THE VARIABILITY OF ICE NUCLEATING AEROSOLS OVER CENTRAL EUROPE

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1. Introduction

The role of ice nuclei (IN) in the development of clouds and precipitation is poorly understood. Understanding the growth of hydrometeors and development of precipitation from mixed-phase clouds in a given situation requires knowledge of the generation of primary ice. Therefore, the number concentration of ice nuclei and their activation behavior have to be known. We attempt to characterize the natural variability of ice nucleus concentration as a function of airmass history and degree of pollution. This may serve as a basis to further study the sensitivity of cloud microphysical development on the conditions of primary ice initiation.

We report measurements of ice nuclei concentration on a diurnal basis at the Taunus Observatory on Mt. Kleiner Feldberg (825 m above sea level), about 25 km north of Frankfurt/M, Germany. Sampling conditions includes airmasses of continental, marine, subpolar or subtropical character, and various degrees of pollution. Interpretation is based on trajectories, local meteorological and air pollution data and aerosol physical spectra in the 5-1000 nm size range.

2. Experimental Method and Results

Aerosol has been sampled on substrates. Samples were analyzed in a static vapor diffusion processing chamber. Substrates are exposed to temperatures of between -5°C and -25°C and to supersaturation with respect to ice of 0 to 40%. Ice crystals grow by deposition and condensation freezing. They are viewed by a CCD camera, and are counted automatically. The experimental setup of the processing chamber FRIDGE (Frankfurt Ice Nuclei Deposition freezInG Experiment) is described by Bundke et al. (2008) and by Ardon et al. (2008) in the proceedings of this conference.

The sampling of aerosol on filters and subsequent processing and detection of ice nuclei is a well established technique and has been applied since several decades, using chambers of various designs (Bigg, 1963, Gravenhorst and Meyer, 1976). In the past, intercomparisons (Vali, 1975) had shown large differences of deposition mode freezing IN concentrations measured by various methods. However it appears that continuous-flow-device measurements (e.g. Rogers et al., 1982; Al-Naimi and Saunders, 1985) exhibit roughly a factor of 10 higher concentrations of IN at warmer temperatures than filter processing systems (Levin and Cotton, 2007). A recent intercomparison of techniques for the measurement of ice nuclei (Moehler et al., 2008) again revealed a large underestimate of IN number concentration by the technique of filter sampling and subsequent processing and detection in a vacuum diffusion chamber. While the processing chamber and detection system successfully reproduce the nucleation characteristics (temperatures and supersaturations at the onset of icing) of various test substances like silver iodide, kaolinite and Arizona test dust ATD (see Figure 1) it obviously underestimates the number of natural ice nuclei present in an aerosol sample on a filter substrate. We currently believe that this may be caused by the recondensation of Vaseline ® organic vapour onto the active ice nucleating sites of aerosol particles during filter processing. During filter processing under
vacuum a small amount of Vaseline ® is applied to improve the heat conduction from the filters to the cooling plate underneath and to inhibit condensation and freezing at the metal surface of the filter support.

Figure 1. Ice onset temperatures of Silver iodide (AgI), Kaolinite, Illite measured by FRIDGE and FINCH and Arizona Test Dust (ATD) measured with FINCH in comparison with data published by Schaller and Fukuta (1979), Salam et al. (2006), Zimmermann et al. (2007). Adapted from Bundke et al., (2008)

As a new approach to the quantitative sampling of ice nuclei on substrates we have recently set up a device for the charging of aerosol in a sample air flow and its subsequent electrostatic precipitation onto the surface of 47 mm diameter circular silicon wafers (yet unpublished). The design of the Electrostatic Aerosol Collector (EAC) is shown in Figure 2.

These substrates are then processed in the chamber. In atmospheric samples (urban air) collected in parallel on filters and on wafer substrates the IN concentration on the wafers on average was higher by a factor of 45 (Figure 3). This finding is supported by the relatively good agreement (Figure 4) between atmospheric IN concentrations (urban air) sampled with this new technique and those measured by the continuous–flow IN instrument FINCH (Bundke et al., 2008) during parallel measurements in our laboratory. In contrast, our previous intercomparisons pointed to a serious underestimate of the ice nuclei concentration by the filter method.
Figure 2. Design of the Electrostatic Aerosol Collector developed at the University Frankfurt. Particles are precipitated in a field of corona-discharge.

Figure 3: Analysis of parallel samples on wafer/filter (30 l) at -14°C. Results of the filter analysis are shown in blue, while results of the wafer analysis shown in red. Thick lines represent average values, with standard deviation (black bars). The sampled aerosol is ambient aerosol from Frankfurt.
Figure 4: Comparison between the FRIDGE – Chamber (sampled of wafers, green lines) and the Fast Ice Nucleus Chamber FINCH (described in Bundke et al., 2008).

Furthermore, for Arizona test dust sampled with the new technique at our laboratory the nucleating conditions for activation of a 0.1% fraction of ATD matches the envelope of data obtained from other instruments during the ICIS campaign reasonably well (Figure 5).

Figure 5: Threshold of 0.1% Ice-Nuclei activated fraction of Arizona Test Dust – Particles. Dust from an aerosol-generator was dispersed in a clean air flow and collected on silicon-wafers. Red diamonds show the FRIDGE-Results. Total Particle Concentrations were measured with a CN-Counter.
Figure 6: Measurements of particle concentration (TSI WCPC 3785, upper part) and ice nuclei concentrations (lower part) for a sequence of days at the Taunus Observatory Mt. Kleiner Feldberg. Ice nuclei concentrations are shown for -8°C, -13°C, and -18°C.

Measurements of the concentration of atmospheric ice nuclei using the electrostatic precipitation onto silicon wafers were started at the Taunus Observatory on regular basis. First results (Figure 6) show IN to be highly variable between 10 to 160 IN/L, with their mean of 49 IN/L at -18°C and water-saturation being roughly a factor of 100 higher during that period than the mean of 0.5 /L reported for this location by Stein (1984).
3. References

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Acknowledgements: We gratefully acknowledge financial support by the German Science Foundation DFG under “SFB 641: The tropospheric ice phase”. 