus and sizing of the new instrument. Presumably the researchers have already preformed a sizing verification study with the imaging system, so including results from this work should be straightforward and not require additional tests. It would also be helpful to show results for different magnifications, since that is an option for this instrument.

The discussion of scattering theory and the Nephelometer design is reasonable and thorough, and I appreciate the detailed simulations in Figure 7. However, I am disappointed in the laboratory data presented in Figure 8. I am most concerned by the appearance of the “crosstalk corrections,” which are not mentioned in the previous sections or in the earlier 2011 PHIPS article. “Calibration factors” are mentioned in section 3.2 of the 2011 article but it is unclear what the difference between these and “crosstalk correction” is. While the discrepancy between observed phase function and a Mie theory phase function, might be explained by channel crosstalk, there is no effort to prove that this is the cause of the discrepancy. If an empirical correction factor is required, it should be extensively verified for as many particle sizes and types as possible. Different empirical corrections may be required for each particle type (aerosol, water, ice, etc.), and if that is the case than perhaps a redesign to eliminate PMT crosstalk would be warranted.

I will address my issues in order of importance:

1. I would like reasonable justification that channel crosstalk can explain the phase function discrepancy.

This could be accomplished by covering some of the collection optics (ever other channel, or all

channels except those with large deviation) and repeating the glass bead tests. If crosstalk is the explanation than you should see better agreement with the theoretical MIE curve with this simple test.

2. The description of the glass bead calibration procedure should be provided. It is unclear if the glass beads were aspirated through the sample volume (to simulate aircraft speeds) or simply allowed to fall through the instrument.
3. More particle sizes should be tested to verify the crosstalk correction factors. It should be fairly easy to test a multitude of mono-dispersed glass bead sizes in the simulated size regime (5-200um).
4. In addition to glass beads, a water droplet test should be performed to verify that the crosstalk correction factors are valid for particles with different index of refraction.

Specific Comments

1. Page 2 line 8. Here different scattering theories are discussed, and it is ostensibly implied that new Nephelometer measurements will help to improve our understanding of particle scattering. This is somewhat false because a “crosstalk correction” factor must be applied to the PHIPS data based on a theoretical Mie scattering curve. Therefore the Phase function data is constrained to Mie theory, so a discussion of other scattering theories is superfluous.
2. Page 2 line 39. Inter comparison between the CASPOL and a CPI would be more relevant to the PHIPS instrument, which records a true image of a particle unlike the SID instrument.
3. Page 7 line 8. In figure 2 the expected crosstalk value of 15% is stated, but here a value of 20% is presented. Which value is correct?
4. Page 17 Line 25. A maximum resolution of 2um for the imaging system is stated, but in section 3.1.2 a maximum resolution of 0.72um is implied (6.45um pixel / 9X magnification). Can you please explain how you arrive at a 2um resolution limit?