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Ice Nucleation studies at the Jungfraujoch

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with contributions from

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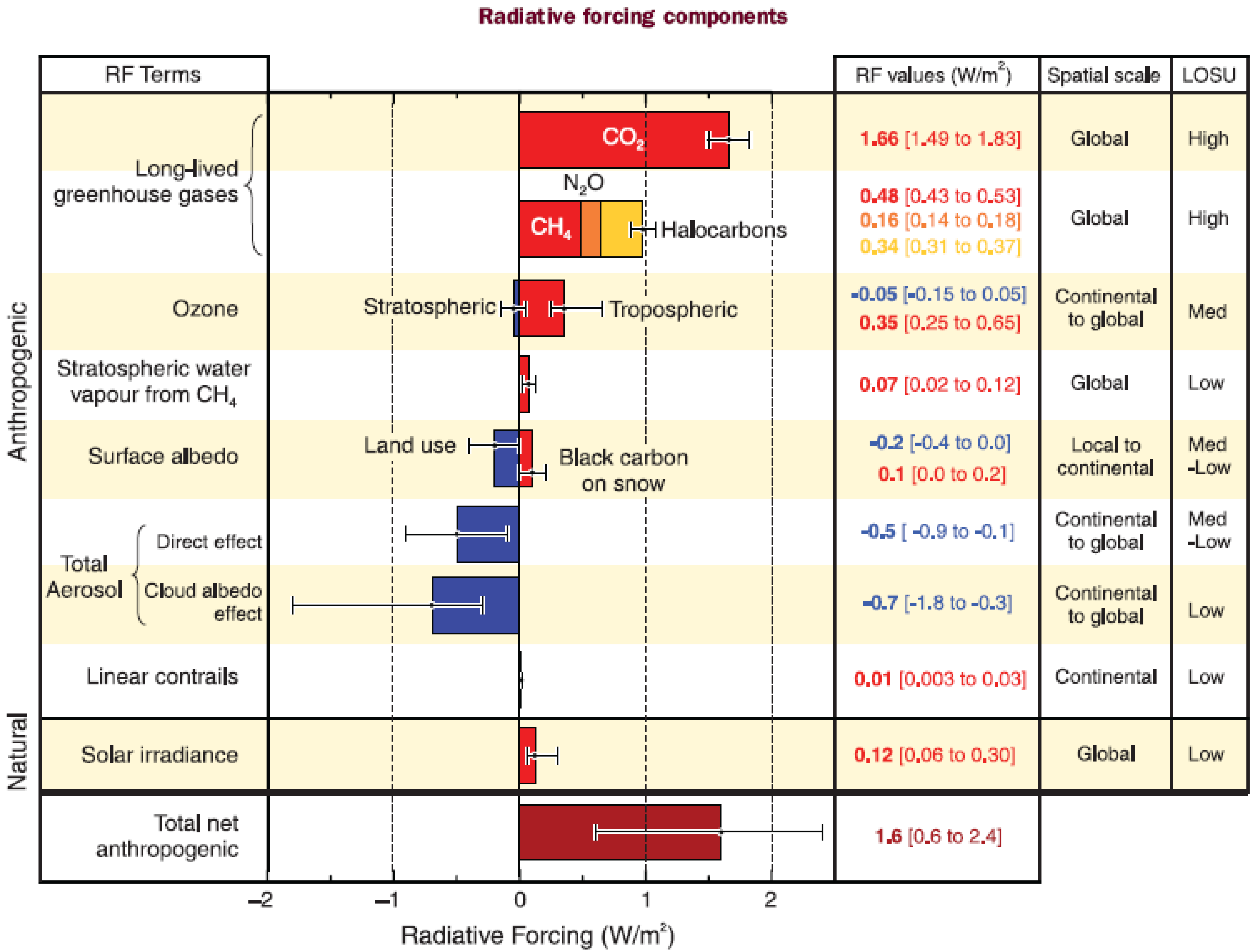
Overview

- Introduction
- Mass-Spectrometry of Ice Residuals
- Direct measurements of Ice Nuclei with ZINC and PINC
- Validation of Ice Nucleation Schemes in Climate Models using data from the Jungfraujoch
- Outlook

Why Are Aerosol/Cloud Interactions Important?



IPCC, 2007

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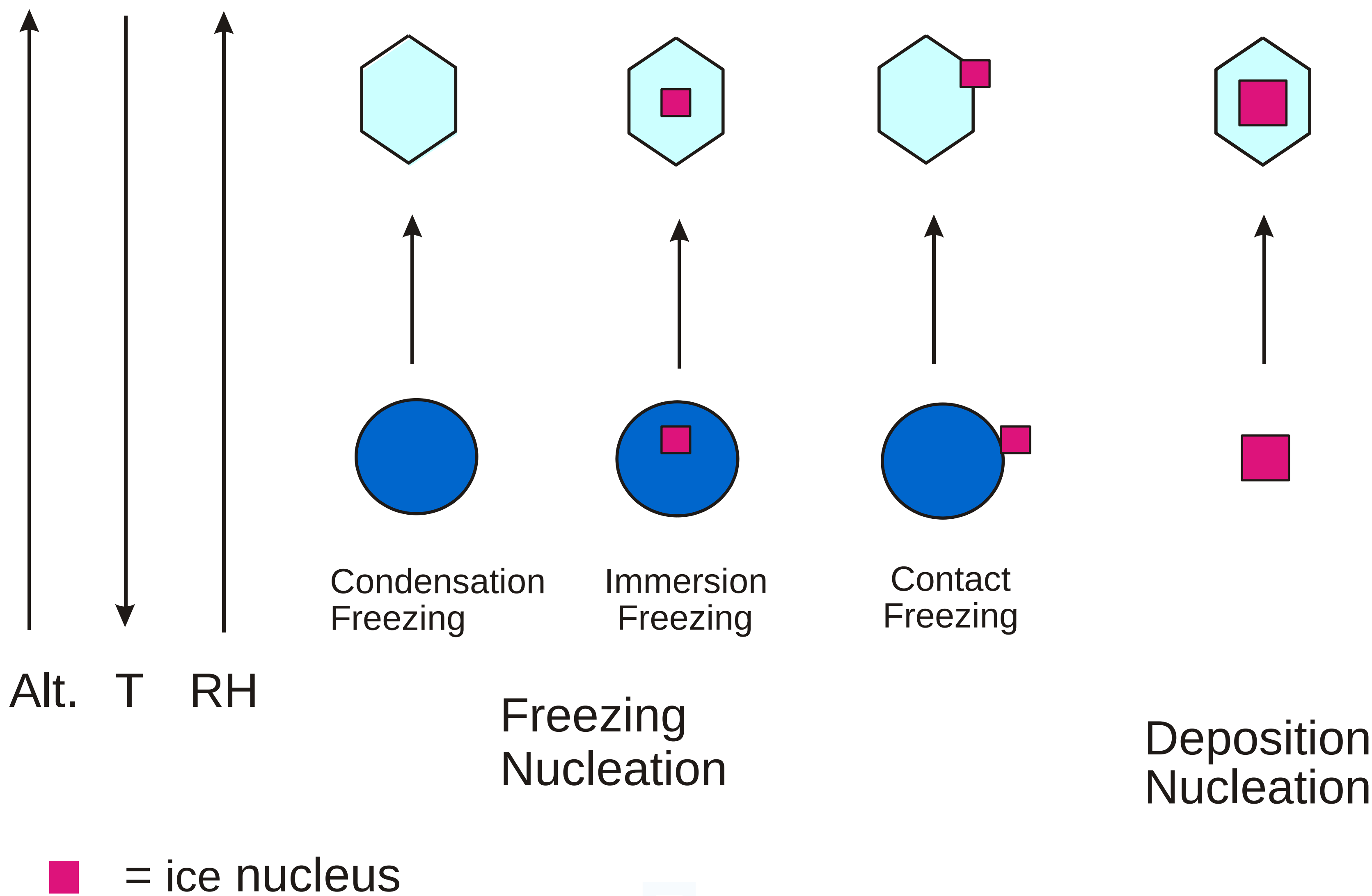
Introduction:
Ice Nucleation Mechanisms



Modes of Ice Nucleation (Vali, 1985)

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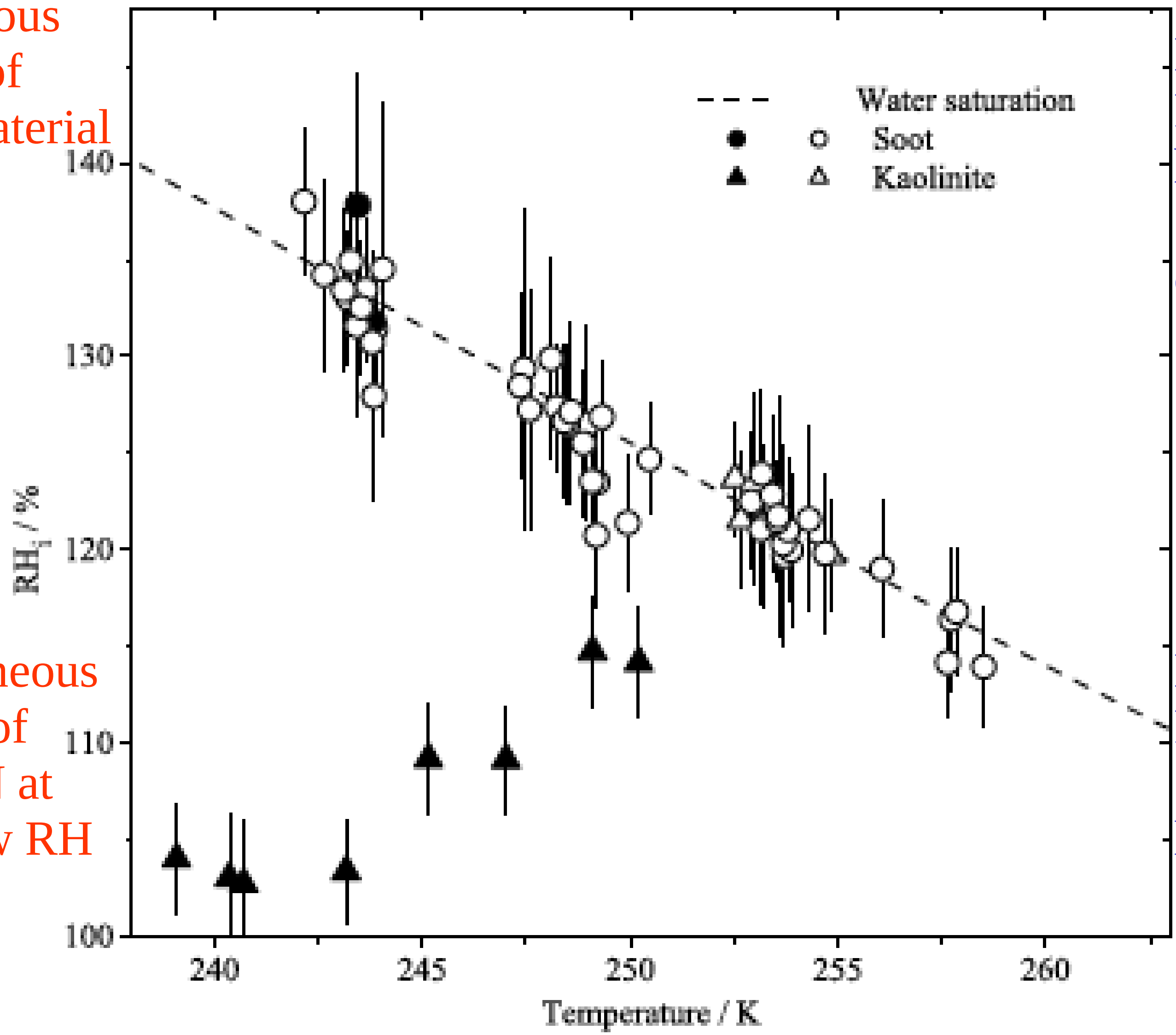
How does this Compare to Ice Clouds?

Homogenous Freezing of soluble material at water saturation

Heterogeneous Freezing of ‘Good’ IN at low T, low RH



No Homogenous Freezing (T too high). Freezing of ‘Bad’ IN (BC, coated minerals)?

Heterogeneous Freezing of ‘Good’ IN at low RH, T high

Dymarska et al., JGR, doi:10.1029/2005JD006627, 2006.

How to Study Mixed-Phase Clouds ?

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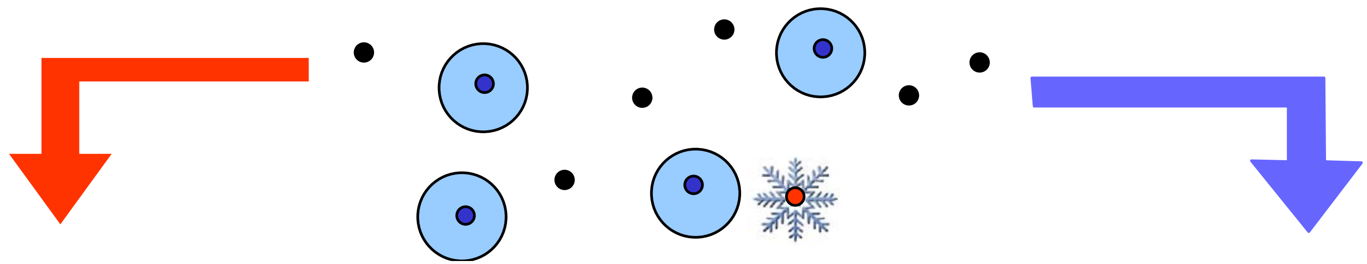


Ice CVI inlet:

removes :

- droplets
- int. particles
- large ice crystals

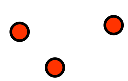
(Size : 5-30 µm)

Total inlet :

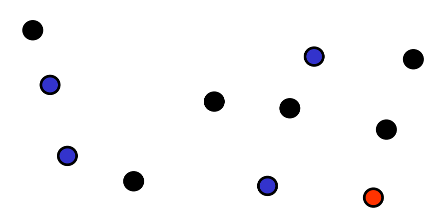
(all particles, including activated ones)

heated inlet

→ dry residuals



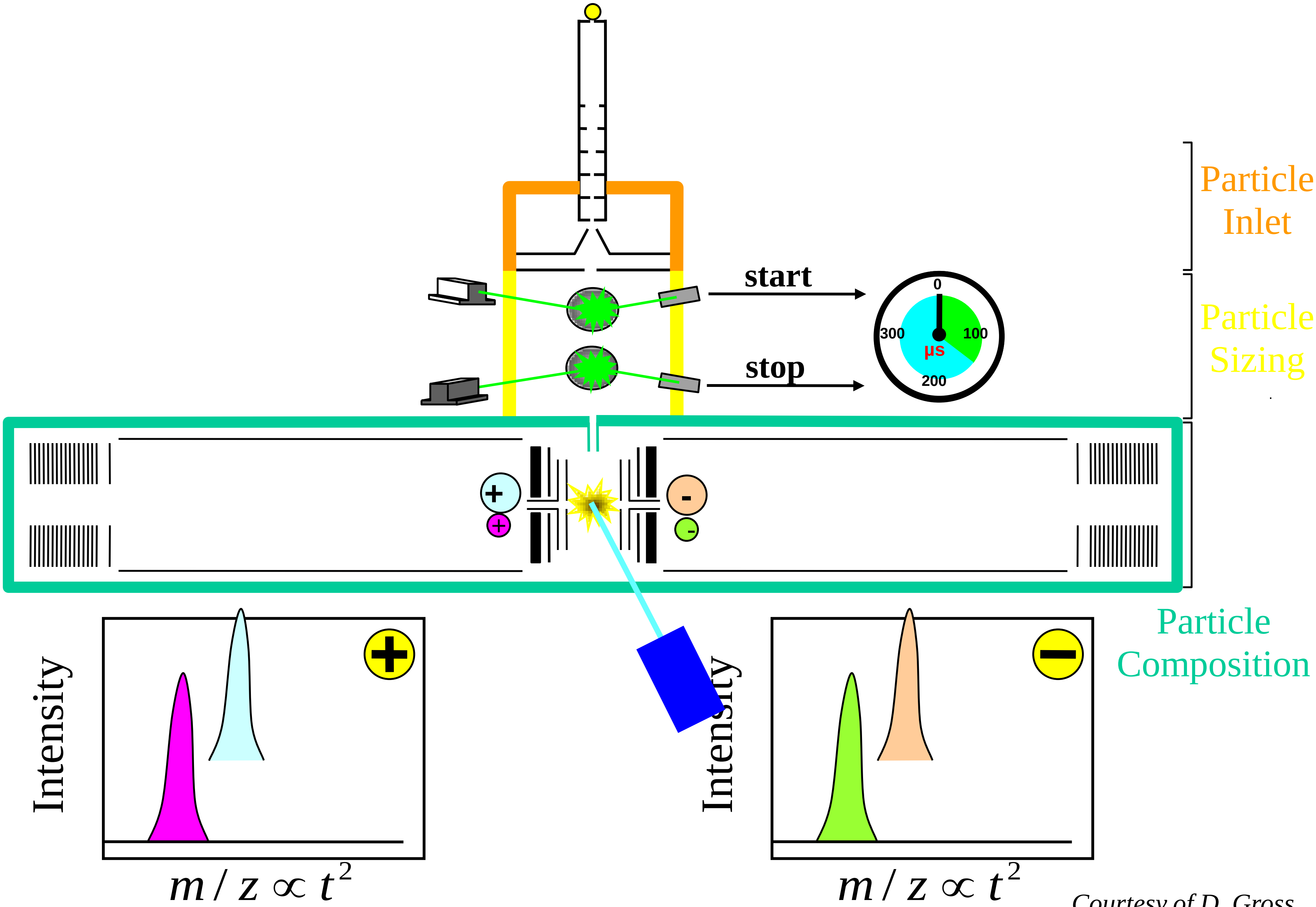
Ice residuals



All particles

Courtesy of S. Mertes, J. Cozic

Analysis of Cloud Elements : Single particle Mass-Spec. - ATOFMS



Courtesy of D. Gross

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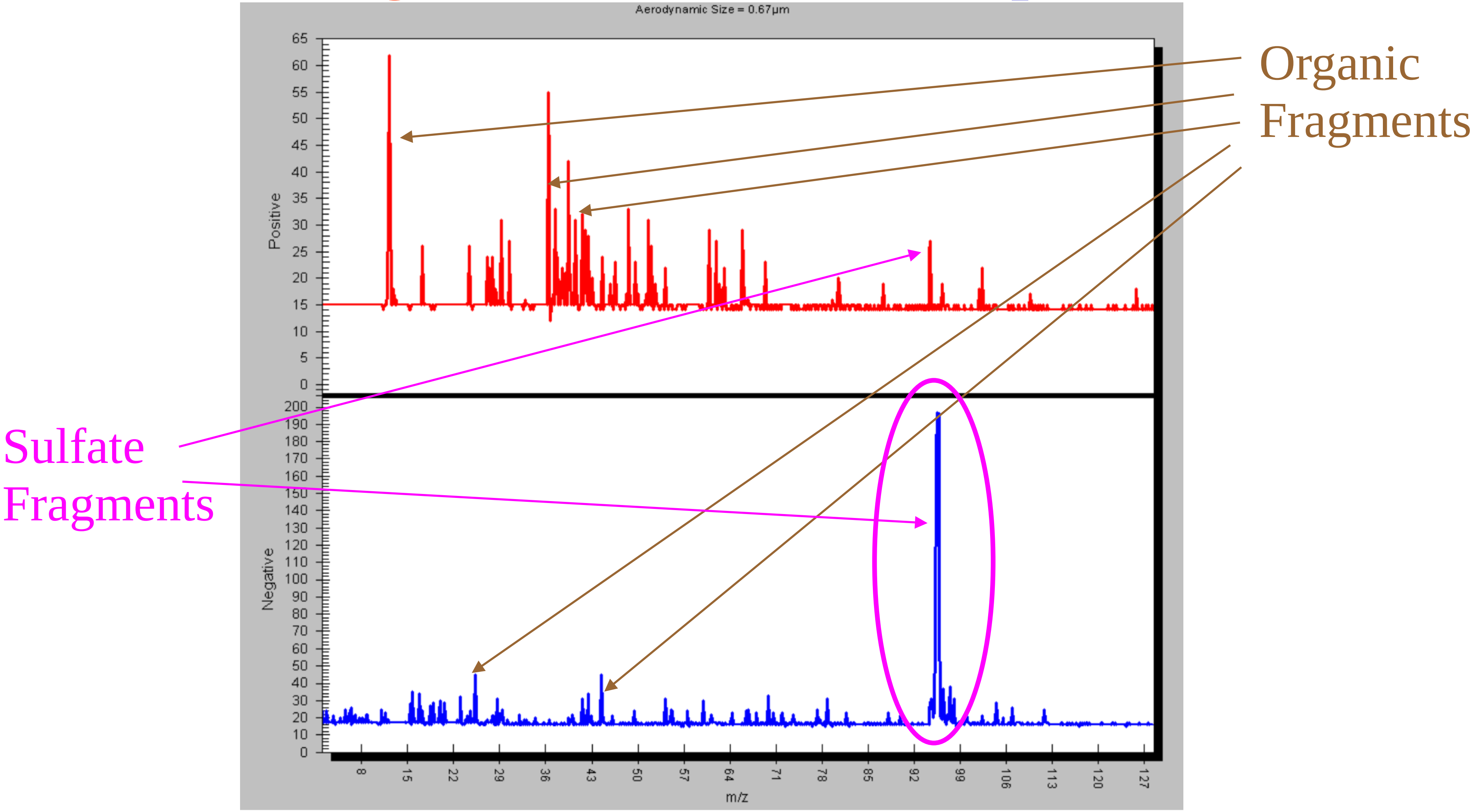
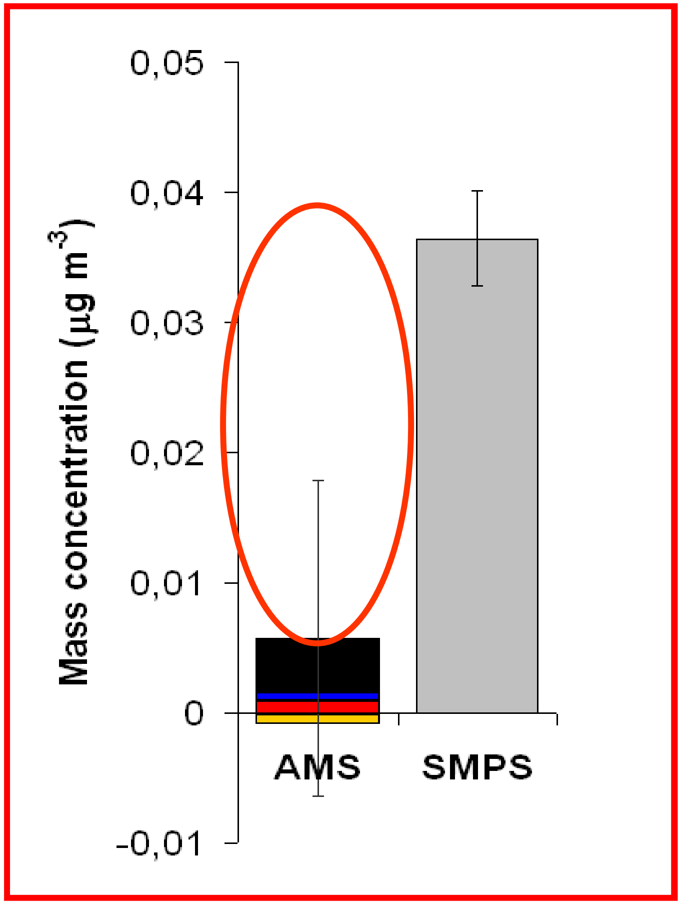
Background Aerosol Composition



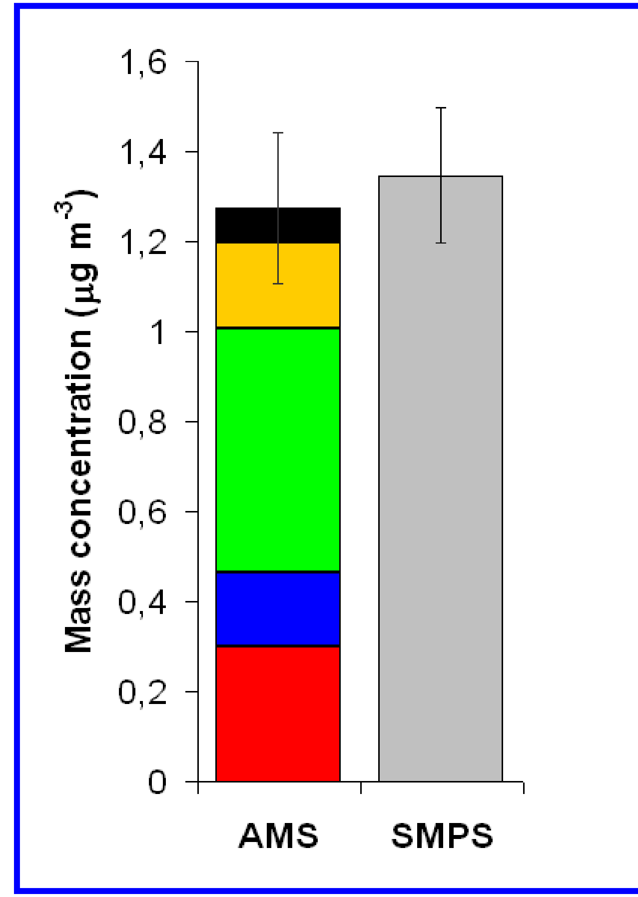
In the mid-troposphere the typical background aerosol (~90%) is composed of sulfates and organics.
Insoluble ‘cores’ are not uncommon (30%; biomass burning, etc.)

What is the Aerosol and IN Composition ?

Ice Residue



Total



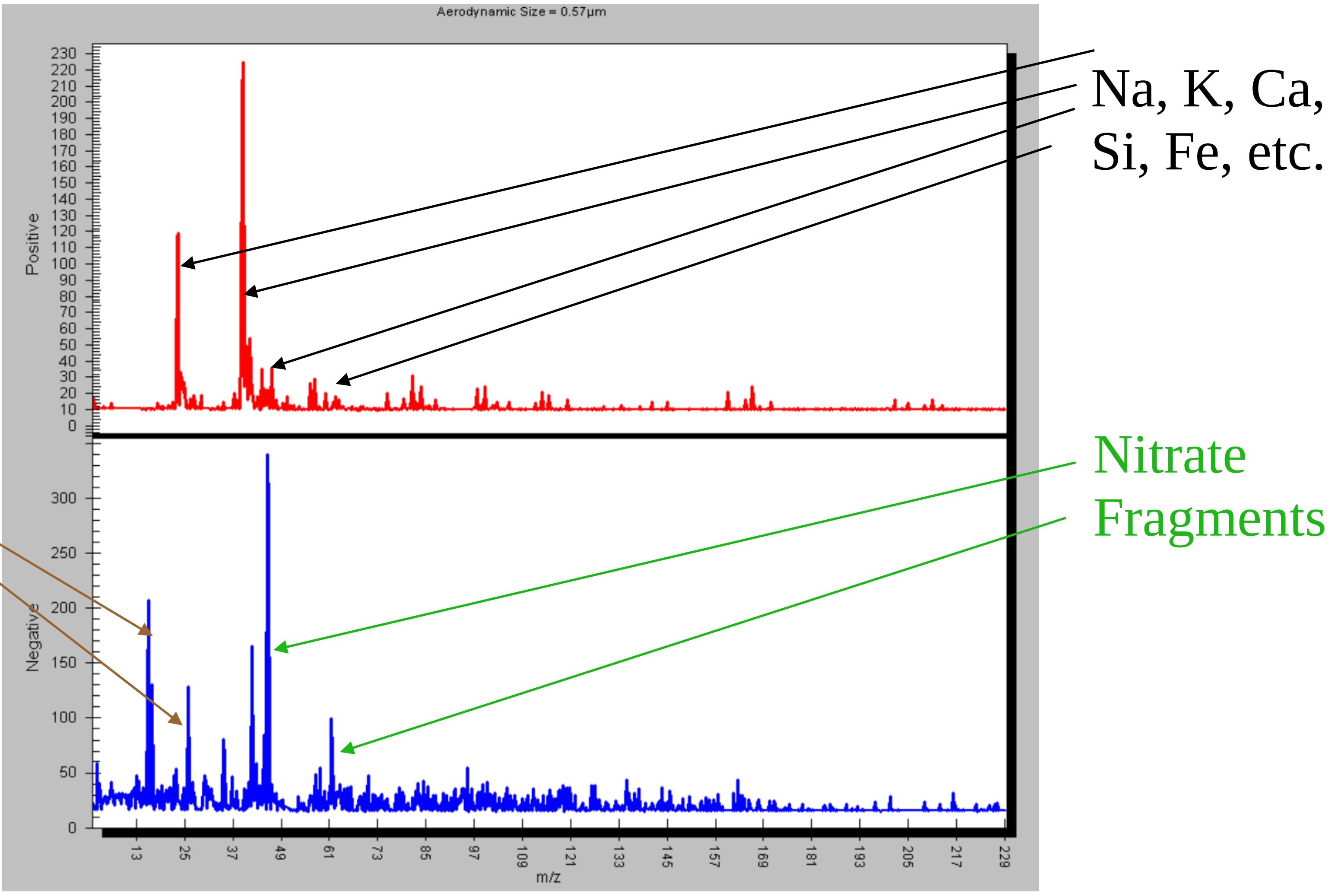
Ammonium
Organics
Nitrate
Sulphate
BC

- Composite from AMS (volatile components) and BC (EC/soot) measurements.
- Lack of 'closure' between the volatile components + BC and ice residue.

What are the missing ice forming aerosols?

Courtesy of J. Schneider and S. Walter

2007 Ice Residue with ATOFMS



- Composition consistent with mineral dust which has uptaken some nitrate (see work of Grassian, Laskin, and others)
- No significant sulfate

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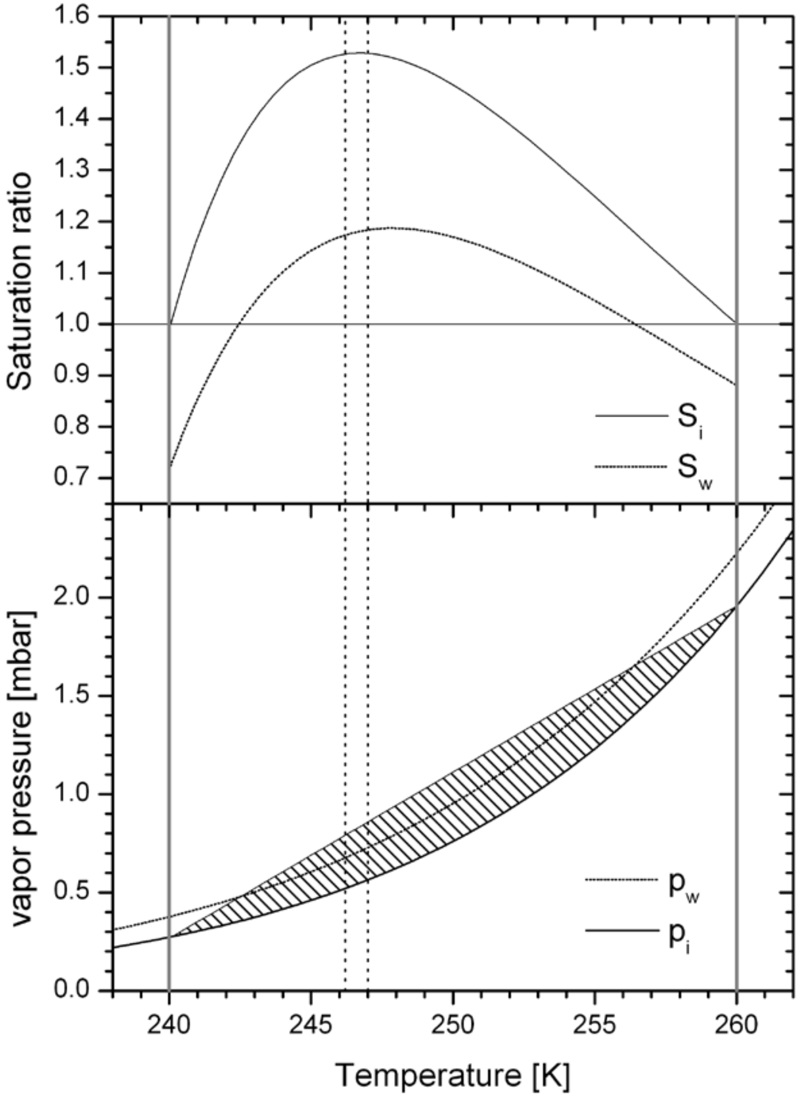
PINC: Setup

Temperature and saturation ratio profiles in the ZINC/PINC instruments:

Both walls are held at different temperatures and are covered with ice.

Linear profiles in absolute water vapour pressure and temperature develop by molecular diffusion.

Because of the Clausius-Clapeyron-Law a supersaturation wrt ice exists in the chamber and peaks roughly at the same position where the aerosols are injected (dotted lines).



Stetzer et al., Aerosol Science & Technology 2008

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Design concept of ZINC/PINC

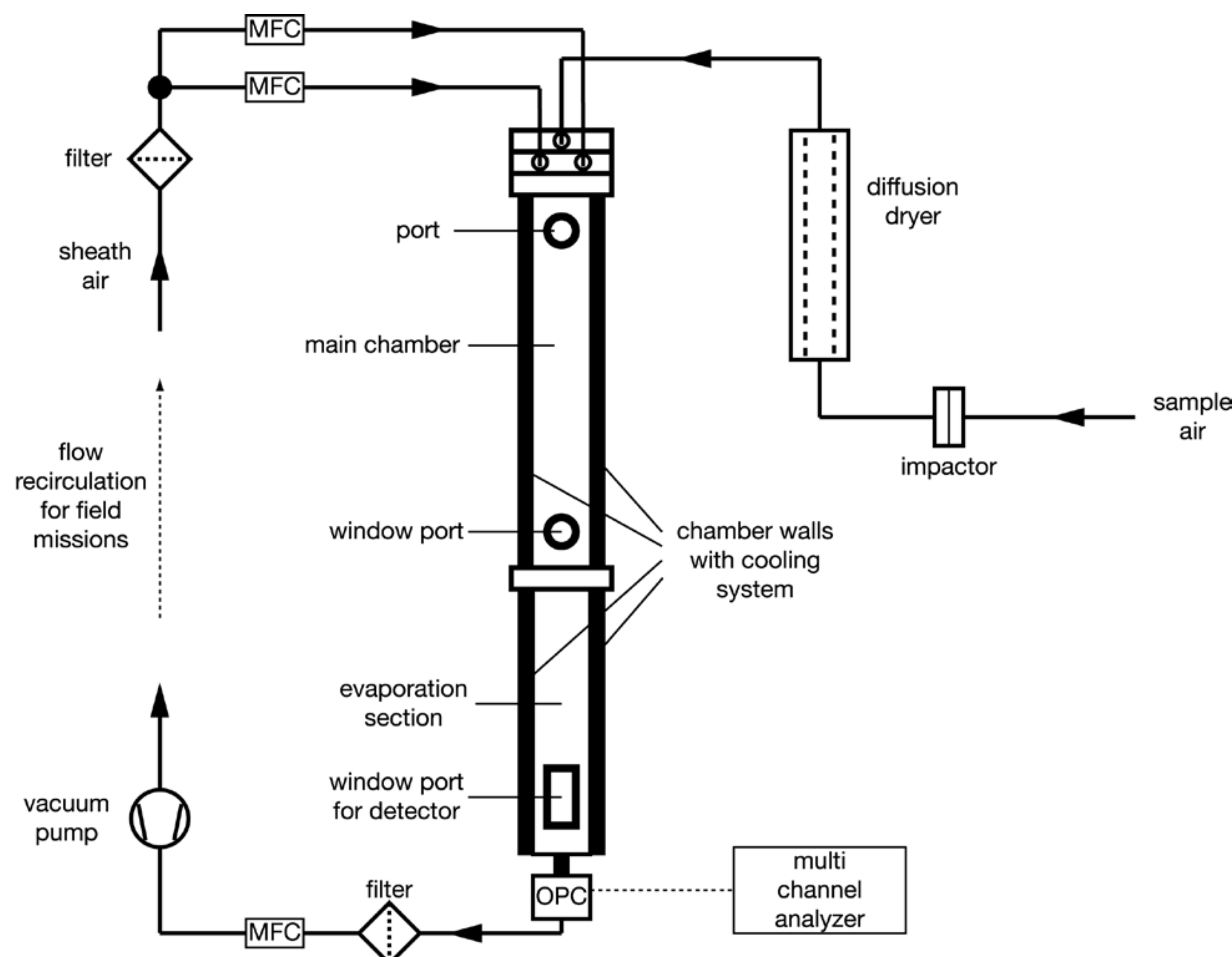
The Zurich Ice Nucleation Chamber (ZINC) is based on the principle of the Continuous Flow Diffusion Chamber by Dave Rogers and Paul DeMott (Colorado)

These chambers generally consist of two cooled, ice covered walls (Colorado: two cylinders, ZINC: two parallel plates).

Between these walls a laminar flow of air containing the sample aerosol is drawn.

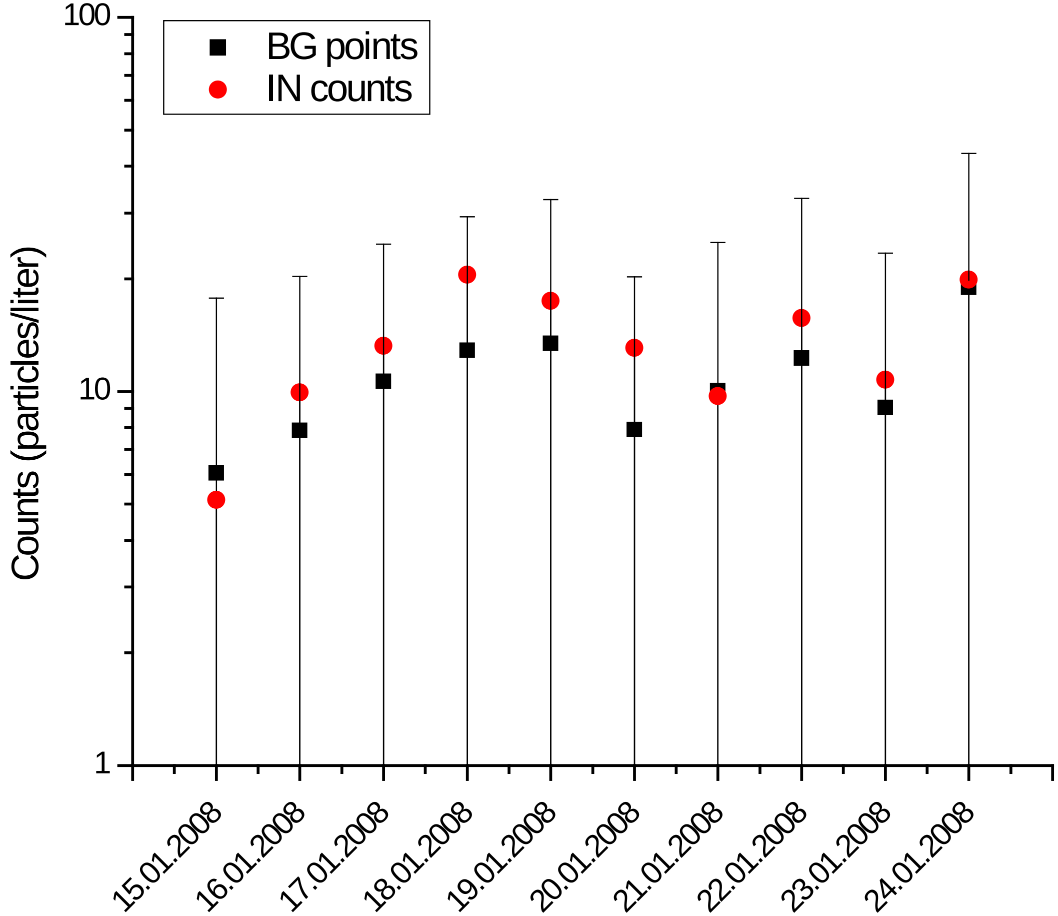
The sample flow (typically 10% of the total flow) is layered in between two clean, particle free sheath flows.

Ice crystals are detected at the outlet of the chamber (OPC)



PINC: First field data from JFJ

PINC was able to measure IN concentrations for the first time in Jan. 2008 on the JFJ
However: Still a very high background due to
- bad statistics (IN conc. are very low)
- instrument noise (will be worked on)



PINC on the Jungfraujoch
(January 2008)

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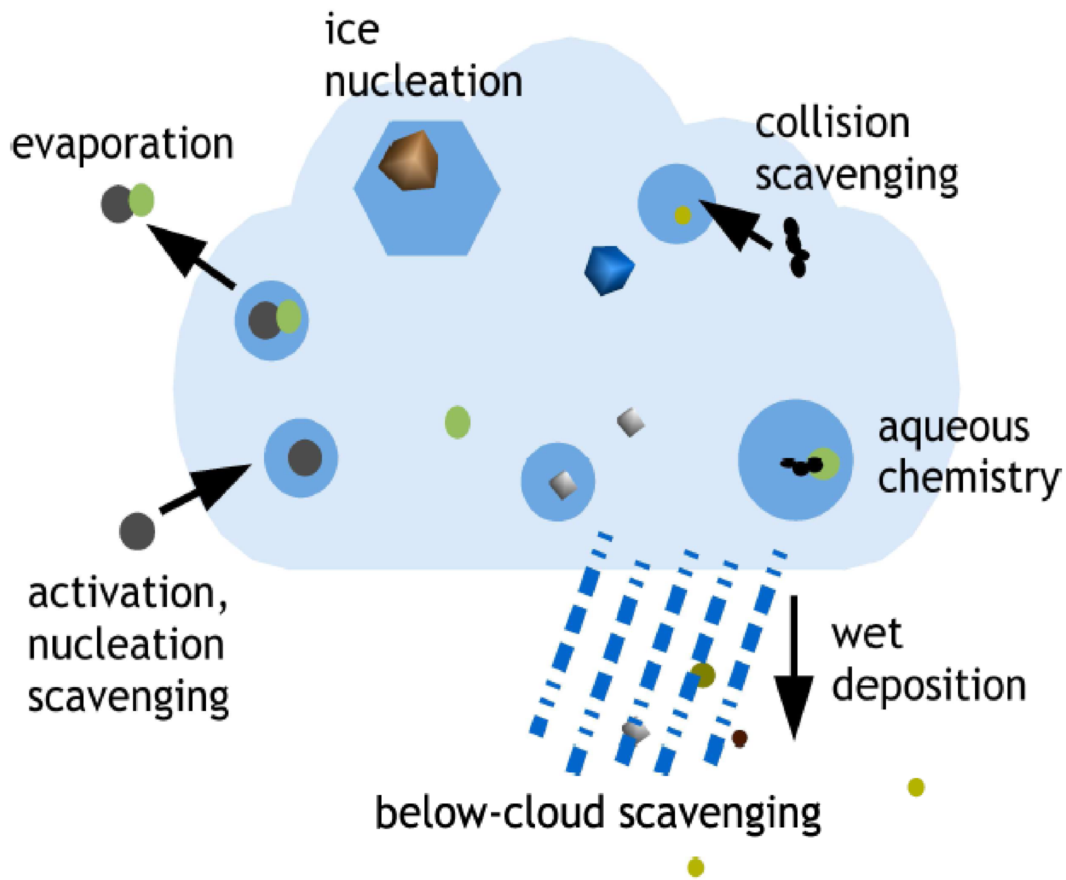
Aerosol processing and its effect on mixed-phase clouds in a global climate model



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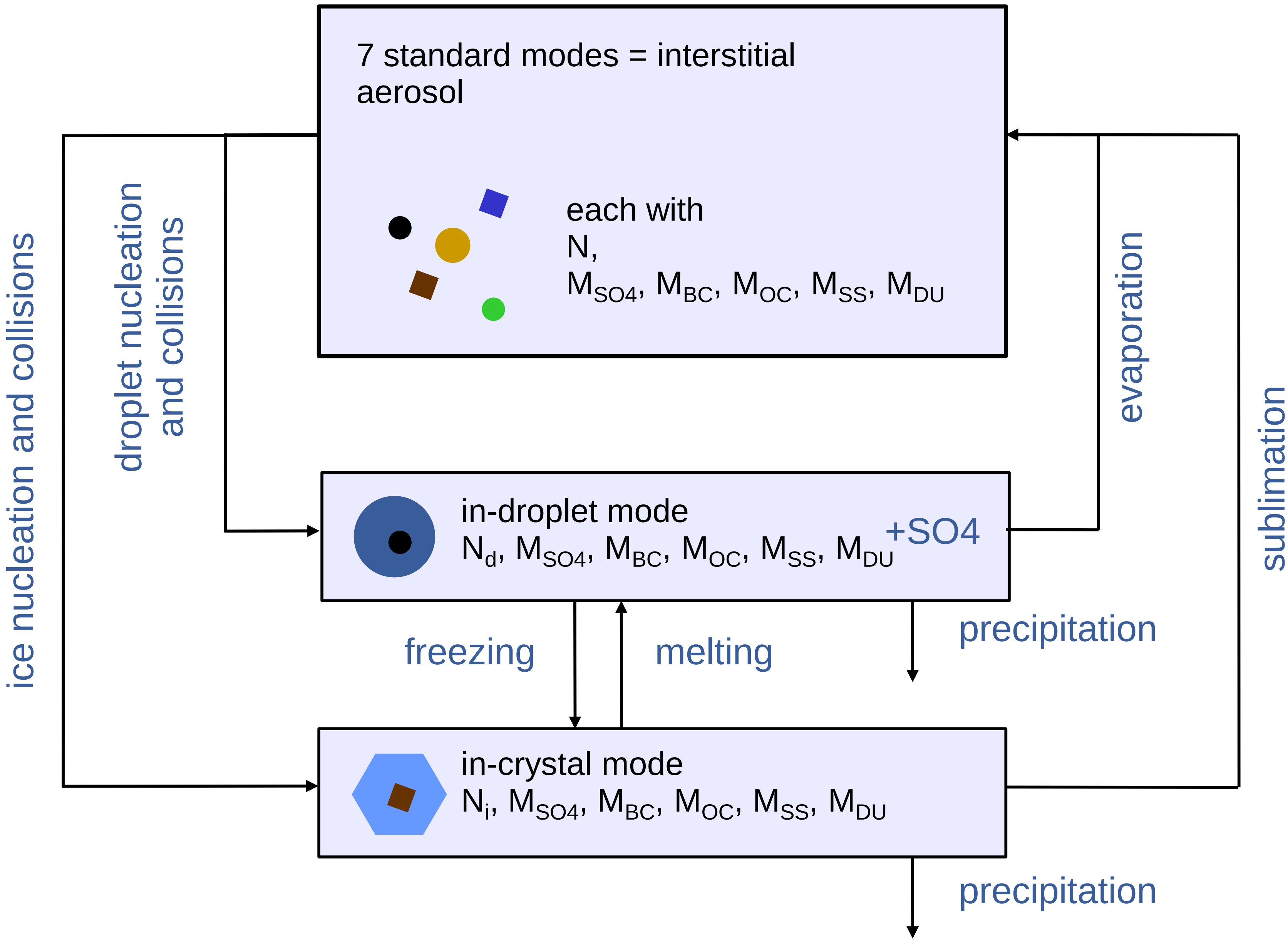
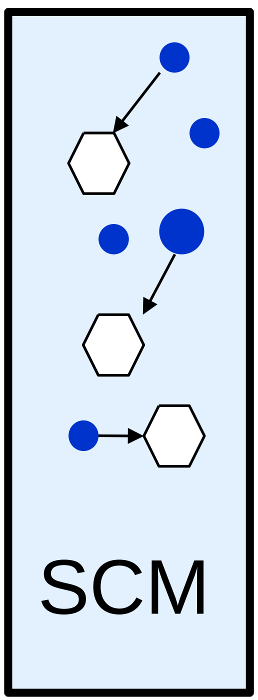
ECHAM5-HAM with aerosol processing



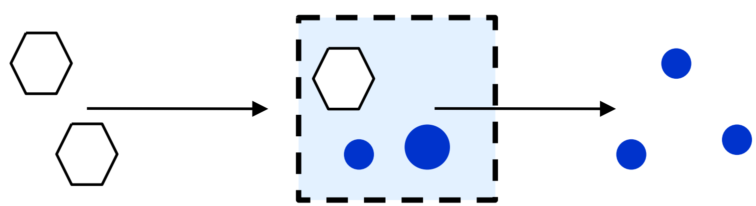
Hoose, Lohmann, Stier, Verheggen & Weingartner (2008)

Single Column Model simulations for Jungfraujoch (CLACE 3)

- total and interstitial aerosol size distribution measurements available *(Verheggen et al, 2007)*
- model initialisation from radio soundings



- caveat: no temporal correlation expected
- closed versus open system (SCM: no advection)



CLACE observations

Hoose, Lohmann, Stier, Verheggen & Weingartner (2008)

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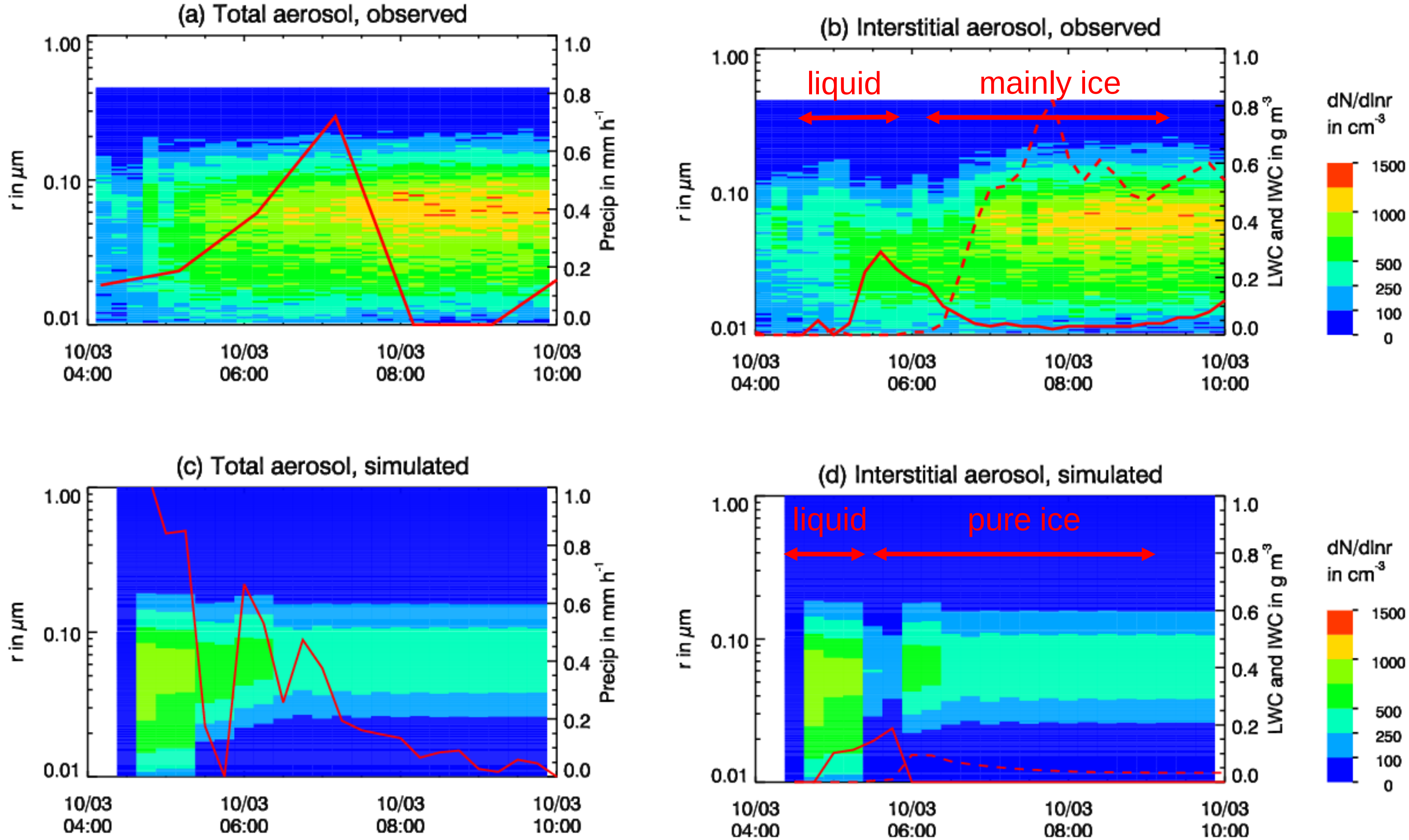
Size distributions in a glaciating cloud



- first liquid, then complete glaciation (Bergeron-Findeisen-process)
- depletion of interstitial aerosol in liquid cloud, release during glaciation
- losses by precipitation
- collision scavenging of small particles

Hoose, Lohmann, Stier, Verheggen & Weingartner (2008)

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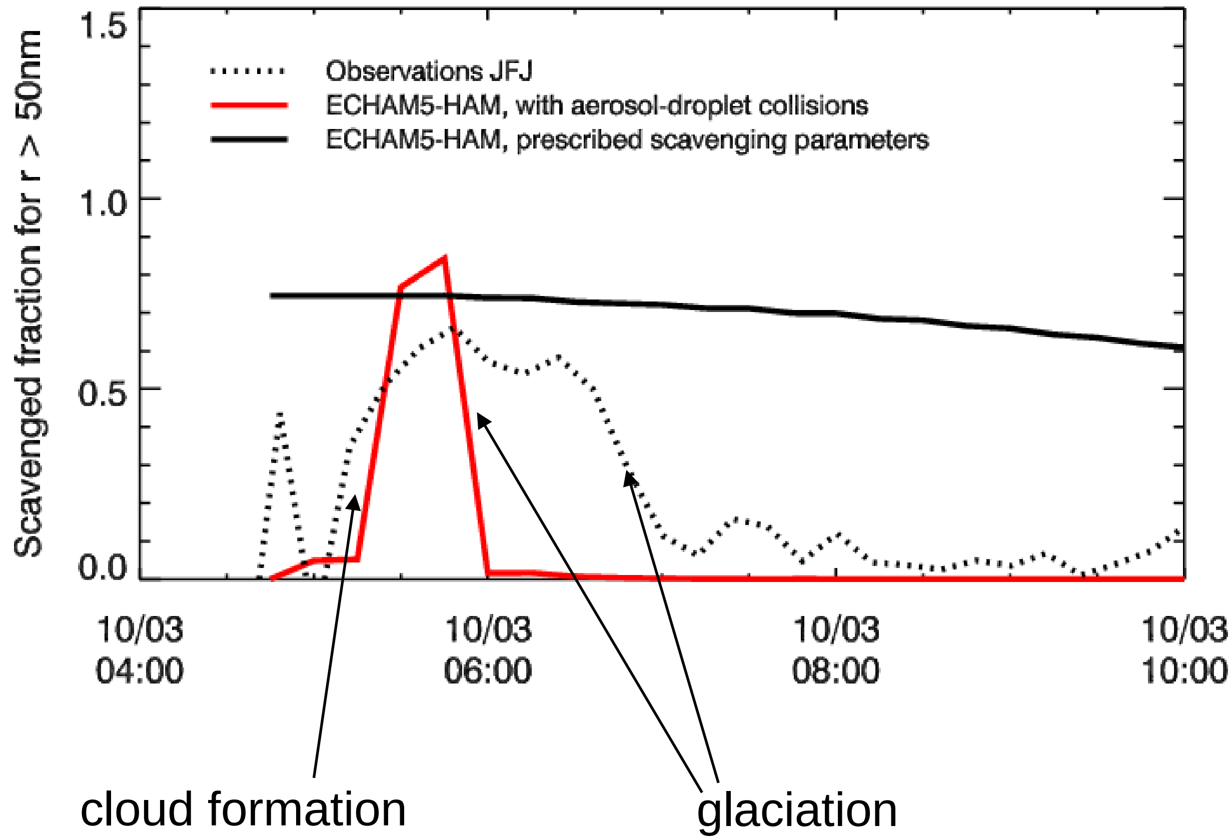
$$\text{Scavenged fraction} = \frac{N_{aer,\,\text{in hydrometeors}}}{N_{aer,\,\text{total}}}$$



- high scavenged fraction in liquid cloud phase
- decrease due to cloud glaciation (overestimated)
- prescribed scavenged fractions are too high for glaciated cloud

Hoose, Lohmann, Stier, Verheggen & Weingartner (2008)

Outlook

- PINC is currently being overhauled to improve instrument performance, increase temperature control and reduce background
- PINC will also be equipped with the depolarisation detector IODE to disriminate ice from water droplets at high supersaturations
- PINC will then be deployed to the Jungfraujoch for further measurements during diferent seasons of the year - of special interest is a correlation if IN with dust events as measured by PSI
- Holography: along with PINC there will be a holographic microscope at the JFJ to image ice crytals and droplets within mixed phase and ice clouds
- In addition the Fog Sampler from DMT will be installed on the JFJ as well

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