Inter-comparison of size distribution measurements in cloud expansion studies

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In cloud expansion studies, the size distribution of droplets and/or ice particles is measured using optical particle counters (welas, Benz et al. (2005)). In addition, other instruments are in addition able to distinguish the particle phase by the forward scattering from particles (PPD) or by backscattering linear depolarisation ratio (SIMONE, Schnaiter et al. (2012)). The method of retrieving the size information from the measured spectra varies, but is usually based on Mie scattering of liquid droplets. As result we get the equivalent forward, side or backward scattering diameter of measured droplets based on the instrument used.

It is not established, what instrumentation is optimal for getting the most accurate information from size distribution in expansion chamber experiments. In our work we compare and evaluate the quality of size distributions retrieved from optical measurements from welas and from PPD. Based on our inter-comparison, we discuss the validation and weaknesses of both instruments and give recommendation on how to measure droplet and ice distributions.

The experimental results presented here were conducted in the AIDA (Aerosol Interaction and Dynamics in the Atmosphere) cloud chamber (i.e. Möhler et al. (2003)) during the INUIT-3 campaign. As test particles we used polydisperse Snomax and Illite dust aerosol or monodisperse Snomax and Illite dust aerosol combined with sulphuric acid. The starting temperatures of the experiments varied from 268 K to 246 K.

Figure 1 shows one expansion experiment run from the campaign. The pumping of the chamber was started at the time 0 seconds. When the temperature dropped to 243 Kelvins at around 80 seconds, we observed the formation of droplets by an increase in particle diameter measured by welas and PPD. The droplet formation is also seen in the increase of forward and backward scattering measured by SIMONE. At around 400 seconds after the pumping was started, ice particle formation was iniated. This was detected simultaneously by an increase of the depolarization ratio measured by SIMONE and the particle counters welas and PPD. The size range of droplets given by welas and PPD are comparable, but the ice particles detected by PPD seem to be smaller than those detected by welas. In addition, according to PPD the ice particles are growing straight from droplet mode, while in welas measurements a gap between droplet mode and ice mode is observed. This relates to different angular ranges that are used for interpretation of the scattering from the ice particles. The welas is measuring close to 90° scattering angle where ice particles show enhanced scattering compared to droplets of the same volume. Freezing of a droplet already leads to a sudden increase of the measured optical size.

In future work we want to compare the statistics of both size distributions during the times when just droplets or ice particles are present. We will compare the size distributions measured for Snowmax particles and Illite particles. Here, our goal is to determine how well the sizing works for different used aerosol types and for spherical droplets compared to non-spherical ice particles. As shown in fig. 1, we expect differences in the ice particle size distribution measured with welas and PPD, but for droplets both should agree.

The final step in our work is to reconstruct the depolarization ratios measured with SIMONE by using the size distributions measured with PPD and welas fitting the Mie-theory to those size distributions assuming single shape for the particles. By comparing the modelled depolarisation ratios to the measured ones, we are able to know if it is possible to have closure for one or both instruments to measure the size distribution.

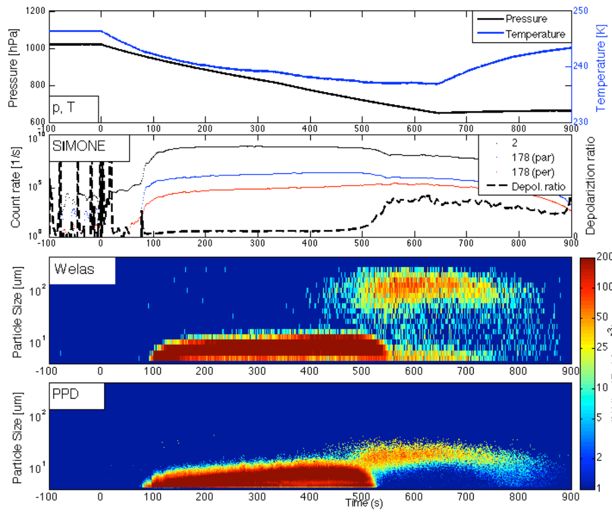

Figure 1. Pressure and temperature, SIMONE forwards scattering, backward scattering and depolarization ratio and the size distribution plots from welas and PPD during one expansion experiment.

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