A new device for the investigation of nucleation, dynamic growth and surface properties of single ice crystals

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Because a) the nucleation and growth of atmospheric ice particles is of great importance for both, weather and climate on earth, and b) the knowledge considering the influence of ice particle surface properties on the radiative properties of clouds is still sparse, we developed a new device to investigate nucleation, dynamic growth and light scattering properties of a fixed ice crystal in dependence on the prevailing thermodynamic conditions. The instrument is based on our experiences with the laminar flow tube chamber LACIS (Leipzig Aerosol Cloud Interaction Simulator, Stratmann et al., 2004). Connected to the flow tube is a SID3-type (Small Ice Detector, Kaye et al., 2008) instrument. This instrument, called LISA (Leipzig Ice Scattering Apparatus), has been additionally equipped with an optical microscope. A single ice nucleus (IN) with a dry size of 2-5 micrometer is attached to a thin glass fiber and positioned within the optical measuring volume of LISA. The fixed particle is exposed to the thermodynamically controlled air flow, exiting the flow tube. Two mass flow controllers adjusting a dry and a humidified gas flow are applied to control both, the temperature and the saturation ratio. The thermodynamic conditions in the experiments were characterized using a) computational fluid dynamics (CFD) calculations, b) temperature and dew-point measurements, and c) evaluation of droplet and ice particle growth data. Dependent on both, temperature and saturation ratio, ice nucleation and ice particle growth/shrinkage occur and can be studied. Thereby, the optical microscope allows a time dependent visualization of the particle/ice crystal (Fig. 1a), and the LISA instrument is applied to obtain 2-D light scattering patterns (Fig. 1b). Both devices together allow to investigate the influence of thermodynamic conditions on ice particle growth, the particle shape and its surface properties.

In first experiments we could show the feasibility of the setup to investigate droplet activation, as well as ice particle nucleation and growth. We successfully performed condensation freezing and deposition nucleation experiments considering kaolinite and Snowmax™ (Johnson Controls Snow, Colorado, USA) particles. Thereby, we could prove that different temperatures and saturation ratios result in different growth rates and ice crystal shapes, but also in different surface properties. Examplarily, Fig. 2 shows the time dependent evolution of ice particle size and relative surface roughness (0 – smooth, 1 – rough) calculated from the LISA data. In general, comparing simple ice particles (like single columns) with more complex crystals (such as dendrites), the surface roughness value is larger for the latter ones. But in the experiments we also found that, regarding one single ice crystal, the surface roughness can be also modified by (small) variations of the prevailing thermodynamic conditions. Thereby, the surface roughness tend to increase for growing, and to decrease for shrinking ice particles. We could also prove that these findings are independent of the absolute particle size (Fig. 2). Further investigations and data evaluation are ongoing.

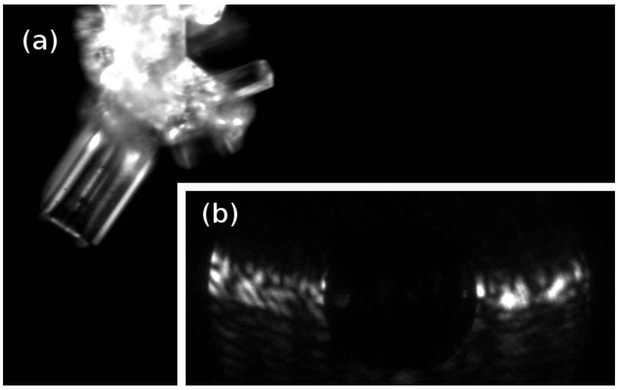

Figure 1. Example for a microscope picture of ice crystals growing over the fibre (a) and the corresponding scattering pattern measured with LISA (b).

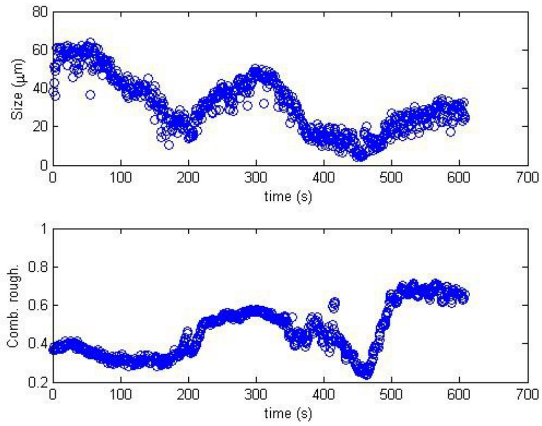

Figure 2. Example for the time dependent evolution of ice particle size and combined surface roughness.

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