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A ’virtual wall’ ice reaction chamber for growing airborne ice crystals to investigate their interaction with volatile organic compounds (VOC) under laboratory conditions

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Interactions of volatile organic compounds (VOC) with airborne snow and ice crystals play an important role in atmospheric transport processes and precipitation formation. In laboratory studies using stationary ice crystals, an uptake of lower volatile aromatic hydrocarbons (AH) from the gas phase could only be observed during vapor depositional ice crystal growth, whereas there was no adsorption of AH on non-growing ice crystals (Fries et al. 2006, 2006a). Since the detected concentrations of AH resulting from gas-scavenging processes were rather low, other pathways, e.g. scavenging on aerosol particles and via ice nucleation must exist to explain the observed amount of AH in atmospheric ice crystals.

We present a new experimental approach that enables the generation of airborne ice crystals on aerosol particles acting as ice nuclei either consist of AH or are covered with these compounds. The constructed ’virtual wall’ ice reaction chamber inside a walk-in cold chamber in the laboratory allows the investigation of gas- and particle scavenging. Its operating principle is molecular water vapor diffusion from the moist inner chamber wall heated at a temperature (T) of 278 K into a cold air mass (T= 253 K). This leads to supersaturated conditions with respect to ice. Temperatures at the chamber outlet were kept well below the freezing point to prevent the grown ice crystals from unwanted melting prior to detection. Measured temperatures in different heights across the chamber diameter show a profile according to Poiseuille's law with a distinct reaction zone characterized by well-mixed conditions and a laminar sharp 'jet stream' of cold air in the centre. The experimentally observed temperature profiles demonstrate the feasibility of the chamber for heterogeneous ice crystal formation within residence times up to one minute given by the size of the effective reaction zone and the chosen flow rate of 30 L*min^{-1}. To verify the laboratory results, theoretical considerations based on Nernst's equation were made which allow a rough estimation of the ice mass grown in a certain amount of time. Furthermore, hydrodynamic parameters like Prandtl-, Reynold- and Peclet number were theoretically determined. The results indicate laminar flow conditions with only negligible turbulence and are in good agreement with the measurements of temperature profiles after Poiseulle.

In addition Sahara dust particles were injected in the ice reaction chamber. Ice crystal formation was proven with an optical particle counter developed by Bundke et al. (2006). However, at present only a few ice crystals of usable size range ($d_p \sim 3.5\ \mu m$) were grown per liter and there is still potential for optimization. First approaches like slight modifications of the process parameters and the realization of a second reaction zone downstream of the chamber outlet will be discussed.