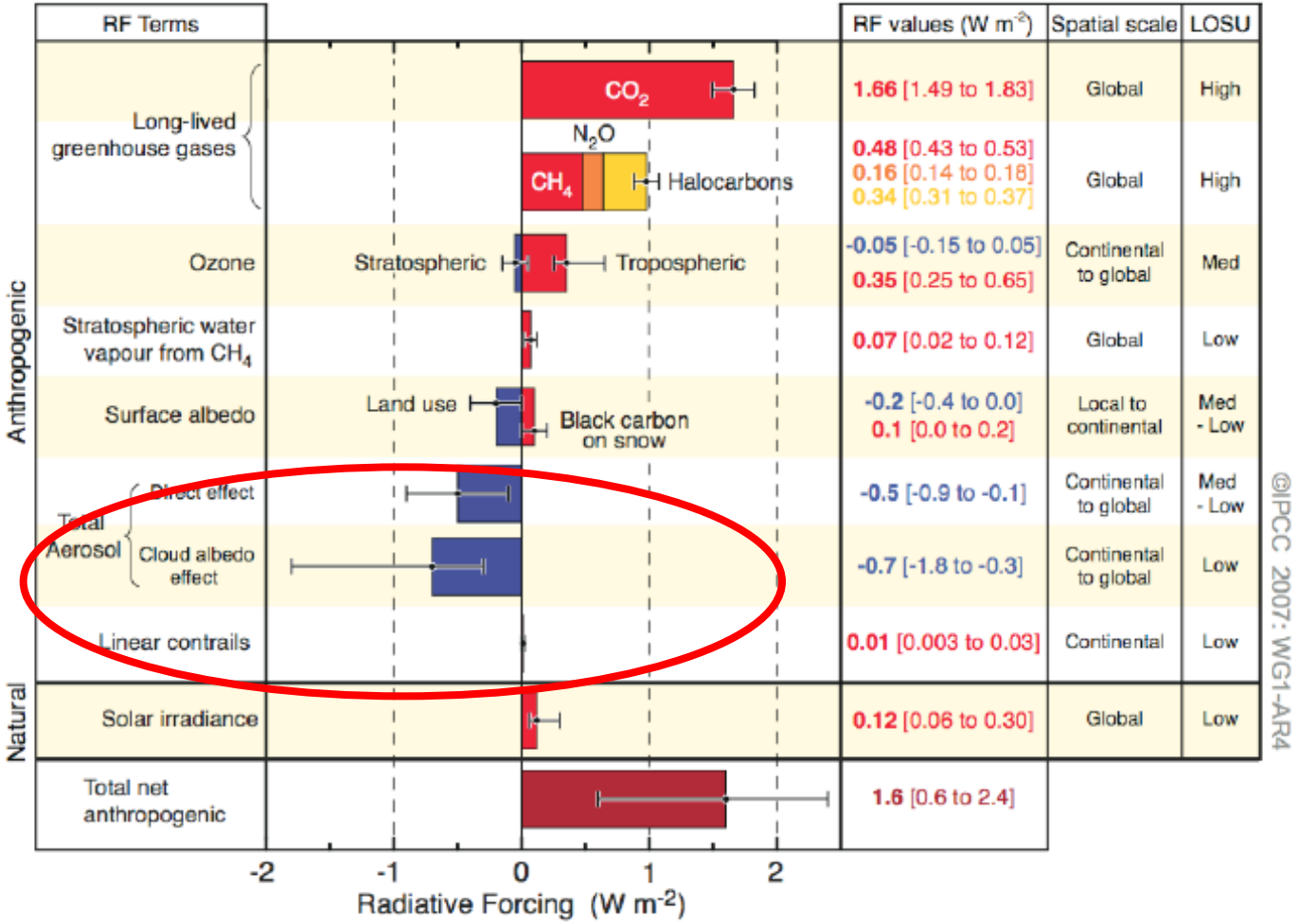
PAUL SCHERRER INSTITUT

LABOR FÜR ATMOSPHÄREN-CHEMIE

CLOUD results

Francesco Riccobono
Laboratory of Atmospheric Chemistry
Paul Scherrer Institut
CHIPP plenary meeting, 2 September 2011, Leysin

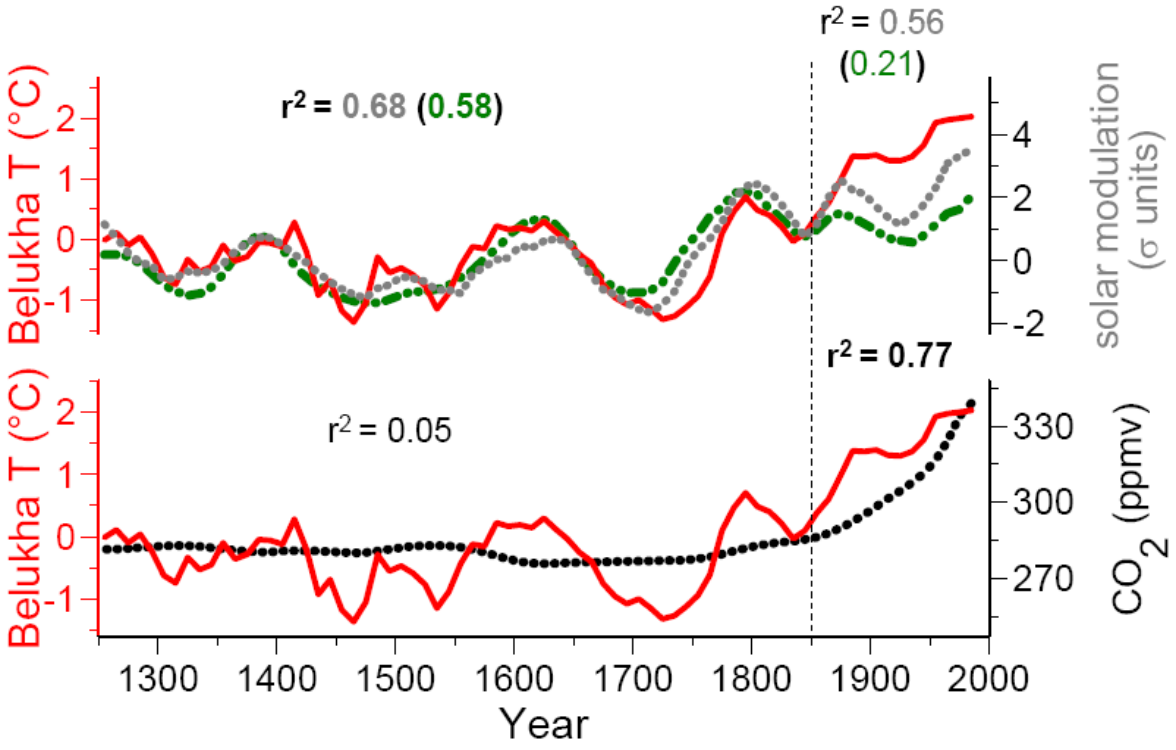
radiative forcing



www.ipcc.ch

solar activity & temperature

Before 1850 changes in solar activity was the main driving force of temperature changes in the Central Asian Altai.
After 1850 additional contributions as greenhouse gases.



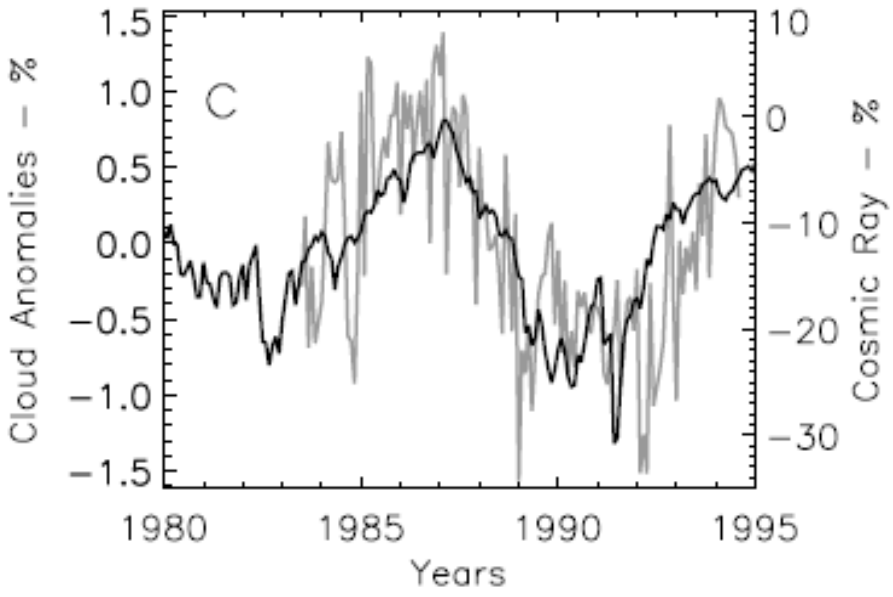
Temperature proxy: ice core oxygen isotope

Eichler et al. GRL 2009

cosmic rays and cloud cover

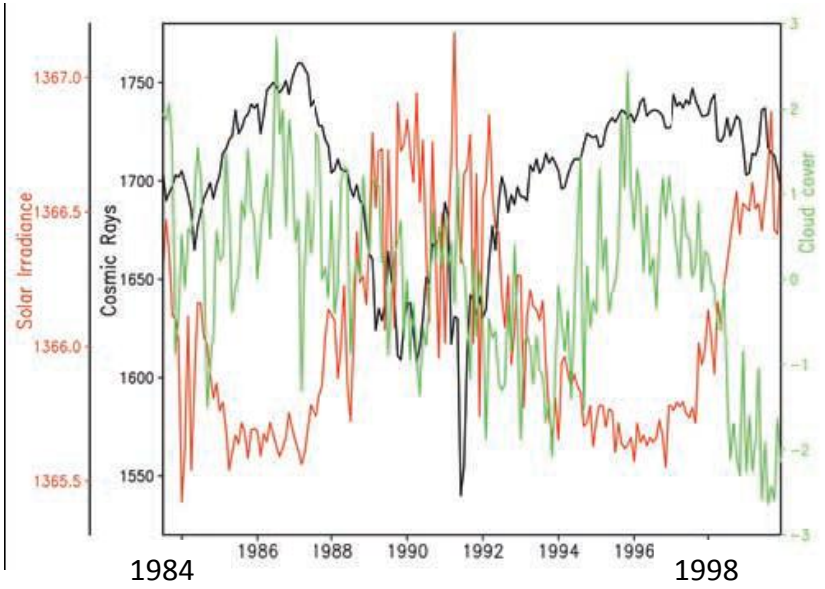
Conflicting data

Cosmic rays
Cloud anomalies



Marsh and Svensmark, 2000

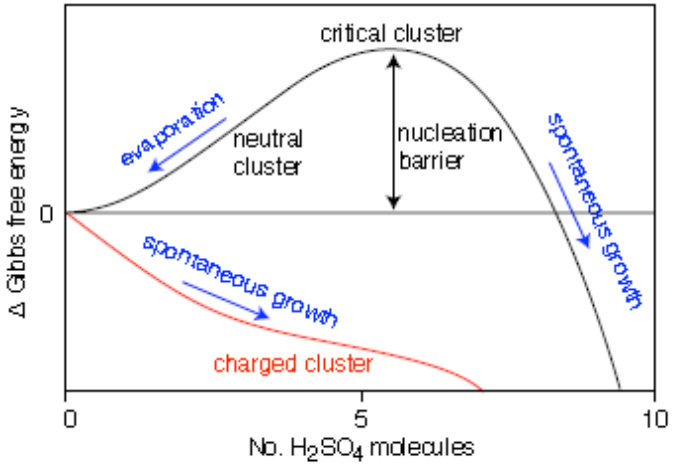
Cosmic rays
Solar irradiance
Cloud cover

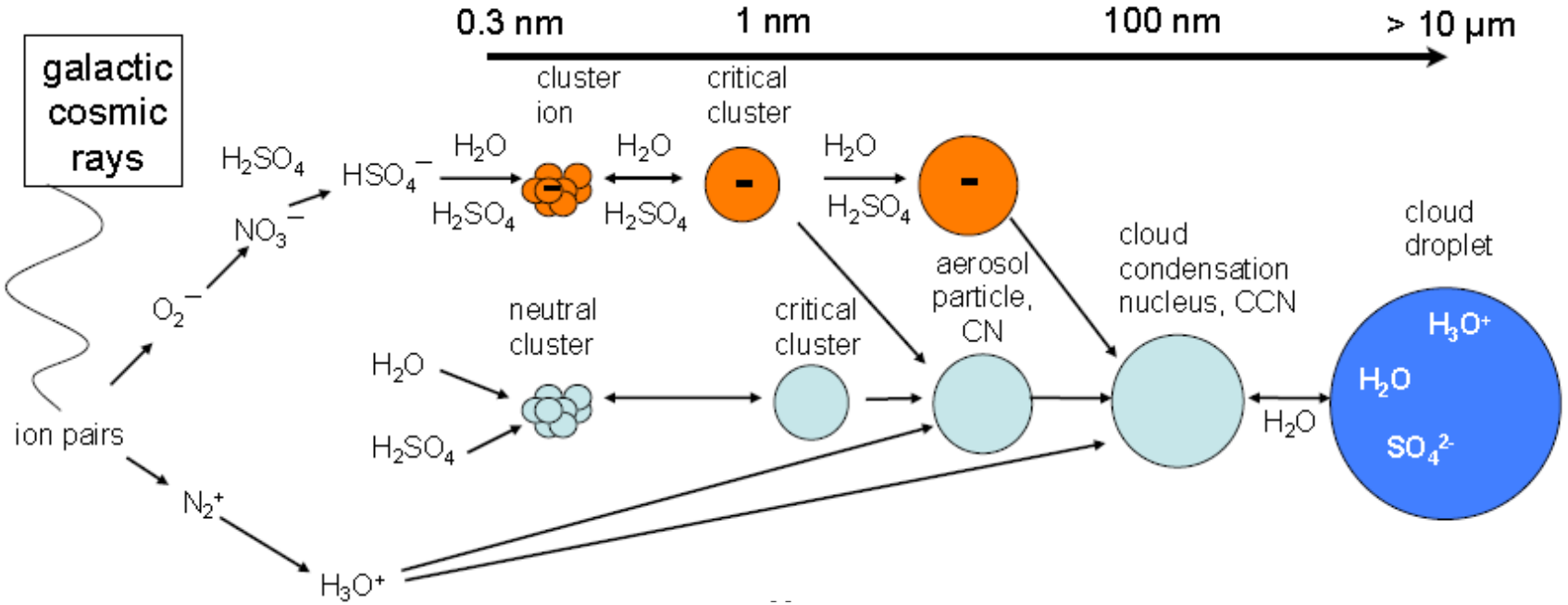


Kristjansson et al., 2002

possible mechanism

- Important source of cloud condensation nuclei is gas-to-particle conversion:
  trace gas → CN → CCN
- Ion-induced nucleation pathway is energetically favoured but limited by the ion production rate and ion lifetime

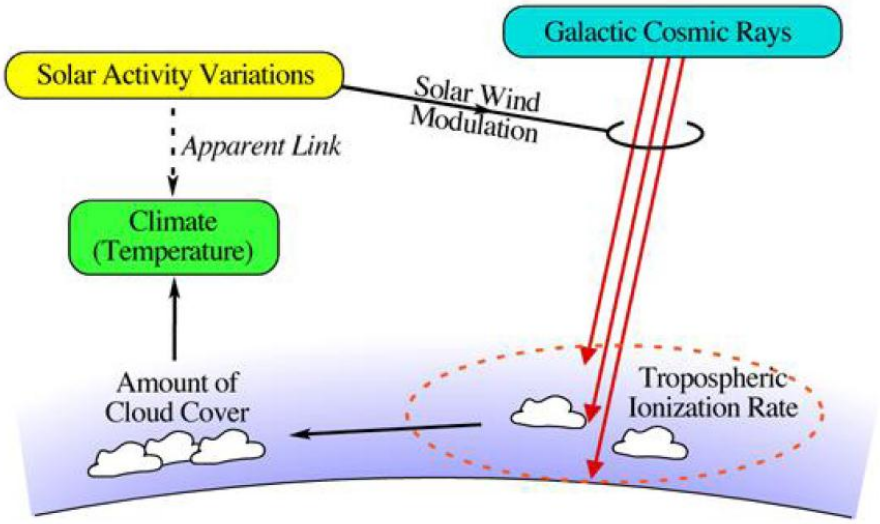




CLOUD

Cosmics Leaving OUtdoor Droplets

cloud



GCR → Ions → Nucleation → Growth → CCN → Cloud cover → Climate change

CLOUD collaboration

- 19 institutes from Europe, Russia and USA
- 14 atmospheric institutes + 5 space/CR/particle physics
- CLOUD-ITN network of 10 Marie Curie fellows: 8 PhD students + 2 postdocs

Support in Switzerland:
- **FORCE project (linked to smog chamber project at PSI)**

Support in Germany:
- **BMBF**

Austria:
University of Innsbruck, Institute of Ion Physics and Applied Physics
University of Vienna, Institute for Experimental Physics

Bulgaria:
Institute for Nuclear Research and Nuclear Energy, Sofia

Estonia:
University of Tartu, Department of Environmental Physics

Finland:
Helsinki Institute of Physics and University of Helsinki, Department of Physics
Finnish Meteorological Institute, Helsinki
University of Kuopio, Department of Physics
Tampere University of Technology, Department of Physics

Germany:
Goethe-University of Frankfurt, Institute for Atmospheric and Environmental Sciences
Leibniz Institute for Tropospheric Research, Leipzig

Portugal:
University of Lisbon, Department of Physics

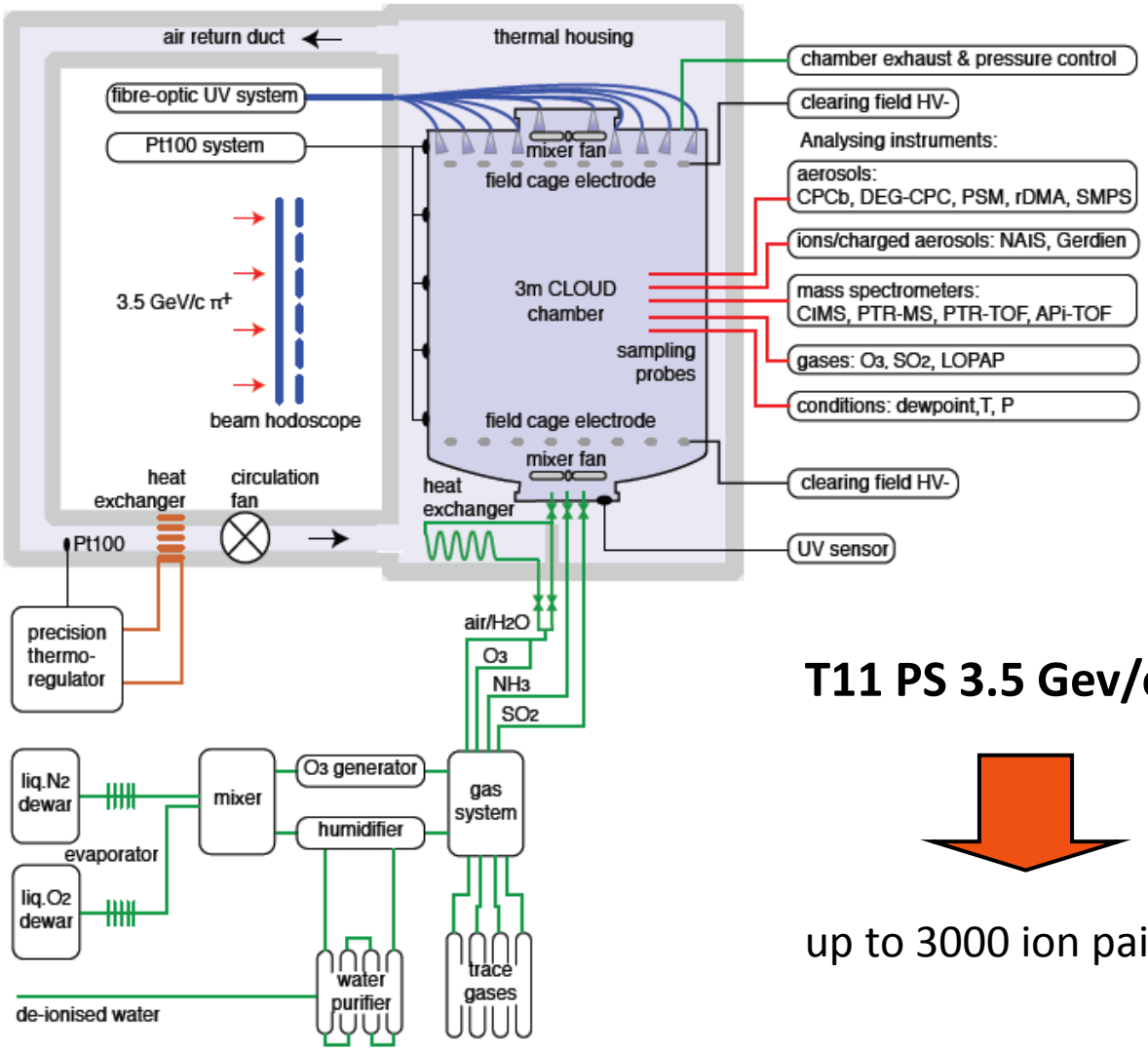
Russia:
Lebedev Physical Institute, Solar and Cosmic Ray Research Laboratory, Moscow

Switzerland:
CERN, Physics Department
Fachhochschule Nordwestschweiz (FHNW), Institute of Aerosol and Sensor Technology, Brugg
Paul Scherrer Institute, Laboratory of Atmospheric Chemistry

United Kingdom:
University of Leeds, School of Earth and Environment
University of Reading, Department of Meteorology
Rutherford Appleton Laboratory, Space Science Department

United States:
California Institute of Technology, Division of Chemistry and Chemical Engineering

CLOUD chamber



T11 PS 3.5 Gev/c π^+

up to 3000 ion pair/cm^3

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PSI

CLOUD chamber

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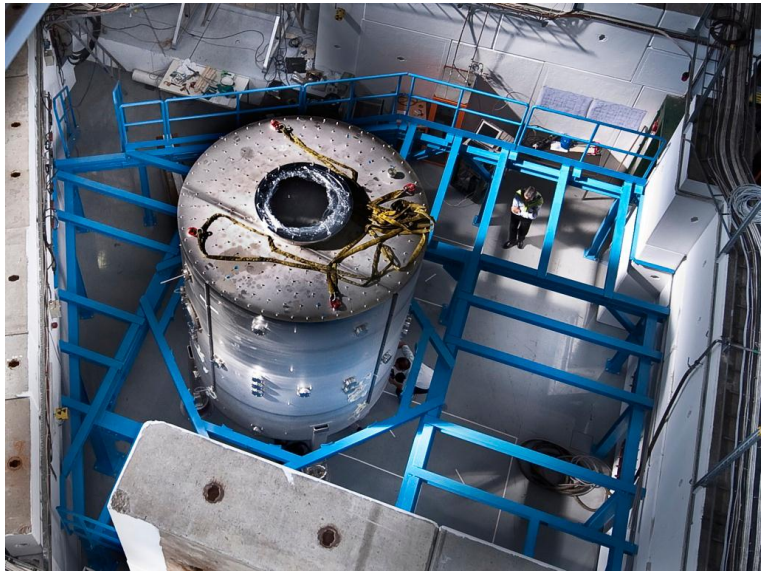


Tages-Anzeiger 25.08.2011

Cern-Experiment stellt Wissen über Wolken infrage

Schwefel- und Ammoniakdämpfe, die unter anderem der Mensch produziert, sind für die Wolkenbildung weniger relevant als angenommen. Dafür spielt die kosmische Strahlung eine Rolle.

Die Entstehungsgeschichte der Wolken muss nach den jüngsten Forschungen neu geschrieben werden. Foto: Edgar Herbst (13 Photo)

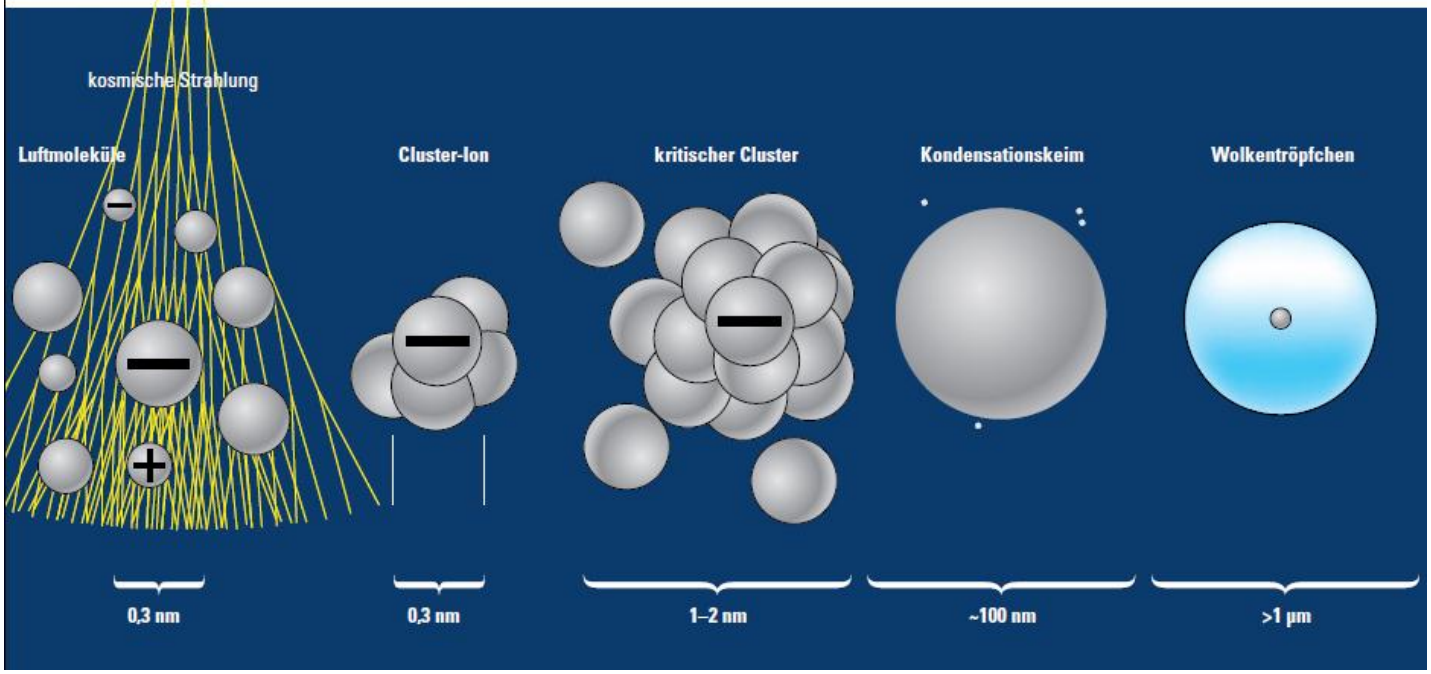
Neue Zürcher Zeitung
SCHWEIZER AUSGABE

31.08.2011

Klimaexperiment mit Teilchenbeschleuniger trägt Früchte

Wie kosmische Strahlung und Spurengase bei der Entstehung von Aerosolen und Wolken mitmischen

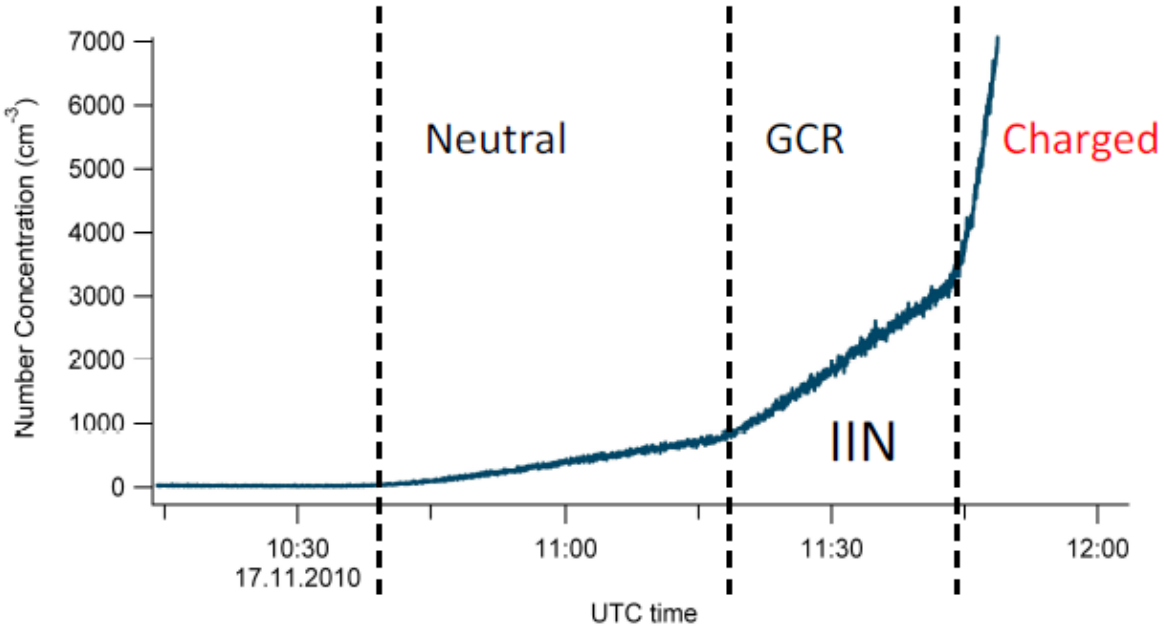
Der Weg vom Molekül zum Wolkentröpfchen



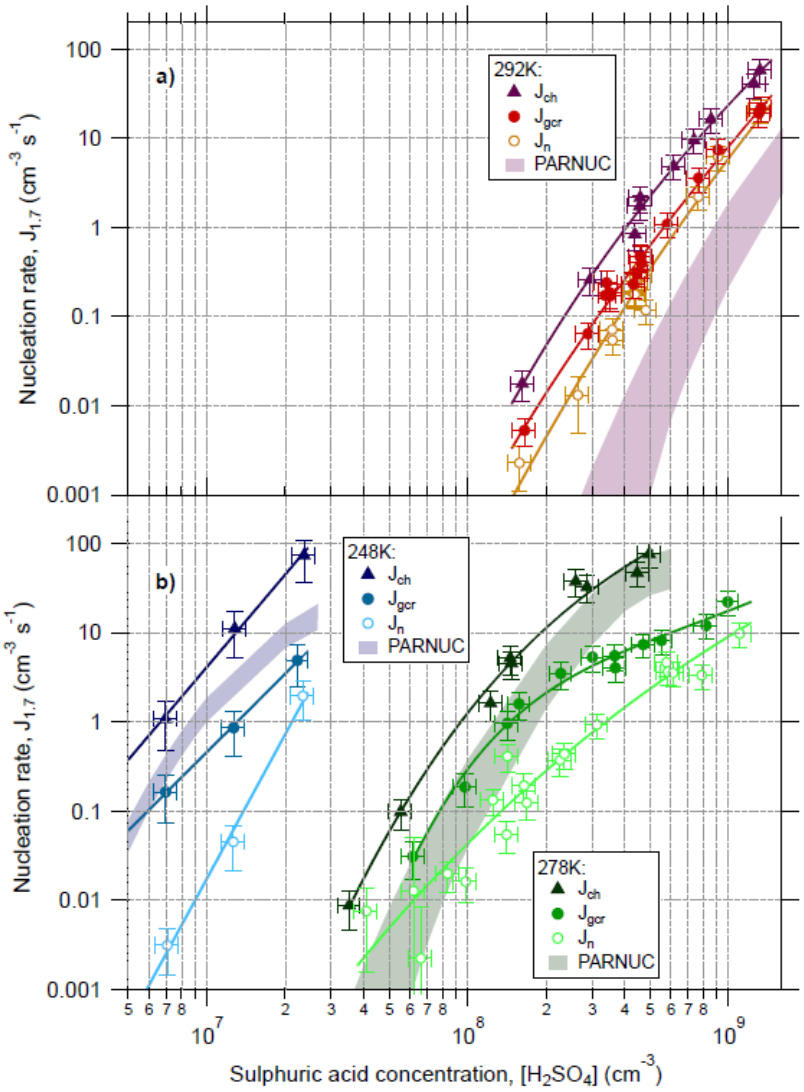
typical experiment

Ternary nucleation $H_2SO_4 + H_2O (+ NH_3)$

Experimental temperature range +20° C to -25° C



results nucleation rates

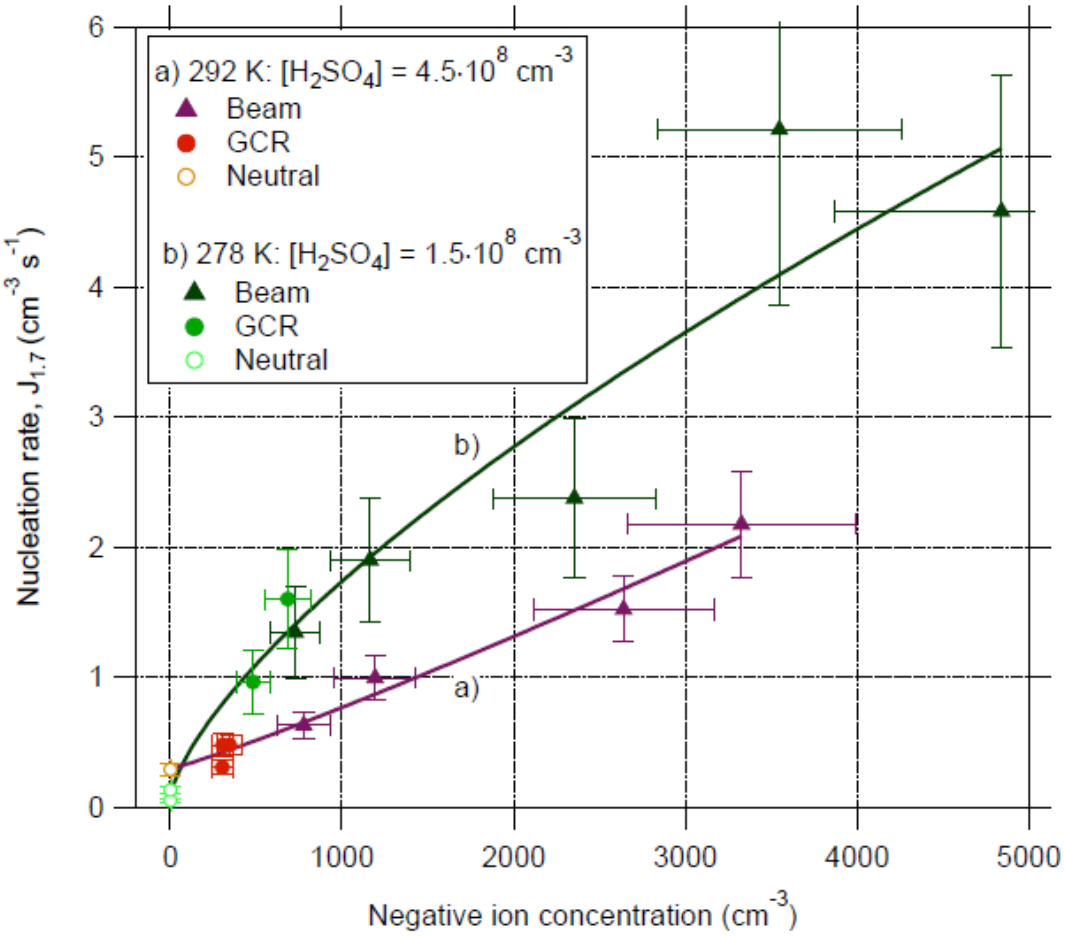


Ground level ionisation enhances the neutral nucleation rate by a factor of 2 at 298 K.

As the temperature is reduced, lower H_2SO_4 concentrations are sufficient to maintain the same nucleation rates, due to decrease of the H_2SO_4 saturation vapour pressure.

Kirkby et al. Nature 2011

results role of ions



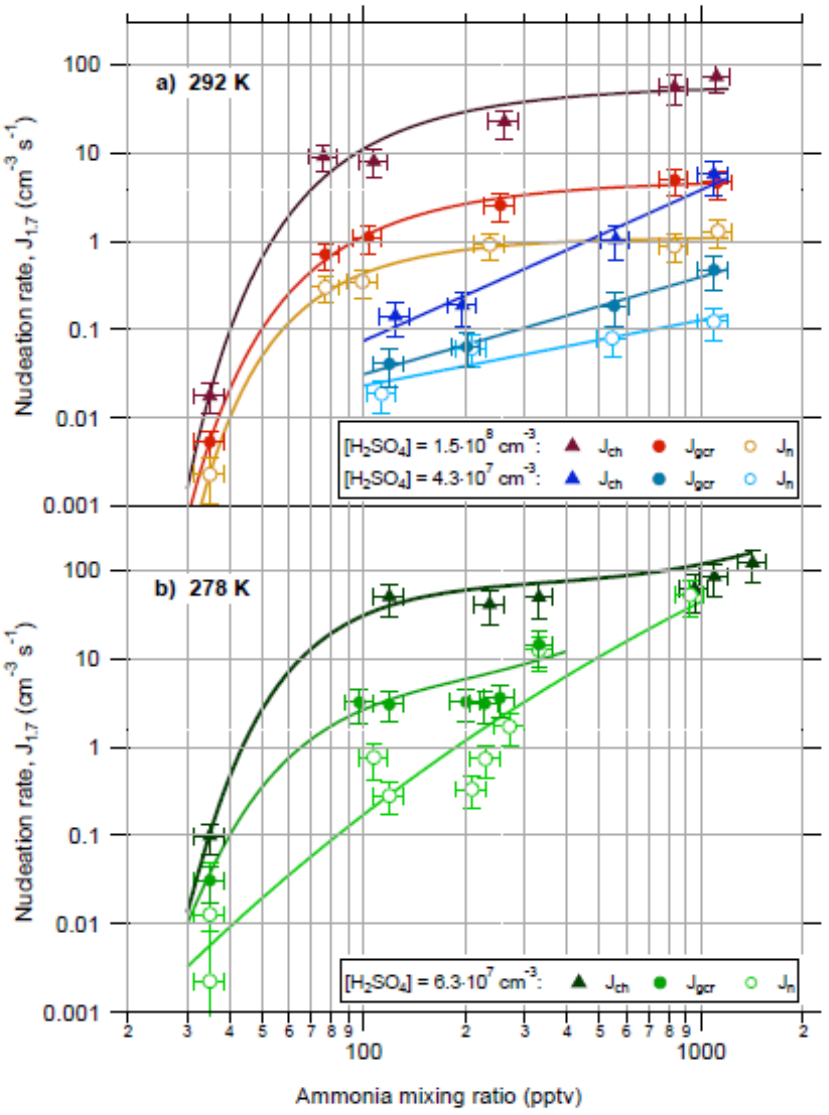
$J = J_n + k[Ion^-]^p$ $p = 0.7–1.0$

results ammonia

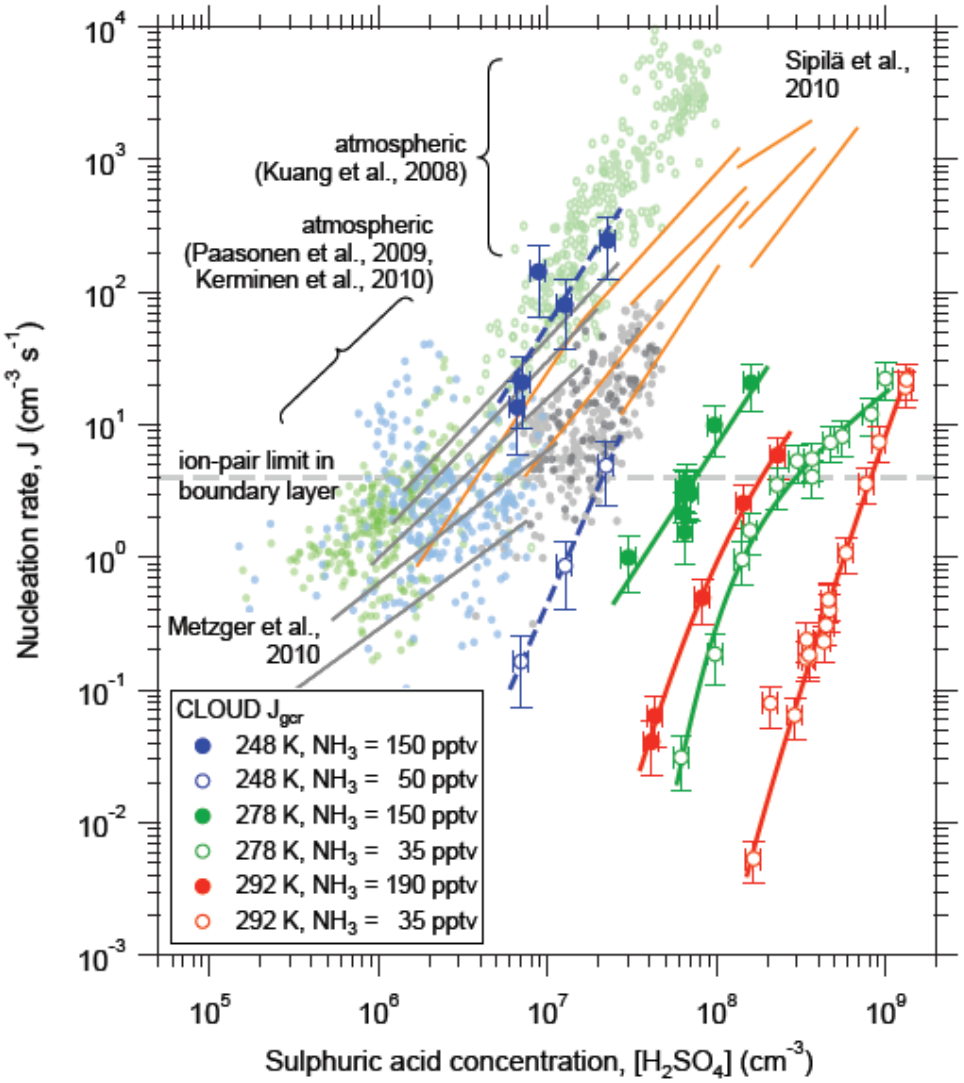
Contaminants play a crucial role.

Mass spectrometry shows that at 292 K the clusters containing more than 4 sulfuric acid are found always together with additional nitrogen-containing molecules (NH_3, amines, urea).

NH_3 intentionally added.



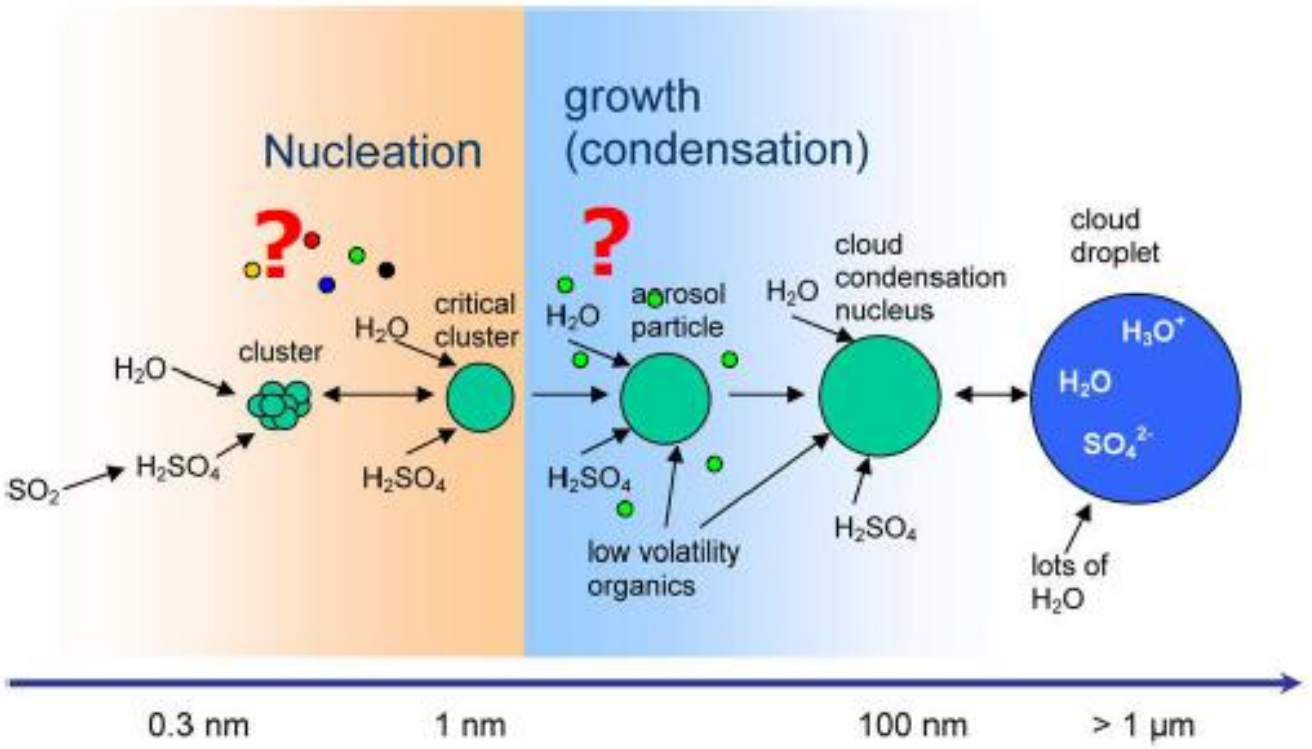
results ambient data



At 292 K we measured nucleation rates 1000 times smaller than the nucleation rates observed in the atmosphere

additional nucleating vapours are needed

Ion induced growth enhancement?

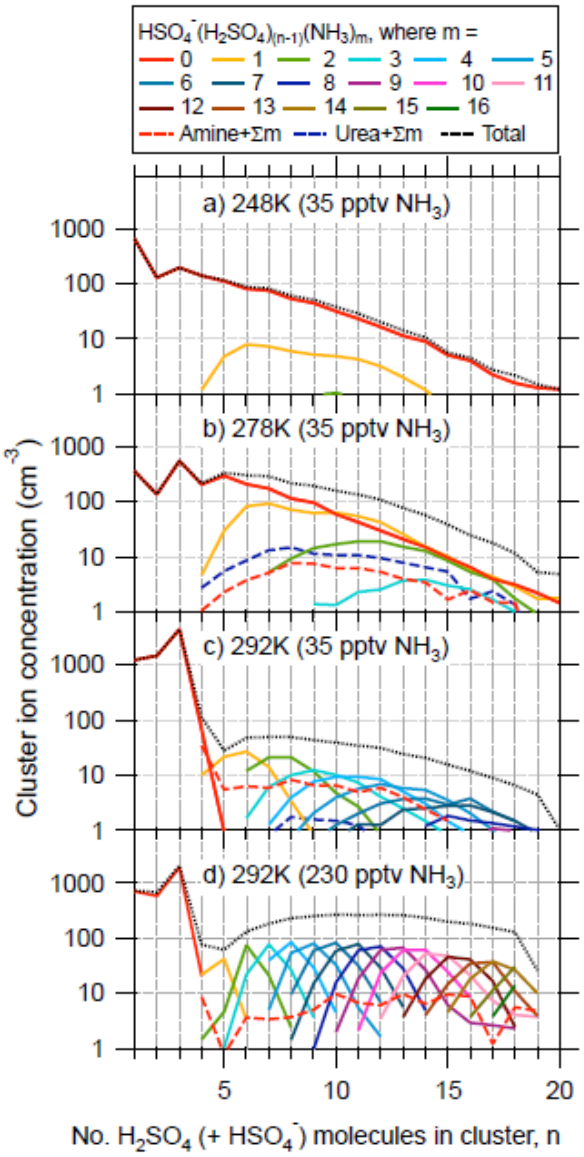


conclusions

- First quantitative measurement of ion-induced nucleation.
- H_2SO_4+H_2O alone cannot explain atmospheric nucleation.
- Background contamination resulted in an interesting "fault".
- New experiments with organics in 2011.
- Chamber performance test 2011: T down to -88° C.

Thank you for your attention!

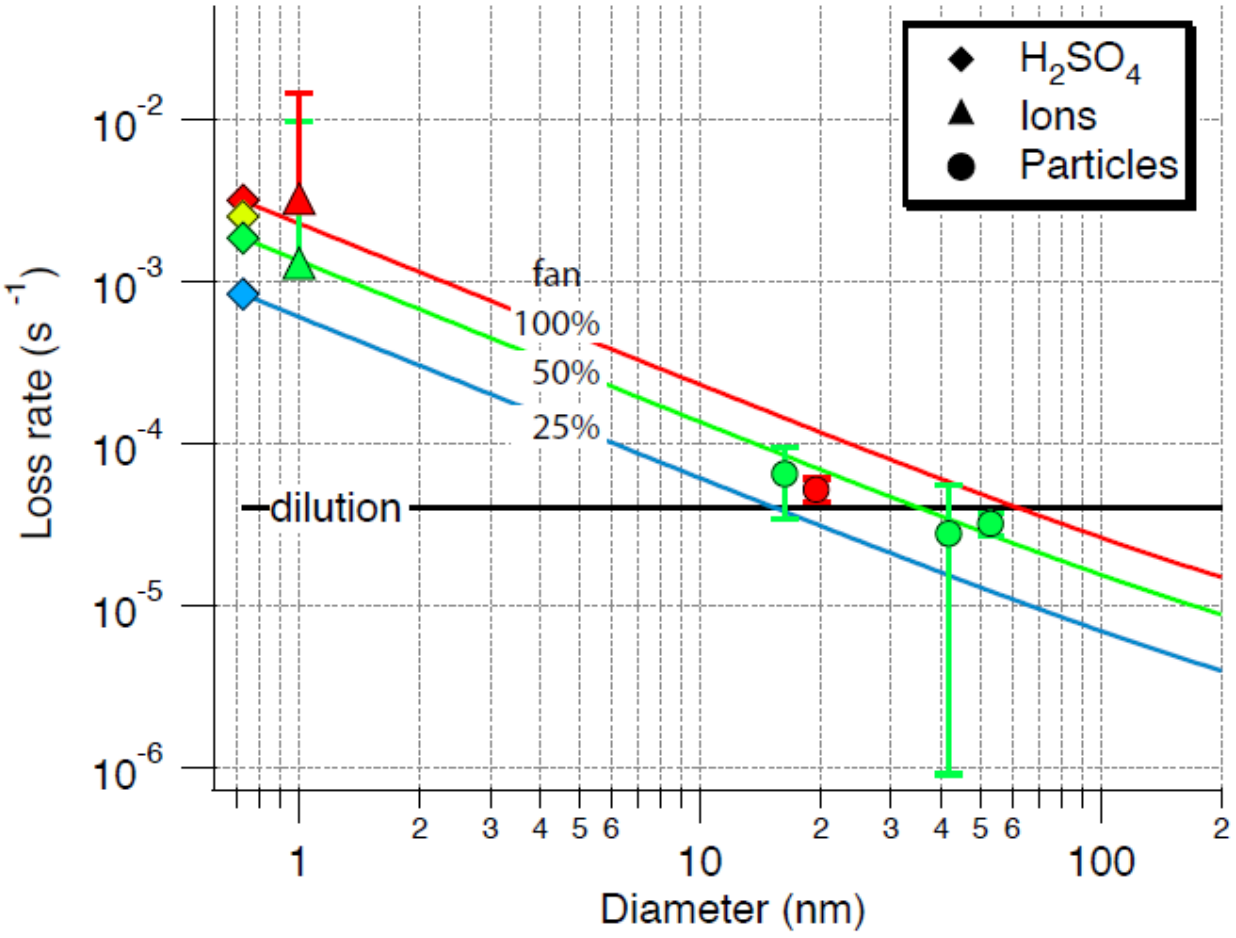
results APiToF



The negative cluster ion spectra display strong, quasi-stable peaks corresponding to the charged pure monomer, dimer and trimer of sulphuric acid.

At 292K, pure acid clusters with n=4 are highly suppressed, showing that the charged pure tetramer is unstable and evaporates rapidly. The clusters are seen to grow by a striking stepwise accretion of NH3 molecules, each one stabilising a distinct additional number 90 of acid molecules, depending on the ammonia concentration

wall losses


H2SO4
Ions
Particles
fan
100%
50%
25%
dilution
Loss rate (s-1)
10-2
10-3
10-4
10-5
10-6
1
2
3
4
5
6
10
2
3
4
5
6
100
2
Diameter (nm)

negative ions nucleation