New evidence of soot particles affecting cloud formation and climate

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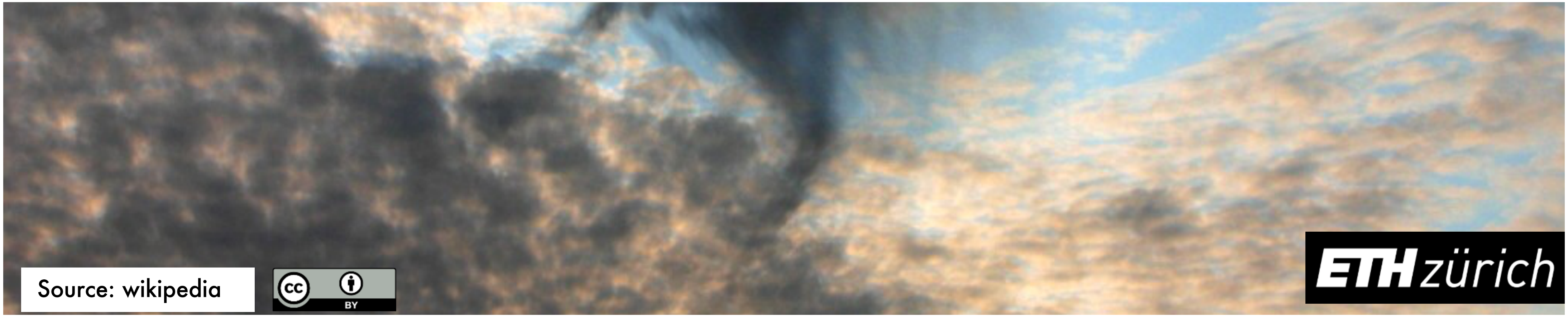
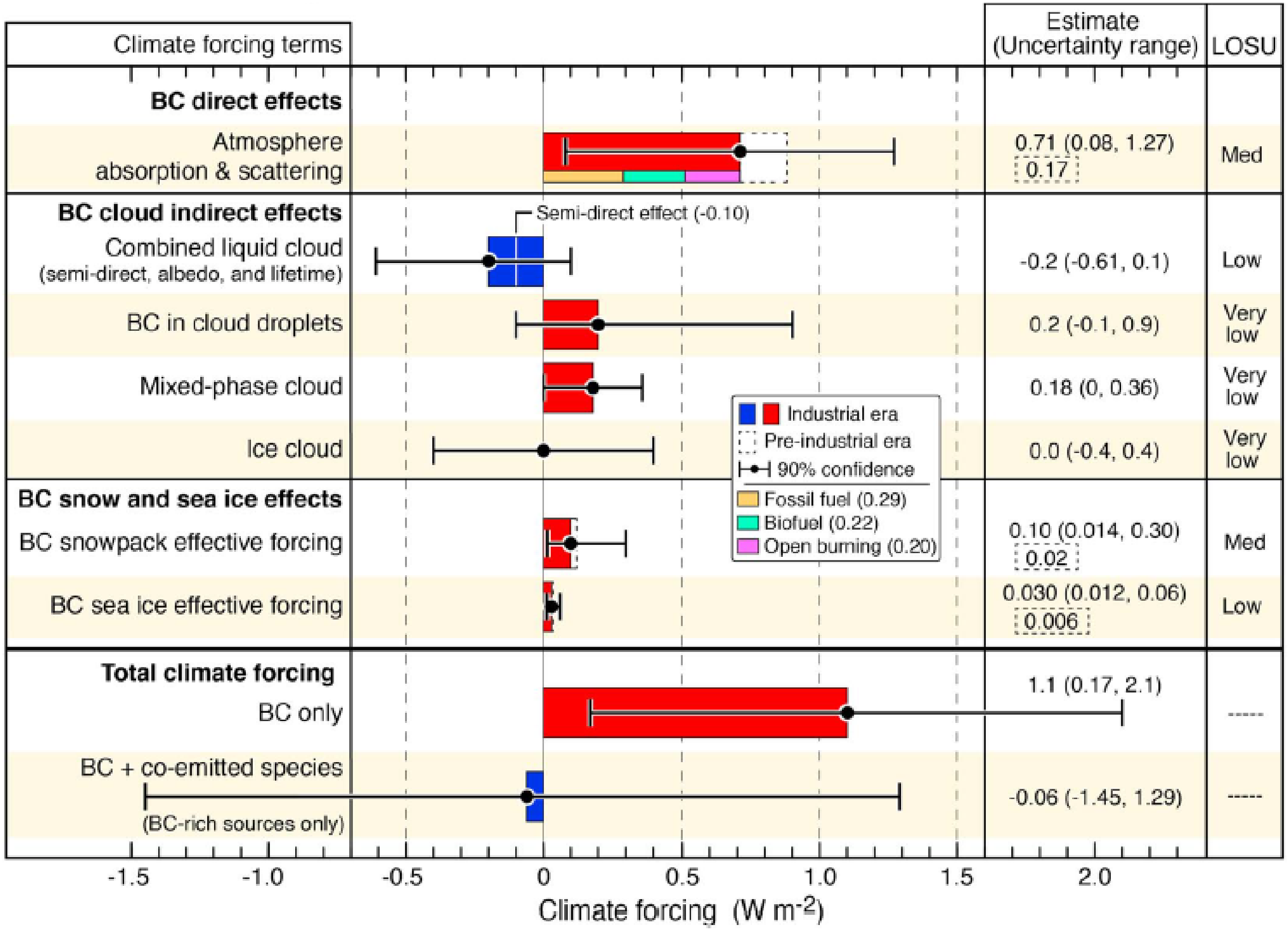


Source: wikipedia

ETH zürich

Climate forcing of soot and co-emitted species (1750-2005)

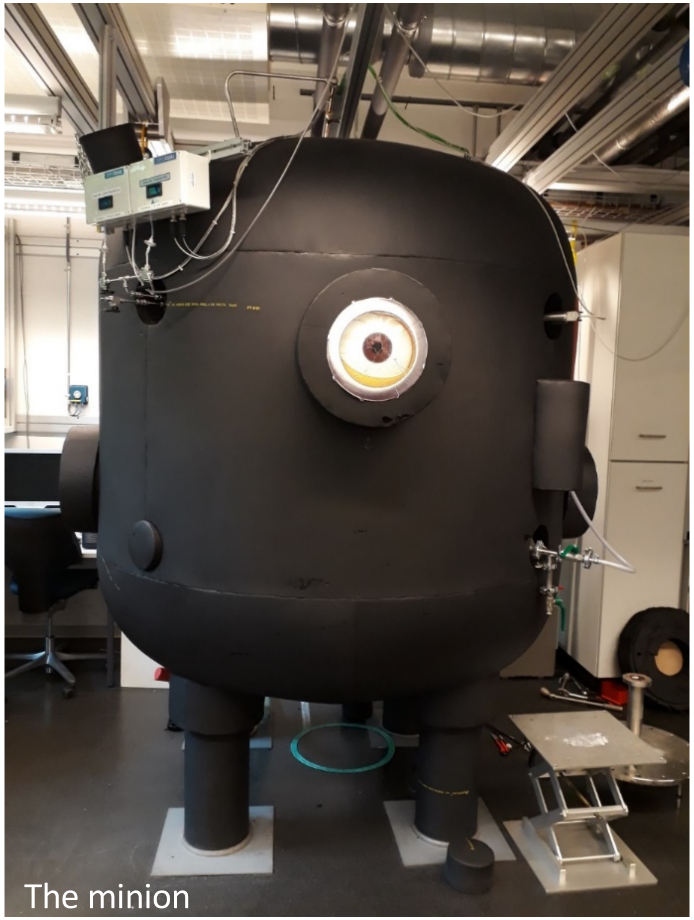


Bond et al., 2013

Experiments to study oxidation of soot by ozone

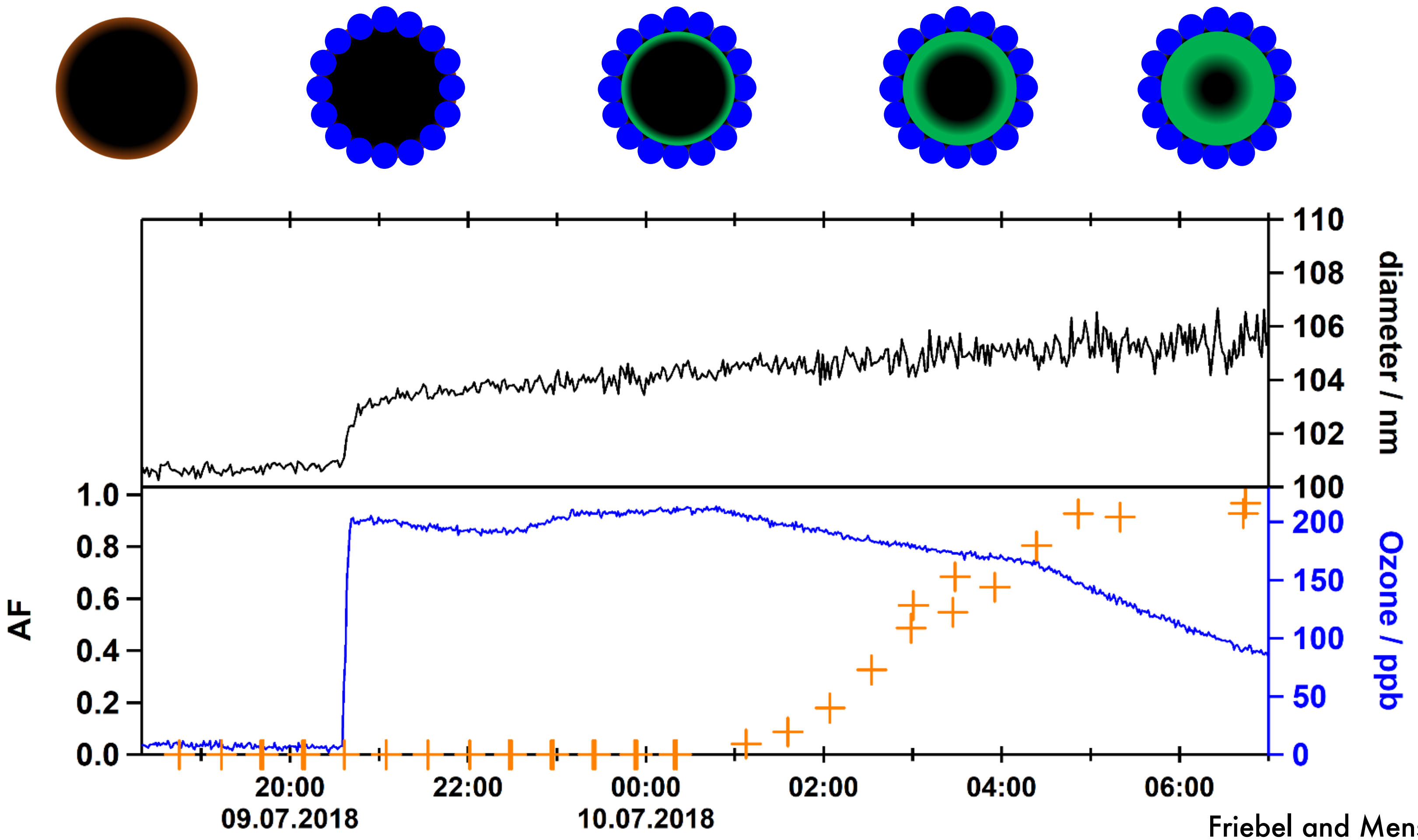
- Continuous-flow Stirred Tank Reactor (CSTR)
- 100 nm soot particles
- 16 h aging time
- miniCAST brown (organic carbon rich soot)

Temperature 5 - 35 °C ⟷ Ozone 0 - 200 ppb


The minion

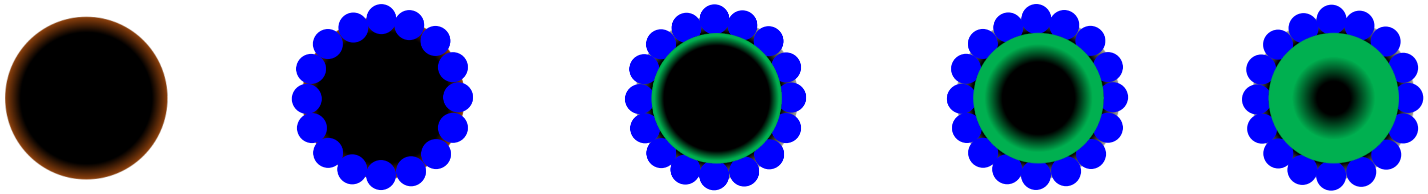
Friebel and Mensah, AMT, 2019

Continuous exposure to 200 ppb ozone

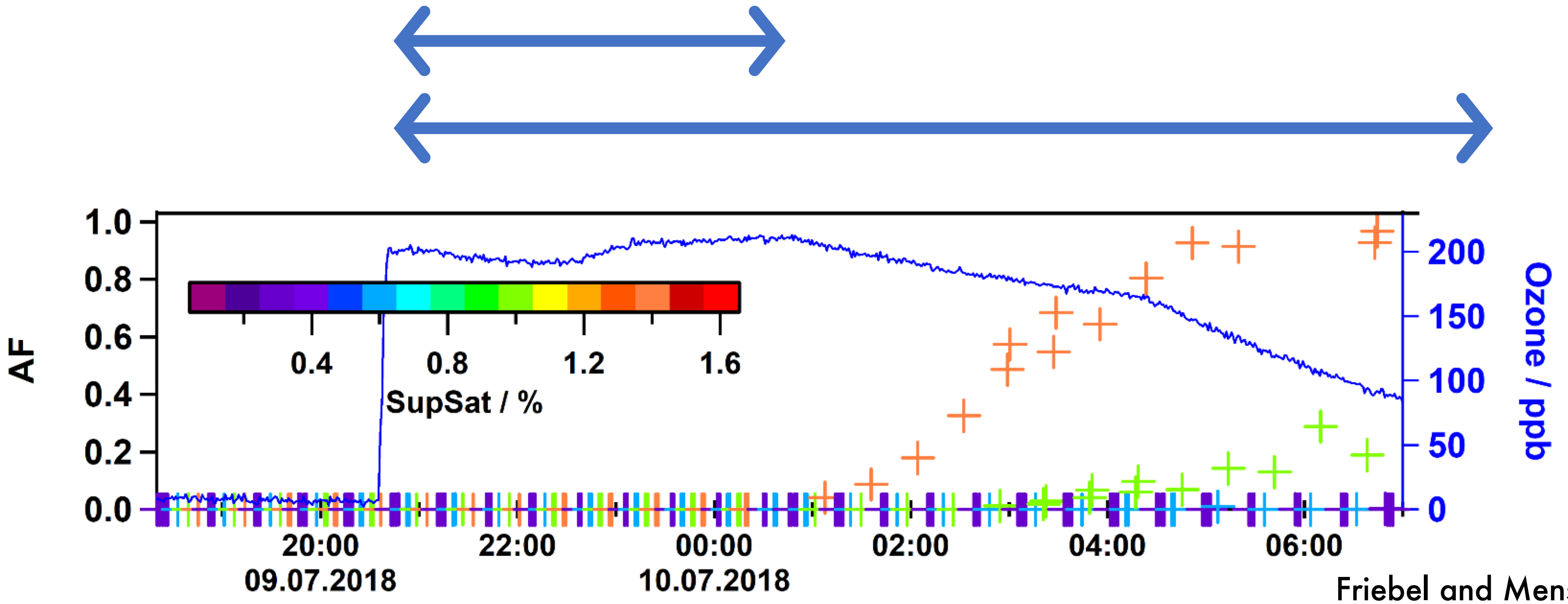


Friebel and Mensah, AMT, 2019

Activation time t_{act}

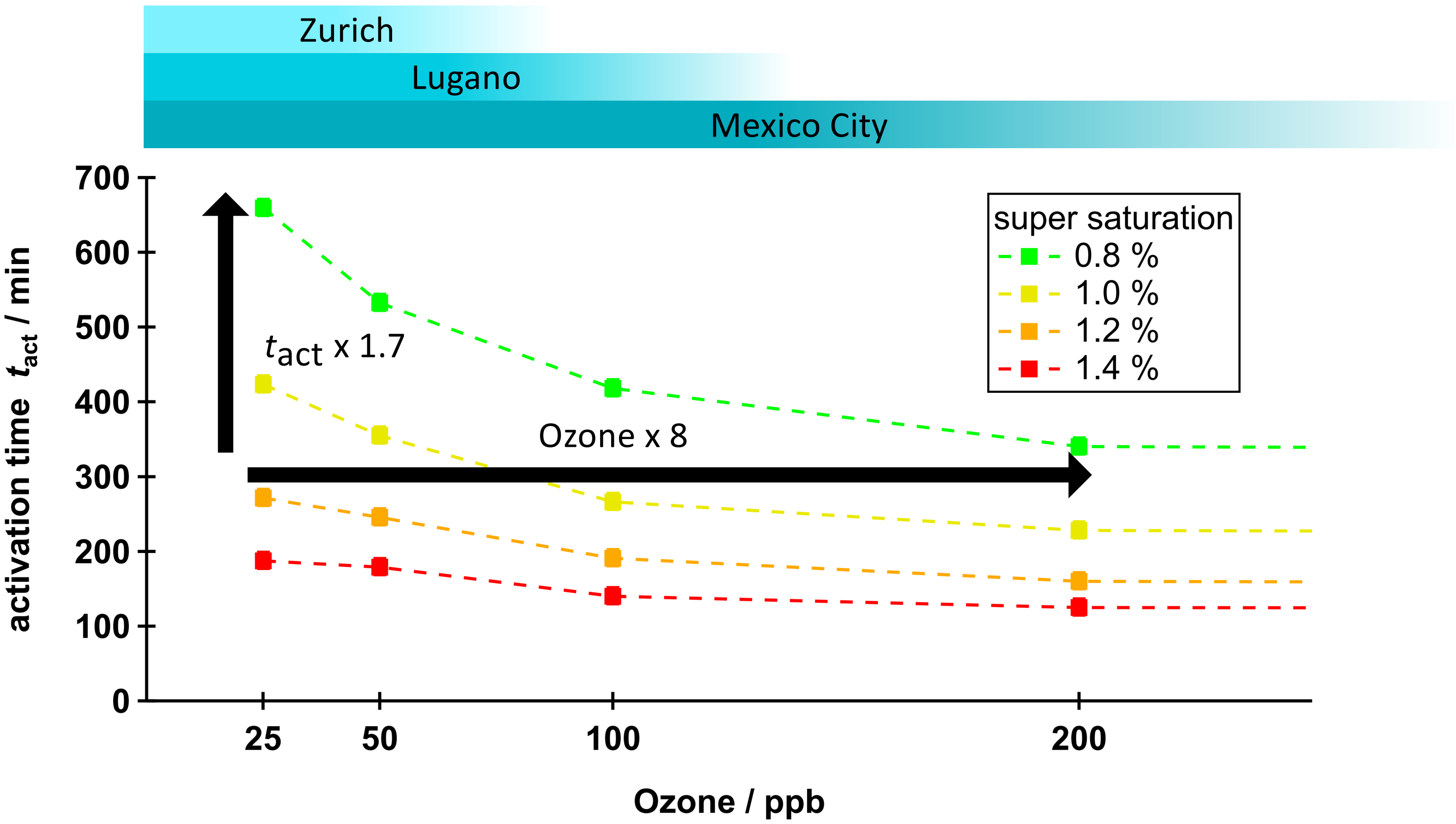


t_{act} = 3 - 12 h



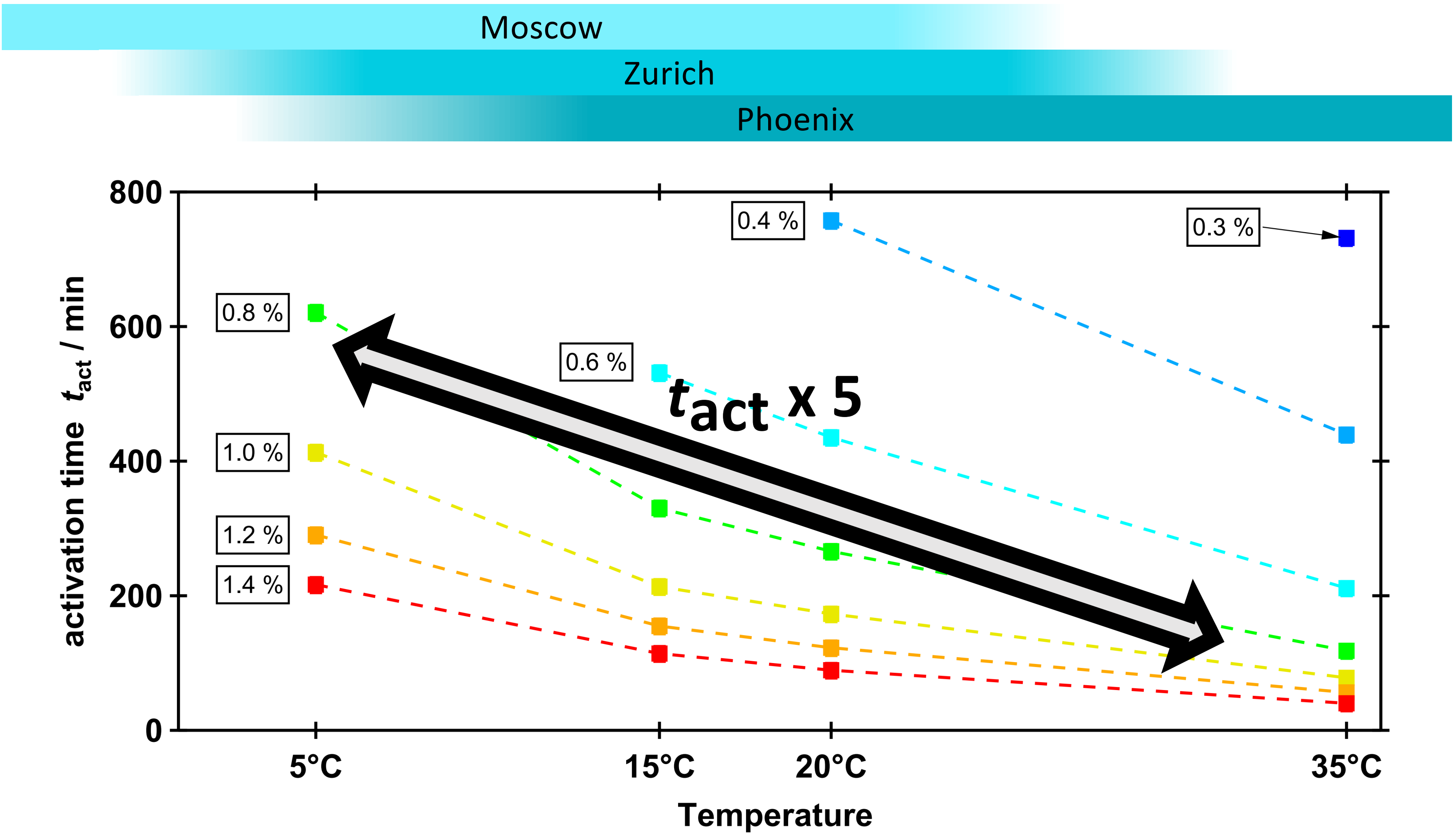
Friebel and Mensah, AMT, 2019

Activation time vs. ozone concentration



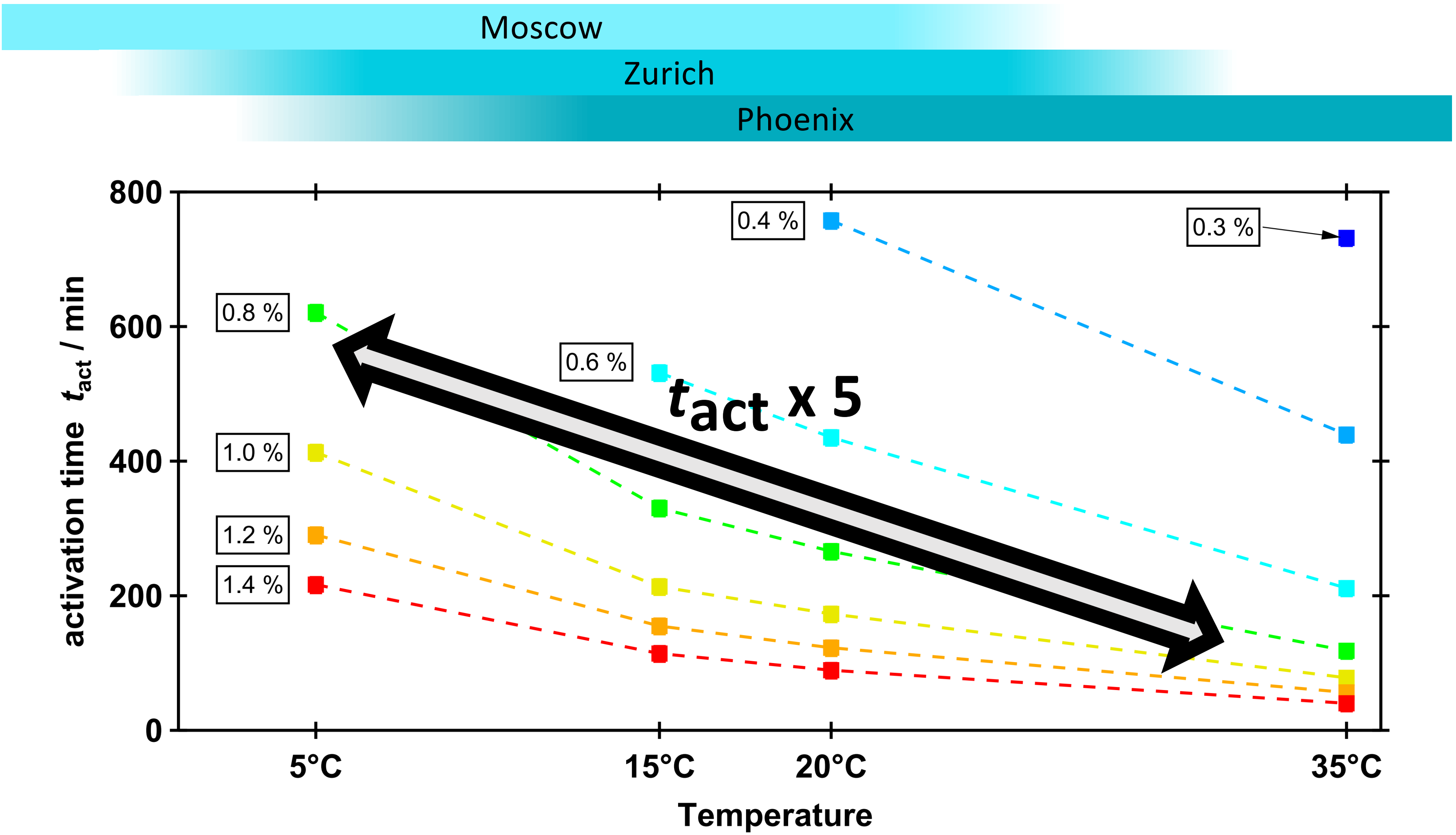
Friebel and Mensah, Langmuir, 2019

Temperature dependency at 200 ppb O_3



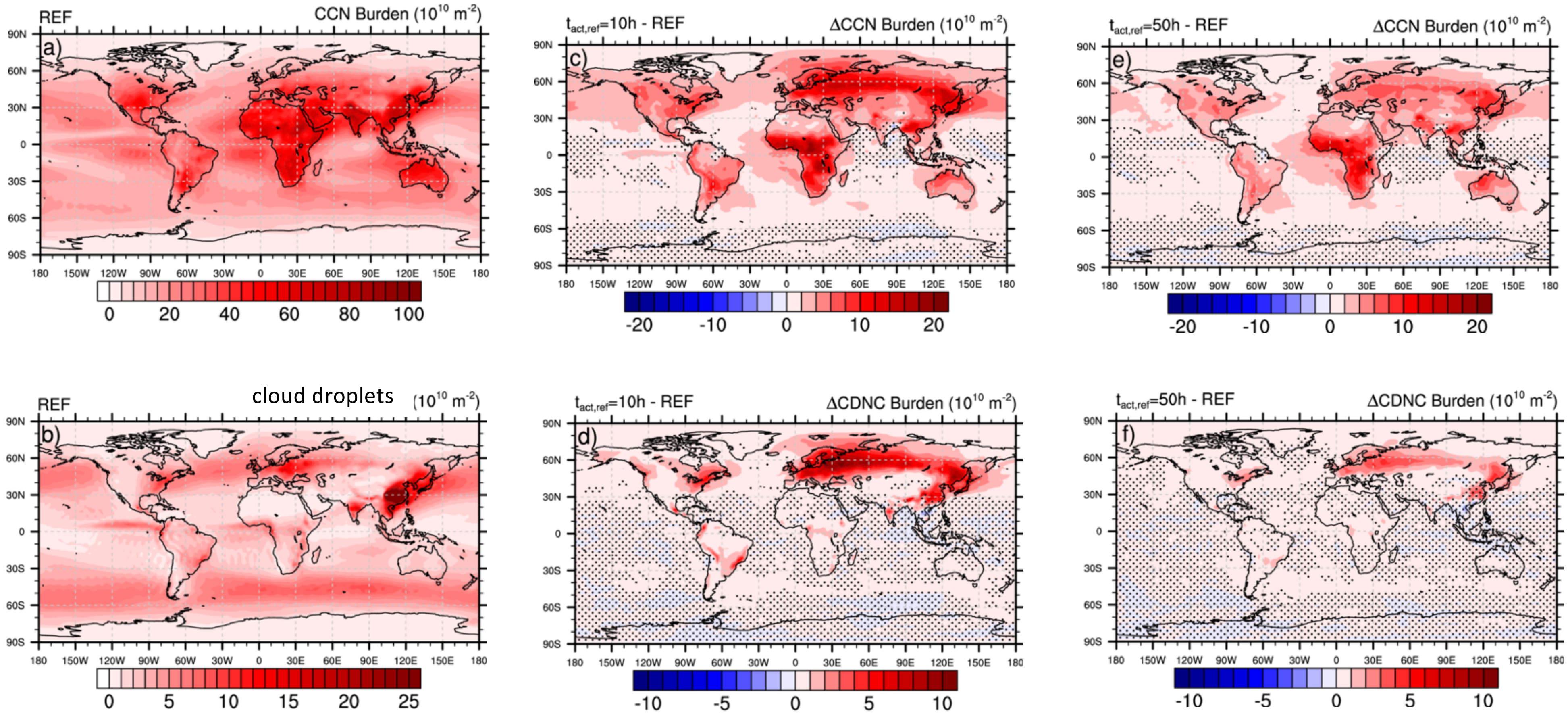
Friebel and Mensah, Langmuir, 2019

Temperature dependency at 200 ppb O_3



Friebel and Mensah, Langmuir, 2019

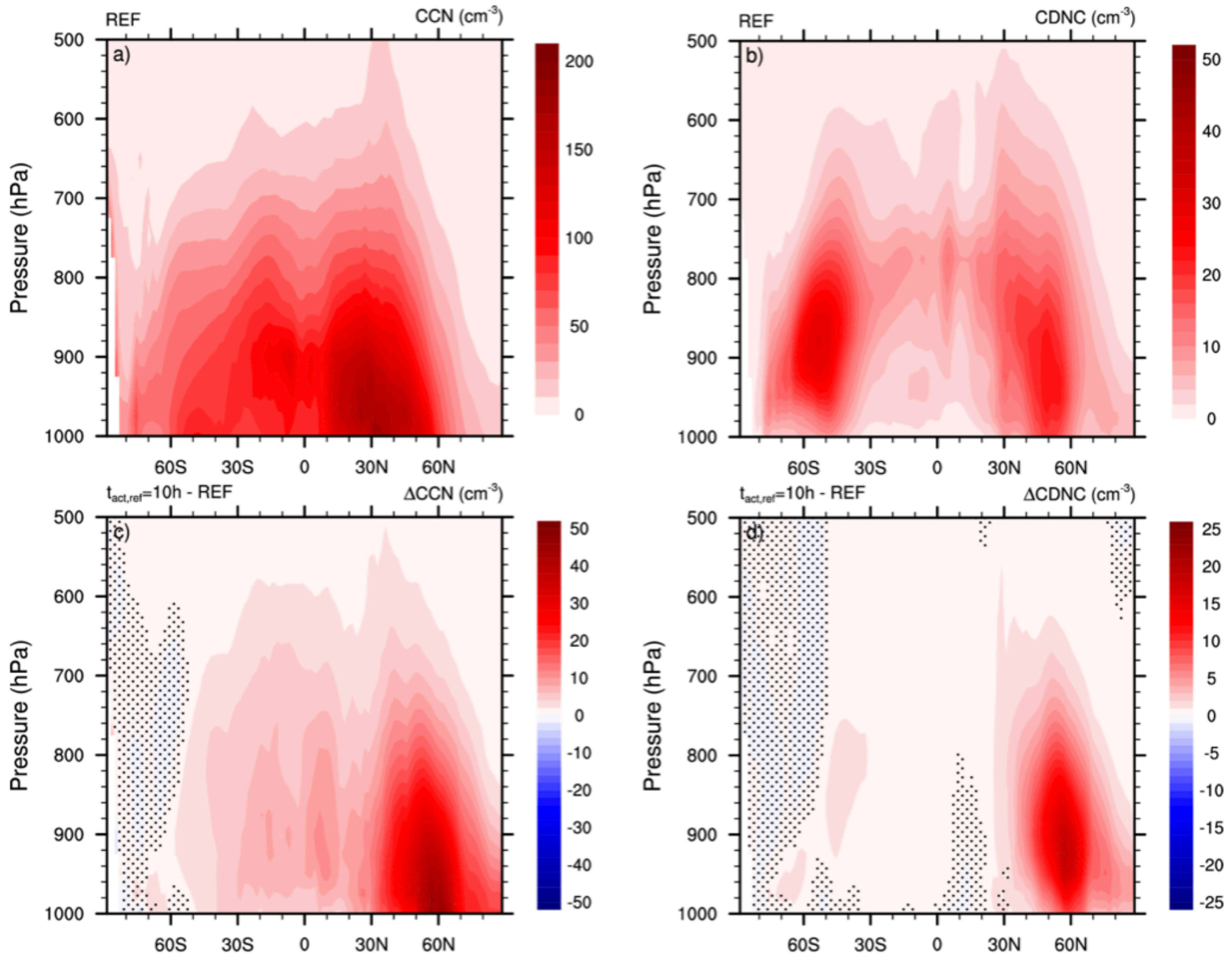
Change in cloud condensation nuclei (CCN) and cloud droplets (CDNC) due to ozone-aged soot



→ 93% increase in cloud droplet burden north of 60 ºN for 10h activation time

Friebel et al., ACP, 2019

Change in CCN and CDNC due to ozone-aged soot

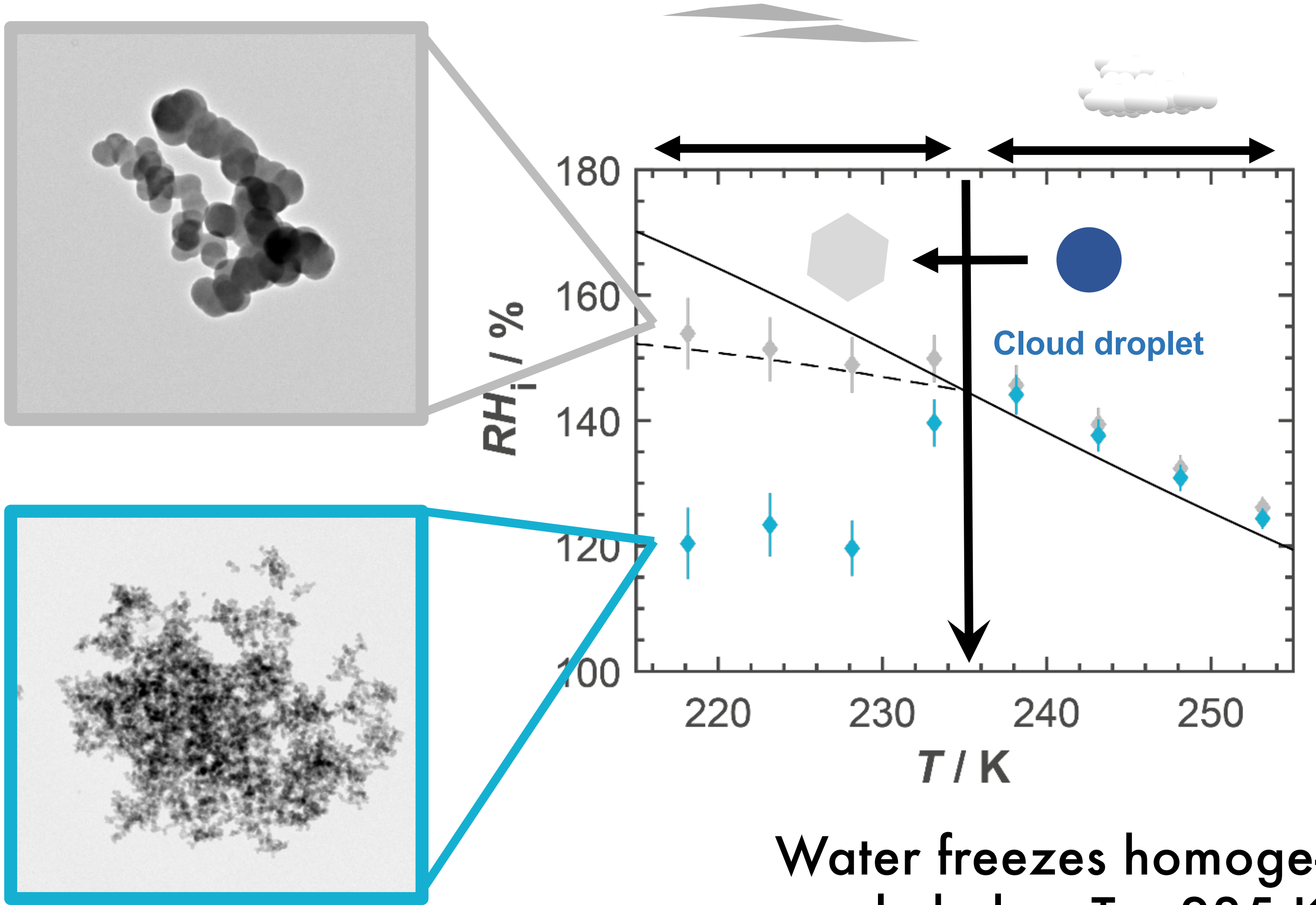


--> Largest impact of ozone as CCN at around 60 ºN

Friebel et al., ACP, 2019

Ice nucleation activity of soot particles

- Different soot types have different physicochemical properties.
- Strong temperature dependence of ice formation.
- Implies involvement of liquid water.



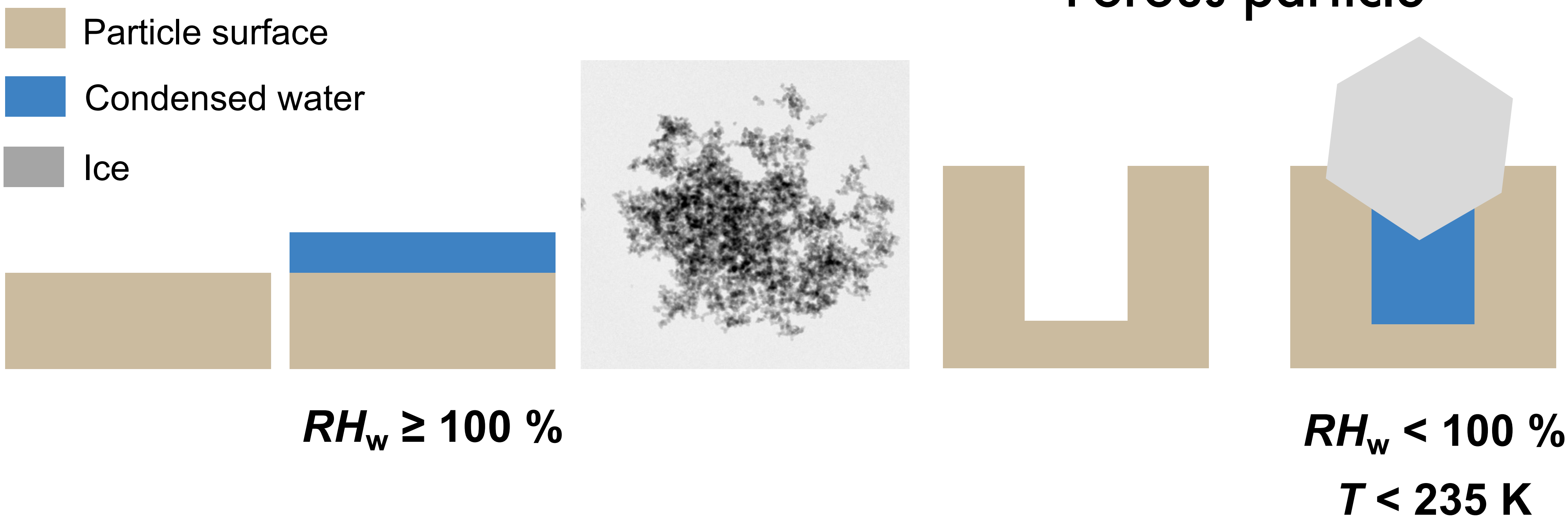
Water freezes homoge-
neously below T = 235 K

Mahrt et al., ACP, 2018

Pore condensation and freezing

Non-porous particle

Porous particle

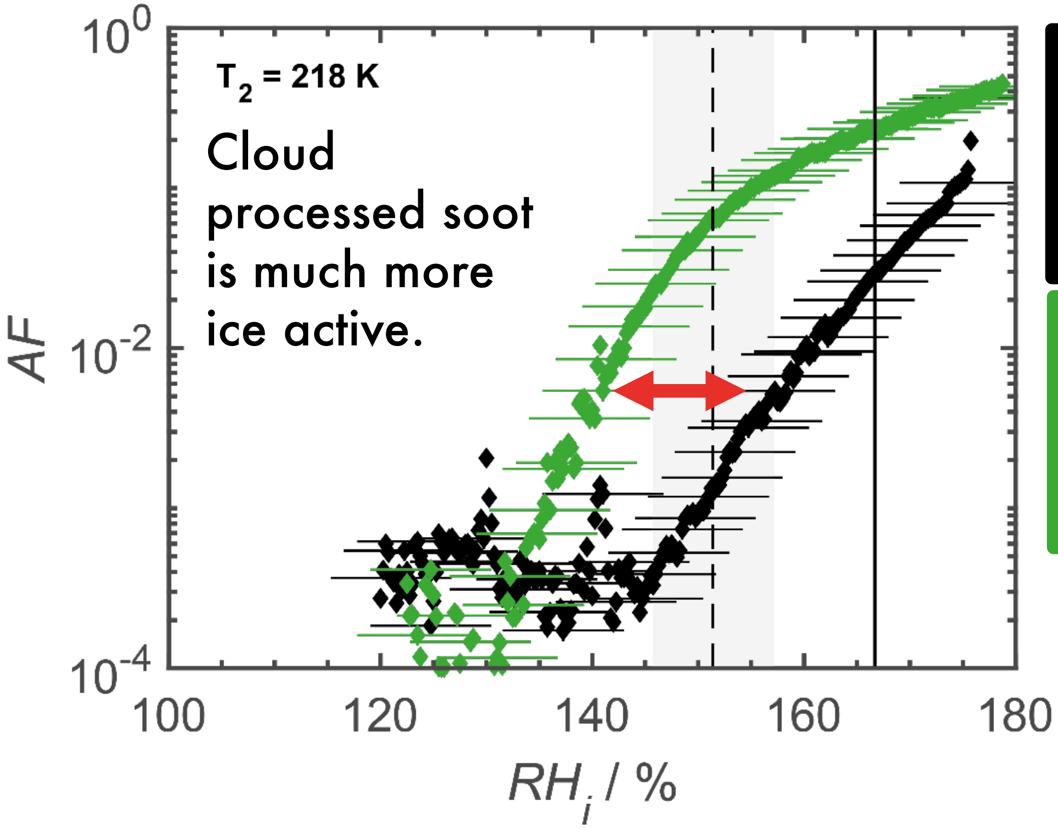


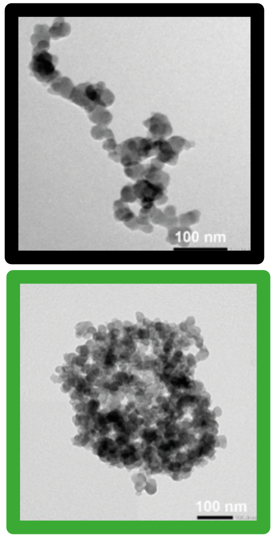
- Water is taken up by capillary condensation at $RH_w < 100\%$.
- Pore water freezes homogeneously at T < 235 K

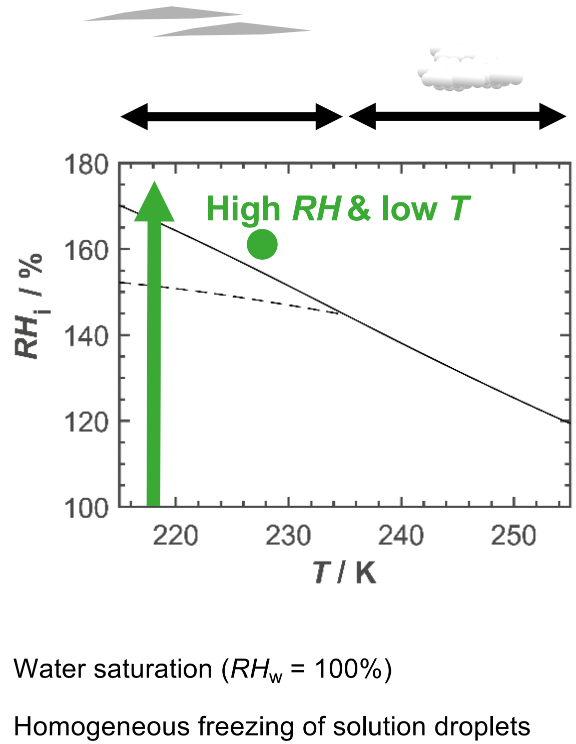
Marcolli, ACP, 2014; David et al., PNAS, 2019

Cloud processing

Unprocessed soot
Processed (Cirrus)

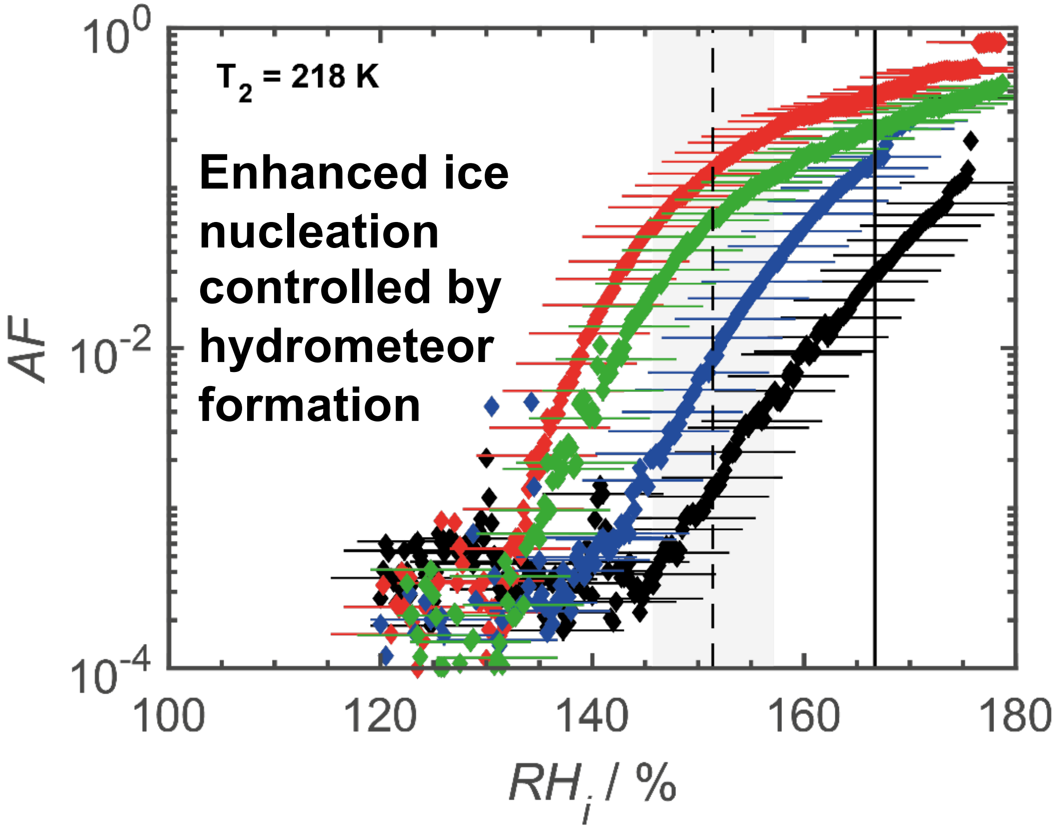






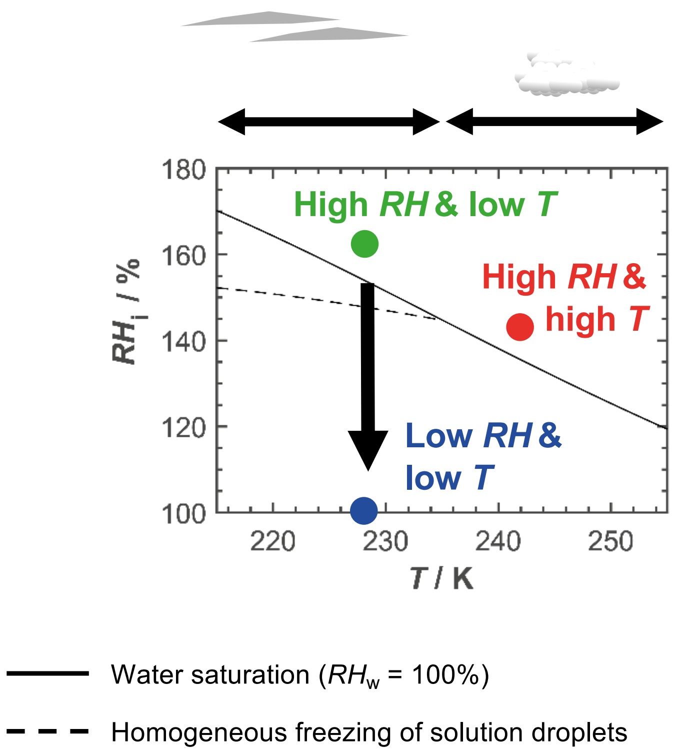
Mahrt et al., JGR, 2020

Cloud processing



Mahrt et al., JGR, 2020

Unprocessed soot
Processed (Cirrus)
Processed (MPC)
Pre-cooling



Summary of the impact of aged soot particles as CCN and INPs

- Soot particles can be aged chemically and physically
- Ozone-aging of soot increases the cloud droplet burden north of 60 °N by 93% for a 10h activation time
- Cloud processed soot is much more ice active