Karlsruhe Institute of Technology

Crystallization, deliquescence and ice nucleation ability of ammoniated sulphate particles in the cirrus cloud temperature range

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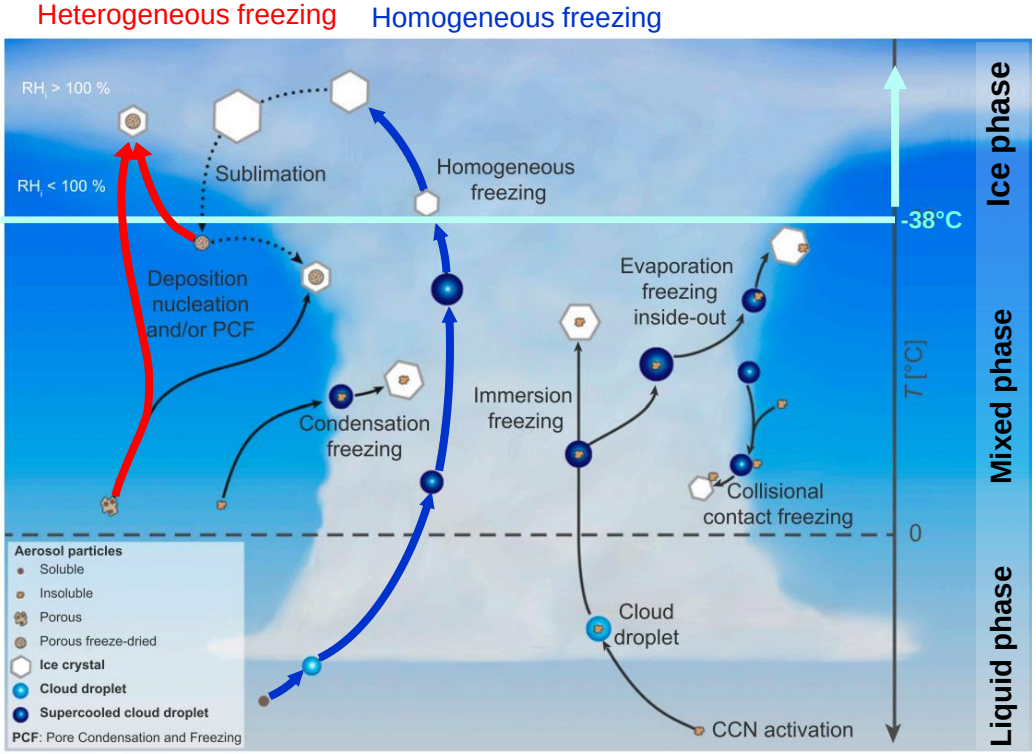
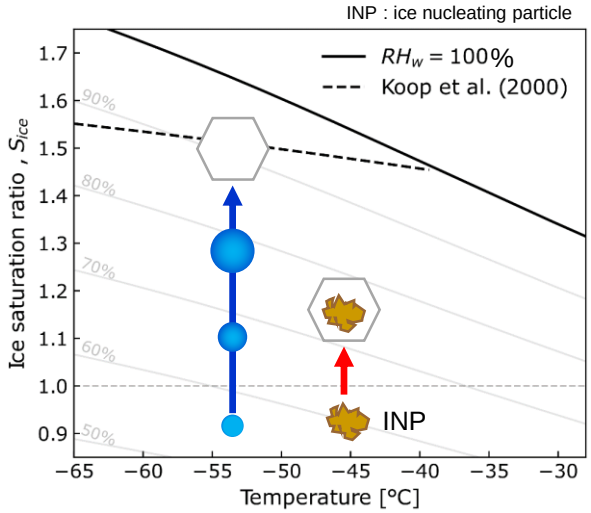
Ice nucleation in the atmosphere



Kanji et al., 2017



Competition homogeneous vs heterogeneous

↓

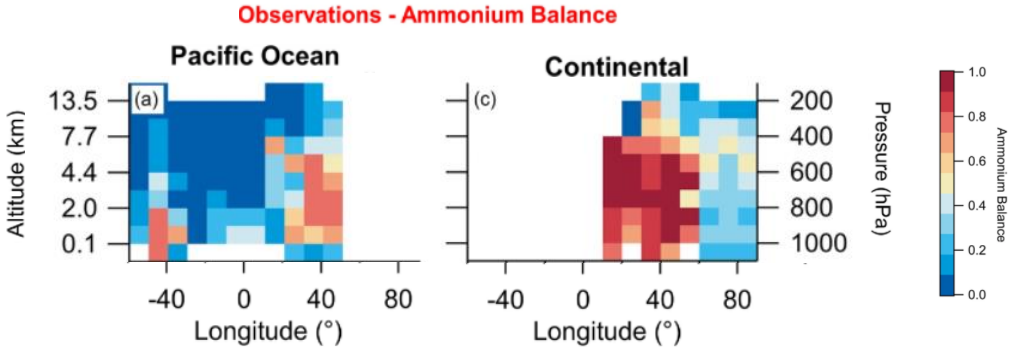
Microphysical and optical properties of the cloud

↓

Different radiative effect

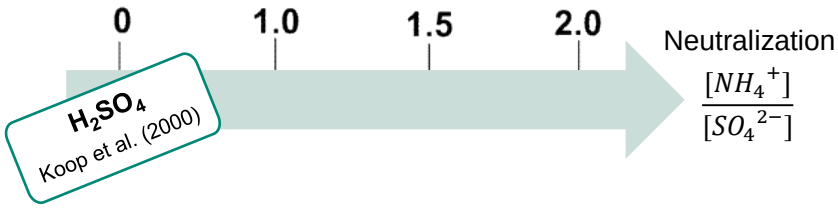
Aerosol particles in the upper troposphere (UT)

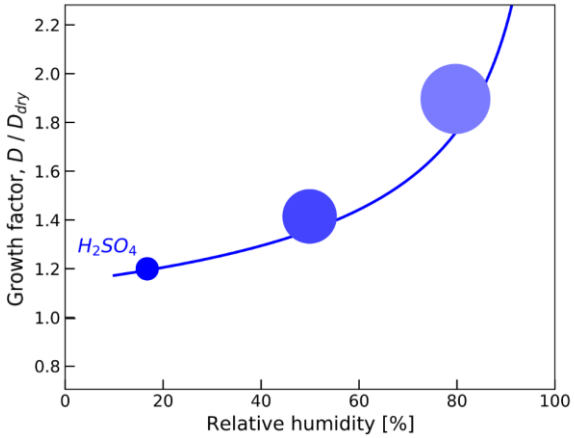
- Sulphate particles
  - Geographical and vertical variability in neutralization state (acidity)
- Organics
  - Often internally mixed with sulphate
- Crustal elements (e.g. mineral dust)
  - Coated by a S-rich layers
- Marine origin (e.g. sea salt)
- Soot
- Ammonium nitrate (Höpfner et al., 2019)
- …

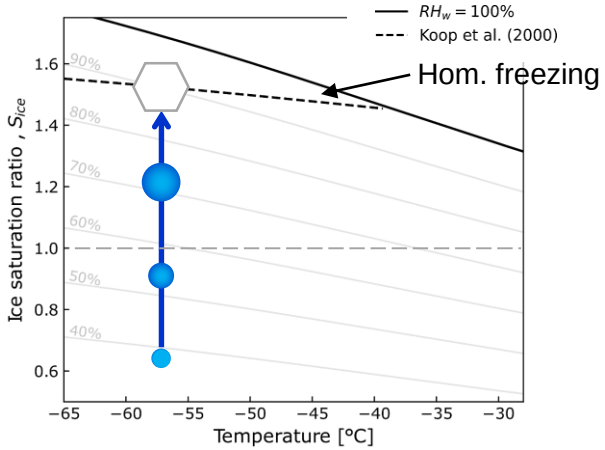


Nault et al., 2021

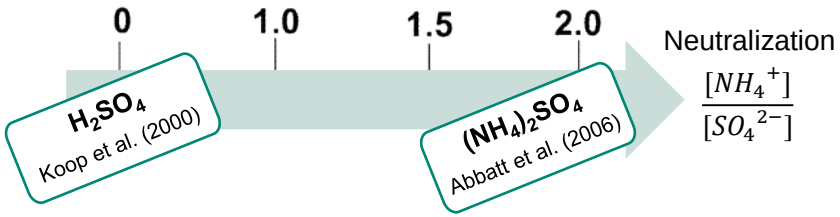
Ice nucleation ability of sulphate particles





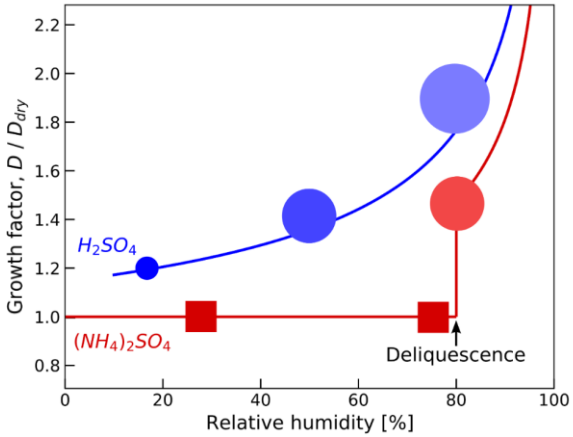


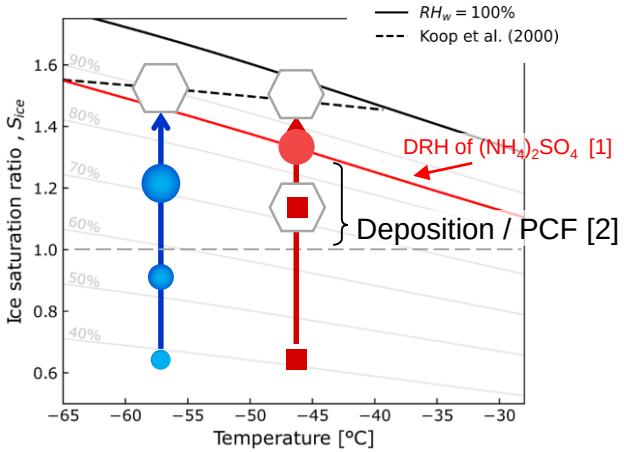
Ice nucleation ability of sulphate particles



Neutralization

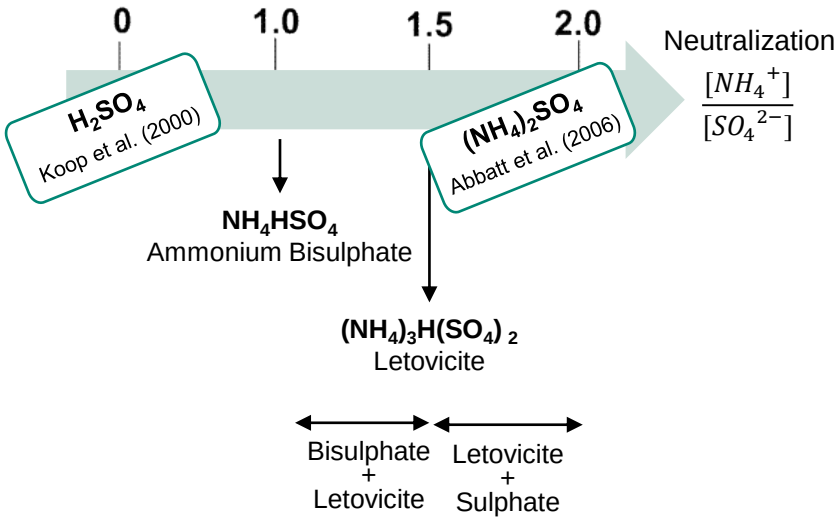
$$\frac{[NH_4^+]}{[SO_4^{2-}]}$$

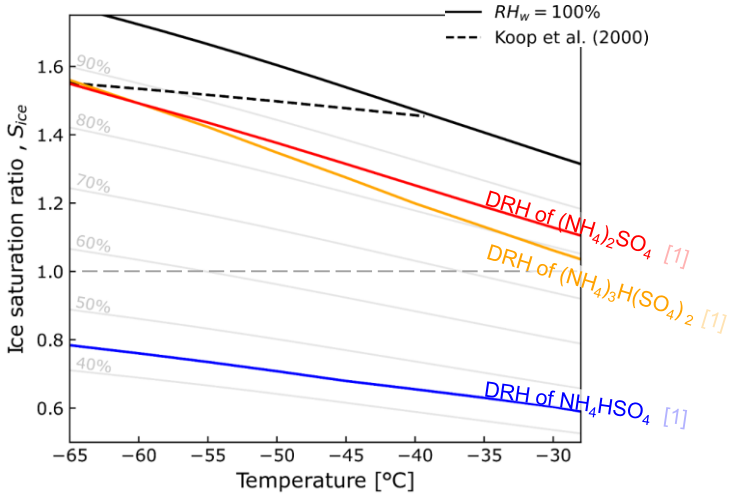




[1] Clegg et al., 1998
[2] Abbatt et al., 2006

Ice nucleation ability of sulphate particles





[1] Clegg et al., 1998

Experiments with bulk solutions

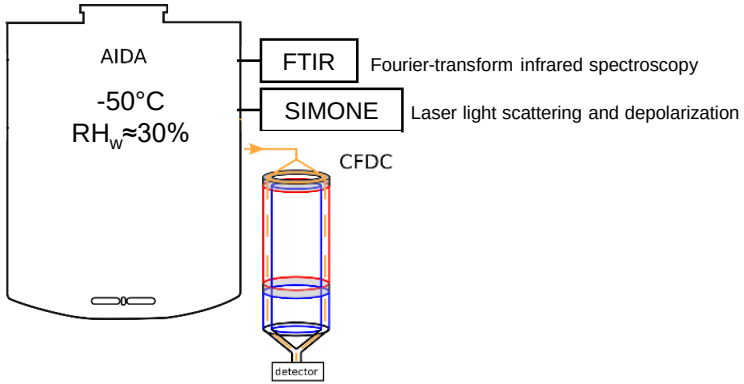
Solutions with exact composition:

Crystallization ?
T ≈ 20°C
RH_w ≈ 3%

Ammonium-to-Sulphate ratio:

neutralization

- 1.0 - Amm. Bisulphate
- 1.1
- 1.2
- 1.35
- 1.5 - Letovicite
- 1.6
- 1.8
- 2 - Amm. Sulphate

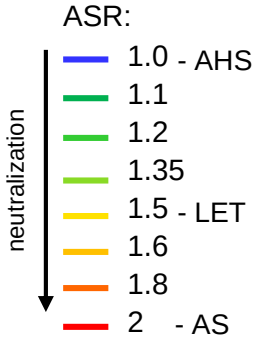


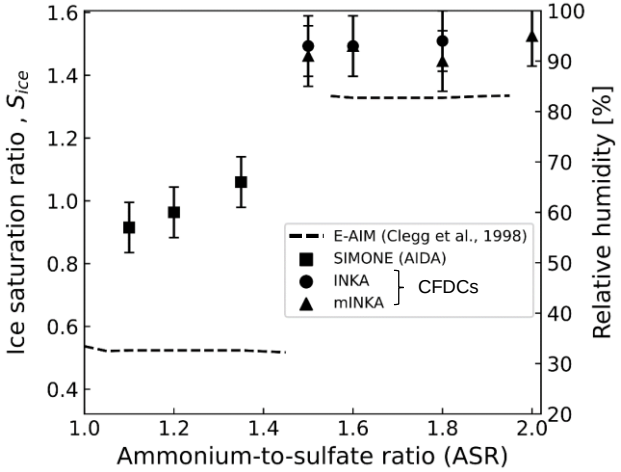
Deliquescence and IN ability:

- Expansion cooling experiments
  - -50°C < T < -60°C
  - 0.7 < S_{ice} < hom. freezing
- Continuous flow diffusion chambers
  - -40°C < T < -60°C
  - 1.0 < S_{ice} < water saturation

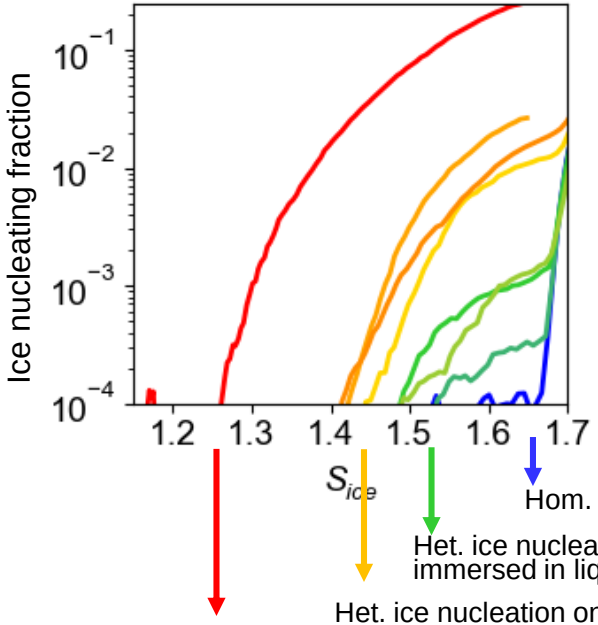
Experiments with bulk solutions - Results

Partial deliquescence
(from -56 to -52°C)



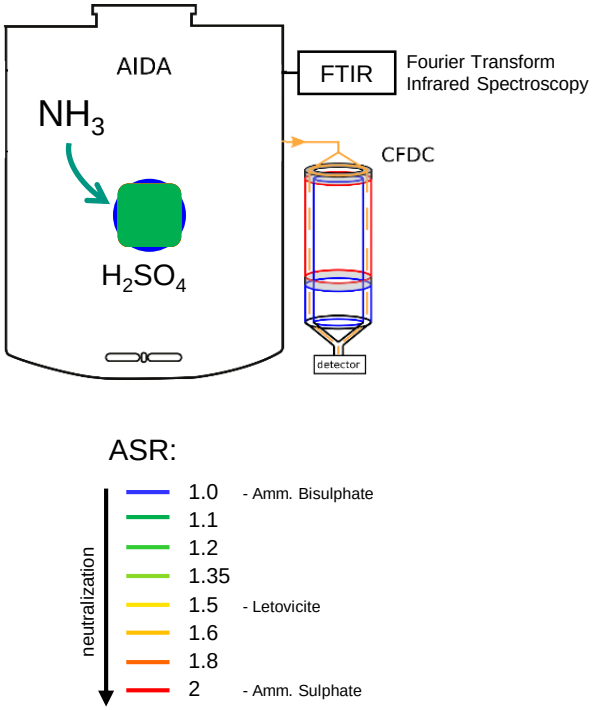


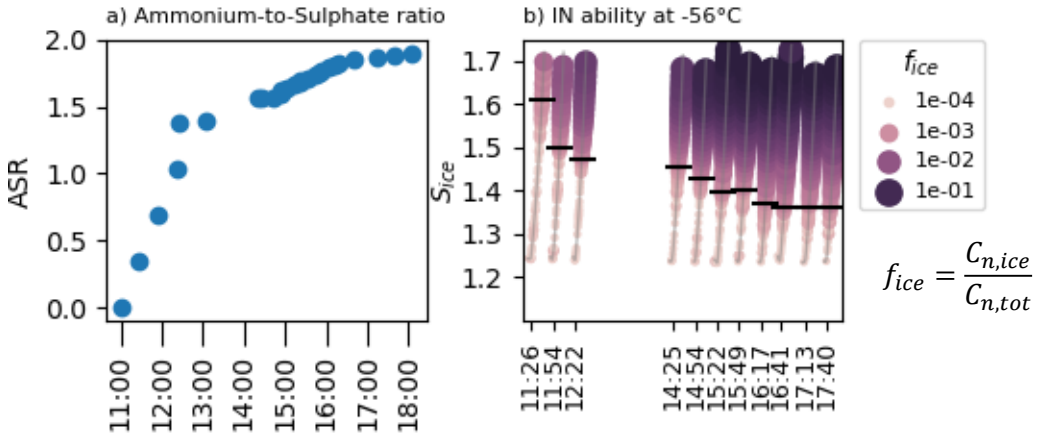
Ice nucleation (-56°C)



AHS : Ammonium bisulphate
LET : Letovicite
AS : Ammonium sulphate

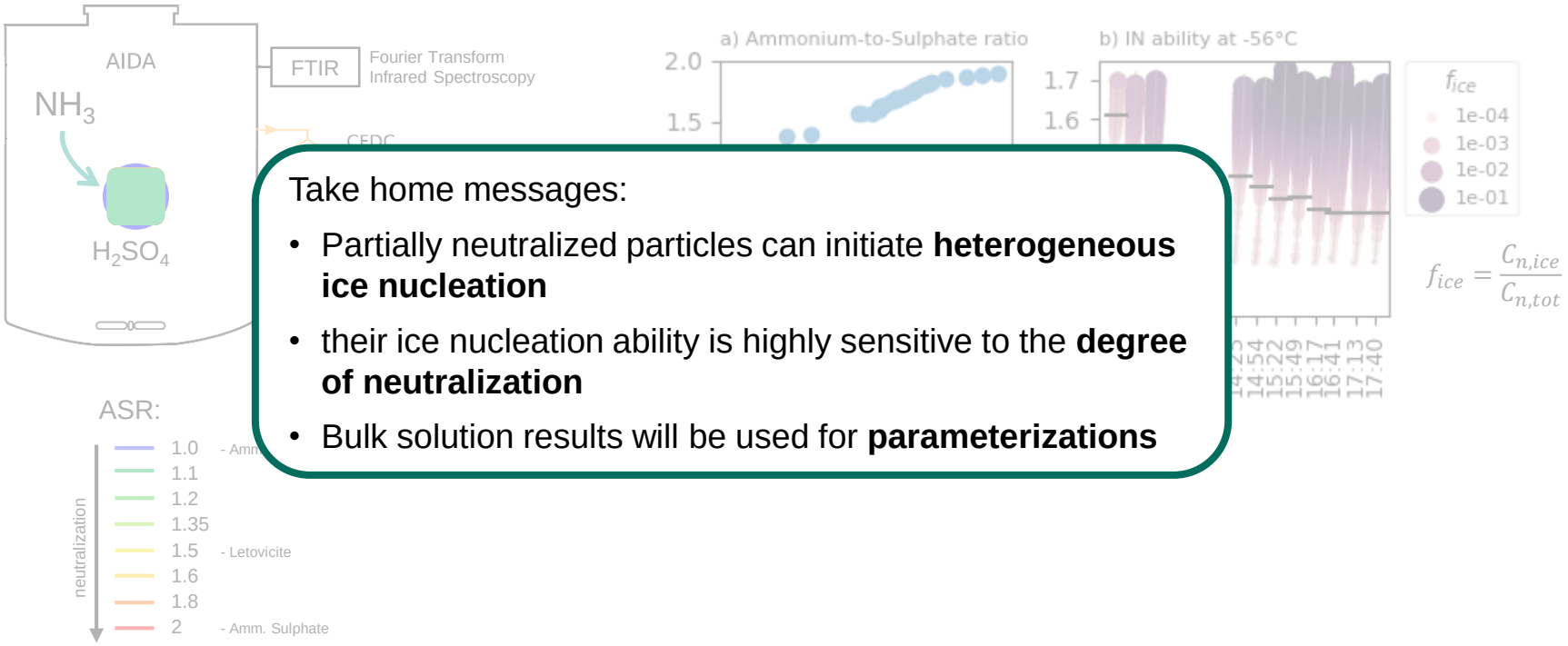
In situ neutralization experiments





$$f_{ice} = \frac{C_{n,ice}}{C_{n,tot}}$$

In situ neutralization experiments



Take home messages:

- Partially neutralized particles can initiate **heterogeneous ice nucleation**
- their ice nucleation ability is highly sensitive to the **degree of neutralization**
- Bulk solution results will be used for **parameterizations**