The CLOUD experiment

Cosmics Leaving Outdoor Droplets

Hanna Manninen, PhD
CLOUD Run Coordinator

Studies the influence of
galactic cosmic rays on aerosols and clouds,
and their implications for climate

Photo: NASA ISS007E10807

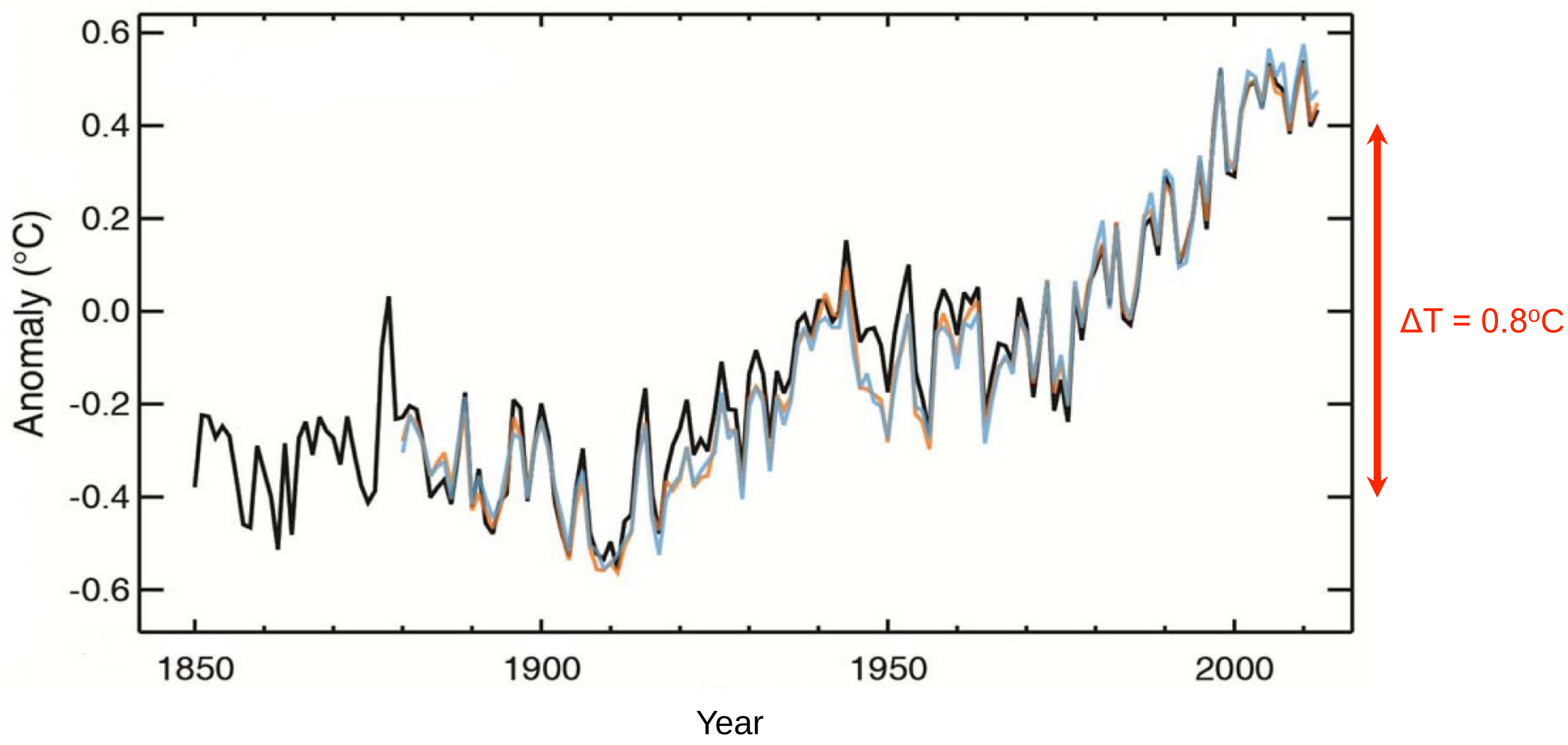
What is in common with the cloud chamber tracks and the air plane contrails?

The cloud collaboration is atmospheric scientists… and CERN:

Aerodyne Research Inc., Billerica, Massachusetts 01821, USA
California Institute of Technology, Div. of Chemistry & Chemical Engineering, Pasadena, California 91125, USA
Carnegie Mellon University, Center for Atmospheric Particle Studies, Pittsburgh PA 15213-3890, USA
CERN, CH-1211 Geneva, Switzerland
Finnish Meteorological Institute, FI-00101 Helsinki, Finland
Goethe-University of Frankfurt, Institute for Atmospheric and Environmental Sciences, 60438 Frankfurt am Main, Germany
Helsinki Institute of Physics, University of Helsinki, FI-00014 Helsinki, Finland
Karlsruhe Institute of Technology, Institute for Meteorology and Climate Research, 76344 Eggenstein-Leopoldshafen, Germany
Lebedev Physical Institute, Solar and Cosmic Ray Research Laboratory, 119991 Moscow, Russia
Leibniz Institute for Tropospheric Research, 04318 Leipzig, Germany
Paul Scherrer Institute, Laboratory of Atmospheric Chemistry, CH-5232 Villigen, Switzerland
TOFWERK AG, CH-3600 Thun, Switzerland
University of Eastern Finland, Department of Applied Physics, FI-70211 Kuopio, Finland
University of Helsinki, Department of Physics, FI-00014 Helsinki, Finland
University of Innsbruck, Institute for Ion and Applied Physics, 6020 Innsbruck, Austria
University of Leeds, School of Earth and Environment, LS2-9JT Leeds, UK
University of Lisbon and University of Beira Interior, 1749-016 Lisbon, Portugal
University of Manchester, School of Earth, Atmospheric and Environmental Sciences, Manchester M13 9PL, UK
University of Stockholm, Department of Applied Environmental Science, 10691 Stockholm, Sweden
University of Vienna, Faculty of Physics, 1090 Vienna, Austria


Why do atmospheric scientists come to CERN?
Andri Pol

Climate is already changing: global surface temperature change since 1850



Source: IPCC, Summary for Policymakers, 2013

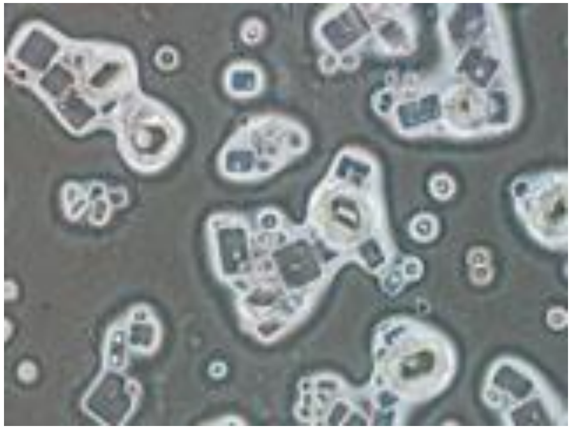
WHAT WILL HAPPEN WITHIN NEXT 40-50 YEARS?

MOTIVATION: COSMIC RAYS, AEROSOLS AND CLOUDS

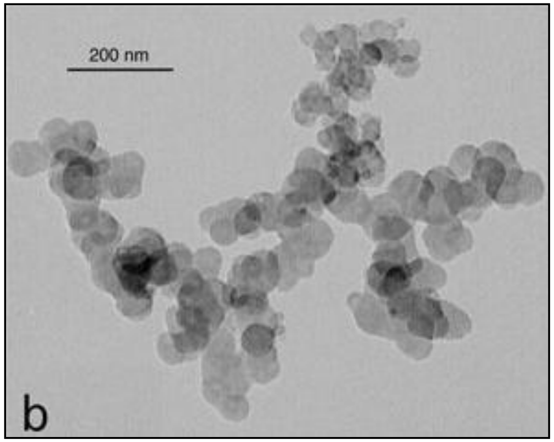
Aerosol particles: what are they?

Definition: Suspension of small (liquid or solid) particles in a gas

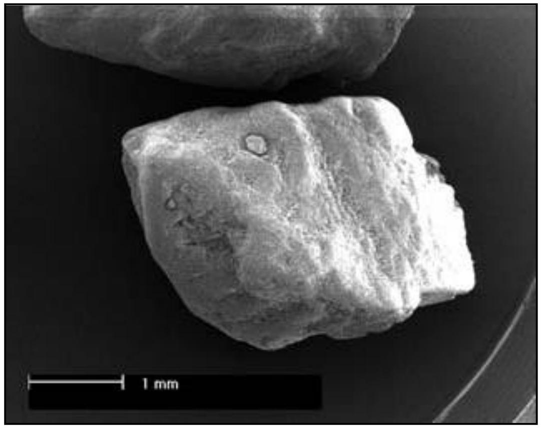
Ammonium sulphate: 10 - 100 nm



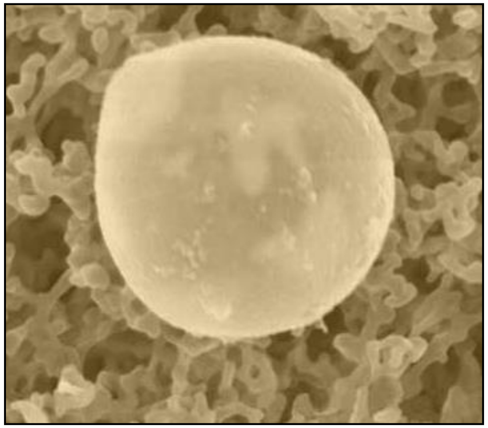
Diesel soot: ca. 100 nm



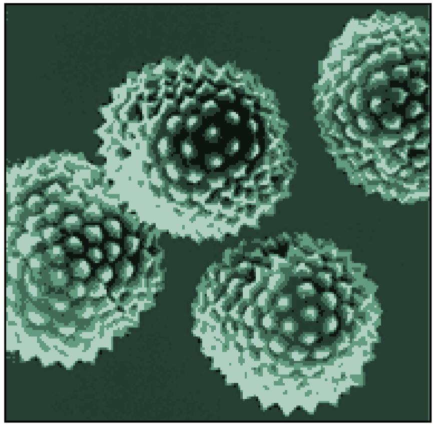
Sea salt: 0.2 - 10 μm



Mineral dust: 0.2 - 10 μm



Pollen: 10 - 100 μm



PRIMARY (directly produced) ATMOSPHERIC AEROSOLS

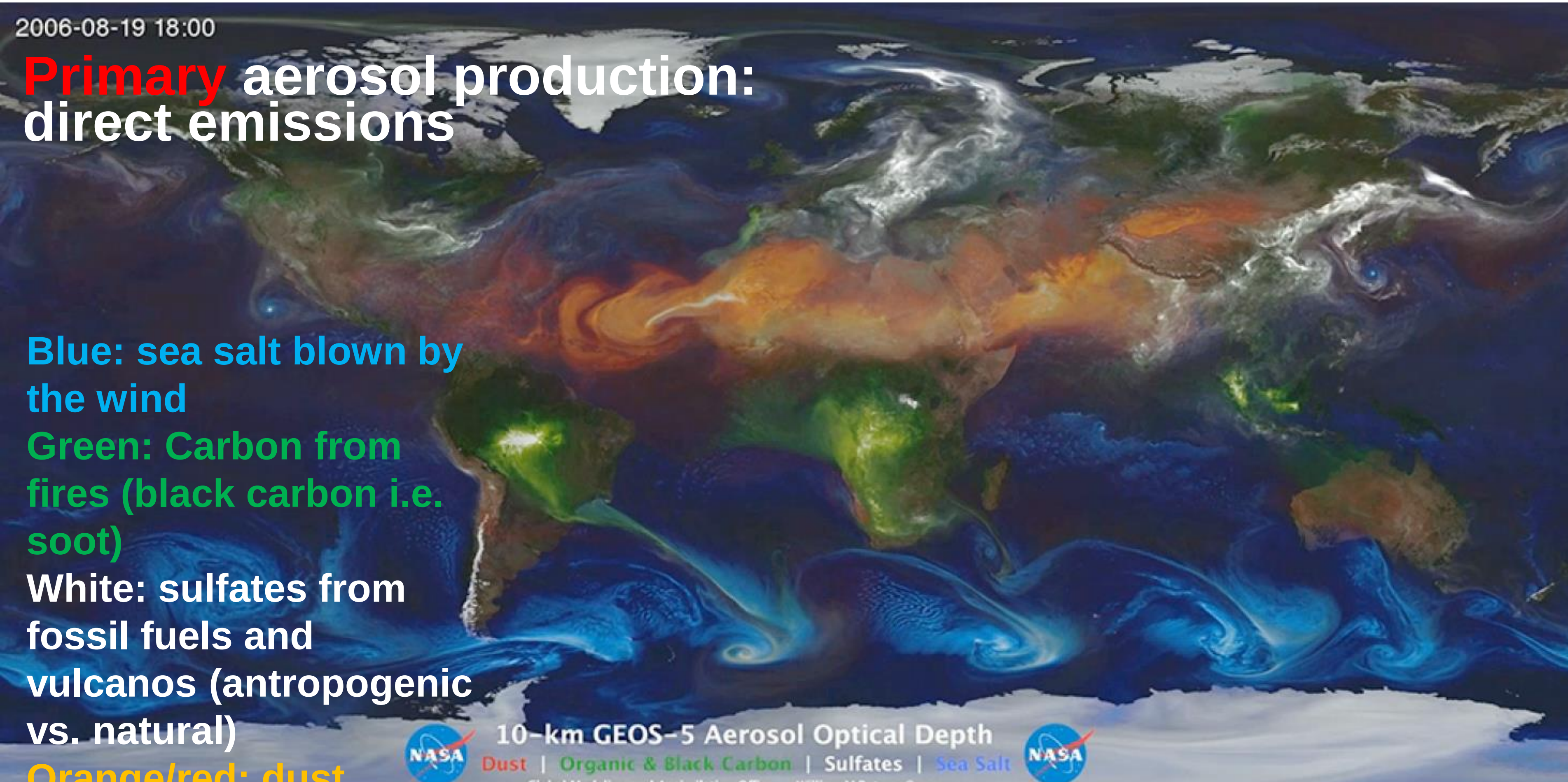
SECONDARY AEROSOLS (indirectly produced, gas-to-particle conversion i.e. nucleation)

About half of climate-relevant particles

Primary particles are emitted globally:
https://www.youtube.com/watch?v=YtJzn8A725w

Blue: sea salt blown by the wind
Green: Carbon from fires (black carbon i.e. soot)
White: sulfates from fossil fuels and vulcanos (antropogenic vs. natural)
Orange/red: dust

Primary aerosol production: direct emissions



Blue: sea salt blown by the wind
Green: Carbon from fires (black carbon i.e. soot)
White: sulfates from fossil fuels and vulcanos (antropogenic vs. natural)
Orange/red: dust

https://www.youtube.com/watch?v=YtJzn8A725w

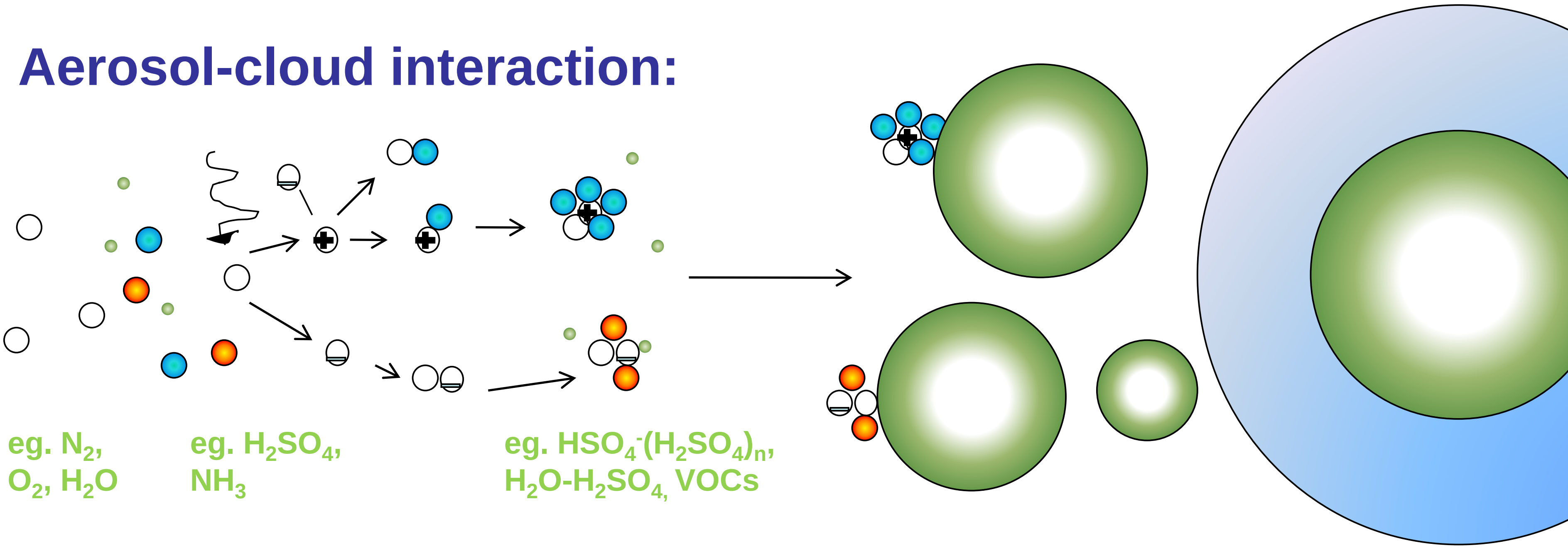
Secondary aerosol source: gas to particle conversion

Gas phase precursors

Particle formation by nucleation

Enhanced growth by condensation and coagulation

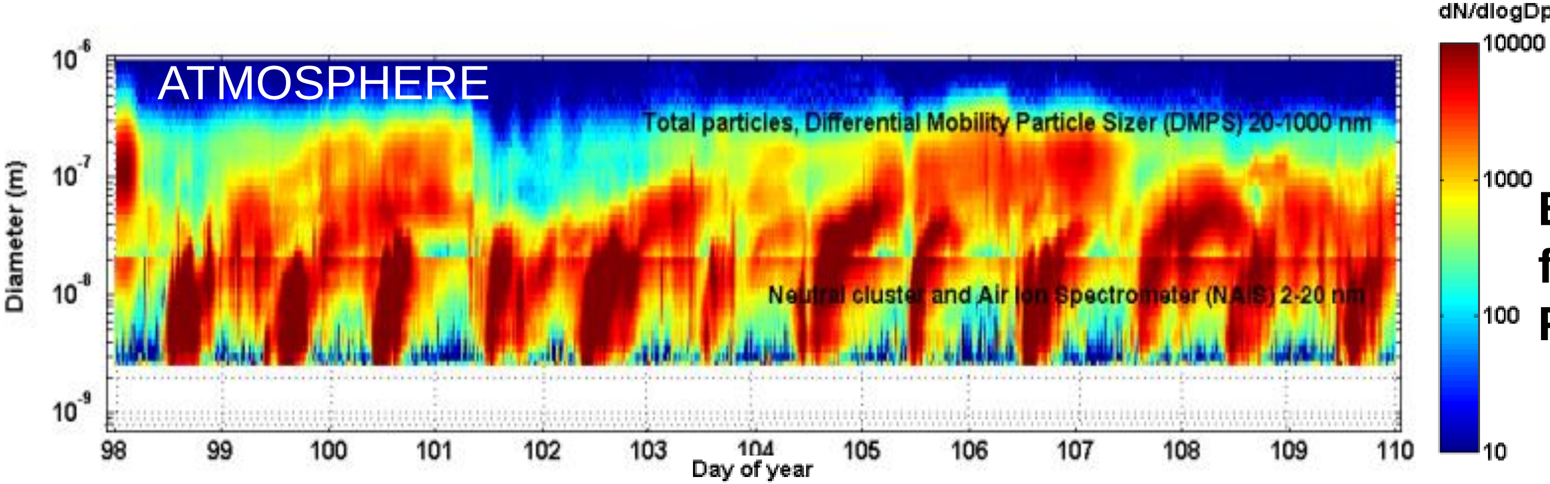
Aerosol-cloud interaction:



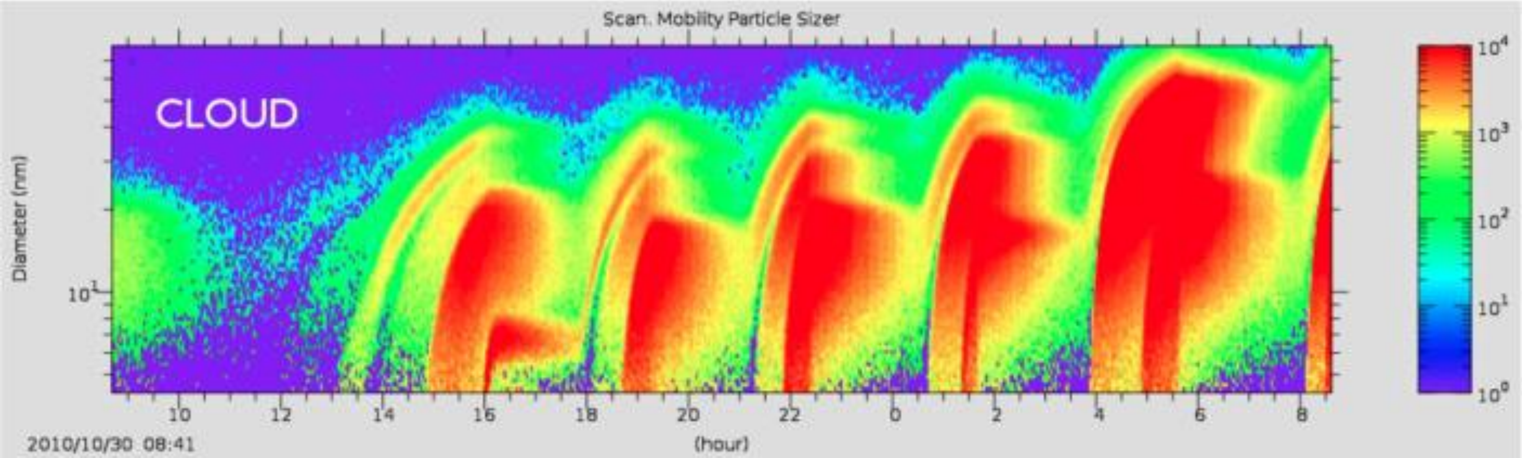
Gas	Molecules	Cluster ions and neutral clusters	Particles	Cloud condensation nuclei (CCN)
	< 1nm	~1-3 nm	> 3 nm	> 100 nm

CLOUD simulates real atmosphere

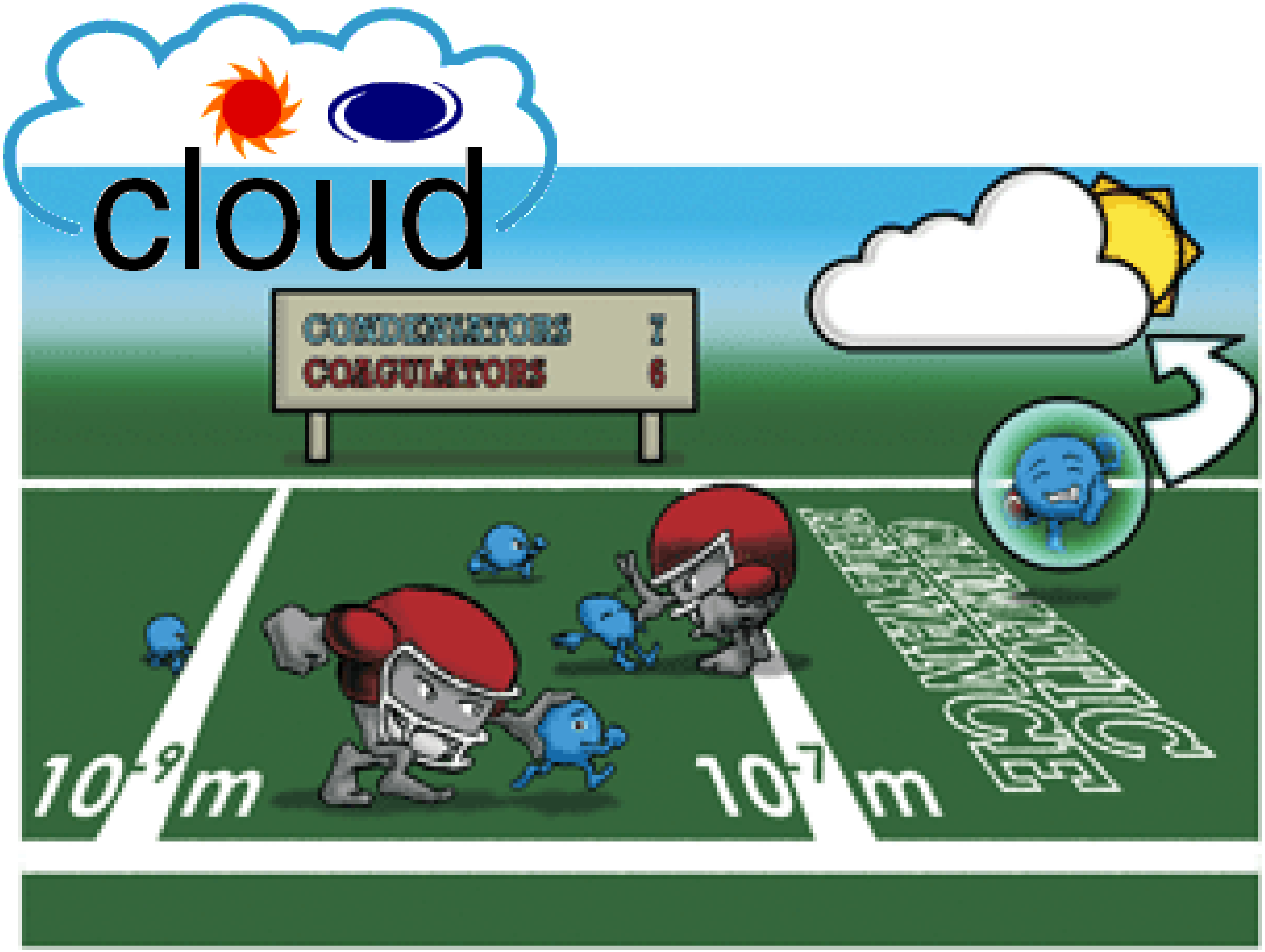
12 consecutive particle formation event days 8–19 April 2007 in Hyytiälä, Finland



Boreal forest, Finland



CLOUD, CERN



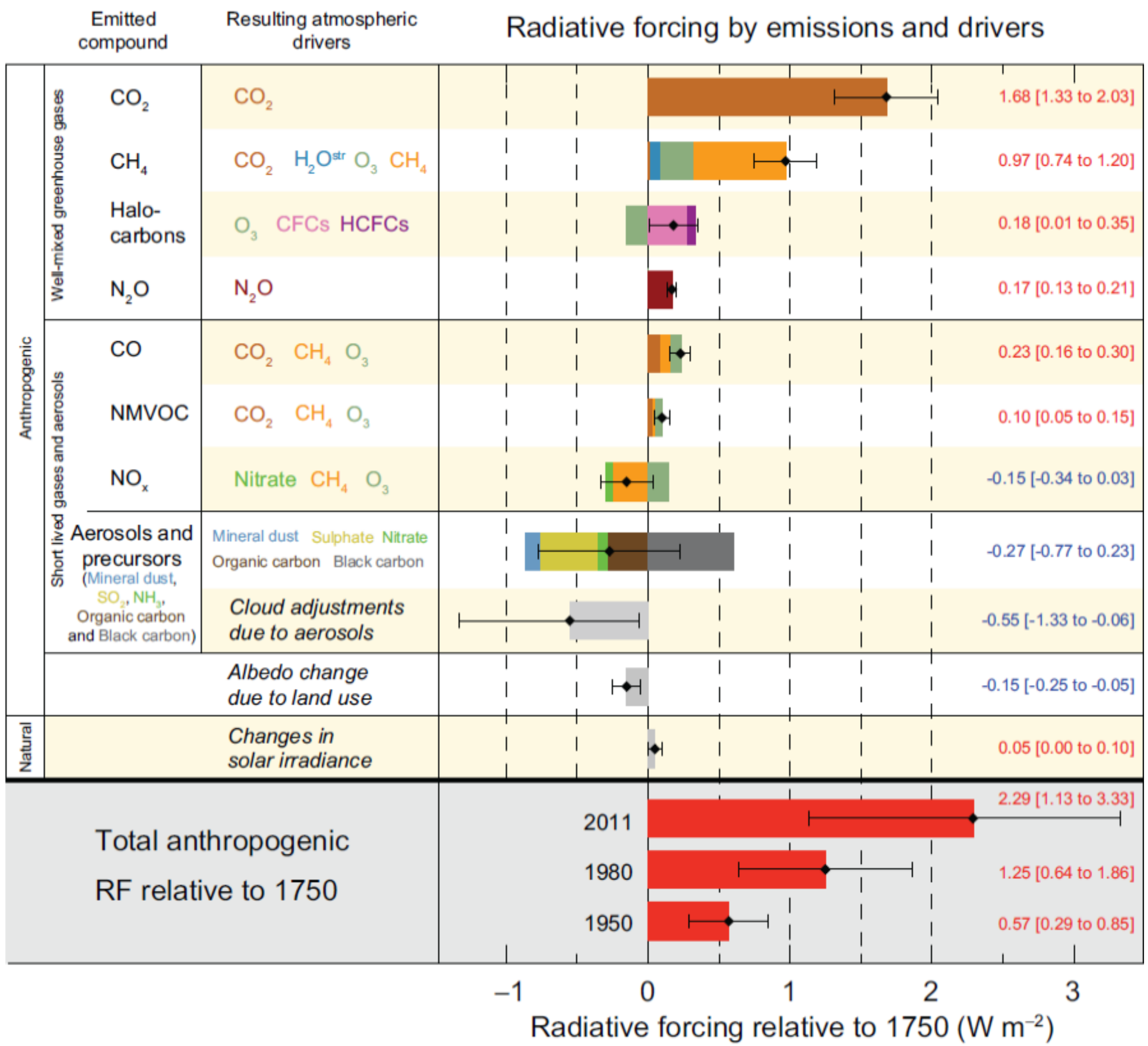
Thermodynamics and kinetics of atmospheric aerosol particle formation and growth

Hanna Vehkamäki and Ilona Riipinen, 2012

These natural aerosols i.e. secondary particles are formed via new particle formation.

Newly formed particles need to grow all the way to cloud droplets to affect global climate.

Scientific understanding of climate radiative forcing in Industrial Age



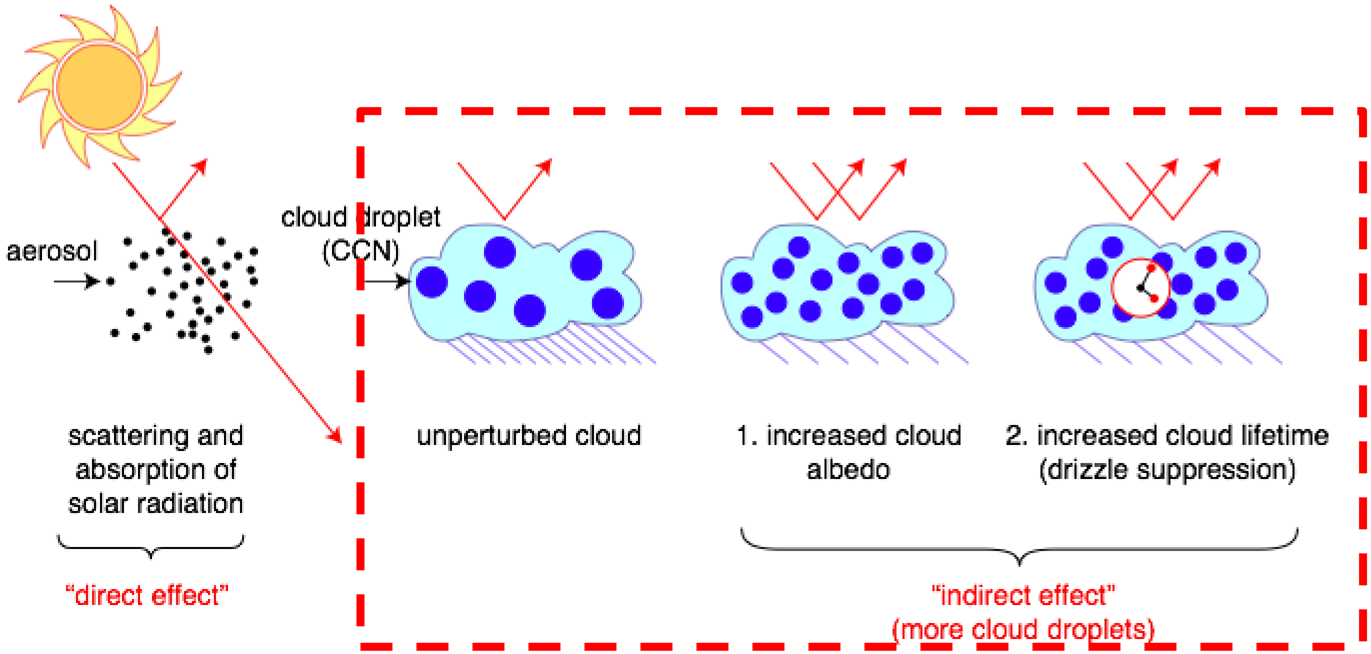
A. **Anthropogenic aerosol forcing are poorly understood.**

B. Natural part is very small.
Is there a missing natural forcing?
Is that from varying cosmic ray flux, modulated by sun?

Source: IPCC, Summary for Policymakers, 2013

A + B → The CLOUD experiment

Role of aerosols on Sun's radiative forcing



- **All cloud droplets form on aerosol "seeds" known as cloud condensation nuclei - CCN**
- Cloud properties are sensitive to number of droplets
- More aerosols/CCN:
  - Brighter clouds, with longer lifetimes
- **Sources of atmospheric aerosols:**
  - Primary (dust, sea salt, fires)
  - Secondary (gas-to-particle conversion)

See youtube: "No particles no fog" https://www.youtube.com/watch?v=EneDwu0HrVg

CLOUD IN A BOTTLE

Cool Science Experiment:

https://www.youtube.com/watch?v=msSVQ903T8k

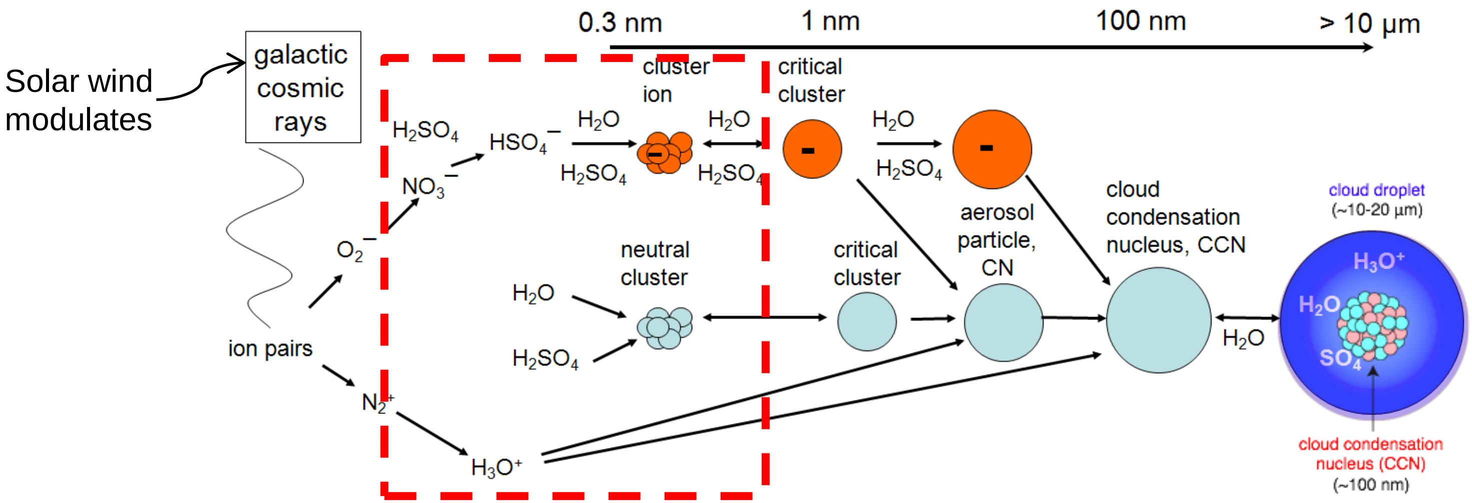
CLOUD EXPERIMENT: CONCEPT, METHODS, RESULTS

WHY ARE WE AT CERN?

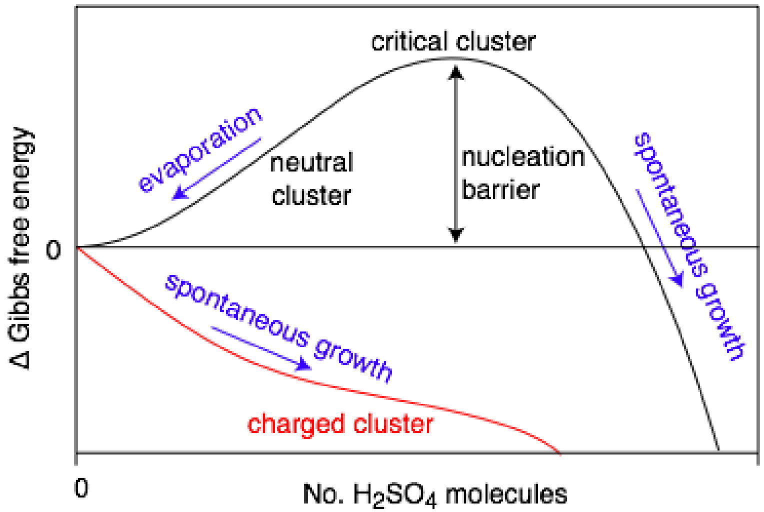
- Secondary beam of pions from the CERN PS (3.5 GeV/c); spanning the galactic cosmic-ray intensity range from ground level to the stratosphere

- Study the effect of cosmic rays on aerosols and clouds, under precisely controlled laboratory conditions.

Ions enhance aerosol nucleation and growth: how much?

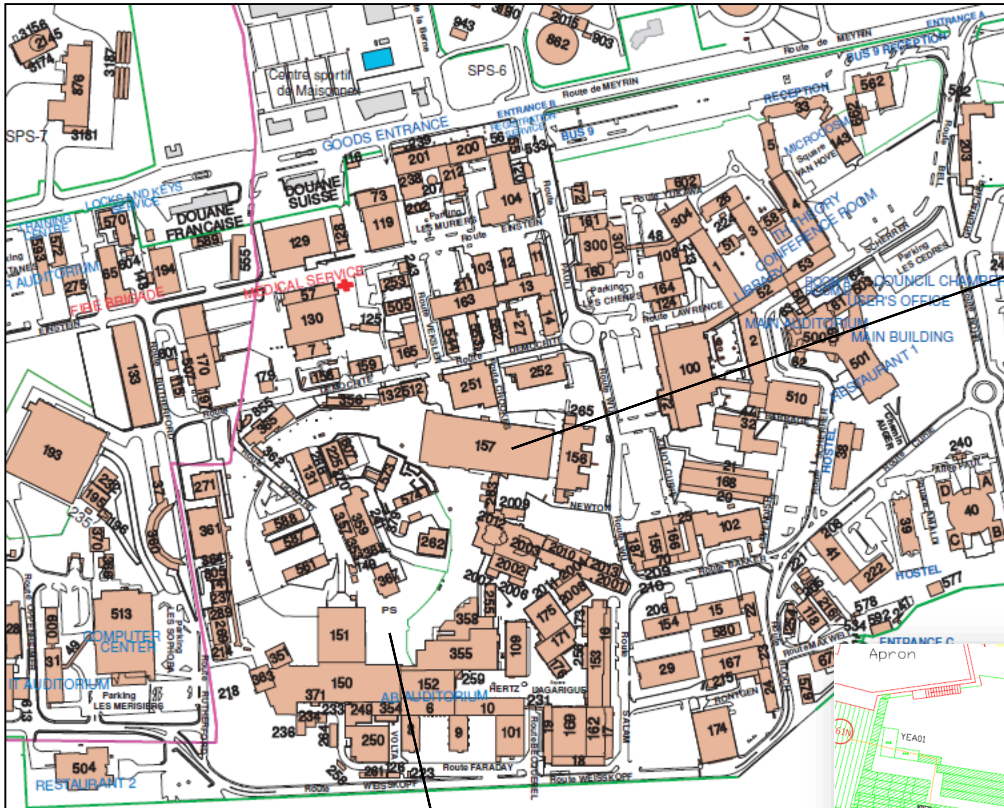


- **Trace condensable vapour → CN → CCN**
- **But contributing vapours and nucleation rates poorly known**
- H_2SO_4 is thought to be the primary condensable vapour in atmosphere (sub ppt)
- **Ion-induced nucleation** pathway is energetically favoured but limited by the ion production rate and ion lifetime



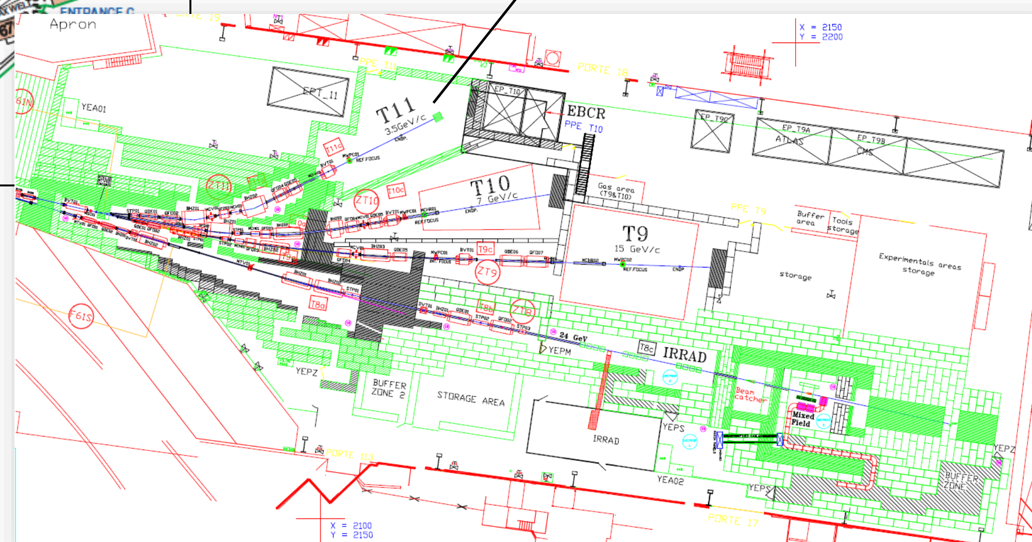
CLOUD is using CERN Proton Synchrotron PS-T11 beam

CERN PS-T11: control of the 'cosmic ray' beam intensity



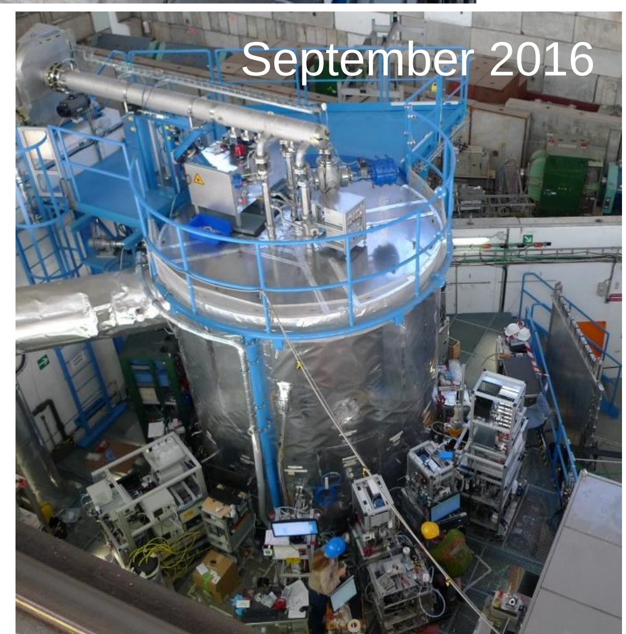
PS East Hall

T11 beam area
(3.5 GeV/c)



Proton Synchrotron (PS) accelerator,
first operation in 1959

CLOUD chamber was build in 2009 and is located in T11 beam area:



The core of the experiment is a stainless steel chamber (26m³) filled with synthetic air

- Pressure: Atmospheric ± 0.3 bar
- Only metallic seals
- Electropolished inner surfaces

World's cleanest laboratory for studies of atmospheric particle formation

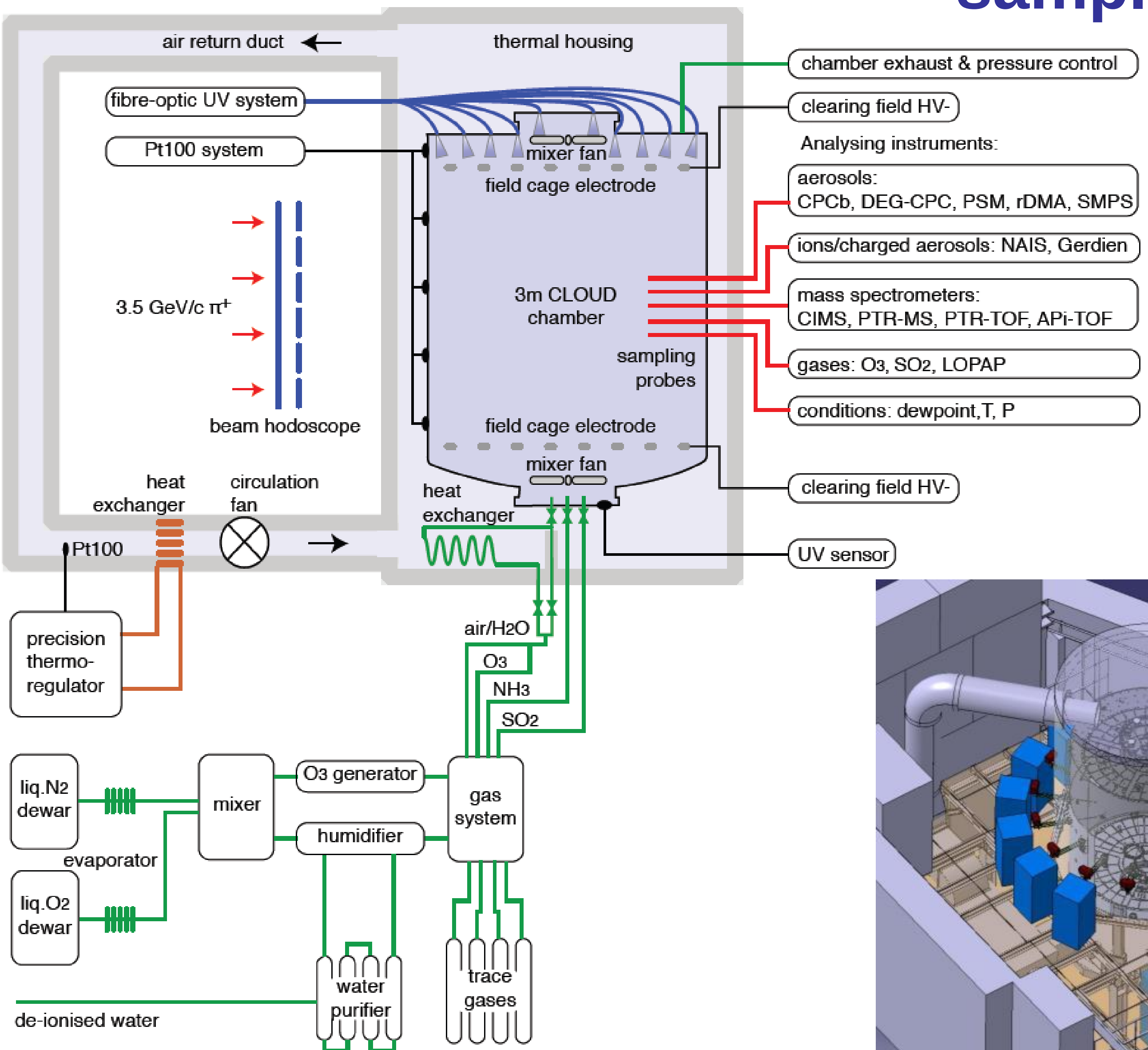
CLOUD is run under precisely controlled laboratory conditions:

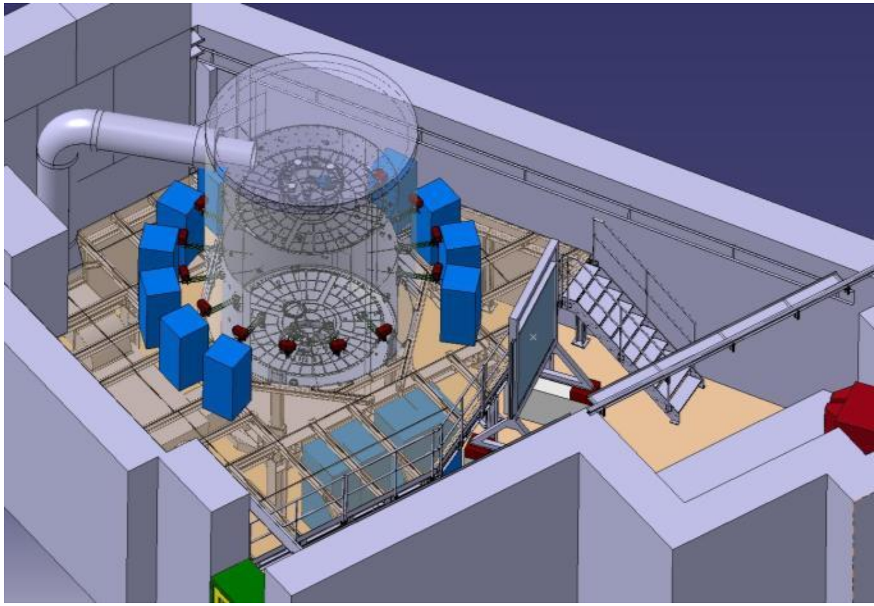
- temperature stability: <0.1°C
- temperature range: -90°C to +30°C; cleaning at +100°C
- surface cleanliness: <10 pptv*) organics contamination, stainless steel (and gold), no teflon, no O-rings
- ultrapure gas supplies
- UV system: negligible heat load by use of fibre optics.
- field cage 30 kV/m

Unique and highly advanced aerosol chamber already as such!

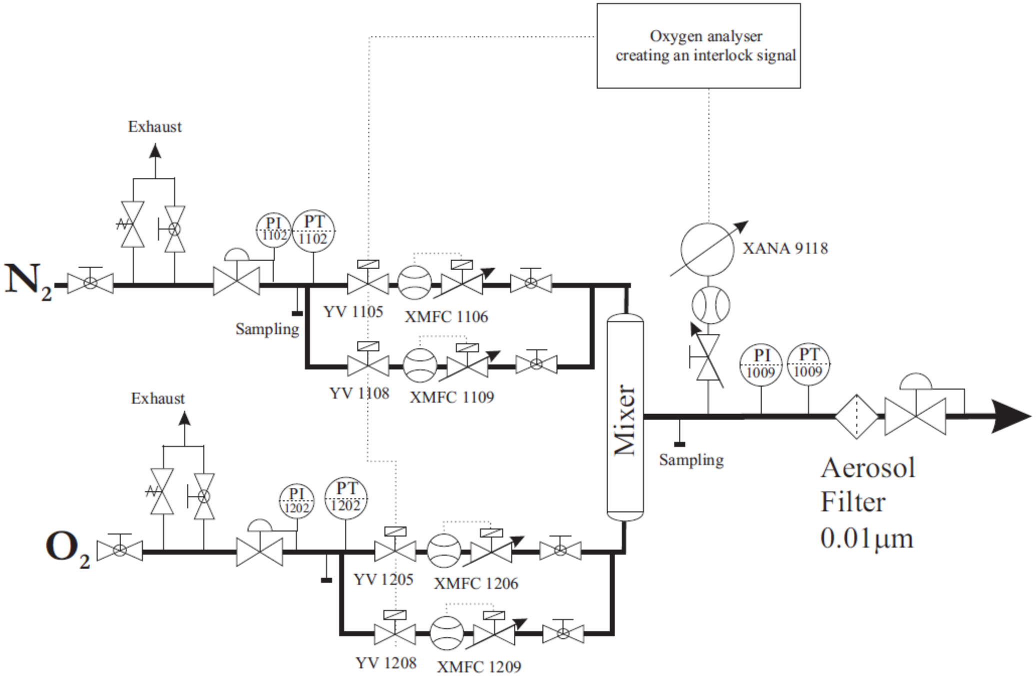
*) pptv = part per trillion, $1 / 10^{12}$

CLOUD set-up: instruments connected to sampling probes

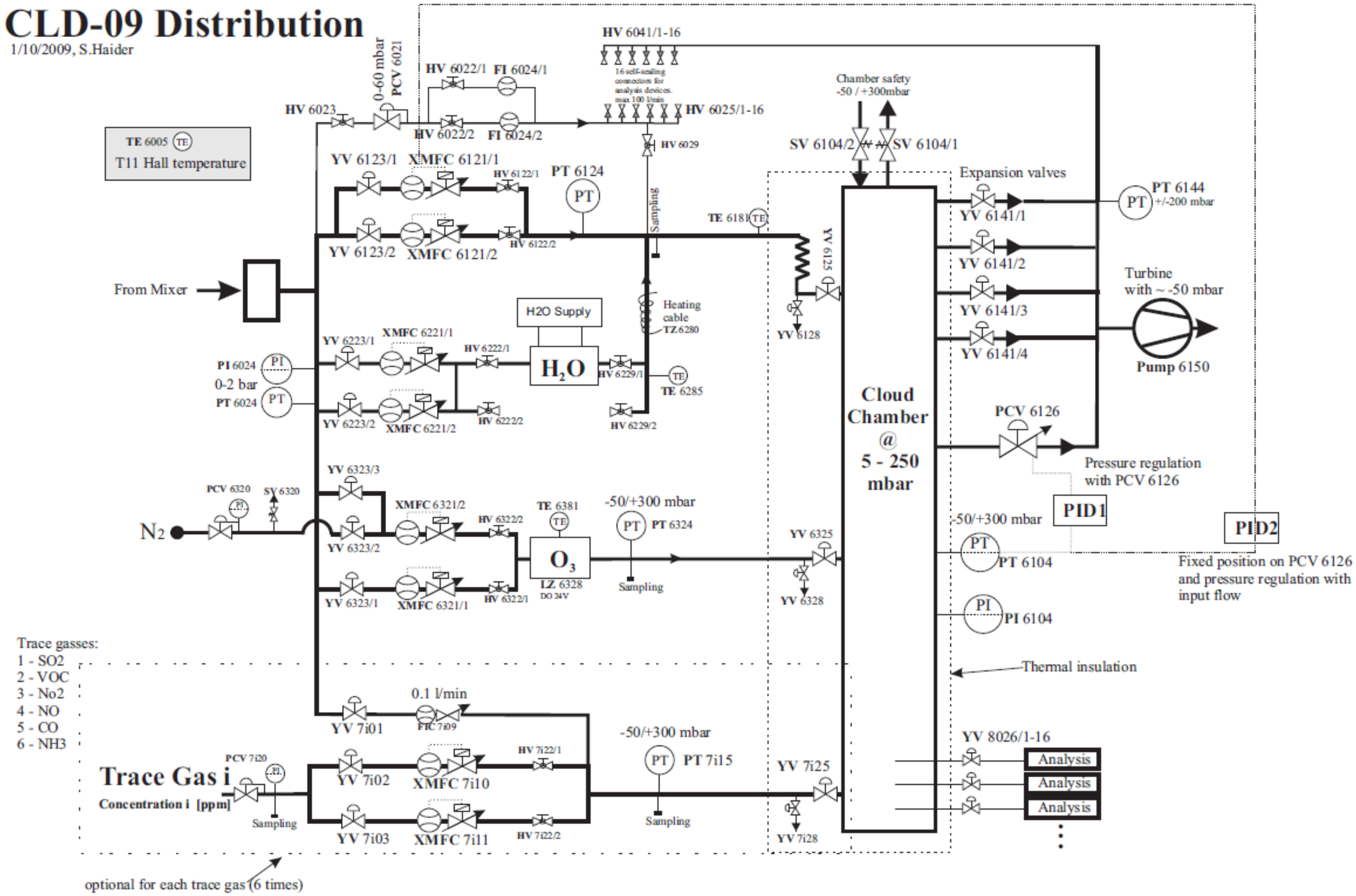




Ultra-pure air: synthetic air made from liquid nitrogen and liquid oxygen



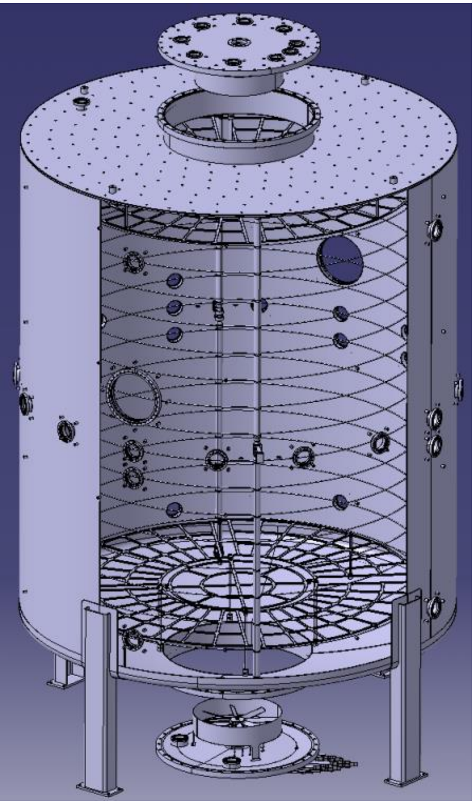
Gas system built to the highest technical standard of performance



UV illumination from a fibre-optic system

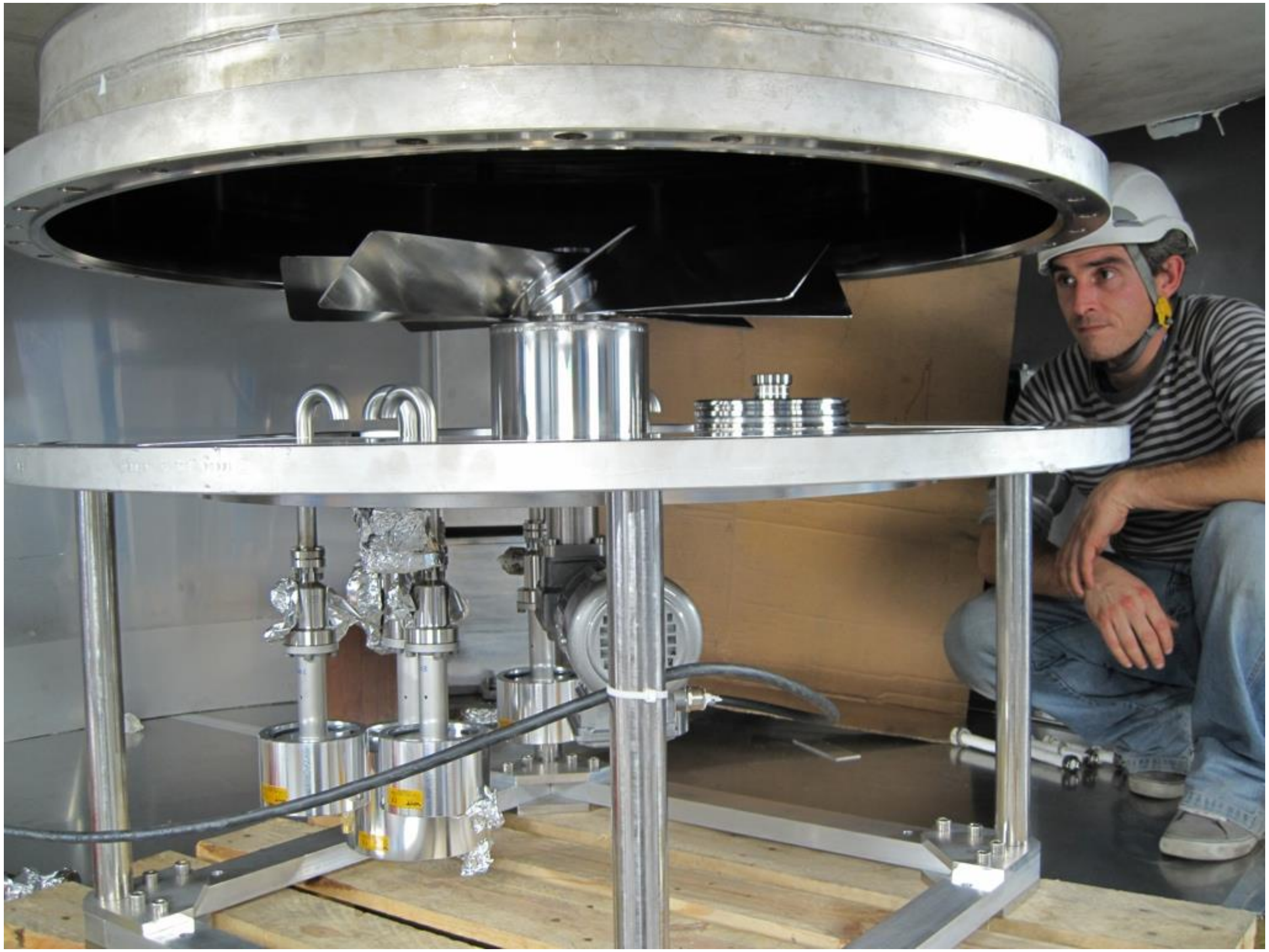
Precise and uniform adjustment of the H2SO4 concentration by means of UV laser system for the homogeneous, in-situ generation of the precursor gases

Ion-free conditions with a HV field cage



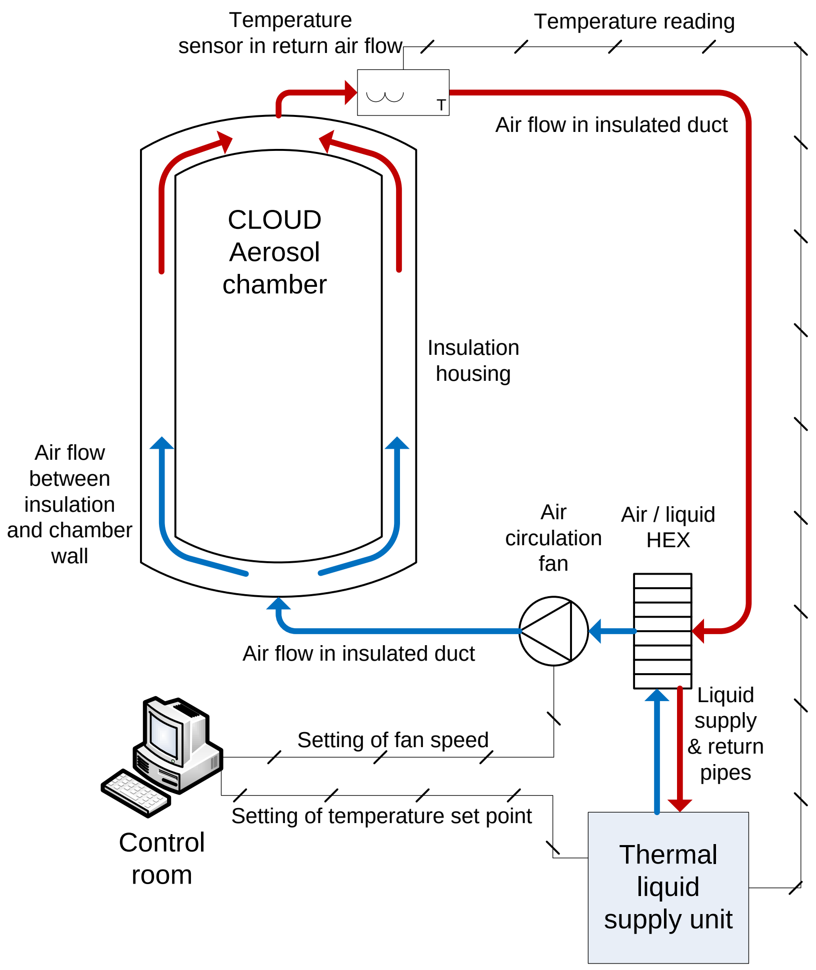
To study neutral nucleation, the beam is turned off and an internal electric field of up to 20 kV/m is applied by means of two transparent field cage electrodes. This rapidly (in about 1 s) sweeps out the background ions produced by galactic cosmic rays.

Metallic fan mixing rapidly the fresh gas and ions generated by the pion beam



The fans produce a counter-flow inside the chamber, and ensure good uniformity.

Thermal system enables highly stable operation at any temperature (300-183 K)

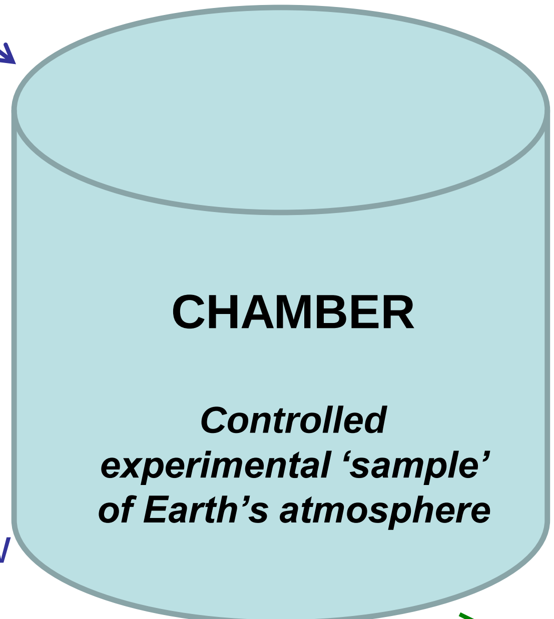


How to build up a CLOUD run?

1. Fill chamber with clean air + water vapour

2. Set temperature and pressure

3. Add trace gases, condensable species in atmospheric, extremely low concentrations
~1 molecule in 10^{12} air molecules



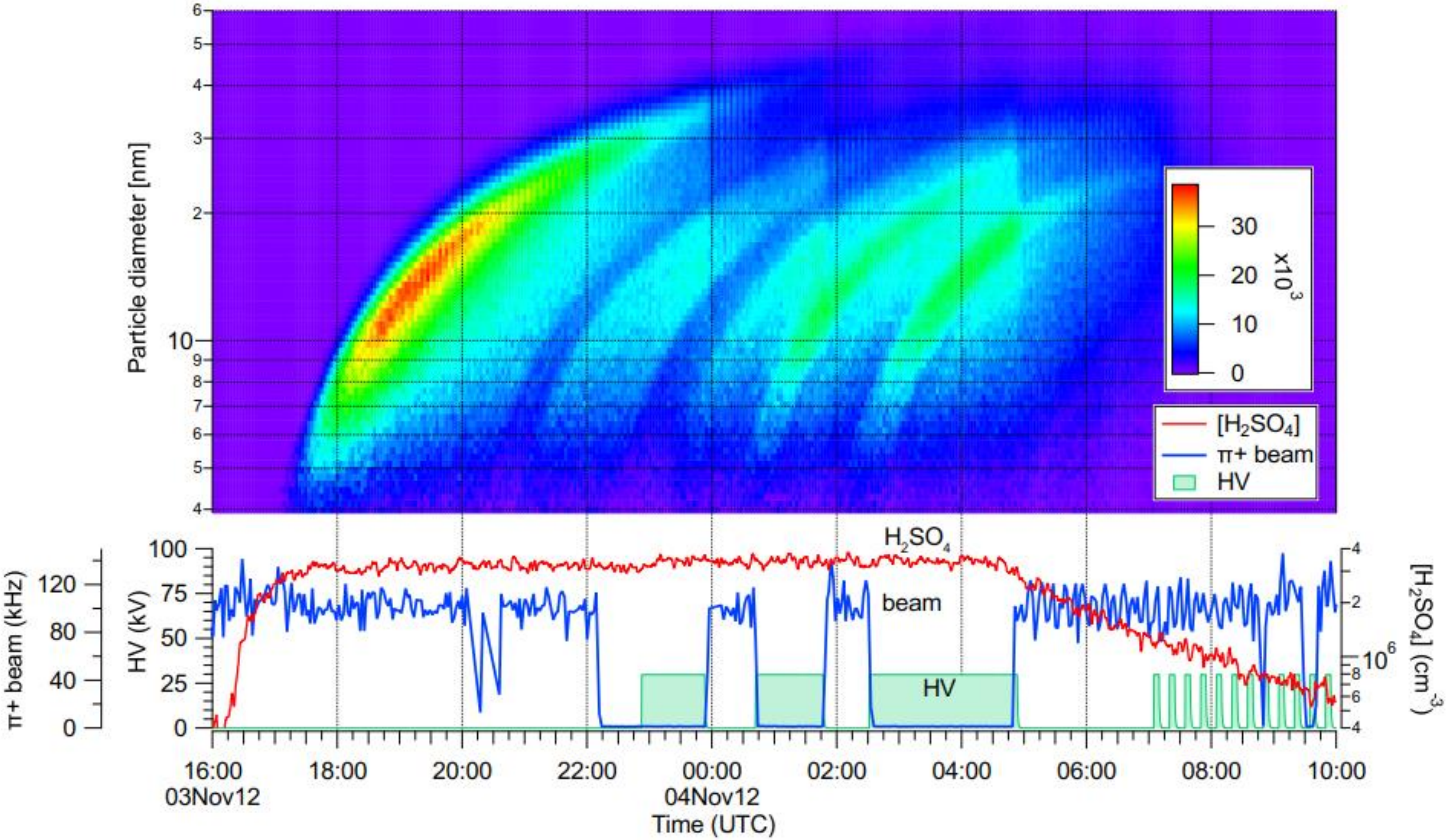
4. Expose to ionizing beam, and possibly to UV-light

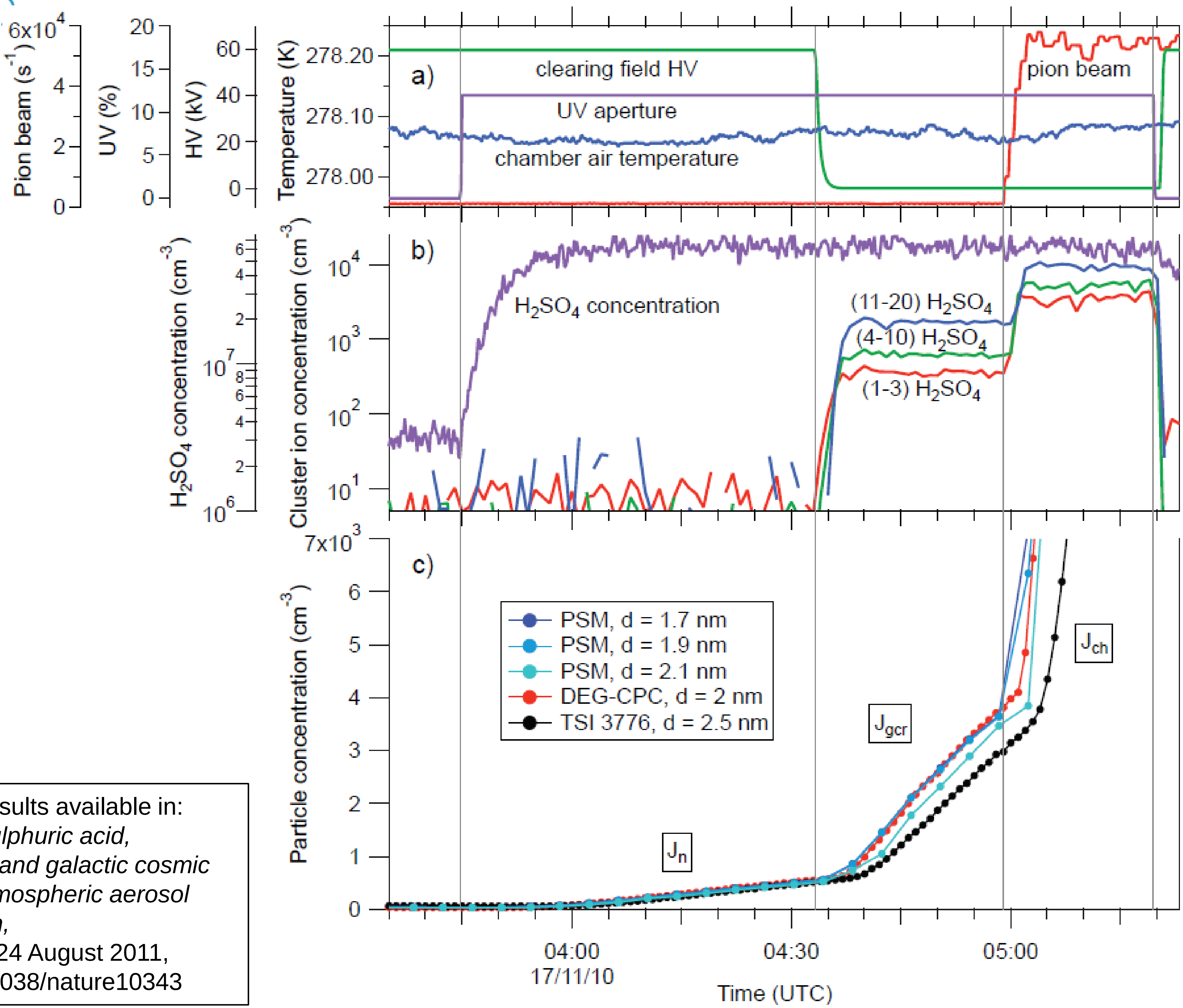
5. Observe
- **Particle growth size distribution**
- **Electrical charge distribution**
- **Cloud droplet/ice particle concentrations,**
- **etc.**

6. Repeat experiment (typically some hours), possibly with varying parameters

7. Carefully flush the chamber and clean the chamber walls between experiments

CLOUD run: instruments sampling from chamber and recording continuously

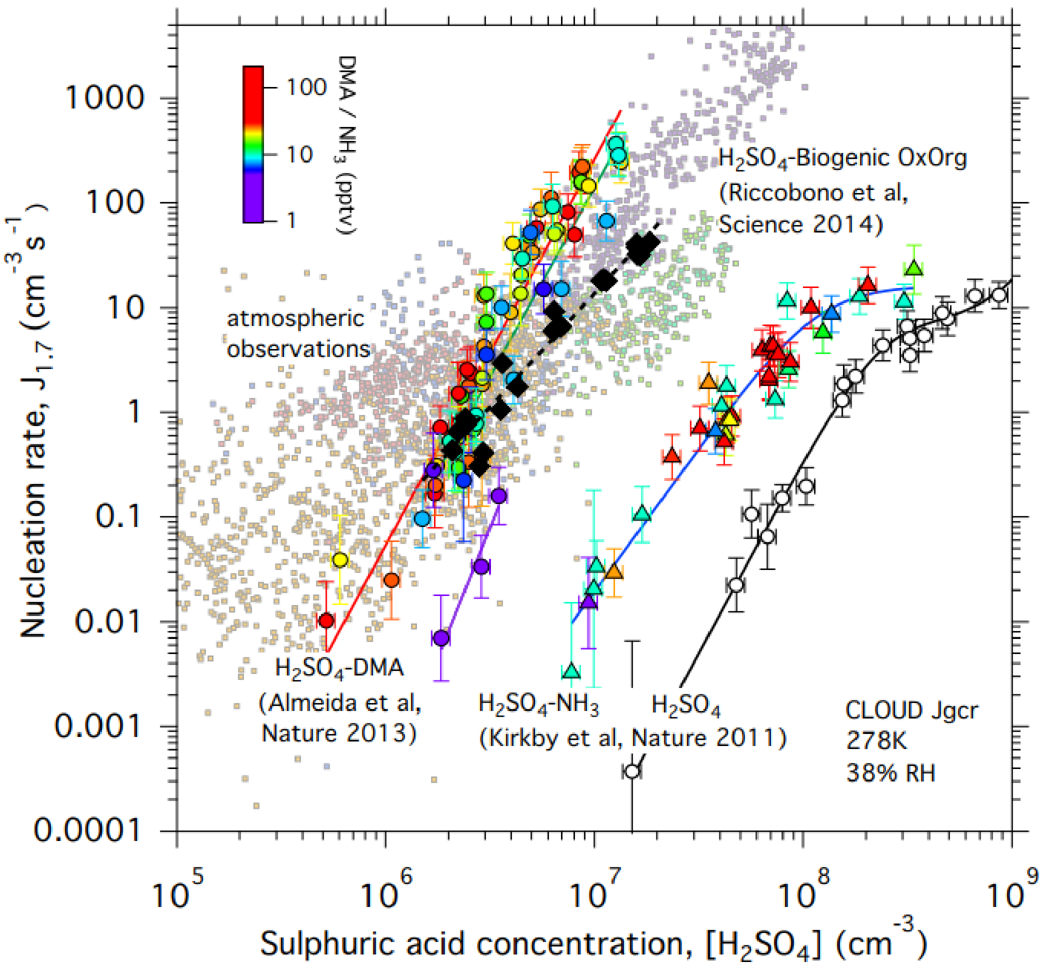




Further results available in:
Role of sulphuric acid, ammonia and galactic cosmic rays in atmospheric aerosol nucleation,
nature, 24 August 2011,
doi:10.1038/nature10343

Importance of biogenic aerosol particles

- Huge discovery that ***biogenic vapours emitted by trees*** and oxidised in the atmosphere have a significant impact on the formation of clouds, *thus helping to **cool the planet***
- Addition DMA into system brings the nucleation rate into the range of atmospheric observations



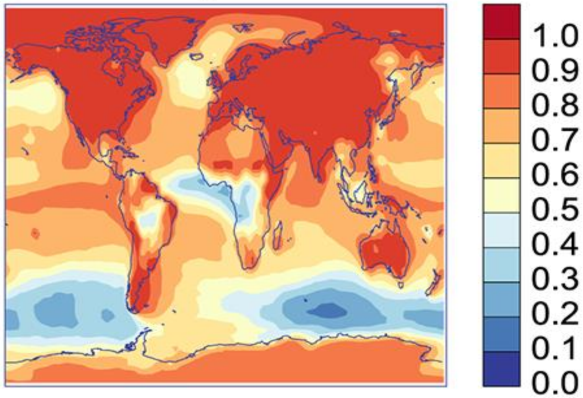
Nearly all nucleation throughout the present-day atmosphere involves ammonia or biogenic organic compounds, in addition to sulfuric acid

Global importance of nucleation using global aerosol models

Parametrizations of nucleation from H2SO4/NH3 + H2SO4/Biogenic + Pure biogenic + ions experiments

Pre-industrial nucleation fraction

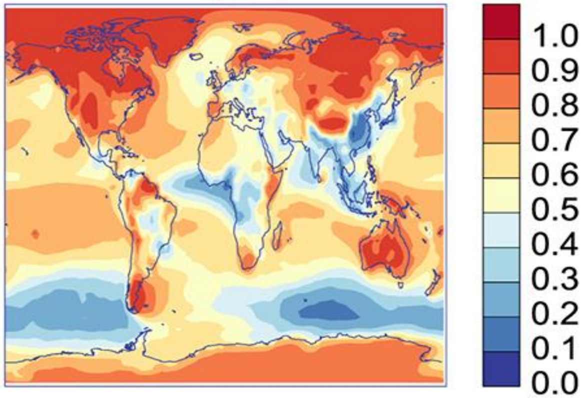
(c)



65% **(45-84%)**

Present day nucleation fraction

(d)



55% **(39-66%)**

65% of climate-relevant aerosol particles in the preindustrial atmosphere come from nucleation, and 55% today

Gordon et al. Causes and importance of new particle formation in the present-day and preindustrial atmospheres, JGR 2017

How is the experimental data from CLOUD connected to our daily lives?

- Within the CLOUD experiment **both measurements and modelling** are needed for assessing connection between aerosols, clouds and climate

Us

↓

Experimental measurements

↓

Mathematical equations

↓

Model to describe climate system

↓

Climate prediction

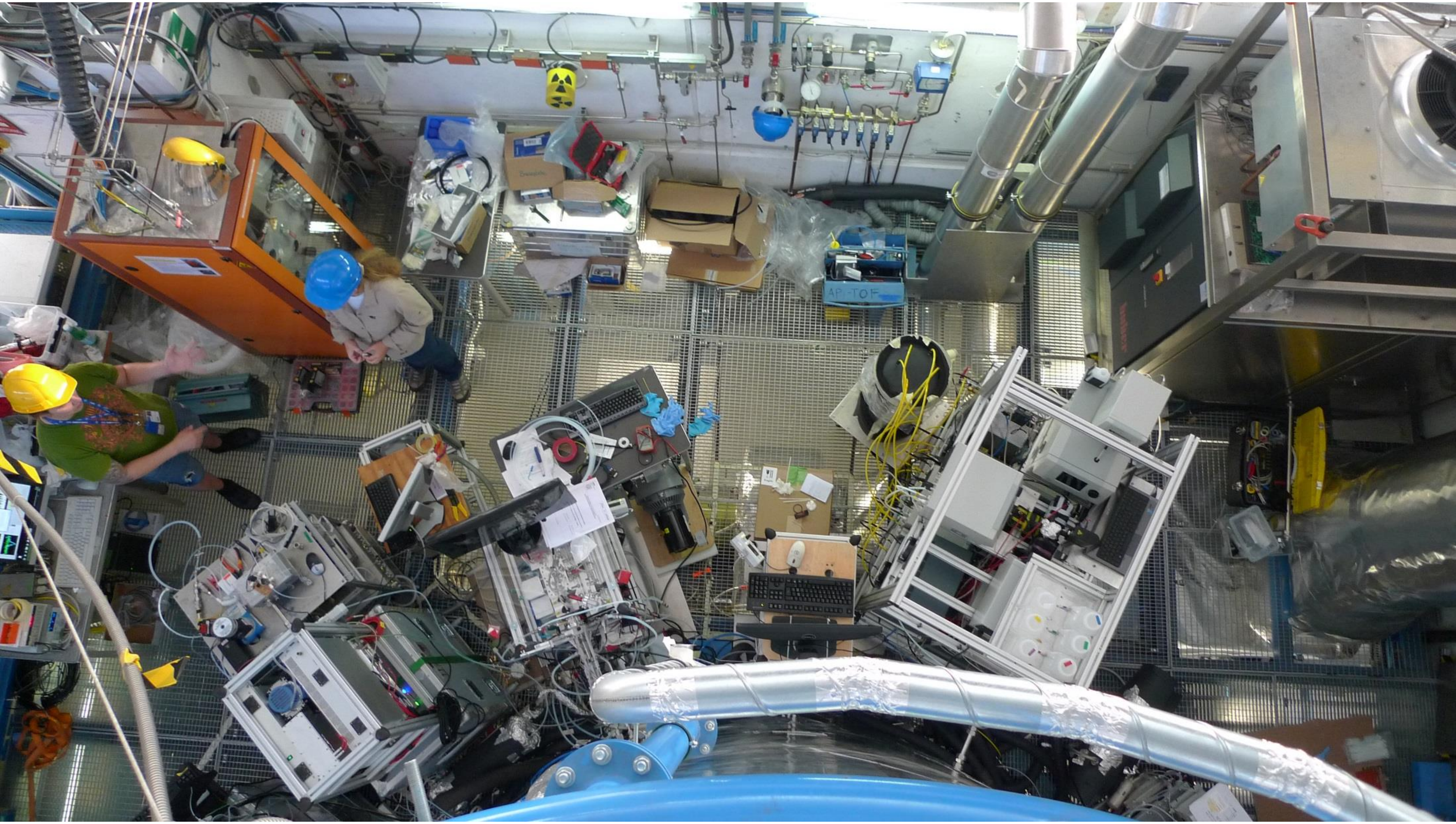
↓

Advice to climate policy makers

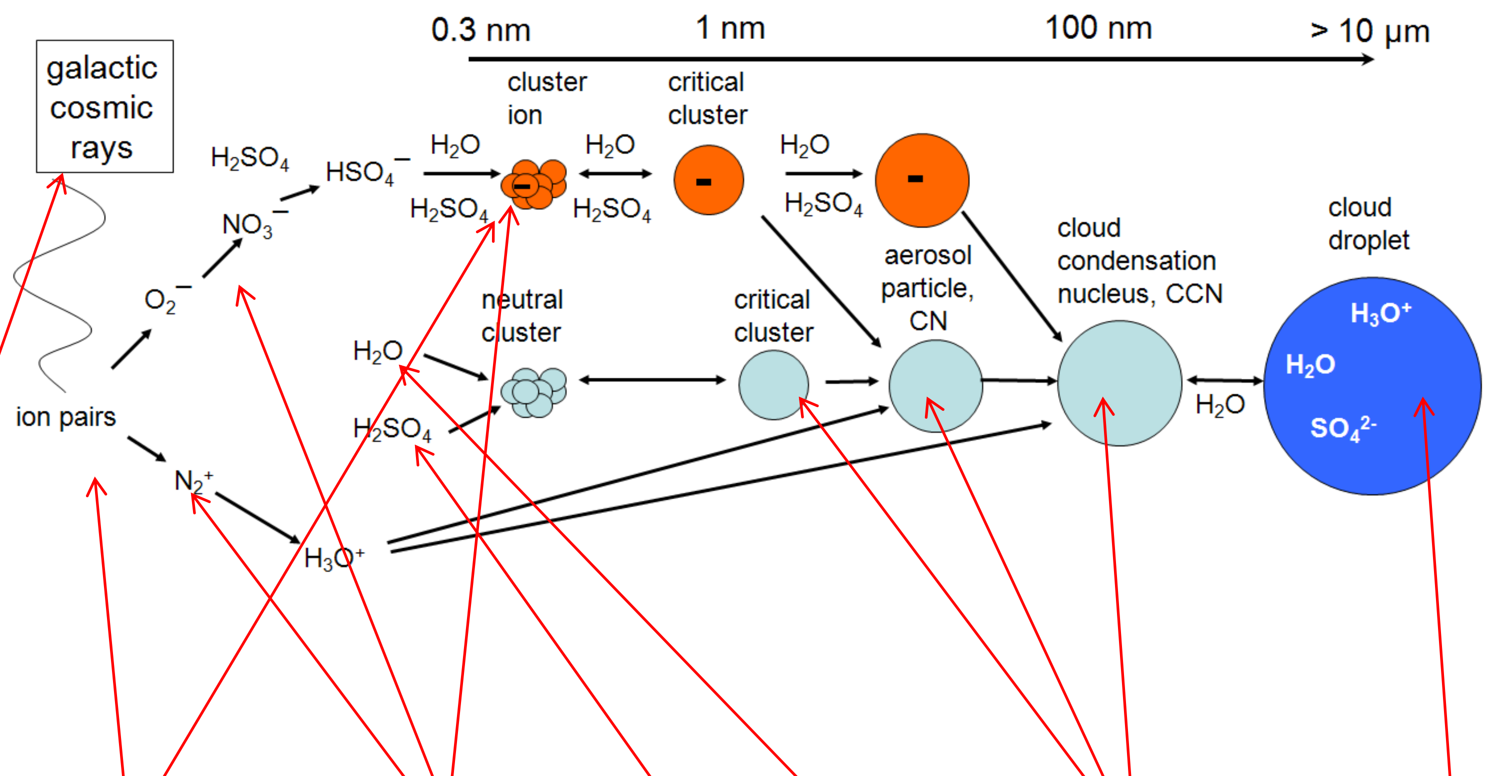
↓

You

CLOUD with the measurement instruments and their users during a campaign



State-of-the-art gas and aerosol analysis instruments from collaborating institutes:



PS Beam, Hodoscope
CERN

NAIS, Gerdien
CERN / Helsinki

API-tof-MS, PTRMS (VOC)
Frankfurt, Innsbruck, Helsinki

CIMS
Frankfurt

DewPoint
CERN

CPC, SMPS, Snapper, AMS
Vienna, Frankfurt

CCNC, HTDMA
Kuopio

Original slide courtesy of J.Kirkby

cloud

Results from CLOUD

First major publication 5 years after CLOUD approved in CERN programme, 2 years after first run

CERN

LETTER

25 AUGUST 2011 | VOL 476 | NATURE | 429

doi:10.1038/nature10343

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

Jasper Kirkby[1], Joachim Curtius[2], João Almeida[2,3], Eimear Dunne[4], Jonathan Duplissy[1,5,6], Sebastian Ehrhart[2], Alessandro Franchin[5], Stéphanie Gagné[5,6], Luisa Ickes[2], Andreas Kürten[2], Agnieszka Kupc[7], Axel Metzger[8], Francesco Riccobono[9], Linda Rondo[2], Siegfried Schobesberger[5], Georgios Tsagkogeorgas[10], Daniela Wimmer[2], Antonio Amorim[3], Federico Bianchi[9,11], Martin Breitenlechner[8], André David[1], Josef Dommen[9], Andrew Downard[12], Mikael Ehn[5], Richard C. Flagan[12], Stefan Haider[1], Armin Hansel[8], Daniel Hauser[8], Werner Jud[8], Heikki Junninen[5], Fabian Kreissl[2], Alexander Kvashin[13], Ari Laaksonen[14], Katrianne Lehtipalo[5], Jorge Lima[3], Edward R. Lovejoy[15], Vladimir Makhmutov[13], Serge Mathot[1], Jyri Mikkilä[5], Pierre Minginette[1], Sandra Mogo[3], Tuomo Nieminen[5], Antti Onnela[1], Paulo Pereira[3], Tuukka Petäjä[5], Ralf Schnitzhofer[8], John H. Seinfeld[12], Mikko Sipilä[5,6], Yuri Stozhkov[13], Frank Stratmann[10], Antonio Tomé[3], Joonas Vanhanen[5], Yrjo Viisanen[16], Aron Vrtala[7], Paul E. Wagner[7], Hansueli Walther[9], Ernest Weingartner[9], Heike Wex[10], Paul M. Winkler[7], Kenneth S. Carslaw[4], Douglas R. Worsnop[5,17], Urs Baltensperger[9] & Markku Kulmala[5]

CLOUD institutes:

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
Switzerland:	CERN
	Paul Scherrer Institut
United Kingdom:	University of Manchester
	University of Leeds
United States of America:	California Institute of Technology

CLOUD now "in production". Examples of the produced results:

- J. Almeida et al., *Molecular understanding of amine-sulphuric acid particle nucleation in the atmosphere,* Nature, 2013
- H. Keskinen et al., *Evolution of particle composition in CLOUD nucleation experiments*, Atmospheric Chemistry and Physics, 2013
- S. Schobesberger et al., *Molecular understanding of atmospheric particle formation from sulfuric acid and large oxidized organic molecules*, PNAS, 2013
- F. Riccobono et al., *Oxidation Products of Biogenic Emissions Contribute to Nucleation of Atmospheric Particles*, Science, 2014
- F. Bianchi et al., *Insight into acid-base nucleation experiments by comparison of the chemical composition of positive, negative and neutral clusters*, PNAS, 2014
- J. Kirkby et al., *Ion-induced nucleation of pure biogenic particles*, Nature, 2016
- J. Tröstl et al., *The role of low-volatility organic compounds in initial particle growth in the atmosphere*, Nature, 2016
- E. Dunne et al., *Global particle formation from CERN CLOUD measurements*, Science, 2016

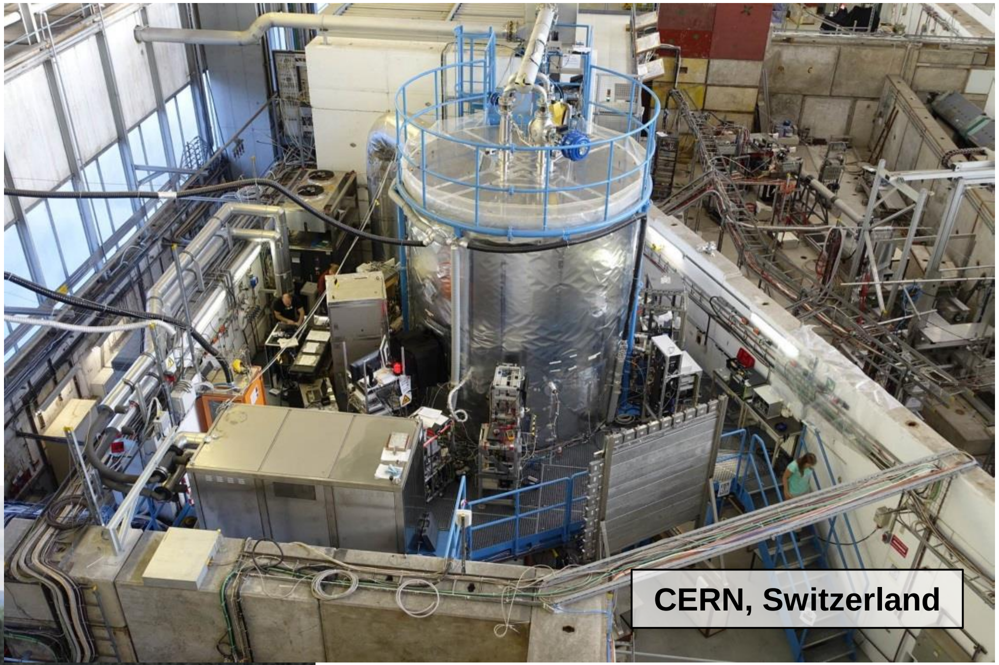
Further information on the CLOUD experiment:
https://home.cern/about/experiments/cloud

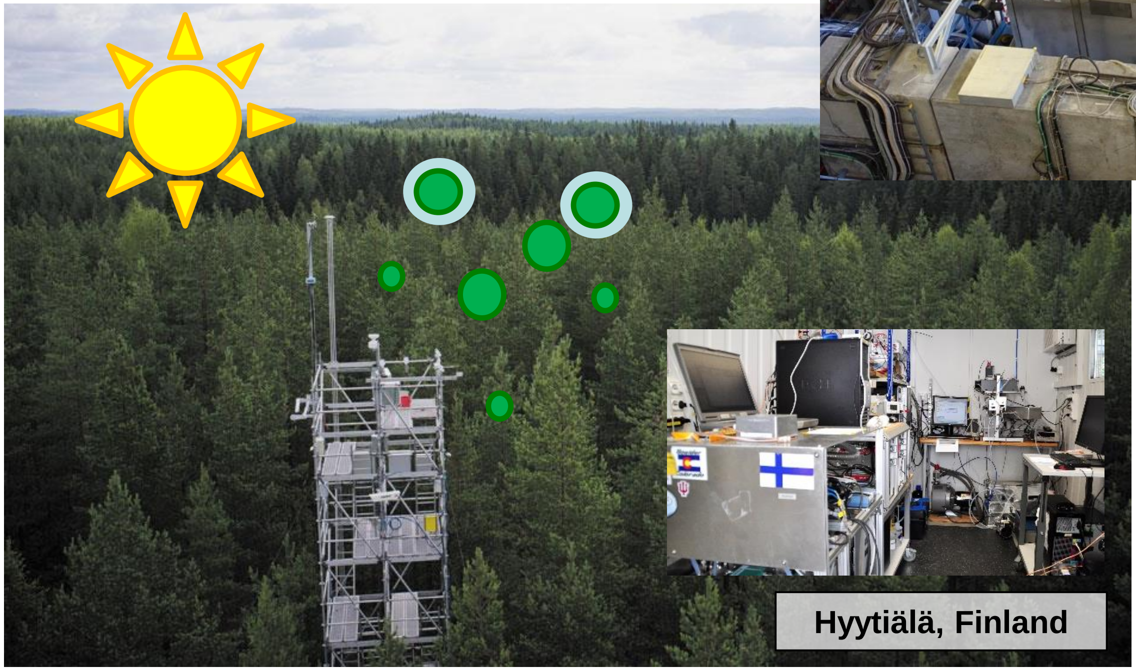
Thank you for your attention!

EXTRA SLIDES:

Example of on-going CLOUD measurements:

Recreating of boreal forest conditions, to understand the observed aerosol particle nucleation and growth.





Similar instrument set-up used in field as well (direct atmospheric measurements)!!

https://www.youtube.com/watch?v=EneDwu0HrVg

See youtube:
"NO PARTICLES NO FOG"

What's Up with Clouds - Today I Found Out. We look at them every day, but few of us realize what they are made of.

www.todayifoundout.com/index.php/.../whats-up-with-clouds/

HOW WOULD YOU MAKE A BIG CLOUD UP IN THE AIR?

Researcher's work day at CLOUD campaign on a morning shift at 07:00-15:00:

- 06:00 Wake-up and morning coffee
- 07:00 To CLOUD: updates from last shift and checking the instruments
- 07:00-14:00 Starting new run: operators present and others monitoring remotely their instruments or fixing their instrument if needed
- 12:00-13:00 Lunch break
- 12:00-15:00 Analysis and plotting of the experimental data
- 15:00-17:30 Daily meeting: quick-look to the data and planning next runs
- 18:00-22:00 Instrument calibrations and preparation/modifications for nights and next day's experimental runs

During the CLOUD campaign we work in 3 shifts (07:00-15:00, 15:00-23:00, 23:00-07:00). Two operator present all times.

Air pollution control and decreasing new particle formation may lead to strong climate warming

30 OCTOBER 2009 VOL 326 SCIENCE www.sciencemag.org
Published by AAAS

PERSPECTIVES

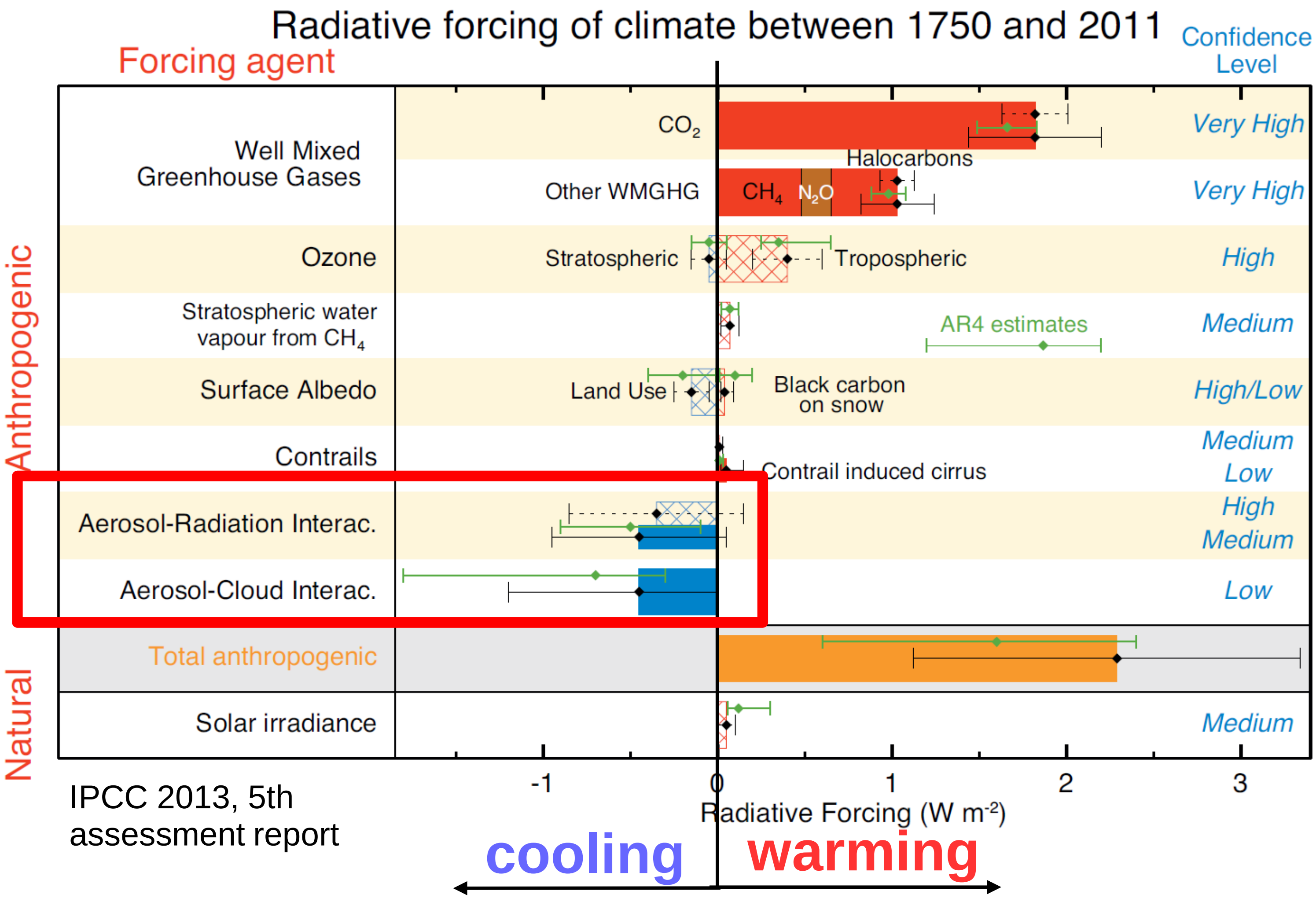
ATMOSPHERIC SCIENCE

Clean the Air, Heat the Planet?

Almut Arneth,[1,2*] Nadine Unger,[3] Markku Kulmala,[2] Meinrat O. Andreae[4]

Measures to control emissions of air pollutants may have unintended climatic consequences.

Aerosol particles have a net cooling effect on the global climate (IPCC, 2013):

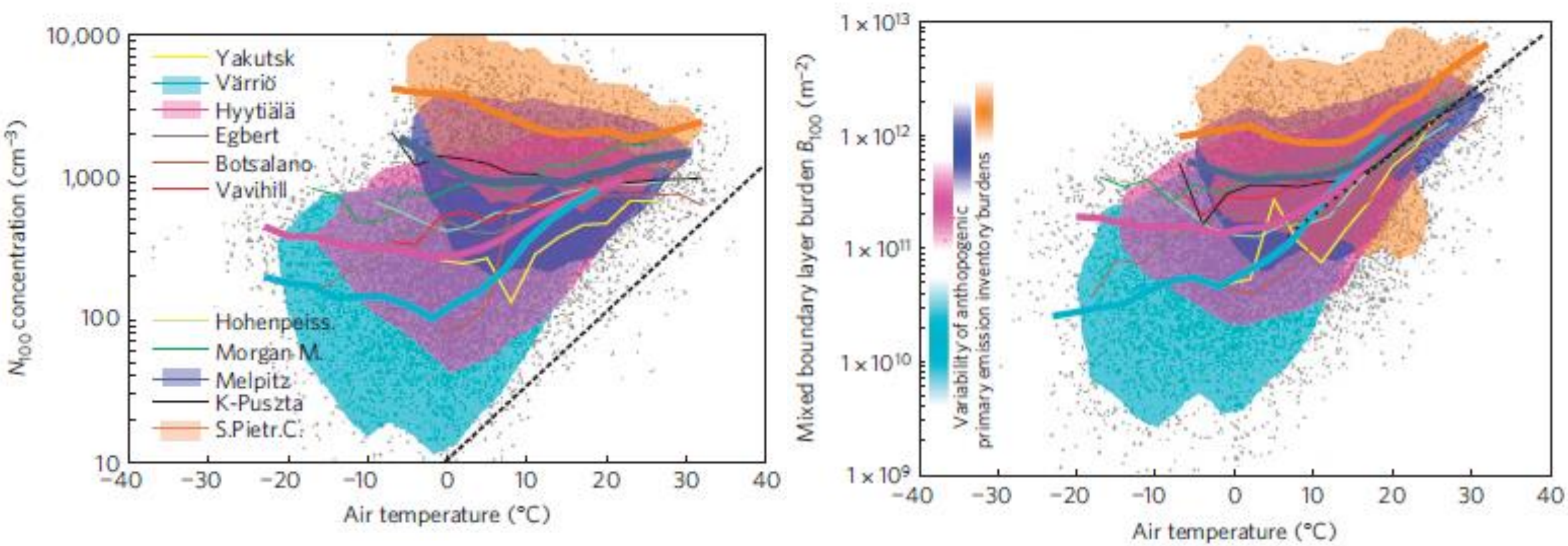


IPCC 2013, 5th assessment report

Warming-induced increase in aerosol number concentration likely to moderate climate change

<u>Feedback</u> on increasing air temperature relation to aerosol-cloud interactions:
Relationship between air temperature and the number concentration and burden of CCN-sized aerosol particles

Paasonen et al., *Nature Geo.Sci.* 2013

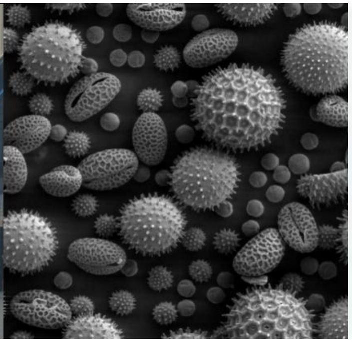


Atmospheric aerosol particles: why so diverse and complex?

- Aerosol is a mixture of gas, and solid or liquid particles floating in the gas

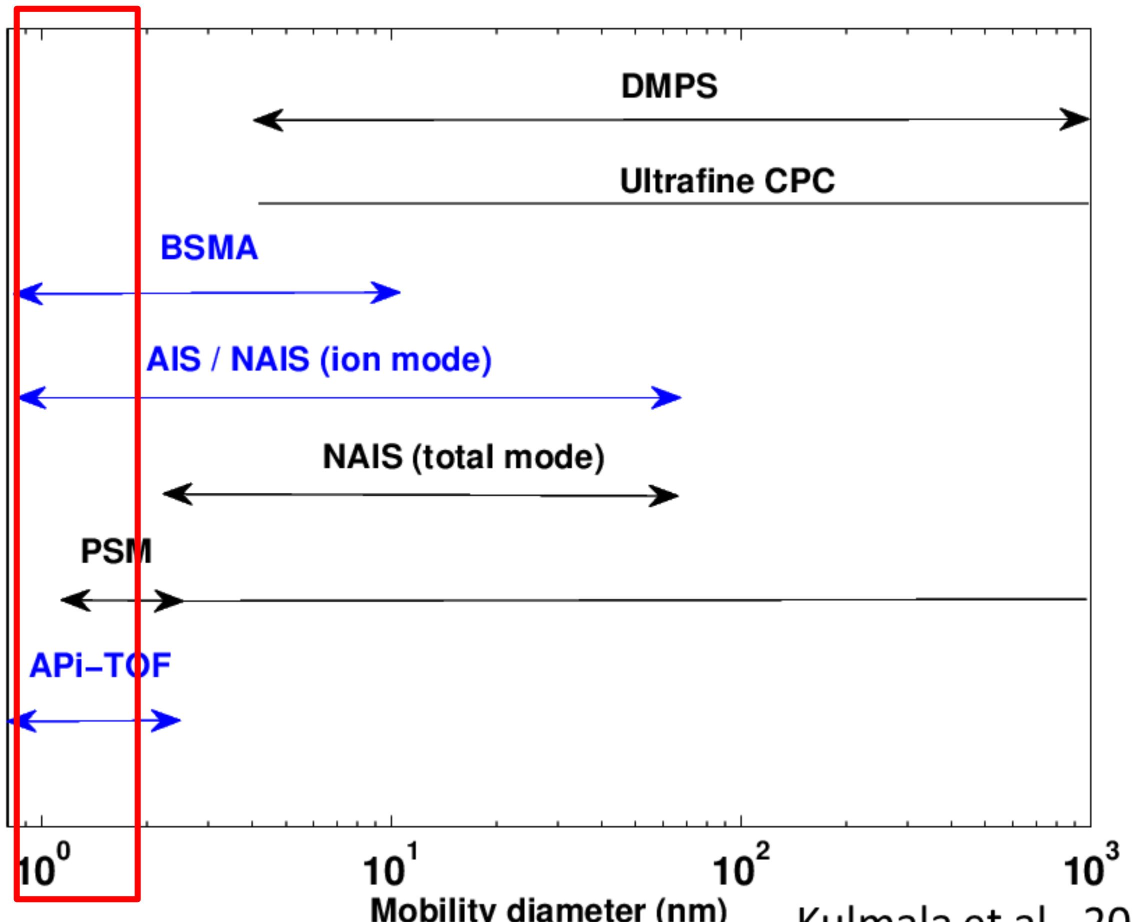
- Diameters ~10^{-9} – 10^{-4} m
- Concentrations ~10^{0} – 10^{5} cm^{-3} (10^{-1} – 10^{2} μg m-3)

- Sources and sinks of aerosols: particles constantly interact physically, chemically and dynamically with gases and each other


Key steps of clustering process occur in the sub–2 nanometer (nm) size range via neutral pathways

- Direct size-segregated observations have not been possible until very recently



Measurements started in Hyytiälä:

1996

1996

2003

2003

2006

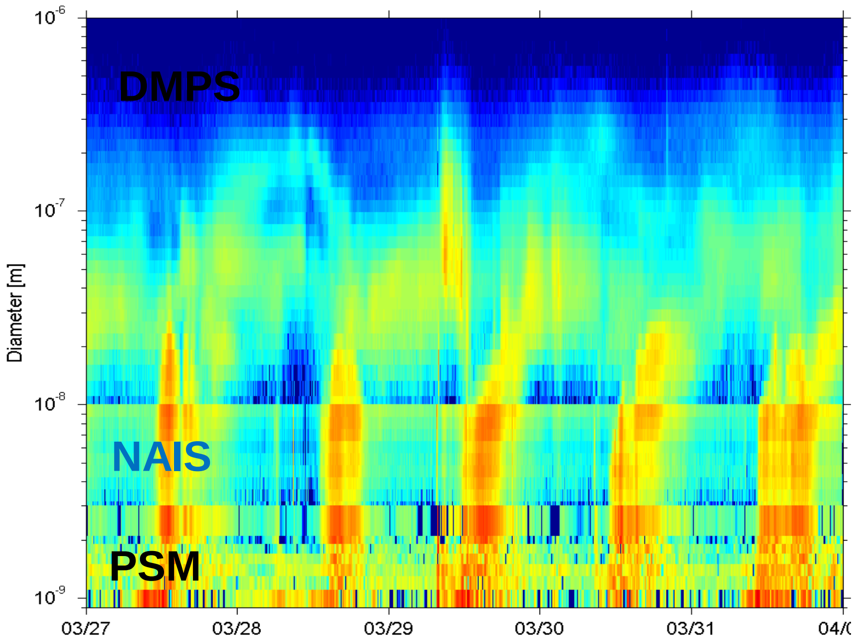
2009

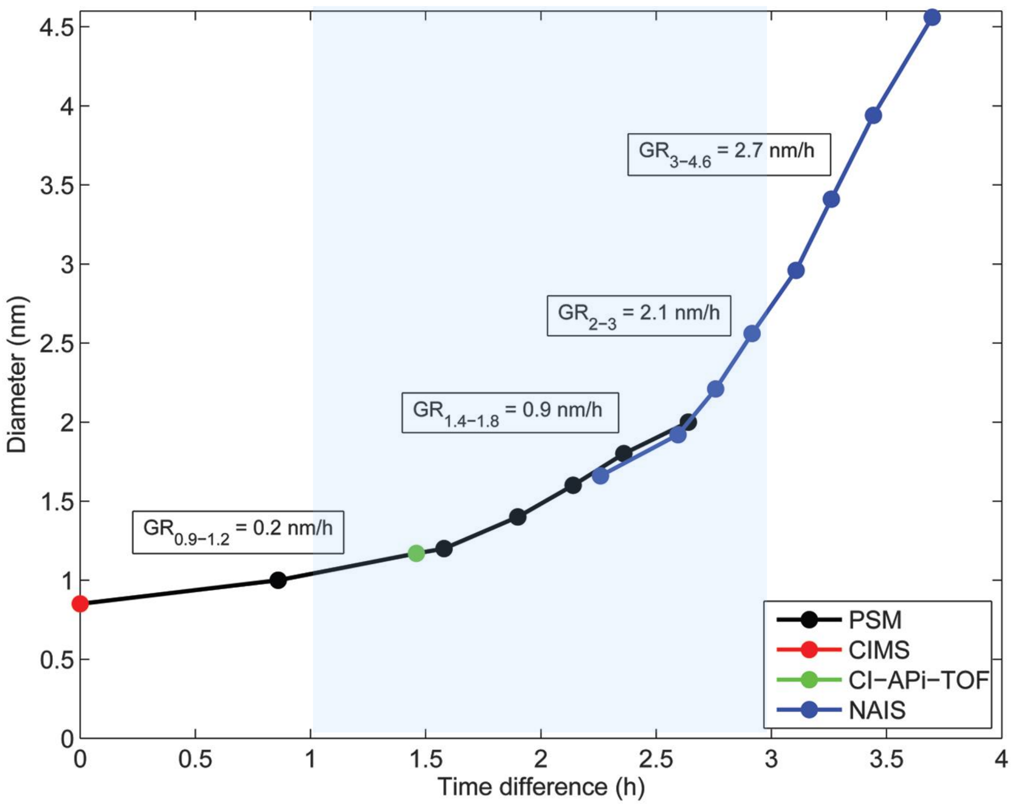
2009

Kulmala et al., 2013, Science, SOM

Direct observations on atmospheric "cluster by cluster" growth rates with novel instrumentation

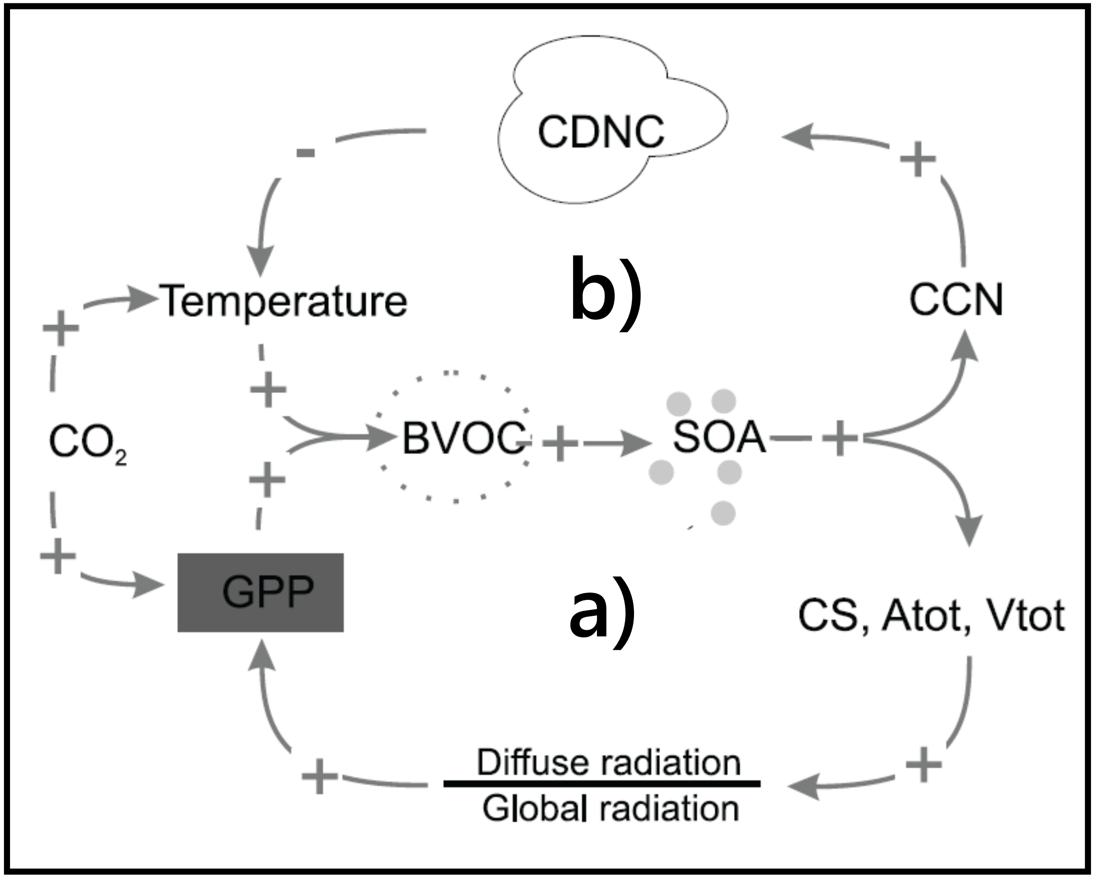
- Detection of sub-3 nm atmospheric clusters and particles with newly developed novel instrumentation





Kulmala et al., 2013, Science, SOM

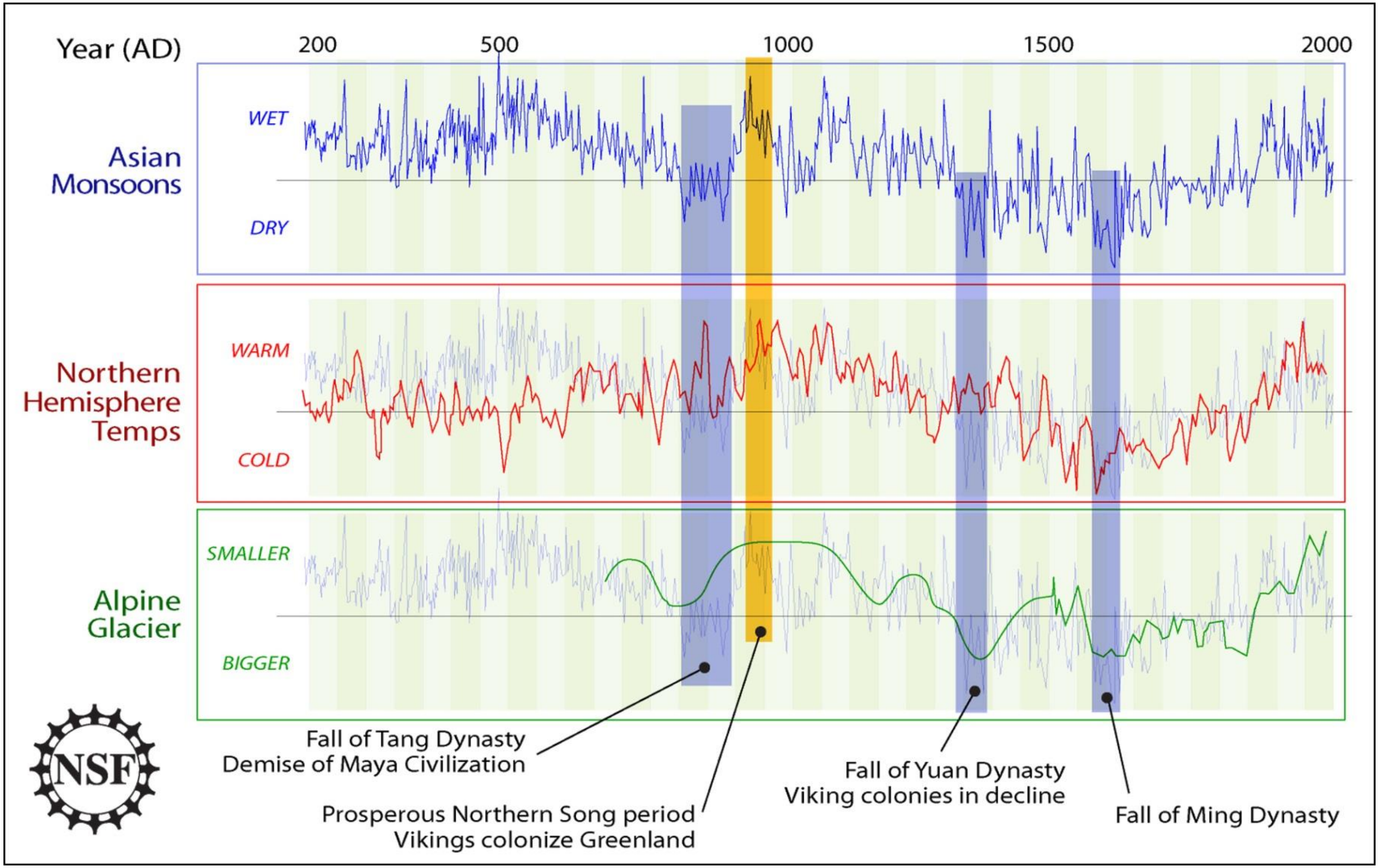
Feedback loops on biosphere-atmosphere interaction with increasing CO_2:



Kulmala et al. *Boreal Envin. Res.* 2014

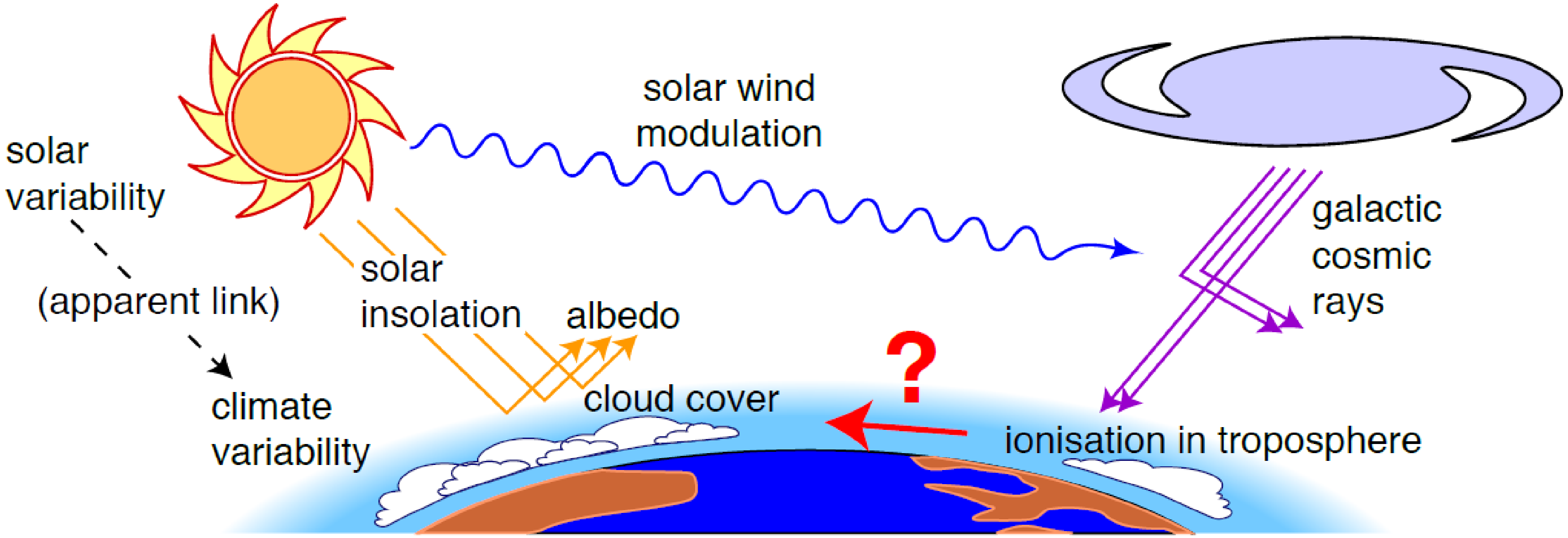
- Increasing atmospheric CO_2 concentration, changes GPP associated with carbon uptake, SOA formation in the atmosphere, and transfer of a) both diffuse and global radiation in cloud-free air, b) cloud cover.

Why to study changes in Earth's climate? Past vs. future climate



Source: U.S. National Science Foundation, 2008

Suggested Solar → Cosmic ray → Climate mechanism??



- **Higher solar activity → reduced GCRs →? reduced cloud cover → warmer climate**
- Satellite observations not yet settled:
  Significant GCR-cloud correlations reported by some (Svensmark, Laken...) and weak or excluded by others (Kristjansson, Wolfendale...)

Aerosol particles have an effect on human health

REGIONAL, GLOBAL

Aerosol particles have a regional effect on air quality and visibility

REGIONAL

Helsinki August 2006,
Piia Anttila FMI

Run list at CLOUD11 campaign: nucleation with pure organics

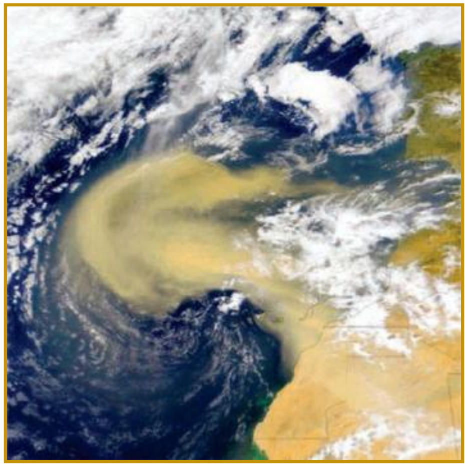
	Start time	Run	Type	Run description
1				
2	**Start time**	**Run**	**Type**	**Run description**
3	dd.mm.yyyy HH:MM:SS			**Ammonia makes the party :)**
111	11.10.2016 23:33:30	1,811.10	CLEAN	Beam on, UVX 0%, UVH 0%
112	12.10.2016 01:51:25	1,812.01	N	Soup with NOx, UVS30%; AP 9/225/2.7, BCY 1/1000, IP 5/10.5/2.5
113	12.10.2016 03:54:30	1,812.02	N	Soup with NOx, UVS30%; AP 9/225/5.4, BCY 2/1000, IP 5/10.5/5
114	12.10.2016 06:16:30	1,812.03	N	Soup with NO UVS30%x; AP 9/225/10 (1200ppt), BCY 400/1000 (400ppt), IP 5/10.5/10 (10ppb)
115	12.10.2016 08:55:30	1,812.04	N	Soup with NOx, UVS80%; AP 9/225/10 (1200ppt), BCY 400/1000 (400ppt), IP 5/10.5/10 (10ppb)
116	12.10.2016 10:49:30	1812.05	CLEAN	Cleaning
117	12.10.2016 13:28:30	1,812.06	GCR	Soup with NOx, AP 300ppt, BCY 100ppt, IP 2.5ppb
118	12.10.2016 16:22:00	1,812.07	GCR	Reduce NOx flow to get 300ppt instead of 1ppb, rest constant
119	12.10.2016 18:30:00	1,812.08	GCR	Soup with NOx, AP 600ppt, BCY 200ppt, IP 5ppb
120	12.10.2016 21:42:00	1,812.09	GCR	Soup with NOx, AP 1200ppt, BCY 400ppt, IP 10ppb
121	13.10.2016 00:01:00	1,812.10	GCR	High conc Soup with UVX 400x5
122	13.10.2016 01:03:00	1,812.11	N	High conc Soup with UVX 400x5
123	13.10.2016 01:35:00	1,812.12	CLEAN	Cleaning
124	13.10 [illegible]	[illegible]	[illegible]	[illegible]
125	13.10 [illegible]	[illegible]	[illegible]	[illegible]
126	13.10 [illegible]	[illegible]	[illegible]	[illegible]
127	13.10 [illegible]	[illegible]	[illegible]	[illegible]
128	13.10.2016 12:37:00	1,813.05	BEAM	Soup AP 600ppt, BCY 200ppt, IP 5ppb, Beam 14mm
129	13.10.2016 15:13:00	1,813.06	BEAM	Soup AP 600ppt, BCY 200ppt, IP 5ppb, Beam 25mm
130	13.10.2016 17:10:00	1,813.07	BEAM	Soup AP 600ppt, BCY 200ppt, IP 5ppb, Beam 50mm
151	15.10.2016 19:39:00	1,816.06	GCR	J+25C with NO2, organic soup 600/200/5
152	16.10.2016 00:49:00	1,816.07	GCR	J+25C with NO2, organic soup 1200/400/10
153	16.10.2016 03:52:26	1,816.08	GCR	J+25C with NO2, organic soup 1200/400/10 + UVX 400x5
154	16.10.2016 05:32:32	1,816.09	N	CS step
155	16.10.2016 05:57:15	1,816.10	BEAM	beam cleaning
156	16.10.2016 07:56:22	1,817.01	N	Pure biogenic soup at 25C Daytime

Soup = mixture of organic gases; AP= alphapinene; BCY = betacaryophyllene; IP = isoprene; CS = condensation sink; J = particle formation rate

Primary Aerosol Sources: natural vs human-made

Natural sources:

Sea spray



Mineral dust

Volcano ► Sulfates, dust

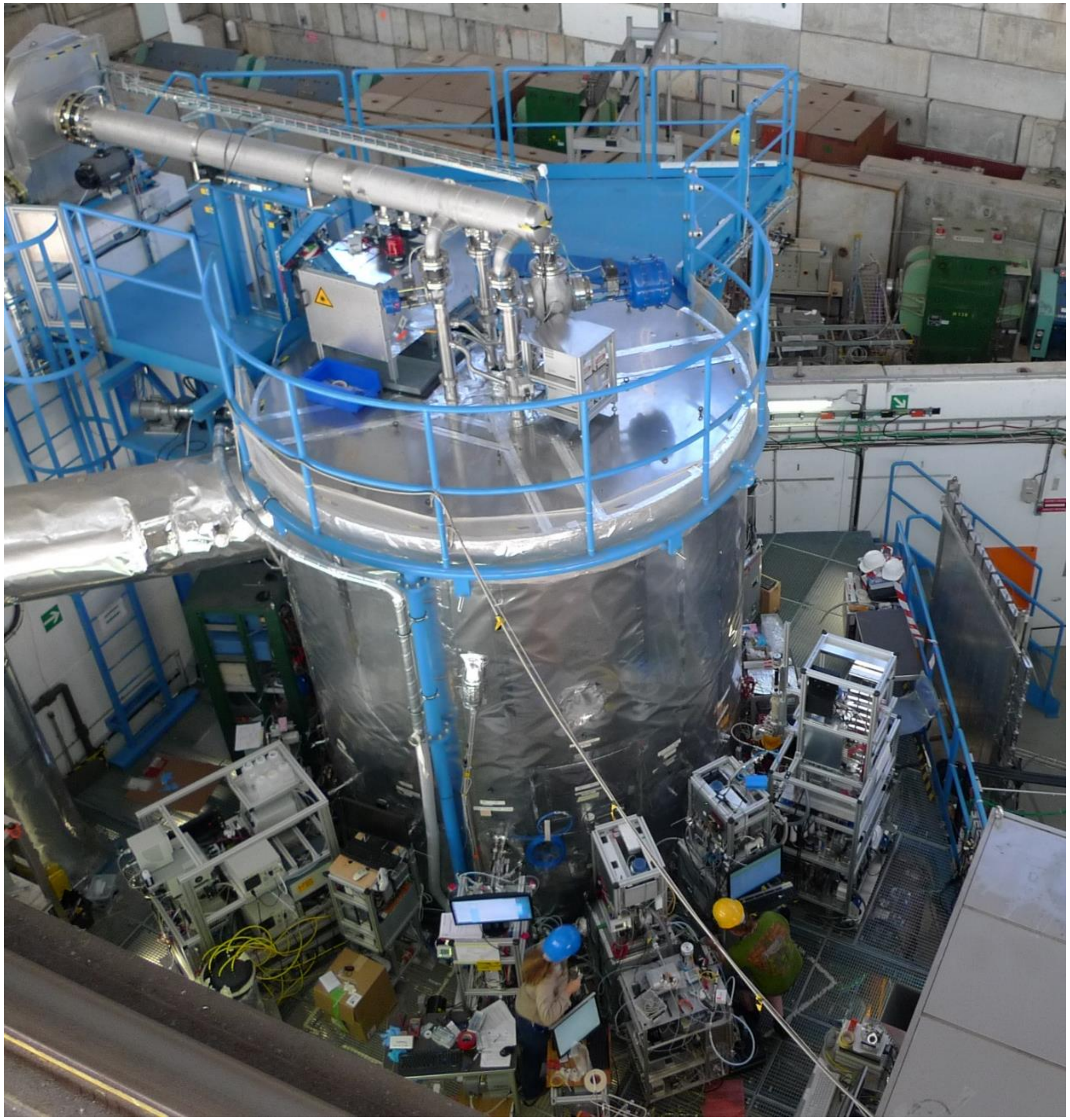
Biomass burning ► Organics

Human-made sources:

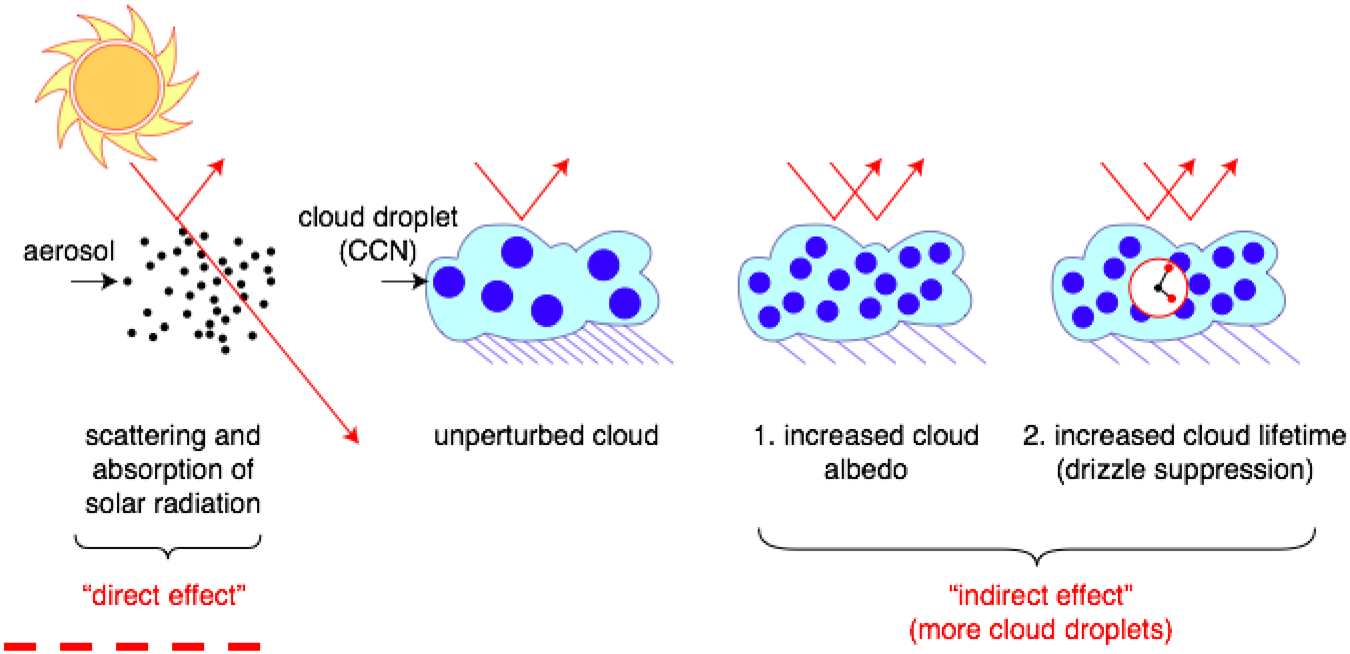
Traffic emissions ► Soot

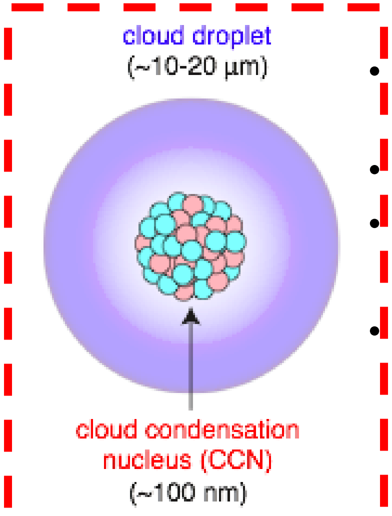
Industrial Emissions

CLOUD line beam area just before the CLOUD11 runs at September 2016:



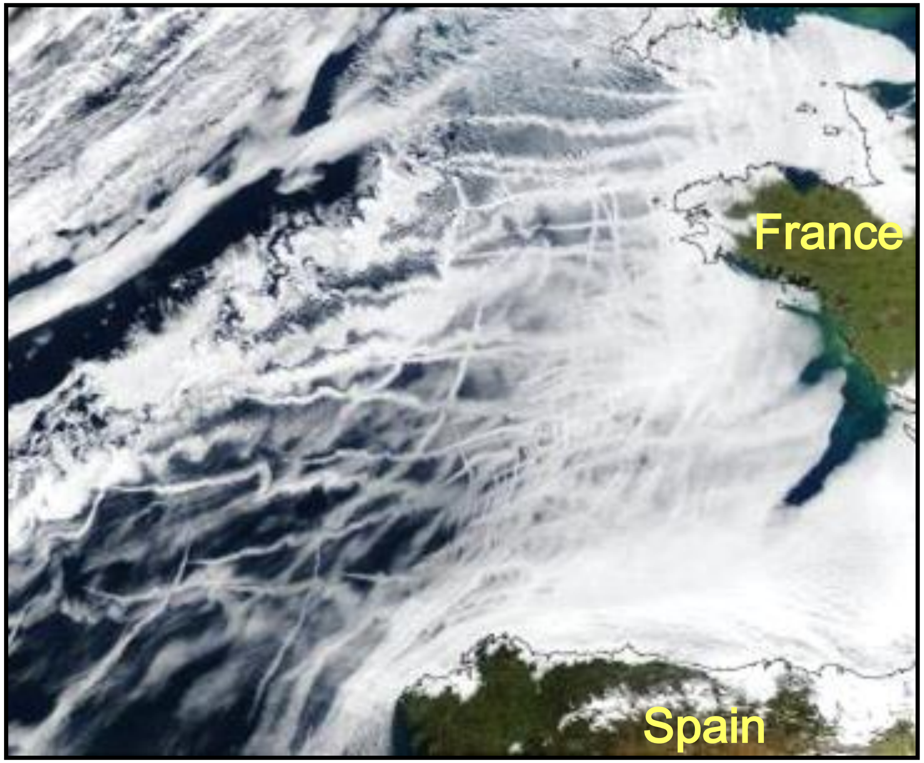
Role of aerosols on Sun’s radiative forcing





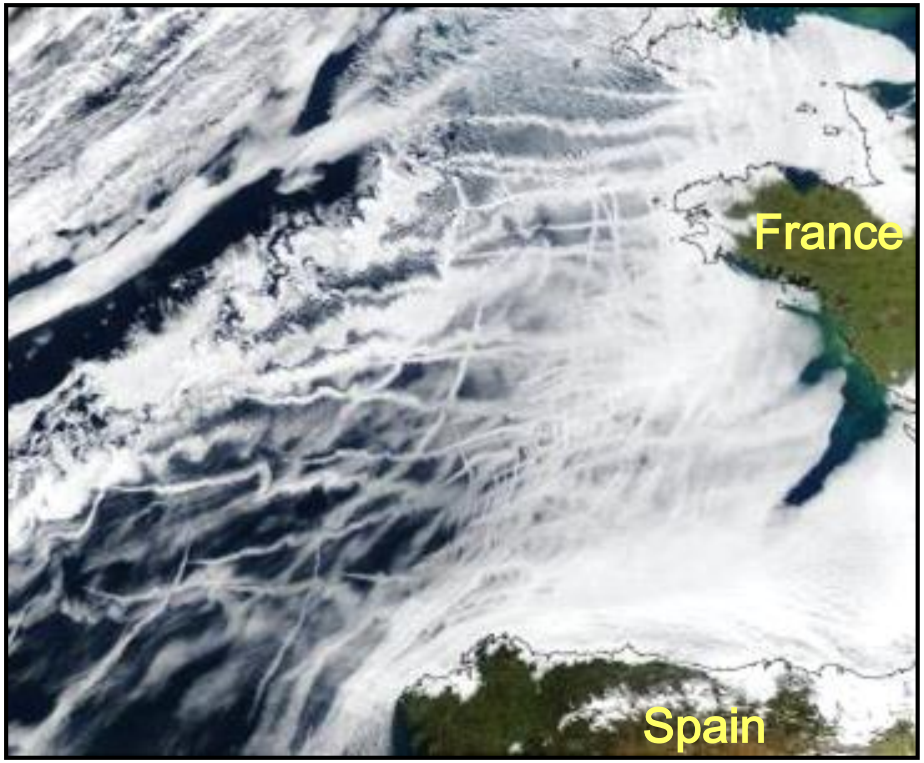
- **All cloud droplets form on aerosol “seeds” known as cloud condensation nuclei - CCN**
- Cloud properties are sensitive to number of droplets
- More aerosols/CCN:
  – Brighter clouds, with longer lifetimes
- **Sources of atmospheric aerosols:**
  – Primary (dust, sea salt, fires)
  – Secondary (gas-to-particle conversion)

See youtube: “No particles no fog” https://www.youtube.com/watch?v=EneDwu0HrVg



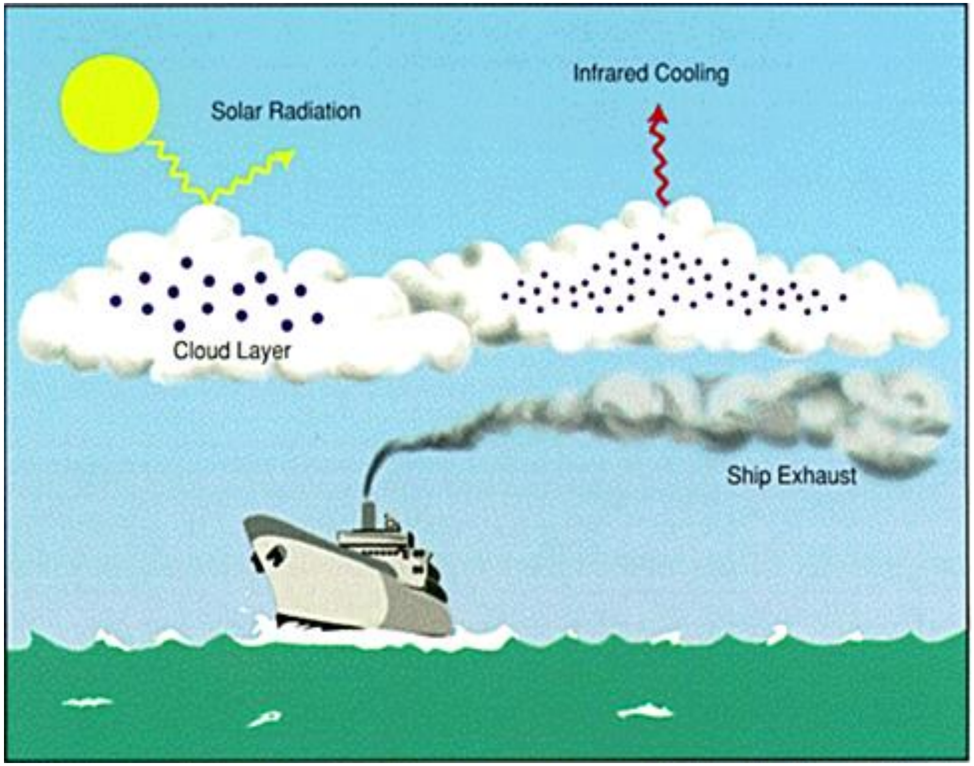
http://visibleearth.nasa.gov/

Indirect effect of carbonaceous particles: Ship tracks

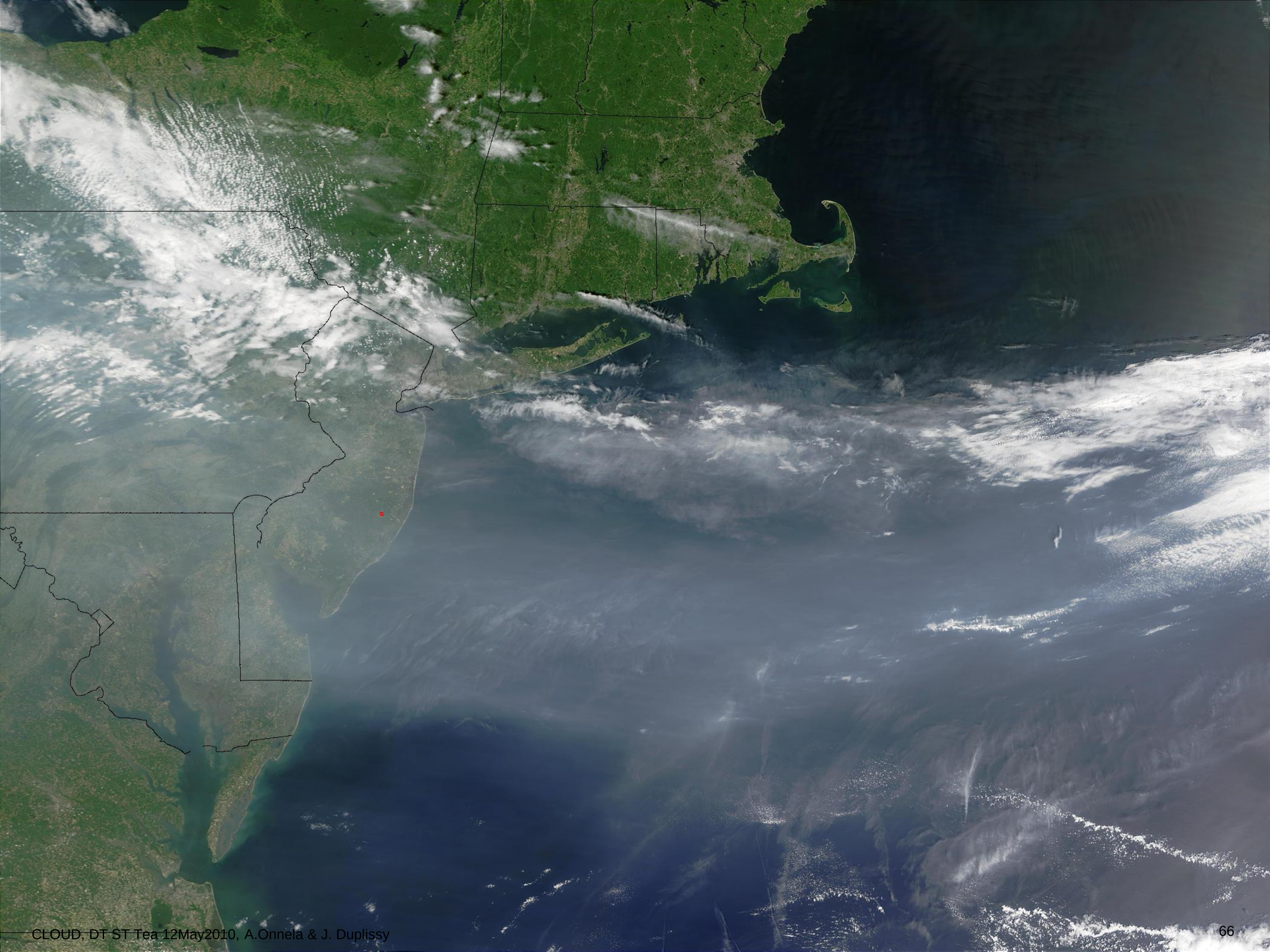


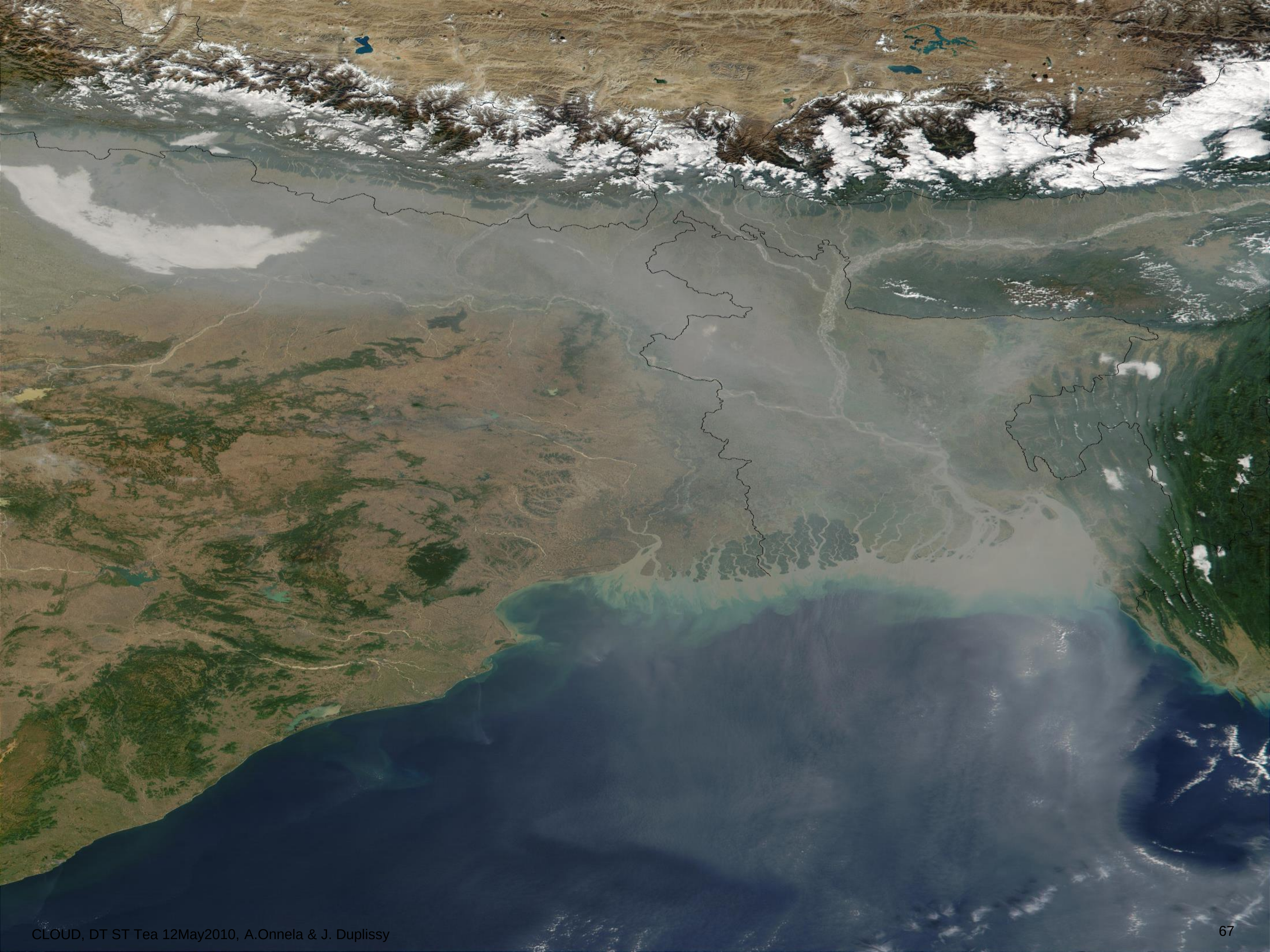
Ship tracks on the East Atlantic

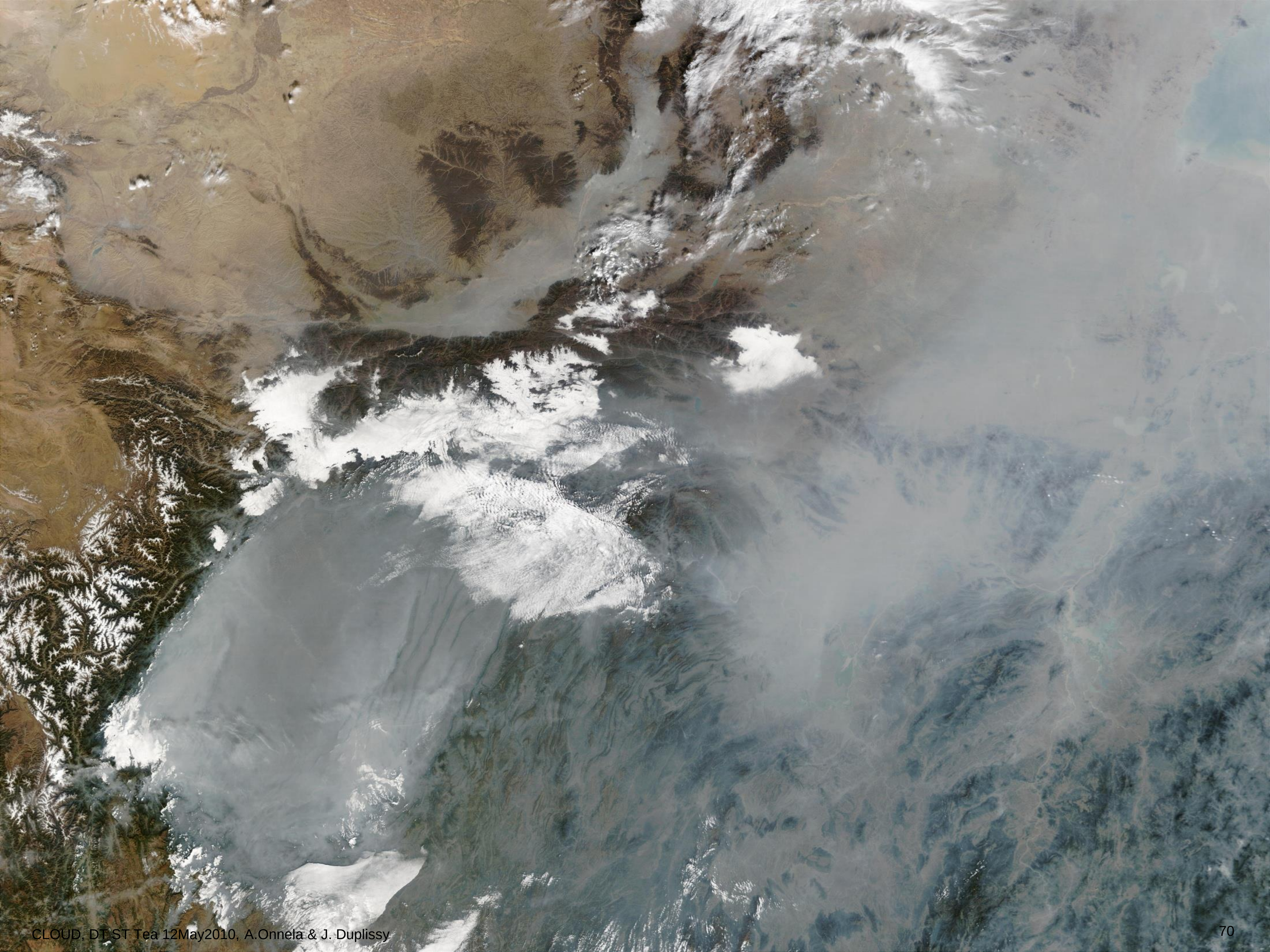
http://visibleearth.nasa.gov/



Aerosol particles emitted by ships (soot particles with a high sulfur content) act as CCN and form clouds and enhance cloud reflectivity







What is in common with the cloud chamber tracks and the air plane contrails?