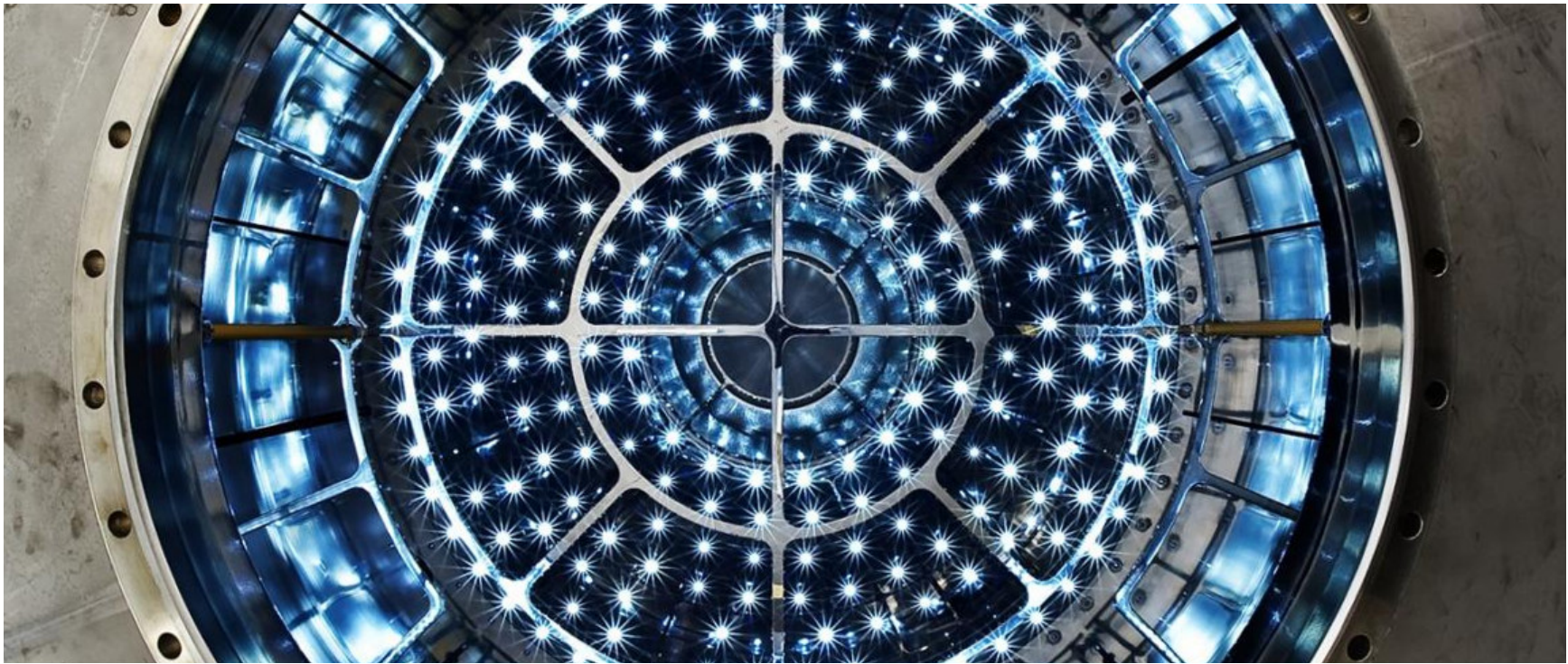


Atmospheric New Particle Formation and Climate Sensitivity: the CLOUD experiment



4th April 2017

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About me

- Master degree in Applied and Environmental Chemistry at the University of Milan
- PhD student at the Laboratory of Atmospheric Chemistry, Energy and Environment Research Division at the Paul Scherrer Institute

<https://www.psi.ch/lac/>

Laboratory of Atmospheric Chemistry (LAC)
About LAC
People
Research Groups
Instruments and Tools
Facilities
Models
Projects
Teaching and Seminars



LAC - Laboratory of Atmospheric Chemistry

The Laboratory of Atmospheric Chemistry (LAC), established 1 January 2000, is a laboratory of the Energy and Environment Research Division (ENE) at the Paul Scherrer Institute.

Our laboratory comprises four interacting groups that operate a large variety of facilities and instruments in the lab and in the field.

Contact

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5232 Villigen PSI
Switzerland

Hannelore Krüger

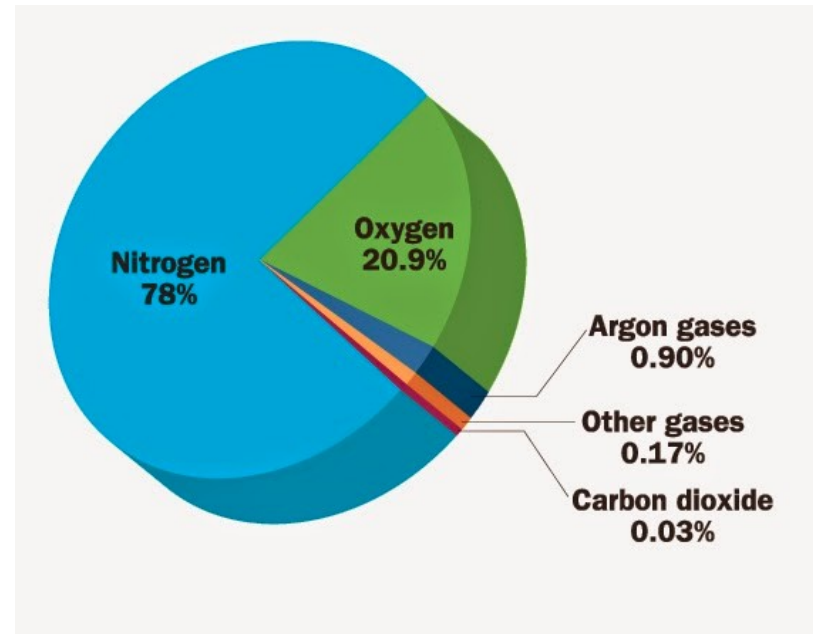
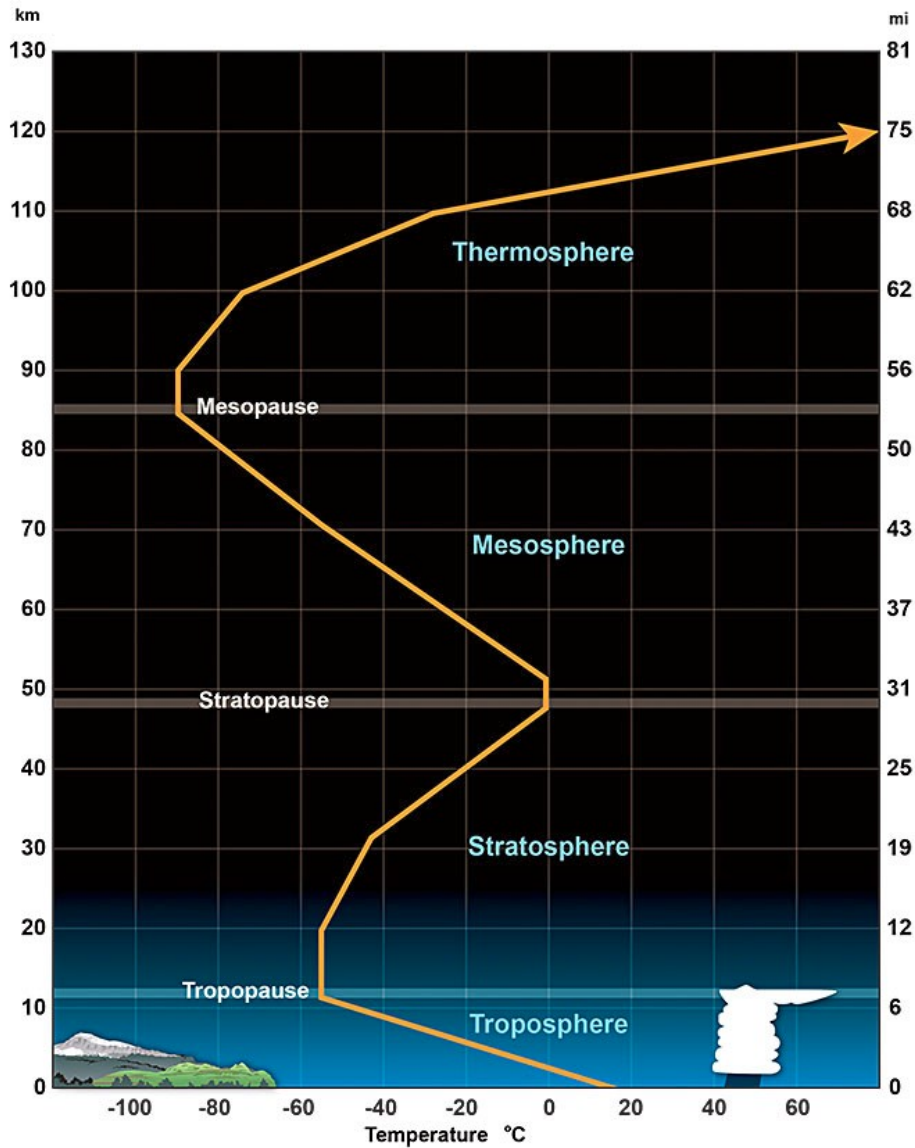
Telephone:
+41 56 310 2522
E-mail:
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- Working at the CERN CLOUD (Cosmics Leaving OUtdoor Droplets) experiment

Outlook

- Aerosol and the impact on visibility, health and climate
- New particle formation in troposphere
- The CERN CLOUD experiment and recent results
- Field results an the High Altitude Jungfrauoch Research Stations

Atmosphere



Atmospheric New Particle Formation and Climate Sensitivity: the CLOUD experiment

- Aerosol is defined as a suspension of fine solid or liquid particles in a gas:
 - Dust, Fog, Fume, Hazes, Mists, Particles, Smog, Smoke, Soot

We will focus on the dispersed phase

Few hundred to few thousand particles per cc

Diameter: few nm – few μm

Atmospheric Science - History

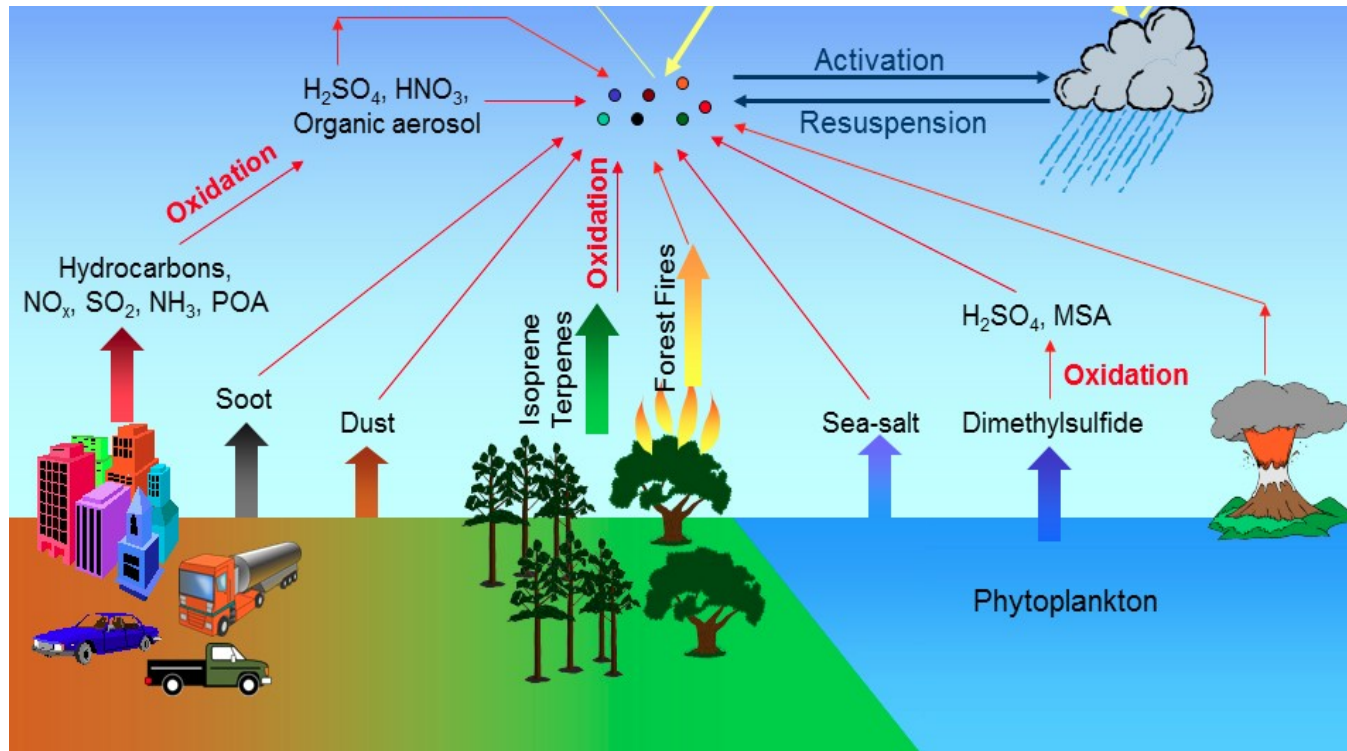
- Ancient Greeks thought that emissions from their cooking activities were reaching the mount Olympus and feeding gods.
- The Great Smog of 1952, London
- Photochemical Smog, LA basin '70
- Ozone hole - 1995 Nobel Prize in Chemistry

Aerosol Sources

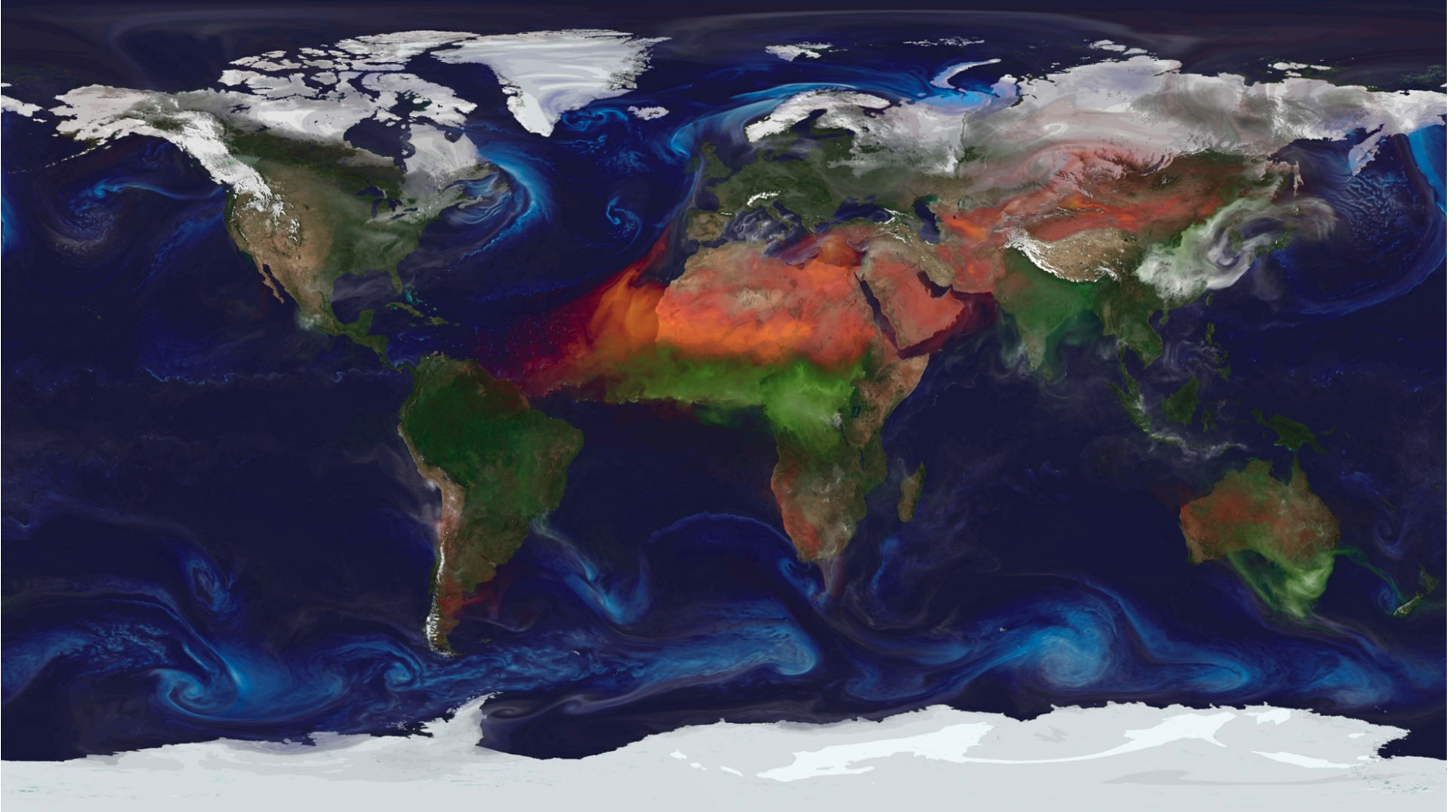
- Biogenic
- Anthropogenic

- Primary
- Secondary

Ozone, OH, NO₃
Oxidation processes



Aerosol global distribution



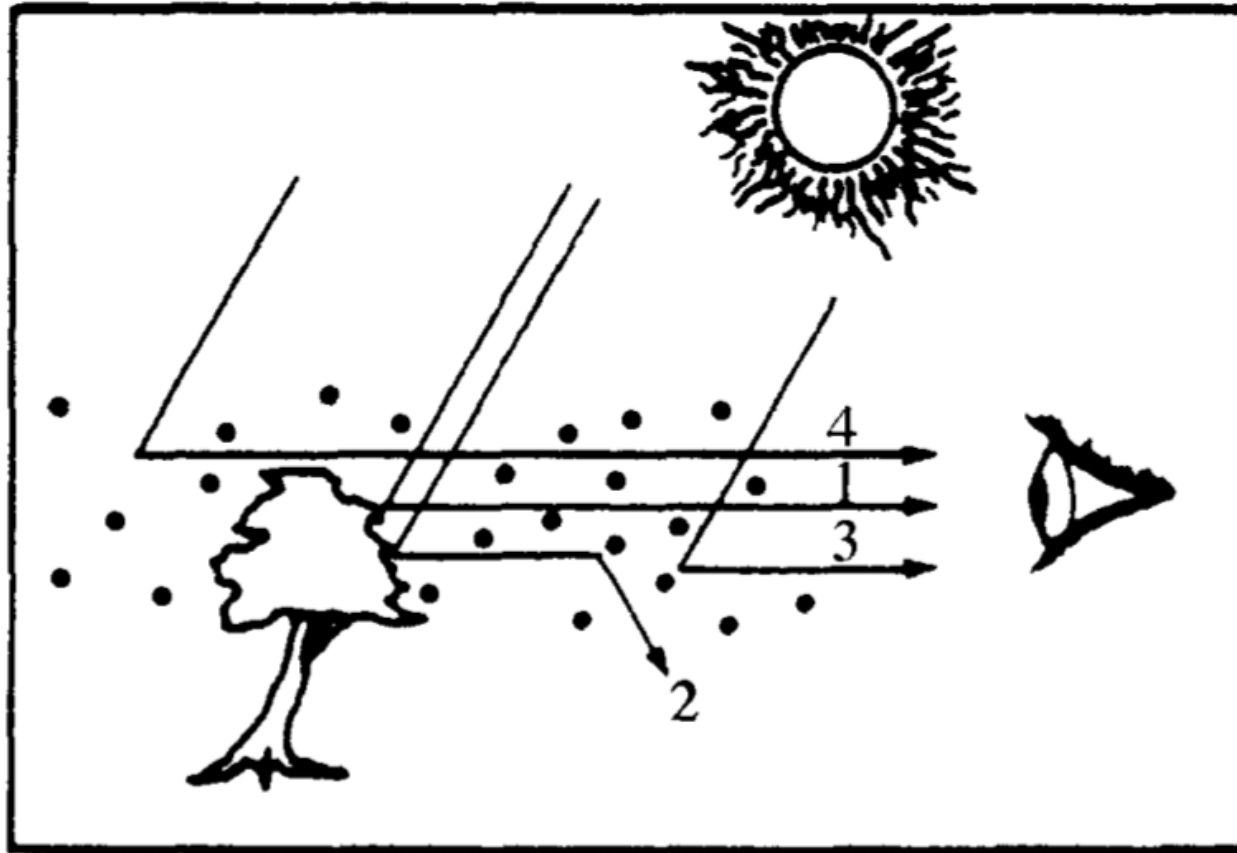
Dust (red), sea salt (blue), organic/black carbon (green), and sulfates (white)

<https://svs.gsfc.nasa.gov>

Why do we study aerosol?

- Visibility
- Health
- Climate

Visibility



Seinfeld and Pandis, 1998

- 1) Residual light from the target reaching the observer
- 2) Light from the target scattered out of the observer's line
- 3) Light scattered into the observer's line
- 4) Background scattered light

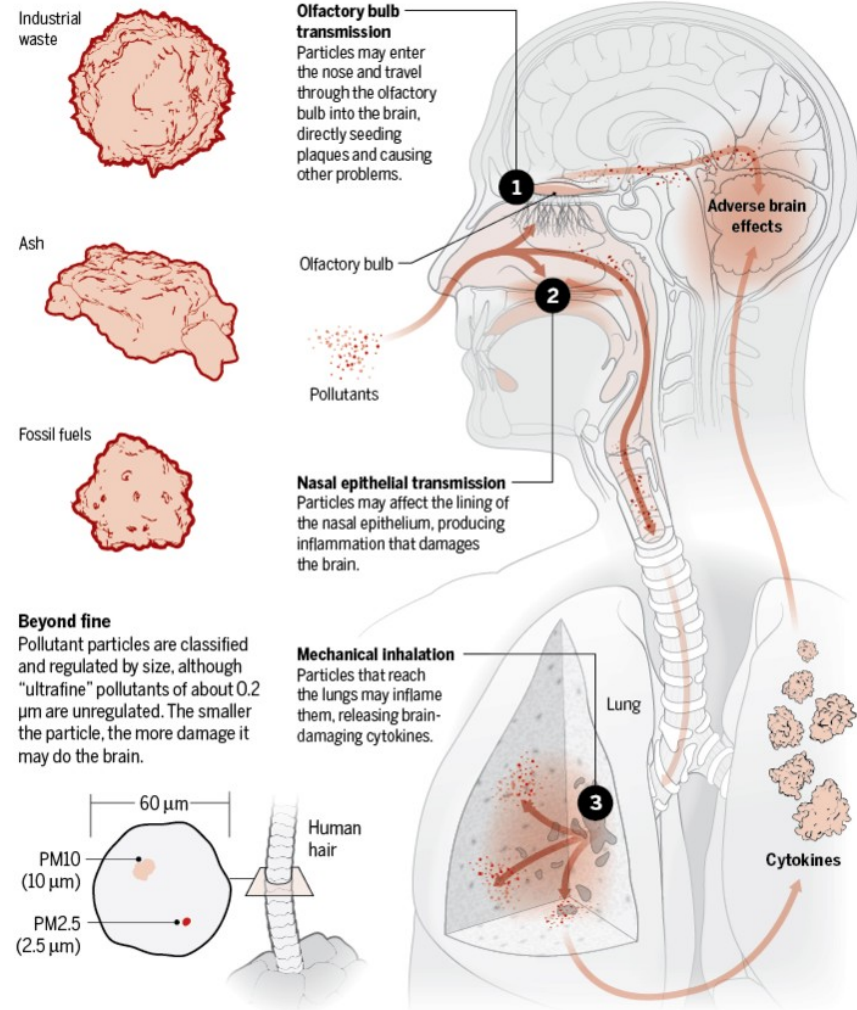
Visibility



Shanghai

Health

- asthma,
- lung cancer,
- heart disease,
- cognitive aging,
- Alzheimer's disease and other forms of dementia.



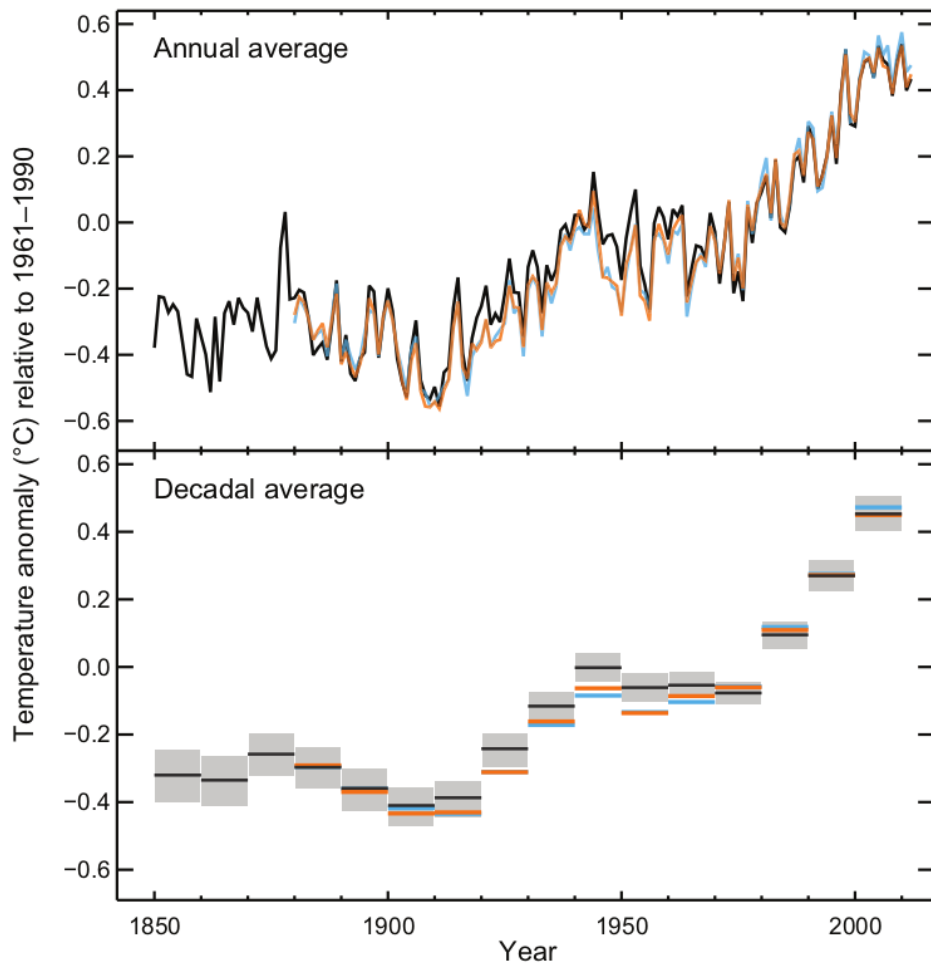
Emily Underwood,
Science Magazine

Aerosol and Climate

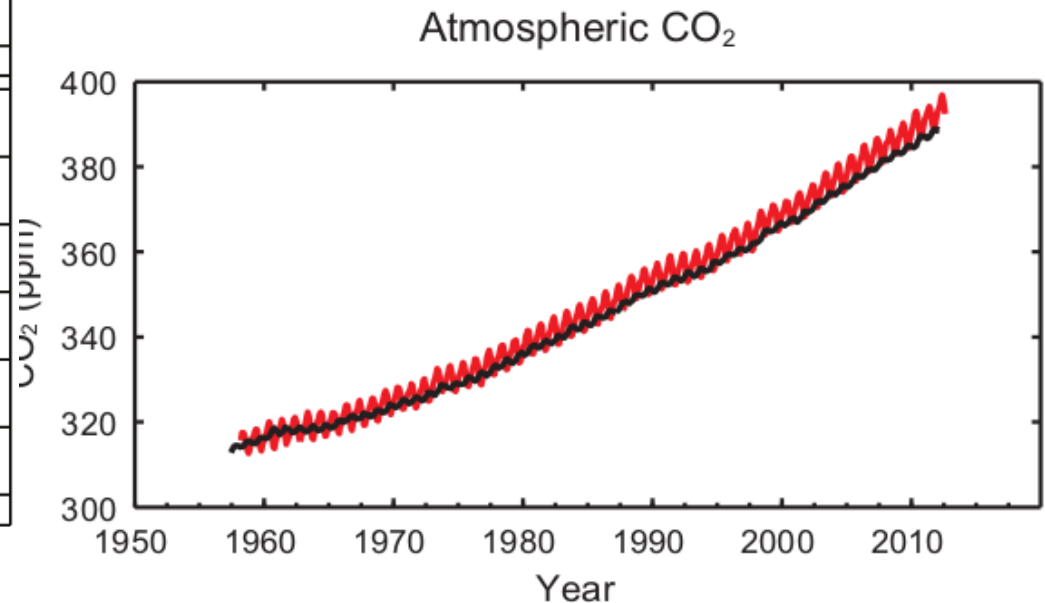
IPCC (Intergovernmental Panel on Climate Change) Fifth Assessment Report:

- The Physical Science Basis → Clouds and Aerosols
- Impacts, Adaptation, and Vulnerability
- Mitigation of Climate Change

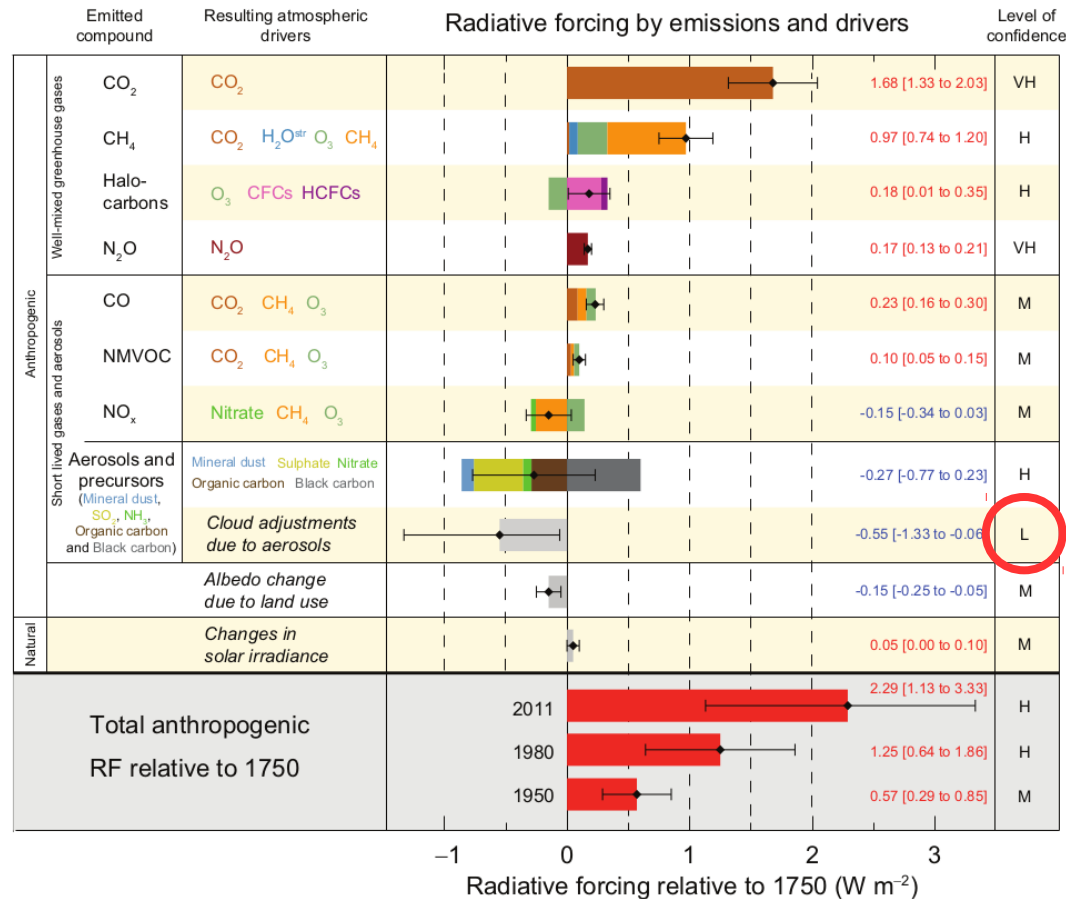
Radiative Forcing – greenhouse gases - CO₂



Svante Arrhenius 1896, first evidence of the link between CO₂ and greenhouse effect



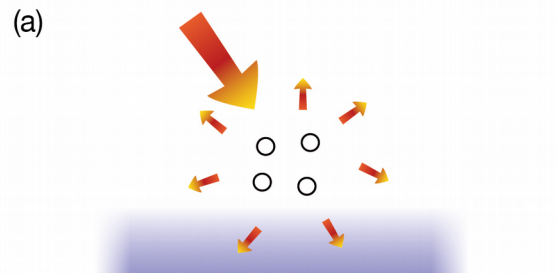
Climate Sensitivity – Radiative Forcing



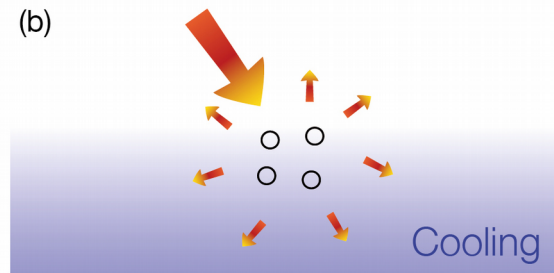
Radiative Forcing - Aerosol

Aerosol-radiation interactions

Scattering aerosols

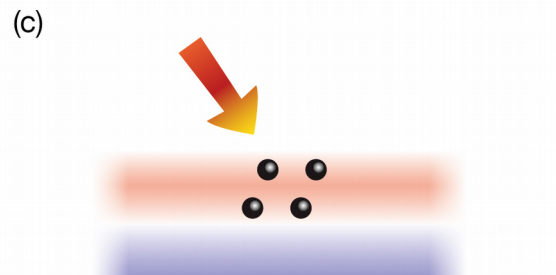


Aerosols scatter solar radiation. Less solar radiation reaches the surface, which leads to a localised cooling.

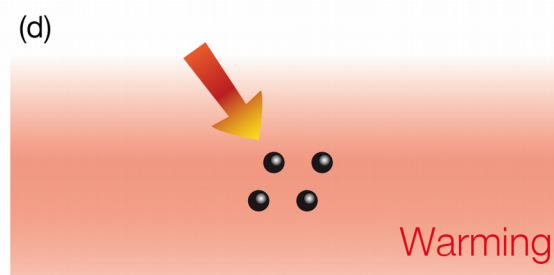


The atmospheric circulation and mixing processes spread the cooling regionally and in the vertical.

Absorbing aerosols

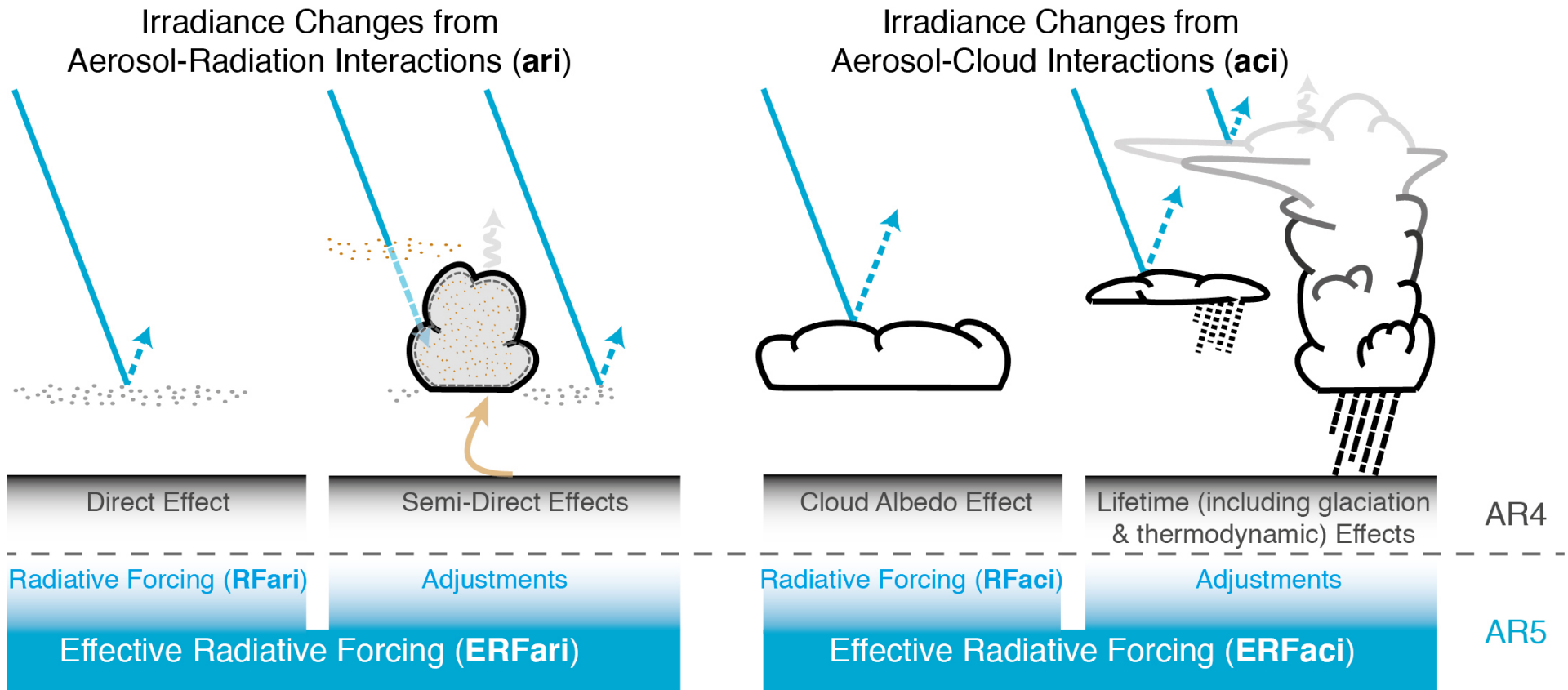


Aerosols absorb solar radiation. This heats the aerosol layer but the surface, which receives less solar radiation, can cool locally.



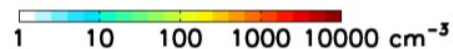
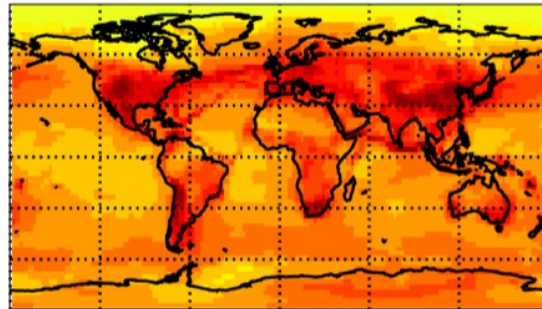
At the larger scale there is a net warming of the surface and atmosphere because the atmospheric circulation and mixing processes redistribute the thermal energy.

Radiative Forcing - Aerosol

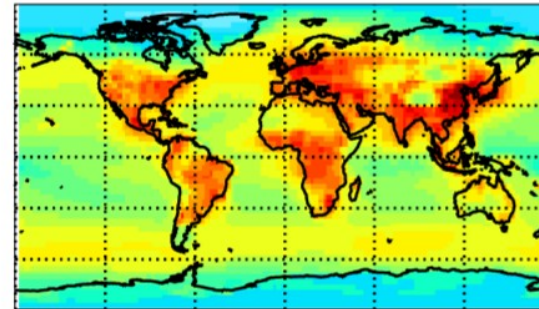


Particles act as cloud condensation nuclei.
Globally half of them are primary emitted, half are
formed in the atmosphere

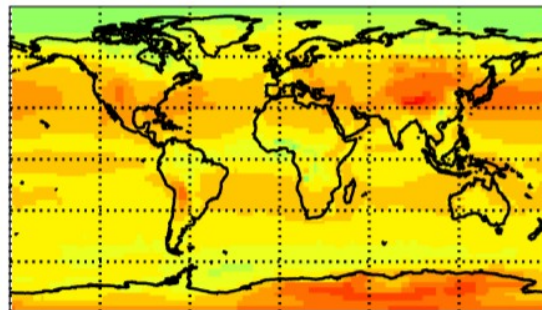
A: Total CN



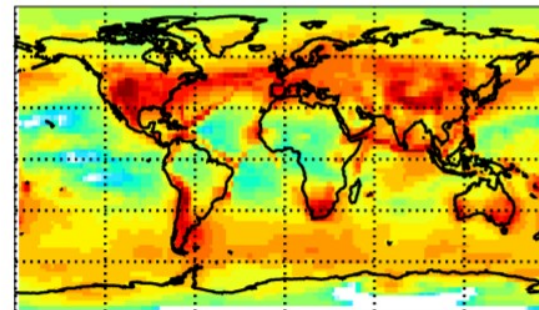
B: CN from Primaries



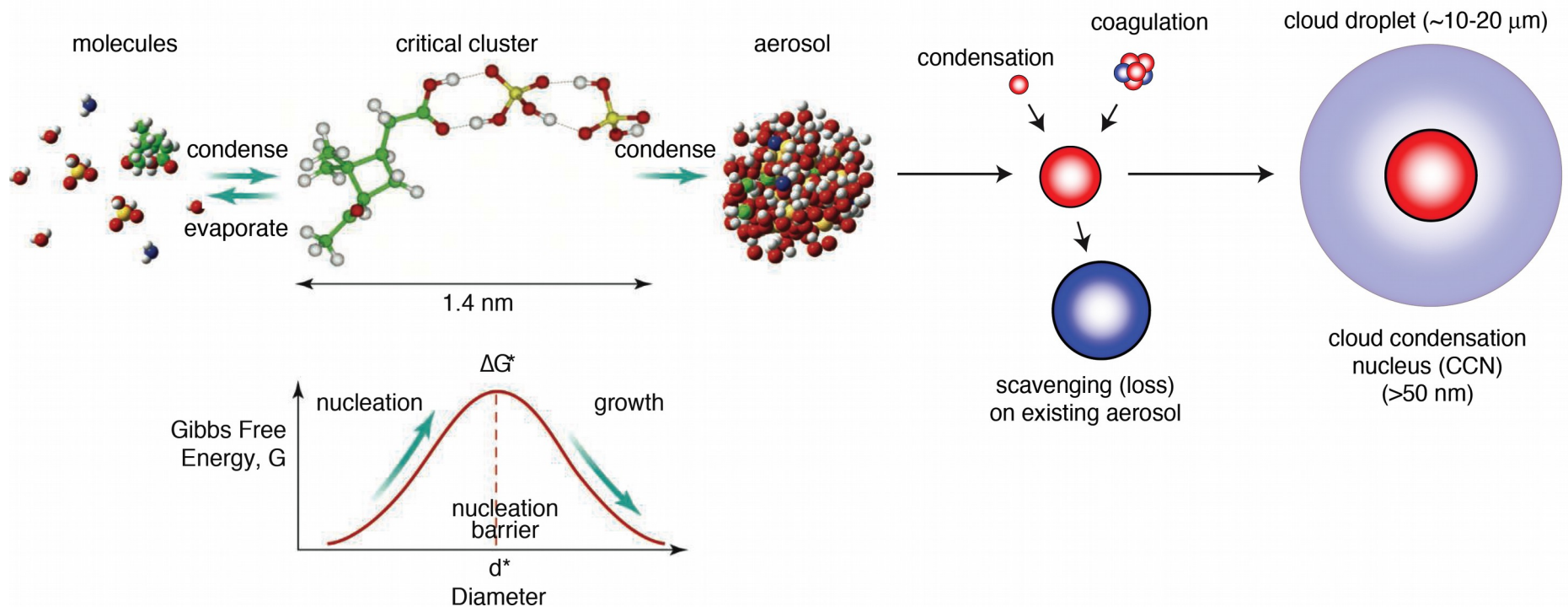
C: CN from UTN



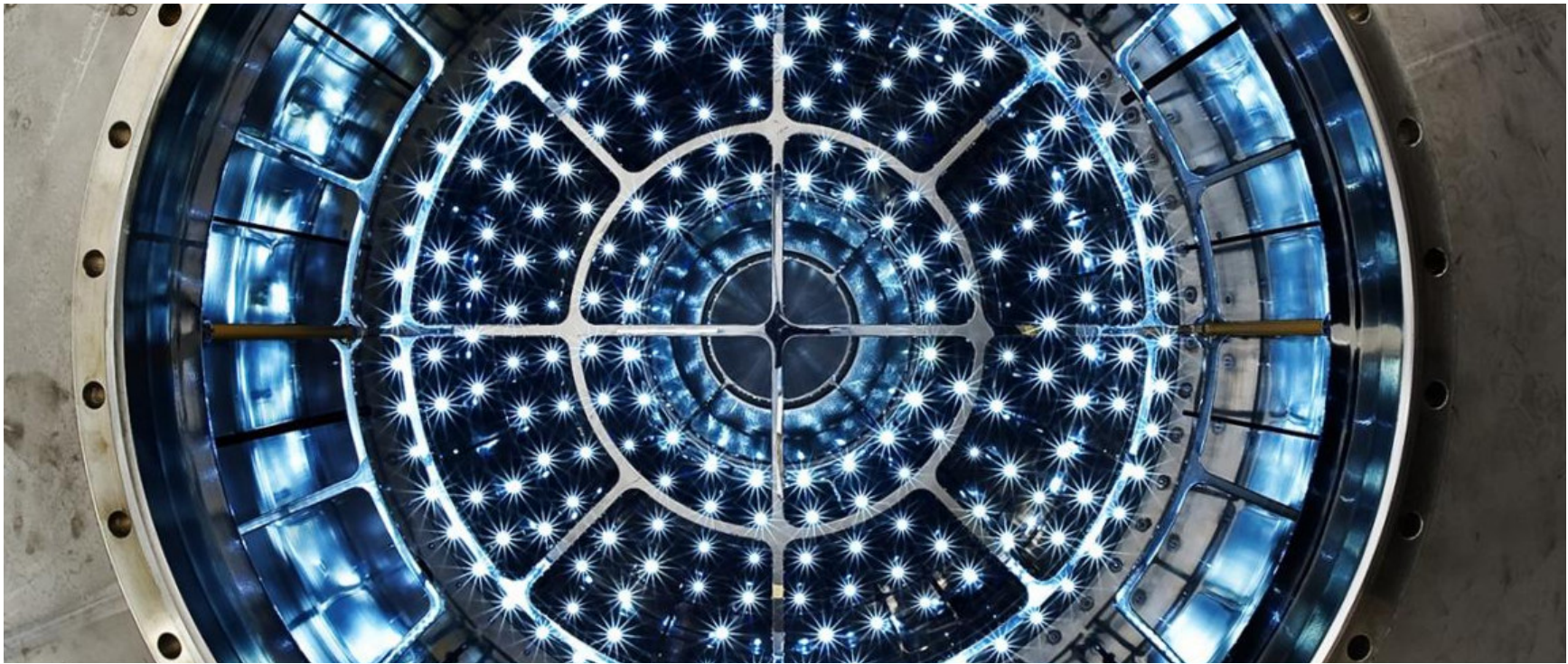
D: CN from BLN



Nucleation or new particle formation



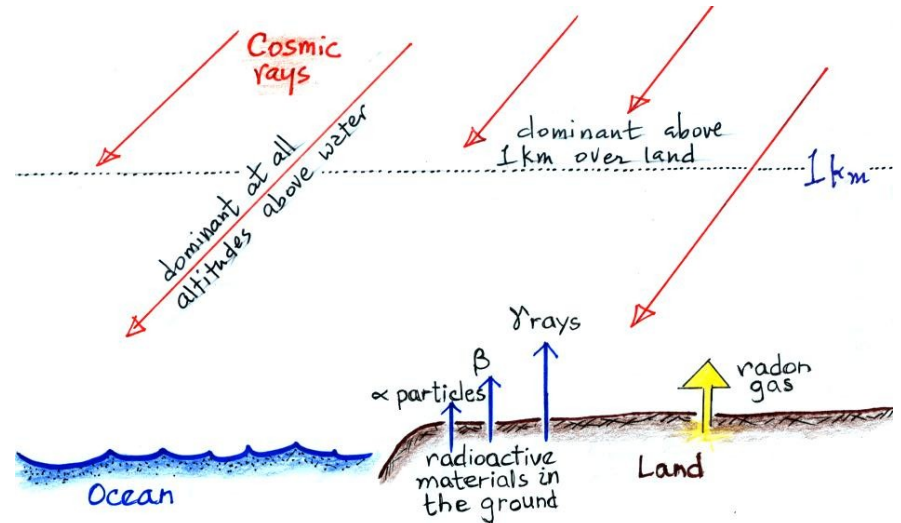
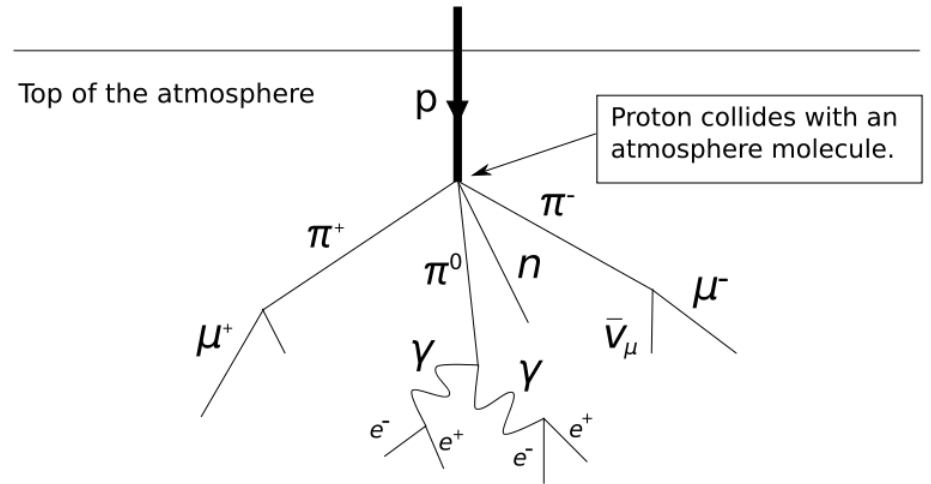
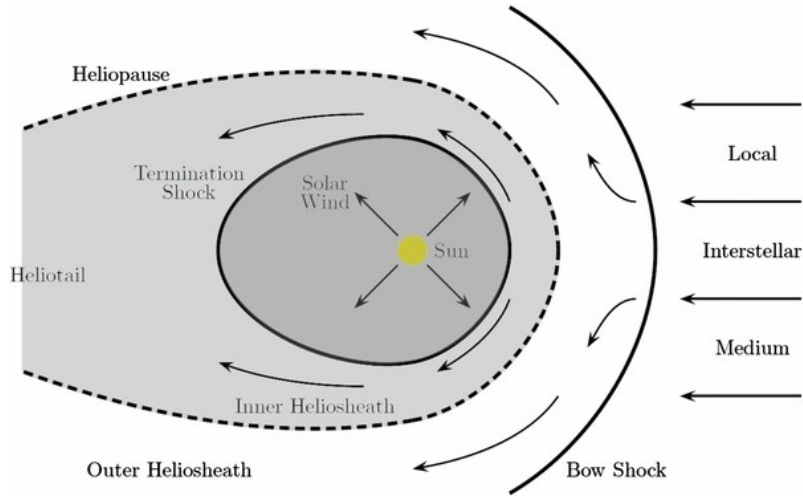
The CLOUD (Cosmics Leaving OUtdoor Droplets) experiment at CERN



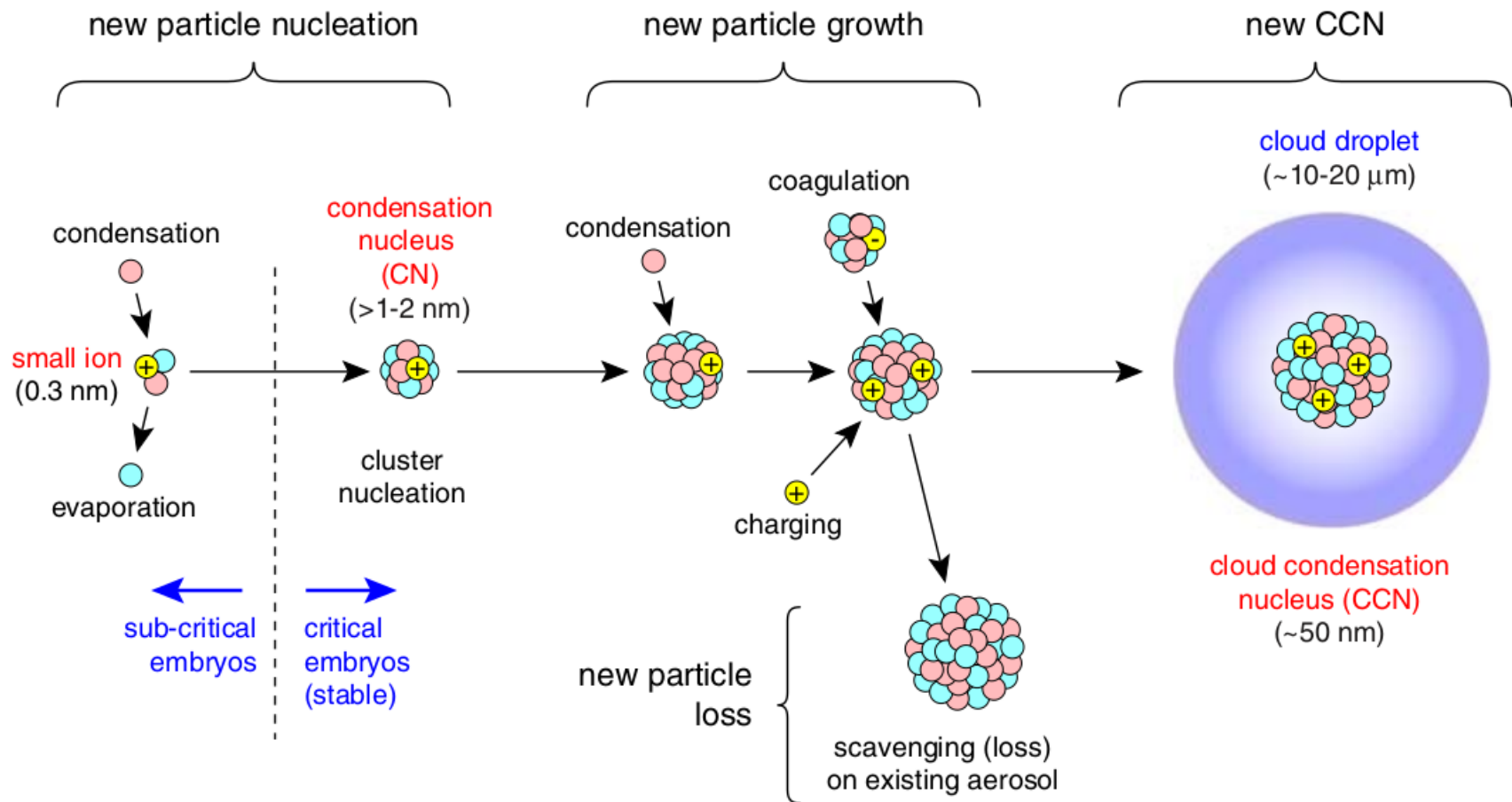
The CERN CLOUD experiment

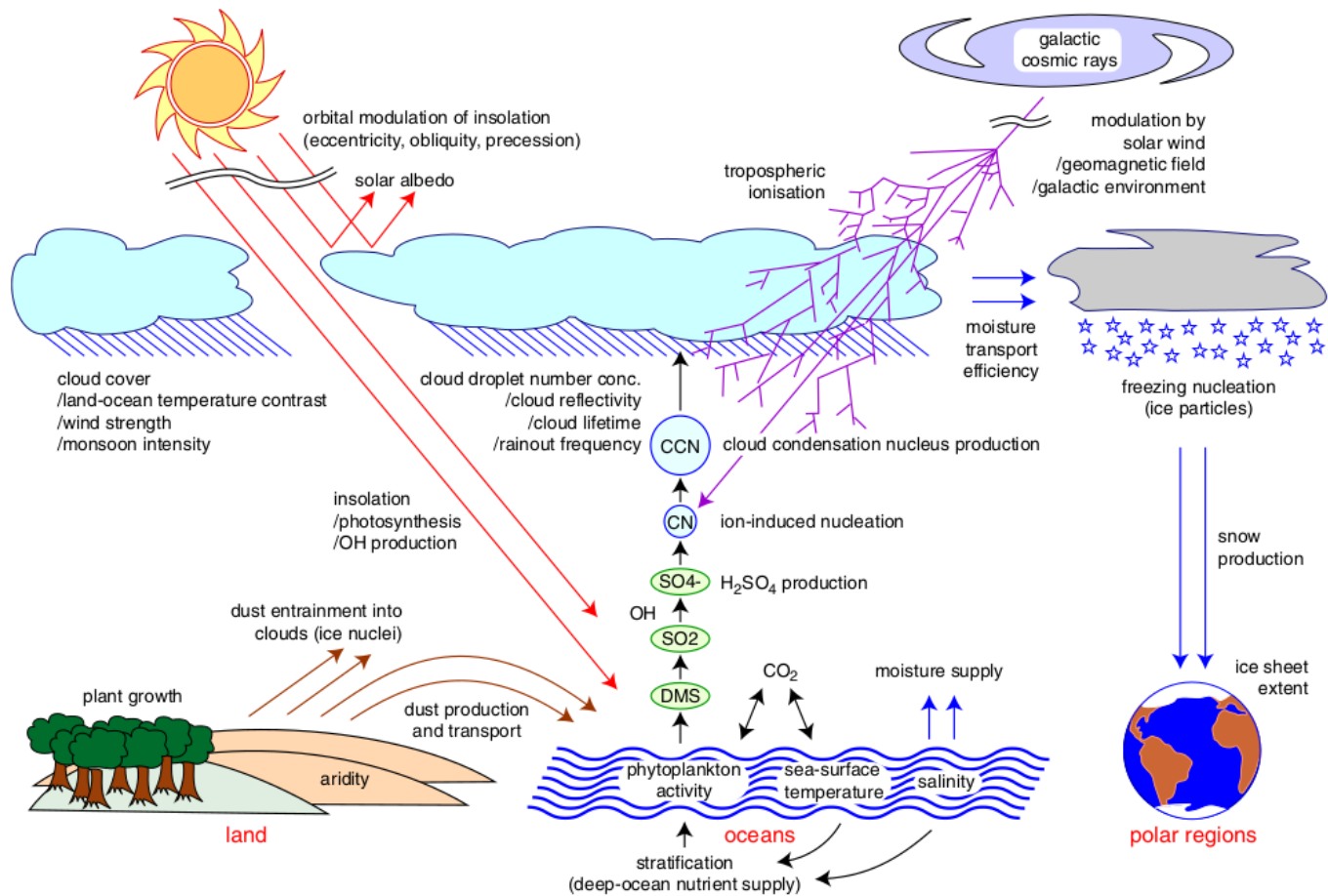
- Which chemical species are involved in new particle formation?
- Do galactic cosmic rays play a role in new particle formation?

Galactic cosmic ray

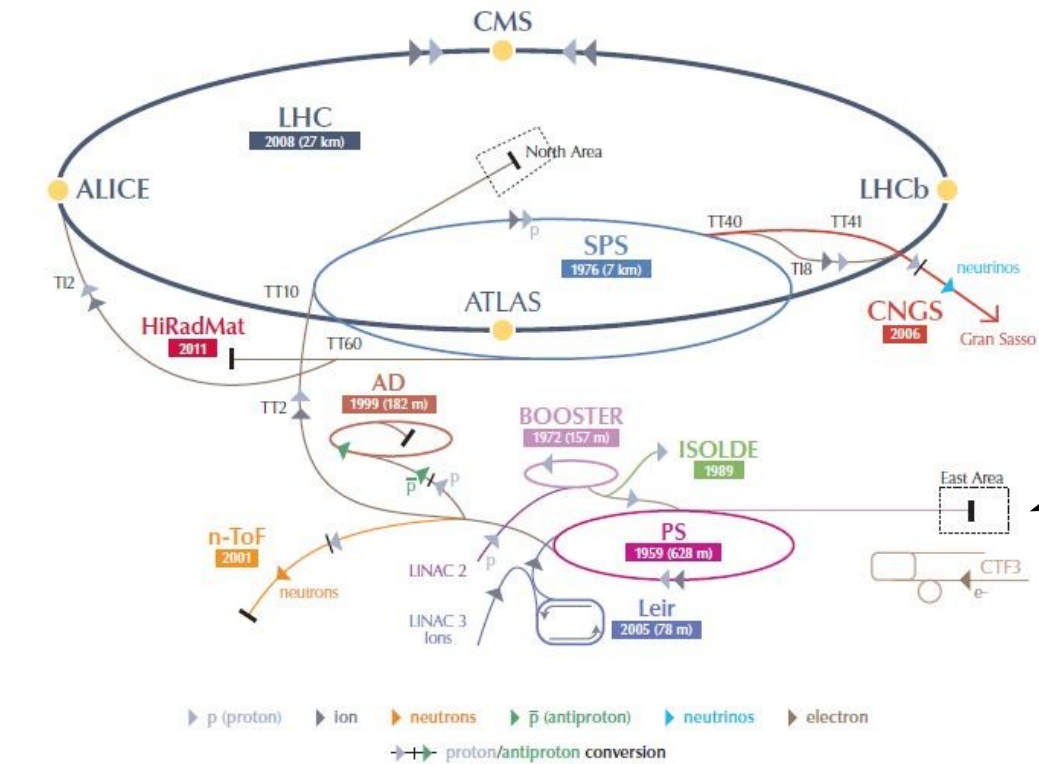


Ion induce new particle formation





CERN facility

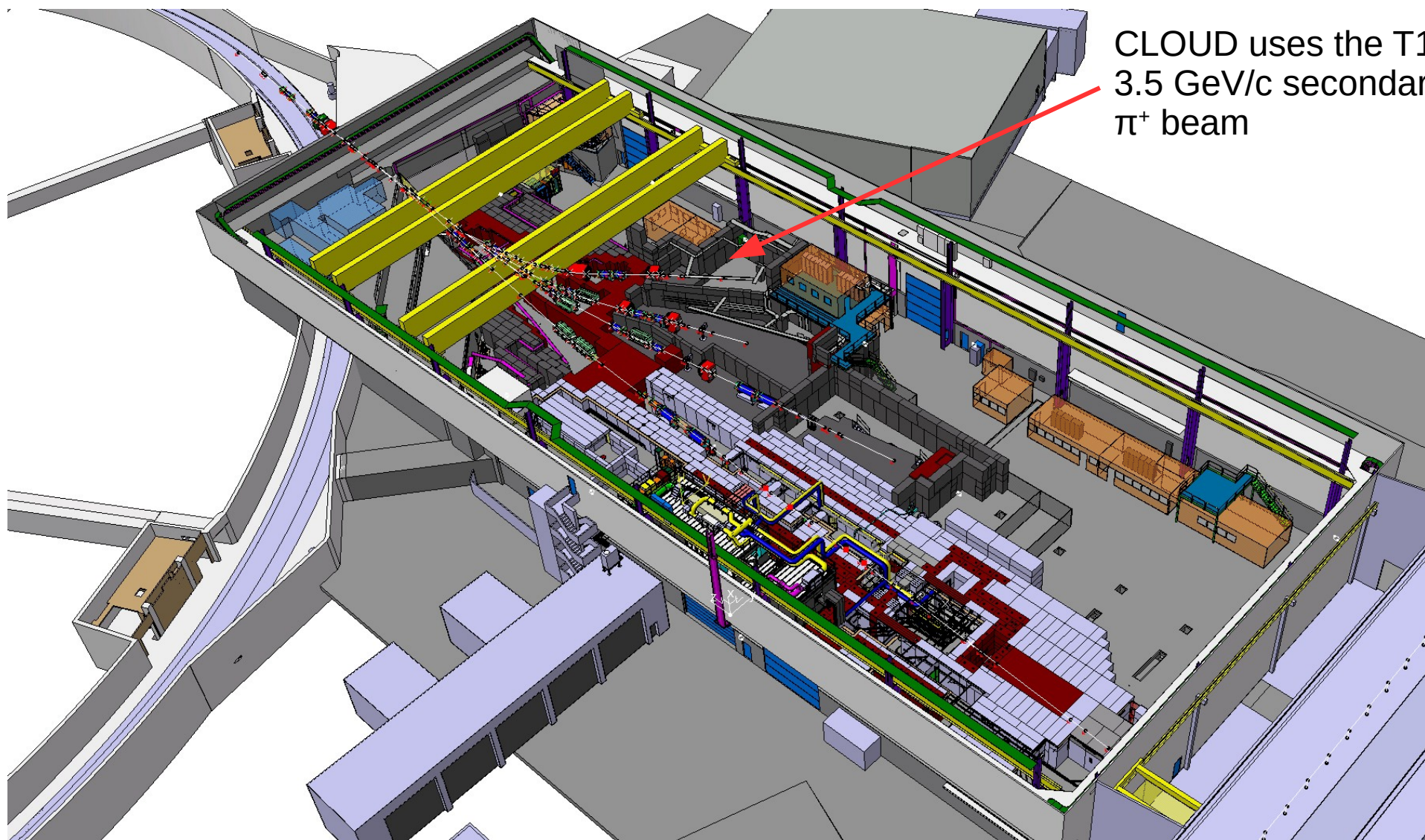


CLOUD is here!

- LHC Large Hadron Collider
- SPS Super Proton Synchrotron
- PS Proton Synchrotron
- AD Antiproton Decelerator
- CTF3 Clic Test Facility
- CNGS Cern Neutrinos to Gran Sasso
- ISOLDE Isotope Separator OnLine DEvice
- LEIR Low Energy Ion Ring
- LINAC LINear ACcelerator
- n-ToF Neutrons Time Of Flight
- HiRadMat High-Radiation to Materials

<http://cern.ch>

East Hall



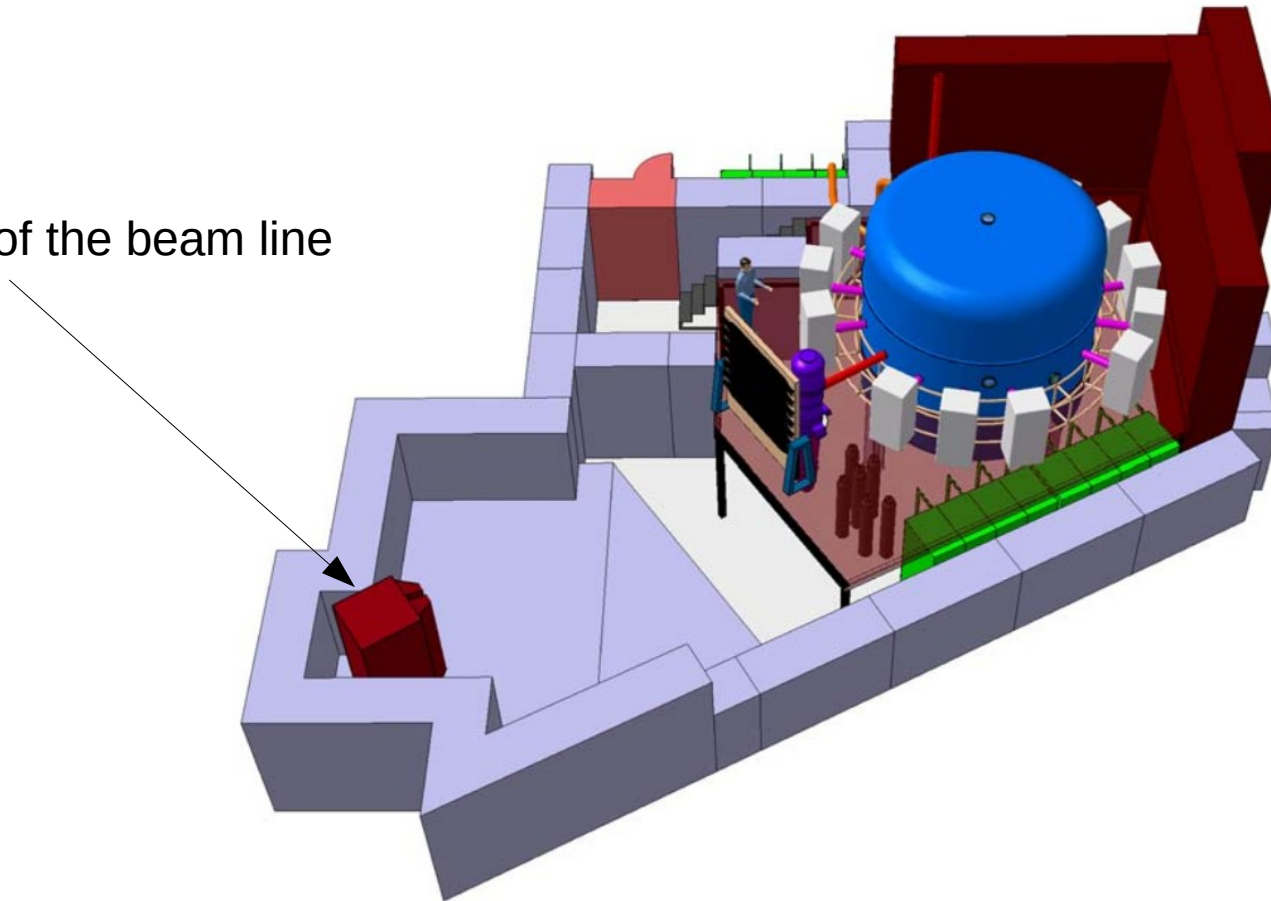
CLOUD uses the T11
3.5 GeV/c secondary
 π^+ beam

The CLOUD chamber is a 3 m diameter electro-polished stainless steel cylinder of 26.1 m³



T11

End of the beam line

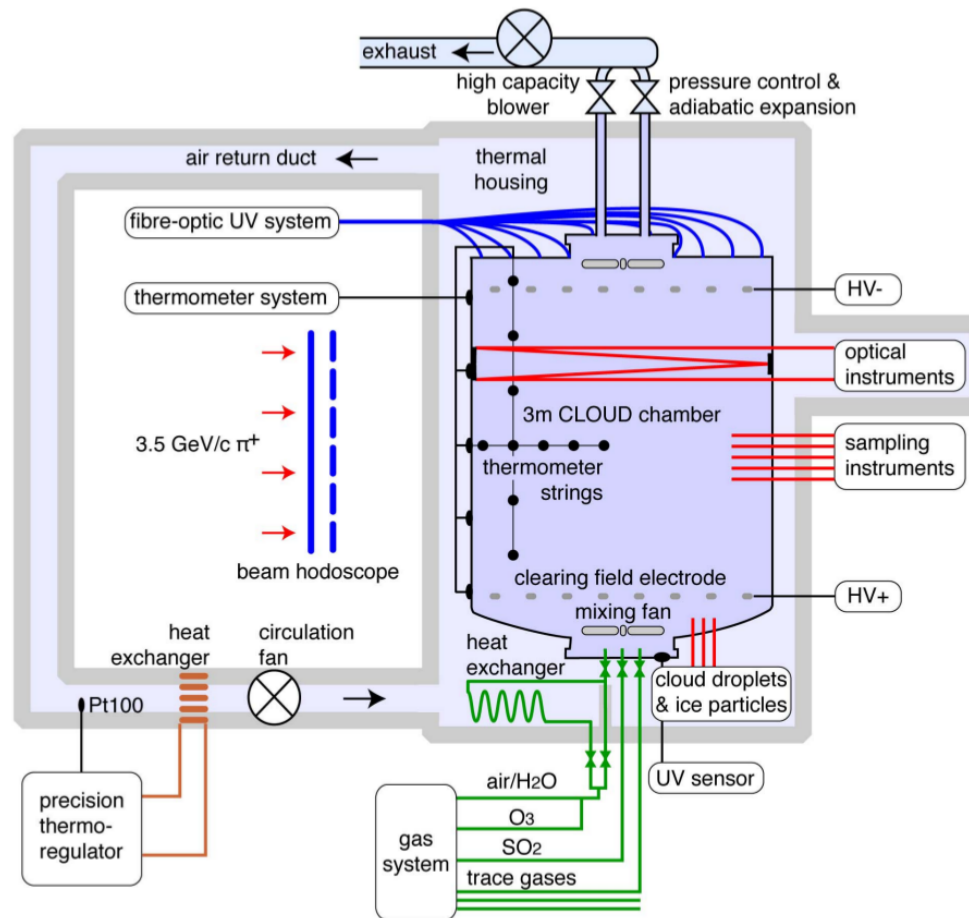


East Hall - T11

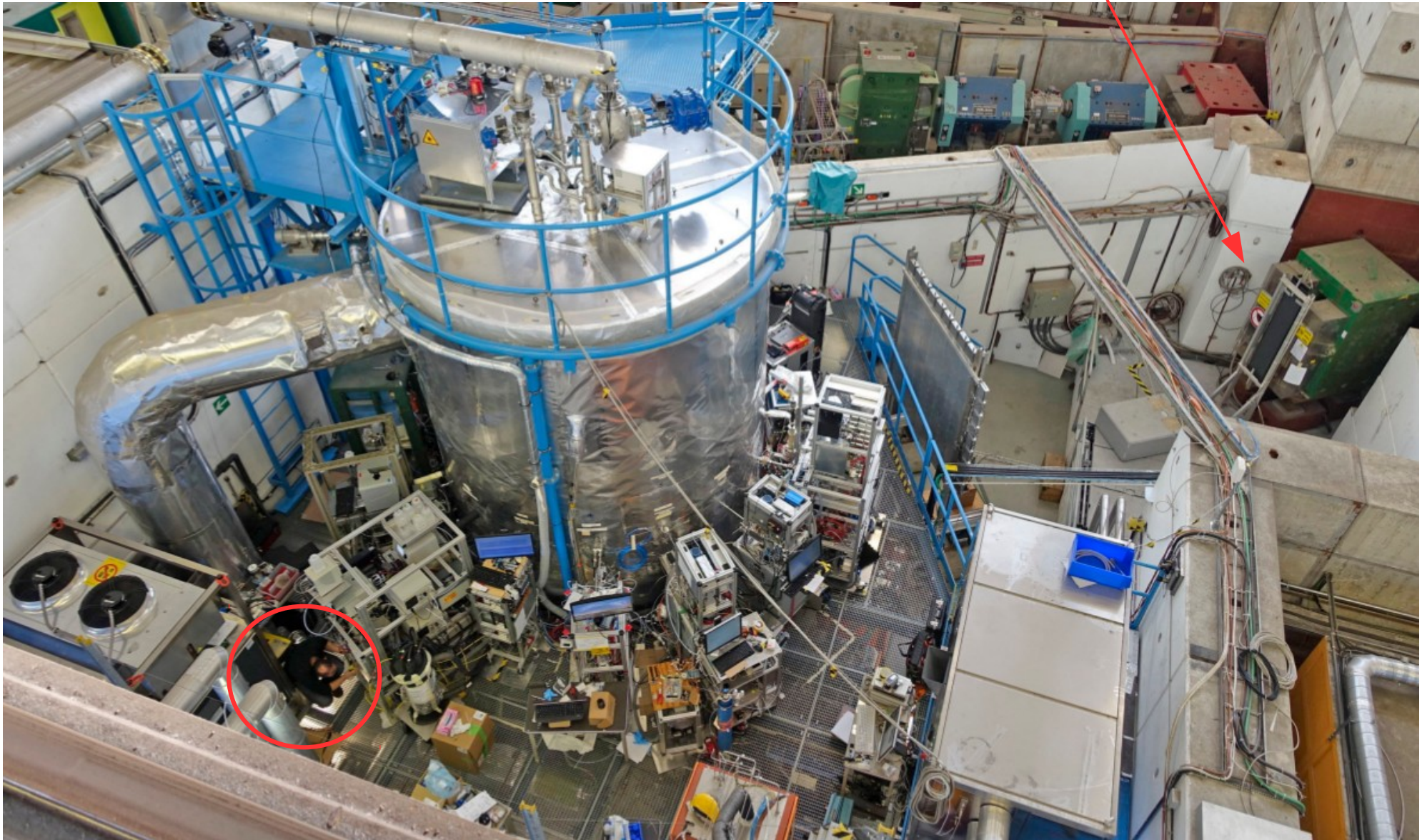


<http://cloud.web.cern.ch/>

The Chamber



Beam Shutter

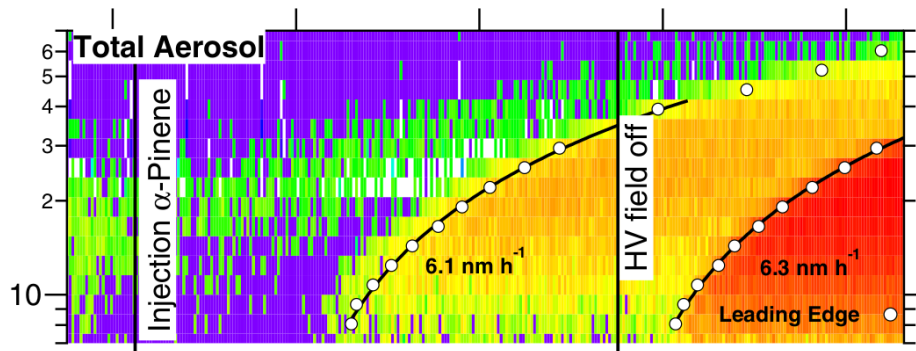


<http://cloud.web.cern.ch/>

Instrumentation

- Physics

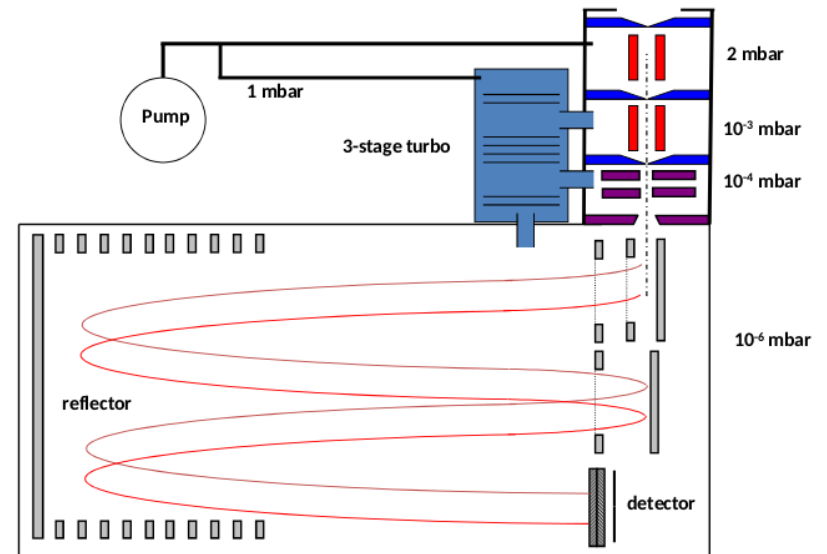
- Particle number
- Size distribution
- Ion distribution



Kirkby et al., 2016

- Chemistry

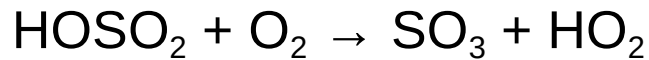
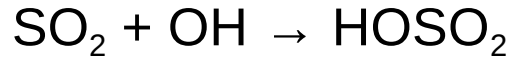
- Precursors
- Cluster composition
- Particle composition



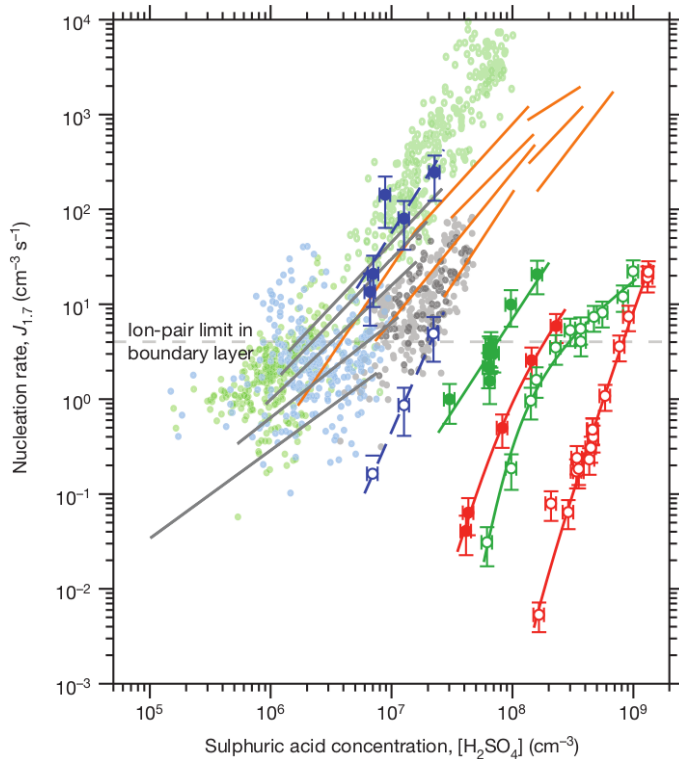
Junninen et al., 2010

New particle formation

- Binary nucleation



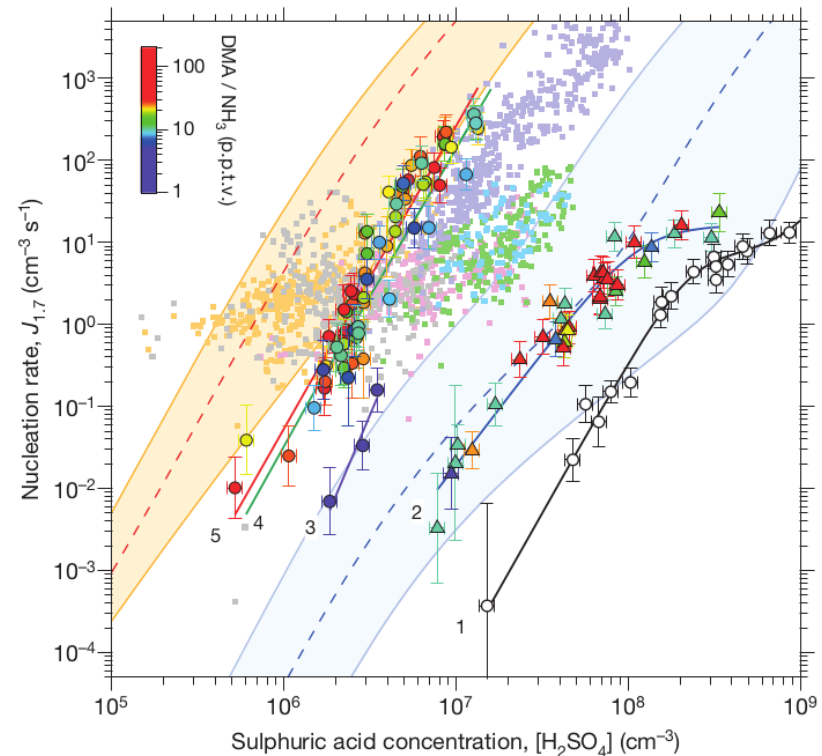
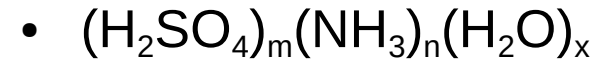
Clusters $(\text{H}_2\text{SO}_4)_m(\text{H}_2\text{O})_x$



Kirkby et al., Nature (2011)

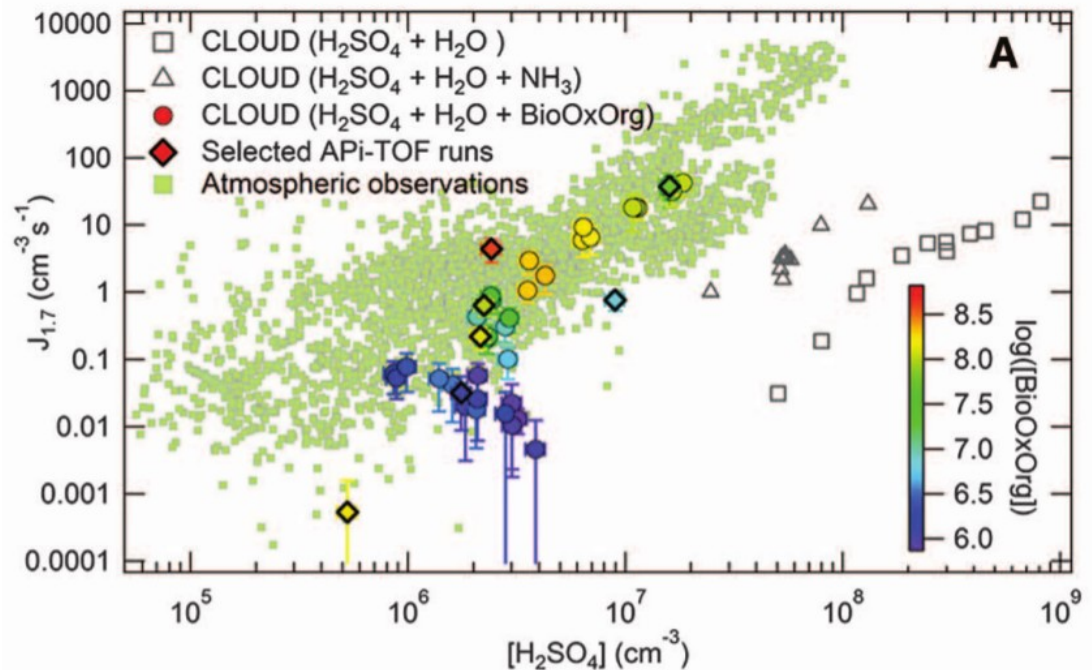
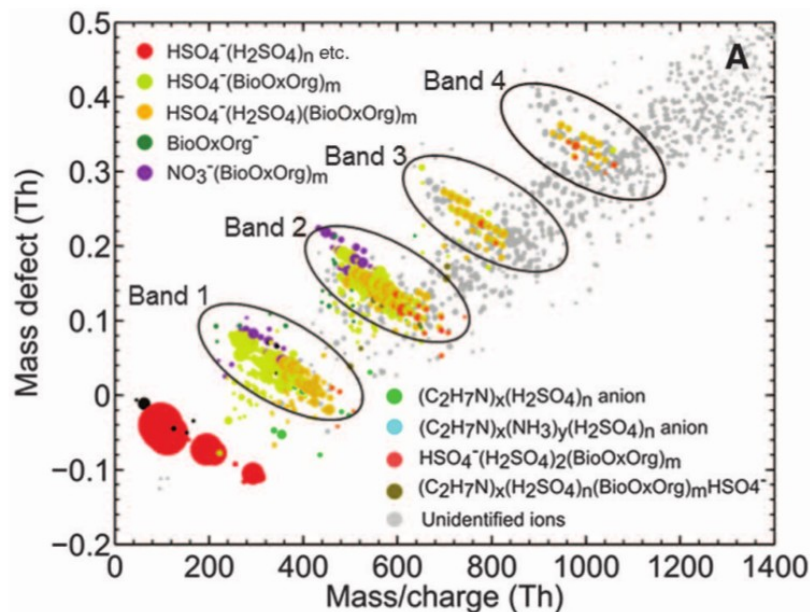
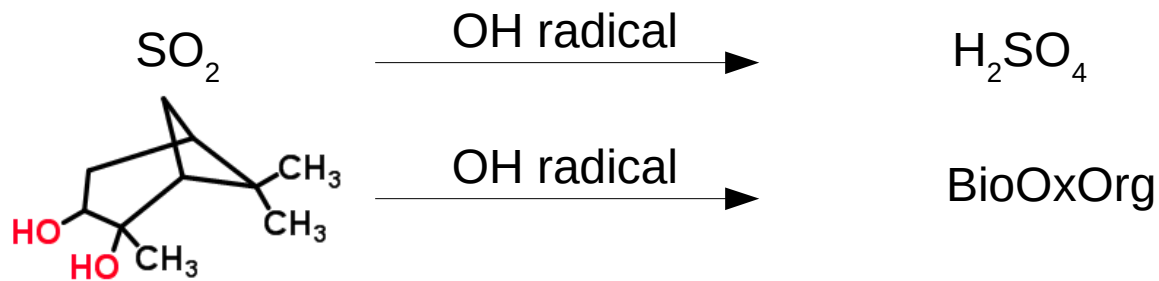
- Ternary nucleation

Clusters:



Almeida et al., Nature (2013)

Oxidation Products of Biogenic Emissions Contribute to Nucleation of Atmospheric Particles

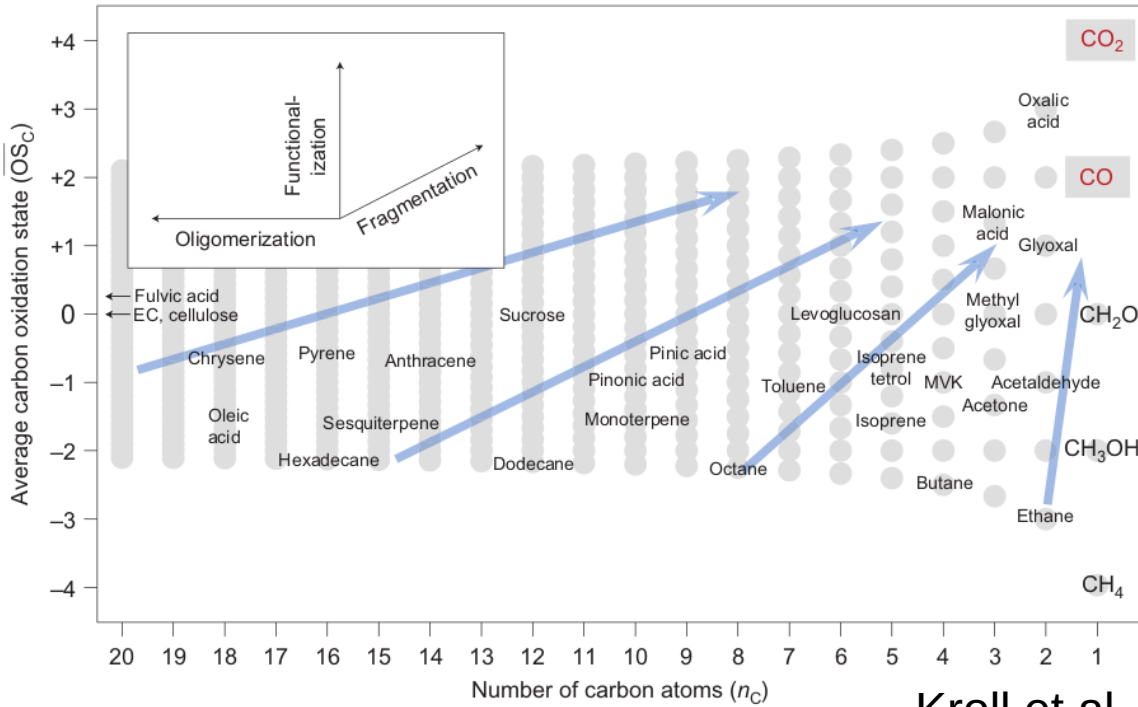


Riccobono et al., Science (2014)
 Schobesberger et al., PNAS (2013)

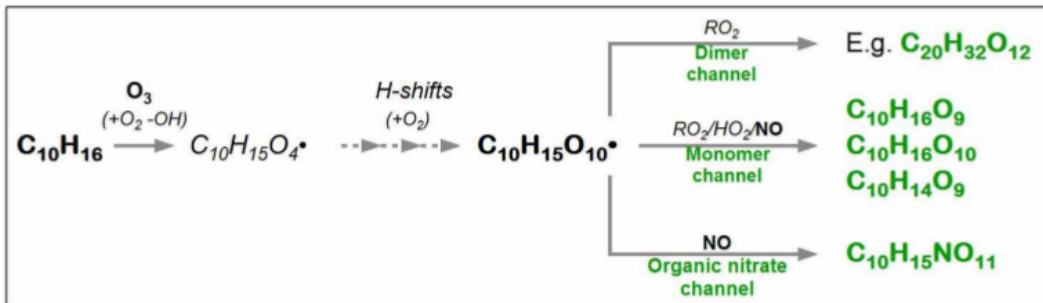
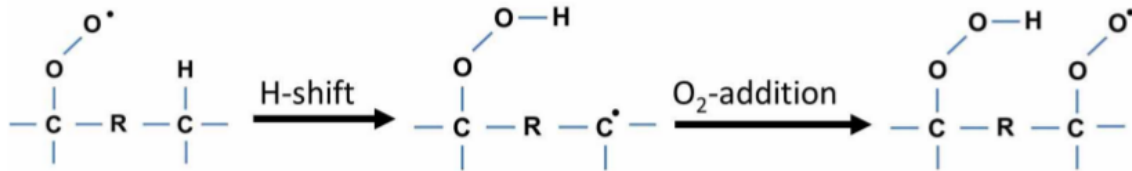
New particle formation in pre-industrial, pristine environment: pure biogenic nucleation



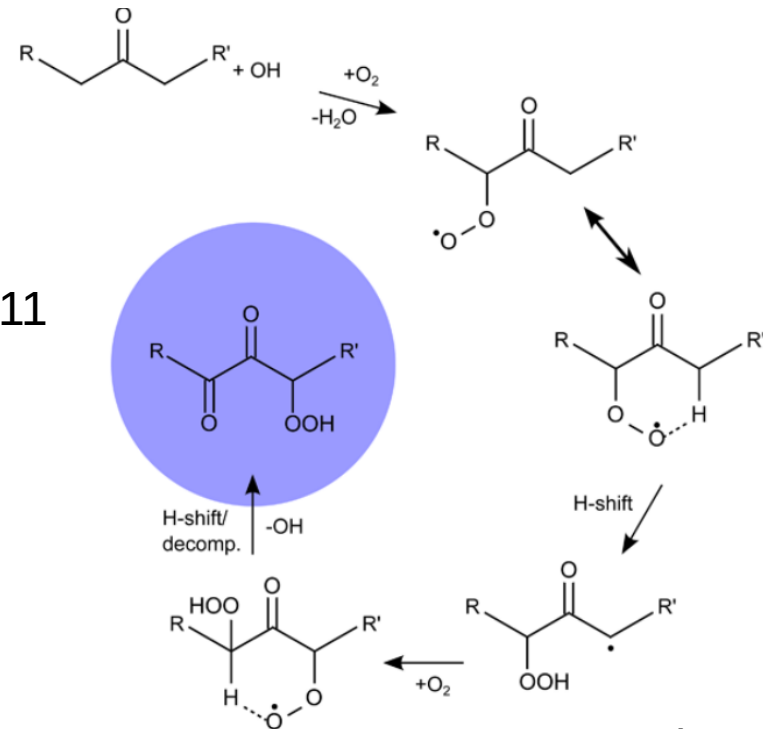
The Autoxidation mechanism



Kroll et al., 2011



Ehn et al., 2013



Crouse et al., 2013

Pure biogenic new particle formation

Volatile organic compounds

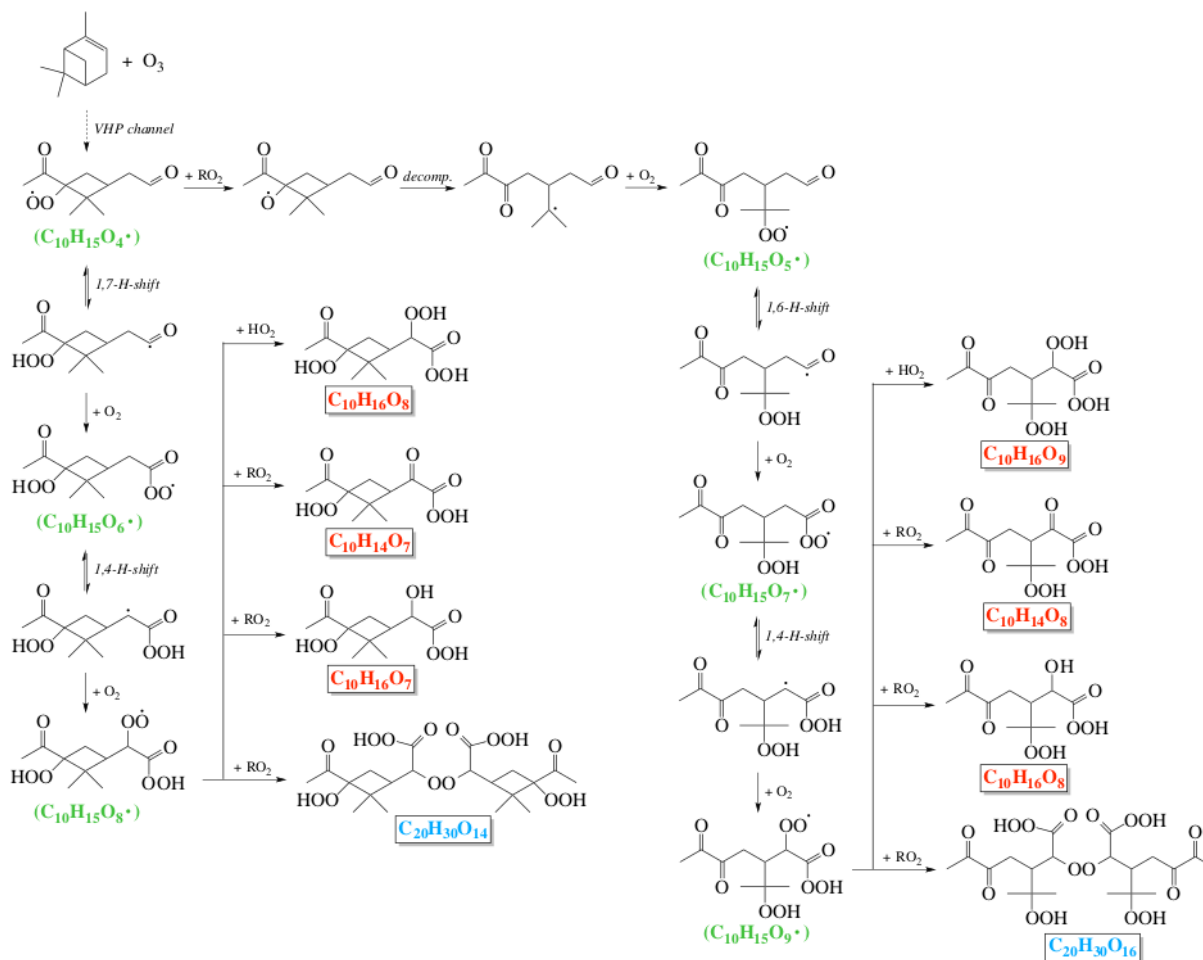
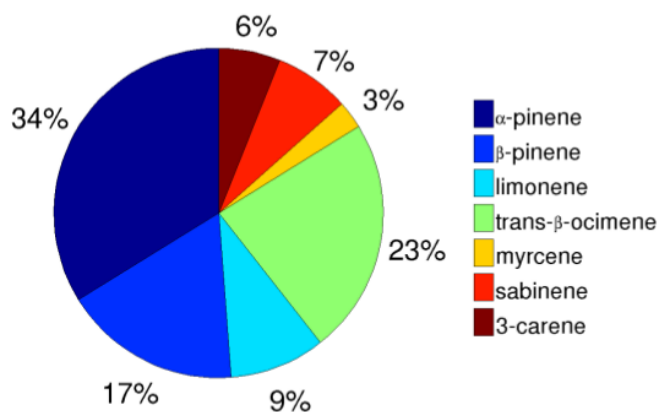
2.4 Pg/y of reactive carbon

90% Biogenic:

44% isoprene

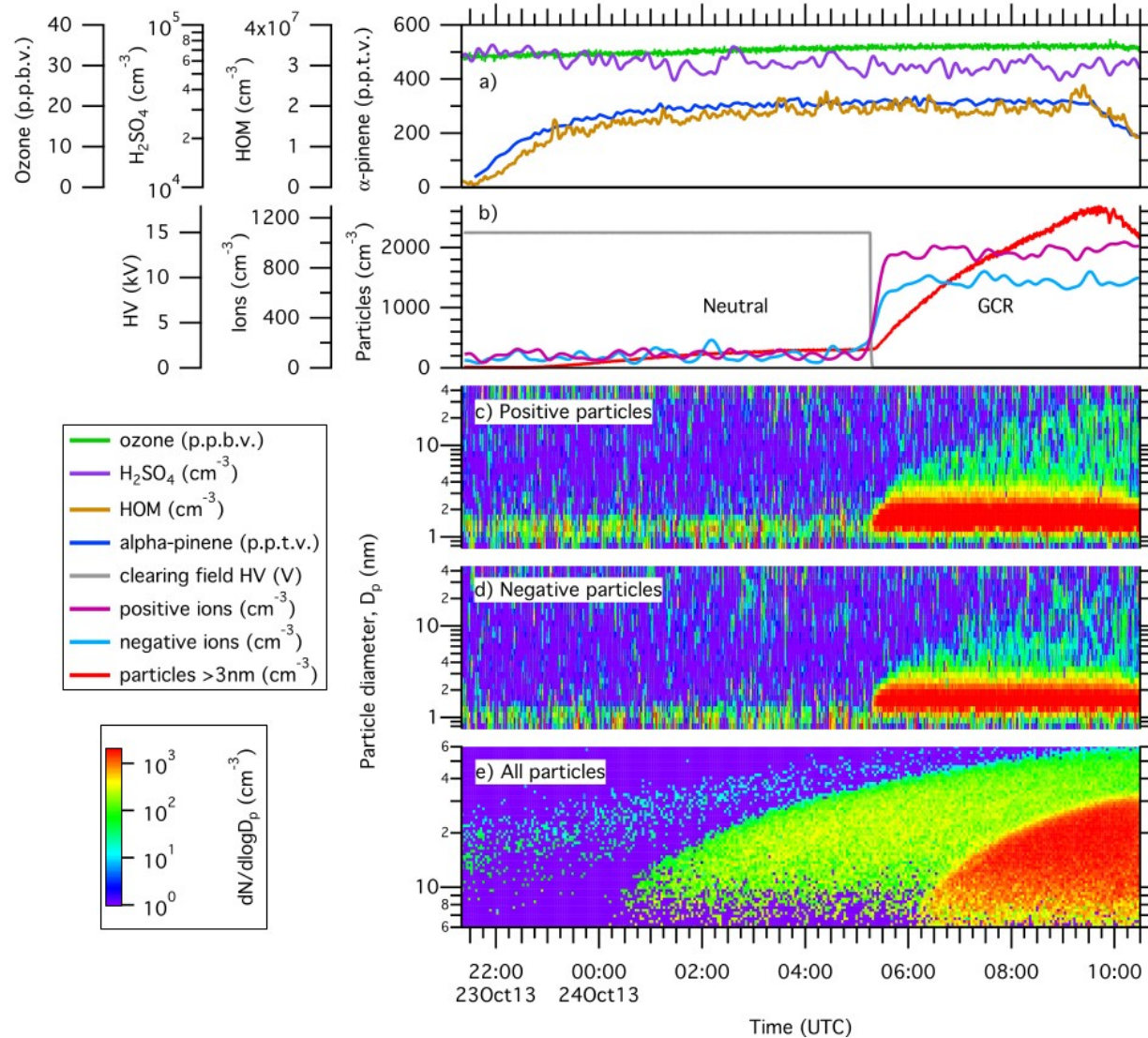
11% terpenes

10% Anthropogenic

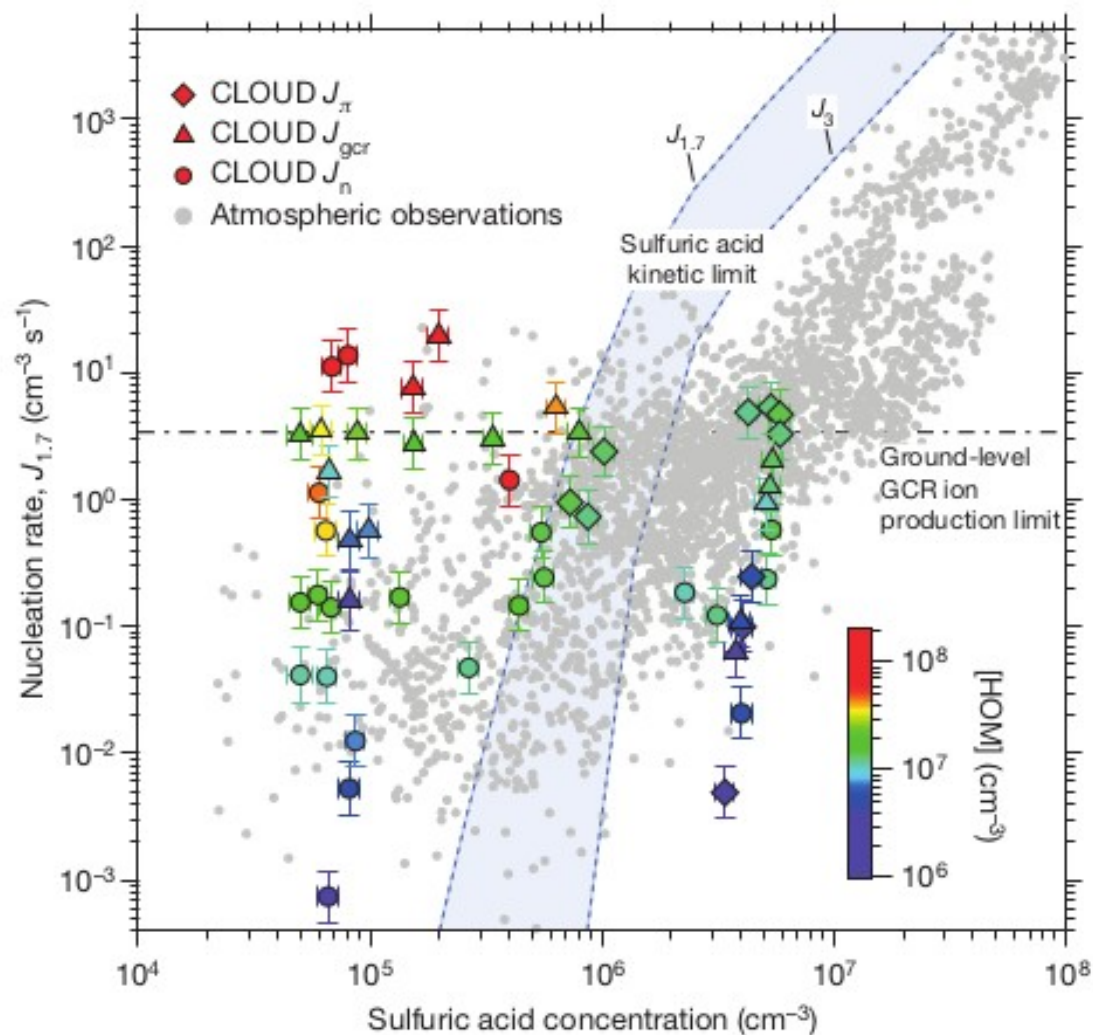
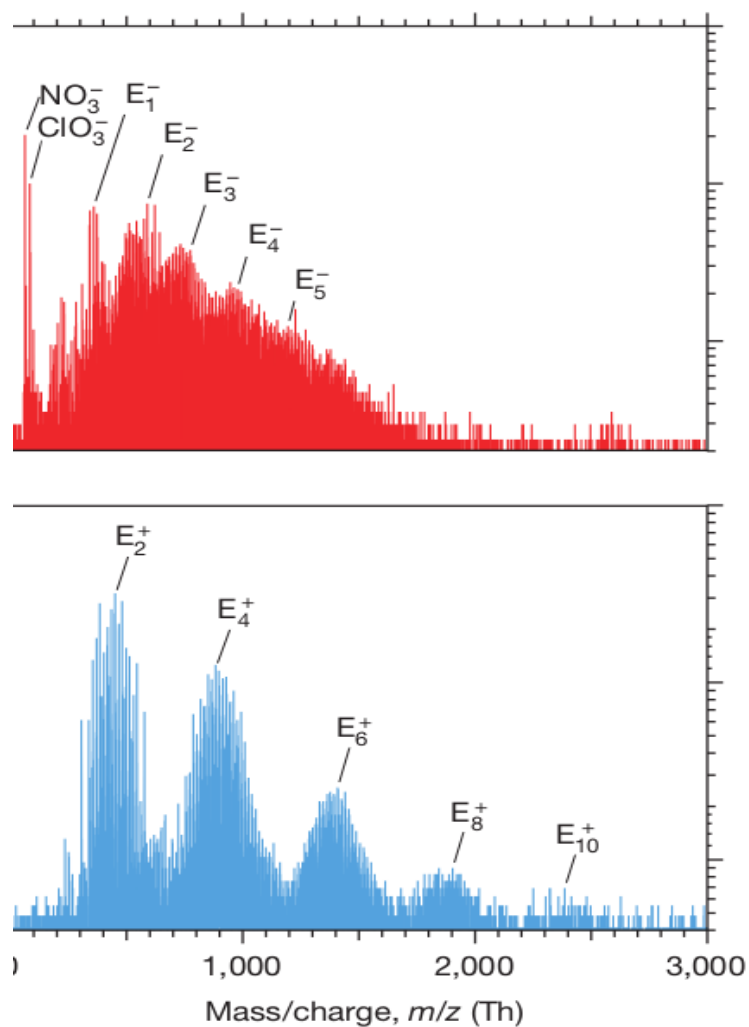


Sindelarova et al., (2014)

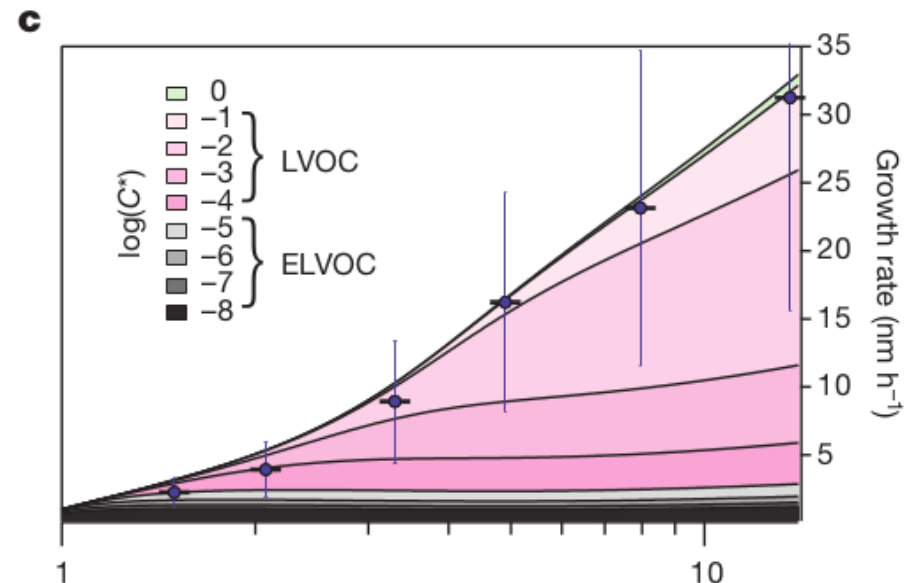
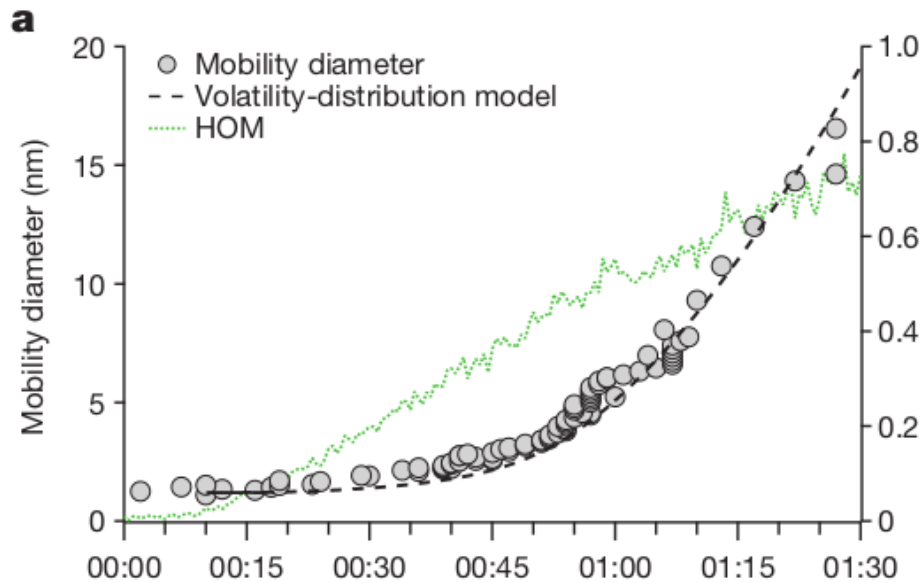
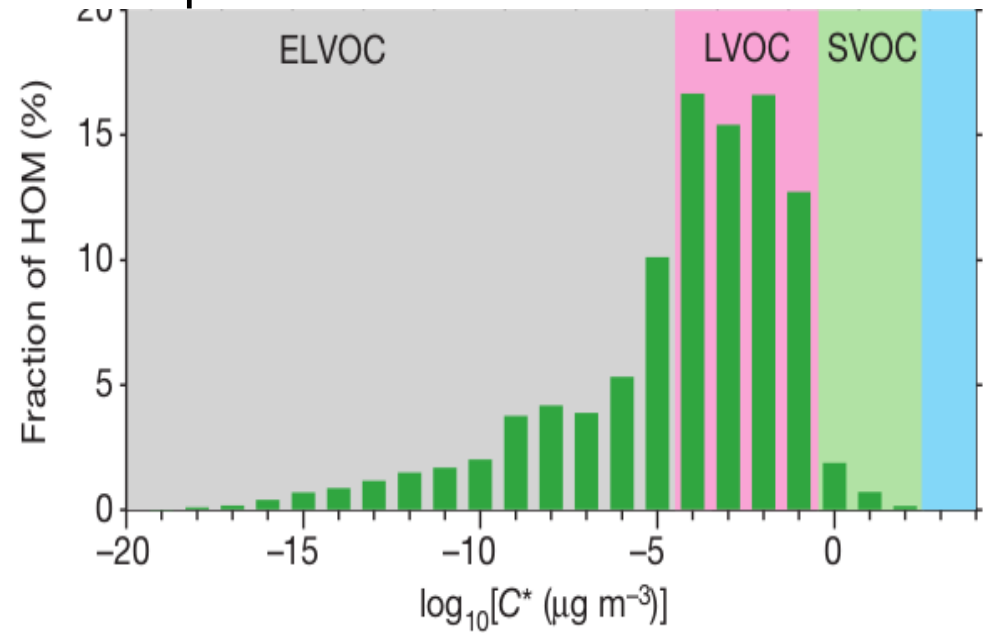
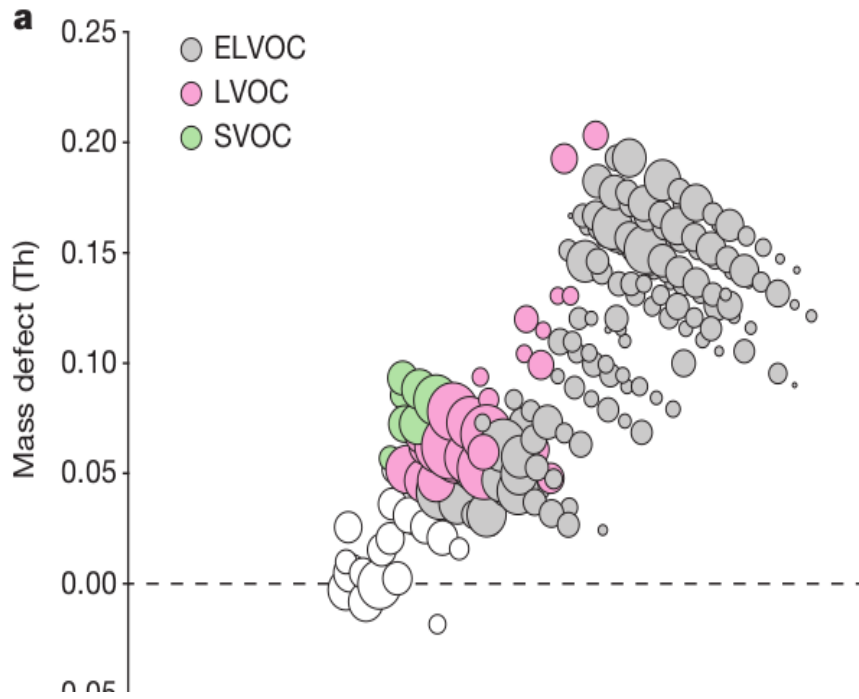
Kirkby et al., Nature (2016)

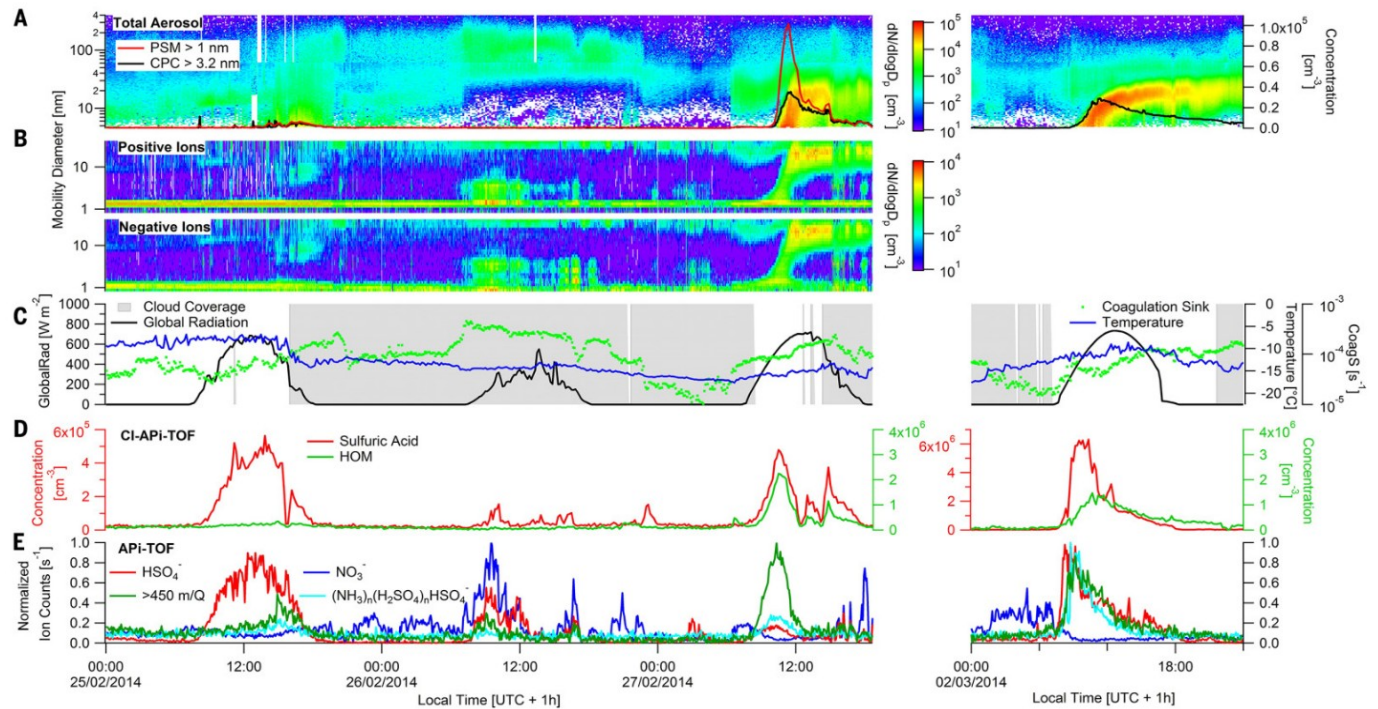


Pure biogenic new particle formation



The role of low-volatility organic compounds in initial particle growth in the atmosphere





Bianchi et al., Science (2016)

Conclusion

- Climate change is linked to climate sensitivity: a temperature change in response to radiative forcing
- We well know the temperature increased from 1750 and we well know greenhouse gases concentration from ice cores but we have large uncertainty on aerosol load
- CLOUD in the past 5 years of operation identified precursors of new particle formation
- CLOUD answers 2 big questions: how cloudy was the pre-industrial climate and how much clouds have changed due to human activities
- Pure biogenic nucleation was **the process** in pristine environment
- CLOUD knowledge will help reduce uncertainty in climate projections



Thanks for your attention

More at <http://cloud.web.cern.ch/>

ugo.molteni@psi.ch