A High Speed Particle Phase Discriminator (PPD-HS) for the classification of airborne particles, as tested in a continuous flow diffusion chamber by Mahrt et al.

The authors present a new instrument, a High Speed Particle Phase Discriminator (PPD-HS), for phase discrimination of cloud particles. The instrument is an extension to the Small Ice Detector (SID) family but compared to the SID-3 and the Particle Phase Discriminator (PPD) it uses two CMOS arrays instead of a CCD camera. This modification allows recording of two 1D rows of scattering information, which reduces the amount of recorded data and allows higher detection rates of several hundred particle per second. The 1D scattering patterns are analyzed for their symmetry to discriminate between spherical and aspherical particles. The authors present characterization of the new instrument and have developed a supervise machine learning algorithm to automatically classify particles for their phase. The paper is well written and the used approach justified. However, few aspects should be addressed before publication.

Major comments

1. The random forest model was trained with a test particle dataset of droplets and NaCl particles. However, it is somewhat questionable if NaCl particles would be a good proxy for aspherical ice particles. Why the random forest model was not trained using real ice particles from the experiment where NH_4NO_3 aerosol was frozen at T = 223 K? Alternatively, would it have been possible to use SID-3 and PPD 3D scattering patterns of ice particles as training sets?

2. The authors do not discuss what is the upper size limit of the PPD-HS. Although the method is calibrated up to 32 μm using the test particles, the HINC experiments do not produce particles >10 μm. It is unclear how well the PPD-HS discriminates phase in the size range of 10-30 μm. For example, how would 1D patterns of large droplets with multiple rings be classified? Also, larger complex ice particles have 3D scattering patterns showing frequent speckles (as seen in Fig. 2b). How would the symmetry of such particles look like in the PPD-HS?

3. The dead time of the instrument (177 to 267 μs) is high and its consequences to sampling statistics are only discussed quantitively in the supplementary materials. However, this discussion should be incorporated into the main text. In chapter 5 the issue is mentioned but there is no discussion of the implications for future ice spectrometer and field measurements. If at a typical mixed-phase concentration of 100 cm^{-3} 100% or more particles are missed, how representative are the retrieved PPD-HS ice concentrations, especially if looking for the first ice? Consequently, the last sentence in the abstract should be modified accordingly.

Minor comments

p.2, line 18: "This is despite the knowledge that cloud particle size distributions comprised of a mixture of cloud droplets and ice crystals are affected by the presence of small ice particles". Please provide references.

p.2, line 34: Spherical particles can change the incident polarization state. The incident polarization state remains unchanged in the case it is linearly polarized (horizontal or vertical). This is why depolarization techniques use linearly polarized light.

p.3, line 1: Depolarization techniques are sensitive to even small changes from a spherical shape, e.g. spheres with surface roughness or oblate/prolate particles do cause a measurable depolarization signal. However, commercial polarization sensors, like the one used in Zenker et al., 2017, can have difficulties discriminating small ice particles from droplets. These two techniques should not be mixed.

p.3, line 3: The ability to discriminate phase based on particle shape depends on the used method. Shadow imaging and optical microscopy in best case have an optical resolution around 2 μm and, thus, cannot be used to discriminate the phase of small (<50 μm) cloud particles. 2D diffraction patterns can reveal more details that cannot be resolved by traditional imaging methods.

p.3, line 9: small-scale complexity, please add the following references: Ulanowski et al., 2014; Schnaiter et al., 2016

p.7, line 4: The discussion of the electronic dead time is crucial for understanding the instrument performance and should be added to the main text. The dead time of 177 to 267 μs is high compared to other cloud instrumentation, which will lead to reduced sampling volume. Fig. S11 shows that at a typical mixed-phase concentration of 100 cm^{-3} 100% or more particles are missed, which will have severe consequences for detecting ice in mixed-phase conditions.

Fig. 2: The example droplet (a) is a larger droplet with multiple visible rings that does not correspond with the scattering data from CMOS array (d) that shows 1 or possibly 2 maximums corresponding to a small droplet. How would scattering data from a larger droplet with multiple rings look like?

p.11, line 20: Are the calibration datasets from the VOAG experiments representative for cloud particles? First, the particle sizes are limited to 32 μm, whereas ice crystals can be significantly larger. More importantly, are salt particles a good proxy for ice crystal shapes? Why not use HINC experiments in cirrus conditions as training data sets?

p.13, lines 4-5: The scattering cross section of aspherical particles between 10.6° to 101.0° can be very different to NaCl. Therefore, it cannot be stated that PPD-HS correctly sizes all aspherical particles <20 μm.

Fig. 4: Please explain $d_{o,g}$ and $d_{a,g}$ in the figure caption.

Fig. 7: All the particle concentrations are given as counts and not as number concentrations within a volume. Since the sensitive area of the PPD-HS is known the instrument counts can be converted to concentrations. Also, it would be illustrative if the mean modal diameter would be marked in panel e.

P. 24, line 8: What would be the maximum data acquisition rate of the RT-electronics if using priori specified parameters?

P. 25, line 12: Please define small.

References

Schnaiter, Martin, et al. "Cloud chamber experiments on the origin of ice crystal complexity in cirrus clouds." *Atmospheric Chemistry and Physics* 16.8 (2016): 5091-5110.

Ulanowski, Zbigniew, et al. "Incidence of rough and irregular atmospheric ice particles from Small Ice Detector 3 measurements." *Atmospheric Chemistry and Physics* 14.3 (2014): 1649-1662