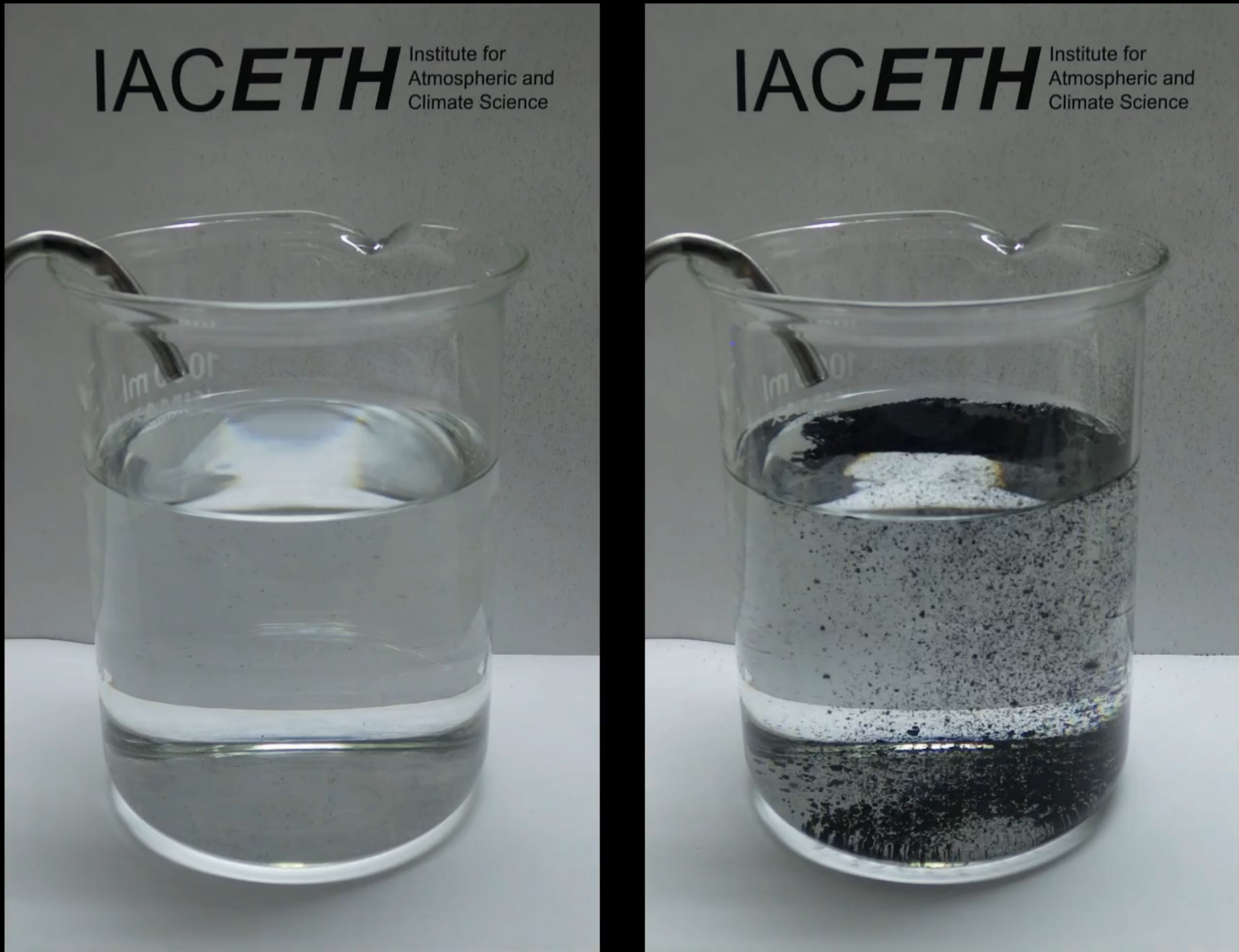
IACETH Institute for Atmospheric and Climate Science
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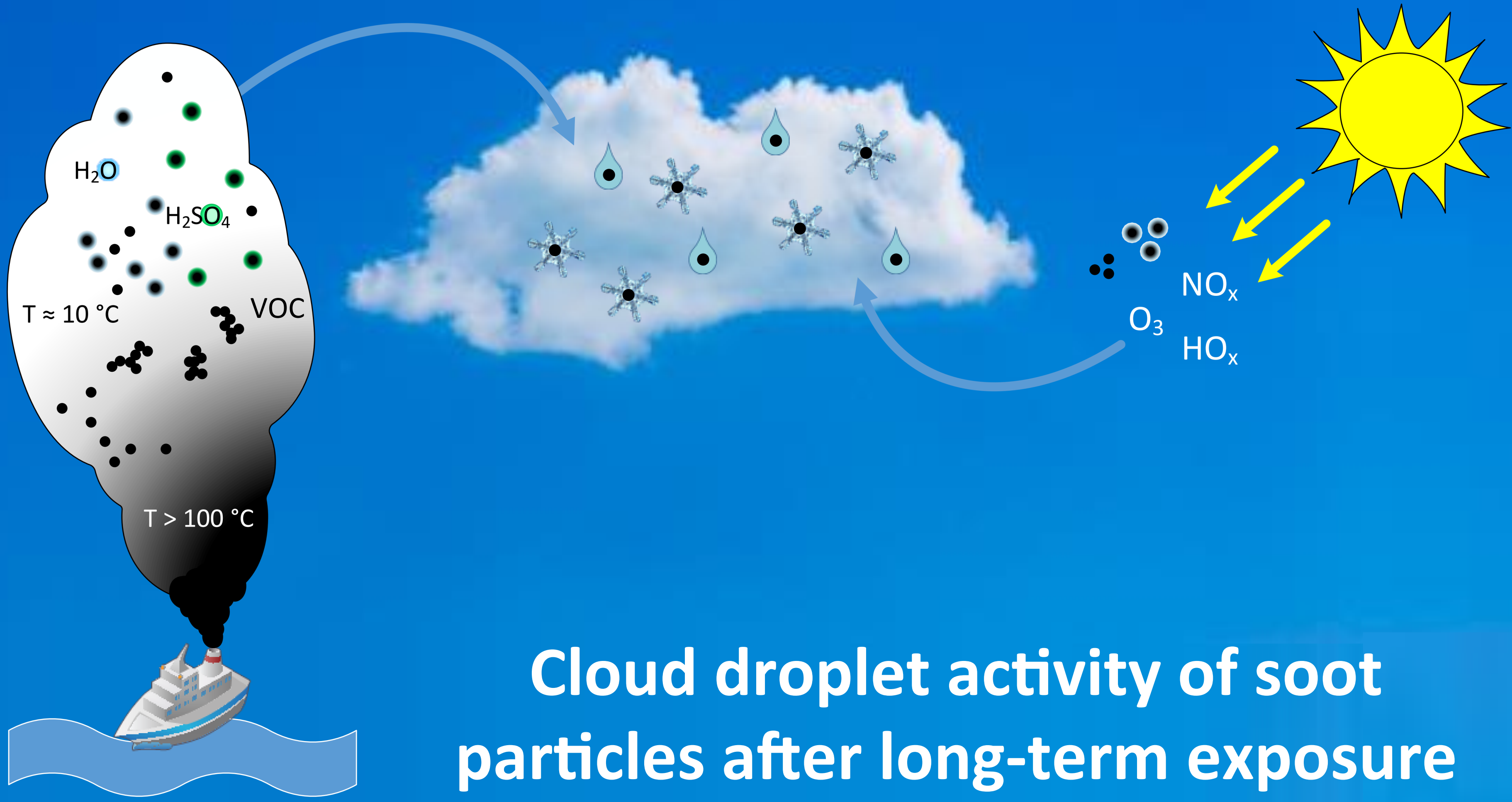
Air Ozone



Cloud droplet activity of soot particles after long-term exposure to ozone and α-pinene

Franz Friebel and Amewu A. Mensah

ETH zürich

Cloud Condensation Nuclei Activity

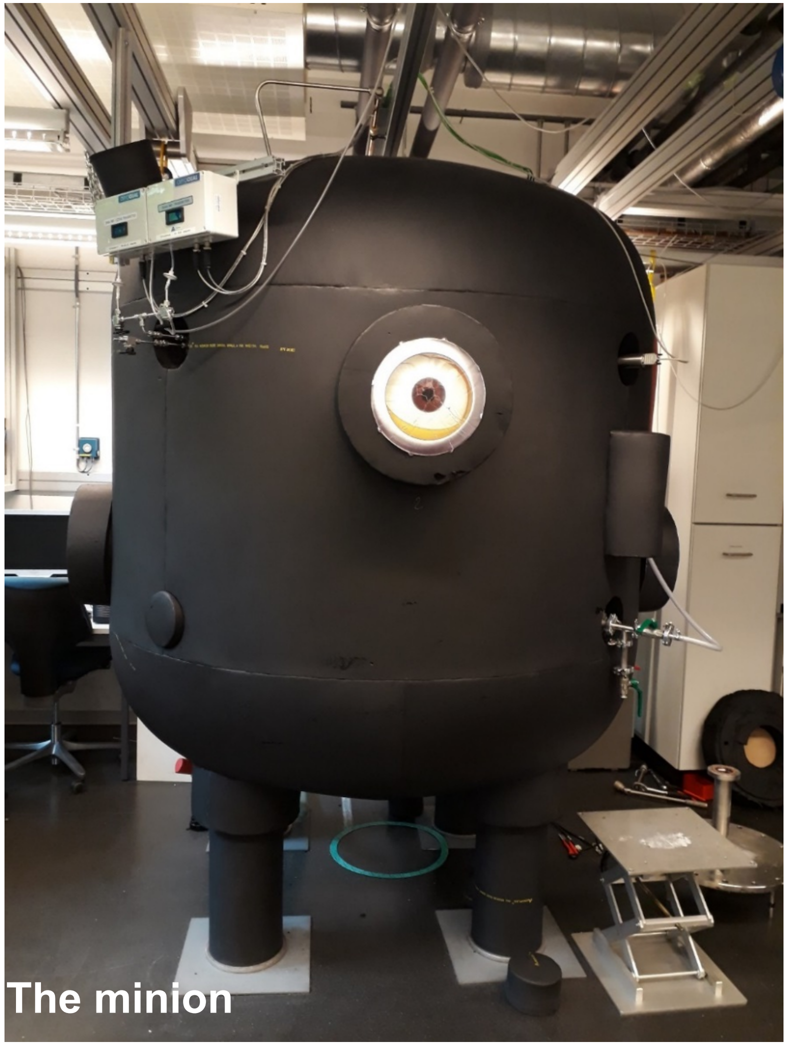
Cloud Condensation Nuclei Activity

Continous-flow Stirred Tank Reactor (CSTR)

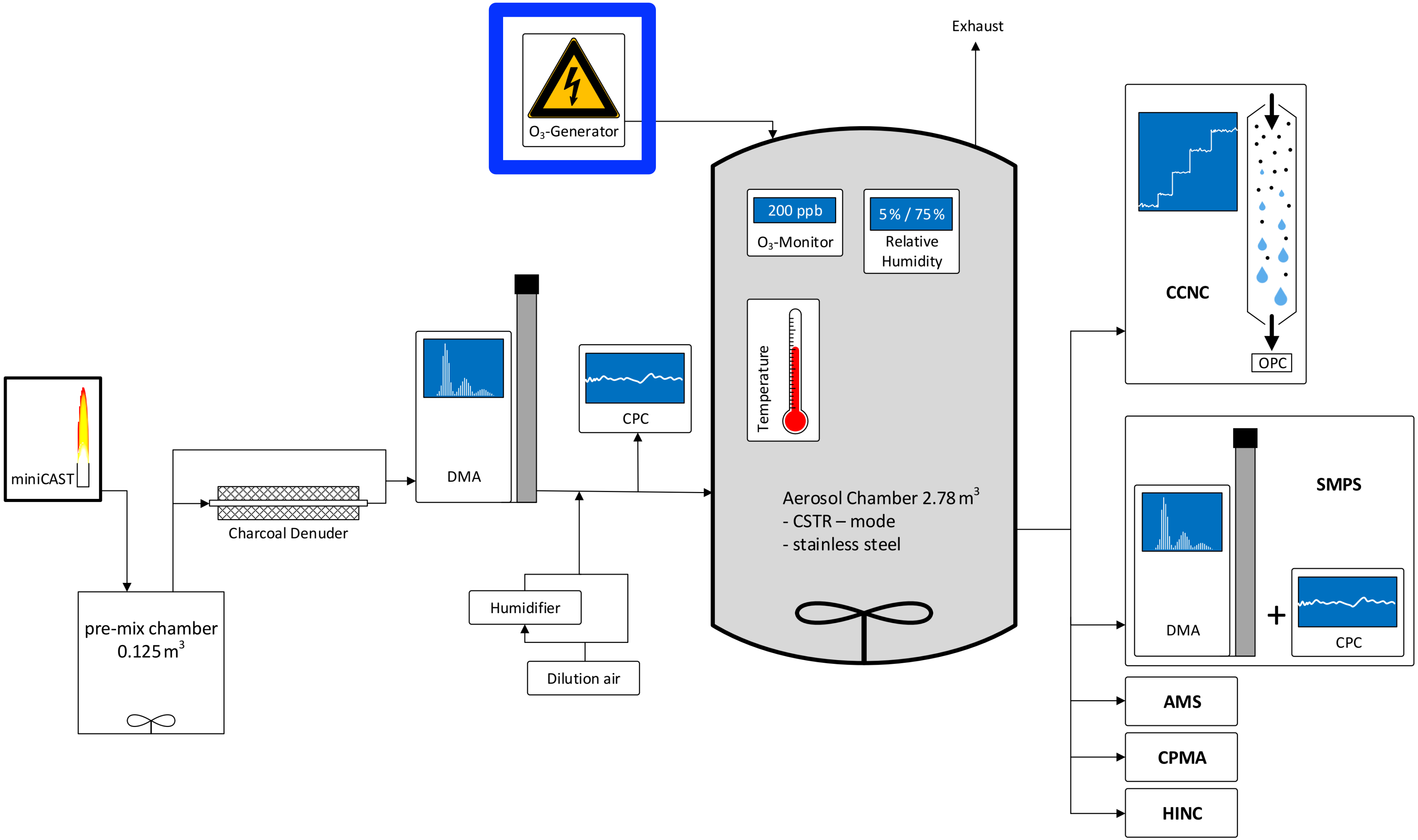
- 100 nm soot particles
- 16 h aging time
- miniCAST brown / black

VOCs Yes/No ⟷ Ozone 0 - 200 ppb

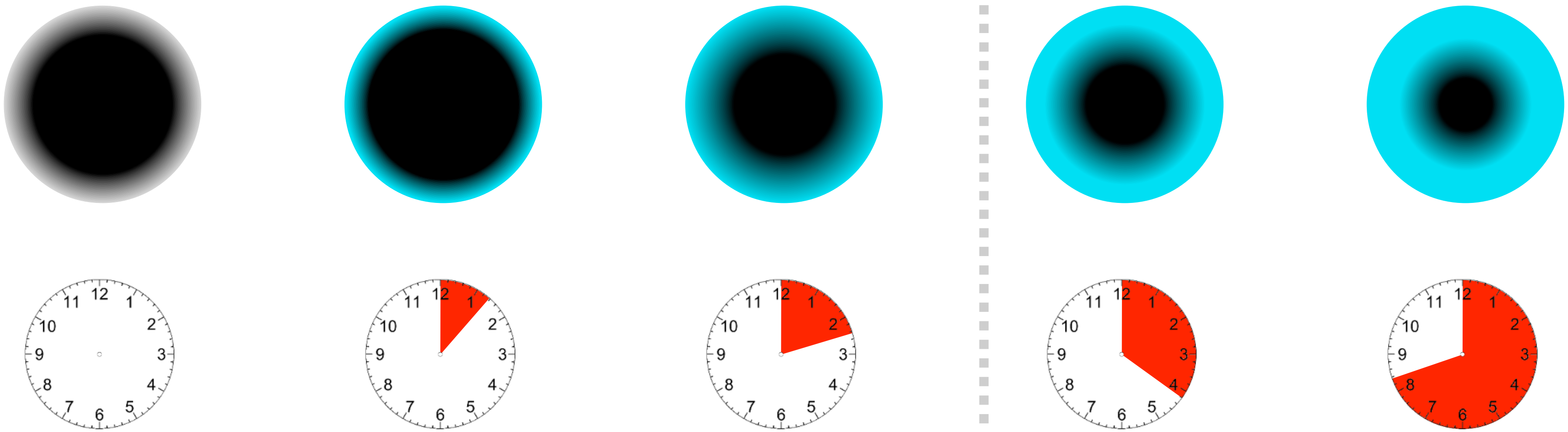
RH 5-80% ⟷ Temperature 5 - 35 °C



Setup 1


O$_3$-Generator
Exhaust
200 ppb
O$_3$-Monitor
5 % / 75 %
Relative Humidity
Temperature
Aerosol Chamber 2.78 m^3
- CSTR – mode
- stainless steel
CCNC
OPC
SMPS
DMA
CPC
AMS
CPMA
HINC
miniCAST
pre-mix chamber 0.125 m^3
Charcoal Denuder
DMA
CPC
Humidifier
Dilution air

Activation time ($t{\downarrow}act$)

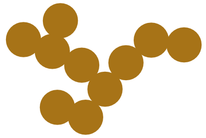
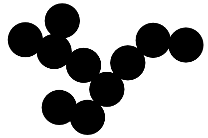


$t{\downarrow}act$ … activation time

CCN-inactive

CCN-active

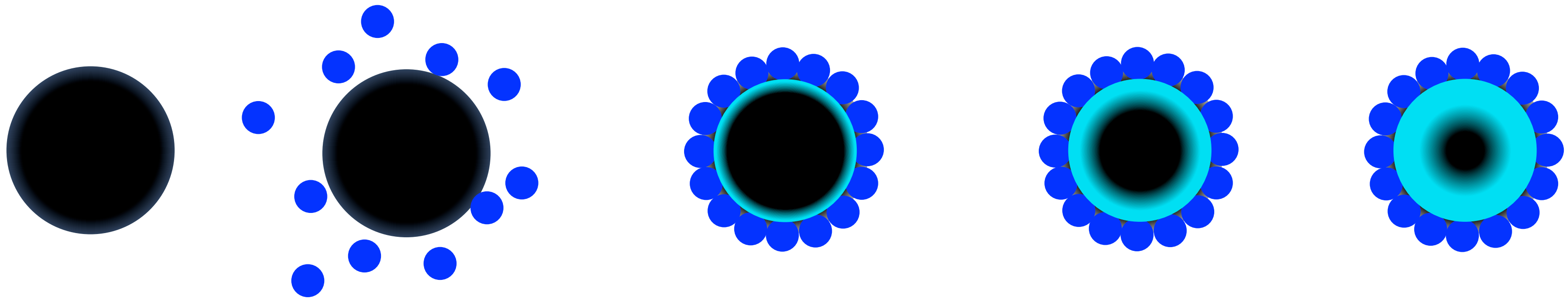
miniCAST Soot + 200 ppb O_3

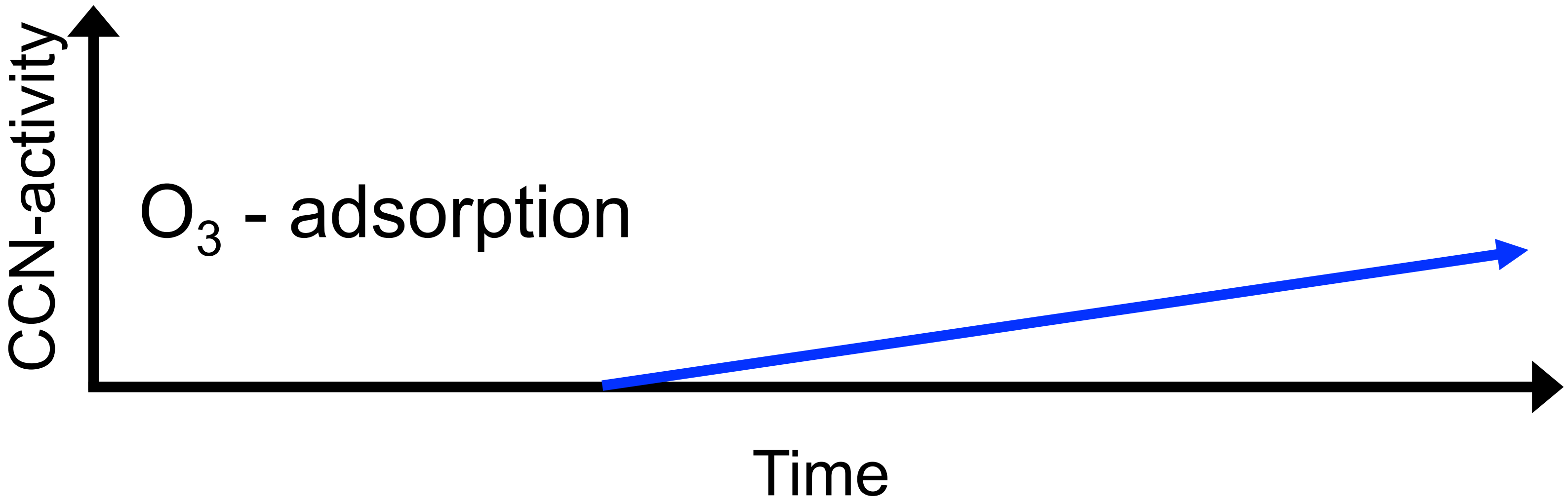
	CBw 	CBk 
fuel / air - ratio	**1.03**	**0.95**
organic carbon content [1]	**30 – 60%**	**≈ 10%**

super saturation	**activation time (t_{act}) / min**	
1.2 %	**151**	**---**
1.4 %	**116**	**733**
1.6 %	**---**	**568**

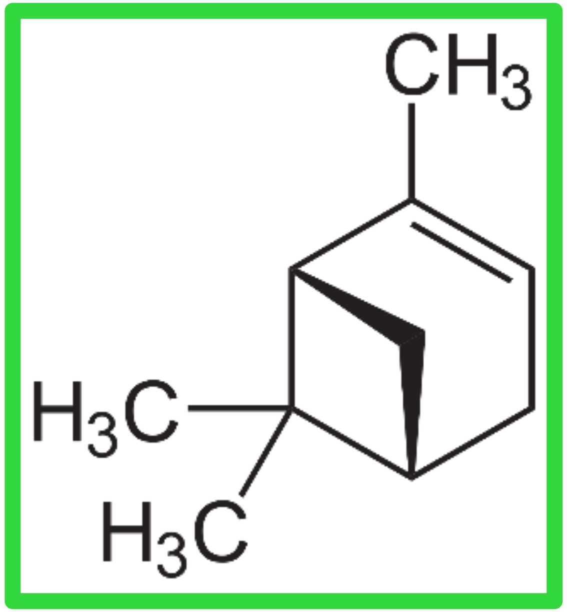
[1] Török, S. et al., AST 2018.

O_3 - heterogenous oxidation





Soot + O_3 + volatile organic compounds (VOCs)

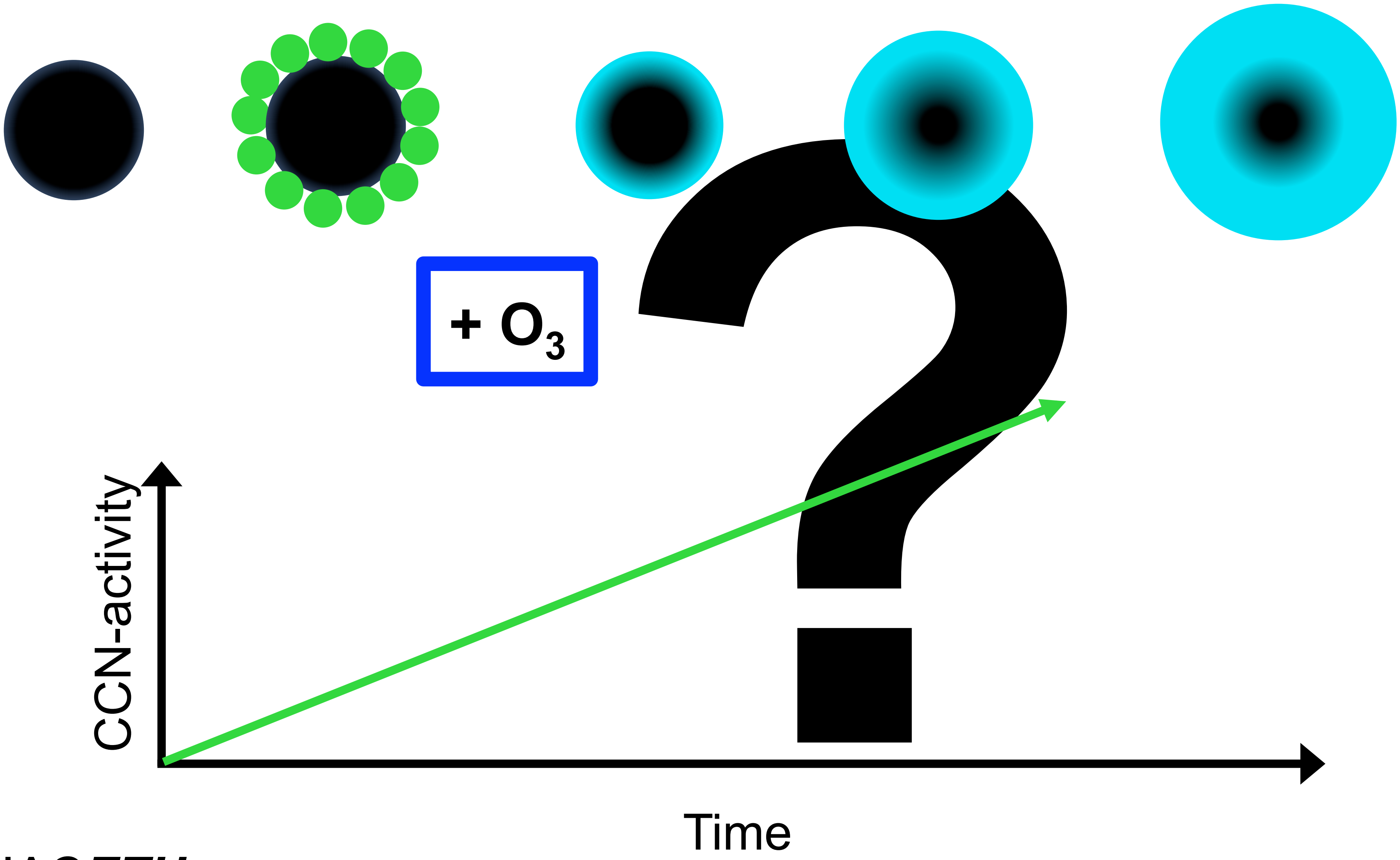


α-pinene

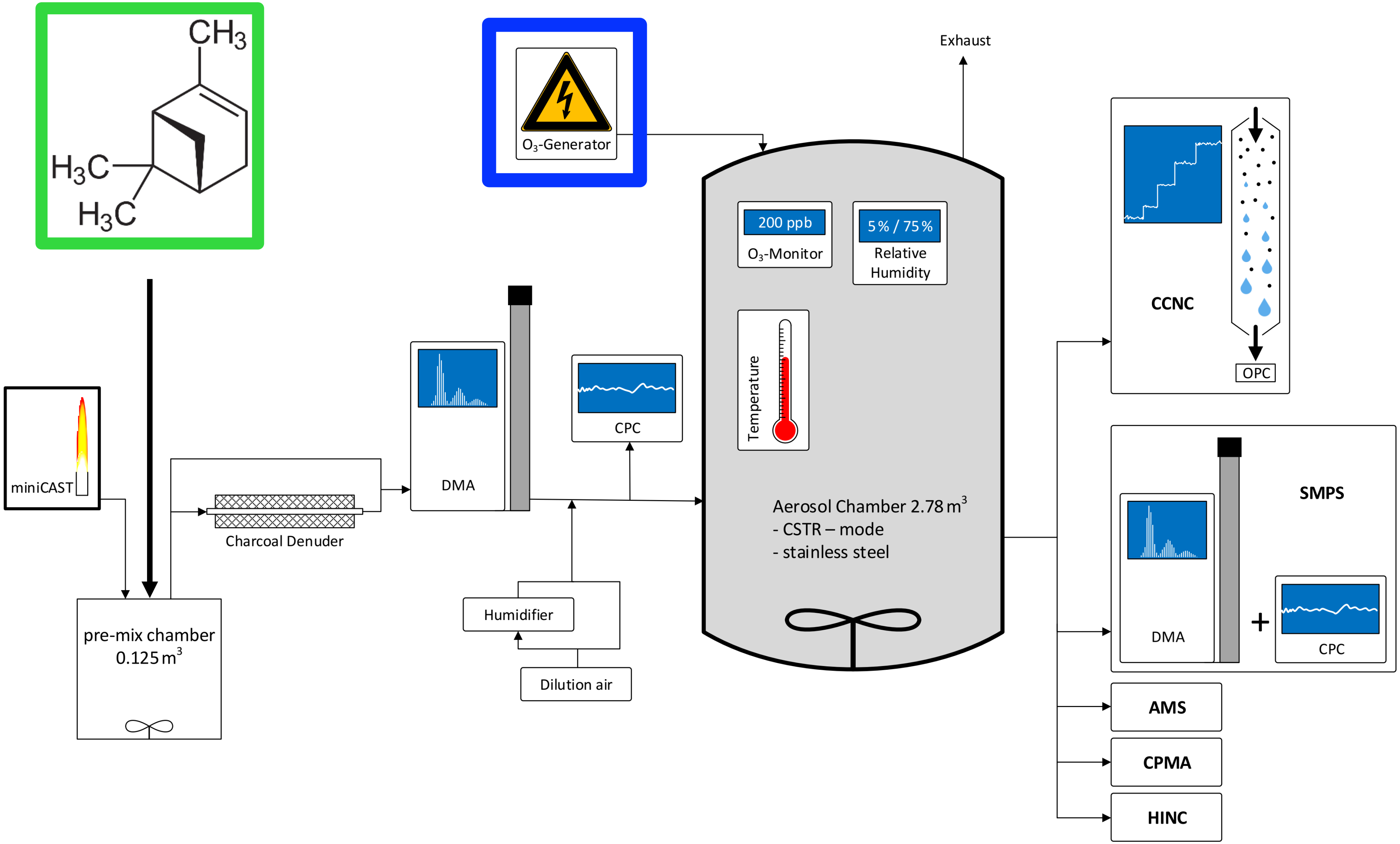
Pine tree


ETH zürich
IAC Institute for atmospheric and Climate Science
150
100
50
MHD: 8.1.2021
Tel. 044 241 10 50;

Idea: α-Pinene coating and oxidation



Setup 2



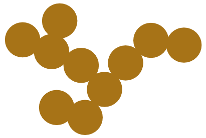
CH3
H3C
H3C
O3-Generator
Exhaust
200 ppb
O3-Monitor
5 % / 75 %
Relative Humidity
Temperature
Aerosol Chamber 2.78 m3
- CSTR – mode
- stainless steel
CCNC
OPC
SMPS
DMA
CPC
AMS
CPMA
HINC
miniCAST
Charcoal Denuder
DMA
CPC
Humidifier
Dilution air
pre-mix chamber
0.125 m3

miniCAST Soot + 200 ppb O_3 + α-pinene

	CBw	CBk
fuel / air - ratio	**1.03**	**0.95**
organic carbon content [1]	**30 – 60%**	**≈ 10%**

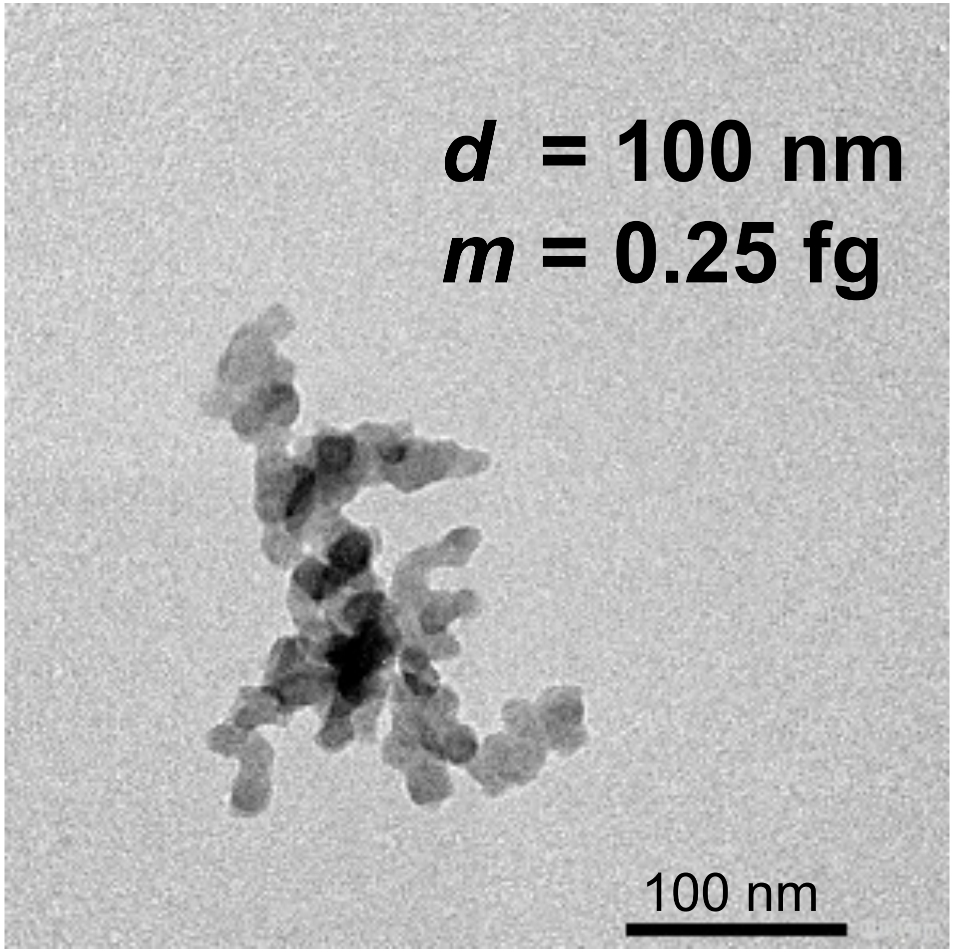
super saturation	**activation time (t_{act}) / min**			
1.2 %	**151**	**68**	**---**	**46**
1.4 %	**116**	**30**	**733**	**32**
1.6 %	**---**	**---**	**568**	**---**

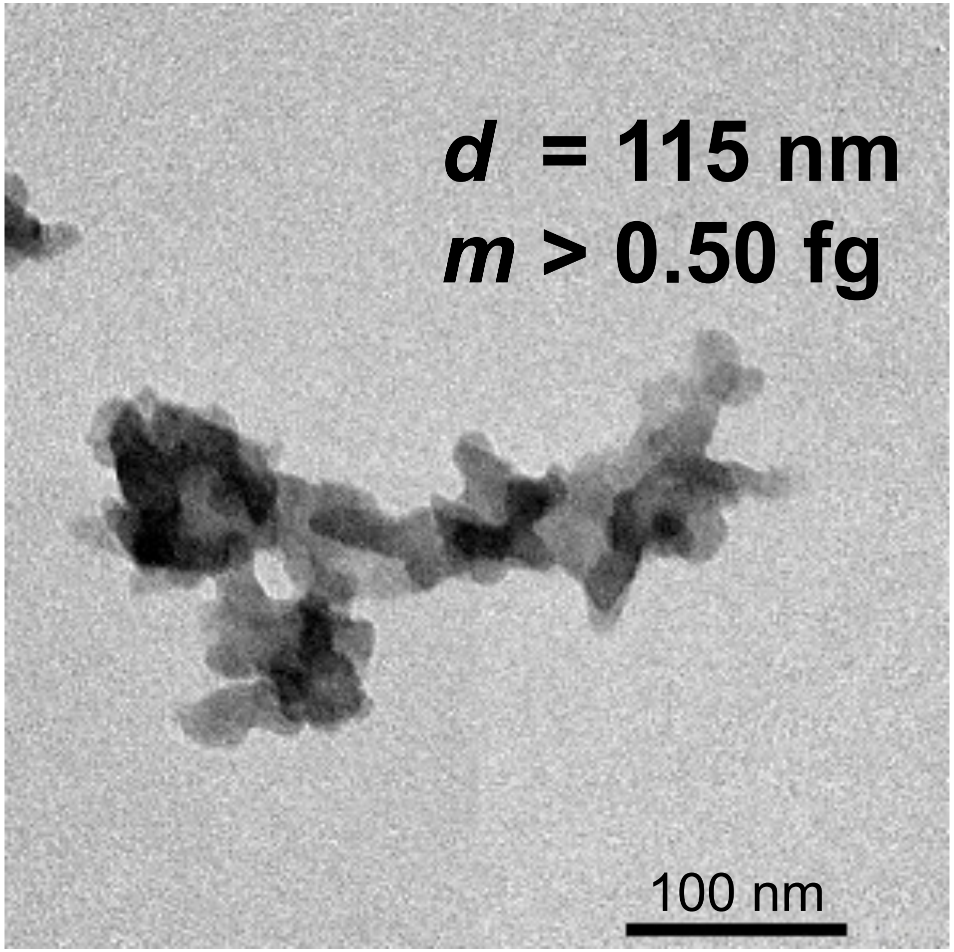
CBw



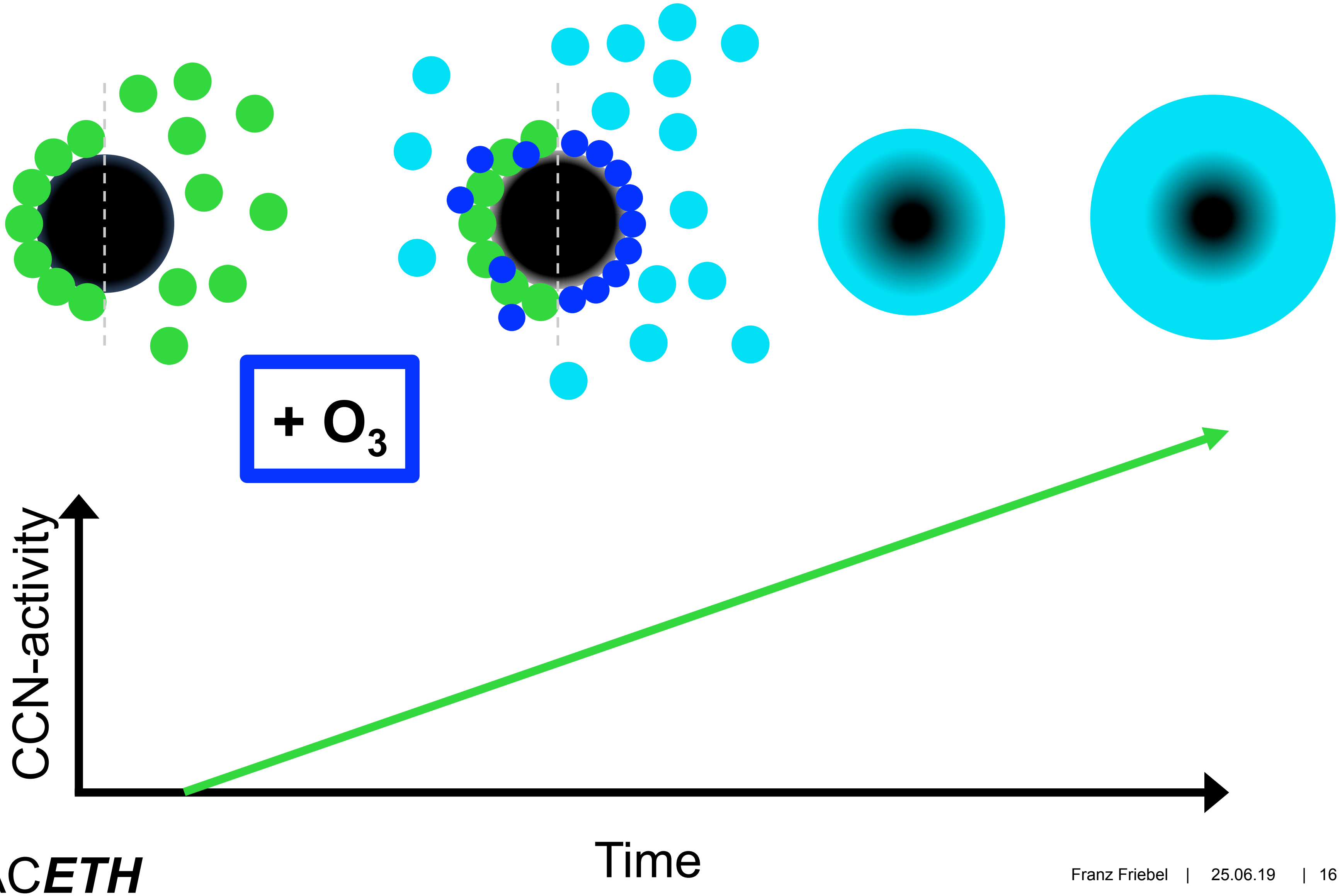
unaged

O_3 + pinene + 16 h



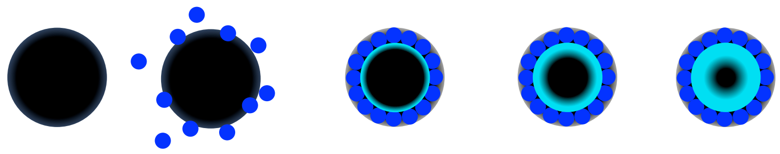


α-Pinene; homogenous oxidation

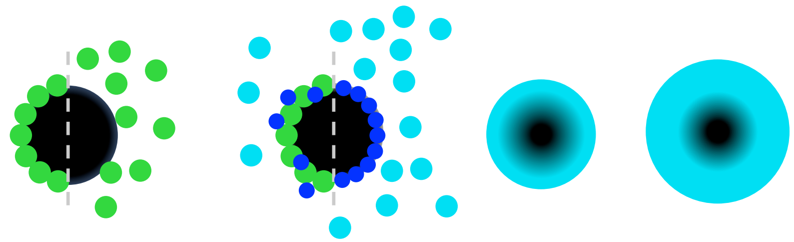


What do learn from that?

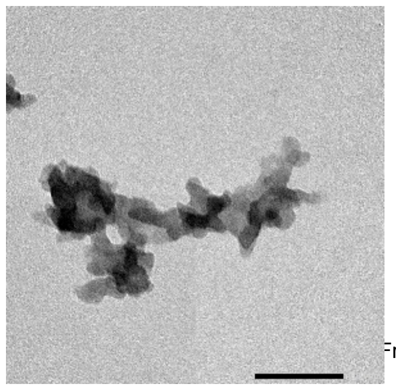
- CBw becomes CCN-active **faster** than CBk **upon** exposure to O_3

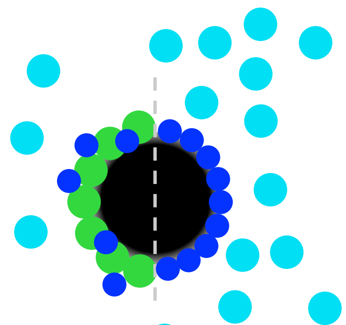


- CCN-activity ↑ with α-pinene + O_3
  - **no difference** between CBk and CBw



- Gas phase oxidation of α-pinene and condensation



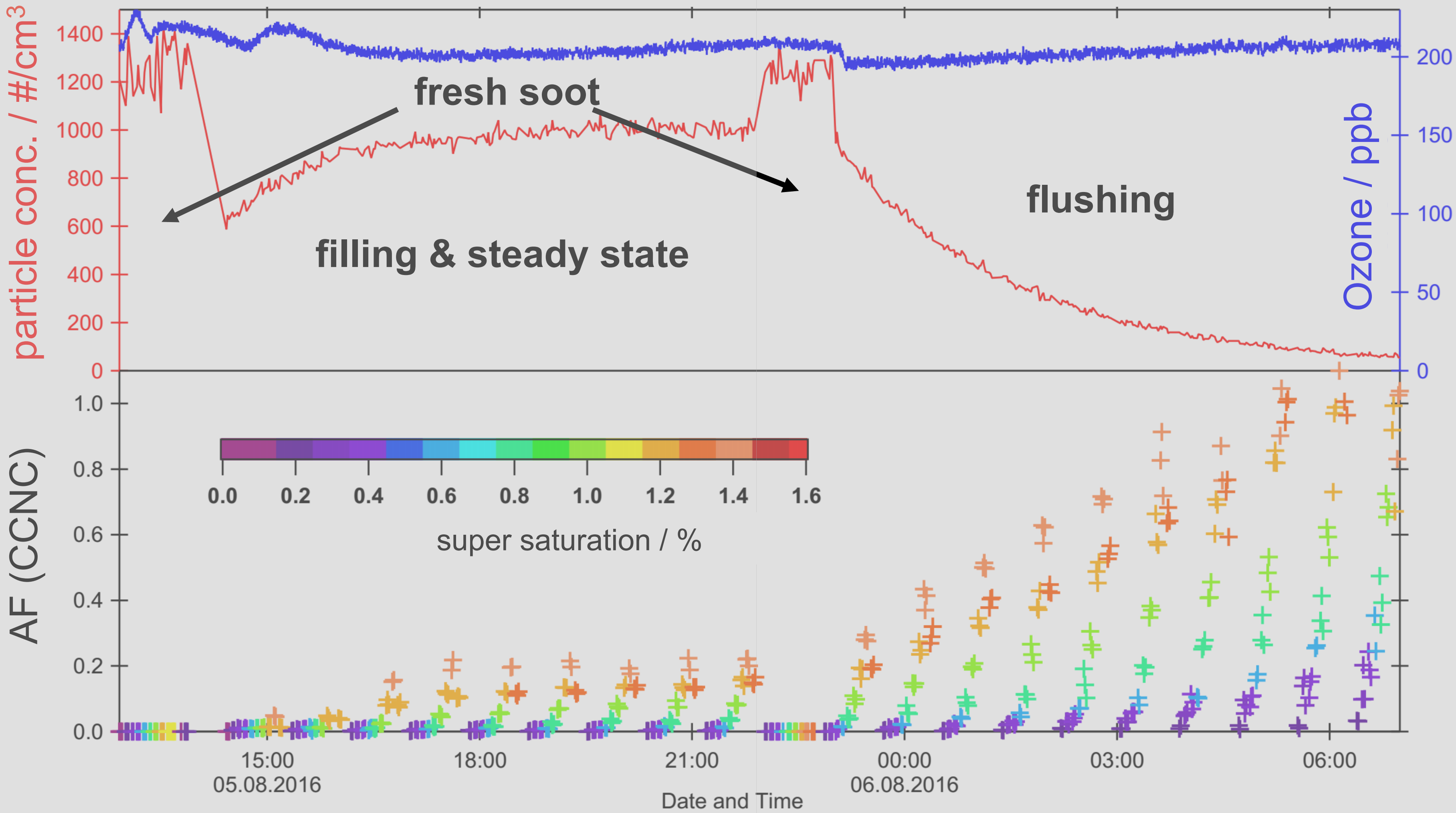


http://tiny.cc/NPC2019

Photography encouraged

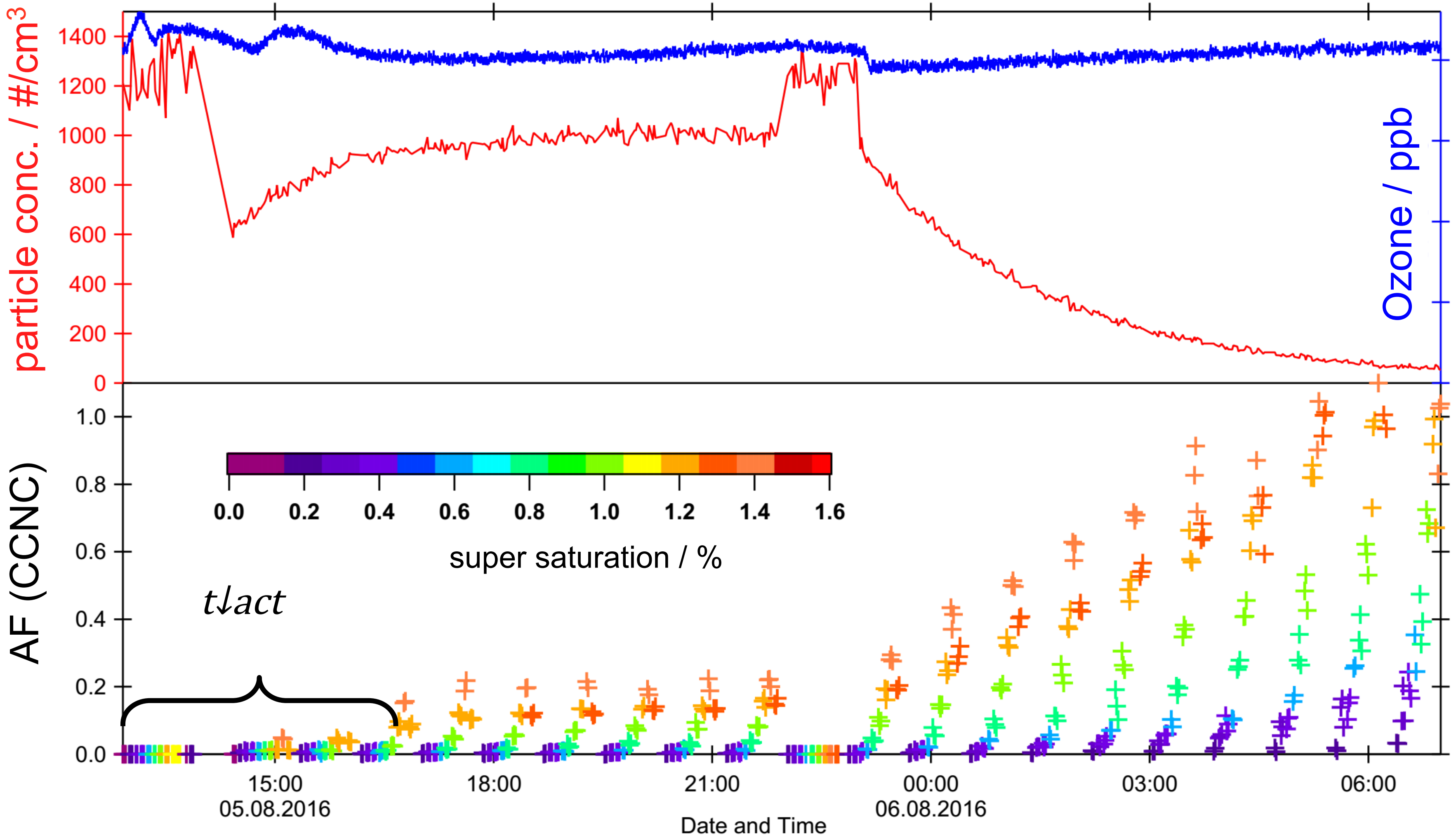
Stages of the experiment

CBw

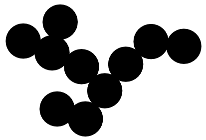


Stages of the experiment

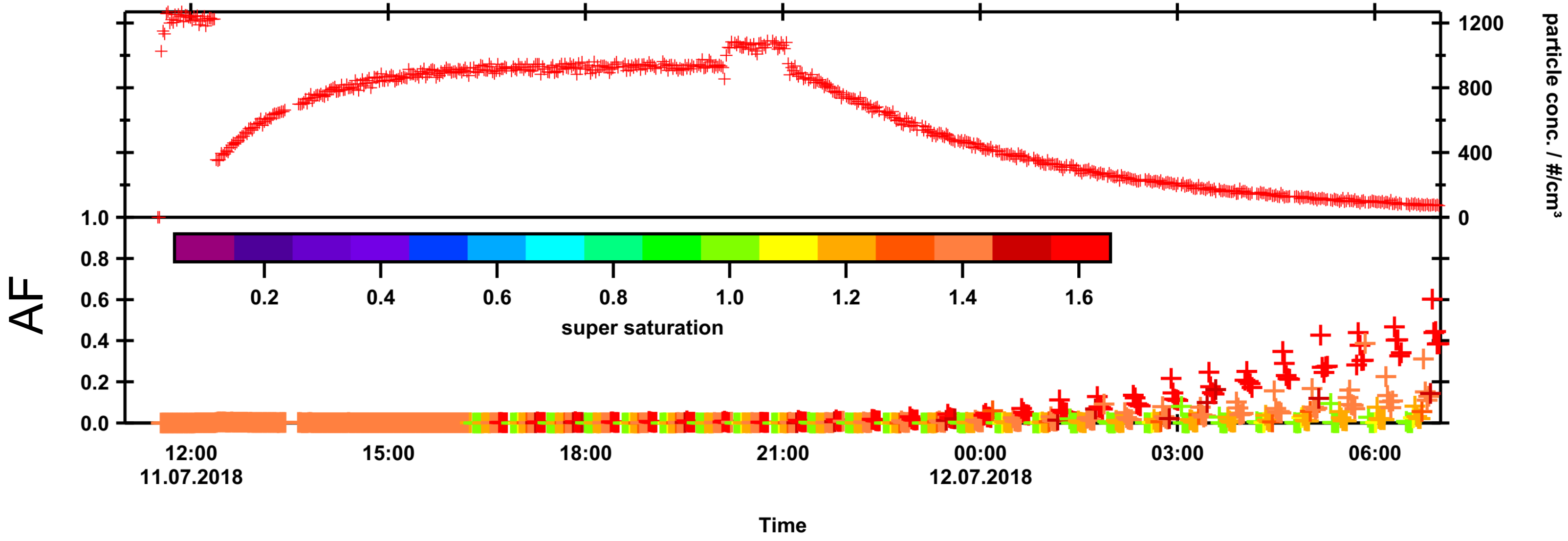
CBw



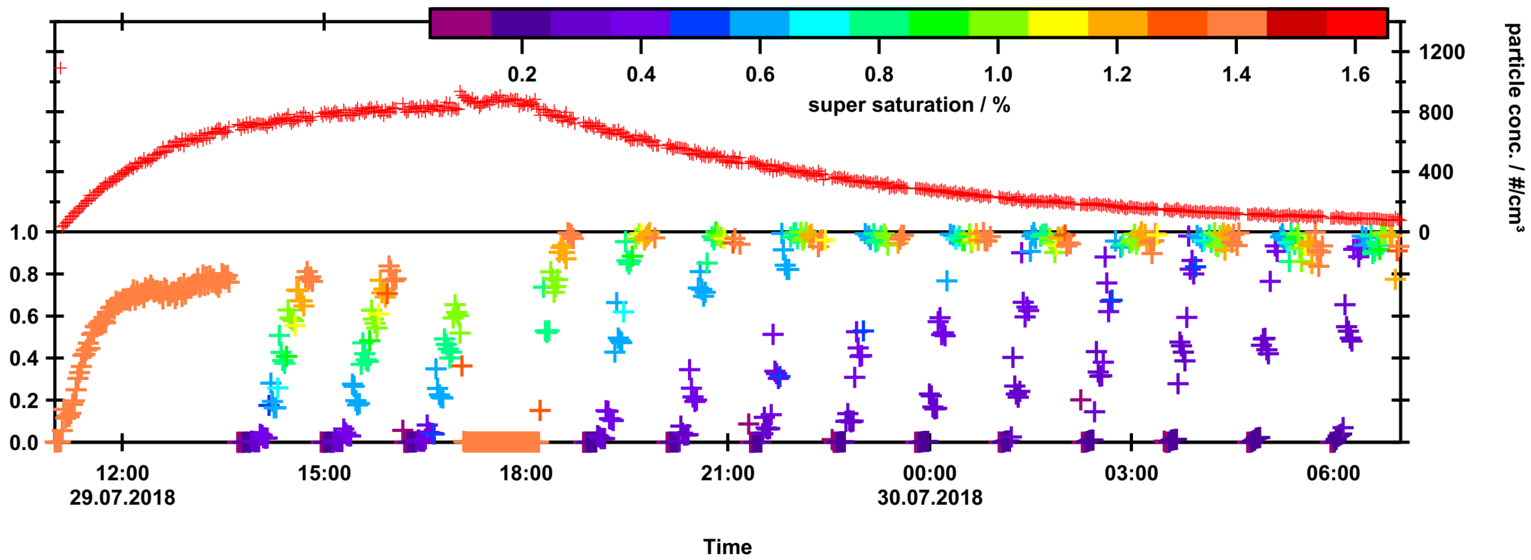
CBk



O_3



O_3 + pinene



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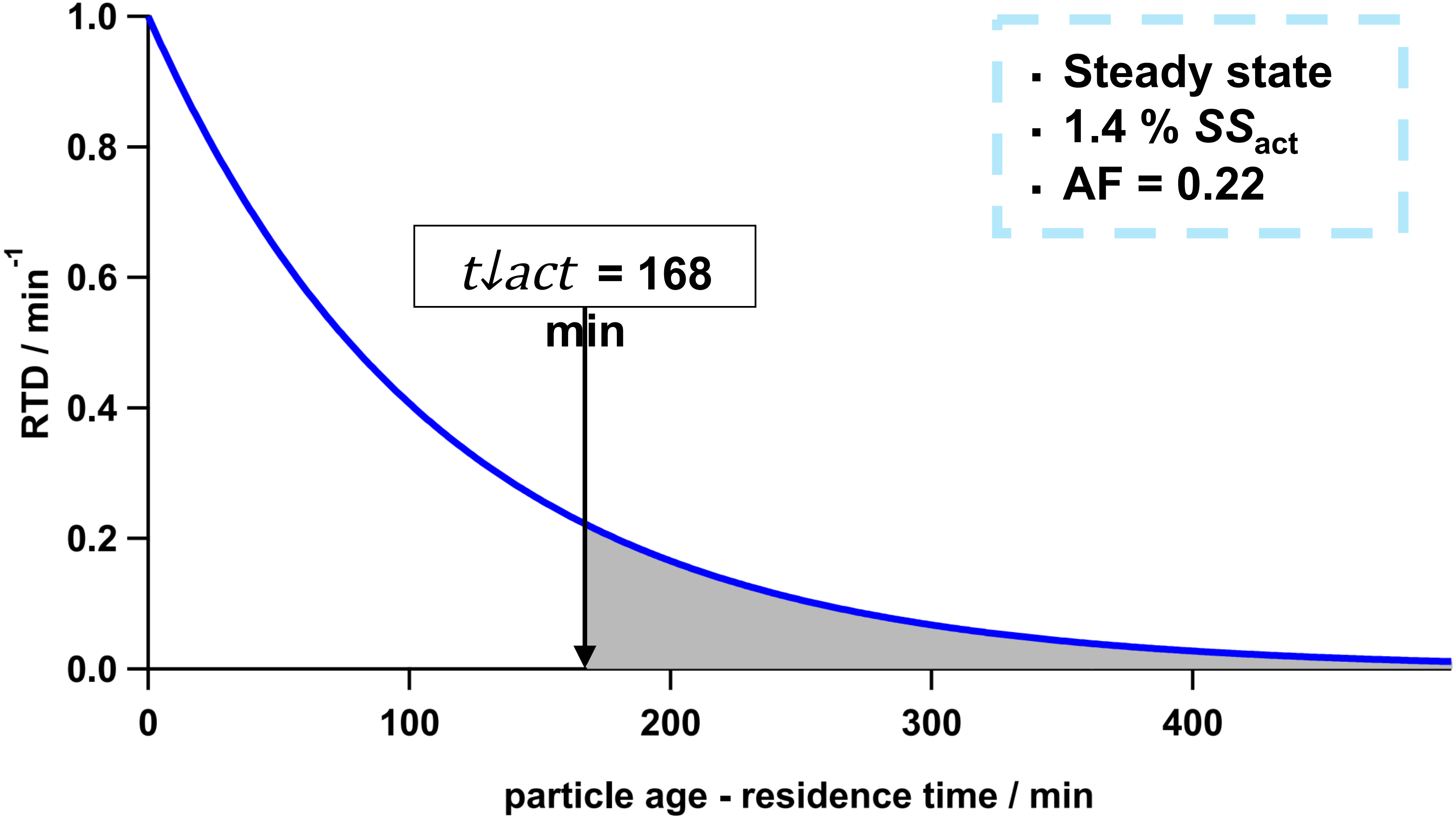
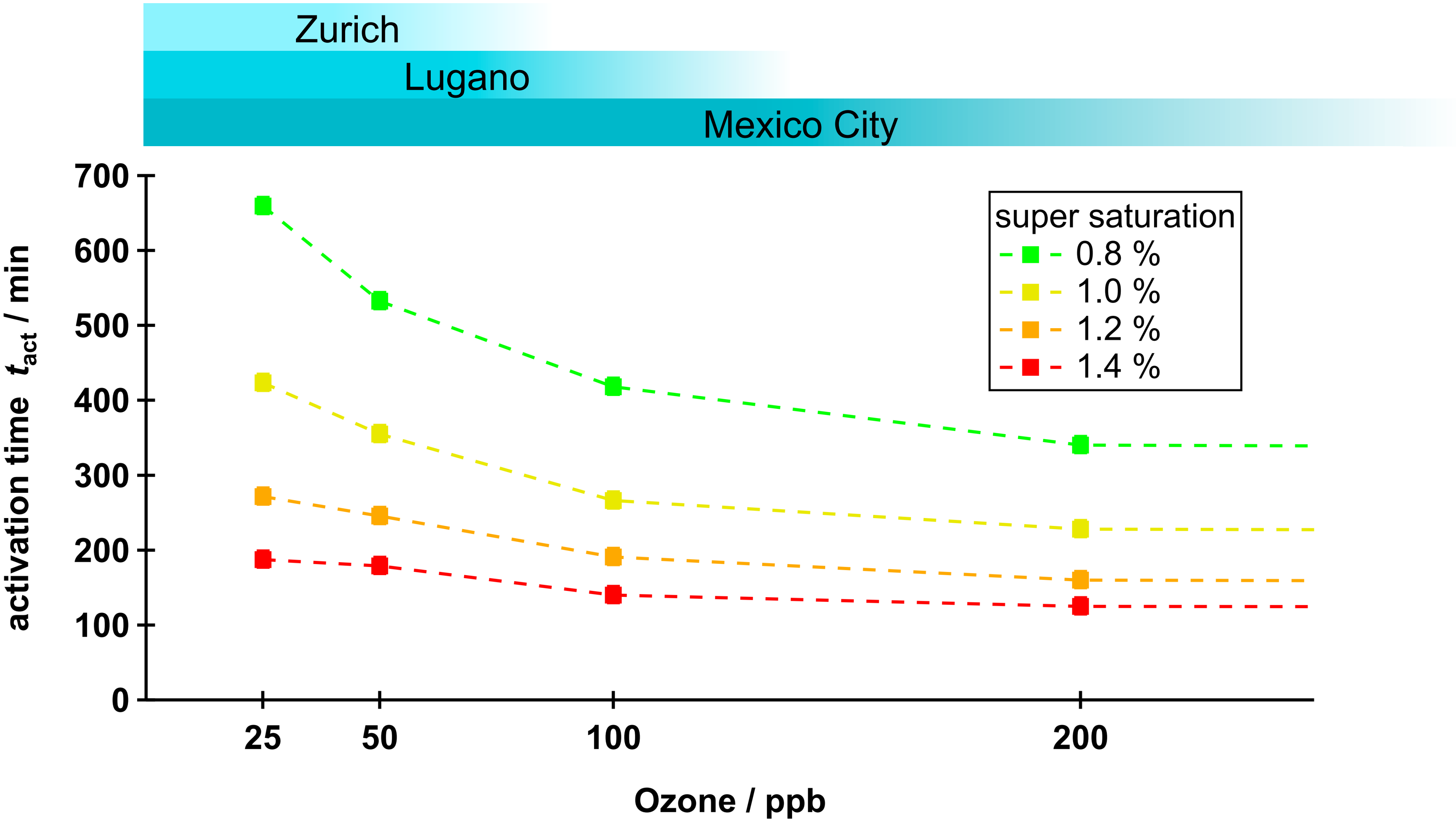
Residence Time Distribution (CSTR)



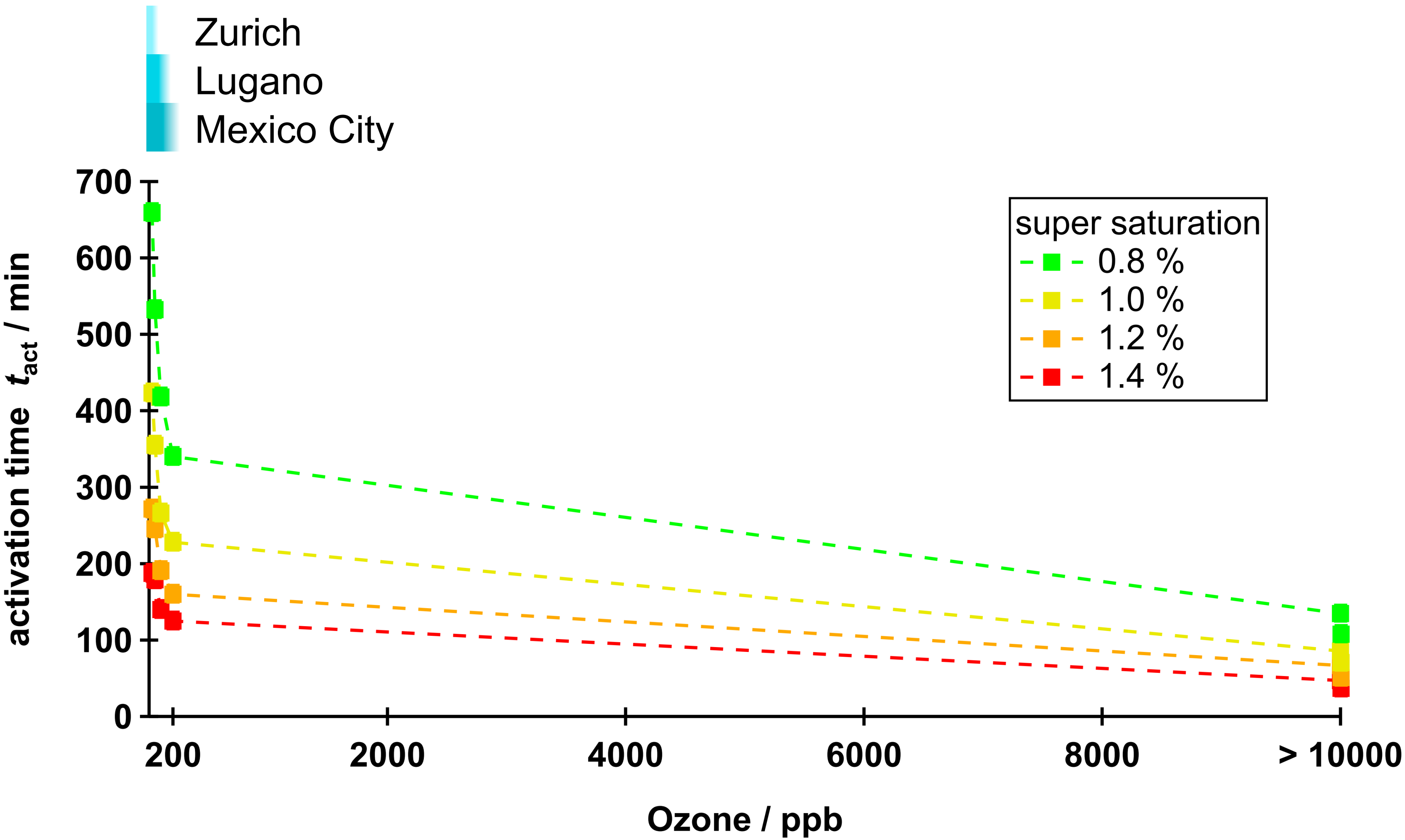
- Steady state
- 1.4 % SS_{act}
- AF = 0.22

vs O_3 at 25°C



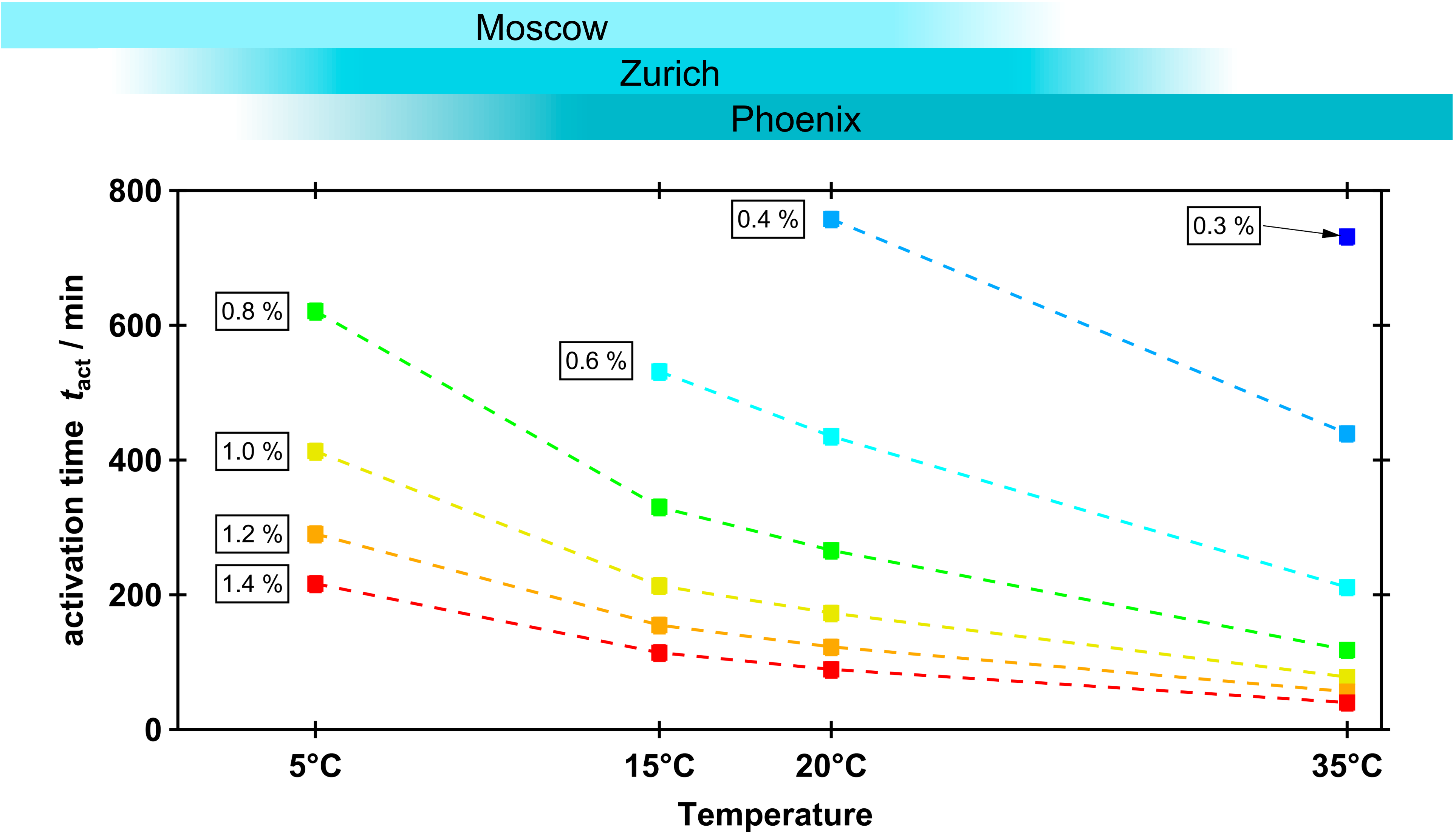
IACETH

vs O_3 at 25°C



IACETH

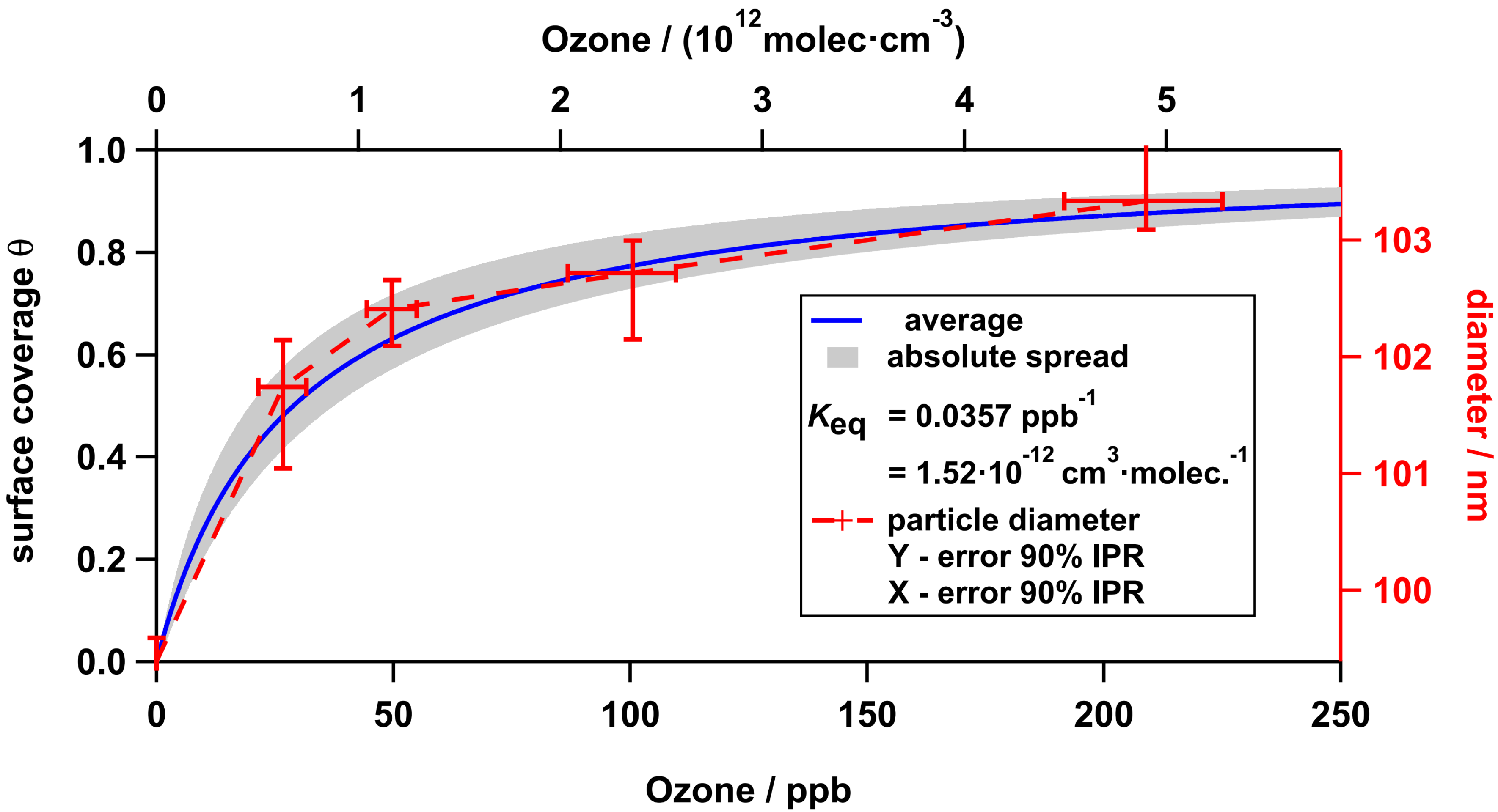
Temperature dependency at 200 ppb O_3



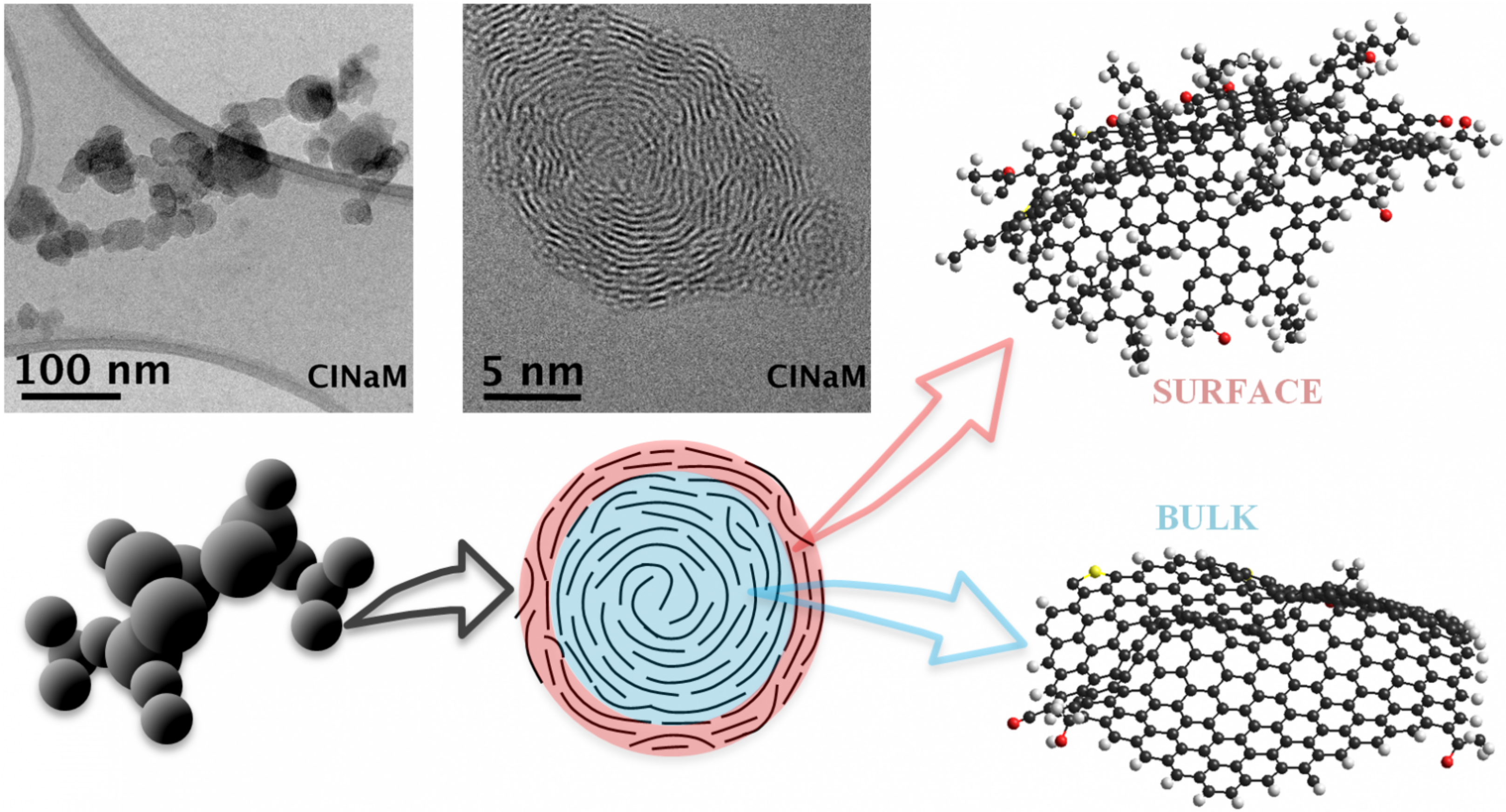
IAC*ETH*

Langmuir-adsorption

$/t\downarrow act \;\; = aging\ rate \approx constant \cdot \theta \qquad \theta = K\downarrow eq \;\; \cdot C\downarrow ozone\ /1+ K\downarrow eq \;\; \cdot C\downarrow ozone$



What is soot?

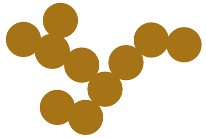
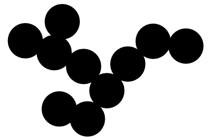


soot aggregate
50-500 nm

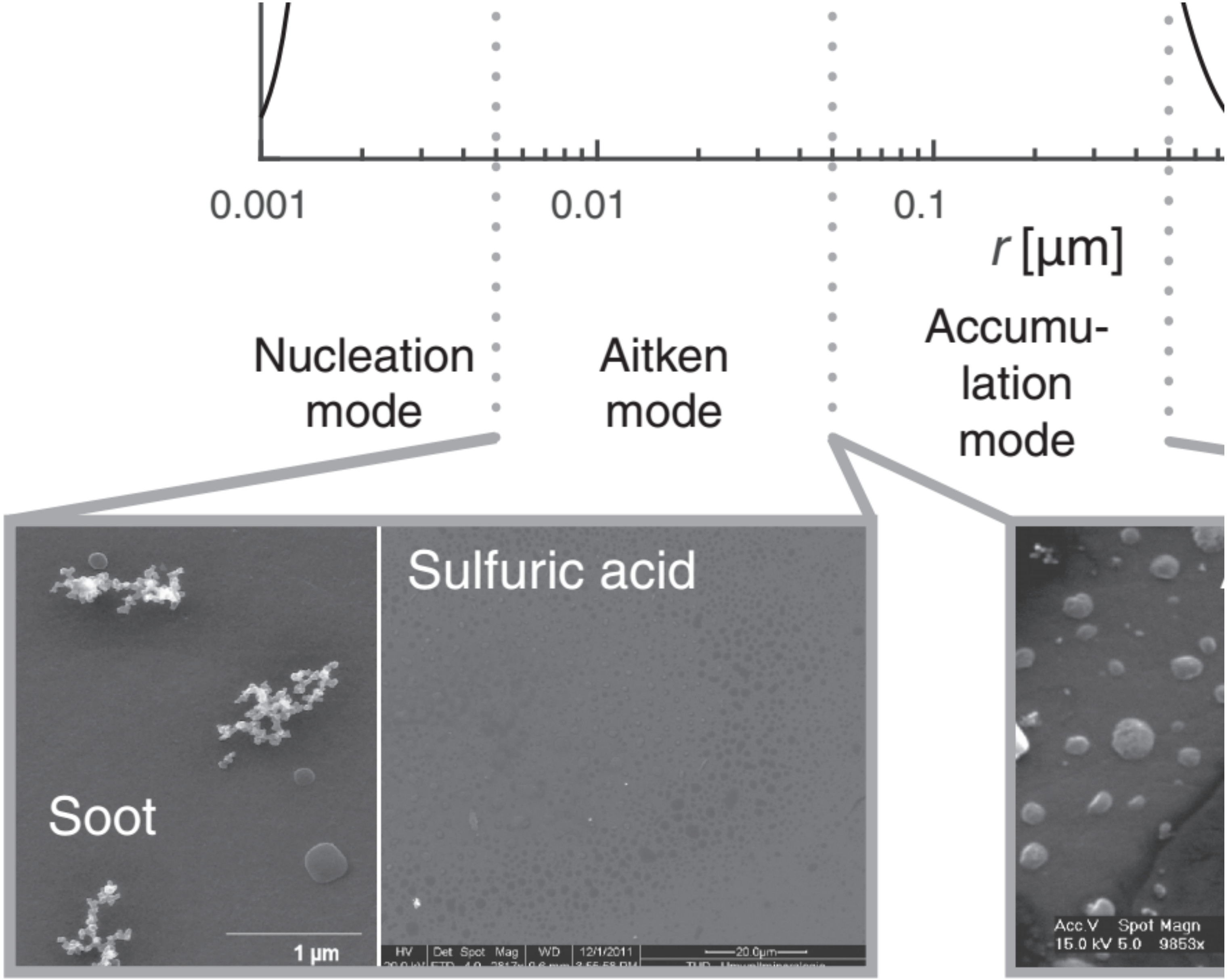
soot primary particle
5-50 nm

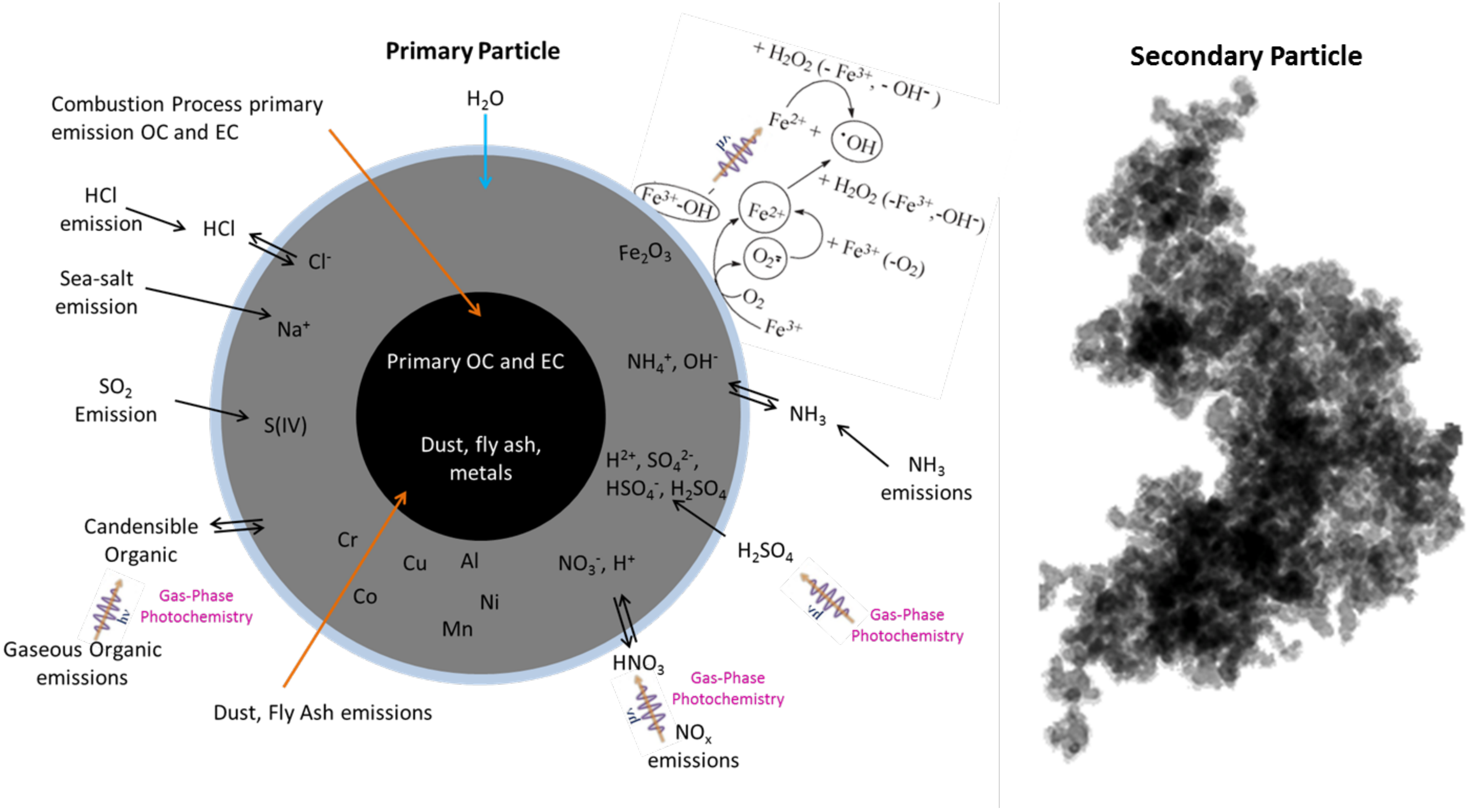
soot crystallite
0.5-5 nm

miniCAST Soot

CBw  CBk 

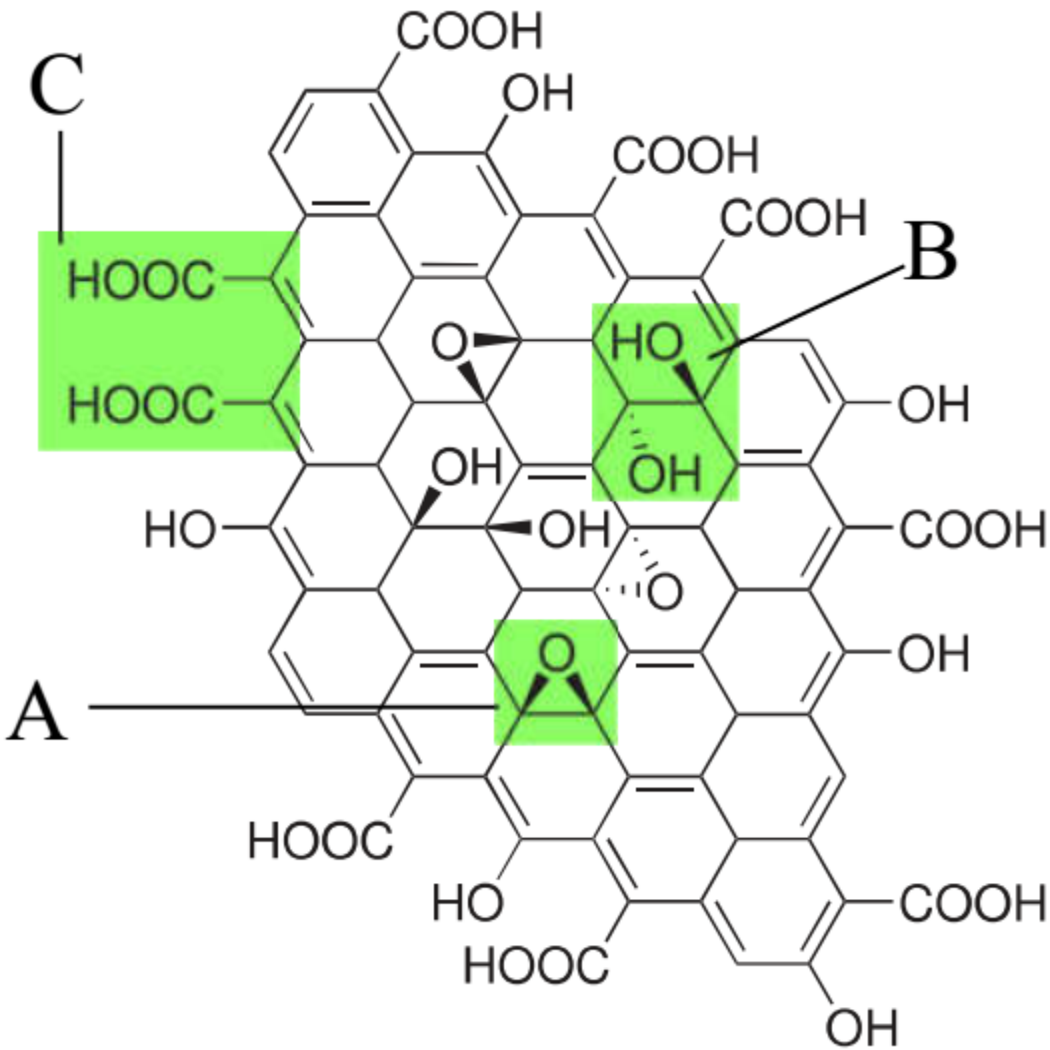
super saturation	activation time (t_{act}) / min			
	CBw		CBk	
0.4 %	---	567	---	420
0.6 %	497	257	---	208
0.8 %	313	139	---	116
1.0 %	212	90	---	79
1.2 %	151	68	---	46
1.4 %	116	30	733	32
1.6 %	---	---	568	---


0.001
0.01
0.1
r [µm]
Nucleation mode
Aitken mode
Accumu-lation mode
Soot
1 µm
Sulfuric acid
HV Det Spot Mag WD 12/1/2011
20.0µm
Acc.V Spot Magn
15.0 kV 5.0 9853x



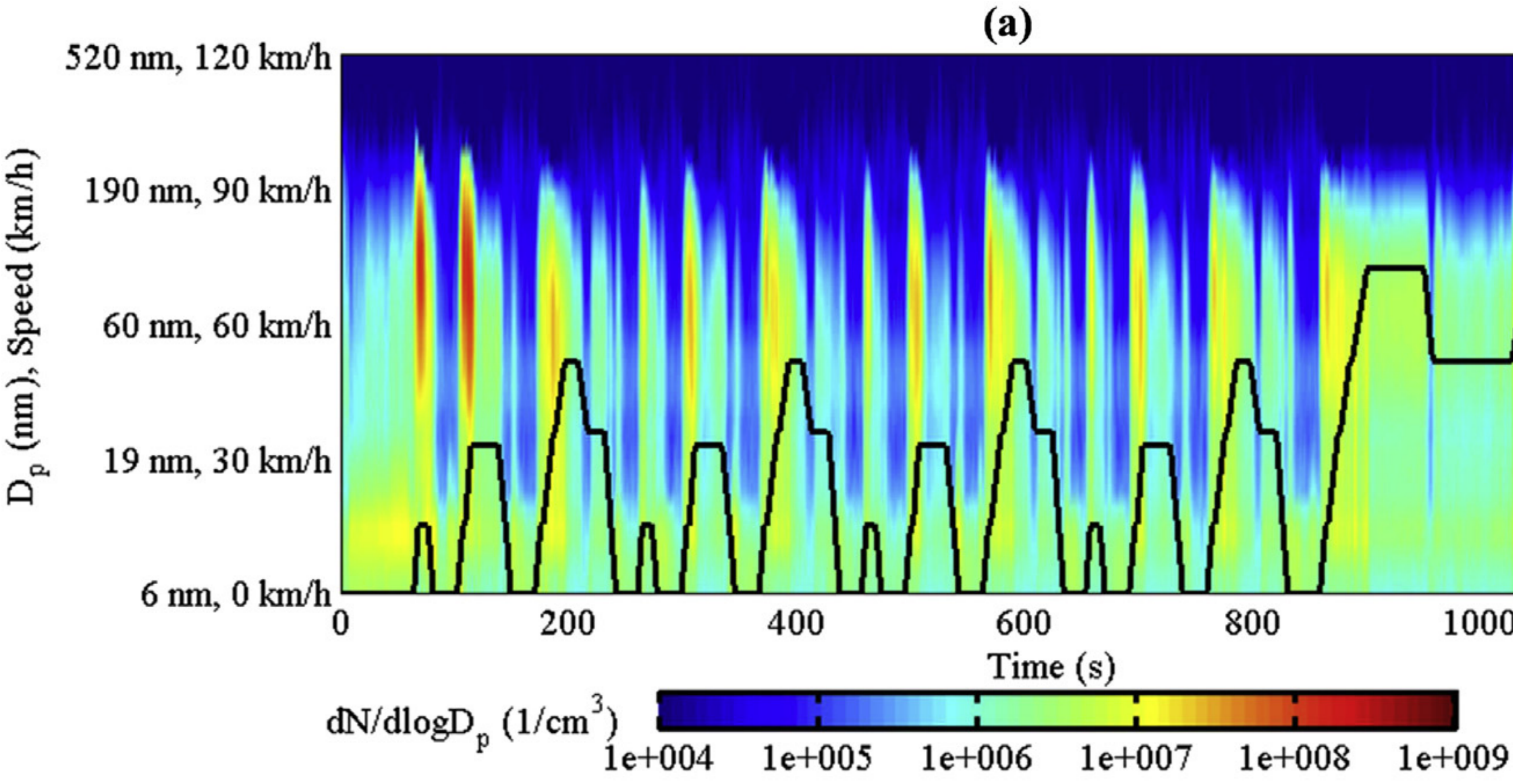
Soot surface chemistry. [5]

IACETH


C
B
A
COOH
OH
COOH
COOH
HOOC
HOOC
O
HO
OH
OH
HO
OH
OH
COOH
O
OH
O
HOOC
HO
HOOC
COOH
OH

Size distribution of soot (Karjalainen et al., 2014)

- Gasoline engine exhaust



Sharing is caring

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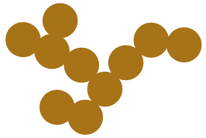
mass and diameter – O_3 / O_3 + pinene

CBw



CBk