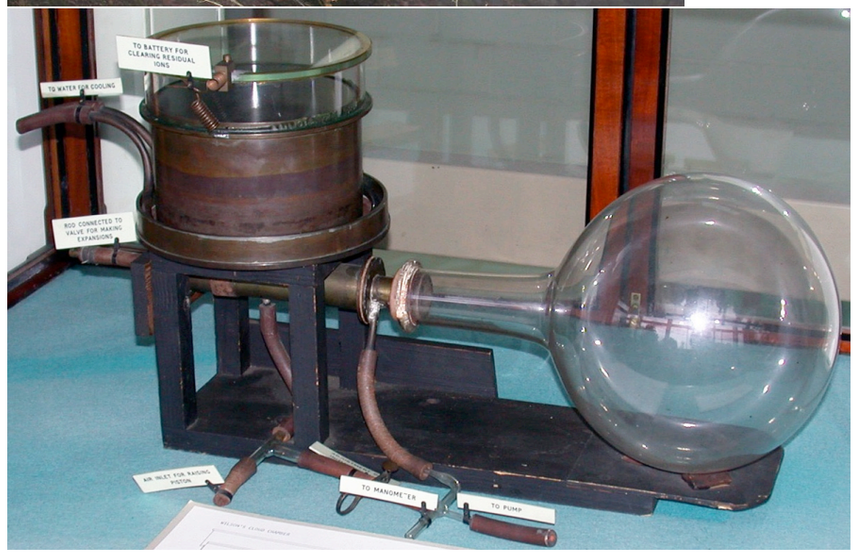
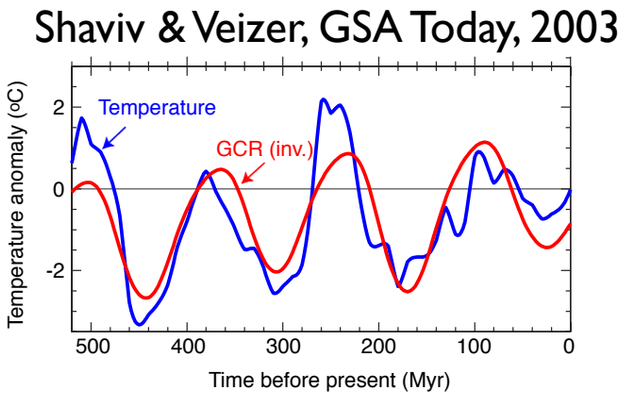
Cosmic rays, climate and the CERN CLOUD experiment

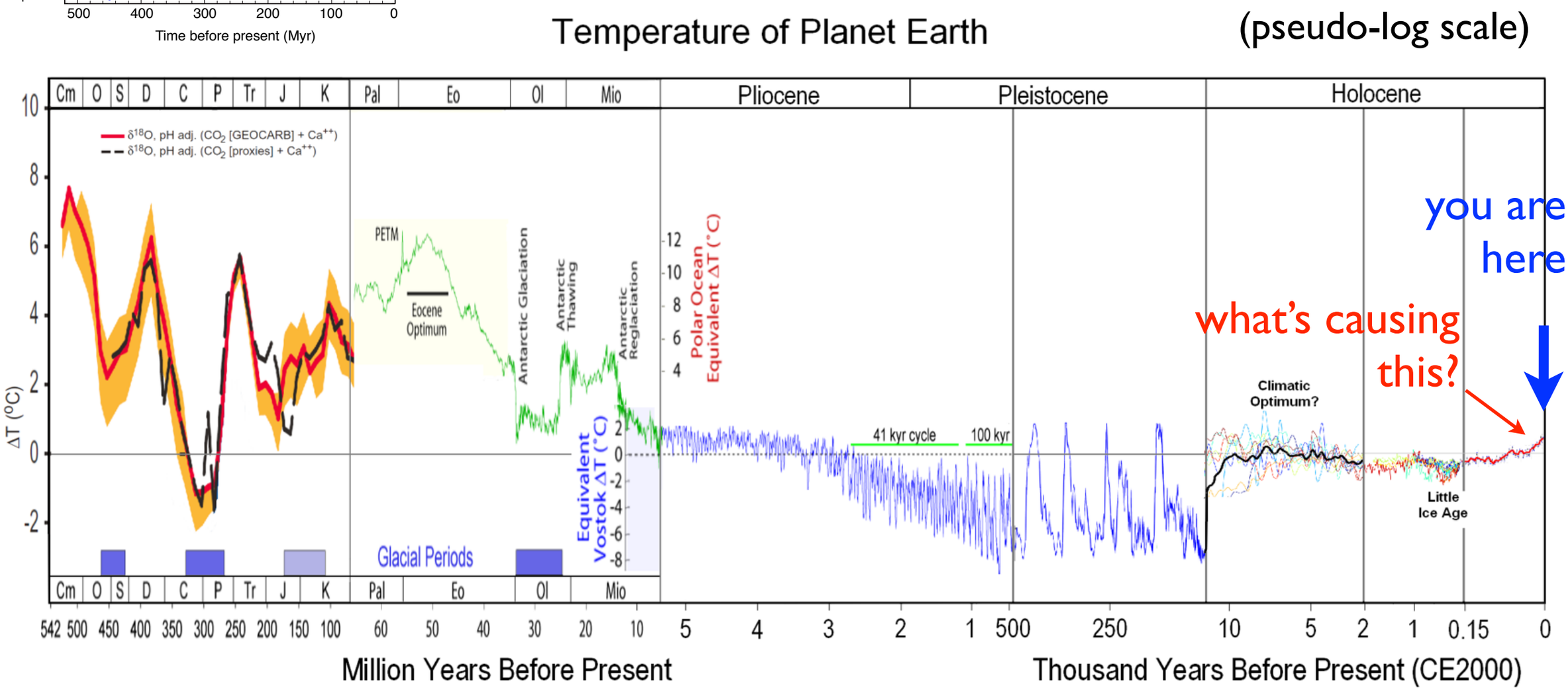


Spacepart12 Conference
CERN, 7 Nov 2012

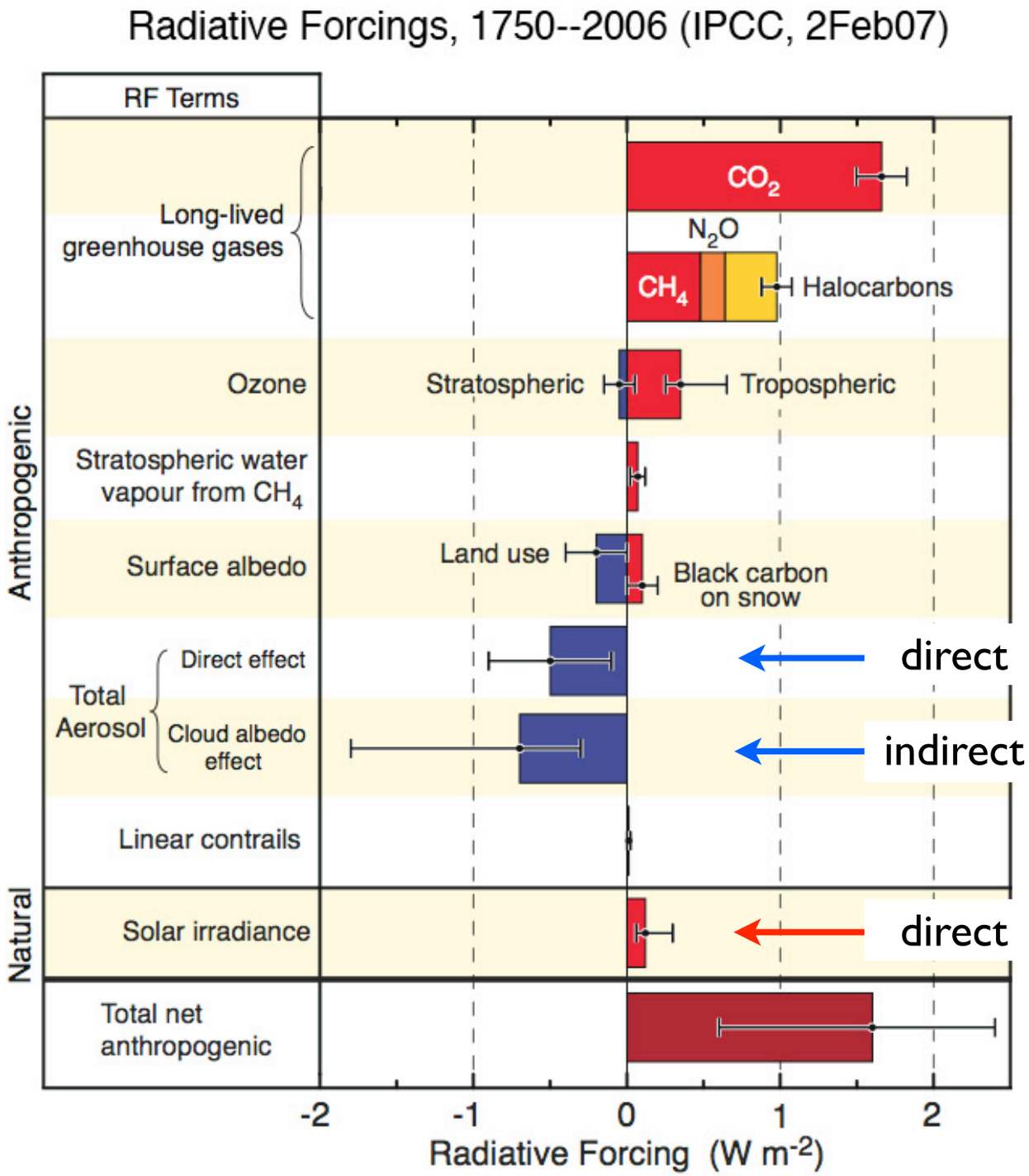
Jasper Kirkby, CERN

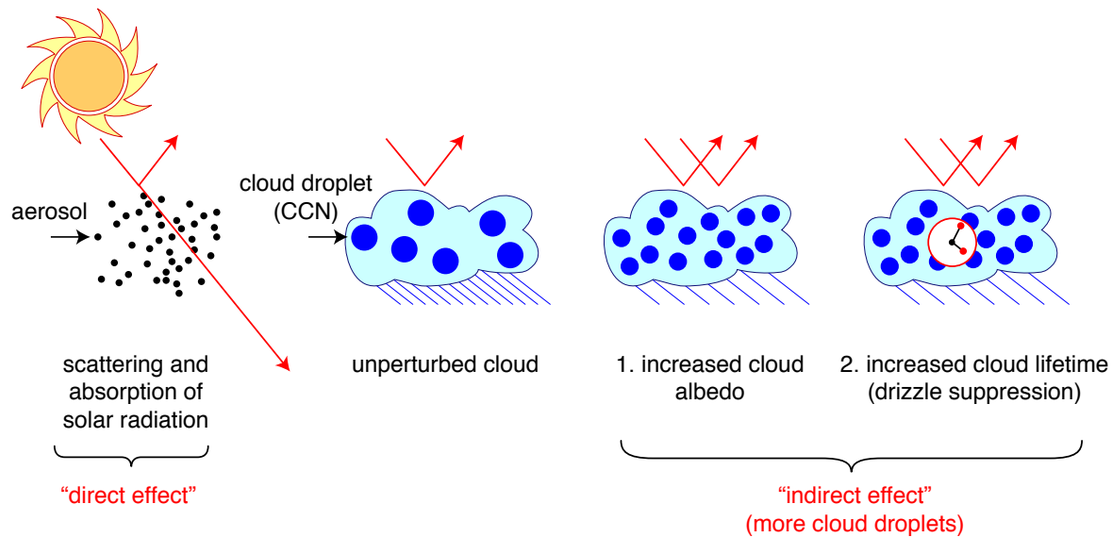
A brief history of Earth's climate





Climate radiative forcings in Industrial Age (IPCC 2007)

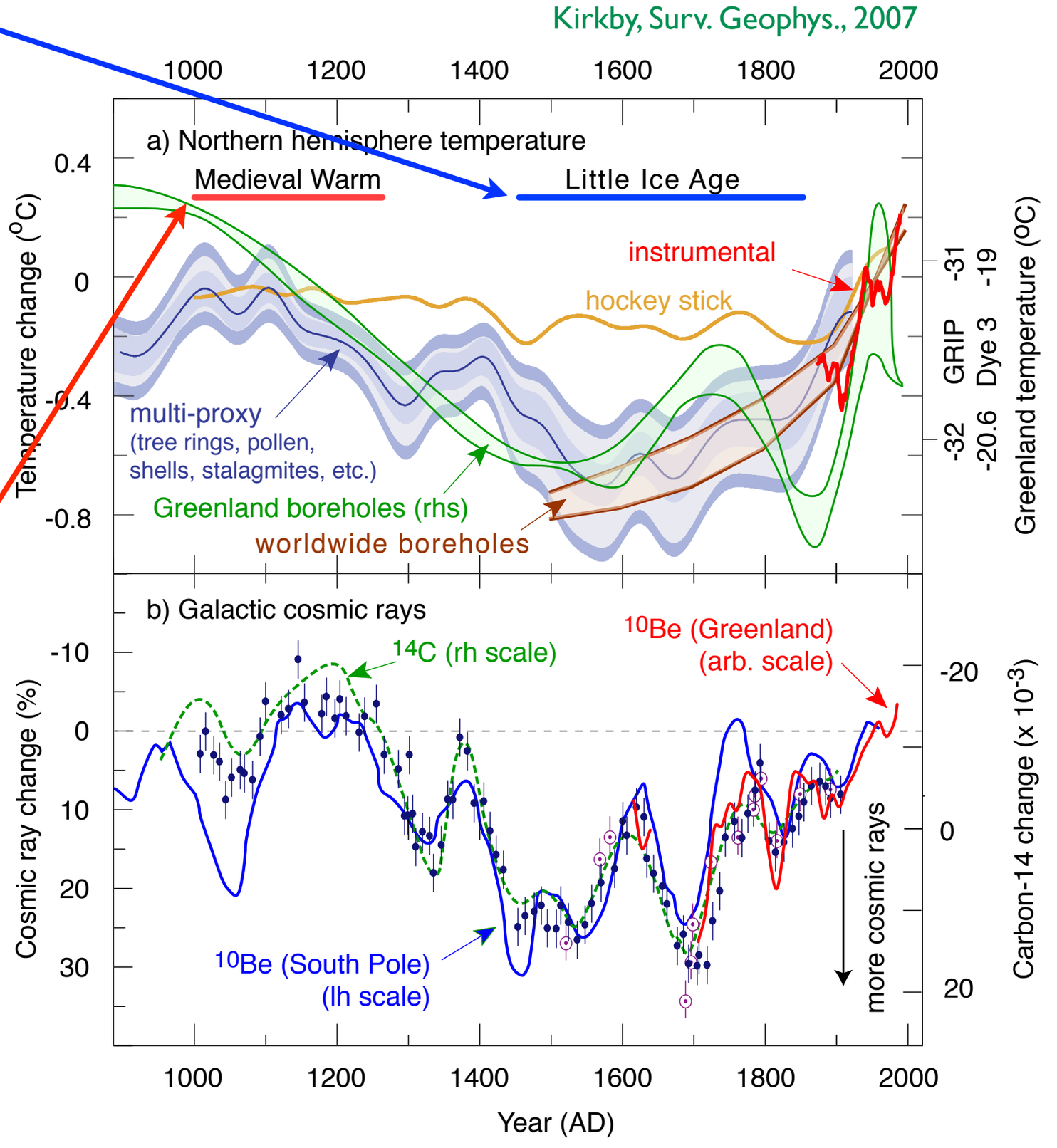




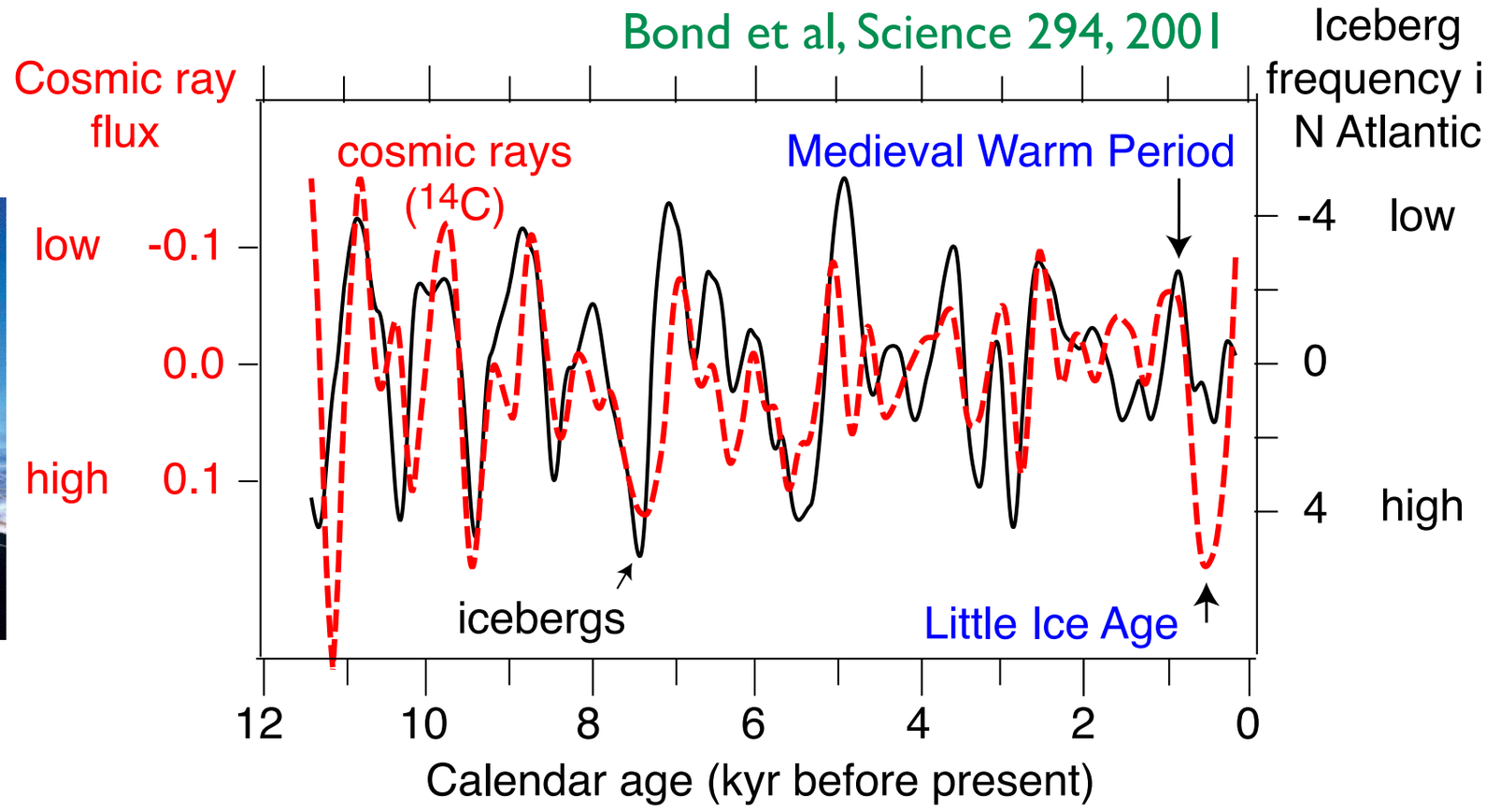
- aerosol forcings are important (but poorly understood)
- is there an unaccounted forcing from solar variability?

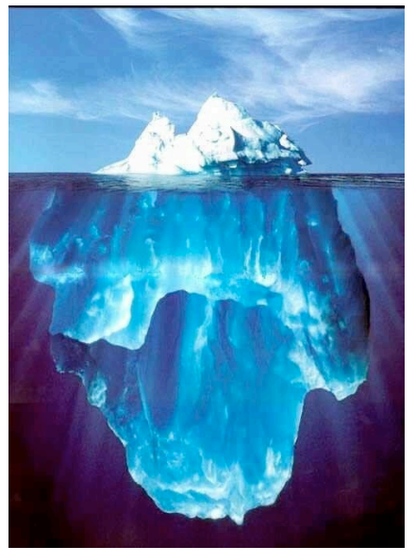
Pre-industrial climate change

Peterborough Psalter, England, 1300-1318

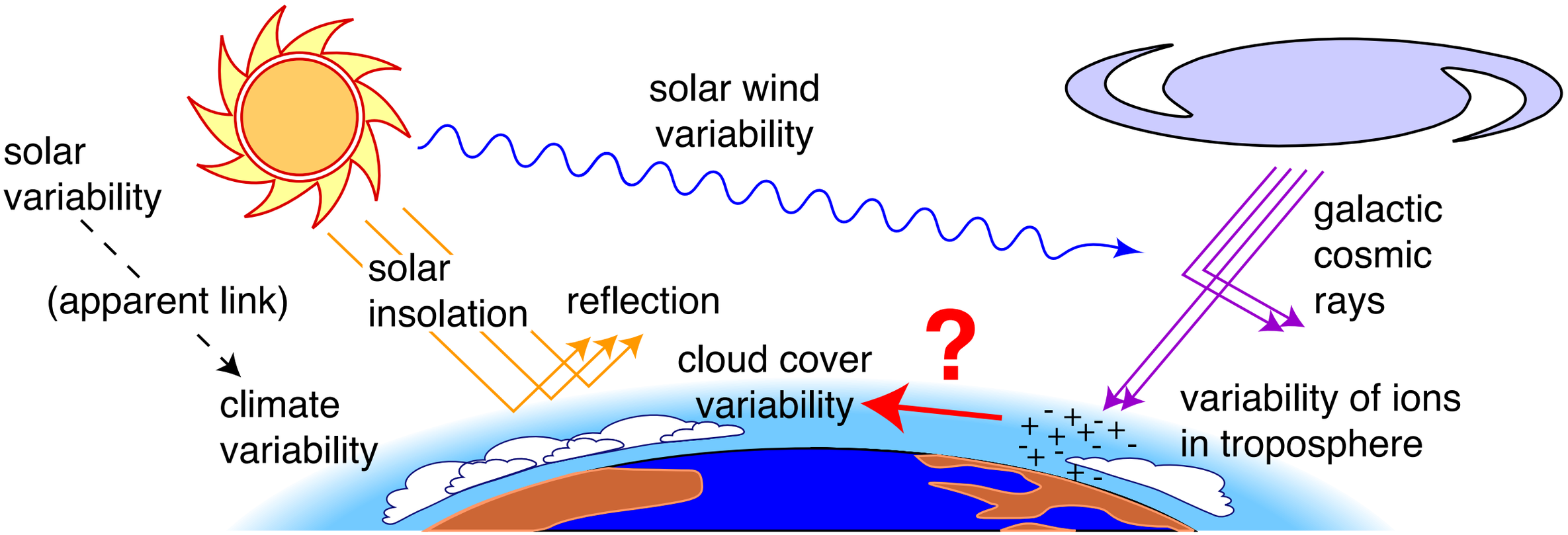


Climate during the last 10,000 yr

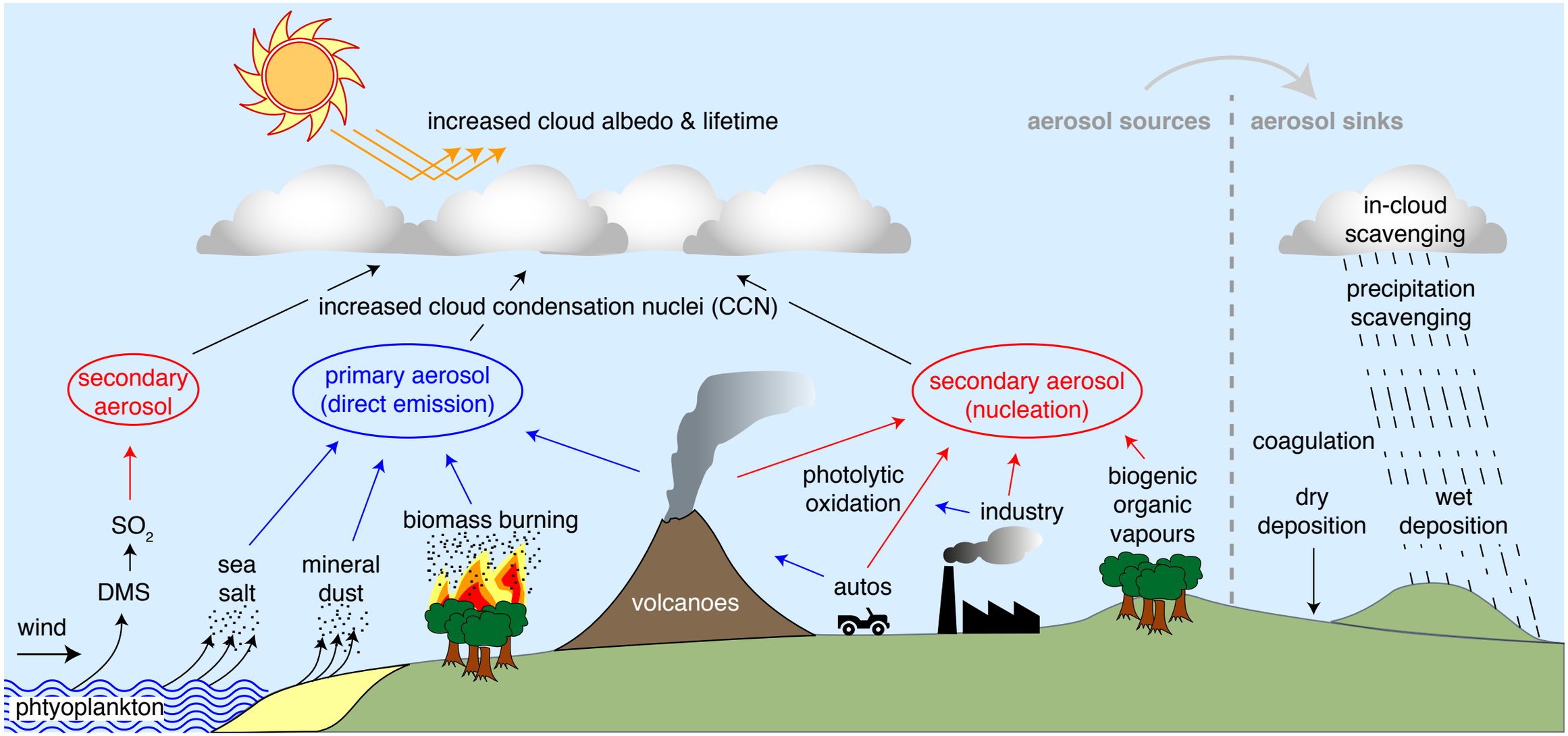




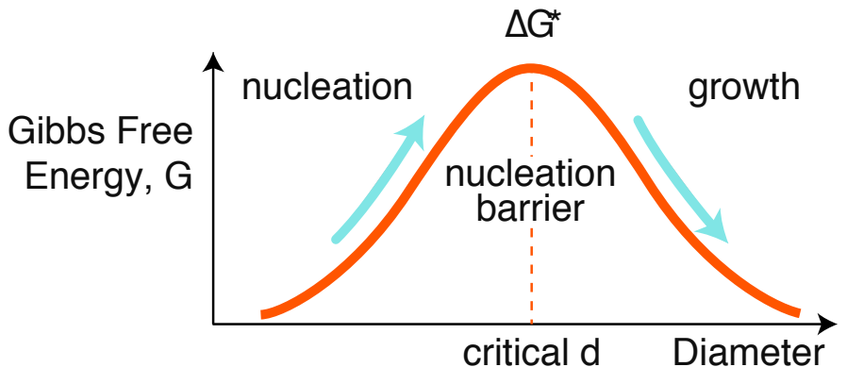
Solar-cosmic ray-climate mechanism

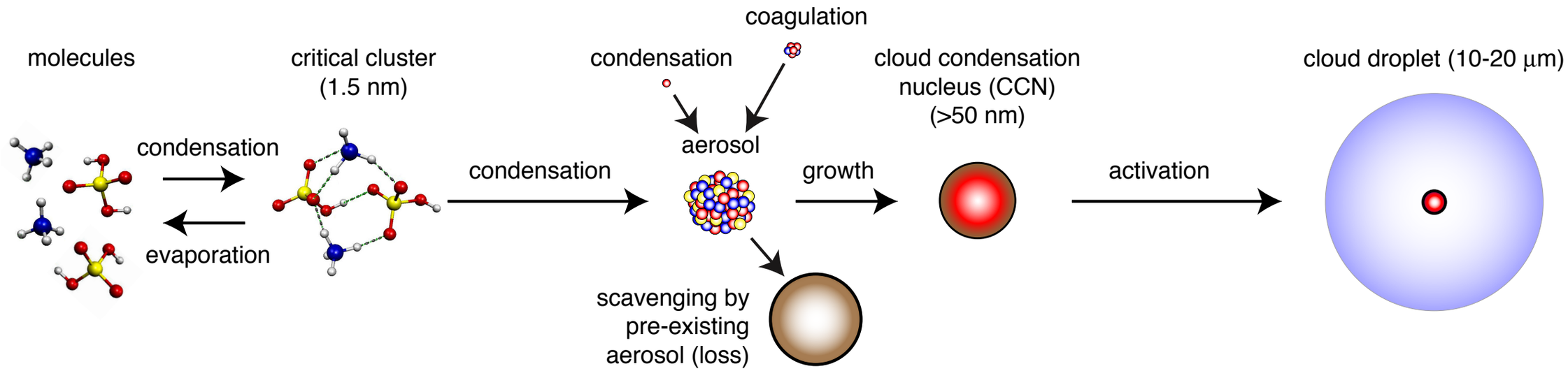


Atmospheric aerosols and clouds



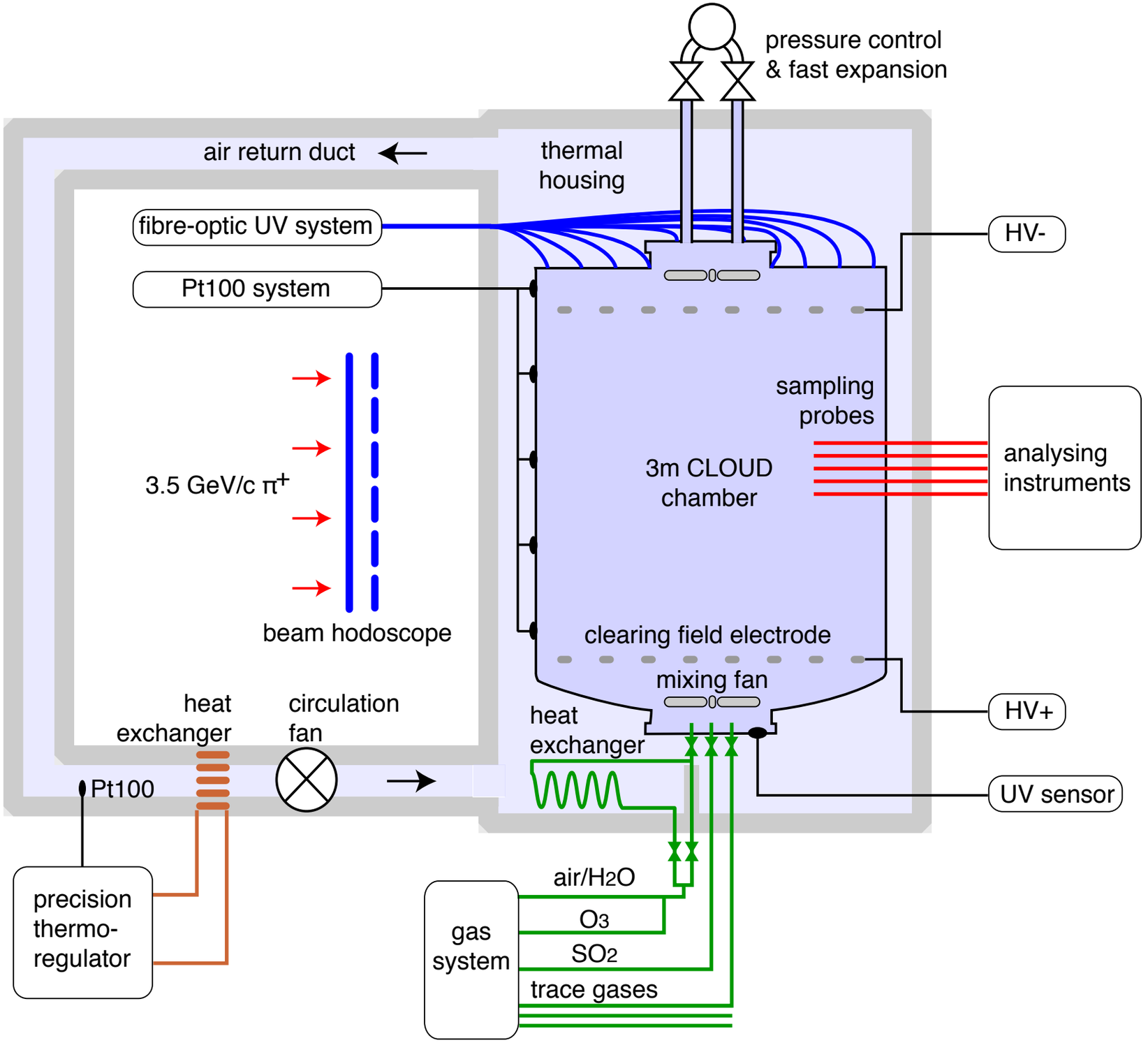
Atmospheric aerosol nucleation (gas-to-particle conversion)





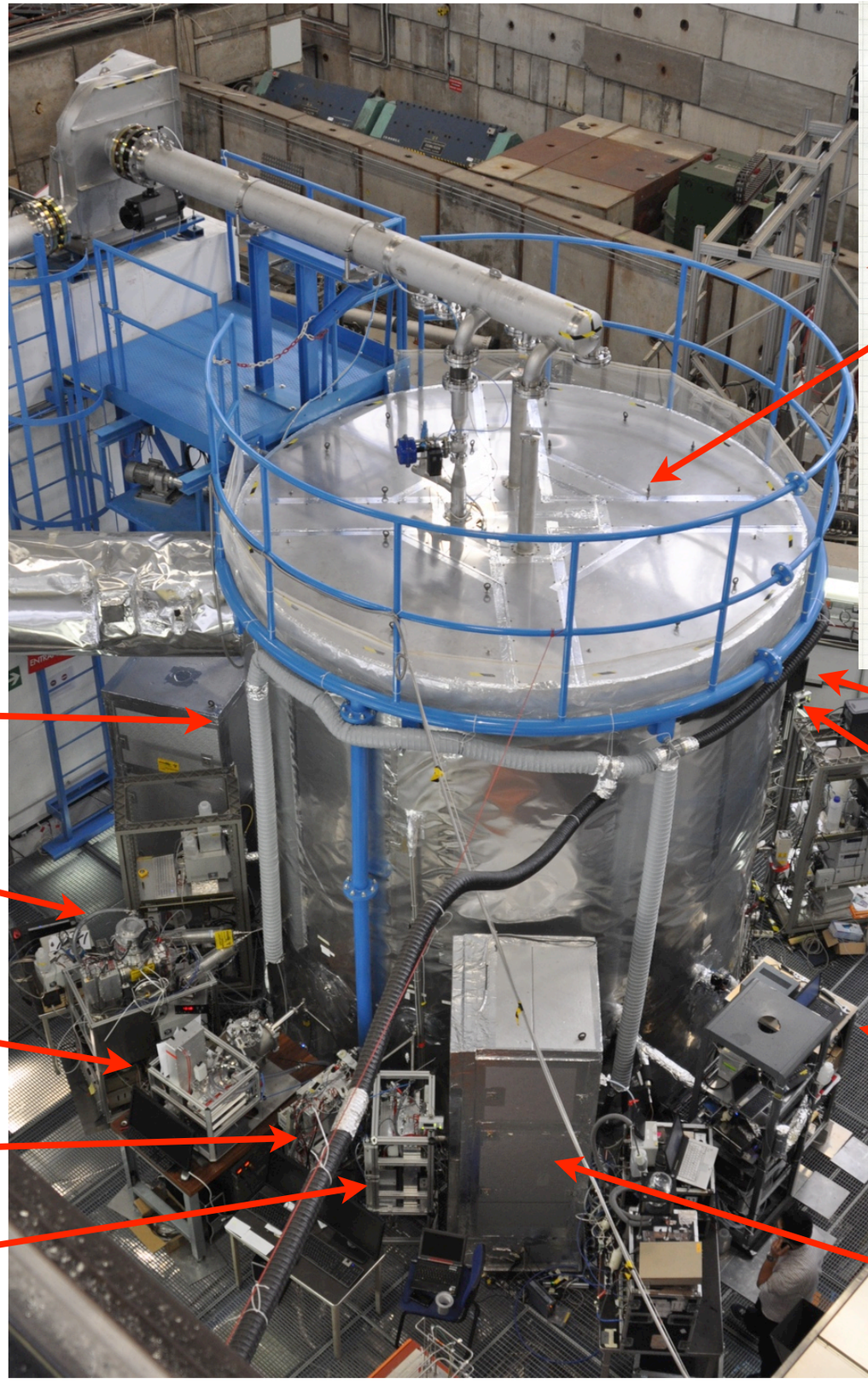
CERN CLOUD experiment

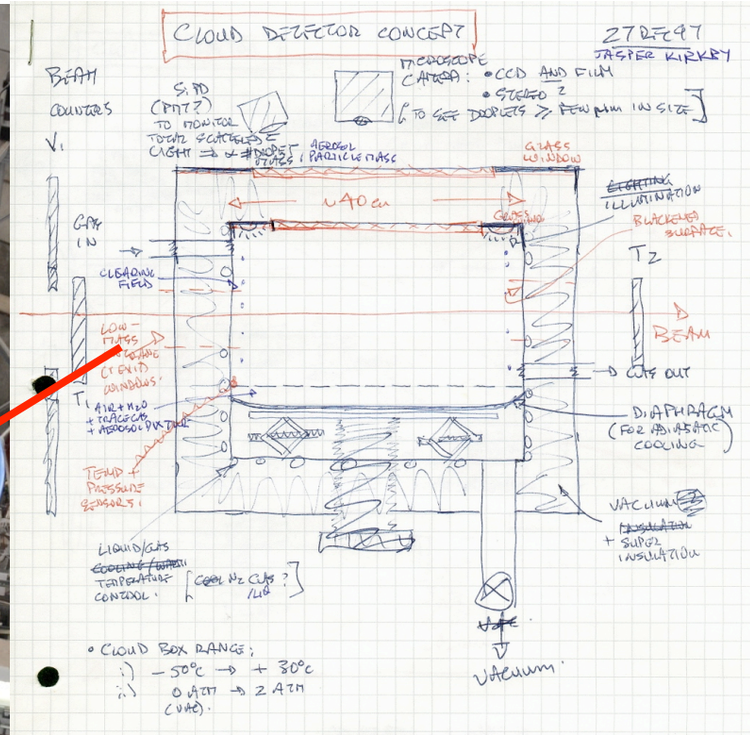
- Key features:
  - beam ionisation (influence of cosmic rays)
  - suppression of contaminants
  - experimental stability & control (gas concentrations, temperature...)
  - comprehensive, state-of-art instrumentation



The CERN CLOUD experiment

- 30 sampling instruments are currently attached to CLOUD, including 9 state-of-art mass spectrometers for unprecedented ion and molecular information on aerosol particle nucleation and growth:





PTR-TOF (U Innsbruck)

TD-CIMS (NCAR)

IMS-TOF (U HEL)

API-TOF- (U HEL)

API-TOF+ (PSI)

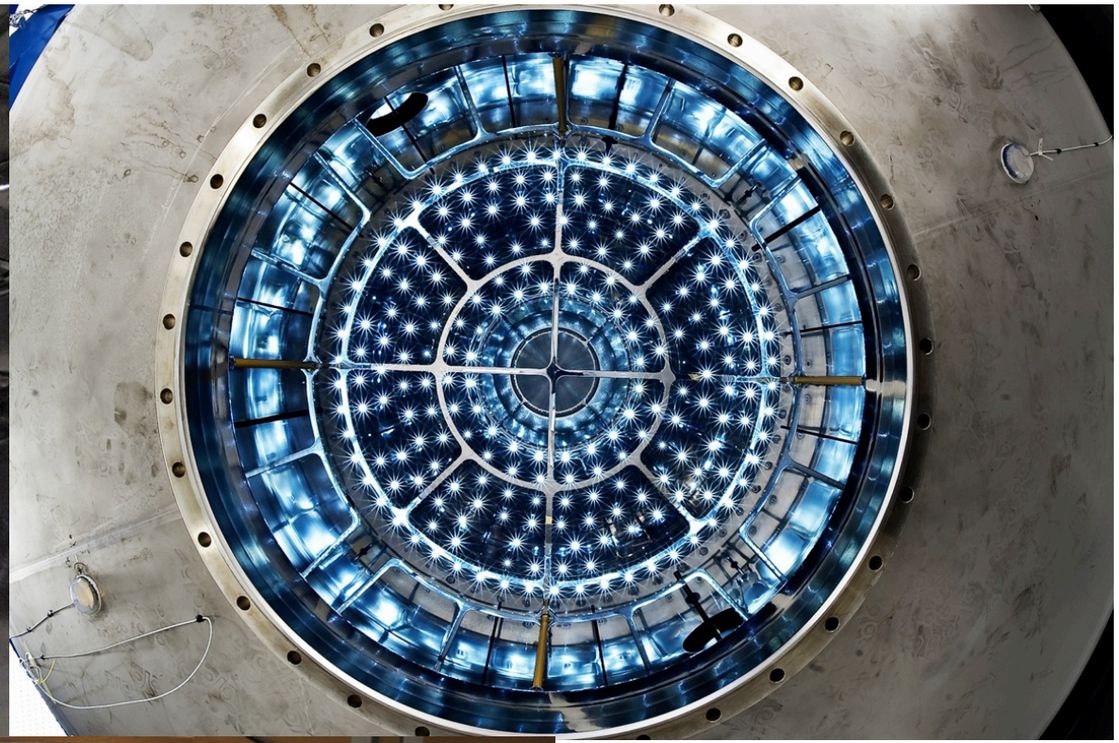
CI-APITOF (U HEL)

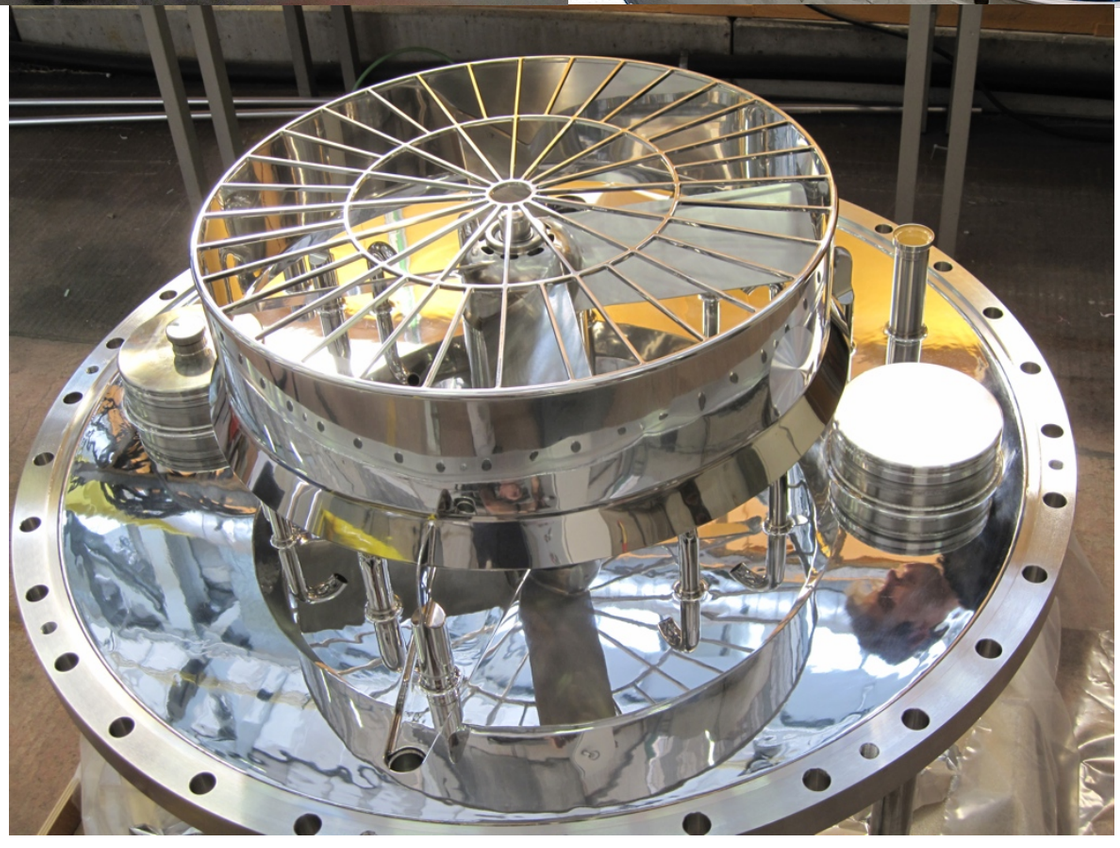
CI-APITOF (U Frankfurt)

CIMS (U Frankfurt)

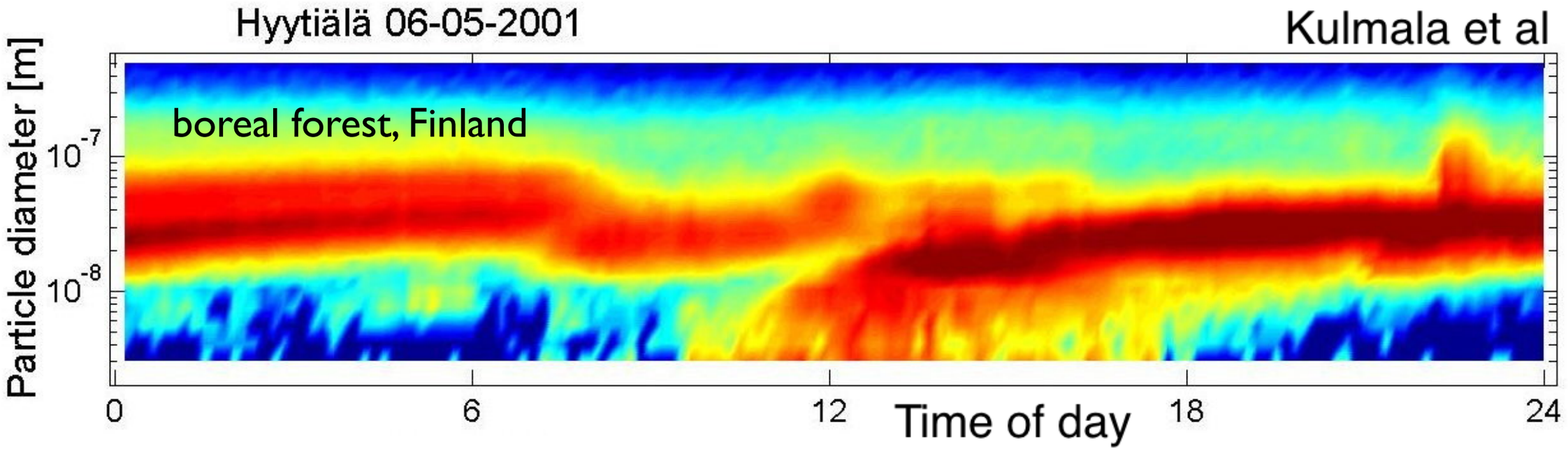
NAIS (U HEL)

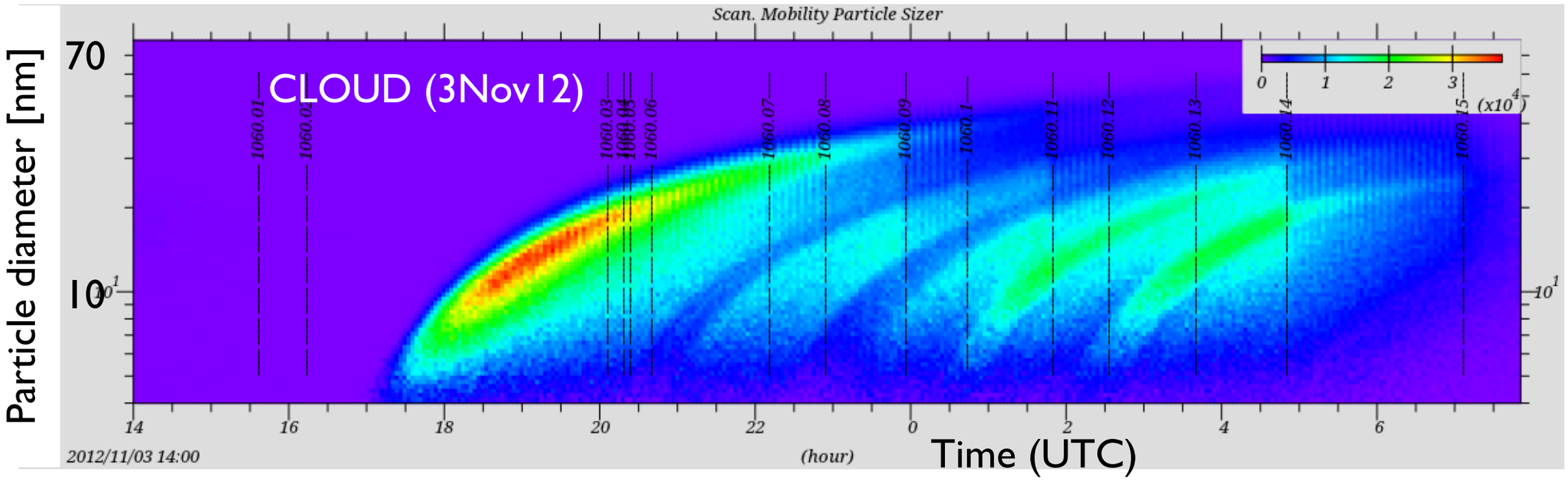
Inside the CLOUD chamber





Atmospheric aerosol formation from trace gases





Nucleation rates

LETTER

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Role of sulphuric acid, ammonia and galactic cosmic rays in atmospheric aerosol nucleation

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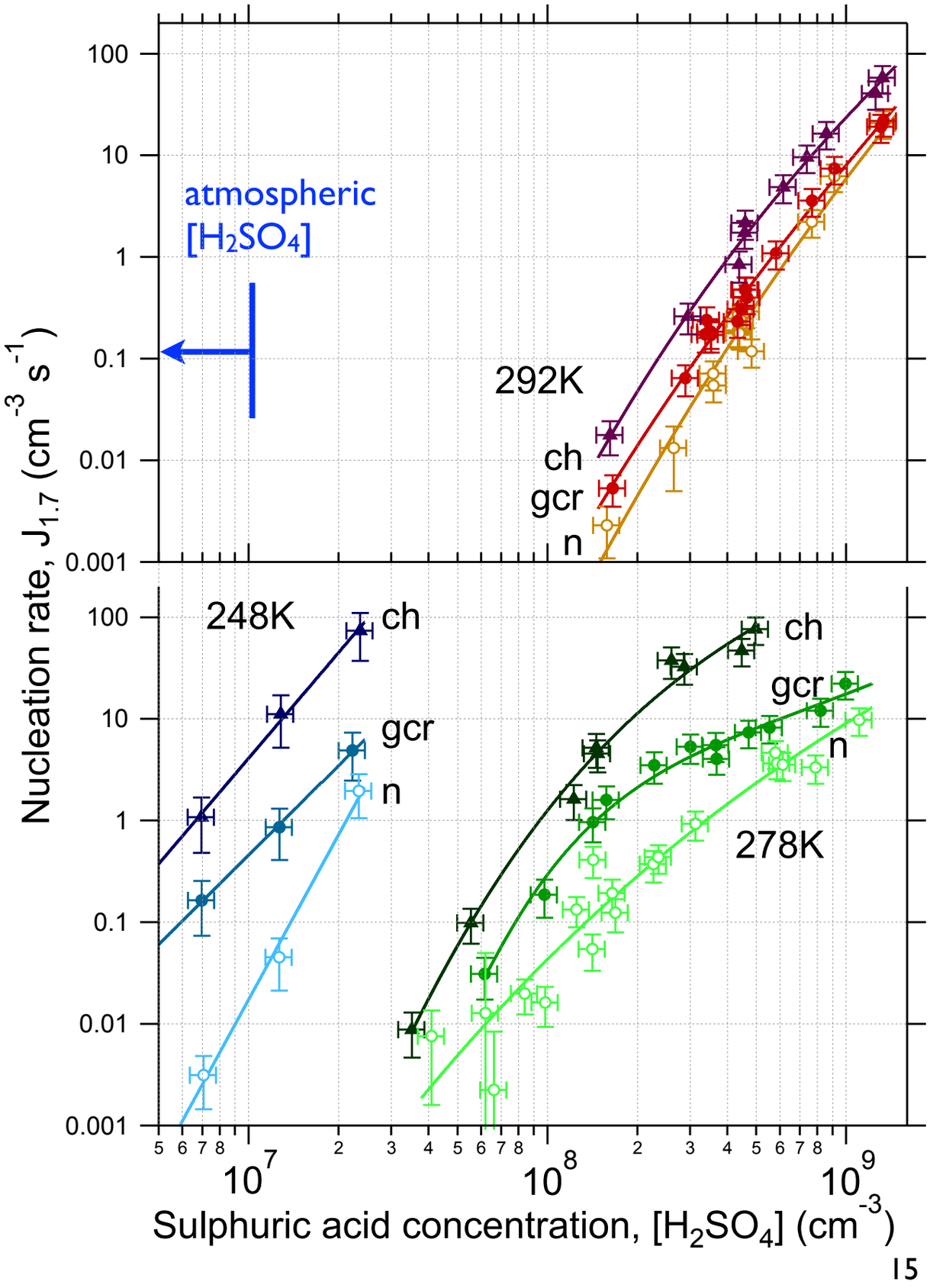
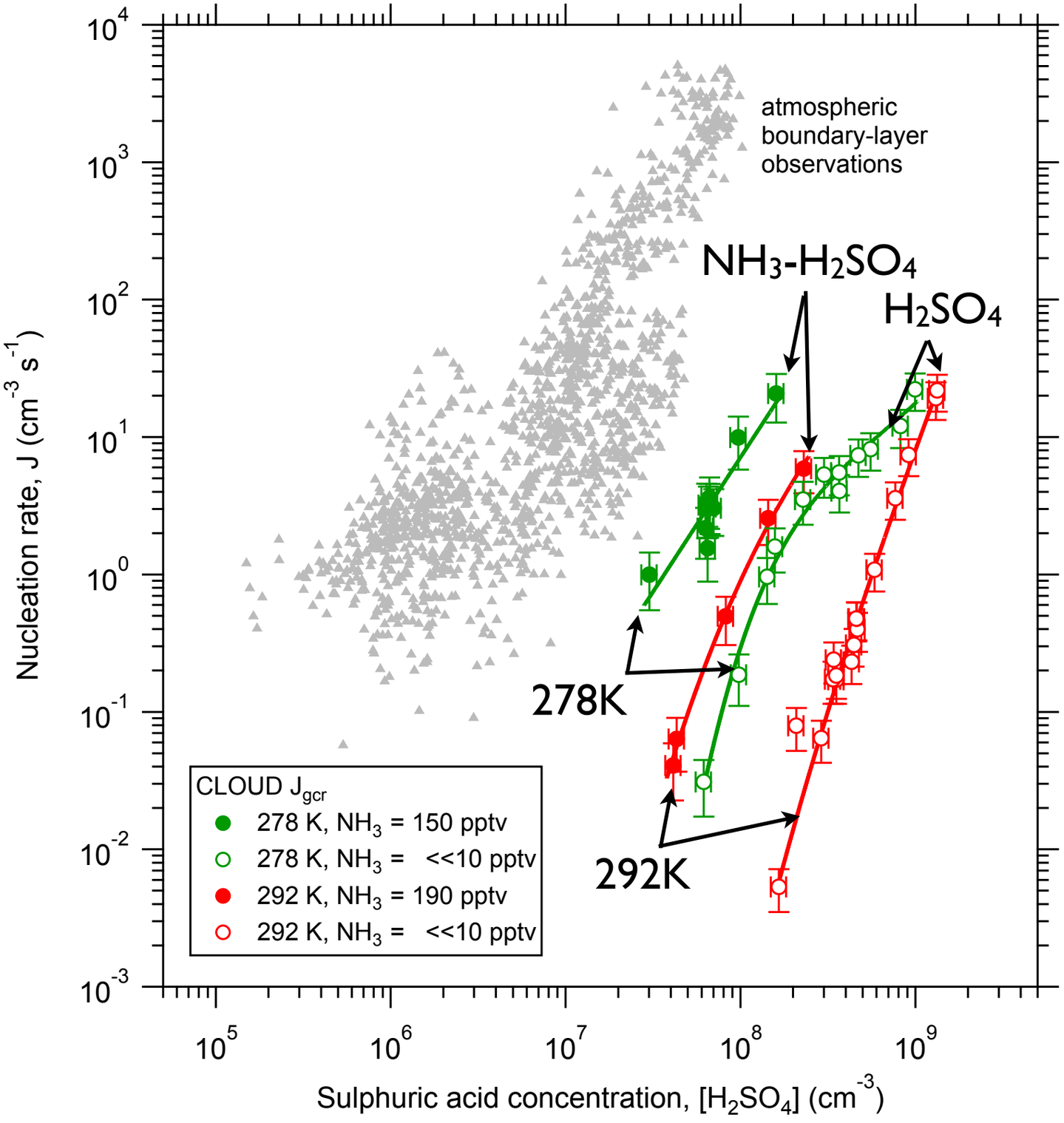
Austria:	University of Innsbruck
	University of Vienna
Finland:	Finnish Meteorological Institute
	Helsinki Institute of Physics
	University of Eastern Finland
	University of Helsinki
Germany:	Johann Wolfgang Goethe University Frankfurt
	Karlsruhe Institute of Technology
	Leibniz Institute for Tropospheric Research
Portugal:	University of Beira Interior
	University of Lisbon
Russia:	Lebedev Physical Institute
Sweden:	University of Stockholm
Switzerland:	CERN
	Paul Scherrer Institut
United Kingdom:	University of Manchester
	University of Leeds
United States of America:	California Institute of Technology
	Carnegie Mellon University

CLOUD: H_2SO_4 binary nucleation



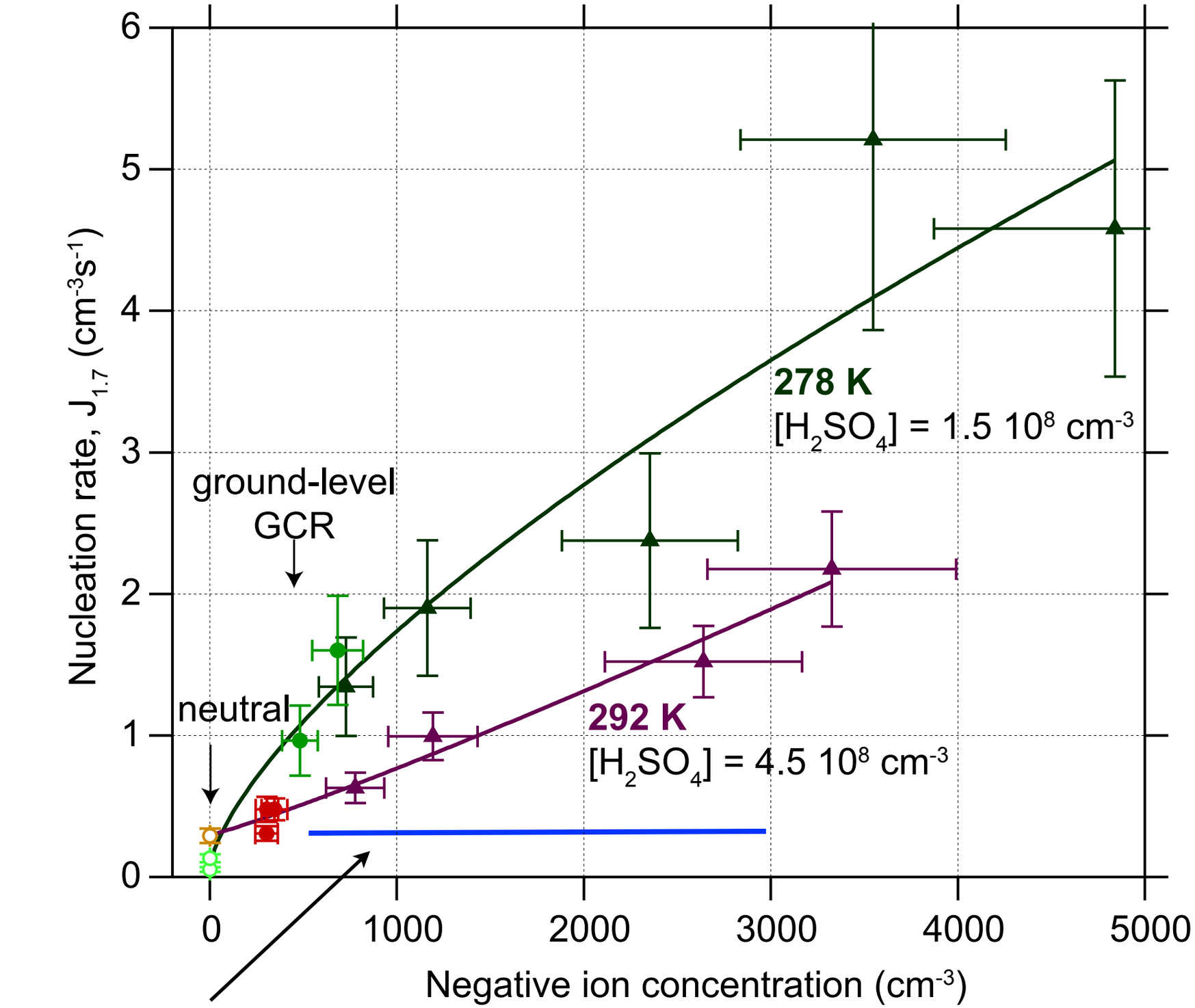
- Nominally "pure" binary H_2SO_4-H_2O nucleation (but few ppt NH_3 contaminant is present)
- Significant GCR/ion enhancement (factor 2-10)
- Binary nucleation can only take place under coldest conditions (FT or polar)

CLOUD vs. atmospheric observations: NH_3+H_2SO_4



- ~100 pptv NH_3 increases nucleation by up to factor 1000 but is too low to explain BL nucleation

CLOUD: nucleation rate vs [ion-]



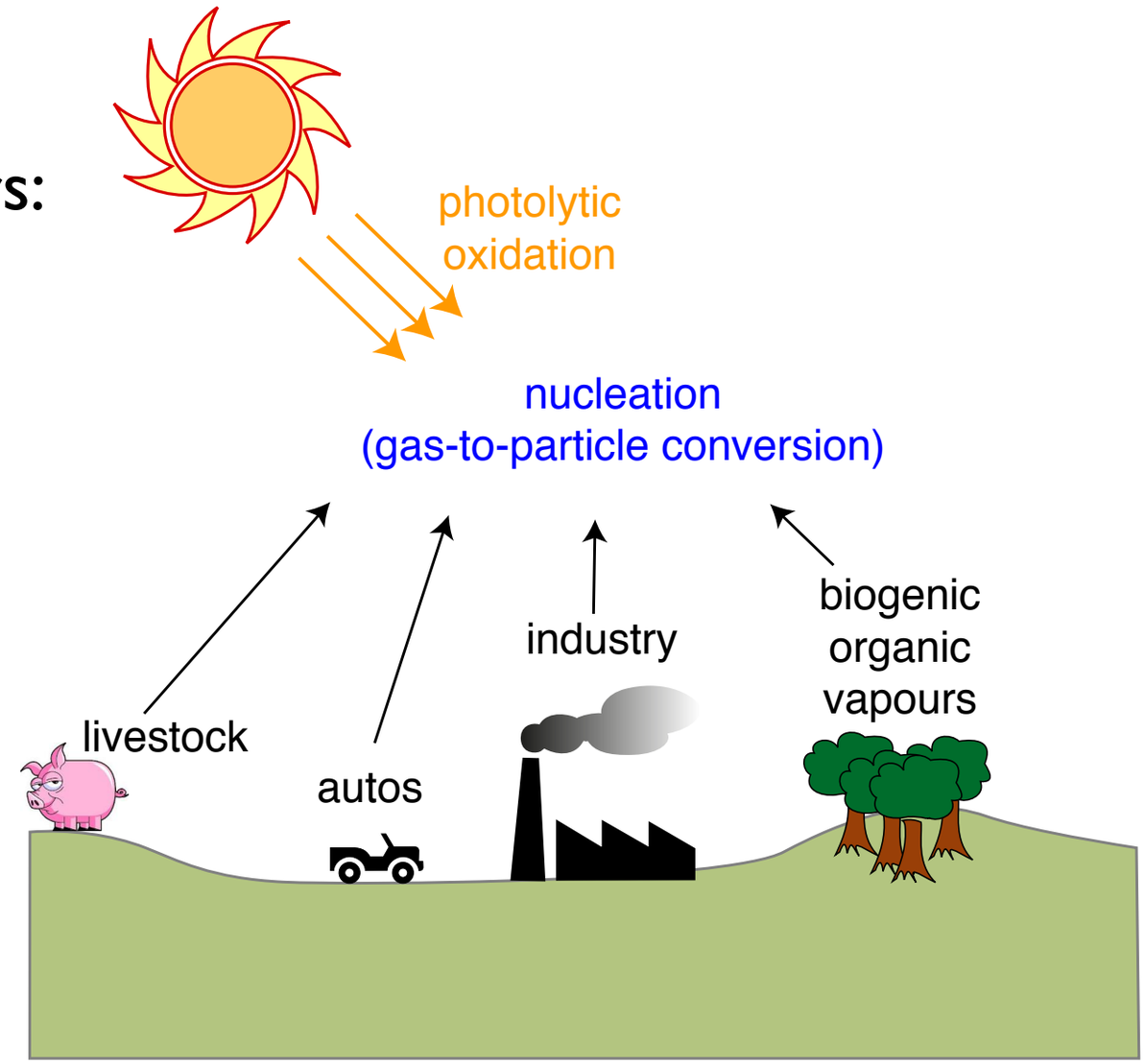
Implications of first CLOUD results for lower atmosphere

- Poorly-known organic vapours are participating with sulphuric acid to form aerosol particles in the lower atmosphere

- Important to identify these vapours:

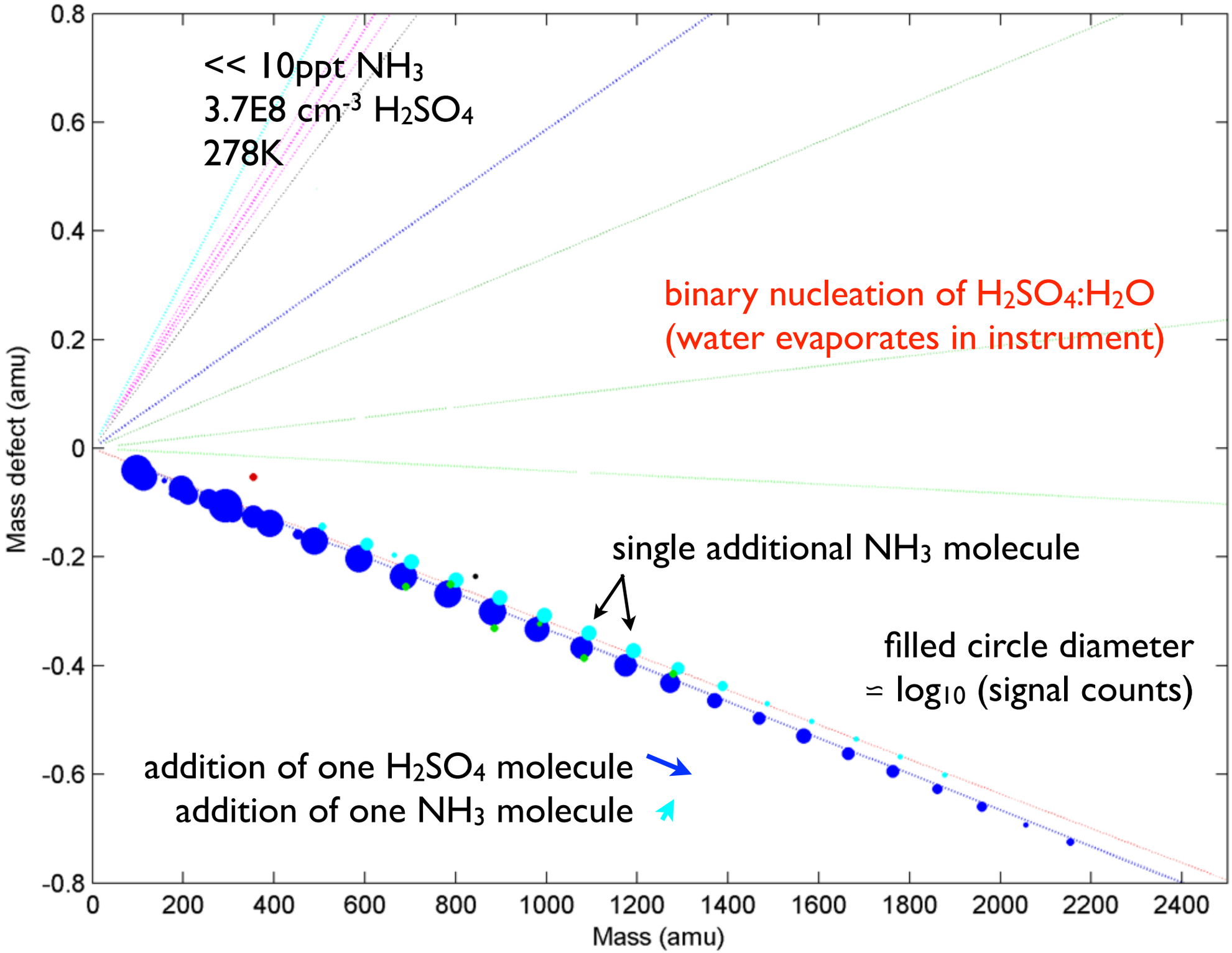
  - If mainly anthropogenic:
    - ✦ New climate forcing from human activities?

  - If mainly biogenic:
    - ✦ New negative feedback of biosphere to reduce temperatures?

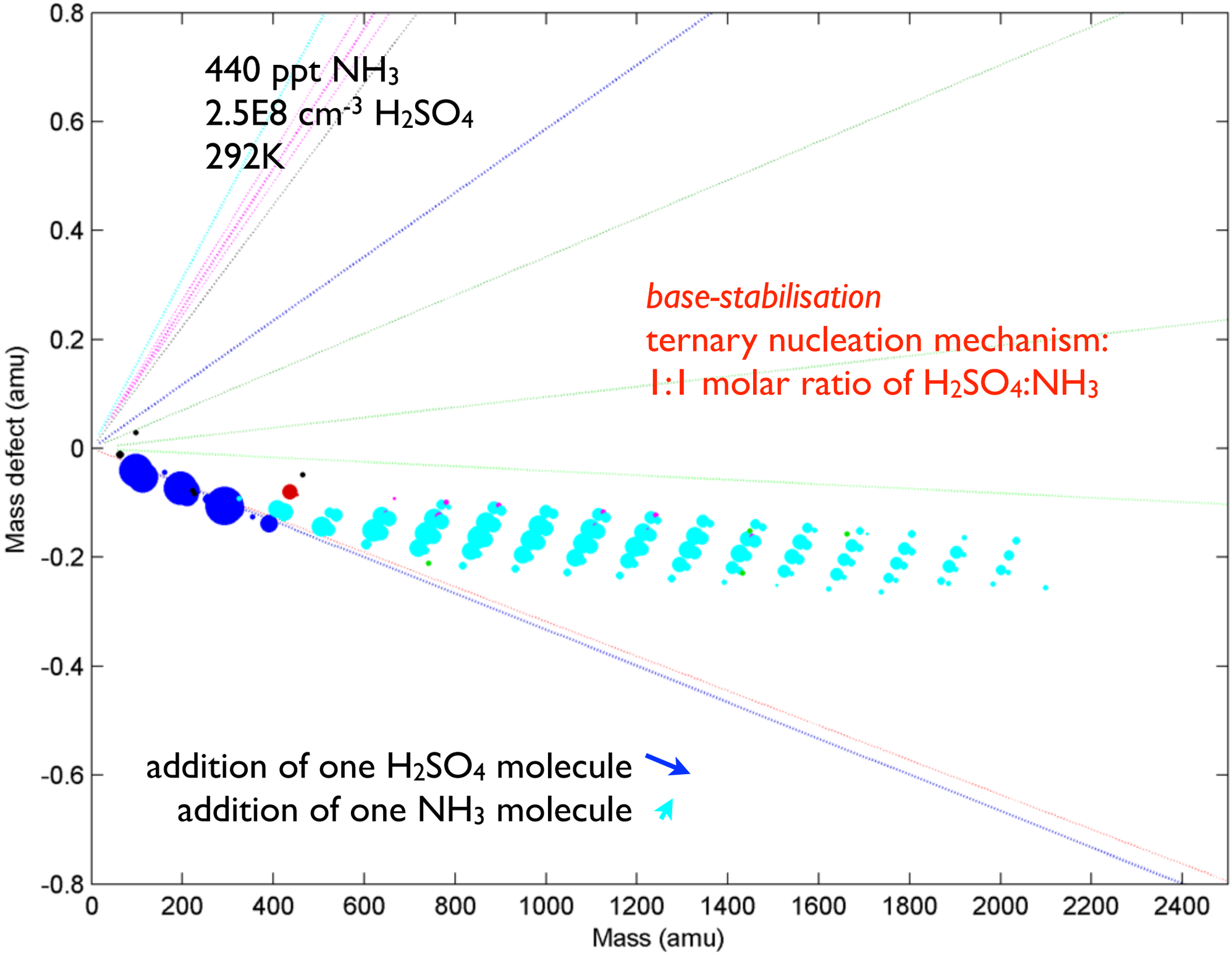


Molecular composition of nucleating clusters

Binary nucleation mechanism (+ contaminants)

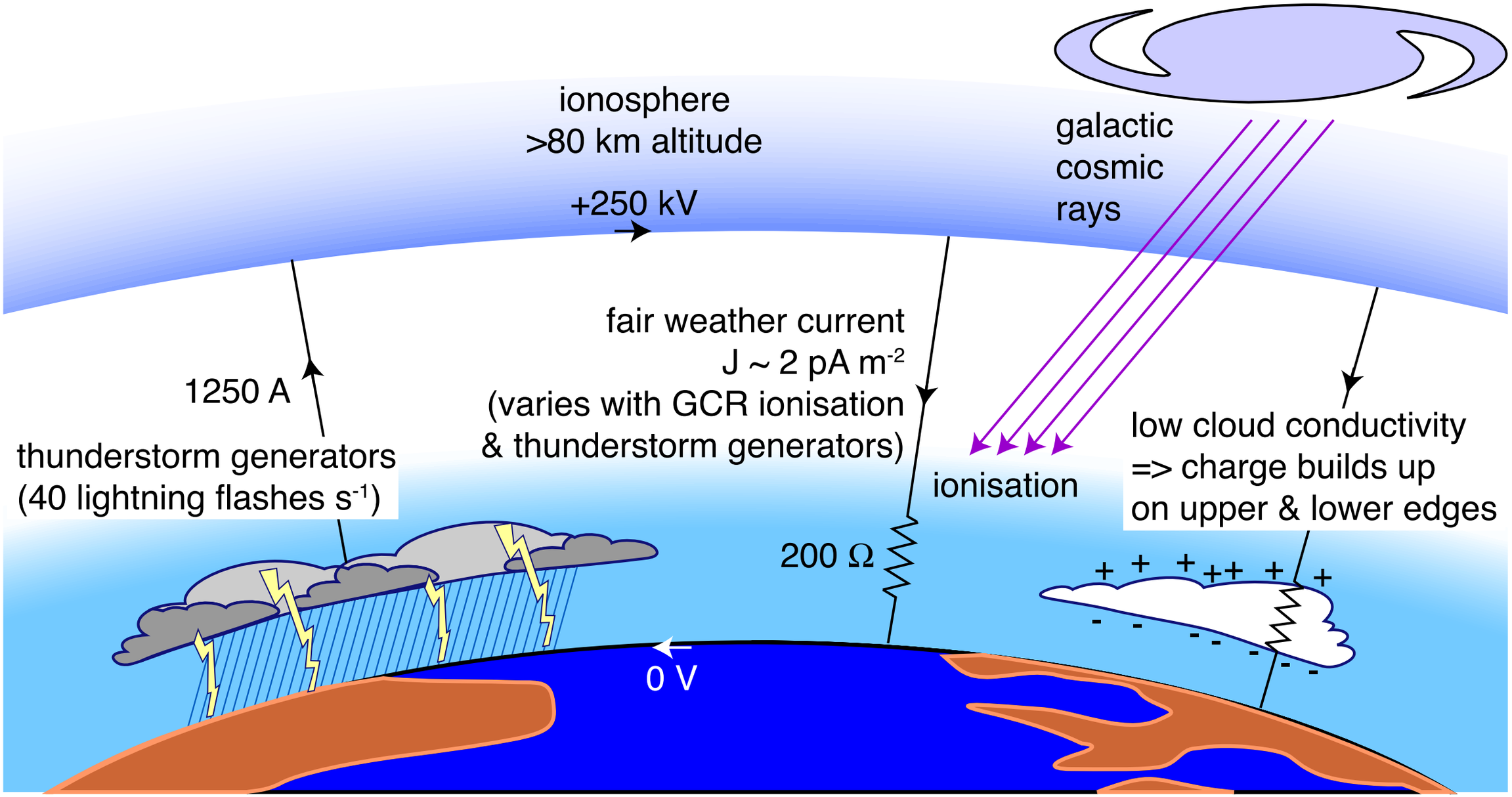


Ternary nucleation mechanism: NH_3

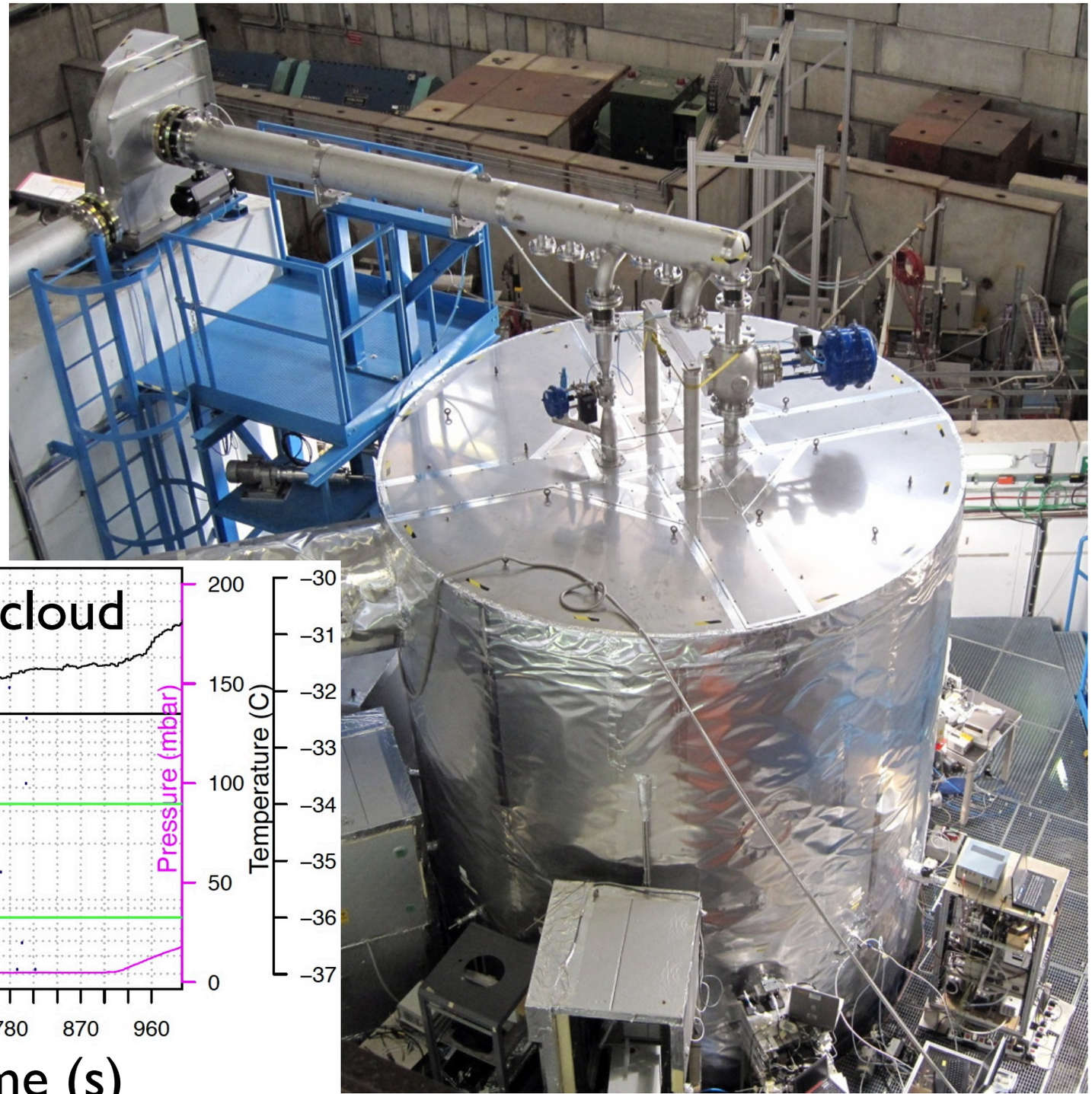


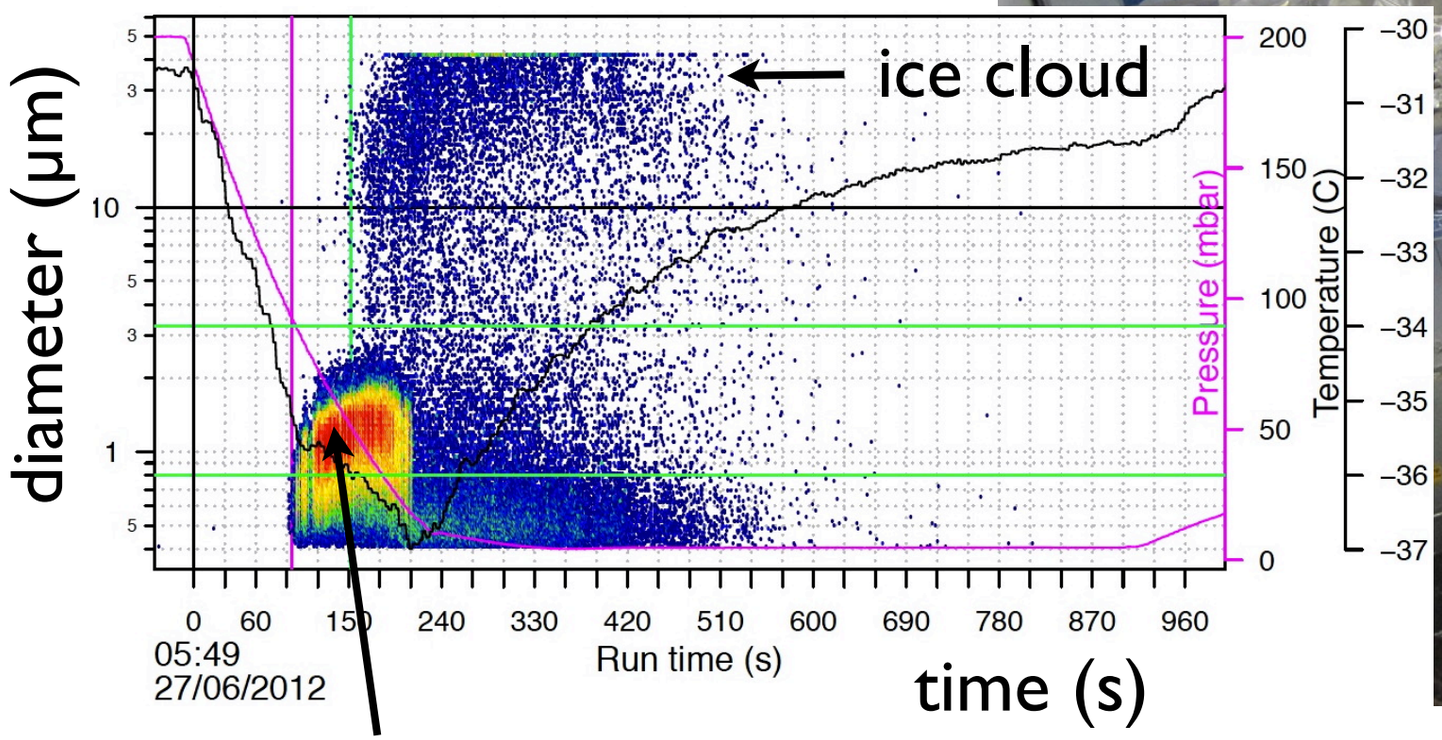
Clouds in CLOUD

Candidate GCR-cloud mechanism no.2



CLOUD at the CERN PS, June 2012





Summary

- Aerosols & clouds represent the largest uncertainty in anthropogenic climate change

- Natural climate change / solar-climate variability on the century time scale is comparable to the present warming. The physical mechanism is unknown but could involve an influence of cosmic rays on clouds

- CLOUD is the world's leading laboratory experiment to quantify the fundamental processes underlying both these questions

- First CLOUD results:
  - Cosmic rays enhance formation of H_2SO_4 and NH_3-H_2SO_4 particles in the upper atmosphere
  - But we know even less than we thought we did:
    - ✦ Sulphuric acid and ammonia vapours are insufficient (by up to a factor 1000) to account for atmospheric aerosol formation