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Atmospheric Measurement Techniques
Discussions

Interactive comment on "In situ characterization of mixed phase clouds using the Small Ice Detector and the Particle Phase Discriminator" *by* P. Vochezer et al.

Anonymous Referee #2

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The paper describes data from the SID-3 and PPD, both of which are new instruments designed for mixed-phase and ice cloud studies. The paper is well written and includes a wide range of observations.

However, I have two major issues with this paper. The key weakness of the SID class of instruments is the extended sample volume of the main detector which, for typical mixed-phase clouds, leads to a high probability of two particles in the sample volume. This will lead to a false identification of small ice. The authors for the most part ignore this and concentrate on the coincidence of two particles within the much smaller trigger volume. The identification of a small number of just nucleated ice within a large

population of drops is the key measurement requirement of mixed-phase clouds. Only at the end of the paper do the authors discuss this problem and a manual classification of the scattering pattern images. Only with this manual reclassification is it possible to use SID-3 in mixed-phase cloud and there are no details on how this reclassification is done. The second issue is the discussion of ice crystal habit classification using the FFT of the scattering pattern. Again there are no details of how well this works, just that it does. For example what is particle size range, or the effect of particle orientation. Is it really only capable of distinguishing between irregular crystals and 'other habits'?

Abstract, line 11: There is no evidence within this paper for ice crystal habit classification, and roughness is not defined nor reported in any detail.

Introduction, line 1: The observation of small ice particles indicates recent ice formation by droplet freezing, ice multiplication processes and heterogeneous ice nucleation.

Introduction, line 7: Other instruments and techniques are mentioned but the ability to phase discriminate is dismissed quickly. Can the authors include the minimum particle size for which these other instruments are able to properly discriminate the phase.

Introduction, line 15: The scattering pattern observed with both the SID-3 and PPD also depends on the particle orientation. This dependence is not really discussed later in the paper but this weakness is crucial to understanding how well the crystal habit classification works.

Methods, SID-3 and PPD, line 24: The authors mention sensitive volume throughout the paper, but do not make it clear what volume they mean. For both the SID-3 and PPD there are two particle detecting volumes, the first defined by the trigger optical detector with simple pulse height and timing, and the second defined by the main optical detector with the detailed scattering pattern. The second main detector volume is much larger than the trigger volume which leads to high probability of second particles (other than that causing the trigger) to add to the scattering pattern.

Methods, SID-3 and PPD, line 17: The authors need to make it clear that 0.47mm2 is the trigger sensitive area (and 0.47*0.16=0.075mm3 the trigger sensitive volume). The sensitive area for SID-3 main detector is defined by the laser width and camera optics, probably around 1.2mm*8mm=9.6mm2 as discussed in Johnson et al 2014.

Methods, SID-3 and PPD, line 20: The sensitive area of the PPD is specified as 2.5mm2. This is a key property of these instruments and the authors should include the justification for using this. Is it for example, defined by the air stream focusing system with the PPD optical cell? If so, what range of sample flow rates is this valid for.

Analysis, coincident particle sampling, line 20: Only coincident sampling for the trigger sensing volume is discussed. This is the main weakness of the paper. The authors correctly state that coincidences are not an issue for particle concentrations often observed in clouds, but this is true only for the information from the trigger system, particle size derived from the pulse height recorded by the trigger PMT. Coincidences where two particles are within the much larger main detector sensing volume is not mentioned.

Analysis of scattering patterns, line 25: What is the resolution of the 'grey levels', is it 0 to 255 (8-bit) or higher?

Analysis of scattering patterns, line 1: The criteria for rejection of q<0.2 will bias the sizing and ice crystal habit classification. The authors need to discuss this in more detail.

Analysis of scattering patterns, equation 2: The variance Vaz is different to the asphericity Af used in Cotton et al 2010 and Johnson et al 2014. Is Vaz better than Af in terms of being able to discriminate drops and crystals? What is the value of N and what is the minimum number that still gives discrimination. For example, SID-2 has 28 azimuthal detectors so N=28. This is enough to discriminate drops and ice crystals in mixed-phase cloud, but it not enough to identify and reject coincident images where two particles are in the detector sensing volume. Knowing the minimum N would be very helpful if SID-2 where to be improved with higher resolution detectors (the CCD

technology in SID-3, while high resolution, is slow).

Size calibration, line 21: What is the accuracy of the drop sizing using the Mie angular dependence and how does this compare with the usual CDP type of measurement? What is the minimum size, presumably it is when the first secondary peak (those at 12 degrees in figure 3) is within the angular coverage of the detector.

Size calibration, line 8: Is the larger collection angle of the SID-3 trigger the reason for the increased irradiance between figures 4 and 5?

Size calibration, line 20: The non-linear behaviour of the camera image intesifier leads to the key conclusion that the main detector signal cannot be used for particle sizing. Can the authors plot the trigger signal versus the main detector signal to show more clearly this non-linearity. They should then change the image selection criteria q<0.2 to see if this is causing the non-linear behaviour.

Ice particle shape classification: This is a key capability of the SID-3 and PPD but the authors do not really show how well this works. The scattering pattern depends on particle orientation as well as habit.

Roughness analysis: This is mentioned briefly here but no other results or analysis. This section should be removed.

Quantification of specific particle types, line 24: The equation for Pthr=0.023 s/Tav, I assume that the s is seconds and should not be in the equation.

AIDA cloud chamber measurements, line 16: What do the typical scattering patterns look like for ice during the RICE 03 expansion, are they columns, plates or irregulars?

AIDA cloud chamber measurements, line 27: Why is the size detection threshold of the PPD so much higher than SID-3? Is it related to the angular coverage of the trigger detector? This does not explain the factor of five discrepancy in the total number concentrations in figure 11 between the PPD and the WELAS/SID-3 because according to figure 10, most particles are above the 7micron threshold.

Measurements during CLACE, line 14: In figure 15 the overlap between drops and ice crystals is explained as coincidences where two particles are in the sensing volume of the main detector. This coincidence is the big weakness of the SID class of instruments in mixed-phase cloud where the many small drops lead to a false signal of ice. The authors manually identify 2460 images out of 133,284 where coincidence of drops give a high Vaz (1.8%). Figure 11 indicates that the drop concentration was below 20cm-3, and using equation 1, the sensing volume of the main detector can be calculated as 9.5mm3 (as discussed in Johnson et al 2014).

Conclusion, line 3: The crystal shape deduction has not been adequately discussed and the roughness should not be mentioned.

Conclusion, line 8: The comparison of the total number concentrations, in figure 11, shows significant disagreement.

Figure 1: What is the gamma correction?

Figure 2: Why is the droplet azimuthal distribution not exactly flat? Is this scattering pattern not exactly central?

Figure 5: Is the band of scattered points to the right of the main band from coincidences? Can the authors include some scattering images.

Figure 7: If a future camera had higher sampling rate, how would the lines move?

Figure 15: This if similar to the scatter plots in Cotton et al 2010. Can the authors plot cumulative PDFs as in figure 9 of Cotton et al 2010 for comparison.

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