Ice Nucleation Measurements using PNNL mobile ice chamber: Immersion freezing spectra

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Motivation

Immersion freezing is the most important ice nucleation freezing mechanism in mixed-phase clouds that persists between 0 to ~-38°C. The immersion freezing becomes more efficient with decreasing temperature, and the INP efficiency highly depends upon physical and chemical properties of the aerosol particles. The sensitivity of fraction of ice-containing clouds towards the aerosol sources are shown in figure 1.

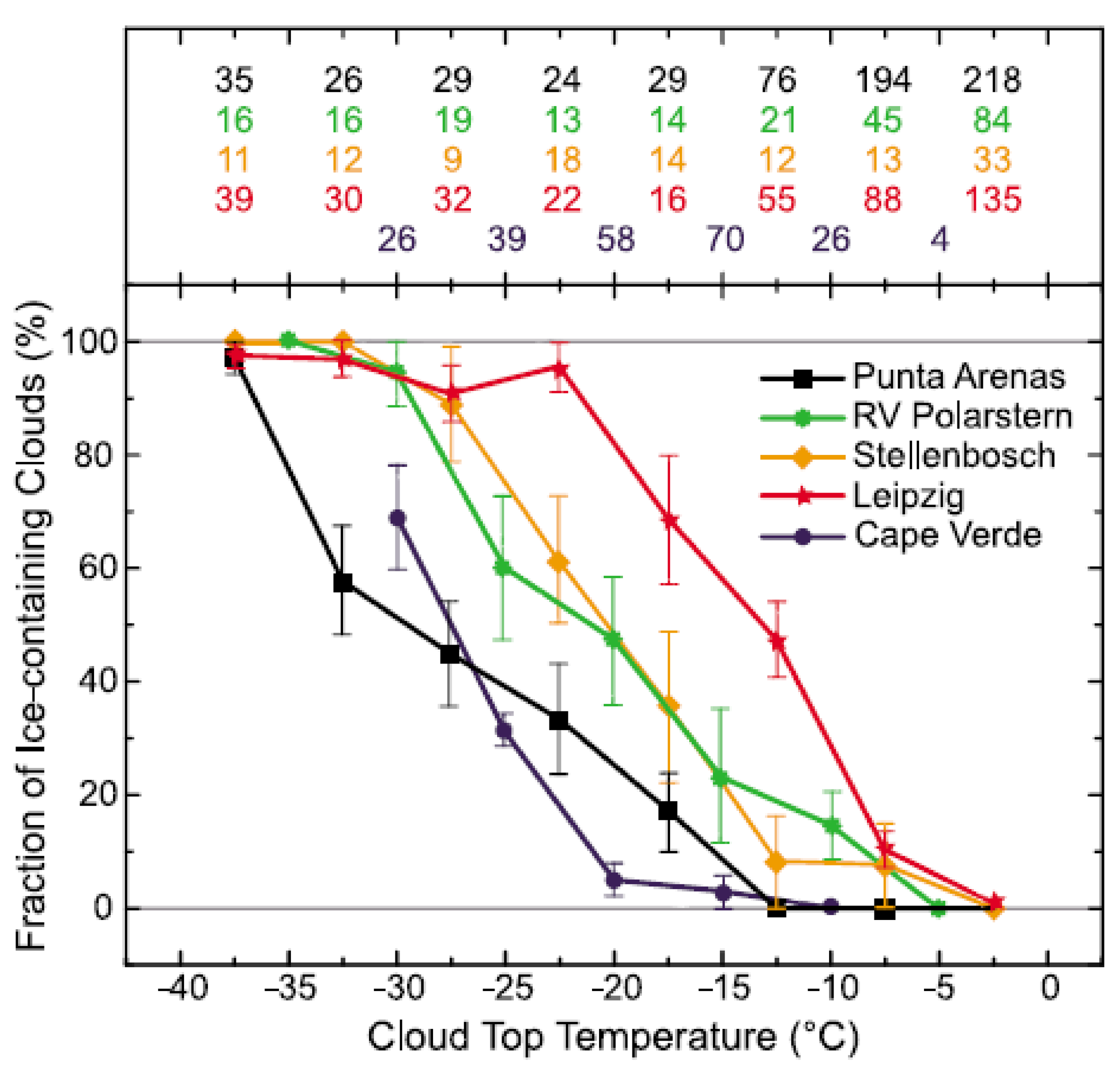

Figure 1: Fraction of ice-containing clouds (adapted from Kanitz et al (2011)) at various locations determined using polarization lidar. Reference: Kanitz, T., et al. (2011), Geophys. Res. Lett., 38, L17802.

The immersion INP efficiency is investigated using various methods, for *e.g.* cloud expansion chambers: AIDA and Manchester cloud chambers, single droplet freezing substrate technique where single droplet contains multiple aerosol particles and using continuous flow diffusion chambers (CFDC) where freezing efficiency of single droplet (containing individual aerosol particle) can be determined in real-time. The current CFDC design can be further improved to obtain immersion freezing spectra at higher temporal resolution, close to the precision level as CCN instrument and without droplet breakthrough ambiguity. Such measurements are useful where ambient particle concentration is low and mixing state of particles is rapidly changing.

Performance Validation

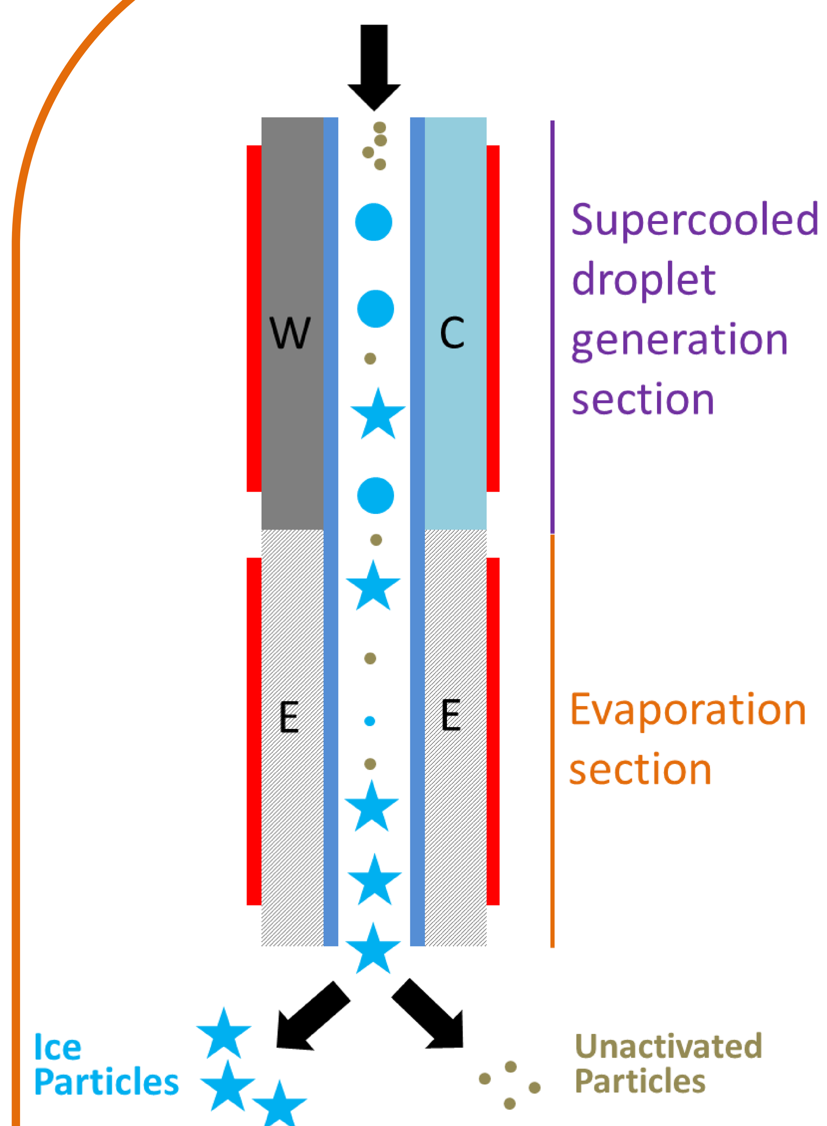

Figure 2: A vertical cross-section of the portable ice nucleation chamber. The supercooled droplets are generated within the top section of the chamber, which is held at constant temperature and humidity conditions. The temperature of the bottom section of the chamber, called evaporation section, is varied to obtain the freezing efficiency of supercooled droplets.

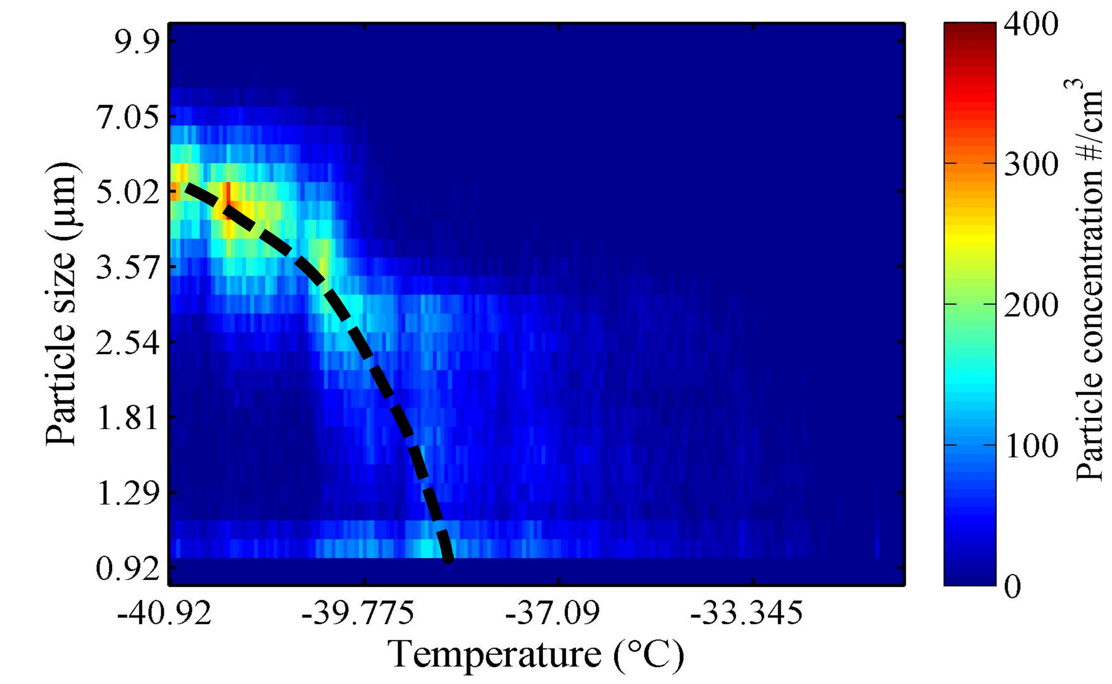

Figure 3: Validation experiment using size-selected ammonium sulfate particles. Homogenous freezing of supercooled aqueous droplets begins at ~ -37 °C.

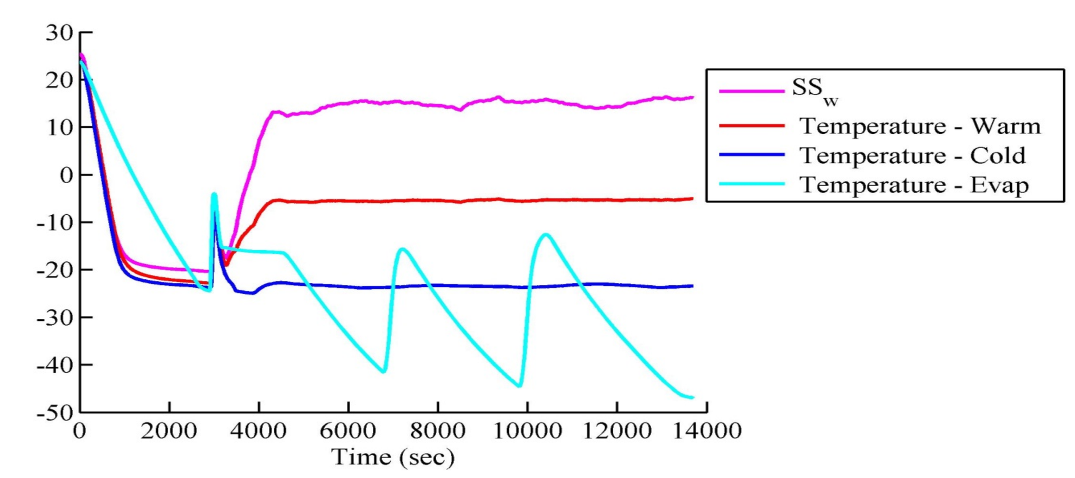

Figure 4: (left)Temperature and supersaturation with respect to water conditions inside the portable ice nucleation chamber. The temperatures of warm and cold plates are held constant, and the temperature of evaporation section is continuously varied to obtain the high resolution immersion freezing spectra.

Preliminary results and summary

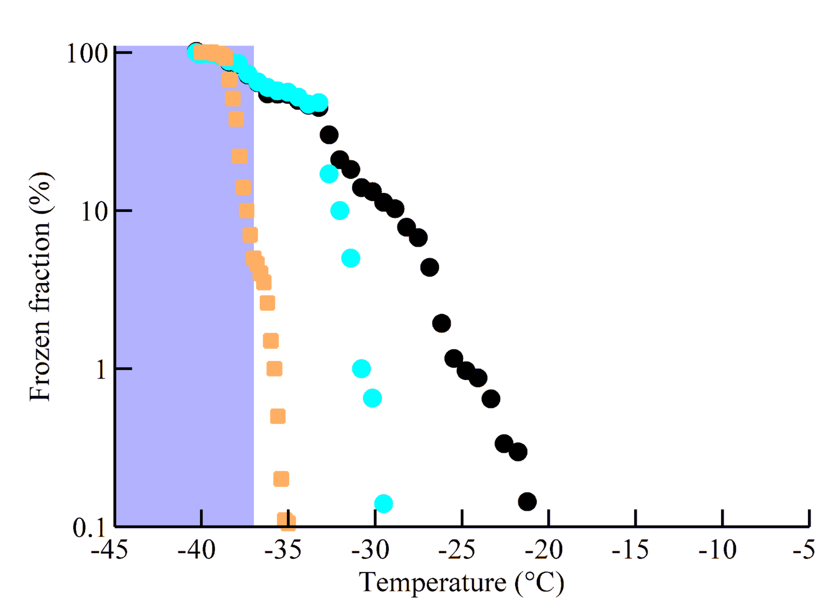

Figure 5: Homogeneous freezing of sulfate droplets (orange) and heterogeneous freezing of soil dust (black) and treated soil dust (green).

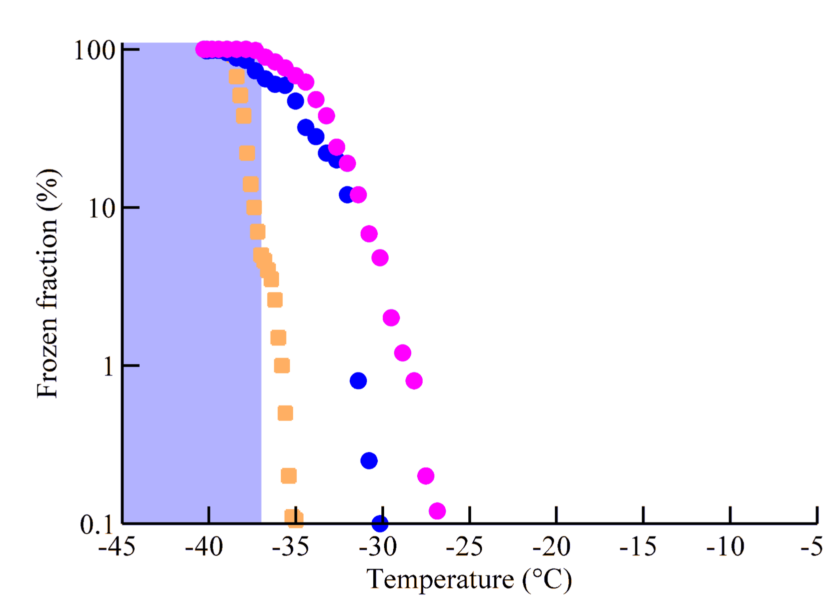

Figure 6: Heterogeneous freezing efficiency of illite (blue) and kaolinite (magenta) mineral dust particles (400 nm).

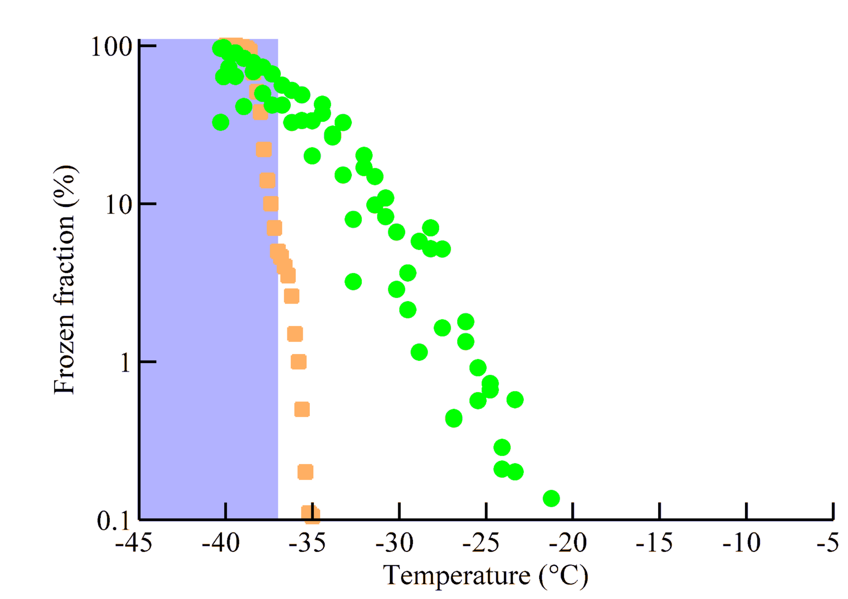

Figure 7: Heterogeneous freezing efficiency of ambient particles (< 2.5 µm).

New chamber allows to obtain immersion freezing spectra (-15 to -40°C) at high temporal resolution, as fast as under 30 minutes, in real-time, and the chamber operation do not suffer from droplet breakthrough artifact.

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