Efficiency of aerosol particles at nucleating ice as a function of size at Alert, Canada during the Polar Spring

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Introduction

Ice nucleating particles (INPs) are a small subset of aerosols that can trigger heterogeneous freezing in the atmosphere. They can influence climate and the hydrological cycle by acting as nuclei for ice clouds and mixed-phase clouds[1]. In order to improve climate predictions, characterization of INP properties is needed, such as the freezing efficiency. Here we investigated the efficiency of aerosol particles at nucleating ice as a function of size at Alert, Canada during a 3-week campaign in March, 2016.

Questions

- What is the size distribution of INPs and total aerosol particles?
- How does the freezing efficiency change as a function of size?
- Can the size distribution of INPs be explained by the size distribution of total aerosol particles with different freezing efficiencies of each size mode?

Methods

Aerosol particles with sizes from 0.1 to 10μm were collected on hydrophobic glass slides using Micro-Orifice Uniform Deposit Impactor (MOUDI). INP concentrations were measured with the droplet freezing technique (DFT).[2] The aerosol particle concentrations were determined with scanning mobility particle sizer (SMPS) and optical particle counter (OPC).

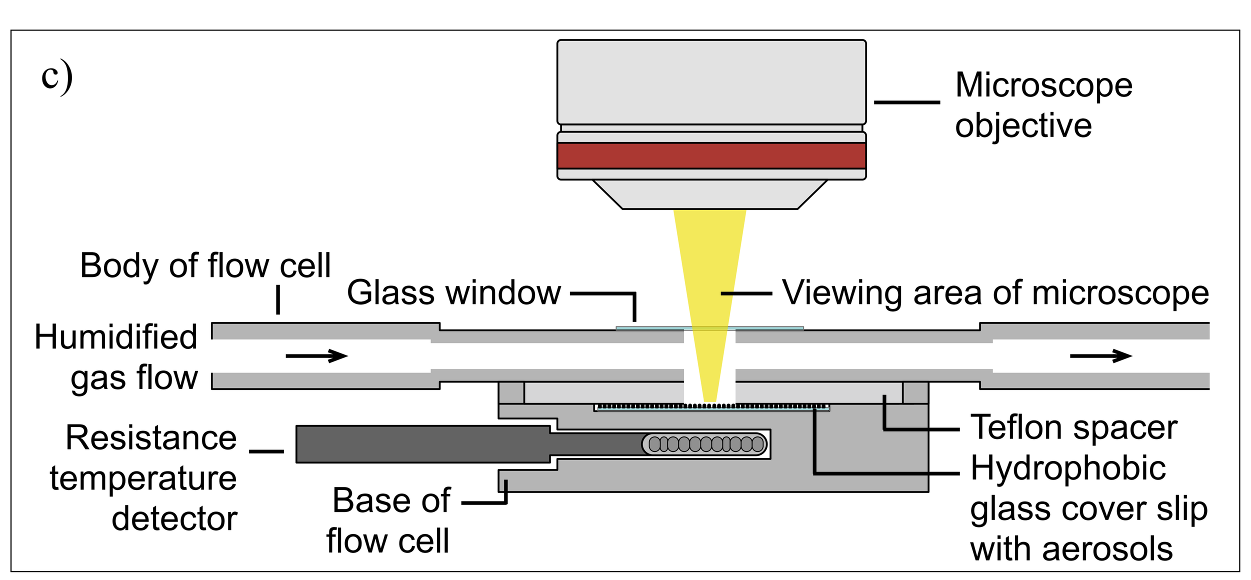

Figure 1. a) Location of Alert; b) MOUDI; c) Schematic of DFT setup

Results I

- Size distribution of INPs and total aerosol particles.
- Fraction of INPs ≥1μm is 0.77 at -15ºC, 0.73 at -20ºC, 0.68 at -25ºC
- Particles ≥1μm represent 0.2% of the total numbers and 9.5% of the total surface areas of aerosol particles

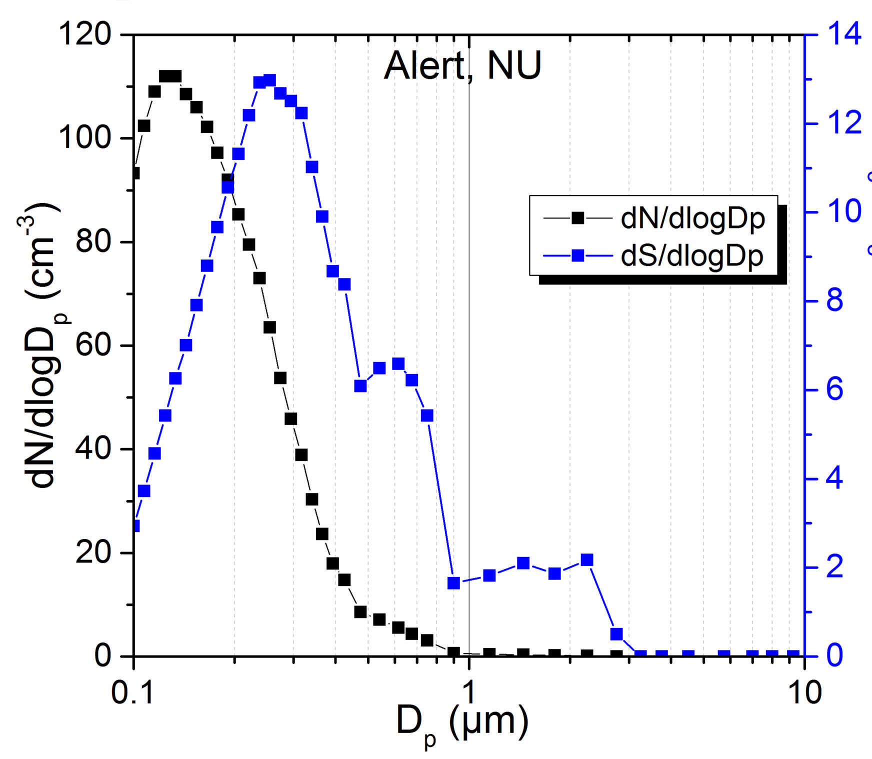

Figure 3. The number (N) and surface area (S) size distributions of total aerosol particles.

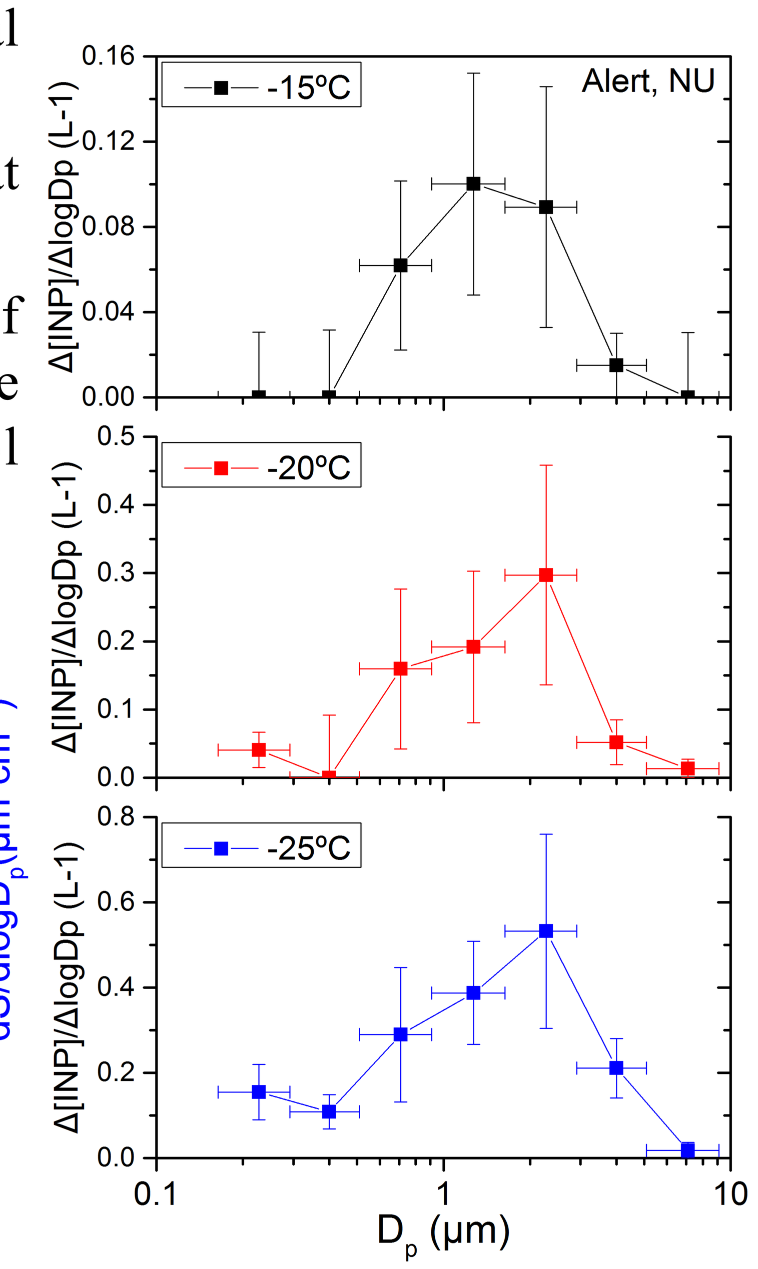

Figure 2. Number distribution of INPs at -15ºC, -20ºC and -25ºC, respectively.

- Freezing efficiency as a function of size. When size changes from 4μm to 0.2μm, INPs/particle decreases by 5 orders of magnitude, and INPs/surface area decreases by 3 orders of magnitude at -25ºC.

$$\frac{INPs}{particle} = \frac{N_{INP}}{N_{aer}} \qquad \frac{INPs}{surface\ area} = \frac{N_{INP}}{S_{aer}}$$

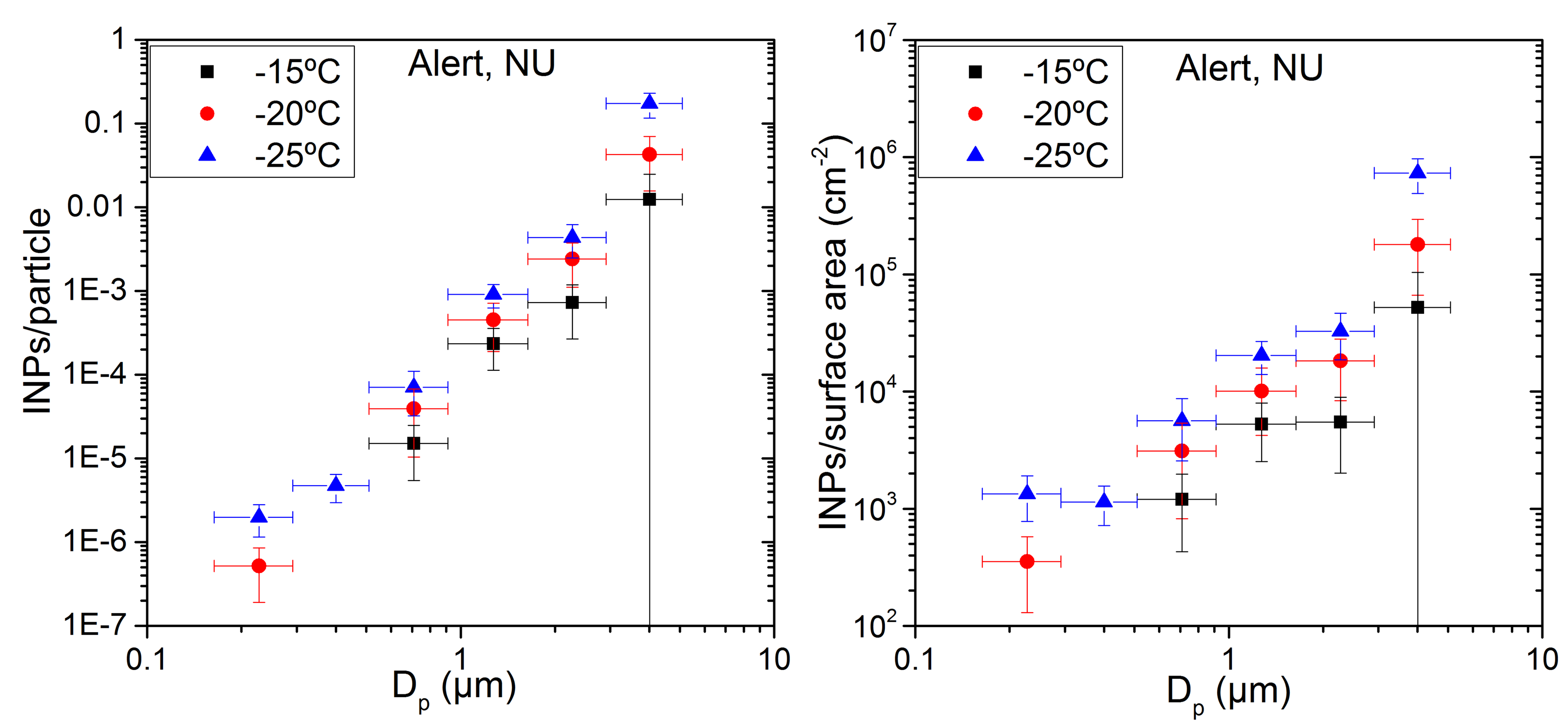

Figure 4. Freezing efficiency as a function of size at -15ºC, -20ºC and -25ºC, respectively.

Results II

- The surface area distribution of aerosol particles can be described as the sum of n lognormal distributions[3] (three modes in this case), where N_i is the number concentration, $\overline{D}_{pi}$ is the median diameter and σ_i is the standard deviation of each mode. By using the n_s ($n_s \approx$ INPs/surface area) values shown in Figure 4 for each size mode, the INP number distribution can be well explained.

$$dS/dlogD_p = \sum_{i=1}^{n} \frac{\pi D_p^2 N_i}{(2\pi)^{\frac{1}{2}} log\sigma_i} exp\left(-\frac{(\log D_p - log\overline{D}_{pi})^2}{2log^2\sigma_i}\right)$$

	Mode 1	Mode 2	Mode 3
N_i (cm^{-3})	68	0.7	0.2
$\overline{D}_{pi}$ (μm)	0.14	0.6	1.2
σ_i	1.7	1.25	1.6
n_s at -15ºC (cm^{-2})	0	1.1E+03	5.0E+03
n_s at -20ºC (cm^{-2})	3.3E+02	3.0E+03	1.0E+04
n_s at -25ºC (cm^{-2})	1.1E+03	6.0E+03	2.0E+04

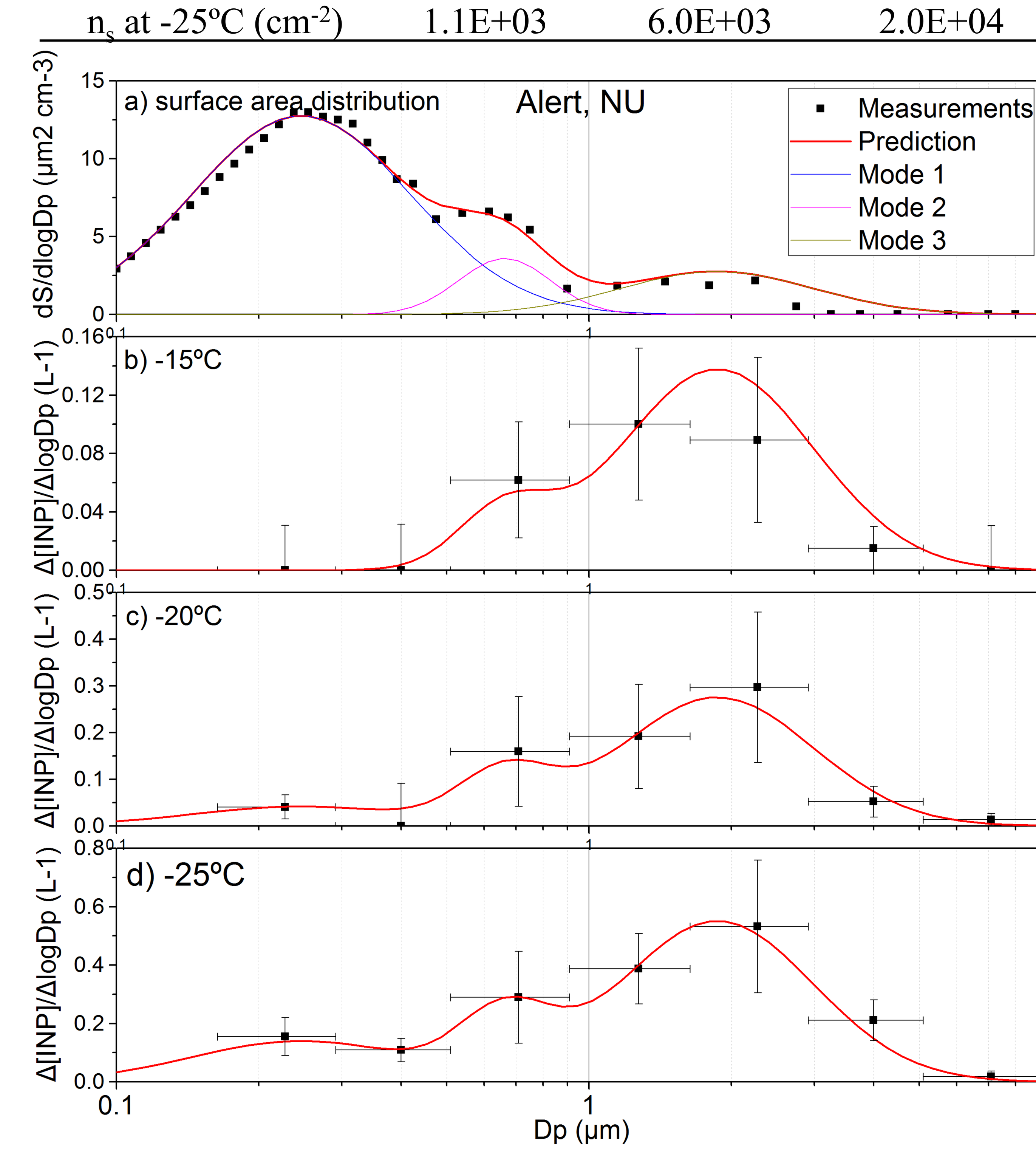

Figure 5. Prediction of aerosol surface area distribution and INP number distributions using the parameters in the table above.

Conclusions

- Supermicron particles only make up a small fraction of total aerosol particles, but contribute to a large fraction of INP concentrations.
- The freezing efficiency of aerosol particles depends strongly on size with large particles being more efficient.
- The INP distribution can be well explained by combining the size distribution of aerosol particles with different n_s values for each size mode.

References and Acknowlegement

[1] Ramanathan, V., Crutzen, P.J., Kiehl, J.T., Rosenfeld, D., Aerosol, Climate and the Hydrological Cycle, Science, 294, 2119-2124 (2001)

[2] Mason, R.H., Chou, C., *et al.*, The micro-orifice uniform deposit impactor-droplet freezing technique (MOUDI-DFT) for measuring concentrations of ice nucleating particles as a function of size: improvements and initial validation, Atmos. Meas. Tech., 8, 2449-2462 (2015)

[3] Seinfeld, J.H., Pandis, S.N., Atmospheric chemsitry and physics: from air pollution to climate change. Hoboken (NJ), Wiley, P370 (2006)

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