



HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
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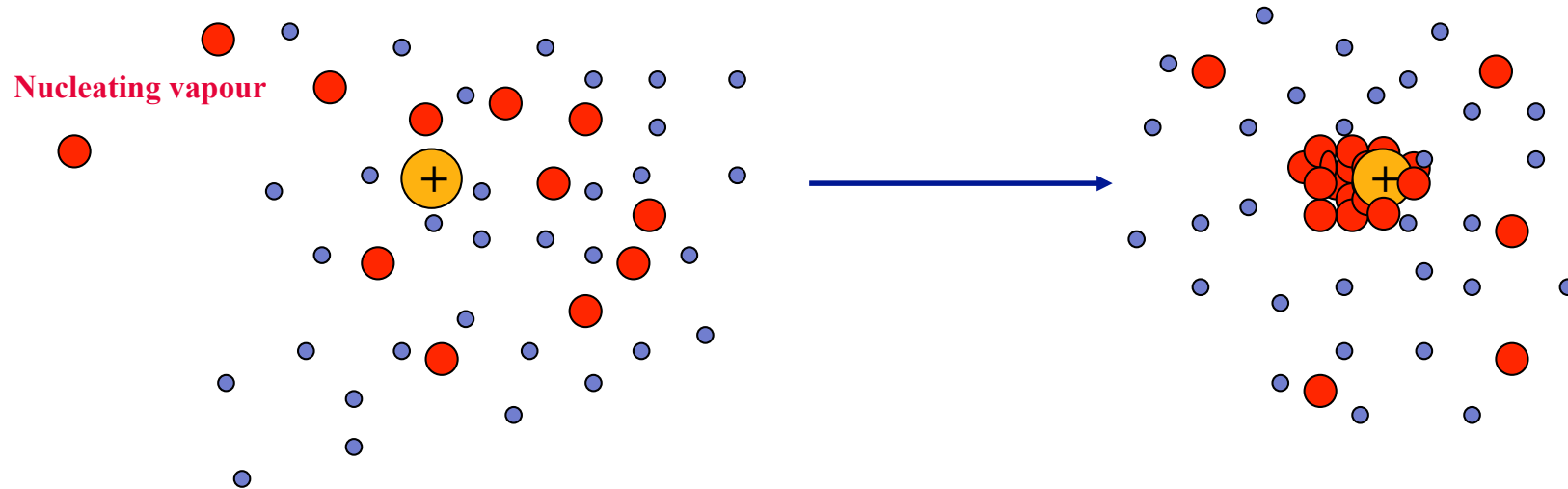
Ion-induced nucleation

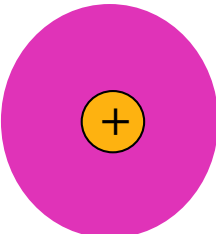




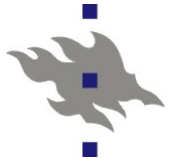
Nucleation around electrically charged molecules or particles

- Electrostatic charge-dipole interaction makes cluster formation easier



$$\Delta G = -NkT \ln S + A\sigma + \frac{q^2}{8\pi\epsilon_0} \left(1 - \frac{1}{\epsilon_r}\right) \left(\frac{1}{r} - \frac{1}{r_{ion}}\right)$$


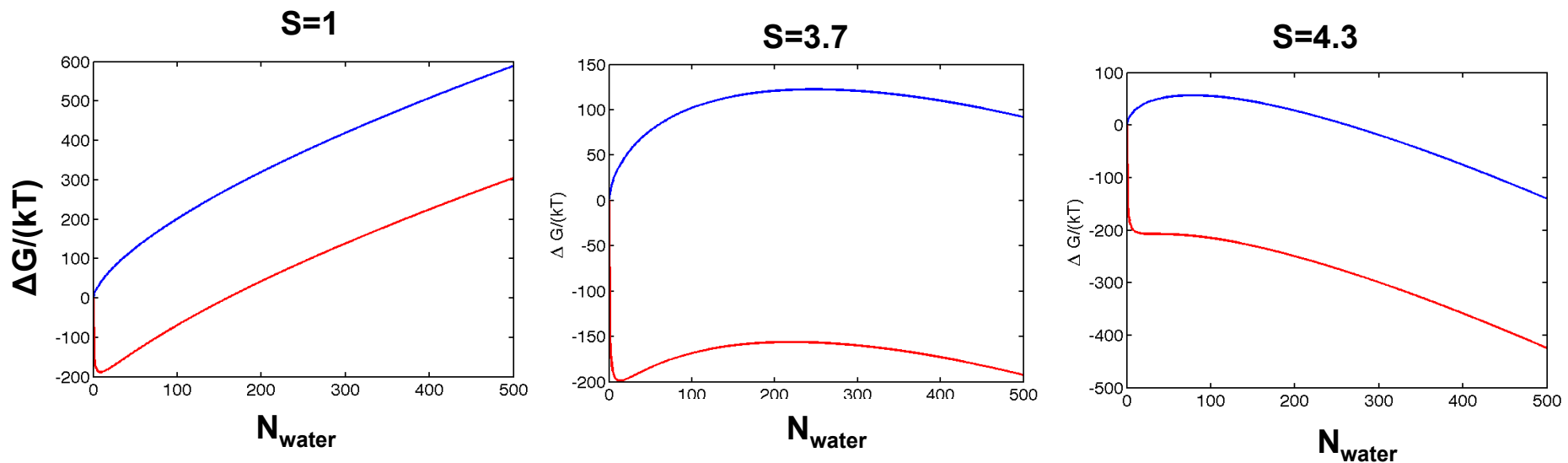
ϵ_0 permittivity of vacuum, ϵ_r dielectric constant



Free energy curve has a minimum and a maximum for moderate S (compare to hydrates)

■ Nucleation barrier is the difference in free energies between the minimum and the maximum

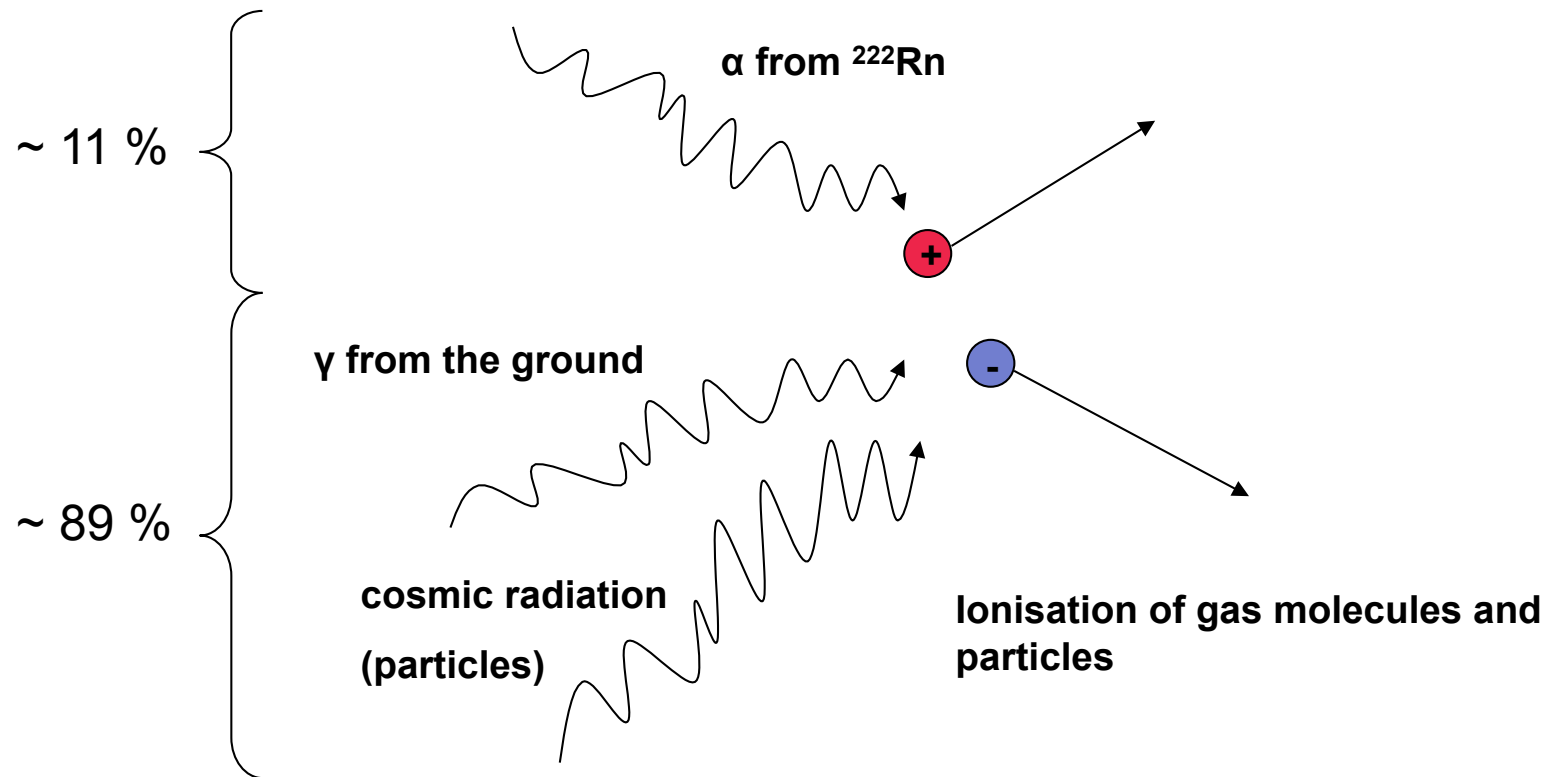
■ Water, 273.15 K ion radius = 1Å





Atmospheric ion production

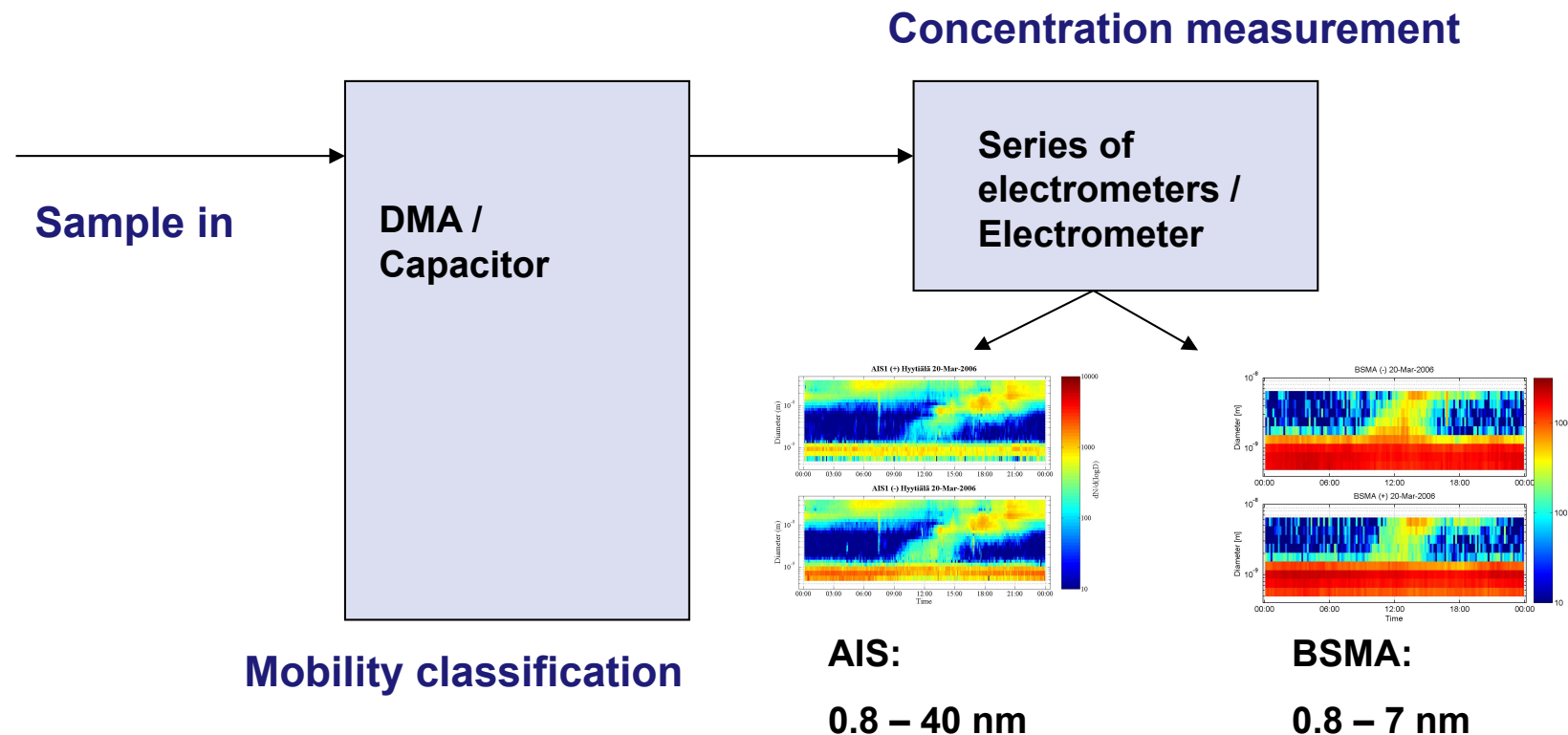
■ Total ionisation rate in Hyytiälä 4.2 – 17.6 ion pairs $\text{cm}^{-3} \text{s}^{-1}$





Observing atmospheric ions: Ion spectrometers, AIS and BSMA (Mirme et al., *BER* 2007; Tammet, *Atmos. Res.* 2006)

- Sizes even below 1 nm can be reached
 - No charging required-measure naturally charged fraction
 - High flow rates can be used (particle counting with electrometers)

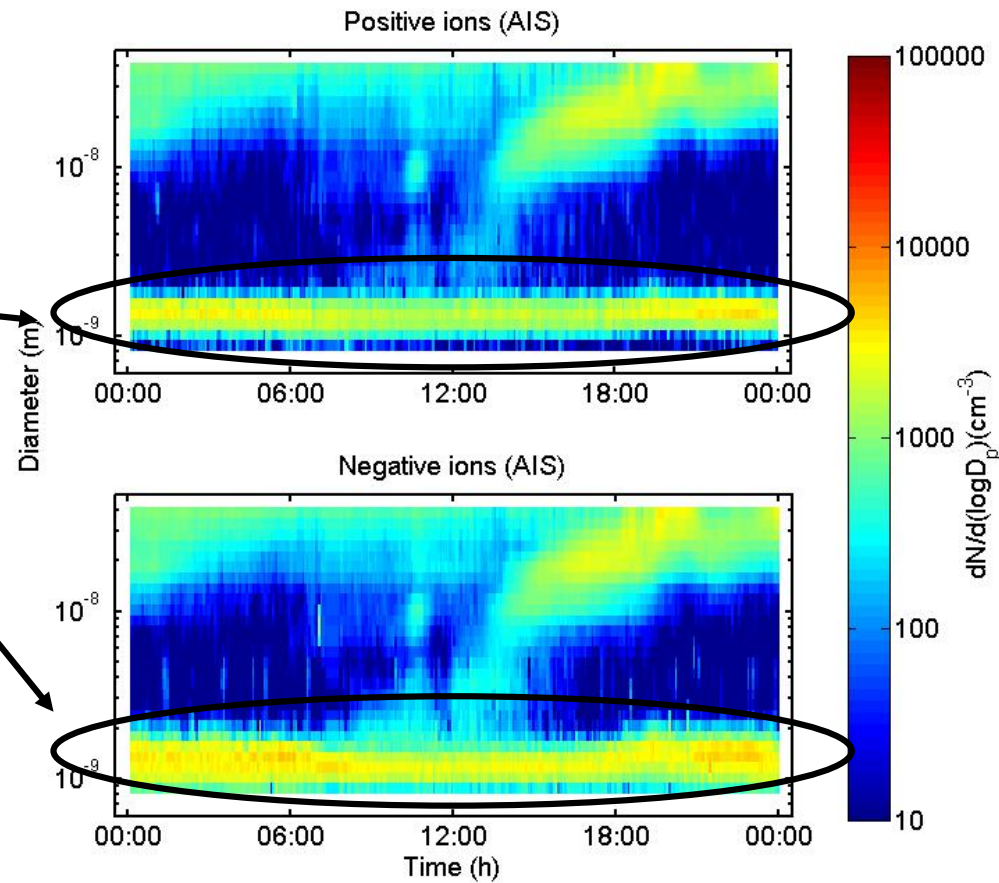




Size distributions of charged atmospheric particles in Hyytiälä

- Concentrations ~1- 10 % of total concentrations

Ion clusters,
~ 100 – 1000 cm⁻³

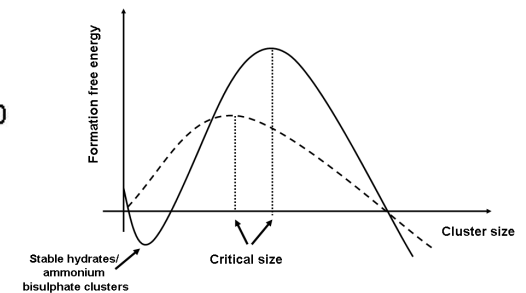
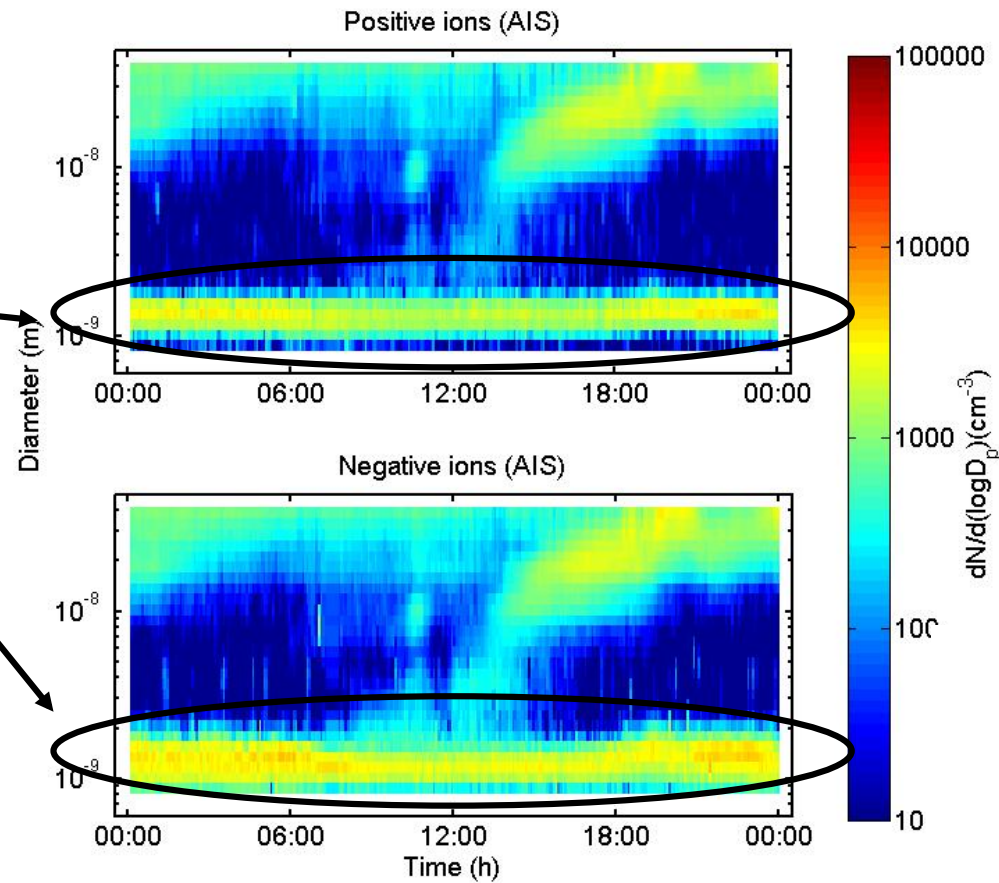




Size distributions of charged atmospheric particles in Hyytiälä

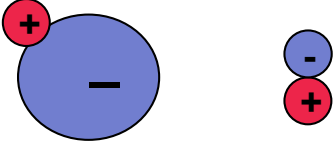
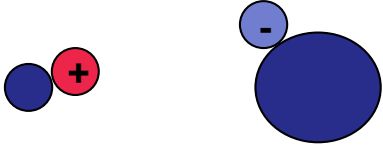
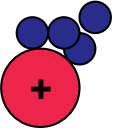

■ Concentrations ~1- 10 % of total concentrations

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Air ion / charged particle dynamics

Recombination / neutralisation	
Charging / coagulation	
Condensational growth	
Nucleation	



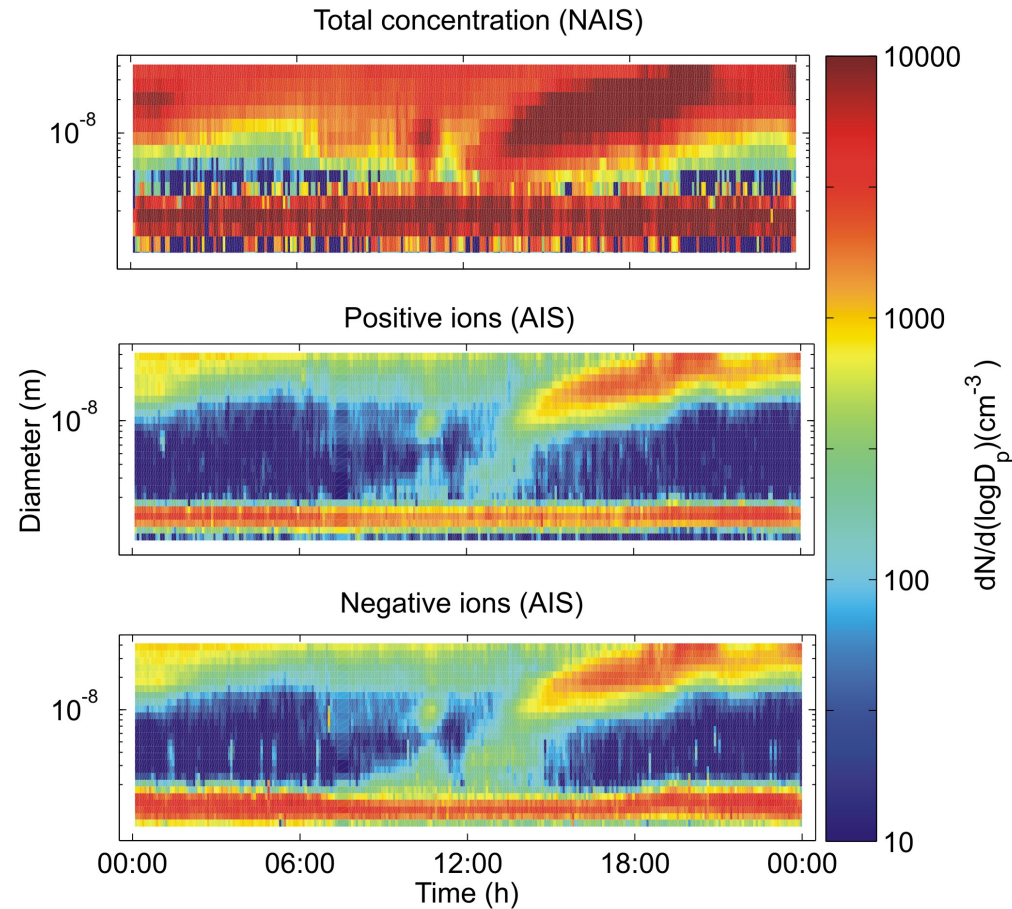
Proposed ion-related particle formation mechanisms / models

- Ion-induced 2-component or 3-component nucleation (e.g. Yu and Turco, 2000)
- Ion-induced cloud formation (Svensmark and Friis-Kristensen, 1997)
- Production of stable neutral clusters by ion cluster recombination and the activation of these clusters (ion-mediated nucleation) (e.g. Yu, *ACP* 2006)



How to assess the importance of ion-related nucleation mechanisms?

- Measurements on both neutral and charged particles now possible: NAIS, newly-developed CPCs

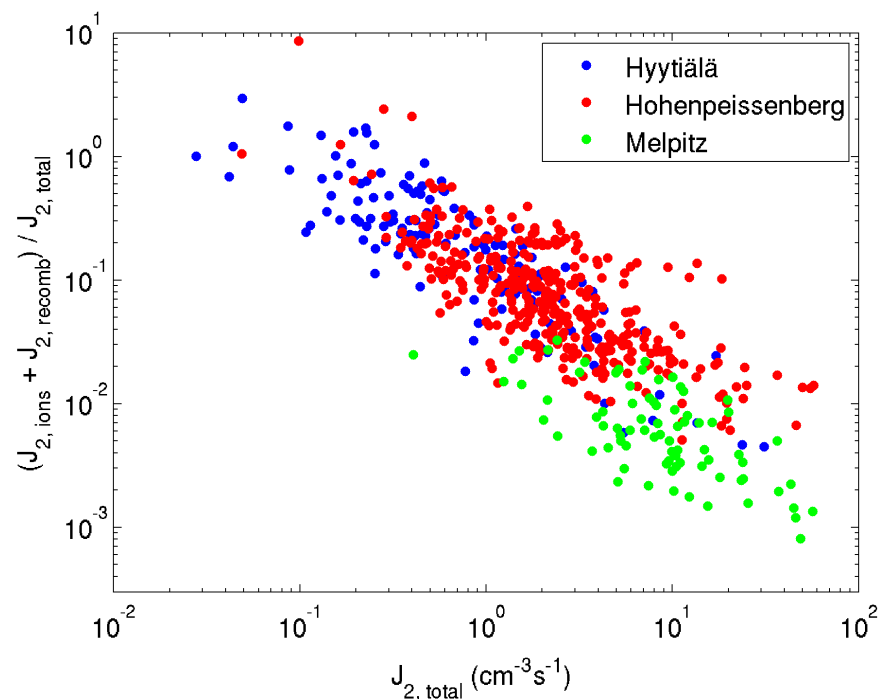
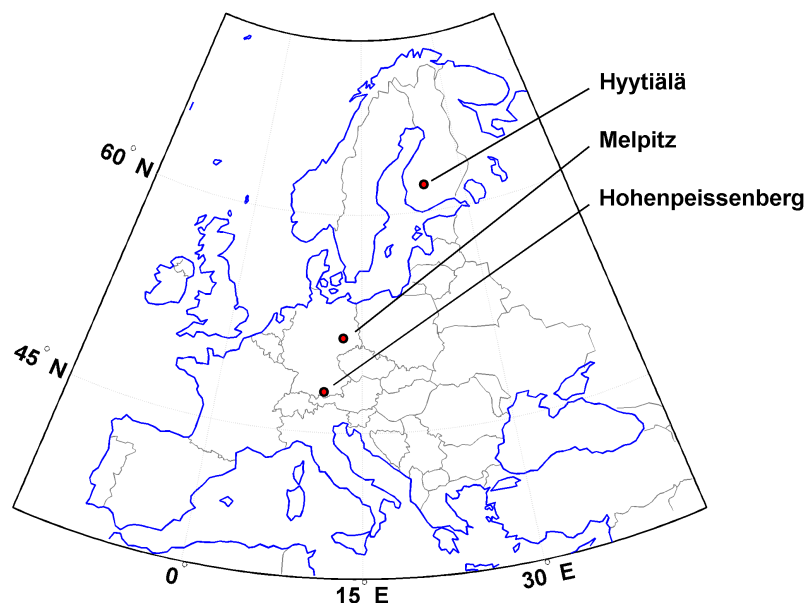


- Comparison of total vs. charged particle concentrations

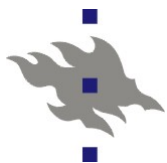


Neutral vs. charged 2 nm formation rates give some indication on the role of ion-induced processes

- Ions seem not to dominate (typically < 10% of the formation rate)

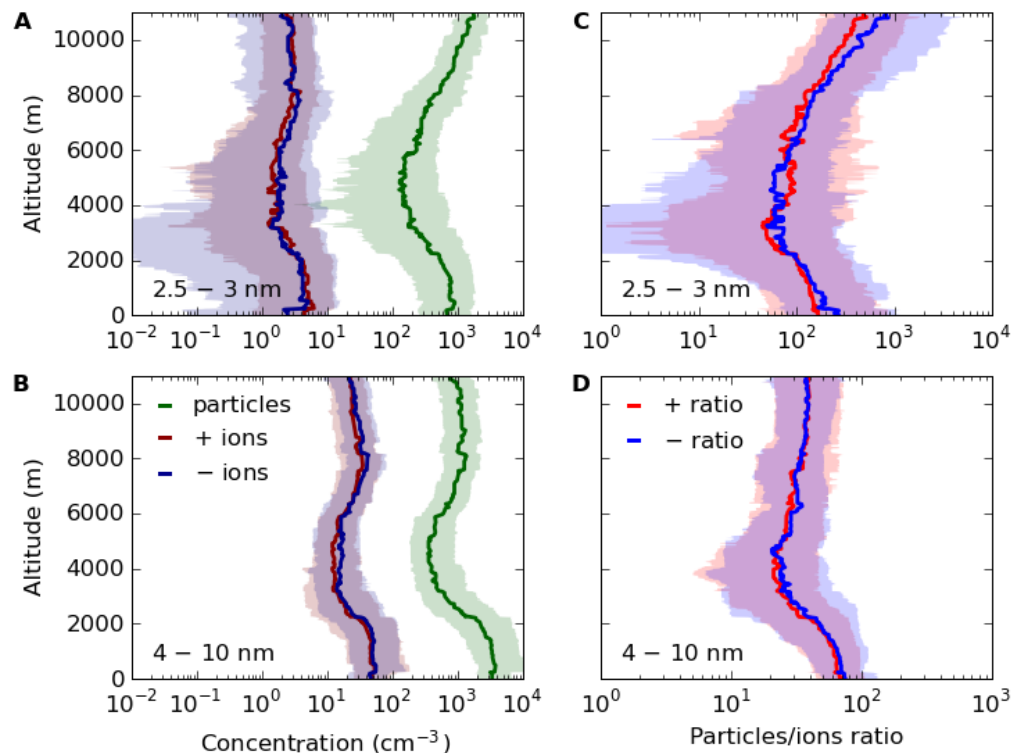
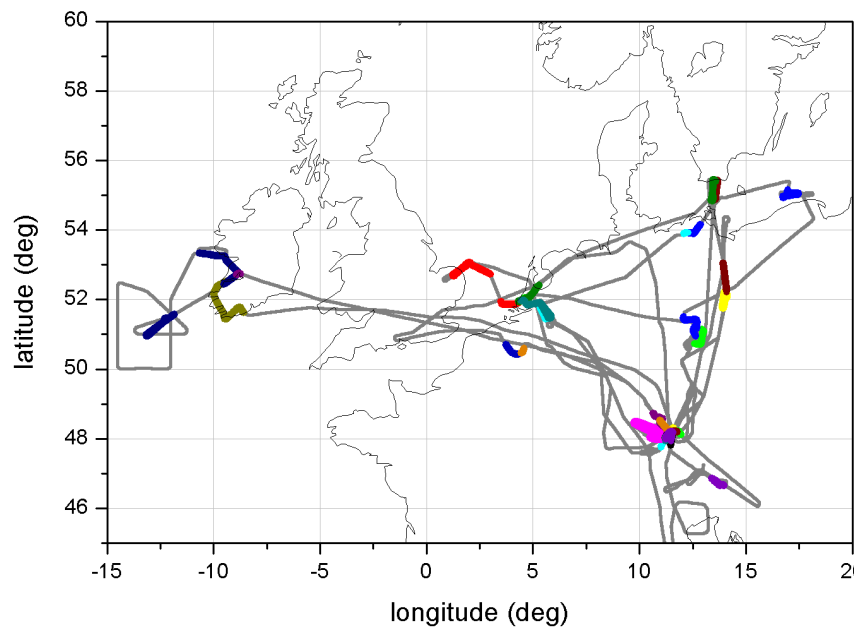


- Is 2 nm small enough?



Ion-neutral fractions: vertical profiles

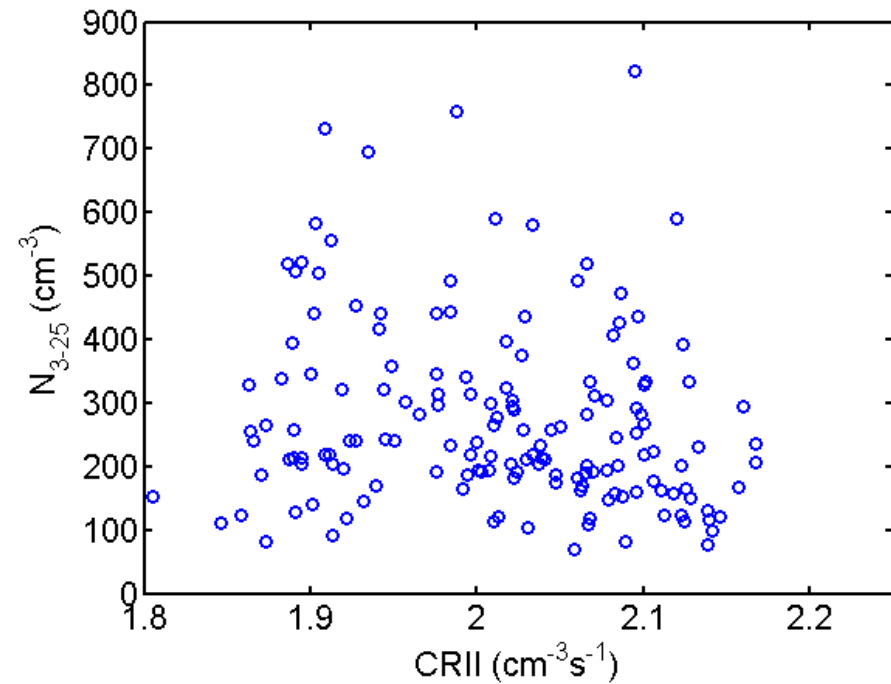
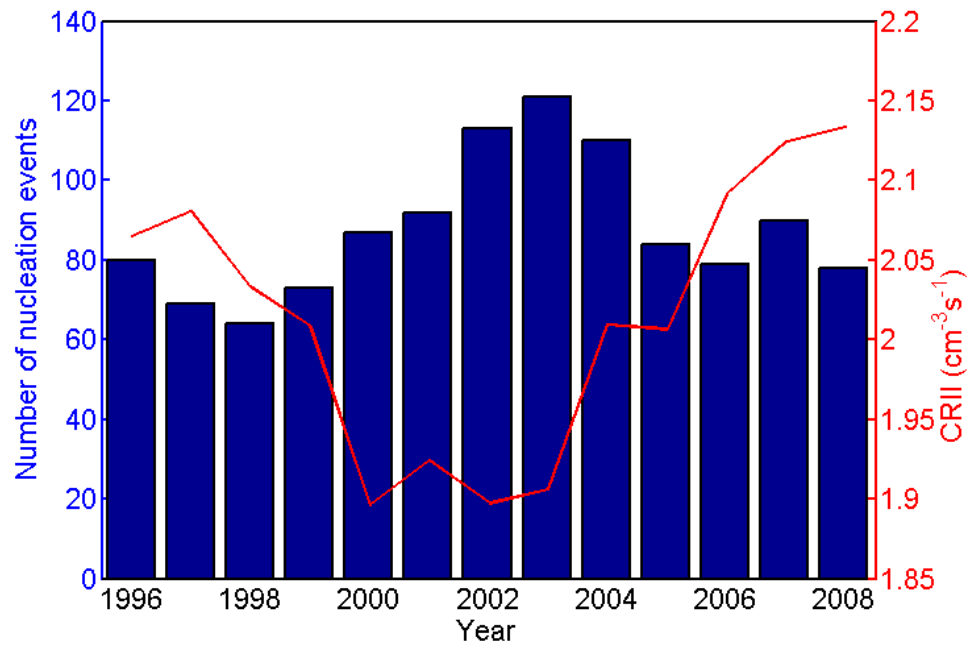
- No clear signs of dominance of the ion-induced mechanism





Aerosol formation and galactic cosmic rays

■ No correlation at any particle sizes



■ Radiation and production of vapours better explaining factor

■ Some other connection between clouds and CRII?