

Proposal for the CLOUD
experiment;
Cosmic Ray – Aerosol – Cloud -
Climate Interactions

Markku Kulmala
University of Helsinki
Department of Physical Sciences

CLOUD Collaboration (22 partners):

Univ. Aarhus, Denmark

Univ. Bergen, Norway

Caltech, USA

CERN, Switzerland

Danish Space Res. Inst., Denmark

Ecole Polytechnique, France

Finnish Meteorological Inst., Finland

Univ. Helsinki, Finland

Ioffe Physical Technical Inst., Russia

Univ. Kuopio, Finland

Univ. L'Aquila, Italy

Lebedev Physical Inst., Russia

Univ. Leeds, UK

Univ. Mainz, Germany

MPIK - Heidelberg, Germany

Univ. Missouri-Rolla, USA

Univ. New York at Albany, USA

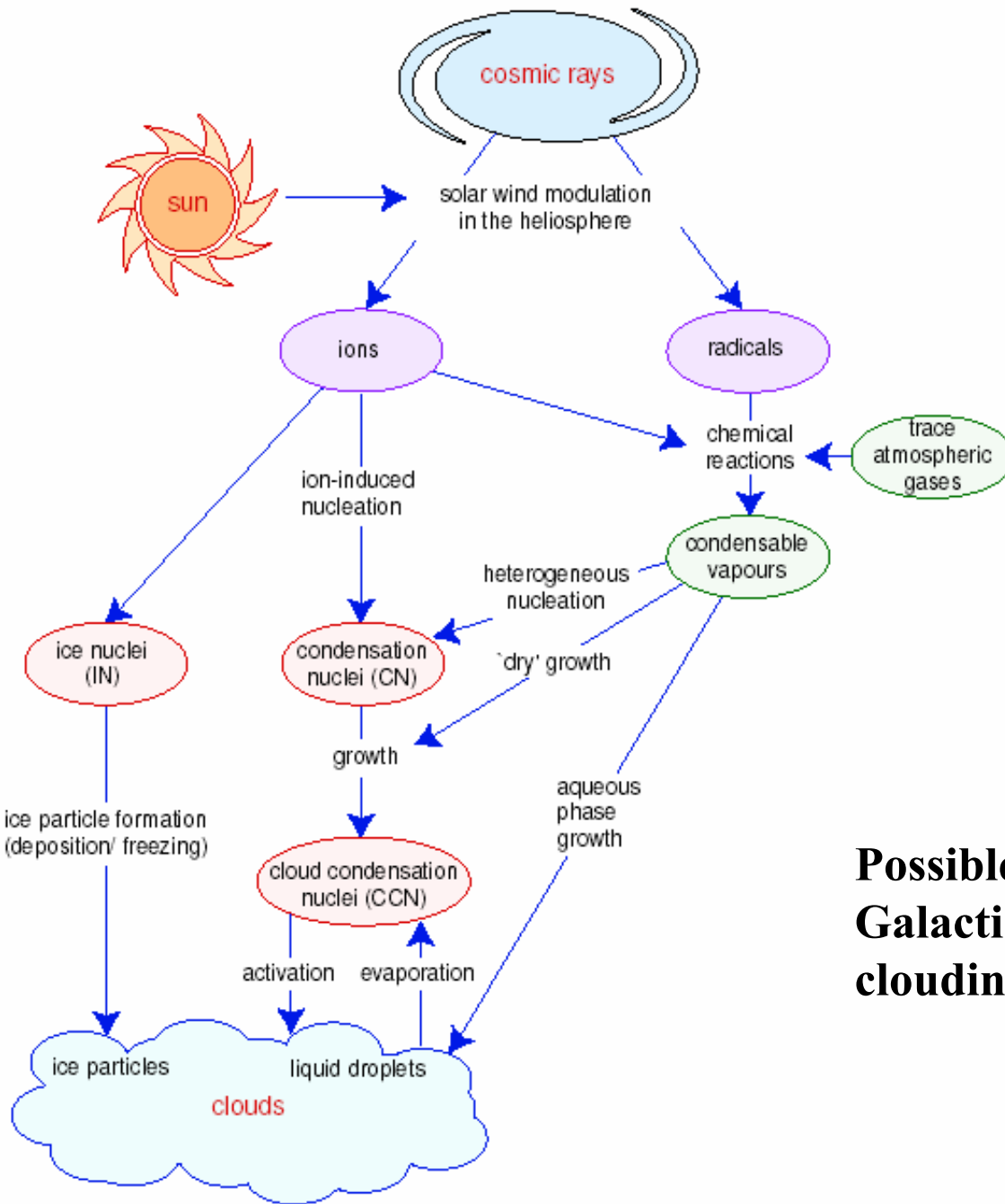
PSI, Switzerland

Univ. Reading, UK

Rutherford Appleton Lab., UK

Univ. Tampere, Finland

Univ. Vienna, Austria

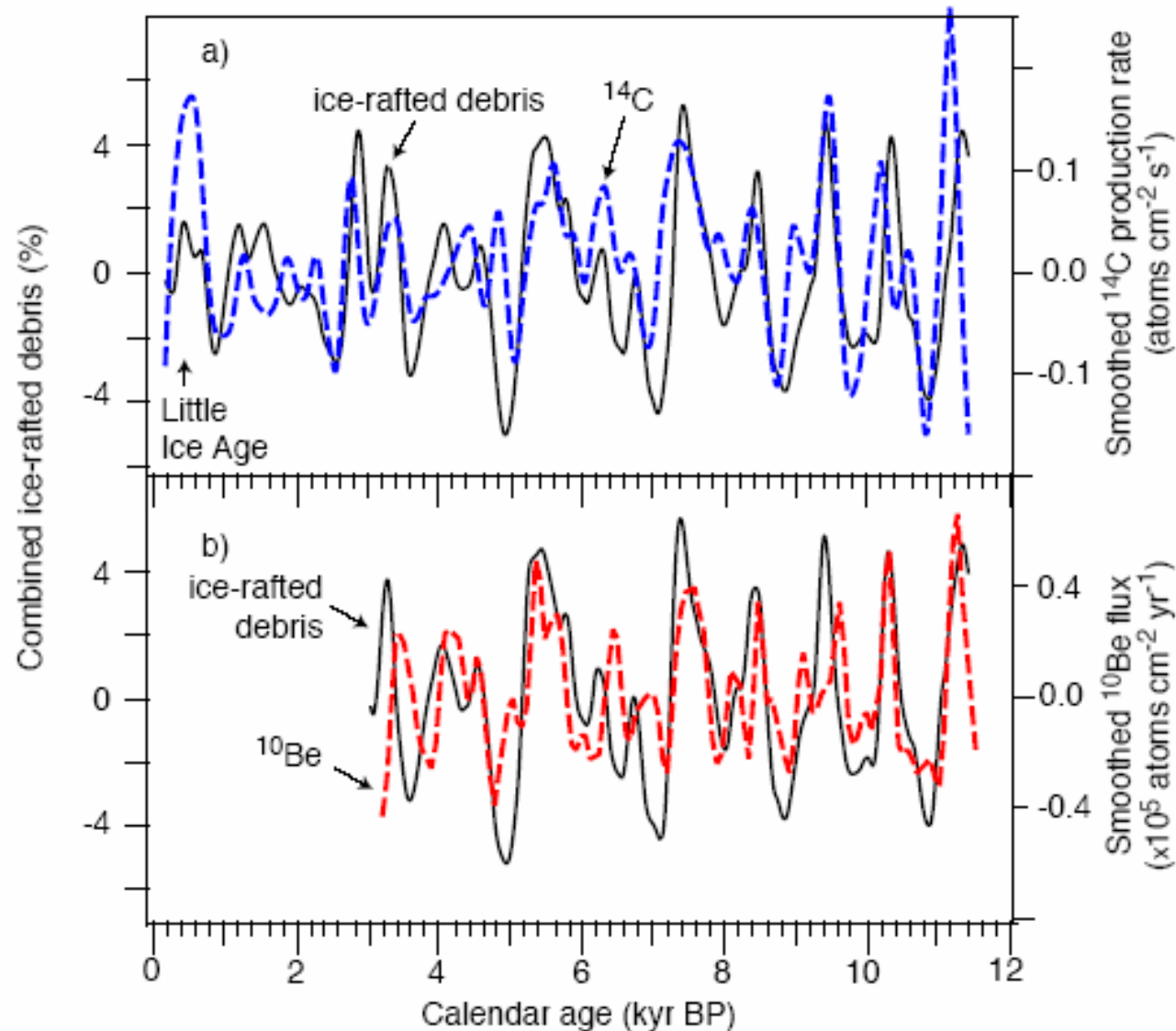


Possible mechanisms linking Galactic Cosmic Rays and cloudiness

CLOUD concept

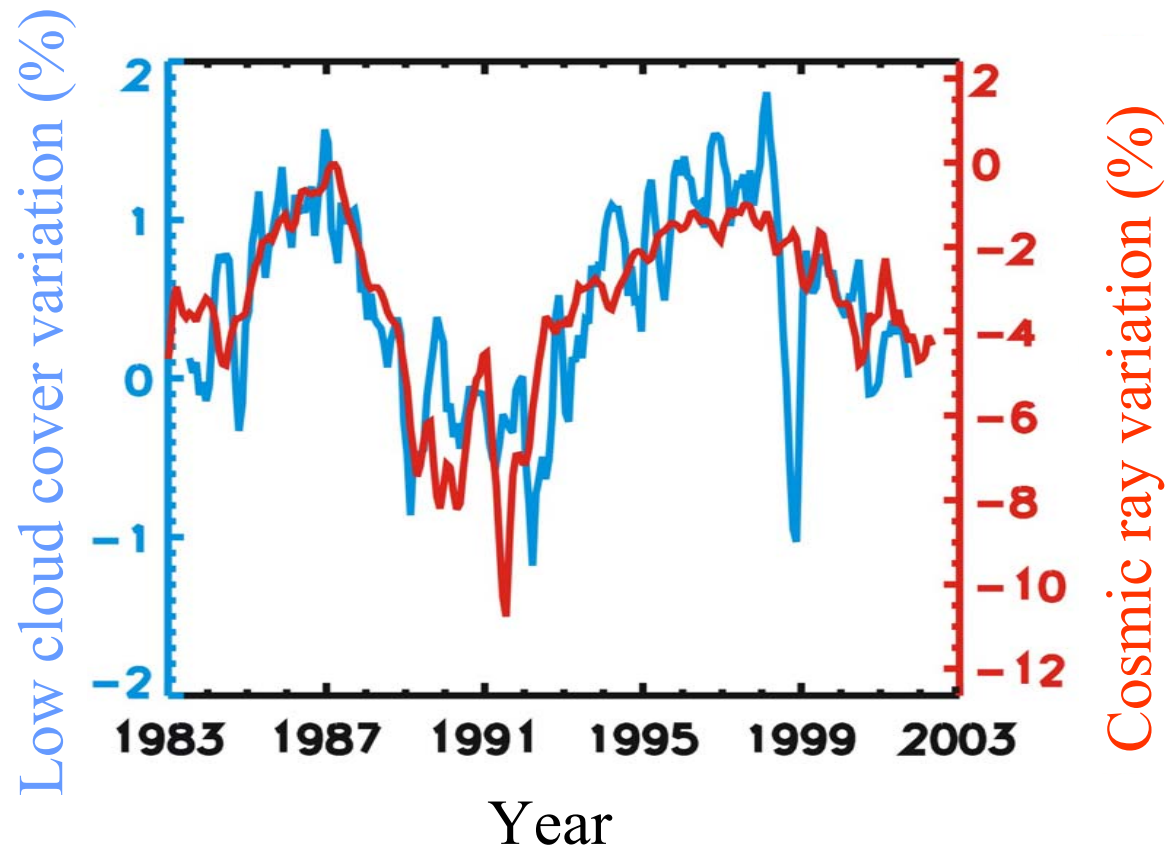
- Laboratory experiment to investigate Galactic Cosmic Rays(GCR) – aerosol – cloud interactions
- nm scale physics and chemistry
- Use CERN particle beam as an artificial source that closely simulates natural GCRs throughout atmosphere => nucleation processes are highly non-linear so need to closely reproduce atmospheric conditions (ionisation, trace gas concentrations,...)
- General purpose: advanced detector to reproduce conditions anywhere in troposphere or lower stratosphere: cloud chamber, reactor chamber + instrumentation

Correlation of GCR variability with temperature proxies over the last 10 kyears



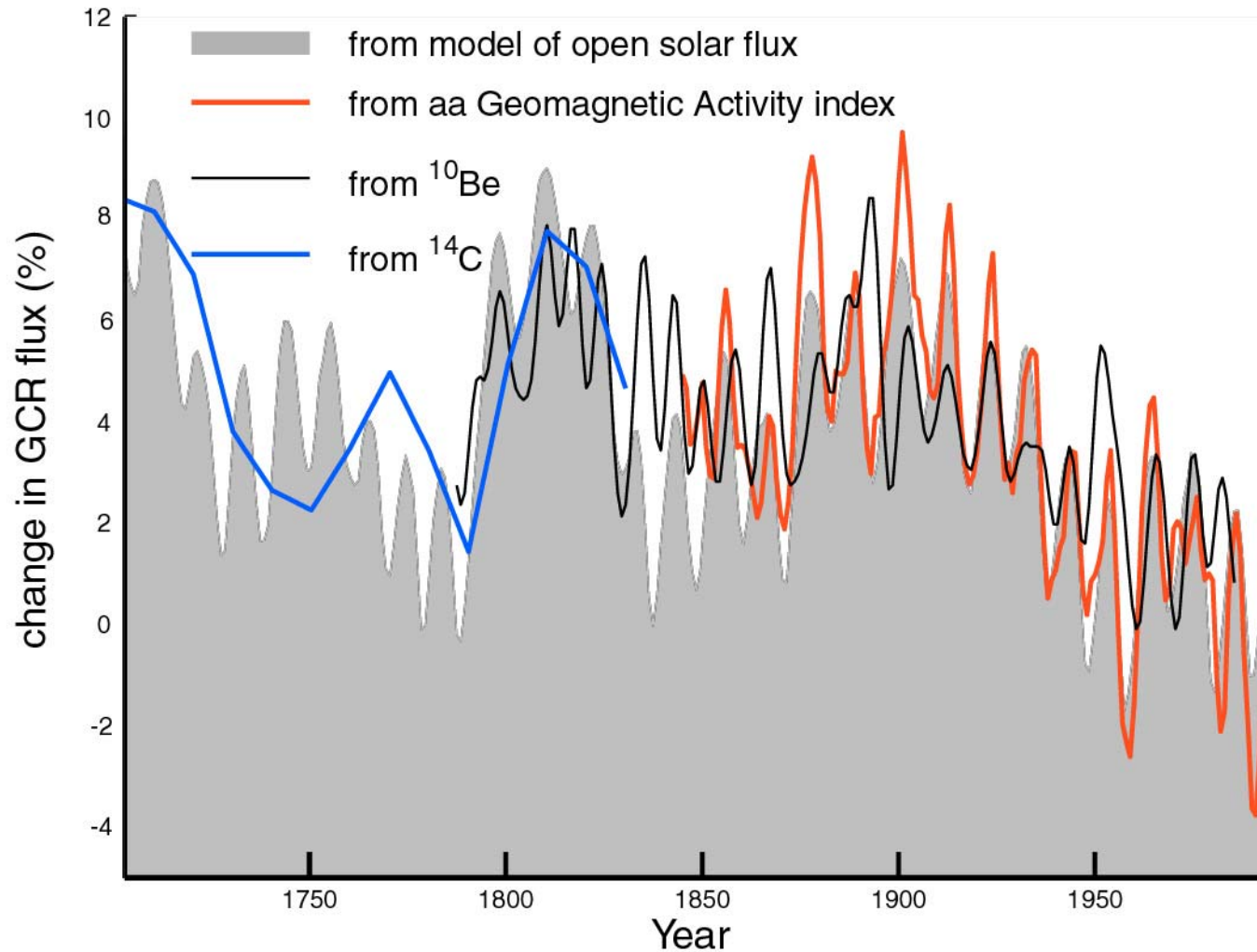
A possible link between Cosmic Rays and Climate

Cosmic Rays and Earth's Cloud Cover



N.D. Marsh & H. Svensmark (2003)

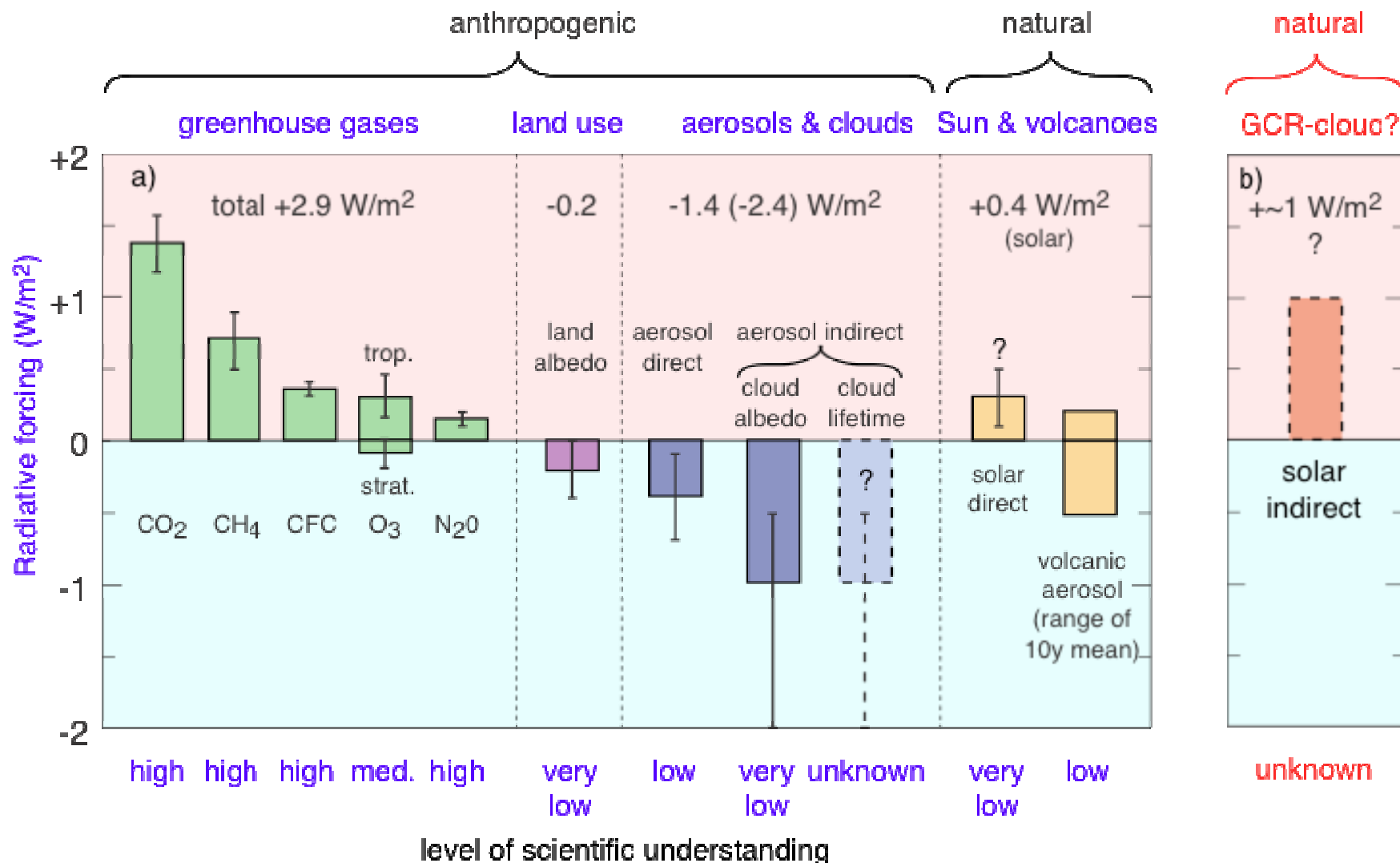
Recent Cosmic Ray Variations



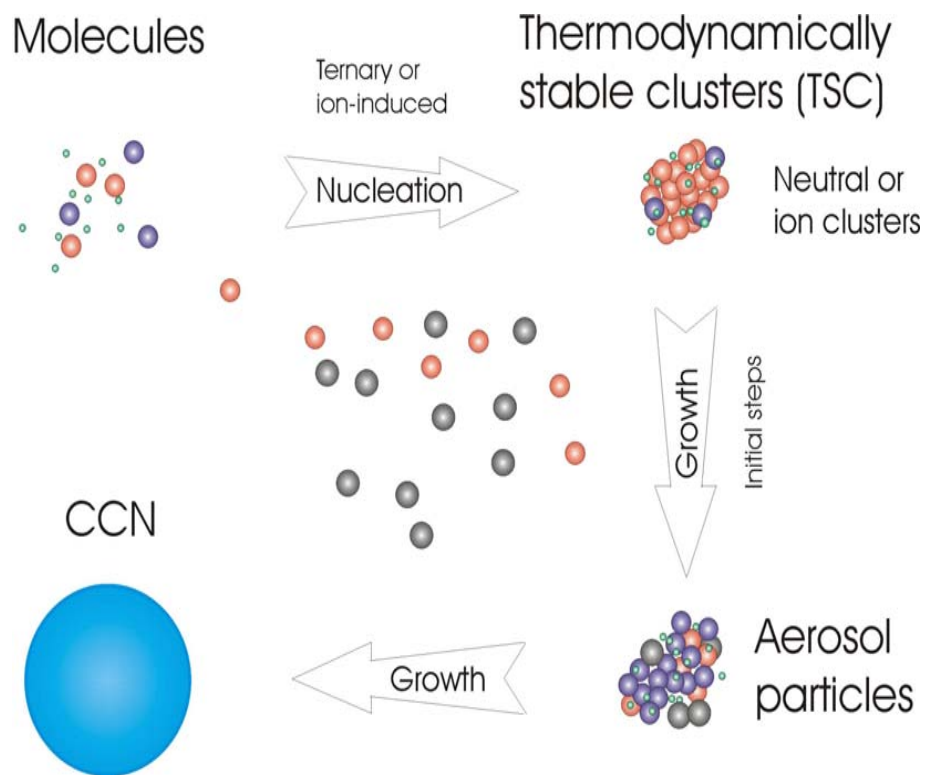
Lockwood et al., Science, 1999

Radiative forcing of climate, 1750-2000

From IPCC, 2001

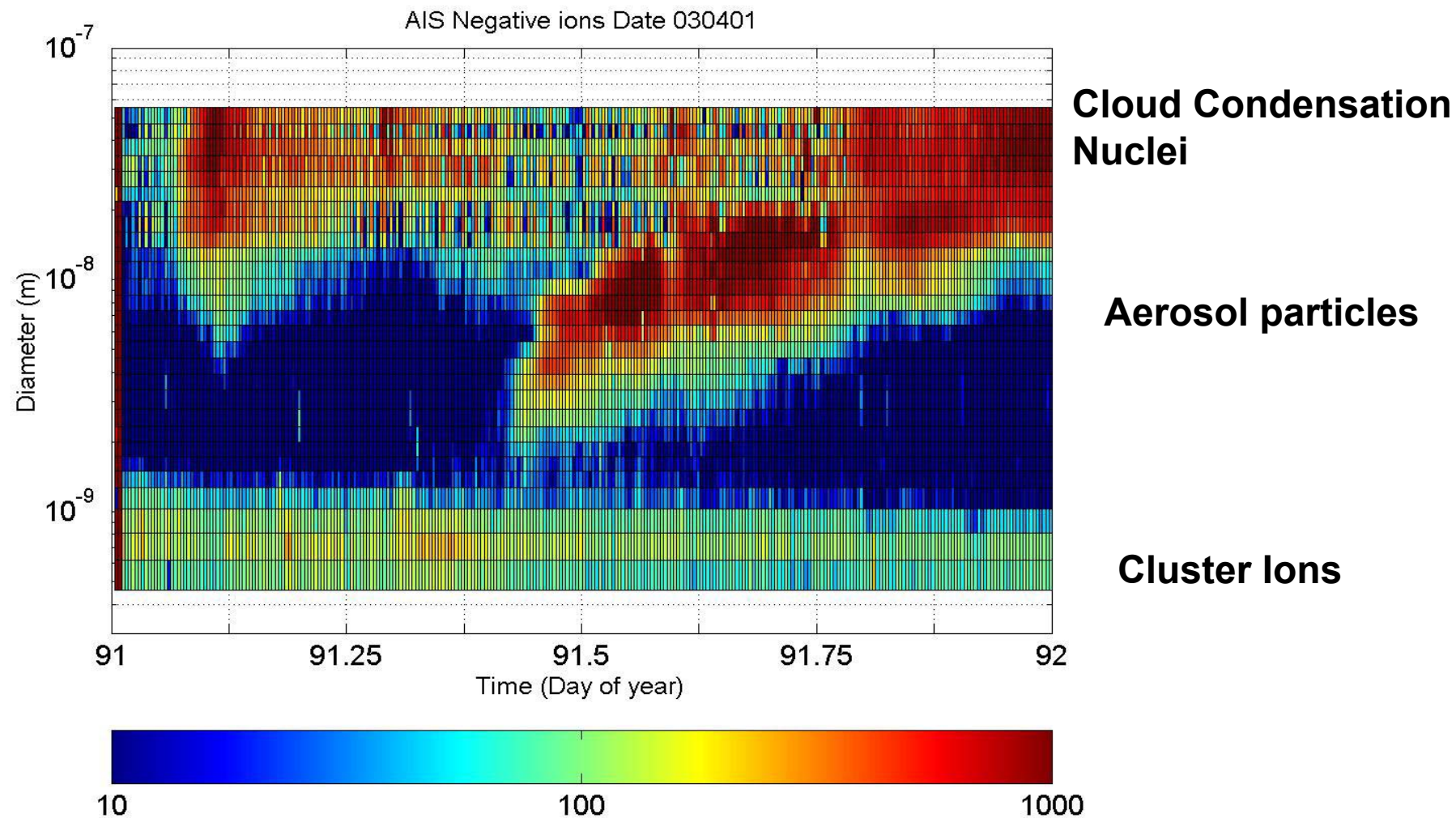


Processes

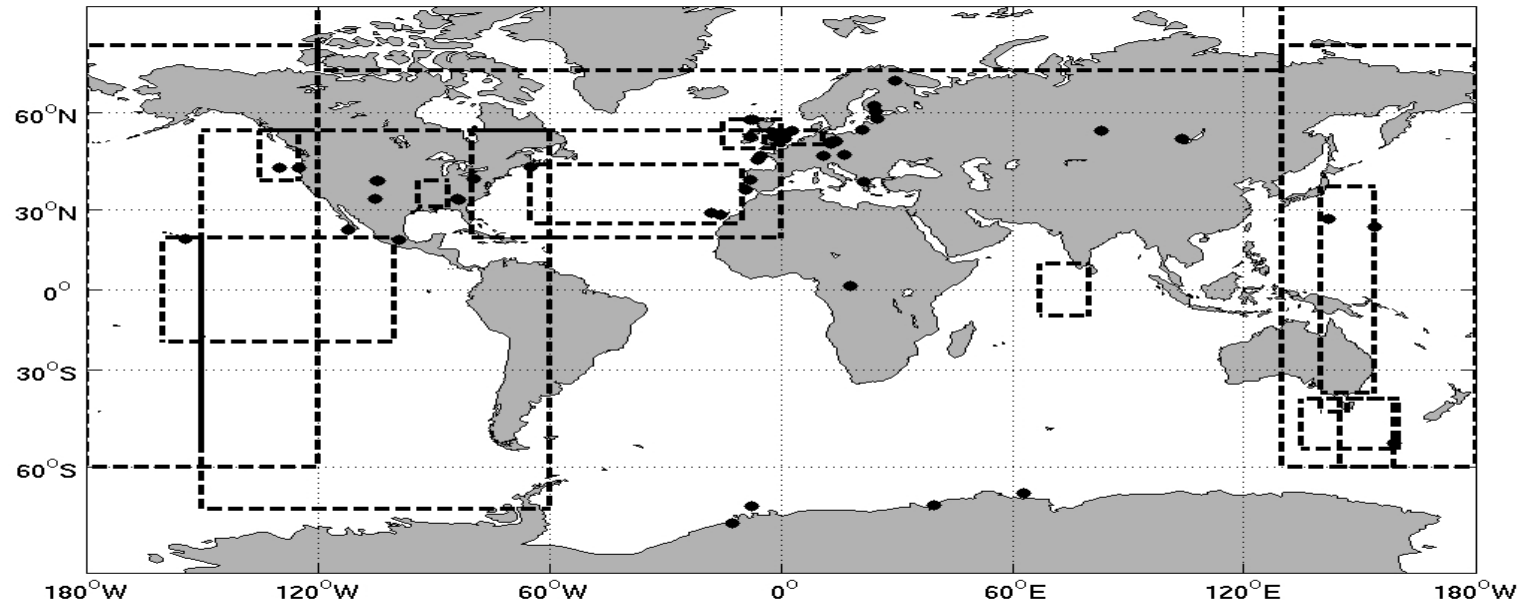


- **Nucleation**
 - Ternary/Kinetic Nucleation
 - $\text{H}_2\text{SO}_4\text{-NH}_3\text{-(H}_2\text{O)}$
- **Initial steps of the growth**
 - Nano-Kohler
 - Heterogeneous Nucleation
- **Growth**
 - Organic vapours
- **Aerosol dynamics**
 - competition between processes

Observation of Nucleation Burst in Finland



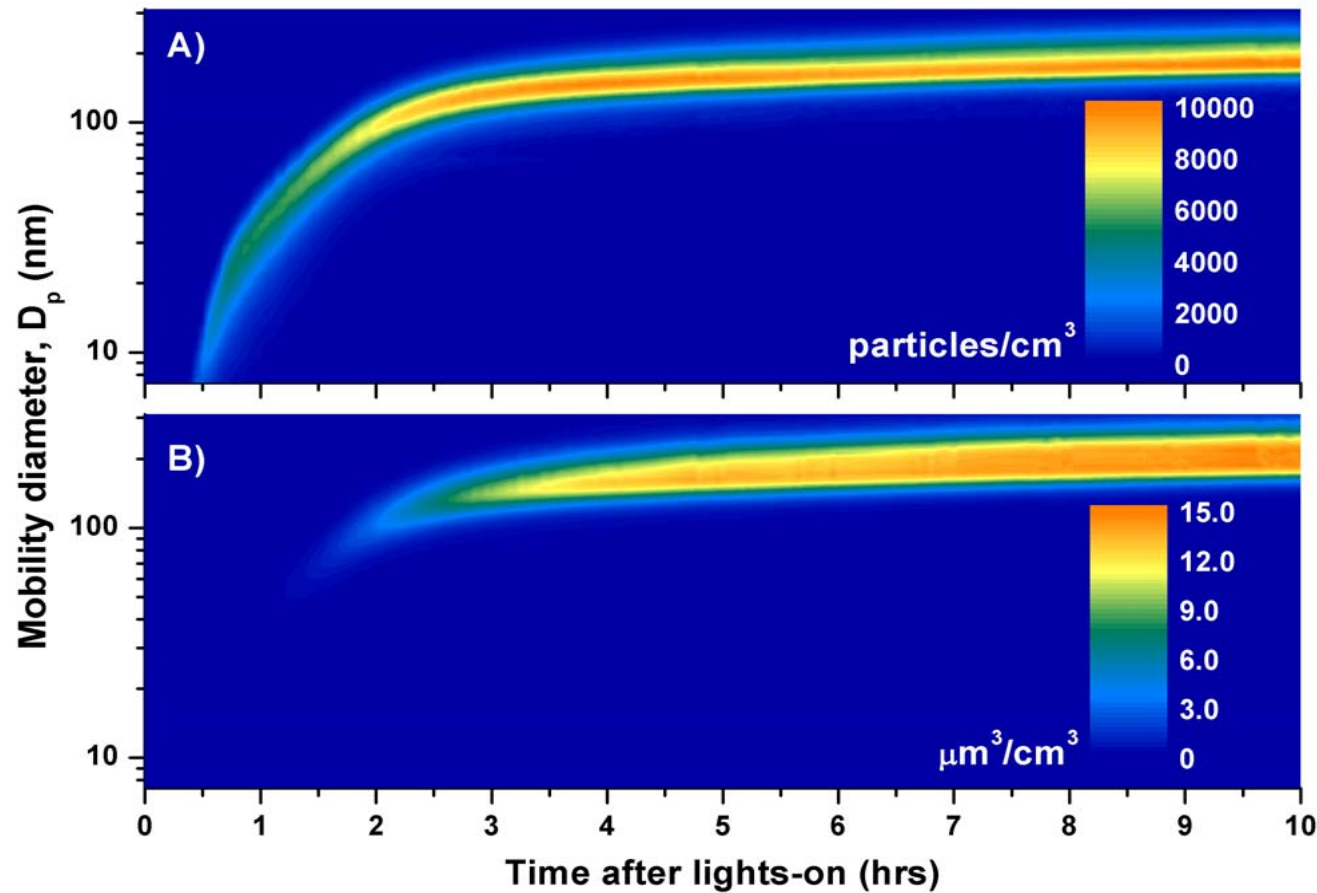
Observed formation of fresh aerosol particles



The dots indicate observation sizes, the dashed lines and rectangles indicate regions where airborne or ship observations have been made. (Kulmala et al., J. Aerosol Sci., 2004)

Aerosol Nucleation and Growth reproduced in the laboratory

(Kalberer, Baltensperger et al., Science, 2004)



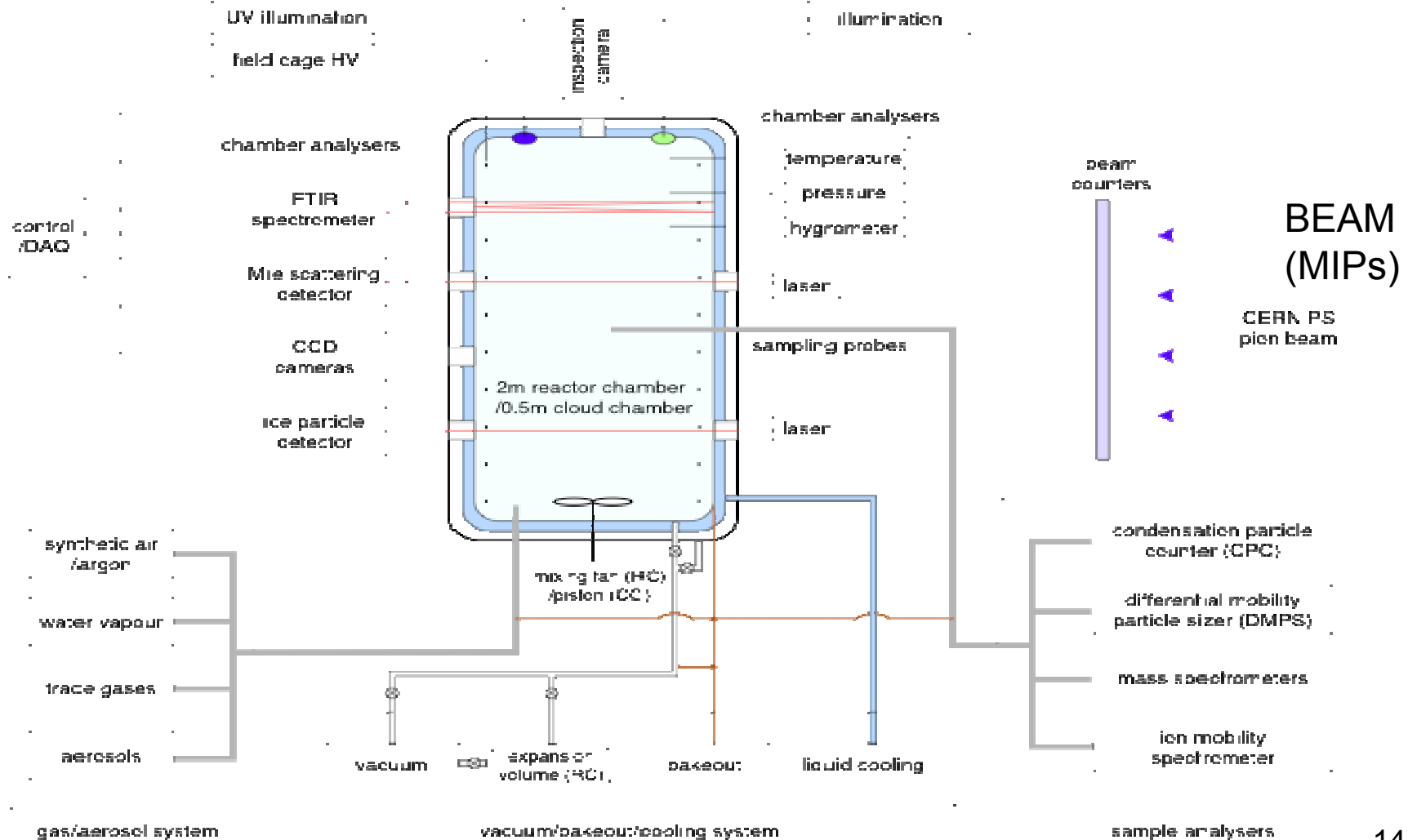
Demonstrates technical feasibility of CLOUD

How does cosmic ray ionization influence

- the production of aerosol particles ?
- the growth to Cloud Condensation Nuclei (CCN)?
- the formation of clouds ?

To answer this, we need laboratory experiments under well controlled conditions

CLOUD instrumentation



CLOUD: Measurement cycle

1. Fill chamber with clean air
2. Add trace gases / condensable species
3. Reactions / Adiabatic Expansion
4. Observe cloud droplet size distribution etc.

Repeat the cycle with beam on/off

Each experiment to last several hours

For a Successful Experiment

- Excellent Collaboration, experienced in
 - field observations
 - lab experiments
 - modelling and theory
- CERN beam
 - total 56 weeks (in 3 years)
- CLOUD chamber
- Instrumentation
 - aerosols, ions, trace gases, chemical analysis

CLOUD aims at

- exploring link between Cosmic Rays, aerosol and cloud formation
- understanding this central element of climate change
- providing fundamental new data for climate models