Status and Plans of the CLOUD Experiment

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For more information:
see video on CLOUD:
http://www.cloud-train.eu/index.html
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or just google CLOUD-TRAIN

The CLOUD Collaboration

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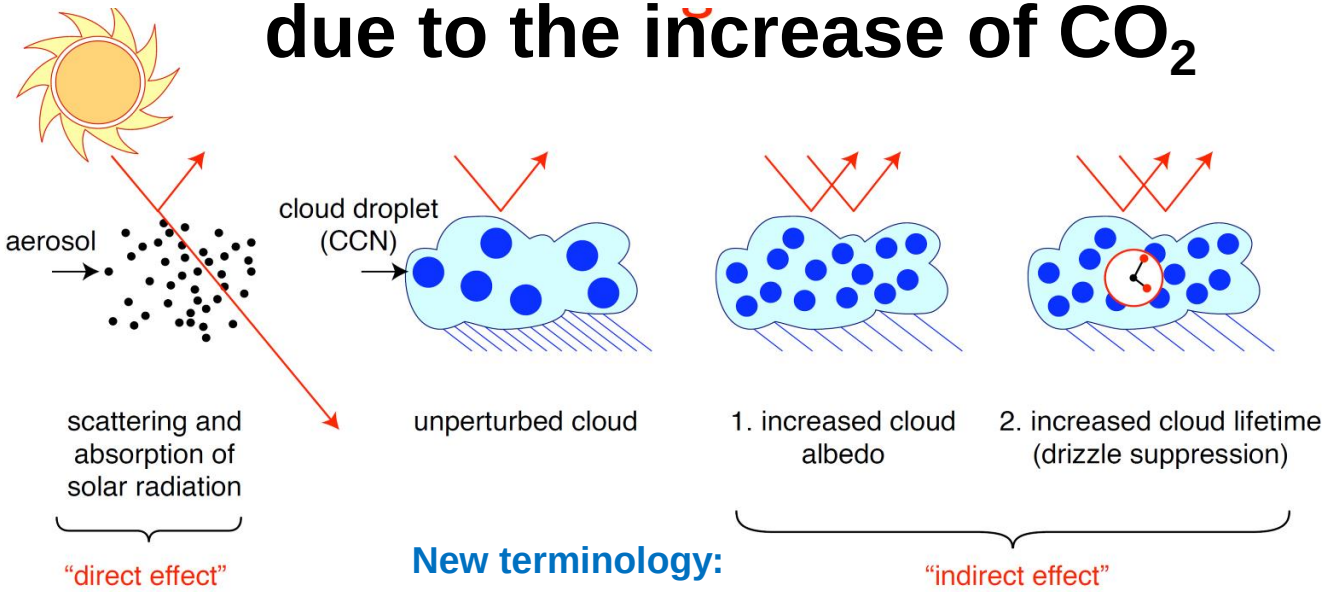
The radiative forcing of aerosols is highly uncertain and a major reason for our inability to predict the warming due to the increase of CO_2

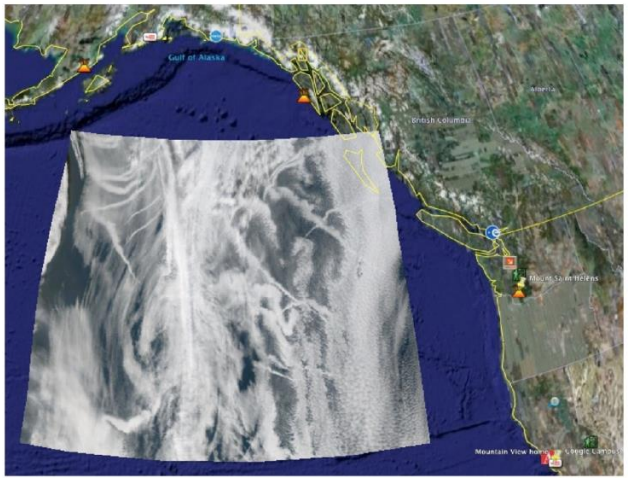


Aerosol-Radiation Interaction

New terminology:

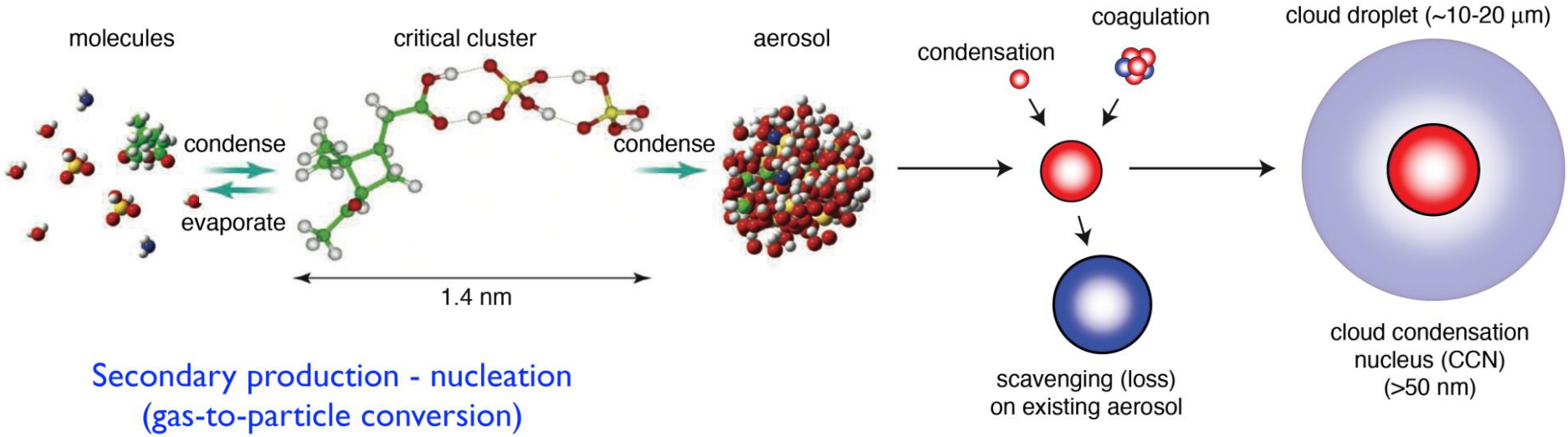
Aerosol-Cloud Interaction

- Aerosols are tiny liquid or solid particles suspended in the atmosphere
- Above 50nm size they provide Cloud Condensation Nuclei (CCN)



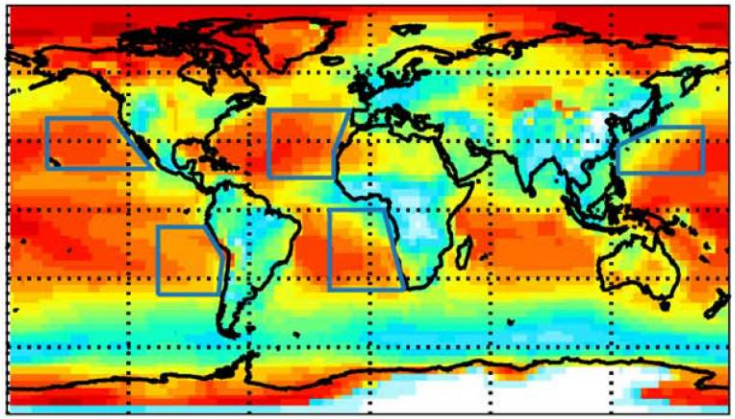
ship tracks forming stratocumulus deck in North Pacific

About 50% of the particles that are able to form cloud droplets are formed by nucleation



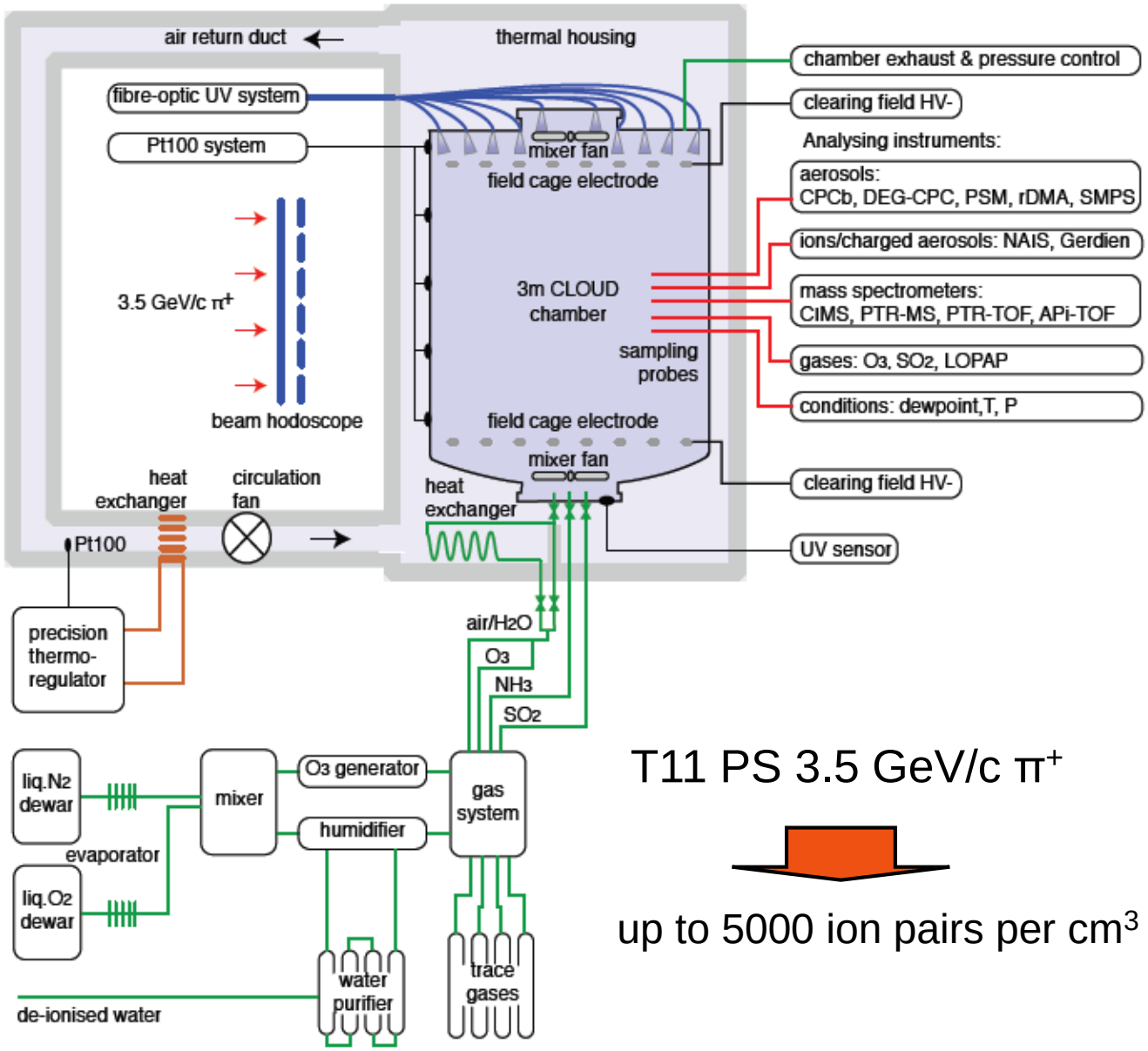
Secondary production - nucleation
(gas-to-particle conversion)

A: CCN(0.2%) contribution from nucleation



Merikanto et al., ACP 2009

The CLOUD chamber



T11 PS 3.5 GeV/c π^+

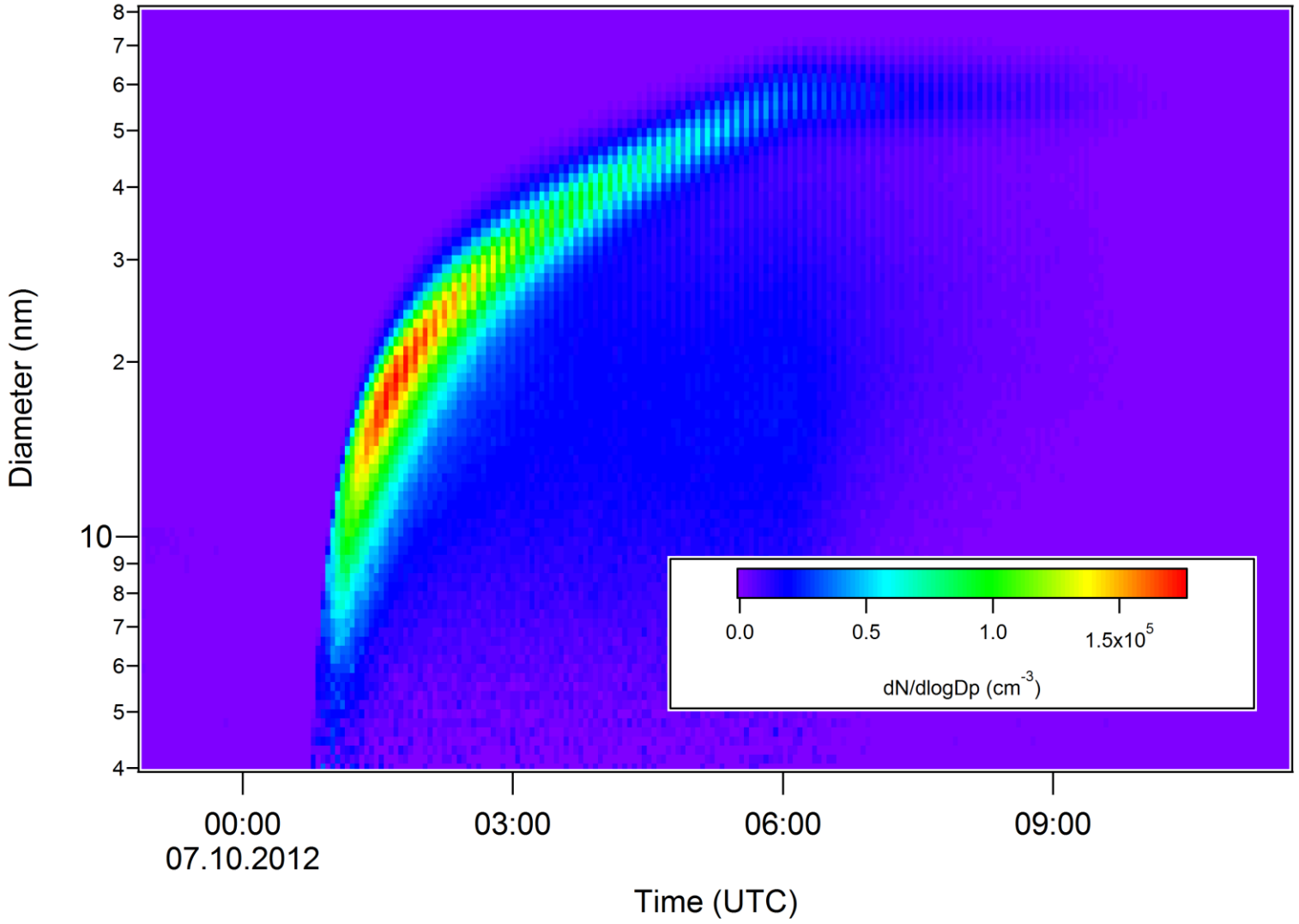
up to 5000 ion pairs per cm^3

Worldwide accepted as the gold standard for nucleation experiments
This is due to:

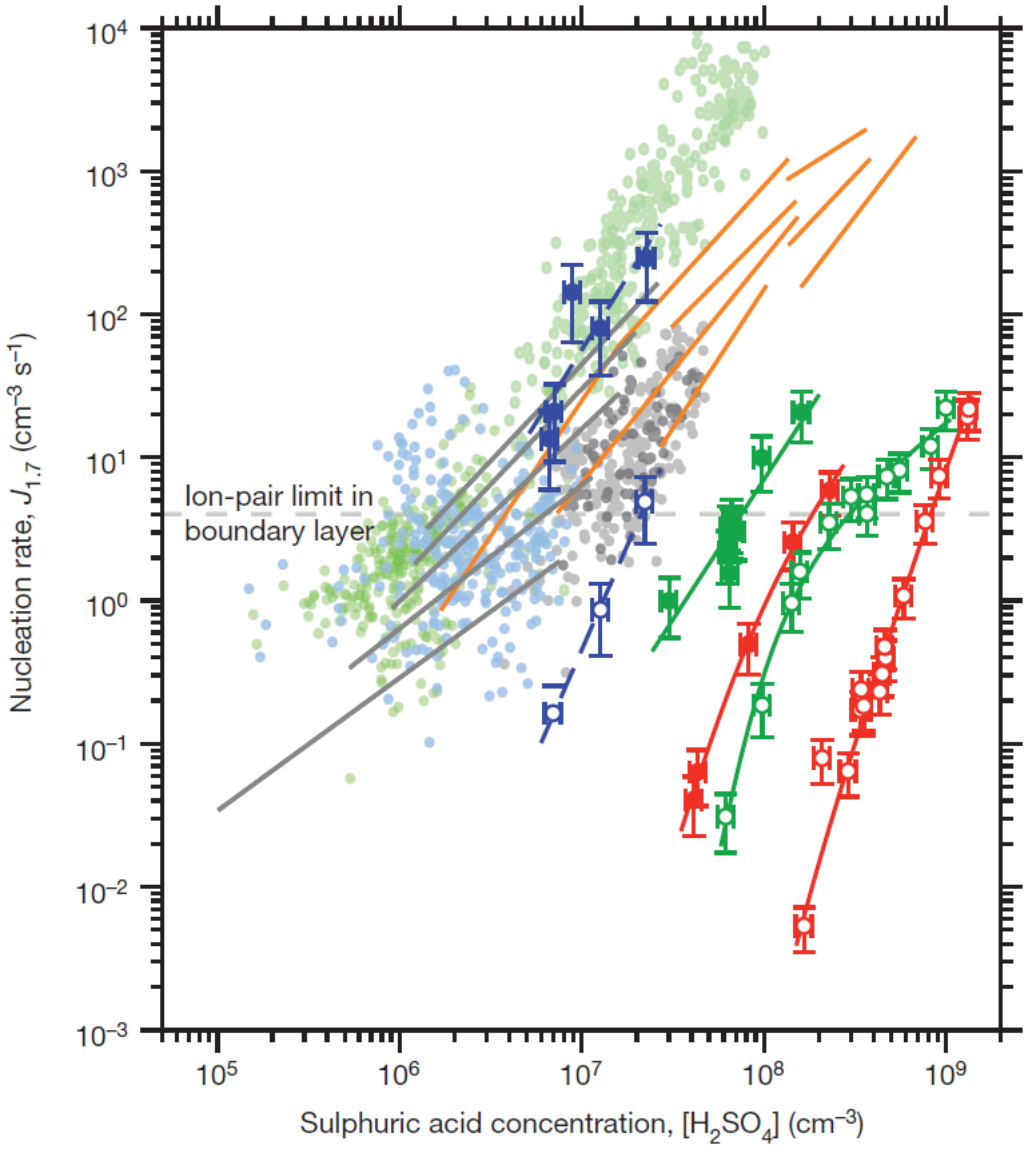
- Construction of a chamber with CERN standard ('no compromises')
- The availability of the beam allowing us to simulate the atmosphere up to the top of the troposphere
- The unique collaboration providing all instruments that one could dream of

Kirkby et al., Nature 2011

A typical ‘nucleation banana’



The first result in 2011:



Red: 19°C
Green: 5°C
Blue: -25°C
Open: without NH_3 (<35 ppt)
Filled: with NH_3 (150-200 ppt)

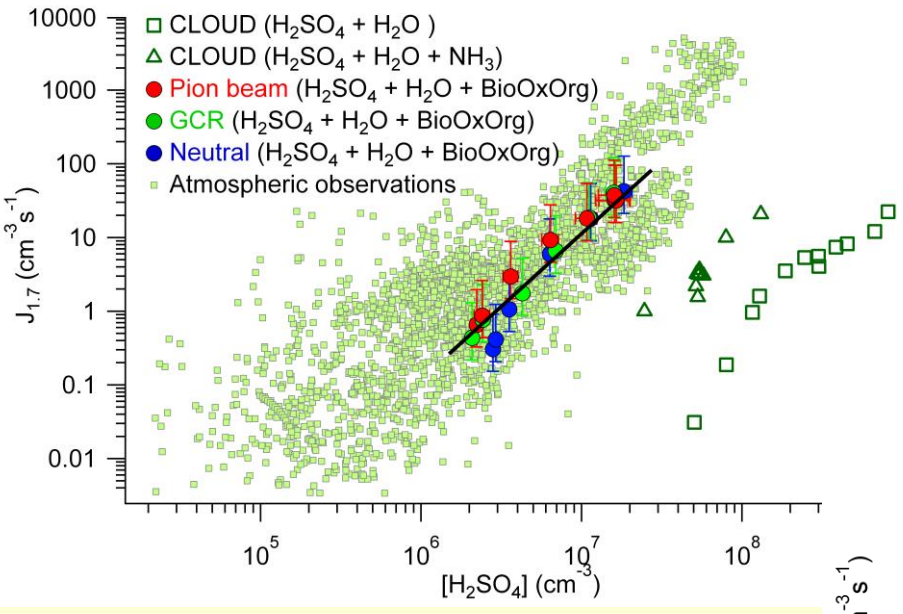
Boundary layer nucleation cannot be explained either by binary (H_2SO_4-H_2O) or by ternary nucleation with ammonia

Even with ion enhancement, ternary NH_3-H_2SO_4-H_2O is too low by a factor 10-1000

Kirkby et al., Nature 2011

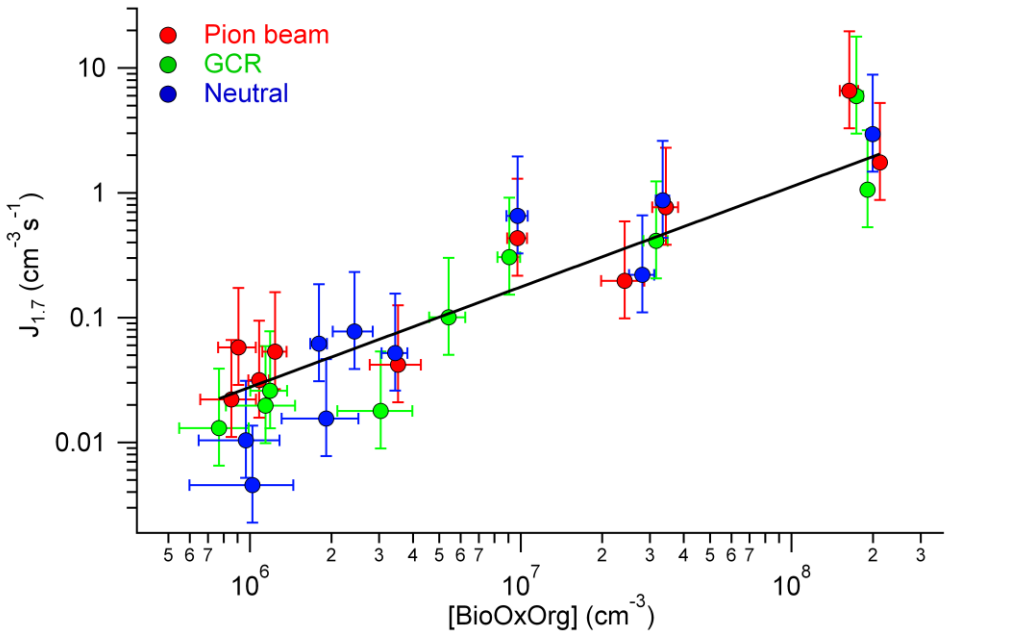
Light dots: atmospheric observations

Nucleation with sulfuric acid and pinanediol oxidation products



H_2SO_4 ~ const

$J \propto$ [BioOxOrg]

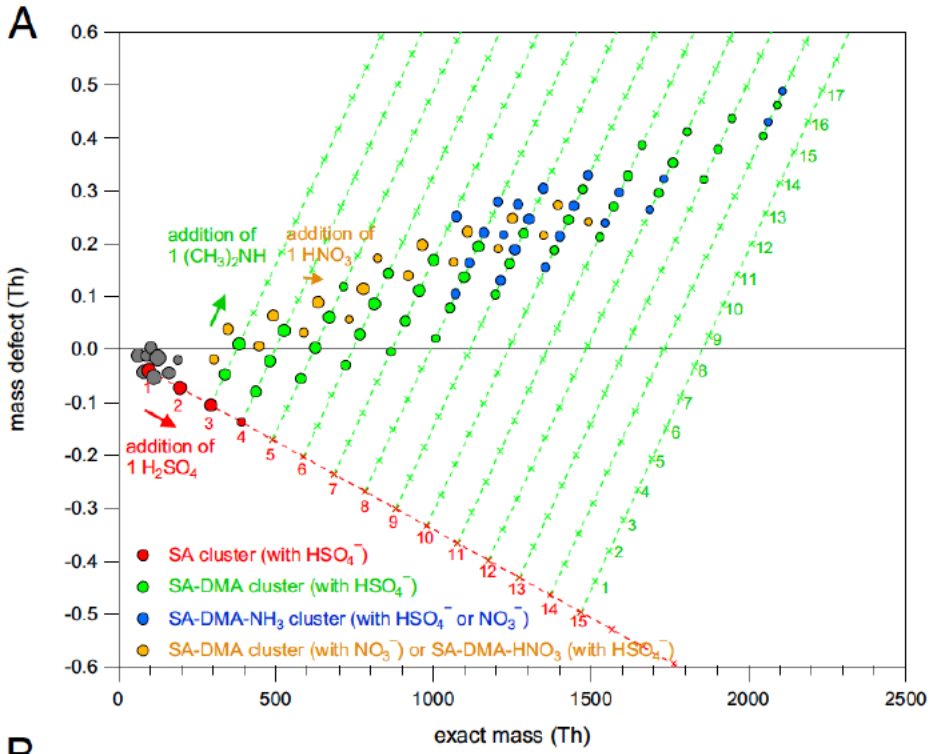


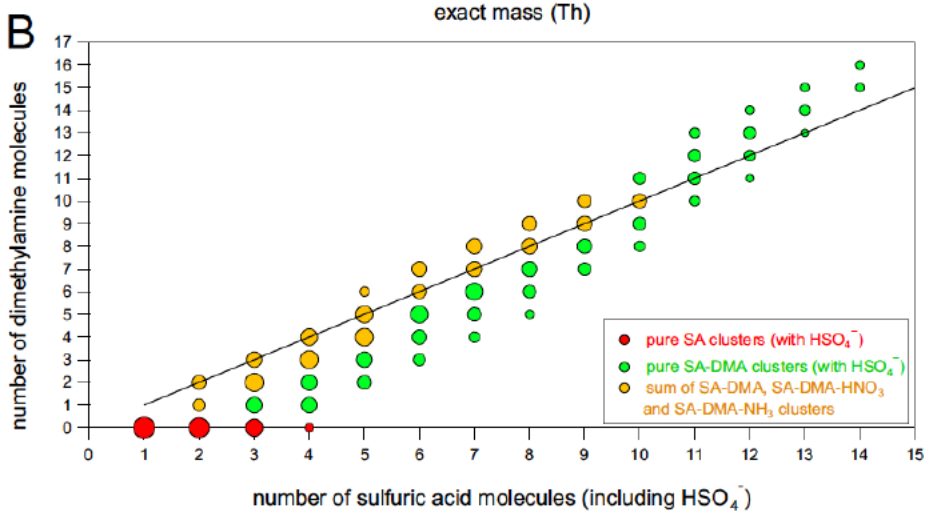
BioOxOrg ~ const

$J \propto [H_2SO_4]^2$

Riccobono et al., Science 2014

First measurement of the molecular composition of neutral nucleating clusters



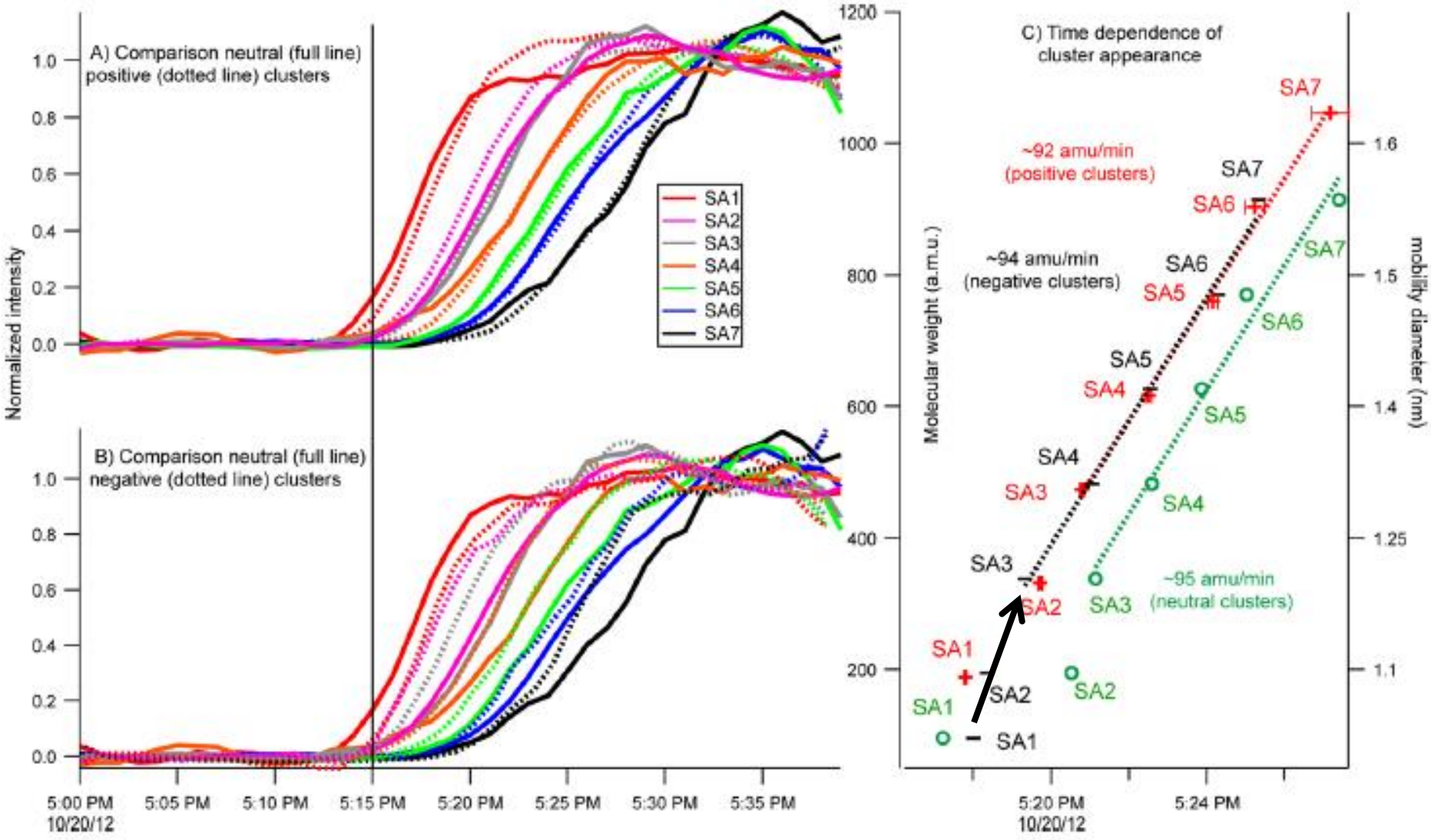


Clusters containing up to 14 SA molecules and 16 DMA molecules detected, corresponding to a mobility diameter near 2.0 nm

Kürten et al., PNAS 2014

Appearence time of clusters

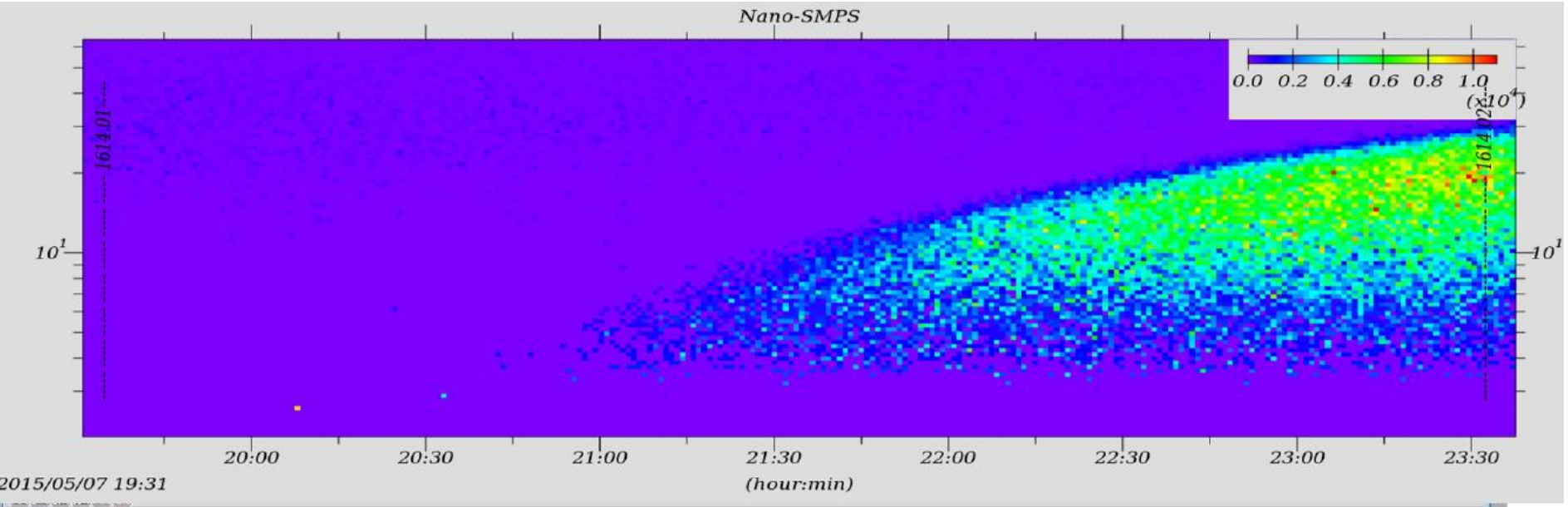
➔ **Comparison of neutral, negative, and positive clusters**

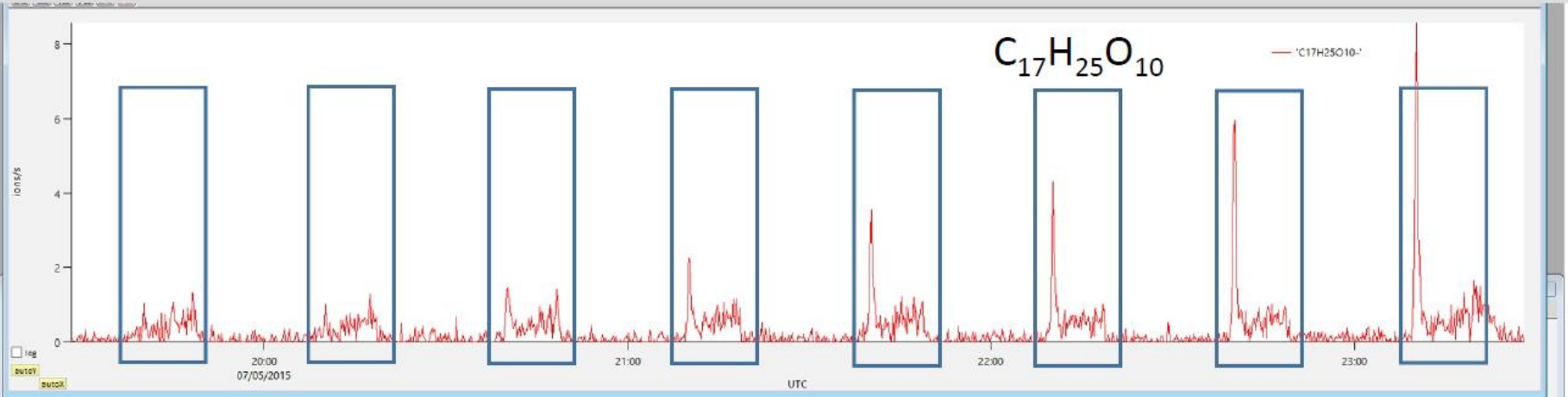


Bianchi et al, ES&T 2014

First measurements from the FIGAERO mass spectrometer in May 2015: Identification of compounds in the particle phase

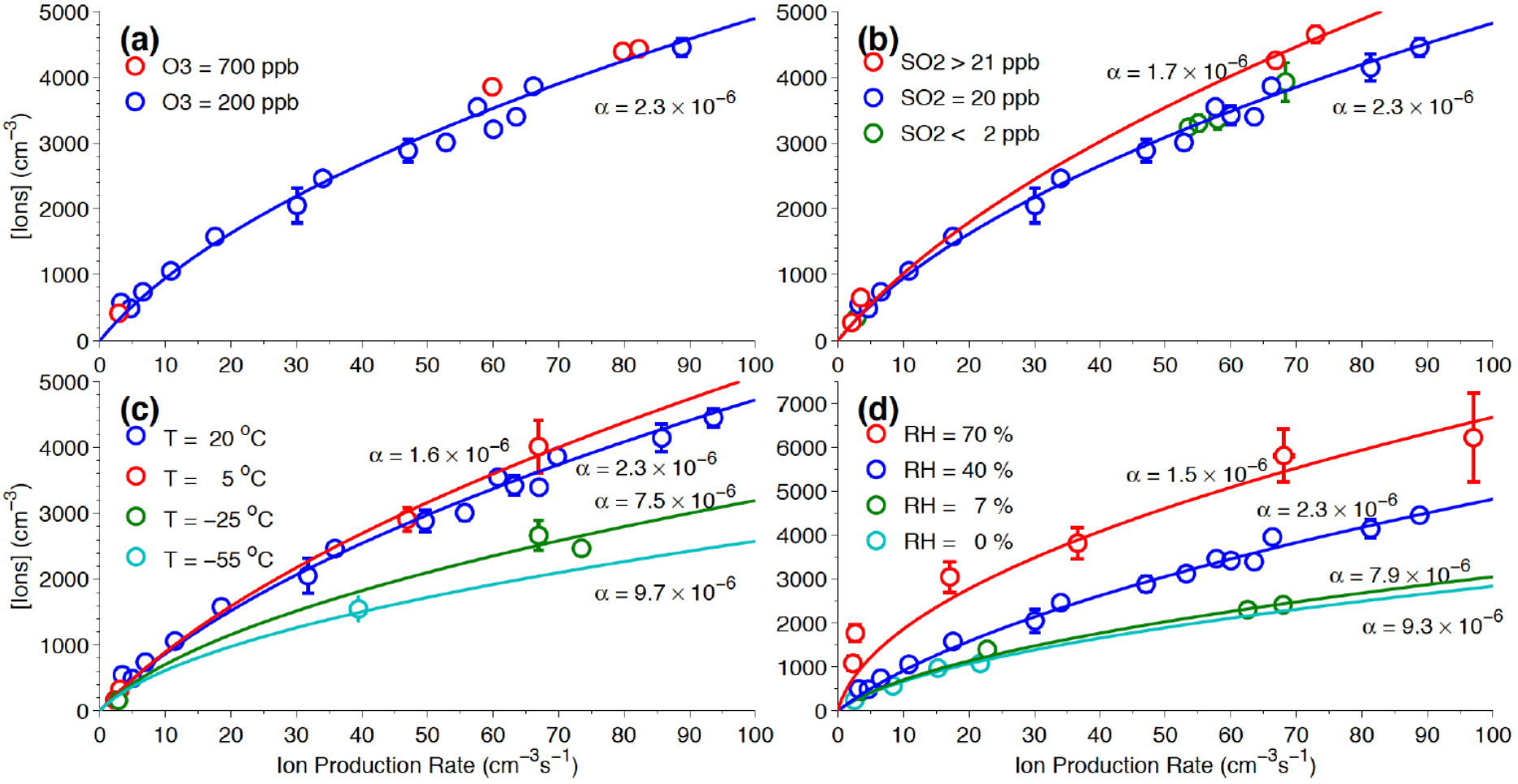
(CLOUD10T (20 Apr – 7 Jun 15)





Dependency of the ion-ion recombination rate on ambient conditions

(larger ions ➔ smaller recombination rate)

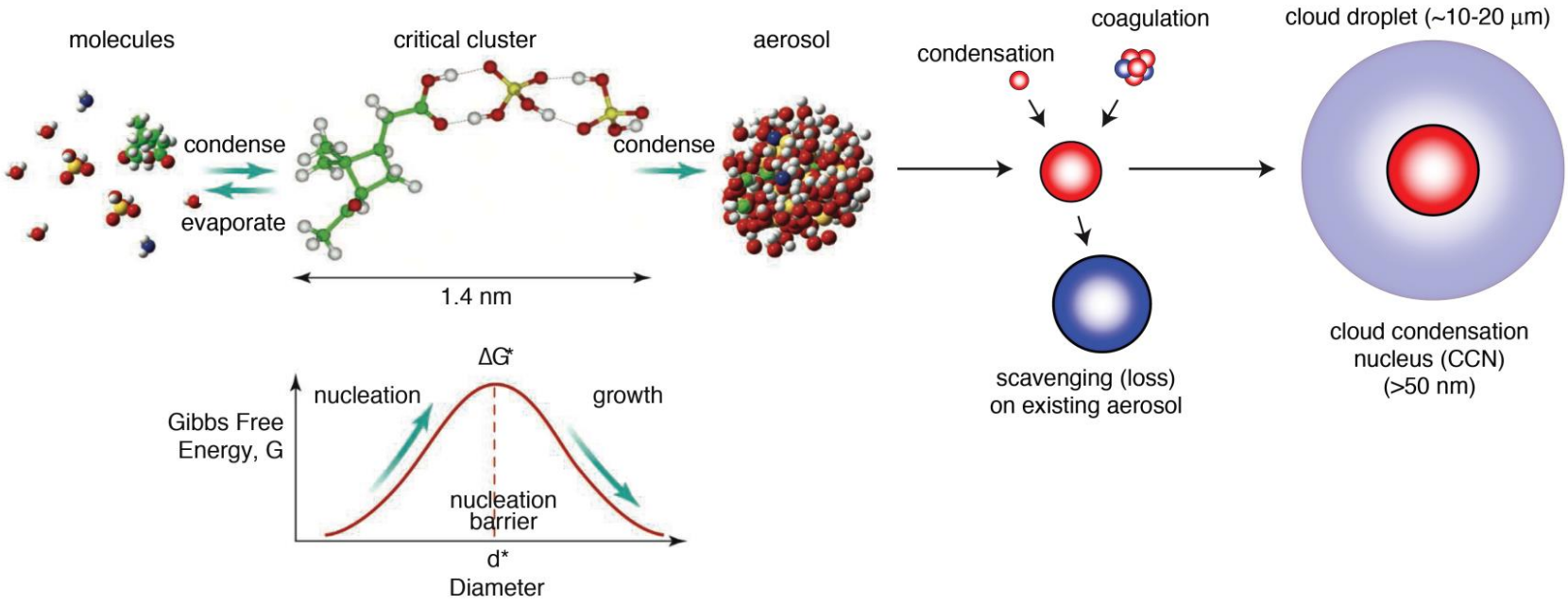


Franchin et al., ACPD, 2105

Achievements so far

- Very high recognition for CLOUD experiments in the scientific community
- CLOUD perceived to be able to answer the open research questions related to nucleation
- Very high echo in media (of the positive kind…)
- Research groups in other continents consider seriously building their own CLOUD chamber
- Papers in high profile journals:
  2011: 1
  2013: 2
  2014: 2
  2015: 1 under review, 2 to be submitted within a month
- Other papers: 12 published, 3 in review, up to 10 expected to be submitted this year

So, why do we need another 10 years to answer the research question?



- Which components stabilize sulfuric acid clusters (enhancing the nucleation rate)?
  ➔ Amines, oxidized organics, and to a lesser extent ammonia)
- Degree of stabilization for full range of atmospheric conditions
  ➔ Temperature, concentrations, combinations of components , oxidants
- Nucleation also possible without sulfuric acid?
- What is the effect of ions for the full range of atmospheric conditions?
- Feed a global model wit the fully parameterized experimental space

Experimental plan for CLOUD 10 (28 Sep – 4 Dec 2015)

1. Simulation of aerosol particle nucleation and growth at the Hyytiälä boreal forest station under daytime and night-time conditions, involving mixtures of gases that include SO_2, O_3, α-pinene, Δ3-carene, NH_3, NO, NO_2 and H_2O.
2. Systematic data at a range of vapour concentrations, beam intensities and temperatures to parametrise H_2SO_4/biogenic nucleation for evaluation of its climate impact using the Leeds global aerosol model, GLOMAP.
3. Isoprene (C_5H_8) oxidation chemistry, and the effect of ions.
4. First look at particle production from anthropogenic volatile organic compounds.

Instruments during CLOUD 10

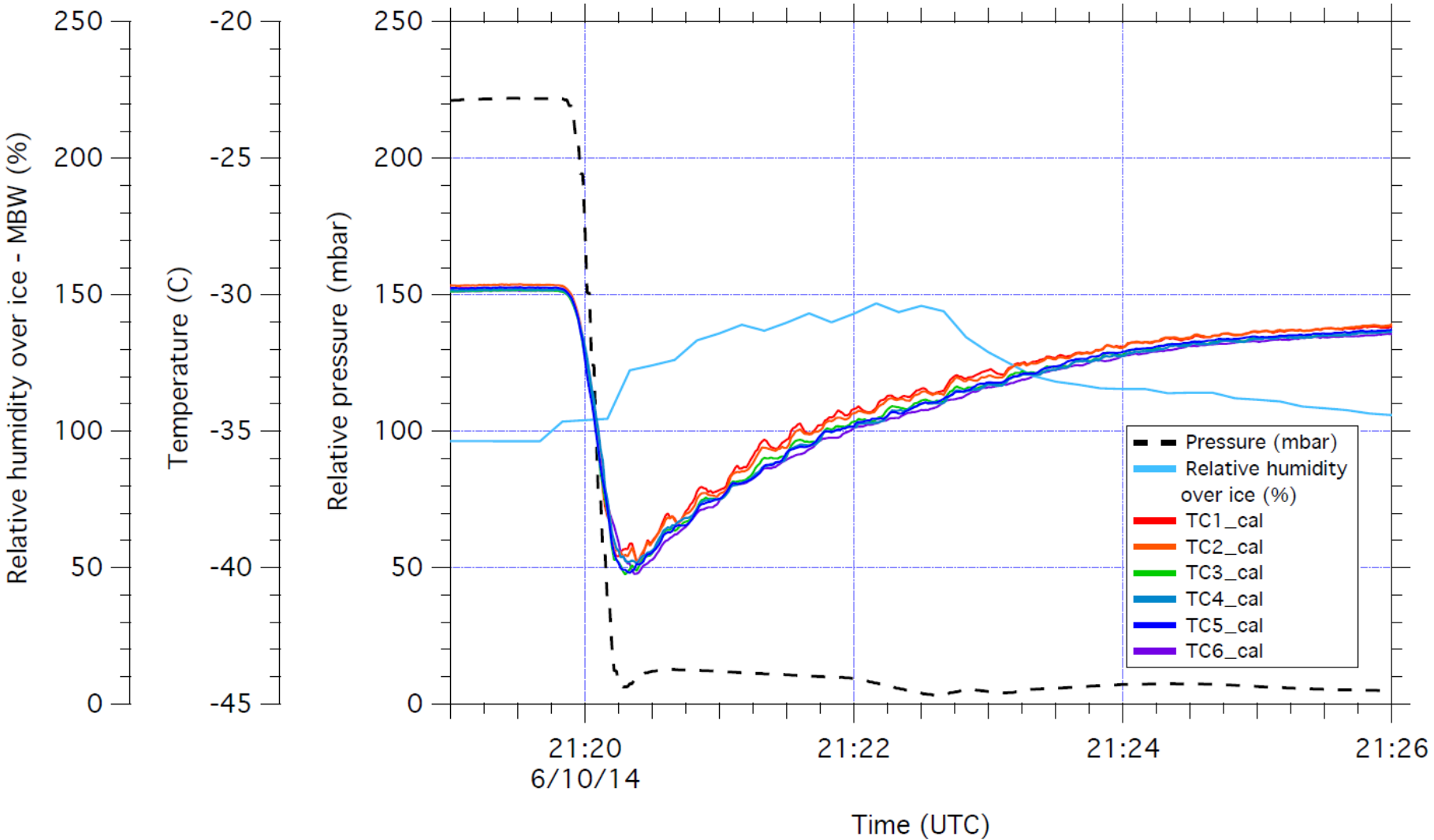
Mass Spectrometers:	
NO3- CI-API-TOF	UHEL
NO3- CI-API-ToF + TD-DMA	Frankfurt
Acetate CI-API-TOF	Kuopio
Acetate CIMS (NH3)	Frankfurt
API-TOF (-ve)	UHEL
NH4+ CI-APi-ToF	PSI/Tofwerk
IMS-TOF	PSI
PTR-TOF	Innsbruck
FIGAERO I- CIMS	Aerodyne/CERN
TDCIMS	Kuopio
Peroxy-CIMS	CMU

Particle counting / sizing:	
NanoSMPS	PSI
SMPS	PSI
CPC 2.5	PSI
CPC 3010	PSI
DMA Train	Vienna
PSM scanning	UHEL
PSM 1.3 nm	UHEL
PSM 1.5 nm	UHEL
PSM Ion	UHEL
NAIS	UHEL
Nano HT-DMA	Kuopio
VIPER	Frankfurt
nano radial DMA	Caltech

Gas measurements / UV / DP / other:	
O3 monitor	CERN/EMPA
O3 monitor	Frankfurt
SO2 monitor	Frankfurt
NO 10 ppt	PSI
NO2 10 ppt	PSI / CU-Boulder
NO2 30 ppt	PSI
CO/ CO2 monitor	Frankfurt
DOAS (glyoxal)	CU-Boulder/PSI
Dew Point Mirror	Tropos
Dew Point Mirror	CERN
Dew Point TDL	KIT
GCR counter & Hodoscope	Lebedev
Temperature sensors	CERN
UV spectrometer	CERN / CMU
UV laser (248 nm)	CERN
absolute air pressure	CERN
cryogenic N2 and O2 gauges	CERN

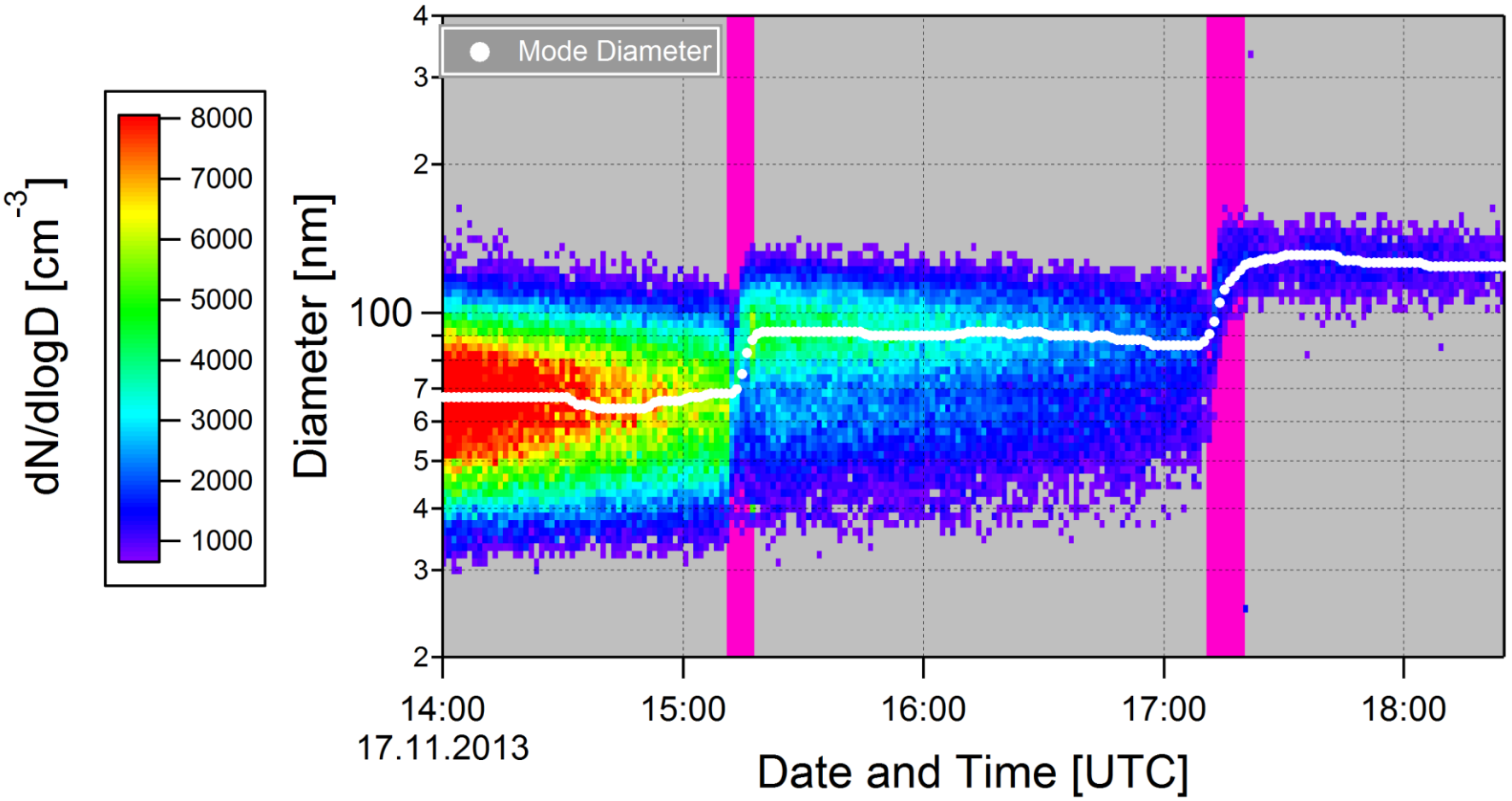
Unprecedented suite of instruments, example: 11 mass spectrometers

Other important research areas: Activation of clouds in the CLOUD chamber by controlled adiabatic pressure reduction: Effect of ions?



Aerosol processing of SO_2 into H_2SO_4 in cloud droplets: Fully controlled in situ chemistry in cloud droplets

up to 50% of secondary organic aerosol expected to form in aqueous phase



Hoyle et al., in prep.

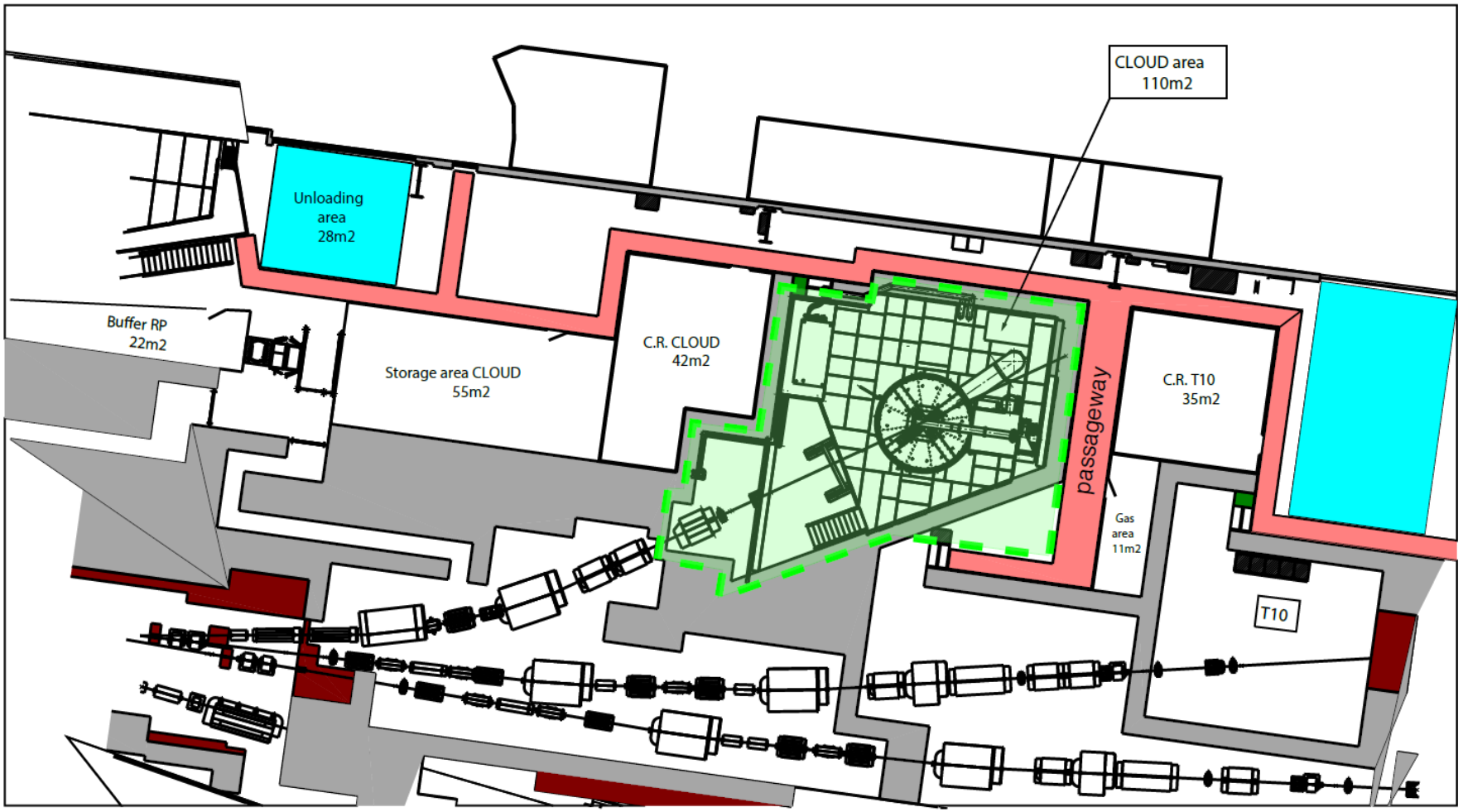
PAUL SCHERRER INSTITUT

PSI

cloud

Issues

We need the T11 beamline (with a small extension)



A potential move to T9 would be extremely costly, would prevent us from 2 years of productivity, and would severely constrain our flexibility in the use of the beam time

We need a permanent CLOUD open office/meeting room of 50 m^2 close to T11

- Daily data analysis and run coordination meetings during data taking at the CERN PS.
- Weekly technical planning and physics meetings for the CERN team throughout the year, including audio-visual communications with the CLOUD members.
- An open office for the CERN CLOUD team.
- Open office space for CLOUD experimenters during experimental runs at the CERN PS (T11 CLOUD counting room not suitable for this)

We need a minimum of 2 FTE CERN technical support staff

This is needed just to prepare CLOUD for each run at the PS, without even considering detector upgrades

Without adequate technical support from CERN there is a real danger that CLOUD will be unable to carry out its planned scientific programme

Thank you for your attention

Acknowledgment:
We would like to thank CERN PH-DT, EN-MME, Lau Gatignon, the PS Coordinator and the CERN PS machine team for their support of CLOUD.

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