New cloud chamber studies on the ice nucleation efficiency of airborne bacteria

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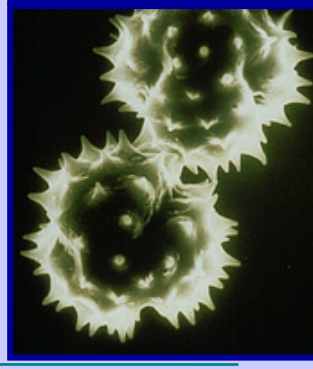


Outline

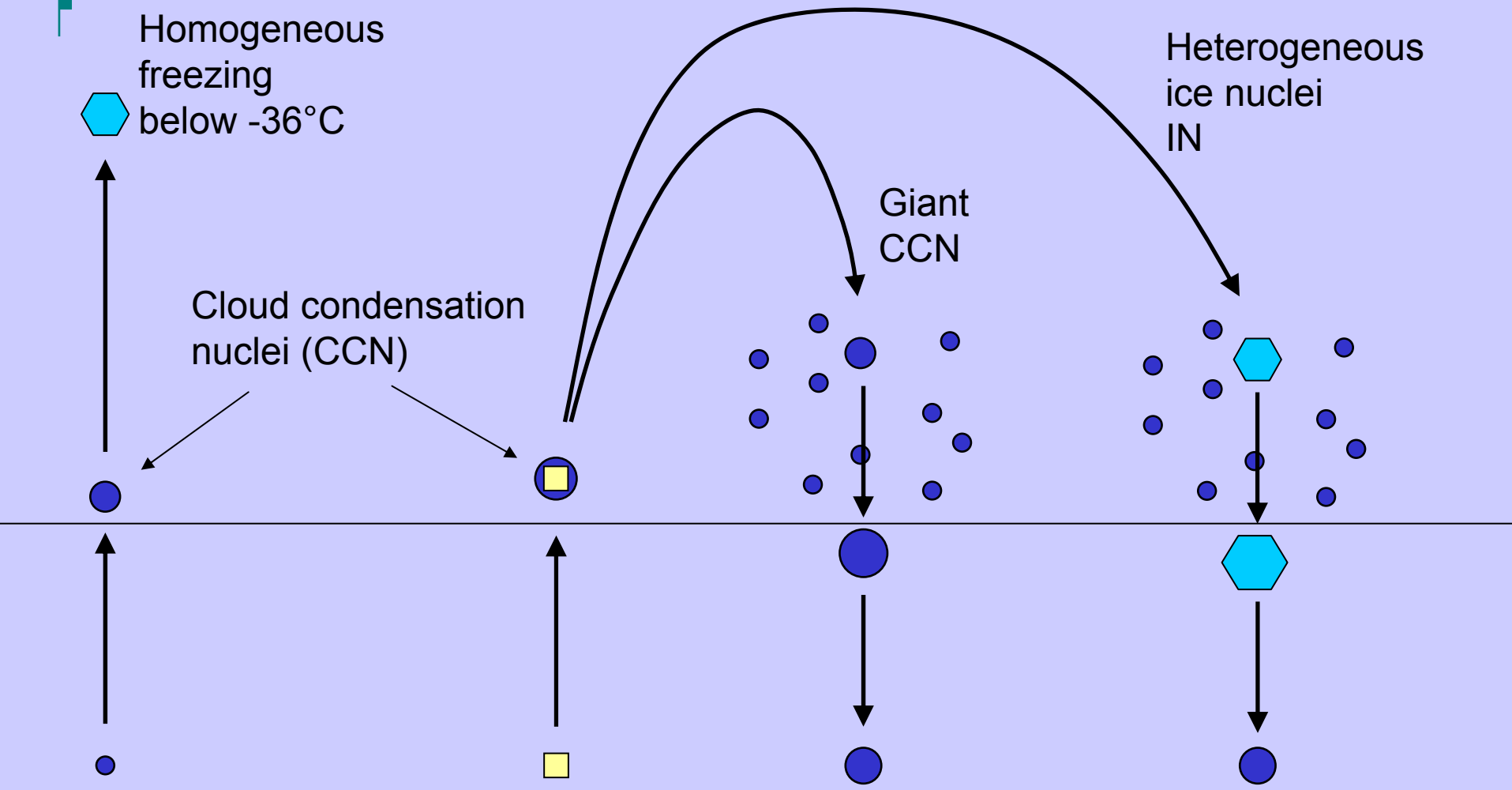
Intro

Methods

Results - Snomax and cultured cells

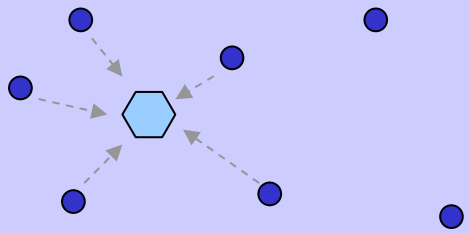
Summary

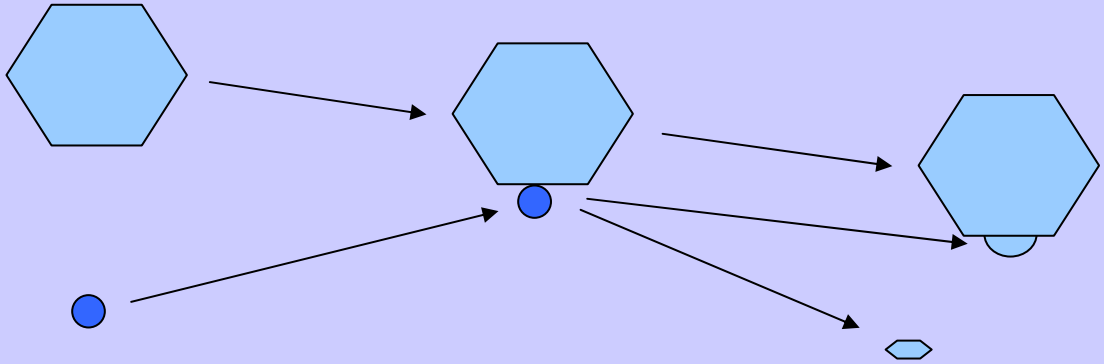
Introduction to aerosol-cloud processes

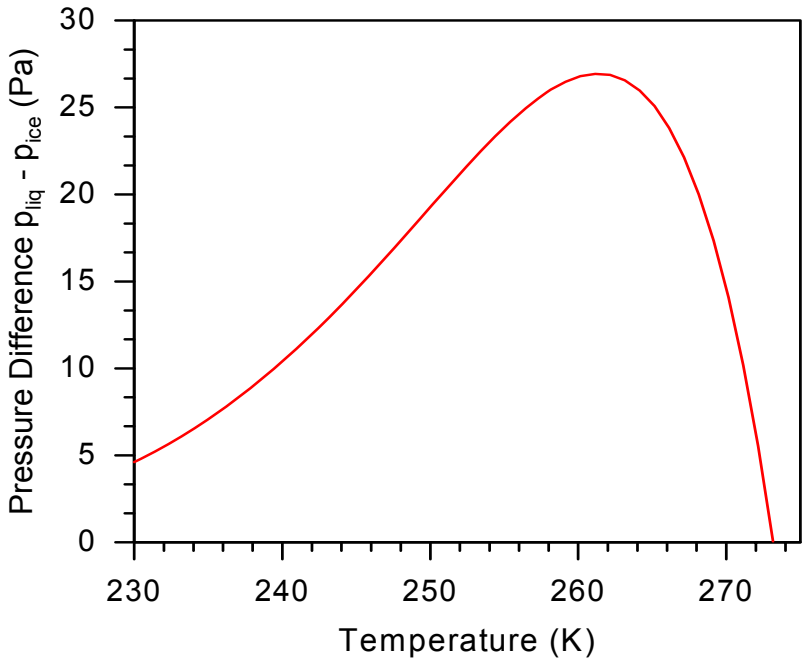


Introduction to aerosol-cloud processes

Bergeron-Findeisen mechanism of diffusional ice growth







Formation of secondary ice particles by collision between ice particle and supercooled droplet
Hallett and Mossop, Nature, 1974

Both mechanisms of ice groth and ice multiplication are most efficient at T between -5 and -15 °C

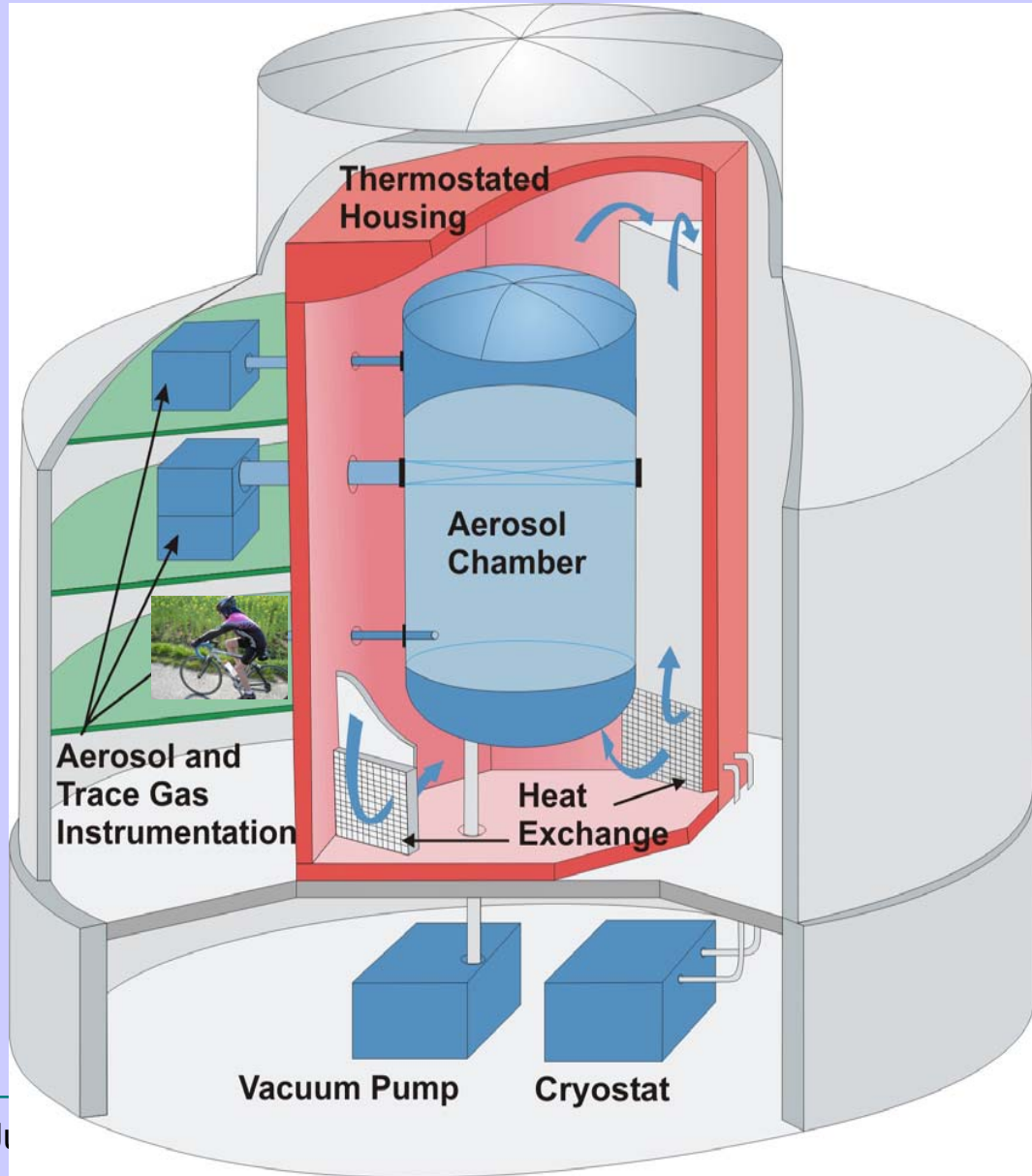
→ Biological particles are candidates for ice nuclei at these warm temperatures

AIDA cloud chamber

Laboratory facility to investigate
Aerosol
Interactions and
Dynamics in the
Atmosphere

Large aerosol vessel with **volume of 84 m^3**.

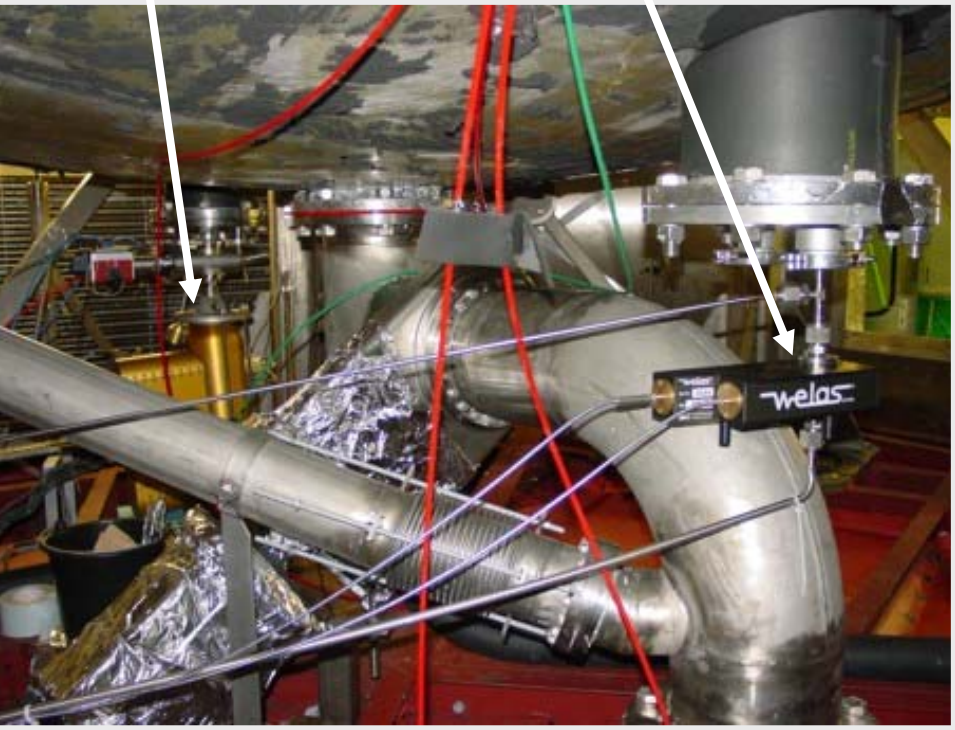
Thermostated housing with **T-range -90°C to +30°C** and extremely homogeneous **T-control within ±0.3°C**.



Ice number concentration

Cloud
Particle
Imager
CPI

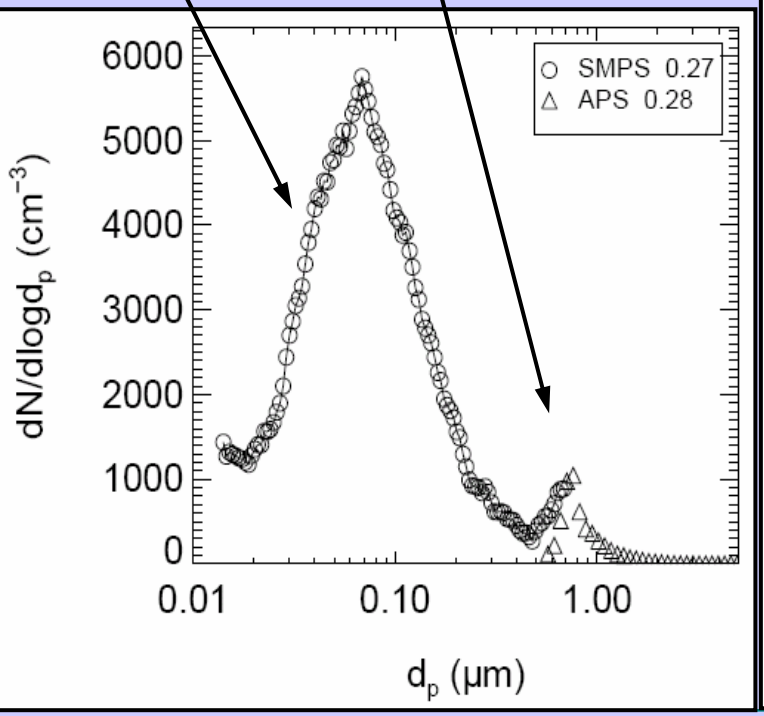
Optical Particle Counter
WELAS

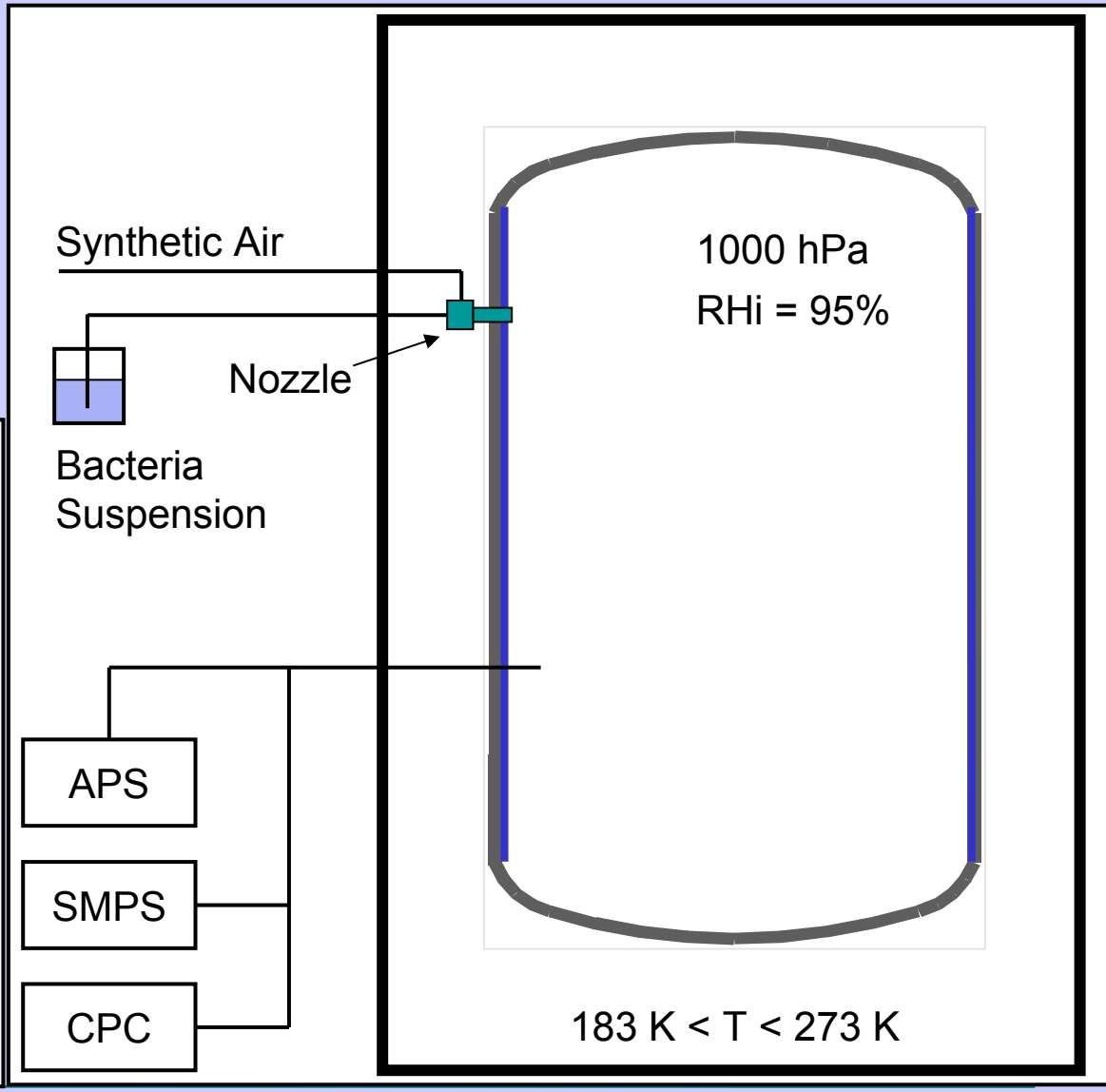


Generation and characterisation of aerosols

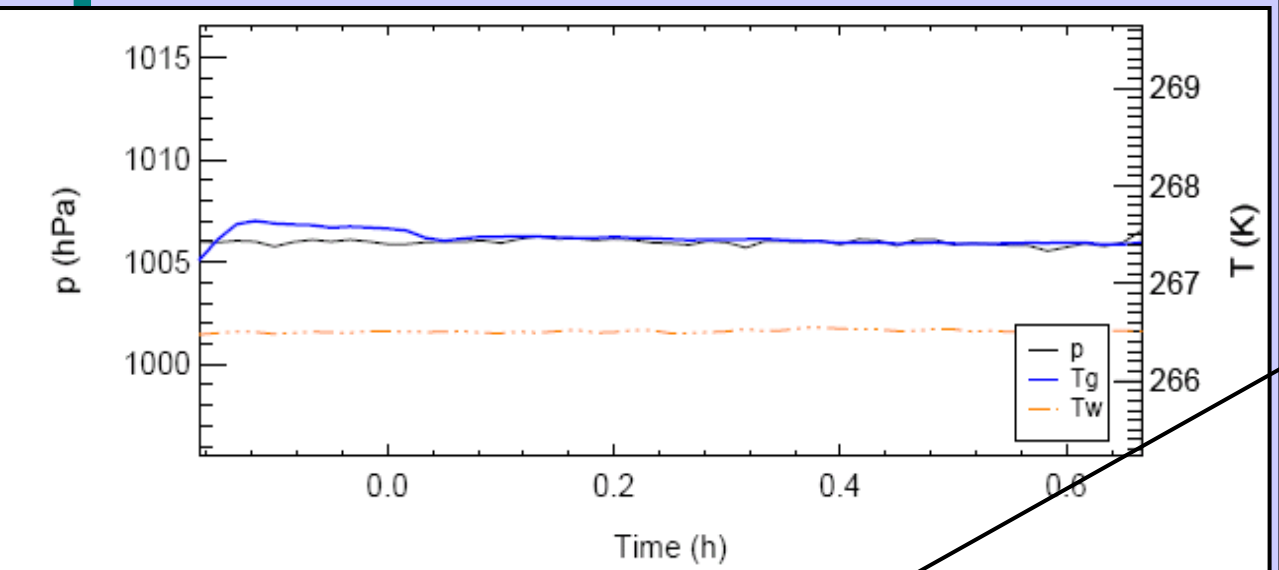
Residual particles
0.02 to 0.4 µm

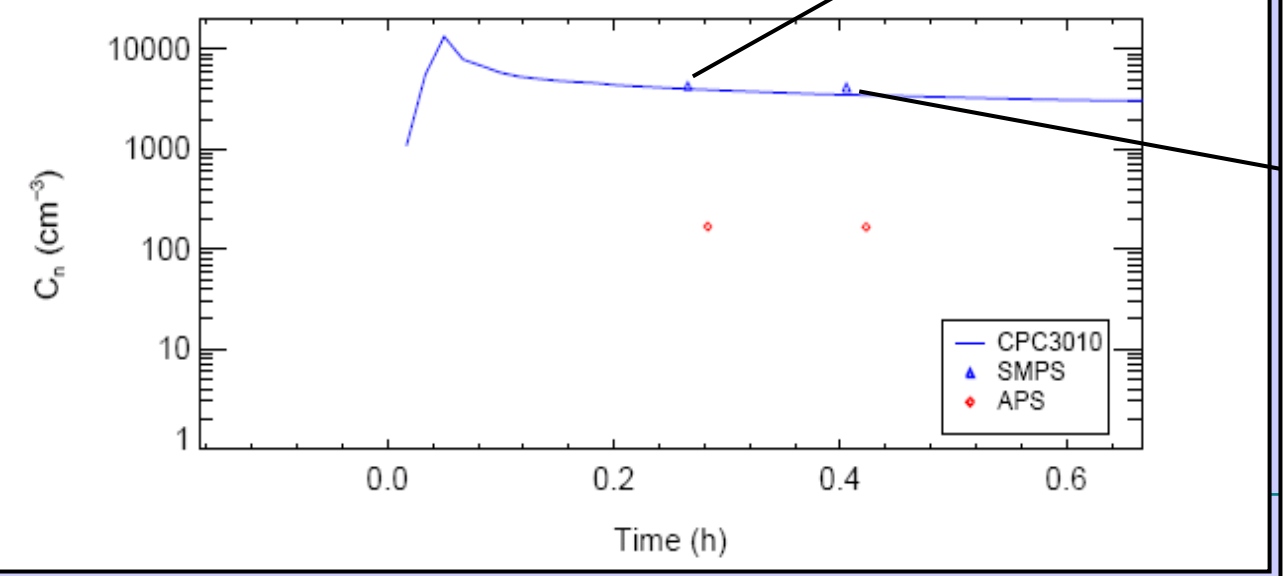
Bacterial cells
0.8 µm

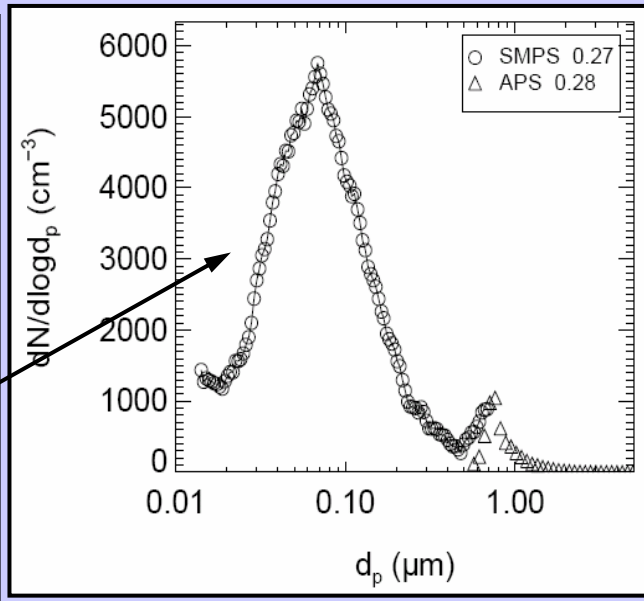


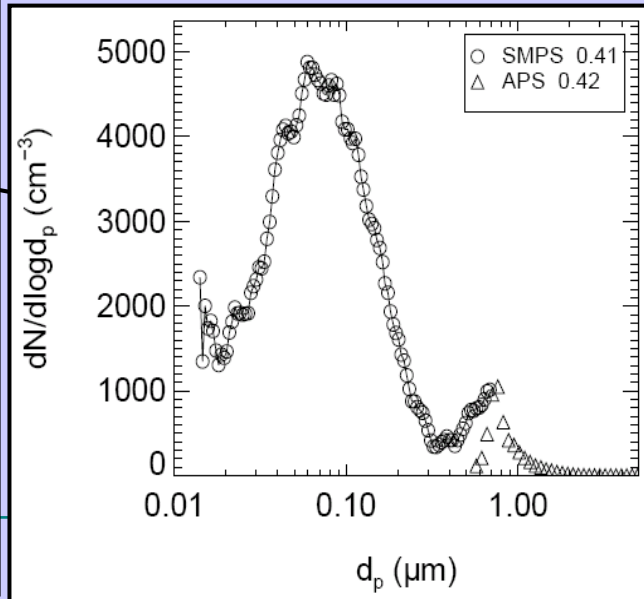


Aerosol generation (BIO03_08, PS31R1)







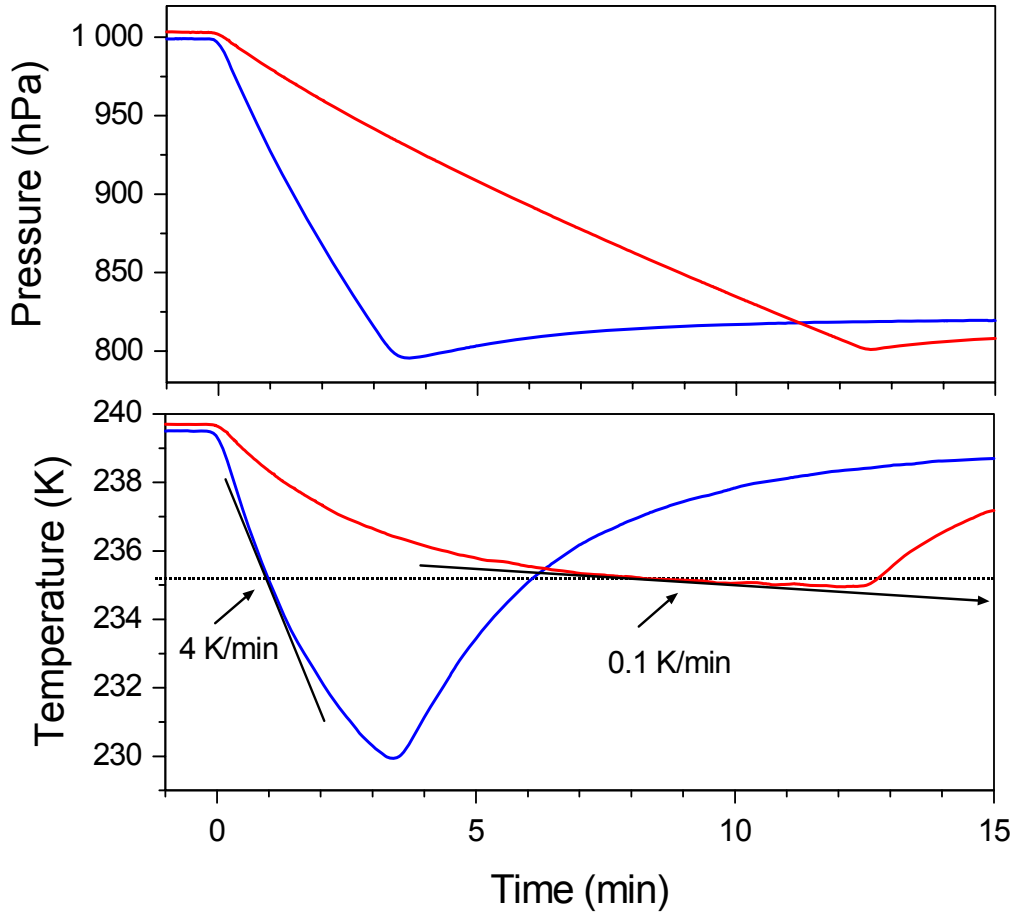


Experiments with dynamic expansion cooling

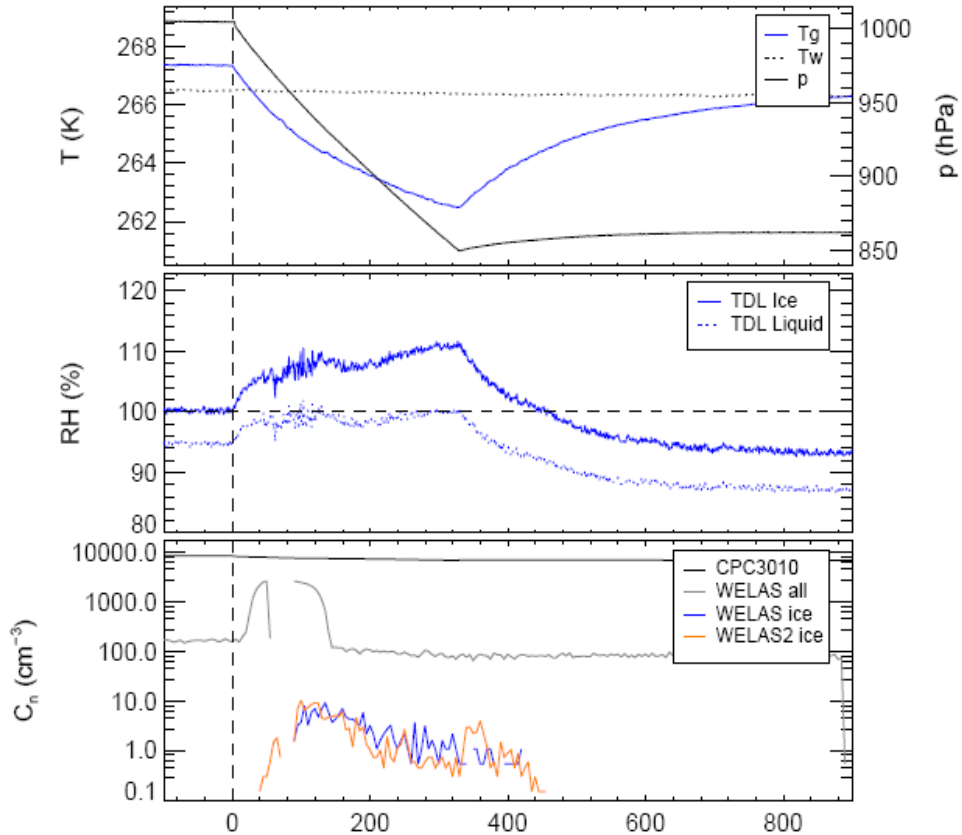
Expansion experiment:

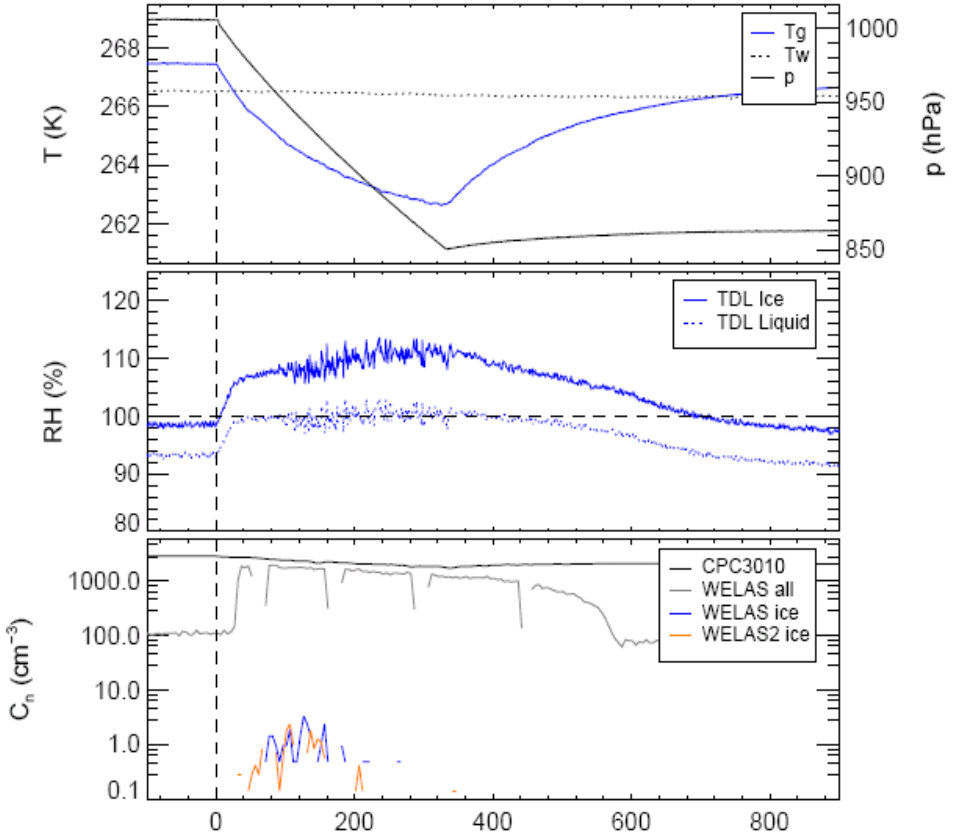
- Constant wall temperature
- Pumping from 1000 to about 800 hPa
- Super cooling up to -9°C
- Relative ice humidity more than 200%

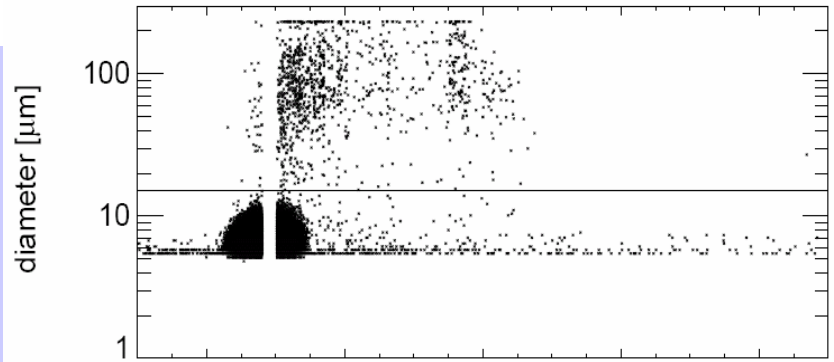
$$\left(\frac{d\ln T}{d\ln p}\right)_{ad}^{air} = \frac{R}{c_p} = 0.29$$

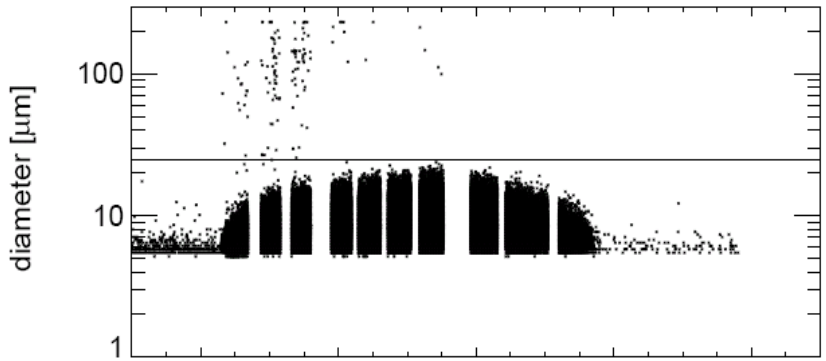


IN of Snomax and P.S. 31R1









Summary of experiments and results

Exp	Bacteria	n_{ae}	n_{bc}	n_i	n_i/n_{ae}	n_i/n_{bc}	T
		cm^{-3}	cm^{-3}	cm^{-3}			°C
BIO02_05	Snomax	4000	200	40	1×10^{-2}	0.2	-7 to -9
BIO02_07	P.S. 1	15000	400	1	7×10^{-5}	2.5×10^{-3}	-9 to -11
BIO02_10	P.S. 2	15000	600	< 0.1	$< 7 \times 10^{-6}$	$< 2 \times 10^{-4}$	-12 to -15
BIO03_07	Snomax	5000	200	8	2×10^{-3}	0.04	-7 to -9
BIO03_09	P.S. 31R1	3000	200	1	3×10^{-4}	5×10^{-3}	-7 to -9
BIO03_12	P.S. Cit7	4000	200	0.2	5×10^{-5}	1×10^{-3}	-7 to -9
BIO03_20	SH268Rb-2	2000	250	< 0.2	$< 1 \times 10^{-4}$	$< 8 \times 10^{-4}$	-8 to -11

Conclusions

Ice nucleation of Snomax and 5 different strains of INA bacteria

No significant IN observed at T warmer than -7°C

Most bacteria induce freezing at T < -7°C

Fraction of active cells ranges from about 0.2 (Snomax) to below 1×10^{-3}

Outlook:

More experiments with ice particle residual analysis